The WooDestress Index: a tool to evaluate the destressing potential of urban woodlands, through the assessment of their naturalness
A case study in Malmö

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“I think that I cannot preserve my health and spirits, unless I spend four hours a day at least — and it is commonly more than that — sauntering through the woods and over the hills and fields, absolutely free from all worldly engagements” (Walking-David Henry Thoreau)

ABSTRACT: According to the United Nation the next years will be characterized by an urbanization process that will lead to the increase of densely populated areas. One of the possible consequence could be the increase of stressful factors, which can lead to chronic stress and chronic stress related diseases. To face this situation, a new approach in city planning is required. One of the aspect that urban managers should take into account is the important role that natural environments play to improve the citizen life quality. It was shown that the wooded areas characterized by the presence of many natural elements are among the most effective environments to reduce stress. However, an empirical method to characterize different urban woodland in order to know their "destressing potential" does not exist. For this reason, the purpose of this study is to develop an index to evaluate the naturalness of urban woodlands based on how they offer relaxing and destressing experiences. The result is the WooDestress index (WDI), a tool that considers five features already adopted to assess the naturalness in forest ecology. The evaluation of each feature depends on how it can contribute to offer relaxing experiences in an urban woodland. The index was tested for the first time in four urban parks located in Malmö (SE). According to the results, the main frame of the index seems to be valid, but it should be considered as a first draft. Some components of WDI should be improved and tested in different areas. However, with WDI it was possible to evaluate different woodlands in Malmö, obtaining different values. This result, even though it should be verified, it can be considered as a spark for the future research.

Key words: *WooDestress index, stress, green management, naturalness, urban woodland.*

RIASSUNTO: Secondo le Nazioni Unite i prossimi anni saranno caratterizzati da un processo di urbanizzazione che determinerà l'aumento delle aree densamente popolate. Una delle possibili conseguenze potrebbe essere l'aumento di fattori causa di stress, i quali possono portare allo stress cronico ed a malattie ad esso correlate. Per affrontare questa situazione c'è bisogno di un nuovo approccio nella pianificazione della città. Uno degli aspetti che i gestori del verde urbano dovrebbero considerare è l'importante ruolo che ricoprono gli ambienti naturali nel migliorare la qualità della vita dei cittadini. E' stato dimostrato che le aree boscate caratterizzate dalla presenza di molti elementi naturali sono tra gli ambienti più efficaci per la riduzione dello stress. Tuttavia non esiste un metodo empirico per caratterizzare diversi boschi urbani col fine di conoscerne la loro capacità di ridurre lo stress. Per questo motivo lo scopo di questo studio è di sviluppare un indice per valutare la naturalità di boschi urbani sulla base di come questi offrano esperienze di de-stress e rilassamento. Il risultato è l'indice WooDestress (WDI), uno strumento che considera 5 caratteristiche già adottate per la stima della naturalità in ecologia forestale. La valutazione di ciascuna caratteristica è basata su come queste contribuiscano ad offrire esperienze di rilassamento in un bosco urbano. L'indice è stato testato la prima volta in quattro parchi urbani di Malmö (SE). Stando ai risultati, la struttura principale dell'indice sembra essere funzionale, ma dovrebbe essere considerata come una prima bozza. Alcuni componenti del WDI dovrebbero essere migliorati e testati in diverse aree. Tuttavia, con il WDI è stato possibile valutare diverse aree boscate di Malmö, ottenendo valori differenti. Questo risultato, sebbene debba essere verificato, può essere considerato uno spunto per ricerche future.

Parole chiave: *WooDestress index, stress, gestione del verde, naturalità, aree urbane boscate.*

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1 INTRODUCTION

1.1 Urbanization and stress

The United Nations (2014) estimated that 54% of the world's population is residing in urban areas and that it will increase to 66% by 2050. This urbanization process leads to disadvantages such as increase of densely populated areas or polluted environments with consequences for the mental health of humans (Srivastava, 2009). Living in densely populated areas has been proved to be associated with increased social stress (Adli 2011). People who live in densely populated areas show weaker psychological health than those who live in low-density places (Fassio et al. 2011). Among other reasons, there is the fact that people are not able anymore to control their everyday life (Grahn and Stigsdotter 2003). According to Adli (2011) human brain does not seem to be optimally designed for living under the densely populated city's conditions. The overcrowding in cities leads to an increase of stressful factors, such as noise and visual complexity, which can overwhelm people (Choen 1978). In a study conducted by Stress in America TM (2013), it was reported that the stress in 42% of adults was increased in the previous year, and it was the same for 31% of teens. This means that "stress" is a problem that afflicts all society and that cannot be ignored. Moreover, stress can lead to psychic disease and psychic disease and it is considered one of the reasons of ill-health in modern society (Nygren et al. 2002). The feeling of stress can cause alterations e.g. on blood pressure and intestinal functions (Grahn and Stigsdotter 2003) or it can impair the time needed to get wounds healed (Christian et al. 2006). Chronic stress leads to other chronic diseases that have a significant public cost. For example in 2001 in Sweden, the public costs of stress-related diseases were estimated to be about 13.5 billion U.S dollars for a country with 10 million inhabitants (Sahlin 2001).
For the reasons above, issues of health and well-being are important in the urbanization scenario and they should be taken into account in the future integrated policy making (UN 2014). Town planners and landscape architects have the important task of giving a contribute in diminishing the problems related to human health. To achieve this they should focus their work also on the stress and the stress-related illnesses, trying to improve the living environment in cities (Grahn and Stigsdotter 2003). The relationship between planning and health in urban areas was one of the topics addressed by The Charter of European Sustainable Cities and Towns towards Sustainability (Aalborg charter 1996). The concept of sustainability has a wide meaning (Gatto 1995), but in a general context it can be

defined as an indefinite endurance of a given balance. The Aalborg charter (1996) presents a set of objectives to manage in order to "*sustain over time the lives and well-being of humans and animals and plants*". Among the objectives, "*human health*" is taken into consideration as something that must be "*maintained at a sufficient level*". For this, in the charter the signatory countries considered the importance of "*local actions for health*", which can be pursued mobilizing urban planners "*to integrate health considerations in their planning strategies and initiatives*".

1.2 Ecosystem services: nature and health

One of the strategies that in the last decades has increasingly assumed importance for human health is to consider natural elements and environments in urban planning. According to Chiesura (2004), the presence of natural assets in cities, like public parks and recreational areas, is an aspect with strategic importance to improve the quality of life in the urbanized society.

It has been proven that green spaces have a considerable importance in the everyday life (e.g. Hickman 2013; Ulrich 1991; de Vries et al. 2003, Bolund and Hunhammar 1999). Nature produces benefits at different levels and the study of these led to the definition of the "ecosystem services" (ESS).

According to the "Millennium Ecosystem Assessment" (MEA, 2003), the ESS are the benefits that people obtain from ecosystems. Boyd and Banzhaf (2007) defined the ESS as the components of nature, directly enjoyed, consumed, or used to yield human well-being. From their definition it is clear how people can obtain the "benefits", by enjoying, consuming and using nature components. Humankind has a close relationship with nature and it tries to get the "well-being" taking advantages of the natural services in different ways. The natural ecosystems are also present within the city limits and they contribute to increase the citizens´ quality of life (Bolund and Hunhammar 1999). The same authors named these ecosystems "urban ecosystems", including all natural green and blue areas in a city, like parks, urban forests but also cultivated lands, lakes and many others. The "Economics of Ecosystems and Biodiversity" study (TEEB, 2013) gathers the ESS into four categories: provisioning, regulating, habitat or supporting and cultural.

In the urbanization's scenario with the increase of stress related illnesses, the "cultural" category seems to assume a crucial role. Almost all the ESS classifications that consider the cultural value (e.g. Costanza et al. 1997; MEA 2003; TEEB 2013) usually refer to the concept of “enjoying the nature”. This means that humans deduce a benefit through an indirect use of natural resources, neither using nor consuming them. One of this benefits, named by TEEB “Recreation and mental and physical health”, represents the possibility of achieving well-being by walking, playing and relaxing in green spaces. In this way, natural environments seem to play a relevant role in urban planning.

Kaplan & Kaplan (1989) were among the firsts studying how nature affect mental health. They developed the Attention Restoration Theory (ART), underlining the positive effect that natural elements can have towards attention and stress reduction. The ART is based on the concept that mental fatigue can be recovered spending time in nature or looking at her. The theory proposes that exposure to nature can not only improve brain functions, but also recover and replenish its direct attention capacity. The capacity of the brain to focus on a specific task is limited and it results in ‘direct attention fatigue’, which can lead e.g. to frustration and inability to concentrate. According to Kaplan (1995), the restorative environments should have four components to be effective: extent, being away, compatibility and soft fascination. Especially the last one seems to be fundamental because it represents the environment’s aspects that can capture effortlessly the attention.

A second relevant theory in the field of the relationship between environments and health is the Stress Reduction Theory by Ulrich et al. (1991). They asserted that being in nature or viewing natural elements results in stress reduction. Hansmann et al. (2007) showed that visiting urban nature reduces the suffering from headaches and stress. According to Bodin and Hartig (2003), natural environments can be considered more restorative than urban ones. In addition, the experience in natural environments does not only help mitigate stress, but it can prevent it through aiding in the recovery of this essential resource (Kaplan, 1995).

The positive effects of the natural environments, therefore, do not occur just because physical activity is encouraged, but also for a simple passive experience: parks, trees and gardens can actually reduce stress (Ulrich and Addoms, 1981; Ulrich, 1979). The exposure to natural scenery is sufficient to reduce stress effects (Tyrväinen et al. 2005; Maas et al. 2006) and the higher the levels of stress, the more natural environments are effective (Ulrich 1986). Also, Grahn and Stigsdotter (2003) demonstrated that the more people spend time in open green spaces, the less they are affected by stress.

Many different studies demonstrate the relationship nature-destress (e.g. Pearsons et al. 1998, Kuo 2010, Alvarsson et al. 2010, Ulrich et al. 2003, Ulrich 1986, Grahn and Stigsdotter 2003). Kjellgren and Buhrkall (2010), for example, studied how some highly stressed individuals responded to 30 minutes of relax in natural environment and in simulated natural environments. The results showed that in both situations the level of stress decreased. However, the higher rate of stress reduction was obtained with the natural environment. In sight of this, the presence of urban green spaces appears not only useful but also necessary both for the human health and for a sustainable city development.

1.3 The role of management in green spaces

The management of urban green spaces has received more attention in the last years, due to the proved importance of nature in the everyday life (see above). Jansson and Lindgren (2012) connect the management of open urban spaces, such as parks and playground, to the concept of "landscape management". This discipline is closely related to other fields such as urban forestry and park management, and it can be viewed as a complex process that includes a number of different actors, elements and relationship, mutually affecting each other (Jansson et al. 2012). The actors are the formal decision makers, the politicians, their administrative staff, but also those who are outside the public administrative system, including citizens and users who have a close relation to the actual green spaces (Randrup & Persson, 2009). Users are involved in the management process through the dialogue and the participation. They play a fundamental role in the creation of spaces that fit their needs, cooperating with managers of green areas (POU model, Randrup & Persson, 2009).
A good management of urban parks should be strategic, but developed on a local community level where it can be adapted to the users' needs (Page et al. 1994).
Therefore, management seems to play a crucial role to satisfy citizens' needs in the context of a sustainable city and the importance of green spaces is increasingly taken into account by policy. Many countries in the last years have been considering the importance of creating or improving green environments within their cities. For example, a recent Italian law (L. 14 January 2013, n. 10) enunciates that regions, provinces and municipalities should promote an increase of urban green spaces. Also in Munich, Germany, specific urban forestry programs and quantitative targets were proposed for urban zones with the intention to increase the forest cover to 22% of the city's area (Pauleit and Duhme 2000). However, management has not only the role of increasing the number of green environments, but it also has to improve the knowledge on the green spaces that cities can offer. A good example is the increasing use of the urban green inventories (Escobedo and Andreu 2008). According to Semenzato (personal communication 2015), inventories plays an important role in the relations between administration and citizens. He asserts that only the knowledge of what is

managed together with the ability to plan long-term choices can enable government to explain and justify actions of management that may be unpopular and unwelcome. It is clear that the importance of urban green management in the intent of achieving the Aalborg charter’s objective (see urbanization and stress) is a process that involves both decision makers and users. However, to improve the quality of green environments it is necessary increasing the knowledge about citizens’ needs, in order to adapt the management. One of the challenges faced by urban planning in the last years was to identify and evaluate recreational and social values of urban and peri-urban green spaces (Lindholst et al. 2015).

1.4 Human needs and experiences in nature

Matsuoka & Kaplan (2008) gathered 90 articles published in Landscape and Urban Planning to have an insight on the people needs in the urban landscape. They identified six major categories further divided in two groups: nature needs, directly linked with the physical features of environments, and human-interactional needs, where the environment role is less direct. In the first group the needs of “contact with nature”, “aesthetic preference” and “recreation and play” are included. The second group refers to “social interaction and privacy”, “citizens’ participation in design project” and “sense of community identity”. These needs often interact with each other and have, as a setting, a wide variety of spaces such as parks, derelict lands, woodlands or town and residential neighborhoods. This distinction in “nature” needs and “human" needs to highlight that the frequentation of green environments can have different purposes. People can join a park to do physical activities (Cohen et al. 2007), for dog-walking (Rock et al. 2016; Koohsari et al. 2015), for social interactions (Peters et al. 2010) and many others. Chiesura (2004) examined people’s reasons to visit natural areas with the intent to help decision makers to advance strategies in adapting to people needs. The 73% of the 476 respondents indicated “to relax” as the most important reason followed by “to be in nature” and “to escape from city” respectively with 54% and 32%. Conversely, only 12% gave the answer “to meet others”. This result suggests that more people need to leave the rhythm of the city searching silence, fresh air, relax, feel the nature around and experience it through the sense (Chiesura 2004).

1.5 Park characteristics and stress reduction

In the 1990s, Grahn & Berggren-Barring (1995) developed a first classification of user's preferences and experiences in urban green areas, based on the significance of the structure of green areas. It was called the ‘8 Park Characteristics (PCA) and was intended to identify the most important characteristics and functions of recreational urban green spaces. The authors detected eight different experiences: quietness, wilderness, biodiversity, space, common, view, social and culture. Grahn et al. (2005) updated this method suggesting that human’s perception or experience of recreational qualities in urban green spaces can be captured by a range of ‘perceived sensory dimensions’ (Lindholst et al. 2015).

Most recently, Grahn and Stigsdotter (2010) applied this method to explore human’s experiences in nature. Their goal was to find out what these experiences were and what people preferred. They considered both the general preferences and the stressed people’s preferences. In their work, they detected eight kinds of experiences (almost similar to the PCA characteristics) but it turned out that only some of them were determinant for de-stress. Grahn and Stigsdotter (2010) identified “nature” as the most helpful dimension to use in case of creating an area with one single characterization for de-stressing users. However, they concluded that the combination of nature, rich in species and refuge were the most restorative experiences for stressed individuals. The “Nature” was interpreted “*as comprising an experience of the inherent force and power*” which gives a relaxing atmosphere that makes visitors feel safe. “Rich in species” is otherwise referred to “*the importance of finding a wide range of expression of life*”, like birds, flowers etc. Even though both nature and rich in species can be found in the PCA (Grahn & Berggren-Barring 1995), refuge appears like a newly found experience. In reality it can be associated to the “secure” experience but it assumes a different meaning. Indeed the authors interpreted the refuge experience like the need of “*a place enclosed by bushes and higher vegetation where people can feel safe*”. According to this study, stressed visitors prefer places wild and untouched with growing lawns (wilderness), many bushes and high vegetation (rich in species) possibly silent and calm (quietness) where they can relax and feel safe (refuge). However, Grahn and Stigsdotter (2010) do not identify a specific environment where these experiences can be found. Although any case model offers interesting insights, they need further development before they can be adopted in daily planning and management (Peshardt & Stigsdotter, 2013).

The first attempt to understand where the eight characteristics could be physically detected in parks were done by Randrup et al. (2008). They developed an index to summarize the most significant experience values for different areas using the 8 park's characteristics. They chose ten parks in the northeast of Denmark as study areas, and divided each park in different "rooms". These rooms were representative of four different types of areas with vegetation texture as discriminating. In sight of this, they divided the parks in open areas, spread areas, enclosed areas and closed areas. In each park, they identified the degree of each of the eight different dimensions within each room. Based on this analysis they developed the GreenSpex index and its value (from 0 to 24) would represent the experience potential of an area. One of the results shows that dimensions like "wilderness", "biodiversity" and "serene" are generally detected in closed and enclosed rooms, where the vegetation is dominant. According to Randrup et al. (2008) the *enclosed* rooms are characterized by the presence of high vegetation that provide a sense of space. This space is rounded by a "wall" of plants, have no ceiling and it gives the impression of glade. Otherwise, the *closed* rooms are areas where the high vegetation is still dominating but the trunks create the interior of the room and the treetops form a ceiling. In this way, the closed and enclosed structures can be interpreted like a "forest structure". This means that the experiences that are considered more powerful for relaxation and de-stress, are principally located in rooms with a forest structure.

Moreover, Randrup et al. (2008) found out that the park with the higher Greenspex index value was a forested area with a quite low maintenance level, which is related to the concepts of "wild" and "untouched" and so to the concept of "nature" (Grahn & Stigsdotter 2010). According to this study, it can be assumed that in rooms with a forest structure and a certain degree of naturalness it is more probable to find the experiences that according to Grahn and Stigsdotter (2008) are preferred by stressed users.

1.6 Urban woodlands are recreational environments

Bell et al. (2005) gives a very effective definition of urban woodland, which is described as "*a forested ecosystem of natural, semi-natural or man-made origin, used for a variety of purposes including recreation*".

The recreation is generally intended as an activity done for enjoyment, but in the precise context of visiting a forest it concerns the research of natural sceneries, solitude, peace and quietness (Tyrväinen et al. 2005). Woodlands offer these experiences because they act as a kind of intermediate landscape between the built city and the nature where people can feel the strongest sense of separation from the city (Bell et al. 2005). The high vegetation creates an inward looking landscape where quietness and harmony of nature isolate the visitor from the negative sights and sounds of an urban setting (Bell 1999). Woodlands can be pleasant environments in which it is possible to experience nature in the middle of urban life, providing people with the opportunity to recover from daily stress (Tyrväinen et al. 2005). According to Rydberg and Falck (2000), the most frequent activities in recreational woodlands are long walks or other types of activities that fulfill the desire to experience nature. For this reason, the management of these areas should probably tend to create a high degree of naturalness (Nielsen and Jensen 2007). In order to have woodlands to provide the experience of “psychic distance”, Bell et al. (2005) suggested that it might be preferable to “create impression of naturalness or wildness”. The concept of “impression” is strictly connected to the visual aspects of a woodland, which can be intended as the perception of the surrounding environment. Ode and Fry (2002) examine how urban woodland management in Sweden and UK take into account these aspects and they come up with some visual concepts used for their assessment. The main four concepts are defined as scale, diversity, naturalness and visual accessibility. Each of these is strictly related to different experiences, according to a reworking version by Nielsen and Jensen (2007). *Scale* represents an experience associated to the absolute and relative size of stands and elements. In some way, it is similar to the concept of rooms expressed by Randrup et al. (2008). *Diversity* concerns an experience at human scale, given by the number and the variation of a stand’s traits. Texture, density, species, ages and vegetation structures are the main traits that affect the diversity experience. *Naturalness* express the presence of wilderness and of stands controlled by natural processes. Finally, *visual accessibility* is the accessibility at eyelevel, expressed both as visibility and ease of movements.

It is understandable how all these aspects play a fundamental role in providing opportunity to experience recreation, intended as research of relaxation and destress through the nature and the quietness. However, even though the experiences that a woodland can promote and their main traits are clear, there is still a lacking of knowledge about the “ideal” woodland’s natural structure.

1.7 Purposes of the study

The closed and enclosed rooms defined by Randrup et al. (2008) are simplifications of a general “forest structure” that can be more variable. Both the “closed” and “enclosed” rooms can be potentially divided in infinitive other rooms depending on the variation of the traits described by Ode and Fry (2002). Between these traits can be assumed that “naturalness” is the most important. This assumption is upheld by the fact that all the other traits depend directly from “natural elements”. Both diversity, scale and visual accessibility describe experiences directly correlated to the presence of a precise set of natural elements and on their organization. Indeed the natural processes like e.g. plants competition affect characteristics like e.g. density, texture and species (Ford 1975), which can modify the other visual aspects. Moreover, as explained above these natural elements are linked to the experiences of “refuge” and “nature”, which are the preferred by stressed people.
In sight of this, “naturalness” can be taken as criterion to identify different structures in the urban woodland in which “relaxing” and “destressing” can be the main experiences.
A practical method that permits to evaluate the naturalness of a wooded area with the “relaxing potential” as discriminator does not exist. Ideally, from an urban green management perspective, it could be important to have a method that allows to estimate the woodland in a city. In that way, it should be possible to identify the more relaxing wooded areas, but also those that need to be improved to encourage citizens to frequent them. Additionally, it should be also possible to evaluate a “city’s relaxing potential” depending on the quality of the woodlands present in a city. This would help municipalities in the planning of green improvement, if necessary.
The purpose of this study is to develop an index to evaluate the naturalness of urban woodlands based on how they offer relaxing and destressing experiences. Consequently, the index is tested and used to identify which level of destressing experience the urban woodlands in Malmö (SE) offer.
For this purpose, two objectives are defined in this thesis:

1. Development of an index to assess the degree of naturalness in urban woodlands,
2. Test of the index in Malmö’s parks (SE) to describe the degree of their naturalness, and in doing so, evaluate to which degree parks users in Malmö can experience relaxation and destress.

2 PHASE 1: DEVELOPMENT OF AN INDEX

2.1 A literature review

Two steps where necessary for the development of an index useful to assess the naturalness of an urban wooded area. The first one was to deepen the concept of “naturalness” as perceived by the potential users, who are searching for relaxation and destress experiences. The second was to detect some features commons to all the wooded environments whose variability can affect the final “naturalness” degree. These achievements necessarily passed through a literature review.

2.1.1 The naturalness in wooded urban areas

The main problem in giving a definition of “naturalness” is to choose how to include in it the obvious human presence. Winter (2012), attempting to give a definition valid for a forest context, gathered different studies in which “naturalness” was already defined. From her work emerges that “naturalness” is often defined as “the similarity to the natural state”. Almost all the definitions gathered in her study tended to see human presence as a discriminator. E.g. for Anderson (1991), “naturalness” is the degree to which a system would change if humans were removed and according to Petriccione (2006) it depends also by the intensity of human interventions. Haber (1991) defined a “naturalness” scale in which he/she considered the cities as environments opposite to the primeval forests. This means that the more an environment is correlated to a city the more distant from a concept of natural is. In this way, urban parks and woods should be in principle “unnatural” because they are very distant from a “primeval forest”. The reality is that it is not possible to exclude the human presence neither from these environments nor from the naturalness’ concept.

2.1.2 Naturalness in people’s mind

The development of an index to assess naturalness “according to people” necessarily needs a background of knowledge about human preferences and needs in nature. This consideration is legitimate if we take into account that people may have preferences that not necessarily match with the traditional concept of “naturalness”, even though ecology in urban forest management gained increasing importance in past decades (Tyrväinen et al. 2003).

As discussed in the introduction, people frequent natural environments for different reasons but different are also the perceptions and the visual preferences of these environments (Nielsen and Jensen 2007). However, this work focuses on the experiences of relaxation and destress. What should be debated are therefore the natural traits that in a wooded area are able to affect those experiences. Supposing that the main function of an urban forest is to provide humans with the opportunity of feeling a kind of “distance” from the urban scene, the impression of naturalness and wildness should be preferred (Bell et al. 2005). At the same time, also “usability” is a necessary feature in urban green areas (Bonnes et al. 2007). This permits to suppose that people search an environment both wild and usable. The natural characteristics should encourage users to enter in the forest to explore it, feeling the distance from the city to relax and destress. The typical user of these areas is supposed to be a normal citizen not necessarily educated about “nature”, who choose to go for a walk with the intention of distancing him/herself from the urban environment. Kaplan et al. (1998) proposed four features in people perception of a natural setting that give interesting sparks about how an area should be structured. Three of these precisely fit to the case of a wooded area: complexity, mystery and legibility.

Complexity and mystery represent the potential for the exploration, which is influenced e.g. by the variety of the visual elements. The possibility to have focus on different components invite the user to entry and to explore. The vegetation that partially obscures the view can invite to go ahead to take a better look, giving a feeling of mystery. In this situation, it assumes importance the legibility, the presence of memorable elements like large trees that can help the user to find his way. The degree of canopy closure, the prospect and so the vegetation density, provide refuge situations (Hofmann et al. 2012, Grahn & Stigsdotter 2010) and improve the legibility (Kaplan & Kaplan 1989). The refuge play a fundamental role because it satisfies the basic human need “to see without being seen” (Hofmann et al. 2012) and it permit to avoid people crowds (Grahn & Stigsdotter 2010, Schroeder 1982). Even though density is important to create refuge and prospect, it defines also the possibility of entering in a site: the “physical accessibility” (Hofmann et al. 2012, van den Berg et al. 2007). In addition, to the structural traits also the quality of a green area assumes importance. Despite people want to experience naturalness and wilderness they dislike unsafe, overgrown and too wild areas and consider an adequate level of maintenance an important feature (Schroeder 1982, Özgüner & kindle 2006). The feeling of being safe while visiting an urban park is another need that people have (Yang et al. 2013) together with the feeling of quietness (Grahn & Stigsdotter 2010). According to Yang et al. (2013), people feel safer and more serene in environments with a large amount of woody vegetation but with the evidence of maintenance and with a cleared understory. Concerning the quietness, an important role is played by tall dense trees that can reduce the noise level (Cook 1978).

These characteristics have not an absolute value because they depend on studies carried out in precise situations and in precise geographical contexts. Nevertheless, they are very useful reference sparks and were kept in mind during the next step of the work: detect the features that define a natural structure and evaluate them.

2.1.3 Assessing the nature

In literature, different attempts to assess nature in forest stands already exist (e.g. Šaudytë et al. 2005, McRoberts et al. 2012). Naturalness assessment in forests has usually precise purposes such as to establish protection areas (e.g McRoberts et.al. 2012) and it plays an important role in nature conservation and forest management (Reif & Walentowski 2008). Despite the assessment's purposes in an urban forest are different, the structures of urban forests are often more similar to those of real forests (see introduction) and the same features observed in forestry can be adapted to this context. According to Winter (2012), the most considered features in forestry assessment literature are tree species, forest structure, fauna, ground vegetation and deadwood. The feature "structure" implies both horizontal and vertical structure represented by e.g. tree density by diameter class and vertical heterogeneity in layers.

McRoberts et al. (2012) proposed a naturalness assessment method that considers some precise features, as follows:

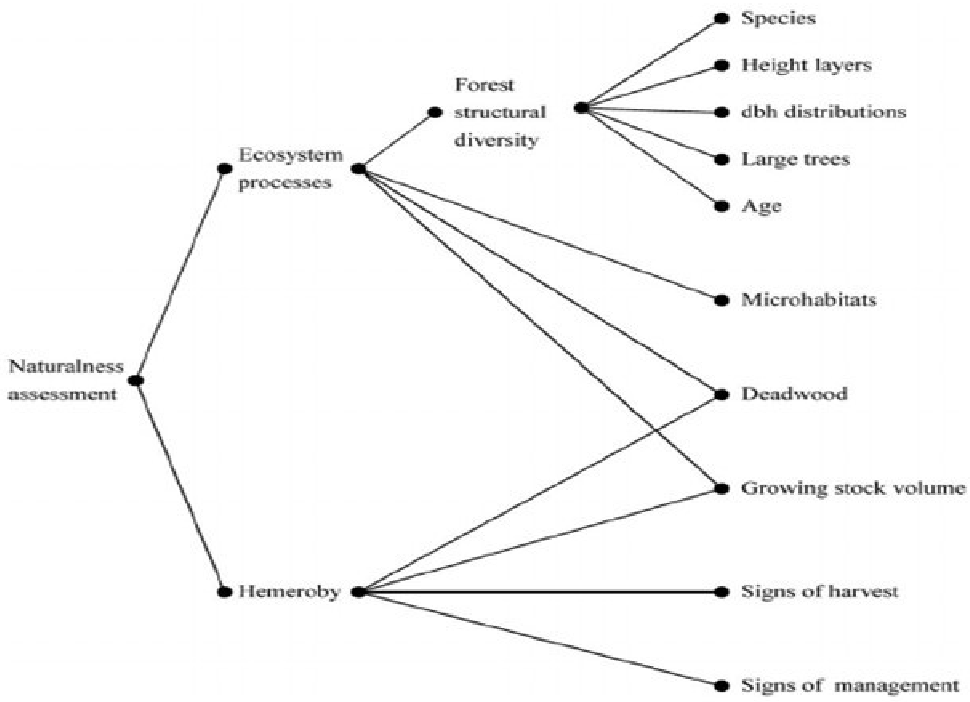


Figure 1-Reiterative scheme with the features useful to assess naturalness according to McRoberts at al. (2012).

In this method, naturalness is considered as the result of ecosystem processes and hemeroby. The ecosystem processes imply all the natural features that can be observed also with the hypothetical human absence. On the contrary, hemeroby means the influence degree of human impact on the ecosystems (Tasser et al. 2008). This distinction and the features selected in that work are useable in urban naturalness assessment, with some changes. Firstly, all the features that distinctly belong to "timber production" are neglected. This means that growing stock volumes and signs of harvest are not considered, supposing that the timber production is not allocated to urban forests with recreational value. Also, though the trait "microhabitats" is recently more considered in natural assessment (Winter 2012) it is supposed that it does not play a fundamental role in conditioning directly the user's experience. The remaining features are all adaptable to the urban forests and they can be divided in two main groups. The first one is "natural structure and diversity" and it implies all the traits that can offer to the users different degrees of naturalness and experience. In this case, they are dbh distribution, height layers, large trees, species diversity (trees and bushes) and deadwood. The second group represents the human influence and it implies the level of maintenance.

2.2 Features considered

2.2.1 Natural and structural features

The variability of these features is considered in this work as the more sharp in modifying the general structure of a wooded area, permitting different experiencing degrees.

Dbh distribution

Dbh distribution is closely related to the horizontal structure of a stand, which is important for the diversity of a forest (Forestry Commission, 1991). A large dbh variation defines an irregular spatial distribution where the small trees are clumped together distant from the large trees and that is what generally can be observed in unmanaged stands (Larocque, 2016). On the other hand, when a stand is managed, it presents an unimodal distribution (Larocque, 2016). It is supposed that to enjoy an urban forest it should be possible to walk through it and to feel the experience of isolation. For these reasons, the ideal dbh distribution stays between the two opposite extremes that Larocque (2016) describes. Indeed, if the lowest classes prevail, a situation with a high vegetation density can be determined. As a consequence, there is a lack of physical and visual accessibility. Conversely, if the large stems prevail with a few small trees, it is the opposite situation. In these areas it is more difficult to find refuge experiences because there are more empty spaces between plants or, on the contrary, there is too much space for the understory vegetation to overgrow creating a high density. A distribution concentrated on the low-middle classes can permit both accessibility, movement and refuge experience.

Large trees

According to Stagoll et al. (2011), large trees have a great natural value as they provide resources and habitat to several species. According to the same authors, large trees are keystone structures in urban parks. They are also important for the community (Jim 2005) and their aesthetical value (Millward and Sabir 2011). Large-diameter trees dominate structure, dynamics and ecosystem function in a forest stand (Lutz et al. 2013) and can be memorable elements for the users, helping them with orientation (Kaplan et al. 1998). Because large trees are identified through their diameter, this feature is combined with Dbh distribution and both these features are considered as a unique feature named DBH.

Height layers

Trees' height and canopy complexity affect the vertical diversity in a stand (McCleary & Mowat 2002). E.g., despite little trees are generally not preferred, they can improve the aesthetic value of a stand if they form a canopy layer lower than the dominant in two-story forests (Tyrväinen et al 2005).

Three main height layers are here considered:

- Layer 1 is the layer composed by all the canopies of the dominant layer.
- Layer 2 is composed by canopies' height included between the first and the third layer.
- Layer 3 is the lowest, composed by canopies lower than 3 meters (e.g. renewal vegetation, bushes).

A stand with three layers has a high distribution of prospects and is more probable to observe a wide canopy variability. It is easier for users to find refuge situations and the perceptual intelligibility is maximized. Canopies at different height can isolate the user from the city's sounds and sights, permitting a more natural experience. The presence of the first layer imply an outstanding height (>15 meters) that improve the “scale” diversity while the second layer improves the glimpses between the canopies and the third guarantees the refuge experience. If this last layer is sparse, the visual accessibility increase and the refuge experience is lacking.

Trees and bushes diversity

According to Gulik (2014), tree species diversity is paramount to maintain a long-term stability in an ecosystem. The natural conditions of environments is necessary to maintain and preserve native biodiversity (Steinhoff 2012). Considering that a positive relation between the plant community stability and the diversity of an ecosystem exists (McCann 2000), the role of trees appears to be important.

According to Nielsen and Jensen (2007) different species can indicate a high rate of diversity experience. To a species variability necessarily corresponds a canopies variability, which can improve the experience of “refuge” and “prospect” (Kaplan et al 1998). This depends on the fact that different species have different canopy shapes e.g. round, oval (Müderrisoğlu et al. 2005) but also different trunk’s shapes and colors. For this reason more species affect positively experiences of diversity and naturalness (Nielsen and Jensen. 2007). Moreover, according to Fuller et al. (2007), plants richness can contribute to enhance human psychological well-being.

The species of a wooded area for this work are divided in two main groups: trees of the dominant layer and trees/bushes of the dominated layer. The species of the dominant layer are those that define the main structure of the forest and it is more probable to find them also in the dominated layer due to the natural renewal. Supposedly, the more the species in that layer are, the more is the diversity. The diversity increases also with species of the dominated layer, which usually correspond to the second and third layers (see “Height layers” features) and to the bushes in the understory vegetation. With this classification, a great importance is given to the main species because they define the general structure and the ecology of the wooded area. The fewer are the species, the more a stand assumes the characteristics of a monoculture in which diversity and naturalness generally are lacking (Nielsen et al. 2007).

Deadwood

Deadwood is among the most often considered indicators of forest naturalness (Kunttu et al. 2015). Fallen and decaying trunks and branches on the ground form one of the most important microhabitat for biodiversity's conservation (Marchetti & Lombardi 2006). The most important fact in this context is that the conservation of microhabitat nurtures the presence of micro fauna and consequently of birds and little mammals (Morrison & Chapman, 2005). The presence of animals confers a wild and untouched quality to an area and improve the "rich in species" experience. Moreover, it is supposed that the view of the deadwood can create a feeling of "wilderness" and "untouched". However, the role of deadwood in recreation forests is unclear and still investigated (Pastorella and Paletto 2015). According to Tyrväinen et al. (2005) deadwood presence can be not preferred. It is associated to an "ecological" management that is generally accepted by the educated individuals. Also Pastorella and Paletto (2015) studied the perception and preference of deadwood in forest with 154 samples visitors. Among them, 60 visitors perceived positively the presence of deadwood component while 37 disliked it. That is to highlight how this feature is differently perceived.

In order to evaluate this feature has been adopted a rapid approach based on the quantity of deadwood covering the ground in the visual range. A neighborhood of 20-40% in ground coverage is supposed to be the perfect quantity to provide wilderness, without giving the area an aspect of messy nature.

In forestry, the quantity of dead wood is studied through the compiling of inventories. These consider the deadwood as divided in different typologies: standing deadwood, snag, dead downed trees, lying coarse wood pieces, lying fine wood pieces and stumps (e.g. Marchetti and Lombardi 2006). Considering the urban park context, only the typologies supposed to be more affecting were considered: standing deadwood (with or without branches), lying dead trees, lying fine wood pieces ($D < 8$) and lying coarse deadwood ($D>8$-10 cm).

2.2.2 Human influence feature

Maintenance

Maintenance consists of different actions like pruning or lawns cuts. In the context of this study, overgrown understory vegetation (UV) and litters (L) are considered the two main elements that can affect the perception of an area. If the understory vegetation is restrained it can contribute to the feeling of wilderness. However, when it is overgrown it can create a high density situation that can obstruct both physical and visual accessibility (Tyrväinen et al. 2005). Wooded areas with too much understory vegetation do not invite users to go inside and they can create a sense of disorder and unsafe. The overgrown understory vegetation assumes less importance if there are some paths that can promote the accessibility

(Schroeder 1982). In this situation, even when it might be complicated to go through the woods, a good experience can be guaranteed.
Concerning the litters, their absence is required and users avoid the untidy areas (Gobster, 2002). No matter how perfect the structure of a forest is, if it is dirty no one is interested in hanging out in it.

2.3 Results

2.3.1 The "WooDestress" Index

The WooDestress index (WDS) evaluates to which degree an urban wooded area can offer relaxation and destress experiences, depending on its naturalness. The features selected above are evaluated on the base of the previous debate about "naturalness" as perceived by users.
The index links to each feature a Likert scale with values included between 1 and 5, where 1 is the minimum and 5 the maximum. The higher value has a feature, the more it contributes to offer an "ideal structure" to experience destress and relaxation. On the contrary, low values mean that the feature is less sharp in providing those experiences. Each feature has a weight, depending on the importance that they have for the final natural structure, as perceived by users. Each Likert's value is multiplied by his weight and in the end it is added to the other values.

The score of each wooded areas is the result of the following formula:

$$\text{WooDestress value} = M[(0.35DBH) + (0.3HL) + (0.2SD) + (0.15DW)]$$

Where:
DBH is Diameter at breast height distribution and large trees; HL is height layers; SD is species diversity; DW is deadwood; M is maintenance. The coefficients represents the weight for each feature.

In this formula, four features (DBH, HL, SD and DW) determine the main value of the index. The feature M is not included among the main traits. Indeed, M multiplies the main value and make it decrease when the maintenance is lacking, from the moment that dirty and inaccessible woods are avoided. On the contrary, if the area is well maintained the value of M is 1 and it does not change the final value of the index. Each feature is multiplied for a weight included between 0 and 1. The higher is the weight the higher is the importance of that feature in the final value. The final score of a wooded area varies between 1 and 5 and

the higher the value the more likely it is for users to experience relaxation and destress in that area.
An important annotation has to be done. The purpose of this index is not to indicate if a wooded area is good or not; that would mean that an area with the value 5 is not better than an area with the value 1. It is just more probable that it can offer a higher quality experience because it represents the preferences of the average user. However, urban woodlands have a variation of uses and their structure is differentiated according to these (Nielsen and Jensen 2007). For this reason, a wooded area that is right or wrong in an absolute way does not exist, but what can exist is a wooded area that is better than another one for a precise use. In this case, the criterion of use is whether one can experience or not relaxation and destress. An area evaluated with a low value in this model is lacking in these terms but it can better fulfill other functions. For example, the function of a wooded area can be to mitigate near-road air pollution (Steffens et al. 2012) and it does not necessarily have to offer experiences like refuge, prospect or usability.

When to use it

The index is developed to assess the wooded areas in a city. This has to be kept in mind because the feature's evaluation is strictly linked to the context of the study. The study areas in which the index is used are meant to have a restrained dimension, they are rounded by man-made elements and can be crossed by cycling lanes, streets or open spaces. Because stressed people tend to avoid crowded areas (Grahn & Stigsdotter 2010), these woodland should have a structure able to close off the visitors. The less likely is the area to provide experiences of "isolation", the less it can be considered restorative in an urban context. A valid example can be the case of a structure with large spaces between trees. Though this structure can be considered fascinating in a normal forest, in an urban wooded area it cannot be considered of high value because the potential user would have an excessive visual accessibility.
This index can be helpful for the management of urban green areas. Firstly, it focuses on concrete features, which can be easily recognized and evaluated. In this way it is possible to have a precise set of information about an area, which should facilitate its management. With the knowledge of the features and their values, it would be easier to improve the quality of an area, focusing e.g. on the feature that are penalizing it.

2.3.2 Evaluating the features

As asserted above, the purpose of the index is to be easy to apply. For this reason, all the following features are structured to be evaluated at sight. The index is adopted evaluating the features within a visual range (see below, materials and methods). The problem of an evaluation in view is that it risks being subjective. In order to avoid that, some numeral parameter for each feature are offered.

DBH distribution and large trees (DBH)

Tab. 1, Criterion of evaluation for DBH

Description	**Value**
Prevalence of low-middle diameter classes (15-35cm) with presence of trees with diameters larger than 50 cm	5
Prevalence of low-middle diameter classes (15-35 cm) without larger trees	4
Prevalence of larger trees (D > 40 cm) and thin trees; the middle classes are lacking	3
Prevalence of larger trees (D > 40 cm)	2
High dense areas where the low classes are clearly dominant	1

The cm values inserted in the table are referred to the diameter classes.
The meaning of “prevalence” indicates that more than the 60% of the observed elements (diameters) belong to a precise class (e.g. D>40). For example, the value “1” will be assigned to the areas with more than 60% of the trees with diameter lower than 12.5 cm.

Height layers (HL)

Tab. 2, Criterion of evaluation for HL

Description	**Value**
All the layers are present and the 3rd is dense	5
All the layers are present but the 3rd is sparse or too dense	4
There are only two layers, the dominant and the dominated (3rd). This one is dense.	3
There are only two layers, the dominant and the dominated. This one is sparse or too dense	2
There is only one dominant layer; the 3th is absent.	1

The layers represent the different canopies levels. The third layer is the more easy to detect because it includes the canopies at eyes height (1.5-2.5 m). These canopies belong to the wooden understory vegetation, which is composed by the renewal vegetation and by bushes. The first layer corresponds to the dominant/higher layer, irrespective of the height, and it includes the canopies that form the stand's roof. The second layer corresponds to the canopies between the third layer and the first layer and it is generally absent in the youngest stands. A layer is identified only if it is composed by more than one tree, with the same height. Isolated plants in the visual range do not correspond to any layer.

The concepts of "dense" and "sparse" are correlated to the way in which the third layer affects the visual accessibility. If the canopies do not obstruct the visual range (in a 360° turn, see below materials and methods), it means that the third layer is absent. When the canopies obstruct the visual range, the layer is sparse or dense depending on how much the visual is obstructed.

- The view of the surrounding area is denied for 0-20%: no third layer
- The view of the surrounding area is denied for 20-40%: third layer sparse
- The view of the surrounding area is denied for 40-60%: third layer dense
- The view of the surrounding area is denied for more than 60%: third layer is too dense

The optimum is when the third layer is dense, improving the refuge experience. If it is sparse or absent the refuge experience will lack. An excessive dense layer, otherwise, can affect the anxiety or the perception of risk in the lone users (Nielsen et al. 2007).

Species diversity (SD)

Because it is generally difficult to find more than 2-3 species in the dominant layer, the classification used for this model is as follows:

Tab. 3, Criterion of evaluation for SD

Description	**Value**
The dominant layer is composed by at least 2 species and the dominated layer is composed by at least 1 species, different to those of the dominant layer.	5
The dominant layers is composed by at least 2 species, there are no different species in the dominated layer.	4
Only one species in the dominant layer and the dominated layer is composed by at least 1 species, different to those of the dominant layer.	3
Only one species at all (monoculture)	2

No values lower than "2" are assigned because also a monoculture (e.g. pine) with only one species can be fascinating and preferred by users (Tyrvainen et al 2003).
Isolated species in the dominated layer are not considered part of that layer. A species, in order to be considered in the dominant layer, should have a coverage of at least the 15%.

Dead wood (DW)

The value of this feature increases according to the presence of elements with a higher visual impact for the visitor. Lying coarse deadwood are supposed to be more important in shaping an area rather than lying fine deadwood.

Tab. 4, Criterion of evaluation for DW

Description	**Value**
The deadwood ground coverage in the visual range is >40%	2
The deadwood ground coverage in the visual range is lower than 20% or it is absent. This value is also assigned to the areas with a prevalence of lying fine wood pieces even if in the optimal range.	3
The deadwood ground coverage in the visual range is between 20-40% and it is prevalently composed by lying coarse deadwood and/or lying dead trees. Lying fine wood pieces can be present or absent.	4
The deadwood ground coverage in the visual range is like the previous class but there is the presence of standing deadwood	5

Maintenance (M)

The M value is calculated as the product between the understory vegetation and litters.

$$M = UV \times L$$

UV and **L** are evaluated separately because they are independent from each other.

Understory vegetation

- **UV=1** absent understory veg. or if it is present it is not overgrown; people are invited to enter and they walk through the trees.
- **UV=0.9** the area has an understory vegetation that allows the access. Here it is possible to find a way to walk through the trees, e.g. with some paths.
- **UV=0.8** the area has an understory vegetation that doesn't allow the access. It is impossible to enter or find spaces to walk through the trees.

The choice of values like 0.9 and 0.8 relates to the fact that the purpose is to reduce the final value of an area without penalizing it excessively. Despite the denial of accessibility, an area offers a natural experience that can be enjoyed even if it does not allow a direct entrance in a stand.

Litters

- 1= the area is clean
- 0.7 = presence of some litter, disturbing for the experience.
- 0.5 = presence of much litter; the area is avoided.

The choice of 0.7 is to underline the weight of litter's presence, in comparison to the understory vegetation. Allegedly, people prefer the overgrown vegetation rather than the litter's vision. For the same reason, an excessive presence of litter reduce to half the final value, supposing that no one is interested in walking through a dirty wood.

Taken the value above for granted, **M** varies between two values:

- **1** (with **UV=1** and **L=1**); the maintenance in the area is good
- **0.4** (with **UV=0.8** and **L=0.5**); bad maintenance, the area is dirty and inaccessible

Tab. 5, Values for L and UV and their relationship.

M		Litter		
		1	0.7	0.5
Und. Veg.	1	1	0.7	0.5
	0.9	0.9	0.63	0.45
	0.8	0.8	0.56	0.4

2.3.3 Weights of the features

Not all the features selected have the same significance in contributing to the final "naturalness" degree. For this reason to each of them is assigned a weight and the weight's amount has to be 1. "DBH" and "HL" are considered the main features because they affect directly the shape of a woodland and, as discussed, their variability define the basic structure, the prospect and the visual impact of a wooden area. To these features is assigned a total value of 0.65/1, with 0.35 to DBH and LT, and 0.30 to HL.

"SD" can ameliorate the basic structure of the urban forest contributing to increase the diversity and the complexity. Different plants and different crown shapes can eventually give a contribute to the final structure of the wooden area. For these reason a 0.2/1 value is assigned.

"DW" have the latest importance with 0.15/1: even though it produce wildness, it is not pivotal basic for primary users' needs and it does not contribute to create the main structure of the wooded area.

Tab. 6, The feature´s weights and the min. and max. value that can be obtained considering the natural fetaures.

Natural features	Range values	Weight	Max weighted value	Min weighted value
DBH	1-5	0,35	1,75	0,35
HL	1-5	0,3	1,5	0,35
SD	2-5	0,2	1	0,4
DW	2-5	0,15	0,75	0,3
TOT.		1	5	1,4

2.3.4 Index structure

The index is organized in three sections.

The first section is necessary for the formal identification of the studied area:

Locality	Name of the city where the studied area is
Area name	Name of the urban/peri-urban park where the model is applied
Date	Date in which the model is applied. To have a time reference is important, especially for features that can change during the seasons.
Wooded area	Tracking number to identify the considered wooded area. It is especially necessary in parks where different wooded areas are studied.
Sample	Tracking number to indicate different samples used to study the same wooded area

The second section concerns a description of the studied area. Here all the features not directly considered by the model can be noted, e.g. the age of the stand, its accessibility, the name of the observed species, the slope etc. This section is fundamental for a green manager because it works as a support to the final value of the model, giving him/her some extra information.

The last section includes the real index with the features' schedule. Here, all the features are listed with their Likert's scale and for each value a synthetic description is given. The different weight for each feature are already inserted for an easy compiling.

The final format of the index is in the Appendix section.

3 PHASE 2: TESTING THE INDEX

3.1 Materials and methods

Areas of interest: the parks and their woodlands

Malmö is the third main Sweden's city, has around 20 parks and it is plenty of neighborhood's green areas. Four of these were selected, with the suggestion of the Malmö Stad Commun, and examined before to choose the wooded areas in which testing the index. The selected areas are: Kungsparken/Slottsparken, Pildammsparken, Bulltofta rekreationsområde and Remonthagen, as shown in Figure 2

Figure 2 – An overview of the city of Malmö and the four study's areas

Kungspaken/Slottsparken and Pildammsparken are located close to the downtown and they can be considered as the main city's parks, which makes them probably the most frequented green areas in the city. Bulltofta and Remonthaghen, otherwise, are suburban parks, located close to the east limits of the city's municipality. These parks are frequented for different purposes according to their dimension and location.

Tab 7 - Reiterative table with the main parks' information. [1]The main parks characteristics are based on the Grahn and Stigsdotter (2010) classifications. To each park are assigned the characteristics that seem prevail, according to their description.

Name	Typology	Main parks characteristics [1]
Kungsparken/Slottsparken	Downtown park	Social, culture, rich in species, prospect
Pildammsparken	Downtown park	Space, social, culture, prospect
Remmonthaghen	Neighborhood green area	Nature, social, refuge, serene
Bulltofta	Recreational/sport area	Nature, prospect, social, rich in species, refuge, serene

Kungsparken/Slottsparken (Kun)[2]

Kungsparken is a park with the typical century style characteristic. It covers 21 hectares and it present large sections of forest, open grassy areas and a variety of viewpoints and seating. It is a park prevalently to stroll and to have sits to admire the area. There are two large ponds, a high variety of plants and a small Japanese garden. In the heart of the park, there is the "Saturday Plan", which is used for socializing or concerts and all sorts of arrangements. Slottsparken has a plenty restrained wooded stands. Two of the larger stands are located next to Linnèplatsen and cover around 2 ha each. The other stands are located between Kung Oscars väg and Regementsgatan or Mariedalsvägen. They are no larger than 1.5 ha and they are bordered by cycling lanes on three sides and by Kung Oscars väg on the last side.

Pildammsparken (Pil)[2]

Pildammsparken is the largest among the Malmö's downtown parks. It is constituted by different attractions as a great pond with three fountains or themed playgrounds and open-air gyms. The park has many paths connecting different areas among which running routes, a restaurant area or a great beech forest. This forest cover almost the half of the total park's area and t surrround a circolar lawn more used by the citizens, e.g. to play or have a pic-nic. The forest is fragmented by passageways, roads and some structures like an open-air nursery.

Bulltofta (Bul)[2]

Bulltofta is a recreational area projected in the late 1970s and, among the chosen parks, is the one with the most abundant kinds of natural settings. The construction of this park started in 1983 and it is located on what until 1972 was the Bulltofta airfield. The main reason that encouraged its creation was the need to improve the number of natural lands close to Malmö. Indeed, due to its position on the plain of Skåne, the third Sweden's city completely lacks natural forests. The basic idea was to create a green area with strong

natural flavor and, through an ecological approach, holding down both construction and maintenance costs. Around 250.000 half-meter high trees were planted between 1983 and 1992 so that the trees nowadays are 25-35 years old. The goal was to obtain in 20 years a plantation that would be experienced like a forest. In order to accelerate the growth were firstly planted species as willow, poplar, alder, birch and larch which were in competition for the light. In the understory were planted slower-growing noble deciduous trees as oaks, beeches, ashes and maples. More of the pioneer plants were thinned and gradually removed and the noble broadleaf trees are going to dominate the stands. Bulltofta today offers various natural sceneries with forests, water, meadows and hills with richness both in flora and in fauna. Moreover, it is an area that offer the possibility to practice many different sports.
The natural zones in bulltofta occupy the majority of the area and various deciduous section can be found. These have different sizes, from restrained stands around 0.2 ha to larger wooded areas of 16 ha.

Remonthagen (Rem)

Remonthagen is a restrained neighborhood green area with a small playground and many wooded stands. These are scattered in all the surface and they create an alternation of closed, enclosed and open stands.

[2] *the information on the parks were obtained through the Malmö Stad website.*

Wooded areas: selection and criteria

The main purpose in selecting the wooded areas was to have at least one woodland from each of the described parks to study. It was independently from the dimension and the location. Indeed, only Pildammsparken and Bulltofta have wooded areas larger than 3 ha and only in Bulltofta and Remonthagen many of them are located far from roads. The choice of areas so different between each other was also justified by the purpose of this work: a variation of positions and dimensions could have been connected to different index’s values. Therefore, the studied areas were not randomly chosen, but they were detected in order to represent each park and different situations at the same time. The first step in selecting the wooded areas was conducted consulting some park maps provided by the Malmo Stad Commun (see appendix). In these maps, the wooded areas are recognizable for their color and code. Within each selected areas were distinguished different stands. In this work, the “stands” are areas with a dominant vegetation homogeneity. The border between two different stands can be represented by a variation in the dominant vegetation or by a physical distance e.g. roads or large passageways. Each selected stand is named with the first three letters of the park's name (e.g. Rem, Pil) followed by a general letter. According to these premises, the table xxx shows the selected stands for the model testing. The maps of the areas are attached in appendix. They were tracked adopting the open source softwere Quantum Gis. The maps used are from Google Satellite 2016 and they were obtained through the plugin "open layer" available on QGIS.

Tab. 8, The selected stands for the study

Bulltofta		Remmonthagen		Pildammsparken	Kungsparken	
Bul_A	Bul_B	Rem_A	Rem_B	Pil_A	Kun_A	Kun_A1
Bul_C	Bul_D	Rem_C	Rem_D		Kun_B	Kun_C
Bul_E	Bul_F	Rem_E	Rem_F			
Bul_G	Bul_H					
Bul_I						

<u>Malmö stad's maintenance plan</u>

In order to investigate the nature of the different stands, the maintenance plan of Malmö stad (Gemensam arbetshandling Funktion, 2012) and the linked maps were consulted. In the maps, each area, belonging or not to a park, is marked with a code. Each code corresponds to a general description of an area's kind, which is described in the maintenance plan. The codes corresponding to the selected stands are basically two: VY4 and T0. The first code belongs to the context of "*Vattenanlägging*", and precisely to section "other water" (*vatten övrigt*). Indeed, VY4 represents areas with streams, constructed or natural, useful to improve both the city biology richness and the beauty of those stands. Actually only one among selected stands (Rem_B) is marked with this code. The second concerns the trees (*Trad*) section, and precisely it represents the general stands with trees and bushes (*trad och buskbestand*). These stands are composed by native species of trees and bushes that shape a kind of forest relatively young and natural. All the selected stands are marked with this code.

<u>Method: application of the model</u>

Given that the character of the model is to be easy to use, also its application should be simple. The goal indeed was to adopt a "sampling" method that could make the data collection faster. In sight of this, the method is thought to observe an area as large as possible; emulating the user's walking experience. This is useful for the green managers that potentially could use this model: it accelerates the fieldwork, with economic advantages, and it allows a stand's visual similar to the one that the users have.

The model was adopted according to the following phases:

1. **Tracking a route**

In this phase after having consulted the park's maps, a linear route within each stand was determined. The line's length depended on the surface of the area. Each point of this line was, where possible, distant at least 15-20 m from the vegetation's border. That was to avoid the areas with a different structure in comparison with the inner of the stand.

2. **Walking the route**

Each stand was crossed walking along the linear route determined in phase 1. In that way the user's walk was emulated. While the stand was crossed, the surrounding area was observed. In that phase eventual notes were written in the "forest description" section of the model and some pictures were taken.

3. **Evaluating the features**

Along the route, roughly every 50 meters, was made a stop. Standing on the stop position, the surrounding area was observed at 360°. In this phase the model was adopted and each feature was evaluated. All the features were evaluated in view without any measurement. The only instrument adopted in this phase was a caliber to measure the tree's diameter, when it was not clear to which class it belonged. The distance between two consecutive stops was checked with a normal watch equipped with a GPS sensor. However, it was not always accurate and it changed depending on the kind of the stand. The stand with high variability required more frequent stops while those with a lower variability needed of less stops. The smaller stands had only one stop in the middle of the area. This phase and the previous one were performed during the month of May in order to have an adequate evaluation of the features SD and HL.

4. **Calculating the value**

The collected data were organized on a spreadsheet and the value of stands was calculated, through the formula already explained:

$$\text{WooDestress Index} = M[(0.35DBH) + (0.3HL) + (0.2SD) + (0.15DW)]$$

The value of each single feature in the stands with more than one stops was calculated as:

$$X = (\sum_{1}^{n} \frac{St_1 + St_2 + St_n}{N})w$$

Where X is a generic feature, *St* is the value assigned in each single stop, *N* is the total number of stops within a stand and *w* the weight conferred to the feature.

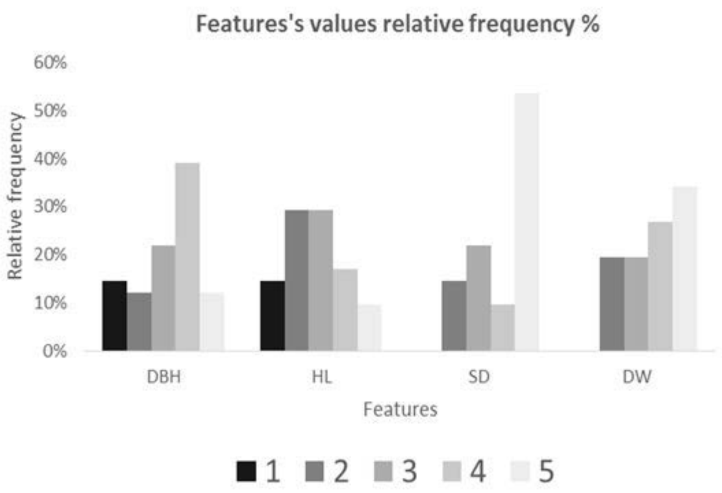
3.2 Expected results

Concerning the application of the index, no precise results where expected by the fact that the index was adopted for the first time. A particular attention was pointed to the different features and to their division in classes. In the moment that the model considers a restrained number of features and values, it is supposed that the components chosen to develop the index are sufficient to describe the parks. The results should indicate if the features and the values are adequate to describe the Malmö's parks. Among the features, SD and DW are the two more interesting parameters to observe. The first one was divided according to the hypothetical number of species in a stand, without knowing what the norm in an urban forest is. For this reason, the values that will be assigned to this feature will be very useful to increase the knowledge about the diversity in parks and to improve the model itself. Concerning DW, the expected result is to find more deadwood in the suburban parks rather than in the downtown parks where the cleaning is probably higher. Moreover, the value that represents the presence of dead standing trees is attended to be the less used, especially in Pildammsparken and Kungspaken. Another important expected result is the ability of the parks in offering "destressing experience", according to their naturalness. After a reconnaissance, a classification of the studied parks is hypothesized. Bulltofta is supposed to be the better area. It has very large stands that seems to be wild but in the same time they are served with path that encouraged the user to enter in. Pildammsparken is collocated in the middle because has a very huge old wood but it doesn't seem to offer refuge experience. Kungsparken and Remonthagen are supposed to be worst areas. In Kungsparken the social factor prevails and it does not seems to be designated to activities different from the user's estrangement. Remonthagen, contrarily, seems too wild, young and with a catchment area restrained that probably determines a little attention from the municipality.

3.3 Results

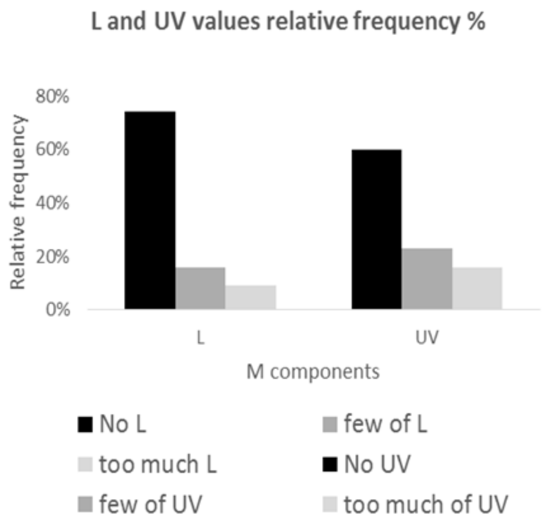
The features

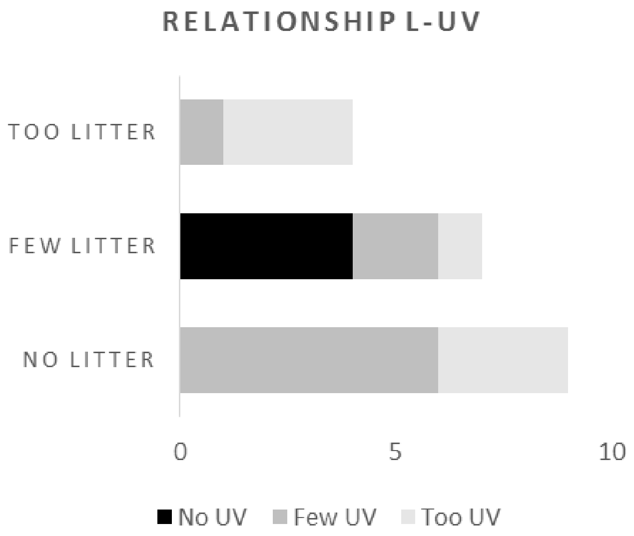
The index is based on 5 features and on their relative set of values. The first step to test the index was to understand if the features and the values were adequate to assess the naturalness in the urban woodlands. In order to study their effectiveness, the frequency in which they were used was examined. The model was applied 43 times in 43 different areas and each feature has the same number of measures. The values that could be assigned during the measures were different according to the feature: "DBH" and "HL" have value that change between 1 and 5, while "SD" and "DW" have value varying between 2 and 5.
The first result is that all the values, within each feature, was assigned at least one time. In addition, it was possible to connect each feature observed in field to a precise chosen value. This indicates that the different chosen values within each feature can represent the woodlands in Malmö. In order to deepen the efficiency of each value, their relative frequency was studied. The relative frequency considers all the 43 values that where assigned with the model distributed for each feature.



Graph 1-The relative frequency of the assigned values in each feature

An interesting result concerns the SD feature, there is a great difference between the most used value and less used value. The value "5" has been assigned 22 times while "4" has been assigned only 4 times. These classes describes similar situations and this result underlines a probable inadequacy in their differentiation. The feature DW shows a good balance among the classes but most interesting result is that the classes "4" and "5" are the most used. In more than the 60% of the times it was found the lying deadwood, and in 39% of the stops were detected some dead trees standing. This means that the deadwood is a common feature in parks in Malmö, especially in the downtown parks where the classes “4” and “5” are the most used.





Graph. 2 (left) and 3 (right) –The relative frequency of L and UV in all the 43 stops and the relationship between UV and L in these stands. UV is more frequent than L but often if there is UV is more probable to find also L.

The same study was done for maintenance components: L and UV. It resulted that the most frequent condition is the absence both of litters and understory vegetation. The UV is more frequent than the litters that are resulted “too much” only in the 9% of stops. This percentage is mainly concentrated in Kungsparken’s stands. However, the higher frequency of the classes that represent “absence of UV/L” indicates that in general the Malmö’s parks are well maintained. The graph 3 shows the relationship between L and UV. It can be observed that in 3 stands of 4 there are both high levels of L and UV. This suggests that cleaning the understory vegetation can be less probable to find high quantity of litters.

The stands

Among the 43 times in which the model was adopted, 17 times was in Bulltofta, 11 in Remonthagen, 9 in Pildammsparken and 6 in Kungsparken. Concerning Bulltofta and Kungsparken, the number of observations is coherent to the surface area. The larger woodland (Bulltofta) has the higher number of model application while the smaller (Kungsparken) has the lower observation's number. The situation is different concerning Remonthagen and Pildammsparken. Though the woodland in Pildammsparken is larger than the total wooded surface of Remonthagen, the model was more used in the last one. The reason is in the homogeneity of the Pildammsparken's forest, which permitted less observation. The following table represents the value obtained with the model for each stand. These values are included between 0.86 (Rem B) and 3.6 (F).

Tab. 9, The values of each stand obtained applying the WooDestress model.

	STANDS AND VALUES								
Bulltofta	Bul_A 2.3	Bul_B 3.35	Bul_C 3.4	Bul_D 3.3	Bul_E 3.5	Bul_F 3.6	Bul_G 2.7	Bul_H 3	Bul_I 3.5
Remmonthagen	Rem_A 3.05	Rem_B 0.9	Rem_C 2.6	Rem_D 1.9	Rem_E 3.3	Rem_F 2.4			
Kungsparken/Slottsparken	Kun_A 1.2	Kun_A1 1.2	Kun_B 3.1	Kun_C 1.2					
Pildammsparken	Pil_A 3.3								

The 20 values obtained with the index can be divided into 4 classes. This process of clusters division is generally conducted through a cluster analysis but in this study it was not applied. The index, indeed, conferred to each stand a score, which already permits to gather them according to their similarity. Considering the distribution of the values, the classes corresponds to four neighborhood: 1±0.5, 2±0.5, 3±0.5 and 4±0.5. These classes were representing different degrees of naturalness and the higher is its value, the more the stand is supposed to offer a relaxing experience. For this reason, the classes were named according to the kind of experience that could be offered: good experience (Ge), fair experience (Fe), poor experience (Pe) and no experience (Ne). Moreover, the score 2.5 is proposed as separating value between two general kinds of areas. It is supposed that the stressed people prefer to frequent the areas contained in Fe and Ge, avoiding those in Pe and Ne. With this further simplification, according to the results, 13 stands are higher than 2.5 while 7 stands are lower. The stands of Bulltofta and the one of Pildammsparken belong to the first group. The stands of Remonthagen and Kungsparken belong to the second, with the exception of Rem_E and Kun_B.

Tab. 10, Here are represented the four range with the stands that composed them. The red line on the value 2.5 represent the division between frequented and avoided areas.

Range values	4 ± 0.2	3 ± 0.5	2 ± 0.5	1 ± 0.5
	good experience	*fair experience*	*poor experience*	*no experience*
Stands	Bul_F Bul_E Bul_I	Bul_C Bul_B Bul_D Rem_E Pil_A Kun_B Bul_H Bul_G Rem_A Rem_C	Bul_A Rem_F Rem_D	Kun_A Rem_B Kun_A1 Kun_C

Frequentated areas<-------2.5 ------> Avoided areas

The table 10 shows that the stand's distribution within the classes is not homogenous. The 50% of the stands are included in "fair experience" while only the 15% of the stands offer a "good experience". The remaining 35% is gathered between Pe and Ne. Supposing that the stands within the same class had similar features, an analysis of the most frequent values (MFV) was conducted to evaluate them. The intent was to characterize each class, where possible.

The results are gathered in the following table.

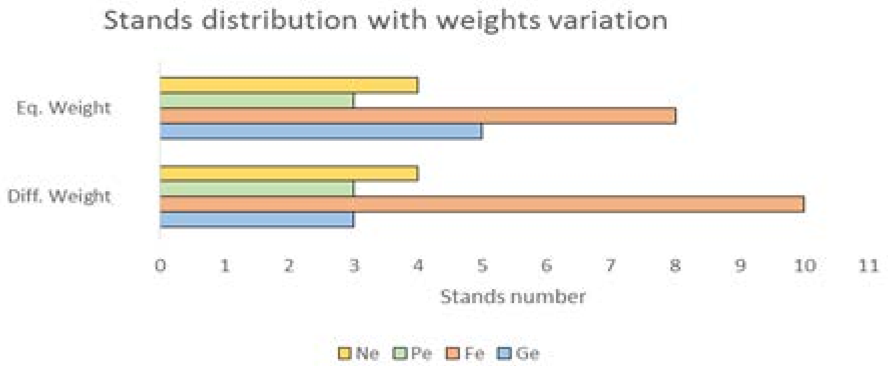
Tab. 11, The most frequent values (MFV) and their relative frequency within each range.

	Good experience N=7			Fair experience N=26			Poor expereince N=6			No expereince N=4		
Features	**MFV**	**frequency**	**Relative frequency**	**MFV**	**frequency**	**Relative frequency**	**MFV**	**frequency**	**Relative frequency**	**MFV**	**frequency**	**Relative frequency**
DBH	4	6	0.86	4	10	0.38	1, 5	2	0.33	2	3	0.75
HL	5, 3, 2	2	0.30	3	9	0.35	1, 2	2	0.33	2	3	0.75
SD	5	4	0.57	5	13	0.50	5	4	0.67	5	3	0.75
DW	4, 2	3	0.43	5	10	0.38	2	4	0.67	4	2	0.50
L	1	7	1.00	1	14	0.54	0.7	4	0.67	0.5	4	1.00
UV	1	6	0.86	1	8	0.31	1	3	0.50	0.8	3	0.75

The table 11 shows that common characteristics among the stands, within a same range, are lacking. Among the features evaluated between 1 and 5, SD is represented with high frequency in all the ranges. This aspect was already described in the features section. The high frequency of DW, with the values 4 and 5 in the first two ranges, suggests that it contributes consistently to the final value of the stands. The same is for DBH which is mainly represented by the value 4, that is also weighted for the highest weight. This can explain the presence of many areas with DBH = 4 in the higher ranges. However, should be considered that the stands are few and that they are not all represented by the same number of values. E.g. the range Fe has a total number of 26 model application but the 35% of them belong to only one Park (Pildammsparken). This means that the number of observation is probably too small and heterogeneously distributed to can characterize the ranges. The only indicative feature is M, considering that only L and UV have a prevailing value in all the classes. The most assigned values for both the M components is 1 concerning the ranges Ge and Fe. In Pe the relative frequency of the value 1 is lower and it disappears in Ne. The decrease of M from the higher to lower ranges suggests that M is the feature that affects the more this precise stand distribution among the ranges.

A further step to analyze the functionality of the index was conducted through some comparisons between the values obtained after the variation of the features' weights. The intent in varying the weight was to understand if they were necessary or not in order, eventually, to simplify the index. For these reasons, the values obtained were considered both the original weights and the equal weights (all the feature with a weight of 0.25).

To compare the different situation were considered the same ranges obtained with the original formulation. In that way was possible to observe how the variations were changing the quantity and the dimension of the ranges.



Graph 4, The comparison between two different situation varying the weights. Eq is "equal" while diff. is "different".

The graphs 4 shows that the ranges remain nearly unchanged with the weights variation. This suggests that probably the chosen weights are not strictly necessary. However, from the moment that the graph shows only the ranges variation and not the stands values, a comparison between each single value was performed. In order to do that, the difference between the values for each stand was calculated. The result shows that all the stands have a variation lower than 0.3. With this variation 19 stands of 20 had their value changed but only 3 among them changed range. Bul_B and Bul_D pass from the range Fe to the range Ge, while Rem_E passes from Pe to Fe. (Tab. 12).

Tab 12, Comparison between the stands that change range modifying the weights. The table show the increasing Importance that DW and SD assume for the final value.

	(SD+DW)/tot value		***DBH and H = 1***	
	Diff. Wgh	Eq. Wgh	Diff. Wgh	Eq. Wgh
Bul_B	40%	57%	4	3.75
Bul_D	53%	70%	2.7	2.16
Rem_F	60%	74%	2.25	1.9

In the table 12 the first column represents the increasing contribute of SD and DW to final values if the weight would be equal. The second column shows the variation of the stands values if, hypothetically, DBH and H would be 1. The result indicates two aspects. The first is that in these areas, equalizing the weights, SD and DW assume more importance than HL and DBH. Their contribution to the final value is >50%. The second is that the contribution of SD and DW in 2 of these stands is higher than the contribution of DBH and HL also if the different weights are considered. This suggests that the weights are important but also that they should be inspected. The lower are the values with the high weights (DBH and HL), the higher become the contribution to the final value of SD and DW. The problem could be that areas potentially inaccessible but with high values of DW and SD could have a final value higher than 2.5, which collocates them among the good areas.

The parks

One of the purposes of the study was to understand which degree of relaxing experience the parks in Malmö are able to offer, according to their naturalness.

The answer to this query can be given through two different procedures. The first is to focus on the single stands within a park while the second is to consider the entire parks as composed by the different stands. Focusing on the single stand values, the previous results are quoted. Considering the ranges detected and the number of stands in each of them can be proposed a general classification of the parks. The areas that belong to the high range are all from Bulltofta and for this reason this park is considered the best. People that search a relaxing experience know that Bulltofta offers some stands in which is possible to escape from the city and have e.g. a destressing walk. The second range is always represented by a higher number of Bulltofta's stands followed by 2 from Remonthagen and one both from Pildamspaken and Kungsparken. Given that Kungsparken is represented by the stand with the lower value in comparison with the others, it represent the park where is more hard finding a relaxing experience. Concerning the stands in Rem and Pil there are no great difference in value and so these parks can be considered a middle way between BUL and KUN.

The second method considers the parks as the result of the set of each stand within its borders. To calculate the value of each park has been used a weighted average, as follows:

$$\sum_{0}^{n} \frac{\boldsymbol{Sv_1 W_{1,2,3,4} + Sv_n W_{1,2,3,4}}}{\boldsymbol{W_{1,2,3,4}}}$$

Where Sv is the stand value while W is the weight, that change between 1 and 4 depending on the range in which the stand is. W is 1 in the lower range (Ne) and it is 4 in the higher range (Ge).

The weighted average of each park has been calculated considering or not M and also changing some weights.

Table 13 - The value obtained by the different parks considering the variables. OW is original weights, No W is no weights, CW is changed weights (0.6 DBH, 0.2 HL, 0.15 SD, 0.05 DW), No DW and SD is without considering these features. The higher and the lower values for each scenario are underlined.

	With M				without M			
PARKS	OW	No W	CW	No DW and SD	OW	No W	CW	No DW and SD
PIL	3.3	3.4	3.2	3.2	3.3	3.4	3.2	3.2
BUL	3.25	3.3	3.4	3	3.5	3.5	3.61	3.2
REM	2.6	2.7	2.4	2.2	3	3.2	2.9	2.7
KUN	2.1	2.3	2	1.8	3.3	3.6	3	2.7

The results show that when M is considered, PIL and BUL have always the higher values, while Kungspaken is always lower than 2.5. Remonthaghen has lower values when SD and DW are less or not evaluated. When M is not considered, many values change. With the original weights, Bulltofta results as the best park but with equal weights Kungsparken become the best one. However if SD and DW are less or not evaluated KUN has a value just higher than 2.5 and PIL is the park that offers the best experience. However, considering or not M, the difference between REM/KUN and BUL/PIL is common in almost all the areas. That permits to confirm partially the expected results and the following classification can be proposed:

A) Bulltofta and Pildamsparken
B) Remonthagen
C) Kungsparken/Slottsparken

The features that mostly characterize the parks are gathered in the table below.

Tab. 14- The most frequent values (MFV) and their relative frequency within each park. The stands are 17 in Bulltofta, 9 in Pildamsparken, 6 in Kungsparken and 11 in Remonthagen.

	DBH			HL			SD			DW			L			UV		
Parks	MFV	Freq.	rel. Freq	MFV	Freq.	rel. Freq	MFV	Freq.	rel. Freq	MFV	Freq.	rel. Freq	MFV	Freq.	rel. Freq	MFV	Freq.	rel. Freq
Bulltofta	4	13	0.76	3	7	0.41	5	9	0.53	4	6	0.35	1	14	0.82	1	11	0.65
Pilldamsparken	3	5	0.55	4	4	0.44	2	5	0.55	5	7	0.77	1	9	1	1	9	1
Kungsparken	2	3	0.5	2	4	0.67	5	6	1	5-4	3	0.5	0.5	3	0.5	0.8	5	0.83
Remmonthagen	1	6	0.55	3	6	0.55	5	9	0.82	3	5	0.45	1	7	0.64	1	6	0.55

The table 14 shows the values for each feature that are the most frequent within each park. Almost all the relative frequency for each MFV are higher than 0.5 but only three times the rel. freq. is 1. This means that within each parks there is a great variability among the features and all the parks are constituted by different stands. The only park that has all the relative frequency higher than 0.5 is Kungsparken but it is principally due to the low number of stands (6).

A-Bulltofta

Bulltofta is the park that offers the woodlands with the higher values, according to the index. Among the 9 stands identified, 7 have a value higher than 3 and that means that are collocated in the range that offers a fair experience. The woodlands in Bulltofta are various and that is correlated to the story of this park (see materials and methods). The vegetation within each stand is generally equal in age. In this park is possible to observe a comparison between stands with different kind of vegetation and natural structures.

Bul_F is the stand with the highest value (3.6). The vegetation in this area is varius and the main species are oaks (*Quercus robur),* limes *(Tilia platiphyllos*) and ashes (*Fraxinus* *excelsior*). There are also many *Prunus avium*, *Corylus avellanae*, *Ulmus glabra*, *Acer campestre*, *Acer platanoides* and *Cornus mas.* It is easy to walk through the stand because the trees are distant and the understory vegetation is absent. The layers vary along the stand that is composed by an alternance of zones with only one layer to other with all the layers. The DW is too abundant and it generally gathered in pile, which are not aesthetic.

Figure 3. The inner visual of Bul_F with an Ulmus glabra in foreground. Figure 4. A wooden pile in the middle of Bul_F.

The worst area in Bulltofta is Bul_A. It has a value of 2.3 and it located close to the main entrance of the park. There is no a precise vegetation within this stand: in some zones prevail beech and larch with some birch, while in other prevail *Quercus robur*. Probably in this stands is going on the thinning to favor the broadleaves (see material and methods) and the inner of the stands seems empty and the visibility is high. More cut trunks are left untidily lying on the ground.

Figures 5, 6. The inner visual of Bul_A. In both the pictures can be observed the large amount of deadwood. In fig. 5 it is constituted by large trunks.

2-Pildammsparken

The selected areas are not homogeneous in the space because they are interrupted by paths and streets. However, considering the homogeneity of the dominant species (*Fagus sylvatica*), they can be considered as part of the same forest. In this woodland the model has been applied 9 times in order to represent in the best way the largeness of the area. The final value assigned to the woodland in Pildamsparken is 3.3. The first evident characteristic of this area is that the understory vegetation is lacking. This is due to the characteristics of the beech that dominates the area. These plants sprout early, at the very beginning of the vegetative period, overshadowing all the underlying ground impeding in that way the overgrowth of the understory vegetation. The only different species that can be found in the dominated layer are *Symphoricarpos albus* and *Sambucus nigra*. Many birches (*Betula pendula*) where present before to be dominated by the beech and now they contribute to enhance the area as standing deadwood. Moreover, it must be consider that Pildammsparken has a connected system of path and it is frequented for activities like walking or running. This habitual useage by many people probably determines a high maintenance level in the area. Birch is the only species in the dominant layer different from the beech, also if it is represented prevalently by dead examples and so it contributes to the amount of deadwood in the woodland. The woodland in Pildammsparken is relatively monotonous and does not present diversity both in vegetation composition and structure. The range of vision is wide and the high frequented areas like roads or meadow are sufficiently visible, impeding a total experience of separation from the city.

Figures 7, 8- Inner visuals of the woodland in Pildammsparken. Here the prevalence of one dominant top layer and the wide range of vision can be noticed.

However during the application of the model was observed an interesting aspect. Precisely in the stops 7 and 8 the structure of the stand was totally different from the rest. The peculiarity of this stand is the presence of a gap in the canopy layer that allowed the light to reach the ground. In this area indeed, the renewal layer is developed and the structure is more complex with the presence of other species as *Ulmus glabra*. Standing in the middle of this area, the range of vision is limited and only some glimpses are visible. The structure isolates the user and encourage him to go ahead to explore. At the same time, the understory vegetation does not complicate the passage and the area does not seems unsafe but natural and with a right amount of wilderness.

In order to underline this difference, the value of Pildammsparken was calculated again to examine the importance of the high-diverse areas.

Tab. 15, *The value obtained by Pildammsparken in different situation: considering all the areas, excluding the areas with high diversity and considering only the high-diverse areas. OW is original weights, No W is no weights, CW is changed weights (0.6 DBH, 0.2 HL, 0.15 SD, 0.05 DW), No DW and SD is without considering these features. The higher and the lower values for each scenario are underlined*

PIL. Park	OW	No W	CW	No DW and SD
All 9 stops	3.3	3.4	3.2	3.2
Diverse areas excluded	3	3.2	2.8	2.7
Only diverse areas	4.3	4.1	4.5	4.75

The result shows that Pildamsparken actually has a value lower than the one assigned before, if the high-diverse area is excluded. On the contray, one can observe that if Pildammsparken would be constituted only by those areas, it would have an increased value.

Figure 9, 10- Inner visual into the stand with the gap in the top layer. The difference between this and fig x is evident: here the vegetation is more expanded and it offers a totally different experience.

B- Remonthagen

Remonthagen is composed with different stands that do not constitute an homogeneous woodland. Despite of the present species are almost the same in all the area, they are not distributed uniformly and each stand is separated from the other by opened surfaces. Rem_E is the stand with the highest value (3.3). The vegetation is mainly composed by ashes (*Fraxinus excelsior*), and oaks (*Quercus robur*). Here the plants are higher in comparison with the other stands and the structure is more complex. The medium diameter class prevails and the movement in the stand is easier. The stand with the lower values in Remonthagen are Rem_B and Rem_D, respectively with 0.9 and 1.9. These stands are close to the stream and they have the most different vegetation in comparison with the others. In both the stands the Salix ssp. are dominant with a high density that impede the access. Rem_D has an area dominated by ashes (Fraxinus excelsior) with high accessibility but there is only one layer with high visibility as consequence. In both these areas there is the presence of litters and the understory vegetation is overgrown and not managed.

Figure 11, 12. The inner visual in Rem_B (11) and Rem_E. The difference is evident: the first shows an high-dense area where it was hard to access. The second shows a structure in which the walking is note impeded.

C-Kungsparken/ Slottsparken

Kungsparken is represented by scattered wooded areas of restrained dimension and it do not have a real walkable woodland. The observed stands has the values lower than 1.5, except for Kun_B that is evaluated with 3.1. An unvaried characteristic of these stands is the presence of an overgrown UV, mainly represented by *Symphoricarpos albus.* The UV in some zones has favored the presence of an excessive quantity of litter, in addition to the fact that it is quite impossible to walk through the stands. The dominant species in these stands are beeches (*Fagus sylvatica*) and oaks (*Quercus robur*) but many other species were found in the dominated layer e.g. *Acer platanoides* and *Fraxinus excelsior*. The feature SD and DW are the more constant within each stands and are evaluated with high scores. Kun_B is the only stand in Pildammsparken that has a structure potentially good, but its position and its restrained largeness probably do not permit to offer relaxing experiences.

Figure 13, 14. Two different stands in Kungsparken: Kun_B (13) and Kun_C(14). It can be observed the high quantity of understory vegetation and the excessive density of the third layer.

4 DISCUSSION

4.1 Premise

The aim of this work was to develop an index to assess the naturalness of urban woodlands based on how it can offer relaxing and destressing experiences. The index has been created connecting two different disciplines. The naturalness and its assessment concern the forestry ecology while the experience in the urban nature is more related to urban planning. These components were already partially gathered in the discipline of urban forestry (Konijnendijk et al. 2005). However, an evaluation of the degree of naturalness with the experience as main variable was never done before. This means that the result of this study, the WooDestress index, can be used to evaluate the urban woodlands with a criterion never used before. Therefore, the value that was assigned to each area with the index is not comparable to any other value. The higher this level is, the more a woodland is supposed to offer a relaxing experience. However, even if the basis of the index came from a literature review, it cannot assure that its value effectively shows the real potential of a wooded area. The real potential can be found investigating on what people perceive in a determinate area. For this reason, the effectiveness of this index cannot be proved in the context of this study. However, through the test of the index it was possible to obtain some information about the components of the index as well as some characteristics of Malmo's parks.

Given that, the discussion is focused on two aspects:

1. The applicability and functionality of WooDestress index
2. The woodlands in Malmö: natural characteristics and levels of relaxing experience they can offer.

The first aspect concerns an evaluation of some intrinsic traits of the index in order to have an overview about its applicability and functionality. The questions that are posed in this context are: is the index in its entirety usable in a real woodland? Are the components of the index well organized and structured to obtain a reasonable result? To answer these questions the attentions is focused on the single components of the index, with the purpose of understanding their strengths and weaknesses. In this phase, some improvements are suggested. The second aspect concerns the information that are obtained about the parks after the application of the index.

4.2 Applicability and functionality of WooDestress Index

The results have demonstrated that the main frame of the WooDestress index is valid. The features that constitute the index were always detected in the parks and they were easily evaluated. It is demonstrated that the set of proposed values within each feature is appropriate. Indeed, it was possible to connect each of the observed situations to a precise value of the index. However, it should be considered that the developer and the first user of the index coincide. One can assume that the application of the index is easier to the developer. Therefore, the project does not permit to understand if all its features are comprehensible and recognizable. Moreover, the features are evaluated at sight and this can cause inaccuracy in the evaluation. For these reasons, many users besides the author should conduct the test of the index in order to have more precise information about its applicability. In its entirety, the functionality of the index is positive. The study areas purposely differ from one another in aspects like the location and the dimension. For this reason a wide range in the final evaluations was expected. The fact that the values obtained with the index are different and they are not clumped in a restrained range is a good result. It means that through the index is possible to distinguish different areas. Although WooDestress Index certainly needs to be improved and tested in many different situations, the premises are positive.

The three single components that constitute the index and that determine the final value will be now considered: the values within each feature, the weights of each feature and the role of maintenance.

4.2.1 The features

The results show that all the features are represented by each value, whose frequency is generally balanced. The only exception concerns the feature “species diversity”. The great difference in the relative frequency between the values 4 and 5 can be a signal of a wrong division. Class “4” is represented by the presence of at least 2 species in the dominant layer and at least another different species in the dominated layer. Class 5 is equal to the 4 but it also considers the presence of more species in the dominated layer. This distinction was proposed supposing that in an urban woodland species diversity would be lacking. However, the parks taken into consideration for this study that are characterized by at least two species in the main layer generally have more than two species also in the dominated layer. The attempt to include the number of species in four strict classes appeared ineffective and another classification probably should be proposed. The inclusion of the species diversity in the model was correlated to its importance for the naturalness assessment (Winter 2012, McRobert et al. 2012). However, McRoberts at al. (2012) in order to measure this feature adopted an ecological index (e.g. Shannon 1949). This index is used to find, among different areas with similar vegetation, which one is more rich in species. The application of this index was not possible in this study because of the lack of a vegetation reference. Nonetheless, a new evaluation for this feature should be proposed and tested in different parks. An example could be to exclude the division in layer, focusing on the total number of species. A minimum number of expected species can be decided, depending on the kind of wooded area in which the index is adopted. When the number of species observed is consistently higher, the feature assumes a value of e.g. 5, otherwise the value is lower.

4.2.2 The weights

The results have shown that the role of the weights in the index is fundamental. It was observed that excluding the weights, the value of the stands has a minimum variation. This suggests that the variance among the weight values is probably not high enough to diversify the features. When the weights are not considered some stands improve their value due to the features that before weighted less. The contribution on the final value of DW+SD is generally higher than the 50% with some stands where contribution is up to more than the 70%. This means that excluding the weights from the index, the less important characteristics become more determinant. The role of the weights should be to reduce the importance of DW and SD, which should contribute to the value without being the main features. It was assumed that the features did not have the same importance in contributing to the final experience of a woodland. An impenetrable area should be evaluated with a low score also if it is characterized by a perfect amount of deadwood and by a great species richness. However, considering the original weight proposed in the index, the contribution of SD+DW in some stands is still higher than 50%. For this reason was finally proposed a different set of weights that permits to maintain the contribution of SD+DW lower than the 50% of the value. With the alternative set, SD and DW just contribute to improve the value. A green manager who uses this index obtains firstly an information on the main structure of the woodland. The final value of an area is mainly correlated to DBH and HL. If the value is high enough it means that the area can offer a relaxing experience and it can also be improved managing the other features. In the same way, if the value is insufficient, the manager knows that the problem is about the main structure of the wood and he can decide either to improve it or to allocate that area to other purposes.

4.2.3 The maintenance

The high quantity of litter was detected only in the zones where UV was present too. This suggests that maintenance of the understory vegetation can also make the litters decrease. For this reason, the UV maintenance or the creation of a path system would be a great way to improve the quality of an area, if the intention is to address it to the destressing restoration.

4.2.4 The woodlands in Malmö

Firstly, the results show that the parks are constituted by different stands with different features' values. For this reason is not possible to define a precise value of the features within each park. E.g. Bulltofta's DBH value is principally 4 but this is not sufficient to assert that Bulltofta, concerning DBH, is represented by the value 4. The lower is the relative frequency of the most frequent value within each feature, the less it is possible to characterize a park with a single feature's value.

Concerning the overall value of the parks, it was calculated through a weighted average in order to give to the best stands a greater importance. The good and bad woodlands in a certain park cannot be considered equal. Allegedly, a citizen who needs to relax is more interested in a woodland that can satisfy his/her needs. He/she will frequent a precise park mainly for the value that he/she attributes to the good stands. The bad stands will be simply avoided and they will have no weight on the user's experience. This could justify considering only the best stands in a park, when the goal is to attribute to it a general value. However, from a management prospective it is useful to have a general overview on what the entire park can offer. This permits e.g. to plan the management of the area.

The results of the index have confirmed what was expected. Considering each single stand, the best woodlands are located in Bulltofta. However, with the intent of assigning a value to the parks as a whole, Bulltofta and Pildammsparken resulted to offer the best relaxing and destressing situations.

Remonthagen and Kungsparken recived the lowest values.

Bulltofta has plenty of wooded stands and most of those have a dimension that permits the users to feel apart when they walk through it. The age of the stands guarantee the possibility to walk freely without specific impediments due to e.g. the vegetation density. The management of this park (as discussed in M&M) is favoring also the presence of different layers in many stands.

Despite the high visibility and the low species diversity that characterize the wooded area in Pildammsparken, its value resulted always positive. It was observed that the analyzed stand is composed by two different vegetation one of them particularly contributes to increase the value. The diverse structure was found in correspondence to a gap in the dominant canopy layer. Supposing the absence of this zone, the final value assigned to Pildammsparken would be lower than the original. On the other hand, if only the area below the gap is considered, the value is the higher obtained in this test. This should be an interesting spark for the planning of the woodland´s management. Through the opening of some gaps in the beech layer, a higher complexity could be favored and the "destressing potential" could be improved.

Remonthagen has stands too young and too restrained with a structure not yet adequate to permit to walk freely. The stands with more mature trees instead are too wild, with impenetrable areas and an excessive amount of dead wood. In general, this is not an area suitable to offer relaxing experiences. Besides, one of the stands is marked, in the Malmö´s maintenance plan, with the code VY4. This indicates areas close to water resources where the main purpose is to improve the biodiversity, the number of plants and animals. This aspect probably clashes with an adequate maintenance´s level.

Kungsparken, when the maintenance is considered in the calculation, resulted to be the less appropriate park to offer relaxing experience. Its value is strictly correlated to the presence of UV and L in all the observed stands. Excluding M and assuming the cleanliness of the stands, the value of Kungsparken increases. This indicates that cleaning the stands will also increase the potential in offering relaxing experience. When the weights are not considered, it assumes the highest value among all the parks. This is correlated to the features SD and DW that have high values (see above "the weights"), and by the presence of Kun_B that is better than the other stands. In any case, the woodlands in Kungsparken are too small for the purposes of destressing and relaxing users, also if well structured.

The cases of Kungsparken and Remonthagen suggest the need of an improvement in the model. Both these parks received a low value correlated to the restrained dimension of their stands. Probably, a surface threshold should be established and the woodland smaller than that surface should be excluded from the beginning. This should be valid especially for the scattered stands not even linked by a path. It is supposed that the smaller a stand the less it is attractive. A stressed individual probably have no interest in approaching a stand whose dimensions would not allow him to enter it and have a walk. Moreover, a restrained woodlands does not permit to the user to feel apart because its midpoint is too close to the areas surrounding the stand. In Malmö that aspect assumes importance from the moment that most of the areas surrounding the studied stands are marked in Malmö´s maintenance plan with the code G2. This code represents the grass areas for recreation, game and sports and they are potentially high frequented by crowds. A last aspect correlated to dimension concerns the vegetation. It was observed that the larger stands have a better vegetation structure and rarely the UV was excessive. This happened because there is a differentiation between the vegetation of the border and the inner vegetation. The borders are generally denser and the UV is overgrown because the light can easily reach the ground. Moving to the inner of a stand, the canopies of the dominant layer overshadow the underlying area and the UV can only grow scattered. When the stands are restrained it is more probable to observe the UV overgrown till their inner. A valid example is given by the difference between Pildammsparken and Kungsparken. They have similar dominant vegetation (mainly *Fagus sylvatica*) but in Pildammsparken the dense UV is scattered while in Kungspaken is everywhere and does not permit to enter in the stands.

Concerning the other information obtained applying the model, an interesting common characteristic in Malmö's parks was found. The results showed that all the parks have a certain amount of DW, especially the downtown parks. This means that the management of the green areas in Malmö Stad probably follow an ecological approach. Moreover, even though the presence of dead trees standing or lying trunks was not expected, they were found almost everywhere, especially in Bulltofta and Pildamsparken. This indicates that it was reasonable to insert them into the model and it demonstrates the increasing importance of this feature. The results concerning M indicates that the Malmö's park are generally clean and well maintained. Concerning the species diversity, as explained beforehand, Malmö´s woodlands has a fair diversity in native species. The stands in Bulltofta are the richer in species, followed by those in Remonthagen and Kungsparken. This aspect is important for the management and the planning of these areas. A stand rich in species offers interest insights for its management: for example different inner visuals within the same stand can be created to improve complexity and legibility (Kaplan 1998, Nielsen and Jensen 2007).

4.2.5 For the future research

The WooDestress model as explained in this work is just the first draft of a model that have to be improved. Even though its basis derived from the literature are valid, it cannot assume a universal value until it will be tested in many and different ways. Therefore, in this section some suggestions for the future research are made. The first purpose concerns the main goal of the model: detecting the relaxing and destressing potential of an area. The model is based on some general aspects about what people prefer in an urban natural scenario and uses them for a practical purpose. However, the study about the relationship between humankind and natural preferences has not given definitive conclusions yet. The conclusions are many and different and often based on studies conducted in precise geographical contexts. In the case of this work a lot of north-European literature (e.g. Tyrväinen et al. 2005, Randrup et al. 2008, Grahn and Stigsdotter 2003, Grahn and Stigsdotter 2010, Ulrich 1979) was consulted and the conclusions do not necessarily fit with the preferences of people from other countries. For this reason, the first step to improve the model is to test if the result of its application matches with people's preferences. It should be necessary to study how people evaluate a set of stands in which WooDestress model is applied. Through a questionnaire, people can assign a value to the area between 0 and 5 or define the level of perceived experience between "no experiences" and "good/excellent experiences". In the same questionnaire the features that are composing the model can also be judged. Based on the responses, the model can be adjusted and improved. This process can be carried out in different cities and countries in order to make the model fit to different contexts.

A second purpose, as discussed in the premises of the discussion, is to make the model tested by users different from the developer. The goal is to understand if its application and the evaluation of its features are universally comprehensible.

In order to improve the knowledge about the potential of the Malmo's woodlands in terms of offering relaxing experience, both the purposes described above are valid.

5 CONCLUSION

The increase of stress related disease, due to the urbanization, highlights the need to improve the management and the planning of cities. From the moment that it was proved that natural environments have a positive effect on the citizens health, urban green managers should take them into account. In that way they could be able to contribute to improve the quality of city life, also considering the citizens` preferences. Urban woodlands are among the environments that mostly affect destress and relaxation, offering the possibility to run away from the city´s sceneries. The trait of “naturalness” is one of the most valued and attractive for the citizens. In this work, I propose an index to assess the naturalness in urban woodland based on how it can affect relaxation and destress. The index is developed to be easy to understand and to apply, and it combines the disciplines of forestry ecology and landscape management. The addressees of WooDestress index are mainly urban green managers who want to improve the knowledge about the relaxing qualities in urban woodlands, to plan their management. For these reasons, I also tested the index in four urban Parks in Malmö (SE). The results indicates that the model has a good prospective but it needs further improvements. If my interpretation of the results is correct, some intrinsic components of the index should be tested in different contexts and eventually they should be modified. However, supposing a partially accuracy of the model, it was possible to detect the differences in the Malmö`s parks. Two of them contain some wooded stands with a good potential to offer relaxing and destressing experiences. The other parks resulted to be inadequate to offer the same kind of experience.

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7 APPENDIX

WooDestress Template

WooDestress MODEL

Locality________________________
Name area _____________________
Forest number __________________
Sample number _________________
Date ___________________________

Forest description

____
____
____
____
____-
____

DBH

DBH CLASSES DISTRIBUTION	V
Low classes predominant	1
High classes predominant	2
High classes with thin classes	3
Low-middle without large trees	4
Low-middle classes with trees larger than 50 cm	5

DBH: (__x 0.35)
=__

HL

LAYERS	V
Top layer only	1
Top layer with 3 sparse/too dense	2
Top layer with 3 dense	3
All layers with 3 sparse/too dense	4
All layers with 3 dense	5

HL: (__x 0.3)
=__

SD

NUMBER OF SPECIES	V
Only one species	2
Only one species in the dominant layer and at least 1 different in the dominated	3
At least 2 species in the dominant layer but no different species in the dominated one	4
At least 2 species in the dominant layer and 1 different species at least in the dominated layer	5

SD: (__x 0.2) =_

DW

DEADWOOD %	V
Too much wood (>40%)	2
Deadwood < 20% / No deadwood	3
Lying coarse deadwood/lying dead trees	4
Lying coarse deadwood/lying dead trees + standing deadwood	5

DW: (__x0.15) =__

M

UNDERSTORY VEGETATION	V
It is possible walking through the wood	1
It is generally impossible walking through the wood	0.9
It is impossible entering and walking through the wood	0.8

LITTER	V
Clean area	1
Some litters	0.7
Too much litter	0.5

M: (__x__) = __

WooDestress Value

FV= (DBH+LT+HT+SD+DW) x M

FV value ____x____=______

Area of interest

Here are represented the four parks and their stands.

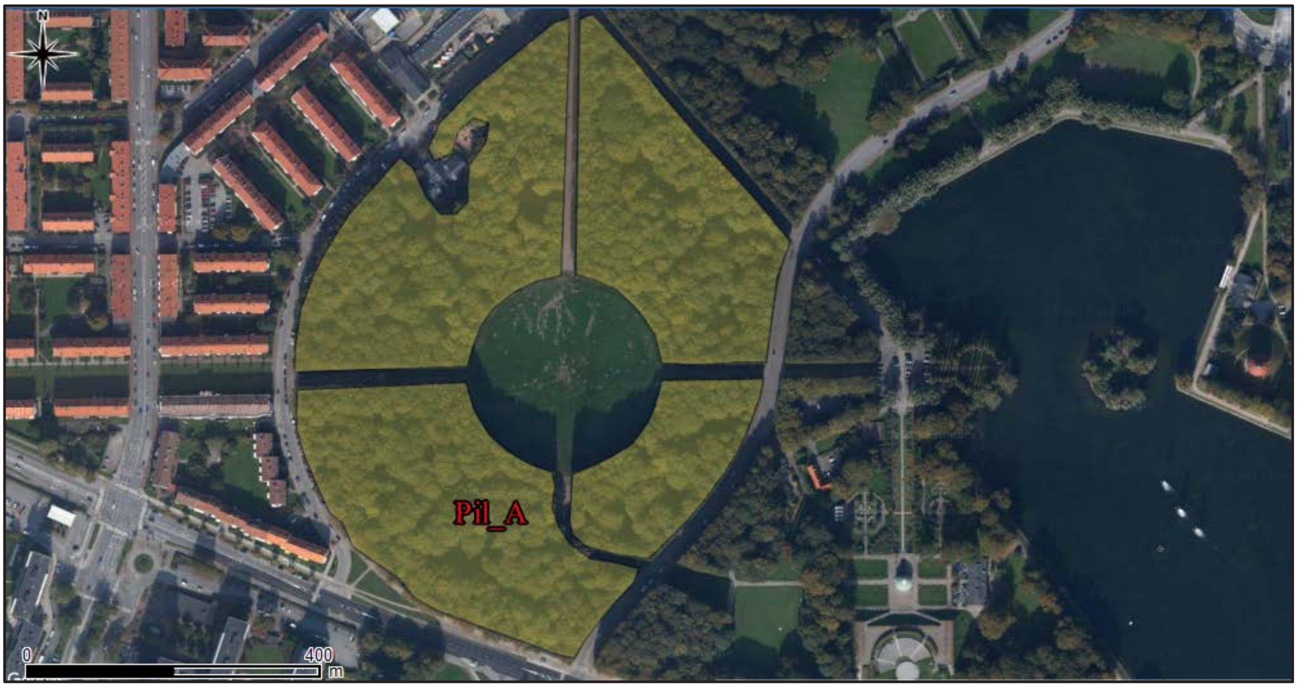

Fig. A, Pildammsparken with 1 stand.

Fig. B, Bulltofta rekreationsområde with 9 stands.

Fig. C, Kungsparken/Slottsparken with 4 stands.

Fig. D, Remonthagen with 6 stands.

Application of the model

Fig. E, The four parks with the relative stands. The dotted green line represents the line that was followed to cross the stand. The red point are the point in which the model was adopted.