Ecosystem Service Hubs Under the Microscope

An Explorative Study on the Added Value of the Urban Open Spaces

Antonios Roussos

Master Thesis

This work is dedicated to my grandfather Antonis and my grandmother Maria.

Master Thesis

"Ecosystem Service Hubs Under the Microscope"

An explorative study on the added value of urban open spaces

by

Antonis Roussos

In partial fulfilment of the requirements for the degree of Master of Science (MSc) in Construction Management and Engineering at Delft University of Technology

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This thesis report is the pinnacle of my studies in Delft University of Technology. Beginning the MSc in "Construction Management and Engineering", at the Civil Engineering and Geosciences faculty, I ought to admit that I was highly uncertain what my thesis research topic would eventually be. Nevertheless, after navigating through various potential subjects and suffering a handful of rejections and dead-ends, I converged towards the domain of nature valuation. Although seemingly irrelevant to the MSc, this topic has large implications in public policy and decision-making, since urban green settings are closely correlated with real estate value. Therefore, managing and achieving the optimal configuration of green and civic spaces could prove to be crucial in maximizing the overall value. Needless to say, "maximizing the value" should be the motto of every successful manager.

Throughout this special journey there were several people that I have to thank. Regardless if it was insightful guidance or emotional support, these people were constantly by my side, "cheering me on" in their own way. First on this list is my first supervisor, Daan Schraven, who always found time for my queries and concerns and provided significant advice throughout this research. It goes without saying that the experience and objective outlook of Henk Jonkers was also pivotal in approaching and executing this study. Additionally, I would like to thank Marcel Hertogh for overviewing this research and providing key comments during its execution.

I also have to devote a distinct section to the people I worked with at Kadaster, who made me feel like I was not the only non-Dutch person in the building. Firstly, I have to thank Paul de Vries for his valuable insights in structuring this study, as well as Peter Merx, Lianne Hans and Leo Prins, who were constantly available and positive to help me and discuss any methodological or technological issues. Lastly, I would like to thank Ramona van Marwijk who helped greatly with any issues I encountered during my internship.

Last but not least, I have to express my particular gratitude to my family and friends, who ceaselessly drove me to outperform myself, even when myself was my only obstacle. Whether they were in the Netherlands, Greece or Switzerland, their help and support were of immeasurable value. They were always present from the very start and will hopefully continue to stand by me.

Enjoy reading!

Antonis Roussos,

November 2019

The cover page was created by Faye Vasileiou.

Executive Summary

Introduction

Urban open spaces, such as parks and urban forests, have become an integral and crucial part of modern urban settings. Their quantity and quality have lately become a subject of particular interest, triggering steadily increasing "natural capital" demands in cities. Notably, experts highlight the plethora of benefits, generated through ecosystem services, and consider them as the largest reason behind this trend. Nevertheless, the inherent uncertainties surrounding open spaces and ecosystem services jeopardize their consideration in public decision making. The lack of information on ecosystem services required by land planners and policy makers often leads to their neglection or poor economic recognition. Certain aspects of ecosystem services are neither fully translatable nor comparable in economic terms, primarily due to the absence of proper valuation tools. Therefore, the aforementioned omissions result in not only the under-provisioning of natural capital, but also the uncontrollable and unsustainable urban development. Hence, an imperative need to incorporate efficient ecosystem valuation in the decision-making process emerges. This would allow sounder land use management, based on a refined and more comprehensive understanding of every involved parameter.

The objective of this research is twofold. Firstly, it aims to prove and quantify the influence of urban open spaces on the surrounding real estate's market value. Secondly, it investigates which characteristics of these spaces bear the largest impact, with a particular interest in ecosystem services. Eventually, the indirect economic effects of urban open spaces are underlined and associated with these particular characteristics. Moreover, the optimal composition of an urban open space is explored. In order to achieve these objectives, the following main research question is formulated:

- *What is the added value of urban open spaces on real estate market prices and which of their characteristics, especially the provided ecosystem services, contribute the most to this added value?*

Reaching the previously mentioned objectives has several practical implications, since it would provide planners a more spherical and comprehensive overview of the available alternatives. Value gains and losses stemming from new spatial configurations will encompass the indirect economic effects of urban open spaces. Thus, based on sounder discourse, the optimal policy alternative will be opted for, leading to more balanced urban development. Furthermore, the gathered information could be streamlined into the management and maintenance process as well, allowing constant adjustments and improvements.

Besides providing such an explicit overview of urban open space value, this study aspires to contribute to the growing body of literature concerning integrated valuation methods. More specifically, it is deemed necessary to include ecological and socio-cultural aspects as well in order to produce a comprehensive and efficient valuation framework. Hence, it would be possible to weave a more nuanced picture of the situation. This study includes suggestions of incorporating stated preferences and views (social), as well as biophysical measurements of ecosystem services (ecological).

Methodology

The methodology employed in the present study is a combination of both quantitative and qualitative methods and consists of five parts. The first part is an extensive investigation of the theoretical underpinnings of various key concepts. Initially, the vast array of benefits generated by urban open spaces are explored, ranging from environmental and economic to health-related and social. Ecosystem services, which are conceptualizations of these benefits, have been widely discussed and clustered in literature. The most prominent classification is TEEB's (2010), which divides these services into provisioning, regulating, supporting and cultural. A list of relevant indicators is also discovered, as well as potential synergies and trade-offs between them, suggesting optimization possibilities. Afterwards, the various value dimensions (economic, socio-cultural and ecological) are discussed and correlated with appropriate valuation methods. This indicates the need for integrated valuation frameworks, whose composing methods are both commensurable and compatible. Lastly, similar valuation studies are scrutinized, hinting that Hedonic Pricing (HP) and Contingent Valuation (CV) are predominantly being used. It is unanimously stated that proximity to open spaces is positively correlated with both real estate's market prices and residents' willingness to pay.

Thence, the second part ensues, which is the definition of the research's scope. This involves selecting the city of Delft as the area of interest. Within the defined area, the major open spaces are identified and clustered into "Ecosystem Service Hubs" (ESH), which cumulate the benefits generated by the composing green and blue spaces. The eventual selections are: Delftse Hout & Hertenkamp (ESH1); Buitenhof park and surrounding spaces (ESH2); and Abtswoudse Bos and surrounding spaces in Tanthof (ESH3). Additionally, housing information within 500m from each ESH is analyzed, through the aid of Kadaster and their database.

The third part, also designated as Phase I of this study, includes the establishment of the proper hedonic pricing model for our cases. Firstly, the provided data is evaluated and filtered, in order to remove irrelevant or incomplete information. After imposing the 500m cut-off limit, the housing samples are further filtered from outliers in order to improve their homogeneity. Appropriate explanatory independent variables are selected, as well as the crucial dependent variable. The transaction price per m^2 is opted for the latter, while the former encompasses structural (house surface, house type), time-related (year of sale, year built) and spatial (neighborhood, surrounding greenery) variables. Our focus lies on the effect of the "distance to the hub", which is inserted both as a logarithmically transformed continuous and dummy variable.

The fourth part, also addressed as Phase II, swifts the focus from the housing samples to the ESHs. It consists of personal field visits to the hub sites, where an ecological profiling of the areas is attempted. Additional photographic material is gathered, as well as pinpointing spots of recreational value. Afterwards, an extensive exploration of the available mapping information is executed to further refine the previous findings.

In the final fifth part, the quantitative results of the Hub Hedonic Pricing model are combined with the qualitative information gathered from the field visits. Notably, a qualitative correlation between the added value of each Ecosystem Service Hub and its specific characteristics is attempted.

Results

Phase I's Hub Hedonic Pricing model revealed that ESH1 bears the largest influence on surrounding real estate, when a particular house is "moved" by a distance delta (Δ) from its initial position of 1m away from the hub (Figure 1). Overall, a 1% increase in distance would lead to approximately 2,7€, 0,8€ and 1,6€ per m^2 for each hub respectively. These figures amount to 0,10%, 0,03% and 0,06% of the average house price. Furthermore, it becomes evident that the largest price drop happens for a distance delta of around 100m.

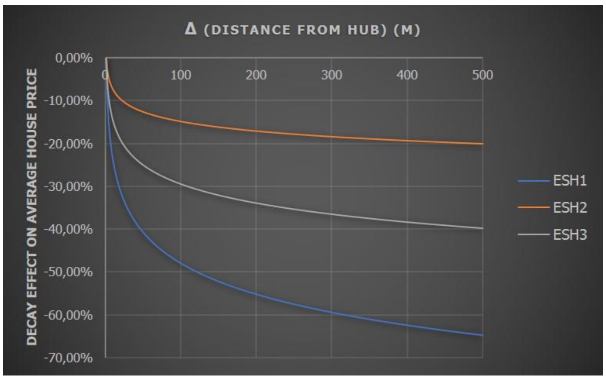

Figure 1: Cumulative graph of the distance decay effect.

Inserting the distance variable as a dummy variable through 100m-zones, displayed a similar behavior, further underlining the large price influence triggered by ESH1, followed by ESH3 and ESH2 (Figure 2). The largest price premiums are encountered in the inner zones (0-100m and 100-200m), whereas the outer zones show the lesser values.

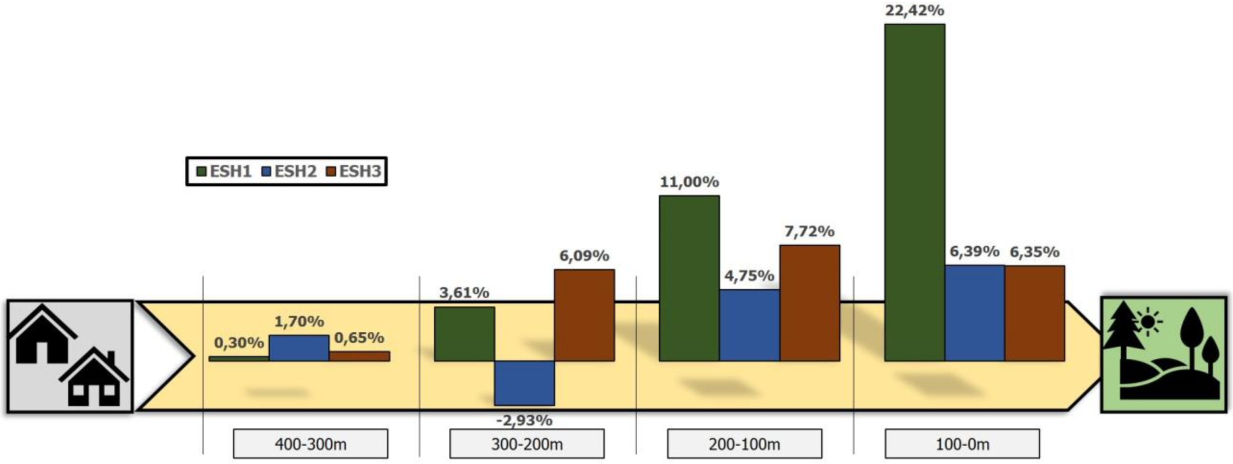

Figure 2: Cumulative graph of relative price influence differences between distance classes.

Thence, each housing sample is sub-divided into several categories depending on their surface, type, age and surrounding green percentage. Thus, a distance effect sensitivity analysis is carried out in order to reach the optimal house profile. However, due to the heterogeneity of the house sample characteristics, the only definitive conclusion is that "row" type houses in "greener neighborhoods" exhibit a greater distance decay effect sensitivity. However, it should be reminded that this conclusion is bounded by its spatial applicability and limited reproducibility, since it concerns solely the hubs under investigation and suffers from statistical insignificance.

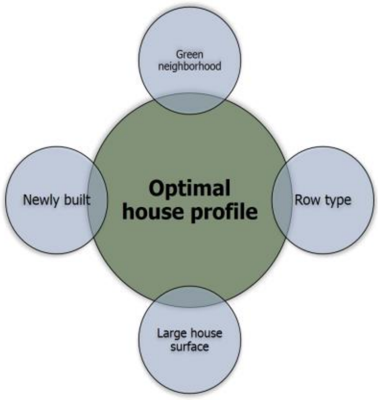

Figure 3: Optimal house profile as suggested from sub-divisioning and combinatorial categorization.

Applying a combinatorial categorization, despite witnessing similar issues as before, completes the picture concerning the optimal house profile, since it is found that larger and "younger" houses display the largest distance sensitivity. Thus, integrating both remarks, it is suggested that "young, large, row houses in greener neighborhoods" exhibit the largest distance decay effect (Figure 3).

A rough estimation of the overarching economic benefits accrued by each ESH is also executed. Despite the significant simplifying assumptions, the total monetary values calculated are approximately 5,81, 1,98 and 3,28 million € for each hub respectively. On the other hand, the average value per m^2 per house is 77,44€, 57,68€ and 107,47€ respectively, indicating a stronger impact per house for ESH3 (Figure 4).

Figure 4: Average generated value per house per m^2.

As far as Phase II is concerned, the ESHs' core components and characteristics are identified. These refer not only to particular green or blue elements, such as forests, grasslands, canals and lakes, but also type of plantation, hub size and recreational opportunities (bar-restaurants, sport fields, bike trails). Additionally, the field visits further validate and refine the previous mapping findings, as well as produce a broad list of potential ecosystem service presence. Overall, ESH1 is the largest hub, also displaying both a significant green and blue element diversity and a plethora of recreational opportunities. ESH3 ensues in terms of size and recreation, followed by the ESH2. The largest composition diversity is evidenced by ESH3, despite the absence of a lake. Lastly, all three hubs are deemed to possess a similar "arsenal" of ecosystem services. The only differences lie in the provisioning, supporting and cultural services. Notably, ESH1 only lacks a cultural inspiration dimension, similarly to ESH2, while ESH3 does not encompass private gardens for residents to grow their own vegetables and food. On the other hand, ESH2 genetic diversity is deemed trivial compared to the rest of the hubs. Nevertheless, it should be underlined that the intensity and exact measurement of the observed ecosystem services, especially the regulating ones, are not captured.

Discussion and Conclusions

While the results of Phase I are pretty straightforward, suggesting the strong influence of the Ecosystem Service Hubs, the confidence interval boundaries of the decay effect curves demonstrate a considerably wide range. This result not only suggests the presence of significant uncertainty, but also urges for further examinations and analyses. Overall, while the hypothesized relationship between the transaction price and distance to the hubs is validated and confirmed by our hedonic pricing models, estimating values through these particular models is dubious.

Comparing the calculated values with the literature's empirical findings denotes the same overall behaviour and tendencies. Therefore, it is further validated that close proximity to open spaces leads to higher real estate market prices. Notably, other studies, especially those using integrated methods, generate higher price premiums, while researches employing dummy variable zoning produce smaller differences between inner and outer zones.

Thence, an association between the calculated economic benefits and the Ecosystem Service Hubs' elements and characteristics is attempted. Taking into account the results of Phase I and II, in order to proceed to a synthesis, a few qualitative indications emerge. These can be summed up in the following statement: "Ecosystem Service Hubs generate higher economic benefits when they are larger and more diverse, in terms of both composition and ecosystem services, with a significant sensitivity to recreational opportunities". Nevertheless, due to the lack of professional expertise in ecological profiling and absence of biophysical measurements regarding the efficiency and effectiveness of ecosystem services, these conclusions are not deemed as reproducible.

Besides incorporating such an ecological valuation method, a social survey is also proposed as a valuable addition. This survey will aspire to derive both monetary and non-monetary values, constituting a hybrid of Contingent Valuation and Social Ranking. Combining these valuation methods would not only incorporate the necessary bounded rationality of the buyer's perspective, but also incur monetary terms, which are effortlessly "translatable" for relevant stakeholders, urban planners and decision makers. The survey process should be handled meticulously and diligently in regard to its content and format, in order to induce valuable insights. Thus, the survey most appropriate and fit for the purpose ought to be selected, based on the its scope and objectives.

This research's findings could prove to be insightful for public policy makers and urban planning developers. The previously discussed conclusions could be applied in two major ways. First of all, given a certain identified Ecosystem Service Hub, the development of the surrounding area could be adjusted to encompass primarily the optimal house and neighborhood characteristics (Figure 5). Therefore, a maximization of the property values in the newly developed urban area will be achieved, incurring not only direct house tax gains, but also personal welfare gains. On the other hand, given the "house composition" of a certain area, the optimal location and profile of a new Ecosystem Service Hub could be selected (Figure 6). Thus, the most profitable package included in the Ecosystem Service Hub will be selected. In both cases, maximizing the value of surrounding real estate is achieved through applying the optimal spatial configurations. Overall, the economic benefits triggered by ESHs are considerable and ought to not be overlooked in public policy discourse, since they might be a crucial deciding factor.

Figure 5: First scenario where optimal houses are developed around a given ESH.

Figure 6: Second scenario, where the optimal location and profile of the ESH is selected.

Therefore, answering our main research question, the added value of urban open spaces is plural and reflects the use and non-use value derived from residents. This research's rough estimation of an average of 80,86 € per m^2 per house is an indication of this added value, subject, however, to the narrow scope of the study. Attributing this added value to particular open spaces' characteristics could only be executed through qualitative correlations. In order to enrich the previous results, an integration of multiple valuation methods, which incorporate the various value dimensions, is recommended. More conclusive and definitive results will motivate planners and decision-makers to promote and opt for polices revolving around ecosystem services and natural capital, thus, satisfying the steadily increasing demand.

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1 INTRODUCTION

This first chapter introduces the topic of ecosystem services and their valuation importance. It sets the context and foundations for the present thesis, through the exposition of the problem analysis, as well as the formulation of both the problem statement and research questions. Section 1.1 provides an overview of not only the upsurge in demand on urban open spaces and their inherent ecosystem services, but also the increasing awareness of their significance. Section 1.2 presents the problem of under-provisioning ecosystem services through public policies, mostly due to the complications their valuation methods entail. Section 1.3 establishes the thesis' aim, while Section 1.4 defines the research questions this thesis intends on answering. Section 1.5 depicts the conceptual framework of this research and section 1.6 elaborates on the expected results to be generated by this research. Lastly, sections 1.7 and 1.8 discuss the practical implications and research gap to be enriched respectively.

1.1 Topic Analysis

Over the last years, an upsurge has been identified in interest in both quantity and quality of urban open spaces. These open spaces are identified as an integral part of modern urban settings, containing both green and civic spaces. The previously mentioned upsurge is driven primarily by not only the increased awareness of their benefits and significance, but also the concerning decline of existing spaces (Swanwick, Dunnett, & Woolley, 2003). Ecosystem damage is accelerating and might incur costs, expanding much further than the traditional markets and far beyond the present, unless they are offset (P ten Brink, 2009).

The rising reputation of open spaces is also reflected in the academic field as well. Notably, research on ecosystem services has seen its importance demonstrate a remarkable rise. Academic literature referring to ecosystem services and urban open spaces is rising with exponential pace (Fisher, Turner, & Morling, 2009). For instance, research has shown that one of the major gains from the conservation and restoration of ecosystem services is the reduction of ecological footprints of cities, while simultaneously ameliorating the health and life quality of their residents. Moreover, ecosystem services produced by open spaces are perceived as ideal for adapting nature-based solutions to mitigate environmental problems (e.g. air purification and climate control through urban parks) (Brown & Mijic, 2019; Mexia et al., 2018).

All the aforementioned recorded positive evidence by academics has led to a steady increase in natural capital demands, while also highlighting the relevant knowledge gaps (Gómez-Baggethun & Barton, 2013; Tzoulas et al., 2007). Notably, the desirability of green spaces was proven to be independent of residence characteristics, while their "utilization" metrics further suggest the imperative need for green urban development (Maat & de Vries, 2003). Furthermore, the close interconnectedness and strong dynamics between humans and ecosystems is also displayed (Andersson et al., 2015).

Therefore, it becomes apparent that decision makers should gradually detach from the status quo, which suggests that such nature conservation policies and management are "a trade-off between the environment and urban development". Contrariwise, investments in both creating and maintaining sustainable ecosystem use are deemed as beneficial for both parties, with considerable ecological, economic and social benefits (Groot, Alkemade, Braat, Hein, & Willemen, 2010). As indicated in Figure 1-1, ecosystems are translated into economic values, as well as multiple intangible benefits through their generated functions, which in turn produce a service to human well-being. Urban open spaces could be considered as such ecosystems.

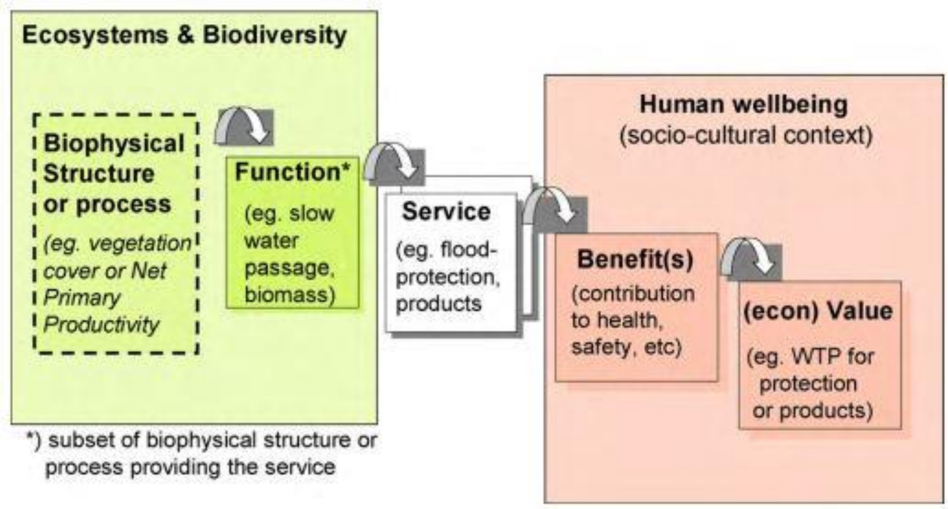


Figure 1-1: Linkage of ecosystems to human well-being (Groot et al., 2010).

Satisfying the green preference tendency might become increasingly problematic and challenging, since existing infrastructure and land development planning might not be able to accommodate the demand of open spaces over time (M. Daams & Sijtsma, 2017). Thus, thorough monitoring and careful adaptations to the pressures of change drivers (e.g. social and technological changes) ought to be ensured (James et al., 2009). Additionally, continuously increasing efforts are required in determining improved mapping, accounting and valuing methods and models. This development of standards and frameworks will aid in dealing with the various challenges related with ecosystem services and their inherent uncertainties (Crossman et al., 2013). De Groot et al (2010) furthers stress this necessity to establish proper measurements and practices, which will ensure their universal applicability and transferability.

1.2 Problem Statement

Despite the growing interest on ecosystem services, their uncertainties and complications hinder their consideration in decision-making. De Groot (2010) raises a plethora of questions, gathered from existing literature, regarding the challenges of integrating the concept of ecosystem services and values in land planning and management. The most notable ones are:

- What is the relationship between ecosystem characteristics and components and their associated functions and services and how could it be quantified?
- What are the most appropriate valuation methods for ecosystem services and what indicators could help towards that direction?
- How could we incorporate the aforementioned knowledge on ecosystem services in planning, design and management of open spaces?

This research's focus lies primarily on the latter two. It is widely acknowledged that ecosystem services, although valuable, are poorly recognized economically (H. A. Sander & Haight, 2012). Notably, land development's proneness to overemphasize economic arguments results in the ecosystem services' omission and trade-offs (J. Kronenberg, Andersson, E., Rall, E., Haase, D., Kabisch, N., Cummings, C., and Cvejić, R., 2017). Acknowledging ecosystem services as public goods is their largest disadvantage, while relating them with private values constitutes a considerable challenge (Brown & Mijic, 2019).

Land use planning and decision-making demands an abundancy of information on ecosystem service values in order to weigh in the different alternatives and their respective opportunity costs (Koetse, Verhoef, & Brander, 2017). However, traditional valuation methods fail to take into consideration the ecological and social aspects of open spaces, thus weakening their role in the decision-making process (James et al., 2009).. Furthermore, the fact that ecosystem services, such as recreational and aesthetic, are neither fully translatable in traditional markets nor comparable to other goods and services, means they are not directly observable. In other words, certain value domains are neglected or downplayed (Costanza et al., 1997; Koetse et al., 2017; Martín-López, Gómez-Baggethun, García-Llorente, & Montes, 2014). Therefore, an absence of proper and dedicated tools for evaluation and monitoring is quickly noticeable (Fontaine et al., 2014). Moreover, the uncertainties surrounding ecosystem services also lead to a bias against them in decision-making (P ten Brink, 2009). Lastly, there is a lack of environmental legislation which could both safeguard ecosystem services and constitute them appealing to policy makers, and legally cement them into enforceable directives (Maes, Paracchini, Zulian, Dunbar, & Alkemade, 2012).

This inability to include ecosystem services in decision-making under equal terms is the major factor leading to the unsustainable use of available land and uncontrollable urbanization (Fontaine et al., 2014). The vigorous competition between alternatives leads to "greener" policies being overpowered by more easily observable profitable ones. Comprehending the true value of open spaces and their limited substitution potential could set the discussion on an absolutely different basis, since the returns offered by green infrastructure are estimated to be far greater (P ten Brink, 2009). Figure 1-2 depicts an alteration of Figure 1-1, highlighting the various values of ecosystem services and the role of policy and decision-making.

The aforementioned under-provisioning, provoked by the erroneous and uninformed decisions, should be addressed through explicit attempts to express the overall value of ecosystem services in monetary terms. Thus, the socio-economic importance of ecological factors will be quantified, enhancing their significance in the decision-making process (Luttik, 2000). This research aims to utilize such an expression of the socio-economic dimension; a premium included in the real estate market value, caused by the presence of open spaces.

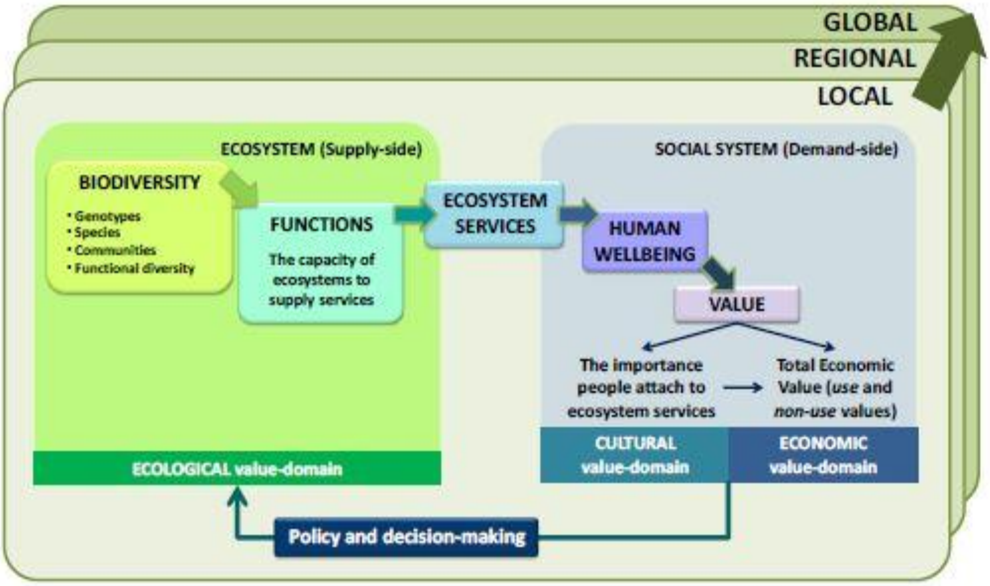


Figure 1-2: A framework for integrated valuation of ecosystem services which considers both the ecosystem services delivery (supply-side) and the use, by stakeholders (demand-side), including ecological, cultural and monetary value-domains (Gómez-Baggethun et al., 2014, p. 5).

1.3 Research Objectives

The aim of this research is twofold. Firstly, it aims to prove and quantify the influence of urban open spaces on the surrounding real estate's market value, the so-called "added value" (Figure 1-3). Secondly, it intends on investigating which factors and characteristics, connected with ecosystem services, bear the largest impact (Figure 1-4). This will allow these impacts to be taken into solid consideration when the decision makers are faced with a dilemma of whether to implement a certain public policy, regarding land development. Thus, it would not only increase the overall awareness of ecosystem services value, but also ensure the avoidance of their neglection in urban development and land management.

AIM 1	AIM 2

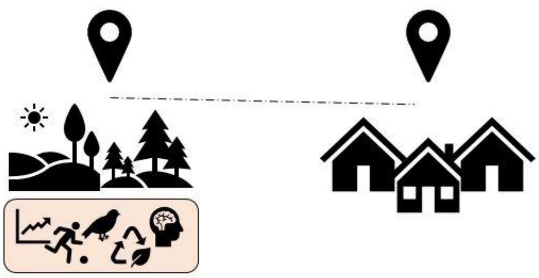



Figure 1-3: Prove the "added value" of urban open spaces on real estate market value.	Figure 1-4: Identify which characteristics bear the largest impact on real estate market value.

According to Daily et al's (2009) figure (Figure 1-5), our research intends to connect ecosystem services with values, under a socio-economic valuation model, which will be further explained in ensuing sections.

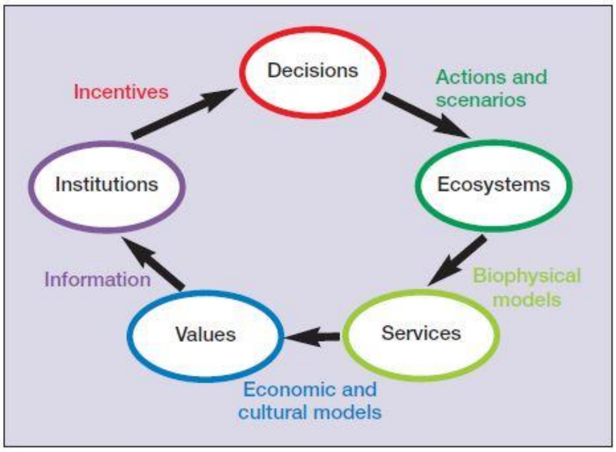


Figure 1-5: Connections between ecosystem services and decision making (Daily et al., 2009).

1.4 Conceptual Model

The following conceptual model (Figure 1-6) originates from the synthesis of the topic analysis, problem statement and aforementioned research objectives. Although an upsurge in interest in urban open spaces and ecosystem services is evident nowadays, their economic valuation and public good characterization render them easily negligible in urban planning. Nevertheless, the need to incorporate effective ecosystem valuation methods in decision-making is imperative, because of the plethora of benefits, ranging from economic to environmental and human well-being related.

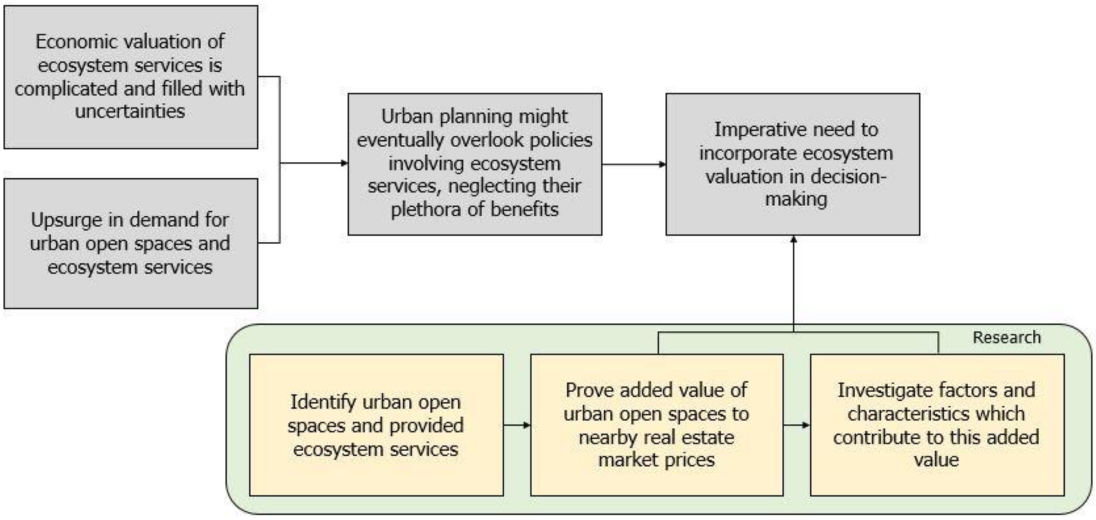


Figure 1-6: Conceptual model (Own illustration).

1.5 Research Questions

In order to aid in achieving the aforementioned research objectives, the following research questions have been formulated:

Main research question:

- What is the added value of urban open spaces on real estate market prices and which of their characteristics, especially the provided ecosystem services, contribute the most to this added value?

The following sub-questions were drawn up to facilitate the research process:

Theoretical sub-questions:

- What can be defined as an urban open space (green and blue spaces) and what ecosystem services are they capable of providing?
- What valuation methods could be employed in order to quantify the urban open spaces' influence on real estate market values?

Empirical sub-questions:

- What is the eventual relation between urban open spaces, their characteristics and real estate market value?
- What are the implications of the added value of urban open spaces and ecosystem services on real estate market prices, in regard to public policies?

1.6 Expected Results

As far as the first objective is concerned, which is "proving the added value of urban open spaces on real estate market value", relevant existing literature suggests that we should be anticipating a positive relationship. More specifically, real estate within a reasonable distance to open spaces records higher bidding prices, regardless of the building's characteristics. Nevertheless, the exact percentage increase or "price premium" for each of the selected case study areas is expected to differ, as existing literature also indicates.

The second objective is anticipated to clarify the previous deviations of "price premiums". Since the case study areas are not homogeneous, their varying characteristics and notably the ecosystem services provided will be play a pivotal role in explaining the "price premium" differences. Additionally, the contribution of each individual factor is expected to be identified whether quantitively or qualitatively.

1.7 Practical Relevance

Ecosystem services valuation is regarded as "primarily practical" and intended to aid decision-making. Providing explicit information to planners and all relevant stakeholders will be sufficient in covering every value dimension, as well as every perspective within a policy. Furthermore, this information is recommended to be funneled into not only the planning, but also the management and maintenance phase (Andersson et al., 2015; Panduro & Veie, 2013; P ten Brink, 2009). Potential applications of ecosystem valuation include: raising awareness by rendering each type of value distinct; improving accounting systems of ecosystem services; formulating policy instruments; and setting priorities between alternative land uses (Costanza et al., 1997; Gómez-Baggethun et al., 2014; Tyrväinen & Miettinen, 2000).

It is believed that open spaces are capitalized in surrounding real estate prices, implying that residence buyers derive welfare benefits from them (M. N. Daams, Sijtsma, & van der Vlist, 2016). This price premium, as previously mentioned, might be crucial in policy discourse and urban planning, provided that it offers more gravity to ecological factors (Luttik, 2000). Under a policy scenario involving area change and new spatial configurations, the relationship between distance and real estate will shed light on value gains and losses emanating from the specific policy (Brander & Koetse, 2011).

These value gains, attributed to ecosystem services, could contribute directly to tax gains, since they illustrate property value changes. Thus, they would constitute a public policy more favorable for technocrats, improving their consideration in land planning and decision-making. Additionally, efforts to maximize these value gains, through optimization and scenario testing, could be attempted in order to reach the ideal land use configuration and ensure its sustainability (Fontaine et al., 2014; H. A. Sander & Haight, 2012). For instance, Fernandez, Mukherjee, and Scott (2018) claim in their study that conservation policies influence real estate market values in multiple neighboring counties and could prove to be insightful for policy makers and land use planning (Fernandez et al., 2018). Latinopoulos (2016) also maintains that economic valuation of non-priced aspects of conservation strategies could offset both their own costs and benefits of alternative solutions, rendering them the most favorable option.

It is this researcher's intention that eventually an explicit overview of the urban open spaces' and their ecological factors' impacts will be "constructed". This overview will be an insightful tool for policy and decision makers, allowing for more balanced urban development and sounder land management (Łaszkiewicz & Andersson, 2016).

1.8 Scientific Relevance

It is widely recognized that a key challenge in ecosystem service research is developing a comprehensive valuation framework, where ecological, economic and socio-cultural perspectives are taken into consideration. In order to address this challenge, integrated approaches of monetary and non-monetary techniques have been proposed, where the system under investigation dictates the variety and complexity of methods to be employed (Martín-López et al., 2014).

These combinations of methods aim at offsetting their components' disadvantages and omissions, while also reflecting more precisely and comprehensively the stated human preferences (Czembrowski, Kronenberg, & Czepkiewicz, 2016). An integrated ecosystem service valuation would exceed technical measurements through simple strict indicators, going as far as to reveal not only the prescribed significance assigned by end-users, but also the derived marginal utility. Therefore, public participation is key to both broadening the valuation process and strengthening the trust in urban planning and development (Fontaine et al., 2014). Furthermore, valuation methods demonstrate high context dependency, given that their areas of applicability show elevated levels of heterogeneity. Thus, careful consideration should be taken to account for the proper combinations, which ought to be characterized by commensurability and compatibility (Gómez-Baggethun et al., 2014). However, it should be denoted that one of the composing methods will still remain dominant, while the rest have a complimentary role (Łaszkiewicz & Andersson, 2016).

Overall, each integrated valuation study contributes towards the comprehension of underlying synergies and trade-offs between different value dimensions, while simultaneously widening our scope of understanding. Delineating their interactions and providing an eventual effective synthesis, is the primary objective of such valuations (J. Kronenberg, Andersson, E., Rall, E., Haase, D., Kabisch, N., Cummings, C., and Cvejić, R., 2017; Łaszkiewicz & Andersson, 2016). It will weave together a more substantial and nuanced picture of the situation, thus facilitating decoding complex information (J. Kronenberg, Andersson, E., Rall, E., Haase, D., Kabisch, N., Cummings, C., and Cvejić, R., 2017). For instance, expanding on growing literature on integrated valuation methods, sociotope mapping was employed to account for social aspects of urban open spaces, which under normal circumstances would be omitted (Czembrowski, Łaszkiewicz, Kronenberg, Engström, & Andersson, 2019). Biocultural value perspectives were also attempted to be associated with open spaces but without conclusive results (Czembrowski, Łaszkiewicz, & Kronenberg, 2016).

The present research aspires to employ such an integrated method, where urban open spaces' value is "dissected" not only according to the revealed preferences of buyers (real estate market prices), but also depending on their views and stated preferences (public participation). Since accurate valuation of ecosystem services through integrated methods is scarce, our attempt conduces to this growing literature, despite having a primarily economic focus. It is expected to generate empirical results, which could potentially be further enriched with additional valuation methods of different nature.

2 LITERATURE STUDY

This chapter describes the fundamental theoretical background surrounding open spaces, ecosystem services and their valuation. It also presents several similar studies conducted on relevant topics. Section 2.1 investigates the terms and concept of urban open space and ecosystem services, as well as some of their attributes and characteristics. Section 2.2 showcases the definition of value and its sub-categories, while also presenting the various valuation methods and their integration potential. Finally, section 2.3 mentions several ecosystem valuation studies, mostly dominated by monetary valuation methods, while also mentioning a selection of integrated ones as well. This chapter is supplemented by Appendices B, C, D and E.

2.1 Urban open spaces and ecosystem services

2.1.1 Open spaces and inherent benefits

First of all, the concept of urban open spaces and its various sub-categories will be examined. Tzoulas et al. (2007) describe the concept of green infrastructure in urban spaces as "all natural and artificial networks of ecological systems within and around urban areas". On the other hand, Swanwick et al. (2003) describe the various sub-divisions of urban areas. It is suggested (Figure 2-1) that urban areas consist of the built environment and the external mediating environment. Open spaces are defined as the part of urban areas, which includes green spaces and civic spaces. The former is described as "unsealed, soft surfaces such as grass, shrubs and trees", whereas the latter is designated as "publicly accessible areas such as squares and paved areas". In general, grey spaces are mentioned as "sealed, hard surfaces". An extensive typology showing typical examples of urban green space is also presented in Appendix A. It should be mentioned that the urban open spaces that will be investigated in the present research also include additional "blue" components such as lakes and canals. Therefore, within this research, a new definition is introduced, the term "Ecosystem Service Hub". These hubs cumulate the benefits of individual open spaces such as parks and forests and function as a larger source within the urban setting.

All of the aforementioned open spaces generate a plethora of benefits, which deserve wider recognition and publicity. Their spectrum ranges from social and health to social and of course environmental. Social benefits include: increased social inclusion because of their open accessibility; social interaction opportunities; and educational opportunities and activities (Swanwick et al., 2003). The undeniable provided health benefits deserve a distinct reference, because of their indirect contribution to the socio-economic ones (Tzoulas et al., 2007). Psychological benefits such as reduction of stress self-regulatory experiences, are also included in this category (James et al., 2009). The main environmental benefits consist of: improvements in air and water quality, and carbon storage; enhancement of water and climate regulation; noise reduction; biodiversity conservation and lastly, improved resource efficiency (Brown & Mijic, 2019). Lastly, economic benefits comprise of both on-site generated revenues and indirect effects such as real estate value influences (Swanwick et al., 2003).

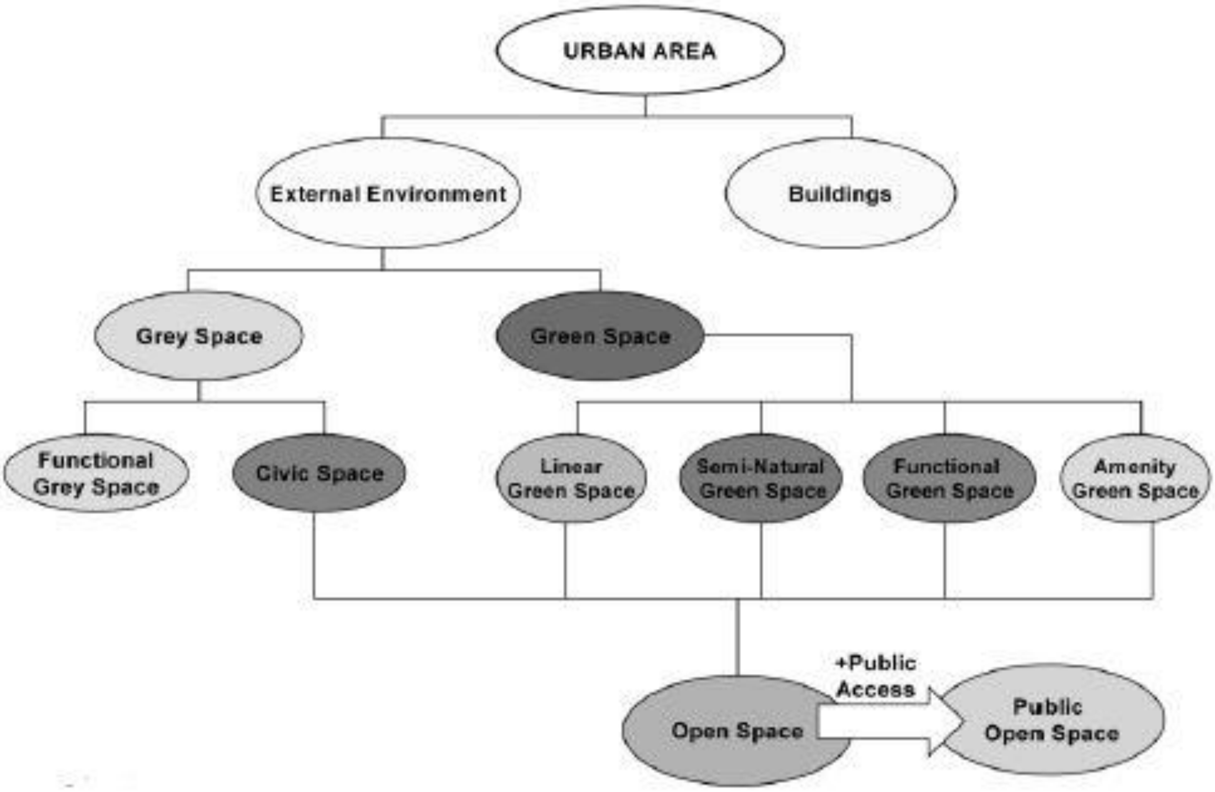


Figure 2-1: Figure of urban area division (Swanwick et al., 2003).

2.1.2 Ecosystem services

Therefore, it becomes evident that the aforementioned benefits of urban open spaces include both goods and services, where the former one can be obtained from both ecosystem and abiotic sources, whereas the latter are primarily derived from ecosystems (Liu, Costanza, Troy, D'Aagostino, & Mates, 2010). This research will concentrate on ecosystem services.

The global initiative called "The Economics of Ecosystems and Biodiversity" (TEEB), whose objective is to "make nature's values visible", identifies ecosystem services as "the direct and indirect contributions of ecosystems to human well-being" (TEEB, 2010, p. 19). In fact, services are conceptualizations of the previously mentioned direct and indirect benefits people derive from ecosystems (TEEB, 2010). A supplementary definition that clarifies the term was given by Costanza et al (1997), who defines ecosystems services as "flows of materials, energy, and information from natural capital stocks which combined with manufactured and human capital services produce human welfare" (Costanza et al., 1997, p. 254). Furthermore, Fisher et al. (2009) propose that ecosystem services are regarded as "the aspects of ecosystems utilized (actively or passively) to produce human well-being" (Fisher et al., 2009, p. 645). The key takeaways from this definition are that services must be ecological phenomena and that they are not required to be directly used.

TEEB proposes a list of twenty-two ecosystem services, divided into four major sub-categories: provisioning; regulating; habitat/supporting ; and cultural/recreational (Table 2-1). Since this particular documentation has influenced most of the relevant literature, it was decided to be the basis of this research as well. In Appendix B, short definitions and information about these particular twenty-two ecosystem services are presented, as well as a table including similar lists, drawn from indicative studies.

	Main service types
	PROVISIONING SERVICES
1	**Food** (e.g. fish, game, fruit)
2	**Water** (e.g. for drinking, irrigation, cooling)
3	**Raw Materials** (e.g. fiber, timber, fuel wood, fodder, fertilizer)
4	**Genetic resources** (e.g. for crop-improvement and medicinal purposes)
5	**Medicinal resources** (e.g. biochemical products, models & test-organisms)
6	**Ornamental resources** (e.g. artisan work, décorative plants, pet animals, fashion)
	REGULATING SERVICES
7	**Air quality regulation** (e.g. capturing (fine)dust, chemicals, etc)
8	**Climate regulation** (incl. C-sequestration, influence of vegetation on rainfall, etc.)
9	**Moderation of extreme events** (eg. storm protection and flood prevention)
10	**Regulation of water flows** (e.g. natural drainage, irrigation and drought prevention)
11	**Waste treatment** (especially water purification)
12	**Erosion prevention**
13	**Maintenance of soil fertility** (incl. soil formation)
14	**Pollination**
15	**Biological control** (e.g. seed dispersal, pest and disease control)
	HABITAT SERVICES
16	**Maintenance of life cycles of migratory species** (incl. nursery service)
17	**Maintenance of genetic diversity** (especially in gene pool protection)
	CULTURAL & AMENITY SERVICES
18	**Aesthetic information**
19	**Opportunities for recreation & tourism**
20	**Inspiration for culture, art and design**
21	**Spiritual experience**
22	**Information for cognitive development**

Table 2-1: Typology of ecosystem services (TEEB, 2010).

Gómez-Baggethun and Barton (2013) also pinpoints certain ecosystem services, which he characterizes as “disservices”, due to their negative effect on human welfare and well-being (Table 2-2).

Disservices	Indicators
Air quality problems	Emission of VOCs (tons yr−1)/vegetation unit
View blockage	Tall trees close to buildings
Allergies	Allergenicity (e.g. OPALS ranking)
Accidents	Number of aged trees
Fear and stress	Area of non-illuminated parks
Damages on infrastructure	Affected pavement (m2)/ wood (m3)
Habitat competition with humans	Abundance of insects, rats, etc.

Table 2-2: Table of ecosystem disservices and their indicators (Own illustration based on Gómez-Baggethun and Barton (2013)).

In order to better grasp and visualize the concept of ecosystem services, establishing indicators and measures is indispensable. These indicators enable the documentation of the flow of benefits provided by open spaces. Indicators ought to be specific, measurable, achievable, realistic and time-specific (SMART) in order to keep track of ecosystem services and evaluate their performance. Their usefulness is considerable in all policy cycle stages, from planning and selection between alternatives to execution and monitoring. Notably, it includes: aiding the public and decision makers to better comprehend the current situation of ecosystem services; illustrate more effectively the expected results of the measures to be taken; and monitoring the progress of these actions. Moreover, despite qualitative indicators not quantifying in monetary terms the benefits accruing from ecosystem services, they provide underlying monetary information and help to close knowledge gaps (TEEB, 2010; P ten Brink, 2009). An overview of potential ecosystem service indicators, as found in relevant literature, is exhibited in Appendix C.

Andersson et al (2015) broaden the conceptualization of ecosystem services by associating them with "service providing units" (SPUs), in order to showcase their context dependency and provide planners useful insights. These SPUs range from singular trees and shrubs to large crops, forests, as well as lakes and parks. It could be argued that they are closely interconnected with each ecosystem services' indicators. They also underline the various internal dimensions of SPUs, which are temporal, spatial, organizational and contextual. Understanding the SPUs' definition and the influence of each case's scale and context is essential for an effective assessment and operationalization of ecosystem services in urban planning and development (Andersson et al., 2015). The influence of spatial and time dynamics is further stressed by Groot et al. (2010), who also recommend thorough mapping approaches and land-use scenario testing in order to achieve the optimal service package.

Crossman et al (2013) created such a mapping tool , which can be used as a template for gathering all required information and providing an explicit overview of ecosystem services. It is intended to not only aid researchers executing an ecosystem service-related study, but also contribute as growing database of past studies' information and methods (Crossman et al., 2013).

Lastly, it has been observed that ecosystem services are capable of creating synergies and trade-offs between them (TEEB, 2010). Deeper comprehension of how these relationships evolve through time and space, as well as how they could be quantified, might allow their manipulation. Thus, efficient, sustainable bundles could be formed in order to provide cost-effective measures and solutions, satisfying the demand and reaching the set targets (Bennett, Peterson, & Gordon, 2009; Maes et al., 2012). For instance, Mexia et al. (2018) emphasizes the heterogeneity of urban parks, whose type, location and amount of vegetation significantly affects the package of provided ecosystem services. Ecological performance was also found to be severely and adversely affected by the urban density and form of an area, according to measures of maximum temperature and carbon sequestration among others (Tratalos, Fuller, Warren, Davies, & Gaston, 2007). Thus, based on a thorough mapping and measurements, the eventual service package could be altered to include different "quantities".

2.2 Value and valuation methods

2.2.1 Value types

Value is characterized by dimensions, which can be associated with the broader disciplines within which they are analyzed. Our focus is on monetary (economic), ecological and social dimensions (J. Kronenberg, Andersson, E., Rall, E., Haase, D., Kabisch, N., Cummings, C., and Cvejić, R., 2017).

Ecosystem services have been conceived as a form of positive externalities, who possess a monetary value. Adding up all types of monetary value results in the total economic value (TEV) which consists of use and non-use values. Use values are further divided into direct use, accrued from conscious utilization of services; indirect use, characterized by the unawareness of utilization; and option values, the potential direct and indirect uses to be gained in the future. Non-use values reflect the public satisfaction and sense that ecosystem services are existent, well-maintained and easily accessible. They are further referred to as existence values, altruist values (under an intra-generational perspective) or bequest values (under an inter-generational perspective) (Gómez-Baggethun et al., 2014; TEEB, 2010). A more analytical typology can be found in Appendix D. The following figure displays the application of a TEV framework to ecosystem services.

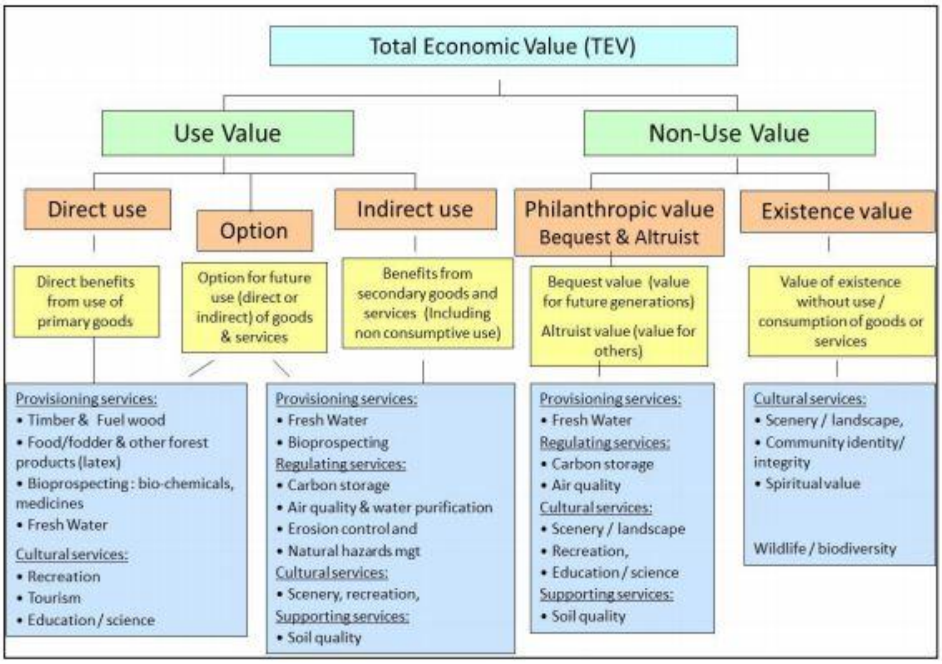


Figure 2-2: The Total Economic Value (TEV) framework applied to ecosystem services (Patrick ten Brink et al., 2011).

On the other hand, sociocultural value comprises of aesthetic, spiritual, educational and moral values, referring to primarily intangible concepts. For instance, people might value particular nature features, which contribute to people's happiness, quality of life, and social cohesion (J. Kronenberg & Andersson, 2016). Lastly, ecological value can be understood as "an evaluation of the degree to which an ecosystem component contributes and achieves an objective or condition". Therefore, it is mostly an assessment of ecological functionality (J. Kronenberg, Andersson, E., Rall, E., Haase, D., Kabisch, N., Cummings, C., and Cvejić, R., 2017).

2.2.2 Valuation methods

Valuation methods should be carried out when: there are missing or imperfect markets; it is essential to evaluate certain ecosystem services; and there is uncertainty involved in future demand and supply (TEEB, 2010). This research concentrates on two valuation methods: monetary and non-monetary.

Monetary valuation is based on information gathered from market transactions, where ecosystem services are directly traded. The main advantage of this method is the fact that the easily obtainable data sources are real markets, reflecting real preferences and costs. Lack of such information is offset through either the use of proxies derived from peripheral markets (e.g. hedonic pricing method) or observed consumer behavior (e.g. travel cost method). In this case it is stated that economic agents "reveal" their preferences through their choices (TEEB, 2010). Another potential alternative is stated preference methods, which are surveys emulating hypothetical market environments. They can be used to estimate both use and non-use values of ecosystems (Gómez-Baggethun et al., 2014). The afore described three methods are called "direct market-based", "revealed preference" and "stated preference" methods respectively. Their relationship with different value types is demonstrated below (Table 2-3). By aggregating Figure 2-2 and Table 2-3, a correspondence between valuation method and specific ecosystem services can be achieved.

Approach		Method	Value
Market valuation	Price-based	Market prices	Direct and indirect use
	Cost-based	Avoided cost	Direct and indirect use
		Replacement cost	Direct and indirect use
		Mitigation / Restoration cost	Direct and indirect use
	Production -based	Production function approach	Indirect use
		Factor Income	Indirect use
Revealed preference		Travel cost method	Direct (indirect) use
		Hedonic pricing	Direct and indirect use
Stated preference		Contingent Valuation	Use and non-use
		Choice modelling/ Conjoint Analysis	Use and non-use
		Contingent ranking	Use and non-use
		Deliberative group valuation	Use and non-use

Table 2-3: Relationship between valuation method and value types (TEEB, 2010).

Non-monetary valuation is distinct in a sense that it investigates the significance, needs, demands and preferences stated by people towards ecosystems. Nevertheless, clarifications are required on the methods' terminology and methodological boundaries, in order to broaden their applicability and credibility (Gómez-Baggethun et al., 2014). Ecological non-monetary methods' primary objectives are to inform about environmental objectives and whether compliance with environmental legislation was achieved. As far as social non-monetary methods are concerned, they render possible the ranking of people's perceptions and preferences and are particularly insightful in regard to non-material benefits. There has been an upsurge in their usage and publicity, mainly because of their improved applicability and provision of comprehensive results (J. Kronenberg, Andersson, E., Rall, E., Haase, D., Kabisch, N., Cummings, C., and Cvejić, R., 2017).

An extensive list and descriptions of several monetary and non-monetary (social and ecological) methods is presented in Appendix D. Additionally, the following figure corresponds the various valuation methods with value dimensions.

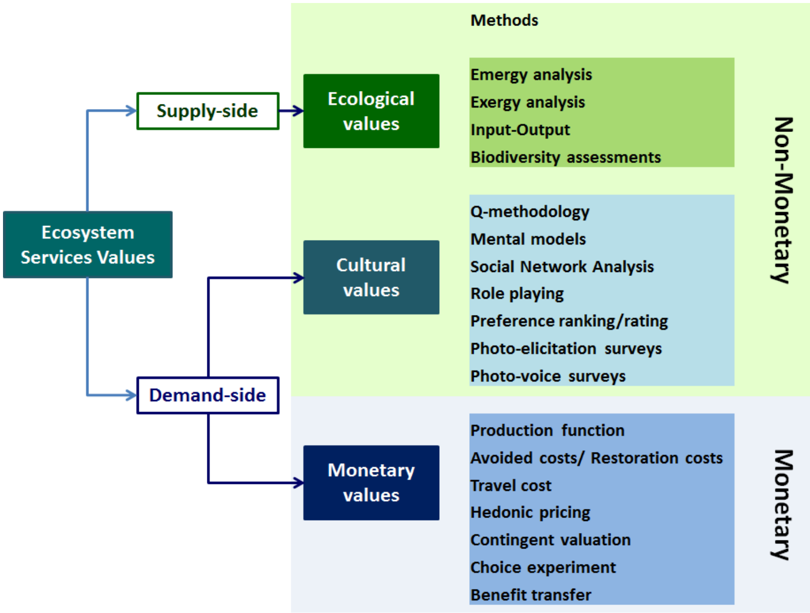


Figure 2-3: Toolbox for an integrated valuation of ecosystem services, considering non-monetary and monetary valuation methods, as well as value-pluralism (Gómez-Baggethun et al., 2014).

2.2.3 The need for integrated valuation

Over the past decades, ecosystem service valuation literature has emphasized the significance of incorporating social, ecological, and monetary value aspects in environmental decision making. Moreover, the need to establish a multifaceted value framework for ecosystem services has been a constant topic of debate and discourse. In order to improve the reliability of ecosystem service valuation approaches, it is imperative to pair and integrate direct biophysical measurements with economic valuation; applying non-monetary methods in order to encompass health, social and cultural aspects of ecosystem services; and developing spatially and timely explicit models (Daily et al., 2009; Martín-López et al., 2014).

Gómez-Baggethun et al. (2014) suggests the following working definition for <u>integrated valuation</u>: " the process of synthesizing relevant sources of knowledge and information to elicit the various ways in which people conceptualize and appraise ecosystems services values, resulting in different valuation frames that are the basis for informed deliberation, agreement and decision" (Gómez-Baggethun et al., 2014, p. 20). Such an integrated valuation method should take into consideration both quantitative and qualitative information, while also accounting for the various levels of "societal organization" (Gómez-Baggethun et al., 2014).

The degree of integration depends on two characteristics: <u>commensurability</u>, which refers to whether the provided results are deemed consistent regardless of the value dimensions they address; and <u>compatibility</u>, which indicates how "organically" underlying data can be joined and analyzed together (Łaszkiewicz & Andersson, 2016). The following Figure 2-4 exhibits the three potential integrations: full integration, where composing methods are perfectly tailored; combination, which is characterized by flexibility and inter-interpretability; and parallel use with limited synthesis potential. A table with comments on the commensurability and compatibility of several methods is presented in Appendix D, accompanied with tables indicating integration potential. Specifically, the latter tables suggest an overwhelming percentage of possible integration between different methods.

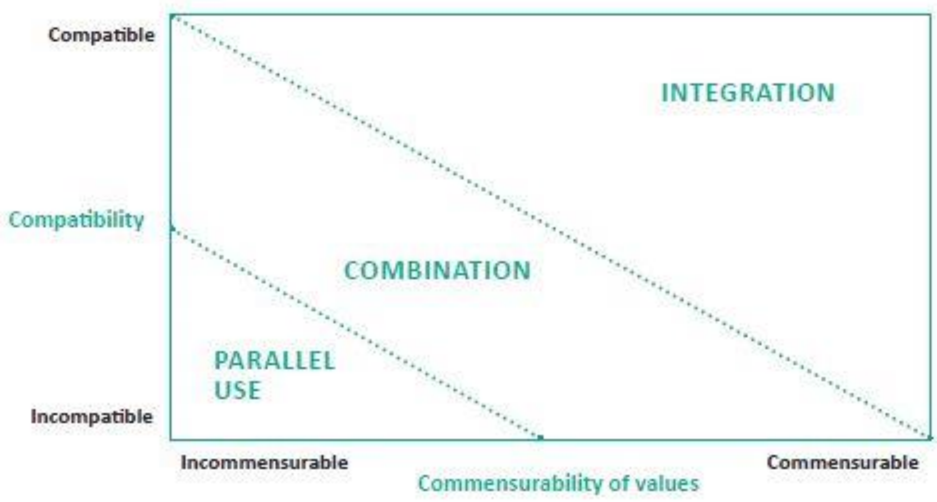


Figure 2-4: Integration framework (Łaszkiewicz & Andersson, 2016).

One has to bear in mind that synthezing and creating a new hybrid method will inherit the flaws and limitations of each component. Furthermore, it should be mentioned that, despite the integration, one composing method would still remain dominant and will more likely be the economic and monetary based one. However, this should be not be perceived as a limitation, since different value dimensions would still be considered, rather than an advantage, provided that policy makers and urban planners are more positively biased towards monetary terms (Łaszkiewicz & Andersson, 2016).

It should also be denoted that integrated valuation approaches are very case-specific and have a narrow but refined scope (J. Kronenberg & Andersson, 2016). Nonetheless, through the use of the Benefit Transfer method, this "circumstance sensibility" can be dealt with and produce reliable results (Liu et al., 2010).

2.3 Hedonic Pricing and Contingent Valuation studies

In this section the relevant literature on valuation of urban open spaces and ecosystem services will be reviewed. In order to be more efficient, the results of this review will be presented with the aid of the Environmental Valuation Reference Inventory ("Environmental Valuation Reference Inventory (EVRI),"). Through this website, relevant research and studies were assembled and concentrated in cumulative tables. Afterwards, these tables were enriched with additional literature gathered from other sources such as Elsevier and Google Scholar. The full tables can be found in Appendix E, while a small part of it is displayed below.

Author(s)	**Valuation technique(s)**	**Estimated values**
Bockarjova, M., W. Botzen, and M.J. Koetse (2018)	Contingent valuation (Meta-analysis)	Using the European model, value per ha ranged from $46,336 (2016 USD) for The Royal National City Park in Stockholm to $33,527,530 per ha for Danube Eco-District in Strasbourg. Using the Global model, average willingness-to-pay (WTP) per ha values for various types of urban nature, holding other variables at their mean, were computed: $11,007 for parks, $1,523 for forest, $1,955 for 'Green connected to grey', $1,895 for Blue, and $1,187 for peri-urban areas.

Czembrowski, Kronenberg, et al. (2016)	Hedonic Pricing and SoftGIS	Every additional percent of increase in the distance to the Łagiewniki forest decreases the apartment price by 177 PLN per square meter, whereas a corresponding increase in distance to a forest of no net preference decreases the square meter price by 96 PLN. The parks influenced the property prices to smaller extent: a 1% increase in the distance to the nearest park of high perceived value was associated with a decrease of the apartment price by 26 PLN. There were also two categories of green spaces which were seen as disamenities: cemeteries – decreasing the apartment price by 109 PLN with every 1% decrease in distance there to; and parks with low perceived value were associated with a corresponding decrease of 62 PLN (Czembrowski, Kronenberg, et al., 2016, p. 172).
Daams, M.N., F.J. Sijtsma, and A.J. van der Vlist (2016)	Hedonic property	The following percentage effect on property price of nearest attractive natural area were estimated by distance to the property: 0-0.5km (+16%), 0.5-1km (10.7%), 1-2km (8.8%), 2-3km (6.3%), 3-4km (3.7%), 4-5km (3.5%), 5-6km (3%), and 6-7km (1.6%). No significant price effect was found for properties beyond 7km away from the nearest attractive natural area. Regarding effects of the share of natural space within 7km of a property, a 0.22% effect on property prices was found for a marginal (1%) increase in natural area density at the expense of developed areas.
Sander, H., S. Polasky and R. G. Haight (2010)	Hedonic property	In Model 1, the marginal implicit price of a 10 % increase in tree cover within the 100-metre buffer evaluated for the mean house value was estimated to be $1,371 (2005 US), and the equivalent figure for the 250-metre buffer was estimated to be $836. For Model 2 increasing the tree cover increases home sale value up to 44% tree cover in the 100-metre buffer and 60% in the 250-metre buffer. Tree cover beyond 250 metres was found not to contribute significantly to sale price.

Table 2-4: Part of cumulative tables of ecosystem valuation studies (Own illustration).

Taking into consideration the studies included in this table, it becomes evident that current literature employs predominantly monetary valuation methods. This could be attributed to the fact that, in order to promote and favor open spaces and ecosystem services in both policy and urban planning, the results ought to be "translated" in monetary terms. Consequently, the negative bias towards them would be offset by rigorous arguments of tangible economic benefits.

The majority of monetary valuations reviewed employ the Hedonic Pricing method, while Contingent Valuation also appears to be equally reputable. This indication led the author to opt for the former, while also proposing an integration with the latter. Hedonic pricing (HP) estimates values based on how selected tangible and intangible attributes of the surroundings influence the value of a market good, most commonly in the case of the real estate market. Such models these models are developed by using the coefficients generated from a regression analysis (Monson, 2009). Contingent valuation, on the other hand, estimates values based on people's declared willingness to pay for a certain aspect of nature in hypothetical scenarios (J. Kronenberg & Andersson, 2016).

Whether it is associated with a price premium (Bolitzer & Netusil, 2000; Brander & Koetse, 2011; Cavailhès et al., 2008; Chen & Jim, 2010; Cho, Clark, Park, & Kim, 2009; Czembrowski & Kronenberg, 2016; Czembrowski, Kronenberg, et al., 2016; Czembrowski, Łaszkiewicz, et al., 2016; Czembrowski et al., 2019; M. N. Daams et al., 2016; Fernandez et al., 2018; Luttik, 2000; MacDonald et al., 2010; Panduro & Veie, 2013; H. Sander, Polasky, & Haight, 2010; H. A. Sander & Haight, 2012; Tyrväinen & Miettinen, 2000) or an average willingness to pay (WTP) (Bockarjova, Botzen, & Koetse, 2018; Brander & Koetse, 2011; Koetse et al., 2017; Latinopoulos, Mallios, & Latinopoulos, 2016; Martín-López et al., 2014; Van Berkel & Verburg, 2014), reduced proximity to urban open spaces is proven to be positively correlated. Notably, urban parks, forests and lakes demonstrate the largest influence (Cho et al., 2009; Czembrowski & Kronenberg, 2016; Czembrowski, Kronenberg, et al., 2016; Czembrowski, Łaszkiewicz, et al., 2016; Czembrowski et al., 2019; M. N. Daams et al., 2016; Koetse et al., 2017; Panduro & Veie, 2013; Remme, Edens, Schröter, & Hein, 2015; H. A. Sander & Haight, 2012; Tyrväinen & Miettinen, 2000). Moreover, a portion of literature attempted to correspond ecosystem services not only with green or blue assets, but also with infrastructure related with recreation and culture. However, only a few managed to offset hedonic pricing's main weakness, which is the bounded rationality of the buyer's perspective (Czembrowski, Kronenberg, et al., 2016; M. N. Daams et al., 2016). This means that a buyer ought to be aware of the environmental factors included in a hedonic pricing model to ensure its credibility and validity.

The aforementioned monetary methods are occasionally combined with socio-cultural and ecological methods, providing insightful results and a more comprehensive overview. Notably, Czembrowski and Kronenberg led several integrated studies in the area of Lodz, attempting to integrate social participatory methods and cultural categorization. The former induced increased price premiums, whereas the latter, despite the cultural benefits being acknowledged, did not bear monetary impacts. Moreover, they attempted to combine sociotope mapping as well, which resulted in much more conclusive results. Koetse et al. (2017) and Van Berkel and Verburg (2014) applied combinations of contingent valuation with choice experiment and travel cost respectively, producing substantial results. Furthermore, the framework, recommended by Fontaine et al. (2014) and tested in a case study in Belgium, argues in favor of integrating the various value dimensions of ecosystem services, while Martín-López et al. (2014) claim that an adaptation of different valuation methods would produce dissimilar results and rankings of preferences towards ecosystem services. Thus, it becomes evident that the method to be employed in the current research ought to be a synthesis of economic, social and ecological. However, since our scope of research is confined to the economic practicality of the results, a hedonic pricing model is opted for, while simultaneously gathering information which will be the basis for a subsequent social questionnaire. The latter will aim to induce monetary values for the specific characteristics recognized from field visits.

2.4 Key takeaways from literature review

Summarizing the previous sections, urban open spaces, being an integral part of modern urban settings, generate a vast array of benefits, ranging from environmental and economic to health and social. These benefits are conceptualized through ecosystem services. Several lists of ecosystem services have been proposed in academic literature, with the most prominent being TEEB's (2010). Moreover, a variety of ecosystem indicators have been proposed in order to achieve a better understanding of the status quo of ecosystem provisioning, predict and measure efficiently the expected outcomes, as well as monitor the overall progress. Lastly, the synergy and trade-off potential between ecosystem services also ought to be highlighted, since different "service packages" could lead to significantly different outcomes. Thus, selecting the optimal configuration should be a time-dynamic process.

Due to the fact that value has different dimensions (economic, sociocultural and ecological), various valuation methods exist to measure each respective dimension. Therefore, it is indispensable to employ an integrated approach where, for instance, biophysical measurements are combined with economic valuation, while also utilizing non-monetary methods to account for social and cultural benefits. In order to achieve an optimal integration of methods, the composing methods ought to be both commensurable and compatible.

Findings of ecosystem service research suggest that hedonic pricing and contingent valuation are the most prominent valuation methods. Furthermore, the vast majority of studies conclude that green spaces positively correlate with both the surrounding real estate's market prices and their inhabitants' willingness to pay. However, despite the existence of a few integrated methods, there is still a significant research gap, which this research aims to fill.

3 METHODOLOGY

This chapter illustrates the research method which will be employed in the present thesis. Section 3.1 describes the overall methodology by depicting its sub-parts. Each sub-part is further explained in ensuing sections. Section 3.2 depicts the theoretical investigation of the concepts to be scrutinized, whereas section 3.3 describes the research's scope definition, in regard to transactions and ecosystem service hubs to be considered. Section 3.4 explicitly describes the research's Phase I, which is the creation and execution of the hedonic pricing model. Notably, how the data was processed and "cleaned" is illustrated, while simultaneously thoroughly explaining the variable selection and setup. Afterwards, it is clarified how the ESH hedonic pricing model was established, as well as how the various sub-divisions were executed. Appendix F supplements this section. Finally, section 3.5 provides the overview of Phase II, when the field visits and hub identification take place, while section 3.6 explains how the conclusions are presented and linked together.

3.1 Research Method

The research method, intended to be used in the present thesis, is a combination of both quantitative and qualitative research. The following figure (Figure 3-1) depicts an overview of the overall methodology. It is divided into 4 distinct parts. The first part includes the theoretical underpinnings of the research topic, consisting of the research proposal and the literature review. The second part of the research is the definition of the research's scope, primarily identifying which open spaces are explored and clustered into "Ecosystem Service Hubs", and which house transactions are considered. The third part, designated as Phase I, involves the formulation of a hedonic pricing model aimed to reach the first objective of section 1.3. In the fourth part of the research, appointed the name Phase II, field visits to the selected ESHs take place, which are intended to aid in reaching the second objective of section 1.3. These visits also provide the ground work for the subsequent supplementary partly qualitative, partly quantitative survey. Lastly, the conclusions drawn from each respective Phase are integrated into the final fifth part.

It should be denoted that Figure 3-1 does not represent a strict chronological order of the research's tasks. In fact, activities of Phase I and II are carried simultaneously, whereas the literature review is constantly enriched with new studies, if deemed useful. The purpose of this scheme is to provide explicit and comprehensive insights on the set milestones and methodology to be applied. A more detailed description of each part ensues.

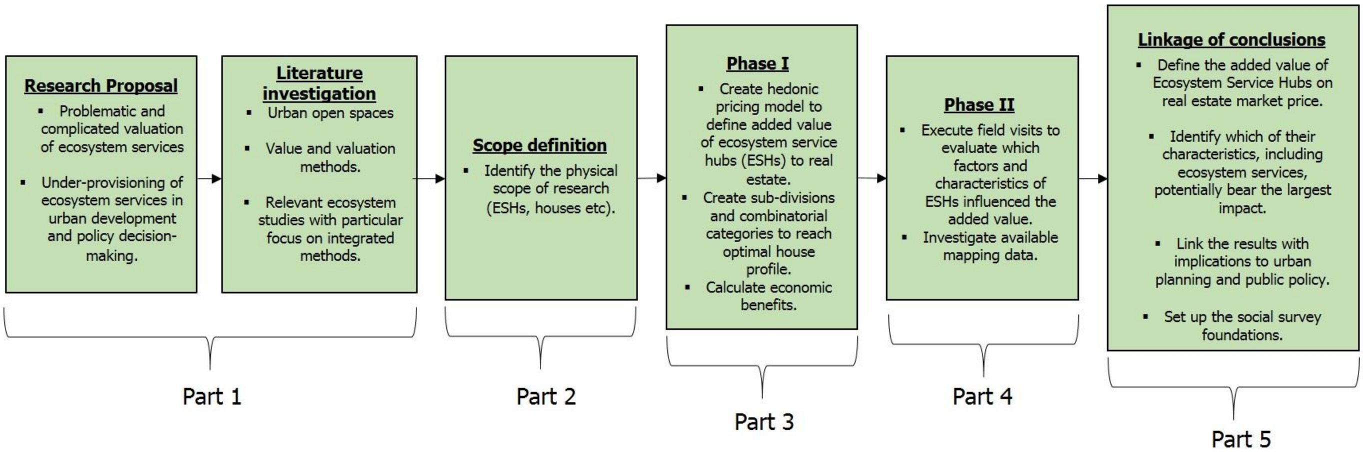


Figure 3-1: Overall methodology scheme (Own illustration).

3.2 Part 1 - Theoretical underpinnings

The beginning of the research is an extended problem analysis. The significant upsurge in interest and demand in urban open spaces is underlined, as well as the jeopardizing implications of the lack of properly developed valuation frameworks and practices. The absence of such methods results in unsustainable land use and urban development, since policies and plans favoring ecosystem services are faced with vigorous competition.

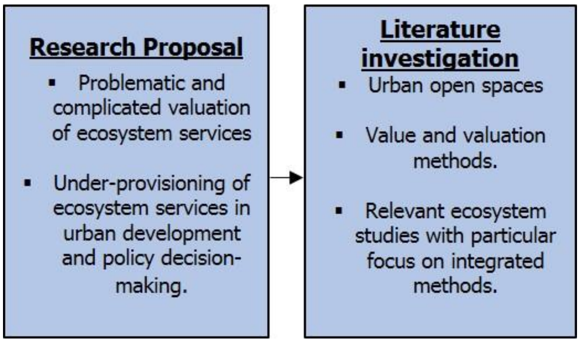


Figure 3-2: Methodology part 1 (Own illustration).

Afterwards, a rigorous literature study is presented. Initially, this review takes into consideration available academic literature associated with the concepts of urban open spaces and ecosystem services. The theoretical background of urban open spaces, including topics such as their types, sub-divisions and plethora of benefits, is developed. Additionally, lists of generated ecosystem services and their characteristics are discussed, as well as potential indicators to measure their performance and efficiency. Subsequently, the concepts of value and different valuation methods are explored. The various dimensions of value are distinguished: monetary, socio-cultural and ecological. Thence, an investigation of the available monetary and non-monetary methods ensues, accompanied by a correspondence between them and the previously mentioned value dimensions. The integration potential is also thoroughly discussed. Lastly, relevant ecosystem valuation studies, with a particular focus on integrated, multidimensional methods, are examined and presented in cumulative tables. The most dominant method employed is the hedonic pricing model, which relates house prices to not only the proximity to open spaces, but also high green cover percentages as a measure of the willingness to pay for ecosystem services. This unanimous result motivates positively this research in adapting this method. The eventual combination of hedonic pricing with a survey is inspired by the documented integrated methods, which provided more comprehensive overviews of the actual situation.

3.3 Part 2- Scope definition

The second part of this research contains the scope definition (Figure 3-3). First of all, the physical scope of research ought to be properly defined. It is agreed that the city of Delft (Figure 3-4) is a suitable choice, due to its proximity to the university and possible facilitation of the eventual survey distribution. Afterwards, the major open spaces within the set boundaries are identified. This research intends in pinpointing several "Ecosystem Service Hubs" (ESHs), which are comparable in context but varying in content. These hubs ought to contain a variety of not only green and blue spaces, but also generated ecosystem services.

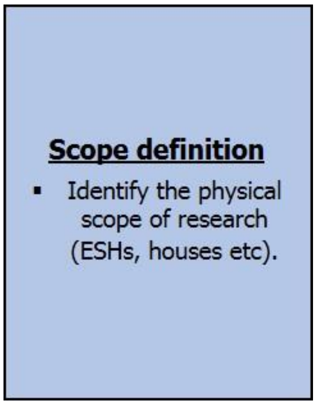


Figure 3-3: Methodology part 2 (Own illustration).

The eventual selections are: Delftse Hout & Hertenkamp (ESH1); Buitenhof park and surrounding spaces (ESH2); and Abtswoudse Bos and surrounding spaces in Tanthof (ESH3). A brief description of the areas, as well as photographs of the hubs and their boundaries is presented in section 4-2. On the other hand, it is deemed unnecessary to confine our house transaction data in Delft. Therefore, it is decided to include all houses within a 500m radius from each respective ESH. This means including houses in Delft, Rijswijk and Den Haag. The specific 500m cut-off distance is selected according to research results, which evidenced significant influence reductions when exceeding this limit (Bolitzer & Netusil, 2000; M. N. Daams et al., 2016). Furthermore, since a survey is intended to be distributed, restricting the sample size could aid the overall survey distribution process and facilitate the analysis.

Figure 3-4: Map of Delft city (Google).

The house related data and information is retrieved in cooperation with Kadaster, the Dutch Cadastre, Land Registry and national mapping agency in the Netherlands. Their provided list includes a few structural and locational attributes, as well as transactional data (dates, amounts, addresses).

3.4 Part 3- Phase I

3.4.1 Data preparation and variable setup

An overview of Phase I is depicted in Figure 3-5. First of all, after retrieving and assembling all available data together, an initial filtering and evaluation ought to be carried out. The data provided by Kadaster includes all house transactions, recorded over the past ten years (2009-2019) and within the municipalities of Delft, Den Haag and Rijswijk. Furthermore, additional information regarding the houses is supplied, containing the exact transaction date, address and zip code, house type, year built, square meter surface and function.

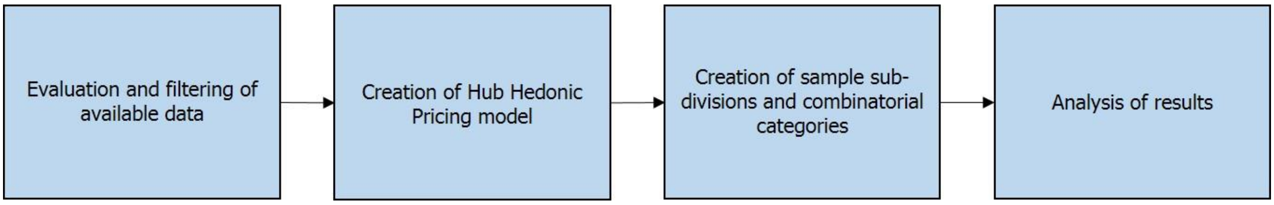


Figure 3-5: Methodology part 3 (Own illustration).

The initial database consists of 74665 transactions. This list is filtered to get rid of data, which either falls outside of the research's scope or is deemed irrelevant. Thus, after eliminating missing data rows (692) and excluding buildings which are not currently being used (2137), as well as those that have not a residential function (e.g. offices, shops) (936), 71199 transactions are left. Thence, duplicate rows are deleted, leaving 71180 transactions to be linked with ArcGIS. Nevertheless, this linkage leads to 40 transactions not being displayed. Displaying the transactions in a Geographic Information System (GIS), allows for an accurate spatial depiction of the transaction and an equally precise measurement of their distance to the hubs. It also permits the addition of a spatial variable, derived from the CBS (Dutch statistic agency) database. This would be the neighborhood variable, with which we eventually replace the zip codes in order to achieve improved accuracy.

Afterwards, for each hub case study, the distance cut-off limit of 500m is imposed. Therefore, each hub case study (ESH1, ESH2 and ESH3) is left with 585, 298 and 326 transactions respectively. In order to construct a reliable and efficient hedonic model, the data ought to be "cleaned" from outliers and unknown values. This process is carried out for all case studies; however, it is explicitly described only for the first one (ESH1).

The following scatter plots demonstrate how transactions were filtered out. Essentially, houses sold for prices higher than 5000 € per m^2 (2) or lower than 1000 € per m^2 (7) are discarded, as well as houses larger than 250 m^2 (7). Thence, the dummy variable categories are designed accordingly. For instance, built year classes are created on the basis of similar structural characteristics, inspired by relevant literature. The transactions of each sub-category are also examined thoroughly through scatter plots to confirm whether they encompass enough observations or display "well-spread" distances and prices. In case either of these conditions is not met, a merge of different sub-categories is attempted, provided that the respective data has a good fit. For example, as far as ESH1 is concerned, the neighborhood of "Indische Buurt" is eliminated because of both its low observations (7) and its inability to incorporate with the other neighborhoods. Lastly, houses, whose type is prescribed as "unknown" (5) or has a zero distance (1) to the ESH, are also eliminated from the dataset. Thus, 557 transactions are left in the case sample.

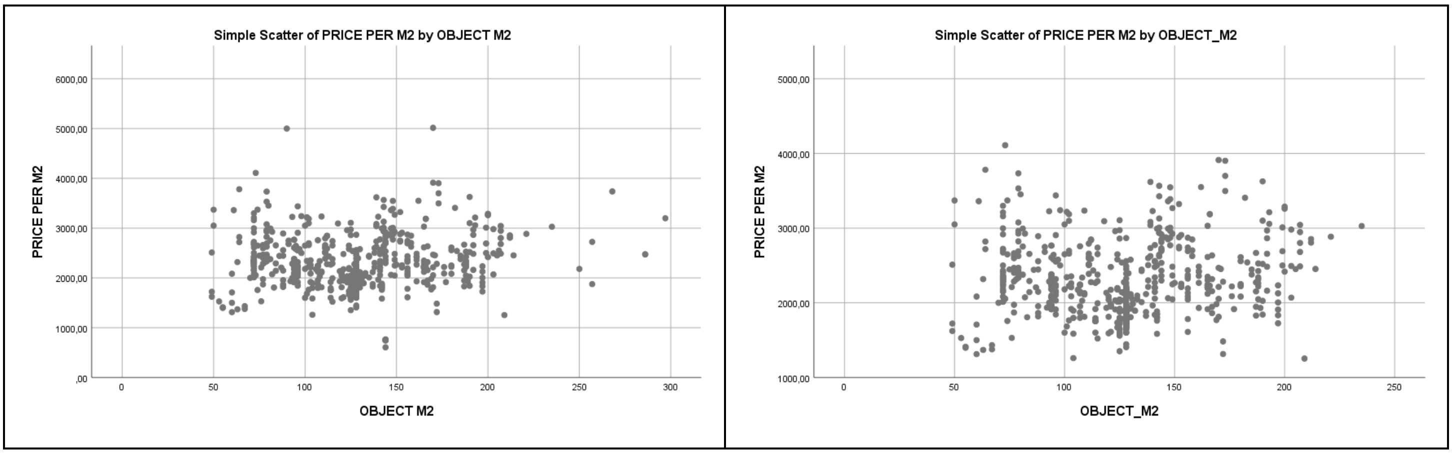


Figure 3-6: Transactions before and after filtering outliers.

After excluding redundant data, establishing our basic hedonic pricing model follows. Hedonic pricing models are capable of measuring the indirect effect of environmental tangible and intangible characteristics on the overall transaction price. These models are developed by using the coefficients generated from a regression analysis (Monson, 2009). Monson (2009) mentions a list of building characteristics which could be considered, containing total square feet, parking ratio, floors, year built and tenancy status. Visser, Van Dam, and Hooimeijer (2008) confirm that regional price variations could be explained by such attributes of the physical, social and functional environment. Goodman (1978) however emphasizes the need to also include variables accounting for the spatial and time variations of the transactions. Kadaster provided the recorded exact date of the transaction, as well as X,Y coordinates in order to deal with this issue. Thus, three vectors are required: a structural, a spatial and a time-related.

As previsouly stated, the hedonic pricing model is carried out through a multiple linear regression. The selected independent variables provide the causal explanation of the dependent variable's variance. Essentially, the impact of each single independent variable X_n could be investigated separately. More specifically, each coefficient displays how much Y will increase if X_n increases by one unit, assuming the rest of the independent variables are constant. The used function of the multiple linear regression is the following:

Market Price = f(tangible & building characteristics, other influencing factors)

or

$$Y_i = (b_0 + b_1 X_{i1} + b_2 X_{i2} + \ldots + b_n X_n) + \varepsilon_i$$

Where:

- Y_i is the dependent variable
- X_{in} is the amount of the n-independent variable
- b_0 is the intercept
- b_n is the coefficient of the n-independent variable
- ε_i is the standard error

In this study, the transaction price per m^2 (in €) is opted as a dependent variable, instead of the plain transaction price. This decision is based on the intention to diminish the influence of the house size on the price. It is expected that the house size will have the largest impact if the plain house price is to be selected, as previous studies have evidenced. Therefore, the selection of the price per m^2 limits the influence of the house size, while magnifying the role of the rest of the explanatory variables and particularly the distance to the hubs. Besides, the aim of this research is not to create a model with high explanatory power of the price's variance, rather than to capture the added value of the ecosystem service hubs. It should also be underlined that a correction according to the real estate market developments is implemented. This implies that houses sold for identical amounts during different years, would not be valued the same if the transaction occurred during the same year. Thus, in order to achieve this, the Housing Price Index (HPI) is employed. HPI reflects the price changes of residential housing compared to a specific reference year. In the following table (Table 3-1), which is used to adjust the transaction prices, annual HPI changes are depicted, with general inflation also taken into consideration. 2019 is selected as a reference year (=100).

Year	Inflation-adjusted (%)	HPI
2009	-4.36%	99.24
2010	-3.15%	96.20
2011	-4.74%	91.85
2012	-9.09%	84.20
2013	-8.83%	77.37
2014	0.51%	77.76
2015	2.66%	79.89
2016	4.88%	83.99
2017	6.24%	89.58
2018	7.31%	96.64
2019	3.36%	100.00

Table 3-1: Annual house price changes (%) and HPI (Sources: Statistics Netherlands (CBS), Global Property Guide).

Table 3-2 depicts the descriptive statistics of the un-adjusted dependent variable for ESH1. It shows that the average house price is almost 300.000€, while the average house price per m^2 is 2.300€, with both demonstrating a high standard deviation, indicating a broad range of prices.

	Dependent variables	Mean	Minimum	Maximum	Std. Deviation
€	Transaction price	292.804,62 €	76.875 €	711.600 €	117.096,28 €
	Transaction price per m^2	2.306,51 €	1.253,59 €	4.109,59 €	499,52 €

Table 3-2: Descriptive statistics of the dependent variable.

As far as the independent variables are concerned, the following list (Table 3-3) is used, which also contains descriptive statistics of these variables.

	Independent variables	Minimum	Maximum	Mean	Frequency
	Year of sale	2009	2019	2014,42	
	Year of sale= 2009 (dummy)			,08	44
	Year of sale=2010 (dummy)			,06	35
	Year of sale=2011 (dummy)			,09	50
	Year of sale=2012 (dummy)			,06	34
	Year of sale=2013 (dummy)			,06	32
	Year of sale=2014 (dummy)			,09	49
	Year of sale=2015 (dummy)			,10	55
	Year of sale=2016 (dummy)			,17	93
	Year of sale=2017 (dummy)			,15	82
	Year of sale=2018 (dummy)			,10	58
	Year of sale=2019 (dummy)			,04	25
	House type=Apartment (dummy)			,16	88
	House type=Corner house (dummy)			,16	91
	House type=Semi-Detached house (dummy)			,14	79
	House type= Row house (dummy)			,48	269
	House type= Detached (dummy)			,05	30
	Year built	1890	2015	1990,25	
	Year built=Before 1500-1905 (dummy)			,03	15
	Year built= 1906-1944 (dummy)			,04	24
	Year built=1945-1970 (dummy)			,11	61
	Year built=1971-1990 (dummy)			,01	8
	Year built=1991-2000 (dummy)			,05	27
	Year built=2001-Today (dummy)			,76	422

	House size (m^2)	49	235	126,15	
	Neighborhood=Biesland (dummy)			,01	8
	Neighborhood=Bomenwijk (dummy)			,09	52
	Neighborhood=De Bras (dummy)			,29	162
	Neighborhood=Heilige Land (dummy)			,15	84
	Neighborhood=Koepoort (dummy)			,07	41
	Neighborhood=Waterbuurt (dummy)			,38	210

Table 3-3: Descriptive statistics of the independent variables.

The year of sale represents one of the time variables of the hedonic model. As seen in the following figure (Figure 3-7), the number of houses sold between 2009 and 2013 is significantly lower than after 2013. However, the average house price remained relatively stable, while only peaking in 2018 and 2019. These remarks could be explained based on the economic crisis which stroke the real estate market in 2008. Moreover, the time period in which the house was built also seems to impact the mean price. Particularly, the vast majority of houses was built in 2000s, which led to higher prices, probably due to their improved quality. These figures aim to showcase the significance of time's influence on transaction prices, which reflect relevant social and economic developments.

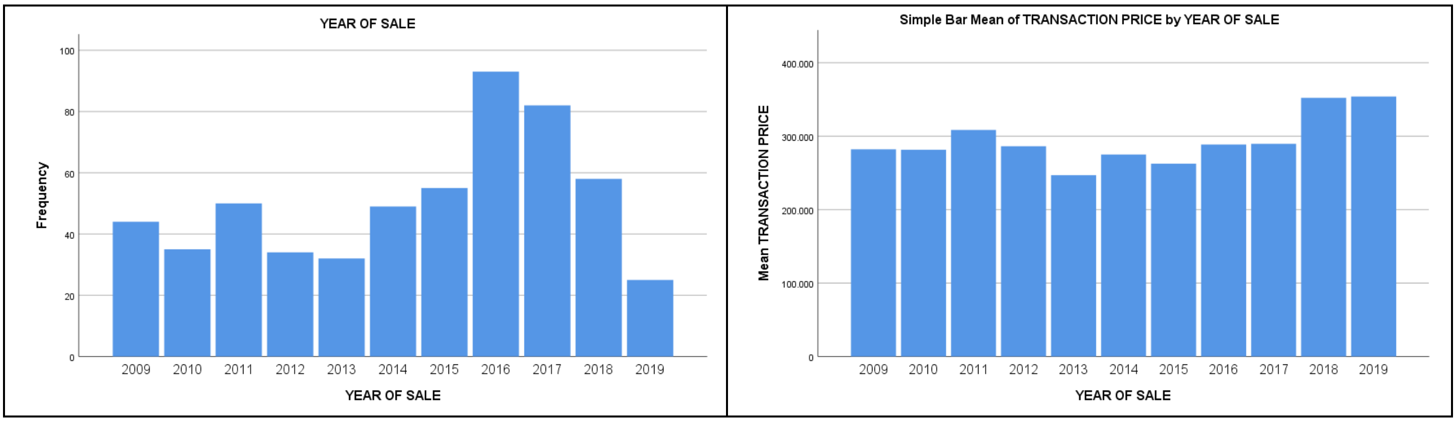


Figure 3-7: Year of sale frequency and mean house price (Own illustration).

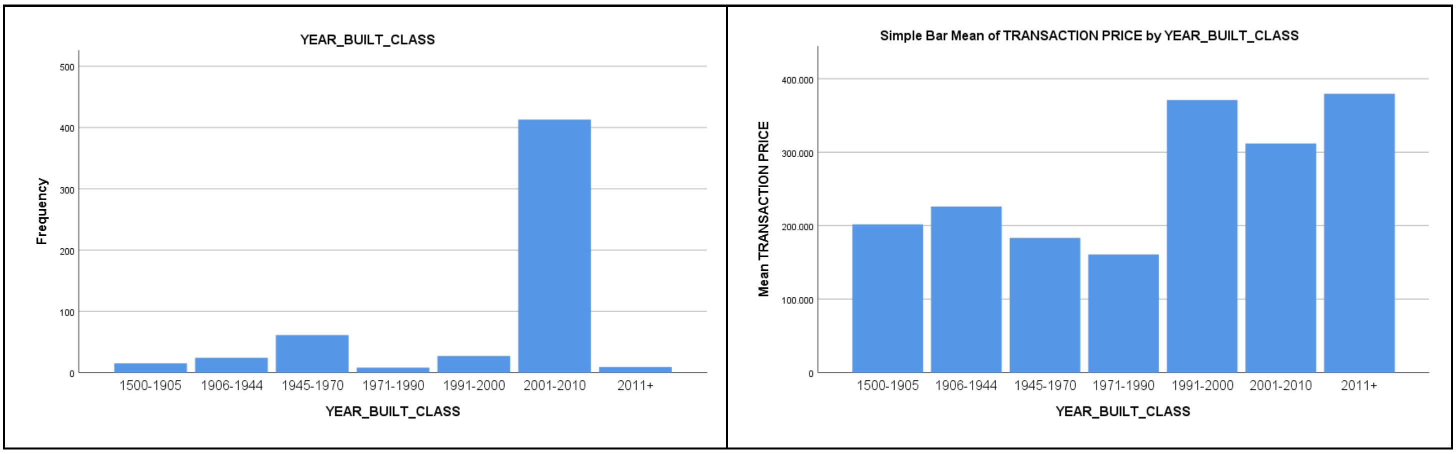


Figure 3-8: Year built frequency and mean house price (Own illustration).

The structural variables included are the house's type, in the form of dummy variables, and the house size, which is a continuous variable. The latter is further transformed through the natural logarithmic function, in order to account for non-linearity. Nevertheless, it should be stated that, despite relevant literature proposing additional structural variables such as existence of garden or number of rooms and floors, the Kadaster databases does not possess such information and is, thus, omitted.

Lastly, as far as the locational variables are concerned, these are all incorporated in the neighborhood variable. Relevant academic studies have been calculating the minimum distances to several amenities and disamenities, such as schools, hospitals, city centre and highways separately, in order to take into consideration the locational effect. Nonetheless, in this study, it is assumed that houses within the same neighborhood are influenced by the same factors. Therefore, this variable is used to replace all others. Moreover, it is preferred over the zip codes since it is a more comprehensive representation.

House Type	Mean house price per m^2
Apartment	2049,59 €
Corner	2275,59 €
Semi-Detached	2523,50 €
Row	2281,20 €
Detached	2809,51 €

Neighborhood	Mean house price per m^2
Biesland	1961,9513
Bomenwijk	2315,2242
De Bras	2600,0585
Heilige Land	2128,8549
Koepoort	2730,7978
Waterbuurt	2079,2627

Table 3-4: Mean house price per m^2 for each house type and neighborhood.

In appendix G, similar descriptive statistical tables are displayed, referring to ESH2 and ESH3 respectively.

3.4.2 Hub Hedonic Pricing model

Afterwards, the basic hedonic pricing model is adjusted to account for the presence of the Ecosystem Service Hub. This is achieved by linking the Kadaster data with ArcGIS, where the exact locations of the transactions are projected, thus rendering the measurement of the distance easier. The calculated distance reflects the Euclidean distance, which is the straight line linking the house and the hub's boundary. It is preferred over alternatives, such as the travelling distance, primarily because of its simple and straightforward calculation, as well as due to our intention to measure the proximity to the hubs. This distance variable is inserted in the model in two ways: first as a continuous variable, logarithmically transformed to account for non-linearity; and secondly by creating distance dummy variables, increasing by 100 meters (0-100, 100-200, etc). The latter is purposed to demonstrate how much house prices increase when moving from the outer rim (400-500m) closer to the hub. The results of these analyses are presented in chapter 4.

	Independent variable	Minimum	Maximum	Mean
	Distance to ESH1 (m)	14,02	499,71	332,15
	Distance classes	Frequency	Mean house price per m^2	
	0-100 m	26	2928,97	
	100-200 m	51	2511,52	
	200-300 m	108	2262,41	
	300-400 m	209	2157,47	
	400-500 m	163	2363,38	

Table 3-5: Descriptive statistics of the distance variable.

3.4.3 Subdivision of samples

In order to better grasp the influence of the hub's proximity, a sub-division of the house sample into homogeneous categories is executed. The purpose is to gather insight on which types of houses are more "sensitive" to the presence of an ecosystem service hub. Therefore, a clustering of the sample is carried out according to: house size (0-100m^2, 100-150m^2, 150+m^2); house type (apartment, corner, split, row, detached); and year built (depends on case).

Furthermore, a new continuous variable is created in order to substitute the neighborhood variable. This variable displays the percentage of public green surrounding the house within a 250-meter radius. It is selected instead of the neighborhoods due to its larger generalizability and comparability between cases. This particular cut-off distance selection is inspired by the results of Sander et al's (2010) work. It should be remarked that the hub areas are left out of this calculation to avoid double counting. Thus, green spaces included in this variable contain "landscape" and "transition" greenery.

	Independent variable	Minimum	Maximum	Mean
	Percentage of surrounding public green	5,1%	29,1%	12,76%
	Percentage classes	Frequency	Mean house price per m^2	
	0-10%	171	2382,76 €	
	10-15%	247	2218,90 €	
	15-20%	109	2285,55 €	
	20+%	30	2669,46 €	
	0-100m^2	154	2376,10€	
	100-150m^2	274	2196,16€	
	150+m^2	129	2456,77€	

Table 3-6: Descriptive statistics of the surrounding green variable and house size.

3.5 Part 4- Phase II

During Phase II, an extensive investigation of the Ecosystem Service Hub sites is performed. Initially, field visits to the hub sites take place, where photographic material is gathered, as well as a personal identification of green and blue components. Furthermore, recreational facilities such as sport fields are also pinpointed. Afterwards, a thorough exploration of the available mapping information of the hubs is carried out in order to further refine the its composition and provided ecosystem services. The graphs of the hub's composition is created according to information retrieved from the ObjectenHandboek ("Objectenhandboek BGT | IMGeo,"). Lastly, the results of these analyses are also presented in chapter 4.

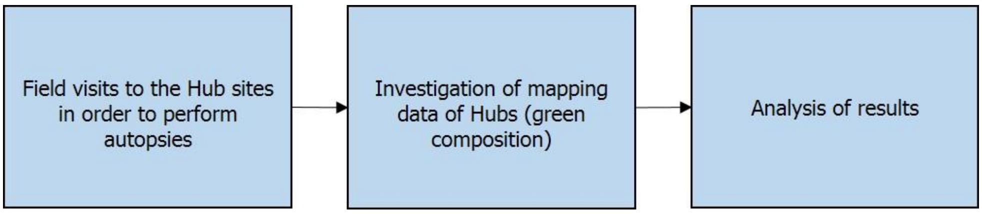


Figure 3-9: Methodology part 4 (Own illustration).

3.6 Part 5- Conclusions

In the end, the quantitative results of Hub Hedonic Pricing model are combined with the qualitative, information gathered from the field visits. Notably, the added value of each Ecosystem Service Hub is distinguished and defined through price premiums, while specific characteristics of each hub are qualitatively correlated with these premiums. Thus, the research objectives are attained. Lastly, the research's implications to public policy and urban development are investigated, while also setting up the foundations of the subsequent complimentary social survey.

Linkage of conclusions

- Define the added value of Ecosystem Service Hubs on real estate market price.
- Identify which of their characteristics, including ecosystem services, potentially bear the largest impact.
- Link the results with implications to urban planning and public policy.
- Set up the social survey foundations.

Figure 3-10: Methodology part 5 (Own illustration).

4 RESULTS

Chapter 4 demonstrates the outcomes of Phase I and II, in both graphical and textual form. Initially, section 4.1 focuses on the results of the Hub Hedonic Pricing model. The ANOVA and coefficient tables are displayed, as well as graphical representations of the hub proximity, both as a continuous and as a dummy variable. Moreover, the results of the sub-divisioning and combinatorial analyses are depicted. Lastly, the estimation of the overarching benefits generated by these hubs in regard to real estate is carried out. This section is complemented by Appendix G. Thence, the results of the hub composition analysis are demonstrated. Notably, the green composition and potential ecosystem service presence is underlined, as well as other information. This section is supplemented by Appendix H.

4.1 Phase I results

4.1.1 Hub Hedonic Pricing models outcomes

A hedonic pricing model is created for all three Ecosystem Service Hub cases and is executed through a multiple linear regression analysis. This analysis includes all the variables mentioned in sections 3.4. Initially, the distance to the hub is investigated as a continuous variable. The model summaries and ANOVA tables of each regression are depicted below.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
ESH1	,765	,585	,565	364,69807
ESH2	,708	,501	,460	356,20174
ESH3	,791	,625	,602	239,53499

Table 4-1: Model summary cumulative table for each hub.

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
ESH1	Regression	99437784,424	26	3824530,170	28,755	,000
	Residual	70492481,831	530	133004,683		
	Total	169930266,255	556			
ESH2	Regression	32980060,699	21	1570479,081	12,378	,000
	Residual	32861837,246	259	126879,680		
	Total	65841897,946	280			

ESH3	Regression	28243458,846	18	1569081,047	27,347	,000
	Residual	16926218,159	295	57377,011		
	Total	45169677,004	313			
a. Dependent Variable: ADJUSTED_PRICE PER M2						

Table 4-2: ANOVA cumulative table for each hub.

It becomes evident that the hedonic pricing models are all statistically significant. Nevertheless, their adjusted R^2 are not particularly high. This means that the independent variables, despite being significant, do not entirely explain the dependent variable's variance. This is expected, since a few structural variables are not available and not included in the model (See section 3.4.1). However, this is not deemed as a problem, since our model is not destined as a prediction model, rather than simply as a tool to identify the influence of the hub distance. The variables incorporated in the model should suffice to accurately capture this impact.

The regression coefficients of ESH1 are displayed below, while ESH2's and ESH3's respective coefficients are presented in Appendix G. Since dummy variables are used, a reference dummy ought to be established for each category. This reference is selected based on the largest frequency (see Table 3-2). The distance variable coefficient is negative as predicted, demonstrating the decay effect on the house price. Additionally, the house size effect is in fact limited, evidencing a negative coefficient due to the price per m^2 being used as a dependent variable. Lastly, a few of the sale year dummy variables are statistically insignificant, which is expected due to the price correction that took place.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
ESH1	(Constant)	8214,625	557,235		14,742	,000
	Year of sale= 2009 (dummy)	-499,203	69,903	-,244	-7,141	,000
	Year of sale=2010 (dummy)	-304,340	75,640	-,134	-4,024	,000
	Year of sale=2011 (dummy)	-207,455	66,404	-,107	-3,124	,002
	Year of sale=2012 (dummy)	-115,349	76,276	-,050	-1,512	,131
	Year of sale=2013 (dummy)	79,665	77,180	,034	1,032	,302
	Year of sale=2014 (dummy)	-78,331	68,091	-,040	-1,150	,251
	Year of sale=2015 (dummy)	-50,089	64,321	-,027	-,779	,436
	Year of sale=2016 (dummy)	-14,855	55,808	-,010	-,266	,790
	Year of sale=2017 (dummy)	-83,473	58,047	-,054	-1,438	,151
	House type=Apartment (dummy)	-682,059	79,549	-,450	-8,574	,000
	House type=Corner house (dummy)	57,536	45,142	,039	1,275	,203
	House type=Semi-Detached house (dummy)	254,789	51,633	,161	4,935	,000
	House type=Detached house (dummy)	778,868	82,134	,318	9,483	,000
	Year built=Before 1500-1905 (dummy)	-347,012	137,297	-,102	-2,527	,012
	Year built= 1906-1944 (dummy)	-333,541	122,057	-,123	-2,733	,006
	Year built=1945-1970 (dummy)	-520,409	100,104	-,294	-5,199	,000
	Year built=1971-1990 (dummy)	-661,175	145,088	-,142	-4,557	,000
	Year built=1991-2000 (dummy)	154,280	111,121	,060	1,388	,166
	House size in LN (m^2)	-684,270	87,371	-,386	-7,832	,000
	Distance to ESH1 in LN (m)	-273,671	40,809	-,241	-6,706	,000

	Neighborhood=Biesland (dummy)	412,382	183,823	,089	2,243	,025
	Neighborhood=Bomenwijk (dummy)	593,026	97,426	,312	6,087	,000
	Neighborhood=De Bras (dummy)	566,211	46,844	,466	12,087	,000
	Neighborhood=Heilige Land (dummy)	455,481	81,144	,295	5,613	,000
	Neighborhood=Koepoort (dummy)	1213,441	115,514	,574	10,505	,000
	Percentage of surrounding public green (LN)	436,885	61,751	,264	7,075	,000
a. Dependent Variable: ADJUSTED_PRICE PER M2						

Table 4-3: Coefficient table for ESH1's independent variables.

4.1.2 Graphical representations of the distance effect

The following figure shows the graphical representation of the distance decay effect on the mean house price per m^2 and is created based on the beta coefficients derived from each regression. More specifically, it represents the situation where the house is "moved" by a distance delta (Δ) from its original position. This initial position is set at the unrealistic 1m away from the hub. It becomes immediately apparent that ESH1 has the largest influence on surrounding real estate price (β=-273,671), whereas ESH2 has the lesser impact (β=-78,354). Between them lies ESH3 with a β-coefficient of -159,433. These betas' interpretation is that a 1% increase in distance from each hub would lead to approximately 2,7€, 0,8€ and 1,6€ per m^2 decrease respectively. It should be denoted that, despite ESH2's figure being above ESH1's, gradually closer proximity to ESH1 induces a larger increase in house price than ESH2 and ESH3 respectively. Furthermore, it becomes evident that the largest influence drop happens for a distance delta of approximately 100m, especially for ESH1, where there is a 50% decrease observed.

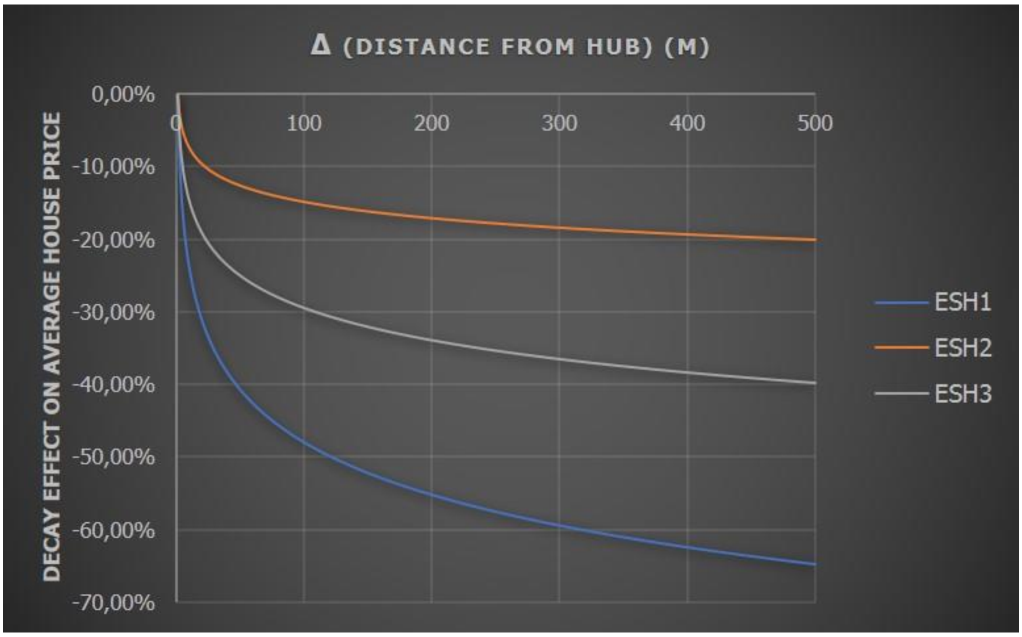


Figure 4-1: Cumulative graph of the distance decay effect on the mean house price per m^2 for all three hub cases.

Afterwards, the distance continuous variable is replaced by distance class dummy variables, as described in section 3.4.2. The beta coefficients of these dummy variables are shown below for the case of ESH1 (Table 4-4) and in Appendix G for ESH2 and ESH3. These betas reflect the relative difference between the reference case, the outer rim of 400-500m away from the hub, and the rest. This is clearly demonstrated in Figure 4-2, where these differences are displayed for all three hubs, normalized by the average house price per m^2 for the 400-500m class. For instance, for ESH1, all values were divided by 2700,86€.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
ESH1	0-100 m	605,641	90,557	,231	6,688	,000
	100-200 m	297,190	70,229	,155	4,232	,000
	200-300 m	97,449	56,334	,070	1,730	,084
	300-400 m	8,167	45,837	,007	,178	,859
a. Dependent Variable: ADJUSTED_PRICE PER M2						

Table 4-4: Coefficient table for ESH1's distance dummy variables (Adjusted R^2=0,571).

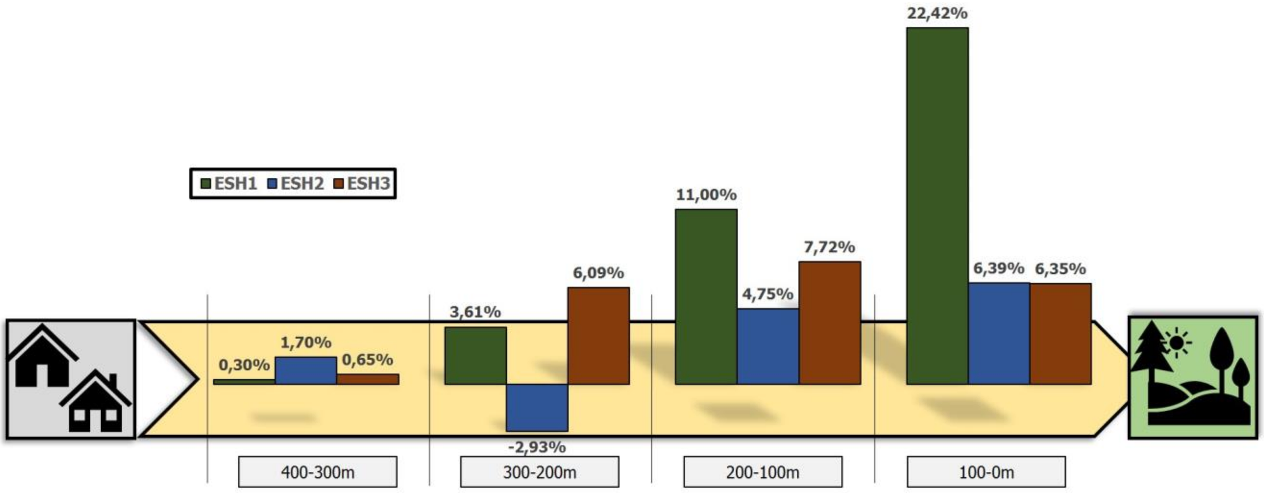


Figure 4-2: Cumulative graph of relative price influence differences between distance classes for all three hubs (Own illustration).

A progressive and steady increase is observed for almost all three hubs. ESH1 is presenting the largest increase and most linear behavior, as it was also suggested in Figure 4-1. On the other hand, similar behavior is revealed for ESH2, which exhibits a lesser gradual increase with the exception of a negative value in the 200-300m zone. This could be attributed to the house sample within that zone and its particular characteristics (year built, house type or neighborhood). Thus, this value should be disregarded. Lastly, as far as ESH3 is concerned, in spite of a similar rise in house prices, a sudden drop is detected in the 0-100m zone. This could be explained by the lack of diversity of houses composing this zone, since they: are all built between 1981 and 1990; belong to the Bosrand neighborhood; and include the only apartments documented in ESH3's case. Otherwise, it could be the case that the distance-price relationship has a turning point within the 100-200m zone.

4.1.3 Subdivision results

Afterwards, the housing samples are sub-divided into several categories depending on their size, type, age and surrounding green percentage (see section 3.4.3). For each sub-division a reference category is selected, based on the largest frequency. For example, concerning ESH1, the reference category for the "house type" sub-divisioning is "row" houses. Thence, an "interaction" variable is created in order to calculate the relative differences between the distance betas of each sub-category. These beta coefficients can be found in Appendix G. The following figures depict the relative differences between the reference and each sub-category, when they "move" 1% further away from the hub. For instance, if an apartment and a row house (reference) were "moving" away from the hub, the apartment's value decrease would be 0,79€ per m² less.

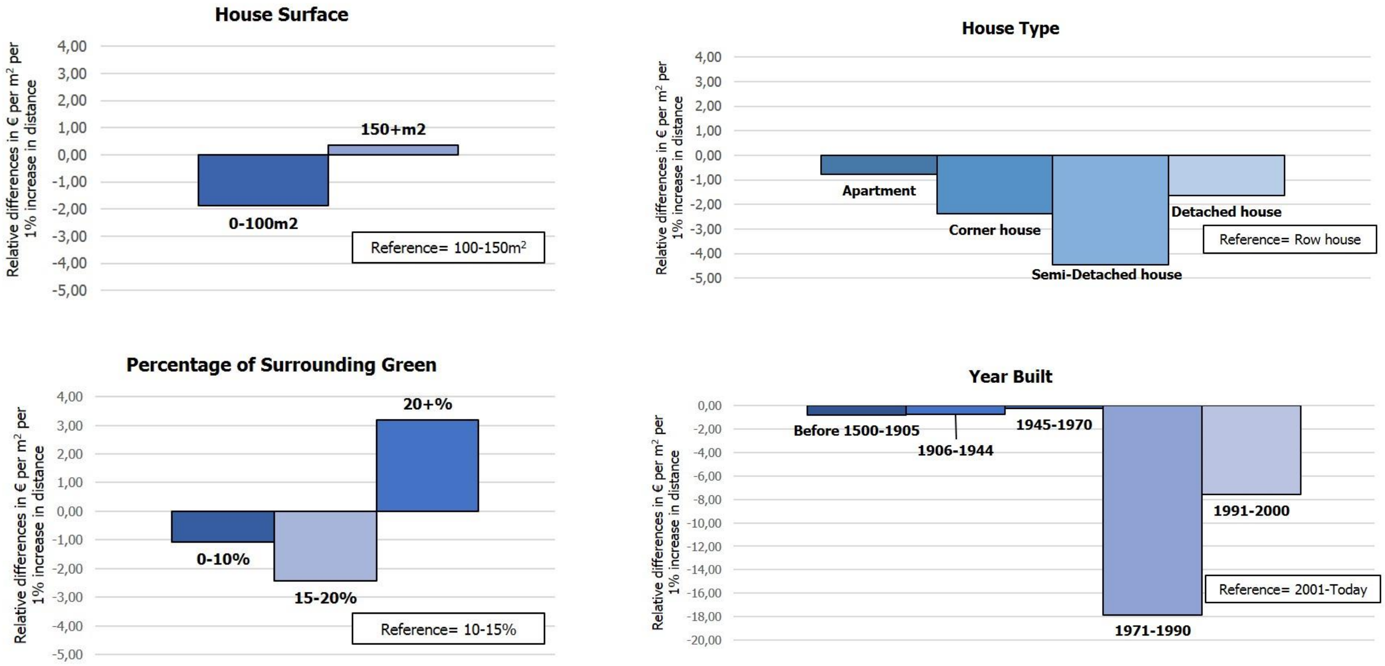


Figure 4-3: Relative differences in distance sensitivity between each sub-category (ESH1).

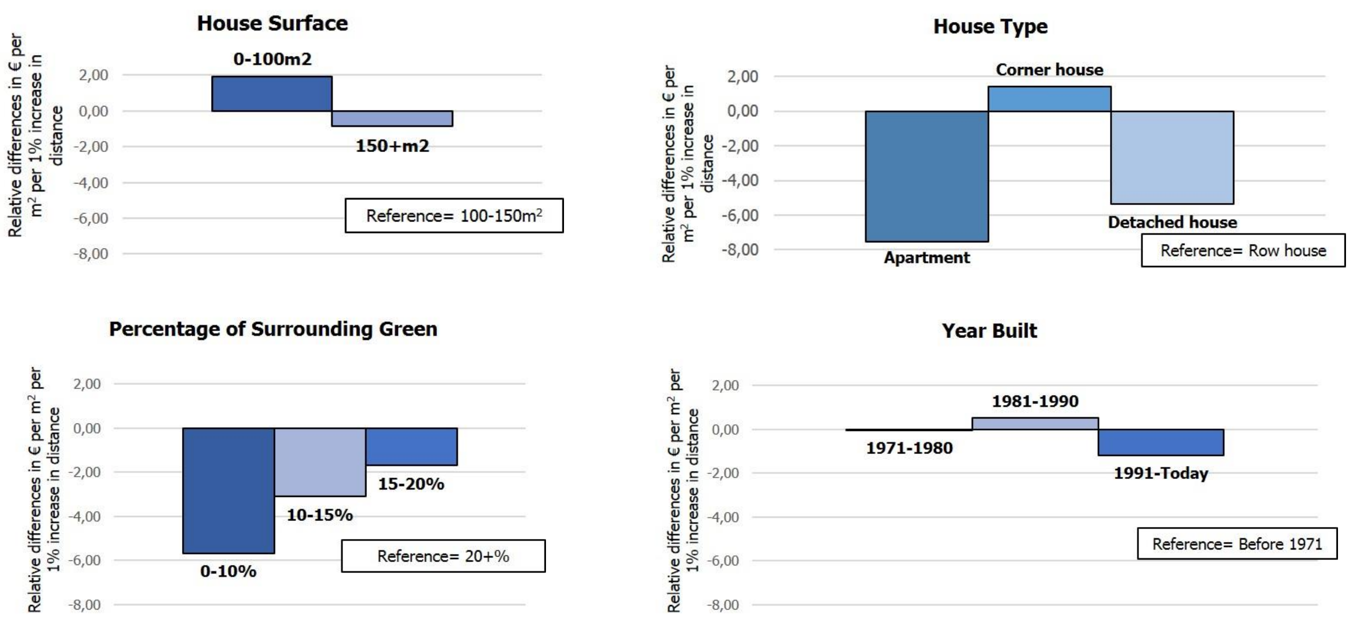


Figure 4-4: Relative differences in distance sensitivity between each sub-category (ESH2).

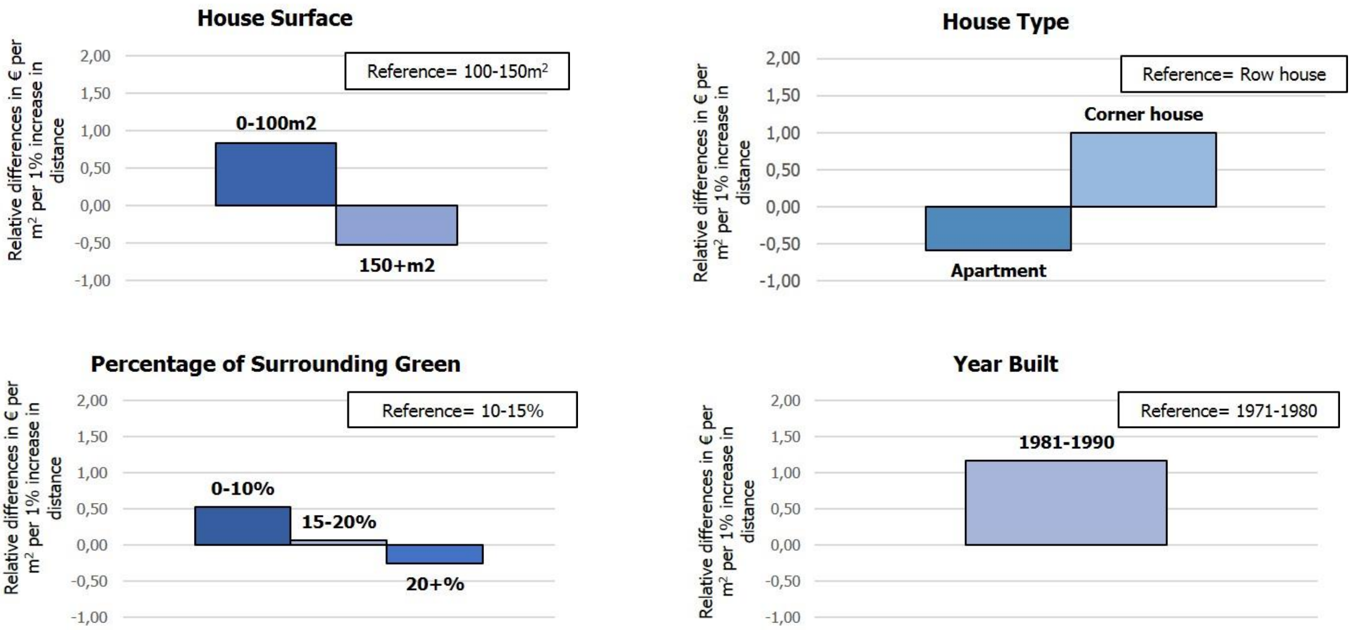


Figure 4-5: Relative differences in distance sensitivity between each sub-category (ESH3).

For the case of ESH1, it appears that houses over 150m^2 are affected the most by the proximity to the ecosystem service hub, evidencing a slighlty larger value drop (0,34€ per m^2) compared to the 100-150m^2 reference category. Moreover, the reference category of "row house" is affected the most, with apartments witnessing a 0,79€ per m^2 lower effect. Lastly, the age reference category, which is newly built houses constructed after 2000, and "very green neighborhoods" also are influenced the most by the distance to the hub. However, it should underlined that houses built before 1970 evidence very slight deviations of maximum 0,80€ per m^2 compared to the "2001-Today" reference category.

As far as ESH2 is concerned, it is noticed that houses under 100m^2 show the largest distance efffect, while corner houses evidence a slightly increased effect than the "row house" reference category. Furthermore, "older houses", erected before 1991, demonstrate similar distance effects, whereas "greener" neighborhoods are also influnced the most by the proximity to the hub. Nevertheless, it should be stated that the deviations observed in the age sub-division are relatively small.

Lastly, in ESH3, houses under 100m^2 are affected the most, whereas every house type category shows approximately the same behavior, with "corner houses" evidencing a slight lead. On the other hand, "lesser green neighborhoods" seem to be affected the most, in contrast to the two previous cases. Moreover, house built between 1981 and 1990 are affected more by the proximity to the hub, rather than those constructed between 1971 and 1980.

Overall, it becomes apparent that, taking into consideration all three cases, "row" houses within "greener neighborhoods" witness the largest proximity impacts. Nevertheless, such a generalized conclusion cannot be drawn for the "age" category nor the house size. Furthermore, it should stressed that the vast majority of these results are based on "interaction variable" beta-coefficients which are not statistically significant. Therefore, these results are not characterized by spatial reproducability and only account for locational behaviors.

Thence, the next step is to fomulate combinatinatorial categories between the sub-divisions. Notably, the house size and age category are selected, since they are the most representative housing characteristics. After creating the appropriate dummy and interaction variables, the following distance sensitivity differences are calculated, similarly to the simple sub-divisioning process. The following tables demonstrate the relative differences between the reference and each sub-category, when they "move" 1% further away from the hub. All table values are in € per m².

	Before 1905	1906-1944	1945-1970	1971-1990	1991-2000	After 2000
0-100m²	0,25€	0,46€	-0,87€	-12,65€	-5,50€	-1,19€
100-150m²		-0,87€	4,34€	-0,67€	0,29€	REFERENCE
150+m²				0,26€	5,39€	1,68€

Table 4-5: Table of relative percentage differences between each combinatorial category and the reference (ESH1, Adjusted R^2=0,591).

	Before 1971	1971-1980	1981-1990	After 1991
0-100m²		2,04€	0,53€	-6,43€
100-150m²	REFERENCE	-0,15€	-4,31€	-0,11€
150+m²	-2,48€	-76,38€	-0,58€	2,46€

Table 4-6: Table of relative percentage differences between each combinatorial category and the reference (ESH2, Adjusted R^2=0,544).

	1971-1980	1981-1990
0-100m²	2,21€	1,58€
100-150m²	REFERENCE	0,87€
150+m²	18,02€	

Table 4-7: Table of relative percentage differences between each combinatorial category and the reference (ESH3, Adjusted R^2=0,508).

Taking into account the previous comparative tables, it becomes evident that houses over 150m² who are also relatively "young" in the area, seem to be more influenced by the proximity to an ecosystem service hub. Therefore, although the statistical significance of the results cannot be confirmed, a local house profile emerges from this sensitivity analysis.

4.1.4 Overarching value gained by ESHs

Lastly, the overall value gained by each hub is approximately estimated. In order to calculate this amount, the zoning division is utilized (per 100m). It is assumed that a house within the outer rim (400-500m) demonstrates no value gains. Thus, the beta coefficients of the rest "distance zone" dummy variables represent the value gains generated by the hub. The following table (Table 4-8) depicts the individual value gains generated within each "distance zone" for each ESH case, both in euros per m² and million euros. In accordance to previous results, ESH1 induces the largest value gains, while ESH2 produces the lowest. It should be denoted that the 200-300m zone for ESH2 is omitted due to the negative beta coefficient observed.

		0-100m	100-200m	200-300m	300-400m
ESH1	Value per zone (€ per m²)	15746,67	15156,69	10524,49	1706,90
	Total value per m²	43.134,75 €			
	Value per zone (in million €)	2,35	1,94	1,31	0,21
	Total value	5,81 million €			
ESH2	Value per zone (€ per m²)	4669,78	5601.40	-	2644.09
	Total value per m²	12.915,27 €			
	Value per zone (in million €)	0.57	0.68	0.00	0.33
	Total value	1,58 million €			
ESH3	Value per zone (€ per m²)	13905,18	9873,29	8990,40	976,91
	Total value per m²	33.745,79 €			
	Value per zone (in million €)	1,26	1,01	0,90	0,11
	Total value	3,28 million €			

Table 4-8: Cumulative table of total value gained in each case study.

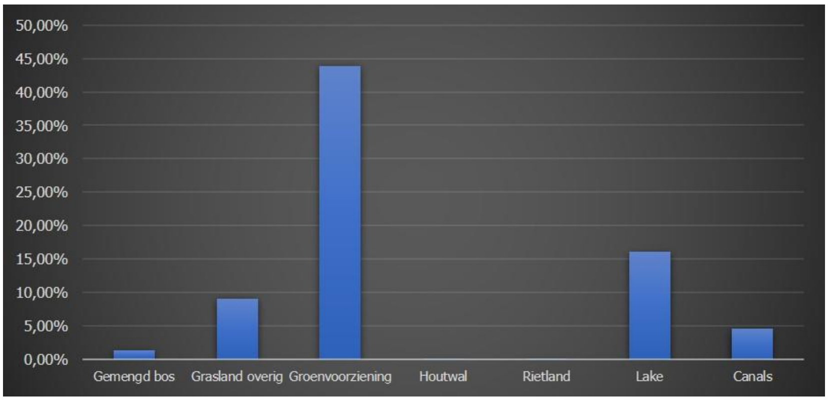
4.2 Phase II results

As stated in section 3.1.2, three study sites are selected and assigned the role of "Ecosystem Service Hubs": Delftse Hout & Hertenkamp; Buitenhof park and surrounding spaces; and Abtswoudse Bos and surrounding spaces in Tanthof. This selection is also inspired by the typology created by Swanwick et al. (2003). The results of both the extensive investigation of mapping information the field visits are presented below.

4.2.1 ESH1-Delftse Hout & Hertenkamp

ESH1 includes the areas of Delftse Hout and Hertenkamp, as well as a few surrounding green spaces. Its total area is around 158 hectares. Its specific boundaries are displayed in Figure 4-6. Delftse Hout is a district in the northeast part of Delft, which consists of a forest, a lake and surrounding greenery. This lake was created in the 1960s, when the construction of new residences led to excavating sand. The "green composition" of this area is demonstrated in Figures 4-7, according to information retrieved from the ObjectenHandboek ("Objectenhandboek BGT | IMGeo,"). It becomes obvious that there are significant "blue" spaces in ESH1 which constitute 20% of the entire area.

Figure 4-6: ESH1's boundaries (Own illustration through ArcGIS).



On the other hand, the green elements are primarily "landscape greenery" and "grassland". A smaller part of the area is characterized as "mixed forest", which contains several coniferous and deciduous trees. Lastly, further investigation of this area indicates that it comprises of mostly "forest plantation", "grass and herbaceous plants".

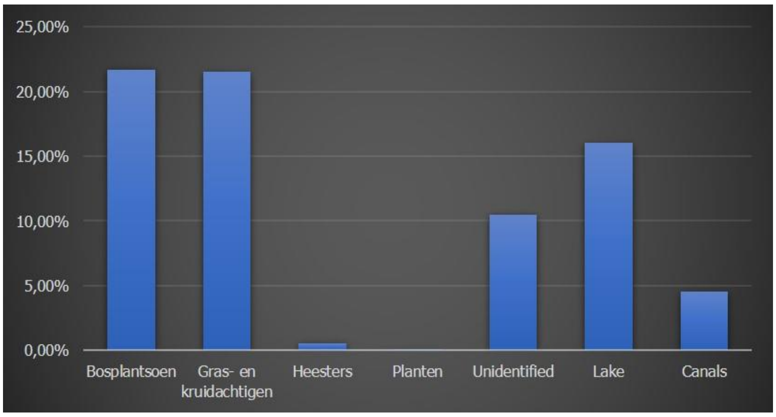


Figure 4-7: ESH1's "green and blue" composition.

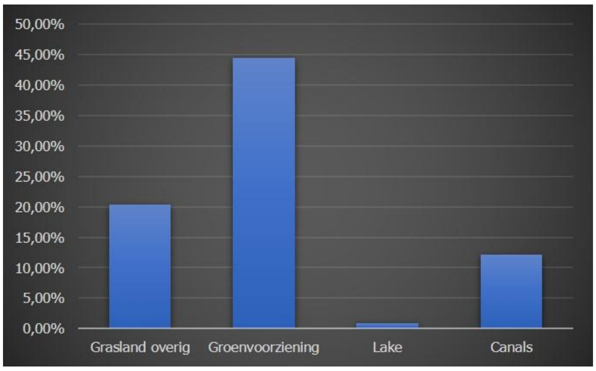
Analytical definitions for these categories are presented in Appendix H, as retrieved from the ObjectenHandboek. Besides the neighboring Hertenkamp (Deer camp), multiple recreational areas are located, including: a children's farm and water playground, operated by BuytenDelft; a beach site on the bank of the lake; and an organised family campsite.

Furthermore, scattered within the natural environment, a plethora of picturesque cycling and hiking routes can be found. ESH1 also offers a wide variety of sports activities, which are either practiced individually or through sports organizations. A few of these sports are for instance: football, tennis, golf, cricket (Delftse Sportvereniging Concordia), track & field (Delftse Atletiekvereniging AV'40), rugby, archery, skating (Delftse Kunstijsbaan Vereniging), as well as surfing, paddle boats and canoeing in the lake. Lastly, there are not only various event halls and bar-restaurants (Knus, De Schaapskooi, Hertenhorst, Het Rieten Dak), but also private gardens where one can grow and harvest their own products.

4.2.2 ESH2-Buitenhof park

ESH2's precise boundaries are depicted in Figure 4-8. It contains the Buitenhof Parkje area as well as surrounding greenery, with its size being roughly 53 hectares. The dominant "blue" elements witnessed in this area are several scattered canals. A rough representation of the hub's contents is depicted in Figure 4-9. Indeed, canals comprise 12% of the prescribed area, whereas greenery constitutes the rest. It immediately becomes evident that there is an absence of terrain parts which are characterized as "mixed forest". Instead, "landscape" and "grassland" greenery dominate the area. Upon further analysis of these components, it should be mentioned that there is a significant presence of "shrubs", compared to the other hubs.

Figure 4-8: ESH2's boundaries (Own illustration through ArcGIS).



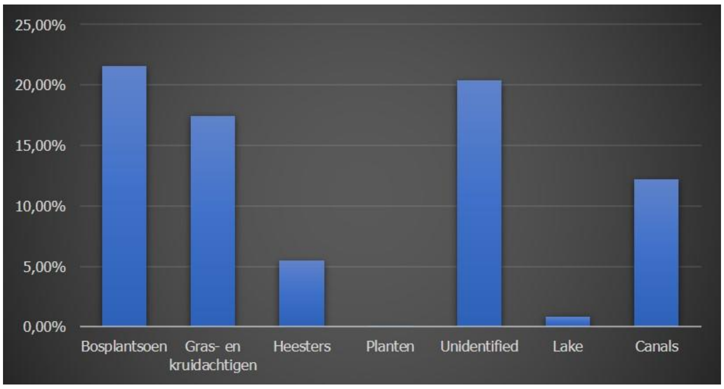


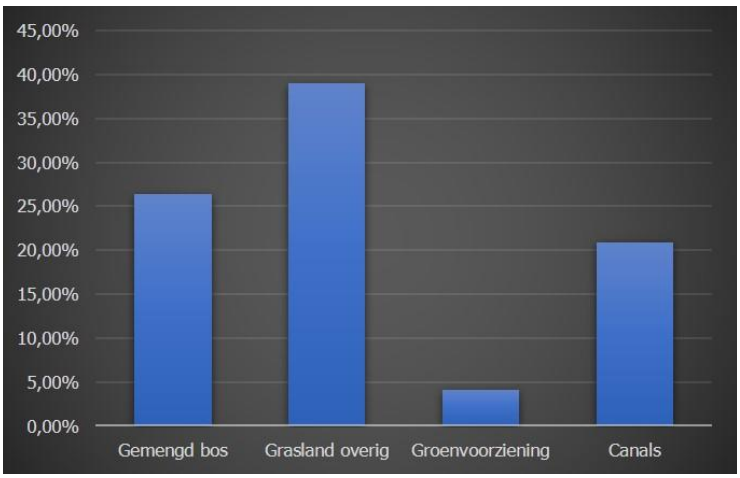
Figure 4-9: ESH2's "green and blue" composition.

ESH2 exhibits a vast array of recreational opportunities. Notably, it offers numerous sports opportunities through the "Sporthal Kerkpolder", which has a multifunctional floor suitable for the following sports: volleyball, futsal, handball, korfball, tennis, badminton, gymnastics. In addition, it possesses areas outside, appropriate for beach volleyball or beach soccer. Moreover, there are football fields, utilized by the local clubs (D.V.V. and DSV Delft), as well as swimming pool facilities. Lastly, private gardens also exist in the area.

4.2.3 ESH3- Abtswoudse Bos

ESH3 includes primarily parts of Abtswoudse Bos, a landscaped park and forest area, situated in the southern edge of Delft. During the mid-1990s, this part of the Lage Abtswoudse Polder was still used as pasture land. In order to offset the increasing urbanization on the southern outskirts of Delft, this area was opened around 2000, offering various recreational opportunities, and was characterized as a land art project. Thus, Abtswoudse Bos is a relatively young forest. Moreover, this area has a rich historical background, including the remains of old Roman farms.

Figure 4-10: ESH3's boundaries (Own illustration through ArcGIS).



Although its entire size is 190 hectares, within the scope of this research, only 95 hectares are taken into consideration (Figure 4-10). It encompasses a varying landscape, ranging from forests, swamps, ponds and grasslands to rugged areas, canals, shrubs and reed. The significant presence of "mixed forest" and "grasslands" is further exhibited in Figure 4-11. Unfortunately, the sub-components of this area are mostly unidentified. Furthermore, not

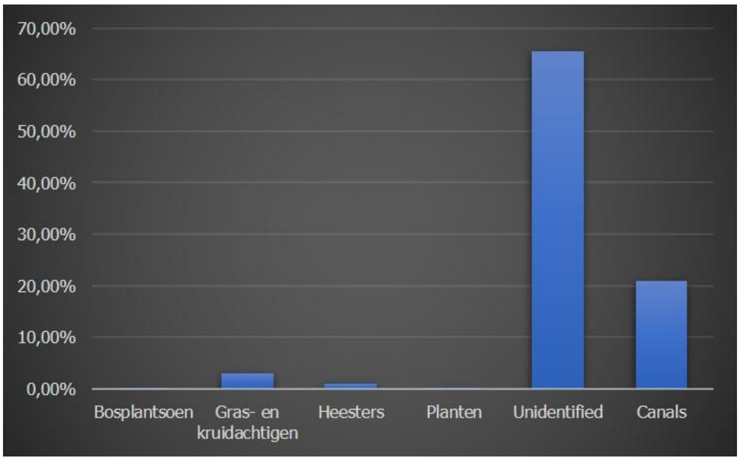


Figure 4-11: ESH3's "green and blue" composition.

only are there are hiking trails and cycling paths spread across ESH3, but also a wide meandering creek with particular ecological value.

Of noteworthy interest is the art exhibit located in the centre of the forest, the "Moeder Aarde", a hillside depicting the shape of a female figure. It consists of an artificial hill of around 200 m wide, 170 m long and 5 m high. . Around this hill "Es" trees were planted in circular rows, while the center of "Moeder Aarde" is a circular pond.

The arms and legs were planted with berry bushes, whereas the knees, hands and feet were left as open meadows. Lastly, the paths on the hill were meant to resemble blood veins. From the highest point, one could experience an exceptional view of the entire forest and nearby cities. As far as sports facilities are concerned, Vitesse Delft club's football fields are located on the northwestern part.

4.2.4 Field visits' insights

As previously mentioned, field visits to all study sites took place, in order to evaluate the precision of the aforementioned compositions, as well as to identify potential ecosystem services. Photographic material for each hub is presented below (Figure 4-12). Overall, the hubs' composition described in the previous section is verified to a certain degree. Nonetheless, additional elements are identified. For instance, regarding ESH2 the existence of small forests is confirmed, contradicting Figure 4-9, while the "unidentified sub-components" of ESH3 are discovered to be predominantly "forest plantation" and "grass and herbaceous plants", along with a significant presence of "shrubs".

Ecosystem Service Hub 1-Delftse Hout & Hertenkamp

Grassland close to the lake's banks.

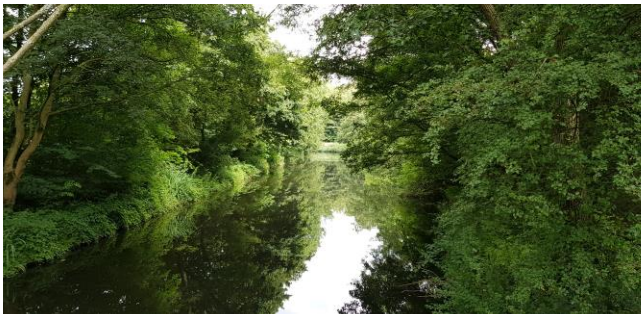
Forest plantation and shrubs next to a wetland.

Lake area.

Grassland surrounded by forest plantation.

Ecosystem Service Hub 2-Buitenhof park

Hiking trail within Buitenhof park.



Canal surrounded by forest plantation.

Grassland meadow.

Canal surrounded by shrubs and forest plantation.

Ecosystem Service Hub 3- Abtswoudse Bos

Biking trail next to the forest.

Canal area with shrubs and herbaceous plants.

Biking trail traversing the forest area. Moeder Aarde hillside.

Figure 4-12: Pictures from field visit to hub sites.

An approximate documentation of the potential ecosystem services' presence is also attempted in the form of a checklist table (Table 4-8). The basis for this list was Table 2-1, produced by TEEB (2010). Filling up this table is executed based on the researcher's own personal expertise and opinion, taking into consideration the definitions proposed by TEEB (2010) (Table 8-2), as well as the service providing units suggested by Andersson et al. (2015). In order for an ecosystem service to be ticked, it ought to be relevant to nearby residents. Services which are not corresponded with any hub are eliminated from the list.

	Ecosystem Service	ESH1	ESH2	ESH3
Provisioning	Food provisioning	✓	✓	
	Ornamental resources	✓	✓	✓
Regulating	Regulation of water flows	✓	✓	✓
	Moderation of extreme events	✓	✓	✓
	Air quality regulation	✓	✓	✓
	Water purification	✓	✓	✓
	Biological control	✓	✓	✓
	Climate regulation	✓	✓	✓
Supporting	Maintenance of genetic diversity	✓		✓
	Pollination	✓	✓	✓
Cultural	Aesthetic value	✓	✓	✓
	Opportunities for recreation	✓	✓	✓
	Inspiration for culture, art and design			✓

Table 4-9: Table of personally identified ecosystem services from field visit to hub locations.

It becomes evident that the three selected hubs display a similar "arsenal" of ecosystem services. All hubs are believed to provide a full set of equivalent regulating services, whereas the only differences lie in the provisioning, supporting and cultural services. Notably, ESH1 only lacks a cultural inspiration dimension, similarly to ESH2, while ESH3 does not encompass private gardens for residents to grow their own vegetables and food. On the other hand, ESH2 genetic diversity is deemed trivial compared to the rest of the hubs. Nevertheless, it should be underlined that the intensity and exact measurement of the observed ecosystem services are not captured. Furthermore, relative differences between each hub's provided services are also deemed doubtful and are, thus, omitted.

5 DISCUSSION

This chapter elaborates on the overall outcomes of this research. Section 5.1 explores Phase I's outcomes and potential methodological issues, while also comparing the results with existing literature. Thence, section 5.2 attempts a synthesis between the two Phases' outcomes, whereas section 5.3 investigates the possible integration of a supplementary follow-up survey. Section 5.4 discusses the policy implications of the findings.

5.1 Economic effects of Ecosystem Service Hubs

Phase I deals with the estimation of a price premium, generated by the defined Ecosystem Service Hubs (ESHs). First of all, these aforementioned ESHs are determined based on the typology of Swanwick et al. (2003), where the various urban green spaces are showcased, such as parks, sports areas, grasslands and woodlands. Thus, similar open spaces within the Delft area are identified and clustered into hubs. These hubs are expected to cumulate the generated benefits of their components, despite including grey and civic areas as well. Thence, a 500m radius is drawn around the boundaries of each hub in order to determine which house transactions are to be included in the analysis' scope. This 500m restraint is selected both according to relevant literature (Bolitzer & Netusil, 2000; M. N. Daams et al., 2016) and our intention to limit the computational burden of this research. Furthermore, it is a way to isolate each case site and negate their intercorrelations. Needless to say, this option might have had an effect on the outcomes of the eventual hedonic pricing model. A larger sample, through a widened effect radius (>500m), could produce more generalizable results and additional insights. For instance, the 500m cut-off limit decision might underestimate the overarching economic benefits, since it has been proven that, although significantly lesser, areas further than 500m also demonstrate price premiums (Bolitzer & Netusil, 2000; Chen & Jim, 2010; Cho et al., 2009; Czembrowski & Kronenberg, 2016; Czembrowski, Kronenberg, et al., 2016; M. N. Daams et al., 2016; Fernandez et al., 2018; H. Sander et al., 2010). Another potential issue of the aforementioned restraint could be the unequal hub samples, since it could be argued that some correction should be applied. Nevertheless, this difference implies the hub area's influence on the eventual effect range. More specifically, a larger ESH would, by default, affect more houses than a smaller ESH, given a certain range.

With the aid of Kadaster, the house transactions occurring between 2009 and 2019, within the selected range, are retrieved. Afterwards, the Hub Hedonic Pricing model is set up, where particular attention is given to the socio-economic developments influencing the transaction prices. This is performed through the establishment of proper "sale year" and "built year" dummy variables. However, a lack of structural variables is observed, for instance the number of rooms and floors. Nevertheless, since our aim is not to create a predictive model, rather than confirm and quantify the impact of the ESHs on real estate, this omission of data is overlooked. Additionally, despite including "sale year" dummy variable, a correction on the transaction prices, according to the Housing Price Index occurring in the Netherlands, is implemented. The inflation is also accounted for by an additional adjustment. This correction is carried out in order for the outcome to better reflect the actual value of money. It is widely acknowledged that houses sold for identical amounts during different years, would not be valued the same if the transaction occurred during the same year.

The outcomes of Hub Hedonic Pricing model reveal a relatively low adjusted-R^2, indicating a medium explanation of the dependent variable's variance. However, for the reasons stated above, the variables incorporated in this model are deemed sufficient to reach the set objective. The generated beta regression coefficients evidence their expected sign, with the vast majority of independent variables turning out to be statistically significant. Notably, the "year of sale" dummy variables were expected to be statistically insignificant, because of the correction that took place. Moreover, houses sold during 2018 and 2019, which are relatively young in the area and are characterized as "detached" display the largest price effects. Nonetheless, our primary focus is the "distance to hub" variable which turns out to be statistically significant for all three cases and displays a negative sign, suggesting the hypothesized decay effect.

The following figures are crucial in delineating the eventual demonstrated relationships between the hubs and surrounding real estate. Figure 5-1 underlines that ESH1 has a significantly stronger distance decay effect than ESH2 and ESH3, as evidenced by the "steepness" of each curve. More specifically, an identical house "moving away" from each hub by 1% would induce losses of approximately 2,7€ (0,10%), 0,8€ (0,03%) and 1,6€ (0,06%) per m^2 respectively.

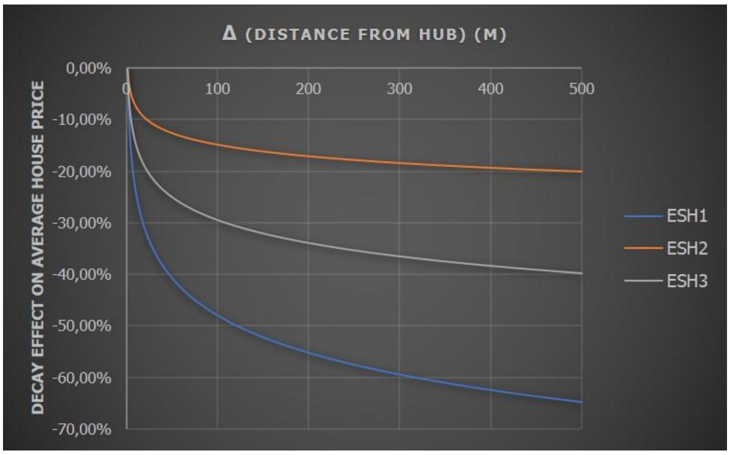


Figure 5-1: Cumulative graph of the distance decay effect.

As mentioned in section 4.1.2, this particular graph represents the decay effect that a house suffers when "moved" by a distance delta from its initial position of 1m away from the hub. The selection of this initial position is grounded on the natural logarithm's distinct properties, which facilitate this kind of representation.

In the hypothetical scenario where a house would "move" the largest possible distance away from the hub (D=500m), ESH1 would then decrease the price by almost 65%, whereas ESH2 and ESH3 by 20% and 40% respectively. Nevertheless, it should be highlighted that the largest part of this decrease occurs for deltas of approximately 100m for all three cases. Notably, concerning ESH1, this drop is measured around 50%, whereas the same drop for ESH2 and ESH3 is 15% and 30%. This considerable difference could be attributed to the relatively lower amount of observations of ESH1's "0-100m" zone (26), which could disrupt the data analysis. The reason behind these limited observations could be the A13 motorway, situated near the southwest boundary of the hub, which restrains the amount of available urban development space. Eventually the decay effect for larger deltas seems to exhibit a smoother behavior. Nonetheless, while ESH2's curve appears to flatten, it does not seem to be the case for ESH1 and ESH3, where a potential further increase beyond the 500m mark is suspected.

The 95% confidence interval boundaries for the previous decay effect curves are depicted below (Figure 5-2). These graphs reveal that considerably wide range of the potential decay effect, which is ± 29%, ±94% and ±52% respectively. This result not only suggests the presence of significant uncertainty, but also urges for further examinations and analyses in order to produce definitive and replicable conclusions. Overall, while the hypothesized relationship between the transaction price and distance to the hubs is validated and confirmed by our hedonic pricing models, estimating values through these particular models is dubious. It would require the enrichment of these models with further transactions in order to increase the sample size and diminish these intervals, especially for ESH2.

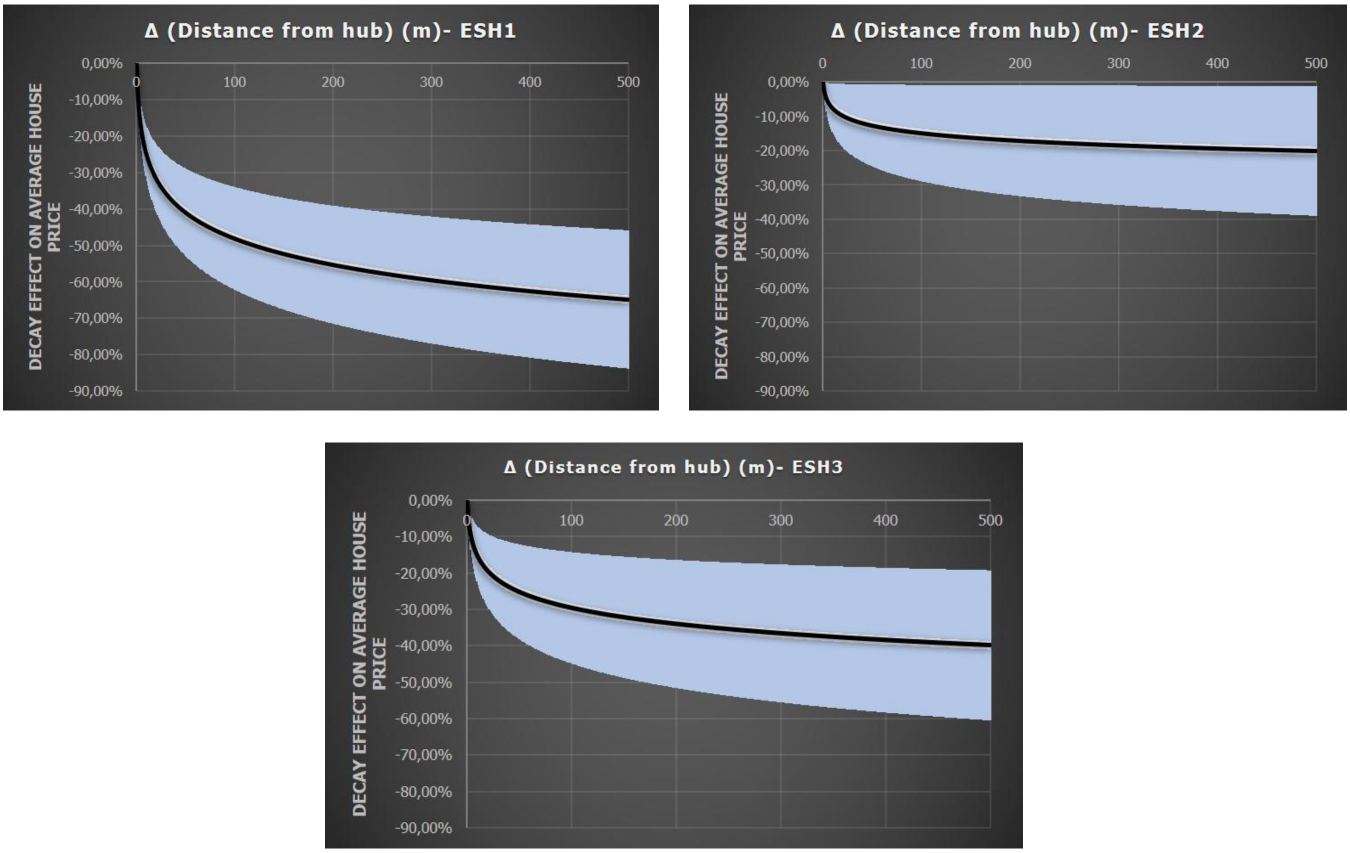


Figure 5-2: 95% confidence intervals of the distance decay effects.

Figure 5-3 exhibits relative differences between a house price in the 400-500m zone and the rest. It immediately becomes apparent that ESH1 demonstrates the most intense behavior with steadily increasing price premiums. Also, the behavior implied by the previous graph, where ESH1's decrease of "moving away" is the largest, is further confirmed since the 0-100m zone's 22% falls to 0,30% in the 300-400m zone. On the other hand, ESH2 evidences a similar, less intensive behavior, with the distinct exception of the 200-300m zone, where a negative value is observed. This is attributed to the particular characteristics of houses encompassed in this zone, especially the "sale year" and "year built". It is discovered that the 200-300m zone includes predominantly house built before 1971, which were sold during the financial crisis period. This could indicate why the transaction prices are lower and the price premium negative compared to the outer zone. Thus, this value is omitted and, instead, an estimate through non-linear extrapolation is calculated. Using a natural logarithmic trend line and the rest of the values, an anticipated price premium of 2,91% is computed. The non-linear extrapolation is preferred rather than a linear despite showing a slightly improved fit ($R^2_{non\text{-}linear}=0{,}971<R^2_{linear}=0{,}999$) for consistency reasons. Lastly, ESH3 demonstrates its largest price premium in the 100-200m zone, indicating the possible presence of a turning point. It might be the case that this hub creates nuisances and disservices to the nearest houses or that the 0-100m zone is significantly remote in comparison to urban amenities such as schools and shopping districts. Overall, it is deduced that ESH1 bears the largest price impacts in the closest zones, whereas ESH2 and ESH3 create the largest price premiums in the outer zones. Nevertheless, it should be denoted that several of the dummy variables used in the hedonic pricing model are statistically insignificant, particularly for ESH2.

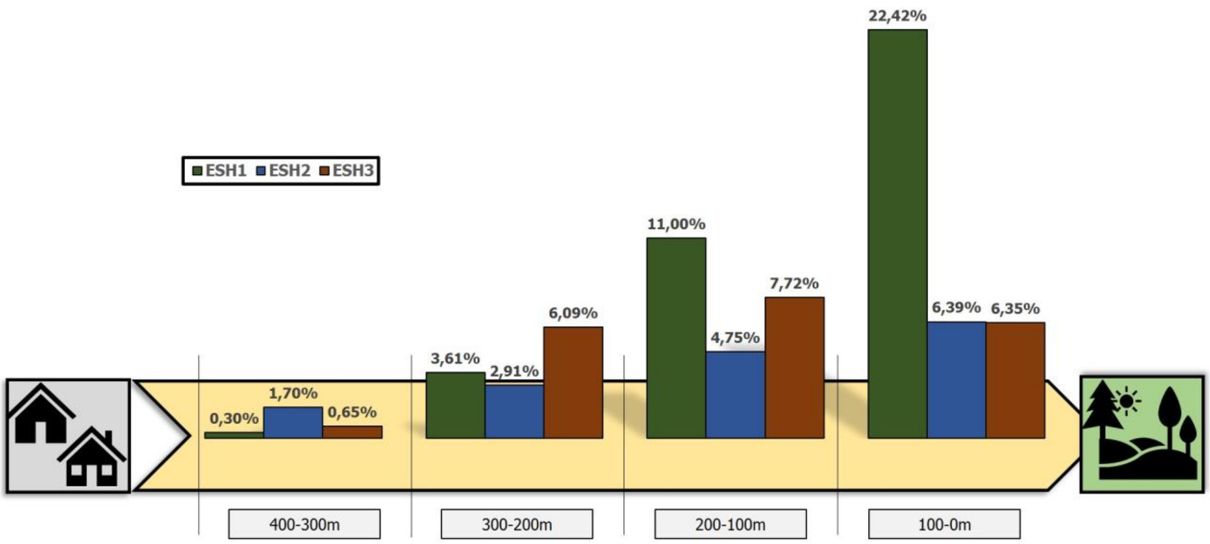


Figure 5-3: Corrected cumulative graph of relative price influence differences between distance classes for all three hubs (Own illustration).

Overall, the aforementioned results confirm the empirical findings. Comparing these results with existing relevant literature (Table 5-1) could prove to be insightful and a clear indication of the research's credibility. It becomes evident that our study produces generally lower value losses per 1% distance increase than most relevant un-integrated studies (Czembrowski & Kronenberg, 2016; Fernandez et al., 2018). Integrated studies reveal even larger differences, showcasing the superiority and cutting edge of such multifaceted methods (Czembrowski, Kronenberg, et al., 2016; Czembrowski et al., 2019).

Czembrowski and Kronenberg (2016)	1,5% to 3% for parks and forests per 1% distance increase.
Czembrowski, Kronenberg, et al. (2016)	0,7% to 4,5% per 1% distance increase, with social ranking integrated.
Czembrowski et al. (2019)	0,7% to 10% per 1% distance increase, with sociotope categorization integrated.
Fernandez et al. (2018)	0,20% per 1% distance increase.
Panduro and Veie (2013)	Average of 0,5% price decrease per 100m distance increase.
Bolitzer and Netusil (2000)	Average of 1% price decrease per 100m distance increase.

Table 5-1: Cumulative table of price premiums from literature.

As far as the zone dummy coding method is concerned, similar researches have exhibited the same overall behavior between zones. Nevertheless, the average price premiums between the inner and the outer zones are significantly, only showing an average of 2% to 4% on the mean house price (Bolitzer & Netusil, 2000; Panduro & Veie, 2013), whereas for ESH1 it is 22% and 6% for the other two. Lastly, there are researches using different distance measurements, such as feet or larger zone classes, as well as log-log models, which could not be directly compared (Chen & Jim, 2010; Cho et al., 2009; M. N. Daams et al., 2016; H. Sander et al., 2010; Tyrväinen & Miettinen, 2000).

The sub-divisioning procedure is executed in order to reach an optimal house profile, which exhibits the largest distance sensitivity. Figures 4-3 to 4-5 describe the relative differences between the sub-categories for each individual hub case. However, due to the heterogeneity of the hubs and the housing samples, the results demonstrate considerable complications. For instance, the "age" categories are not the same for each case, thus an explicit conclusion cannot be drawn. Additionally, the results are contradicting between the hubs, concerning the house surface. ESH1 seems to affect larger houses more, whereas the rest bear a larger influence on smaller houses. Moreover, the vast majority of the used interaction variables' beta coefficients are statistically insignificant, which restrains the generalizability and reproducibility of the "house profiling".

Nevertheless, a few remarks should be made. Differences under 1€ per m^2 are deemed neglectable, primarily because of both the sample size restraints and inherent statistical insignificance. Therefore, it could be suggested that ESH3 does not generate an optimal house profile, because of the slim relative differences between the sub-categories. Hence, taking into consideration ESH1 and ESH2, it emerges that "greener neighborhoods" demonstrate a larger distance sensitivity, while "row" type houses appears to be a common factor emerging from both cases as well. Thus, overall, the definitive conclusion is that "row" houses in "greener neighborhoods" exhibit a greater distance decay effect sensitivity. However, it should be reminded that this conclusion is bounded by its spatial applicability and limited reproducibility, since it concerns solely the hubs under investigation.

Identical statistical issues are encountered when implementing the combinatorial categorization, since, due to small samples, statistical insignificance is witnessed. Additionally, the "age" categories can only be translated in "younger" and "older" houses in the area, due to the differing housing samples. Overall, larger and "younger" houses display the largest distance sensitivity, as indicated by all three cases. Houses built before 1970 around ESH1 constitute an exception, since they are the only ones built before WWII, and are considered a special category due to their uniqueness in the area.

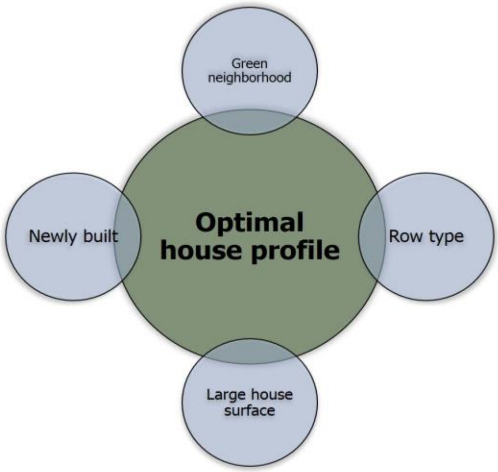


Figure 5-4: Optimal house profile as suggested from sub-divisioning and combinatorial categorization (Own illustration).

The previous deduction seems to fill the gap left in the house profiling, since it provides an indication concerning the "age" and "house surface" sub-divisions. Thus, this remark, integrated with the simple sub-divisioning results, suggests that "young, large, row houses in greener neighborhoods" exhibit the largest distance decay effect (Figure 5-4).

A suggestion of the value generated by the hubs through surrounding real estate is presented in the following table (Table 5-2). Assuming that houses in the 400-500m zone are unaffected, representing a "zero value gain area", and that for ESH2 the non-linear extrapolation value is used, the total value gained by houses is 5,81, 1,98 and 3,28 million euros respectively. These values are calculated based on the beta coefficients of the "zoning" dummy variables, multiplied by the number of houses within that particular zone sample and their respective square meters.

		0-100m	100-200m	200-300m	300-400m
ESH1	Value per zone (€ per m^2)	15746,67	15156,69	10524,49	1706,90
	Total value per m^2	43.134,75 €			
	Value per zone (in million €)	2,35	1,94	1,31	0,21
	Total value	5,81 million €			
ESH2	Value per zone (€ per m^2)	4669,78	5601,40	3293,47	2644,09
	Total value per m^2	16.208,74 €			
	Value per zone (in million €)	0,57	0,68	0,41	0,33
	Total value	1,98 million €			
ESH3	Value per zone (€ per m^2)	13905,18	9873,29	8990,40	976,91
	Total value per m^2	33.745,79 €			
	Value per zone (in million €)	1,26	1,01	0,90	0,11
	Total value	3,28 million €			

Table 5-2: Corrected cumulative table of total value gained in each case study.

The aforementioned cumulative amounts stem from different sample sizes and house surfaces and, thus, should not be directly compared. Instead, a comparative overview occurs by dividing the "total value per m^2" with the sample size. Hence, each hub site generates 77,44 €, 57,68 € and 107,47 € per m^2 per house respectively (Figure 5-5). Therefore, contrariwise to the distance decay effect and total economic value, the average economic benefits emanating from ESH3 are higher than ESH1. This insinuates that sample size plays a pivotal role when determining the overarching economic effects of the hubs, underlining once more the heterogeneity of the hub cases. On the other hand, the selected housing samples are directly influenced by the total area of the hubs, since larger hubs possess a wider effect range. Therefore, it would be incorrect to adjust these values for sample size, because it would remove the influence of this particular hub characteristic.

Figure 5-5: Average generated value per house per m^2 (Own illustration).

Needless to say, given the oversimplification of this process, these values are actually an understatement, since not only is the outer rim zone omitted, but also the houses beyond 500m and sold outside of our 10-year period could be affected and exhibit price premiums. Furthermore, only residential properties are examined, omitting other functions (e.g. offices). Therefore, the actual value generated would certainly be larger, since more houses would be included in each zone. Furthermore, these economic benefits represent only the value gained through real estate market price observations. As previously mentioned, different valuation methods capture different value aspects. Hence, the selected Hedonic Pricing method elicits solely a fraction of the total value of the Ecosystem Service Hub. Integrating additional methods is, thus, required, in order to conceive a more comprehensive picture of the situation.

5.2 Phase synthesis

The field visits of Phase II aim at dissecting the ESHs into their core components and characteristics. More specifically, the hubs' composition and potential ecosystem service presence are pinpointed. The objective is to associate them with the heterogeneity of their inherent economic effects (Figure 5-6). Taking into account the graphs and tables presented in section 4.2 and 5.1, a few distinct indications emerge.

Figure 5-6: Characteristics of ESHs leading to higher economic benefits.

Firstly, it immediately becomes apparent that hub size plays a pivotal role in the generated value, since the larger hub (ESH1) displays the most intense decay effect and produces the highest total value. As far as the hub composition is concerned, blue elements appear to induce higher benefits, since ESH2 demonstrates both the lowest benefits and blue elements presence. Moreover, it could be argued that ESH1's lake is the difference maker when compared with ESH3's blue elements. On the other hand, a diverse green composition seems to induce higher price premiums, as suggested by the ESH2's absence of "mixed forest". However, similar definitive conclusions cannot be reached based on neither the green elements' nor the sub-components' presence. Furthermore, the quantity and diversity of recreational opportunities encountered within each hub, demonstrate a dynamic proportionate to the generated economic benefits. Lastly, only slight differences in ecosystem service presence between hubs are noticed. The major differences are the absence of fauna diversity in ESH2 and the distinct cultural value of ESH3.

All of the aforementioned relationships between hub characteristics and economic benefits are predominantly qualitative and, thus, cannot produce generalizable and quantitative conclusions. Instead, a qualitative indication is drawn, stating that "Ecosystem Service Hubs generate higher economic benefits when they are larger and more diverse, in terms of both composition and ecosystem services, with a significant sensitivity to recreational opportunities" (Table 5-3).

Hub Characteristic	Qualitative Indication related with higher economic benefits
Ecosystem Service Hub size	Large
Blue element composition	Diverse (lakes and canals)
Green element composition	Diverse (Landscape green, grassland and forest)
Recreational opportunities	Quantity and variety
Ecosystem Services	Diverse (provisioning, regulating, supporting and cultural)

Table 5-3: Qualitative indications of hub characteristics, which are associated with higher economic benefits.

A few remarks on the aforementioned statements should, however, be expressed at this point. First of all, the ecological profiling of the hubs is based on the researcher's own expertise and views and ought to be further enriched by not only an expert's opinion, but also the residents' views, as the hedonic pricing theory suggests. It could be the case that there are elements unknown to the researcher emanating from the hubs, which are deemed important by the residents and affecting their willingness to pay for a certain property. Additionally, the intensity of ecosystem services could not be measured and could prove to be a crucial factor as well. Especially as far as regulating ecosystem services are concerned, the degree of their effectiveness is considered more important than their mere presence. The aforementioned necessities are further argumented by the imperative need to integrate ecological and social valuation methods with a strictly economical one, such as hedonic pricing, as also stressed in chapter 2. Subsequently, a direct and quantitative correlation of elements and economic benefits cannot be really achieved.

5.3 Integrating a social survey

As mentioned in previous chapters and particularly in section 2.2.3, in order to establish a multifaceted valuation framework for ecosystem services and open spaces, it is imperative to incorporate social and ecological aspects, besides monetary values (Martín-López et al., 2014). Despite integrating direct biophysical measurements being deemed important, executing such measurements and computations falls outside of this study's scope. Nonetheless, this study could establish the groundwork for future enrichment with social valuation methods. Such a valuation method would contribute towards covering the non-use value of the Total Economic Value (TEV) in addition to the use value accounted for by the hedonic pricing method (see Figure 2-2).

Hence, a social survey is proposed as a potential addition to the present hedonic pricing model. This survey will aspire to derive both monetary and non-monetary values. This means that it will be a hybrid of Contingent Valuation and Social Ranking. The compatibility of hedonic pricing with this hybrid social method is ensured, because of the identical spatial circumstances, as well as the investigation of factors and characteristics, which are comprehensible and relevant to real estate buyers. As far as the commensurability is concerned, since our target audience would be the same, the derived results could smoothly joint and analyzed (see tables 8-10 and 8-11). The integration potential is also further supported with examples from relevant literature in section 2.3 (Czembrowski, Kronenberg, et al., 2016; M. N. Daams et al., 2016; Fontaine et al., 2014; Martín-López et al., 2014). Lastly, it should be stated than combining these methods would not only incorporate the necessary bounded rationality of the buyer's perspective, but also incur monetary terms, which are effortlessly "translatable" for relevant stakeholders, urban planners and decision makers.

This hybrid method will aim to induce not only the willingness to pay of respondents for the hubs and their characteristics in hypothetical scenarios, but also aid in deriving a ranking of social preferences concerning these characteristics and aspects. The content of the aforementioned social survey would consist of two parts. Firstly, it is imperative for the respondents to be able to acknowledge the presence of the hubs and their characteristics. Thus, elements associated with the hubs, contributing to the respondent's willingness to pay, could be added or removed from the hedonic pricing model depending on the outcome of the survey and the threshold set. Furthermore, even the boundaries of the hubs could be adjusted through the survey. M. N. Daams et al. (2016) and Czembrowski, Kronenberg, et al. (2016) both proposed a GIS-based method to pinpoint the "hotspots" within an urban open space, based on public opinion and preferences. A similar application could be implemented in the Ecosystem Service Hub concept, where the specific areas of "ecosystem service interest" could be highlighted. Thence, the proximity to these spots would be measured and translated into economic benefits, through the hedonic pricing model. A ranking of the selected hub features based on their stated importance should ensue, followed by a hypothetical scenario testing. This hypothetical scenario will elaborate on how the house price is influenced by the distance to the hub, as well as the potential ecosystem service presence.

A suggestion of the survey's format can be found below (Figure 5-7 and 5-8). These figures depict indicative questions regarding the previously mentioned content and format. Nevertheless, additional sections describing key concepts, such as the survey's purpose, Ecosystem Service Hubs and ecosystem services, should also be included. Moreover, it is recommended that the final format should be less "chaotic" and better structured, in order to become more "user-friendly".

1. **Did you take the presence of ESH into consideration, when bidding for your current real estate?**
Mark only one oval.
- Yes
- No (If you select No, skip to next section)

2. **Did the proximity of ESH influence your bidding offer?**
Mark only one oval.
- Yes
- No

3. **Did the total area of ESH influence your bidding offer?**
Mark only one oval.
- Yes
- No

4. **Did the presence of "regulating" ecosystem services, provided by ESH, influence your bidding offer?**
Mark only one oval.
- Yes
- No (If you select No, skip to next section)

5. **If yes, please indicate in the following list which ones**
Tick all that apply.
- Regulation of water flows
- Moderation of extreme events
- Air quality regulation
- Water purification
- Biological control
- Climate regulation
- Noise reduction

6. **Please rate how important the selected "regulating" ecosystem services are to you. (1 being unimportant and 5 being very important)**
Tick all that apply.

	1	2	3	4	5
Regulation of water flows					
Moderation of extreme events					
Air quality regulation					
Water purification					
Biological control					
Climate regulation					
Noise reduction					

Figure 5-7: Survey questions eliciting the acknowledgement and ranking of the hubs and their characteristics.

7. **Consider that the distance of your house/apartment from ESH X is divided into 5 zones (0-100m, 101-200m, 201-300m, 301-400m and 401-500m). Assuming you are in Zone 5 (401-500m), state the percentage of the price of your property that you would be willing to pay to move into that zone.**
Tick all that apply.

	0%	1-2%	2.1-3%	3.1-4%	4.1-5%	5+%
Zone 4 (301-400m)						
Zone 3 (201-300m)						
Zone 2 (101-200m)						
Zone 1 (0-100m)						

8. **Assuming you are living close to an ESH which has a specific area in square meters. State the percentage of the price of your property that you would be willing to pay for an increased ESH area.**
Tick all that apply.

	0%	0.1-1%	1.1-2%	2.1-3%	3.1-4%	4.1-5%	5+%
Increase of 0.10 sqm							
Increase of 0.20 sqm							
Increase of 0.30 sqm							
Increase of 0.40 sqm							
Increase of 0.50 sqm							

9. **Assume that from the aforementioned list of ecosystem services, none are present in your proximity. State the percentage of your property price that you would be willing to pay for the presence of each respective ecosystem service within a radius of 500m.**
Tick all that apply.

	0%	0.1-1%	1.1-2%	2.1-3%	3.1-4%	4.1-5%	5+%
Provisioning services							
Regulating services							
Supporting services							
Cultural services							

Figure 5-8: Survey questions testing hypothetical scenarios.

Another potential survey form would be to encompass questions based on recollection rather than recognition. This implies creating open questions instead of multiple-choice ones, where the respondent is requested to capture his personal beliefs and preferences rather than select from the author's perspective. Overall, the survey process should be handled meticulously and diligently in regard to its content and format, in order to limit potential respondent confusion and induce valuable insights. There are several formats and methodologies widely being applied and, thus, the most appropriate and fit for purpose ought to be selected, based on the survey's scope and objectives.

5.4 Public policy and urban planning implications

The observations elaborated upon in the previous sections could prove to be massively useful for public policy makers and urban planning developers. The previously discussed conclusions could be applied in two major ways.

First of all, given a certain identified Ecosystem Service Hub, the development of the surrounding area could be adjusted to encompass primarily the optimal house and neighborhood characteristics stated above (Figure 5-9). For instance, if a new urban complex was to be developed near ESH1 or ESH3, then constructing large, row houses, as well as establishing greener surroundings would be opted for, based on this study's results. However, since the aforementioned optimal house profile stems from analyzing the particular hub sites, its effective application on other areas is doubtful due to this spatial boundness. Instead, it would be preferable to perform a similar sensitivity analysis in the area surrounding this new Ecosystem Service Hub and retrieve its own optimal house profile. Therefore, a maximization of the property values in the newly developed urban area will be achieved, inducing not only direct house tax gains, but also personal welfare gains.

Figure 5-9: First scenario where optimal houses are developed around a given ESH (Own illustration).

On the other hand, given the "house composition" of a certain area, the optimal location and profile of a new Ecosystem Service Hub could be selected (Figure 5-10). Characteristics such as size and content composition have already been proven to affect the range of the economic effects. Thus, properly opting for the location and size of the under-development hub could maximize the effect range and generate larger gains. Furthermore, carrying out the social survey beforehand could signify which particular hub characteristics and ecosystem services are more favorable to residents. Thus, the Ecosystem Service Hub's characteristic synthesis will be optimized. For example, a direct and quantitative relationship between the resident's willingness to pay and the quantity and quality of the provided ecosystem services will be estimated. This will lead to the most profitable package of provided ecosystem services, which could be further refined by applying amplifying synergies, based on the green and blue element composition (Bennett et al., 2009; Maes et al., 2012; Mexia et al., 2018).

Figure 5-10: Second scenario, where the optimal location and profile of the ESH is selected (Own illustration).

In both cases, maximizing the value of surrounding real estate is achieved through applying the optimal spatial configurations. Overall, it becomes evident that value generated by Ecosystem Service Hubs through price premiums is considerable and should not be neglected, since it could make the deciding difference in whether a certain policy or land use plan should be adopted. The value generated by either of these two scenarios could turn out to be the crucial factor in offsetting the scenarios' costs, on the grounds of a Cost-Benefit analysis (CBA), and might eventually lead to their implementation.

6 CONCLUSIONS

This chapter is devoted to the final conclusions and remarks on the present research. Section 6.1 is dedicated in answering the various research questions set in the first chapter. Afterwards, section 6.2 elaborates on the study's limitations, whereas section 6.3 proposes recommendations for future research and practices.

6.1 Research Questions

In section 1.5, five research questions were formulated in order to aid in achieving the set research objectives. They are answered in reverse order, leading up to the main research question.

Theoretical sub-questions:

- What can be defined as an urban open space (green and blue spaces) and what ecosystem services are they capable of providing?

Although literature suggests several definitions for urban open spaces, the two most prominent will be presented. Tzoulas et al. (2007) describe urban open spaces as "all natural and artificial networks of ecological systems within and around urban areas". On the other hand, Swanwick et al. (2003) suggest that urban open areas are defined as the part of urban areas, which includes green spaces and civic spaces (see Appendix A for typology). However, this research establishes its own "Ecosystem Service Hub" definition, where such neighboring urban open spaces are clustered and their generated benefits cumulated and amplified.

The TEEB (2010) initiative suggests that ecosystem services are "the direct and indirect contributions of ecosystems to human well-being", while Costanza et al. (1997) define them as "flows of materials, energy, and information from natural capital stocks which combined with manufactured and human capital services produce human welfare".

Several lists of ecosystem services have been proposed in academic literature, with the most prominent being TEEB's (2010). TEEB proposes a list of twenty-two ecosystem services, divided into four major sub-categories: provisioning; regulating; supporting; and cultural/recreational (Table 2-1).

A full set of definitions and indicators can be found in Appendix B. It should also be mentioned that Gómez-Baggethun and Barton (2013) underline the presence of disservices as well (Table 2-2).

- What valuation methods could be employed in order to quantify the urban open spaces' influence on real estate market values?

Since value has different dimensions, such as economic, sociocultural and ecological, several valuation methods exist to measure each respective dimension. These can be monetary and non-monetary. The former refers to market transactions and could either be "direct market-based", "revealed preference" or "stated preference", depending on the source of the information. Non-monetary methods are distinct in a sense that it explores the significance and preferences stated by people towards ecosystems. They can either be ecological, whose objective is to inform about the "ecological performance" or social, whose application produces a social ranking of people's preferences and perceptions towards nature.

Nevertheless, because of this multifaceted nature of valuation, it is imperative to adopt an integrated approach, where biophysical measurements are combined with economic valuation, while also utilizing social non-monetary ranking to account for public preferences and needs. It should be stressed that all composing methods ought to be both commensurable and compatible.

An extensive literature review of ecosystem studies suggests that Hedonic Pricing and Contingent Valuation are the most prominent and applicable methods. These two methods are also the basis for integration with other methods and calculate the impact of urban open spaces through either "price premiums" or the residents' "willingness to pay".

Empirical sub-questions:

- What is the eventual relation between urban open spaces, their characteristics and real estate market value?

The Ecosystem Service Hub proximity effect varies for each case under examination. The distance decay effects, derived from the Hub Hedonic Pricing model, suggest that ESH1 bears the largest influence. Notably, a 1% decrease in hub proximity induces losses around 0,10% of the average house price, while ESH2 and ESH3 incur 0,03% and 0,06% respectively. This decay effect is further highlighted by the fact that within 500m from the hub, ESH1 demonstrates a 65% loss of house value, whereas ESH2 and ESH3 display 20% and 40% respectively. Moreover, it should also be mentioned that the largest portion of this value drop is observed within the first 100m. Lastly, the use of 100m zones further indicates ESH1's stronger influence, since it exhibits the largest price premiums in the closest zones (0-100m, 100-200m), while ESH2 and ESH3 create the largest price premiums in the outer zones.

A qualitative correlation between the aforementioned economic effects and the hubs' characteristics is then carried out. It appears that a larger hub size is associated with higher economic benefits. Furthermore, a diverse "green and blue" composition of the hub also seems to be related with higher price premiums. As far as ecosystem services are concerned, providing a vast "arsenal" of provisioning, regulating, supporting and cultural services, with a particular focus on recreational opportunities, also appears to induce larger economic benefits. However, this afore described correlation is dubious because of the lack of biophysical measurements of ecosystem services, which could measure their degree of effectiveness and efficiency. Thus, the necessity to integrate ecological valuation methods is stressed.

- What are the implications of the added value of urban open spaces and ecosystem services on real estate market prices, in regard to public policies?

The total value generated by each Ecosystem Service Hub is calculated, under several important assumptions. ESH1 generates 5,81 million € in the entire area under investigation, whereas ESH2 and ESH3 induce 1,98 and 3,28 million € respectively. Hence, it becomes evident that such hubs incur considerable economic benefits and should not be overlooked, since they could favor a particular "green" policy or land use plan.

Furthermore, the optimal house profiling could also be a useful tool for decision makers and planners. It is deduced from this study that "young, large, row houses in greener neighborhoods" exhibit the largest hub proximity influence. Therefore, policy makers could apply this conclusion: either by developing residential areas according to this optimal profile; or by selecting an ESH's location and composition based on the nod of maximizing the economic benefits, in other words applying the optimal spatial configuration. The benefits generated by the implementation of either of these two optimizations could be pivotal in offsetting a certain policy's or land use plan's costs.

Main research question:

- What is the added value of urban open spaces on real estate market prices and which of their characteristics, especially the provided ecosystem services, contribute the most to this added value?

The literature findings are confirmed by the investigation of the three Ecosystem Service Hub sites. The positive proximity influence on prices is evident and statistically significant for all cases. This is further demonstrated by the total economic value generated by the hubs, which is on average 80,86 € per m^2 per house. Despite the exact price premiums and distance decay effects differing, it could be concluded that an increase of 1% in distance leads to an average drop of 0,06% in the average house price. However, it should be underlined that a social survey ought to be incorporated as well in order for the hedonic pricing model's results to incorporate the bounded rationality of the buyer's perspective.

As far as the contribution of specific hub characteristics such as size and composition, no definitive conclusion can be drawn, rather than a qualitative indication that larger and more diverse hubs seem to be associated with higher economic benefits. Additionally, the presence of several and diverse ecosystem services is also related with higher economic benefits. Nevertheless, it is deemed that the effectiveness and intensity of these services are more important than their mere existence, thus an integration with ecological valuation methods is imperative.

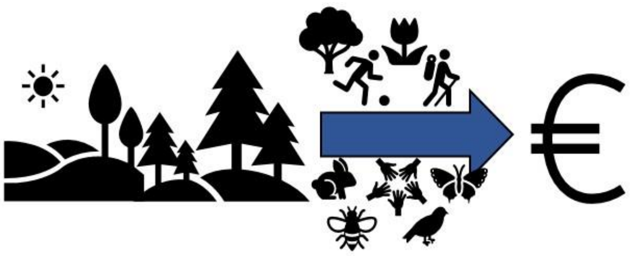


Figure 6-1: Characteristics of ESHs leading to higher economic benefits.

Overall, the added value of urban open spaces is plural and reflects the use and non-use value derived from residents. This research's rough estimation of an average of 80,86 € per m^2 per house is an indication of this added value, subject, however, to the narrow scope of the study. Attributing this added value to particular open spaces' characteristics could only be executed through qualitative correlations. The integration of multiple valuation methods, which incorporate the various value dimensions, is recommended in order to enrich the previous results.

6.2 Limitations

First of all, the narrow locational scope of this research is problematic, since it limits the reproducibility of the results and conclusions. Furthermore, selecting only three hub cases is also a restraining factor, since including more sites could improve the generalizability of our conclusions, especially the optimal house profiling procedure. Additionally, narrowing our housing sample within 500m of the hubs, although inspired by relevant literature, could lead in neglecting part of the ESHs influence, since studies have evidenced price effects beyond this particular boundary as well. Similarly, taking into consideration transactions between 2009 and 2019 and concerning only residential use might also understate the ESHs' overarching economic effect.

It should also be denoted that the price premiums found might not be entirely attributed to the hub proximity effect. Despite adjusting the house transactions with the Housing Price Index and inflation indicators, as well as incorporating time and locational variables in the model, it might be the case that other developments in the area or unknown house elements influenced the house transactions.

As far as the Hub Hedonic Pricing model is concerned, it necessitates the use of social survey in order to back up the selection of the explanatory variables. It is imperative for the buyer to be aware of the environmental elements included in the model, in order for the results to be reliable. Moreover, the statistical significance of our variables is also warning about the credibility and reproducibility of our results because of the low sampling size, especially for the sub-divisioning part and combinatorial categories.

Lastly, the ecological profiling of the hubs requires evaluation from experts, as well the incorporation of biophysical measurements. These absences affect the correlation between hub characteristics and economic benefits, leading to only qualitative indications. It is constantly stressed by relevant nature valuation literature to include a multifaceted framework, which takes into consideration every value dimension.

6.3 Recommendations

Further research could be used to extend the physical scope into including multiple cities and more Ecosystem Service Hubs. Incorporating more diverse open spaces and different urban setting could lead to new significant and generalizable universal conclusions. The effect exploration could even be investigated between neighboring cities as well. Additionally, expanding the houses under examination could also significantly ameliorate the reproducibility and credibility of the produced results, since it is expected to improve the statistical significance of the model and its variables. This could be carried out by expanding not only the effect range and time horizon of the study, but also the house function included (e.g. offices).

Thence, incorporating the suggested social survey format and content will offset the hedonic pricing method's weakness of including the buyer's perception. It will also validate and improve the HP's results, though a conjunction with the stated willingness to pay. Moreover, the inclusion of an ecological valuation method, encompassing biophysical measurements of the provided ecosystem services might also be integrated to enhance the ecological profiling of the hubs and generate a precise association between economic benefits and hub characteristics. Overall, in order to reach definitive and solid conclusion, an integrated method should be applied, accounting for all value dimensions.

Last but not least, since the total economic benefits presented in previous sections are undeniable, this study strongly recommends incorporating multifaceted valuation frameworks in decision making and land use planning. Under a policy scenario involving new spatial configurations, such a valuation tool might aid in comprehending the value gains and losses stemming from the implementation of this specific policy. These potential gains will contribute to direct house tax gains, as well as private welfare gains, thus potentially rendering a policy more favorable for technocrats to opt for. Hence, this kind of information ought to be used to stimulate discourse and guarantee a sounder basis for land management and urban planning.

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8 APPENDICES

Appendix A-Green space types

MAIN TYPES OF GREENSPACE			
ALL URBAN GREEN SPACE	Amenity Green Space	Recreation Green Space	Parks and gardens
			Informal recreation areas
			Outdoor sports areas
			Play areas
		Incidental Green Space	Housing green space
			Other incidental Space
		Private Green Space	Domestic gardens
	Functional Green Space	Productive Green Space	Remnant farmland
			City farms
			Allotments
		Burial Grounds	Cemeteries
			Churchyards
		Institutional Grounds	School grounds (including school farms and growing areas)
			Other institutional grounds
	Semi-natural habitats	Wetland	Open/running water
			Marsh, fen
		Woodland	Deciduous woodland
			Coniferous woodland
			Mixed woodland
		Other Habitats	Moor/heath
			Grassland
			Disturbed ground
	Linear Green Space		River and canal banks
			Transport corridors (road, rail, cycleways and walking routes)
			Other linear features (e.g. cliffs)

Table 8-1: Typology of urban green space (Swanwick et al., 2003).

Appendix B-Ecosystem services

Provision of food	Agro-ecosystems and marine biomes provide food for human consumption ensuring global food security.
Water provision, including regulation of water flows and water purification	Ecosystems play a key role in contributing to water provision through their water storages and subsurface flows; seasonal regulation; and purification by the addition and removal of substances through soil.
Fuels and fibers	Ecosystems provide various materials for construction and fuel, especially wood and oil. Renewable energy sources could also be drawn from ecosystems.
Genetic resources	Genetic resources can be used to enhance breeding programs for agriculture, with the intention to increase yield, disease susceptibility and climate change adaptation.
Medicinal and other biochemical resources	Biochemicals include a wide range of chemicals, important for industrial use and notably pharmaceuticals.
Ornamental resources	Animal and plant parts are used for decorative and entertainment purposes is evident throughout history.
Air quality regulation and other urban environmental quality regulation	Ecosystems are capable of significantly reducing air pollution and noise, mitigating the "urban heat island" effect and minimizing climate change impacts. Most urban ecosystems can contribute, however to a varying degree.
Climate regulation	Forests and soil store great amounts of carbon, regulating the "greenhouse effect" that keeps Earth's temperature in check.
Moderation of extreme events	Extreme weather events or natural hazards are limited by natural barriers and buffers such as forests and coral reefs.
Erosion prevention	Vegetation cover prevents soil erosion and subsequent landslides.
Maintenance of soil quality	Soil quality is affected by nutrient cycling, which occurs in all ecosystems, with nitrogen bearing a key role.
Pollination services	Most of the world's plants rely on animal pollinators, particularly the honeybee, and its importance is being acknowledged.
Biological control	Ecosystems regulate pests and diseases through predators and parasites, such as birds, insects and fungi.

Maintenance of life cycles of migratory species	Ecosystem products (e.g. seeds, nutrients) could be partly or entirely used to sustain a specie's life cycle.
Maintenance of genetic diversity	Genetic diversity is distinctive for all ecosystems and results in evolution through natural selection
Cultural services: aesthetic information, opportunities for recreation and tourism, inspiration for culture, art and design, spiritual experience, information for cognitive development	"Cultural and amenity services refer to the aesthetic, spiritual, psychological, and other benefits that humans obtain from contact with ecosystems". It could refer to commercial or non-commercial use of ecosystems.

Table 8-2: Table of ecosystem service information (TEEB, 2010).

	Andersson et al (2015)	Costanza et al (1997)	Gómez-Baggethun, E., & Barton, D. N. (2013)	De Groot et al (2010)	TEEB (2010)
Provisioning	Provision of food	Food production	Food supply	Provision of food	Food
	Provision of water	Water supply		Provision of water	Water
	Provision of materials	Provision of raw materials		Provision of materials	Raw materials
		Provision of genetic resources		Provision of genetic resources	Genetic resources
				Provision of biochemical products and medicinal resources	Medicinal resources
				Provision of ornamental species and/or resources	Ornamental resources
Regulating	Erosion control	Erosion control and sediment retention		Erosion protection	Erosion prevention
	Flood control				
	Water runoff mitigation	Water regulation	Water flow regulation and runoff mitigation	Water regulation	Regulation of water flows
		Soil formation		Soil formation and regeneration	Maintenance of soil fertility
		Nutrient cycling			
	Water quality enhancements				
		Disturbance regulation	Moderation of environmental extremes	Natural Hazard mitigation	Moderation of extreme events
	Air quality regulation	Gas regulation	Air purification	Air quality regulation	Air quality regulation
		Waste treatment	Waste treatment	Waste treatment	Waste treatment
	C sequestration				
	C storage				
	Pest control	Biological control		Biological Regulation	Biological control

	Temperature regulation	Climate regulation	Climate regulation	Climate Regulation	Climate regulation
	Noise reduction		Noise reduction		
Supporting		Refugia		Nursery habitat	Maintenance of life cycles of migratory species
				Genepool protection	Maintenace of genetic diversity
	Pollination and seed dispersal	Pollination	Pollination and seed dispersal	Pollination	Pollination
Cultural	Aesthetic value	Cultural		Aesthetic	Aesthetic information
	Recreation	Recreation	Recreation	Recreational	Opportunities for recreation
				Inspiration for culture, art and design	Inspiration for culture, art and design
				Cultural heritage and identity	
				Spiritual & religious inspiration	Spiritual experience
	Educational opportunities			Education & science	Information for cognitive development
	Animal sighting		Animal sighting		

Table 8-3: Comparative table of ecosystem service lists from literature (Own illustration).

Appendix C-Ecosystem service indicators

Ecosystem service	Ecosystem Service Indicator
Provisioning Services	
Food Sustainably produced/harvested crops, fruit, wild berries, fungi, nuts, livestock, semi-domestic animals, game, fish and other aquatic resources etc.	• Crop production from sustainable [organic] sources in tonnes and/or hectares • Livestock from sustainable [organic] sources in tonnes and/or hectares • Fish production from sustainable [organic] sources in tonnes live weight (e.g., proportion of fish stocks caught within safe biological limits) • Number of wild species used as food • Wild animal/plant production from sustainable sources in tonnes
Water quantity	• Total freshwater resources in million m^3
Raw materials Sustainably produced/harvested wool, skins, leather, plant fibre (cotton, straw etc.), timber, cork etc; sustainably produced/ harvested firewood, biomass etc.	• Forest growing stock, increment and fallings • Industrial roundwood in million m^3 from natural and/ or sustainable managed forests • Pulp and paper production in million tonnes from natural and/or sustainable managed forests • Cotton production from sustainable [organic] resources in tonnes and/or hectares • Forest biomass for bioenergy in million tonnes of oil equivalent (Mtoe) from different resources (e.g. wood, residues) from natural and/or sustainable managed forests
Genetic resources Protection of local and endemic breeds and varieties, maintenance of game species gene pool etc.	• Number of crop varieties for production • Livestock breed variety • Number of fish varieties for production
Medicinal resources Sustainably produced/harvested medical natural products (flowers, roots, leaves, seeds, sap, animal products etc.); ingredients / components of biochemical or pharmaceutical products	• Number of species from which natural medicines have been derived • Number of drugs using natural compounds
Ornamental resources Sustainably produced/harvested ornamental wild plants, wood for handcraft, seashells etc.	• Number of species used for handcraft work • Amount of ornamental plant species used for gardening from sustainable sources

Regulating services	
Air purification	• Atmospheric cleansing capacity in tonnes of pollutants removed per hectare
Climate/climate change regulation Carbon sequestration, maintaining and controlling temperature and precipitation	• Total amount of carbon sequestered / stored = sequestration / storage capacity per hectare x total area (Gt CO_2)
Moderation of extreme events Avalanche control, storm damage control, fire regulation (i.e. preventing fires and regulating fire intensity)	• Trends in number of damaging natural disasters • Probability of incident
Regulation of water flows Regulating surface water run off, aquifer recharge etc.	• Infiltration capacity/rate of an ecosystem (e.g. amount of water/ surface area) - volume through unit area/per time • Soil water storage capacity in mm/m • Floodplain water storage capacity in mm/m
Waste treatment & water purification Decomposition/capture of nutrients and contaminants, prevention of eutrophication of water bodies etc.	• Removal of nutrients by wetlands (tonnes or percentage) • Water quality in aquatic ecosystems (sediment, turbidity, phosphorous, nutrients etc)

Erosion control / prevention Maintenance of nutrients and soil cover and preventing negative effects of erosion (e.g. impoverishing of soil, increased sedimentation of water bodies)	• Soil erosion rate by land use type
Pollination Maintenance of natural pollinators and seed dispersal agents (e.g. birds and mammals)	• Abundance and species richness of wild pollinators • Range of wild pollinators (e.g. in km, regular/aggregated/ random, per species)
Biological control Seed dispersal, maintenance of natural enemies of plant and animal pests, regulating the populations of plant and animal disease vectors etc., disease regulation of vectors for pathogens	• Abundance and species richness of biological control agents (e.g. predators, insects etc) • Range of biological control agents (e.g. in km, regular/ aggregated/random, per species) • Changes in disease burden as a result of changing ecosystems
Cultural services	
Aesthetic information Amenities provided by the ecosystem or its components	• Number of residents benefiting from landscape amenity • Number of visitors to a site to enjoy its amenity services
Recreation & ecotourism Hiking, camping, nature walks, jogging, skiing, canoeing, rafting, diving, recreational fishing, animal watching etc.	• Number of visitors to protected sites per year • Amount of nature tourism
Cultural values and inspirational services, e.g. education, art and research	• Number of products which's branding relates to cultural identity • Number of visits to sites, specifically related to education or cultural reasons • Number of educational excursions at a site • Number of TV programmes, studies, books etc. featuring sites and the surrounding area

Table 8-4: Table of ecosystem service indicators (P ten Brink, 2009).

	Maes (2012)	Gómez-Baggethun, E., & Barton, D. N. (2013)
Provision of food	Percentage of land under crop production/ Livestock density	Production of food (tons yr^{-1})
Provision of water	Percent of wetlands and lakes	
Provision of materials	Timber stock	
Erosion control	Percentage of vegetated land weighted by erosion risk	
Water runoff mitigation	Water infiltration capacity of soils	Soil infiltration capacity; % sealed relative to permeable surface (ha)
Water quality enhancements		
Maintenance of soil fertility	Soil organic matter content	
Waste treatment		P, K, Mg and Ca in $mgkg^{-1}$ compared to given soil/water quality standards
Air quality regulation	Deposition velocity of particles on vegetation	O_3, SO_2, NO_2, CO, and PM_{10} μm removal (tons yr^{-1}) multiplied by tree cover (m^2)
Moderation of environmental extremes		Cover density of vegetation barriers separating built areas from the sea
Temperature regulation	Carbon storage	CO_2 sequestration by trees (carbon multiplied by 3.67 to convert to CO_2)

Noise reduction		Leaf area (m^2) and distance to roads (m); noise reduction dB(A)/ vegetation unit (m)
Pollination and seed dispersal		Species diversity and abundance of birds and bumble bees
Biodiversity	Mean Species Abundance	
Recreation	Recreation potential	Surface of green public spaces (ha)/inhabitant (or every 1000 inhabitants)
Animal sighting		Abundance of birds, butterflies and other animals valued for their aesthetic attributes

	De Groot et al (2010)	Martín-López et al (2014)
Provision of food	Total or average stock in kg/ha	Crop production/ Number of livestock units (LSU)/ Fishing and shell-fishing harvest
Provision of water	Total amount of water (m^3/ha)	
Provision of materials	Total biomass (kg/ha)	
Erosion control	Vegetation cover Root-matrix	
Water runoff mitigation	Water retention capacity in soils, etc. or at the surface	
Water quality enhancements		Eutrophication level in surface waters
Maintenance of soil fertility	E.g. bio-turbation	
Waste treatment	Denitrification (kg N/ha/y); Immobilization in plants and soil	
Air quality regulation	Leaf area index NOx-fixation, etc.	
Moderation of environmental extremes	Water-storage (buffer) capacity in m^3	
Pest control	Number & impact of pest-control species	Alien species registered
Temperature regulation	Greenhouse gas-balance (esp. C-sequestration); Land cover characteristics, etc.	Natural and semi-natural forest surface
Pollination and seed dispersal	Number & impact of pollinating species	
Natural habitat	Number of transient species & individuals (esp. with commercial value)	

Biodiversity	Natural biodiversity (esp. endemic species); Habitat integrity (irt min. critical size)	
Aesthetic value	Number/area of landscape features with stated appreciation	
Recreation	Number/area of landscape & wildlife features with stated recreational value	Tourists visiting for nature tourism
Educational opportunities	Presence of features with special educational and scientific value/interest	Scientific publications

Table 8-5: Tables of existing indicators of ecosystem services (Gómez-Baggethun & Barton, 2013; Groot et al., 2010; Maes et al., 2012; Martín-López et al., 2014).

Appendix D-Valuation methods

Value type	Value sub-type	Meaning
Use values	Direct use value	Results from direct human use of biodiversity (consumptive or non consumptive).
	Indirect use value	Derived from the regulation services provided by species and ecosystems
	Option value	Relates to the importance that people give to the future availability of ecosystem services for personal benefit (option value in a strict sense).
Non-use values	Bequest value	Value attached by individuals to the fact that future generations will also have access to the benefits from species and ecosystems (intergenerational equity concerns).
	Altruist value	Value attached by individuals to the fact that other people of the present generation have access to the benefits provided by species and ecosystems (intragenerational equity concerns).
	Existence value	Value related to the satisfaction that individuals derive from the mere knowledge that species and ecosystems continue to exist.

Table 8-6: Value typology (TEEB, 2010).

Broader approach	Method	Brief description
Revealed preferences – existing markets	Market price	Value estimates are based on prices available in the market (available only when a given aspect of nature is subject to market exchange).
	Avoided or replacement or substitute cost	Value estimates are based on how much damage can be avoided thanks to a given aspect of nature, or how much one would have to pay to replace it.
Revealed preferences – surrogate markets	Hedonic pricing	Value estimates are based on how much a given aspect of nature contributes to the value of a market good, most commonly in the case of the real estate market.
	Travel cost method	Value estimates are based on how much people pay to reach a certain destination which is attractive for environmental reasons.
	Productivity method	Value estimates are based on how much a given aspect of nature contributes to the production of commercially marketed goods/services.
Stated preferences	Contingent valuation	Value estimates are based on how much people declare they would be willing to pay for a given aspect of nature in the context of hypothetical scenarios (or how much they would be willing to accept as compensation for the loss of this aspect).
	Choice experiment	Similar to contingent valuation, but value estimates are derived from choices that people make in hypothetical market situations (trade-offs which they make between the different attributes), rather than upon a direct request to state their willingness to pay.

Table 8-7: Table of economic valuation methods (J. Kronenberg & Andersson, 2016).

Method	Brief description
Rankings, including Q sort and conjoint analysis	Values are derived from comparisons that people make between different aspects of nature or statements regarding environmental management.
Observation, including participant observation, time use, roleplaying	Values are derived from people's behaviour – the observation of how people behave, how they spend their time, what roles they adopt in certain circumstances, in certain situations that involve their interaction with the environment.
Storytelling, photo elicitation	Values are derived from how people represent reality in their stories or through their pictures and photos. Such studies may involve asking respondents additional questions regarding why certain things are of importance.
Content/document analysis	Values are derived from the analysis of different documents, including official documents, legal texts, newspaper articles etc., based on the different representations of nature and nature protection in those documents.
Non-monetary deliberative and participatory approaches	Deliberative and participatory processes where participants reveal their values and contrast them with those of other participants. As a result of such interaction, they arrive at a joint value statement. Specific methods include citizen juries, focus groups, Delphi surveys, participatory mapping, participatory rural appraisal (PRA), participatory action research (PAR).
Psychometric methods	Values can be revealed based on the study of people's emotions and physiological responses to different stimuli (e.g. with the use of eye movement or brain scans), often referred to as experiential values.
Health-based methods	Values can be derived based on the influence of nature on people's health. The more positive are such health impacts, the higher is the value of the associated aspects of nature. Specific methods include clinical measurements and census data.

Table 8-8: Table of social valuation methods (J. Kronenberg & Andersson, 2016).

Method	Brief description
Number of species surveys and models	The most basic form of 'ecological/biological valorisation' within which the perceived value increases with the number of species that use a given ecosystem.
Phylogenetic analysis	The ecological value of an ecosystem depends on the taxonomic diversity and thus different evolutionary pathways of species (more distant taxa translate into higher diversity/value as it reflects higher evolutionary processes). Such an analysis is usually based on genetic information.
Functional diversity analysis (assigning and quantifying traits)	Ecological value depends on the diversity of niches, which in turn reflects the different traits of species or their life history characteristics. Again, the higher diversity, the higher value.
Functional performance analysis	Measurements of performance (speed, magnitude, efficiency) of specific processes and functions, such as pollination, decomposition, nutrient cycling, soil stabilisation. In principle, the better performance, the higher value.
Spatial heterogeneity analysis	Ecological value depends on variation among species assemblages (based on species lists or subpopulations, genetic information etc., analysed at different levels of biodiversity: alfa, beta, gamma diversity). The higher the diversity of an ecosystem compared to selected geographical reference points (for example, a similar but larger ecosystem with a larger pool of species), the higher is its value.
Conservation status surveys and models	Ecological value is sometimes assessed based on population sizes and trends, and the more threatened a given aspect of nature is, the higher is its value.
Focal species identification (expert assessment)	Ecological value is sometimes perceived through the lens of the role that a species plays in an ecosystem (such as keystone, umbrella, indicator species). One of the reasons for this might be that the protection of such species often translates into the protection of the whole habitat. The more important a species is for an ecosystem, the higher is its value.

Table 8-9: Tables of ecological valuation methods (J. Kronenberg & Andersson, 2016).

METHOD NAME	COMPATIBILITY	COMMENSURABILITY
Hedonic pricing	Compatible with spatially explicit valuation methods, the results of which can be assumed to be understandable and relevant to real estate buyers.	Monetary value dimension is largely commensurable with any other valuation dimension that focuses on instrumental values, and use values in particular. Hence, depending on the perspective from which one conducts social or ecological valuation studies, monetary valuation can often be successfully integrated with them. The exception here are market prices which are the least flexible because they only refer to the very limited number of goods and services which are traded in the market and are not adjusted to cover any other value dimension.
Choice experiment	Compatible with valuation methods, the results of which can be used to characterise the attributes valued within the choice experiment.	
Contributions to the local economy	Compatible with valuation methods which refer to amenities influencing the behaviour of consumers, the productivity of employees, the competitiveness of cities etc.	
Replacement cost	Compatible with methods which can be used to distinguish different sites, habitats or functions that would have to be replaced/ restored.	
Market prices	Compatible with any other method that refers to what is traded in the market (hence the most limited).	
Species richness Functional diversity Pattern analysis Species rarity/threat status Functional performance	Compatible with any other method for which these ecological valuation methods might provide relevant indicator of the value of a green space.	Ecological valuation dimension which focuses on instrumental values, such as with the use of methods considered here, can be commensurable with most other value dimensions which reflect instrumental values.
PPGIS Photo elicitation Content analysis of social media profiles Health-based models Rankings	Social valuation methods are compatible with other methods which provide results which can be understood by those whose preferences we depict. For example, we cannot expect social media users or (in an extreme case) the illiterate respondents to a photo elicitation survey to understand complex ecological or monetary expressions of value. Technically compatible methods have to share the same resolution.	Social value dimension is potentially very broad, covering many types of values which would not be commensurable with the instrumental values considered in this report. Within our framework this would only allow for parallel use. However, if different methods refer to instrumental values, they are in principle commensurable.

Table 8-10: Compatibility and commensurability check table (J. Kronenberg, Andersson, E., Rall, E., Haase, D., Kabisch, N., Cummings, C., and Cvejić, R., 2017).

(I – integration, C – combination, P – parallel use).

	Market price	Cost methods	Hedonic	TCM	Produc-tivity	CV	CE
Number of species	I	I	P	I	I	I	I
Phylogenetic diversity	C	C	P	P	P	P	P
Functional diversity	C	I	I	C	I	I	I
Functional performance	I	I	I	C	I	I	I
Spatial heterogeneity	C	I	I	I	P	I	I
Conservation status	I	I	P	I	P	I	I
Focal species	I	I	I	I	P	I	I

(I – integration, C – combination, P – parallel use).

	Market price	Cost methods	Hedonic	TCM	Productiv-ity	CV	CE
Rankings	C	I	I	I	P	I	I
Observation	C	I	I	I	P	I	I
Storytelling	C	I	I	I	P	I	I
Content analysis	C	I	I	I	P	I	I
Deliberative	C	I	I	I	P	I	I
Psychometric	I	P	I	I	P	I	I
Health-based	I	I	C	I	P	I	I

(I – integration, C – combination, P – parallel use).

	Rank-ings	Observa-tion	Storytell-ing	Content analysis	Delibera-tive	Psycho-metric	Health-based
Number of species	I	C	I	I	I	P	P
Phylogenetic diversity	I	C	I	I	I	P	P
Functional diversity	I	C	I	I	I	P	P
Functional performance	I	I	I	I	I	I	I
Spatial heterogeneity	I	C	I	I	I	I	P
Conservation status	P	I	I	I	I	P	P
Focal species	P	I	I	I	I	P	P

Table 8-11: Tables of integration potential between different methods (J. Kronenberg & Andersson, 2016).

Appendix E-Ecosystem service studies

Author(s)	Valuation technique(s)	Estimated values
Bockarjova, M., W. Botzen, and M.J. Koetse (2018)	Contingent valuation (Meta-analysis)	Using the European model, value per ha ranged from $46,336 (2016 USD) for The Royal National City Park in Stockholm to $33,527,530 per ha for Danube Eco-District in Strasbourg. Using the Global model, average willingness-to-pay (WTP) per ha values for various types of urban nature, holding other variables at their mean, were computed: $11,007 for parks, $1,523 for forest, $1,955 for 'Green connected to grey', $1,895 for Blue, and $1,187 for peri-urban areas.
Bolitzer, B. and R. N. Netusil (2000)	Hedonic property	Based on the linear Model A1, a home located within 1,500 feet of any open space sells for US$2105 (1990 United States Dollars) more than a home located more than 1,500 feet from an open space and an acre of open space is estimated to increase the price of a house by US$28.33. Based on the semi-log Model A2, open spaces located within 1,500 feet of a home increase the price of the home by 1.43%. In the linear Model B1 and semi-log Model B2, a public park within 1500 feet of a home increased the home's sale price by US$2262 and US$845 respectively while proximity to a golf course increased a home's sale price by about US$3400 and US$3940 respectively. A 20-acre public park was estimated to increase the price of a house by US$2780 and US$1360 in the linear Model B1 and semi-log Model B2 respectively while a 116-acre golf course was estimated to increase the price by US$6408 and US$6926 in the linear and semi-log model specifications respectively. The impact of open-space proximity on the sale price of a home based on the semi-log Model C ranged from US$1,004.16 to US$ 3,522.80 depending on the distance.
Brander, L. M. and M. J. Koetse (2011)	Contingent valuation & Hedonic pricing (Meta-analysis)	Using the contingent valuation meta-analysis, the estimate of the annual value of open space with average characteristics is $1,550 per hectare (2003 US Dollars). Average corresponds to an area of 9,918 hectares with a population density of 218 people per square km and a GDP per capita of $20,542. Open spaces that are 10 percent larger than the average are estimated to have an annual value per hectare of $1,432. The hedonic pricing results are presented in percentage terms and are therefore not included in this summary.
Cavailhès et al. (2008)	Hedonic Pricing	In this area, tree-cover and farmland have positive hedonic prices, and networks negative prices, but only when these items are very close to houses and mostly when they are in view. Beyond a few tens of meters or 100–200 m at most, consumers appear indifferent to the presence of viewsheds and their contents (Cavailhès et al., 2008, p. 97).
Chen, W. Y. and C. Y. Jim (2010)	Hedonic property	The results indicated that residential gardens were the most attractive landscape (an average increase of 17.2% of housing price) and urban villages had disamenity effects (a decrease of 3.72% for visibility and 2.5% for availability). The visibility of landscape was more valued than the accessibility (Chen & Jim, 2010, p. 227).
Cho et al (2009)	Hedonic Pricing	The marginal effect of distance to the nearest golf course in 1990, evaluated at the mean house price of $132,847 and an initial mean distance of 1.9 miles, means that moving 1,000 feet closer to a golf course would increase the mean

		house price by $305. Similarly, moving 1,000 feet closer to a water body would increase the mean house price by $361 in 1990. For 2000, the mean house price is $131,929 and moving 1,000 feet closer to a greenway, park, golf course, or water body would increase this price by $171, $180, $290, or $460, respectively. The value of proximity to parks and water bodies has increased from the 1990 to the 2000 time period.
Czembrowski and Kronenberg (2016)	Hedonic Pricing	As expected, different types of green space exert different impacts on property prices. The environmental variables with the strongest impact were the distances to the Lagiewniki forest (3%) and to large parks (1.5%). On average, an additional 1% of greenery increases the apartment sale price by 3.95 PLN per square meter.
Czembrowski, Kronenberg, et al. (2016)	Hedonic Pricing and SoftGIS	Every additional percent of increase in the distance to the Łagiewniki forest decreases the apartment price by 177 PLN per square meter, whereas a corresponding increase in distance to a forest of no net preference decreases the square meter price by 96 PLN. The parks influenced the property prices to smaller extent: a 1% increase in the distance to the nearest park of high perceived value was associated with a decrease of the apartment price by 26 PLN. There were also two categories of green spaces which were seen as disamenities: cemeteries – decreasing the apartment price by 109 PLN with every 1% decrease in distance there to; and parks with low perceived value were associated with a corresponding decrease of 62 PLN (Czembrowski, Kronenberg, et al., 2016, p. 172).
Czembrowski, Łaszkiewicz, et al. (2016)	Hedonic Pricing	The lack of impact of green spaces adjacent to the Priest's Mill complex and the negative impact of the LRG might result from their specific neighborhoods. However, it seems plausible that the biocultural value of green spaces does not matter when it comes to buying an apartment. Instead, real estate buyers appreciate other aspects of green spaces, and green spaces in general seem to be perceived as important amenities.
Czembrowski et al. (2019)	Hedonic Pricing and Sociotope mapping	The model revealed that green spaces representative of the categories: "aesthetics", "social" and "nature", are perceived as amenities by real estate buyers. The green spaces qualified as being representative of the category "physical activity" are insignificant in explaining the property prices while those assigned to category "play" seem to be disamenities. Water bodies also have a positive and strong impact on property prices, but not as strong as green spaces assigned to the "aesthetics" sociotope category. Surprisingly, an additional percentage point of the share of greenery in the 500-meter buffer is associated with a decrease in property prices. A 1% increase in the distance to the nearest green space without any sociotope characteristics decreases the property price by only 0.7% whereas the same 1% increase in the distance to the nearest green space with all five characteristics decreases the property price by as much as 10.4%.
D, H. MacDonald, N. D. Crossman, P. Mahmoudi, L. O. Taylor, D. M. Summers and P.	Hedonic property	For each additional meter a property is located from a large hiking reserve, the value of the property increases by $11 (Australian Dollars, currency year not given). Property values are decreased by $24 and $18 for a metre increase in distance away from a watercourse and golf course, respectively. For small playgrounds, property values decrease as distance to the nearest playground

C. Boxall (2010)		increases, and this negative relationship increases with increasing severity of water restrictions.
Daams, M.N., F.J. Sijtsma, and A.J. van der Vlist (2016)	Hedonic property	The following percentage effect on property price of nearest attractive natural area were estimated by distance to the property: 0-0.5km (+16%), 0.5-1km (10.7%), 1-2km (8.8%), 2-3km (6.3%), 3-4km (3.7%), 4-5km (3.5%), 5-6km (3%), and 6-7km (1.6%). No significant price effect was found for properties beyond 7km away from the nearest attractive natural area. Regarding effects of the share of natural space within 7km of a property, a 0.22% effect on property prices was found for a marginal (1%) increase in natural area density at the expense of developed areas.
Fernandez et al. (2018)	Hedonic Pricing	A 1% increase in distance from wild leads to a 0.07% drop in residential real estate prices during 1996–99 and 0.20% drop in residential real estate prices in 2000–04. These coefficients indicate a higher marginal value for open space in the post-policy period in Riverside County. A 1% increase in distance from wild leads to a 0.04% drop in residential real estate prices during 1996–99 and 0.11% drop in real estate prices during 2000–04 in San Bernardino County. The increase in marginal value of wild habitat open space in San Bernardino County (where policy is not implemented) captures the spill over effect (Fernandez et al., 2018, p. 484).
Koetse et al. (2017)	Contingent valuation & Choice experiment	The results further show that natural areas with water and forests are preferred to grasslands. Increasing the size of an area and decreasing the distance between an area and the residential location have substantial positive effects on the derived WTP values. The results suggest that medium levels of fragmentation have limited consequences but that high levels of fragmentation have substantial detrimental effects on values of natural areas. The effect of fragmentation by transport infrastructure is somewhat stronger than the effect of fragmentation by urban sprawl. Also, areas that are not accessible for recreation have substantially lower values, and it is likely that many respondents made their choices from a recreation perspective (Koetse et al., 2017, p. 176).
Latinopoulos, D., Z. Mallios and P. Latinopoulos (2016)	Contingent valuation - dichotomous choice (referendum)	The mixture model estimates represent the estimates once the results from the participation model are taken into account. The total annual value of the program ranges between 7.8 and 9.1 million (2013 Euro) depending on the model used.
Liu, S., R. Costanza, A. Troy, J. D'Aagostino and W. Mates (2010)	Benefit transfer	On a per acre basis, beaches appear to provide the highest annual values ($42,147). Next, it appears that both freshwater wetlands ($8,695) and saltwater wetlands ($6,527) contribute significantly to the annual value flow throughout the State of New Jersey. At the other end of the value spectrum, cropland ($23) and grassland/rangeland ($12) provide the lowest annual values documented on an annualized basis. Finally, the authors test the convergent validity of the benefit transfer results and conclude that the results meet this criterion. They do so by comparing their transferred results with those derived from a primary hedonic pricing study conducted in New Jersey with the study site consisting of seven local housing markets, which in most respects are demographically similar to the state as a whole (Liu et al., 2010, p. 1277).

Luttik, J. (2000)	Hedonic property	These environmental features were estimated to add 4% to 12% to property prices.
Martín-López et al. (2014)	Market-based/Public investments/Travel cost/Contingent valuation/Surveys	The use of different valuation methods uncovers the fact that methods to elicit value actually shape and define the values being elicited. Thus, monetary value seemingly prioritized marketed services, such as provisioning services and ecotourism, obscuring the socio-cultural importance given by stakeholders to regulating services. In fact, while regulating ser-vices were recognized by respondents as being those of highest importance for human well-being, they have the lowest monetary value and their delivery (measured in biophysical terms) was decreasing (Martín-López et al., 2014, p. 220).
Panduro and Veie (2013)	Hedonic Pricing	For houses, proximity to parks and size of the park is associated with higher prices—the effect of size is small with approx. 0.01 percent increase in the price with a one percent increase in the size. Houses with a view of a lake are more expensive with approx. 7 percent higher prices. Proximity to green buffers is associated with a significantly lower house price even though we have controlled for the proximity of the undesirable neighbour separately. For apartments the access to parks is also associated with higher prices. Having a view of a park is associated with a price premium of almost 6 percent. Proximity to natural areas is not associated with a similar significant increase in prices, nor does the size of nearby natural areas play a significant role.
Remme, R. P., B. Edens, M. Schroter, and L. Hein (2015)	Actual expenditure/market price of output|Replacement costs	The highest ES values were for crop production (45.9 million) and nature tourism (38.7 million) (2010 Euros). Cropland, pastureland, and forest were the land cover types with the highest estimated total value and constitute over 65% of the land area of Limburg. In total, the value of the ES in 2010 was 112 million, or 508 per hectare.
Sander, H. A. and R.G. Haight (2012)	Hedonic property	In terms of variables related to access to outdoor recreation areas, the model predicts that housing sales prices would increase by $13 given a decrease in 100m to a park, and that they would increase by $129 for a decrease in 100m to a lake. For tree covers, a 10% increase in tree cover in the 100m radius was associated with a marginal increase in housing sales price of $1853, and of $1030, $1947, $1102 for the 250m, 500m and 750m radii, respectively. In terms of results relating to the home's viewshed, a one-hectare increase of a home's viewshed was associated with an increase in sales price of $181. Increases in grass views and water views (per ha) were associated with marginal implicit prices of $1741 and $81, respectively, while forest views were not significantly associated with sales price. Lastly, an increase of 1 ha in 26-50% of impervious land cover in the home's viewshed was associated with a negative marginal implicit price of $831, while an increase of 1ha in 51-75% of impervious land cover in the home's viewshed was associated with a negative marginal implicit price of $1035.
Sander, H., S. Polasky and R. G. Haight (2010)	Hedonic property	In Model 1, the marginal implicit price of a 10 % increase in tree cover within the 100-metre buffer evaluated for the mean house value was estimated to be $1,371 (2005 US), and the equivalent figure for the 250-metre buffer was estimated to be $836. For Model 2 increasing the tree cover increases home sale value up to 44% tree cover in the 100-metre buffer and 60% in the 250-

		metre buffer. Tree cover beyond 250 metres was found not to contribute significantly to sale price.
Tyrväinen and Miettinen (2000)	Hedonic Pricing	According to the estimation results a one-kilometre increase in the distance to the nearest forested area leads to an average 5.9 percent decrease in the market price of the dwelling. Dwellings with a view onto forests are on average 4.9 percent more expensive than dwellings with otherwise similar characteristics (Tyrväinen & Miettinen, 2000, p. 205).
Van Berkel, D. and P. H. Verburg (2014)	Travel cost method - single site|Contingent valuation - open ended|Contingent ranking	For the stated preference valuation, the mean WTP per year for landscape maintenance in Winterswijk was estimated at 86.18 Euro per person. Respondents most valued the conservation of the coulisse landscape and were willing to pay an average of 33.30 Euro to prevent farmers from cutting landscape elements to improve agricultural productivity. The conservation of the other landscapes was valued slightly less. Respondents were willing to pay 27.30 Euro to conserve traditional agricultural landscapes from increased residential infill and 23.87 Euro to prevent that extensive farming landscapes from becoming overgrown and wild. For the revealed preference valuation, the total consumer surplus was estimated at approximately 850,000 Euro or about 23 Euro per visit. The total value based on stated preference approach was estimated to be 2.95 million Euro while revealed preference approach provided an estimate of 11.1 million Euro.

Table 8-12: Cumulative tables of ecosystem valuation studies (Own illustration).

Appendix F-Phase I data depiction

Dependent Variables	Minimum	Maximum	Mean			
Transaction price in €	123.750	783.000	262.380,78			
Transaction price per m^2 in €	1076,09	4427,71	2129,67			
Independent variables	**Minimum**	**Maximum**	**Mean**	**Frequency**		**Mean house price per m^2**
Year of sale	2009	2019	2014,27			
Year of sale= 2009 (dummy)			,09	26		2120,55
Year of sale=2010 (dummy)			,07	21		2357,41
Year of sale=2011 (dummy)			,05	15		2114,13
Year of sale=2012 (dummy)			,06	18		2025,72
Year of sale=2013 (dummy)			,09	26		1892,01
Year of sale=2014 (dummy)			,10	28		1882,37
Year of sale=2015 (dummy)			,11	31		2020,82
Year of sale=2016 (dummy)			,12	33		1989,72
Year of sale=2017 (dummy)			,15	43		2079,09
Year of sale=2018 (dummy)			,11	30		2579,98
Year of sale=2019 (dummy)			,04	10		2861,75
House type=Apartment (dummy)			,07	19		2133,16
House type=Corner house (dummy)			,20	56		2092,03
House type= Row house (dummy)			,71	199		2092,20
House type= Detached (dummy)			,02	7		3486,65
Year built	1968	2008	1978,11			
Year built=Before 1971 (dummy)			,36	101		2209,36
Year built= 1971-1980 (dummy)			,32	89		1895,10
Year built=1981-1990 (dummy)			,17	47		2176,31
Year built=1991-Today (dummy)			,16	44		2171,41
House size (m^2)	81	227	121,77	0-100m2	51	2108,86
				100-150m2	209	2062,63
				150+ m2	21	2847,36
Neighborhood= Afrikabuurt-West (dummy)			,16	45		2202,54
Neighborhood=Buitenhof-Noord (dummy)			,36	101		1863,99
Neighborhood=Buitenhof-Zuid (dummy)			,05	15		2344,38
Neighborhood= Verzetstrijdersbuurt (dummy)			,43	120		2299,12
Distance to ESH2 (m)	24,70	499,36	300,21	0-100m	31	2087,49
				100-200m	50	2269,16
				200-300m	48	2085,91
				300-400m	66	2120,17
				400-500m	86	2095,49

Percentage of surrounding public green	6,2%	37,6%	21,46%	0-10%	5	3014,72
				10-15%	34	2337,37
				15-20%	82	2118,98
				20+%	160	2063,36

Table 8-13: Table of ESH2 variables' descriptive statistics.

Dependent Variables	Minimum	Maximum	Mean			
Transaction price in €	130.900	337.500	219.105,89			
Transaction price per m² in €	1222,63	3289,47	2199,02			
Independent variables	**Minimum**	**Maximum**	**Mean**	**Frequency**		**Mean house price per m²**
Year of sale	2009	2019	2014,17			
Year of sale= 2009 (dummy)			,11	33		2258,71
Year of sale=2010 (dummy)			,07	22		2257,95
Year of sale=2011 (dummy)			,09	29		2152,74
Year of sale=2012 (dummy)			,05	17		2031,47
Year of sale=2013 (dummy)			,06	20		1840,79
Year of sale=2014 (dummy)			,09	29		1955,64
Year of sale=2015 (dummy)			,10	30		2024,69
Year of sale=2016 (dummy)			,14	45		2074,23
Year of sale=2017 (dummy)			,13	42		2446,69
Year of sale=2018 (dummy)			,11	35		2549,63
Year of sale=2019 (dummy)			,04	12		2475,64
House type=Apartment (dummy)			,17	54		2330,55
House type=Corner house (dummy)			,23	73		2211,97
House type= Row house (dummy)			,60	187		2155,99
Year built	1978	1990	1983,00			
Year built= 1971-1980 (dummy)			,54	171		2168,52
Year built=1981-1990 (dummy)			,46	143		2235,50
House size (m²)	70	155	101,67	0-100m²	137	2425,88
				100-150m²	174	2024,99
				150+ m²	3	1932,83
Neighborhood= Aziëbuurt (dummy)			,11	35		2342,10
Neighborhood= Bosrand (dummy)			,28	89		2262,56
Neighborhood= Vogelbuurt-Oost (dummy)			,20	64		2129,76
Neighborhood= Vogelbuurt-West (dummy)			,40	126		2149,57
Distance to ESH3 (m)	28,17	499,47	222,63	0-100m	89	2262,56
				100-200m	52	2264,38
				200-300m	60	2296,02
				300-400m	61	1967,19

					400-500m	52	2184,95
	Percentage of surrounding public green	9,62%	50,28%	17,57%	0-10%	46	2358,76
					10-15%	145	2195,62
					15-20%	53	2167,49
					20+%	70	2124,97

Table 8-14: Table of ESH3 variables' descriptive statistics.

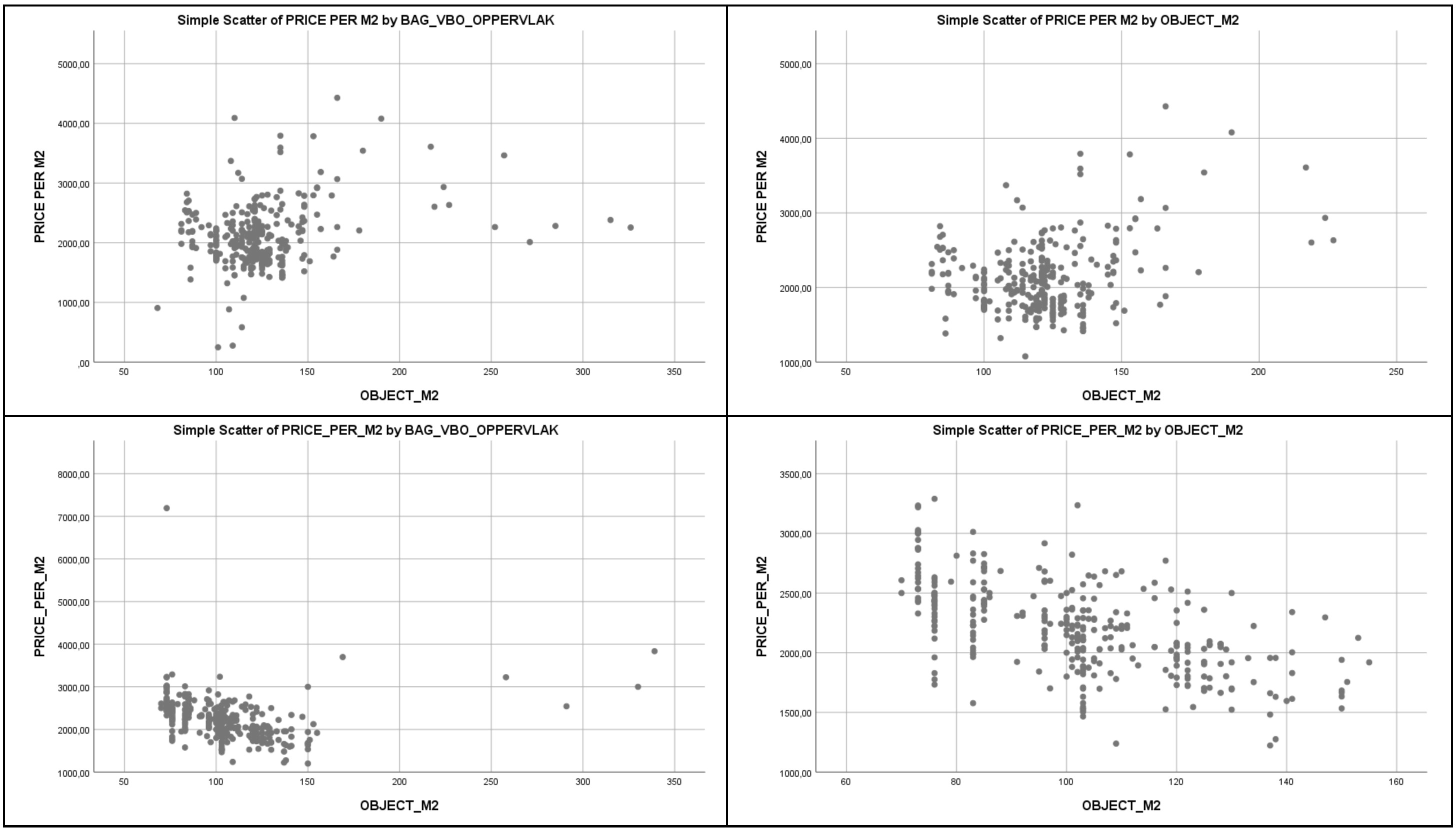

Figure 8-1: Transactions before and after filtering outliers for ESH2 (above) and ESH3 (below).

Appendix G-Phase I results

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
ESH2	(Constant)	4086,649	857,448		4,766	,000
	Year of sale= 2009 (dummy)	-450,612	90,877	-,270	-4,958	,000
	Year of sale=2010 (dummy)	-204,497	97,664	-,111	-2,094	,037
	Year of sale=2011 (dummy)	-245,398	110,828	-,114	-2,214	,028
	Year of sale=2012 (dummy)	-254,519	103,653	-,129	-2,455	,015
	Year of sale=2013 (dummy)	-173,417	94,630	-,104	-1,833	,068
	Year of sale=2014 (dummy)	-158,796	88,846	-,098	-1,787	,075
	Year of sale=2015 (dummy)	-82,691	87,807	-,054	-,942	,347
	Year of sale=2016 (dummy)	-195,899	86,560	-,130	-2,263	,024
	Year of sale=2017 (dummy)	-224,104	80,976	-,167	-2,768	,006
	House type=Apartment (dummy)	125,795	116,014	,065	1,084	,279
	House type=Corner house (dummy)	108,704	56,575	,090	1,921	,056
	House type= Detached (dummy)	1077,413	172,623	,347	6,241	,000
	Year built= 1971-1980 (dummy)	-91,957	66,579	-,088	-1,381	,168
	Year built=1981-1990 (dummy)	166,337	126,116	,128	1,319	,188
	Year built=1991-Today (dummy)	136,868	110,423	,103	1,239	,216
	House size in LN (m^2)	-267,166	181,873	-,096	-1,469	,143
	Distance to ESH2 in LN (m)	-78,354	37,505	-,108	-2,089	,038
	Neighborhood= Afrikabuurt-West (dummy)	-223,367	122,973	-,169	-1,816	,070
	Neighborhood=Buitenhof-Noord (dummy)	-522,709	72,244	-,518	-7,235	,000
	Neighborhood=Buitenhof-Zuid (dummy)	-103,827	143,934	-,048	-,721	,471
	Percentage of surrounding public green (LN)	-245,186	89,914	-,150	-2,727	,007
a. Dependent Variable: ADJUSTED_PRICE PER M2						

Table 8-15: Coefficient table for ESH2's independent variables.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
ESH3	(Constant)	10263,031	470,519		21,812	,000
	Year of sale= 2009 (dummy)	-400,282	54,994	-,324	-7,279	,000
	Year of sale=2010 (dummy)	-332,778	62,641	-,224	-5,312	,000
	Year of sale=2011 (dummy)	-329,441	57,154	-,251	-5,764	,000
	Year of sale=2012 (dummy)	-174,157	68,863	-,104	-2,529	,012
	Year of sale=2013 (dummy)	-195,025	64,923	-,126	-3,004	,003
	Year of sale=2014 (dummy)	-81,778	57,353	-,062	-1,426	,155
	Year of sale=2015 (dummy)	-56,623	56,392	-,044	-1,004	,316
	Year of sale=2016 (dummy)	-175,884	50,355	-,162	-3,493	,001
	Year of sale=2017 (dummy)	-14,736	51,852	-,013	-,284	,776
	House type=Apartment (dummy)	-366,180	69,116	-,364	-5,298	,000
	House type=Corner house (dummy)	-5,168	34,200	-,006	-,151	,880
	Year built=1981-1990 (dummy)	43,300	69,932	,057	,619	,536
	House size in LN (m^2)	-1486,780	93,288	-,776	-15,938	,000
	Distance to ESH3 in LN (m)	-159,433	41,950	-,410	-3,801	,000
	Neighborhood= Aziëbuurt (dummy)	218,489	82,119	,181	2,661	,008
	Neighborhood= Bosrand (dummy)	-201,809	108,240	-,240	-1,864	,063
	Neighborhood= Vogelbuurt-Oost (dummy)	119,872	40,307	,127	2,974	,003
	Percentage of surrounding public green (LN)	-42,921	74,927	-,046	-,573	,567
a. Dependent Variable: ADJUSTED_PRICE PER M2						

Table 8-16: Coefficient table for ESH3's independent variables.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
ESH2	0-100m	150,638	86,867	,097	1,734	,084
	100-200m	112,028	80,983	,089	1,383	,168
	200-300m	-69,155	84,467	-,054	-,819	,414
	300-400m	40,062	70,814	,035	,566	,572
a. Dependent Variable: ADJUSTED PRICE PER M2						

Table 8-17: Coefficient table for ESH2's distance dummy variables (Adjusted R^2=0,463).

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
ESH3	0-100m	156,238	92,459	,186	1,690	,092
	100-200m	189,871	59,477	,186	3,192	,002
	200-300m	149,840	58,586	,155	2,558	,011
	300-400m	16,015	54,301	,017	,295	,768
a. Dependent Variable: ADJUSTED PRICE_PER_M2						

Table 8-18: Coefficient table for ESH3's distance dummy variables (Adjusted R^2=0,604).

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
ESH1	House size=0-100m^2	-188,659	156,358	-,890	-1,207	,228
	House size=150+m^2	34,255	77,228	,149	,444	,658
	House type=Apartment	-78,814	59,976	-,297	-1,314	,189
	House type=Corner house	-239,110	120,804	-,928	-1,979	,048
	House type=Semi-detached house	-444,783	81,970	-1,544	-5,426	,000
	House type=Detached house	-164,038	124,387	-,382	-1,319	,188
	Surrounding green=0-10%	-106,899	75,765	-,504	-1,411	,159
	Surrounding green=15-20%	-243,126	128,707	-1,000	-1,889	,059
	Surrounding green=20+%	319,410	206,163	,750	1,549	,122
	Year built=Before 1500-1905	-80,225	23,480	-,145	-3,417	,001
	Year built= 1906-1944	-71,780	21,040	-,162	-3,412	,001
	Year built=1945-1970	-26,660	167,444	-,086	-,159	,874
	Year built=1971-1990	-1785,305	745,605	-2,269	-2,394	,017
	Year built=1991-2000	-759,960	361,151	-1,797	-2,104	,036
a. Dependent Variable: ADJUSTED_PRICE PER M2						

Table 8-19: Coefficient table for ESH1's interactions (Adjusted R^2=0,631).

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
ESH2	House size=0-100m^2	191,680	85,644	,800	2,238	,026
	House size=150+m^2	-86,579	223,266	-,243	-,388	,699
	Year built= 1971-1980	-1,918	124,904	-,010	-,015	,988
	Year built=1981-1990	52,167	562,169	,238	,093	,926
	Year built=1991-Today	-118,062	161,706	-,513	-,730	,466
	Surrounding green=0-10%	-566,815	877,531	-,659	-,646	,519
	Surrounding green=10-15%	-311,194	187,323	-1,191	-1,661	,098
	Surrounding green=15-20%	-169,722	84,692	-,873	-2,004	,046
	House type=Apartment	-753,894	571,663	-2,205	-1,319	,188
	House type=Corner house	140,153	93,478	,655	1,499	,135
	House type=Detached house	-534,383	645,152	-,838	-,828	,408
a. Dependent Variable: ADJUSTED PRICE PER M2						

Table 8-20: Coefficient table for ESH2's interactions (Adjusted R^2=0,531).

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
ESH3	House size=0-100m²	83,831	7,274	,525	11,525	,000
	House size=150+m²	-52,516	28,514	-,075	-1,842	,067
	House type=Apartment	-58,724	38,204	-,198	-1,537	,125
	House type=Corner house	99,269	65,878	,615	1,507	,133
	Surrounding green=0-10%	52,324	30,002	,165	1,744	,082
	Surrounding green=15-20%	6,032	8,811	,032	,685	,494
	Surrounding green=20+%	-25,853	11,765	-,165	-2,197	,029
	Year built=1981-1990	117,085	135,668	,736	,863	,389
a. Dependent Variable: ADJUSTED_PRICE_PER_M2						

Table 8-21: Coefficient table for ESH3's interactions (Adjusted R2=0,515).

		Year Built					
		Before 1905	1906-1944	1945-1970	1971-1990	1991-2000	After 2000
ESH1	House size=0-100m2	14	18	47	6	3	66
	House size=100-150m²	1	6	14	1	13	239
	House size=150+m²	0	0	0	1	11	117

Table 8-22: Frequency table for ESH1's combinatorial categories.

		Year Built			
		Before 1971	1971-1980	1981-1990	After 1991
ESH2	House size=0-100m2	0	22	20	9
	House size=100-150m²	87	64	26	32
	House size=150+m²	14	3	1	3

Table 8-23: Frequency table for ESH2's combinatorial categories.

		Year Built	
		1971-1980	1981-1990
ESH3	House size=0-100m2	48	89
	House size=100-150m²	120	54
	House size=150+m²	3	0

Table 8-24: Frequency table for ESH3's combinatorial categories.

Appendix H-Objectenhandboek Definitions

All images and definitions were gathered from the Objectenhandboek BGT | IMGeo.

Gemengd bos: Terrain area covered with of coniferous and deciduous trees, which form a closed whole or will eventually after they reached full growth .	
Grasland overig: Terrain area with vegetation comprising of grass and herbs, occurring in grasslands, which is intended for agricultural purposes.	
Groenvoorziening: Terrain area including landscaped greenery, most often grass, shrubs or bushes.	
Houtwal: Part of the terrain, aiming to serve as a fence, with limited width and planted with trees or shrubs.	
Rietland: Terrain area predominantly consisting of reed vegetation.