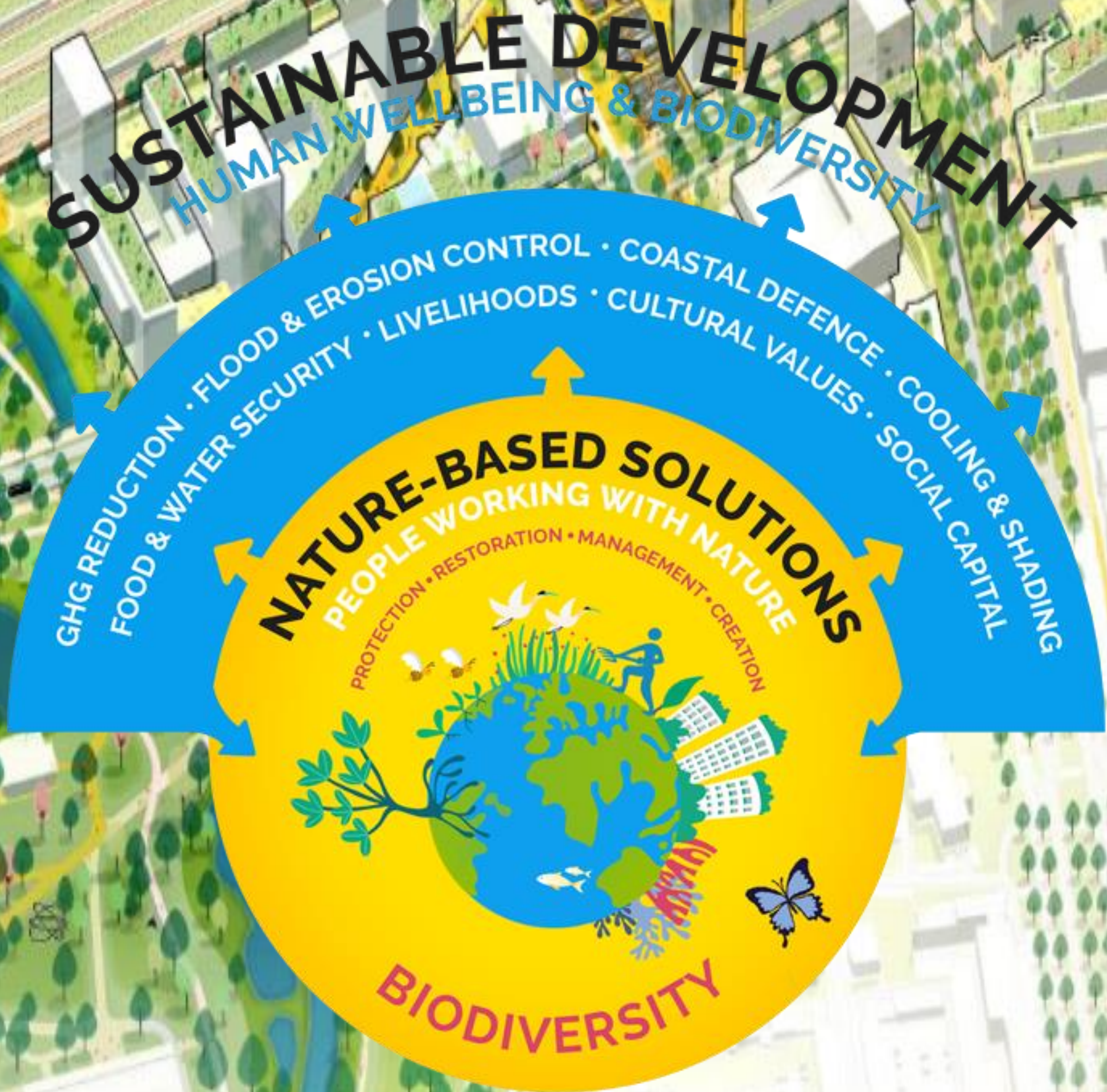
Combining nature based design and ecosystem services within urban development planning

Using a combination of interactive art, nature based and more than human design principles within the framework of urban river landscape redevelopment



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Laymen Summary

Humans and nature are interconnected in a complex and dynamic relationship. Over time, humanity has developed a deep dependence on nature for its survival, relying on its resources and services. However, human activity has also had a significant impact on the environment, disrupting ecosystems and contributing to a range of environmental problems in city environments. In recent years, there has been more recognition of the importance of nature in cities, especially in the context of urbanization and climate change. Urban nature provides a number of benefits to people living in cities, including reduced noise pollution, improved air quality, , and enhanced biodiversity. Urban nature also plays a role in area development, helping with increasing the overall livability and sustainability of urban environments. The KnoopXL development vision in Eindhoven, a densely populated city in the Netherlands, shows the importance of considering an increase in natural resources in urban planning and development. Currently the people making the decisions for the future of this area have differing opinions about the amount of nature in this area. That's why the project DommelPolitics was initiated to bring together these different perspectives and explore the potential of both art and nature-based solutions (NBS) in order to enhance urban redevelopment. DommelPolitics started as an interactive art exhibition to educate residents about the urban nature around them, this created a sense of connection and appreciation for the natural environment. After the exhibition ecosystem services were used as a framework for quantifying the value of the proposed natural changes in the art exhibition. This was done to demonstrate how NBS that were based on the needs of the local animals can contribute to a more sustainable and livable urban landscape. This will not only improve their living environment, but also have an effect on the humans living in the city of Eindhoven. The project's findings indicate that a combination of more-than-human design visions and ecological design can effectively be integrated with NBS into urban redevelopment projects, enhancing the ecosystem services provided by nature and contributing to better coexistence between humans and the environment.

Abstract

Rapid urbanisation in cities like Eindhoven have caused the nature around the river Dommel to become less present. The coming years the cities plans to reintroduce more nature back into the city in one of the neighbourhoods called KnoopXL. The plans that are currently being drawn up are made from a human centric vision, that incorporates little actual nature. That's why in this report we will show how a combined effort of more than human and Ecological design approaches can influence urban redevelopment by showing that NBD interventions can increase ecosystem services. These ecosystem services like water quality, local water storage and biodiversity can be improved drastically within urban environments when Nature Based Solutions based on the local ecology are implemented. The focus points of these interventions should be on the most densely build areas within the city of Eindhoven to get the greatest increase in ecosystem services and therefor the urban nature that is important for both the health of humans and non-humans. Overall this report shows that an framework combining art as a medium to challenge the views of stakeholders, can be combined with elements from scientific fields like Ecosystem services to provide a starting point for future redevelopment projects of urban landscapes.

Introduction

Humanity depends on nature to sustain our population, but human activity is impacting ecosystems around us in unexpected and large-scale ways (Rockström et al., 2009). The global increase in urbanization by humans, in combination with the increasing climate impact, has led to the re-evaluation of nature in the city (De Oliveira et al., 2011; Strohbach et al., 2009). This urban nature can be used to improve the living environment of people within a large city (Aerts et al., 2018; Sandifer et al., 2015). Urban nature also plays a role in the area development within a large city like Eindhoven, where stakeholders benefit from various adaptations in an area. This is also the case within the KnoopXL area, where the Dommel River flows through a densely populated part of the city. According to the concept of social-ecological systems, the residents of the city of Eindhoven are connected to this river and everything that lives around it, and people and nature interact here in a temporally dynamic system (Fischer et al., 2015). This connection and value is only partially taken into account in policy plans and visions for the future. One of the factors influencing this is the large role of socio-economic and other values like, transportation, housing and other infrastructure within policy formation and planning (Cortinovis & Geneletti, 2018; Fischer et al., 2015). These socio-economic components of society, such as the demand for more land for agriculture and the socio-ecological conservation of forests, often stand in direct opposition to each other (Lambin & Meyfroidt, 2011; Lang & Barling, 2012). In order to bring together both the worlds of socio-economic values and values set by nature that are present in different stakeholders within the KnoopXL development vision, a project was started to develop an interactive art exhibition for the Dutch Design Week (DDW) in Eindhoven. Within this project, we also investigated how to create a connecting language to make the bridge between humans and nature more accessible within the scope of the redevelopment of the KnoopXL area. This is where DommelPolitics originated. Through this interactive art exhibition, we enable the residents of Eindhoven to become acquainted with the nature around them. This is done in a way that puts humans and the Anthropocene thought on the back burner by taking a "more than human" design perspective while tackling a problem. Therefore, the ecology and the needs of urban nature were taken into account as a guideline in both the design process of an animated model of the environmental vision and the storytelling of characters and political parties. This is similar to how (Forlano, 2017) described in her article on posthumanism and design, that when designing a chicken coop, one should make sure to think and design like a chicken. This is also similar to concepts from biomimicry, ecological design, or design with nature, where nature or the rules set by nature are used in design (Benyus, 1997; Ryn & Cowan, 2013). The goal of this nature based interactive art exhibition was to inform people about the urban nature around them and make them think about how political visions sometimes don't take the value of nature into account. The specifics of this approach are further demonstrated in chapter 1.

In order to increase the persuasive power of DommelPolitics, next to a more art based approach, another element was added to the concept. This was done because, while art is a good medium to connect people from different backgrounds , this openness also creates room for different interpretations of the same result (Pearson et al., 2018). And when it comes to the connection between humans with the local ecosystem it was important for our team to quantify this relation to urban nature. A widely used method for this is to include Ecosystem Services (ES) within government policy-making (Costanza et al., 1997, 2017; Fischer et al., 2015). These services provided by nature around us can be divided into producing, regulating, cultural, and supporting values (Bolund & Hunhammar, 1999; Costanza et al., 1997). By using these ecosystem services in area development, not only is the function of a particular adaptation considered, but also what the natural value of this intervention is over a longer period of time and for humans in general. This makes the use of ecosystem services within area development and planning an excellent connecting factor between stakeholders with opposing visions (van der Meulen et al., 2011). To express the value of urban nature in factors that are also manageable for stakeholders with a different background, the ecosystem services framework is very useful (van der Meulen et al., 2011). Ecosystem services are also referred to as natural capital, nature's services or ecological economics (Costanza et al., 2017). However, including the value of this natural capital in policy plans and government accounting still has many challenges (Cortinovis & Geneletti, 2018; Saidi & Spray, 2018). The question then became how to couple these ecosystem services to the political visions that were produced during the interactive art exhibition part of DommelPolitics. Three distinct research areas of the watershed of the Dommel in Eindhoven were chosen to perform interventions on (figure 4). These interventions are described here as changes in the buildt environment during urban redevelopment which are based on Nature Based Solutions (NBS) that fit the political views of the three developed political parties; Stroom Opwaarts (SO), Inheemse Belangen Partij(IBP) and Toekomst Bouwers (TB). NBS in this sense, are spatial sustainability elements that contribute to ecosystem services such as biodiversity, natural drainage, or water purification (Dorst et al., 2019). The EcoWebUi was used to map these three areas and calculated how specific interventions to these areas affected the ES scores. Since the river Dommel is the focus point within the redesign of the urban area, the two ecosystem services water quality and quantity were more closely looked at in this report. Although the interventions proposed by the fictitious parties are not actual or realistic within these areas when it comes to socio-economic and other values. The main question in this report therefore is stated as; can a combined effort of more than human and Ecological design approaches influence urban redevelopment by showing that NBS can increase ecosystem services?

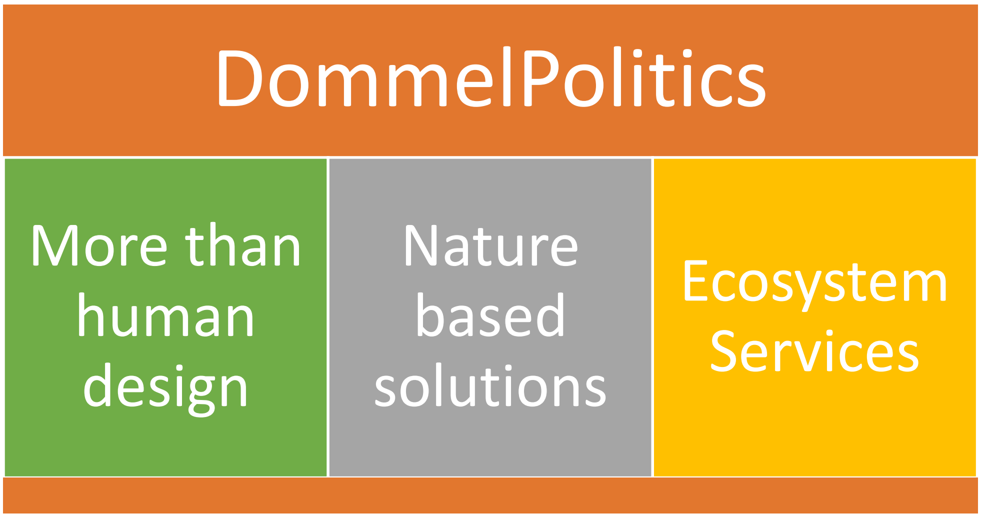


Figure 1: The three pillars holding up the design of DommelPolitics.

1: Case study DommelPolitics: An interactive art exhibition based on more than human and nature based design principles.

Urban development policy has increasingly focused on sustainability and the integration of urban nature in recent years . This is also the case for KnoopXL, the urban area in the city of Eindhoven, which will have to undergo a transition from office area to residential area for 15,000 people in the coming years. However, this area also encompasses the watershed of the Dommel River, whose waters harbor a wide diversity of life. The redevelopment of a land area within an urban area brings with it considerations about how urban nature should be designed. The main stakeholders in this process include the municipality of Eindhoven, the Dommel Water Board, and indirectly the residents of the city of Eindhoven.

This chapter will provide a brief description of a case study in which an attempt was made to combine Nature Based Solutions and art within the creation of a new area vision for KnoopXL or similar urban projects for the reintroduction or adaptation of urban nature. This case study concerns a project from the Innovations Space of Eindhoven University of Technology, in which an interdisciplinary group collaborated to raise awareness of urban nature and sustainability of the KnoopXL area within the local population. This objective within this project came from both the municipality of Eindhoven and the Dommel Water Board and also aimed to connect art, technology, and science within this problem.

From ecology to DommelPolitics

Humans have played a major role in an urban ecosystem and have shaped the environment according to the vision that is beneficial to us as a species. This is also the case within an area such as KnoopXL in the form of infrastructure, buildings, but also in the confinement of the watercourse of a river such as the Dommel. During conversations with both the municipality of Eindhoven and 'Waterschap de Dommel', it emerged that the role of the Dommel River would change during the area developments in the coming years. However, these two stakeholders had different visions on accessibility, amount of vegetation, and processing of waste and wastewater when looking at the interactions between humans, river, and nature. Decisions regarding redevelopments of these densely built-up areas are often capital and time-intensive because a majority of society must support these decisions. In modern redevelopment of urban areas, urban nature and the increase of local biodiversity are often central in the design phase (Botzat et al., 2016; Collins et al., 2017; Oberndorfer et al., 2007). However, this form of urban nature is often designed with a vision in which the needs of humans in place are at the forefront and local ecology is only partially taken into account. One of the reasons for this is that the appreciation of urban nature by local residents and policymakers is not always appreciated for the many benefits it can offer (De Oliveira et al., 2011). The question that is posed by the DommelPolitics project about this issue is, how knowledge about urban nature and ecology can be increased within the redevelopment of an area. Knowledge and connection with the local nature ensures that people in a society are more likely to work to protect or restore this nature. Although scientific knowledge is seen as a communication tool with high integrity and information value (Herrmann-Pillath et al., 2023), DommelPolitics has chosen to integrate science and art. This art-based method is often used in situations where support for social and ecological changes must be increased (Pearson et al., 2018).

Because urban nature and biodiversity were of great importance to both clients in this project, a "more than human design" (MTHD) approach was chosen in the first design phase. This approach was chosen because in general, and especially within designs for urban renewal, human-centric thinking is often used. Wich means that the needs of all non-human organisms and components of urban nature are not taken into account in the thinking process (NTNU, Norway & Tarcan, 2022). In other words, although the design process is still carried out by humans, more than human design will take into account the current needs of urban nature based on a pre-Anthropocene vision without human input (NTNU, Norway & Tarcan, 2022; Smitheram & Joseph, 2020). Looking at the problems caused by the Anthropocene, such as climate change, biodiversity loss, and the depletion of natural resources, which can also be felt in urban environments, it is important to look at problems within society from a human-free perspective (Dalby, 2015). Through these three approaches, the needs of both humans and urban nature, which includes all non-human organisms and vegetation within the city, are taken into account within the area development. Just as (Hernandez-Santin et al., 2023) previously did at a project for urban area development, the biodiversity within the new area of KnoopXL is also taken into account as one of the stakeholders.

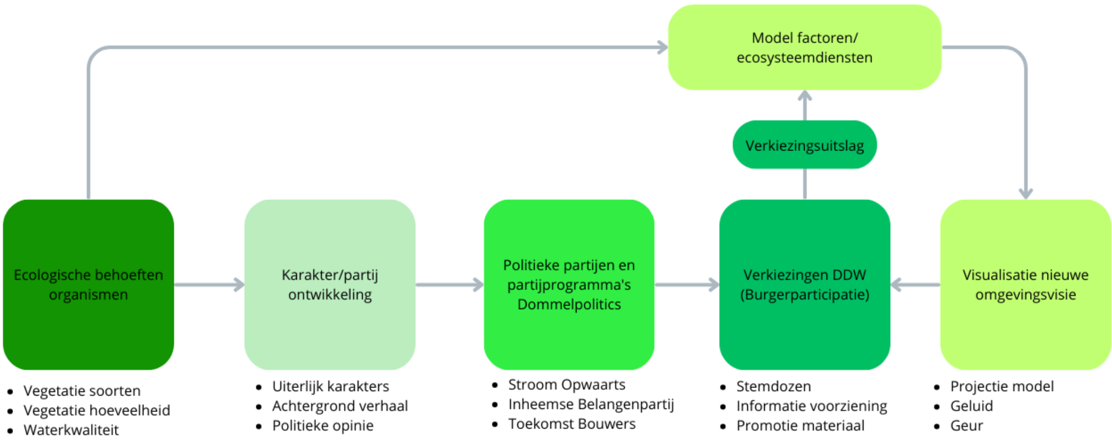


Figure 2: Schematic visualization of how ecological needs of organisms influenced both the visualization and background of character design as well as influential factors of the model visualizing the future watershed of the Dommel.

DommelPolitics interactive art exhibit

The interactive art exhibit of DommelPolitics consists of three parts and represents the political cycle of three political parties within a fictional area of the river Dommel. The first part is informative and consists of both an introduction video to introduce the area and campaign poster to engage the visitor. The second part consists of letting visitors vote on their favourite party, after which the votes are tallied and sent to the visual model. In the third part a visual model of the fictional area is shown in the form of a projection. The voting process can be repeated indefinitely, resulting in changes to the visual model over time.

The results of the more than human and nature based design approaches can be seen both in the character creation and in the environmental factors that influence the visual model of the fictional area. For example, as can be seen in figure 3, the character of Donna Drijver represents a goose as the party leader for Stroom Opwaarts (SO). This party mainly represents the birds and it's party program is designed with their ecology in mind. This party was designed to have more appeal for humans, based on the ability of many bird species to thrive in urban environments (Bonier et al., 2007; Maklakov et al., 2011; Wood & Esaian, 2020). An example of this is their plans to improve picnic locations, as this indirectly might improve feeding locations for all urban birds. Since the focus of this rapport was mostly on the implementation of DommelPolitics within the concept of ecosystem services, the information about its design phase is not further mentioned here. However, a different rapport about this subject can be found in the supplemental files.

Figuur 3: Example of one of the posters and party programs created for DommelPolitics. The party program contains important stances on issues, information about the party leader and their experiences in life.

2: Ecosystem Services and political interventions in the watershed of the Dommel.

How do we assign value to nature in area development? This question played a central role in the DommelPolitics project, followed by the question of how to engage different stakeholders in a dialogue about urban nature and its value. To this end, an interactive art exhibition was used to invite visitors and stakeholders to reflect on the urban nature of the Dommel River. While this was a positive first step towards improving the position of urban nature in the redevelopment of an area, it lacked a quantifiable approach. This is why a follow-up study was conducted, in which the essence of the DommelPolitics parties was translated into different area interventions that have an impact on ecosystem services within three diverse parts of the Dommel watershed in Eindhoven. The choice of using ES as a quantitative approach to see how different political visions on urban planning was made because the method of ES assigns value to nature in such a way that it is useful to humans (Bolund & Hunhammar, 1999). Additionally, since some of the stakeholders in this project can be seen as ecosystem managers (e.g., farmers, nature associations, and government agencies) and they can influence the ecosystem structures that underlie the delivery of the ecosystem service like water quality by influencing the amount of plants in the Dommel, it would be good to show them how costly interventions can actually be of value to themselves. Real world examples of this in for example erosion control include converting an erosion-sensitive soil cover to deep-rooted or dense vegetation (Van Der Biest et al., 2014).

These interventions are associated with high cost, however do not take into account the benefits these interventions have for the ecosystem as a whole and as a protective measure against soil erosion and flooding (Van Der Biest et al., 2014). Using the ES approach makes these future values more visible to stakeholders, which makes it easier for policymakers to implement these interventions even though they might have a higher economic cost (Sandifer et al., 2015; van der Meulen et al., 2011). Since two of the pillars of DommelPolitics are more than human design (MTHD) and Nature Based Solutions (NBS), the choice for interventions that would be implemented by the three parties was also made by using these approaches. Nature Based Solutions are used widely within urban redevelopment and new urban planning (Dorst et al., 2019; Ramírez-Agudelo et al., 2020; Ruangpan et al., 2020). To improve the ecosystem services within an area, interventions or adaptations to this area are often necessary. The scale of these interventions varies greatly, from major changes in infrastructure and buildings to the construction of more parks or gardens.

There are however some area interventions that are more useful to improve local ecology and ecosystem services in urban river areas than others. One example is bioretention areas, a region-based intervention/technique in which (rain) water is both filtered and stored in the soil. This processing area usually consists of filter media in the form of sediments of different diameters with a vegetation layer on top (Roy-Poirier et al., 2010). Modern bioretention systems often also contain drainage pipes or water storage tanks in the form of hydroplanters (Joosten, 2023). A similar area change that influences water availability and quality in a specific area is a Wadi (Zuurman & Verhoeven, 2007). A Wadi is like a bioretention area a processing and storage area for rainwater. However, a wadi is often lower than the surrounding area, making it a drainage area. A intervention that can be implemented within more densely populated areas is the green- blue roof. The roof covering of a building is used for both water storage, water purification, and the increase of vegetation in an area in this intervention. Sedum is often used for the vegetation, but other more herbaceous vegetation is also found. The drainage of rainwater is also slowed down by both the absorption by the roof substrate and the vegetation, which can regulate peak runoff from rain (Hendriks et al., 2016; Hommes et al., 2016). The energy consumption of buildings also goes down through this intervention due to the insulating effect of the water and vegetation (Hop & Hiemstra, 2013). This layer also affects the lifespan of the roof and the ambient temperature. Depending on the type of vegetation on the roof, the biodiversity in an area can also be increased and an increase in greenery also has a positive effect on the health of residents (Tanis, 2020). Another extremely humancentric element in cities is the parking lot. Parking lots often consist of very closed paving and relatively little vegetation. This results in low biodiversity, poor water drainage, and high ambient temperatures (Richards, 2017). Greening of parking lots includes, among other things, replacing the current paving with more permeable paving. Increasing the surrounding vegetation can contribute to the biodiversity of an area, the absorption of rainwater, or the reduction of ambient temperatures (Richards, 2017). Since some parties within DommelPolitics have a stance that is more prone to human activities, recreational paths were also chosen as interventions. These paths are laid in natural areas to give people the opportunity to walk, cycle, or engage in other recreational activities. These paths help people get closer to nature, which has a positive effect on both the mental and physical well-being of people (Aerts et al., 2018; Barton et al., 2009). Vegetation can serve many functions within a functioning ecosystem, native vegetation even more. In contrast to exotic vegetation, this vegetation is often better able to withstand the local conditions in a city, such as diseases, pests, and weather. In addition, these species are often a food source or shelter for native animals (Stotz et al., 1999). This is in contrast to exotics that can spread, which can damage the local ecosystem (Kettenring & Adams, 2011; Mout, 2017). One important factor in ecological value in ecosystem services is the presence of pollinators. Therefore, special bee gardens are being set up in many cities with vegetation specifically aimed at this group of insects (Pawelek et al., 2009; Plascencia & Philpott, 2017). Both honeybees and solitary bees are important in many ecosystems as pollinators and food sources. As a result, they are also important for humans to maintain ecosystems and help with food production (Rahimi et al., 2022). When it comes to the interventions that could be done to the actual flow of the river three choices were made. Both the stream and the stream bank can be restored to more natural widths and natural looks. Rivers such as the Dommel that flow through city centers have often been dammed and narrowed over the years. As a result, many of the banks are steep and unnatural. Restoring these banks to a more natural shape results in an increase in biodiversity and a more natural hydrology and morphology of the river (P. F. M. Verdonschot et al., 2012; R. C. M. Verdonschot et al., 2013). Natural floating marshes are found all over the world and function there as an important ecosystem element by purifying water and creating a habitat for a variety of organisms (Shahid et al., 2018)(Shahid et al., 2018). The artificial variant can fulfill a similar function within an urban area with a lot of water, for example for the purification of river water or to increase biodiversity of insects, plants and fish (Shahid et al., 2018).

To see how the visions of the different parties from DommelPolitics affect different parts of the Dommel catchment area, three areas of approximately 75 hectares each were chosen (figure 4). The first area is the TU/e campus, where the Dommel has surrounding grassland and afforestation in addition to the surrounding buildings. The second area was chosen because the Dommel flows through the city center of Eindhoven here and there is relatively little space for green space and much for buildings. The third area is the outskirts of Eindhoven, where the Dommel mainly flows through an area with a lot of nature, little development and a part of agriculture.

Material and Method:

Area description

To determine the ecosystem services within the three studied areas, the EcoWebUi tool from 'Ecosystem Intelligence' was used. This tool allows the calculation of service hectare scores for each area for seven main categories and ten subcategories. To calculate this, Survey Unit Types (SUTs) were first determined for the areas' surfaces by using satellite images and a field walk (table 1). Additionally, the EcoWebUi tool also allows the implementation of different interventions within these areas that influence the existing ecosystem services. Interventions in this sense are also adjustments to the area that contribute to the improvement of the ecosystem services within an area. Since these area interventions are often additions or adjustments within an area and the surface area does not increase, current elements from an area must be converted to these interventions. An example is the conversion of a SUT such as "High-intensity built-up area" to a Green/blue roof, while the function of this area element remains the same, namely as a building. Because of time constraints not all buildings were individually mapped, but clustered and characterized as populated area. It is unclear whether this affected the scores since the EcoWebUi tool does not provide this information. This clustering was also performed for roads, sidewalks and parking locations which were combined into surface types (e.g. asphalt, concrete). When possible, individual forest and grassland areas where allocated, however in some cases these were combined into forest/grassland patches.

Table 1: Description of the surface area in hectares and as a percentage of each of the three areas without interventions.

Area 1: Survey Unit Types	Surface are (hectares)	Surface area (%)	Area 2: Survey Unit Types	Surface are (hectares)	Surface area (%)	Area 3: Survey Unit Types	Surface are (hectares)	Surface area (%)
Shrubland/shrubland vegetation	0,05	0,1	Pervious surface (gravel)	1,83	2,5	Meadow/grassland	1,38	1,8
Grassland/meadow	3,82	5,1	Traditional landscape design	6,73	9,2	Mixed forest/grassland	24,43	31,3
Mixture of forest/grassland	19,74	26,4	Building area, high intensity	56,18	77,1	Water bodies	0,92	1,2
Building	0,48	0,6	Pervious surface (concrete)	0,15	0,2	Agricultural field	4,45	5,7
Builing area, high intensity	42,42	56,7	Urban gardens	1,4	1,9	Building	1,8	2,3
Builing area, moderate intensity	5,1	6,8	Pervious surface (asphalt)	2,48	3,4	Traditional landscape design	5,28	6,8
Pervious surface (concrete)	0,56	0,8	Stream	2,84	3,9	Deciduous forest	21,27	27,3
Lake/pond	0,28	0,4	Stream bank restoration	1,22	1,7	Pervious surface (asphalt)	0,59	0,8
Pervious surface (asphalt)	0,19	0,3				Grassland/meadow/hay meadow	8,54	10,9
Stream	2,17	2,9				Crops	4,29	5,5
						Stream	5,08	6,5
Total	**74,81**	**100**	**Total**	**72,83**	**100**	**Total**	78,03	**100**

Tree count:

To provide an indication of the number of trees present in each studied area, a combination of the Eindhoven open data database (*Bomen (Database)*, 2023) and line transects was chosen. The line transect was necessary because the database does not count so-called private basic trees. These are all "other" trees in the public space (owned by the municipality of Eindhoven) or private land (*Bomen (Database)*, 2023).

For an indicative line transect that can be used to determine the number of trees within an area, the following formula was used (Franklin et al., 2018):

$$N = n * L / d$$

where:

N is the estimated number of trees in the area

n is the number of trees that were counted in the line transect

L is the length of the line transect

d is the average distance between trees

After this the numbers of the database and of the line transect were added up. The line transect was not performed in area two, because based on the aerial pictures and the coverage percentage of the Eindhoven open database this data was sufficient (supplemental figure 2).

Service hectares:

To make the values of ecosystem services within an area clear on a qualitative and quantitative level, the EcoWebUi tool uses "Service Hectares"(*Reporting Units EcoWebUi*, 2023). This value gives a percentage of the maximum amount that a particular ecosystem service or function can deliver in an ideal situation, weighted based on the investigated territory/area. The total amount of service hectares can be higher than the actual area of the investigated area, as it is taken into account that a quantity of land can simultaneously deliver multiple services (*Reporting Units EcoWebUi*, 2023). Currently, the EcoWebUi tool does not provide access to the underlying calculations for each of the ecosystem service categories, so only the final score for each category can be given. However, these values do provide a way to investigate what the differences are between areas and at area interventions based on potential impact and benefits for the community. In this way, it is possible for area developers to gain insights into how area interventions can contribute to increasing the output of ecosystems within an area.

Main and sub categories of ecosystem services:

The EcoWebUi tool uses the following list of Ecosystem Service categories and sub categories and explanations for each of them (*Reporting Units EcoWebUi*, 2023). Numbers represent the seven main categories, letters represent sub categories.

1. **Air quality:** The properties of landscape and design elements to filter air and protect people from pollutants that are emitted or mobilized by wind, vehicles, or other forces.
2. **Biodiversity total:** Covers the following components of biodiversity:
    a. ***Biodiversity support:*** *The ability of landscape and design elements to support the lifecycle needs for a wide range of species groups. This measure includes performance values for insects/invertebrates, native fish, amphibians, reptiles, songbirds, raptors, bats, small mammals, large mammals, and natural plant succession.*
    b. ***Pollinator support:*** *The ability of landscape and design elements to support the feeding, breeding, and shelter needs of important pollinator species.*
    c. ***Food web support:*** *The ability of landscape and design elements to support the ecological food web, based on primary production and habitat suitability for each trophic level.*

3. **Carbon & climate:** The ability of landscape and design elements to store carbon and mitigate climate change.
4. **Soil total:** Combined score of overall soil condition and erosion regulation.
    a. **Soil quality:** General measure of soil condition, based on soil particle size (e.g., combinations of clay, salt, sand, etc.), the ability of organic matter to be absorbed into the soil, and the protection of soil biota.
    b. **Erosion regulation:** The ability of the soil to resist erosion from wind and water, which helps to conserve essential nutrients and protect water quality. Although an impervious surface can protect the soil within a selected study area from exposure to erosive forces, it can also concentrate the runoff from that study area, which can lead to increased erosion in non-impervious areas downstream.
5. **Water quality total:** The total ability of a landscape to improve water quality.
    a. **Water quality (Remove particles/fine particles):** The ability of landscape and design elements to remove particles, including sediment and other suspended pollutants, from flowing water or runoff.
    b. **Water nitrogen removal:** The ability of landscape and design elements to remove biologically available nitrogen from flowing or infiltrated water (in the root zone of plants) via vegetative metabolic processes and/or denitrification.
6. **Water quantity:** The ability of the landscape to manage and convey a selected storm event (e.g., a storm with a return period of 25 years). This metric includes processes such as interception, evaporation, infiltration, and surface storage to predict the potential of the landscape for water retention.
7. **Well-being total:** Captures the ability of the landscape to improve human comfort and well-being with respect to thermal comfort, visual disturbances, and noise:
    a. **Air temperature regulation:** The local thermal benefits provided by shade, evaporative cooling, surface albedo, and other natural conditions that influence the temperature within a direct environment.
    b. **Aesthetics – visual:** The extent to which visual disturbances from anthropogenic sources can be screened or blocked by the landscape and natural design elements.
    c. **Aesthetics – noise:** The extent to which noise from anthropogenic sources can be screened or masked by the landscape and natural design elements.

Results:

Area descriptions

For each of the chosen areas, five situations were calculated for the ecosystem services indicated above; the current situation of the area, a reference area and the three interventions that the parties of DommelPolitics would like to carry out within each area. The reference area is based on the ecosystem services provided by a temperate broadleaf or mixed forest (TBMF) within the Palearctic ecozone. This area is characterized by four vegetation layers; from older trees, younger trees, shrubs and grasses or herbaceous plants. The most common trees in this biome are; oak, birch, beech and maple (*Temperate Broadleaf and Mixed Forests | Biomes | WWF*, 2023). Within the EcoWebUi tool, this area is characterized by a mix of 71% grassland and forest, 25% shrubland and both 2% water surface and 2% sand/gravel/stone. The chosen areas of the Dommel watershed in Eindhoven can be seen in figure 4 and are described further below together with the current scores for the different ecosystem services scores for all three areas (figure 5).

Figure 4: The three studied areas are located within the Eindhoven municipality. Area 1 is the campus of the Technical University of Eindhoven, area 2 is the city center of Eindhoven, and area 3 is a rural area located outside the built-up area of Eindhoven.

Area 1: TU/e campus terrain

This area describes the campus of the Eindhoven Technical University, located between the John F. Kennedylaan, the Prof. Doctor Dorgelolaan, and the Onze Lieve Vrouwestraat. The area is 74.81 hectares in size and is part of the Dommel catchment area. The water surface of the river covers 2.17 hectares, which is 2.9% of the total area. In addition, there are two ponds in the area, each 0.4% of the total area. The rest of the area is divided into 65.2% built-up and 32.7% unbuilt-up. Of the built-up area, 56.7% is classified as high-intensity development, as it consists of the university's high-rise buildings. The sports center is classified as medium-intensity development and is included in the built-up area along with roads and parking lots. The unbuilt-up area is largely a mix of forests and grasslands. However, a large part of the grassland is planted, also known as short grass or lawn and therefore not natural. This short grass consists of various lawn species, including ryegrass, meadow fescue, and red fescue. According to the open databank of the Municipality of Eindhoven, there are 120 trees in the area, divided into 10 species (table supplemental 1). However, as can be seen in figure 2 supplemental , there are still many trees in area 1 that are not included in this database.

Area 2: City Center Eindhoven

This area describes the city center of Eindhoven, where the Dommel flows under the railway near the station until it flows under the Doctor Schaepmanlaan. The area is 75.83 hectares in size and the distance from each riverbank to the edge of the study area was kept the same. The water surface of the Dommel is 2.84 hectares, which is 3.9% of the total area. In addition, 1.7% of the area was used for restored natural riverbanks. 6.1% of the area is covered by roads and parking lots, which consists of permeable surfaces such as gravel, concrete, and asphalt. 11.1% of the area was urban nature in the form of parks and city gardens. The largest part of the area, with 77.1%, is built-up in the form of residential buildings, offices, and shops.
The urban nature is largely a mix of trees in parks and grasslands. However, a large part of the grassland is planted, also known as short grass or lawn and therefore not natural. This short grass consists of various lawn species, including ryegrass, meadow fescue, and red fescue. According to the open databank of the Municipality of Eindhoven, there are 1,517 trees in the area, divided into 101 species (table 1 suplemental). This high number of species is partly due to the presence of a large park in the area with a diverse range of trees. It is also noticeable that most vegetation occurs in the vicinity of the Dommel.

Area 3: Rural Dommel Eindhoven

This area of 78.03 hectares is located east of the dense built-up area of the Luytelaer and Vaartbroek neighborhoods and north of the Sterrenlaan. The eastern border is about 350 to 400 meters from the right bank of the Dommel. The water surface of the river is 5.08 hectares, which is 6.5% of the total area of the area. In addition, there are also a number of ditches and ponds in the area, which account for 1.2% of the total area. This area was chosen because it is very sparsely populated compared to the other areas, with buildings accounting for only 2.3% of the total area and paved roads only 0.8%. In addition to infrastructure, the rest of this area consists of a combination of traditional landscape management, afforestation, (agricultural) grassland, and horticulture.
According to the open databank of the Municipality of Eindhoven, there are 353 trees in the area, divided into 7 species (table 1 supplemental). However, as can be seen in figure 2 supplemental, there are still many trees in area 3 that are not included in this database. By means of an indicative line transect within the area, a further estimate was made of the rest of the trees. This showed that the area that is not included in the municipality's dataset contains approximately 930 trees. The total comes to 1,283 trees.

Summary:

Area 3 is the least developed, with the majority of the area dedicated to traditional landscape management, afforestation, grassland, and horticulture. Area 2 is the most developed, with a high concentration of built-up areas. Area 1 is in between, with a mix of built-up and green areas. Area 3 has the most natural vegetation, including forests and grasslands. Area 2 has a mix of planted and natural vegetation, with a high concentration of planted grassland. Area 1 has a lower overall density of vegetation, with a mix of planted and natural grassland.

Current scores ecosystem services

In order to see if the proposed interventions put forward by the political parties of DommelPolitics would actually affect the ecosystem service scores in each area, the current situation was firstly assessed using the EcoWebUi tool resulting in the scores in figure 5. These scores here are compared to similar sized reference sites that have no human interventions, and can be seen as target scores for each ecosystem service. The three reference sites are not scoring exactly the same, however this can be explained by the small differences in surface area between the three areas. As expected all three areas do score lower than these target sites across all ecosystem services, however there is a visible trend that less urbanization results in higher ES scores. Area two has the highest density and surface area of buildings and has an overall ES score that is 83.3% lower than the reference site, followed by area one with 61% lower and area three with 24.7% lower. One of the ecosystem services that stands out here is the biodiversity score, especially in area two where it is 94.4% lower than in the reference area, which is the biggest difference of all the ES categories. In comparison for water quantity in area two the score is just 67,9% lower than in the reference site.

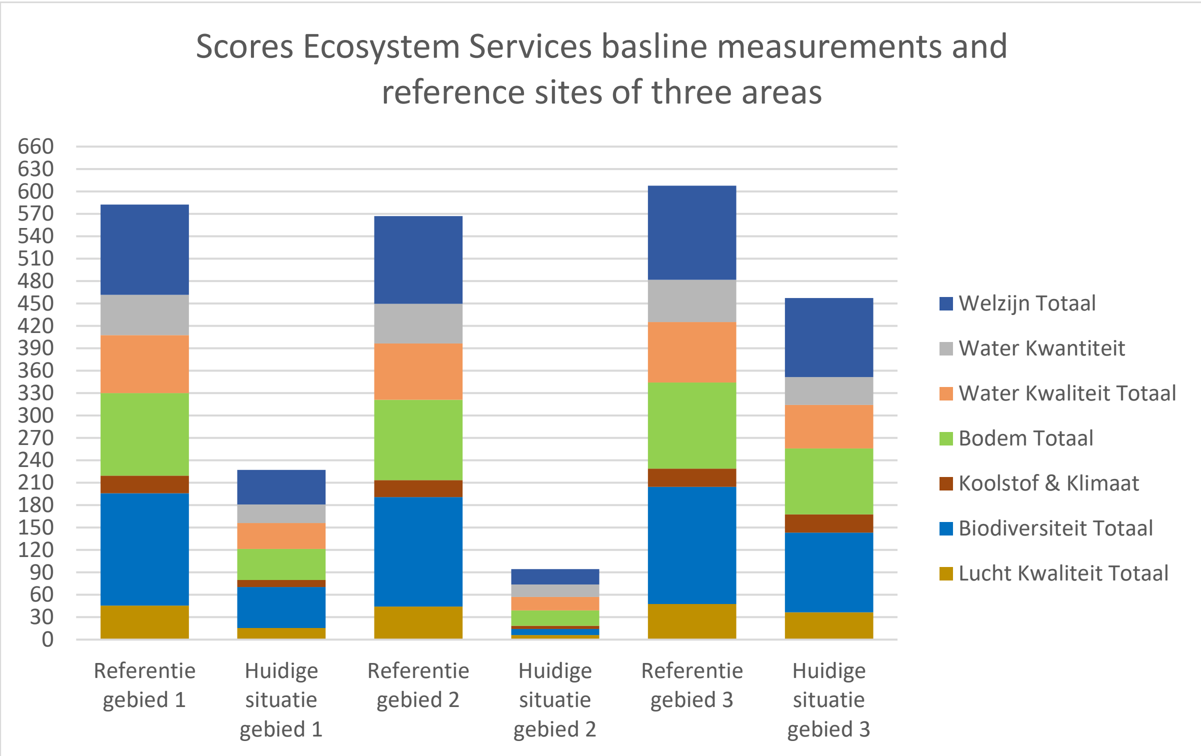


Figure 5: Scores of the ecosystem services for the three areas at the starting point of this research compared to similar sized reference sites.

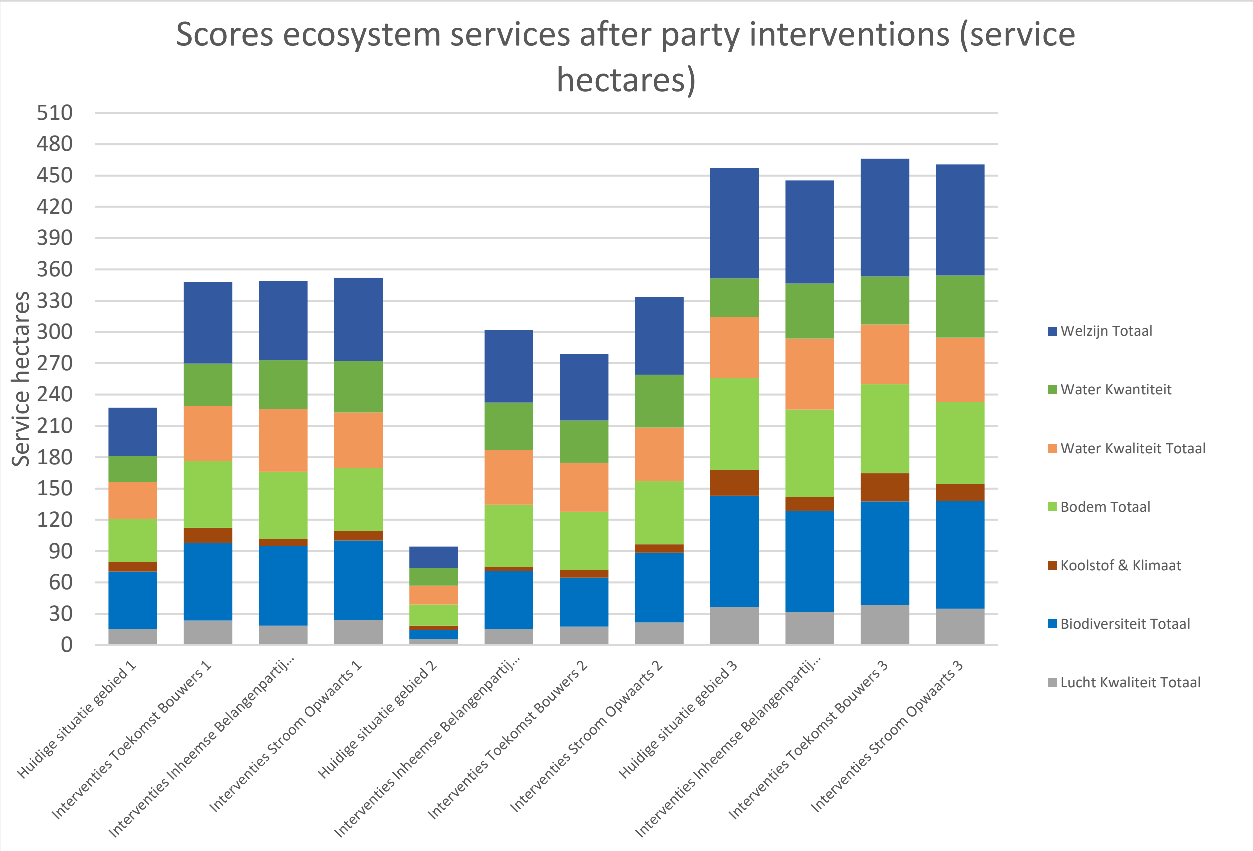
Scores ecosystem services after area interventions:

Within Dommel Politics, three unique political parties have been devised based on different animal groups, each with a different vision for the overall appearance of the Dommel river. This vision is based on the ecological needs of the party members/animals, have also been implemented as weighable factors in the program that has been created for the visualization of the new appearance of the Dommel (figure supplemental 1). For example, one factor might be the amount of water in the river, and another factor might be the amount of vegetation. The parties' different visions are reflected in the weights that they assign to these factors. Because each Dommel Politics party affects the factors in the model by weighing them differently, a large majority vote for one of the parties will result in the ideal image for the organisms in that party. This ideal vision of each party in the visualisation model of DommelPolitics therefor shows extreme values, for example in extremely one-sided vegetation types, or extremely high water levels. To quantify these extreme political views of the DommelPolitics parties, the ideal factor values of each party have been converted into area interventions within the three investigated areas. This conversion was done mainly by looking for Nature Based Design solutions that correspond with the political vision of each party, followed by combining this with how large an area each party would like to intervene with (table 2). As can be seen in table 2, the more progressive party of Stroom Opwaarts (SO) has the largest percentage of 67%, followed by Inheemse Belangenpartij (IBP) with 64% and the more conservative party of Toekomst Bouwers (TB) only changes 51%. This table shows that the three parties have different visions for the Dommel river. However it also shows that all parties agree on quite large area changes of over 50 percent. This choice was made with a more than human design perspective in mind, mainly because this large change would theoretically be beneficial for all non-human life. What further stands out is that all parties look for interventions that increase both water availability and quality in different ways and amounts. Based on general ecology of the main animal groups of each party, vegetation types and coverage area chosen in the interventions are different. This can be seen in that green roofs and local plant restoration are either based on herbs or on bushes. The factors within the DommelPolitics simulation model that changed drastically between parties were both river width and river bank width. This was translated into similar interventions within the EcoWebUi tool where IBP more than tripled the total area of water, TB slightly increased it and SO doubled the surface area in each research area. Additionally, both party and area specific interventions were chosen based both on characteristics of the area (existing agriculture, urban gardens), or on ecological (swamp areas, bee gardens).

The ecosystem services that these areas provide in the current situation have been mapped and compared with the intervention situations that are based on the intended situations from the perspective of the three different parties of Dommel Politics. These interventions can be found in table 2 and were assigned to each party based both on party values that fit or whether the party was progressive or more conservative.

Table 2: Overview of the surface area (%) of the different interventions that have been applied by the 3 parties for each area. When no percentage is given, this intervention is not carried out in this area by this party. The total percentage of the areas that have been adapted by the interventions is also indicated and differs per party and per area.

	Inheemse Belangenpartij (IBP)			Toekomst Bouwers (TB)			Stroom Opwaarts (SO)		
Area number	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Interventions									
Bioretention	0.5	0.5							
Wadi	0.5	0.5							
Green-blue roof (herb-dominant)	20	25							
Green-blue roof (shrub-dominant)				20	30		15	20	
Recreational paths			0.5	0.5	0.5	3	5	5	7
Greening of parking spaces							2	8	3
Deciduous forest				5	3	11			
Coniferous forest									
Mixed forest									
Lake/pond	3	2	4	3	3	5	5	5	7
Dike			1.5						
Native tree restoration				15	5	10			
Native herb restoration	15	8	20						
Native shrub restoration							15	10	20
Bee garden		2					2	4	3
Resilient agriculture			10			10	2		8
Stream	15	10	18	6	4	8	10	7	12
Stream bank restoration	5	8	10	0.5	0.5	3	3	3	5
Urban garden		5		1	5	1	2	5	2
Artificial floating marsh	5	3							
Total changed surface area (%)	**64**	**64**	**64**	**51**	**51**	**51**	**67**	**67**	**67**



Figuur 6: Scores for the seven main ecosystem services within the EcoWebUi after the area interventions of the three parties, compared to the current area situation for the ecosystem services.

As can be seen in figure 6; for area one and two the summed services hectares for all ecosystem services are higher for all party interventions. The largest difference can be seen for area two, where total service hectares are over 200% more than in the current situation. For area one the increases in total service hectares also increase by over 50% for the interventions set by all parties. For area three there is only a slight increase of less than 2% for the interventions by TB and SO and even a decrease in service hectares of 2,6% by IBP. Unfortunately it is not possible to see how each of the interventions implemented by the parties influences the different ecosystem services. However, what stands out is that all interventions, even by the more conservative party TB, resulted in increases of the total ecosystem services compared to the current situation. This increase was greatest in the more densely populated area two, followed by the first area with only 55% urban buildings and only small increases and even a slight decrease in the third area. This can be explained by the small amount of urban development in this area, resulting in a similar score in aggregated service hectares to both the current condition and the non-inhabited reference area.

Since one of the focus areas of this research was on water quality and quantity these ecosystem services are more clearly highlighted in figure 7. For the water quality in area one, IBP shows a large increase of 70,8%, while the other two parties TB and SO showed lower respectable increases of 51,4% and 52,6%. For the water quantity in area one SO and IBP almost show a doubling of water storage capability through its interventions with increases of 96,6% and 88,5%. The TB party showed an increase of 62% in water quantity, which can be explained by the relatively low changes in interventions related to water retention like; river area and river bank restoration. The political interventions in area two resulted in the largest increases in both water quality and quantity of all three areas. Within this area both IBP and SO with 185% and 189% scored higher than TB with an increased value of 160% on water quality. Similarly, IBP and SO also scored higher on water quantity with an increase of 168% and 198% compared to the increase of 140% as a result of TB's interventions. Just like in the overall ecosystem service scores, for water quality and quantity area three shows the least growth compared to the other areas. For water quality, IBP shows the largest increase with 16,8%, followed by SO with 6,5% and TB even showing a decrease of 1% in water quality. This low increase and decrease isn't visible when it comes to water quantity in area three as the interventions by IBP and SO are both 42,4% and 59,8% respectively and even the interventions by TB increase the water availability by 22,9%.

Table 3: Differences in ES scores between the party interventions and the current situations in each area for the total ES, water quality and water quantity. For each ES score the highest scoring party interventions are made green, the lowest red and the middle score orange.

Area 1	Total ES score diff (%)	Water quality diff (%)	Water quantity diff (%)
Interventions IBP	53,38	70,82	88,45
Interventions TB	52,99	51,42	62,03
Interventions SO	54,75	52,57	96,63
Area 2			
Interventions IBP	219,25	189,56	168,89
Interventions TB	195,19	160,11	140,02
Interventions SO	252,82	185,61	198,52
Area 3			
Interventions IBP	-2,60	16,81	42,36
Interventions TB	1,93	-1,03	22,88
Interventions SO	0,75	6,53	59,79

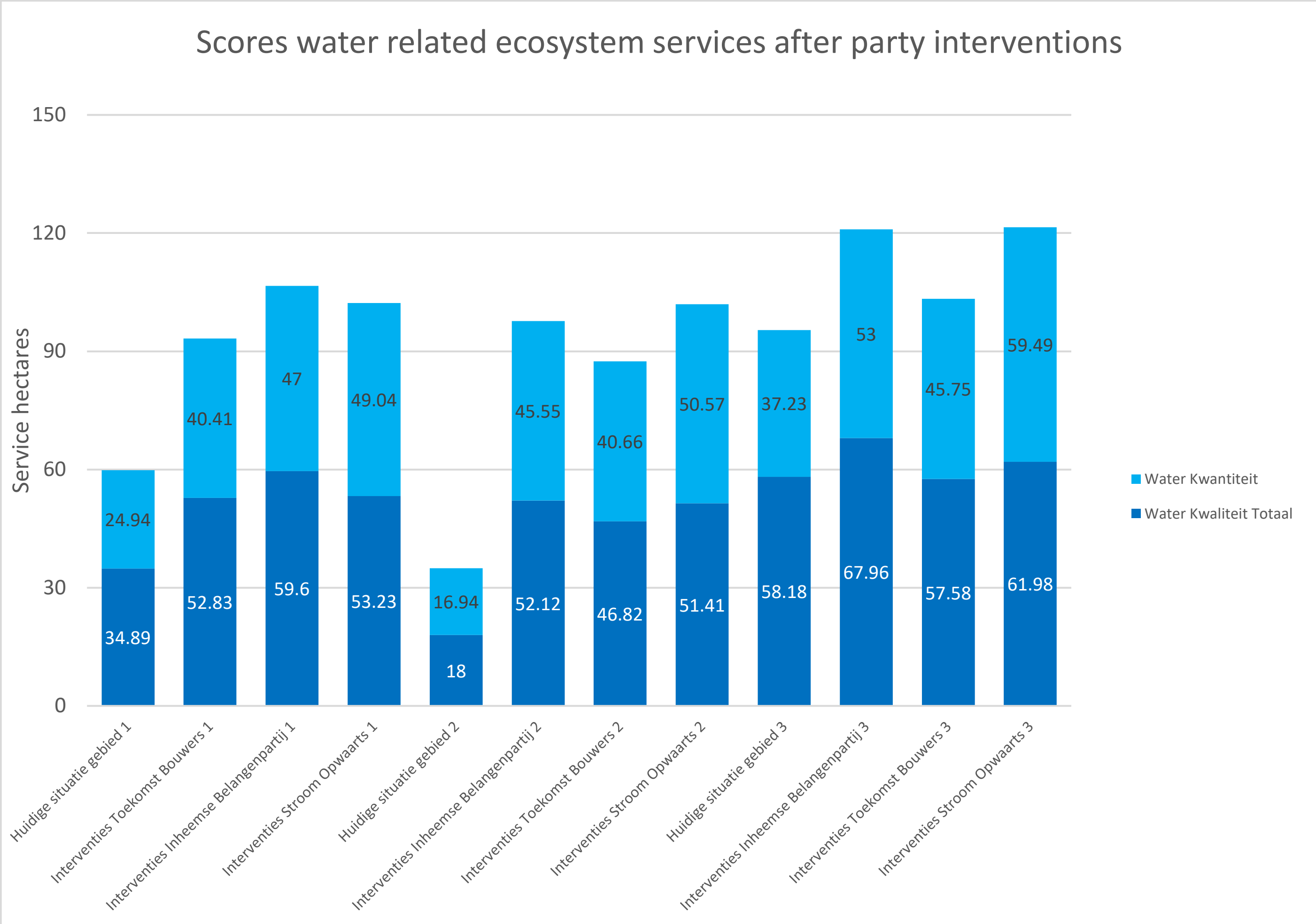


Figure 7: Scores for the two water-related ecosystem services within the EcoWebUi after the area interventions of the three parties, compared to the current area situation for the ecosystem services.

Discussion

We as a species depend on nature to sustain us in our needs, however human activities are not always in line with taking care of the ecosystem around us (Rockström et al., 2009). Especially in urban areas, in the past decade nature has not always been implemented within city planning. The impact of humans on our climate, has led to the reevaluation of this urban nature (De Oliveira et al., 2011; Strohbach et al., 2009). There is however still room for improvement, especially when it comes to the initial importance this urban nature has within the first stages and political vision of redevelopment within urban environments. One of the reasons for this is that the appreciation of urban nature by local residents and policymakers is not always appreciated for the many benefits it can offer (De Oliveira et al., 2011). This is also the case for the watershed of the Dommel River, which cuts through the densely populated section KnoopXL in Eindhoven. When it comes to quantifying this value of nature, the concept of Ecosystem Services is implemented on a wide range of fields including urban development plans (Cortinovis & Geneletti, 2018; van der Meulen et al., 2011). When it comes to these large infrastructure projects a lot of stakeholders with different opinions and background all influence the final design. Many policymakers are still not fully convinced of the value of ecosystem services, and there is a reluctance to implement policies that could have a negative impact on economic development or property values (Bolund & Hunhammar, 1999; Strohbach et al., 2009). This can make it difficult to translate the concept of ecosystem services into tangible interventions within a specific area. For example, the need for more housing, transportation infrastructure, and economic development can often come at the expense of protecting and restoring urban nature (Cortinovis & Geneletti, 2018; Marshall, 2012). This can make it difficult to balance the needs of different stakeholders and ensure that ecosystem services are given the priority they deserve. This is also what we encountered when talking to the two main challenge owners for this research, on the one hand the municipality of Eindhoven represents both its citizens and other socio-economic players, while on the other hand the Watershed of the Dommel represents the values of the ecosystem but is also bound by economic factors. Bringing these stakeholders closer together when it comes to valuing urban nature and what this ecosystem provided for the inhabitants of Eindhoven resulted in the creation of DommelPolitics. This interactive art exhibition had as a main goal to connect people with their local ecosystem and see firsthand how political choices can influence the nature of the area they live in. This art based approach is great when it comes to reaching a wider audience, however the persuasion power, especially when it comes to political views has to be more sound and based on scientific research. This problem resulted in the following research statement: Can a combined effort of more than human and Ecological design approaches influence urban redevelopment by showing that NBD interventions can increase ecosystem services?

Ecosystem services provide a good framework to make stakeholders value nature since they are the benefits people obtain from ecosystems, such as clean air and water, food, and flood protection. By quantifying the value of urban nature in terms of ecosystem services, a more compelling case can be made for the protection or implementation of urban nature (Costanza et al., 1997). Because high density urban areas can have a number of harmful effects on ecosystems, such as increased pollution, habitat loss, and biodiversity decline. By Improving ecosystem services into urban planning, we can design cities that are more sustainable and better connected to nature (Grimm et al., 2008). Next to the effects of using the ecosystem service framework for area redevelopment to improve the biodiversity in a specific area, access to this nature in the form of green spaces, cleaner air and improved water quality has been shown to have a positive effect on health benefits for the people living in urban areas (Aerts et al., 2018; Vanaken & Danckaerts, 2018). This is representative for both bodily health and mental health, especially for children (Vanaken & Danckaerts, 2018; Vujcic et al., 2017). One disadvantage of using the ecosystem framework for measuring the value of nature is that there is no single agreed-upon method for measuring ecosystem services, and the value of these services can vary depending on different perspectives and contexts (De Groot et al., 2002). This can make it difficult to incorporate ecosystem services into urban planning and decision-making (Bennett et al., 2015; Cortinovis & Geneletti, 2018). This disadvantage was less troublesome while making this report since only one calculation tool was used with standardized area interventions and one universal unit of measure called “Service Hectares”(Reporting Units EcoWebUi, 2023). This value gives a percentage of the maximum amount that a particular ecosystem service or function can deliver in an ideal situation, weighted based on the investigated territory/area. The total amount of service hectares can be higher than the actual area of the investigated area, as it is taken into account that a quantity of land can simultaneously deliver multiple services (Reporting Units EcoWebUi, 2023). That’s why for this project the use of Ecosystem Services has the potential to be a valuable tool for promoting urban nature.

In order to translate the values set forth by the political parties created for the interactive art exhibit DommelPolitics into interventions that can influence ecosystem services in a given area Nature Based Solutions proven to improve ES were chosen within the EcoWebUi tool (table 2). Those include interventions that improve biodiversity like, regreening parking lots, green roofs or bee gardens (Oberndorfer et al., 2007; Rahimi et al., 2022; R. C. M. Verdonschot et al., 2013). Others like Wadi’s, blue roofs and floating marshes aid in improving water quality and storage within a given area (Emilsson, 2008; Mondria, 2020; Shahid et al., 2018). Even though these interventions where chosen based on potential areal changes that would be implemented by each party, there was no prior knowledge on how these interventions would affect the ES scores within the EcoWebUi tool. Since the coupling of these party programs was done using my own artistic impression, these couplings and area interventions can be changed based on other party visions. Although this means that the used values are not exactly representative in real world scenarios, the resulting changes in ES scores after these hypothetical interventions can, however provide some insight into how the local ecology would benefit from these changes. When taking this into account it’s easy to see in table 3, that off all the parties TB has the worst ES score improvement in each area, except for in area three for the cumulative ES score, where the interventions of TB are actually the highest scoring. TB is the most conservative party within DommelPolitics and one of their key political points is related to increasing forest areas instead of river widening. This was also taken into account when choosing area interventions that would fit the political vision of this party. Table 3 also shows that IBP and SO both have relatively similar ES scores, however IBP seems to score better on water quality in each are, whereas SO scores better on water quantity in each area. Just like for TB, these scores can be explained by specific party program related intervention choices, like the wishes of IBP to have a cleaner river and for the plans for SO to have more bodies of water. And even though the improvements set forth by TB are compared to the other parties are relatively low, they are still large improvements when compared to the current situations in both areas one and two. And although these proposed interventions where not based on actual political interests or parties, this still shows that these interventions can indeed have large effects on available ecosystem services within an area. We are aware that these changes might not be implementable in these specific areas, because of financial or societal constraints (Strohbach et al., 2009). However, this was also not the main goal of this exercise in combining both an interactive art exhibition implementing more than human design, with a scientific approach that takes this bio inspired art and transforms it into usable data on ecosystem services in a specific area. This method connects both the world of the science that is more closed to the general public, and the world of art that is simpler but might have less persuasiveness within governmental policy making.

Conclusion

At the start of this project, we set out to answer whether a combined effort of more than human and Ecological design approaches can influence urban redevelopment by showing that NBD interventions can increase ecosystem services? This question is partially answered, mainly because based on the feedback we got from the art exhibition, visitors and also stakeholders for KnoopXL really took away from the experience that it is important to improve urban nature within Eindhoven. Since this project started with two stakeholders that both had different visions within the redevelopment of KnoopXL, the conclusion of this report is to advise both parties on how to take this data into consideration. What stood out from this approach of using NBD interventions that were associated with fictitious political visions, was that even conservative visions resulted in improved ES scores in the most densely populated areas within Eindhoven. That’s why for all stakeholders within the redevelopment it is important to focus economical incentives into NBD interventions in these areas to maximize increases in the Ecosystem Services within this urban environment.

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Supplemental information

Factors	ID	Range	Axis dimensions	Stroom Opwaarts (A)		Toekomst Bouwers (B)		Inheemse Belangenpartij (C)	
			2: Linear axis, high or low number 3: 3D axis, muliple options possible	Party influences element	Positive or negative influence (if 2D)	Party influences element	Positive or negative influence (if 2D)	Party influences element	Positive or negative influence (if 2D)
Nature									
Type	Tree	A/B/C	3	Influences		Influences		Doesn't influence	
Quantity	Tree	0-100(%)	2	Influences	Positive	Doesn't influence		Doesn't influence	
Type	Bush	A/B/C	3	Doesn't influence		Influences	large bush	Doesn't influence	
Quantity	Bush	0-100(%)	2	Influences	positive	Influences	positive	Influences	negative
Type	Grass	A/B/C	3	Influences	high grass	Influences	low grass	Influences	negative
Quantity	Grass	0-100(%)	2	Influences	positive	Influences	positive	Influences	negative
Type	Lake	A/B/C	3	Doesn't influence		Doesn't influence		Influences	Large lakes
Quantity	Lake	0-100(%)	2	Influences	positive	Doesn't influence		Influences	positive
Quantity	LandAnimals	A/B/C	3	Influences	negative	Influences	positive	Doesn't influence	
Quantity	Path	0-100%	3	Influences	positive	Influences	negative	Doesn't influence	
Size	Path	A/B/C	3	Influences		Influences	wide	Doesn't influence	
Type	Path	1/2/3	3	Influences	1	Influences	3	Doesn't influence	
Infrastructure									
Type	Road	A/B/C	3	Influences	sand	Influences	asphalt	Doesn't influence	
Type	Building	A/B/C	2	Influences	positive	Influences	negative	Doesn't influence	
Quantity	LeisureItems	0-100(%)	2/3	Influences	positive	Influences	negative	Doesn't influence	
River									
Width	River	0-100(%)	2	Influences		Doesn't influence		Influences	positive
Type	River	A/B/C	2/3	Influences		Influences		Influences	
FlowSpeed	River	0-100(%)	2	Doesn't influence		Influences	negative	Influences	positive
Type	WaterAnimals	A/B/C	3	Doesn't influence		Influences	negative	Influences	positive
Quantity	RiverPlant	0-100(%)	2	Influences	negative	Doesn't influence		Influences	positive
Type	RiverPlant	A/B/C	3	Influences	A	Influences	B	Influences	C
Riverside									
Width	RiverSide	0-100(%)	2	Influences	positvie	Influences	negative	Influences	negative
Type	RiverSide	A/B/C	3	Influences	sand	Doesn't influence		Influences	rocks
Type	RiverSidePlant	A/B/C	3	Influences		Influences		Doesn't influence	
Quantity	RiverSidePlant	0-100(%)	2	Influences	positive	Influences	negative	Doesn't influence	

Figuur supplement 1: Een aantal voorbeelden van factoren die binnen het programma van Dommel Politics kunnen veranderen. De drie partijen kunnen deze factoren positief of negatief beïnvloeden of geen effect hebben

Table suplemental 1: trees found in each area with species and amount per species.

Boomsoort	Gebied 1	Boomsoort	Gebied 2	Boomsoort	Gebied 3
Acer saccharinum	21	Platanus hispanica	131	Populus canadensis	102
Quercus robur	13	Gleditsia triacanthos	101	Quercus robur	60
Populus canescens	12	Alnus glutinosa	87	Fraxinus excelsior	50
Quercus palustris	5	Acer platanoides	80	Salix alba	24
Acer platanoides	4	Betula pendula	65	Alnus glutinosa	12
Betula pendula	2	Carpinus betulus	63	Populus canescens	11
Fraxinus excelsior	1	Salix sepulcralis	48	Betula pendula	2
Acer pseudoplatanus	1	Salix alba	46	Onbekend	92
Ulmus minor	1	Acer pseudoplatanus	45		
Onbekend	60	Tilia europaea	44		
		Fraxinus excelsior	42		
		Pinus sylvestris	36		
		Aesculus hippocastanum	34		
		Quercus robur	31		
		Tilia platyphyllos	31		
		Robinia pseudoacacia	30		
		Fagus sylvatica	23		
		Alnus rubra	22		
		Taxodium distichum	19		
		Populus nigra	17		
		Acer saccharinum	16		
		Quercus cerris	16		
		Quercus rubra	16		
		Prunus serrulata	15		
		Celtis occidentalis	14		
		Magnolia kobus	14		
		Acer campestre	13		
		Taxus baccata	13		
		Ailanthus altissima	11		
		Metasequoia glyptostroboides	11		
		Catalpa bignonioides	10		
		Betula utilis	9		
		Sorbus aria	9		
		Malus	8		
		Quercus palustris	8		
		Alnus spaethii	7		
		Ginkgo biloba	7		
		Picea abies	7		
		Populus tremula	7		
		Tilia americana	7		
		Tilia cordata	7		
		Ilex aquifolium	6		
		Onbekend	6		
		Populus alba	6		
		Pyrus calleryana	6		
		Styphnolobium japonicum	6		
		Thuja occidentalis	6		
		Corylus colurna	5		
		Prunus cerasifera	5		
		Prunus x yedoensis	5		
		Ulmus	5		
		Betula pubescens	4		
		Comus mas	4		
		Juglans nigra	4		
		Pinus nigra	4		
		Populus canadensis	4		
		Prunus avium	4		
		Prunus serotina	4		
		Quercus frainetto	4		
		Salix babylonica	4		
		Ulmus minor	4		
		Alnus incana	3		
		Betula ermani	3		
		Betula nigra	3		
		Cedrus atlantica	3		
		Comus controversa	3		
		Comus florida	3		
		Fraxinus ornus	3		
		Gymnodadus dioicus	3		
		Liquidambar styraciflua	3		
		Liriodendron tulipifera	3		
		Magnolia soulangeana	3		
		Paulownia tomentosa	3		
		Populus canescens	3		

		Pseudotsuga menziesii	3		
		Pterocarya fraxinifolia	3		
		Sorbus intermedia	3		
		Tilia tomentosa	3		
		Tsuga canadensis	3		
		Ulmus glabra	3		
		Alnus cordata	2		
		Amelanchier arborea	2		
		Castanea sativa	2		
		Fraxinus angustifolia	2		
		Juglans regia	2		
		Malus coronaria	2		
		Morus alba	2		
		Populus balsamifera	2		
		Acer freemani	1		
		Acer japonicum	1		
		Acer negundo	1		
		Acer tataricum	1		
		Aesculus flava	1		
		Aesculus pavia	1		
		Broussonetia papyrifera	1		
		Crataegus crus-galli	1		
		Crataegus monogyna	1		
		Crataegus persimilis	1		
		Fraxinus americana	1		
		Magnolia	1		
		Malus cv.	1		
		Malus floribunda	1		
		Nothofagus antarctica	1		
		Picea sitchensis	1		
		Pinus strobus	1		
		Prunus serrula	1		
		Pterocarya rhoifolia	1		
		Pyrus communis	1		
		Quercus petraea	1		
		Sequoiadendron giganteum	1		
		Sorbus	1		
		Onbekend	105		
Totaal	**120**	**Totaal**	**1517**	**Totaal**	**353**

figure supplemental 2: three areas with tree density from Eindhoven open data.