Improving the ecological value of urban green spaces: A scientific method to select the most suitable native plant species

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Bachelor project

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Project provided by Amsterdam Green Campus

Date: 28-06-2021

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Abstract

Public urban green spaces (UGS) have an important ecological, recreational and educational function in cities. The management of these green spaces faces important challenges, since many stakeholders are involved and the environmental condition should be considered. The main challenge when managing biodiversity in cities is the gap between science and policymaker and other stakeholders involved (Aronson et al. 2017). Sharing data between the several stakeholders and interdisciplinary research should therefore be encouraged to conserve biodiversity in UGS. The BIZ Knowledge Mile and the municipality Amsterdam are now working together the project: The Knowledge Mile Park to make buildings streets and squares more sustainable. A renovation of the Hortusplantsoen is part of this project. Recently, the Hortus Botanicus has expressed its interest in the use of native plant species in the renovation, in order to increase its biodiversity. Both the environmental requirements and the interests of different stakeholders should be accounted for with the selection of native plant species. The aim of this study is to provide a sound scientific basis to determine which native plant species can best be used in UGS, applying as case-study the Hortusplantsoen, in Amsterdam. To achieve our aim, we applied a stepwise approach to (i) map out the current habitat conditions, (ii) structure the expectations of the stakeholders for the use of native plant species, (iii) determine the ecological requirements of prospective native plant species and to (iv) match ecological requirements with and the stakeholder The finding of this study will lead to a recommendation of native plant species to use in the Hortusplantsoen, Amsterdam. My first advice is to use humus with the renovation of the Hortusplantsoen. My next advice is to use the listed ten best suited species for the habitat type. Even though there are some disadvantages in this method, it would still be best for the selection of native plant species. This research has contributed directly to the project of Knowledge Mile Park by giving advice on the use of native plant species in the refurbishment of the Hortusplantsoen. This research presents an objective and structured scientific method to use when selecting plant species for the use of UGS in similar project. This could stimulate the use of native plant species in UGS, which could also increase the biodiversity of fauna in these areas.

Dutch abstract

Openbare groene gebieden hebben binnen een stad een belangrijke ecologische, recreatieve en educatieve functie. Bij het beheer van deze groene gebieden in steden zijn er nog een aantal problemen, omdat er veel stakeholders bij betrokken zijn en ook het microklimaat moet meegenomen worden. Het hoofprobleem bij het beheer van biodiversiteit in stedelijke gebieden is (Aronson et al. 2017). Het delen van data tussen de stakeholders en interdisciplinaire onderzoek moet daarom aangemoedigd worden voor het behouden van biodiversiteit in stedelijk groene gebieden. The BIZ Knowledge Mile en de gemeente Amsterdam werken nu samen aan het project de Knowledge Mile park om gebouwen, straten en plein duurzamer te maken. Onderdeel van dit project is de renovatie van het Hortusplantsoen. Kortgeleden heeft de Hortus Botanicus de interesse gedeeld naar het gebruik van inheemse soorten bij de renovatie van het Hortusplantsoen, om biodiversiteit te verbeteren. In dit project moeten ook zowel de interesses van de verschillende stakeholders als het microklimaat van de locatie overwogen worden bij de keuze van specifieke inheemse planten soorten. Het doel van dit onderzoek is om een wetenschappelijk methode op te leveren om inheemse soorten te selecteren voor gebruik in stedelijke groene gebieden, met als casestudy het Hortusplantsoen in Amsterdam. Om het doel te bereiken is er gekozen voor een stapsgewijze methode om (i) een microkartering uit te voeren van de huidige conditie van het gebied, (ii) de interesses van alle stakeholders te ordenen, (iii) de ecologische vereisten en eigenschappen van mogelijk te gebruiken inheemse planten soorten te bepalen en (iv) de ecologische vereisten en eigenschappen van inheemse soorten te matchen aan het gebied en de interesses van de verschillende stakeholders. De resultaten van dit onderzoek zal een advies opleveren van planten soorten die gebruikt kunnen worden in het Hortusplantsoen. Mijn eerste advies is om humus toe te voegen aan de bodem bij de renovatie van het Hortusplantsoen, mijn volgende advies is om lijst van de tien best passende soorten te gebruiken voor de habitat type. Ook al heeft deze methode wat nadelen, is het nog steeds de beste methode voor de selectie van inheemse planten soorten in stedelijk groene gebieden. De resultaten van dit onderzoek hebben direct bijgedragen aan de het project van het Knowledge Mile Park. Deze methode kan bijdrage in soortgelijke projecten in de toekomst omdat er nu een wetenschappelijke methode is om inheemse planten soorten te selecteren voor stedelijk groene gebieden. Dit kan het gebruik van inheemse soorten in stedelijk groene gebieden stimuleren wat ook in deze gebieden de biodiversiteit van fauna verbeterd.

Introduction

Public urban green spaces (UGS) have an important ecological, recreational and educational function in cities. The management of these green spaces faces important challenges, since many stakeholders are involved and the environmental condition should be considered. Several main challenges appear when managing biodiversity in cities (Aronson et al., 2017): overarching issues are the gaps between science and policy, local government access to research findings, and communication of research to stakeholders. Sharing data between the several stakeholders and interdisciplinary research should therefore be encouraged to conserve biodiversity in UGS.

The use of native plant species in UGS is becoming more popular over time. The use of native plant species in UGS makes it easier for people to admire a "natural" landscape (Diekelmann, Schuster, 2021). The use of native plant species can also positively affect the biodiversity of these spaces. The study of Pardee and Philpott (2014) confirms this statement. Their results showed that the bee richness and abundance were positively correlated with presence of native plants and local landscape characteristics. Likewise, Furkase (2016) reported that heightened pollinator activity was observed with an increasing native plant area. Native landscaping may also positively influence the avian and lepidopteran carrying capacity (Burghardt *et al*. 2009). The use of native plant species in UGS should therefore be encouraged.

The use of Native species in UGS is already been implemented in the Netherlands. Examples are the "Heemparken" in Amstelveen. It consists of three parks: "De Braak", "Het Dr. Koos Landwherpark"and "Het Dr. Jac. P. Thijssepark". In these parks are not only native plant species used but their natural habitat is recreated as best as possible (Hennequin, 2016). In Amstelveen the use of native plant species is also implemented in other smaller UGS, for example in the Beneluxbaan in the verges of the roads, native plant species are also planted. And in the Groenelaan native plant species are mixed with non-native species (*Parken in Amstelveen*, no date) the interest of use of native plant species in the Netherlands is clear.

The municipality of Amsterdam made a four-principle strategy on the improvement of UGS. This plan can be read in the "Groenvisie 2020 – 2050: Een leefbare stad voor mens en dier" (Amsterdam (no date b)). The third principle is: the city will be nature inclusive built and maintained. The main focus of this principle is the ecological value of the city. This principle includes the connection of ecological areas, the use of native plant species and much more.

The BIZ Knowledge Mile and the municipality Amsterdam are now working together on a plan to improve buildings, streets and squares to make them greener and more sustainable. This project is called Knowledge Mile Park and covers the area from the IJtunnel to the Amstelplein. A renovation of the The Hortusplantsoen is part of this project. The Hortusplantoen is an UGS located in the center of Amsterdam, at the south side of the Hortus Botanicus, and the BIZ Knowledge Mile are designing the plans for this area (evadidly, no date) Recently, the Hortus Botanicus (Home, no date) has expressed its interest in the use of native plant species in the renovation, in order to increase its biodiversity. The use of native plant species would also adhere to the BREEAM (Building Research Establishment Environmental Assessment Method) certification, native vascular plant species should be included in the refurbishment. The BREEAM is a certification method for a sustainable built environment (Breeam, no date).

Several issues must be considered when native plant species are to be used in designing green city spaces. Different plant species have specific environmental requirements. The soil quality in cities can vary a lot. The soil can lack organic matter and might be polluted with waste. This cause most cities to use imported fertilized soil for the use of UGS. In Amsterdam there are often problems with Soil

compaction, drought, pollution and damage. These problems influence the growth and health of vegetation (Verzandvoort, *et al.* 2020) . These conditions also differ from the natural Habitat of the native plant species. Species should be carefully selected to suit this condition or the choice could be made to treat the soil before adding vegetation. High buildings and current vegetation may cause less light to be available for plant, this should also be considered when selecting prospective plant species. Besides the habitat condition and ecological requirements of selected plant species, the interests of different stakeholders should also be accounted for. These stakeholders can be separated into management, the residents and occasional visitors like tourists.

The aim of this study is to provide a sound scientific basis to determine which native plant species can best be used in UGS, applying as case-study the Hortusplantsoen, in Amsterdam. The two clients in this project are the Knowledge Mile Park and the Hortus Botanicus. To achieve our aim, we applied a stepwise approach to (i) map out the current habitat conditions, (ii) structure the expectations of the stakeholders for the use of native plant species, (iii) determine the ecological requirements and traits of prospective native plant species and to (iv) match ecological requirements ant traits with and the stakeholders and areas. The finding of this study will lead to a recommendation of native plant species for use in UGS in Amsterdam.

Methods

Mapping current habitat conditions of Hortusplantsoen

To determine the current habitat characteristics of the area the following variables were measured and mapped: The soil characteristics, the canopy cover and the current vegetation. Approximately 100 soil samples at 10 cm depth were taken at random locations in the plantsoen, to determine the acidity. The pH was measured pH meter in a mixture of the soil sample and demiwater applying a volumetric ratio of 1:2.5, 24 hours of initial mixing. At each sample site for soil acidity, the soil texture was defined applying procedures listed in FAO (2006). To determine the canopy, cover a smartphone app was used (*CanopyCapture – Apps on Google Play, no date*). Both the soil condition and the light condition measurements were done from the 30th of March until the 5th of April. To further estimate the light availability, the periphery of tree and shrub groups together with their botanical identifications were mapped.

Structuring the expectation of the stakeholders for the use of native plant species.
Several meetings were held with the two clients. The first meeting was held at March 18th with Reinout Havinga Head of Garden and Collections at Hortus Botanicus Amsterdam, and Sanne Horn the landscape designer of the Knowledge Mile Park. In this meeting the two clients expressed their expectation for the project and the renovation of the Hortusplantsoen. On March 31th a small meeting was held with Reinout Havinga to further understand the expectations and concerns of the hortus Botanicus. Lastly a meeting with Sanne Horn on May 19th was held to understand the concerns and expectations of the local residents, and to understand the manner in which the maintenance of this area will be organized.

To understand the interest of the maintenance, a semi structured interview, following Young (2018), was held at April 28th with Walter Busse, the forman of the heemparken of Amstelveen (table 1.). Walter Busse and his team have a wide experience with the maintenance of native plant species of the Netherlands. He also has experience with the maintenance of public UGS in which native plant species are used. Finally, recent publications (Gunnarsson *et al*. 2016, Lindemann-Matthies & Bose, 2007) were studied to understand the expectations of the local visitors of UGS.

Table 1. Interview questions for Walter Busse. *Interview was held in Dutch.*

Theme	Questions
Introduction	How long do you work at the heemparken?:
Hortusplantsoen	Do you know the hortusplantsoen ?: If yes ->: Have you been there before?:
Maintenance urban setting	What are important factors to consider with the maintenance of vegetation in an urban setting?: What are the problems with the maintenance of vegetation in an urban setting?:
Haf district – stinze plant species	In this project I'm researching plant species native to the Haf-district and the Stinze plant species Do you have advice on specific plant species to use with the refurbishment of the Hortusplantsoen?: Will the use of these native species add to the aesthetic value of the Hortusplantsoen One of the clients the Hortus botanicus, finds the ecological value of the plantspecies very important, Can the use of native plant species add to the ecological value of the Hortusplantsoen?
Native plant species	What are important qualities that should be considered when picking native plant species for this location? Do you have any advice on how to lower the cost with the maintenance and planting of native plant species?:
Specific species	Do you have any experience with native plant species that are easy to maintain?

Selection of prospective plant species and the study on plant traits

In the Netherlands a total number of approximately 1574 native vascular plant species occur (CBS, PBL, RIVM, WUR 2018). To reduce the number prospective vascular plant species to be used in the refurbishment of the Hortusplantsoen, it was decided to select native plant species restricted to the Haf district, to which Amsterdam and its surrounding region belong (Soest, 1929). Also it was decided to include species of stinze plants because of their high ecological and aesthetic value. Both groups of species were selected as presented in Wilde planten: Flora en vegetatie in onze natuurgebieden (Westhoff, 1970). From the so obtained list only species from the ecological groups of forest and thickets were selected base on the Arnolds & Van der Maarel ecological groups (information taken from the Standaardlijst van de Nederlandse flora 2003 (Tamis, *et al.,* 2003), since these match mostly with the habitat conditions in the Hortusplantsoen. This selection was based on the advice from Walter Busse. The ecological requirements regarding soil acidity, texture, drainage and light conditions and other properties were studied using De Nederlandse oecologische flora (Weeda, 2003), Heukels' Flora van Nederland (Meijden 2005), the Standaardlijst van de Nederlandse flora 2003 (Tamis, *et al.,* 2004), Bomen en struiken van hier (Ketelaar, et al., 2014) Planten van hier (Ketelaar, et al, 2018), Rode lijsten: soort van Rode Lijst Vaatplanten (no date) and the Doelsoortenlijst Flora- en faunawet (Amsterdam, no date). For the nomenclature of the species Heukels' Flora van Nederland (Meijden, 2005) was used.

Match ecological requirements with the stakeholder criteria and the habitat conditions

To establish which species might be most suitable for a particular kind of refurbishment application, we applied a methodology that is based on Land evaluation methods designed in the nineteen seventies and applied worldwide thereafter (Beek, 1978). Core of the land evaluation method was the establishment of the land suitability by matching land use requirements with land use qualities based on land properties types. In our study we were interested in plant species suitability that we tried to find by matching species properties with the requirements of a particular kind of refurbishment application. Before this matching was undertaken, we first compared how ecological requirements of prospective plant species matched with the habitat conditions encountered at the Hortusplantsoen.

Based on the habitat conditions in the Hortusplantsoen the following habitat types where defined:

- under trees and shrubs without added humus,
- not under tree and shrubs without added humus,
- under trees and with added humus,
- not under tree and shrubs with added humus.

For each of this habitat type, species properties were listed that potentially influence the suitability of a plant species for the habitat. For each of these properties a score was determined to indicate how the property would influence the species' suitability for the habitat (table 2). For each species the scores of the different traits were summed, this resulted in a suitability score for a species. This generated a ranking order of the plant species suitability for each habitat type. A further explanation on the decisions made on the scoring of the traits can be found in Appendix C.

Table 2. Habitat type suitability with the traits and their scoring. *The scores are listed in the same order as the traits.*

Habitat type	Trait	Score
Under trees and shrubs, without added humus	Soil acidity requirement: basic, unknown, other	1, 0, -1
	Habitat: forest, under shrub, other	1,1,0
	Light requirement: Shadow, unknown, other	1, 0, -1
	Soil moisture requirement: Dry, other	1, 0
	Soil nutrients requirement: nutrient poor, other	1, 0
	No requirements soil: yes, no	1,0
Not under tree and shrubs/open places, without added humus	Soil acidity requirement: basic, unknown, other	1, 0, -1
	Habitat: Light forest, forest edges, light/half shadowed areas with low plant types	1,1,1,0
	Light requirement: light shadow, half shadow, other	1,1,0
	Soil nutrients: nutrient poor, other	1, 0
	No requirements soil: yes, no	1,0
Under trees and shrubs with added humus	Soil acidity requirement: basic, unknown, other	1, 0, -1
	Habitat: forest, under shrub, other	1,1,0
	Light requirement: Shadow, light, other	1, -1, 0
	Soil moisture requirement: moist, other	1, 0
	Soil nutrient requirement: moderate nutritious, nutritious, very nutritious, other	1, 2, 2, 0
Not under tree and shrubs/open places, with added humus	Soil acidity requirement: basic, unknown, other	1, 0, -1
	Habitat: Light forest, forest edges, light/ half shadowed areas with low plant types	1,1,1,0
	Light requirement: light shadow, half shadow, other	1,1,0
	Soil moisture requirement: moist, other	1, 0
	Soil nutrient requirement: moderate nutritious, nutritious, very nutritious, other	1, 2, 2, 0

Based on the expectations of the stake holders the following applications of the native plant species were considered regarding the refurbishment of the Hortusplantsoen: the species should be applied to optimize

- a pleasant design for visitors,
- a high biodiversity (fauna)
- an educational purpose
- a reasonable maintenance.

For each of these applications a set of most relevant species properties was determined, after which the influence of the properties on these applications were scored (Table 3).

For each species the scores of the different traits were summed, this resulted in a suitability score for a species. This generated a ranking order of the plant species suitability for each application. A further explanation on the decisions made on the scoring of the traits can be found in Appendix C.

Table 3. Plant species applications with their traits and their scoring. *The scores are listed at the same order as the traits.*

Application	Traits	Score
pleasant design for visitors	Bloom duration: 0-1 months, 2-3 months, >3 months	0, 1, 2
	Big leaves: yes, no	1,0
	Scent: pleasant, unpleasant	1, -1
	Flower colour: green, brown, white, other striking colour	0, 1, 2
	Autumn: green, ripe, blooming, autumn colours, other	1,1,1,1,0
	Winter: green, ripe, blooming, other	1,1,1,0
	Toxic: yes, no	-1,0
	Many Leaves: yes, no	1,0
a high biodiversity	Polinator: Bumblebees, wasp, flies, moths, butterflies, beetles, gliders, bees, none	1,1,1,1,1,1,1,1,0
	Other relationship insect: food, habitat, nestle place, none	1,1,1,0
	Relationship birds: food, breeding ground, eating habitating insects, none	1,1,1,0
	Relationship with target species decided by municipality of Amsterdam: Yes, no	1, 0
	Target species decided by Municipality of Amsterdam: yes, no	1, 0
	Impoverishing effect on fauna: yes, no	-1, 0
an educational purpose	Red list species according to (bron): yes, no	1,0
	Ecological role: yes, no	1,0
	(Historical) Medical use: yes, no	1,0
	Use wood:yes, no	1,0
	Culinair use: yes, no	1,0
	Volkstales/Myths: yes, no	1,0
a reasonable maintance	Easily overgrown: yes, no	-1, 0
	can distribute: yes, no	1, 0
	Wind: resistant, sensitive for wind, other	1, -1, 0
	effect on soil: positive, negative, none	1, -1, 0
	self-pollinating: yes, no	1, 0
	lifespan: annual, remaining	-1, 1
	aging: ages poorly, durable	-1, 0

Results

Current habitat conditions of Hortusplantsoen

The pH of the soil ranged from 6.29 to 7.73. Most samples had a pH between 6.7 and 7 (Figure 1). This means that plant species that require a basic soil are mostly suitable for this area. Most sites at the Hortusplantsoen were covered by the canopy of trees and shrubs, somewhere more open (Figure 2) For the areas covered with canopy, plant species that endure shadow are suitable. Plant species that mostly grow in light- to half-shadow are suitable for the open areas. The soil texture was for 98% loamy sand and 2% sandy loam. so suitable plant species should be able to grow on loamy sand soil.

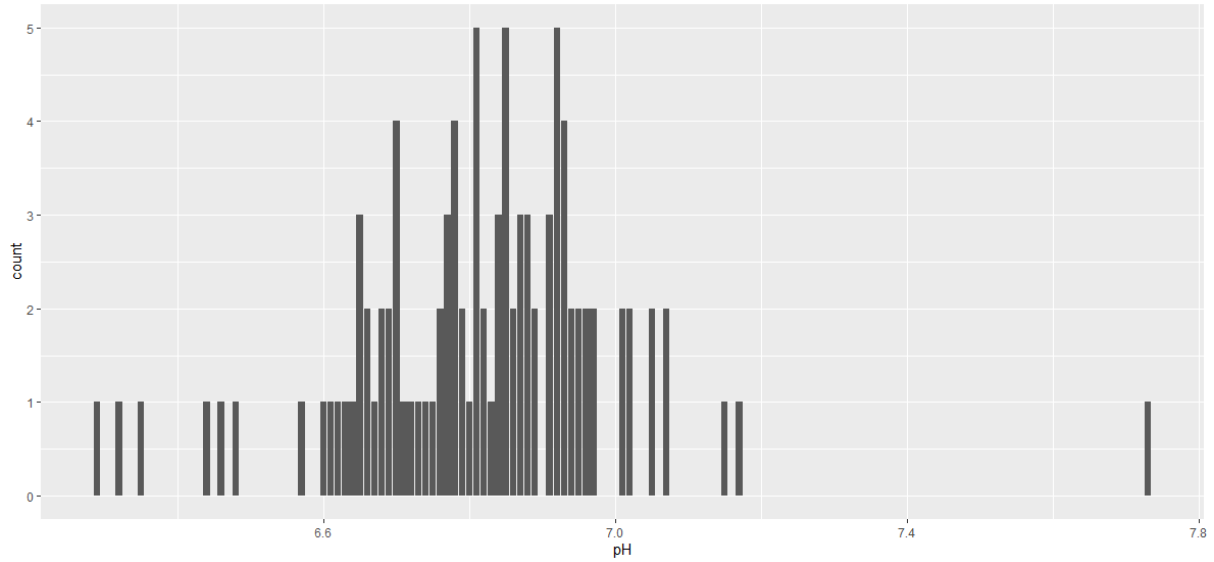

***Figure 1. Soil acidity of the Hortusplantsoen**. N=100*

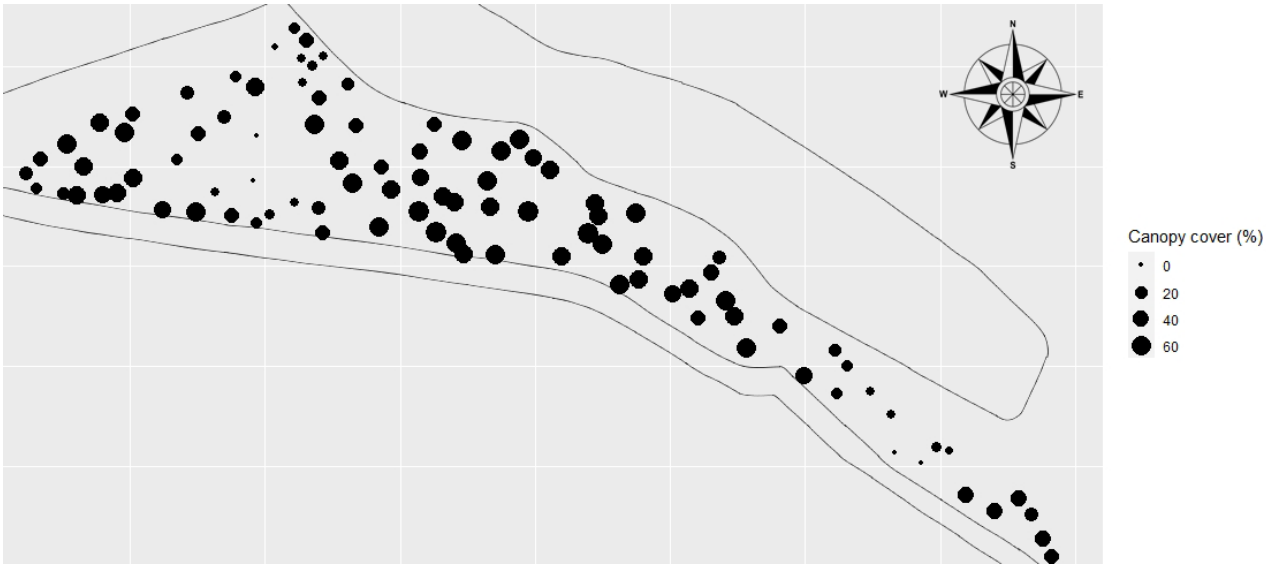

***Figure 2. Canopy cover in percentage of sample spots at the Hortusplantsoen.** Measurements were done from the 30th of March until the 5th of April. N=99*

Expectation of the stakeholders for the use of native plant species

In the meetings with the clients, the expectations of both the clients were discussed. The main interest of the Hortus Botanicus is the use of native plant species to improve the native biodiversity. The plant species used in this area should therefore have a diverse ecological function.
The landscape designers from the BIZ Knowledge Mile were interested the use native plant species to add to the aesthetic, recreational and educational value of the design all year round, while being low in maintenance. The plant species used in these plans should therefore have a high biodiversity and a rich structural diversity. The plant species used should also have diverse life cycles to keep the aesthetic value all year round. Their concerns lied with the suitability of the native plant species and the location. And the amount of maintenance and the costs it would take when including native plant species.

The concerns of the local residents were also mentioned in these meetings. In the past the Hortusplantsoen was covered by more shrubs than found nowadays. This made the area harder to oversee, which caused a lot of crime and drugs use. The residents were therefore afraid that the addition of vegetation, especially shrubs and trees, would cause a rise in crime. For the residents it would be best to keep the plant species shorter and to avoid high shrubs. Another concern was the lack of communication with the local residents. In the past there was little communication with the local residents about changes in the Hortusplantsoen. For example, trees that were highly appreciated by the residents were cut down by the Municipality, without any communication with the residents. This made the residents wary of any change. The BIZ Knowledge Mile have suggested to form a new type of maintenance for this area to make the residents feel more included in this project. They have planned to add a
"green concierge" who oversees the area and its maintenance. The "green concierge" would also form a bridge between the project/area and the local residents.

Figure 3. Example of UGS in Amstelveen with native plant species.

The interview with Walter Busse gave a lot of insight into the interest and concerns of the maintenance when using native plant species in UGS. Most of the times a high amount of money is invested in the planting but not in the maintenance of these plants. Most of the problems with the maintenance are caused by a lack of staff or knowledge. Before starting all the staff should have a basic understanding of the used plant species. That way it is clear which species are weeds and which not. The maintenance should also stay flexible.
To use native plant species, you should start with the soil, when adding humus, the possibilities of survival for planted prospective plant species get are higher. This should not be a thick layer of leaf material, leaving a small layer is fine. Because of the low light availability, it is best to look into forest plant species.
The esthetical and ecological value of the design, when using native plant species, is not a concern according to Walter, when applied correctly native plans species can create a visual pleasing area.
There are some examples in Amstelveen UGS in which native plant species are used. These areas are more feasible to recreate and still look attractive (figure 3.). The Maintenance is done by a small team,

with a flexible schedule. The task is created on the spot. Most of the tasks are to remove weeds and trim shrubs to keep the layering of the area intact. A full overview of the interview can be read in Appendix D.

Visitors would like to see green spaces with a high biodiversity (Gunnarsson *et al*. 2016) and with a rich structural diversity with a mixture of colourful flowers and non-flowering plants (Lindemann-Matthies & Bose 2007). This aligns with the expectations of the Knowledge Mile Park. Occasional might want to be

Table 3. Expectations of the stakeholders of the refurbishment

Stakeholder	Expectations	Concerns	Plant Application
BIZ Knowledge Mile	Plants that add to the visual and educational value of the UGS	High maintenance High costs No suitable species for the habitat	educational purpose pleasant design low maintenance
Hortus Botanicus Amsterdam	Plants with a high ecological value		Ecological value
Local residents	Communication Pleasant design No nuisance	No communication Increase crime due to high covering plants	Pleasant design
Visitors	Visual pleasing design High biodiversity		Pleasant design Educational value
Maintenance	Knowledge Low maintenance plant species Starting with robust species	Staff too small Not enough knowledge High maintenance species	Low maintenance

Match ecological requirements with the stakeholder criteria and the habitat conditions

Suitability for the habitat

Figure 4 shows the 20 highest scored plant species for each habitat type. These species are best used for each habitat type. For each habitat type a different combination of plant species scored higher. The suitability score of species when adding humus to the soil was overal higher, compared to the score without adding humus. The highest scoring plant species for all habitat type consist out of flowering Stinze plants combined with shrubs and trees and flowering ground. The highest scoring plant species when humus is not added also consist ferns.

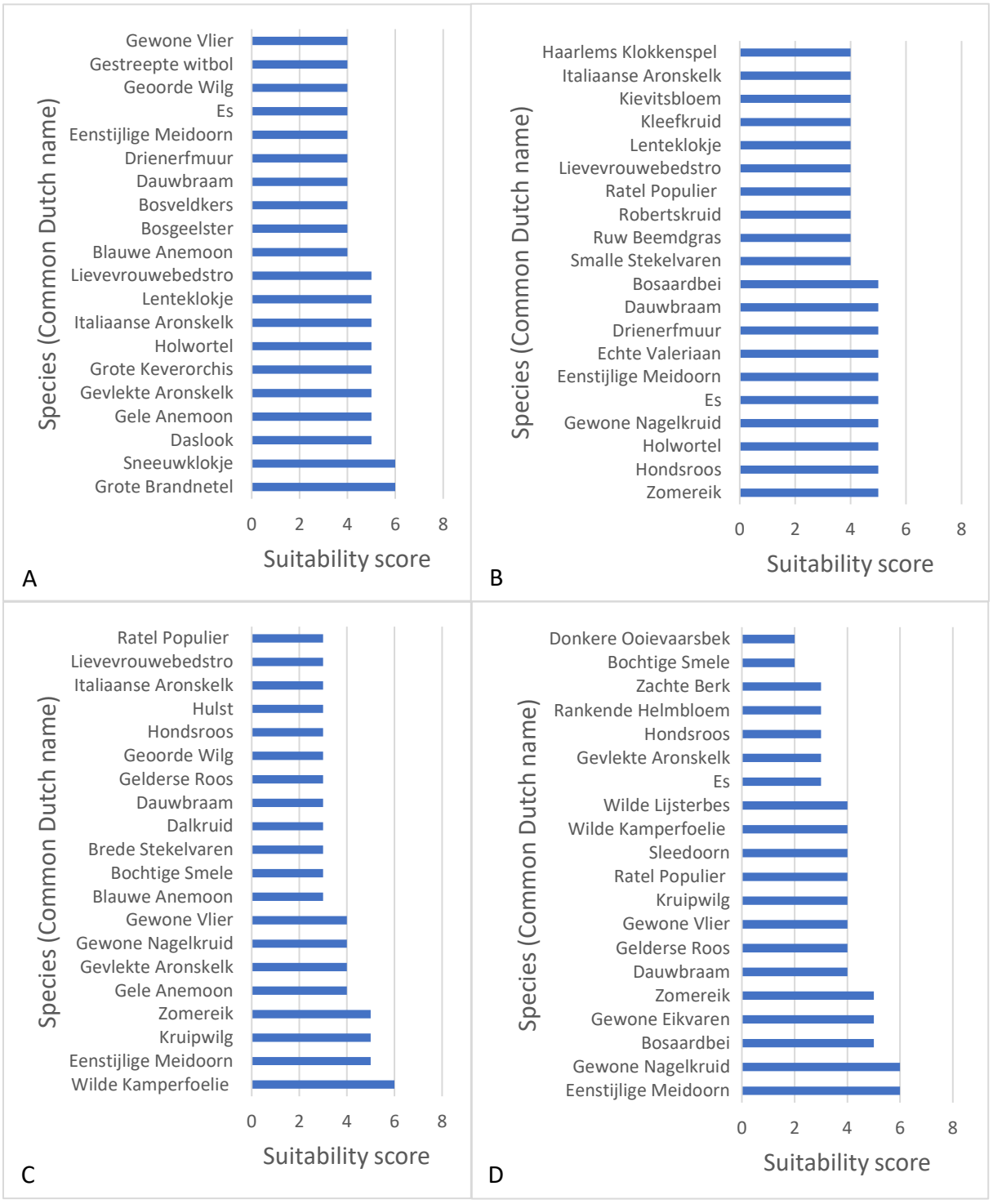

Figure 4. 20 highest scored plant species for the suitability for each habitat type*. A: under trees and shrubs with added humus. B: not under tree and shrubs with added humus. C: trees and shrubs without added humus. D: not under tree and shrubs without added humus.*

Figure 5. shows the 20 highest score plant species for each application. For each application a different combination of plant species scored higher. A: The highest scoring species for a pleasant design consist mostly out of stinze plant and flowering groundcovers, with some shrubs and ferns. The highest scoring species for an educational function consist a combination of groundcovers, stinze plants, shrubs, trees

and ferns. The highst scoring plant species for a high biodiversity consist of Mainly shrubs and trees with some stinze plants and groundcovers. The highest scoring species for a reasonable mainenance is a combination of groundcovers, stinze plants, shrubs, trees and ferns.

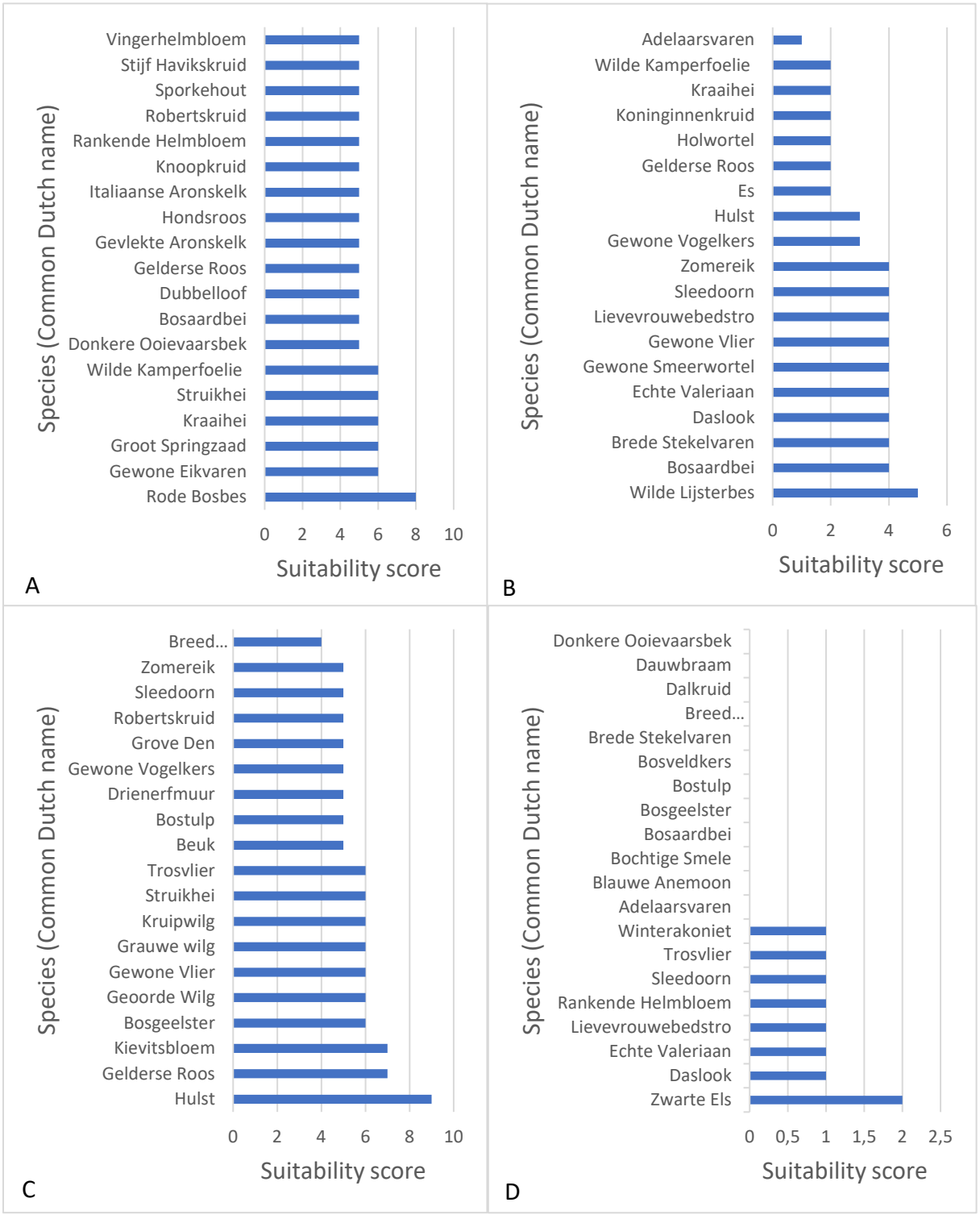

Figure 5. 20 highest scored plant species for each application. *A plant species to use for a pleasant design for visitors. B: plant species to use for an educational purpose C: plant species to use for a high biodiversity. D: plant species to use for a reasonable maintenance*.

Figure 6. shows the 20 highest scoring plant species for all application. When designing a UGS, this combination of species would fit all application the best. The highest scoring species for all applications are a combination of groundcovers, stinze plants, shrubs, trees and ferns.

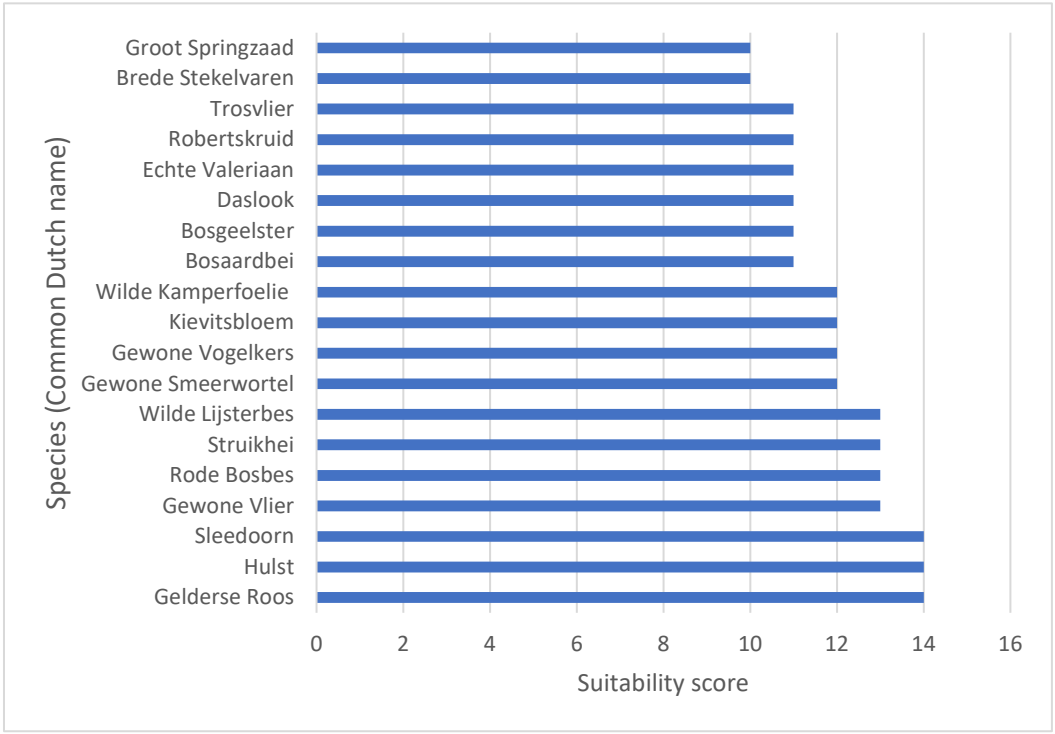

Figure 6. 20 highest scored plant species for all application.

Figure 7 shows the 10 highest scoring plant species that high score for the habitat type and any application. For the combination of the ten highest plants when hummus is added consist of mostly flowering stinze plants with some ground covers and trees. When Humus is not added this combination mostly consist out of trees *and some ferns and groundcovers*.

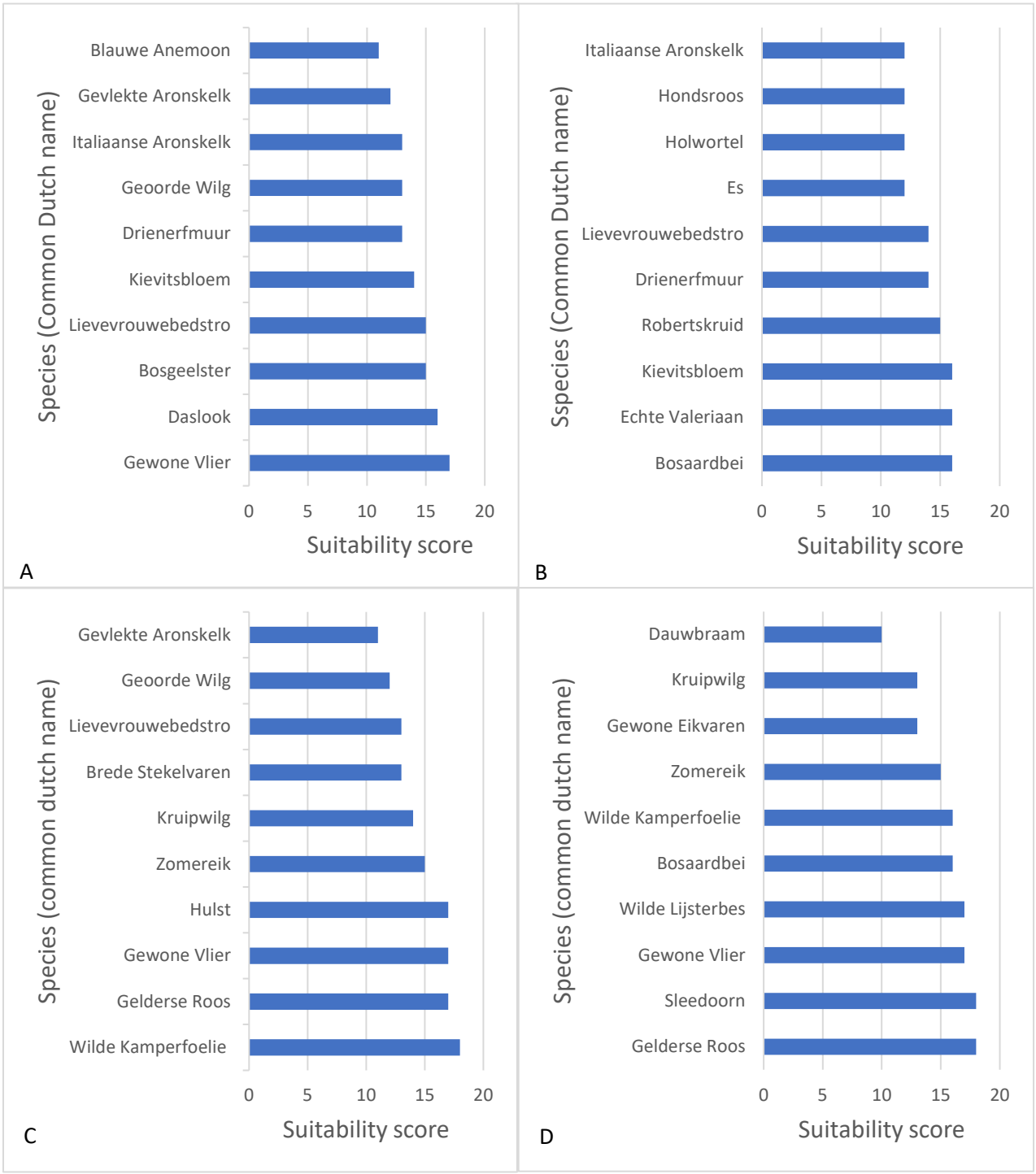

Figure 7. 10 highest scoring plant species that have high score for each habitat type and each and all applications. *A: under trees and shrubs with added humus. B: not under tree and shrubs with added humus. C: trees and shrubs without added humus. D: not under tree and shrubs without added humus.*

Discussion

The highest scoring plant species for all habitat type consist out of flowering stinze plants combined with shrubs and trees and flowering ground.The suitability score of species when adding humus to the soil was overal higher, compared to the score without adding humus. The highest scoring species for all applications are a combination of groundcovers, stinze plants, shrubs, trees and ferns. The highest scoring species that have a high score for each habitat types and the applications, are when adding humus a combination of mostly flowering stinze species together with some other flowering groundcovers and trees. However the ten highest scoring plants for the habitat types without adding humus, consist of mainly trees with one fern and one groundcover.
The twenty highest scoring plants for the habitat types when adding humus on soil have a higher score compared to when the humus is not added. This together with the advice of Walter Busse suggest that placing humus on the soil before planting the native species is best option for this project. This will lead to a higher survival rate for the added native plant species in this location. This will also lead to the 10 most suitable species for each habitat type to be more divers. This would increase the possibilities for the designers. Therefore, first advice is to add humus to the soil. My next advice is to use the species listed in figure (figure x.). These species are the 10 most suitable species for both the habitat types and the application. Which will lead in to a high success rate and a beautiful design.

In this method the assumption is made that he used literature is always true, and even though the literature is true there is in practice there a chance of exceptions. A disadvantage of this method would be the lack of information about some plant species and traits. To address the problems in this method it is best to discuss the research with experienced Landscape designers, gardeners and he maintenance people. Their expertise could rule out or confirm the information. The information exchange of the different stakeholders and scientist can be very important and can make similar decision-making processes, progress rapidly. When using this method, it is also important to use literature in which categories of plant traits are defined, since it makes it easier to match these traits with the measurements of the habitat conditions.

Eventhough there are some disadvantages in this method, it would still be best for the selection of native plant species. For the reason that an experimental design would take too long or would not be feasible for practical use, because of the long list of native species that have to be studied.

A future study could be done on the effects of the added plant species in this location. That could be done by monitoring the survival rate of the added plant species and the changes in biodiversity of the fauna in this area. Another study could be done by interviewing visitors and local residents before and after the refurbishment. To understand how these stakeholders, value the added plant species in the location. These studies could confirm the results of this study.

This research has contributed directly to the project of Knowledge Mile Park by giving advice on the use of native plant species in the refurbishment of the Hortusplantsoen, which could influence the decision making in this project. This advice could also increase the biodiversity of the fauna in this area which is the main concern of the other client The Hortus Botanicus. This research presents an objective and structured method to use when selecting plant species for the use of UGS in similar project. This method can close the gap between science and policy makers and other stakeholders involved, because all stakeholders are considered in this method and the results are shared which could influence the decisions in similar projects. The biodiversity of fauna in UGS will also increase, because the use of native plants species in UGS is easier, because policy makers are now equipped with the tools to select native plant species in UGS.

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Appendix A

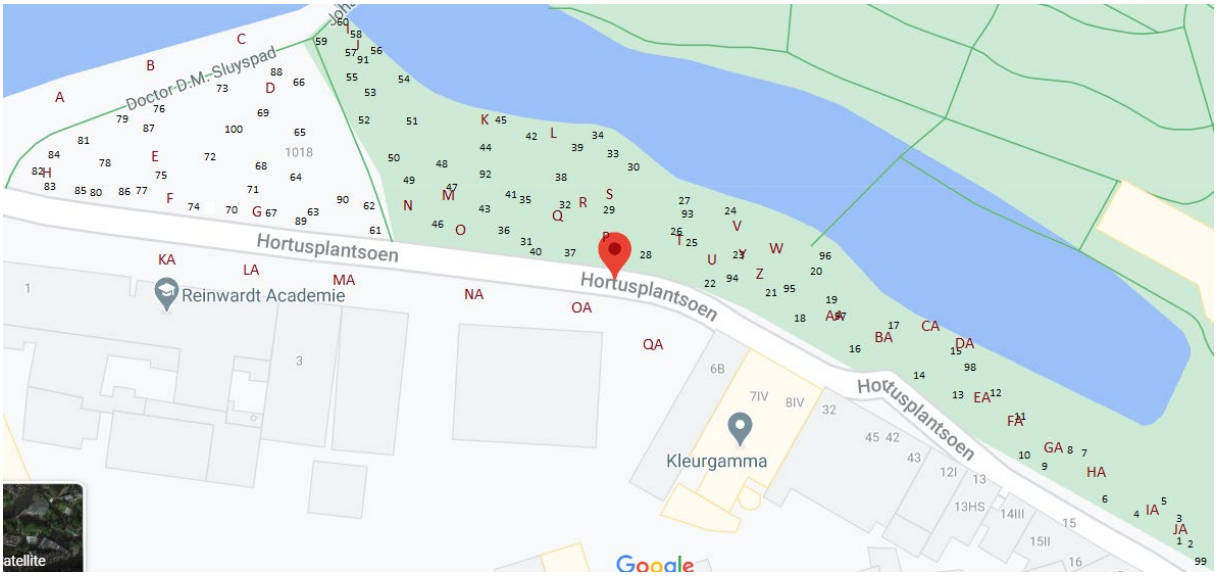

Figure 8. Map of the trees and shrubs and the taken soil samples. *Soil samples are labled with a number, trees and shrubs are labled with letters. This labeling corresponds with the labeling of the data.*

Appendix B

Table 5. Native plant species list.

Dutch common name	Scientific name
Grote brandnetel	*Urtica dioica*
Daslook	*Allium ursinum*
Gele anemoon	*Anemone ranunculoides*
Gevlekte aronskelk	*Arum maculatum*
Grote keverorchis	*Neottia ovata*
Holwortel	*Corydalis cava*
Italiaanse aronskelk	*Arum italicum*
Lenteklokje	*Leucojum vernum*
Lievevrouwebedstro	*Galium odoratum*
Blauwe anemoon	*Anemone apennina*
Bosgeelster	*Gagea lutea*
Bosveldkers	*Cardamine flexuosa*
Dauwbraam	*Rubus caesius*
Drienerfmuur	*Moehringia trinervia*
Eenstijlige meidoorn	*Crataegus monogyna*
Es	*Fraxinus excelsior*
Geoorde wilg	*Salix aurita*
Gestreepte witbol	*Holcus lanatus*
Gewone vlier	*Sambucus nigra*
Zomereik	*Quercus robur*
Hondsroos	*Rosa canina*
Gewone Nagelkruid	*Geum urbanum*
Echte valeriaan	*Valeriana officinalis*
Bosaardbei	*Fragaria moschata*
Smalle stekelvaren	*Dryopteris carthusiana*
Ruw beemdgras	*Poa trivialis*
Robertskruid	*Geranium purpureum*
Ratelpopulier	*Populus tremula*

Kleefkruid	*Galium aparine*
Kievitsbloem	*Fritillaria meleagris*
Haarlems klokkenspel	*Saxifraga granulata*
Wilde kamperfoelie	*Lonicera periclymenum*
Kruipwilg	*Salix repens*
Bochtige smele	*Deschampsia flexuosa*
Brede stekelvaren	*Dryopteris dilatata*
Dalkruid	*Maianthemum bifolium*
Gelderse roos	*Viburnum opulus*
Hulst	*Ilex aquifolium*
Gewone eikenvaren	*Polypodium vulgares*
Sleedoorn	*Prunus spinosa*
Wilde lijsterbes	*Sorbus aucuparia*
Rankende helmbloem	*Ceratocapnos claviculata*
Zachte berk	*Betula pubescens*
Donkere ooievaarsbek	*Geranium phaeum*
Rode bosbes	*Vaccinium vitis-idaea*
Groot springzaad	*Impatiens noli-tangere*
Kraaihei	*Empetrum nigrum*
Struikhei	*Calluna vulgaris*
Dubbelloof	*Blechnum spicant*
Knoopkruid	*Centaurea jacea*
Sporkehout	*Rhamnus frangula*
Stijf havikskruid	*Hieracium laevigatum*
Vingerhelmbloem	*Corydalis solida*
Gewone smeerwortel	*Symphytum officinale*
Gewone vogelkers	*Prunus padus*
Koninginnekruid	*Eupatorium cannabinum*
Adelaarsvaren	*Pteridium aquilinum*
Grauwe wilg	*Salix cinerea subsp. cinerea*
Trosvlier	*Sambucus racemosa*
Beuk	*Fagus sylvatica*
Bostulp	*Tulipa sylvestris*
Breed longkruid	*Pulmonaria officinalis*
Grove den	*Pinus sylvestris*
Zwarte Els	*Alnus glutinosa*
Winterakoniet	*Eranthis hyemalis*
Brede stekelvaren	*Dryopteris dilatata*
Struikhei	*Calluna vulgaris*
Groot springzaad	*Impatiens noli-tangere*
Bosereprijs	*Veronica montana*
Rode Kamperfoelie	*Lonicera xylosteum*
Wilde kardinaalsmuts	*Euonymus europaeus*
Boshyacint	*Hyacinthoides non-scripta*
Sneeuwklokje	*Galanthus nivalis*
Vuilboom	*Rhamnus*
Voorjaarshelmkruid	*Scrophularia vernalis*
Lelietje-van-dalen	*Convallaria majalis*
Longkruid	*Pulmonaria*
Viooltjes	*Viola*
Sint-janskruid	*Hypericum perforatum*
Stinkende gouwe	*Chelidonium majus*
Liguster	*Ligustrum*
Schaduwkruiskruid	*Senecio nemorensis*
Haagbeuk	*Carpinus betulus*
Veldesdoorn	*Acer campestre*

Appendix C

Justification scoring of traits

Under trees and shrubs

The traits relevant for the habitat under trees and shrubs are the light requirement and the habitat. Since the light conditions are low in this habitat type, the trait of a low light requirement had a score of 1. Species that require sunlight or light to half shadow scored -1. And when the light requirement where not noted in literature the score is 0, because in most cases it would mean that light is not an issue for the species. The score is not made higher than 0 since it could also mean that the information is not yet known. The Habitat of forest or under shrub is scored as 1 and any other habitat is scored as 0. This was also done because of the low light availability.

Not under trees and shrubs

The traits relevant for the habitat not under trees and shrubs are also the light requirement and the habitat. The light conditions are a bit higher compared to the previous habitat type, it's however not that high because of the surrounding buildings. Therefore a requirement of half shadow or light shadow is scored as 1, other light requirements are scored as -1. Again the unknown requirements are scored as 0. For this habitat type, the habitats: Light forest, forest edges, shadowd areas with low plant types are scored as 1 other habitats are scored as 0.

Added humus

Adding humus will cause the soil to retain moisture better therefore a requirement for moist soil is scored as 1 while a requirement for a other soil type is scored as 0. Since Humus will cause the soil nutrient to be higher , higher Soil nutrient requirements are scored higher (moderate nutritious, nutritious, very nutritious, other: 1,2, 2, 0)

No added humus

With no added humus lower soil moisture requirements are scored higher (dry, other: 1,0). Since a more sandy soil contains less moisture. Because there is little organic material, a lower soil nutrient requirements scored higher (nutrient poor, other: 1, 0). Because of soil is not suitable for many species, species that are suitable for all soil types were scored 1.

All habitat types:

The measured acidity of the soil was mostly basic therefore the ecological requirement of a basic soil type was score 1, a requirement of other soil types was scored -1 and unknown requirements were scored 0.

A pleasant design for visitors

Many traits are involved with creating a pleasant design. Visitors would like to see green spaces with a high biodiversity (Gunnarsson et al. 2016) and with a rich structural diversity with a mixture of colourful flowers and non-flowering plants (Lindemann-Matthies & Bose 2007). Therefore Flower colour is an important factor, the trait striking coloured flowers is scored as 2, white flowers are scored 1, and no flowers or flowers with a similar colour as the rest of the plant is scored as 0 since it is not as striking. Bloom duration also plays a role, the score therefore increases the longer the duration is. 0-1 months is scored a 0, 2-3 months is scored as 1 and higher than 3 months is scored as 2. To include striking non flowering plants in the design both the traits big leaves and many leaves are scored as 1. It is important that a design keeps the esthetical value all year round, therefore the look of plant species in the winter and autumn are considered. Plants that are green, rip and blooming in the winter are scored as 1. The same goes for autumn except that striking autumn leaves are also scored as 1. The scent of plant species also influence how visitors experience an UGS, the trait a pleasant scent is therefor scored as 1 and a unpleasant scent is scored as -1. No scent is scored as 0 since it has neutral influence. The trait Toxic is scored as -1 since it could influence pets or little children visiting and has therefore a negative influence. Non toxic is scored as 0.

A high biodiversity

For the matching with the application of a high biodiversity, ecological relationships with both insects and birds are all scored as one. These relation ships are for insects: Food, habitat and nestle place. Because the stakeholders involved are mainly interested in the relationship with pollinator I further divided het pollinator relation ships in the type of pollinator: Bumblebees, wasp, flies, moths, butterflies, beetles, gliders and bees. A relationship with any of these pollinators are scored as 1. The relationships for birds are, food, breeding ground and feeding on surounding insects. The target species that were decided by the municipality of Amsterdam were also considerd. A plant being on the list of having a relationship with fauna on the list was scored as 1. A species having an impoverishing effect on the fauna has a score of -1.

An educational purpose

For the educational use of a species, the main focus was on wether or not a sign can be written about a species. So for this purpose the following traits were scored as 1 : being a red list species, having a ecological role, having a (historical medical use, having wood that is being used, having a culinary use and being mentioned in folktalkes or myths.

A reasonable maintenance

There are also many factors that could influence whether a species is easily managed or not. A plant that easily overgrows could increase the amount of trimming and weeding needed, it is therefore scored as -1. Being self polinating and self distributing, can take away the need to manually distribute plants and are therefore are scored as 1. If a plant has a positive effect on the soil it is scored as 1 a negative effect is scored as -1 and no effect is scored as 0. Since less soil treatment is needed when a plant has a positive effect on the soil. Annual plants are scored as -1 because it takes replanting and/or managing the distribution and remaining plant are scored 1 since it need less managment. Plants that resistant for wind are scored as 1 and species sensitive for wind are scored as -1, and species that are neutra to wind are scored as 0. Species that aging poorly are scored -1 since it requires species to be replanted over time. And durable plants are scored 0.

Appendix D

Full Englisch overview of the Interview with Walter Busse

The interview with Walter Busse gave a lot of insight into the interest and concerns of the maintenance when using native plant species in UGS. Most of the times a high amount of money is invested in the planting but not in the maintenance of these plants. Most of the problems with the maintenance are caused by a lack of staff or knowledge. Before starting all the staff should have a basic understanding of the used plant species. That way it is clear which species are weeds and which not. The maintenance should stay flexible, it is not possible to make a weekly planning of the tasks that should be done. Ideally is to begin with analyzing the area and to determine which task should be done on the spot. The maintenance should
also be flexible since nature doesn't adhere to man-made borders. It is expected that species wil grow mixed together. Before adding plant species you have to start with the soil. By adding humus, the possibilities of survival for planted prospective plant species get are higher. Most species can grow when humus is added, according to Busse. This should not be a thick layer of leaf material, leaving a small layer is fine. Because of the low light availability, it is best to look into forest plant species. An example of a shadow plant is boserepris .
Start by adding the more robust species, and slowly add more species. The value of the design, when using native plant species, is not a concern according to Walter, when applied correctly native plans species can create a visual pleasing area. He advised to create patches of perennials to create a

patchwork of colours and structures. This should then be combined with ground cover plants with shrubs to create different layers. These shrubs should be trimmed in way that keeps glimpses through the layers. Example of shrubs that can be used are: rode kamperfoelie, kardinaalsmuts. Try not to make a wall of shrubs, it will make for a more dynamic design when creating glimpses through an area. Some of the groundcovers could be: boshyacinten, sneeuwklokjes or comparable stinze plant species. The use of ferns can create a variation of structure in the area. The use of native plant species will not only create a visual pleasing design but will also increase the ecological value of the area. Some species to use for this application could be: Vuilboom, Voorjaarshelmrkuid, Lelietjes dendalen, Longkruid, Viooltjes, Sintjanskruid Daslook, stinkengauwen. To create a high biodiversity, it is also important for the combination of plant species to have a varied bloom time.

The "heemparken" are the ideal picture of native plant species use, it is however not feasible design for the Knowledge Mile Park since the habitat conditions ae carefully created for these plant species. There are in Amstelveen UGS in which native plant species are used. These areas are more feasible to recreate. The Maintenance is done by a small team, with a flexible schedule. The task is created on the spot. Most of the tasks are to remove weeds and trim shrubs to keep the layering of the area intact. Some plant species that cover the area are: Liguster, Stinkende bosgoud, Schaduwkruiskruid, Haagbeuk and veldesdoorn.

Appendix E

Unused figures

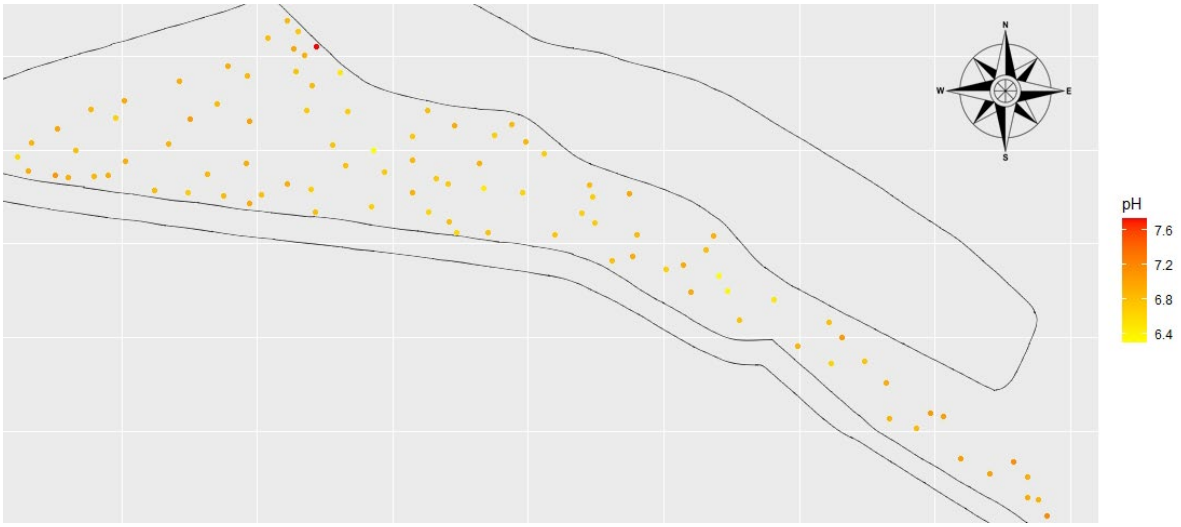

Figure 9. Soil acidity of the Hortusplantsoen. N=100

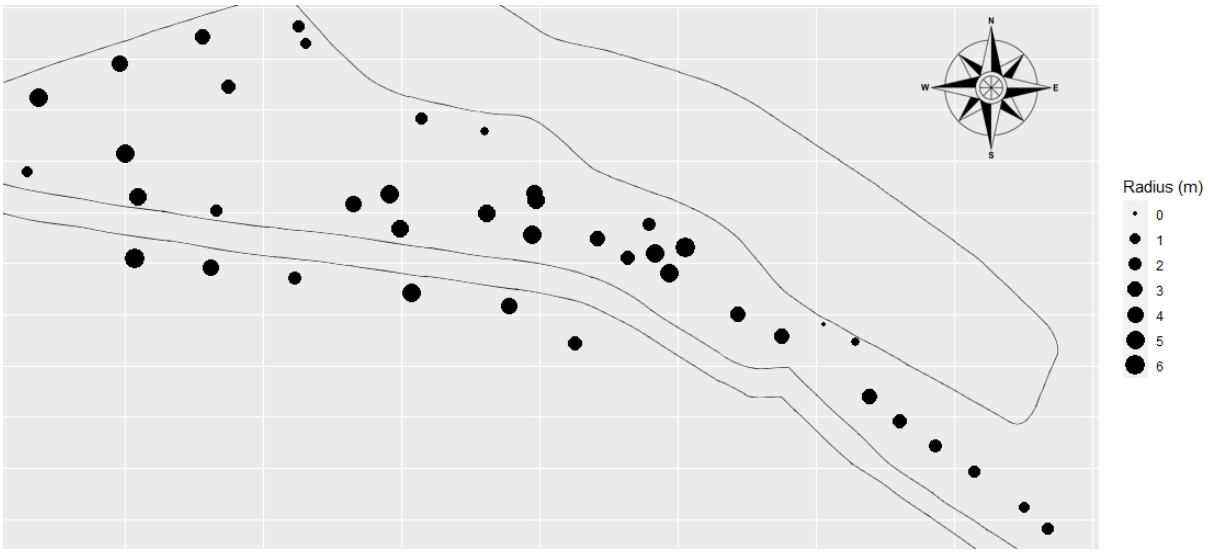

Figure 10. Radius of existing trees and shrubs at the hortusplantsoen.

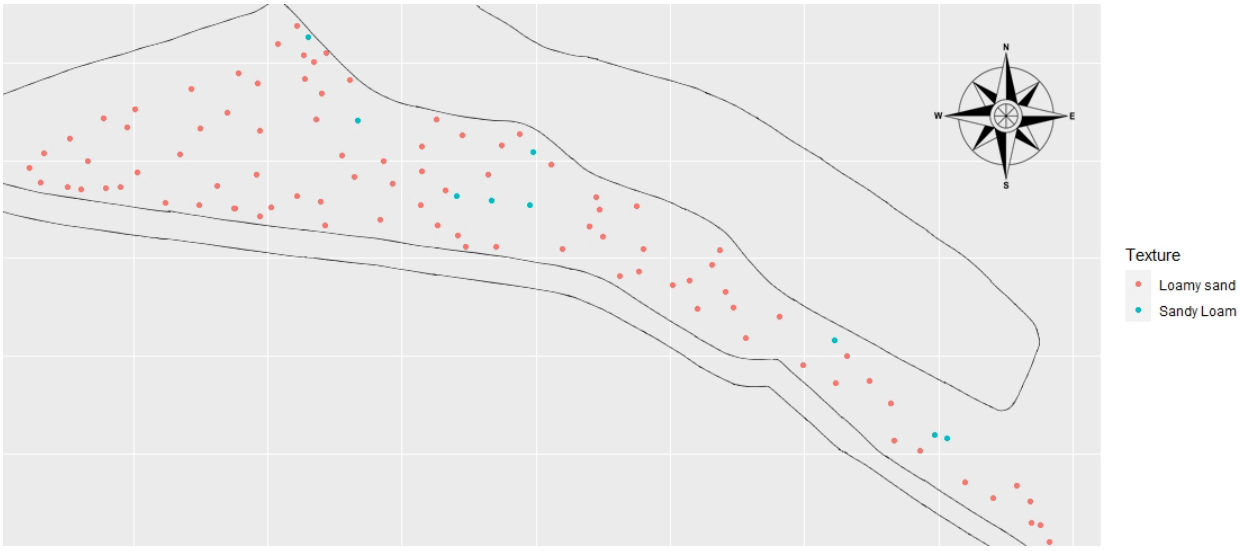

Figure 11. Soil texture at the hortusplantsoen. N=100

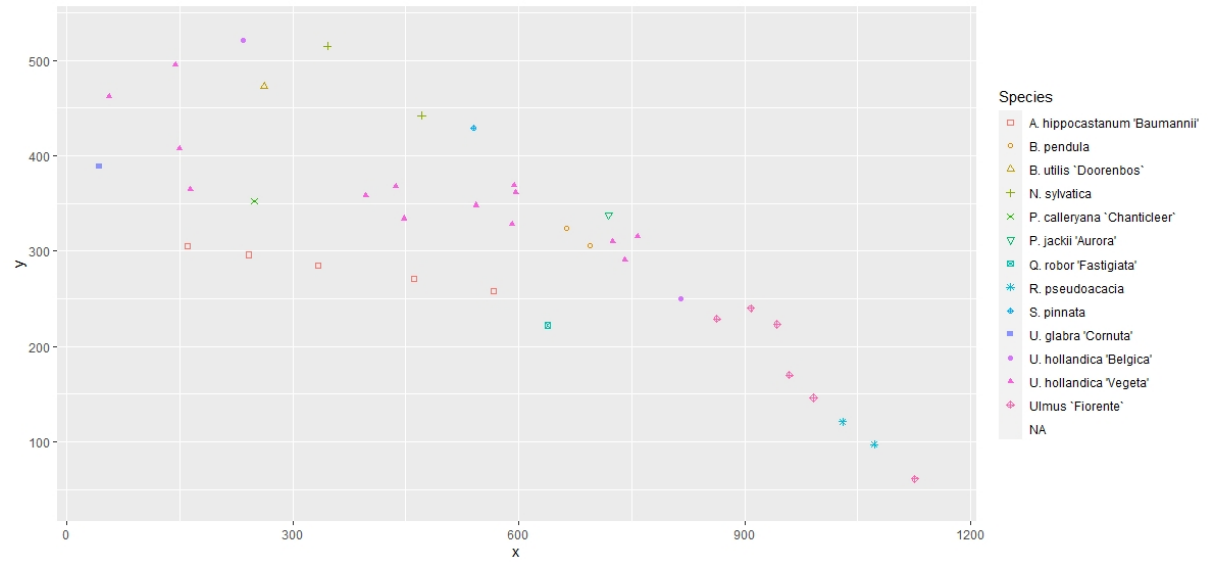

Figure 12. Existing trees and shrubs at the Hortusplantsoen.

Appendix G

Data repository

https://figshare.com/s/2ddbe832adeed6c3a636