THE INTEGRATION OF FOREST ECOLOGIES IN THE URBAN ENVIRONMENT ON A NEIGHBOURHOOD SCALE

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ABSTRACT

As space in urban environments becomes more precious, planning for a nature inclusive infrastructure needs to be considered using a multi-layered approach to ensure effective urban foresting. Therefore, this research focusses on the integration of urban ecologies, forest ecologies and the ecological relationship with the individual, to create circularities on a neighbourhood scale. A qualitative research method is used consisting of both a literature review and interviews with experts. The individual's ecological values and identity are determined by their living environment and can be stimulated through ongoing holistic interactions between residents, buildings, and the surrounding environment. The forest ecologies can be integrated in the urban environment to create local circularities for water and food flows within the neighbourhood.

KEYWORDS: *Forest Ecology, Urban Ecology, Hundertwasser, Urban Foresting, Ecological Self, Biodiversity*

I. INTRODUCTION

In today's world, time seems to be moving faster and faster with cities growing exponentially in size and human inhabitants (Bairoch & Braider, 1988). As a result, land and resources are devoured to enable the growth of these continuous cities. Due to the urbanization, digitalization and people tending to have a busier schedule, the relation between man and nature has been displaced, in which we outsource nature and non-humans to places outside the city (IVN, n.d.). The rapid urbanization and growth of the continuous city pressure the surrounding landscape and the urban landscape, often neglecting the existing ecologies. The disconnected landscapes and relationships accelerate the reduction and extinction of plant and animal species, or even in some cases forcing certain species, forcibly removed from their natural habitat, to invade urban areas that are foreign to them (Stefano Boeri et al., 2015). In 1970, the Austrian artist Friedensreich Hundertwasser was designing a residential building in Vienna with trees in some of the rooms, which he gave the name "Baummieter". Hundertwasser was a painter, sculptor, architect, and ecologist that preached the idea of a new biological architecture (Wieland Schmied, Mattson, & Hundertwasser, 2005). Since then, the development of ecological systems in cities has made several developments resulting in buildings like Bosco Verticale and VDMA Join The Stage. Multiple urbanists, architects and landscape architects have a growing fascination and ambition to design and build nature inclusive buildings and cities (Maike Van Stiphout, Mathias Lehner, & Gilles Havik, 2020). The Italian architect Stefano Boeri, inspired by Hundertwasser, promotes the application of plants and trees in the urban environment. Boeri is known for the Bosco Verticale in Milan, the first vertical forest. He manifests that increasing the number of forests and trees in cities can help absorb CO_2, drastically reduce pollution, energy consumption and the "urban heat island" effect, improve the biodiversity of living species and make cities safer, more pleasant, and healthier (Stefano Boeri et al., 2015). However, in nature inclusive buildings like vertical forests, the natural processes are replaced by technical systems, which can result in high maintenance, costs, resilience, or quality of the nature (Wohlleben, 2018, Timmermans, 2021, Jacobs, 2021). While we start appreciating nature inclusive buildings, the majority of a forest's ecological processes happen underground within the soil, this aspect is often ignored in nature inclusive buildings and urban trees (A. Van Loon, Dubbeldam, Dekker, & Al, 2003). Architecture has the potential to battle the continuous city, through multiplying the places for the generation of plant

biodiversity and wildlife within the denser urban areas. However, this alone will not be enough to limit the pressures of urbanization, therefore there is a need for "urban forestry" where architecture is not just a frame or focal point for nature, but which is created together with it, becoming inseparable. (Stefano Boeri et al., 2015) Therefore, the research focusses on integration of urban ecologies, forest ecologies and the relation to the individual, with the intention to create circularities on a neighbourhood scale, resulting in the research question: *"How can urban ecologies and forest ecologies be integrated?"*. Accordingly, the western historical and cultural disconnection of the individual with nature needs to be redefined, together with research into the ecologies of the forest and urban environment, the individual can be integrated into this framework, resulting in a sustainable qualitative ecological urban forest. By 2050, it is estimated that over 65% of the world's population will be living in cities. City planners can provide an ecological foundation, but it is up to the people who live in these urban forests to make them homes for more than humans (Al, 2020).

II. METHODS

To integrate forest ecologies into the urban environment, a schematic diagram developed by the European Environment Agency (appendix I), is used to research the ecological relations within the urban environment. The diagram divides the urban environment into three sections, first, the societal aspect, which is considering the individual and its ecological awareness. Secondly, the urban technical system including buildings, transport, energy, water, and waste flows, and lastly the environmental aspect on local, regional, and global level. In the research each sub-chapter represents a section of the urban environment. In the first sub-chapter the embedded and interconnected ecological relation between humans and non-humans are researched through a literature study into the work, environmental ethics and ecological approach towards architecture and the individual of Friendsreich Hundertwasser. Secondly, urban ecologies and the urban technical system are researched and schematised through another literature review of data sheets, together with interviews with Geert Timmermans, the city ecologist of Amsterdam, and Jeroen Jacobs, landscape architect at DELVA. Whereafter, forest ecologies, planting methods and local soil and tree species are researched through a literature study and an interview with Jeroen Jacobs. Finally, the qualitative data and schematics are used to link and integrate ecologies and flows to create circularities, a sustainable, resilient urban forest, and an integrated social collective foundation on a neighbourhood scale. To delineate the research, some key terms need to be defined. The term non-humans is used to research the relationship between humans and other living species. The concept derives from Hundertwasser, who uses it to describe plants, insects, animals, and so on, in short, all the living species except for humans (Wieland Schmied, Mattson, & Hundertwasser, 2005). The term ecology describes the relations of organisms to one another and to their physical surroundings, and in specific, 'urban ecology' refers to the study of ecosystems that includes humans living in cities and urbanizing landscapes. Urban ecology has been used variously to describe the study of humans in cities, nature in cities, and the coupled relationships of humans and nature (Endlicher et al., 2007). A forest is an ecological system dominated by trees, in which the primary objective of forest ecology is to understand what controls the patterns of distribution and abundance of different organisms in forests (Fahey, 2013).

III. RESULTS

3.1 Ecological relationship humans and non-humans

What is the ecological and embedded relation between humans and non-humans?

In December 1928, the Austrian artist Friedensreich Hundertwasser was born. Most people are familiar with Hundertwasser through his paintings and art. Hundertwasser was an artist-philosopher, who's thinking was not purely theoretical but focused on the clarity and sensitivity of the complex relationship between humans and non-humans. Hundertwasser's architecture is a physical representation of his philosophy and ethics, in which he strives for an ecological architecture with concepts such as the "Baummieter" (tree tenant), the "Humus Toilet", "Baumpflicht" (tree duty) and "Fensterrecht" (window right). By the means of a study into his architectural project's, knowledge about the ecological relation between humans and non-humans in the urban environment is gained. Hundertwasser's life dream was to build. In his opinion, building meant the need for protection, for

refugee, a secure cave where the non-housed human found a permanent place which allowed him to find his bearings in the permanent world (Wieland Schmied, Mattson, & Hundertwasser, 2005). With the design for 'The Hundertwasser House' in Vienna, Hundertwasser wanted to restore the friendly relations between the people living in the metropolis and nature. Therefore, he was aiming to include vegetation in the buildings as well as stylistic principles like diversity, variety, irregularity, colors, ornaments, and everything that could be identified with organic growth. He opposed the grid system, geometry, and symmetry. The roof surfaces were returned to nature. Grass, bushes, and trees grow from a layer of humus of about 50cm to 1 meter in thickness contained in a concrete shell insulated by several protective sheets and a layer of bitumen. The 'tree tenants' dwell on small balconies integrated into the façade. Behind the outer wall, as well as in front of the removed windows, stand stainless-steel tubs containing about one cubic meter of soil and fitted with root baskets formed of stainless-steel rods. The windows of the Hundertwasser house consist of different sizes and are asymmetrically spaced along the façade. They were intended to give the impression that they were dancing. In total Hundertwasser designed 13 different types and sizes of windows. Besides the windows, the columns differ in shape and proportion as well and are positioned either asymmetrically, vertical, or at an angle. There are two types of columns, supporting and non-supporting ones in which the latter function as shafts for wires, pipes, or cables. Hundertwasser saw columns as trees and believed you could never have enough of them. The façade represents the layout of the flats behind it, this way each unit had its own color on the outside wall. The surfaces with different colors were bordered by a snake-shaped ceramic band. Like the windows on the façade, the tiles in the bathrooms and kitchens were also meant to 'dance'. Hundertwasser said: "If a person, weary of civilization and sullen from rationality, takes of his clothes in the bathroom, he also wants to forget the latent daily discomfort of the straight line and the right angle" (Wieland Schmied, Mattson, & Hundertwasser, 2005). Despite Hundertwasser's ideologies of an ecological architecture, he emphasized that the Hundertwasser house was not an "organic" or "eco-house". The house is not self-sufficient and cannot provide its own energy for lightning or heating. The technology, like wind generators or solar panels was still in an experimental stage. Furthermore, there were no ecological installations like the humus toilet or water-processing facilities using water plants to purify wastewater. An eco-house with modern technology is entirely at the service of a "life of simplicity" and the cautious management of natural resources is still a thing of the future. An important aspect that is missing is the willingness to accept such an "ecological correct" existence in all its aspects and the will to live such a life. Although Hundertwasser wasn't a philosopher he can be linked with Deep Ecology: his art and writing honor the intrinsic value of nature, human interconnection and interdependence with nature, and holism and human embeddedness in nature. Barak tried to incorporate Hundertwasser's ideas in regard to urban environmental ethics and philosophy through a philosophical and interpretive analysis of Hundertwasser's work and the relation to the Ecological Self (Barak, 2017). The Ecological Self is a concept in environmental ethics which expands the boundaries of the egoistic self to include nature as an integral part of the human self. The idea of the Ecological Self comes from Arne Naess, who argued that awareness of our Ecological Self is achieved in a process of Self-realization (Valera, 2018). Self-realization is a term used in the western philosophical field, which represents the whole nature of the human individual and indicates the conditions to be fulfilled to realize all his capabilities (Wright, 1908). Hundertwasser created a model named "The five skins of men", which describes a scheme of creative engagement and interaction between the self and the natural and social worlds. It represents the human being as an essential embedded self with five "skins"; the epidermis (the first skin), clothes (second skin), house and architecture (third skin), the social environment of identity (fourth skin), and the earth (fifth skin), which includes all non-human beings and ecosystems. The third skin focusses on the built environments and on how the built environment can mediate an expansion of the Ecological Self. Careful interpretation of Hundertwasser's architectural ideas shows the relationship between architecture and Self-realization. The Hundertwasser house and other urban Hundertwasser dwellings represent three-dimensional manifestos of Self-realization in urban areas that provoke ongoing interaction between the resident, the building, and the surrounding environment. The aesthetic qualities of the Hundertwasser house in Vienna project these values alongside symbols of holism, interconnectedness, and interdependence with nature in an urban setting. Holism represents the idea that everything relates to each other. Persons who live holistically constantly see themselves as part of its entirety and consider the other human, animal, plant, or object as the other me.

According to Hundertwasser, the third skin behaves holistically. He states: “Some people say houses consist of walls. I say houses consist of windows”. Windows can break down the segregation created by walls.” (Hundertwasser, 1990). Additionally, Hundertwasser criticizes the uniformity and physical symmetry in the popular window construction, which he calls “window dictatorship”. Windows should have “window rights” and enable the individual to interact between inner and outer realities, and to achieve aesthetic pluralism by resisting their uniformity. Individuals should have the ability to reach out of the window and express themselves towards the outer world, creating an interaction between the street, buildings, neighbourhood residents, city and surrounded nature. By doing so, the individuals leave a part of themselves outside and lets a part of the outside in, creating a holistic interaction. Another typical aspect from Hundertwasser’s architecture is the application of vegetational roofs. This application is mostly stimulated through its practical benefits such as, reduced ‘urban heat island’ effect, storm-water management, better air quality, better insulation and beautify the cityscape. Hundertwasser manifested a more fundamental basis for urban-nature considerations with a principle of sharing ‘urban land’. He wrote: “THE HORIZONTAL BELONGS TO NATURE, THE VERTICAL TO MAN. So, everything that is horizontal under the sky belongs to vegetation, and man can only claim for himself what is vertical. In other words, this means: FREE NATURE MUST GROW WHEREVER SNOW FALLS IN WINTER.” (Hundertwasser, 1971) “All that is white in winter must be green in summer … Woods shall grow on streets and roofs. One must again be able to breathe woodland air in the cities.” (Hundertwasser, 1972). The term ‘belonging’ to nature or human beings does not mean ownership but rather suggests a link between the human and non-human worlds by interpreting them from an urban perspective that redefines our conception of urban space. The horizontal/vertical principle offers a framework on how nature and the city are connected. Urban problems such as population density, urban infrastructure and high-rises can be justified if nature is restored horizontally. Furthermore, it leaves space in the vertical realm for human creativity and self-expression. On the other hand, the application of vegetation in the vertical realm, like living walls, climbing plants or trees are getting more attention in the urban architectural field as well. Hundertwasser also applied trees in the vertical realm in the Hundertwasser house. He called them tree tenants, trees that actually live in an apartment building and are integral to its façade (Barak, 2017). The tree tenant needs minimal space and pays his rent in oxygen, beauty, romanticism, his capacity to absorb and filter dust, as a noise reducer and provider of shade and in many other sustainable currencies (Wieland Schmied, Mattson, & Hundertwasser, 2005). Hundertwasser wrote: “A tree tenant is an ambassador of the forest” (Hundertwasser, 1973). Ambassadors are representatives either sent or invited to represent a particular party’s interests. The tree tenants represent both the interests of non-humans while reminding us of the mutuality between humans and nature (Barak, 2017).

3.2 Urban ecologies and the technical urban system

What are the flows and ecologies in the urban environment?

Geert Timmermans, city ecologist of Amsterdam, defines urban ecology as the relationship of plants and animals that occur in the city, and their relation to the spatial developments and behaviour of it. In an average Dutch city, there live approximately 10.000 different plant- and animal species, which is, compared to the average of 40.000 species in the Netherlands, three quarters less. The ecology and presence of other species in the urban environment depends on the availability of food, shelter, sunlight, and space. For instance, if there are many birdhouses available in the city but there are not any lice or seeds around, a great tit will not settle there (Timmermans, 2021). Although it can be rather simple for an architect to produce a nature-inclusive rendering and vision, it is not as easy to predict the performance of the combination of non-humans, humans and built structures (Almut Grüntuch-Ernst & Institute For Design And Architectural Strategies, 2018). In order to design a biodiverse and ecological urban environment, architects and city planners require basic knowledge and understanding of ecological relationships and patterns so they are able to make connections and predictions. With the help of this knowledge, it is possible to design a well-functioning sustainable ecological structure of a city. As mentioned before, the ecological relationship is more than providing single elements like housing, it requires a holistic and integral approach, which contains food networks, housing, and spatial growth. Timmermans suggests developing a plan or design based on

insect management. Insect management forms the basis for a food network that attracts various species. For instance, insects can function as food for many birds and other insects, while at the same time living from plant species and pollinating them. This ecological insect management method also includes accepting unwanted insect species, like the oak processionary caterpillar that can cause allergic reactions. They are part of the ecological processes and larger food chains of their natural enemies. So is for example, the natural enemy of the oak processionary caterpillar the hoverfly, which is on his turn again food for bats and butterflies. As a result of accepting these unwanted species and their natural enemies, there will not be any plagues or large quantities of the species, which cause unwanted problems (Werkgroep Handboek Groen, Timmermans, & Hofman, 2020). Besides a management plan, Timmermans advises to develop various possible future scenarios of the next five, ten and 30 years. The design of an ecosystem in architecture is an unpredictable natural process, where the growth and quality of the plant- and animal species depends on the climate and human interventions (Timmermans, 2021). Future scenarios show how the desired plan might develop and what problems arise when it evolves. A relevant case study is the ecological urban forest in Eindhoven developed by DELVA Landscape Architecture | Urbanism. In order to develop this urban forest, DELVA analysed the local landscape and ecologies and created a management plan with future scenarios of the urban forest in relation to the buildings (Jacobs, 2021). In these plans, DELVA considered problems and solutions for brightness, experience, growth and interaction between humans and non-humans. The site for the design project, Buiteneiland, regards a new manmade island that is part of Amsterdam IJburg. The island will be created through spraying on sand from the IJsselmeer. As a result, the soil of the island mostly consists of sand. The quality of sand, groundwater, and the amount of lime in the soil determines the natural development, the natural succession and all the various species that will grow and live there, if there would not be any human intervention. This was the case in the western harbour area of Amsterdam in 1960, where an industrial site was created by spraying on sand, however, due to economic recessions, the project wasn't developed directly and evolved naturally into a forest. If there will not be any human intervention on Buiteneiland, it would develop naturally into a forest as well. Cities have become biotopes for humans because of their dominant behaviour and actions (TU Delft & Tillie, n.d.). In the 'ideal' ecological city there would be a balanced symbiosis of humans, plant- and animal species. However, due to the dominant behaviour, spatial urban development's form many barriers for non-humans. So have humans, for example, the intention to control nature in cities and to intervene in natural processes. Timmermans and Jacobs suggest creating solutions for these ecological barriers while at the same time having an ecological approach which gives space for natural succession (Timmermans, 2021, Jacobs, 2021). The urban technical system is another result of the dominant behaviour of humans since it supplies the demand for buildings, transport, energy, and water of humans. Research into datasheets of nibud, milieucentraal, ministery of public health and welfare, social and cultural planning office, and the book 'De verborgen impact' from Babette Porcelijn show the amount and impact of this system on the environment and the city. Appendix II represents data of the impact on the environment through plastic pollution, water use, hidden and usage CO_2 emissions, various types of pollution, land use and deforestation, as a consequence of consumer behaviour (Porcelijn, 2016). The graph shows that transportation by car and airplane have a much bigger impact on the environment then public transportation, which barely has a footprint. Another difference in impact is the production of meat compared to the production of vegetables, fish, and drinks. Meat production needs more space while the production of vegetables, fish and drinks use more water and plastic but have a smaller CO_2 and land use impact. The production and consumption of 'stuff' has the biggest impact on CO_2 emissions. Appendix III gives a clearer understanding in actual numbers on how much water, energy, and food is used on average per person and how much of it is lost (NIBUD, 2021, Milieu Centraal, 2019). This data can be used in the design process to make calculations on possible circularities within the neighbourhood. Appendix IV shows data on the weekly activity of an average person and the consequences on his own health and mortality. For example, a person spends on average only 2.5 hours on exercise and sports in the week, the least of any other activity (Sociaal en Cultureel Planbureau & Roeters, 2018). Problems like overweight, high blood pressure and high blood sugar are consequently caused by unhealthy nutrition and a lack of movement, resulting in a higher disease burden, mortality, and costs. Research also shows a correlation between neighbourhoods with unhealthy lifestyles and neighbourhoods with many social problems (Rijksinstituut voor

Volksgezondheid en Milieu, 2018). Social involvement, integration and stimulation of movement can therefore improve the health and quality of the neighbourhood. By, for example, using the social power of sport for integration. Many facilities that supply the urban technical system are outsourced to places outside the city. As a result, high amounts of infrastructure and energy are used to provide these demands. The city of Amsterdam, for example, has only a few sewage treatment plants located outside the city that purify and clean the water, see appendix V (Ministerie van Infrastructuur en Milieu, 2012). Therefore, the urban environment requires a large infrastructure to transport the sewage water to a few plants outside the city. Furthermore, Amsterdam has less and less fresh water due to the decreasing supply from the Rhine and the IJselmeer and the increasing amount salt water through the bottoms of the polders and the locks of IJmuiden (Wageningen University & Didde, 2020). Another example of outsourcing is the food production, from which nearly 70% of the main food products is of foreign origin, while at the same time Dutch farmers export 75% of their products (van der Knijff, Bolhuis, van Galen, & Beukers, 2011). Importing and exporting food has grown steadily for the past fifty years, even in countries with high agricultural diversity (Khoury et al., 2016). Appendix VI portrays this import and export relation, with diagram A demonstrating the most significant linkages between regions, for visibility, whereas diagram B displays the full matrix of linkages.

3.3 Forest ecologies and structure

What is the structure of a forest and how does it work?

A forest is a vegetational landscape consisting mainly of trees in a dominant tree layer with an undergrowth of herbs and shrubs. A similar definition was obtained from a questionnaire of DELVA, which questioned people from Eindhoven about their experience and definition of a forest. The participants responded with various definitions but with one aspect in common; a forest is bursting with trees (Jacobs, 2021). Peter Wohlleben is a German forester and writer who promotes ecologically and economically sustainable forest management. Wohlleben states that trees in forests communicate with and support each other, share nutrients with the ones that are sick and warn each other of impending dangers. In a forest, trees work together through their hidden root and fungal network as one super organism. That way, the trees support their dead ancestors and trade nutrients and water with neighbour trees, while competing for light with their brothers and sisters in the shadows of their mothers (Wohlleben, 2018). Besides working together, forests are key to the earth's biodiversity, worldwide the forests provide homes for 60,000 different tree species, 80 percent of amphibian species, 75 percent of bird species, and 68 percent of the world's mammal species (FAO & UNEP, 2020). Shubhendu Sharma is CEO of Afforestt and the founder of Tiny Forest. Sharma was inspired by the forestry method of the Japanese tree expert Akira Miyawaki. Since the 1970s, Akira Miyawaki has been advocating the restoration of natural forests with native plants and trees. For decades, Miyawaki has been studying potential natural types of vegetation. As part of his research, he has observed that forest covers made up of native plants are more resilient than forest covers full of exotic species. That way, forests with native plants better in coping with natural disasters, such as forest fires, pests and diseases, earthquakes, and climate change. Planting native plant species also helps to encourage biodiversity. Besides observing the primal forests, Miyawaki has also developed a method for rapidly restoring the forest to their original condition. The most important step in his method is to identify which plant communities grew in the location before people began to intervene there. The Netherlands have no pristine forests, but around 3% of the forests still have their original native trees and shrubs. Sharma translated the Miyawaki method to the urban environment, in which the new technique can create a native forest with a full functioning forest ecology within ten years instead of 100 years (Afforest, n.d.). The first step of the Miyawaki foresting method is to determine the type and quality of the soil at the location. The soil is the foundation upon which the forest is built. Soil is a complex ecosystem, where microbes, fungi, and other organisms play a vital role. Soil, plants, and trees are all inseparably linked to one another. In order to grow, a tree needs water, light, space to extend its roots, and nutrients (IVN Natuureducatie, 2019). There are generally three types of soil in the Netherlands: clay, sand, and peat. To create the optimal conditions for a forest, the density, nutrients, and groundwater levels need to be observed and prepared into an optimal loose, airy soil down to a meter deep, which contains enough organic material and can develop a dense network of

fungi within a year. Prepared soil is composed of a subsoil, a mixed layer with humus, a humus layer and a layer of litter cover on top. Humus is organic material created by the partial decomposition of plant and animal remains in the ground, which serve as excellent nutrients for the trees. The table in appendix VII shows which ingredients should be added and mixed into the soil to prepare the soil for planting. In the case of the sandy soil of Buiteneiland, ripe compost from organic waste or peat should be added together with dried manure from goats, horses, or cattle. The next step of the foresting method is to develop a planting plan. Therefore, based on the information about the groundwater level and nutrients from the soil survey, appendix VIII can be used to determine which type of forest cover is suited best for the planting location. The trees of the forest should be planted close together to let the trees compete for light. As a result, the trees grow fast and tall and become typical forest trees. Besides the competition, their root and fungal systems can connect easier. In later stages when the forest is fully grown, some trees can be felled to thin the forest, a similar forest management that DELVA is using as well for the urban forest in Eindhoven (IVN Natuureducatie, 2019, Jacobs, 2021). A forest can be divided into four layers, see appendix IX, the canopy layer, the understory, the shrub layer, and the herbaceous layer. The management of the forest after the planting is the most important step of the process. In the first two to three years, the forest will require some maintenance, but in principle the forest maintains itself through ecological processes after that. The rule for managing the forest is to intervene as little as possible, in order for the forest to be able to grow as naturally as possible. Dead elements in the forest should not be removed since they provide food for many organisms and nutrients for the forest soil (IVN Natuureducatie, 2019). Typical Dutch forests are the oak-beech forest, the elm-ash forest, the ash-elder forest, and the riparian forest, see appendix X. Each forest has its own qualities and benefits, not only for non-humans but also the urban environment. So can the riparian forest purify polluted water and has the oak-beech forest, various species that grow fruits, berries, and nuts (Wageningen University & Didde, 2020).

IV. CONCLUSIONS

How can urban ecologies and forest ecologies be integrated?

To conclude and answer the research question, conclusions from each sub-question are drawn and linked into a matrix. The architecture of Hundertwasser represents three-dimensional manifestos of his study of the complex relationship between humans and non-humans in urban areas, resulting in an architecture that provokes an ongoing interaction between the resident, the building, and the surrounding environment. He was able to return nature into the city, with woodlands on the roofs and terraces that became gardens. It raises awareness about a new type of ecological architecture in an age when we have realized that our resources are finite and that we need a different style of building. From Hundertwasser's perspective, a building that lets us reflect on our own identity and individuality, an expression of our new attitude which would be more in harmony with the environment. In the urban environment architects and city planners, can provide a well-functioning ecological foundation through linking ecosystems, developing insect management plans and several future scenarios, with as little ecological barriers as possible. Facilities like water purification and food production of the urban technical system can be integrated locally to create circularities within the neighbourhood. A holistic approach, education and the constant interaction with the local environment stimulates the ecological awareness of the community. These societal values can reflect a new attitude towards their consuming behaviour and their impact on the environment. Furthermore, can social interaction and integration be stimulated through the social power of sports, resulting in a healthier life and environment. Native forests typologies can be used to integrated ecosystems, ensuring effective multifunctional urban foresting. The soil is the foundation upon which the forest is built and is a complex ecosystem, where microbes, fungi, and other organisms play a vital role. Forests with native plants are better in dealing with natural disasters, such as forest fires, pests and diseases, earthquakes, and climate change. Besides being more resilient, planting native plant species also helps to encourage biodiversity. To plant the urban forest, the Miyawaki foresting method is recommended as proven to be a well-functioning effective foresting method for the urban environment.

The gained knowledge and insights in the ecological systems of the urban environment and forests results in a matrix which represents four different type of ecosystems that can be integrated in the

urban environment. Appendix XI represents this matrix of linked flows, ecological interactions, and corresponding potential design strategies. Per ecosystem, three different design strategies, depending on the urban density of the site, are represented. However, these different design strategies should not be seen as individual applications but as one ecosystem that is linked to one another on the different scales. The matrix can be used to create an ecological, resilient urban forest which stimulates an ongoing interaction between the human world and the non-human world, creating an ecological aware collective and a healthier life and environment for as well humans as non-humans.

The used qualitative research method was appropriate since the goal of the research was to get a clearer understanding of ecosystems such as, the human embeddedness in nature, urban ecologies, the urban technical system, forest ecologies and the structure of a forest. The data acquired through literature and interviews with experts in this field gained valuable knowledge and insights in the research topic. However, the disciplines of the Ecological Self, urban ecology and forest ecology are too large to be completely researched in depth in the given size of the research paper. Therefore, this paper is limited to the basics of urban ecology, forest ecology and the embedded relation of the Ecological Self. The data used for the qualitative research method is based on averages of residents of the Netherlands and thus a large quantity of subjects. As the data contains residents from the countryside as well and not only from Amsterdam or urban environments, the generalizability can be questioned. However, only 26% of the Dutch residents do not live in urban regions, which makes the differences in life less significant (Planbureau voor de Leefomgeving, 2015). Besides the research into the urban technical system, the data on the Miyawaki foresting method is generalizable as well since this method has been used to plant 108 Tiny Forests in the Netherlands, from which most are realised in urban environments. Other studies and experiments regarding urban foresting often waver in four dimensions, the environmental, the ecological, the socio-cultural or the economic dimension. These studies conclude with benefits for the urban environment, like improvement of biodiversity, water management or improvement of health. This paper continues on these research results and tries to connect ecosystems and flows within the urban environment through the advantages of urban foresting, while strengthening the human and non-human relation. The purpose of the design strategies represented in appendix XI can be used by architects and city planners as a guideline for multifunctional integration of forest ecologies and urban ecologies. Further research into the technical connection between the buildings and urban forests is necessary, together with research into the efficiency of riparian or food forests.

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APPENDIX I

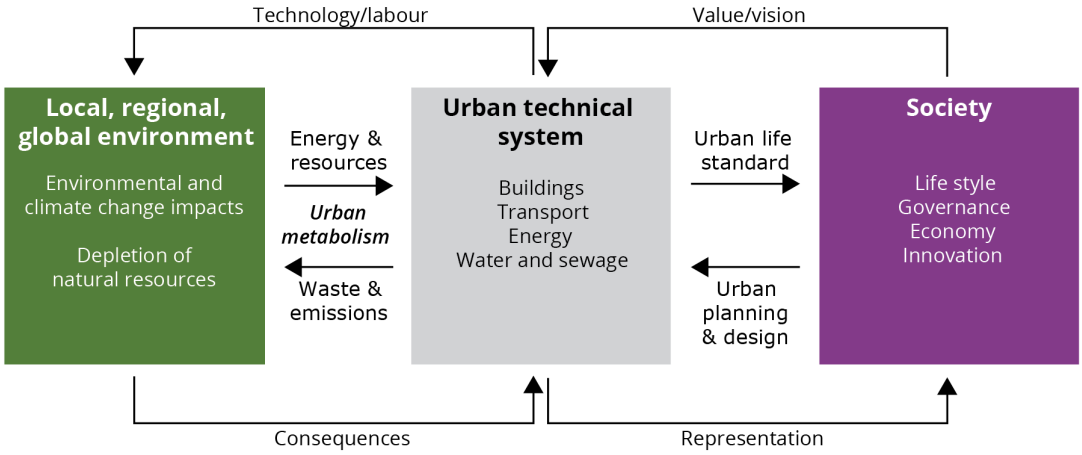

Figure 1. The urban system (European Environment Agency, 2020).

APPENDIX II

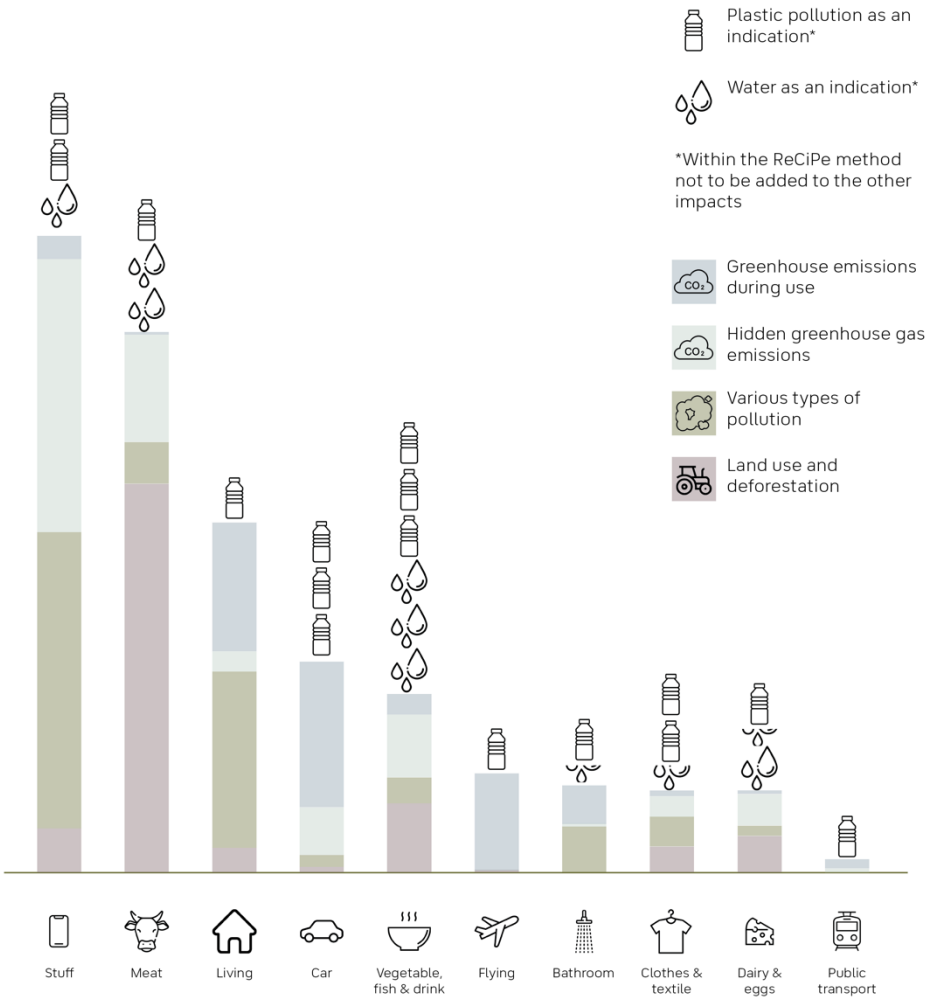

Figure 2. The hidden impact on average of the consumer behaviour of one Dutch person (Porcelijn, 2016).

APPENDIX III

Figure 3. The average use of resources per person in the Netherlands (NIBUD, 2021, Milieu Centraal, 2019).

APPENDIX IV

Figure 4. The weekly activity of a dutch person on average and the consequences on their health (Sociaal en Cultureel Planbureau & Roeters, 2018, Rijksinstituut voor Volksgezondheid en Milieu, 2018).

APPENDIX V

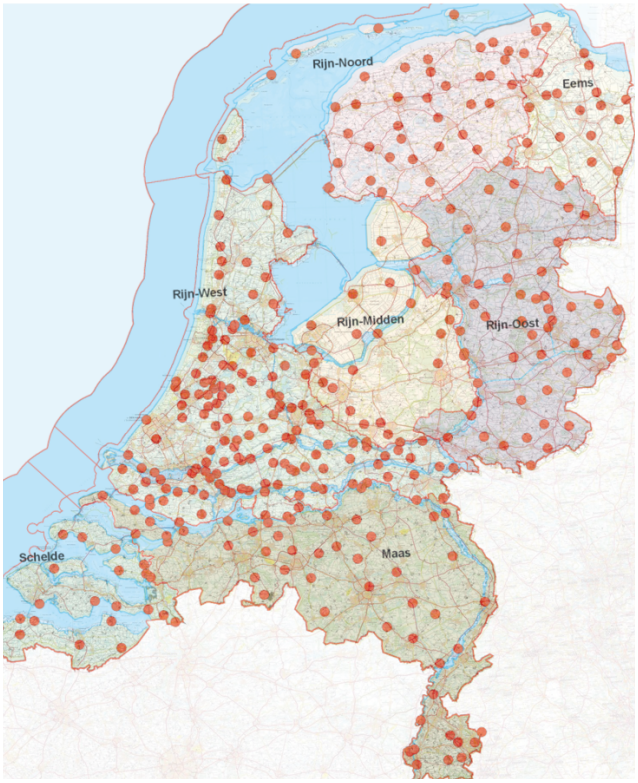

Figure 5. Map of the sewage treatment plants in the Netherlands (Ministerie van Infrastructuur en Milieu, 2012).

APPENDIX VI

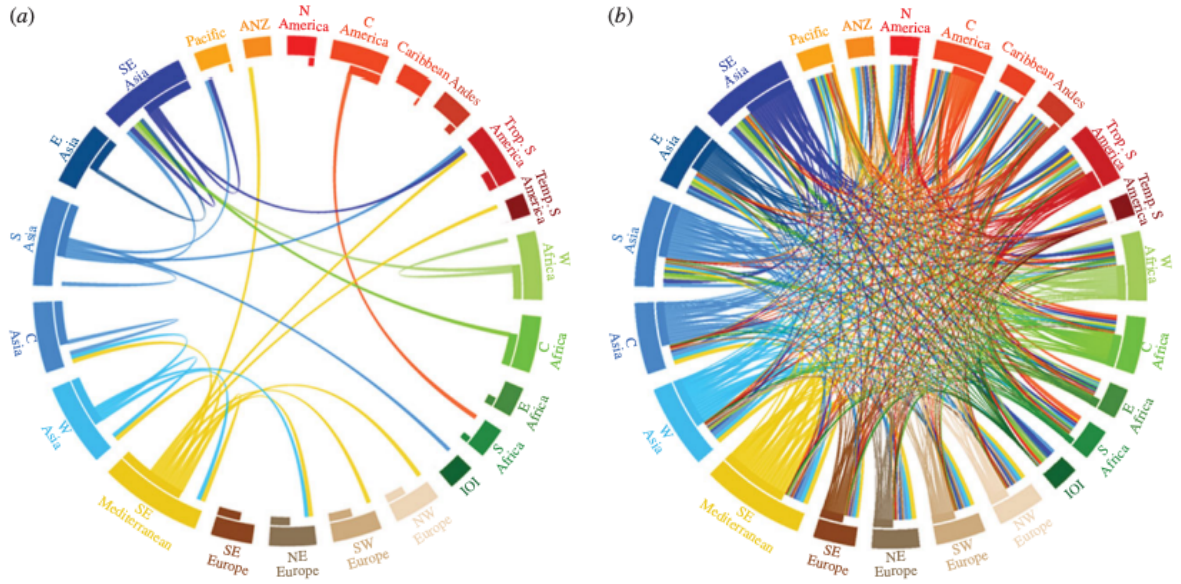

Figure 6. The diagrams portray the import and export relation of food, with diagram A demonstrating the most significant linkages between regions, for visibility, whereas diagram B displays the full matrix of linkages. (Khoury et al., 2016).

APPENDIX VII

Soil type	Which supplement should you add?	Supplement function	How much?
Sand	Ripe compost from organic waste or peat	Ensures that the soil can hold more water, and makes the soil more nutrient-rich.	5-10kg/m²
	Add dried manure from goats, horses, or cattle.	Nutrients for young saplings.	5-10kg/m²
Clay	Straw cut into small pieces.	Straw helps loosen clay soils, which makes it easier for trees to take root.	5-10kg/m²
	Ripe compost from organic waste	Nutrients for young saplings.	5kg/m²
Peat	Straw cut into small pieces.	Straw helps loosen peat soils, which makes it easier for trees to take root.	5kg/m²

Choosing soil supplements

Figure 7. Type of soil supplement, Miyawaki forestry method (IVN Natuureducatie, 2019).

APPENDIX VIII

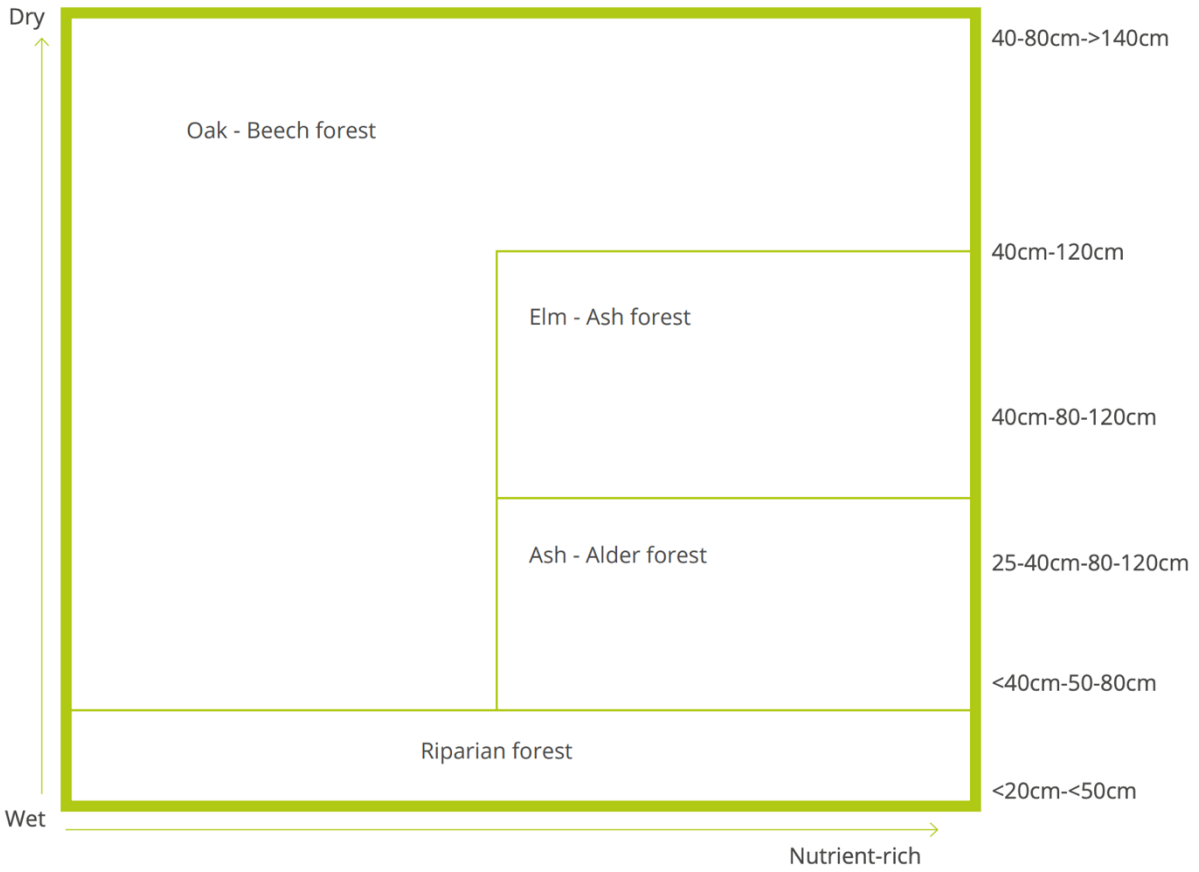

Figure 8. Forest cover typology based on soil type, Miyawaki forestry method (IVN Natuureducatie, 2019).

APPENDIX IX

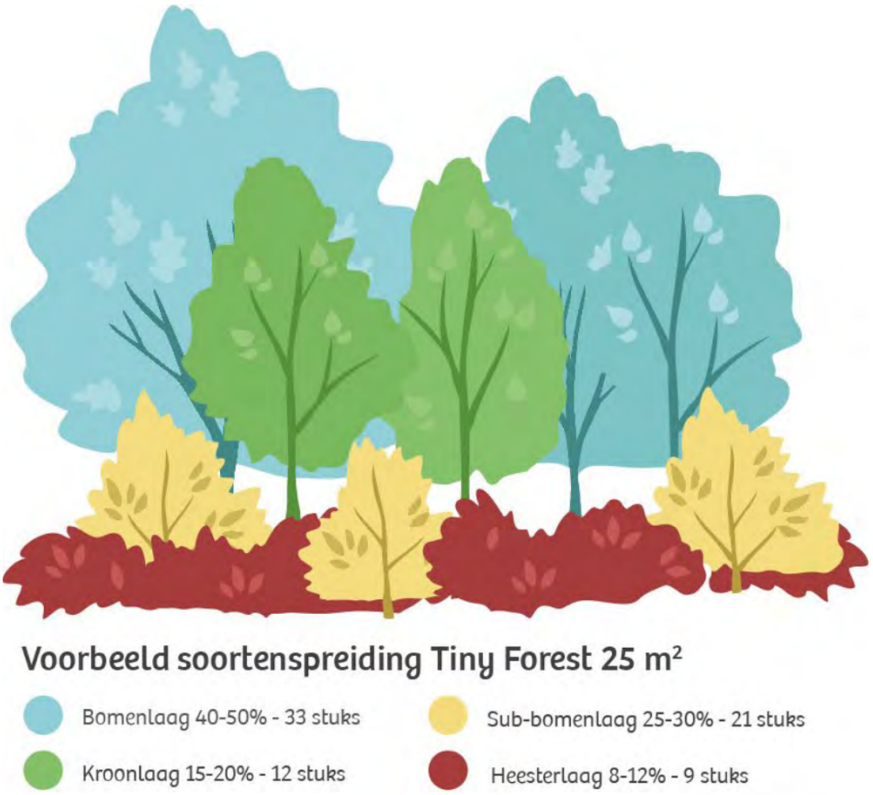

Figure 9. Forest structure species distribution, Miyawaki forestry method (IVN Natuureducatie, 2019).

APPENDIX X

Forest cover type	Oak-beech forest	Elm-ash forest	Ash-alder forest	Riparian forest
Canopy layer 15-20%	Beech Common oak Small-leaved linden Large-leaved linden Aspen Cornish oak	Ash Common oak Black poplar Scots elm	Ash Alder Black poplar Common oak	Alder White birch
Understory 40-50%	Silver birch Ash White birch Field maple Hackberry Hornbeam European crab apple	Field elm Fluttering elm Field maple Hackberry European crab apple	Hackberry White willow Field elm Scots elm	Ash White willow Crack willow
Shrub layer 25-30%	Holly Sorbus Hawthorn European crab apple	Sorbus Hawthorn European crab apple	Pussy willow Grey willow Hawthorn European crab apple	Pussy willow Grey willow Bay willow Sorbus
Herbaceous layer 8-12%	Redcurrant Guelder rose Hazel Dogwood Elderberry Spindle tree Privet Alder buckthorn Common buckthorn	Sweet briar Guelder rose Hazel Dog rose Privet Dogwood Blackthorn Elderberry Blackcurrant Alder buckthorn	Redcurrant Guelder rose Hazel Dog rose Dogwood Elderberry Alder buckthorn Blackcurrant	Purple willow Eared willow Elderberry Myrica gale Alder buckthorn Blackcurrant

Figure 10. Native forest cover typologies and their species per forest layer, Miyawaki forestry method (IVN Natuureducatie, 2019)

APPENDIX XI

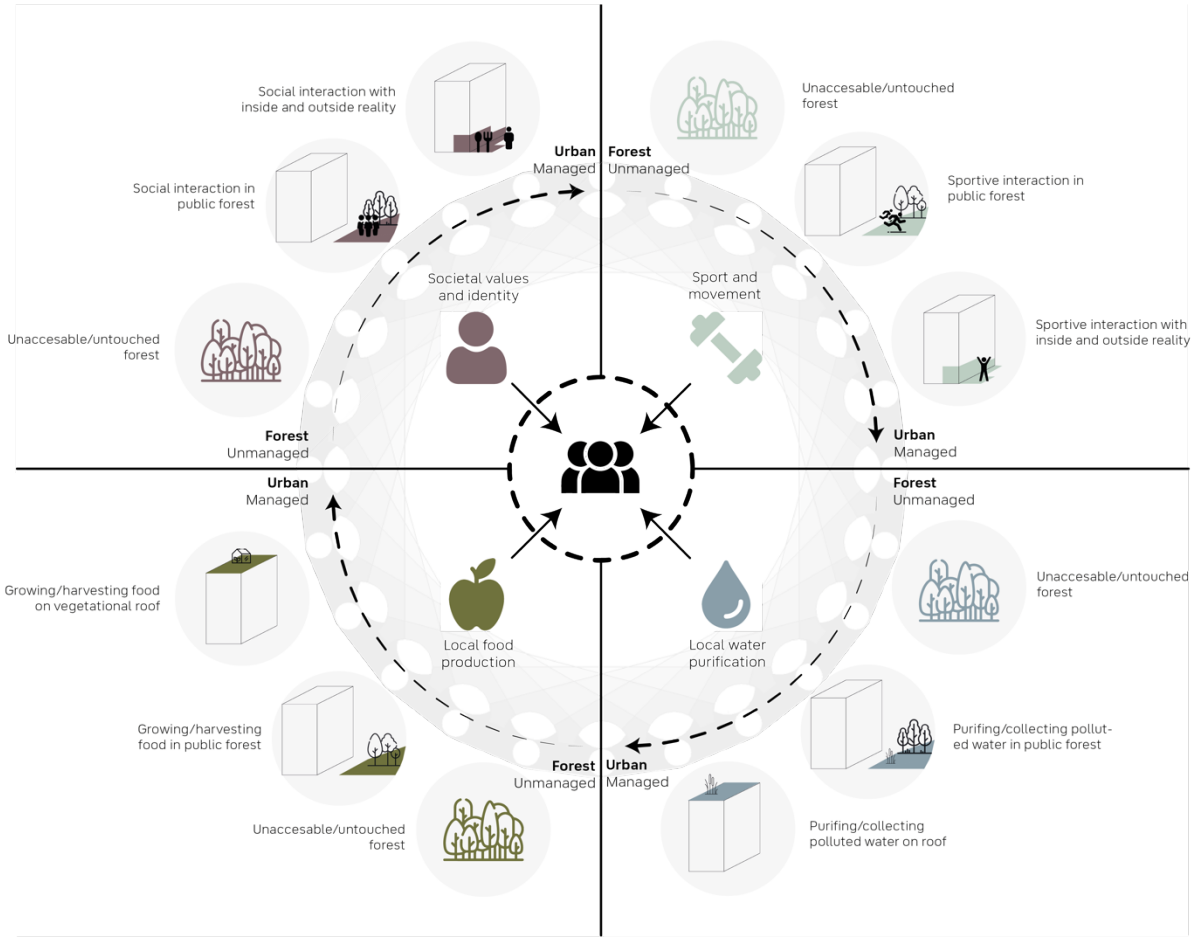

Figure 11. Matrix of linked flows, ecological interactions, and the corresponding potential design strategies for the integration of forest ecologies and urban ecologies based on the qualitative data from the sub-research questions.