Are trees green?

Designing a carbon neutral tree nursery landscape

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MSc Thesis Landscape Architecture
Wageningen University
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By destroying the planet, we act like colonizers of the future generations to.

David van Reybrouck, cultural historian, archeologist & writer

Let's explore different paths now.

Abstract

Afforestation projects in the Netherlands seem a relevant tool to mitigate climate change. However, the production of trees, and further management of the plants have such an impact on the carbon balance of a landscape, that not all projects are net carbon sinks. Additionally, the landscape quality of the tree nursery landscapes in the Netherlands needs to be improved. More knowledge is needed on the spatial implications of a transition to a sustainable carbon neutral tree nursery landscape. This design research investigates potential spatial solutions for carbon neutrality and landscape quality. The nursery hub in Achtmaal, Noord-Brabant, was studied to answer the main research question; what are the constituents of the nursery landscape in Achtmaal as a carbon neutral landscape, with high landscape quality? The metabolism and spatial context of the study site were analysed and a spatial design for a carbon neutral tree nursery landscape was created and tested. This thesis aims to prospect with an eye that welcomes change and tries to identify the beauty in a future agri-energy landscape. The current carbon emissions are 17 421 Tonnes CO_2e/ 151 ha of nurseries/year. Spatial solutions include replacing carbon intensive inputs, like peat, with locally produced alternatives, for instance pine bark. An additional result was a set of design principles and guidelines for landscape quality in the context of Achtmaal, such as in-field buffers, connection of habitats, and the introduction of a green structure. There are promising opportunities for synergies between spatial interventions for high landscape quality and carbon neutrality in this landscape. However, a carbon neutral nursery landscape takes up a lot more space than the current nursery landscape. Economic and political feasibility must be considered too. The design created in this research serves to communicate both the breath of landscape transformation and the carbon neutrality.

Keywords
energy transition, agricultural transition, carbon balance, tree nurseries, research through design, Life Cycle Assessment (LCA), landscape design, landscape metabolism

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Contents

1

Introduction to the research

1.1 Are trees green?

Trees sequestrate carbon and they can contribute to biodiversity. They give our cities a friendly touch and can aid the microclimate, when positioned well. Afforestation helps to reduce the amount of greenhouse gasses in the atmosphere and therefore mitigates climate change. Trees seem a relevant 'green' tool for landscape architects, on the path to a sustainable landscape. However, a closer look at the production of trees shows that its impact on the carbon balance of a landscape is not per definition positive. Landscape architects need to extend their attention, beyond the design of new nature areas and urban green spaces. Design of carbon neutral tree production landscapes is needed. This design thesis identifies the constituents that can make up such a landscape and the constituents that do not fit in it.

Afforestation projects in the NL

LNV, the Dutch ministry of agriculture, nature and food quality proposed to create 37.000 ha new nature in the next 10 years (Rijksoverheid, 2020a). Action plan 'Bos en hout' proposes 100.000 ha new forest before 2050 (VNBL, 2017) (fig. 1). Nursery owners support this idea and are willing to produce for this emerging local market (LTO Vakgroep Bomen en vaste planten et al., 2020).

As illustrated later in this introduction, the Dutch nursery landscapes is likely to emit more CO2eq than tree planting projects sequestrate under current circumstances. This is not the only environmental issue that can be identified linked to the nursery practices. Other forms of pollution are present. Nurseries are associated with water (fig. 3) and soil pollution. Heavy metals from pesticides end up in the water system and excess nutrients cause eutrophication. These pollutants, in combination with large scale monocultures (fig. 4), result in a landscape with a poor biodiversity.

Landscape quality of the nursery landscapes

The nurseries are concentrated in hubs (fig. 2). A visit to several of the biggest nursery hubs of the Netherlands, situated in Brabant, gives the impression that aesthetic experience for inhabitants and visitors can be improved greatly (fig. 5). Incoherent and messy compositions give a cluttered feel and lack unity. Small scale plots don't fit the scale of the open landscape in some places. Occasionally, advertisement aggressively breaks the relative serenity that rural landscapes can possess. Bare soil and fencing give an unwelcoming and dead feel.

The expertise of the landscape architect can contribute to spatial solutions to these environmental problems and landscape architectural research should consider how the biosphere will be involved in a future carbon neutral production landscape.

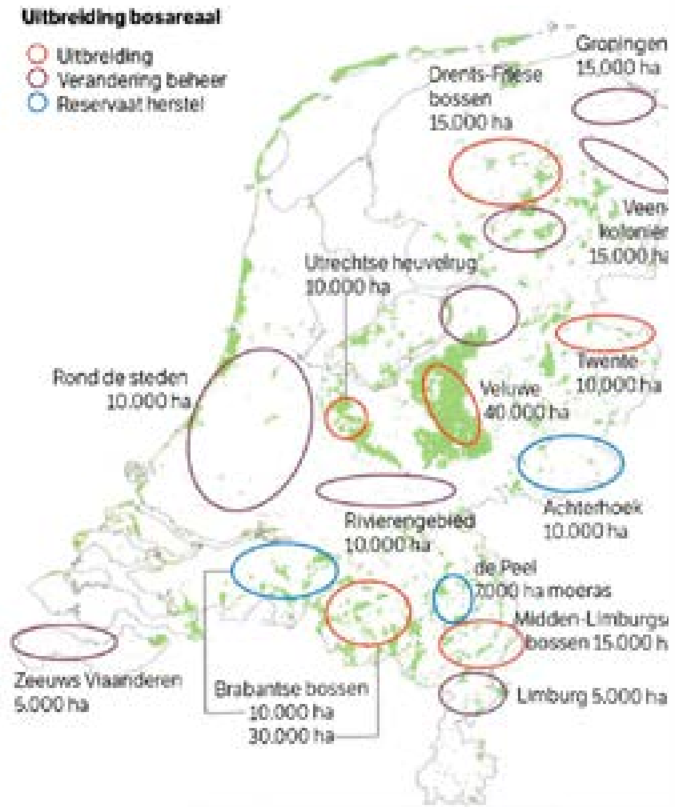


Fig. 1 Areas with potential for afforestation or forest restoration, from Actie plan Bos en Hout. Image source (VNBL, 2017)

Fig. 2 Location of Dutch nursery clusters. Image source (Maas & van Reuler, 2008)

Fig. 3 Biodiversity threat: eutrophication. Image source (Mashangwa, 2016)

Fig. 4 Biodiversity threat: large scale monocultures and pesticide spraying. Image source (Macdonagh, 2021)

Fig. 5 Aesthetic experience for inhabitants and visitors can be improved greatly. Bare soil and fencing give an unwelcoming and dead feel. (Left) Incoherent and messy compositions give a cluttered feel and lack unity. Small scale plots don't fit the scale of the open landscape in some places (right). Image sources Author (2021)

Impact of nurseries on the carbon balance

To assess the carbon neutrality of land use, direct sources and sinks can be identified. Lazzerini, Lucchetti and Nicese (2014) take a different angle and add the arrow of time by looking at the full lifecycle of a product or company, a tree nursery in this case. Several studies are available on the environmental impact of tree nursing in terms of greenhouse gas emissions (Kendall & Gregory McPherson, 2012; Lazzerini et al., 2014, 2016; McPherson & Kendall, 2014; Petri et al., 2016).

Since ornamental trees are nursed for a longer period, more energy is used for production. Kendall and Gregory McPherson (2012) state about a large Californian nursery operation that 'production emissions for trees used in urban forestry are 4.6 and 15.3 kg for a typical #5 and #9 tree, respectively. These emissions are more than 100 times higher than those associated with seedling production for forestry operations, estimated at 0.029–0.133 kg per seedling CORRIM Inc. 2004; Aldentun 2002' (cited in Kendall and Gregory McPherson, 2012, p 450). Fig. 7 shows that the production of an ornamental tree can take about 4 years before sale.

However, there are opportunities for reducing emissions in ornamental nursery practices. As shown in fig. 6 the input of the production process plays an important role in the carbon balance. Energy use for this type of nursery accounts for 44% of the greenhouse gas emissions. The production, use and transportation of materials also contributes significantly to emissions. High survival rates of the trees are crucial to prevent emissions. Lastly, transport to the place where the trees are planted matters.

Management on the destination of the plants

Once they arrive on location, again the survival rate of the trees, but also pruning practices influence the net sequestration of a project. The decomposition and burning of prunings and trees that died prematurely are the biggest emission sources by tree management, followed by energy consumption of watering and of the removal of the dead trees (McPherson & Kendall, 2014) (fig. 8).

Based on the assessment of a large tree planting initiative in Los Angeles, U.S.A., it can be stated that urban ornamental tree management needs to change. '[City tree planting projects] can be net CO2 sinks, especially if trees are strategically located to reduce energy consumed for air conditioning and space heating, and fossil CO2 emissions [are avoided through] energy savings and [a switch to] biopower' (Kendall and Gregory McPherson, 2014, p.1663). Furthermore, due to their survival rate and size, park trees are more likely to store carbon in their lifespan than street trees.

Trees that end up in afforestation projects have a better outset for sequestering carbon in their lifecycle, since emissions in the production phase are lower than ornamental trees. Again, conditions apply for the rest of their lifespan. Transportation distance to the afforestation project from the nursery, forest management, use of machinery and survival rates of the trees all contribute to emissions. The trees must match the changing climate, and resist drought and disease to live long. If the wood gets harvested, high-quality end use is important, like (modular) building materials or furniture.

Solutions

Kendall and Mcperson (2014) propose some solutions to the emissions, of which two have spatial implications: a switch to renewables and sourcing materials and selling the trees and plants locally.

A third solution to add is a switch in land use, from ornamental tree production to forestry planting stock production.

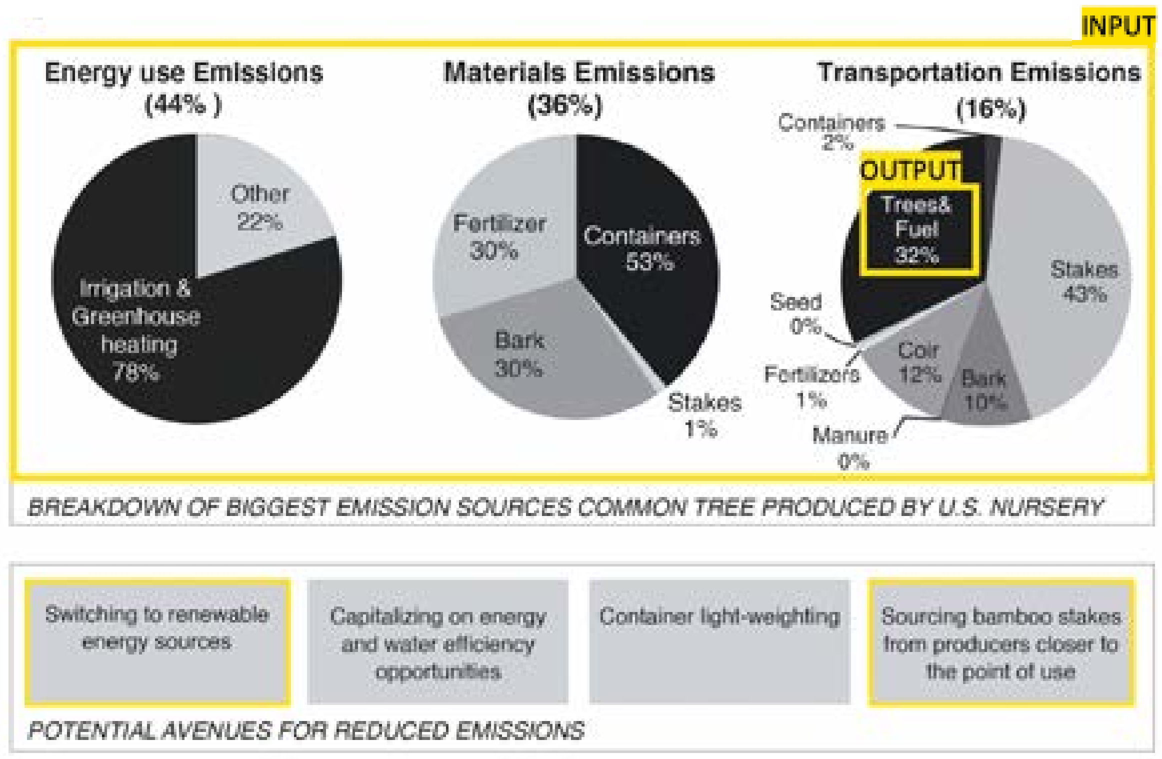


Fig. 6 Emissions of production process of an ornamental nursery. Image source adapted from (Kendall and Gregory McPherson, 2012)

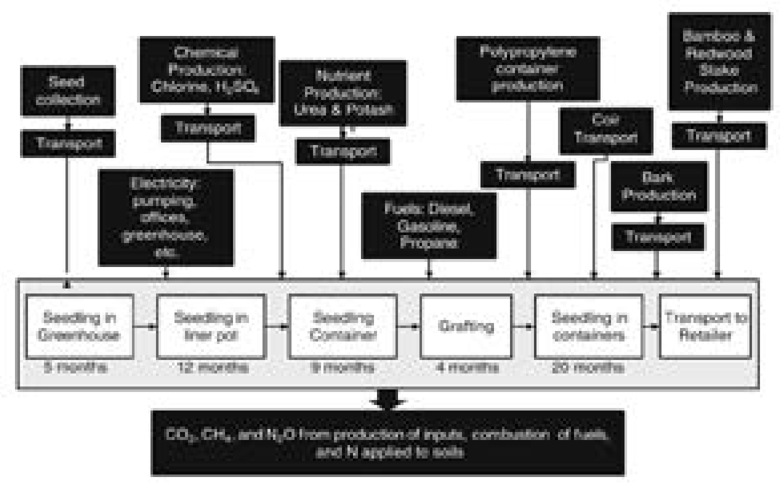


Fig. 7 An ornamental tree can stay at the nursery for 4 years, which increases its impact on the carbon balance. Image source (Kendall and Gregory McPherson, 2012)

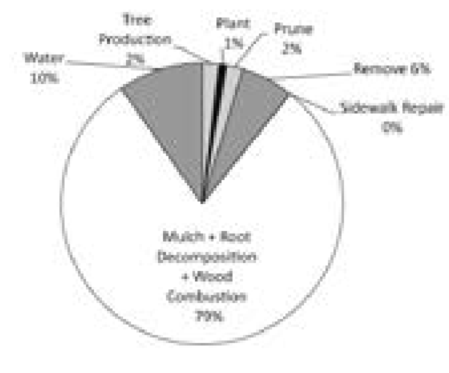


Fig. 8 Large amount of captured carbon by an ornamental tree is released later in its lifespan due to management. Image source (McPherson& Kendall, 2014)

The Dutch nursery sector and climate change

The recent IPCC report (fig. 9) is clear about the human influence on the warming and the subsequent extreme weather events that are occurring worldwide (fig. 10). 'Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change (IPCC, 2014, p.17).'

This thesis zooms in on mitigation. Mitigation is possible through reducing anthropogenic sources of greenhouse gasses (GHG) and creating sinks for GHG.

The Dutch national climate mitigation goals include a 55% reduction of CO2 emissions in 2030 (relative to 1990), 95% in 2050, which means a reduction of 49 Mton by 2030 (Rijksoverheid, 2021). According to CBS (2021) the agricultural sector emitted 26,1 Mton in 2020. A 3,5 Mton reduction in agriculture and land use (Vellinga et al., 2018), would result in residual emissions of 28 Mton in 2030 and 3-11 Mton residual emissions of agriculture in 2050. One measure to reach these goals is 'more trees and woods' (Ministerie van economische zaken en klimaat, 2019). This thesis addresses this measure. As mentioned before, the success of this measure is dependent on the origin of the trees.

The Dutch sector of tree and plant nursing yearly contributes between 0,04-0,7 Mton CO2e emissions/yr. This is a very rough indication, based on CO2eq emission numbers of 2,2-34,7 Tonnes/ha/yr (Lazzerini et al., 2014), from a cradle to gate study on nurseries in Northern Italy, times the 16.830 ha (CBS Statline, 2020) area of tree and plant nurseries in the Netherlands.

0,04-0,7 Mton might not seem a big share of the total 26,4 Mton co2eq emitted by Dutch agriculture (Rijksoverheid emissieregistratie, 2020). However, as big emission sources get reduced over time, smaller sources gain significance. Plus, trees can only be a valid tool to mitigate climate change if their net carbon storage is accounted for.

2780 Nurseries (CBS Statline, 2020) together produce an export value of € 1,3 billion (Smit & Jukema, 2017). Trees and plants are transported across Europe and beyond, which adds to the emissions. Like in other agricultural sectors the amount of companies has decreased and the size of individual companies has increased (CBS Statline, 2020), resulting in largescale production landscapes.

Designability of a carbon neutral production landscape

A spatial follow up of the national climate agreement, the National Program Regional Energy Strategies, mainly focusses on the implementation of renewables (Rijksoverheid et al., no date), and less on the other mitigation measures. It is relatively new practice in landscape design to consider the complete carbon balance of a study area. This thesis shows a way of doing so. In addition to a switch to renewable energy sources, sequestration by trees and woody plants in new forests and landscape elements can form sinks and offer opportunities for reducing emissions. Furthermore, the carbon balance of a production landscape can be influenced by changing production practices.

Both ornamental tree and plant production and forestry stock production contain elements with aesthetic potentials. There is beauty to be discovered in the production process (fig. 11). Ornamental tree production can have park-like qualities. The large scale and repetitiveness of ornamental trees and plants, and forestry stock can provide interesting visuals and the temporal aspect can offer interesting installations and compositions. Moreover, the indoor production spaces, especially greenhouses could form an inviting, literally warm and light space, serving as a stopover for visitors.

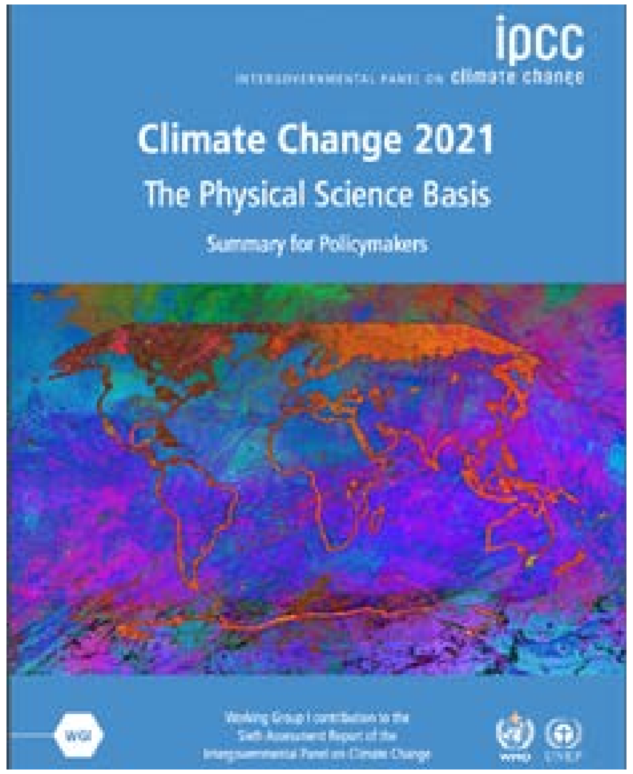


Fig. 9 Recent IPCC report. Image source (IPCC, 2021)

Fig. 10 Extreme wheather event in the news (The economist, 2018; Rhein-Erft-Kreis/AP, 2021)

Fig. 11 Potential of nurseries to enhance spatial quality. Image sources from left to right (Barcham Trees plc, 2021; Leidorf, 2010; author,2021; author, 2021; Nevica, 2007; image.ie, 2021; Topspots BV, 2021)

1.2 State of the art

Design of sustainable carbon neutral landscapes

Stremke and Dobbelsteen (2013) stress the importance of reduction of energy use and energy efficiency in the discussion on sustainable energy transition. One method for assessing sustainability of energy landscapes, is to assess the energy or carbon neutrality of this landscape (Jørgensen in Stremke & Dobbelsteen, 2013) . Also, Landscape Architect Paul Selman (2010, p. 157) advocates 'a shift towards carbon-neutral approaches generally, and not just modes of energy production'. Selman (2010, p.158) states that 'Carbon neutrality' […] commonly refers to radically reduced consumption of fossil carbon and emission of greenhouse gases, to the extent that human habitats could even become energy sinks' (Forum for the Future, 2008). Therefore, more knowledge is needed on the design of carbon neutral landscapes, that don't '[compromise] landscape quality, biodiversity, food production, and other life-supporting ecosystem services' (Stremke & Dobbelsteen, 2013, p. 5). Design research is needed to learn about landscape interventions that help 'reducing our use of carbon-based energy [..] and offsetting carbon footprints […]' (Selman, 2010, p. 158).

Design of sustainable agricultural production landscapes

'The Netherlands has a rich landscape architectural tradition in the (re-)design of agricultural production landscapes, that evolved parallel to the land reclamations and creation of the Ijsselmeer polders' (Steenhuis et al., 2009, p. 196). Post-war landscape architects that worked for state forestry department, like R.J. Benthem, J.T.P. Bijhouwer, N. de Jonge and H. de Vroome, contributed to a shift in approach, away from a purely production-oriented upscaling, that bulldozed over the cultural-historical landscape and it's ecological and aesthetical values. 'Land use has to reflect the needs of its inhabitants' became the device for the designers (Steenhuis et al., 2009, p.189). Though many reclamations happened without one, the efforts of these designers turned the landscape plan, that integrates agricultural production, ecology, aesthetics, recreation, and cultural historical heritage, into a legal tool.

Their work on a high scale level, the thinking in structures and systems and the integration of different spatial claims in a design is reflected in the present-day work of landscape architecture offices (Steenhuis et al., 2009). Even though the current agricultural production landscapes of the Netherlands are facing new threats and arguably more functions than ever before need to find a place in the landscape, an integral and systemic approach is still relevant. Climate change requires a shift towards resilient plants and new water management strategies, to prevent droughts and floods, especially for the Brabant's dry sandy soils, where many of the nurseries are located, and where suppletion of water is not possible (Stichting Climate Adaptation Services, n.d.).

Regardless of the efforts of landscape architects and others, biodiversity has shockingly decreased, as old vegetative landscape structures disappeared from many agricultural landscapes and large-scale monocultures and pesticides and other forms of pollution made their appearance. Almost 40% of species in the NL are on the red list of threatened species, 96% of habitat types and 77% of habitat guideline species had medium weak or weak prospects for conservation (translated from Sanders, Henkens and Slijkerman, 2019, p.7). More knowledge is needed on the incorporation of these present-day challenges in landscape design, by parallel development of agricultural production with biodiversity, in an aesthetically appealing landscape.

Design of sustainable carbon neutral agricultural production landscapes in practice

In landscape architectural practice some examples can be found of landscape designs that combine carbon neutrality with agricultural production. Fabrications and Sant&co performed a land use assessment for land subsidence reduction in the Groene hart (Fig 12). The reduction of emissions of the peat for different land uses, related to new water tables, are shown in tiles (FABRICations, 2019). For the competition 'Brood en spelen', studio Marco Vermeulen proposed Productief Peppelland, related to their Zuid-houtland project. The project entails a transformation of the Brabantse production landscape, to wood production for building materials, creating a landscape that adds to carbon sequestration (Brood en Spelen, n.d.) (fig. 13). In the IABR atelier in 2014, some design interventions for the nursery landscapes of Brabant were shown by Lola (Dutch School of Landscape Architecture, n.d.). In the masterplan for the Van Gogh national park the potentials of nursery landscapes are mentioned (Stuurgroep Van Gogh Nationaal Park & West 8, 2020).

However, none of these examples adress the knowledge gaps that exist on the brink between carbon neutrality and landscape quality. Neither are they specifically focussed on a nursery landscape.

Fig. 12 Brood en Spelen Productief Peppelland (StudioMarcoVermeulen, 2018)

Fig. 13 Assessment land subsidence reduction in Groene hart (SantenCo&Fabrications, 2019)

1.3 Context

Location & situation

The largest nursery landscapes of the Netherlands are located on Brabant's' sandy soils. Due to their large scale, expectations for improvement of their carbon balance are high.

The hubs (fig. 14) in Boskant, Haaren en Zundert are bordering the Nature Network Brabant (NNB) areas and investments are planned to enhance and extent these areas. The largest hub, Zundert, spans an area similar to the city of Utrecht. It possesses the least green landscape elements of the three hubs and landscape quality seems to be relatively low.

Within Zundert, the nursery area of Achtmaal shows the most potential to connect two NNB areas. The area has some momentum, due to the planned expansions of the connection of nature reserve areas, right through the middle of the nurseries (fig 15).

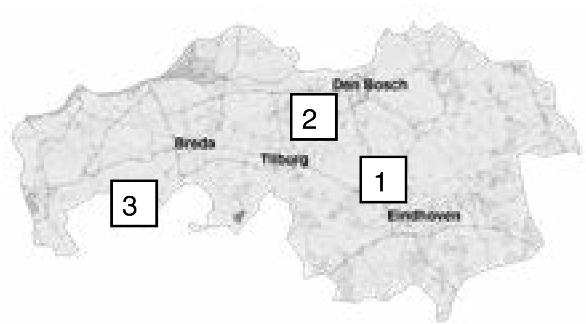


Fig. 14a Largest nursery hubs in Brabant

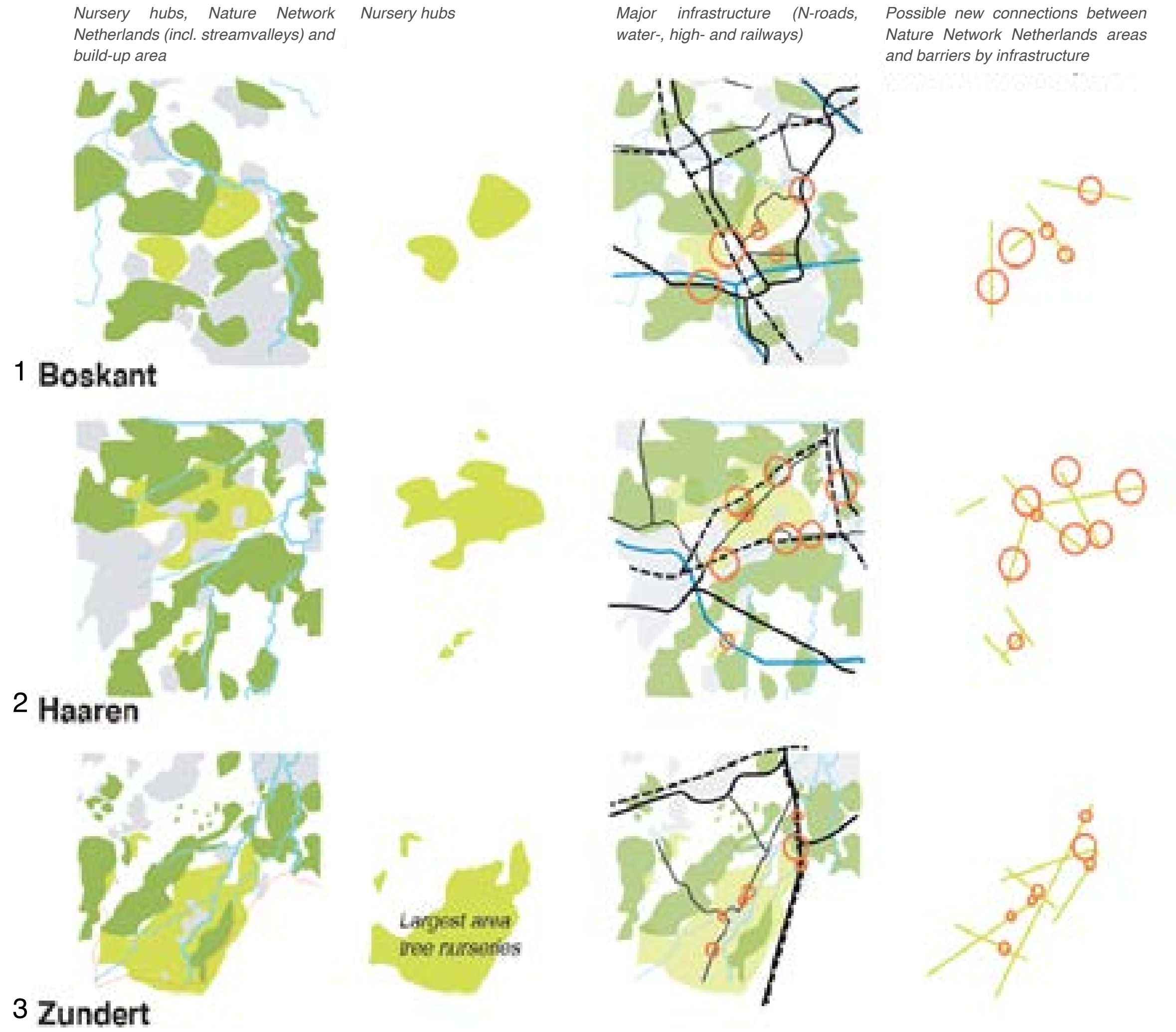


Fig. 14b Selection of study site in the nursery hub of Zundert

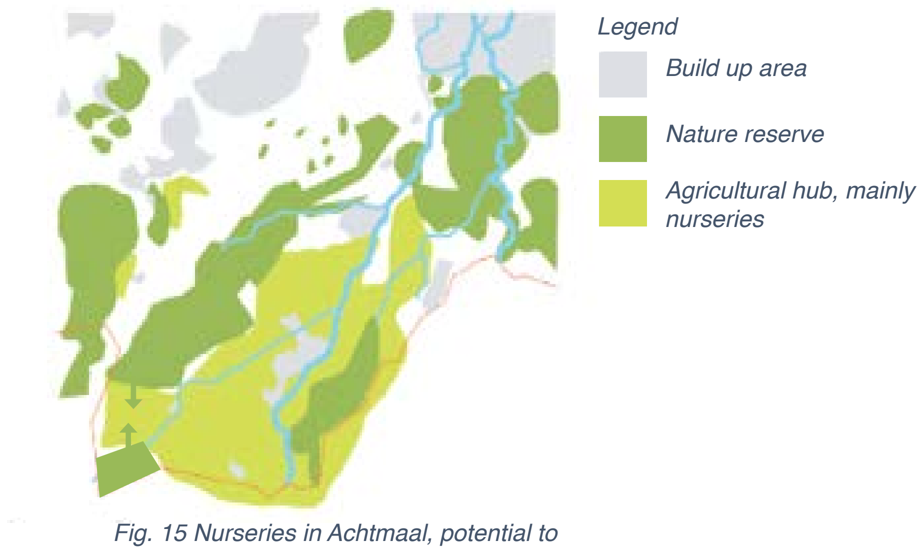


Fig. 15 Nurseries in Achtmaal, potential to connect Nature Network Brabant areas

1.4 Knowledge gap & problem statement

Problem Statement

Climate change mitigation requires a diminishment of sources of GHG and the creation of sinks of GHG. In the Netherlands the process of afforestation needs to be initiated in a sustainable way to create sinks. Management and production of both ornamental trees and plants, and forestry stock need to be changed to reduce emissions.

Knowledge on spatial solutions for carbon neutrality in tree nursery landscapes is missing. Another environmental problem in this nursery landscape is poor landscape quality, caused by a weakened ecological system, and absence of scenic, aesthetic, and recreational qualities.

Knowledge gaps and opportunities

To my best knowledge an unexplored niche for landscape architectural research is the design of carbon neutral tree nursery landscapes, more specifically of the vast tree and plant nursery landscapes of the Netherlands.

The expertise of the landscape architect can help to identify spatial solutions for carbon neutrality in a nursery landscape.

The theoretical knowledge about the design of such a landscape doesn't extend beyond the spatial implementation of renewable energies, in which landscape quality and biodiversity still need more attention.

This design research holds potential to integrate solutions for problems related to landscape quality and carbon neutrality. Design can contribute to advancement of landscape architectural knowledge, by providing a spatial answer to this environmental problem.

To address this design research challenge and to know whether this nursery landscape can contribute to climate change mitigation, a better understanding of its material and energetic flows is needed. Some elements of the plant and tree nurseries bear potential to enhance existing landscape qualities and bring the fragmented Nature Network Brabant conservation areas to unity.

Existing lifecycle assessments are of foreign nursery practices, don't look for spatial and context specific solutions. The experience with carbon neutral landscapes production landscapes in landscape architectural practice, mainly extends to the peat meadows and woods. Nursery landscapes are not addressed.

The knowledge this thesis therefore aims to generate is on spatial insights about carbon neutrality in the nursery landscape of Achtmaal. Knowledge on synergies between spatial interventions to improve carbon neutrality, and spatial interventions focused on biodiversity and aesthetics is sought.

1.5 Purpose statement

Research aim and objectives

The hypothesis is that the tree nursery landscape of Achtmaal in Zundert, Brabant has potential to become carbon neutral. Current land use and production practices of plant nurseries contribute to CO2eq emissions. One of the objectives is to identify components of the metabolism and practices of the Achtmaal nursery landscape that can offer spatial solutions for carbon neutrality. The purpose of this thesis is to create a spatial design for a carbon neutral regional landscape in Achtmaal. The design assignment is to explore the forms of a carbon neutral production landscape that integrates ecological and experiential qualities. These solutions might be translatable to other situations, in the form of design principles. Plus, the tested designs will be the newly produced knowledge, that can serve as a foundation for further landscape architectural research on carbon neutral landscapes.

Main Research Question

What are the constituents of the nursery landscape in Achtmaal as a carbon neutral landscape, with high landscape quality?

2

Conceptual framework & Research approach

2.1 Conceptual framework

CARBON NEUTRAL NURSERY LANDSCAPE

Carbon neutrality is used as a lens to identify, assess, and value different types of nursery practices and the design concepts. To evaluate the carbon neutrality of a design for the nursery landscape in Achtmaal a definition is needed. 'Net zero emissions [of an area] are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period (IPCC, 2018, p. 555)'. IPCC's global warming potential GWP values are defined as a 'time-integrated global mean RF [radiative forcing] of a pulse emission of 1 kg of some compound (*i*) [GHG] relative to that of 1 kg of the reference gas CO_2' (IPCC, 2007, p. 385). The amount of GHG multiplied with the associated GWP value gives the emissions, expressed in CO2 equivalents. In this thesis therefore, carbon neutrality is actually GHG neutrality.

The study area and corresponding carbon balance is spatially demarcated by the area where nursery practice takes place in Achtmaal. The spatial boundaries could extent, to new natural or production areas, when intervention for the purpose of carbon neutrality do not fit in the current area.

Sources of emissions

Inspired by lifecycle assessment studies, the commonly known 'Trias energetica', and by Paul Selman's (2010) expressions of energy drivers in the landscape, the CO2 equivalent flows are analysed within the following categories:
1. The current and future **energy consumption** of the nurseries.
2. The current and future **energy production** of the nurseries.
3. The **embodied energy** of the production by the nurseries. The impact on CO2 balance of the different types of nursery practices is considered.

General conclusions from literature (Kendall and Gregory McPherson, 2012; Lazzerini, Lucchetti and Nicese, 2016) on carbon balance of certain plant production practices are projected on the area. In these studies, the system boundaries include the following.

Firstly, emissions from the use of hard infrastructure on the farms, like buildings, roads, pipes, fencing and machinery. Secondly, emissions from the different type of crops, related to the duration of production. Thirdly, the emissions from 'inputs of cultivation, including their transport to the nursery (fertilizers, pot mixes, pots, chemicals, energy consumption and soil tillage, packaging)' (Lazzerini, Lucchetti and Nicese, 2016, p. 450). Emissions of transportation of the plant products to the next location are taken into account. Lastly, the emissions from the soil are included in the system boundaries of these studies. The use of potting soil and fertilized soil are considered sources of emission (Kendall and Gregory McPherson, 2012; Lazzerini, Lucchetti and Nicese, 2016). Adding to that, lowering groundwater tables in the peaty soils, 'eerdgronden', or other soils with high organic content that are present in Achtmaal, can result in emissions from oxidation. Furthermore, management of by-products, like composting and burning organic waste materials, should be considered in determining the carbon balance.

Carbon Sinks

Another CO2 equivalent flow that is analysed is the flow to **carbon sinks**. The sink is measured by the estimated net sequestration capacities of (newly introduced) green elements in the landscape.

The net sequestration over the full lifespan of the produced plants, after leaving the nursery is considered in the design, but not accounted for in the carbon balance, because this largely depends on management outside of the nurseries.

METABOLISM OF AN AGRICULTURAL PRODUCTION LANDSCAPE

In the Oxford dictionary metabolism is defined as 'The chemical processes in living things that change food, etc. into energy and materials for growth' ('metabolism', no date). In Belanger (2017, p.43) David Harvey draws the parallel between urban production landscape and this living thing and states that 'different flows and calibration of different processes of production bear the potential for [transformation of the landscape]'. In this thesis an analysis of the metabolism of the nursery landscape of Achtmaal results in a spatial toolset to improve carbon neutrality and landscape quality. The analysis focusses on CO2e (energetic) and spatial material flows for the several types of nursery practices.

LANDSCAPE QUALITY

Hooimeijer, Kroon and Luttik (2001) state that spatial quality is highly related to the spatial, temporal, and societal context. Context needs to be considered in the design process. In the Dutch landscape there is always plurality. To establish quality, spatial conflict needs to be avoided and 'form and function should enhance each other by a combination of them in space and time' (Hooimeijer, Kroon and Luttik, 2001, p. 66). Therefore, multifunctionality is a criterium for spatial quality. Hooimeijer, Kroon and Luttik (2001) advocate a conceptual framework for the evaluation of spatial quality. The framework consists of three design criterion, that refer to Vitrivius' criterion for the quality of a building: use value (functionality, coherence, accessibility, etc.), experiential value (identity, readability, meaning, diversity, etc.), and future value (effectiveness over time, expandability, adaptivity to new uses, etc.). These values are set against some societal interests: economic efficiency, ecological sustainability, social justice, and cultural identity.

In this thesis context is considered and multifunctionality is sought, but not all these criteria and interests can be addressed equally.

'Concerning landscape quality, literature reports on functionality and certain aspects of experience rather than firmness (future values) of [large scale transformation projects]' (Oudes and Stremke, 2020, p. 905). The choice was made to first focus on the design criterion future values (carbon neutrality of the landscape), secondly, on use value (functionality of the nurseries as a system), thirdly, on experiential value (scenic and aesthetic qualities of the landscape and suitability for recreation) and, finally, on a selection of societal interests. The societal interests that are emphasised are ecological sustainability (biodiversity enhancement, connection of habitats, serenity) and cultural identity (social encounters, historical identify, future identity) (fig. 16).

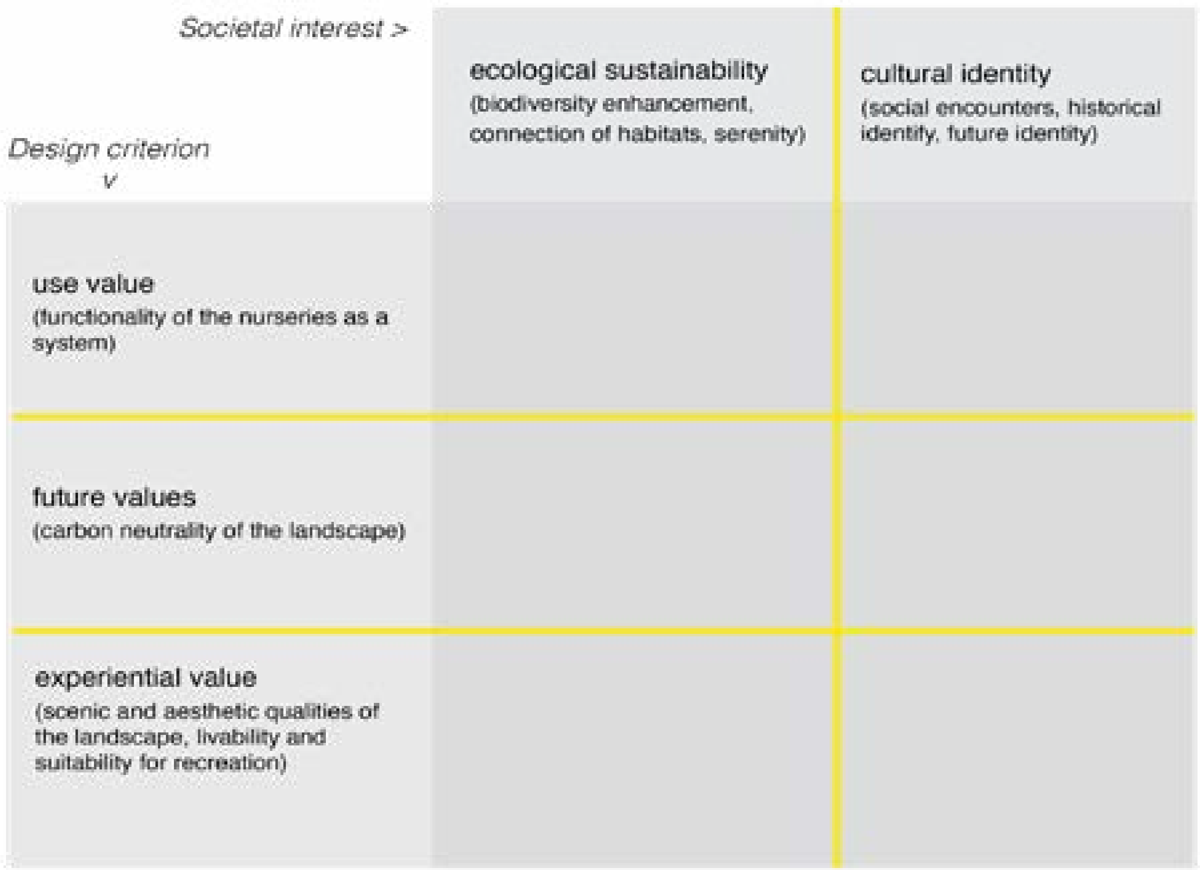


Fig. 16 Landscape quality framework for this thesis. Image amended from Oudes & Stremke's (2020) framework for landscape quality

Experiential quality

'Generally applicable measures for enhancing the visual quality of landscapes are difficult. The visual character of landscapes is very place-specific and dependent upon the quality, location and combination of various landscape components (Haaren, Lovett and Albert, 2020 p. 384)'. There are, however, concepts (beyond the visual sense) that are associated with scenic and aesthetic qualities that can be used as criteria. Image, space and serenity, attractivity, beauty, ecosystem health, character and uniqueness, contrast and diversity are terms associated with scenic and aesthetic qualities (Hooimeijer, Kroon and Luttik, 2001).

Ecology and aesthetics are 'the context in which all recreational activities take place' (Lange-Kabitz et al., 2020). Important layers and spatial features in the landscape for recreation as identified by Albert, et al. (2020) are: networks and furnished, varied, continuous routes past highlights, accessibility for the biggest possible variety of visitors and inhabitants through different modes of transport and availability of information in the landscape.

To arrive at sensible conclusions about scenic, aesthetic, and recreational qualities of Zundert, a site-specific analysis is needed. Spatial conclusions need to be drawn, about the landscape components, describing their current and potential qualities to enhance the aesthetics of the landscape. This can be done through maps, sections, photographs and 3D studies on volumes and verticality. Furthermore, a triangulation of results must take place, where possible. My findings as a landscape architecture student can be compared with the opinion of inhabitants and visitors of this landscape. Those opinions can be gathered through literature and interviews.

Ecological sustainability

'An indicator of ecosystem quality is the number of qualifying species' (CLO, 2016). 'Biodiversity refers to diversity at multiple scales of biological organisation (genes, populations, species, ecosystems and ecological processes (Noss, 1990) and can be considered at any geographic scale (local, regional or global) (Millennium Ecosystem Assessment 2005)' (Lange-Kabitz et al., 2020, p.390). Lange-Kabitz et al. (2020, p. 390) refer to biodiversity as 'the diversity of species and habitats including habitat networks'. Biodiversity is important for the resilience of ecosystems globally and the ecosystem services they provide. Additionally, a healthy, biodiverse ecosystem is of increasing importance for the nursery sector, as nursery practices transition to organic pest and disease control.

Implementation of measures (both restoration and maintenance) to improve the connectivity of the landscape should be prioritized according to their importance for habitat connectivity on the local or regional scale. Species have to be enabled to 'overcome physical barriers' and 'specific habitat requirements of species in different seasons' need to be met, through the creation of 'stepping stone habitats or corridors' (Lange-Kabitz et al., 2020, p. 391-392).

Cultural identity

Cultural development is an evolutionary process in which continuity and change interact (Hooimeijer, Kroon and Luttik, 2001). Preservation of the old and integration of the new contributes to landscape quality. Facilitating encounters and familiarisation with new elements, and with advocates of these elements, can cause a shift in values.

This thesis aims to facilitate those encounters, to familiarize people with the idea of a carbon neutral landscape and with the notion of beauty of production.

2.2 Research approach

Design oriented thesis

This thesis is design oriented. To solve the environmental problem and answer the main research question, both research for design and research through design as described by Lenzholzer, Duchhart and Koh (2013) are employed.

Sub-questions are formulated to answer the main research question:

What are the constituents of the nursery landscape in Achtmaal as a carbon neutral landscape, with high landscape quality?

Fig. 17 shows the research process and the research questions. Research for design will produce criteria and design principles to inform the designs. In the iterative research through design process the models and the final design will be tested on these criteria. The evaluation takes the form of a rating of several models for their effects on carbon balance and landscape quality. Another part of the evaluation consists of testing the design in section and details on several scales. Where needed an extra loop of research for design can be added, when information to inform the designs is missing.

The pragmatic approach results in a mix of positivistic and constructive knowledge claims. The quality of the research results is assured in several ways. Transparency is created by explicating arguments for design decisions. Individual models are included in the report and evaluated in a visual manner. Carbon calculations and interview results are added in the annex. A critical discussion of results specifies flaws in the research. Validity and credibility are assured by selection of seven interviewees, that are representative for the inhabitants and entrepreneurs in the study area. Results of literature on experience of landscape quality are compared to the authors' experience during field visits and to interview results. Accuracy of calculations on the carbon balance of the study area and findings from map studies are checked against several findings in literature. Calculation of the effect of models and designs on carbon balance, are included in the annex. The numbers are triangulated on more general numbers from the Dutch nursery sector. Authenticity and originality are sought, by reflecting on whether the spatial building blocks are worthwhile and multifunctionality is considered throughout the design process. Design decisions are made in search of originality. Transferability is only considered in the reflection chapter. The possibility of wider application of research results is discussed.

Worldview

A change in paradigm (Posad Spatial Strategies / Generation.Energy et al., 2018) is needed to make a transition to a carbon neutral landscape possible. As demonstrated in de Jong and Stremke (2020) our landscapes have been shaped by energy transitions. As mentioned before, a cultural identity evolves over time, and what is despised at first glance, can become protected cultural heritage generations later.

This thesis aims to look ahead and tries to identify beauty in an agri-energy landscape of the future. The choice is made to consciously react to this landscape that is a result of the past. At the same time, a contemporary use is sought for old elements, not everything can be preserved. For example, undisturbed peat relicts, can have a new ecological function. This approach also entails the embrace of an aesthetic that foregrounds production of energy and carbon neutral products.

'Foregrounding suggests a strategy for making infrastructure more visibly useful' (Czerniak, 2013). Besides its energy- or agricultural function, infrastructure can contribute to habitat creation and community revitalization. It can have an aesthetic value and serve as an attraction. Worthwhile examples of foregrounding of energy infrastructure are the heat plant on the Sciencepark, in Utrecht, the Netherlands (dok architecten, no date), the Blue lagoon spa in the Svartsengi Geothermal Power Station, in Iceland (HS Orka, no date) and more can be found on the website of Land art generator (Lagi, no date). Foregrounding of agricultural infrastructure is exemplified in the project of Eliza Hague, who designed origami-like greenhouse (Dezeen, 2020) and in the thesis of Joanne Li (Li, no date), who redesigned sheep farms as a 'land art museum and evolution lab'.

Foregrounding is used to create a shift in values and provoke thoughts about the relations people have towards energy- and horticultural infrastructure. In this thesis, this strategy is adopted in the hope to accelerate the shift in values and to generate acceptance of, and a love for, our future energy- and agricultural landscapes.

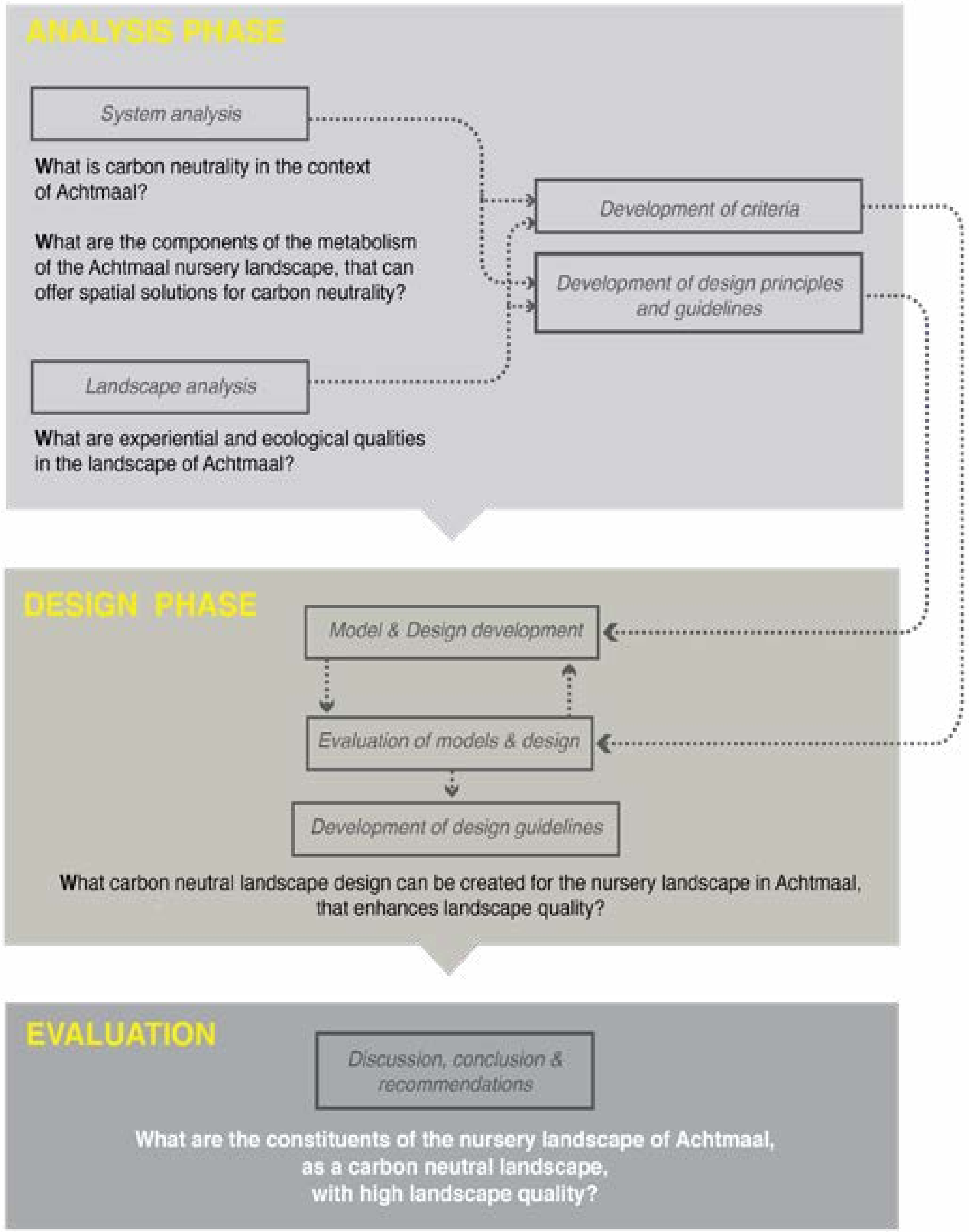


Fig. 17 Research process

2.3 Methods

In fig. 18 a description of the different methods used for each phase and research question is shown. This scheme includes a brief description of the type of data that is used and the resulting products per method are indicated.

Phase	Research question	Method	Specification	Data	Result
Analysis phase	What is carbon neutrality in the context of Achtmaal?	*Interviews with inhabitants and nursery owners*	Gather data on cenergy consumption and production, amounts of input materials used to grow the seedlings and outputs		Overview of metabolism of the nurseries
		Triangulation of findings from scientific and grey literature review, with results from site visits and interviews with inhabitants and nursery owners	Further define carbon neutrality in the context of Achtmaal. Combine available data on emissions of plant nursing, to make an educated estimation of current impact of different components on current carbon cycle of area. Relevant inputs for analysis: Current and future energy consumption and production, spatial distribution of current nurseries, amounts of input materials used to grow the seedlings	Forums, articles, Dutch landscape appreciation literature, notes and pictures field visits, interviews	Borders of study site and boundaries of carbon balance. General numbers about nurseries' impact on carbon cycle.
	What are the components of the metabolism of the Achtmaal nursery landscape that can offer spatial solutions for carbon neutrality?	*Analysis of the metabolism of the nurseries of Achtmaal*	Analyse the components of the metabolism for their suitability as spatial building blocks.	Open databases map materials, literature, interviews, websites of the nurseries	Spatial building blocks for a carbon neutral landscape in Achtmaal
		Development of criteria	Formulate criteria for testing of designs in Research through Design phase		Numerical input for the model study calculations
		Developing design principles and guidelines	Create design principles an guidelines for spatial solutions for carbon neutrality		(Spatial) conclusions about components that can or cannot serve the development of a carbon neutral design for Achtmaal. Overview of available architectural building blocks.
	What are experiential and ecological qualities in the landscape of Achtmaal?	*Interviews with inhabitants and nursery owners*	Gather vernacular knowledge about the landscape quality		
		Multi layered landscape analysis	Asses landscape quality. Relevant layers: geomorphology, cultural historical elements, hydrology, soil, habitats, aesthetic qualities of the landscape, land use, infrastructure and routes	Maps, notes and pictures field visits, interviews, articles, , articles, Dutch landscape appreciation literature, notes and pictures field visits, interviews	Sections, visuals and layered landscape map(s): explaining the landscape and spatialising problems and potentials. Incl. time factor.
		Development of criteria	Formulate criteria for testing of designs in Research through Design phase		Criteria for model evaluation matrix
		Developing design criteria, design principles and guidelines	Create design principles an guidelines for improved landscape quality		(Spatial) conclusions about components that can improve landscape quality of Achtmaal
Design phase	What carbon neutral landscape design can be created for the nursery landscape in Achtmaal, that enhances landscape quality?	*Development and evaluation of models*	Shuffling the land uses and building blocks found in the Research for design phase & designing different alternatives		Maps and schemes of the models, evaluation matrix
		Development of design and testing of design hypothesis	Repeat the assessment of the carbon neutrality of the design		Maps, visuals, schemes and sections of the design
		Development of design guidelines			Design guidelines
Evaluation phase	**What are the constituents of the nursery landscape in Achtmaal, as a carbon neutral landscape, with high landscape quality?**	*Discussion of results*	Critical discussion of methods and results		Textual
		Conclusions and recommendations	Summarizing findings, drawing conclusions about wider application of results, recommendations for further research		Textual

Fig. 18 Methods

3

Results

3.1 Analysis phase (RfD)

In the research for design phase, it is researched what carbon neutrality is in the context of Achtmaal. The components of the Achtmaal nursery landscape that can offer spatial solutions for carbon neutrality are identified. Landscape quality in the context of the study site is researched. A site analysis leads to conclusions in the form of design principles and guidelines.

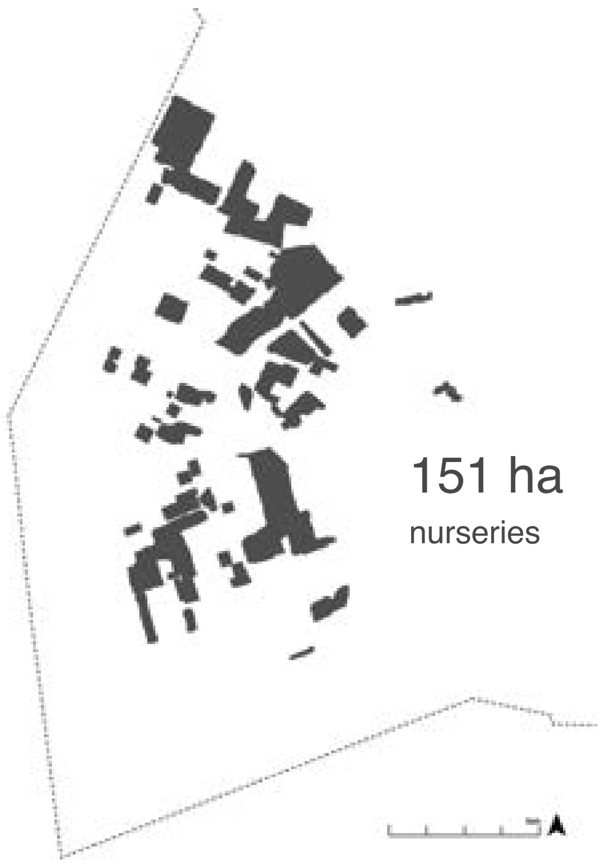


Fig. 19 Location of the nurseries

SITE ANALYSIS

CARBON NEGATIVE PRODUCTION LANDSCAPE

In order to design a carbon neutral landscape, an analysis of the carbon cycle of this landscape has to be made. A closer look at the metabolism of nurseries creates an understanding of the components that offer spatial solutions for carbon neutrality (fig. 20).

Character sketch of the nurseries and their metabolism

There are about seven big nurseries in the study area. Their total surface area spans 151 ha (fig. 19). The seedlings and plants are grown in the ground, in containers, in greenhouses and in tunnels. Species range from hedge and shrub plants to small trees and ornamental pot plants. At the age of one to three years, the plants are sold to gardeners, landscapers, other nurseries, wholesalers, retail shops and national and international traders. Besides the plants, the material input for the nurseries also travels. See annex 1.

From the interview with nursery owner Leenearts (annex 2), it became apparent that it is common practice to import a big share of the materials that are used as input to grow the seedlings. In his case the peat in the growth substrates comes from the Baltic countries, pots from Germany and Great-Britain and wood for crates from Czech Republic.

The fossil fuel for the agricultural plastics and for the operation of agricultural implements doesn't originate in the Netherlands neither. Energy usage for lighting, cooled storage, irrigation, heating of office buildings is supplied through the regular energy grid. Depending on the energy provider of the nursery, this is renewable or fossil energy. See annex 2.

Some of the input materials for the nurseries, are made locally, like pot covering granules and breeding material or cuttings (Annex 1). Other local materials are compost from the local compost plant and manure from the nearby cattle farms (Annex 2). Emissions of transport are nearly absent in this case. However, usage of local materials can still add to emissions when, during the production of these materials, GHG's are released into the atmosphere.

Fig. 20 The flows of carbon are visible in the landscape in the form of the materials and transport. Image source (author, 2021)

Current carbon balance

On the next pages the carbon balance of the study area is diagrammatically illustrated Sankey style (fig. 21). The calculations underlaying this diagram can be found in annex 3.

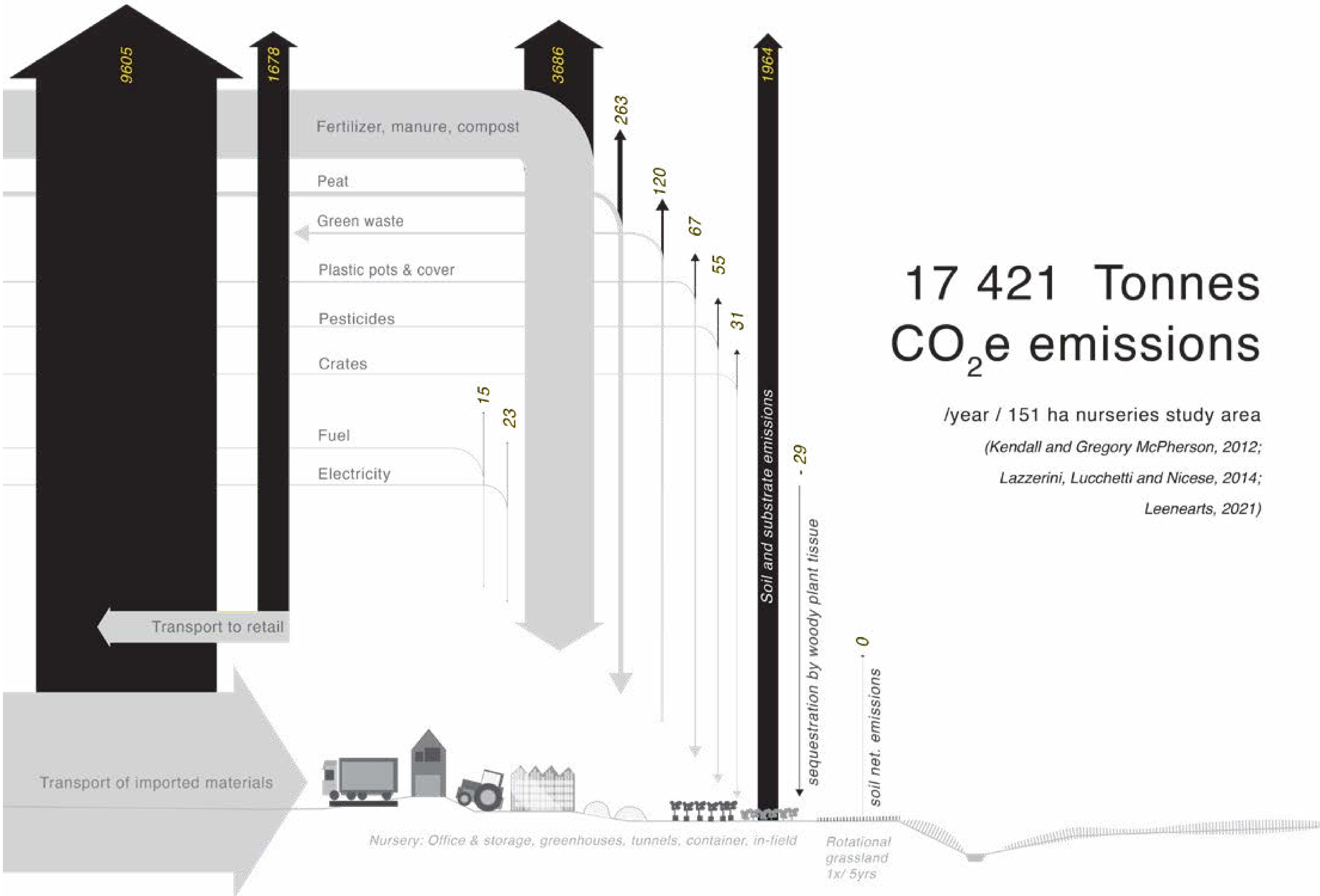
Based on the interview with nursery owner Leenaerts (annex 2) and on data from articles on lifecycle assessments of nurseries and trees (Kendall and Gregory McPherson, 2012; Lazzerini, Lucchetti and Nicese, 2014) calculations were made to estimate the current carbon balance of the 151 ha of nurseries in the study area.

The emissions in the study area, 115 Tonnes/ha/year, seem relatively high compared to the estimation of maximum 35 Tonnes/ha/year for the Dutch sector. This can partially be explained by the inclusion of transport to retail, use of manure and compost, green waste emissions, transport emissions of plastic covers and crates. Numbers for transport of raw materials to the nurseries were estimated based on numbers from Kendall and Gregory McPherson, (2012). Transport numbers are partially excluded, and partially researched in a different context in Lazzerini, Lucchetti and Nicese (2014), which provided the numbers that were used to make the calculation for the sector. A Life Cycle Assessment for this study area would clarify this discrepancy and provide numbers that are specific and accurate for this landscape. However, the numbers in fig. 21 are used to proceed with this research.

Transport of materials like peat, pots etc. to the nurseries is a big contributor to the emissions. Fossil fuels are used to transport these materials.

The production of the materials before they get to the nurseries and the emissions of bare soil and substrates are the second biggest source.

The equation shows a positive carbon balance. By the time that plants arrive at retail or forestation project, the project is already in carbon debt. Whether the plants sequester enough to compensate this, is dependent on factors on the planting site. The focus in this research is on what can be changed in the nursery landscape itself.



17 421 Tonnes CO_2e emissions

/year / 151 ha nurseries study area

(Kendall and Gregory McPherson, 2012;
Lazzerini, Lucchetti and Nicese, 2014;
Leenearts, 2021)

Fig. 21 Current carbon balance of study area

Components that offer spatial solutions for carbon neutrality

To answer the research question: 'What are the components of the metabolism of the Achtmaal nursery landscape that can offer spatial solutions for carbon neutrality?' several approaches are useful.

Trias seminarium

The 'trias seminarium' (Fig. 23), inspired by the 'trias energetica', presents three strategies to reach carbon neutrality and use the available resources sustainably. The solutions in yellow boxes are spatial elements that can be used in the design phase.

The first strategy is conservation. Due to the large share of emissions coming from transport, I strongly argue for localizing the production of the material input for the nurseries. To create economic and functionally more resilient landscapes (Keeffe, 2013) argues for this diversification in scale of economies. The global monocultured markets are partially replaced with more local production and the scale production is matched to the scale of the landscape in his vision, to avoid a system that is too vulnerable due to dependency on global markets.

Wood used in transport crates can be grown locally. Just as some of the materials in the 'alternatives' strategy of the trias.

The second strategy is to replace the materials that have a polluting production process, with carbon extensive alternatives. Replace the use of fossil fuels, used for transport to retail, machinery, and lights, with renewable energy sources. Replace peat with pine bark, that can be made into substrate to grow plants on by a Dutch company called Lensli (R. Keijzer, personal communication, May 5, 2021). Fossil based plastics in pots and covering sheets can be made of the sugars in beetroots, corn, or rice.

The third strategy is to improve the efficiency of use of remaining (fossil) resources. This also relates to 'going local', local resources are used, instead of going wasted. These are the least favourable measures, because they don't prevent emissions as much as the other two strategies. The spatial element that is useful from a landscape architectural perspective is a circular approach to the embodied energy in buildings, materials, and infrastructure. Where possible they should be reused, repurposed, or recycled. The existing nurseries should remain mostly in their place. Energy went into cultivating the soil, into building the roads that make them accessible and into the buildings and other infrastructure.

The net effect of land use change should move up on the 'carbon ladder'. For example, natural grasslands cannot change to nursery or rice fields. Some nurseries might need to become forest, if needed to improve the carbon balance.

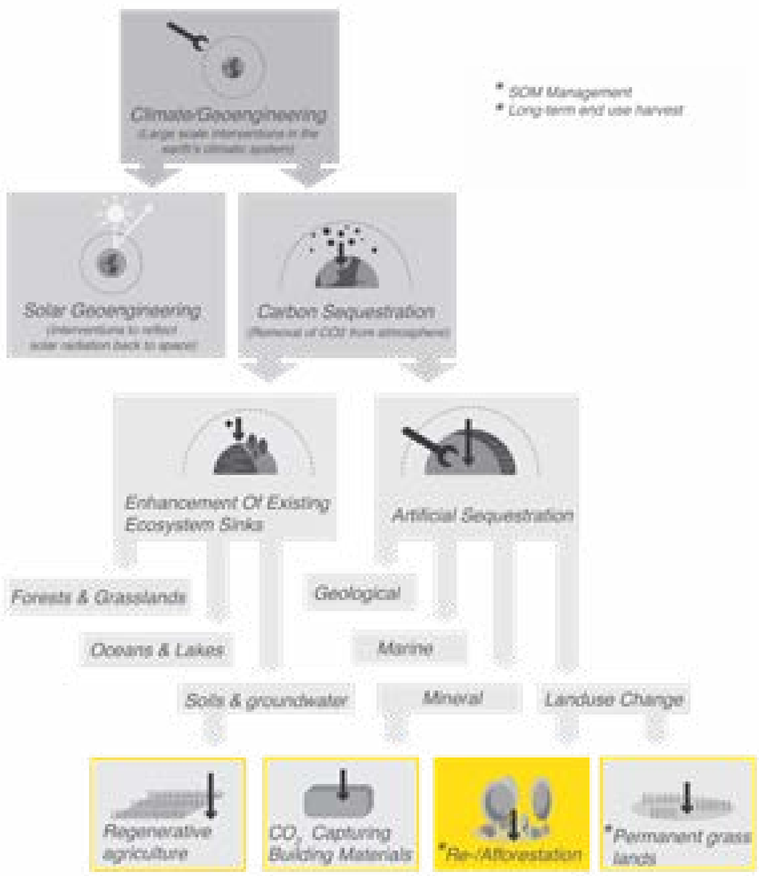


Fig. 22 Compensate for remaining emissions by planting sequestration forest

Sinks

To reach full carbon neutrality, or a carbon negative landscape, sinks need to be created and maintained. Fig. 22 shows that carbon sequestration is a useful component of climate/geoengineering, from a landscape perspective. There are several ways to sequestrate carbon, of which the four yellow-highlighted blocks at the bottom of the scheme show potential as spatial interventions in the study area.

Introducing sequestration forests is an intervention with multiple positive side effects. It can give structure to a cluttered landscape and connect the nature areas surrounding the study area.

Using locally harvested pine to produce Cross Laminated Timber (CLT), which is a long term end use product, could also store carbon.

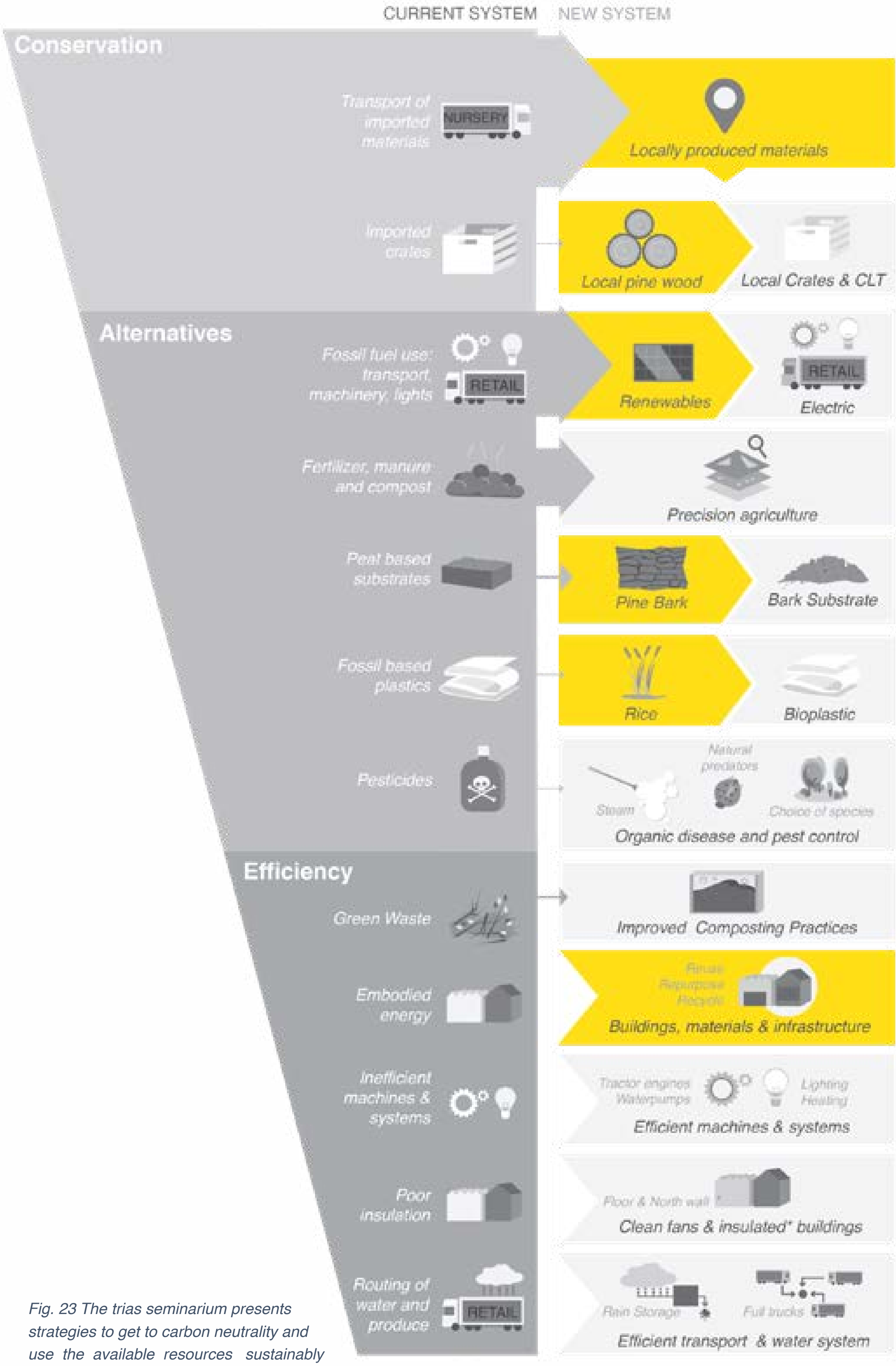


Fig. 23 The trias seminarium presents strategies to get to carbon neutrality and use the available resources sustainably

It is a process

Carbon plays a role in the implementation or realisation phase of the design. Carbon emitted during creation of a new landscape can be set off over time. For example, generally a solar panel needs about three years to offset its carbon footprint, after production and implementation. As shown before in this thesis, forest also needs to offset its footprint. Additionally, a ha of new forest will capture '4,6 Tonnes CO_2 per year, in the first ten years after planting and after that 9,1 Tonnes per year' (Klimaatslim Bos- en Natuurbeheer, 2020). Therefore, the landscape will only gradually reach carbon neutrality or become carbon negative.

Conclusion spatial solutions for carbon neutrality in study area

Currently, the 151 hectares of nurseries in the study area account for yearly GHG emissions of 17421 Tonnes. To offset these emissions, 1921 ha of forest could be planted, but several other possibilities exist, that will be tested in the research through design section of the research results. In annex 3 an overview of the amount of GHG that can be stored or prevented to enter the atmosphere per land use.

LANDSCAPE QUALITY ACHTMAAL NURSERY LANDSCAPE

The analysis of the site is twofold. The systemic analysis of the carbon balance is complemented with an analysis of the biosphere, focused on landscape quality.

History and character sketch of the achtmaal landscape

The genesis of this area is a culmination of geomorphological and cultural factors (Fig. 24a). In the Pleistocene this area was a sandy desert, rivers deposited sand and clay. Sand was blown around, and shaped sand ridges along an East-West direction (Bureau Lantschap, 2009). The stream valleys emerged in lows between the ridges. Later, in the Holocene peat grew on the sandy soils (Bureau Lantschap, 2009). On the higher sandy ridges, where the peat layer was absent, it was easy to settle and Achtmaal and Zundert appeared. The slight elevation differences are still visible in the landscape.

From the 13th until the 19th century (Bureau Lantschap, 2009) the vast peat layer was dug out, transported through canals and sold as fuel. The peatbog at Matjens was excavated between 1500-1700 and became a reed swamp. The other reclaimed land was largely cultivated for agricultural purposes and some 'woeste', or wild, grounds remained occupied with heathlands, stream valley forest and fens (Bureau Lantschap, 2009). Between ca. 1800 and 1900 estates emerged, and from 1900-1935, in Achtmaal a big production forest covered a large surface area around the 'Oude Heihoeve' (Fig. 24b).

When fertilizers were invented and popularised, this area, which I will refer to as the young reclamation landscape of Achtmaal, got transformed into agricultural land that was of a larger scale than the surrounding old reclamation grounds (Fig. 24c).

During this reclamation process the peat canals appeared, moved position, and disappeared (kadaster, no date). Today, the 'Turfvaart', 'Berkenbeek' and 'Kleine beek' (in Matjens) remain.

The recent Zundert 'ruilverkavelingen', or land consolidations, that were only finalized in 2010 (J. de Beer, personal communications, Feb 17, 2021), affirmed the scale difference between the old and young reclamation landscape.

Zooming in to the current area of Achtmaal, it can be noted that the landscape is divided in three types or spheres. Firstly, the NNB estate forests in the North (Fig. 25). The second, central area is characterized by a mix of agricultural uses from agricultural grassland to food crops and nurseries (Fig. 26). Tufts of forest occasionally form little islands. This is the area of the actual study area. The third area, in the South is the NNB reed swamp Matjens (Fig. 27).

Experiential quality- Aesthetics

On the next page fig. 28 displays pictures from several field visits. This selection shows aspects that detracted from my aesthetic experience: small plots and plants, lack of repetition and unity, incoherent and messy compositions of farmyards and some blunt advertisement, fragmentation, and disturbance of views in an open landscape, some fencing in views that give an unwelcoming feel and bare soil under and surrounding trees and plants that give a dead feeling. The nature area through the centre is hard to find. In Noord-Brabant, reserving room for nature is rated as top priority by inhabitants, the biggest worries about the future landscape concerns the disappearance of birds, flowers, insects, trees, shrubs and hedgerows (Buijs et al., 2019).

From field visits and interviews with nursery owners and inhabitants (annex 2) it is apparent that this landscape is partially experienced as messy and cluttered. There is a lack of unity in buildings and

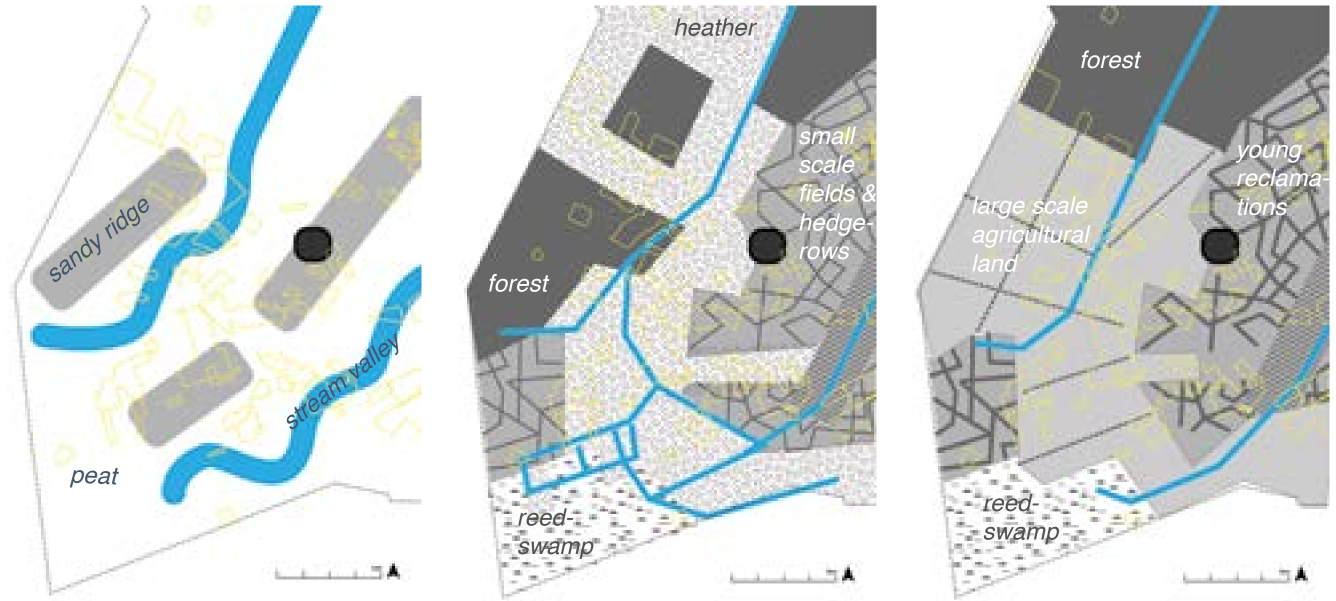


Fig. 24 Historical development of the Achtmaal landscape: a (Pre) Middle Ages, b 13th-19th Century, c 20th Century - 2010

Fig. 25 Spheres: The edge between the nurseries and the estates in the North (left) with heather and forest (right)

Fig. 26 Spheres: Agriculture in the lineairity of the young reclamation landscape, in the streamvalley (left) and on the higher grounds (right)

Fig. 27 Spheres: Peat reclamation relics (left) and the reetswamp of Matjens in the South (right)

the small-scale green structures, that exist(ed) in the old reclamation landscapes in Zundert, are absent here. However, the diversity in land use is also mentioned by interviewees as a quality that characterizes the area. In Buijs et al. (2019) it is also indicated that area specific characteristics, like scale of the landscape are rated as important to preserve, by inhabitants of the Dutch landscape. Inhabitants of Noord-Brabant rate buildings on farmyards and housing as most determinative buildings for the image of the landscape (Buijs et al., 2019).

Readability of current and historical land use can be improved. The natural NNB connection through the area is very narrow and not easy to follow in the North-South direction. Peat relicts along the Turfvaart are relatively hidden. The Turfvaart could easily be mistaken for a ditch in this area and difference between the sunken stream valley and higher grounds could be accentuated.

A first solution is to improve landscape quality, the experience of production practices, and of natural connections needs improvement.

A robust (semi) permanent green structure can help. As mentioned before, the age of the seedlings and plants usually doesn't exceed three years. This means the hight of the plants is relatively low, from centimetres up to a meter. They don't have arcadian qualities as a structuring element. Their aesthetic quality lies in patterns, rhythm, and repetition, which can be framed and emphasized by new green structures or new infrastructure. The patterns are easier perceived from a higher vantage point, like a view platform. A robust green structure would not only frame the nurseries, but also provide a framework for buildings and other objects on the farmyards (fig. 30).

A rich undergrowth for older plants would bring life to the experience of this production landscape and has potential to contribute to the biodiversity. To reveal production practices, the nurseries need to be made accessible. Absence of fencing is a bare minimum requirement. Opening routes through greenhouses and fields would invite people to emerge themselves (fig. 29). An additional solution is enhancement of the readability, while preserving diversity. On the map in fig. 36 on page 47, the nurseries (in bright yellow) line the elevated sides of the wetter and lower lying geomorphological stream valleys. The stream valley and reclamation relicts can be accentuated with vegetation types differing from the types on the higher grounds. Routes in North-South direction are needed to make the natural area experienceable.

Experiential quality – Accessibility, tourism and liveability

The nearest train stations to the study area are Roosendaal (NL) and Essen (BE)/ Wildert (BE). The nearest bus stops are in Achtmaal and Nieuwmoer (BE). It takes 1hr and 15 minutes to travel from Rotterdam central to Achtmaal bus stop by public transport. The town is accessible in that way, but the study area lacks a stop. The same travel time applies for the public transport connection from Antwerpen to Nieuwmoer.

Concerning bike rentals; the nearest 'OV-bikes' are parked at Roosendaal station. The distance from that station to the edge of the study area is 15 km. A bike ride would pass through the Rucphense forests after 9 km. The Belgian stations don't have a 'Bluebikes' parking (fig.31). The distance is bikeable, but requires a sporty attitude or an e-bike.

An extra bus stop on the existing line 220 in the study area would make the area more accessible for people that want to go for a hike (fig. 32).

It takes some effort to get to the study area by public transport, therefore a landmark or special point of interest could lure visitors to the area. There is enough space for leisure in this landscape (J. de Beer, personal communications, Feb 17, 2021). Visitors can generate an extra income. A suitable landmark would be a wind turbine with view platform (fig. 34). The base could form a renewable charging station for e-bikes. Such a landmark would also add to the readability of the landscape and provide a point of orientation. The experience could create awareness of a new type of landscape: a carbon neutral production landscape.

Fig. 28 Room for improvement in aesthetic experience. Image source (author, 2021)

Fig. 29 Reference image for accesible experience of production. Image source (PR dddk.nl, 2015)

Fig. 30 Beautiful repetition and rhythm can be framed by green structure or new infrastructure. More apparent from higher vantage point. Image source (author, 2021)

Fig. 31 Accessibility for cyclists. Image edited from (Stravamap, 2021)

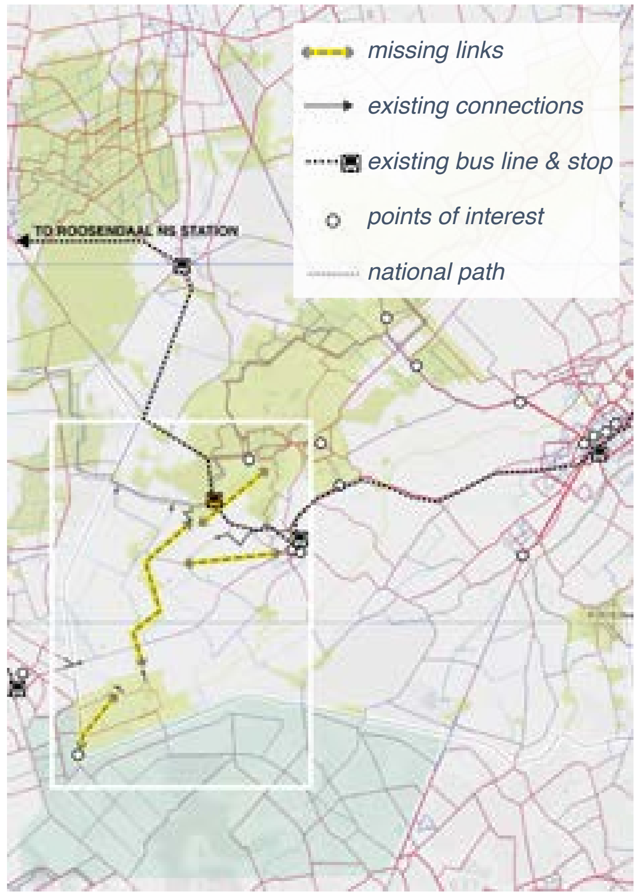


Fig. 32 Accessibility for pedestrians. Image edited from (Stravamaps, 2021)

System quality – Ecology

In the plans for Nature Network Brabant 2027 the province identifies missing links between existing nature areas (Provincie Noord-brabant, no date) (fig. 33). The targeted nature types are also indicated by the Province.

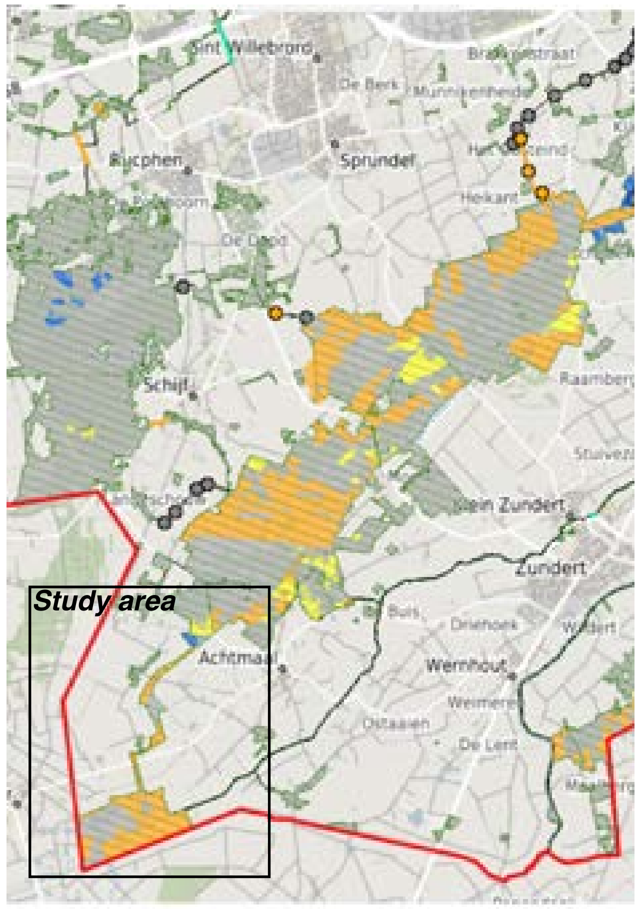
Fig. 38 shows the habitats that are currently not optimally connected, through a small strip of natural grassland and some tufts of forests along the Turfvaart. The main habitat in the yellow areas is pine, oak and beech forest, as described by Bij12 (no date b). Introducing this forest in the study area improves the connection.

Wet forest, as described by Bij12 (no date a), can grow on wetter grounds in the centre of the study area, along the Turfvaart (fig.37). It also forms a suitable ecosystem to connect habitats in the North and South. Like the pine oak and beech forest it is a habitat for red list species, the Oriole and Hawfinch. Variation and a rich forest edge is a requirement for both forest types and 80% of the forest surface cannot be harvested (Bij12, no date a, no date b). The variation is also important to prevent trees like willow to spread large number of seeds to the nurseries, to prevent an overload of weeding work (Leenearts, 2020). For carbon storage purpose, the survival rate of plants is important. Diversity of varieties and species increases the resilience of a habitat.

System quality - Water system

The Turfvaart is polluted with zinc and cobalt, and an excess of nitrogen and phosphor causes eutrophication (Beers et al., 2019).
To improve water quality, and hence biodiversity, buffers of sunflower and canola can filter the metals and excess nutrients from the shallow groundwaters in the nursery fields (Jadia and Fulekar, 2008; Abdel-Sabour and Al-Salama, 2007) (fig. 35). Buffers need to extend in context dependent spray free zones.

(Future) droughts (Geodan, no date) in the area can cause problems for the biodiversity and production. To create a sponge effect water levels in the lows can be raised and forest can be planted. The water retaining capacity of a forest floor is generally assumed to be higher than that of grassland, due to less surface runoff and higher infiltration rate.



Existing NNB   Planned NNB

Fig. 33 NNB map of existing and planned habitats. Image source (Provincie Noord-Brabant, 2021)

Fig. 34 Reference image suitable landmark for the study area. Image source (Knie,n.d.)

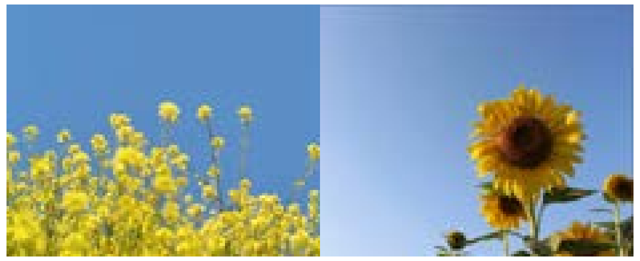


Fig. 35 Buffers of sunflower and canola can filter the metals and excess nutrients from the shallow groundwaters in the nursery fields. Image sources (istockphoto, n.d.; pixabay, n.d.)

Fig. 37 ***Top****: N14 Wet forest can grow on wetter grounds in the centre of the study area, along the Turfvaart. It forms a suitable ecosystem to connect habitats in the North and South. Waterlevels can be raised and the forest floor can function as a sponge. Image source (prachtlint, n.d.)*
Bottom: *a rich forest edge is a requirement for both forest types. Image source (de Redelijkheid 2012)*

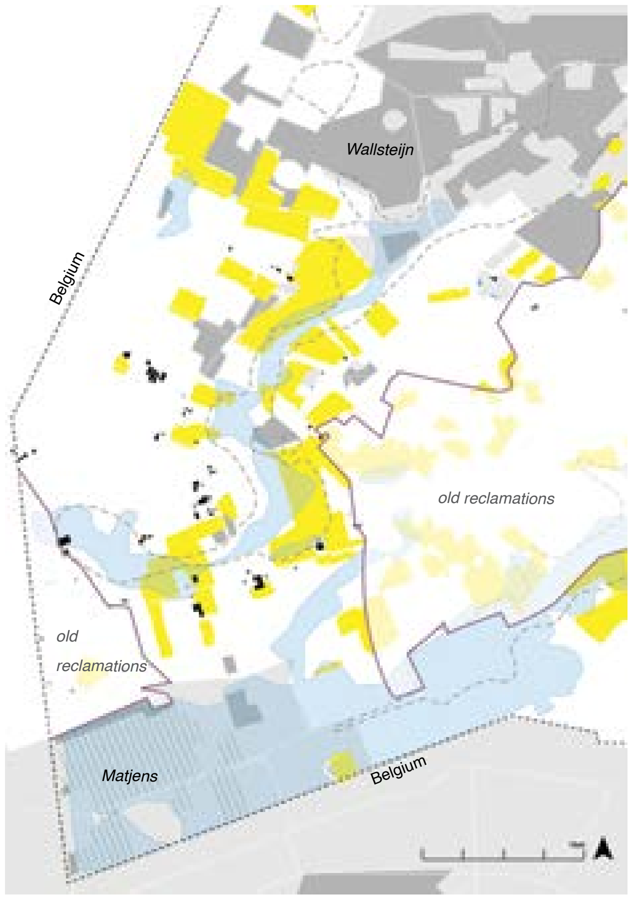


Fig. 36 Landscape structure map. Nurseries in yellow, existing forest in dark grey, nature reserves in light grey. In blue the wetter areas, and lowerlying stream valleys are indicated by the grey striped line.

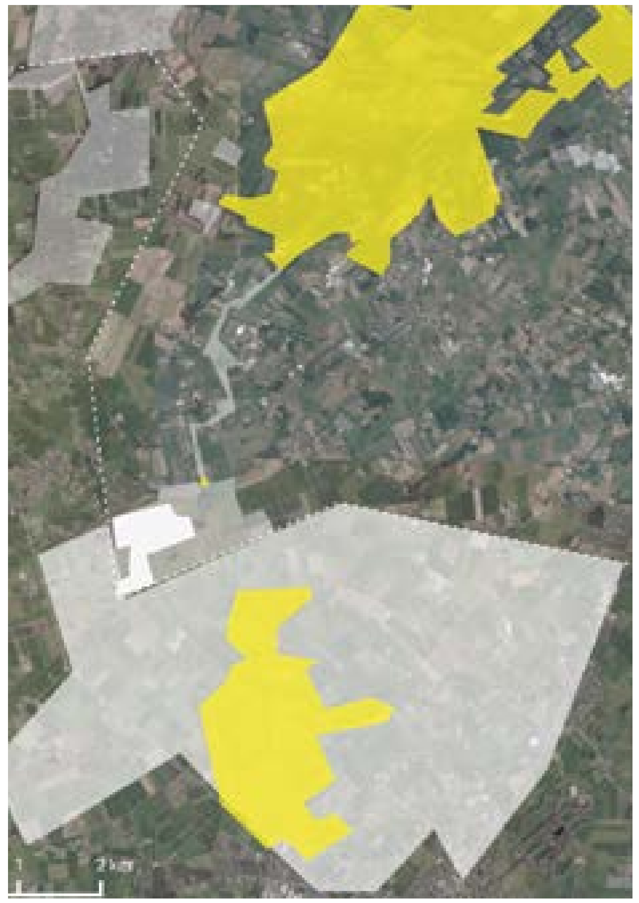


Fig. 38 Habitats to connect (yellow) are N15.02 Pine, oak and beech forest. In white the reedswamp of Matjens and in transparant white the additional nature reserve areas.

DESIGN PRINCIPLES & GUIDELINES FROM THE RESEARCH FOR DESIGN PHASE

To create a bridge between the research through design phase and the research for design phase, the findings of the research for design phase are summarised in design principles and guidelines.

The abstract design principles ‘are […] used to describe general principles that are valid for the design-area as a whole […] and to denominate function for an area’ (van Etteger, 2016).

A design guideline is spatially more specific. ‘It exemplifies how the [design] principle [...] can be applied in a certain prototypical solution [for a typical situation within the study area]’ (van Etteger, 2016).

From the analysis several principles and guidelines can be distilled:

1.1 DESIGN PRINCIPLES CARBON NEUTRALITY

1.1.1 Going local to avoid transport emissions

1.1.2 Fossil resources are replaced with alternatives

1.1.3 Improved efficiency of use of remaining (fossil) resources

1.1.4 Creation of carbon sinks

1.2 DESIGN PRINCIPLES LANDSCAPE QUALITY

1.2.1 Improved experience of production practices and of natural connections

1.2.2 Enhanced readability, while diversity is preserved

1.2.3 Improved water quality

1.2.4 Increased sponge capacity of the area, to mitigate droughts

1.2.5 Strengthened connection between habitats on both sides of the study area

1.3 DESIGN GUIDELINES CARBON NEUTRALITY

1.3.1 Implement renewable energy sources for transport, machines, and lights

1.3.2 Plant pines to harvest bark for substrate, and wood for crates and CLT

1.3.3 Grow rice for bioplastic

1.3.4 Introduction of sequestration forest

Buildingblocks

1.3.5 Reuse, repurpose, recycle buildings and infra

1.3.6 Keep nursery fields where they are, where possible

1.3.7 No land use change from natural grasslands to nursery or rice fields

1.4 DESIGN GUIDELINES LANDSCAPE QUALITY

1.4.1 Introduction of a (semi) permanent green structure around farmyards and nursery fields

1.4.2 Production is framed by (renewable energy) infrastructure

1.4.3 Introduction of rich (temporary) undergrowth under plants and seedlings

1.4.4 Stream valley and reclamation relicts can be accentuated with vegetation

1.4.5 Introduction of routes in North-South direction

1.4.6 Introduction of extra bus stop on existing bus line through the area

1.4.7 Introduction of landmark/point of interest in centre of study area

1.4.8 Creation of buffers of sunflower and canola in nursery fields, intercepting shallow groundwater on its way to surface water

1.4.9 Raised ground water levels in the low lying areas to create larger ground water buffer

1.4.10 Forest can be planted to create sponge

1.4.11 Introduction of two forest habitats, depending on groundwater levels, with varied species and a rich forest edge

3.2 Design phase (RtD)

In the research through design phase, it is researched what carbon neutral landscape design can be created for the nursery landscape of Achtmaal, that enhances landscape quality. A model study compares the different ratios of building blocks and evaluates the spatial implication. The winning model feeds into the landscape design. The landscape design is tested through sections and site designs. Conclusions from this phase take the form of design guidelines. These differ from the guidelines in the RfD phase. The knowledge from the RfD phase is integratedz in the RtD phase. Carbon neutrality meets landscape quality and the guidelines from the RfD phase are tested in designs on several scales.

LANE DESIGN I

Lanes seem to be a suitable element to introduce to this relatively large-scale young reclamation landscape. The pines, that are needed to provide the materials to replace peat and crates and can also be used for CLT, need to be easy to harvest. Energy can be saved by planting them along a path of a minimum of 3 m wide, that can simultaneously function as a path for people visiting the area. The new lanes can connect to the existing tree rows and lanes. They can improve the North-South connections and experience of production.

This cross-section (Fig. 40) represents a typical photovoltaic (PV) pine lane in North- South direction.

The PV panels are introduced in the lane to produce the energy needed for the production process of the area, but also to shade the new seedlings and soil after harvest of the pines. 'Thinning affects C sequestration by reducing the amount of tree biomass and OM [organic matter], and by stimulating microbial decomposition as more solar radiation and throughfall precipitation reaches the forest floor' (Lorenz and Lal, 2010, p. 128). The shading by solar panels is expected to help to preserve the soil organic content.

PV can also protect the new seedlings against heavy rain or hail. Any shade tolerant plants grown by the nurseries are most suitable to grow in such an agrivoltaic system in the lanes. Yield losses are minimized (Dinesh and Pearce, 2016) or even increased (Amaducci, Yin and Colauzzi, 2018) for these species when grown under PV arrays.

An East-West orientation is chosen for the PV arrays. The electricity provision by this type of panel is relatively better divided over the day. More energy is produced closer to peak usage hours, compared to south oriented panel (Spruijt and Terbijhe, 2016).

The rhythm of the lane is shown in this sideview (Fig. 41). The number of subsequent trees of the same age can vary. To keep the rhythm, it is desirable to let the order be ascending in age. Plus, the line of trees of one age, is followed by the same distance of trees of another age. The first harvest happens after 19 years, the PV panels are added. Depending on demand and aesthetic considerations another harvest can happen after 32 or 50 years.

SEESAW MODEL STUDY

The spatial building blocks from the RfD phase are renewable energy sources, rice, harvestable pine trees and sequestration forest. The pine trees are used in lanes in the models (see Lane design I). With the spatial building blocks and the landscape quality analysis in mind some models are designed and tested.

Fig. 39 represents the current situation in the study area and forms the baseline. Per ha of nursery 116 Tonnes of CO2e are net released every year. The balance is positive. During the production process more GHGs are produced than stored.

On the next pages follows a description of each model, with a numerical carbon evaluation and an evaluation of the spatial implications, as they vary in their impact on the carbon balance and landscape quality. The calculations that the models are based on can be found in annex 4.

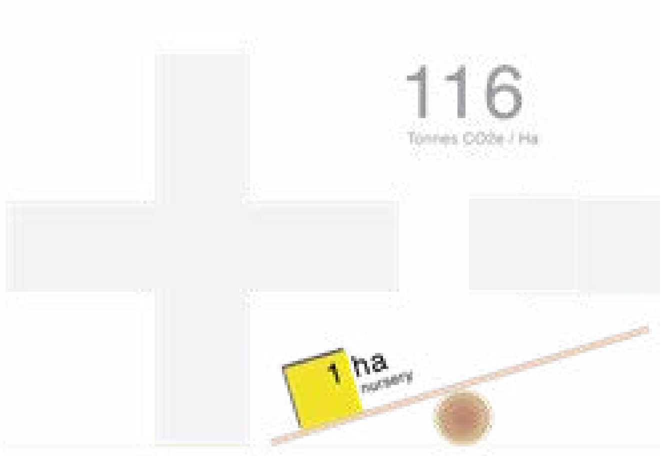


Fig. 39 Seesaw study baseline model. In the current situation one ha of nursery is responsible for 116 Tonnes CO2e emissions/year.

Guidelines lane design

- East-West oriented PV arrays
- PV shades new pine seedlings and disturbed soil after pine harvest
- PV arrays are multifunctional
- Path min. 3 m wide for easy access harvest machines
- Ages of pine in ascending sequence
- Big pines placed so they don't shade the PV
- Pines planted in undeep ditch, to prevent soil erosion (and loss of soil organic carbon (SOC)) after harvest

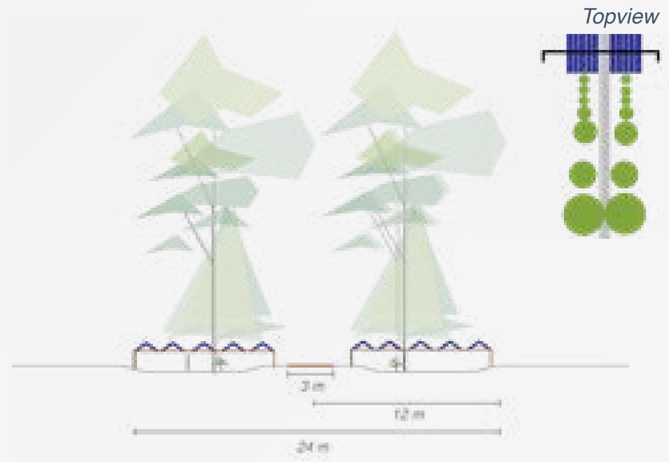


Fig. 40 Cross section standard PV pine lane in N.-S. direction

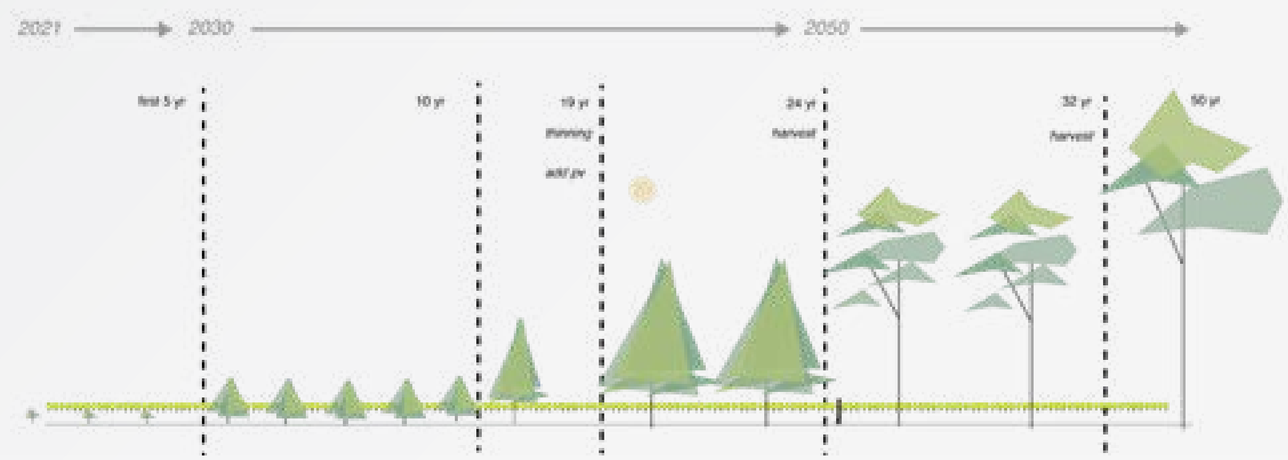


Fig. 41 PV pine lane, elevation of the trees over time creates a rhythm

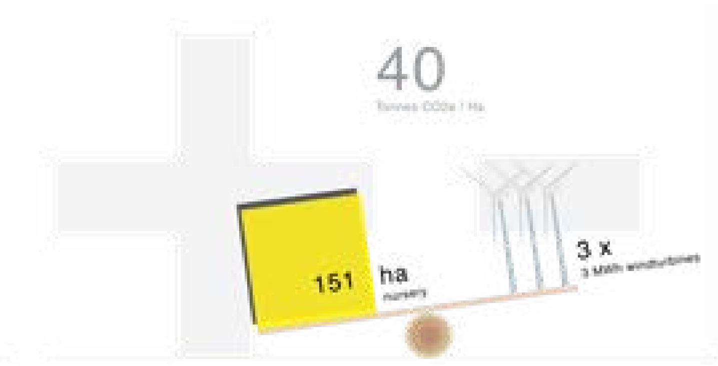


Fig. 42 The wind model does not reach carbon neutrality

Description wind model

On the seesaw in fig. 42 the 151 ha are weighed against renewables, to simulate a simple energy transition. In this model energy consumption emissions (incl. transport of materials to nurseries) are avoided by introducing three 3 MWh wind turbines to the area. In this model all (current) fuel use is replaced by electricity. The remaining emission balance is 40 Tonnes CO2e/ha/yr.

Fig. 44 The lane model does not reach carbon neutrality

Description lane model

On the seesaw in fig. 44 one ha of nursery is weighed against the standard PV pine lanes, to see whether these could enhance connections. In this model the emissions of both substrates and crates, coming from production and transport of these materials is avoided. Per ha of nursery to the area on average 1 m of lane would be enough to establish this. For the whole 151 ha this would mean only 130 m of lane. This amount would not be enough to create the missing connections. The remaining emission balance is 114 Tonnes CO2e/ha/yr.

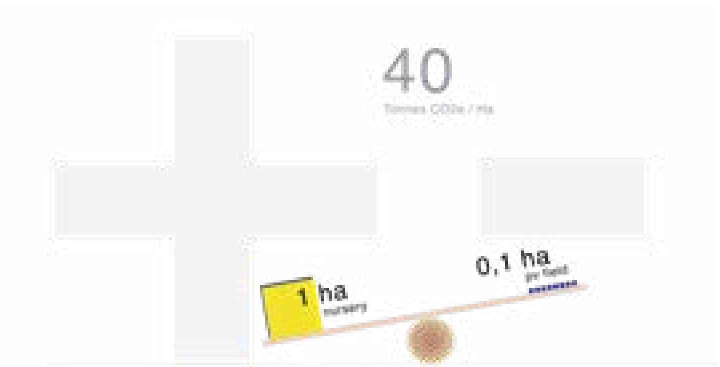


Fig.43 The PV model does not reach carbon neutrality

Description photovoltaic (PV) model

On the seesaw in fig. 43 one ha of nursery is weighed against renewables for the whole area, to simulate a simple energy transition. In this model energy consumption emissions (incl. transport of materials to nurseries) are avoided by introducing 0,1 ha of PV field per ha of nursery to the area. For the whole 151 ha this would mean 17 ha of PV fields. In this model all (current) fuel use is replaced by electricity. The remaining emission balance is 40 Tonnes CO2e/ha/yr.

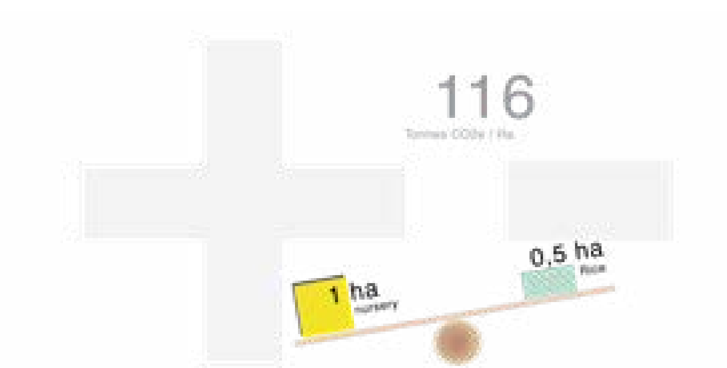


Fig. 45 The rice model does not reach carbon neutrality

Description rice model

On the seesaw in fig 45 one ha of nursery is weighed against rice fields. In this model the emissions of fossil based plastic production for pots and sheets are avoided. Per ha of nursery 0,5 ha of rice would be needed to accomplish this. For the whole 151 ha this would mean 70,5 of rice. The remaining emission balance is 116 Tonnes CO2e/ha/yr.

The "carbon neutral" models

The choice was made on the next pages, to only put the models on the map that can provide (feint) carbon neutrality. It is important to note that the wind+ model and the PV+ model don't provide actual carbon neutrality locally.

Wind+ model

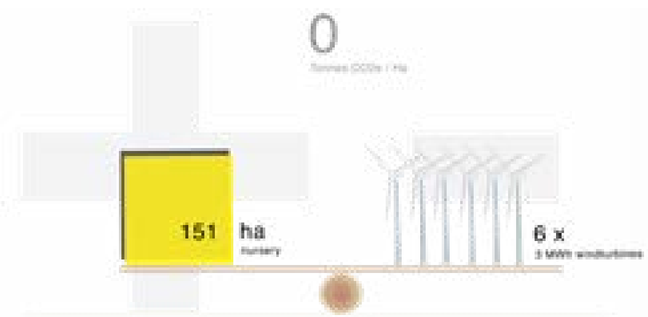
On the seesaw in fig. 46 the 151 ha are weighed against renewables for the whole are. In this model, besides the energy consumption emissions (incl. transport of materials to nurseries), also the remaining emission of the study area are "avoided" by introducing three 6 MWh wind turbines to the area. The remaining emission balance is zero CO2e/ha/yr. This model doesn't count as actual local carbon neutrality. The 6100 Tonnes of remaining emissions, compensated by three extra wind turbines, are just replacing a rough estimate of 24 Gwh energy in diesel used elsewhere. These turbines are thus avoiding emissions elsewhere, not in the study area itself.

On the map in fig.46 two options are shown to position six wind turbines. They are positioned at a minimum distance of 300 m from housing. One formation stretches along the southern border with Belgium. There are recognizable turbines on the Western border already, that give a sense of direction, especially because they have the red tips, that the Dutch turbines don't have. The second option is more suitable to create a point of reference and an attraction in the centre of the area.

PV+ model

On the seesaw in fig. 47 one ha of nursery is weighed against PV fields for the whole are. In this model, besides the energy consumption emissions (incl. transport of materials to nurseries), also the remaining emission of the study area are "avoided" by introducing three 0,2 ha of PV field/ ha of nurseries. For the whole 151 ha, 35 ha PV field is needed in this case. The remaining emission balance is zero CO2e/ha/yr. Just as the wind+ model, this model doesn't count as actual local carbon neutrality, because the PV is compensating or avoiding emissions elsewhere, not in the study area itself.

On the map in fig. 47 the PV fields are placed in between the Turfvaart and the nurseries on the West side of the Turfvaart. They are positioned in lows of the stream valley.



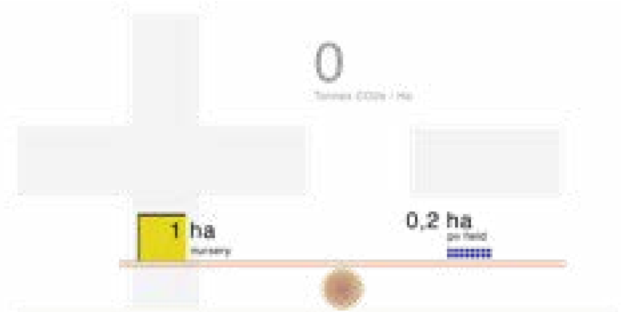
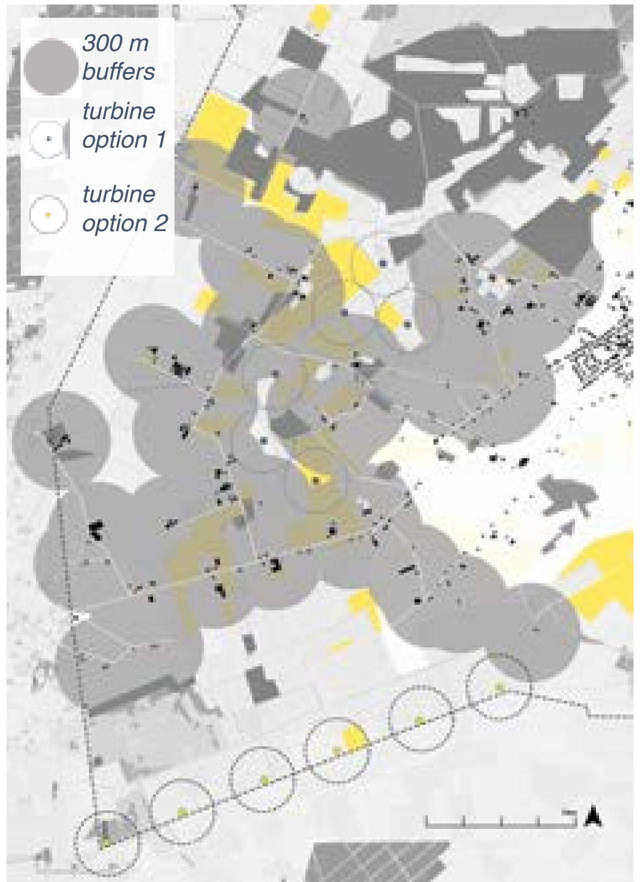
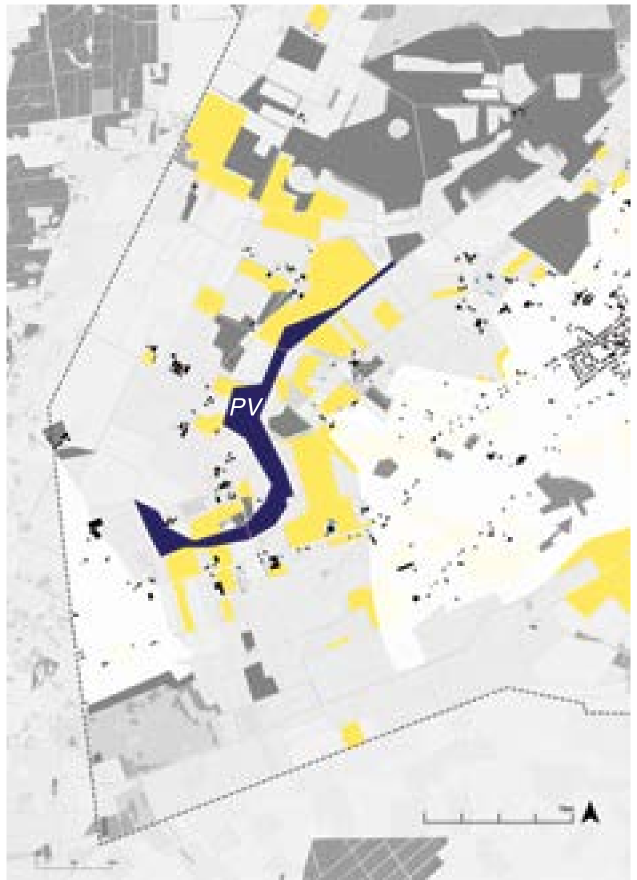


Fig. 46 Wind+ model (top) & spatial implications (below)

Fig. 47 PV+ model (top) & spatial implications (below)





Lane+ model

On the seesaw in fig. 48 one ha of nursery is weighed against lanes that provide bark and wood for crates and CLT. In this model, again all remaining emission, after substraction of the emissions of both substrates and crates, coming from production and transport of these materials of the study area, are offset by introducing 81,6 km of productive PV lane/ ha of nurseries. The wood for CLT is assumed to be used in products and constructions with a long-term end uses. The CLT from the lanes is considered a sink. For the whole 151 ha, 633 km of lanes is needed in this case. The remaining emission balance is zero CO2e/ ha/yr. The carbon balance is closed with local interventions, but since the CLT will likely travel, the carbon is not stored locally.

On the map in fig. 48 it is shown that the lanes' surface area is surprisingly big and doesn't fit the study area or the young reclamation landscape around it. The lane structure would resemble more of a monotonous production forest.

Forest+ model

On the seesaw in fig. 49 one ha of nursery is weighed against the sequestration forest. In this model all current emissions are offset by introducing 13 ha of forest/ ha of nurseries. For the whole 151 ha, 1931 ha of forest is needed in this case. The remaining emission balance is zero CO2e/ha/yr. The carbon balance is completely closed with local interventions.

On the map in fig. 49 it is shown that the forest's surface area again doesn't fit the study area or the young reclamation landscape around it.

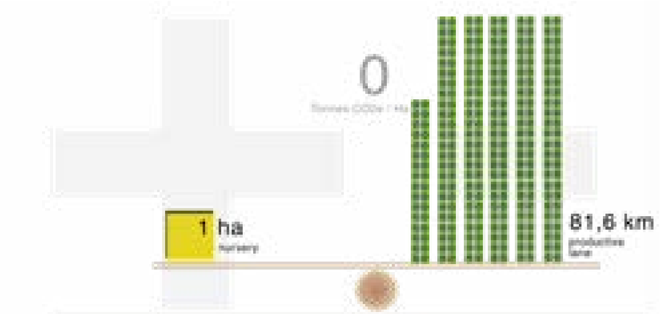


Fig. 48 Lane+ model (top) & spatial implications (below)

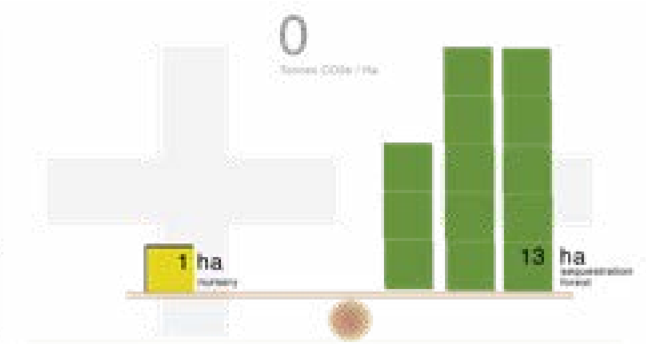
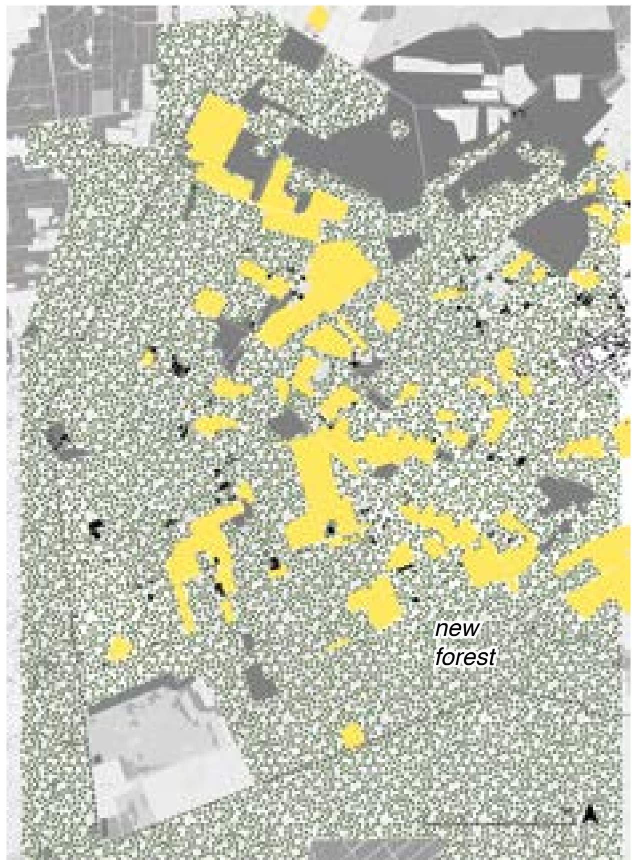


Fig. 49 Forest+ model (top) & spatial implications (below)



Mixed model

On the seesaw in fig. 50 one ha of nursery is weighed against a mix of the previous models. In this model all current emissions are offset by introducing 1 m productive lane, 0,5 ha of rice, 0,1 ha of PV field and 5 ha of forest/ one ha of nurseries. For the whole 151 ha of nurseries this means, 133 m of lane, 71 ha of rice, 17 ha of PV field and 759 ha of forest. The remaining emission balance is zero CO2e/ha/yr. The carbon balance is completely closed with local interventions.

Spatially, however, this still means an increase in area needed to sustain carbon neutrality for the nursery practices. 15% Of the area would be nursery, 85% other land uses. On the map in fig. 50 it is shown that, although less forest is needed than in the previous models, still the forest's surface area doesn't fit the study area or the young reclamation landscape around it.

Mixed Max Lanes model

On the seesaw in fig. 51 one ha of nursery is again weighed against a mix of the previous models. This time the ratio of lanes is increased. Part of the lanes are used for long-term carbon storage in CLT. This decreases the amount of forest needed as sink. In this model all current emissions are offset by introducing 151 m productive lane, 0,5 ha of rice, 0,1 ha of PV field and 4,8 ha of forest/ one ha of nurseries. For the whole 151 ha of nurseries this means 22,6 km of lane, 71 ha of rice, 17 ha of PV field and 718 ha of forest. The remaining emission balance is zero CO2e/ha/yr. The carbon balance is completely closed with local interventions.

Spatially this doesn't change much for the ratio nursery to other land uses. Still 15% Of the area would be nursery, 85% other land uses. On the map in fig. 51 it is shown that a little less forest is needed, but again the forest's surface area doesn't fit the study area or the young reclamation landscape around it.

Fig. 50 Mixed model (top) & spatial implications (below)

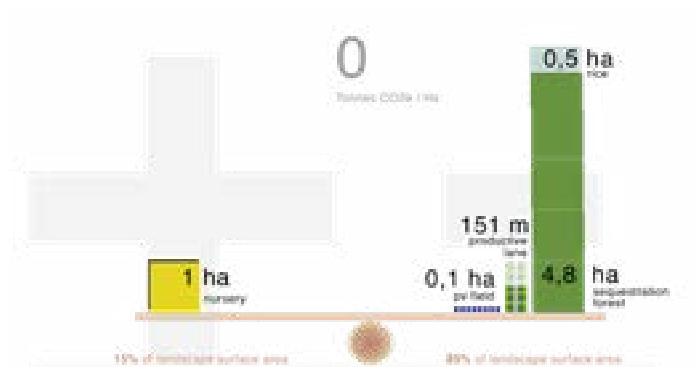
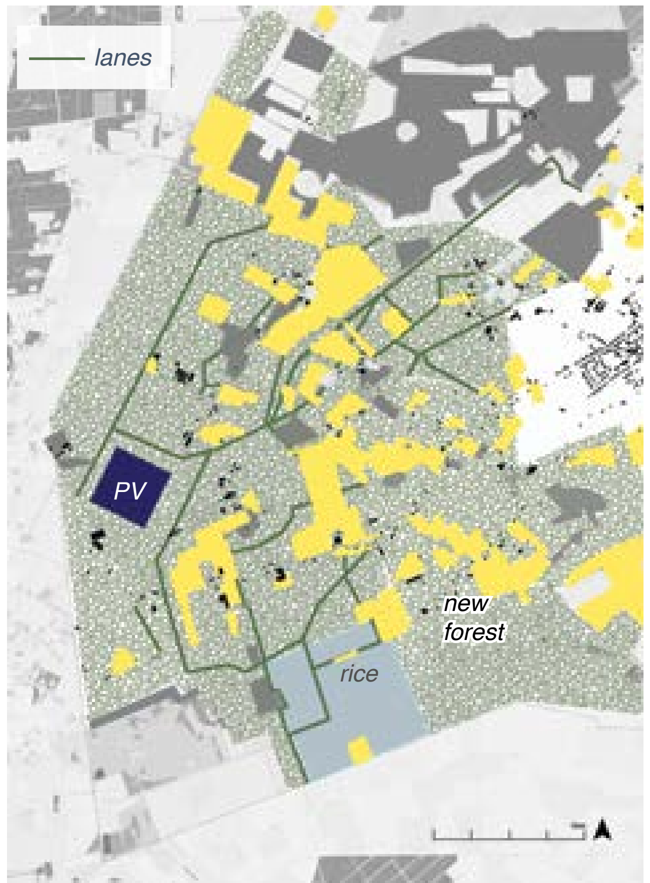


Fig. 51 Mixed max lane model (top) & spatial implications (below)



Numerical model evaluation

The model evaluation matrix in fig. 52 is based on the model evaluation table in annex 5. The evaluation starts with a rating of comparative impact on carbon balance of the area. The rating is based on numerical impact on carbon balance, the potential of the model to avoid emissions locally where possible and the expected timespan for model to take effect.

The mixed models score highest, closely followed by the forest+ model, then the wind model and PV model follow. PV+ and wind+ models only provide 'feint' carbon neutrality, since they prevent emissions elsewhere. The models that can provide actual carbon neutrality are the Lane+, Forest+ and Mixed models. Only these models are considered suitable to feed to the final design.

Spatial implications of the models

The second part of the model evaluation consists of a rating of the comparative impact on the landscape quality of the area.

The rating considers the potential of the models with regards to experience of production practices and natural connections, readability and diversity, accessibility, ecological and water system quality. Since all suitable models take op a lot of extra space, beyond the borders of the nurseries, an extra rating added about the space efficiency of the models.

Spatial evaluation of the lane+ model

This model doesn't perform as well on spatial quality as the mixed models or the forest models. The diversity of species and absence of disturbance in a forest makes it a better option to connect habitats and to store carbon. In the lane, trees get harvested. The soil is disturbed and is likely to build up less organic content. Additionally, there is less space for all sorts of plants to grow, because of a path, and the absence of natural succession. Grass underneath the lane trees could partially compensate for this, but grass doesn't grow very well underneath (young) pine trees. Generally, the soil organic content in a pine forest floor is lower than deciduous forest floor (Cha, Cha and Oh, 2019)

An option would be to spread these lanes over the whole municipality of Zundert. Another option is to have less nurseries in the area.

Spatial evaluation of the forest+ model

This model scores a bit lower than the mixed models because it fails to improve experience and accessibility as much. Like the other models it takes up a lot of space and can't be fitted to the young reclamation landscape, which would make it a non- contextual intervention.

An option could be to zoom out and connect the natural areas in the wider context, as shown in fig. 53. Another option again, is to have less nurseries in the area.

Spatial evaluation of the mixed model

In the amount of space this model takes, it resembles the lane+ model. It is slightly more modest than the forest+ model, but still a huge change in the landscape. The PV element has some potential to improve the accessibility and experience of production.

Once more, shrinking the area of nurseries would increase its impact on landscape quality.

Spatial evaluation of the mix max lane model

This model scores slightly higher on landscape quality, than the mixed model. The maximum use of lanes has potential to improve accessibility and experience of production.

To use this model in the final design, I argue to diminish the existing nurseries with 25 ha (fig. 54). The design would then fit the young reclamation landscape, which seems a more suitable place for a large-scale intervention, than the old reclamations.

Model final design

The model with the highest score on improving the landscape quality and with the highest impact on actual carbon balance is the 'mixed max lane' model. The final landscape design is based on this model.

In the final design the decision is made to stick to the young reclamation landscape and to replace 25 ha of nursery with other land uses.

The specific ratio of land uses that is used in the final design is shown in fig. 55. A wind turbine is added to the mixed lane model, since it can add a strong landmark and attraction to the area.

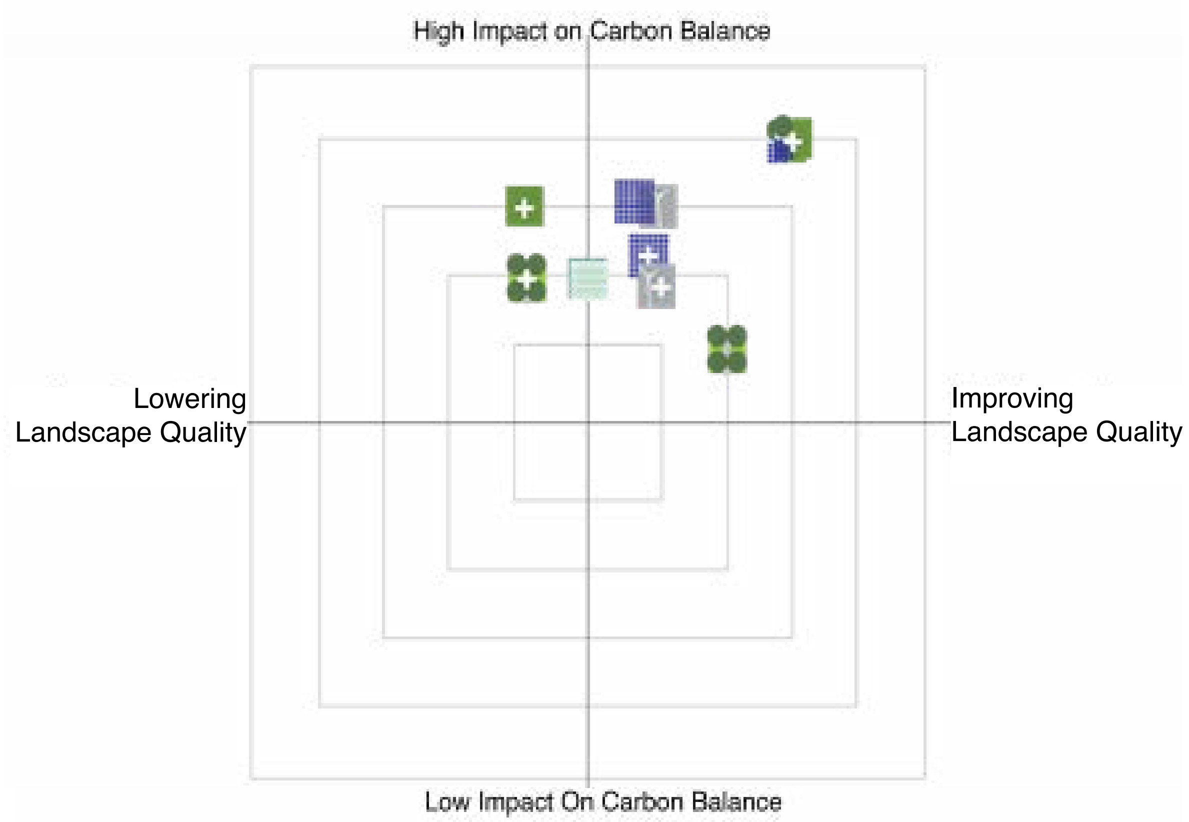


Fig. 52 This matrix evaluates the models. It shows that the mix max lane model scores highest on both axis.

Fig. 53 Forest + model takes up too much space to fit in the young reclamation landscape of Achtmaal. A solution to contextualise this intervention would be to connect the natural areas in wider context to create a 'grenspark', a branded area across borders.

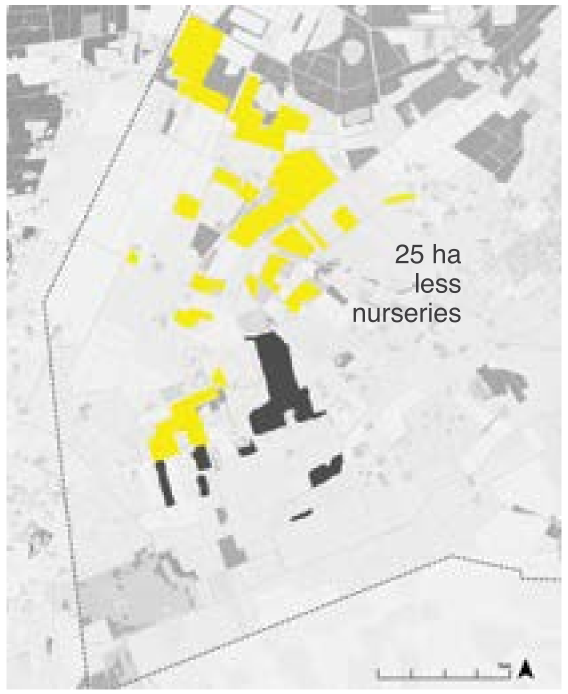


Fig. 54 The model study shows the need to diminish the area of nurseries

Fig. 55 Required building blocks for the design

LANE DESIGN II

To be able to add even more PV to the area without taking up more space, and to improve the visual and physical accessibility of the production, agri-PV could be incorporated in the design of the lanes. PV arrays in East-West direction shade the seedlings in the linear nurseries alongside the lane. The PV helps the growth of the plants. The arrays should be high enough for machinery to pass underneath, at least three meters (fig. 56).

On the lower grounds, the lane can remain narrow, without the linear nurseries on the sides. Here the occasionally wetter grounds are not suitable for growing seedlings, and the geomorphological stream valley remains differentiated in appearance from the higher grounds around it.

Guidelines lane design

On dry grounds, linear nurseries lie along the lanes

The linear nurseries are covered by beneficial PV arrays

Height of PV arrays allows machinery to pass

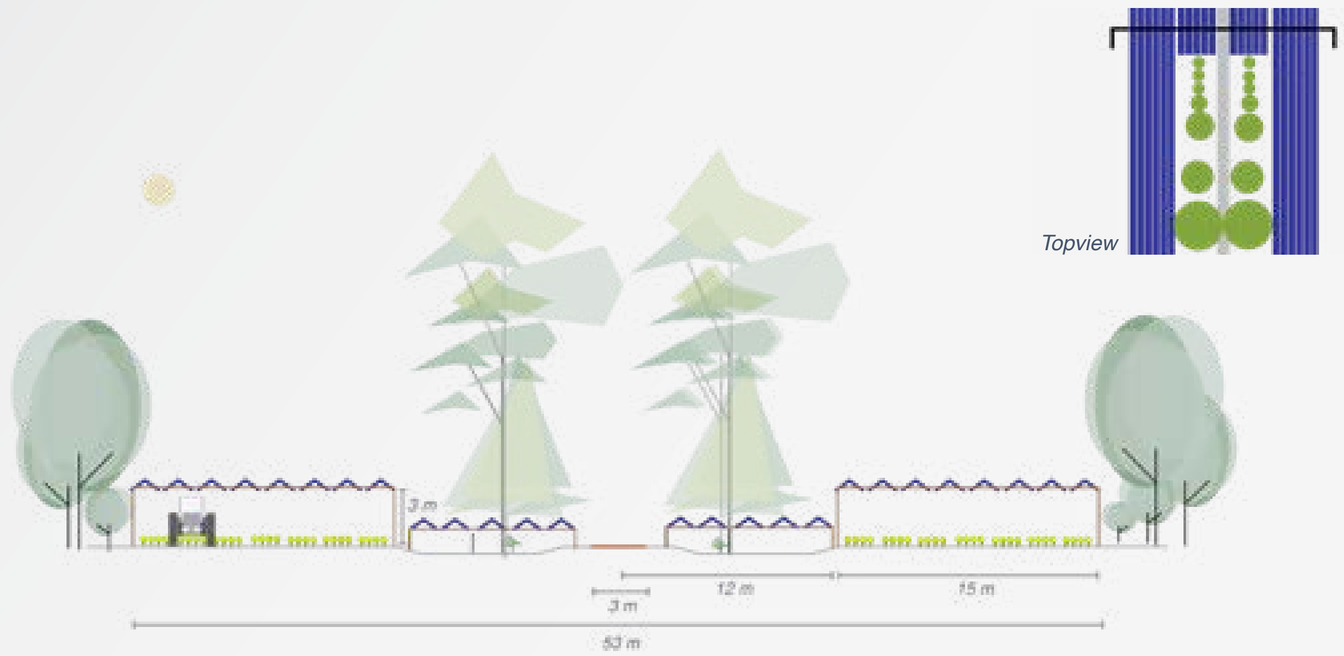


Fig. 56 Lane with linear agri PV nurseries along side, allows for more PV and improves accessibility of production

LANDSCAPE DESIGN

SPATIAL CONCEPT

These two layers of the spatial concept (fig. 57 & fig. 58) show how the two natural areas are connected by means of the elements that are needed for a carbon neutral production landscape.

The productive PV pine lanes in fig. 57 create the missing north - south link for people, discussed in the assessment phase, and reveals the production landscape by taking routes right through it. The thicker lanes are the lanes with the agri-PV alongside, on the dryer grounds. The thinner basic lanes run through the geomorphological stream valleys.

The structuring sequestration forest in this young reclamation landscape in fig. 58 creates an ecological connection between the habitats in the North and South. With pine-oak-beech forest on the sandy ridges and plateau and willow-oak-ash-alder forest in the geomorphological sunken stream valleys. They also provide a green structure for production of seedlings and the rice.

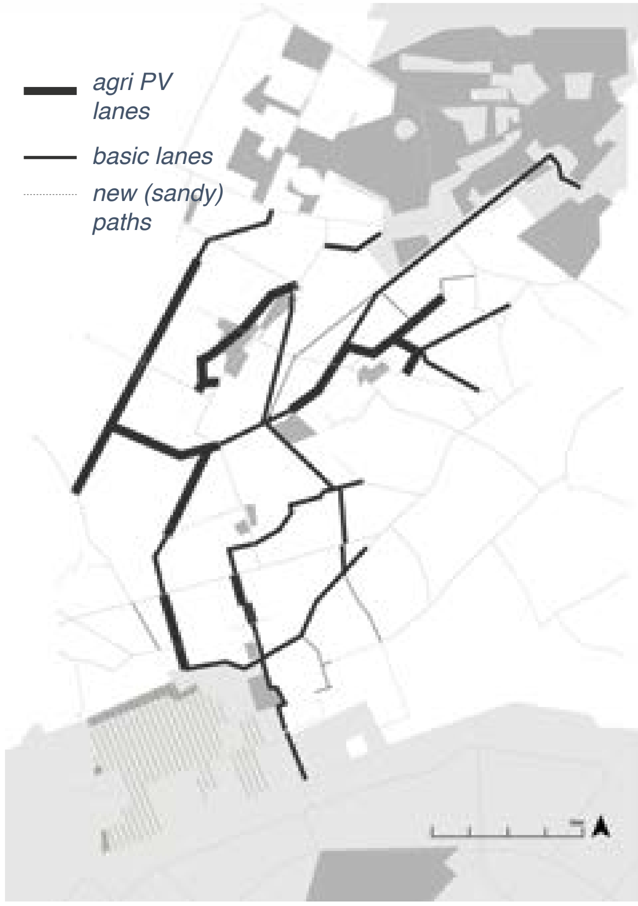


Fig. 57 Lanes provide connection and perspective

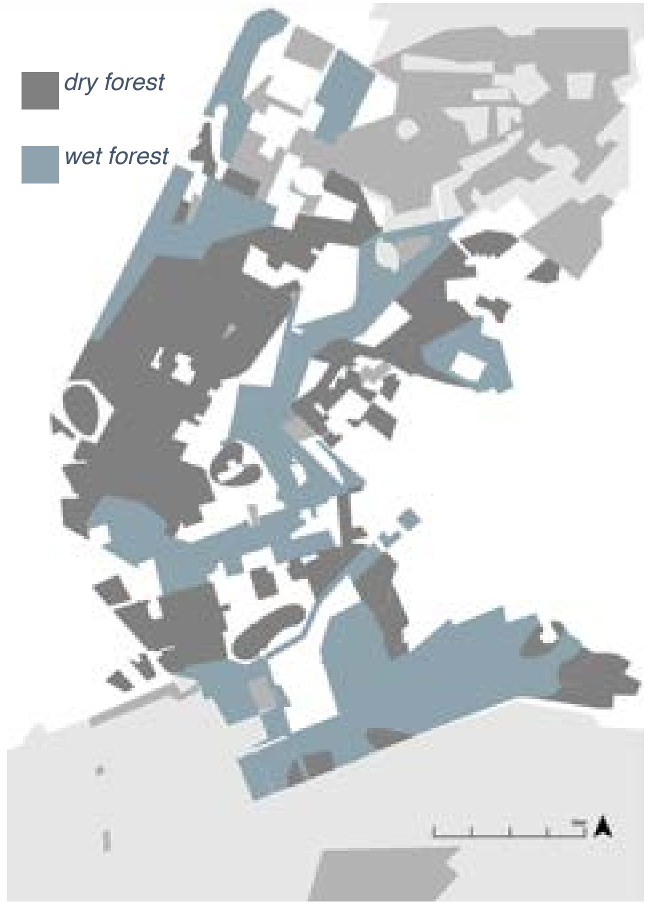


Fig. 58 Two forest types provide structure and connect habitat

LANDSCAPE DESIGN

In this final landscape design (fig. 59), the carbon balance is neutral. The landscape stres as much GHG as it produces. Additionally, the area produces 15,3 Gwh more energy/year than it consumes. This energy can be used elsewhere, to prevent fossil emissions.

Spatially, the forest, paths and lanes replace agricultural fields and nurseries and form a new framework for the farmyards, nursery fields, rice fields, waterbodies, and peat relicts. The edge of the designed area is defined by the mass of the forest.

Quite central, on the Minnelingsebrugstraat the lane cuts through an existing greenhouse, to continue along the nursery fields.

In the centre of the wet forests the wind turbine forms a landmark from which the area can be viewed.

Landscape specific guidelines

On the sandy ridges, smooth forest edges are introduced, that lie free, surrounded by open production space

The lanes cut through selected farmyards to expose production

Peat relicts remain open spaces, framed by the new forests and lanes.

New paths are complementing the lanes in places where lanes would take up too much space

New landscape generally forms a 3D block in the wider area, with open spaces within. The edges are defined by forest, not fields.

Situation at time of writing, with fig. 59

Legend, with fig. 59

- *nursery field*
- *forest*
- *forest on sandy ridge*
- *wet forest*
- *rice*
- *PV pine lane with linear PV nursery*
- *basic PV pine lane*
- *farmyard*
- *greenhouse*
- *tunnels*
- *sandy road*
- *road*
- *waterbody*
- *peat relicts*
- *existing forest*
- *existing farmfields*
- *existing reed swamp*
- *Turfvaart*

Fig. 59 Design for a carbon negative landscape

SITE DESIGNS

LINEAR NURSERIES ALONG THE PRODUCTIVE PV PINE LANES, FRAMED BY THE SEQUESTRATION FOREST

On this first site, the productive PV lane with linear nurseries along sides meets the existing greenhouse on this farmyard (fig. 60). Inspired by suggestions from nursery owner Leenaerts, the greenhouse can be equipped with nesting places for birds and other natural pest predators and PV on the roof. To ensure continuity in the lane, the height of the PV arrays in the lane, roughly match the height of the base of the greenhouse roof. See the visual in fig. 61 and the sections in fig. 62 on the next pages.

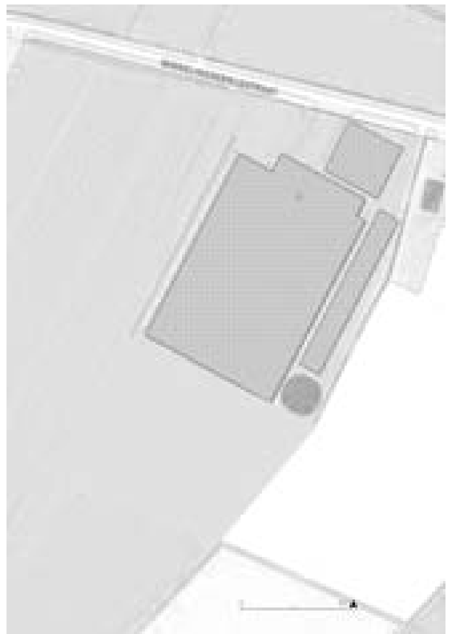
The last block of PV arrays in the lane forms and undulating bench (fig. 64). Visitors can climb and sit on it and charge a phone. It has a frame to emphasise the rhythm of the seedlings. The frame has a QR code that provides more info about how this landscape element relates to the carbon balance of this landscape (fig. 65).

The lane splits to enter and exit the greenhouse. Part of the path lies along the greenhouse extension on the West side (fig. 63). The extension can host a plant shop, café or information point. It can be climbed to get a good view on the patterns of the seedling fields. Simple changes in direction of the lines of seedlings, can create special effects, viewed from above.

There are yellow buffers of sunflower and canola in the fields and along the lanes, to filter shallow groundwater from excess nitrogen and phosphorus. They can also interact with the patterns of the nursery fields. They are situated in places where the groundwater is expected to flow towards.

The forest edge is varied and rich, with a basic shape of gears teeth. This shape lengthens the distance of the edge. Edges are places of high biodiversity.

Location of site, with fig. 60



Situation at time of writing: nursery (grey) & agricultural grassland (white), with fig. 60

Site specific guidelines

Greenhouse transformation to eco greenhouse, with nesting places and PV on the roof

The height of PV matches greenhouse for continuity

Introduction of a multifunctional view platform, materialization matches greenhouse

Creation of land art with the patterns of the plants and seedlings, let buffers interact with the image

Enlengthened forest edge

Legend, with fig. 60

- *nursery field*
- *canola sunflower buffer*
- *forest*
- *natural grass & low bush*
- *path*
- *pines*
- *PV above nursery alongside lane*
- *PV in lane*
- *undulating PV bench*
- *nesting places in greenhouse*
- *PV on green-house & tunnels*
- *greenhouse extension*
- *movable solar objects*
- *water retention basin*
- *house*
- *road*

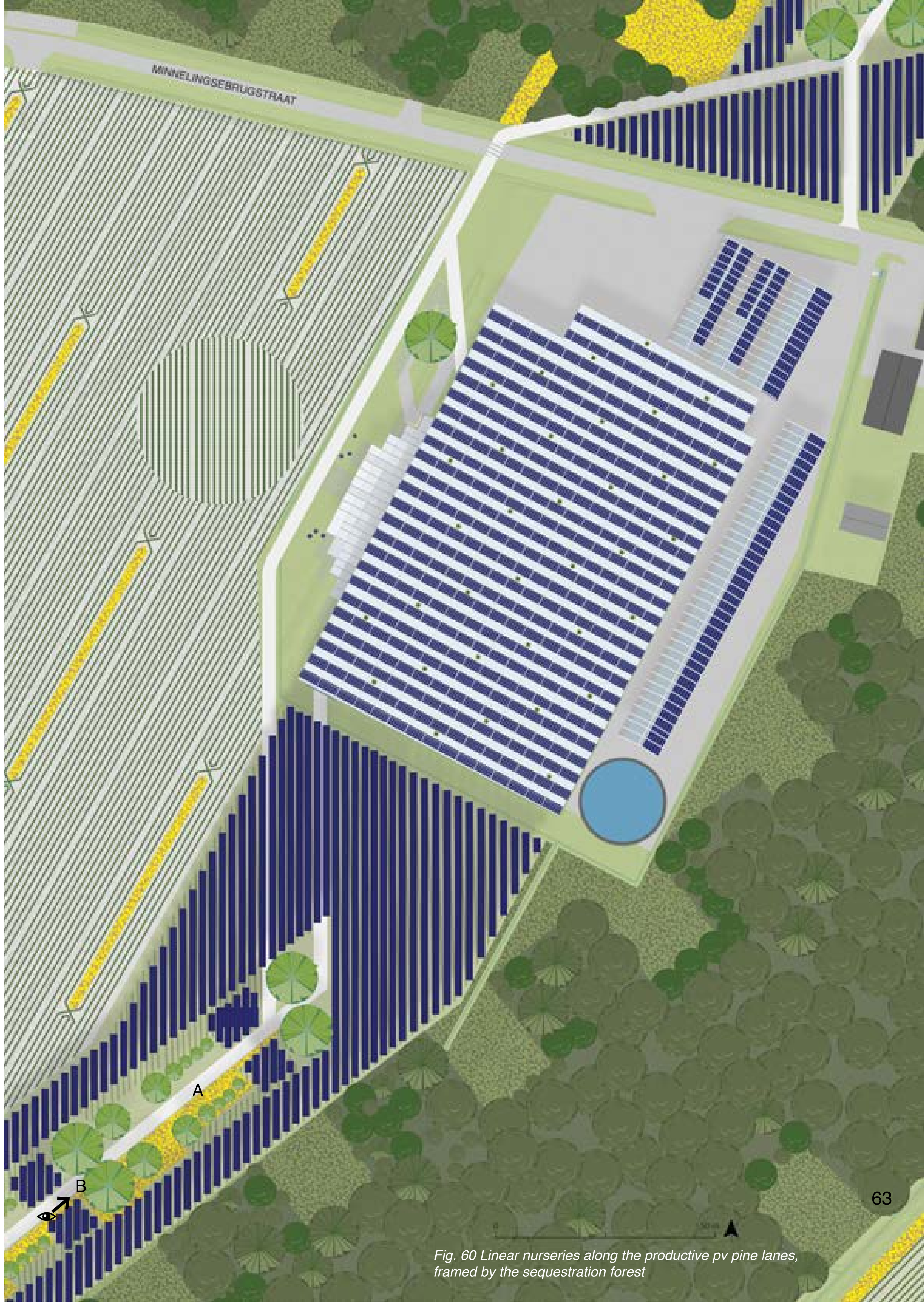


Fig. 60 Linear nurseries along the productive pv pine lanes, framed by the sequestration forest

Fig. 61 Impression (location & direction of view indicated in fig. 60) of productive PV lane with linear nursery along side. In the background the lane enters the eco greenhouse and passes the yellow buffers in the fields and a rich forest edge.

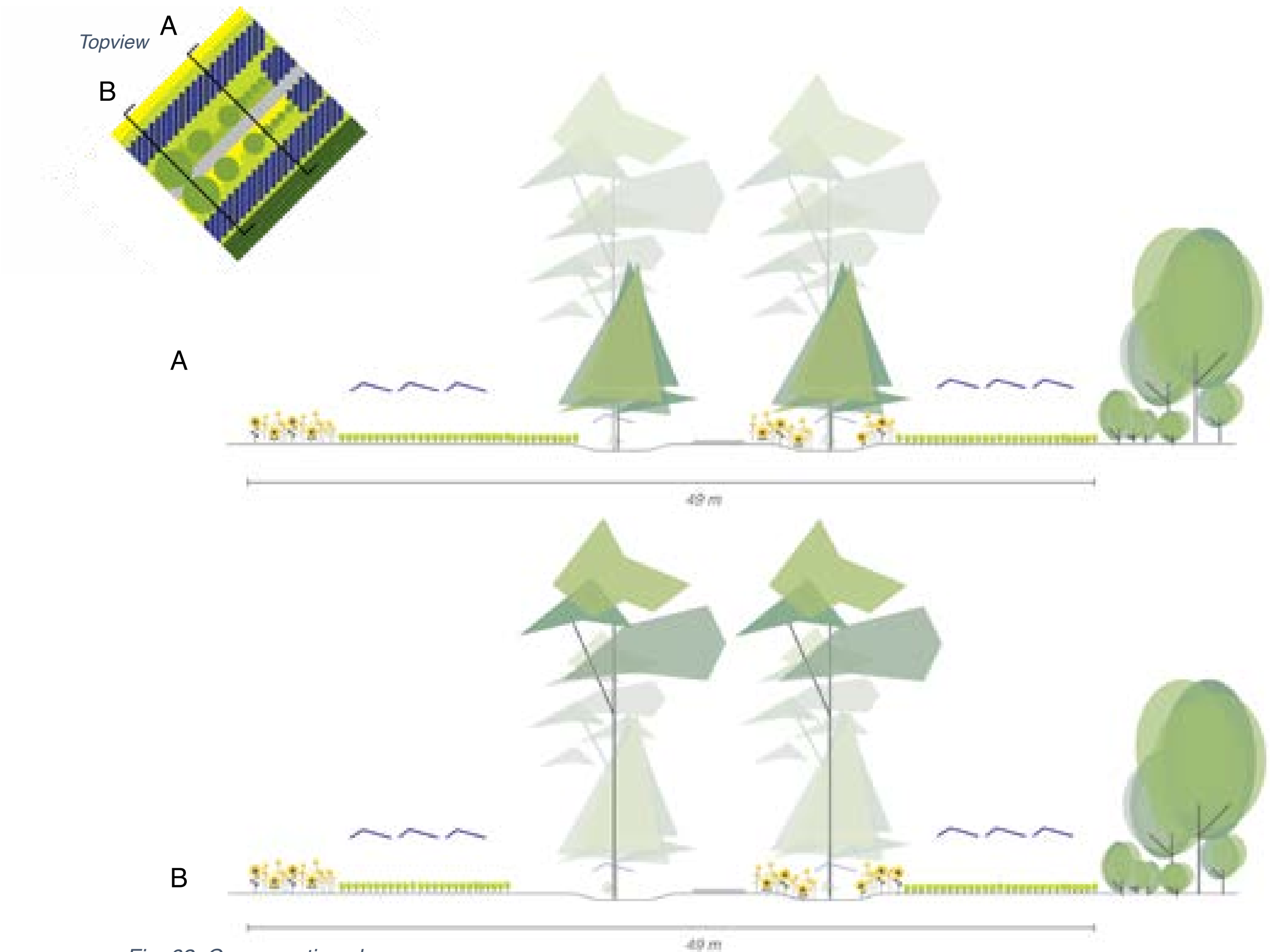
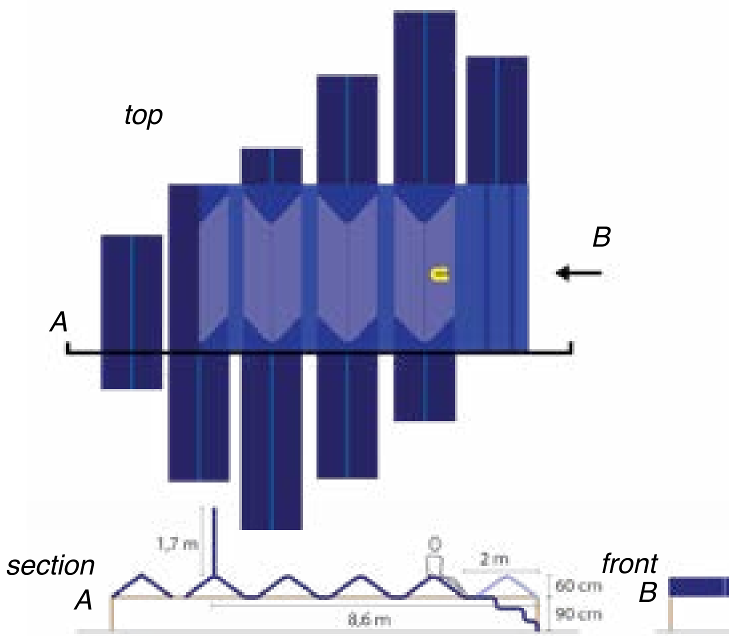
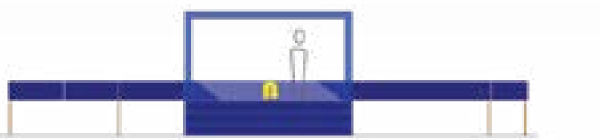


Fig. 62 Cross-sections lanes

Fig. 63 Reference images for greenhouse extension. Image source one on the left (Hiepler, 2020) & two on the right (Tsao, 2019)





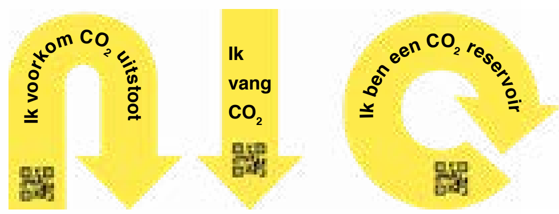


Fig. 65 Icons with QR code on elements in the landscape

Fig. 64 Undulating PV bench. All PV stands are made of wood, sourced as locally as possible.

RICE & RENEWABLES FRAMED BY THE ACHTMAALSE FOREST

The second site, (fig. 66) on the next page, encompasses the rice fields and renewables framed by the Achtmaalse forest. Lanes don't have nurseries alongside here. They are slightly raised, compared to the rice fields and wet forest. Sections of the different directions of lane are shown in fig. 67. The central junction of the lane is lined by PV arrays. A tunnel under PV arrays (fig. 68) leads to a boardwalk to the bird watching PV dome (fig. 69).

There are eco islands spread over the area, with vegetation and gullies that can hold water. The shape of these fauna hideouts, refer to both the peat reclamation relicts in the area and to the PV arrays.

A 'laarzenpad', a path accessible wearing gumboots, leads through the rice fields past one of the fauna hideouts. The rice fields won't be wet paddies, but rather fields of upland rice, that can hold water temporarily when needed. This to prevent extra emissions associated with wet rice paddies (Liu et al., 2021).

The lanes lead to the wind turbine. The turbine serves as a lookout over the entire study site. The base could function as an outdoor boulder wall, e-bike charging station and bar, or gallery linked to the van Gogh NP. Around the base, some moveable spherical PV objects can be spread out over the triangular field. See fig. 70 for reference images. Sphelar PV cells (Sphelar Power Corporation, 2021) can be incorporated in these spheres. People can move them, sit on them and at night they could have a lighting function build in. These objects can even be spread out to specific parts of the study site, like the accessible greenhouse.

The wet forest edge is toothed to enlengthen it. For an impression of the site, see the visual in fig. 71 on page 72.

Site specific guidelines

Lanes in wetter areas are slightly raised

Eco island form land art in wetter areas

Creation of 'laarzenpad', PV bird dome and tunnel for immersion in the production and nature

Wind turbine base is multifunctional

Enlengthened forest edge

Location of site, with fig. 66

Situation at time of writing: nursery fields (West of ditch) and other arable fields (East of ditch), with fig. 66

Legend, with fig. 64

- *rice field*
- *wet forest*
- *forest*
- *natural grass & low bush*
- *path*
- *'laarzenpad'*
- *pines*
- *PV in lane*
- *PV dome*
- *eco island*
- *e-bike charging station at base of turbine*
- *boulder wall*
- *boulder crashpad*
- *entrance trubine base*
- *moveable PV objects*

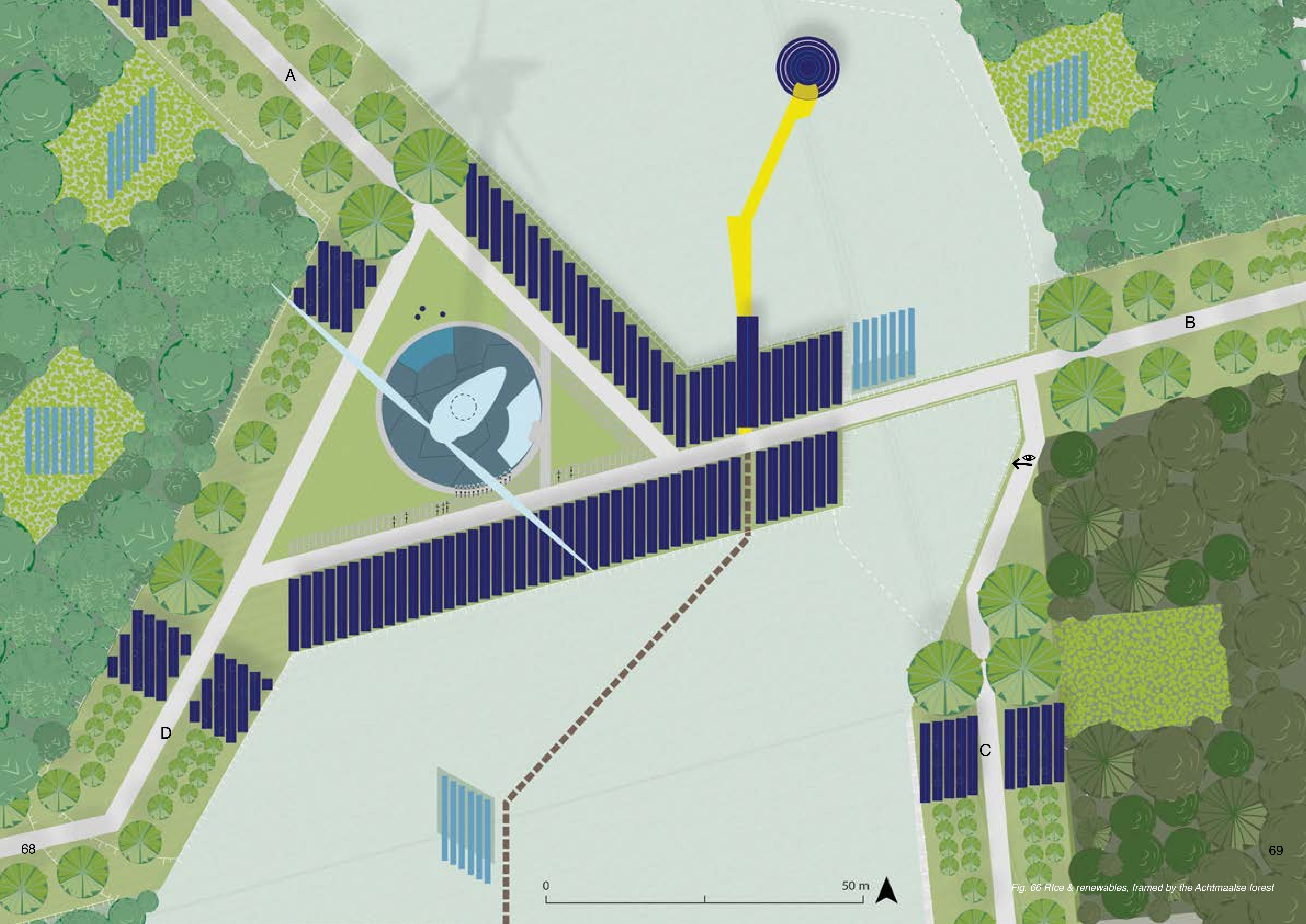


Fig. 66 RIce & renewables, framed by the Achtmaalse forest

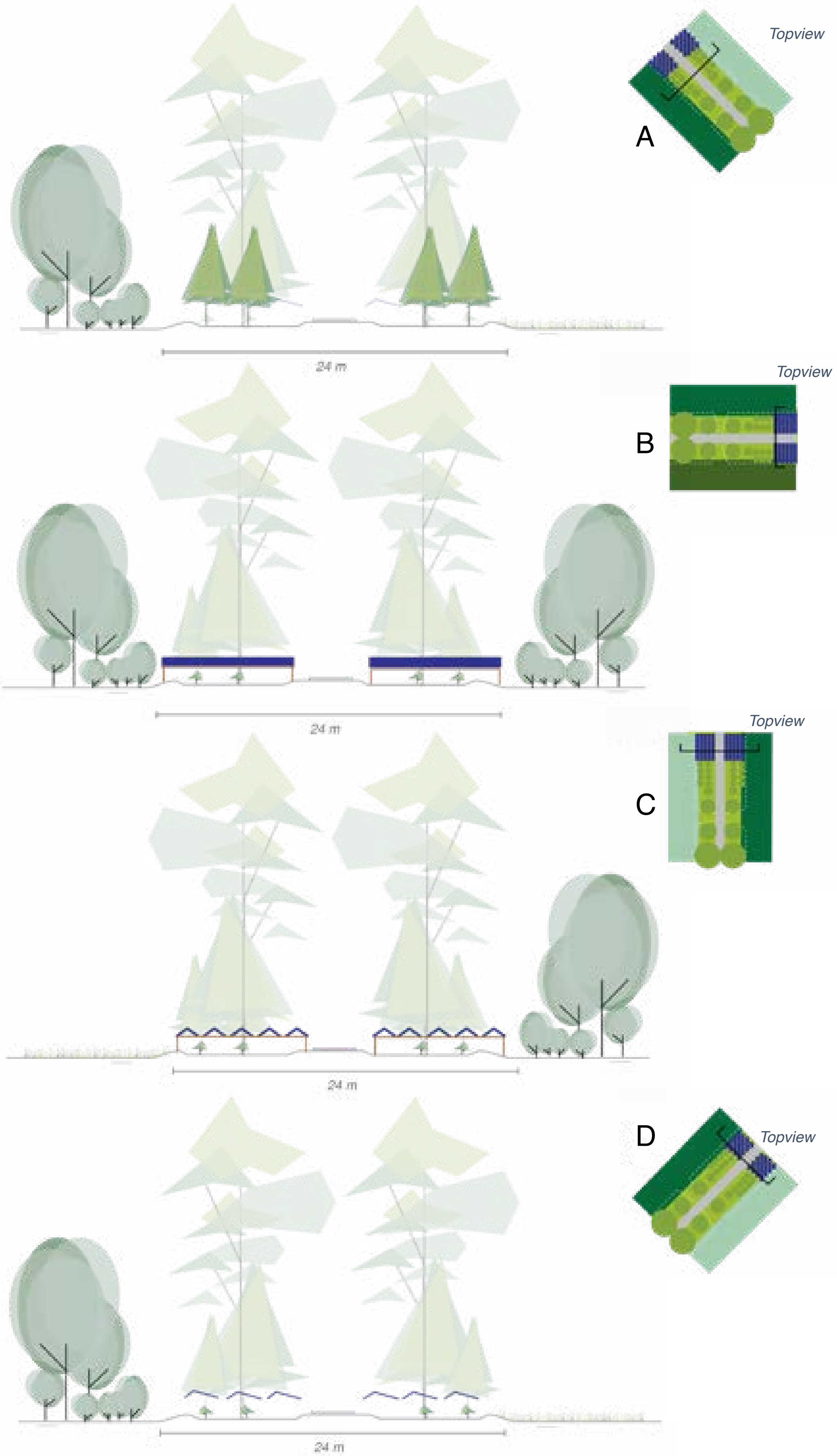


Fig. 67 Cross-sections lanes, locations indicated in fig 64. **A** Lane in N.-W. to S.-E. direction, between rice and forest, **B** Lane in East-West lane between forest and rice, **C** Lane in North-South direction between the wet and dryer forest, **D** Lane in N.-E. to S.-W. direction, between rice and forest.

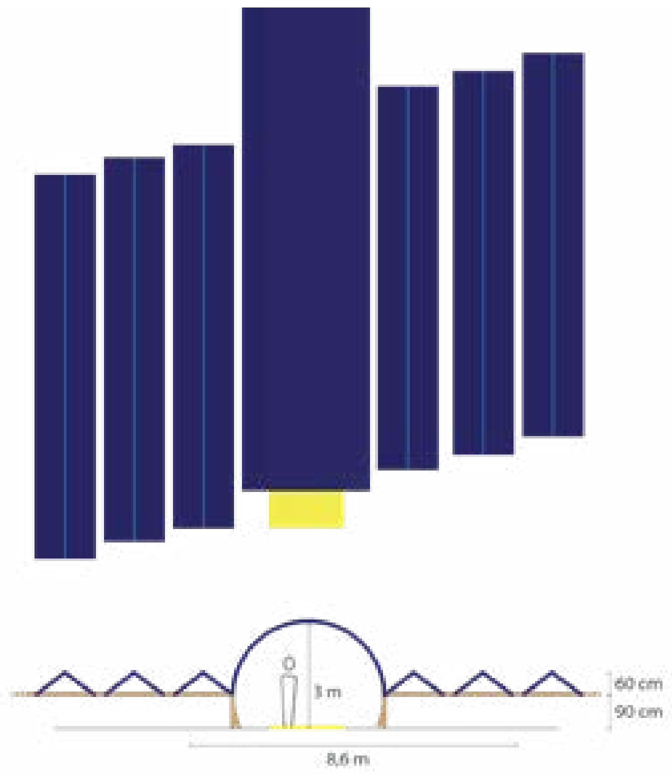


Fig. 68 PV tunnel to the boardwalk

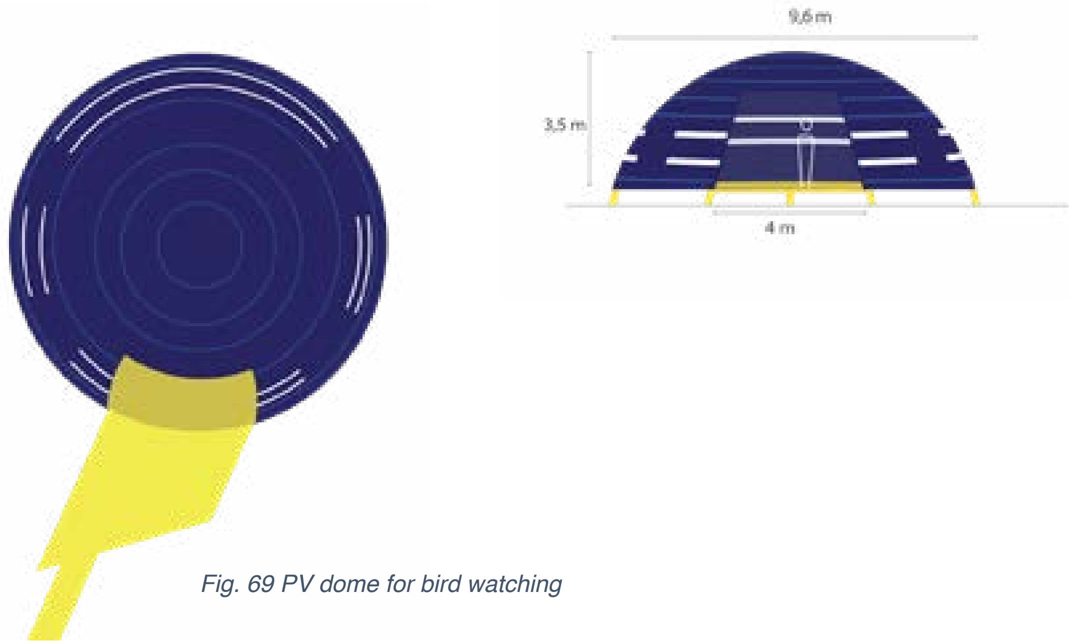


Fig. 69 PV dome for bird watching

Fig. 70 Reference image for moveable spherical PV object, that can function as seat, light, or play object. Image source left (meine lampe, no date), right (Simpson, 2007)

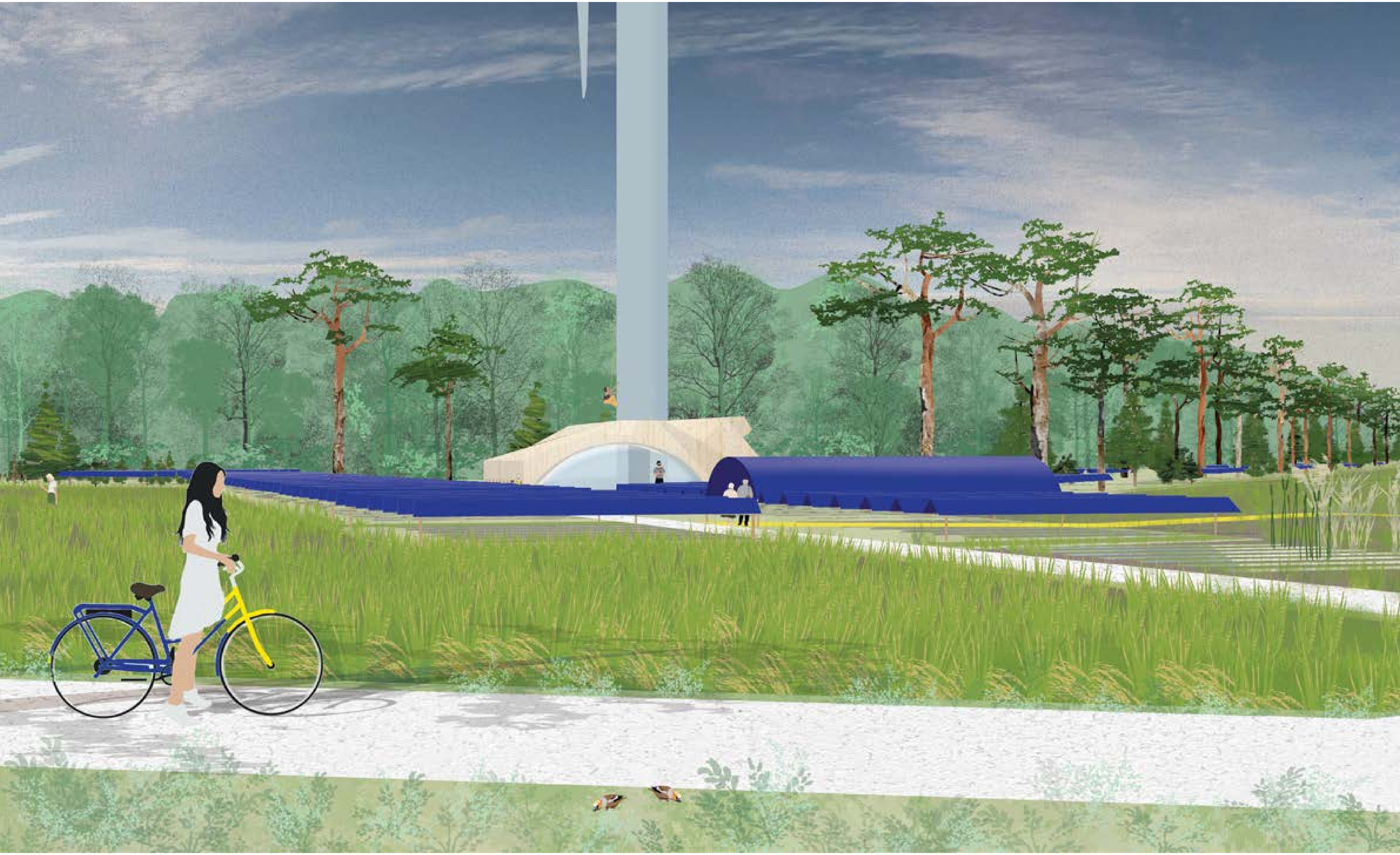


Fig. 71 Impression (location & direction of view 👁 indicated in fig. 66) of renewables in the rice fields between the Achtmaalse forest. Slightly elevated paths in the lanes lead to the turbine base, which is the entrance to the viewpoint up the turbine. The base is a destination for climbers, art fans, and e-bicyclists that want to charge their bikes.

4

Evaluation

4.1 Discussion

Assumptions & the need for specific local data

Calculations of the carbon balance of the current area and final design are based on emission numbers from Life Cycle Assessments (LCA) for Italian and American nurseries (Kendall and Gregory McPherson, 2012; McPherson and Kendall, 2014; Lazzerini, Lucchetti and Nicese, 2016). The use of these LCAs affects the validity of this particular part of the research. The different climate, among other factors, effects the emissions. This effect was partially counteracted by using the LCA's in combination with data acquired from an interview, on the metabolism of one nursery in the study area.

The carbon balance calculation is an analysis of the emissions, but not as extensive as a full LCA. Some data was not available, and an educated guess was made. Transport of fuels to the farms was left out. The average plant weight of the plants in Achtmaal might be lower than the weights of the plants in the nurseries in the literature, which lowers the fuel needed for transport to retail. Transport distances might be larger than the distances in the literature. Peat oxidation after extraction is not completely accounted for, only emissions when applied in a general nursery in Italy were known. The emissions of fertilizers after their application in the study area is not precisely known, so not accounted for. An LCA for several Dutch nursery types, comparable to the analyses of the Italian nurseries, is missing and would be an interesting project for further research by an environmental scientist or thesis student.

Another angle that is interesting for further research is to take other types of agricultural production into account. The current nurseries apply a rotational system, where once every 5-6 years a change to grazed grassland is made. The influence of this land use change is not accounted for in this thesis.

The implementation phase is not tested yet on its impact on the carbon balance. The carbon footprint of constructing the new lanes, some earthworks, etc. can be another topic of study. The sourcing of the first batch of young trees must happen as close by as possible for example. Questions that can be asked are: what is the outcome of an LCA for the bioplastic production out of rice? How does the spatial composition and materialisation of a site influence the carbon footprint of the realisation of that place? These limitations of the research may have an influence on the amount of space that is needed for a carbon neutral nursery landscape in Achtmaal.

It was planned to perform at least three to five interviews, but this wasn't possible due to availability of interviewees. Therefore, the results of the interviews are not representative for inhabitants and nursery owners in Achtmaal. The triangulation with an online review of the nurseries partially compensated for this limitation.

Design phase

In the research through design phase, the design results were properly triangulated with a model study, sketching on several scales and sections. The design decisions are partially transparent and described in this thesis and partially hidden away in the hand sketches and older versions of the digitalized designs of the author, which are archived and available on request.

Feasibility of a carbon neutral nursery landscape

The designed landscape takes up a lot of space. Carbon neutrality is achieved by enlarging the area needed for production and carbon sinks. An important driver for development of a landscape is the land price. Landscape quality and carbon footprint might be improved by this design, but who will pay for the changes?

There are several options. Nursery owners that go the extra mile to invest in a sustainable and carbon neutral nursery, have several ways to create extra value. Firstly, they can brand their products, after the example of carbon neutral vineyards (Natural Capital Partners, 2021). A zero-carbon footprint seedling, from the van Gogh national park gives meaning to a product, an exclusivity, and therefore an added value, that fits the trend of a growing awareness of our impact on the global climate. Therefore, the nursery owners can ask a higher sales price. To be able to create enough green structure, so that the area can be part of the national park, such investments should happen collectively.

Secondly, extra revenues can be made from selling wood from the pine lanes for CLT and from tourist related activities on the nurseries, like profits from a bar or a store.

Since it is a national goal to diminish emissions the national or local government could subsidise the transition to such a landscape and buy (part of) the land that is needed to compensate for the production of the seedlings. However, this means that the costs of preventing pollution are not completely the responsibility of the nursery owner. The taxpayer would then pay for the landscape.

It can be discussed whether this is a fair approach. An argument supportive of using community money, is that the community benefits in multiple ways. The landscape quality increases, and the landscape is made more accessible, which gives direct experiential merits for anyone visiting the area. More importantly, the indirect benefits of increased biodiversity and climate mitigation are crucial in the long run to keep this planet liveable for all.

Multiple initiatives exist to put the financial responsibility for local production and landscape restoration with people that live in, or close to, that landscape. 'Herenboeren' (Herenboeren, no date) projects are collective efforts of consumers and a farmer to finance a local farm. For the landscape of Achtmaal, this could perhaps apply to the energy production. Extra PV could be introduced. Inhabitants of the wider area could purchase personal PV panels for their own consumption and sponsor a panel to help climate mitigation.

A second example are 'red for green' arrangements (Willems, Orbon and Römer, 2020), where house buyers adopt a piece of public nature reserve (or sequestration forest) with the purchase of their house. For the area of Achtmaal this could mean that the empty buildings in the area would be repurposed as housing and sold under conditions.

A point for further research is which (combination) of these options, if any, would be sufficient to cover the cost of the transition. Do the positive effects of this transition outweigh the monetary costs?

Another point that deserves attention is that the current emphasis on monetary costs is an unsustainable way of running the local and global economies in the first place. Assigning value to ecological benefits, quantifying ecosystem services (Perrotti and Stremke, 2020) and social or health benefits are ways to surpass the single goal of economic growth. Mariana Mazzucato who generally advocates for a societal mission based reform of our economy, states that for 'success of innovation and resilience of the [renewable] energy system it is important to understand the directionality of innovation' [after implementation of policies] (Mazzucato and Semieniuk, 2018) 'the type of financial actor matters, and at a more finely grained level than just "private" vs. "public". Awareness that finance can create directions – whether planned by policy makers or not – is an important point to heed when designing policies' (Mazzucato and Semieniuk, 2018).

At a landscape level this approach would mean that, to create a healthy environment for the energy transition to take place, investments in the landscape should probably come from multiple actors, both private and public, but moreover should be monitored for their effects.

From a landscape architectural angle, the question remains whether the carbon balance of the landscape can be fixed with spatial solutions alone. As shown before in the *trias seminarium*, solutions like precision agriculture, improved composting practices and organic pest solutions are not spatial. These solutions are not considered in this design because they are technical/ behavioural. It is valuable to take them into account when further researching the feasibility of a carbon neutral production landscape, since they could diminish the space needed for the design.

The carbon footprint of clustered nurseries

Zooming out again to the spatial configuration of nurseries in the Netherlands, clusters are the default. The benefits of clustering are easy knowledge exchange between companies and economies of scale can provide a competitive position. The clusters are also soil bound.

However, the carbon footprint of clusters might be higher than the footprint of companies spread out over the country, due to travel distances to retail or forest projects. To indicate whether this is true, a detailed analysis of the final destinations of the plants could be made. Additionally, knowledge exchange can happen more easily online, with recent developments in digital communication. In the scenario of 'declustering' it must be taken into account that existing nurseries are invested in their location with time, money and energy.

Still, when excess renewable energy is produced in the landscape, that can be used for transporting plants to their destination and material input to the nurseries, then the clustering is not a problem for the carbon footprint of the nurseries. The effect of clustering on the landscape quality can be a positive one, if a collective effort is made by the cluster to combine forces to create new green structures and energy infrastructure, that fit the landscape character.

4.2 Conclusions

The aim of this thesis was to find knowledge on the design of a carbon neutral nursery landscape in Achtmaal, with high landscape quality. The hypothesis that the tree nursery landscape of Achtmaal in Zundert, Brabant has potential to become carbon neutral was proven right. The objective to identify spatial solutions for carbon neutrality has resulted in a spatial design for a carbon neutral regional landscape in Achtmaal and principles and guidelines. The tested design is the new knowledge, that can serve as a foundation for further landscape architectural research on carbon neutral landscapes.

DESIGN PRINCIPLES AND GUIDELINES

Fig. 69 on page 80 summarizes the principles and guidelines for a carbon neutral nursery landscape in Achtmaal. The principles from the research for design phase link to the guidelines, that are more specific. The guidelines provided building blocks for the seesaw model exercise and guidelines for the final design. The guidelines from the research through design phase emerged from process notes and reflections on the final designs.

Some of the design guidelines can apply to other locations, but possibly need adjustment to context. Several guidelines only work in combination with other guidelines. Planting pines, to produce CLT and substrates for horticulture is linked to introducing sequestration forest, because only planting pines would create too much of a monocultured landscape, from an ecological perspective.

The guidelines that bring the greatest novelty, are the guidelines related to carbon neutrality (1.3), to revealing production (1.4.2, 2.2.2, 2.3.3, 2.3.4, 2.4.3, 2.4.4) and to the productive lane design (2.1).

ANSWERS TO THE SUB-QUESTIONS

First, the brief answers to the sub-research questions of the Research for Design (RfD) and the Research through Design (RtD) phase are presented, before reflecting on the main research question.

1. *What is carbon neutrality in the landscape of Achtmaal?* (RfD)

A carbon neutral landscape has net zero emissions. In Achtmaal this means an emission reduction of 17421 Tonnes is needed for the 151 ha of nurseries.

2. *What are the components of the metabolism of the Achtmaal nursery landscape that can offer spatial solutions for carbon neutrality?* (RfD)

There are several strategies mentioned in the *Trias Seminarium* that offer solutions for carbon neutrality, some do not have spatial implications.

The following strategies have spatial implications. The high emissions of transport should be avoided, by localizing the production of several materials that are used in the production process of plants and seedlings. Fossil energy-use needs to be replaced with local renewable resources. Peat based substrates, fossil-based plastics and crates are replaced by producing pine bark and wood, and rice. Buildings and infrastructure are reused where possible to prevent loss of embodied energy. To compensate for remaining emissions, sinks need to be created in the landscape in the form of 606 ha of forests.

Spatial building blocks that are part of these strategies are the following: the implementation of renewable energy sources for transport, machines, and lights, the planting of pines to harvest bark for substrates, and wood for crates and CLT, the cultivation of rice for bioplastic and an Introduction of sequestration forest. It is important to note that the ratio in which these spatial building blocks and the nurseries are present in the landscape determines the carbon balance.

3. *What are experiential and ecological qualities in the context of Achtmaal?* (RfD)

Experiential quality in Achtmaal is disturbed by lack of connections in North-South direction, cluttering, small and undefined natural areas and inaccessibility of nurseries. The ecological quality is low, because of water quality and lack of steppingstones or corridors between the forests on both sides of the Achtmaal.

The landscape quality of the area can be improved in various ways. The experience of production practices and of natural connections needs improvement, by unlocking the area in North-South direction by introducing a green structure that strengthens the connection between habitats on both sides of the study area. The readability of the historical and the production landscape needs enhancement, while preserving diversity, again by introduction of a green structure. Water quality and quantity is not sufficient for ecology and production to flourish, water needs to be filtered by buffers and the sponge capacity of the area needs to be increased, to mitigate droughts.

4. *What carbon neutral landscape design can be created for the nursery landscape in Achtmaal, that enhances landscape quality?* (RtD)

The first design step was the integration of the several spatial building blocks, mentioned in the answer to sub question 2, into lanes. The ratios of the building blocks were tested in the seesaw model study for impact on the carbon balance and spatial quality.

The model study proved that the total area needed to be increased by five to six times in size to make the current 151 ha carbon neutral.

The winning model was tested on several scales and in sections. In the final design the choice is made to reduce the ha of nurseries, to reduce the number of emissions that need to be compensated for to 14537 Tonnes CO2e, so that the design fits in the young reclamation landscape of Achtmaal.

The pines, and sequestration forests, needed to make the Achtmaal nursery landscape carbon neutral, provide a green structure that enhances the landscape quality. The rice and nursery fields lie in a framework of lanes and forest edges. The PV and wind turbine viewpoint avoid emissions and help the readability of the landscape. Routes lead through production, through a greenhouse, through the rice fields and along the nurseries in the form of lanes, a boardwalk and a 'laarzenpad'. An extension of the greenhouse provides a space for visitors to experience the beauty of the rhythm of the nursery fields.

ANSWER TO THE MAIN RESEARCH QUESTION

What are the constituents of the tree nursery landscape in Achtmaal as a carbon neutral landscape, with high landscape quality?

There are multiple opportunities for synergies between spatial interventions for a high landscape quality and carbon neutrality in this landscape. One example are the lanes, that both contribute to the carbon balance, by providing bark to replace peat and wood to locally make crates and CLT, and to enhancing the landscape quality of the area, by connecting, and revealing the production landscape.

However, a carbon neutral nursery landscape takes up a lot more space than the current nursery landscape. Non-spatial, technical and behavioral, solutions for carbon neutrality are valuable to consider when further researching the feasibility of a carbon neutral production landscape, since they could diminish the space needed for the design.

Additionally, economic and political feasibility must be considered. Land prices are a strong driver. A carbon neutral nursery landscape needs actors that will bear the costs of the transition. Candidates are nursery owners, consumers of the plants, national and local governments and therefore taxpayers and/or other inhabitants of the wider landscape of Achtmaal. Investments in the landscape should probably come from multiple actors, both private and public, but moreover should be monitored for their effects.

To facilitate support to the idea of paying for the transition, the direct and long-term benefits of a transition to a carbon neutral nursery landscape deserve emphasis. The design created in this research serves to communicate both the breath of landscape transformation and the carbon neutrality.

PRINCIPLES & GUIDELINES RESULTING FROM RESEARCH FOR DESIGN PHASE

1.1 Design principles carbon neutrality

1.1.1 Going local to avoid transport emissions

1.1.2 Fossil resources are replaced with alternatives

1.1.3 Improved efficiency of use of remaining (fossil) resources

1.1.4 Creation of sinks

1.2 Design principles landscape quality

1.2.1 Improved experience of production practices and of natural connections

1.2.2 Enhanced readability, while diversity is preserved

1.2.3 Improved water quality

1.2.4 Increased sponge capacity of the area, to mitigate droughts

1.2.5 Strengthened connection between habitats on both sides of the study area

1.3 Design guidelines carbon neutrality

1.3.1 Implement renewable energy sources for transport, machines, and lights

1.3.2 Plant pines to harvest bark for substrate, and wood for crates and CLT

1.3.3 Grow rice for bioplastic

1.3.4 Introduction of sequestration forest

1.3.5 Reuse, repurpose, recycle buildings and infra

1.3.6 Keep nursery fields where they are, where possible

1.3.7 No land use change from natural grasslands to nursery or rice fields

1.4 Design guidelines landscape quality

1.4.1 Introduction of a (semi) permanent green structure around farmyards and nursery fields

1.4.2 Production is framed by (renewable energy) infrastructure

1.4.3 Introduction of rich (temporary) undergrowth under plants and seedlings

1.4.4 Stream valley and reclamation relicts can be accentuated with vegetation

1.4.5 Introduction of routes in North-South direction

1.4.6 Introduction of extra bus stop on existing bus line through the area

1.4.7 Introduction of landmark/point of interest in centre of study area

1.4.8 Creation of buffers of sunflower and canola in nursery fields, intercepting shallow groundwater on its way to surface water

1.4.9 Raised ground water levels in the low lying areas to create larger ground water buffer

1.4.10 Forest can be planted to create sponge

1.4.11 Introduction of two forest habitats, depending on groundwater levels, with varied species and a rich forest edge

GUIDELINES EXTRACTED FROM RESEARCH TRHOUGH DESIGN PHASE

2.1 Guidelines lane design

2.1.1 East-West oriented PV arrays

2.1.2 PV shades new pine seedlings and disturbed soil after pine harvest

2.1.3 PV arrays are multifunctional

2.1.4 Path min. 3 m wide for easy access harvest machines

2.1.5 Ages of pine in ascending sequence

2.1.6 Big pines placed so they don’t shade the PV

2.1.7 Pines planted in undeep ditch, to prevent soil erosion (and loss of soil organic carbon (SOC)) after harvest

2.1.8 On dry grounds, linear nurseries lie along the lanes

2.1.9 The linear nurseries are covered by beneficial PV arrays

2.1.10 Height of PV arrays allows machinery to pass

2.2 Landscape specific guidelines

2.2.1 On the sandy ridges, smooth forest edges are introduced, that lie free, surrounded by open production space

2.2.2 The lanes cut through selected farmyards to expose production

2.2.3 Peat relicts remain open spaces, framed by the new forests and lanes

2.2.4 New paths are complementing the lanes in places where lanes would take up too much space

2.2.5 New landscape generally forms a 3D block in the wider area, with open spaces within. The edges are defined by forest, not fields

2.3 Site specific guidelines – linear nurseries

2.3.1 Greenhouse transformation to eco greenhouse, with nesting places and PV on the roof

2.3.2 The height of PV matches greenhouse for continuity

2.3.3 Introduction of a multifunctional view platform, materialization matches greenhouse

2.3.4 Creation of land art with the patterns of the plants and seedlings, let buffers interact with the image

2.3.5 Enlengthened forest edge

2.4 Site specific guidelines – renewables & rice

2.4.1 Lanes in wetter areas are slightly raised

2.4.2 Eco island form land art in wetter areas

2.4.3 Creation of ‘laarzenpad’, PV bird dome and tunnel for immersion in the production and nature

2.4.4 Wind turbine base is multifunctional

2.4.5 Enlengthened wet forest edge

< Fig. 69 summary of the principles and guidelines

4.3 Recommendations

Recommendations for further research

The design principles and some of the guidelines could be tested on other nursery hubs, since they are context specific, other guidelines could emerge from such research.

Research on the aspect of economic efficiency of a carbon neutral tree production landscape is needed to complement the evaluation of the landscape quality of such a landscape.

An LCA of a Dutch nursery, on sandy soils, can provide detailed and accurate insight on the current emissions of this landscape.

A meta-analysis of whether clustered nursery landscapes have a higher carbon footprint than ones that are spread out and therefore deliver their products more locally, would provide insight in the carbon footprint of the spatial configuration of nurseries on a national scale.

Valuable new knowledge could come from research on how the carbon balance is affected in the implementation phase of a design.

The use of LCAs as a base for landscape design is recommendable for any carbon neutral production landscape design. This angle could be applied to research on other land uses and agricultural production landscapes.

Policy recommendations

It is recommended to start evaluating policies for their contribution to the carbon neutrality of the Achtmaal landscape. The lens of carbon neutrality of the landscape is not present in current policies of the local government of Zundert. The involvement in the Regional Energy Strategy (RES) of Brabant covers the transition to renewable energy resources. These efforts are mainly focussed on the implementation of renewable energies, not on carbon neutrality. The ambitions to join the Van Gogh national Park can contribute to an improvement of the landscape quality in Achtmaal. This thesis offers inspiration for synergies between spatial interventions for a high landscape quality and carbon neutrality in this landscape. Stimulation of the application of these synergies would strengthen the RES and complement the Van Gogh National Park developments.

Secondly, it is suggested that further research could be initiated by the municipality to inform policy, possibly in cooperation with the municipalities of the other nursery hubs in Brabant. A research agency can be hired to perform a Life Cycle Assessment of the nurseries in Zundert, so that further spatial design for Achtmaal has a strong foundation. Another study that could be initiated is a monitoring study on how investments in the landscape create direction, to discover how investments by nursery owners, transactions by consumers of the plants or subsidies by national or local governments steer the development of the landscape towards carbon neutrality.

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Annex

1 Website review nurseries in study area

Nursery	species	time before sale	growing practice	customers	ha volle grond	ha kassen en tunnels	ha container field	plants/yr	materials used	certificates
Leenaerts Bv Minnelingsebrugstraat 12	Buxus Hibiscus Prunus Ilex other	x	containers, volle grond, kas, tunnel containers & volle grond containers & volle grond containers & volle grond containers & volle grond	shops and wholesale gardeners/landscapers other nurseries	30	1,25	x	x	x	x
Leena plant Ellewoird 2	sierheesters bos plantsoen haag paintsoen hibiscus https://leenaplant.nl/wp-conte... container https://leenaplant.nl/wp-conte... volle grond https://leenaplant.nl/wp-con...	x	containers & volle grond volle grond volle grond	shops and wholesale other nurseries national & international trading	worden zowel buiten als binnen geteeld in diverse potmaten			x	zoveel mogelijk te kweken met eigen uit	MPS-A GLOBALG.A.P GLOBALG.A.P GRASP
Boomkwekerij L.A. Oostvogels Nieuwmoerseweg 10	bos plantsoen haag paintsoen 50 species 60-120cm	1 or 2 jr	containers & volle grond	gardeners/landscapers wholesale	11	x	4	900.000 container planten	agricultural foil landbouwfolie pots 2 or 3 L antiworteldoek irrigation from above shed 800m2 tractor	
Ebi-Severs Nursery Eendenkooistraat 5	80 deciduous shrubs 15 Prunus laurocerasus species	x	containers, volle grond, kas **erkend leerbedrijf**		x	x	x	x	x	GLOBALG.A.P (european social fund?)
Boomkwekerij Distus-Hereijgers Kraaiheuvelstraat 1,8	50 soorten bos plantsoen haag paintsoen sierheesters uit wintertak	x	**sustainable practices:** water leavecompost/compost tea precision fertilization weeding with air alleen volle grond?	shops and wholesale gardeners/landscapers other nurseries national & international trading	x	x	x	x	tractor shed	
mouws Ellewoird 6	bosplanten haagplanten spil 3m kleine boom 10-20cm stam solitaire struik 1m +Stak	(1), 2,3 jr	volle grond? **sales of tools and materials** groenbemest, stalmest, mineralen	shops and wholesale gardeners/landscapers other nurseries	x	x	x	x	x	
sprenkels Ellewoird 4	Rhododendron Camellia Kalmia	x	x	x	3 ha containerveld, waarvan 1 ha onder glas en 1 ha volle grond	x	x	x	mos-en onkruidvrije pot door afstrooimiddel zelf ontwikkeld	

2 Interviews results

Invitations for the interviews were send to all the nursery owners in the area. Due to availability only one nursery owner was interviewed. The other interviewee was the alderman of Zundert.

The interviews were done to triangulate some of the findings related to these research questions:

What are the components of the metabolism of the Achtmaal nursery landscape that can offer spatial solutions for carbon neutrality?

What is landscape quality in the context of Achtmaal?

Interview with Johan de Beer, alderman of the Zundert municipality.
Date: 17 February 2021 at 17:30 – 18:30
Location: online meeting

Useful interview highlights [in Dutch]:

- Hij is fervent wandelaar en fietser in Zundert. Hij heeft de RES in zijn portefeuille. Zundert is zoekgebied voor wind en productie bossen.
- Hij vindt de kwekerij een innovatieve sector, er is zeker ruimte om te inspireren met een onderzoek naar carbon neutrality. (Voorbeelden van initiatieven: de zintuigen tuin, open erf kwekerij loop evenement) Men kijkt verder dn produceren.
- Kassen geven licht en horizonvervuiling
- Verandering in het landschap: hij kijkt met nostalgie naar de jaren 60-70, toen er veel gemende boerenbedrijven waren. Later is door de schaalvergroting die diversiteit verloren gegaan. Ruilverkavelingen pas geëindigd in 2010. Er zijn veel knotwilgen en boomgaarden verdwenen. Hij brengt zelf boomgaarden terug, dit geeft hem een imago van de 'groene' in de buurt. De buren zijn belangrijk in de cultuur van Zundert.
- Problemen: in de top 3 voor agrarische leegstand. XTC productie is een probleem. Initiatief 'Vitaal platteland' is daarom ook belangrijk voor de veiligheid in het gebied.
- Benadrukt het belang van communicatie tussen natuurbeheerder, boeren en menner en burgers en bedrijven.
- Noemt grondwaarde als belangrijke driver voor ontwikkelingen in het landschap.
- Gemeente stelt eisen aan bufferstroken op de erfen tegen vervuiling.

Interview with nursery owner Mr. Leenearts.
Date: 19 February 2021
Location: online meeting

See Tables on next pages
Useful interview highlights [in Dutch]:

Ik las dat u zoveel mogelijk eigen uitgangsmateriaal gebruikt, is dit uniek voor uw bedrijf? Gebeurd wel meer, voordeel is dat we controle hebben. Uitstoot is t goed. Collegas halen met t vliegtuig. Hoe ziet dat eruit: geknipt van bestaande planten en in koelcel bewaard.
Wat gebeurd er met organisch afval op uw bedrijf?
Composteerder Pax
Waarom ligt uw kwekerij op deze plek? Komt dat door de waterhuishouding en de grondkwaliteit? Ja. Zand, geen leem. Grond is heel wisselend! 100 m verder is anders. Er zijn wel meer geschikte gronden. Ik doe ook wisselteelt met de veehouder! Flexibel systeem. Jaar rust.
Heeft u natte voeten/droogte problemen op de kwekerij? Tufvaart nat valt wel mee. Meer last van de droogte. Waterberging in de laagtes werken niet zo goed, liggen vaak op verkeerde plek. Moet beter gemonitord.

Hoe heeft de boomkwekerij zich ontwikkeld sinds u kweker bent? Welke veranderingen vonden er plaats in het productieprocces en het landschap? Veel veranderd: tijd terug natte grond ontsmetting mag al 10 20 jaar niet meer, leek groot probleem, maar toch opgelost. Landschap: ruilverkaveling 2010 klaar. Veel te weinig bomen geplant toen!

Wat zijn de (technologische) ontwikkelingen die u voor de boomkwekerij (bedrijf en sector) in Zundert in de komende 30 jaar. Bijvoorbeeld: Wat ziet en hoort u vandaag, en in de toekomst als u op een kwekerij rondloopt? Denk aan drones, precisie agricultuur, zelfrijdende machines, microfarming, verwachte ontwikkeling van de markt. In de kinderschoenen: grondkaarten met bodemonderzoek! , monsters per vierkante meter ipv per ha. Precieze landbouw. Machines hiervoor nodig! Geen drones.. of andere. Op een gegeven moment kunnen we wet minder middelen toe! Bespuiting met lucht ondersteuning.

Mogelijke volledige omschakeling naar bosplantsoen: In het actieplan bos en hout wordt 100 000 ha nieuwe bomen gepland in Nederland, voor 2050. LTO vakgroep bomen en vaste planten zegt hier voor te willen leveren. Heeft u hiervan gehoord en wat is uw mening hierover? Uitgangs materiaal is probleem, gebrek aan. Omschakeling door kwekers mogelijk als dat uiteindelijk opgelost is.

Bijvoorbeeld zijn er elementen verdwenen, veranderd, vermeerderd? Hoe heeft u deze ontwikkelingen ervaren? Welke waarde hecht(te) u aan deze elementen?
Te weinig bomen geplant: wandel en fietsroute nodig, de mix is mooi, de variëteit! De afwisseling.
Hoe zou u willen dat het landschap er uit ziet over 30 jaar? Wisselend karakter behouden. Vroeger veel aardbeien. Nu allemaal onder folie, opstalling.

Hecht u waarde aan het bevorderen van biodiversiteit op of rond uw bedrijf? Ja ! *Ziet u kansen of problemen die nu niet aan de orde komen?* Op mijn kwekerij: kassen , vogelnest kastjes in de kassen. Veel koolmezen vliegen naar binnen. Eten veel insecten weg. Biodiversiteit in de kas. NNB verbindingszone stelt niet veel voor . Hoekje opgeschoten wilgen.
Ik heb gehoord dat sommige bedrijven buffers aanlegen om verspreiding van pesticiden te voorkomen. Liggen deze op de bedrijven? Wat is uw beleid hiervoor? Ik weet er geen. Strookje gras.. aan perceelrand. Bestaan ze niet.

Beeld van een kwekerij door de seizoenen:

November : stekken trekken, kale tak, vriezen in
Maart: mest erop, planten gezet
De planten groeien, bij droogte water geven, staan 1 of 2 jaar
Oktober-november: er wordt gerooid
Om de 5/ 6 jaar grasland ertussen.

In de kassen: gebruiken we planten die we eerst buiten gekweekt worden (in FEB naar de kassen in potten met turf. X aantal weken)
Zelfde verhaal in de tunnels.
Maakt niet veel uit tunnel of kas. Kas is duurzamer, gaat langer mee. Glas. Tunnels goedkoper.

Teelt onderdeel	Ha	
volle grond	30	
kassen	1,2	?
containerteelt	0	
tunnels	3	3000m x 10m
opslag gebouw	0,1	1000 m2
(kantoor gebouw)	In opslag 30m	
total	34,3	
anders namelijk,	x	

Teelt onderdeel	Energie verbruik/jaar (gas, elektriciteit, andere)	use kw /ha/jr	kg CO2 eq/ha	use kw /ha/jr full nursery
kassen	Koude teelt. Wel zuidelijke Elektriciteit 5000 kw/jr voor het licht , gas 0. **Nul lozer** qua water. Hergebruikt. (is wel grijs gebied, wordt niet getest hoe goed t gefilterd is..)	145,7725948	32.5	46,2962963
opslag gebouw	3000 kw /jr incl. verlichting, machines binnen, koelcel	87,46355685	19.8	27,77777778
is (kantoor gebouw)				
machines	Landbouw trekkers voor verzorging 3000L/jr , loonwerker komt ploegen	28 L diesel	0.08	
irrigatie	(Haspel op stroom)			
anders namelijk,	x			

Teelt materiaal	Gebruik /ha/jaar	Herkomst materiaal	use /ha/jr	CO2 eq
turf	Voor kassen. 400 m3	Baltisch	5,3 m3	
bamboe stokken	nee			
compost	Weinig 100m3 (voor volle grond?)	Plaatselijke composteerder, ons afval gaat daar ook naar toe.	3,3 m3	
bemesters	Rundvee mest volle grond, van boer in de buurt. Legale hoeveelheid. Kunstmest, 90% organisch.		?	
pesticiden	Gebruik steeds meer bitterzout ,Magnesiumsulfaat (MgSO4), epson zout engelszout, bladbemester (tegen wespen bijv.)		?	
potten (plastic?)	Kassenteelt, veel ontwikkelingen in t veld, normale potten, 96% gerycled dtls en engels carbon free potten. 200000 potten.jr	Vanuit verschilende landen		1851,851852
kratten (hout?/plastic?)	Box palets, 5%, rest deense karren, vispool dekt heel europa, (worden restanten materiaal,	Hout uit polen tjescie , box palets	?	
plastic wrap, grondbedekker	Plastic buiten, waar stekjes doorsteken, grond bedekken warmte onkruidbestrijding, (is mogelijk om bioplastic te gebruiken, maar werkt nog steeds niet goed) kg 250/jr	Binnen aantal jaar wel voor elkaar		2,314814815
anders namelijk,				

3 Carbon balance calculations

For full excel sheet of carbon calculations contact author.
See colofon for contact details.

Current carbon balance *

input materials	amount	unit	GHG emissions [Tonnes/yr]	fossil energy use	amount	unit	GHG emissions [Tonnes/yr]	breathing of plants and soil	GHG [Tonnes/yr]
crates [1]	215	kg	31	electricity [1]	30523	kwh/yr	23	sequestration [6]	-29
peat [1,2]	1335565	kg	267	fuel [1,5]	2134711,32	L diesel	15	soil & substrates [6]	1987
plastic pots	1851	pots							
plastic sheets [1,2]	2	kg	67						
pesticides [1,2]	2198	kg	55						
compost, org fertilizer and cow manure [2,4]	x	kg	3688						
uitgangsmateriaal [1]	x	kg	0						
transport of all materials to nursery [1,3]	x		9754						

Main sources:
[1] data interview nursery owner (Leenearts,2021)
[2] data Italian nursery systems (lazzerini,2014)
[3] data (kendall and pherson, 2012)
[4] (Vroonhof et al.,2006; Svinartchuk & Hunziker, 2017; Sarri, et al., 2013)
[5] https://tools.genless.govt.nz/businesses/wood-energy-calculators/co2-emission-calculator/, accessed 2021
[6] (Soussana, et al. 2004, p. 62; Nicese &Lazzerini,2013; Zhu et al., 2005; Blonk, 2010, P 70; Brempong, et al., 2019)

Replacing materials with local/ more sustainable alternatives

Currently Produced material [ha/yr]	*Replacement*	*Notes*	*Amount that needs to be replaced*	*unit*	*Replaced with*	*unit*
Crates	wood [3,4]	[illegible] 50% of wood is carbon averagly	28125,74	kg wood/yr whole study area	9,20	trees/yr
Manure and fertilizers	Leaves and greenwaste	kan dat vervangen worden door blad? No, leave desintegrates fast. "little effective as stable carbon storage" (Nicese & Lazzerini, G., 2013)"				
Peat	Pine bark (50% of substrate) [1,2]	plus small scale use up peat, cooperation with [illegible] bark is rest product from sawmills	5097,58	kg Peat /ha/yr	5,10 22,26 0,13	Tonnes bark/yr trees/yr km lane, plant 12 distance, 24m wide, harvest after 25yr
plastics	Sugar canes, beets wheat, potatoes or corn [2]		307,70 39,69	kg plastic /ha/yr tonnes plastic/yr whole study area	23,82 11,91 71,45	ha mais ha sugarbeet ha rice

Sources:
[1] Email contact with Lensli (R. Keijzer, personal communication, May 5, 2021)
[2] (Corbion, 2016)
[3] (Young et al, 1992)
[4] http://extension.tennessee.edu/publications/documents/sp748.pdf, accessed 2021

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Replacing fossil energy consumption with renewables

fossil power used		energy content [1] [Mega joules]	replaced by		unit
electricity use [Kwh/yr]	30523	34165	**windturbines** [2]	3	3MW turbines needed to replace energy consumption whole area
fuel use [L/yr]	275948714	80794840	**pv** [3,4]	17	ha PV field E-W orientation needed to replace energy consumption whole area
total		**80829004,84**			

[1] https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php
[2] https://wind-data.ch/tools/powercalc.php
[3] https://www.zonurencalculator.nl/sun_hours_calculation
[4] (Lagi, 2012)

Current emissions that can't be replaced in this design

	Non-spatial solutions	Compensation needed tonnes/study area
local bioplastic [1]	*current quality bioplastic not yet working very well, but yes in future*	*replace with local bioplastic from corn, beetroot or rice*
insecticides, funghicides, herbicide (production) [2]	*precizie agriculture, natural/robot predators increase biodiversity, steam*	54,56
greenwaste (burning/transport to plant) [2]	*Compost plant exists, not too far from study area, local transport remains*	120,23
manure fertilizer, compost [2]	*More efficient production, fodder and manure management. Lifestock farming needs to improve.*	3688,25
Starting plant materials (uitgangsmateriaal) [1]	*Often from Poland, Turkey, Africa. Use branding, and higher price to enable local production. Leenearts uses his own materials, stores it in fridge.*	*included in transport*
transport of materials that have to be imported [2] (31% transport remains estimate)		3072,59
transport to retail	*switch to electric, renewables are spatial*	*included in new local renewable energy calculation*
current sequestration		-29,47
soil emissions		571,26
Total	*compensate by creating more local sinks*	**7477,41**

Main sources:
[1] data interview nursery owner (Leenearts,2021)
[2] data Italian nursery systems (lazzerini,2014)

GHG reduction

	amount GHG emissions that can be prevented by landuse **[Tonnes/yr for study area]**	amount GHG that can be stored by landuse **[Tonnes/ha/yr]**
rice [1]	67	x
lane [2]	298	7
forest [3]	x	9
	amount GHG emissions that can be prevented by landuse **[Tonnes/yr for study area]**	amount of renewable energy that can be produced **[Gwh/yr]**
pv	1716	1 /ha
wind	1716	8 /3Mw turbine

Sources:
[1] *Prevented GHG emisions, prevention of plastic use (LCA bioplastic and rice production not taken into account)*
[2] *Stored in CLT with long term enduse. Lower storage than in sequestration forest. 85% Of the potential storage of decidious forest floor (Cha, et al., 2019). 12,5% less floorspace to store soc.*
[3] *https://www.vbne.nl/klimaatslimbosennatuurbeheer/maatregel/bebossen-landbouwgronden, accessed 2021*

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4 Models - land use ratio calculations

models	per ha of nursery		per 151ha nurseries				percentages landuse
pv	0,11		17,10				
pv+	0,23		35,38				
wind	0,02		2,94				
wind+	0,04		6,09				
rice	0,47		71,45				
lane	0,00		0,32	ha lane	0,13	km of lane	
lane+	17,10		2582,43	ha of lane	43,05	km of lane	
forest	5,44		821,69				
Forest +	12,79		1931,26				
mixed							
lanes	1,00		133,56	m			
forest	5,44		821,69	ha			
pv	0,11		17,10	ha			
or wind	1,00		3,00	turbine			
rice	0,47		71,45	ha			
mixed (lanes connect N. - S.)							
lanes	0,15	km	54,72	ha per 151 ha nursery			0,05
forest	5,17	ha	760,77				0,74
pv	0,11	ha	17,50				
or wind	1,00	turbine					
rice	0,47	ha	71,45				0,07
			151,42	nurseries			0,14
			1058,36				
total available area final design (young reclamation landscape) ha	820,93						

requierd ratios in final design				
plain lane base	42,71	ha	18,01	km
forest	605,62	ha		
pv nursery part of lane	22,96	ha	8,20	km
turbine				
rice	55,42	ha		
nursery (incl pv lane)	117,45	ha		
total area	820,93			

5 Rating of models

Weight:	Models:	PV	PV+	Wind	Wind+	Lane	Lane+	Rice	Forest+	Mixed	Mix max lane
4	**Comparative Impact on Carbon Balance**										
	Numerical impact on carbon balance	5	10	5	10	3	10	3	10	10	10
	Avoiding emissions locally where possible	10	2	10	2	10	6	10	7	8	8
	Expected timespan for model to take effect	9	9	9	9	6	6	8	7	8	8
	Total	**8**	7	**8**	7	6	7	7	8	**9**	**9**
2	**Comparative Impact on Landscape quality**										
	Improve experience of production practices and natural connections										
	Potential to provide serenity and improved experience of nature	1	1	1	1	8	1	1	6	10	10
	Improve readability keep diversity										
	Fitting landscape character (production, geomorfology & wider context)	10	10	10	10	10	6	8	1	6	6
	Potential to provide landmark(s)	6	7	10	10	3	6	0	1	10	10
	Potential to reveil/ improve experience of production	8	8	10	7	10	10	2	2	7	10
	Accesibility										
	Potential to improve connection between N-S	1	1	1	1	10	6	1	1	7	10
	Ecological quality										
	Potential to connect habitats in N and S	1	1	1	1	3	1	1	10	10	10
	Watersystem quality										
	Improve waterquality	1	1	1	1	2	2	1	8	8	8
	Improve sponge capacity of the area	1	1	1	1	2	2	1	10	10	10
	Interim score landscape quality	4	4	4	4	6	4	2	5	9	9
1	*Amount of extra land that needs to be purchased/space efficiency of model*	**10**	**10**	**10**	**10**	**10**	2	**10**	1	3	3
	Total landscape quality	6	6	6	6	**7**	4	5	4	**7**	**7**
	Total Impact	7	7	7	7	7	6	6	6	**8**	**8**

Desired impact Rating scale:
1 = low impact
10 = high impact

Models that provide carbon neutrality

FEINT (schijn) carbon neutrality