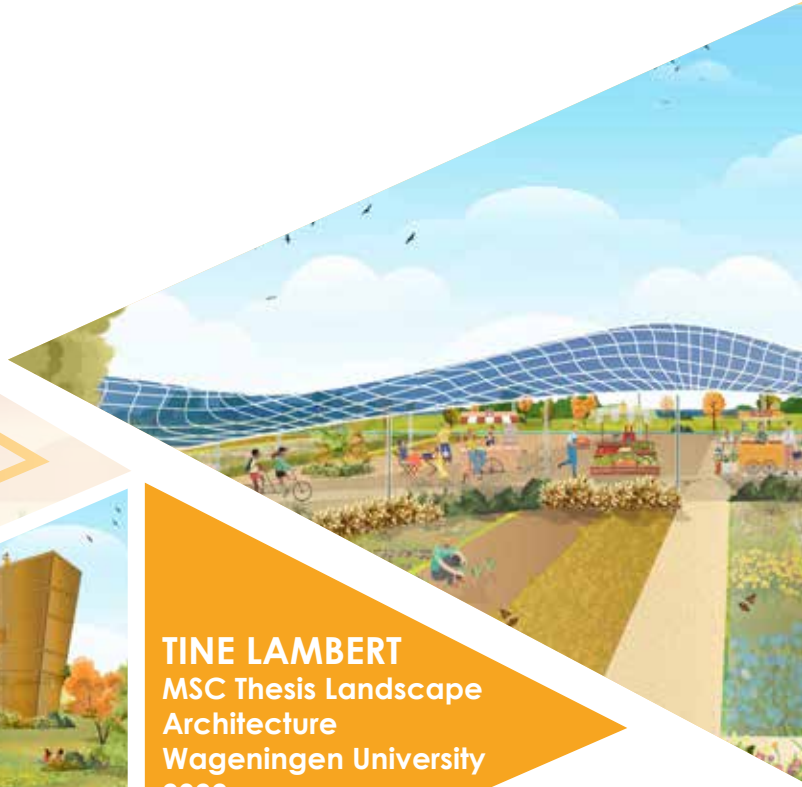
Introducing the ecosystem service concept to solar landscapes

Designing a multifunctional solar landscape near the Millingerwaard by deploying ecosystem services.



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PREFACE

Our planet is increasingly suffering from climate disasters. Heavy storms, extreme temperatures and severe drought have never been so present than in the last twenty years. The recent floods in Belgium, Germany and the southern provinces of the Netherlands opened our eyes and made us realise the need for change. Young people in particular are eager to take action and so am I. As a young landscape architect, I strongly believe that the energy transition, which is one of our generation's most pressing challenges, can be accomplished responsibly, in a way that demonstrates a sustainable interaction with our natural environment. Throughout my education, I realised how important it is to include both ecological and socio-cultural values in the designing process. I regularly had the impression that ecological aspects were undervalued in the design and planning processes, particularly in the creation of energy landscapes. This sparked an interest in learning more about the relationship between design and the natural environment. I came across a concept that relates to this: ecosystem services. During my first year of my Masters program, I explored the notion and discovered that it is a rising concept in research, but it is not yet often linked to energy landscapes. I took up the challenge to explore the combination of this concept and the development of energy landscapes. In particular, I investigated how this combination can improve spatial quality.

I would like to thank my supervisors at Wageningen University, Sven Stremke and Merel Enserink. I am grateful for their willingness to guide me through this process, for the knowledge they shared with me and for the time they took to support me when I had questions. I would also like to thank my family and friends for supporting and encouraging me during the thesis process.

I hope that this master's thesis encourages others to consider solar energy landscapes as an opportunity to improve our landscapes and their ecosystem services, rather than as a threat to spatial quality.

ABSTRACT

The urgency of energy transition in the Netherlands often leads to solutions that do not relate to the existing landscape, putting ecosystems under pressure. The challenge is to ensure that the realisation of renewable energy does not adversely affect ecosystem services, but instead impacts them in a positive way. Therefore, this master's thesis aims to investigate and design how a multifunctional solar energy transition near the Millingerwaard can improve the spatial quality through the deployment of the concept of ecosystem services. This was explored using 16 spatial guidelines obtained from literature on multifunctional solar landscapes and studies regarding the use of the concept of ecosystem services in landscape architecture. The current ecosystem services in the area were analysed, resulting in a map that shows the trade-offs, synergies and hotspots between different ecosystem services and energy generation. Next, expert surveys were used to assess and value the spatial quality of various function combinations with PV. The combination of PV with community gardens and habitat provision was regarded most favourably for spatial quality. Together, the results were incorporated into a design for the landscape near the Millingerwaard which shows that a multifunctional solar landscape can bring about positive changes in the surrounding spatial quality. The result of this study is a showcase example that encourages the application of the methods used, namely the trade-off map and the different surveys to investigate the current services and different function combinations with PV. The use of the different methods stimulates designing sustainable projects that connect people, energy and biodiversity, based on the synergy of different ecosystem services.

KEYWORDS: Spatial quality, ecosystem services, multifunctionality, sustainability, trade-offs and synergies, landscape architecture.

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1 INTRODUCTION

1.1 PROBLEM STATEMENT

The Netherlands is a densely populated country, putting much pressure on its land usage and ecosystems. One of the current main drivers of landscape change is the transition to renewable energy. To meet the 2030 renewable energy targets in the Netherlands, such as increasing the share of renewable energy to at least 32% (Ministry of Economic Affairs and Climate Policy, 2020), innovation is needed.

Renewable energy sources often have a spatial influence, raising concerns about the landscape's future (Sijmons et al., 2017). In the current Dutch landscape, the fossil energy system is less visible because installations are often placed more remote from cities. Renewable energy generation, on the other hand, will be visible everywhere in the living environment (Sijmons et al., 2017). This is due to the lower density of renewable energy compared to fossil fuels, resulting in a larger spatial impact (Stremke & Dobbelsteen, 2012). Currently developed solar power plants aim to maximise energy generation by placing as many panels per hectare as possible. Unfortunately, this results in a lack of quality in the design and integration into the landscape, affecting several ecosystem services (Van der Zee et al., 2019). Furthermore, due to the accompanying changes in the landscape and interactions between supported ecosystem services, local residents frequently resist renewable energy installations (Van der Horst & Vermeylen, 2011). Nonetheless, new potential locations are still being sought to construct large-scale solar power plants (Fig. 1) (Netherlands Enterprise Agency, n.d.).

Wind and solar power must not induce crucial trade-offs among energy supply and other ecosystem functions, such as water regulation or recreation, in order to achieve a sustainable landscape transformation (Picchi et al., 2018). If strategically designed, managed, and supported by spatial disciplines, solar landscapes can secure the provision of ecosystem services and provide opportunities to enhance them (Oudes & Stremke, 2018; Picchi et al., 2018). Furthermore, by combining energy generation with other functional and cultural uses, a multifunctional design can be achieved. Proper management can prevent these multifunctional landscapes from further deteriorating ecosystem services, without diminishing chances for local people to enhance their sustainable lifestyles (Dewi et al., 2012).

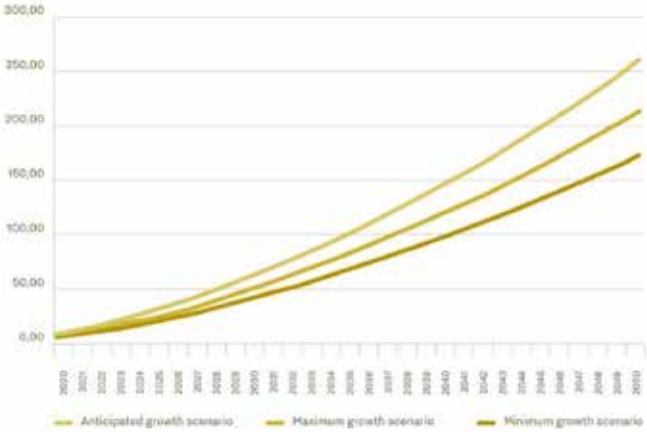


Fig. 1 Growth scenarios of installed PV capacity in the Netherlands (Netherlands Enterprise Agency, n.d.).

1.2 KNOWLEDGE GAP

An increasing number of experts are realising that a turnaround in thinking about renewable energy is needed (Sijmons et al., 2017). However, this must be done in a way that minimises the trade-offs in the landscape and offers opportunities for spatial quality. Little or no design research has been done on combining the concepts of ecosystem services and spatial quality for energy transitions.

Therefore, the aim of this research is to investigate how sustainable multifunctional solar landscapes can improve the spatial quality by applying the concept of ecosystem multifunctionality (Fig. 2).

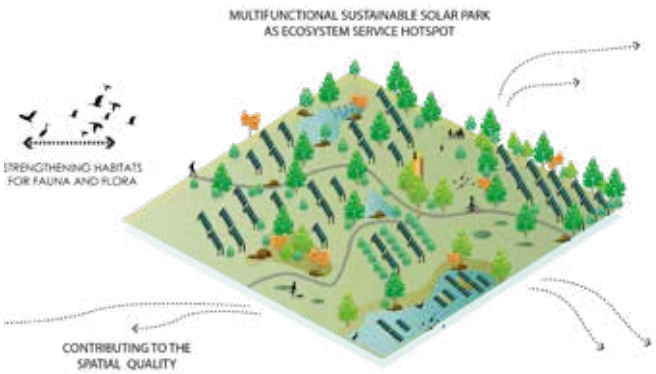


Fig 2. Hypothesis of the possible effect nearby multifunctional sustainable solar landscapes can have on the surrounding landscape.

1.3 KEY CONCEPTS

In this chapter, definitions are given for all key concepts. These definitions are found in peer-reviewed literature. Together, the key concepts form the foundation of this thesis. Firstly, the concepts of ecosystems services and ecosystem multifunctionality will be explained and operationalized. Then the terms landscape, sustainable energy landscape, spatial quality, solar energy and solar landscape will be explained to support the understanding of this thesis.

1.3.1 ECOSYSTEM SERVICES IN LANDSCAPE ARCHITECTURE/DESIGN

Ecosystem services (ESS) focus on trying to unite ecology and design (van Lierop & Matthijsen, 2010). The concept refers to the advantages that ecosystems provide to people, such as food and timber, regulation of floods, soil formation, etc. (Picchi, 2015). This approach also helps evaluating diverse ecosystem services and helps identifying trade-offs between alternative land use scenarios. It also simplifies decision-making for planning purposes (Schaich et al., 2010). The Common International Classification of Ecosystem Services (CICES) divides the concept into three main categories (VivaGrass, n.d.):

• *Provisioning services* – "food, materials and energy, which are directly used by people" (VivaGrass, n.d., para. 1.3);

• *Regulating services* – "those that cover the way ecosystems regulate other environmental media or processes", such as water regulation or pollination (VivaGrass, n.d., para. 1.3);

• *Cultural services* – "the non-material and non-consumptive outputs of ecosystems that affect people's physical and mental state", such as recreation or education (VivaGrass, n.d., para. 1.3).

Van Lierop (2011) states that the concept of ecosystem services is particularly meaningful for landscape architecture. Evaluating these services will help to design a more sustainable living environment where social, economic, and ecological values are aligned and where the benefits for people are clearly indicated. Nowadays, there are many major landscape changes. One of them is the transition to renewable energy. It is therefore essential to fully understand the concept of ESS when designing energy transitions. Picchi et al. (2018) state that research of this concept should be incorporated into sustainable energy planning and design to minimize trade-offs and find possible synergies between generation of renewable energy and other ESS.

As people rely on a variety of ecosystem services provided by landscapes. Continuing to provide these benefits is a challenge, especially as ecosystem services are intertwined, and can interact in surprising and challenging situations (Bennett et al., 2009). Changes in one ecosystem service can have a direct or indirect impact on other services. Trade-off and synergy are two common dynamics in the concept of ecosystem services. A trade-off happens when an improvement in one ecological service causes a reduction in another ecosystem service, either directly or indirectly. For example, when agriculture is intensified, it puts the supply of habitats at risk. In landscape architecture, we do not often speak of trade-offs, but of landscape transformation related conflicts (Erder & Pureur, 2015). Synergies occur when an increase in one ecosystem service leads to a simultaneous increase in another ecosystem service (Tomscha & Gergel, 2016). To evaluate the interactions in the area between the different current services and energy generation, a trade-off map can be created providing a very important point of view of conflicts, sensitivity points and synergies.

1.3.2 MULTIFUNCTIONALITY OF ECOSYSTEM SERVICES

According to Manning et al. (2008), multifunctionality of ecosystem services can be described as the ability of an ecosystem to fulfil multiple functions and services. Considering a trade-off assessment of ecosystem services in the design of sustainable energy will create the possibility to explore new combinations of ecosystem services concerning energy generation.

1.3.3 LANDSCAPE

To understand what is meant by 'landscape', this thesis will refer to the definition provided by the European Landscape Convention (2000, p.2): "Landscape means an area, as perceived by people, whose character is the result of the action and interaction of natural and/ or human factors."

1.3.4 SUSTAINABLE ENERGY LANDSCAPE

Biodiversity and landscape quality can be harmed by renewable energy technologies. For example, the increasing competition between

energy generation and food production, which makes renewable energy often not completely sustainable. As a result, landscape architects should concentrate on creating sustainable energy landscapes that are defined as "a physical environment that can evolve on the basis of locally available renewable energy sources without compromising landscape quality, biodiversity, food production, and other life-supporting ecosystem services" (Stremke and Dobbelsteen, 2013, p. 4-5)

1.3.5 SPATIAL QUALITY

Spatial quality and landscape quality are related concepts. Depending on the language of publication, they are often used interchangeably Spatial quality, the focus of this thesis, indicates the value a user gives a place at a particular moment. This means that spatial quality is highly subjective, varying significantly from one location to another and from one individual to the next (Dauvallier, 2009). When looking into energy transitions, such as the installation of wind turbines or solar power plants, it is notable that there is often some resistance regarding these interventions (Van der Horst & Vermeylen, 2011). To make it more acceptable, a better understanding of local values is needed. Including locals in the design process may help increase local acceptance. However, this is not yet commonly confirmed by scientific studies. Furthermore, it is also crucial to gain insight in the meaning of spatial quality for specific renewable energy landscapes, even before the transition takes place. There are many different aspects that determine spatial quality. This thesis will use the criteria that were selected for the Spatial Quality Framework for Agricultural Landscapes (Bakx et al., 2021). More specifically, the seven most important aspects for the transition from intensive agricultural land to a sustainable multifunctional solar landscape will be applied (Fig. 3). These chosen aspects can be divided into four groups: experiential, economic, ecological, and long-term quality. The seven sub-criteria chosen are briefly described below.

EXPERIENCE QUALITY

1) The term **diversity** refers to a wide range of visual features. It can be defined as a wide variety of land uses, plants, activities, and landscape features. Synonyms are heterogeneity, complexity, and variability (Bakx et al., 2021). Cohesion and diversity are inextricably linked. This is because diversity without cohesiveness leads to chaos, and coherence without variety leads to uniformity (Hendriks & Stobbelaar, 2000).

2) The appearance of unity in the energy landscape is referred to as **cohesion**. It describes how various landscape elements interact with one another. As a result, disruption of synergies might have a negative impact on cohesion. The concepts "unity" and "harmony" are similar (Bakx et al., 2021).

3) **Naturalness** indicates a landscape's natural aspect as opposed to artificiality. The presence of greenery, the variety of planting, and the usage of natural materials all have a significant impact (Bakx et al., 2021).

ECONOMIC QUALITY

4) **Profitability** is defined as the financial gain resulting from the integration of functions (Bakx et al., 2021). Profitability for local residents and stakeholders of a certain function combination.

5) **Recreational opportunities** define whether or not a combination is suitable for recreation. Accessibility, such as the existence of pathways, cycle lanes, and areas of interest, are important factors to consider (Bakx et al., 2021).

ECOLOGICAL QUALITY

6) **Biodiversity** refers to the presence of a variety of animal and plant species in the area. It is linked to the concept of diversity to some extent because various landscape characteristics such as field margins, hedges, and lakes can serve as habitat for a variety of species (Bakx et al., 2021).

LONG-TERM QUALITY

7) The ability to retain and modify the combinations of functions under changing economic, environmental, socio-cultural and technical situations is referred to as **sustainability**. This sub-criterion's principles are flexibility and manageability (Bakx et al., 2021).

Fig. 3 Criteria for spatial quality based on the Spatial Quality Framework for Agricultural Landscapes (Bakx et al., 2021)

1.3.6 SOLAR ENERGY

Solar energy is a form of renewable energy that converts the light falling on earth into energy (Sijmons et al., 2017). By 2050, two-thirds of renewable electricity that will be generated on land, will come from solar power, according to the National Energy Perspective. This means that The Netherlands will be faced with the challenge to install 200 PJ of photovoltaic panels by 2050 (Sijmons et al., 2017). Commonly 1 PJ requires 300 to 500 ha of solar power plant (for panels with a peak power of 270-420 Wp and 850kwh/kwp with 2 rows of panels at an angle of 35 degrees and mutual distance between 2 rows 9 meters) and corresponds with the energy consumption of 100,000 households (Kuijers et al., 2018). It is clear that much space is needed for this transition and that this strategy will cause landscape changes in many places. It is therefore important that solar landscapes are well-planned and designed, and that enough time is spent on finding smart combinations of functions (Kuijers et al., 2018).

1.3.7 SOLAR LANDSCAPE

Oudes and Stremke (2021) state that the term solar landscape refers to a combined approach of solar power plants and landscapes where solar infrastructure is adapted in different ways and landscape features are incorporated, such as hedgerows and wildflower meadows. Solar landscapes aspire to attain other benefits than energy, such as developing habitats whereas today's solar power plants are designed for energy efficiency and economic advantages (Oudes & Stremke, 2021).

1.4 CASE STUDY AREA

Berg en Dal, a municipality in the vicinity of Nijmegen, has the ambition to become climate neutral and sustainable. By 2023, Berg en Dal wants 16% of its total energy to be renewable energy generated within the municipality (Gemeente Berg en Dal, n.d.). To achieve this, the municipality has shown interest in building a solar landscape. Berg en Dal has since worked together with its residents to find ideal locations for such a solar landscape (Gemeente Berg en Dal, n.d.). The area that was selected for this thesis is situated near the Kekerdomse waard and the Millingerwaard, both ecologically important areas belonging to the protection regime of the Ecological Main Structure and the 'Gelderse Poort'. A natural and dynamic river landscape of riparian forests, river dunes, and side channels allows various habitat types to develop in the area (European Commission, 2018). Nevertheless, within these areas, there is still potential for improving biodiversity. Even right now, the region around Berg en Dal continues to serve as a living lab for restoring biodiversity in rural areas (Haverkamp, 2021).

This case study area is chosen because many ecosystem services are combined on one side of the municipality, such as along the Millingerwaard, while very few can be found in the area inside the dike (Haverkamp, 2021). The nearby meadows are therefore a powerful research area, as they currently provide few ecosystem services that could be enhanced in a multifunctional layered landscape. One of the aims of the municipality is to transform the now monofunctional agricultural areas into a multifunctional landscape where recreation, nature and agriculture come together. Therefore, this case study area of about 120 ha (excluding the two reclaimed lakes) is an ideal research area for transforming intensive agricultural land into a sustainable multifunctional solar landscape based on the concepts of ecosystem services and spatial quality.

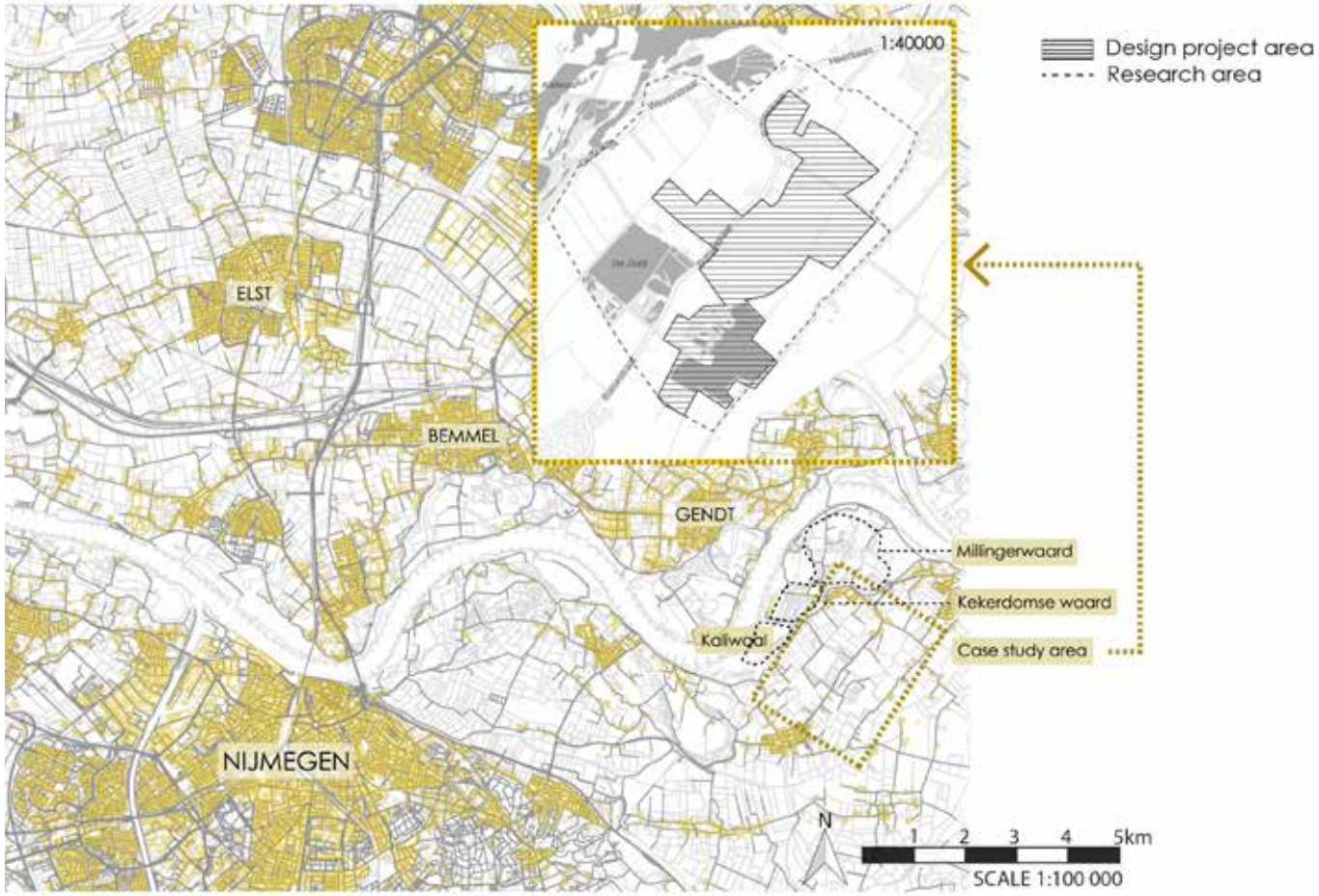


Fig 4. Map of the area with an interest in an energy landscape. The area is situated near the 'Kekerdomse waard' and the Millingerwaard, which are ecologically important.

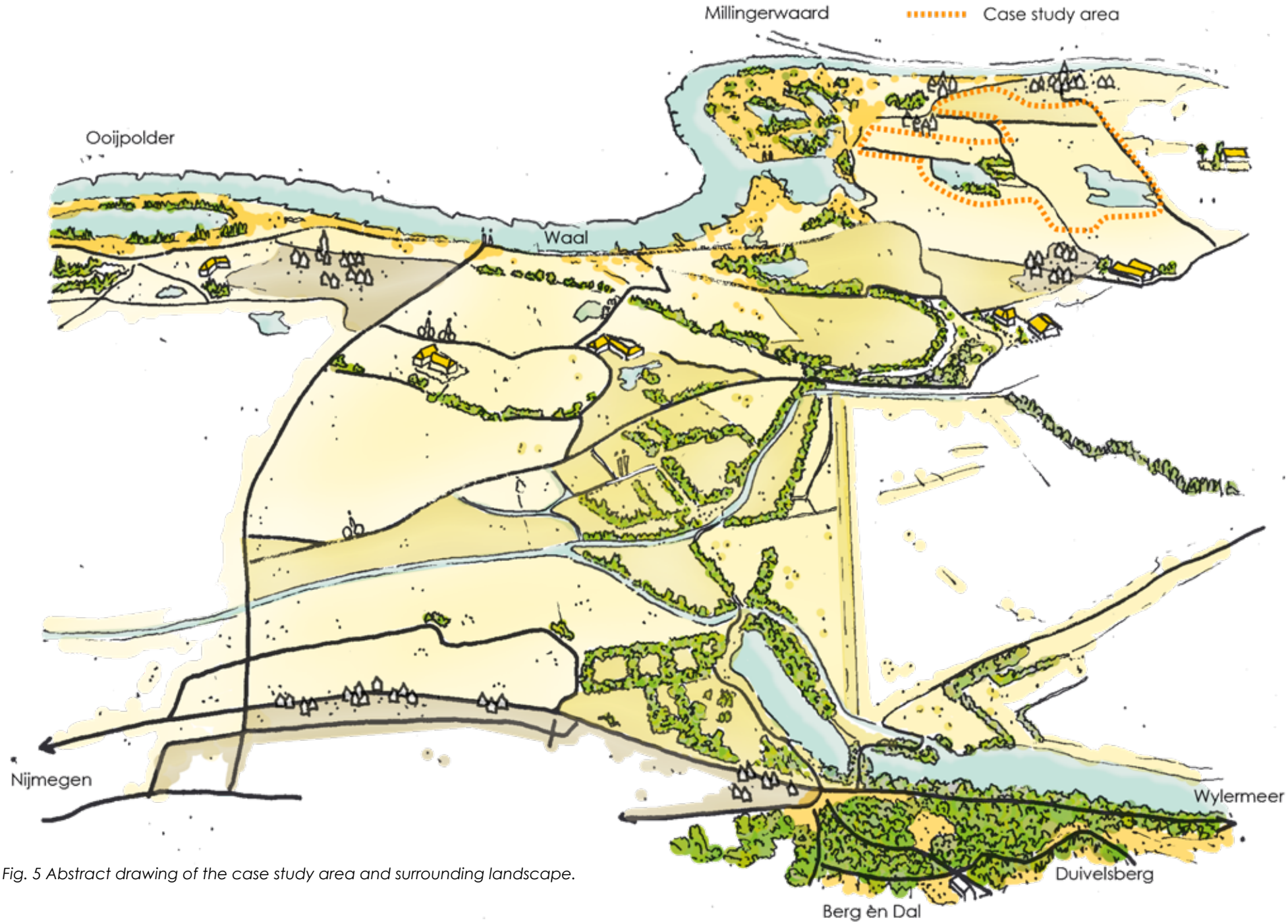


Fig. 5 Abstract drawing of the case study area and surrounding landscape.

1.5 RESEARCH OBJECTIVE

The urgency for energy transition in the Netherlands often leads to solutions that do not look beyond the boundaries of the parcel and do not relate to the existing landscape, putting ecosystems under pressure (Picchi et al., 2019). Today's challenge is to establish renewable energy without negatively impacting the various ecosystem services. Therefore, this study aims to explore and design a multifunctional solar energy landscape near the Millingerwaard area that improves the spatial quality. The approach will be based on minimising trade-offs and creating synergies between ecosystem services.

1.6 DESIGN & RESEARCH QUESTIONS

The main research question is the following:

MRQ: How can solar energy transition near the Millingerwaard improve the spatial quality by applying the concept of ecosystem multifunctionality?

To answer this question, multiple sub research questions must be answered first. SRQ1 will inform the contextual background of this thesis and will help to construct a design in the end.

SRQ1: What are the spatial principles in literature related to sustainable multifunctional solar landscapes and the theory of ecosystem services?

SRQ2.1: How important are the current ecosystem services within and in the vicinity of the case study area?

SRQ2.2: Do these current ecosystem services form a trade-off or synergy when combined with solar energy generation?

The knowledge and principles from SRQ1 and 2 will provide a clearer view of the possibilities and challenges of combining solar energy generation with other ecosystem services.

SRQ3: What are possible (new) design combinations between energy generation and other ecosystem services that contribute to the spatial quality?

1.7 RESEARCH STRUCTURE

The research structure is divided into two parts: Research for Design and Research through Designing. In the former, the answers to the first two research questions will form the background knowledge for the design. Thereafter, the Research through Designing phase will be conducted through iterative design loops, followed by an exploratory site design that focuses on the multifunctionality of ecosystem services.

SRQ1
The result of SRQ1 will be a set of spatial principles related to sustainable multifunctional solar landscapes, obtained by an extensive literature review.

SRQ2
To understand the importance of current ecosystem services and whether these represent a trade-off with respect to energy generation, an ecosystem service analysis will be conducted using literature, field trips, spatial data and a questionnaire for stakeholders and experts (Fig. 6). In a first step, the current ecosystem services will be selected based on current land cover maps and literature. The majority of these selected services will be confirmed through field trips. Next, a survey will be conducted among stakeholders and experts, who will assign a value of importance to each existing ecosystem service in the area. The services will then be classified according to the CICES V5.1 (a classification form). In the realm of ecosystem services, effective and relevant classification systems are extremely crucial. To move forward, many perspectives from other disciplines must be brought together to ensure that we are discussing the same services, therefore CICES V5.1 can be used. In a final step, a trade-off map will be made of the current ecosystem services in relation to energy generation, showing trade-offs, synergies, coldspots and hotspots.

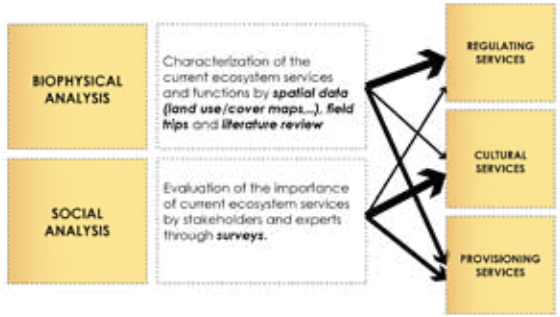


Fig 6. Ecosystem service analysis using literature, field trips, spatial data, interviews with stakeholders and expert knowledge.

SRQ3
SRQ3 is part of the Research through Design methodology. Using the principles and knowledge that have been gathered from SRQ1 and SRQ2, multiple design experiments will be conducted to find out which combinations between energy generation and four other ecosystem services can be applied to improve the surrounding spatial quality. This thesis will focus on the following ecosystem services: energy generation, livestock and crop production, habitat provision, and water regulation (Fig. 7). These five were selected as the most important services for the region around Berg en Dal based on literature and own assessment. Energy generation had already been chosen as the main focus of this thesis. The choice for livestock and crop production is based on the current land use and land cover maps, which show that these are essential ecosystem services in the project area (LGN viewer, n.d.). In addition, the region wants to transform its intensive agriculture into a landscape that combines agriculture, nature conservation, and recreation, with a strong focus on nature conservation to reinforce nearby natural areas (Van Bussel et al., 2020). This proves the need to include habitat provisioning as a service in the design combinations. Lastly, water regulation was chosen as it is one of the objectives of the municipality in the area. The importance of this ecosystem service in the area together with water quality and storage, was also confirmed in the pilot project 'Green Blue Services' that was investigated in the municipality of Berg en Dal (Van Bussel et al., 2020).

These five services will be combined in various design combinations. To investigate the way these different design combinations of functions are valued and interpreted in the landscape such as the mix of arable farming and solar panels, a questionnaire with visualisations will be sent out to stakeholders and experts. This survey will help to evaluate the importance of the various combinations of functions according to criteria selected from the Spatial Quality Framework for Agricultural Landscapes (Bakx et al., 2021). The criteria that were selected are important for the transition from an intensive agricultural landscape to a sustainable multifunctional solar landscape (Fig. 3). These are divided into four groups: experiential quality, economic quality, ecological quality, and long-term quality. Each of these groups are defined using specific sub-criteria. Experts will give every combination of functions a score between one and four for every criterion. One meaning the combination has a negative effect, and four meaning it has a highly positive effect on

the spatial quality. Next, a final design for the case study will be made taking the results of SRQ3 into account. This design will be assessed by outsiders using the same criteria as for SRQ3 (Fig. 3) to check if the different function combinations fit well into the landscape. Ultimately, this final design will answer the main research questions of how a solar energy transition along the Millingerwaard can improve the surrounding spatial quality by applying the concept of ecosystem multifunctionality. The findings and main conclusions from the research and landscape design will be discussed in the final chapter.

	ENERGY GENERATION (provisioning service)
PROVISIONING SERVICES	
Crop production	+++
Timber	+
Fuel and fibre	-
Livestock	++
REGULATING SERVICES	
Water regulation	+++
Erosion control	+
Pollination	++
Pest and disease control	+
SUPPORTING SERVICES	
Habitat provision	+++
Soil formation	+
Nutrient cycling	++

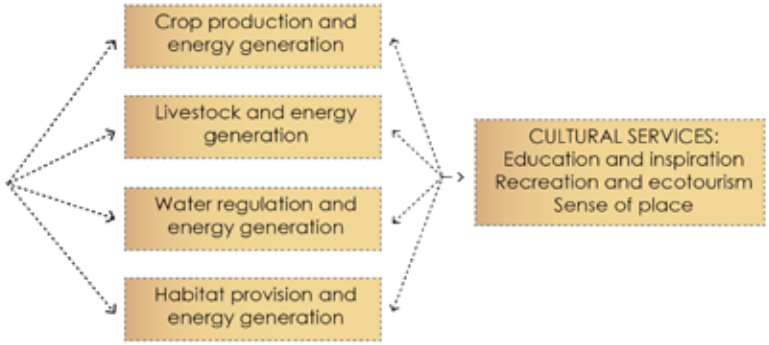


Fig. 7 Four essential combinations with energy generation were chosen for the region around 'Berg en Dal' based on literature and own assessment. The five ecosystem services (energy generation, water regulation, habitat provision, livestock, and crop production) will be the focus of this thesis.

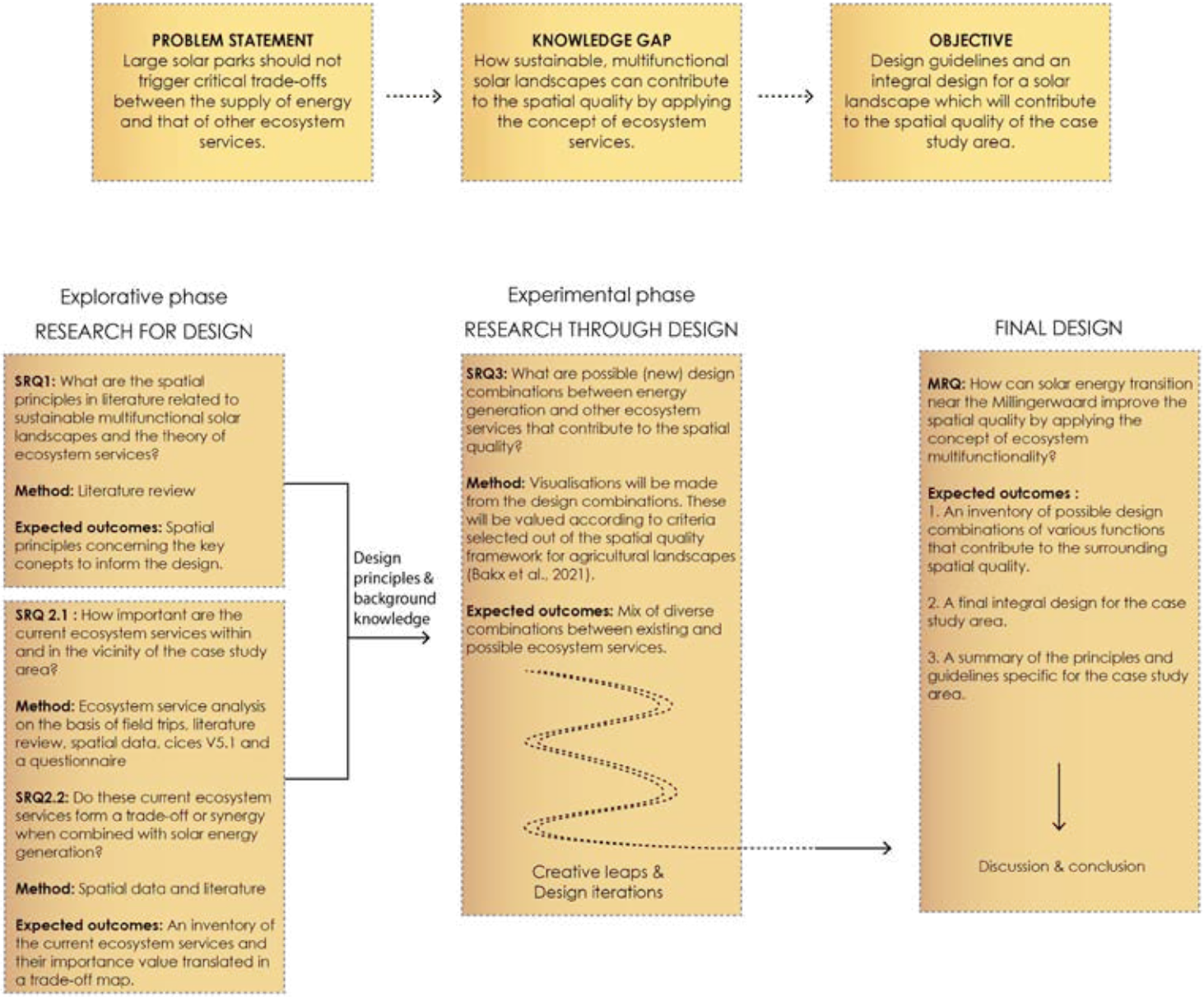


Fig. 8 Visual synthesis of the methodological framework.

2 ANALYSIS CASE STUDY AREA

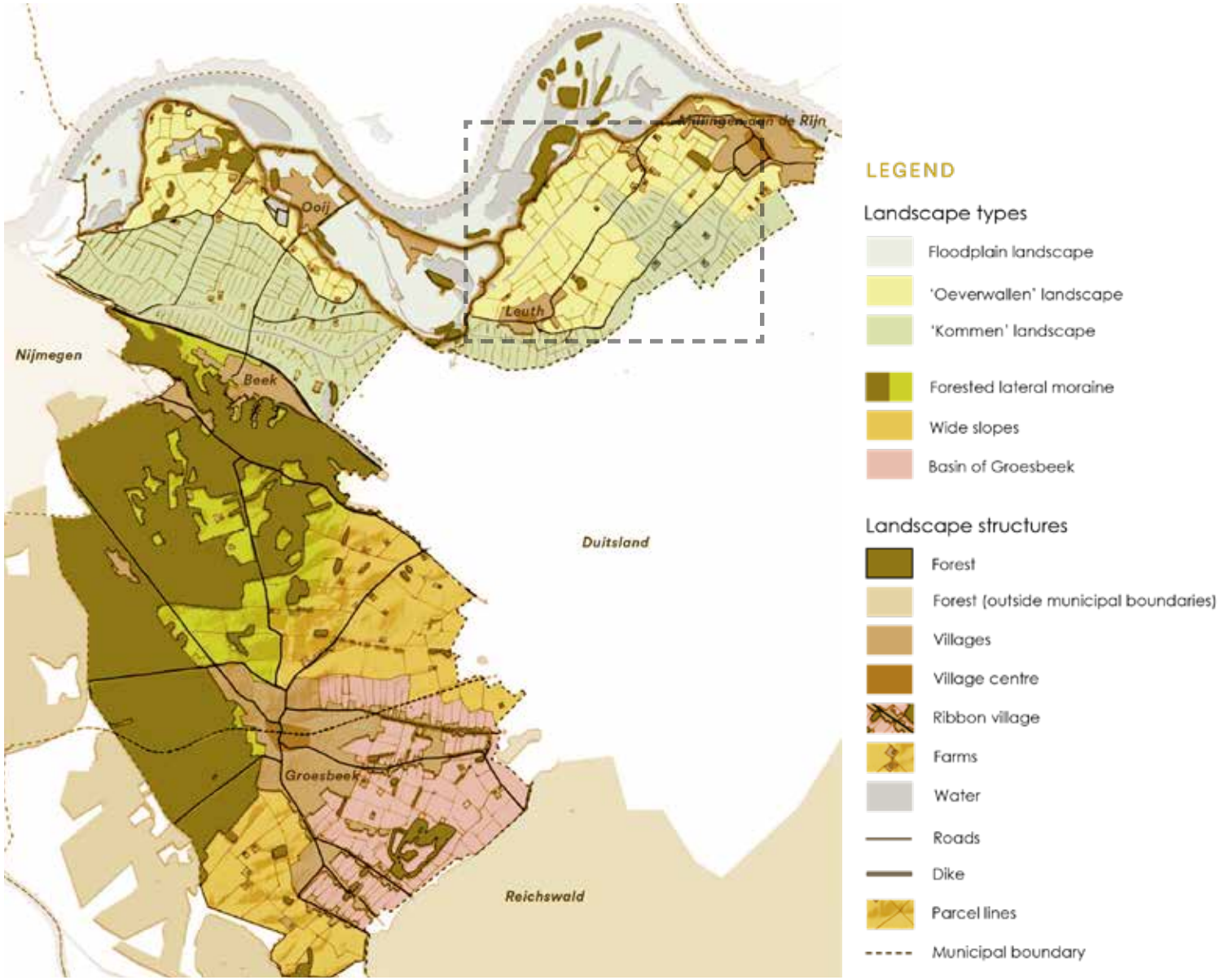


Fig. 9 Landscape types of Berg en Dal (Adjusted map from LOS stadomland, 2021)

Berg en Dal is a unique area characterized by its different landscape types, history and nature. The main aspects of the analysis are briefly discussed below. A brief analysis of the case study area in detail follows at the end.

2.1 LANDSCAPE TYPES AND CHARACTERISTICS

A unique feature of the municipality of Berg en Dal is the strong difference in relief between the river area and the lateral moraine. Six landscape types can be distinguished (Fig. 9), of which three are present in the case study area (Fig.10). Each landscape type is presented with a brief description of its appearance, land use, and opportunities.

2.1.1 FLOODPLAIN LANDSCAPE:

2.1.1.1 APPEARANCE:

The landscape consists of a large-scale, alternating open and enclosed zone with unregular variations of wide river views, sand dunes, meadows, and riparian forests. The area gets flooded regularly, making it a dynamic area with a very sandy to clayey soil.

2.1.1.2 LAND USE:

1) Self regulating nature with walking recreation
2) Industrial landscape of brick factories on raised ground
3) Some extensive cattle breeding in the natural areas
4) Little or no residential development

Fig. 10 Three different landscape types in the case study are (Adjusted map from LOS stadomland, 2021).

Vegetation: Shrubbery of hawthorn, blackthorn and other bushes, grienden, hardwood and softwood riparian forests, pollard willows, marshland and willow bushes.

2.1.1.3 OPPORTUNITIES:
Continuous development of self-regulating nature in the floodplain with side channels and extensive livestock farming. Another opportunity would be the linking of recreational activities inside and outside the dikes.

2.1.2 'OEVERWALLEN' LANDSCAPE:

2.1.2.1 APPEARANCE:
The 'oeverwallen' landscape is located between the nature reserve outside the dike and the open agricultural production landscape inside the dike. The zone is characterised by its orchards and alder groves and consists of sand excavations and forest planting between the villages of Leuth and Kekerdom.

2.1.2.2 LAND USE:
1) Densely built-up villages and an increase in business activity on the outskirts of the villages
2) Agricultural landscape consisting of irregular old block parcelling patterns
3) Recreation consisting out of biking and walking routes and on days when the weather is beautiful at the sand groves
4) Cattle, fruit and tree cultivation on the agricultural lands

Vegetation: Hedges on field boundaries, poplar forests, willow forests, grienden, rows of pollard willows, bushes of hawthorn and blackthorn.

2.1.2.3 OPPORTUNITIES:
The enhancement of a solid green structure in the 'oeverwallen' landscape (zone 2), will allow to link the walks along the villages, which are currently rather difficult to find.

2.1.3 'KOMMEN' LANDSCAPE:

2.1.3.1 APPEARANCE
The 'kommen' landscape (zone 3) is a traditionally low-lying area, intersected by old river arms. It is characterised by an open wide landscape in which large plots connect with the regularly spaced watercourses (Wielsche & Zeelandsche) and the slightly lower zones among these. There are "pollen" in the middle of the plots, these are elevations containing old farmhouses.

2.1.3.2 LAND USE:
1) Large-scale, modern agricultural businesses (cattle breeding and arable farming)
2) Some recreational side activities on a few farms.
3) Few buildings due to wet and low-lying area

2.1.3.3 OPPORTUNITIES:
There is a strong need for a more natural development of the watercourses to improve water quality and biodiversity in the area. Furthermore, hedges, small dikes, and natural field edges along the outskirts of the plots could be stimulated, making the area more attractive for recreational purposes.

2.2 HISTORY

Until the early 1990s, the Millingerwaard was an agricultural area with grain and livestock. 'ARK nature development' is a non-profit organization that promotes open access to nature in the realm of social values such as leisure, climate adaptation and mineral exploitation (ARK, 2021). This organisation was given three hectares of land in 1991 to explore some ideas to restore the river nature and to manage the land with the introduction of horses and cattle (ARK, 2021). Eventually ARK developed five hundred hectares of river nature, in cooperation with local landowners. The maps in Fig. 11 clearly show that the amount of water has continued to increase over time. This is partially due to the artificial gully pattern that flows downstream into the river Waal. As a result, the landscape has transformed into a diversified and dynamic nature area where erosion, sedimentation, and natural grazing have revived the original river landscape. Today, the riverbanks, river dunes, small beaches, riparian forests, and the grasslands form the habitat of thousands of plant species, breeding birds and rare insects (ARK, 2021).

One of the lakes within the area is the 'Recreatieplas de Zeelt' that has historically been formed by the extraction of clay, sand, and gravel. Before the lake was created by land reclamation, this place was an agricultural area surrounded by hedges and willows. As a result, the open water is barely noticeable today due to the dense willows and bushes. The banks have become dangerous as they have eroded over time. Swimming and fishing in the lake has therefore been prohibited since 2008. The village Ubbergen and the water board 'Rivierland' are driven to construct a new and safe embankment (nederlandscultuurlandschap, 2013).

Fig. 11 Historical evolution of the case study area and the surrounding landscape (adjusted maps from topotijdreis, n.d.).

2.3 NATURE

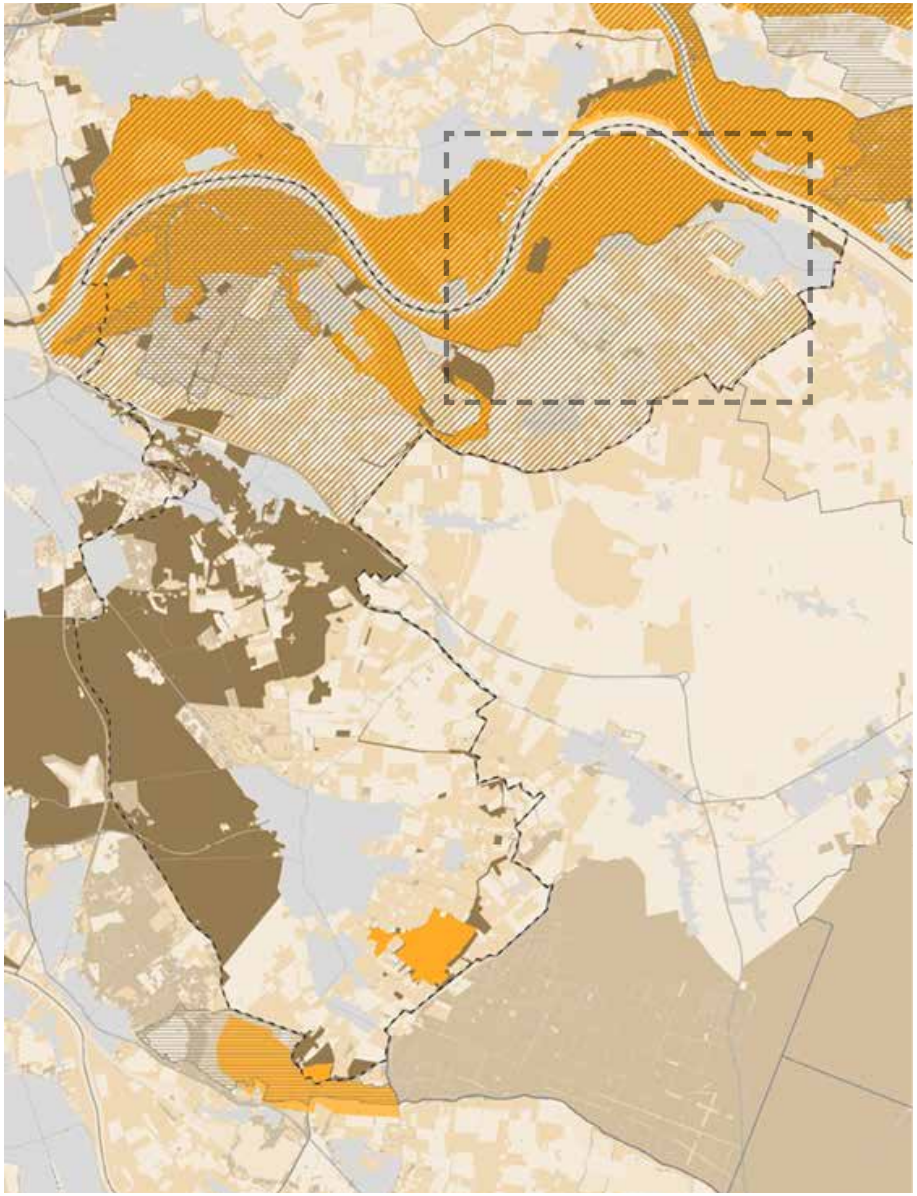


Fig. 12 Nature and biodiversity in Berg en Dal (Adjusted map from LOS stadomland, 2021).

Biodiversity is very important in this region because the area provides habitat for many species, and therefore degradation of nature should be avoided (European commision, 2018). A decline in valuable habitats would have consequences for the surrounding nature and for the food supply in the area. For example, bees are essential for the pollination of crops. If the biodiversity continues to decline, the pollination ecosystem service will in turn also start decreasing, leading to severe negative economic effects (Blaydes et al., 2021). Solar landscapes can play a vital role in fighting this scenario. They can increase mental wellbeing, nature development, habitat provisioning, and pollination by being valuable stepping stones between nature-rich areas (Blaydes et al., 2021). It is therefore important to analyse the landscape to find where valuable nature is located (Fig. 12).

The Millingerwaard area has developed a natural and dynamic river landscape of riparian forests, river dunes, and side channels, allowing various habitat types inside and outside the dike. These will be discussed together with their ecological valuable elements using the image on the following page (Fig. 13).

1) This part of the Millingerwaard area does not flood. At high tide, it is one of the places were foxes, deer, mice, and large grazers find shelter (Teunissen, 2019).

2) Less than 30 years ago, this area was covered by corn fields. It is now overgrown with hawthorns and blackthorns. There is an increasing number of trees growing under the protection of these thorny bushes. During winter this is a good place to spot 'koperwieken', 'kramvogels' , and other field birds (Teunissen, 2019).

3) To guarantee the safety of local residents, the water has been given much space in this area. The large gullies were built to drain the water quicker during extreme high tides. This corresponds to the development of the dynamic river nature (Teunissen, 2019).

4) In the Kekerdomse Waard grows a so-called softwood riparian forest, consisting of mainly silver willows. Many trees have already fallen, and the ones that have not, are full of holes, creating a paradise for woodpeckers. During spring, this forest often gets flooded (Teunissen, 2019).

LEGEND

- Gelderland Nature Network
- Natura 2000
- Resting areas for geese
- Silent areas

5) This field on the other side of the gully is a large beaver habitat.

6) This lake is where large poplars and old willow trees grow on clay mounds that were left behind after most of the clay had been dug up for the brick factories. Large groups of 'aalscholvers' and 'grote zilverreigers' rest in this forest during autumn (Teunissen, 2019).

7) This area represents grasslands that are rich in herbs and fauna where grasses are dominant but where herbs also take up a large share (> ca. 20%). Besides these more nutrient-rich grasses (e.g., 'raaigras, 'ruwbeemdgras'), less nutrient-rich grasses such as 'gewoon kweekgras, 'rood zwenkgras' and 'gewoon ruwbeemdgras' also occur (Bij12_a, 2020).

8) In these marshy areas grow typical marsh plants such as tall grasses like reed and reed canary grass, greater sedge, rushes, and gallows. Marshes like these are of great importance for birds, dragonflies, fish, amphibians, and certain mammals such as beavers, otters, root voles, and water shrews (Bij12_b, 2020).

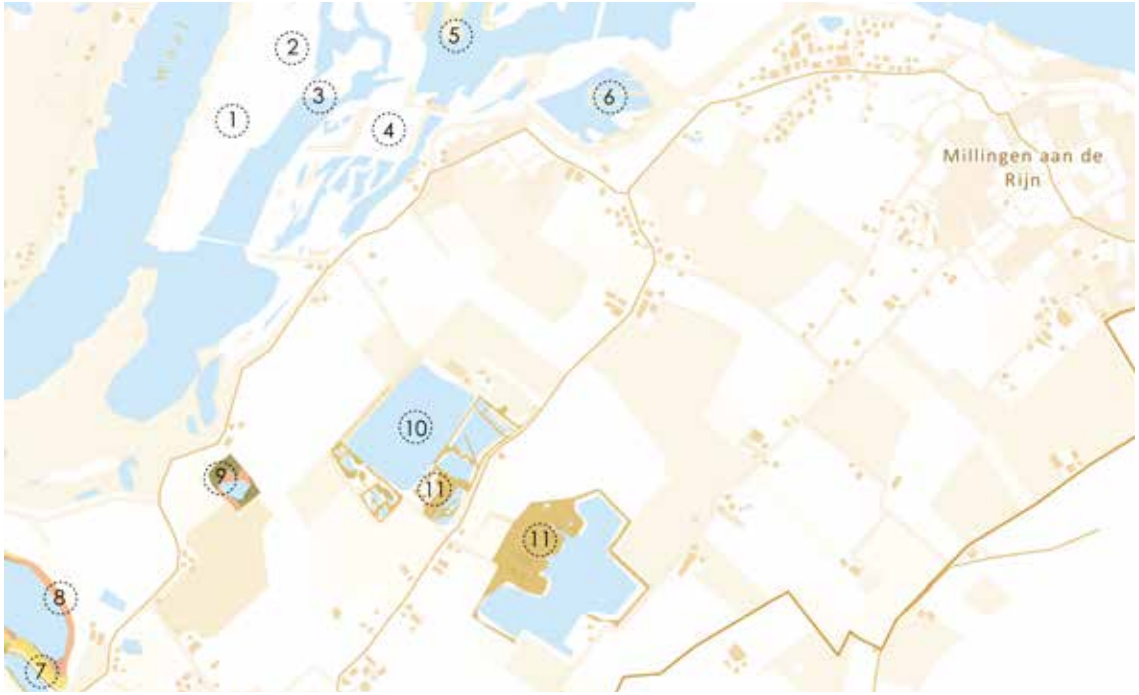


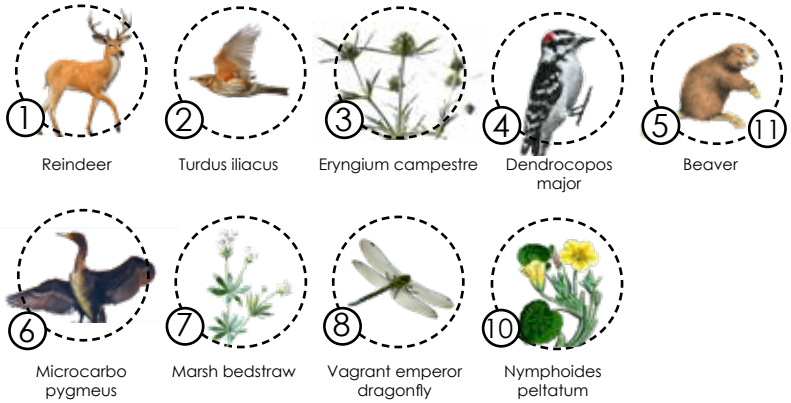
Fig. 13 Valuable fauna and flora in the case study area and its vicinity.

9) Moist forest with wood production

10) These freshwater lakes serves as a habitat for otters, fish such as eels, jellyfish, pike, dragonflies, tubeworms (e.g., green glaziers), pond scrubs, and aquatic plants such as the long-stemmed pondweed and the water gentian (Bij12_c, 2020).

11) This river and stream-supported forest is important for various groups of species, including breeding birds, due to their (often) lush and inaccessible character. Beavers can be found on these banks. Due to the base-rich conditions and high humidity, these forests are crucial for many rare mosses (Bij12_d, 2020).

The various types of nature in the area of this case study were analysed using the following criteria: endangerment, rarity, naturalness or hemeroby presence of species of conservation concern and habitat continuity. The valued habitat types can be found in appendix 2, where they have been ranked according to their value. Per habitat, key species were selected. Their distribution distance (in m) and the area needed for a stable population (in ha) were determined. This exercise allows us to include the desired species in the design phase, considering and improving the desired habitat types.



2.4 WATER REGULATION

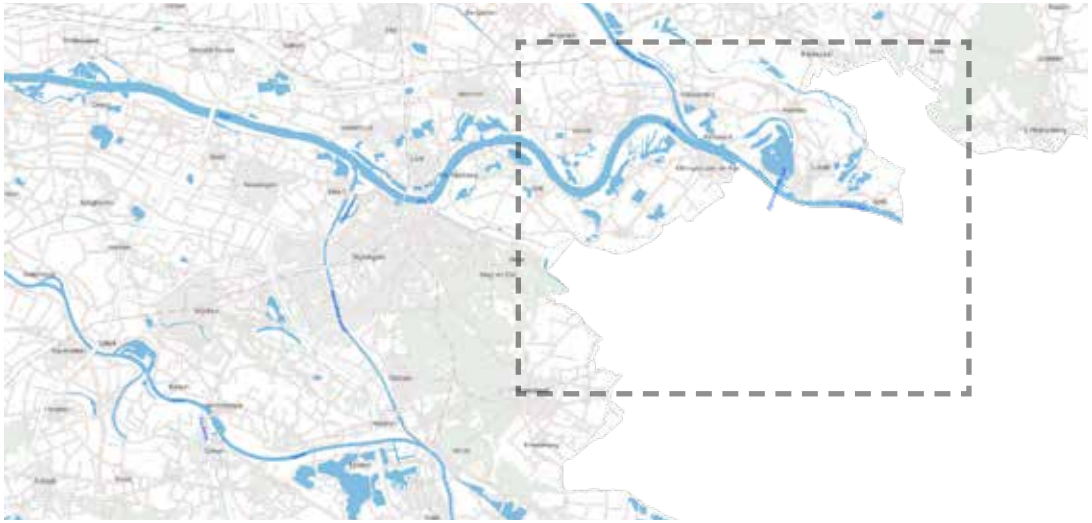


Fig. 14 Water on land after heavy rainfalls (Atlas voor de Leefomgeving, n.d.)

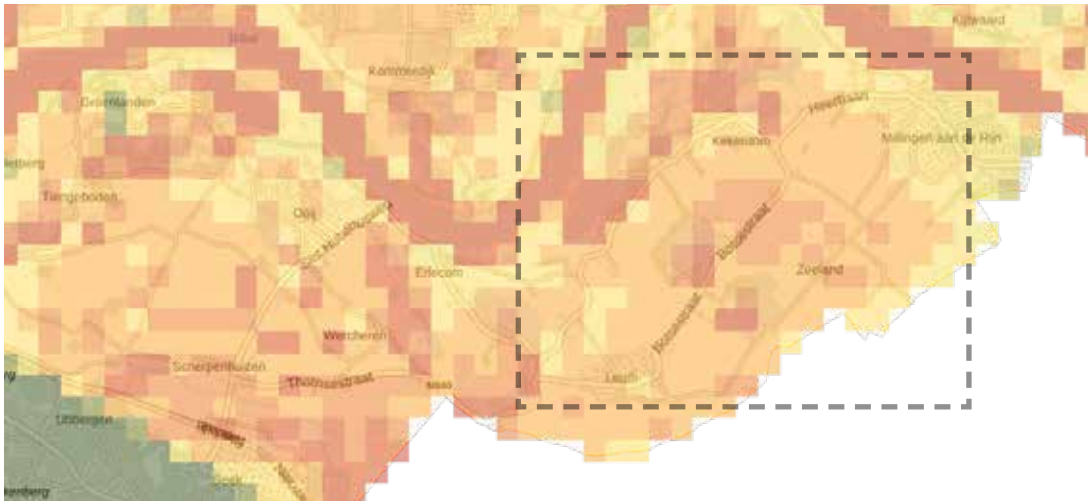


Fig. 15 Underground water storage capacity (Atlas voor de Leefomgeving, n.d.)

The first map shows the water amount during a heavy rainfall (Fig. 14). The darker the colour on the map, the more water is present on land. The study area shows many dark zones, which may be a problem when taking into account the second map, which shows the water storage capacity in the area (Fig. 15). Low infiltration is revealed in most places where the water accumulates (the redder the worse, the greener the better the infiltration). Poor underground water storage capacity and infiltration can lead to drought and flood problems in the area. Therefore, it is important to take the ecosystem services of water regulation and water storage into account in the design.

However, places where much water accumulates can also form interesting habitats if they are adopted in the right design. Take the Millingerwaard as an example: birds and other animals can flourish here in wetter habitats. Water regulation, energy, and nature can thus form interesting combinations, but should be investigated more deeply.

2.5 RENEWABLE ENERGY

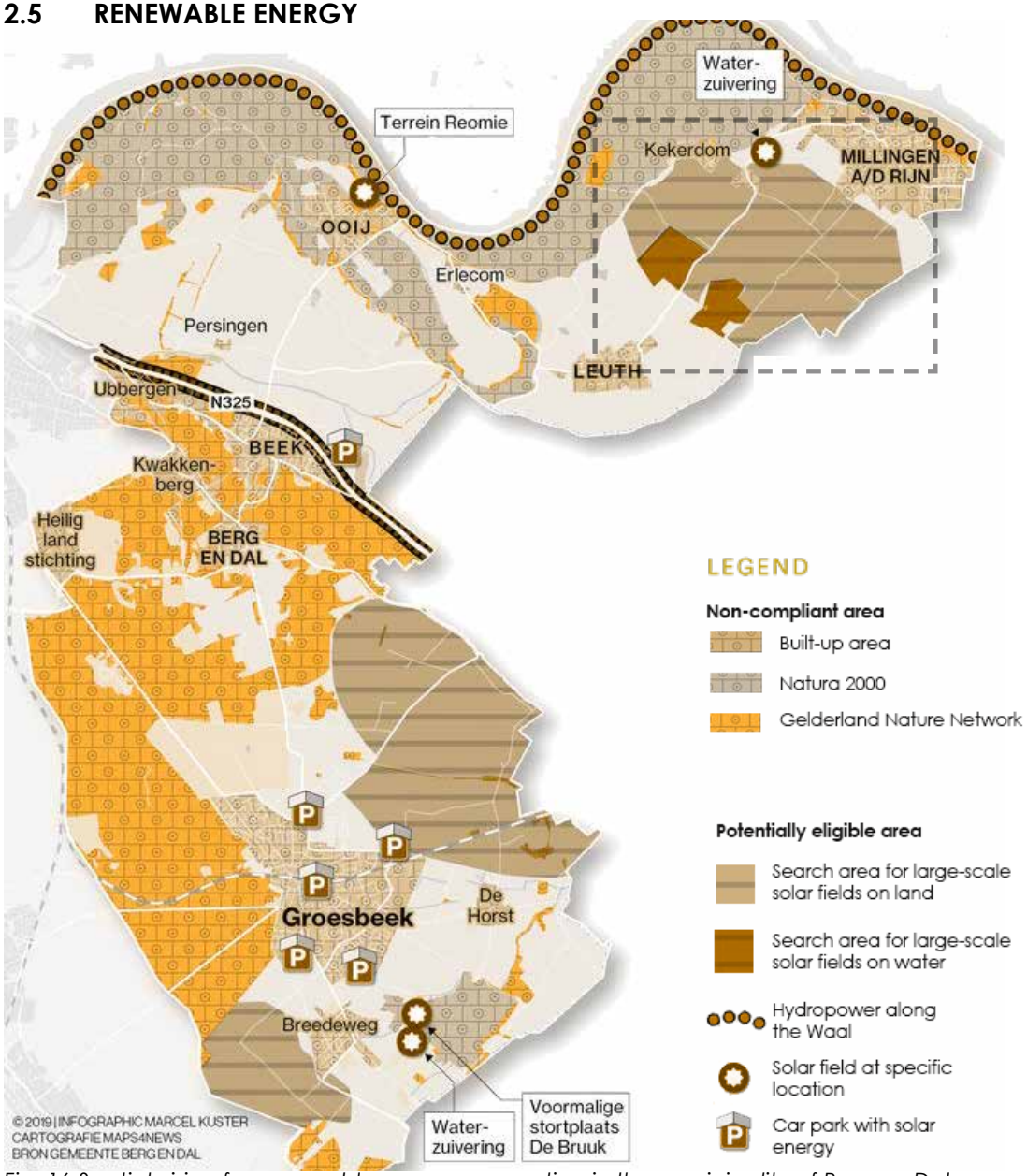


Fig. 16 Spatial vision for renewable energy generation in the municipality of Berg en Dal (Adjusted map from LOS stadomland, 2021).

Figure 16 shows the spatial vision for the generation of renewable energy in the municipality of Berg en Dal. The area for this case study is indicated on this map as a search area for large-scale solar fields on land. However, these search areas are not intended to be used exclusively for the large-scale generation of renewable energy. The importance of the current agricultural use and the landscape and its recreational values transcends this matter. In that regard, the municipality has introduced some conditions for the generation of renewable energy in the area (Gemeente Berg en Dal, 2020):

1) There must be social integration.
Every project in the area must start with participation of the local residents and stakeholders and should always contribute to the local economy.

2) The solar landscape must be ecologically and scenically integrated.
The landscape structures must be preserved and if possible, reinforced. The solar landscape must become an extension of the Millingerwaard or an stepping stone of the existing blue-green veining to create a positive effect on biodiversity.

3) Coordination with the province and network management must be taken into account.
The province of Gelderland has a spatial policy that imposes some restrictive conditions that are important to consider when designing. In addition, the location for the solar landscape must be suitable for connecting to the electricity grid and the maximum energy capacity should not be exceeded.

4) The temporary nature of large-scale renewable energy generation must be taken into account in the design.
The plans must consider the longterm of 25 years from now. Moreover, it has to be possible to return the site to the former landscape or to easily install a new set of (more innovative) solar panels.

2.6 RECREATION AND TOURISM

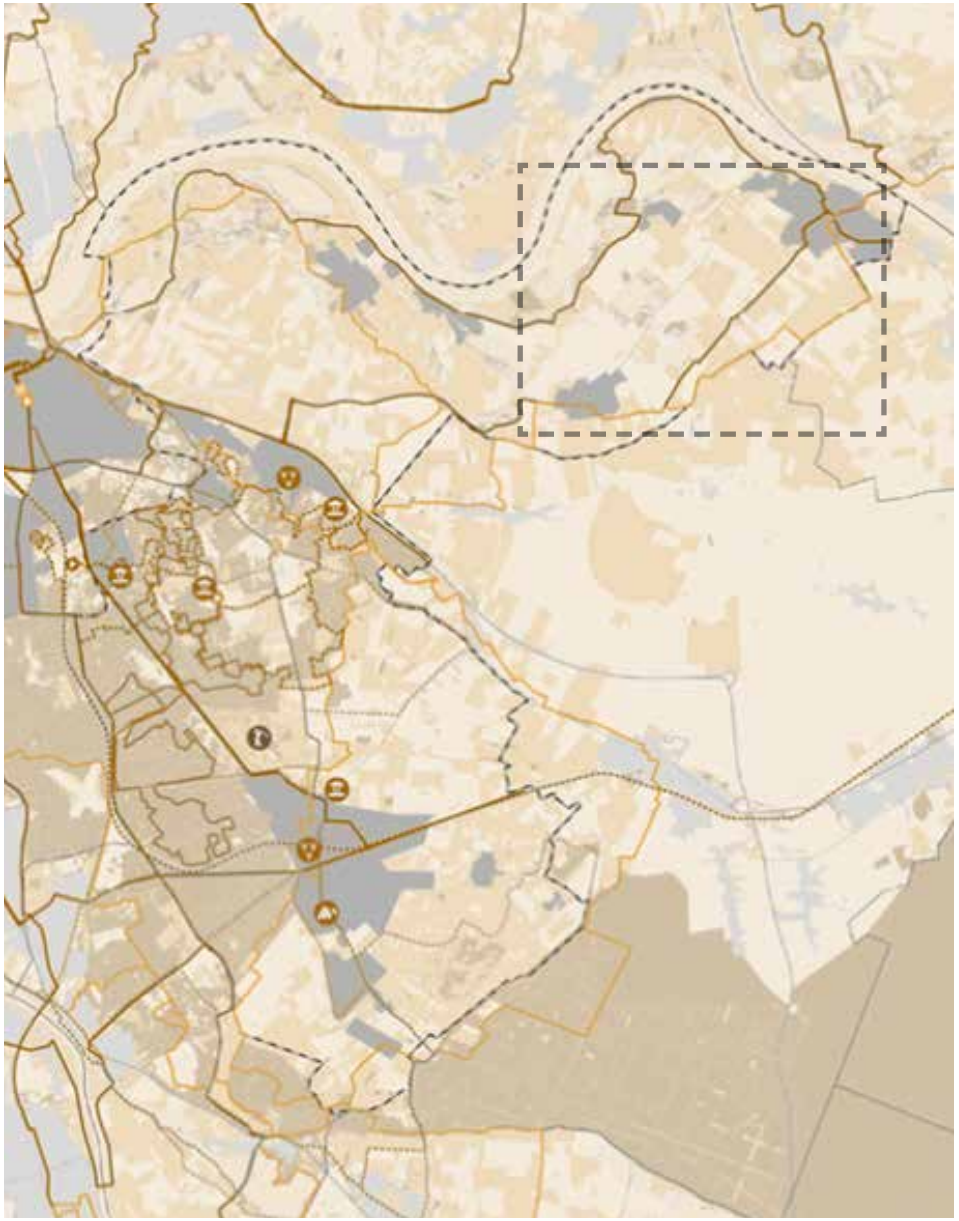


Figure 17 presents an overview of the most important recreational routes and tourist attractions in the area. The case study area has a lower density in attractions than Nijmegen centre because only cycling and walking are possible.

Recreation and tourism have many benefits for the municipality of Berg en Dal and are therefore crucial. However, the increased recreational pressure due to the COVID-pandemic is causing inconveniences to nearby nature reserves, such as the Millingerwaard, damaging the many natural habitats. Creating a multifunctional solar landscape nearby would solve the issues by reducing the touristic pressure and increasing the habitat supply.

Biking route (ARK natuurontwikkeling, n.d.)

Beaversafari (Staatsbosbeheer, n.d.)

Fig. 17 Recreation and tourism in Berg en Dal (Adjusted map from LOS stadomland, 2021).

2.7 GENERAL MOBILITY

Fig. 18 Accessibility in Berg en Dal (Adjusted map from LOS stadomland, 2021).

A good mobility structure is necessary in the areas around Berg en Dal. Cycling and walking routes are becoming increasingly crowded, since the number of cyclists and vacationers has expanded, partially due to the growth in tourism. Public transport in Berg en Dal is struggling financially as the earnings do not cover the costs. Th need for longer bus routes with more frequent stops is therefore being abandoned in favour of fast, short, and efficient routes.

The one bus route that runs through the Ooijpolder and Millingerwaard area includes several stops in the area of our case study, eliminating the need for additional public transport (Fig. 18).

2.8 CURRENT SITUATION PROJECT AREA

TOPOGRAPHY

The area is characterised by multiple geological incisions, which, in addition to a deeper and sandy appearance, are marked by a humid clayey fill. Some remaining gullies can be recognised as an elongated depression in the landscape. This can be seen between the two lakes. Around the lakes and to the south of them, the fields are rather low-lying, in contrast to the higher areas to the north-east of the lakes. The residual gullies are crucial to include in the design to research possible water buffers (Heunks, 2003).

ACCESSIBILITY

There are two main roads in the area. Although these provide efficient access to the case study area, they also divide the area, making it lose its coherence. Along the lakes, there are currently some inaccessible roads for cars, but aslo for cyclists or pedestrians, it is not an attractive route to take. However, this opens great opportunities to extend the slow traffic network and providing decent accessibility.

VOLTAGE CABELS

Fig. 21 shows the current medium-voltage cables within the area. The elektricity staion in Leuthto provide renewable energy to the nearest villages. The electricity station in Leuth supplies the Berg en Dal area (Millingen aan de Rijn, Leuth and Kekerdom) with electricity. A current problem is that the electricity grid in Berg en Dal and the surrounding area has reached the maximum capacity for supplying electricity. The solution to this is the construction of a new electricity substation, for which Berg en Dal is already in discussion (Liander, 2021).

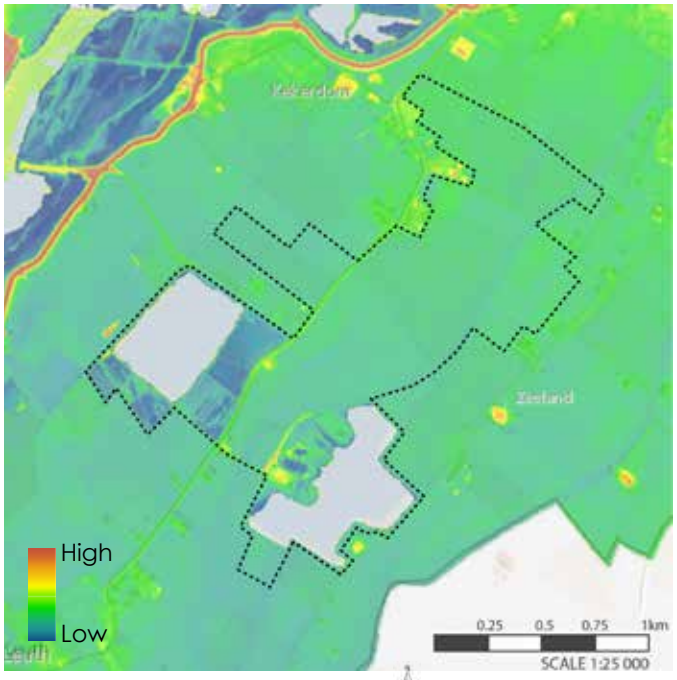


Fig. 19 Elevation map (AHN, 2021)

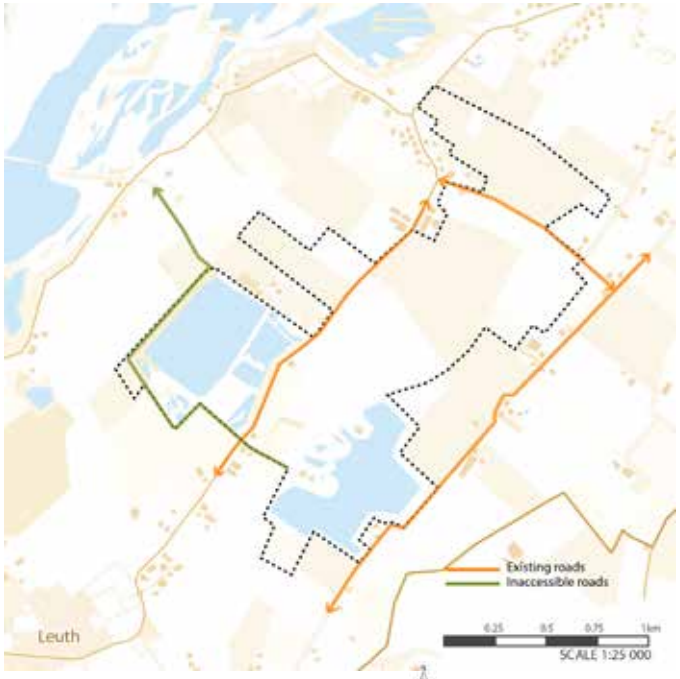


Fig. 20 Accessibility for cars

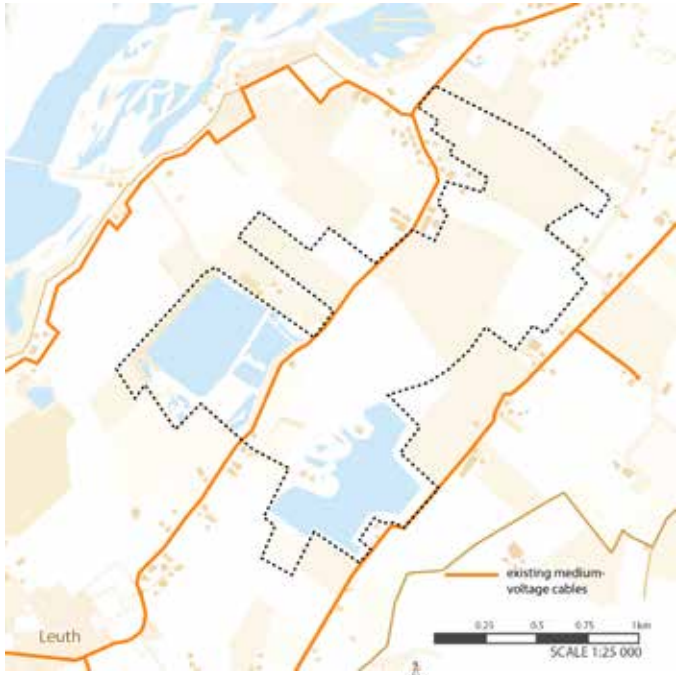


Fig. 21 Existing voltage cables

LAND USE

60% of the area consists of grassland with mainly cattle. The remaining 40% is arable land where mostly potatoes and sugar beets are cultivated. The number of agricultural hectares in Berg en Dal has been decreasing in recent years (CBS, 2021).

The presence of the river confirms the dual land use in the area: On the high and dry parts, orchards and arable farming fields can be found, while the low-laying clayey parts are used as pasture. The relatively light river ridge soils allow the land use of arable farming and fruit cultivation around Leuth.

RECREATION

Nearly half of the visits to the municipality of Berg en Dal involve walking and cycling (ZKA consultants & Planners, 2016). That is why the Millingerwaard has extensive walking routes. Unfortunately, none of these are within our project area. There are some bicycle routes that go through the area. These existing routes present a nice opportunity to extend the slow traffic routes and to provide new connections between the inside and the outside of the dike areas. The new solar landscape with its routes could help with this.

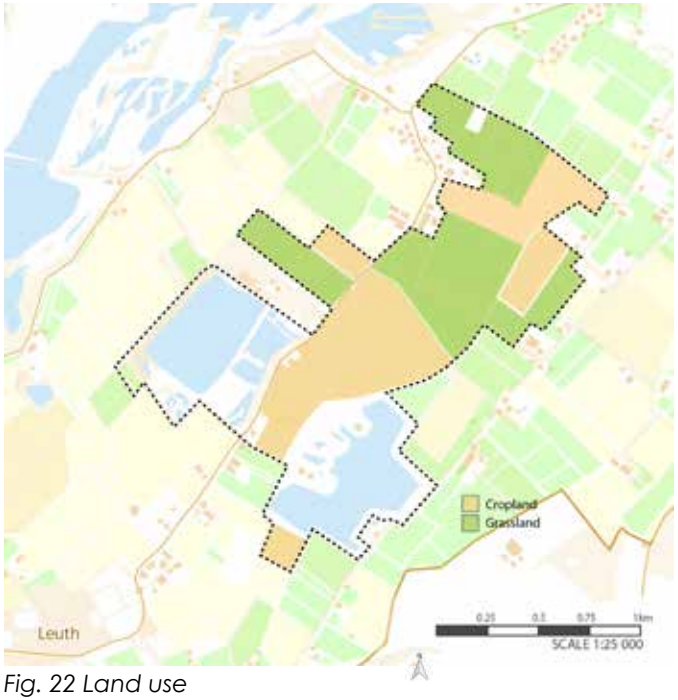


Fig. 22 Land use

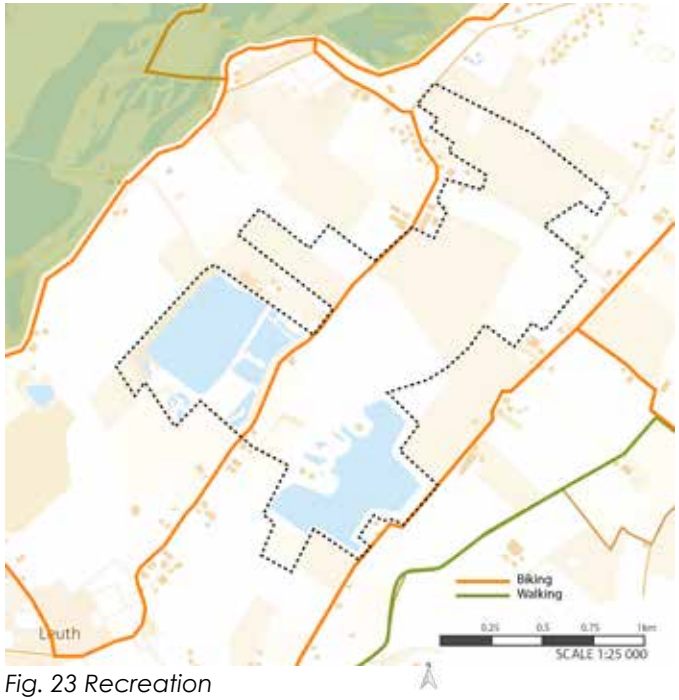


Fig. 23 Recreation

2.9 CONCLUSION

The adjacent area to the case study area is part of the National Landscape De Gelderse Poort. This is a result of the extraordinary relief and diverse natural landscape with riverbanks, dikes, forelands, and the small-scale openness of the agricultural landscape.

The area between Millingen and Leuth is situated on the old river ridges of the Waal and is characterised by three landscape types (Fig. 10). Each of them has its own appearance, land use, and potential. These zones should be preserved and if possible, reinforced. In addition, they each have significant opportunities that can be used in the design (Broplan, n.d.).

Historically speaking, water development has become an increasingly important feature for nature, recreation, and local residents. The final design could further explore the possibilities of water reclamation in combination with energy.

The case study area consists of various habitat types. However, there is still much room for improvement. Solar landscapes could play a vital role by representing a valuable stepping stone in the blue-green veining of the landscape to increase mental wellbeing, nature development, habitat provision, and pollination. It is therefore important to adapt the vegetation and habitats within the solar landscape to the surrounding landscape and its qualities.

The area is struggling to cope with heavy rainfalls, which often leads to floods. Therefore, the nature of the soil should be taken into account when designing. That is why the ecosystem services of water regulation and water harvesting are of great importance. With the necessary design and creative insights, the possibilities between water regulation, energy and nature can perhaps result in some interesting combinations.

Together with the residents of Berg en Dal, the municipality has indicated the area as a search area for sustainable solar energy, allowing more innovative combinations within the project. However, it is crucial to respect the four conditions composed in Berg en Dal's future vision.

Lastly, due to the COVID-pandemic, the recreational pressure in the case study area has been increasing, causing inconveniences to nearby nature reserves, such as the Millingerwaard, damaging the many habitats. By creating a multifunctional solar landscape nearby, the pressure from tourism can be reduced and the habitat supply can be increased.

3 SRQ1 -

LITERATURE REVIEW RELATED TO MULTIFUNCTIONAL SOLAR LANDSCAPES AND ECOSYSTEM SERVICES

3.1 INTRODUCTION

SRQ1. What are the spatial principles in literature related to sustainable multifunctional solar landscapes and the theory of ecosystem services?

To answer the first sub research question, a literature review was conducted of peer-reviewed and 'grey' literature. The sources were found in the online databases Google Scholar and Science Direct using "ecosystem services & landscape architecture" and "multifunctional solar landscapes" as keywords. The search was limited to the years 2014 – 2021 and scientific articles published in English or in Dutch. Once the papers had been selected, a second screening was arranged based on the title, the abstract, and the full text respectively according to their potential of answering SRQ1.

Below is a brief summary of the most important sources for this literature review. The sources have been divided into: literature related to multifunctional solar landscapes and literature concerning the incorporation of ecosystem services in landscape architecture.

3.2 LITERATURE RELATED TO MULTIFUNCTIONAL SOLAR LANDSCAPES

1) De Vries, G. et al. (2020). "Natuur & Landschap in de RES: Bouwstenen voor een natuur- en landschapsinclusieve energietransitie."
This paper claims that nature and landscape are insufficiently taken into account in 30 regional energy strategies, while there are a lot of opportunities to generate renewable energy and preserve and enhance nature and landscape quality at the same time. The article contains concrete steps and recommendations for giving ecological values a place within renewable energy transition.

2) Gulan, F. et al. (2019). "An integrative spatial perspective on energy transition: renewable energy niches."
This scientific article claims that single, though innovative, solutions are insufficient. Renewable energy projects which are not implemented correctly present challenges to sustainability and limit potential synergies with their spatial environment.

3) Oudes, D. & Stremke, S. (2021). "Next generation solar power plants? A comparative analysis of frontrunner solar landscapes in Europe."
In this paper, the spatial characteristics visibility, multifunctionality, and temporality are studied in eleven leading situations to broaden the knowledge of solar landscapes. The visual impact of solar landscapes, the impact on land usage, and the end-of-life stage of solar landscapes are all covered.

4) Stremke, S. & Schöbel, S. (2019). "Research through design for energy transition: two case studies in Germany and The Netherlands."
This scientific article explores how the methodology Research through Designing might assist in establishing design concepts for major energy landscapes in various types of landscape. It also includes several spatial principles for integrating a photovoltaic field into a landscape. During the design phase, these criteria will be vital.

5) Uyterlinde, M. et al. (2017). "De energietransitie: een nieuwe dimensie in ons landschap."
This study proposes that the spatial design of renewable energy transitions, as well as how they are formed, should be considered for every successful energy transition.

6) Van der Zee, F. et al. (2019). "Zonneparken, natuur en landbouw."
This paper describes the energy transition resulting in a significant increase of solar parks on agricultural land. It discusses the questions raised among politicians, citizens, and researchers about the effects of placing large areas of solar panels on soil quality, nature, and landscape.

3.3 LITERATURE RELATED TO INCORPORATING ECOSYSTEM SERVICES IN LANDSCAPE ARCHITECTURE

1) Holland, R. et al. (2018). "Incorporating ecosystem services into the design of future energy systems."
This paper compares influential scenarios for energy and ecosystem services and examines how they can be used in a more beneficial way in the future. The scenarios investigate the causes of environmental change and its consequences for ecosystem services.

2) Mooney, P. (2014). "A Systematic Approach to Incorporating Multiple Ecosystem Services in Landscape Planning and Design."
In this paper, Mooney explores the concept of ecosystem services and proposes a method that can be used by designers to get a better understanding of sustainability and ecosystem services. The author uses his own evaluation matrix to evaluate three designed landscapes.

3) Picchi, P. et al. (2019). "Advancing the relationship between renewable energy and ecosystem services for landscape planning and design: A literature review."
This article includes a literature review based on the current state of knowledge in the field of renewable energy shifts, with an emphasis on methodologies based on ecosystem services.

4) Picchi, P. et al. (2020). "Deploying ecosystem services to develop sustainable energy landscapes: a case study from the Netherlands."
For long-term strategic planning, this article uses an ecosystem services evaluation to construct renewable energy transitions. An example in Shouwen-Duivenland, the Netherlands, was utilized by the researchers.

5) Semeraro, T. et al. (2018). "Planning ground based utility scale solar energy as green infrastructure to enhance ecosystem services."
This scientific article addresses the competition between agriculture and renewable energy, leading to a loss of pollination and biodiversity. The researchers propose a green infrastructure that provides habitats for wildlife and produces other ecosystem services such as energy generation and education.

6) Stremke, S. (2015). "Sustainable Energy Landscape: Implementing Energy Transition in the Physical Realm."
This paper discusses the importance of the ecosystem services framework, as several renewable technologies can be linked to specific ecosystem services. However, this framework cannot describe every facet of the renewable energy shift. As a result, Stremke suggests a four-dimensional conceptual framework (sociocultural, environmental, sustainable technical and economical).

3.4 GENERAL PRINCIPLES RELATED TO THE USE OF ECOSYSTEM SERVICES IN LANDSCAPE ARCHITECTURE

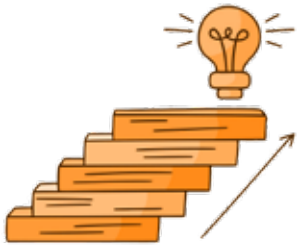
The highest level of sustainability can be obtained by creating multifunctional energy landscapes that maximize the production of ecosystem services. To help future landscape architects, a list of general principles has been created on how to integrate ecosystems in the design of renewable energy technologies. The papers that were used per guideline are indicated with a number in orange (= literature related to the use of ecosystem services in landscape architecture).

② ④

To safeguard the supply of ecosystem services, energy transition must always be supported by spatial disciplines. Using landscape design principles, trade-offs can be minimized while enhancing synergies.

①

In landscape architecture, the ecosystem service theory should not be a stand-alone solution. It needs to be combined with additional criteria that are not directly related to ecosystems but are critical for the development of sustainable landscapes. Examples are the reuse of materials, landscape experience, and affordable energy.



④

The identification of hotspots is always the first step in the integration of ecosystem services. Next, the most suitable areas for renewable energy should be mapped. Then different design concepts can be discussed, so that, in a last step, the trade-off assessment can be made. Different design alternatives can help to eliminate trade-offs and improve ecosystem service synergies.

③

Designers must sit together with key stakeholders and experts to identify the nature of ecosystem services that deserve attention.

⑥

After the designing process, management of the existing ecosystems is very important. It is critical to continue to provide a wide range of human services that are critical to current and future generations' social and economic well-being.

3.5 SPATIAL PRINCIPLES

The spatial guidelines deducted from the literature review are discussed on the following pages. The group of ecosystem services that is the most suited to the principle is presented at the top left each time (P = provisioning services, C = cultural services, R = regulating services). The principles have been ranked according to their applicability to several ecosystem service groups or to a single one.

The papers that were used per guideline are indicated below with a number either in black (= literature related to multifunctional solar landscapes) or in orange (= literature related to the use of ecosystem services in landscape architecture).

P C R

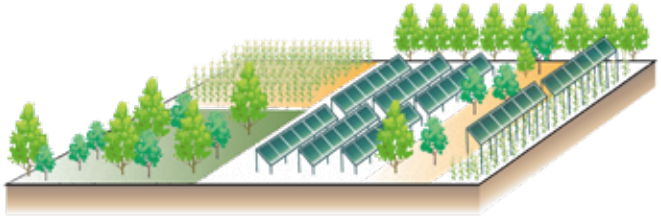
Nature and landscape must be the starting point for new energy transitions

Designing from the perspective of the landscape and, to a lesser extent, from nature will result in attractive and green landscapes, a better understanding for the energy landscapes from residents and less restoration work in the future.

Landscape management principles should be implemented at the landscape scale instead of being limited to a specific ecosystem, since ecosystems function at different scales. Because this case study has many valuable ecosystems, it is important to start looking at the landscape (level) before designing.

5
3

P C R



Energy landscapes should be multifunctional

Renewable energy landscapes should serve multiple purposes and meet different needs simultaneously. This will increase the social value of the project and reduce the pressure on the landscape. Monoculture crops, for example, have a negative impact on ecosystem services such as hydrological flow management and water pollution, as well as soil formation and biological diversity. By changing monoculture crops into agrivoltaics in combination with other functions, the social, economical and environmental value of the project increases. Creating these kinds of multifunctional energy landscapes that maximise the production of ecosystem services also achieves the highest level of sustainability.

3 5 6
3 6

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Consider the temporal aspects of energy transition

Solar landscapes have a short lifespan, ranging from 15 to 25 years depending on the panel yield. When the solar landscapes are becoming less efficient over time, one might think of removing the panels. Usually the land will be used rapidly for other large-scale spatial challenges, given the current pressure on the landscape. On the other hand, the removed solar landscape will be able to act as a biodiversity reserve and source over time. Another alternative is to extend the life of the panels by replacing the old ones with new ones without having to use more land or increase the number of panels. The installation of these new and more efficient panels would not have a significant impact on the area; biodiversity and the production of ecosystem services would continue to be stimulated. Taking the temporal aspects of energy transition into account will increase the ecological, social, and economic values of the area.

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Create room for experimentation

Leave room for experimentation. This is needed to get more innovative combinations within multifunctional solar landscapes. It is also a good exercise to define which ecosystem services can be matched to provide a better landscape quality. The experimentation area should form one big space, and not multiple smaller fields scattered around the project area, resulting in poor cohesion.

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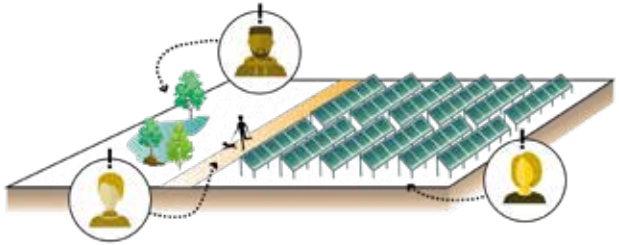

Take local needs and wishes into account when designing

The needs of local residents and the future vision for the region must be considered when designing. This implies looking beyond the realm of energy transition and adopting an integral approach that shows the opportunities for connection. Any landscape can be transformed into a multifunctional one with many functions and ecosystem services, but every place has its own needs. The municipality of Berg en Dal, for example claims that recreation and nature are essential functions within their area. These two will therefore be more critical during the design process than e.g. housing. If the design takes into account the social needs and together with the socio-cultural, sustainable technical, economical and environmental dimesion (Stremke, 2015), while at the same time providing ecosystem services in a sustainable way, we can speak of a sustainable design.

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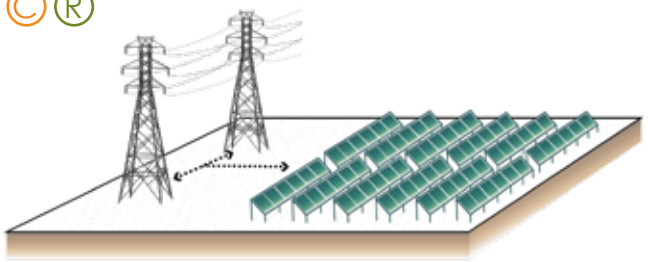

Existing landscape infrastructure as a prerequisite for site selection

Solar arrays should be placed as close to a roadway and current electric grid as possible, while staying as far away from items which cause shadows. The location for multi-purpose solar fields is therefore often chosen based on the existing landscape infrastructure. The spatial characteristics of the landscape infrastructure should also be considered, since these often contain regulating and cultural ecosystem services. Examples are recreational paths and tree-lined roads. A thorough analysis of the existing landscape infrastructure is therefore crucial in order to create an ultimate hotspot of ecosystem services.

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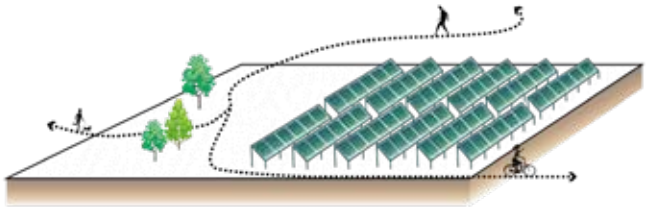

Make the solar landscape accessible and experienceable

Connect the multifunctional solar landscape to an existing local recreational network to make it accessible and recreationally attractive. On top of that, educational activities can be linked to the use of renewable energy and to the increase in biodiversity. This could positively change people's attitudes to renewable energy. People can even improve their general state of health, since it has been scientifically proven that access to a natural environment is an important factor for overall well-being.

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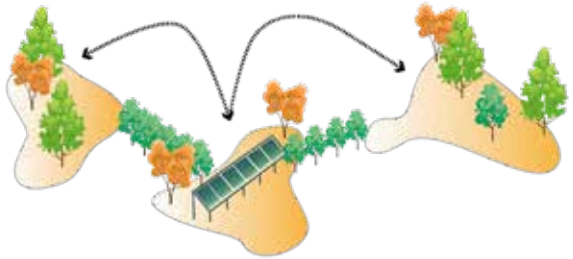

Multifunctional solar landscape as stepping stone or corridor

Multifunctional solar landscapes should serve as a stepping stone or as a green-blue corridor within a nature network. For example, a finely meshed network of green landscape elements such as rough grass verges, hedges or shrubs and ditches can be created in combination with solar panels. Structures like these in a monoculture landscape can support the nature network for local insects and animals (e.g. bees), reinforcing the ecosystem service of pollination and habitat provision. In this case study it is of great importance to consider the solar landscape as an extension of the Millingerwaard nature reserve enlarging its specific habtats.

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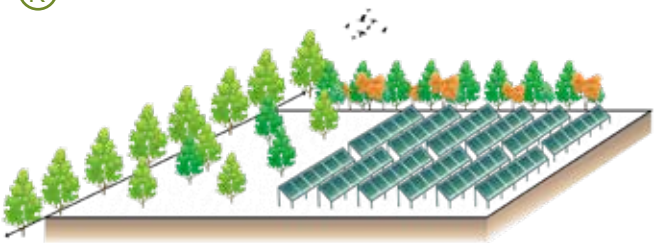

Preservation and restoration of existing landscape qualities

Existing landscape qualities should be respected and integrated in the solar landscape during the design process. Restoration of the historical landscape structures could further improve the landscape and add value. By using the nature values that are already present on the adjacent plots, the carrying capacity of the natural areas can be increased.

The ecosystem services provided by a given ecosystem are unique to that location. A single row of trees along the solar landscape, for example, increases the ecosystem services of carbon sequestration, air pollution removal, and oxygen production. To avoid a loss of services and biodiversity, it is essential to preserve the existing landscape quality. Three tree species that make a major contribution to ecosystem services are Acer saccharinum, Betula nigra and Salix alba (Hiemstra, 2018).

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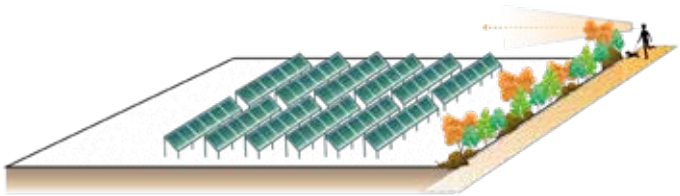

Visual shielding of perceivable trade-offs

The visibility of observable trade-offs for landscape users, such as agrivoltaics, can be adjusted by utilizing greenery for covering or altering the scale of the solar panels to the landscape's features. Screening unsightly things is a regulating ecosystem service called visual screening. It is an important ecosystem service as local communities are more concerned with observable trade-offs. In case a trade-off is perceived as negative, its visibility can be reduced and vice-versa. However, it is important to be careful when using high hedges in an open landscape. The shielding should always fit within the landscape.

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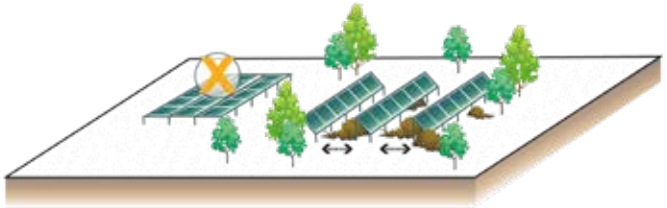

Extensive management to improve pollination and habitat provision

The design and the extensive management of solar landscapes should ensure the preservation of flower- and herb-rich vegetation. This is essential for the solar landscape's ecological balance. By replacing vegetation with indigenous honey and medicinal flora, the habitat can attract various insects and bees (= habitat provision). Extensive grazing or management of the solar landscape can also lead to an increase in the number of bees and butterflies that will become the net producers of pollinators (= pollination), which benefits the area and its surroundings. The Dutch Nature and Environment Federations (NMF) argue to place the panels in landscape orientation and with a minimum gap of 1 cm between the panels, so that as much water as possible can drain between the panels and reach the ground under the panels (M. Enserink, personal communication, 16 March 2022).

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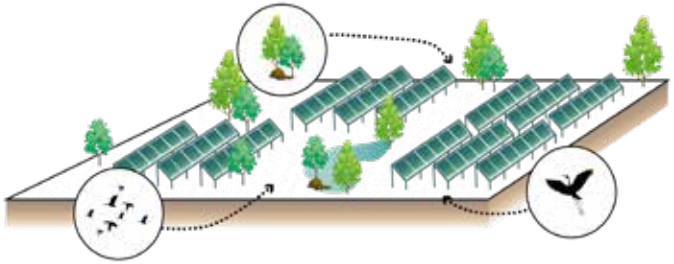

Tailoring to specific target species as well as using native and endemic plants

When designing, specific target species should be considered, and native and indigenous plants should be used. This will increase the number of native pollinators and maintain or even enhance the ecosystem service of pollination, while supporting terrestrial biodiversity. Indigenous plants also provide a habitat (= habitat provision) for indigenous species and increase genetic diversity. To determine the target species, the existing habitat types must first be evaluated. These can be evaluated using evaluation criteria which allow for an area-wide and objective, rather than subjective, evaluation. The criteria used in this thesis are threat or rarity of certain habitat types, naturalness, continuity of habitat, and presence of species of conservation concern. Once the different habitat types have been evaluated, the most valuable habitat types of the area will be known. After this, target species for each valuable habitat type can be investigated. It is important to consider two factors in the design phase, namely the area needed for a stable population and the dispersal distance. Target species for this thesis can be found in appendix 1.

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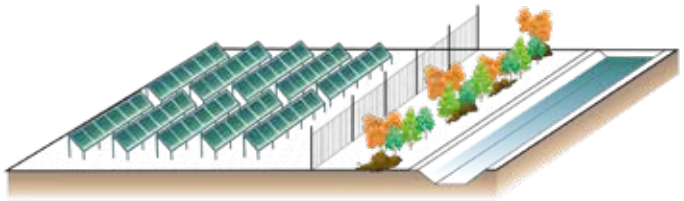

Barrier as ecological habitat

The borders of the solar landscape should function as ecological habitats. Hedges and ditches can work as a natural border to the solar landscape, these are preferred over fences from an ecological point of view. They do not only provide protection, but they also serve as a habitat for various animal species. Birds in particular find a hedge with several types of shrubs very attractive. Wide-growing hedges of a few meters high are a popular choice for solar landscapes and are put back every 5-7 years. Ditches with natural banks are more suited for open landscapes.

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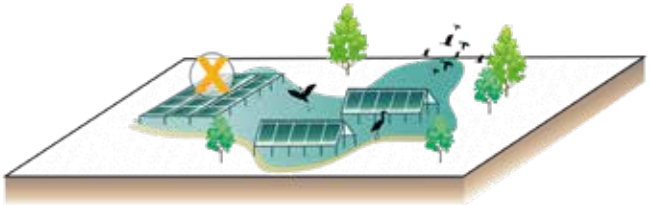

Floatovoltaics

Bifacial panels that do not completely cover the water surface are preferred from an ecological point of view to single-sided panels on pontoons that shut off the light. Panels that completely seal off the water may form a great danger to the aquatic life. This would strongly reduce the habitat provision. Floatovoltaics are therefore only recommended if the structures do not cover the water entirely.

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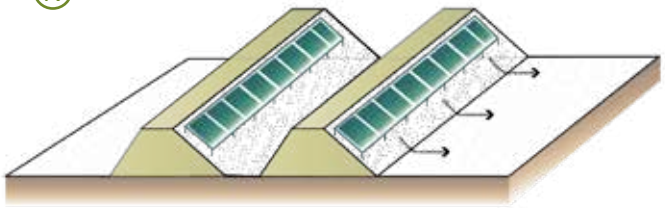

Solar energy on slopes

Solar panels on slopes can increase the risk of erosion. However, these hills can also increase the variety of habitat for fauna and flora. Another benefit of using slopes for panels is the reduced visibility on one side, which can be the side of recreationists.

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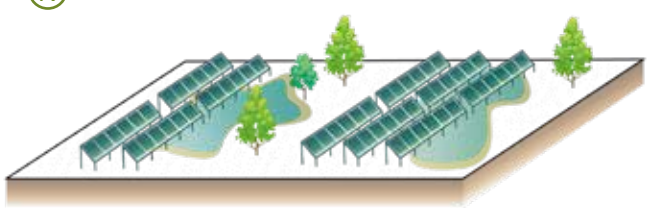

Solar landscape as buffer

A solar landscape can serve as a buffer for higher groundwater or for buffering the inflow of fertilisers, preventing the latter from entering nature-rich areas. The risk of floods will also be reduced since the solar landscape can function as a water buffer. It might therefore be interesting to look at the possibilities of using the solar landscape as a buffer in this case study area. Although additional investments for the safety of the panels and cables must be taken into account. Such as installing cables above the ground.

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3.6 CRITICAL TRADE-OFFS

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Meadow bird habitat

Building solar landscapes often happens at the expense of the meadow bird habitat, a habitat that is already under great pressure. Most meadow birds are migratory birds that only visit the Netherlands during the summer (Klaassen et al., 2018). They incubate and look for food in the grassland. The meadow birds prefer areas that are very open and spread out and therefore form a trade-off with solar panels.

However, it is important to note that some birds like farmland birds tend to use ecologically managed solar landscapes similarly to how they use arable land, pasture, and meadows (Klaassen et al., 2018).

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Soil quality

The soil under the solar panels should preserve its natural conditions. If it is completely isolated from daylight and rainwater (= a reduction of 75% or more), the subsoil will die. Therefore, the access to daylight and rainwater are very important aspects to keep the soil cycle alive. Other risks include soil degradation during the construction phase due to erosion and compaction, as well as possible soil contamination through the use of galvanised structures (Van der Zee et al., 2019).

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Nature-rich location

Solar landscapes can only increase local biodiversity in certain situations. Ecologically sensitive areas should be avoided (De Vries et al., 2020), whereas intensive agricultural landscapes or fallow land typically sees an increase in biodiversity with the creation of a solar landscape. Valuable natural areas lose their biodiversity mainly as a result of construction. A reduced amount of available light on the soil could also cause certain important habitats to change to a less valuable type.

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Landscape experience, recreation and tourism

Due to the perceived landscape change and interactions between supporting ecosystem services, local populations often resist the installation of renewable energy (Van der Horst & Vermeylen, 2011). Since solar landscapes are seen as a disruptive aspect in the landscape, there is often a negative mentality towards them. People are therefore less likely to spend their free time in the area. The solar landscape can however introduce educational activities linked to renewable energy and the increase in biodiversity due to the solar landscape itself. This in turn could positively change the attitude of communities towards renewable energy (Van der Horst & Vermeylen, 2011).

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Increased threaths to cultural heritage and scenery

The integration of solar panels within areas of cultural heritage is often a sensitive matter. Cultural heritage is often subject to strict regulations to keep things as they are today, such as the visual axes in a landscape that excludes the possibility to install solar panels (Huber et al., 2017). Experts believe that conservation of cultural and natural heritage and renewable energy initiatives can coexist. Only if the latter are organized, reviewed, and constructed in a manner that preserves valuable cultural assets (UNESCO World Heritage Centre, n.d.). In the case study area, there is no cultural heritage of interest, but maintaining vistas in the current semi-open landscape is essential.

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Specific requirements

Land uses must be analysed before they can be combined with each other. Agrivoltaics, for example, can only form a synergy in certain cases (Trommsdorff et al., 2020). When designing a solar landscape, it is important to look for arable species that could benefit from their location below the PV panels, such as berries, strawberries, and potatoes (Toledo & Scognamiglio, 2021). Crops that heavily rely on irradiation will not be likely to perform well with solar panels (Toledo & Scognamiglio, 2021).

3.7 CONCLUSION LITERATURE REVIEW AND SPATIAL PRINCIPLES

This literature review has given a wide range of insights, critical trade-offs, and principles that will be useful as a base for the design phase.

There is much information available in literature about multifunctional solar landscapes and to a lesser extent, about the use of ecosystem services in landscape architecture. However, a combination of the two subjects is hard to find. Despite the fact that Picchi et al. (2020) argue for including the ecosystem services concept into the creation of sustainable energy landscapes, very little scientific literature helps landscape architects and planners to do so. When a combination of ecosystem services and renewable energy is mentioned, the focus is often solely on one ecosystem service such as habitat provisioning or food supply. However, by creating multifunctional energy landscapes that maximise the production of ecosystem services, the highest level of sustainability can be achieved. Ecosystem services are therefore more often employed as a measure for sustainability and multifunctionality (Mooney, 2014).

Cultural services such as recreation, education, and sense of place are the least often discussed in literature. The fact that cultural ecosystem services are intangible (e.g., describing experiences, belongings, and a sense of identity) and therefore harder to analyse might be the root of that issue (Langemeyer et al., 2018). Cultural services also significantly influence landscape transformation and play a vital role in landscape architecture. Unfortunately, the research into the evaluation of these services is often still in its early stages (van Lierop, 2011). As a result, spatial guidelines on multifunctional solar landscapes concerning ecosystem services will often be incomplete. The number of guidelines from this literature review is still limited, further research on ecosystem services in multifunctional solar landscapes will be necessary. The more generic guidelines can be found in Appendix 1.

The list of spatial guidelines and critical trade-offs presented in the previous sections has been extracted from existing projects or literature. Even though these guidelines will help during the beginning of the design phase, there is no guarantee that they will result in an optimal design. Coherence between the spatial guidelines, creative insights, and answers to the following sub research questions is therefore essential.

4 SRQ2 -

EVALUATION OF THE CURRENT ECOSYSTEM SERVICES

4.1 INTRODUCTION

A better understanding of the characteristics and the current ecosystems within and in the vicinity of the case study area is needed before we can apply the retrieved spatial principles. This chapter explores the area and its ecosystem services using literature, field trips, spatial data, CICES V5.1 (a service classification form), and a questionnaire for experts. With these methods SRQ2.1: *"How important are the current ecosystem services within and in the vicinity of the case study area?"* and SRQ 2.2: *"Do these current ecosystem services form a trade-off or synergy when combined with solar energy generation?"* will be answered.

4.2 CURRENT ECOSYSTEM SERVICES ASSESSMENT

The current ecosystem services were selected based on the national land use file of the Netherlands (LGN) (Fig. 24). The LGN is a land cover file that uses a combination of geodata and satellite data. It shows the Dutch land use in 2020 for 48 land use classes at a resolution of 5m (Wageningen University & Research, n.d.). The different land uses such as grassland, deciduous forest, and orchards were translated into current ecosystem services classes using the CICES V5.1 classification system. For example, the cultivation of potatoes was translated into the CICES classification class "Cultivated terrestrial plants grown for nutritional purposes". Less tangible ecosystem services, e.g., pollination, were found in literature. For example, Van Bussel et al. (2020) have proven that water regulation, pollination, and recreation are also important ecosystem services to consider in the area. These services were then also translated using the CICES V5.1 classification. This led to a final list of the current ecosystems within and around the project area (table 1).

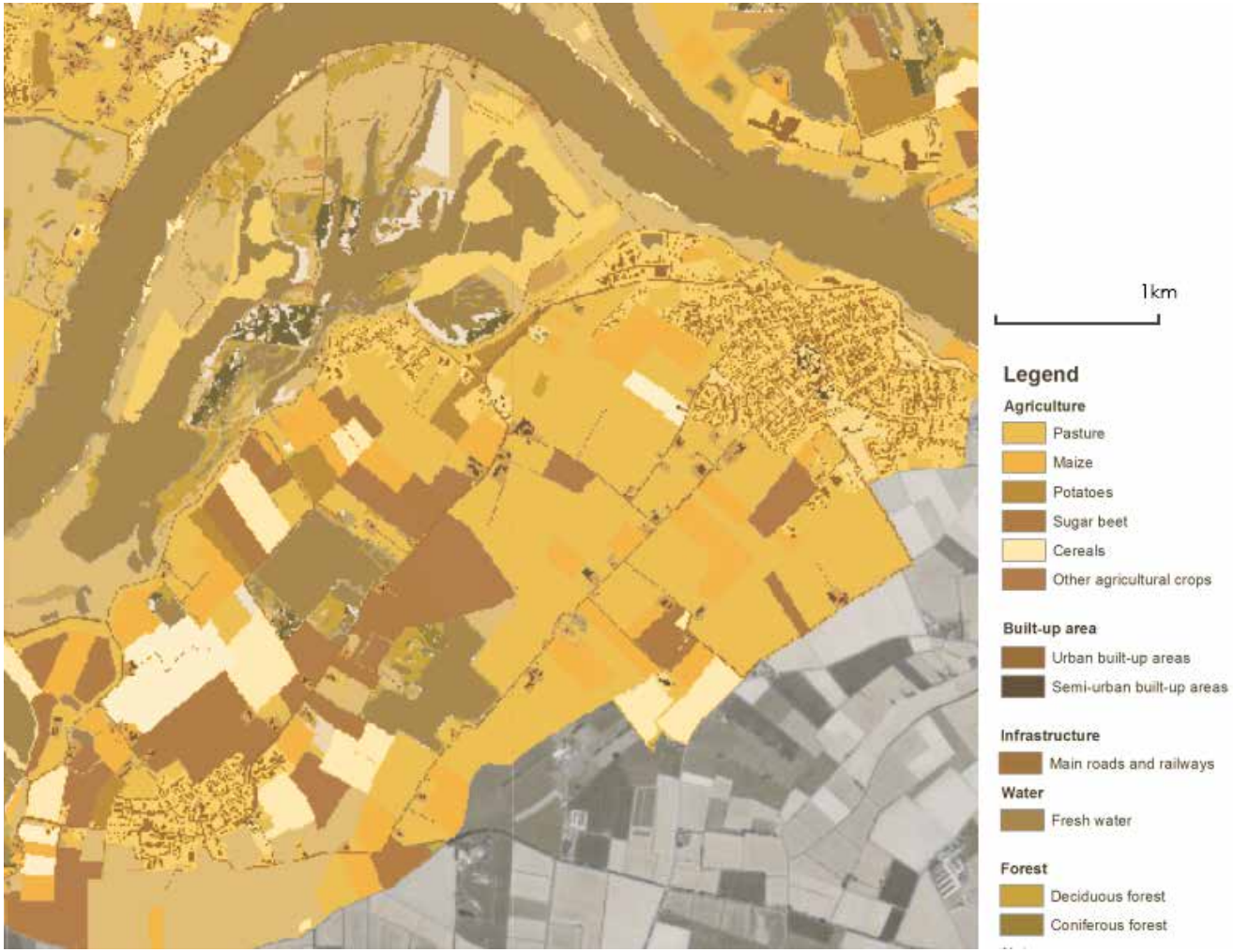


Fig. 24 LGN 2020 (Wageningen University & Research, n.d.)

Table 1 List of the current important ecosystem services within and around the project area

PROVISIONING SERVICES

LGN land cover/literature	CICES Class	Simple discriptor	Field trips
Grassland	Animals reared for nutritional purposes	Livestock raised in housing and/or grazed outdoors	X
Arable land (Beets, potatoes,..)	Cultivated terrestrial plants grown for nutritional purposes	Any crops and fruits grown by humans for food; food crops	X
Orchards			X

REGULATING SERVICES

LGN land cover/literature	CICES Class	Simple discriptor	Field trips
Water regulation	Hydrological cycle and water flow regulation	Regulating the flows of water in our environment	
Pollination	Pollination	Pollination	
Pollination	Seed dispersal	Seed dispersal	
Fresh water	Surface water used as a material	Surface water for non-drinking purposes	X
Pest and desease control	Pest and desease control	Controlling pests, deseases and invasive species	
Shrub vegetation	Maintaining nursery populations and habitats	Providing habitats for wild plants and animals that can be useful to us	X
Swamp vegetation			X
Deciduous forest			X
Forest in swamp areas			X
Heavily eroded heathland			X
Natural grasslands			X
Drifting sands/river sandbanks	Mass stabilisation and control of erosion rates	Stabilisation and control of erosion rates	X
Dikes	Storm protection	Regulation of baseline flows and extreme events	X

CULTURAL SERVICES

LGN land cover/literature	CICES Class	Simple discriptor	Field trips
Recreation and tourism (Walking, biking)	Physical use of landscape in different environmental settings	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	X
Landscape experience	Landscape aesthetics, amenity and inspiration	Characteristics of living systems that enable aesthetic experiences	X
Cultural heritage	Natural heritage and natural diversity	Characteristics of living systems that are resonant in terms of culture or heritage	X

The majority of these services were confirmed through field trips. Other services where found in literature about the area. A questionnaire (appendix 3) was conducted among experts who are familiar with the case study area. The nine respondents were well-spread over the age group of 20 to 65. They were asked to assign a value of importance to each ecosystem service in the area (Fig. 25). With a score of 3.3 out of 4, both the "cultivated terrestrial plants grown for nutritional purposes" and "maintenance of nursery populations and habitats" were chosen as the most important ones. The ecosystem services "hydrological cycle and water flow regulation" (3.2) and "landscape aesthetics, amenity, and inspiration" (2.8) are also of great importance. The ones that had a rather low score were "pest and disease control" (1.9) and "seed dispersal" (2.0). The fact that these are often not visible might be the reason why these ecosystem services received a very low score.

The survey also contained open questions to explore what the experts think are the most important landscape elements in the area or how they would improve the spatial quality. These questions were asked before the rating of the listed ecosystem services. Surprisingly, the answers were all similar: the Millingerwaard nature reserve and the agricultural landscape bordered by hedges and thickets are worth preserving. Improving the spatial quality could be done by providing sufficient small landscape elements forming a connecting zone between the nature areas and Nijmegen.

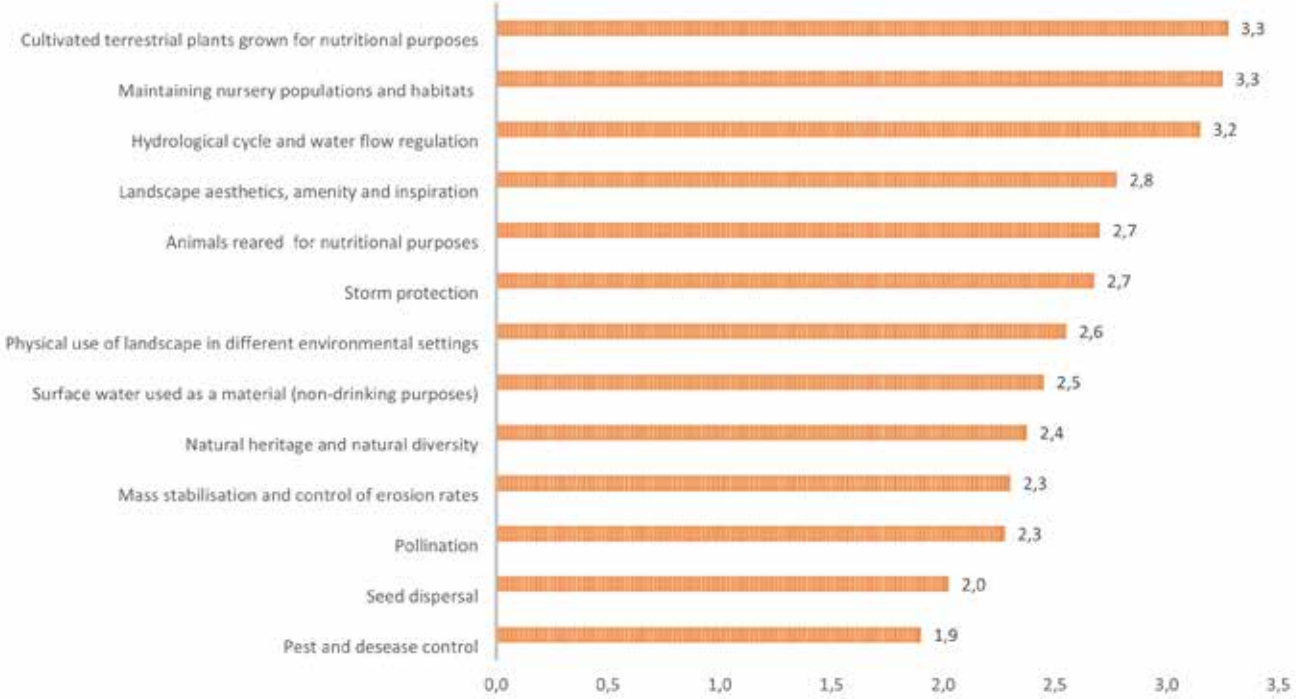
4.3 EVALUATION OF INTERACTIONS BETWEEN DIFFERENT SERVICES

As discussed in the introduction, ecosystem services are intertwined, and can interact in surprising and challenging situations (Bennett et al., 2009). Trade-off and synergy are two common dynamics in the concept of ecosystem services. To evaluate the interactions in the area between the different current services and energy generation, a trade-off map was created providing a very important point of view of conflicts, sensitivity points and synergies (Fig. 26).

The maps and data used to create the trade-off map can be found in appendix 4. The choice was made to include the surrounding environment in the evaluation. This way, the evaluation looks beyond the study area and comparisons can be made with the surrounding region. If later on the choice is made to spread the solar landscape in the area, good synergies and locations can be found through this map.

Interesting synergies that can be extracted from the trade-off map are the dark green patches. For example, the freshwater lakes could be combined with PV (floatovoltaics). These would form a good interplay since the biodiversity in the lakes is very low and since the lakes are not used anymore for recreational purposes. The application of floatovoltaics could increase other services, such as the provision of habitats. Furthermore, some grasslands that have good self-cleaning capacity in the top layer of the soil and offer potential for pollination would form a good synergy with PV.

Fig. 25 Current ecosystem services and their importance value



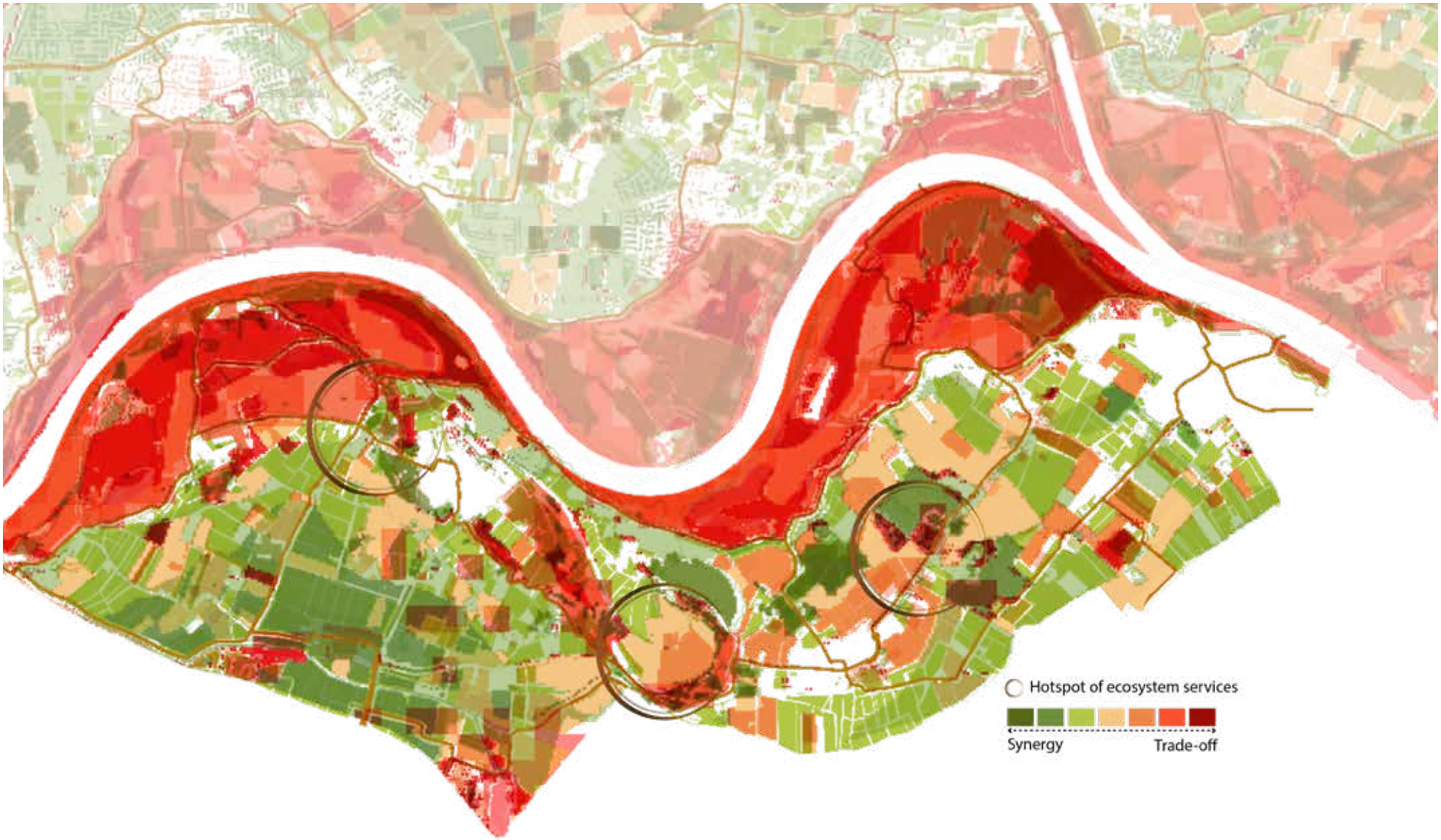


Fig. 26 Map showing the synergies and trade-offs between different ecosystem services and solar energy generation.

By combining these areas with solar energy, the ecosystem services mentioned above will have the opportunity to develop further. The darker the red on the map the harder the trade-off is between energy generation and other ecosystem services. For example agricultural areas with valuable crops that have a high economic value would form a trade off with solar energy. Also the habitat loss of nature rich locations would be very unfortunate in this area. There are also places with poor topsoil recovery or low water-storage capacity that would reduce the success of a solar landscape here. Therefore it is important to study the red zones well and avoid conflicts in the design.

Hotspots, are places where many ecosystem services are found in a small area. The hotspots for the case study area and its surroundings were determined by summing the number of ecosystem services found in a 250,000 m² grid square. Hotspots are therefore important places to consider in the design phase.

4.4 CONCLUSION ON ECOSYSTEM SERVICES ASSESSMENT

This research has been crucial to understand the importance of ecosystem services in the case study area. Food production and habitat provisioning are exceptionally important to take into account during the design phase since these two are the key services in the area. Unfortunately, the list of current ecosystem services used for the survey is incomplete since many services are intangible or invisible, making it hard to collect them all. Furthermore, more general ecosystem services have been omitted in order to prevent complicating the study. More general services refer to services such as “removal of air pollution” and “production of oxygen”.

The trade-off map shows a very important point of view of conflicts, sensitivity points and synergies. Essential places where potential synergies are possible should be included in the design. Based on this map, it is also known that it is better not to (or to a lesser extent) locate energy generation at hard trade-off (dark red) locations to avoid a loss of valuable ecosystem services.

5 RtD - SRQ3

THE PERCEIVED SPATIAL QUALITY OF FUNCTION COMBINATIONS WITH PV

5.1 INTRODUCTION

SRQ3, "*What are possible (new) design combinations between energy generation and other ecosystem services that contribute to the spatial quality?*", is part of the Research through Design methodology. Using the principles and knowledge that have been gathered in SRQ1 and SRQ2, multiple design experiments are conducted to identify different design combinations between energy generation and four other ecosystem services (habitat provision, water regulation, livestock, and crop production) that improve the surrounding spatial quality. These four services were selected as the most important ones for the region around Berg en Dal. This is based on literature and own assessment.

To be able to form different combinations between these services, a solid understanding and knowledge is needed of the existing combinations and their barriers and benefits. Therefore, energy is combined and analysed with different ecosystem services in the following order: crop production, livestock, water regulation, and habitat provisioning. The barriers and benefits are briefly summarised based on a literature study in the following sections. At the end of this chapter, these various function combinations are applied in different scenarios and evaluated according to criteria.

5.2 AGRIVOLTAICS

The literature review for this first section was conducted in online databases Google Scholar and Science Direct using the keywords agrivoltaics and solar crop production. The search was limited to the years 2019-2021 in order to focus on the latest findings.

The first combined function that will be discussed is agrivoltaics. Agrivoltaics is a dual-use design that combines solar electricity and agricultural for a maximum simultaneous yield of equal value. This method strives for a crop yield of at least 80% compared to the yield of unshaded crops (Trommsdorff et al., 2020).

5.2.1 OPPORTUNITIES AND BARRIERS

New studies have demonstrated promising outcomes in terms of improving light availability while reducing watering needs and safeguarding harvest from harsh weather conditions like intense sunlight or hailstorms (Trommsdorff et al., 2020). However, there are still barriers to the adoption of agrivoltaics. These are mentioned in table 2, together with some opportunities for implementing agrivoltaics in open-field systems. The main barriers found in the literature are: long-term land productivity uncertainty, market potential, remuneration, the necessity for a pre-designed system, the ability to apply at multiple scales, changing farming practices and social acceptance (Pascaris et al., 2020). The studies suggest that these barriers can be overcome, if they are handled properly, with thoughtful preparation and cooperative land contracts between the solar and agriculture industries (Pascaris et al., 2020).

Agrivoltaic benefits are significantly dependent on the location of installation and the crop production underneath the PV panels (Trommsdorff et al., 2020). Species that can benefit from PV panels such as berries, strawberries, and potatoes (Toledo & Scognamiglio, 2021) need machines to be harvested. The tallest harvesters require a clearance height of 5 meters, and sprayer vehicles are often 6 metres long (Trommsdorff et al., 2020). This will need to be considered in the design. In order to reduce the costs of mounting structures and installations, Trommsdorff et al. (2020) suggest focusing on agrivoltaic projects which do not depend on massive land machinery.

5.2.2 STILT-MOUNTED PV

Combining solar energy with farm activities is often problematic since energy efficiency frequently clashes with ideal food production and landscape conservation (Toledo & Scognamiglio, 2021). Therefore the design should take into account local weather factors, crop varieties, landform and energy requirements. A new set of standards is required to assure and comprehend the strong link between land, agriculture and energy. Stilt-mounted PV installations are an example of a design adaption that integrates crop production and energy generation (Fig. 27). These installations bring some benefits for the environment, but they also entail some disadvantages. Because of the negative influence on recreation and tourism, taller structures like this may cause public rejection (Toledo & Scognamiglio, 2021). They also raise the cost of construction and increase emissions significantly (Toledo & Scognamiglio, 2021). However, stilt-mounted PV installation can be beneficial for plants and crops since they allow better solar energy collection and a better connectivity. The PV pattern's degree of porosity influences irradiation and connectivity (pore space area= total area – area covered by the ground-based photovoltaic system). A general rule of thumb is that the stronger the irradiation, the more porous the pattern is, whereas large distances from the surface often mean higher connectedness and less solar irradiation (Toledo & Scognamiglio, 2021).

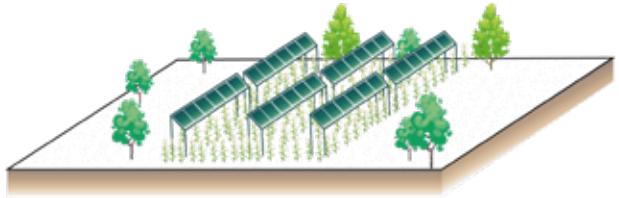
Besides crop types and design applications, it is important to consider the different crop zones with the use of ground-mounted PV structures (Fig.

28). The irradiance in Zone 1 is low, and the moisture level is high. Zone 2 offers regular sun intensity and a wetter soil, and the maximum irradiance and lowest humidity are found in zone 3. The type of crop should be adjusted to these zones depending on the kind of light, humidity, and temperature they need.

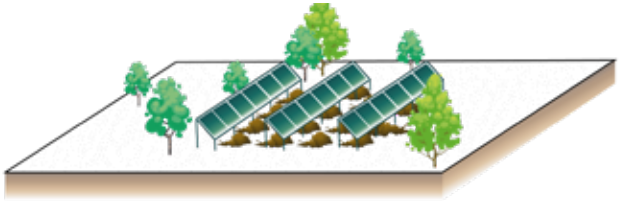
Table 2 Barriers, opportunities and future research to the adoption of agrivoltaics (Pascaris et al., 2020).

BARRIER	OPPORTUNITY	FUTURE RESEARCH
Include longterm vision*	To reduce ground disturbances, photovoltaic (PV) racking can be installed on removable foundations or precast kids or poured-in-place cement ballasts.	Additional research into the long-term effects of solar infrastructure on land, soil, and productivity is needed.
	Impacts from modules, such as trace metal leaching and a reduction in future agricultural production, have been shown to be exceedingly unlikely.	
	Contractual agreements that outline plans to return land to its natural state when the solar system has been decommissioned.	
Agricultural production and future farming practices are hampered by permanent constructions*	Changes in water productivity and extra shading are projected to boost crop yield in arid areas affected by climate change.	Agrivoltaic PV optimization and cost-benefit analyses for various PV systems, such as PV racking systems with adjustable panel height.
	Semitransparent PV or vertical bifacial PV.	
	Raised racking structures let agricultural equipment to pass through, potentially allowing practically any crop to be utilised in agrivoltaic production.	
	Create open source racking systems with variable panel height, tilt angle, and spacing.	
	When compared to traditional south-facing designs, east-west tracking array arrangements provide the best conditions for plant development.	
Uncertainties in business management and planning*	Partnerships and contracts that are legally binding and establish upfront fees and compensation for both parties.	University extension programs could increase the pressure to improve information sharing and collaboration across energy and agriculture businesses. Furthermore, market mechanisms could be the focus of additional policy studies.
	Solar PV development being supported by a local government initiative.	
	Education and outreach from the PV sector to the farming business to lower knowledge barriers and build trust.	
	Flexibility and adaptation to changing market conditions.	
Social acceptance	Aligne PV arrays to the parcel. To reduce visual disruption, use natural fencing and low-rise structures. Furthermore removable constructions can be used.	More research into how to increase public acceptability of renewable energy systems is needed.
	Increased economic efficiency per acre of land (farmer perspective).	
	Benefits to the local economy and employment (tourism, local recreation).	

** source: Pascaris et al., 2020*



Stilt-mounted PV (2-5m)



Ground mounted PV

Fig. 27 Open field PV design applications

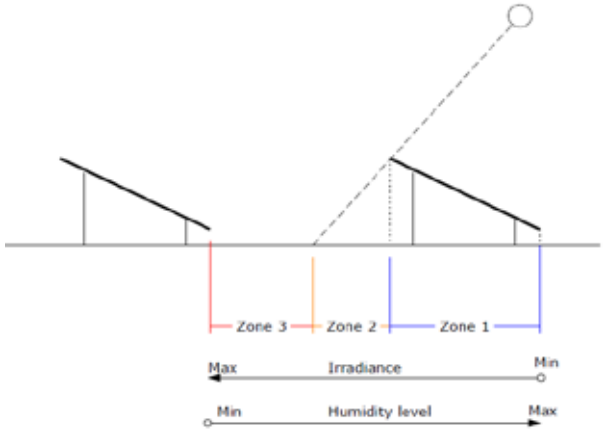


Fig. 28 Ground-mounted PV and crop zones (Toledo & Scognamiglio, 2021).

5.3 SOLAR GRAZING

In this section, energy generation and livestock will be combined. The increase in the world's population together with the increase in prosperity has been driving up meat and dairy consumption and food production (Maia et al., 2020). The lack of agricultural land has increased the need for multifunctional use of space. One such farming application is solar grazing. The mixed-use of PV panels and livestock will be discussed to improve the comfort and well-being of the latter (Maia et al., 2020).

5.3.1 VERTICAL BIFACIAL PANELS

The most appropriate type of PV combined with cattle breeding are vertical bifacial photovoltaic systems (Fig. 29 & 30). Vertical bifacial photovoltaic PV systems use double-sided photovoltaic cells that are mounted vertically instead of traditional, tilted PV systems. They can not only generate higher specific energy outputs and alleviate the network due to their bifacial features, but they can also be used in a variety of ways due to their fixed direction. This opens up much possibilities, especially when combined with livestock farming or crop production (Rödl & Partner, 2020). With bifacial panels the use of agricultural land (pasture and grassland) remains possible. Due to the vertical construction, there is no sealing of the ground and the land use for the panels is less than one percent, which is ideal for agricultural use. Furthermore, they provide some artificial shade to protect livestock from intense solar radiation. This is something that animal welfare committees highly appreciate. Studies have shown that lambs and ewes spend on average respectively 40% and 60% of their lives in the shade (Maia et al., 2020), indicating that many grazers need a large amount of shade. The authors also found that animals preferred the shade of solar panels to the shade of cloths, regardless of the intensity of solar radiation.

5.3.2 OPPORTUNITIES

Sheep grazing serves a unique purpose in solar landscapes by sustaining vegetation while also enhancing farmer income and financial sustainability (Kochendoerfer & Thonney, 2021). Moreover, it lowers the barrier for new farmers since the cost of equipping animals that graze on solar farms is lower than for other pasture management systems (Kochendoerfer & Thonney, 2021). In addition, low intensity grazing can be beneficial for habitat provision and pollination (Kochendoerfer & Thonney, 2021). Rest times should be introduced to prolong the time frame for plant growth and to boost the availability of floral resources (Blaydes et al., 2021). By applying a grazing rotation, the vegetation, habitat, and soil of the area can be optimally maintained. As a result, "it may lead to environmental benefits providing regulating, supporting, and provisioning ecosystem services like pollination, soil health and food" (Kochendoerfer & Thonney, 2021, p. 4).

5.3.3 BARRIERS

Solar grazing offers many advantages, but there are still some barriers to the application of solar grazing. One of the main barriers are the uncertainties in operation and business planning. To secure the farmers land lease revenue, partnerships and contracts can be used to define upfront fees and payments for both parties. However, solar farm owners then often have the problem of holding multiple contracts with livestock producers to the use of the solar power plants size. Therefore, there is a need to inform solar farm owners and further research is needed on holding multiple contracts. Table 3 discusses the barriers together with the opportunities for implementing solar grazing in open pastures.

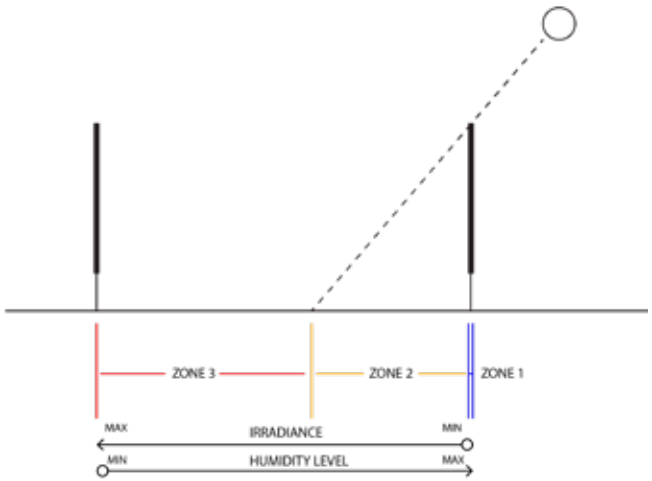


Fig. 29 Vertical bifacial panels and different zones

Fig. 30 Vertical bifacial panels and livestock combined (Next2Sun, n.d.)

Table 3 Barriers, opportunities and future research on combining solar panels and livestock (Kochendoerfer & Thonney, 2021).

BARRIER	OPPORTUNITY	FUTURE RESEARCH
Needed exptertise and knowledge	PV industry education and outreach to farmers to ensure good animal care and quality meat, as well as to build trust.	University extension programs could increase their efforts to improve informati-on sharing and collaboration between energy and livestock farmers.
Uncertainties in operation and business planning	Increased meat supply and market potential will necessitate improved marketing methods for locally produced, welfare-approved, solar-raised beef.	More research into marketing methods and the difficulty for solar farm owners to hold multiple contracts with livestock producers due to the solar parks' size.
	Land lease revenue can be secured through legitimate partnerships and contracts that define upfront fees and payments for both parties.	
Increase in GHG emissions and pollutions	To ensure appropriate management practices and reduce the amount of emitted climate pollutants and nitrogen run-off, manure management rules will be required.	There is a need for more research into how to improve management guidelines.
	The worldwide flock must not be increased by livestock grazing solar installations. It must be used to replace sheep or other livestock in other areas.	
Social acceptance	If the benefits of grazing can be listed as mitigation opportunities, such as reduced vegetation management and greenhouse gas emissions, biodiversity and habitat creation, soil protection, carbon sequestration, and reduced foodshed size, community acceptance can be raised.	More research into how to increase public acceptability of renewable energy systems is needed.

5.4 SOLAR ENERGY AND HABITAT PROVISION

Increased land use for renewable energy landscapes could negatively impact certain populations by modifying or deteriorating their habitat (Blaydes et al., 2021). Solar power plants can also be a physical barrier to other areas of suitable habitat. However, if they are wisely build and managed they can provide unique potential to improve the local environment and biodiversity (Blaydes et al., 2021). One solution is maximising mutual benefits of multiple ecosystem services. It is therefore important to find a common ground by restoring and managing the native grassland vegetation under the panels. This can both protect and improve the biodiversity, and restore related ecosystems services such as pollination and water retention. Pollination is critical since it is closely linked to habitat supply, as pollinators help to maintain wild plant species, biodiversity, and environmental balance, as well as contributing to food supply (Blaydes et al., 2021). Managing and designing solar landscapes as specific habitats could therefore not only contribute to the provision of habitats. It also could offer a refuge for pollinators in landscapes where many ecosystems have been destroyed, while simultaneously improving the diversity and connection of the landscape (Blaydes et al., 2021).

Solar panels provide shade, which could potentially be seen as harmful for the development of vegetation. However, they also allow favourable microclimate conditions such as lower temperatures and greater soil moisture. These conditions can, in turn, enhance the effectiveness of natural grasses, resulting in increased biomass above surface and related carbon capture (Walston et al., 2020). Additionally, these grasses contain deeper roots, which means they have a better chance of stabilising the topsoil and minimising water runoff (Walston et al., 2020).

5.4.1 RECOMMENDATIONS

There are several recommendations in literature on how to improve habitat provision and pollination in solar landscapes (table 4). The first one is to supply a varied range of important blooming vegetation types. Pollinators require foraging resources, and the variety is beneficial to wild pollinators (Blaydes et al., 2021). A second recommendation is to plant or maintain hedgerows at the border of the site if the characteristics of the landscape (e.g., the level of openness) allow this. Hedgerows provide several habitats for different species such as birds, and they are incredibly beneficial for pollination and visual screening (Blaydes et al., 2021). They also support breeding and the movement of species, provide shelter and favourable microclimates. The quality of the hedgerows is important. A hedgerow is considered to be of good quality if it contains at least three woody plant species that are continuous and unbroken (Blaydes et al., 2021). Another way to improve biodiversity and pollination is by ensuring season-long access to foraging resources. In other words, seed combinations should include vegetation that develop at various times across the season to ensure that they are always available. Late season resources are particularly important for pollinators and insects (Blaydes et al., 2021).
A fourth recommendation to improve habitat provision and pollination is to maintain

variation in the vegetation structure. Solar landscapes should aim to create heterogeneity because structurally diverse or taller vegetation structures have a more positive impact according to Blaydes et al. (2021). Lastly, it is important to promote connectivity to semi-natural habitats. This allows solar landscapes to act as a stepping stone to connect with otherwise isolated or abandoned habitat patches. Table 4 shows a summarised list of the opportunities and barriers of nature provision in combination with solar energy.

Table 4 Barriers, opportunities and future research on combining solar panels, nature provision and pollination (Blaydes et al., 2021; Randle-Boggis et al., 2020).

BARRIER	OPPORTUNITIES	FUTURE RESEARCH
Barrier effects to animal movement	Hedgerows/shelterbelts could improve biodiversity and serve as a corridor	Additional research into how the solar landscape can serve as a corridor and if municipal/provincial support is possible in this context.
	Special attention to habitat elements including ditches, buffers, field borders, and hedgerows.	
Decrease in biodiversity due to the installation of the panels	Natural nesting options should be available.	Further research into which management guidelines work best for the combination between nature and solar panels.
	Flower/nectar seed meadows should be planted and maintained to improve biodiversity.	
	Vegetation should be sown instead of natural and established vegetation.	
	Vegetation that is planted or sowed needs to be structurally varied and should provide resources for the entire season.	
	Reduced use of pesticides and fertilizers than with an agricultural field.	
	Grazing at a low intensity and cutting in winter will increase biodiversity.	
	Solar landscape can act as a corridor/stepping stone towards other natural habitats.	

5.5 FLOATOVOLTAICS

The development of solar solar energy systems is accompanied by a significant demand for land, which will always be a scarce resource in the Netherlands. Installing photovoltaic systems on water bodies such as lakes and canals helps to safeguard precious land. This dual use has the potential to improve the overall integrated and interconnected global system's efficiency (Sahu et al., 2016). Aquaculture (farming on aquatic organisms) and floatovoltaic technology (water-based solar photovoltaic systems) are two examples of dual use. Both improve the sustainability of the food-energy water nexus (Pringle et al., 2017).
There are multiple design options to install PV panels on water bodies. The choice for fixed installations, for example, optimise the available area's coverage. Tracking installations, on the other hand, maximises energy collection. These considerations are highly dependent on the location and its characteristics (Pringle et al., 2017).

5.5.1 OPPORTUNITIES AND BARRIERS

Floatovoltaics and aquavoltaics have many potential synergies and benefits compared to ground-mounted solar panels, such as an increase in water conservation. Water bodies with solar panels reduce the water loss with 70% (Pringle et al., 2017). However, there are also some barriers to adopt this dual use. One of the most significant obstacles is that PV panels absorb sunlight, which means that the light is no longer transmitted to the water habitat underneath. Because many organisms require light to exist, the modules' imposed shading creates a competition for light. The quantity of plants and microbes will decrease if shade is not taken into account, affecting the entire food chain in the water ecosystem (Pringle et al., 2017). One way to solve this problem is using bifacial panels or reflecting backsides (Fig. 31). In this way sunlight is still reaching the water surface. The most important benefits and conflicts of solar energy on water are summarised in table 5.

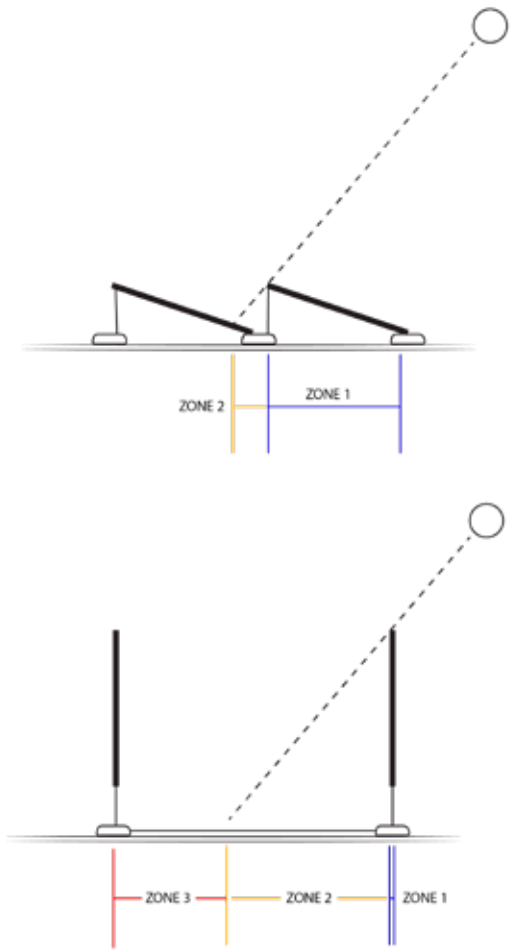


Fig. 31 Floatovoltaics versus vertical bifacial floatovoltaics

Fig. 32. Floatovoltaics (Y.-G. Lee et al., 2014)

Table 5 Barriers, opportunities and future research regarding the adaption of floatovoltaic technology and aquaculture (Pringle et al., 2017; Sahu et al., 2016).

BARRIER	OPPORTUNITIES	FUTURE RESEARCH
Needed exptertise and technical knowledge	Proper education and technical help from universities	Additional research into how they could inform solar farms and give them the knowledge of fish cultures, bacteria nutrition cycling, fluid pumping, and water quality
	Education and outreach from the PV sector to the farming business to lower knowledge barriers and build trust.	
Expensive installation of structures and maintenance (To maintain the same direction and location on the water, floating solar panels require directional control mooring systems.)	Since floating PV panels operate in a low-dust environment, there's little to no dusty effect.	More research into how to improve management guidelines for floatovoltaics.
	It saves land for agricultural and other land incentive operations, as well as converting underutilized and non-profitable water surfaces into commercial solar power parks.	
	For the installation of floating PV, there are a number of subsidies, grants, and incentive programs available.	
	The structure may be erected without the need of heavy equipment, making installation relatively simple. Installation time and expenses are reduced due to the minimal preparation required.	
	Greater productivity: The reflection of light from the water and the cooling provided by the water can keep PV panels cooler than land-based panels, resulting in higher efficiency.	
Impacts on water quality and ecosystem	Due to the perceived shadowing, water evaporation is reduced.	Additional research into the structures, cables and silicon modules if they have an impact on water quality and the natural environment. Additional research if the reduced solar light penetration into water bodies can affect the growth of aquatic creatures and seaweed.
	Reduced photosynthesis and algai development result in improved water quality.	
	Since several species are involved, integrated systems such as aquaponics that use farmed aquatic animals in conjunction with plant systems can give reduced risk in production, a reduction in ecological contamination, and a boost to environmental conservation.	
	Aquatic species production can relieve strain on wild stock populations, allowing them to recover.	

5.6 FUNCTION COMBINATIONS

To investigate the way different design combinations of functions are perceived in the landscape, a questionnaire with visualisations of these function combinations was sent out to 34 landscape architects which is a representative sample for this thesis. This survey helped to understand the value of the various combinations of functions according to the criteria that were selected from the Spatial Quality Framework for Agricultural Landscapes (Bakx et al., 2021; Fig. 3). These criteria are important for the transition from intensive agricultural land to a sustainable multifunctional solar landscape. They are divided into four groups: experiential quality, economic quality, ecological quality, and long-term quality. Each group can be defined using specific sub-criteria, namely diversity, cohesion and naturalness for experiential quality. Profitability and recreational opportunity for economic quality. Ecological quality is determined by biodiversity and sustainability is a sub criterion from long-term quality. 34 landscape architects were asked to give each visualisation of a function combination (Fig. 33-38) a score between one and four for every criterion. One meaning the combination has a negative effect, and four meaning it has a highly positive effect on the spatial quality. The full questionnaire can be found in appendix 5.

Fig. 33 Combination between fruit cultivation and solar energy generation

Fig. 34 Combination between water and solar energy generation

Fig. 35 Combination between community gardens and solar energy generation

Fig. 36 Combination between livestock and solar energy generation

Fig. 37 Combination between water retention/storage and solar energy generation

Fig. 38 Combination between habitat provsion and solar energy generation

5.7 PERCEIVED SPATIAL QUALITY OF FUNCTION COMBINATIONS WITH PV

The results from the survey show that the combination of PV with community gardens and with habitat provision are evaluated most positively when it comes to their effect on spatial quality (Fig. 39). These combinations also receive the highest scores on the question, whether they experience the visualisation of the function combination with solar panels rather positive or negative. This can be explained by the fact that community gardens and PV can be combined on a small surface. According to several landscape architects, it would therefore be easier for the local population to accept this change than, for instance, agrivoltaics over a large area. Floatovoltaics is believed to have a rather negative effect on spatial quality because this synergy is considered to be more disruptive in the landscape (Fig. 41). This combination also scores the lowest for the other criteria (Fig. 41-47). Floatovoltaics probably score low since there are not many good examples in practice, although the synergy is positively recommended in literature. Another reason why floatovoltaics may score low is because the visualisation of this combination without panels is perceived as the most positive. Therefore, the transition to the use of panels is probably seen as something very disturbing as solar panels still have a poor image. Solar grazing is believed to be the most profitable synergy. This is important to consider in the design since agriculture is important alongside nature within the area. The evaluation of the different function combinations made no difference according to the gender of the respondents (Fig. 40.

Although some synergies score high, for each combination the visualisation without solar panels is still experienced as more positive than in combination with solar panels. However, the functionality of the various combinations with solar panels is always given a higher score by the 34 respondents than without the PV panels (Fig. 48).

The final design will focus on the synergies that score the highest on the spatial quality criteria. The following combinations will thus receive the most attention: habitat provision and PV, solar grazing, fruit cultivation and PV/ agrivoltaics. Community gardens combined with PV will also be part of the design but since the neighboring communities are quite small there is no need to apply this function combination over a large area.

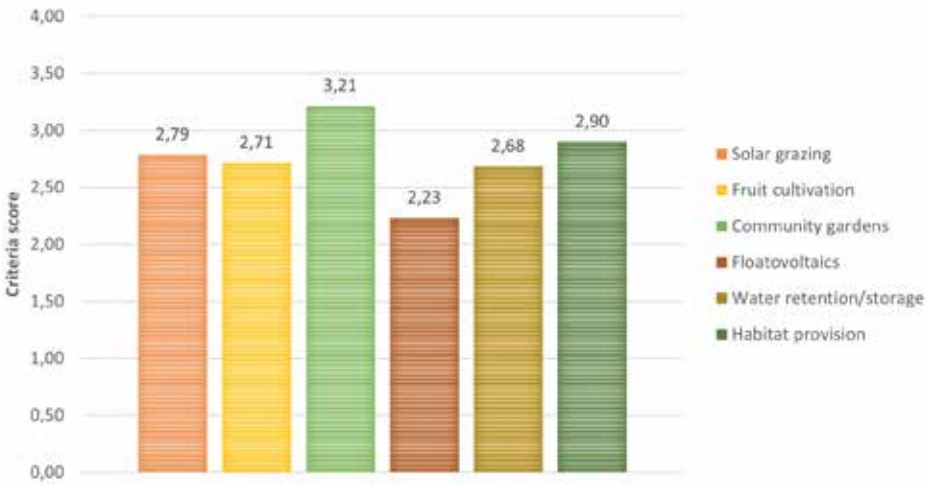


Fig. 39: Effect on spatial quality of different function combinations with PV

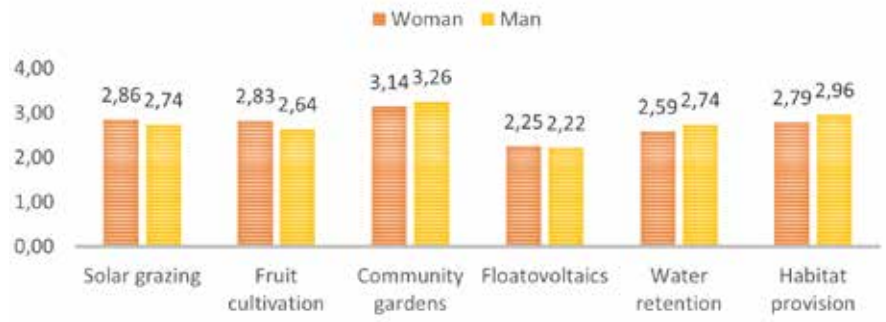


Fig. 40: Effect on spatial quality of different function combinations with PV according gender

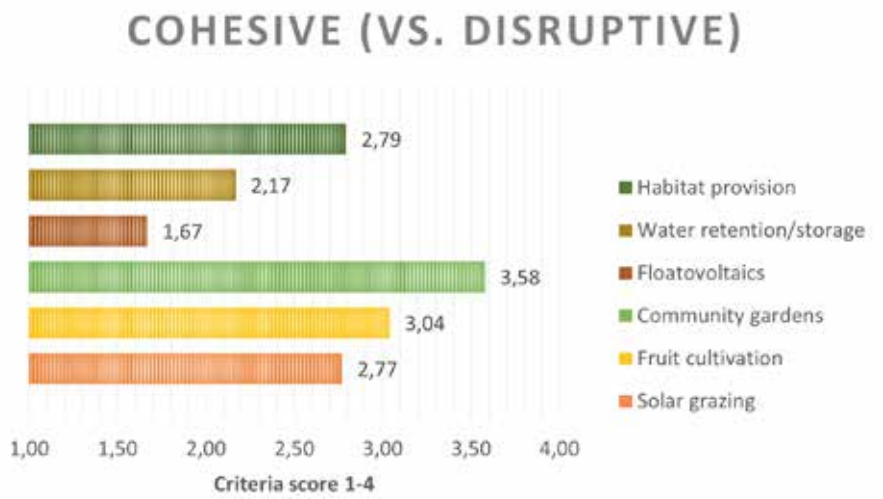


Fig. 41: Effect of function combinations on the spatial quality criterium cohesive

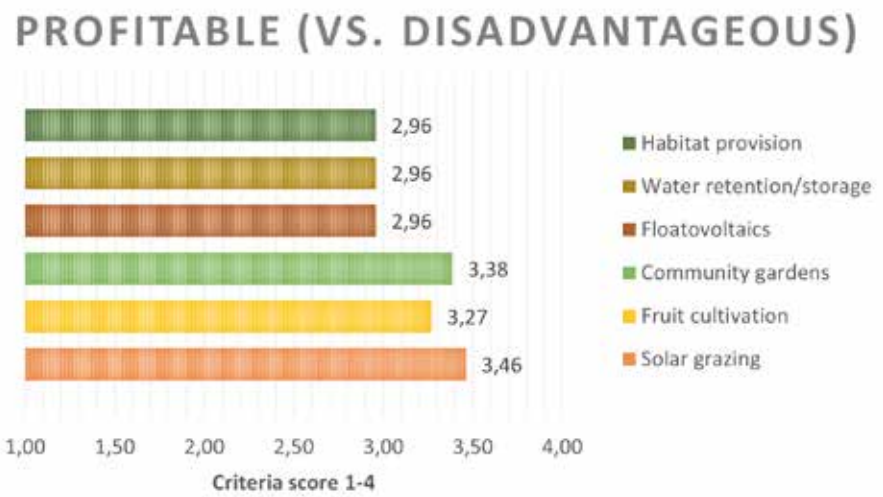


Fig. 42: Effect of function combinations on the spatial quality criterium profitable

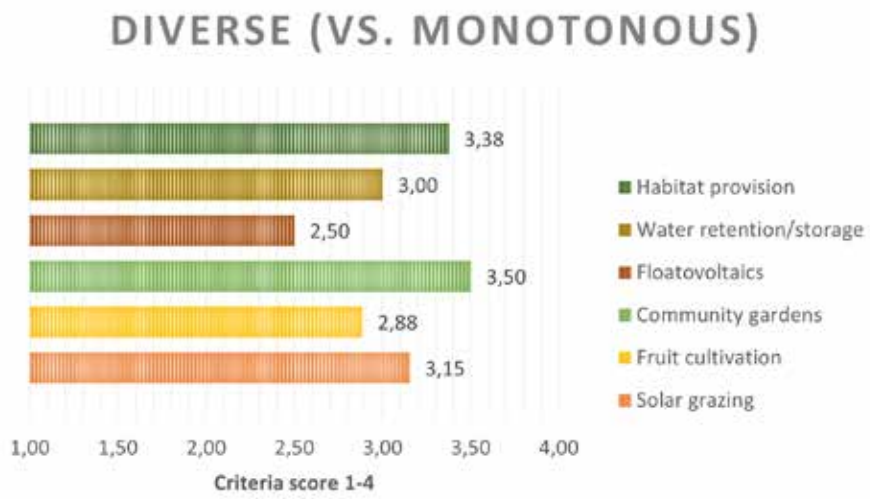


Fig. 43: Effect of function combinations on the spatial quality criterium diverse

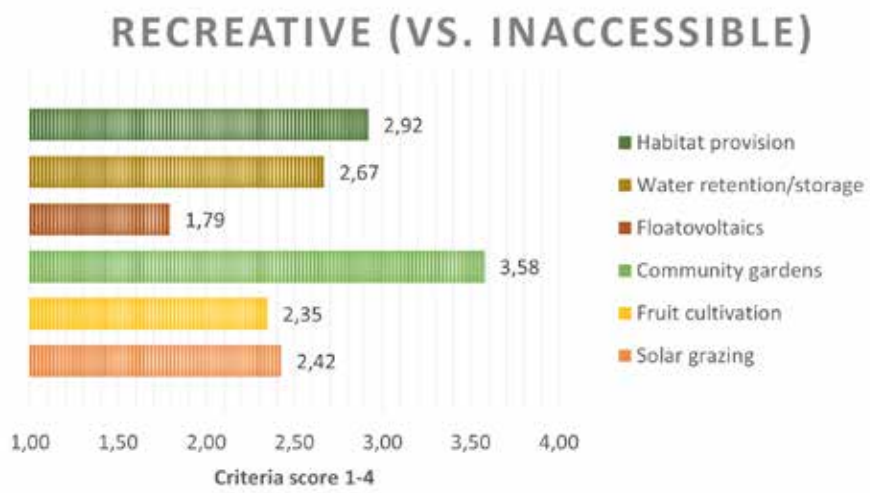


Fig. 44: Effect of function combinations on the spatial quality criterium recreative

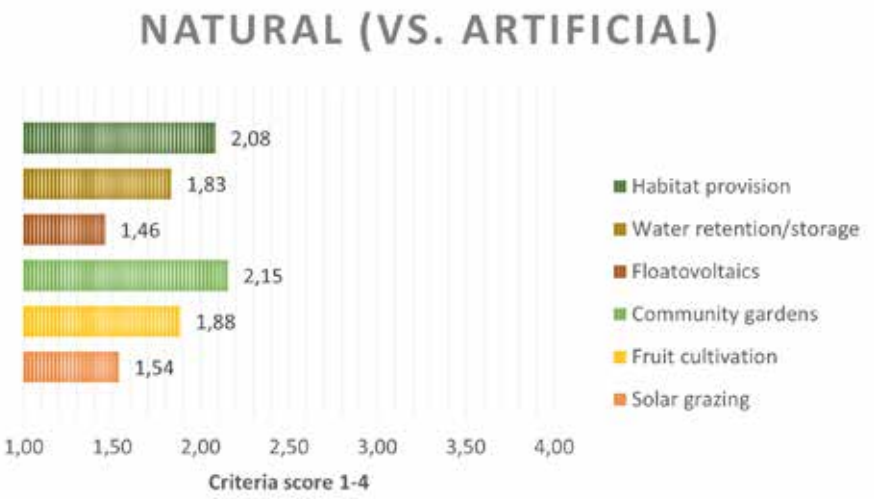


Fig. 45: Effect of function combinations on the spatial quality criterium naturalness

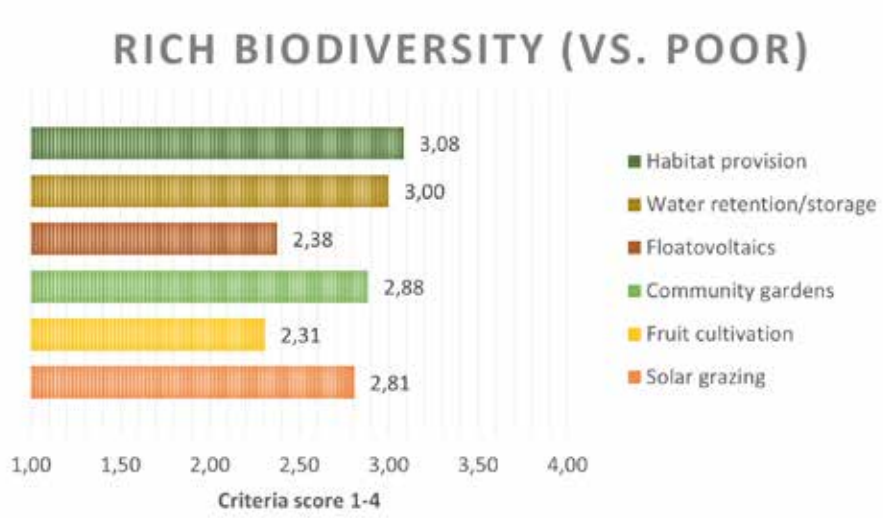


Fig. 47: Effect of function combinations on the spatial quality criterium biodiversity

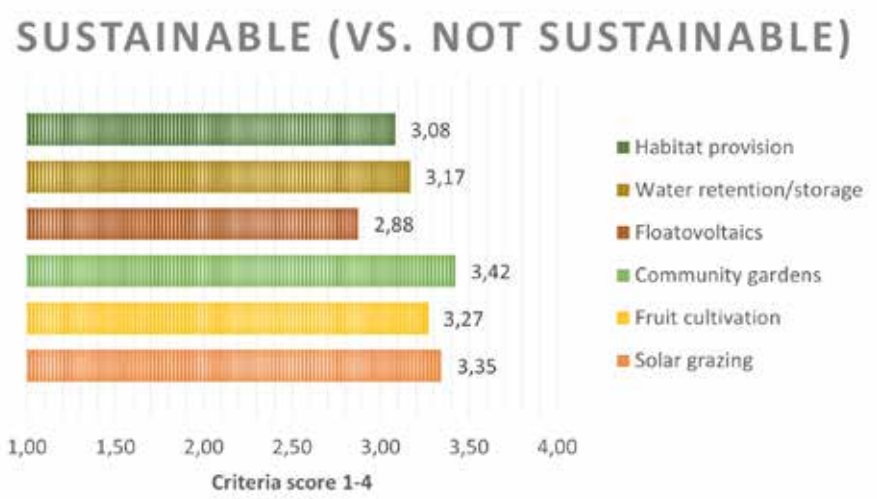


Fig. 48: Spatial perception of the visualisation

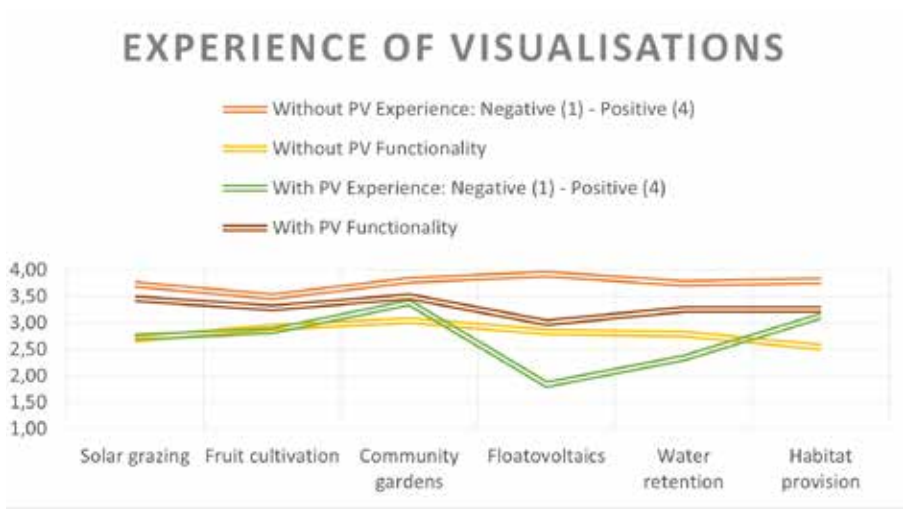


Fig. 46: Effect of function combinations on the spatial quality criterium sustainable

** More general graphs about the respondents can be found in appendix 6*

5.8 DESIGN SCENARIOS AS FOUNDATION FOR FINAL DESIGN

The scenario-based approach in landscape architecture involves developing scenarios for future landscape changes. It also entails simulating the changes in land use and land cover that may occur as a result of these potential futures, as well as assessing the resulting implications (Albert, 2011). Developing scenarios can not only support decision making but also helps to stimulate creative ideas before designing (Lenzholzer et al., 2013). Scenario-based designing is therefore applied in this study. The four scenarios that are described below, each have their own focus based on the results from the surveys in SRQ2 and SRQ3. The most important current services that resulted out of the survey are crop production and nature provision. These services combined with PV also scored quite well on the spatial quality survey. Therefore, these two are given a place on one axis. The literature review done for SRQ1 showed that it is important to apply visual screening, but also to be able to experience the solar landscape. Therefore, the option of experiencing the solar landscape is used on the other axis.

5.8.1 SCENARIO 1: CROP PRODUCTION X EXPERIENTIAL (Fig. 49)

Scenario 1 places the emphasis on agriculture, characterising the area by crop production, fruit growing, and cattle breeding. These forms of agriculture are combined with solar energy generation, which visitors are able to experience through a cycling and walking loop that winds through the different fields. An organic form was chosen to intersect with the technical straight parcels with PV. In this way, recreationists can still experience the solar landscape, but they cannot enter the different agricultural plots. This will make it technically easier for the farmers. Around the loop, more attention is paid to nature development since recreationists pass by there. Beyond the loop, most of the percellation forms have been retained. The plots are edged with various hedges to screen the solar panels from surrounding residents as well as to bring back the character of the past.

5.8.2 SCENARIO 2: NATURE PROVISION X EXPERIENTIAL (Fig. 50)

The second scenario focuses on the provision of nature serving as a habitat for various plants and animals. Next to habitat provision, water regulation will also form an important ecosystem service here. Next to these services, arable farming, cattle breeding, and fruit cultivation are given a place near the borders of the area but to a lesser extent than the first two services. These different functions will all become multifunctional with the use of PV panels, which are

Fig. 49 Scenario 1: crop production x experiential

Fig. 50 Scenario 2: nature provision x experiential

made experienceable by various cycling and walking routes that cut through the fields. The fields where nature provision is central are mainly characterized by organic forms and small pieces of PV that fit with the loose structures of nature and in addition, to soften the technical structures of the panels. Within these fields, the water buffers and shrubby areas are given the function of stepping stones and are therefore centrally located.

5.8.3 SCENARIO 3: NATURE PROVISION X NOT EXPERIENCEABLE (Fig. 51)

The emphasis in the third scenario is on nature provision and water regulation. In this scenario, visitors are not able to experience the area. Which means that access to the solar landscape is avoided for the purpose of nature development. In addition, the panels are hidden for surrounding residents by the use of vegetation. The surrounding straight parcel forms are preserved for agricultural use. Centrally, the choice was made to merge parcels into one large piece where nature has the opportunity to develop in different habitats. The water buffers are given organic shapes to soften the shape of the solar panels.

5.8.4 SCENARIO 4: CROP PRODUCTION X NOT EXPERIENCEABLE (Fig. 52)

The last scenario focuses on crop production, livestock farming, and fruit cultivation, just like the first scenario. The various combinations with PV are not visible or experienceable for residents and visitors, like in scenario 3, to optimize agriculture economically and functionally. This scenario is focused on generating income from agriculture and solar energy therefore all plots are given straight structures that follow the surrounding landscape. Since solar grazing is seen as the most profitable function combination in chapter 5, most attention is paid to this combination. Nature development is seen in this scenario by forming corridors of hedges and bushes along the plots.

Fig. 51 Scenario 3: nature provision x not experienceable

Fig. 52 Scenario 4: crop production x not experienceable

6.2 SCENARIO COMPARISON

The scenarios are assessed according to the criteria used in SRQ3. Each criterion from the Spatial Quality Framework for Agricultural Landscapes (Bakx et al., 2021) is discussed and is personally rated by giving a score from 1 to 4 (table 6).

All four scenarios have a diverse land use. Scenarios 2 and 3 have a larger variety of planting, giving them a higher score. The former even received four points since it has an altered open and closed landscape, which allows more variation in landscape features.

Diversity must be analysed together with cohesion since diversity without cohesion creates a chaotic landscape. Scenarios 1 and 2 score the best on the level of cohesion. These scores are given since the scenarios have a lower density of solar panels and because they alternate between open and closed landscape, therefore the area is never completely cut off from its surroundings.

In terms of naturalness, scenarios 2 and 3 score the highest because rather than forming a row of PV panels, panels are designed in lower densities scattered over the landscape. Moreover, by combining livestock or nature with PV panels that have a lower density, more vegetation is given the chance to develop which reduces the sight on the solar panels.

Because of the lower densities, scenarios 1 and 4 contrastively score the highest on the level of profitability. Higher density of PV panels in combination with agriculture therefore results in economically profitable scenarios. By excluding recreation from the production area as in scenario 4, a more practical economically focused landscape is created than in scenario 1.

Scenarios 1 and 2 score the highest in terms of recreational opportunities. This is self-explanatory, considering these scenarios are open to cyclists and pedestrians passing through the different function combinations.

Biodiversity is the highest in scenarios 2 and 3, since the density of the panels is lower, allowing more opportunities for nature provision.

Finally, sustainability received the highest score for scenario 4 since the plot forms are preserved and could easily be made reversible to the current situation. For other changing conditions, additions can easily be made to this scenario. Implementing the loop in scenarios 1 and 2 makes it less easy to adapt to changing economic, technical, environmental, cultural and social conditions. For example, if suddenly the use of huge machines is required for agricultural production then this could be interfering with keeping the solar landscape open to visitors.

The purpose of the scenario analysis is to determine which scenarios focusing on specific ecosystem services have the most positive impact on spatial quality. By comparing the scenarios using the scores for the seven criteria, which all have the same weight, the best scenario is chosen. Scenario 2 is considered the most positive according to spatial quality. Therefore, this scenario will serve as the foundation for a single integrated design for a multipurpose energy transition aimed at improving the spatial quality of the Millingerwaard's landscape.

Table 6: Scenarios rated according to criteria

CRITERIA	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Diversity	2	4	3	1
Cohesion	3	3	2	1
Naturalness	2	3	3	1
Profitability	3	2	2	4
Recreational opportunities	3	3	1	1
Biodiversity	2	3	3	2
Sustainability	2	2	3	4
	17/28	20/28	17/28	14/28

7 THE DESIGN

7.1 INTRODUCTION

In this chapter, the information from the subresearch questions 1, 2 and 3 are synthesised into a design for a solar landscape along the Millingerwaard. The design is based on the scenario resulting from the previous chapter, namely with a focus on nature provision and the opportunity to experience the landscape. In contrast to conventional landscape designs, this design is based on the concept of ecosystem services. Therefore, the design components are explained by describing each ecosystem service and its development. Not all steps taken to arrive at the final design are included for the sake of clarity. The long-term vision of the design and the phasing plan for its realization are discussed at the end of this chapter. Lastly, there is an evaluation of the design using the selected criteria from the spatial quality framework.

7.2 PURPOSE OF THE DESIGN

The purpose of this design is to generate public awareness about different combinations with PV that are connected to the landscape in a sustainable way without having a negative impact on the spatial quality and to highlight the function combinatons effectiveness. Therefore, the design not only focuses on energy generation, but also on biodiversity, agriculture, water regulation, recreation, education and pollination. The aim of the design is that the public becomes genuinely curious about it and therefore experiences and learns about the solar landscape and renewable energy in general.

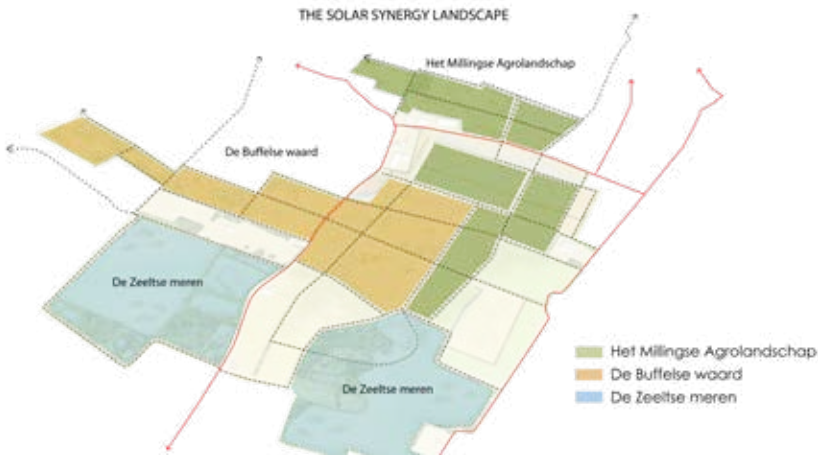


Fig. 53 The Solar Synergy Landscape of Berg en Dal

7.3 ENERGY GENERATION

The ecosystem service 'energy generation' is the main focus of this thesis. According to the spatial principles of SRQ1, renewable energy landscapes should serve multiple purposes. They must satisfy several needs simultaneously. This design therefore includes multiple features combined with PV. 50% of the surface area has been assigned to nature development (The Bufferse waard, Fig. 53) while the other 50% is devoted to agriculture (The Millingse Agro Landscape). These are the most important current ecosystem services as described in Chapter 4 of this thesis. Furthermore, roughly 50% of the total area is dedicated to energy generation through multifunctionality with other functions. For example, when entering the solar landscape, an artistic PV canopy covers a large public square where local markets can be held or where people can picnic together while charging their electric bikes (Fig. 55). This combination with PV is another way of getting to know solar energy. It allows visitors to familiarize themselves with PV at a smaller scale than usual. The shape of the PV canopy is very organic and moves up and down. This artistic form was chosen to attract people to the solar landscape and as a contrast to the straight pathways and PV rows. The solar panels above the public square can be used to power a water pump and provide electricity for lighting, for the adjacent community gardens. This allows residents to experience the dual-use benefits of PV.

The middle part of the solar landscape is characterised by a low concentration of solar panels divided into small patches allowing for natural development in combination with PV. The panels are playfully divided into small patches to create different habitats and to provide a playful alternation between open and closed. Furthermore, the PV rows vary in length to create a softer edge. The panels are positioned at a low angle of 20°, 0.5 metres above ground and up to 1.6 metres high, with a spacing of about five and a half metres to six metres between the PV rows to allow for sufficient vegetation development. The PV rows are 2.6 m wide and consist of two panels placed above each other. The irregular patterns of PV are situated in straight blocks following the ditches and historical boundaries of the agricultural fields. These blocks are edged with medium-high hedges to reinforce the historic lines and vistas.

Agriculture in combination with PV (agrivoltaics) is emphasized at the edges of the area, namely in the Millingse Agrolandscape (Fig. 53). These fields focus primarily on fruit cultivation, arable farming, and livestock. Here the blocks of PV are more densely positioned than in the area which emphasizes nature provision. Agrivoltaics unites the growing demands for energy and food. Solar power and agriculture are therefore combined for equal maximum output. The agrivoltaics above crop production are organized in straight blocks following the plot boundaries and the existing landscape.

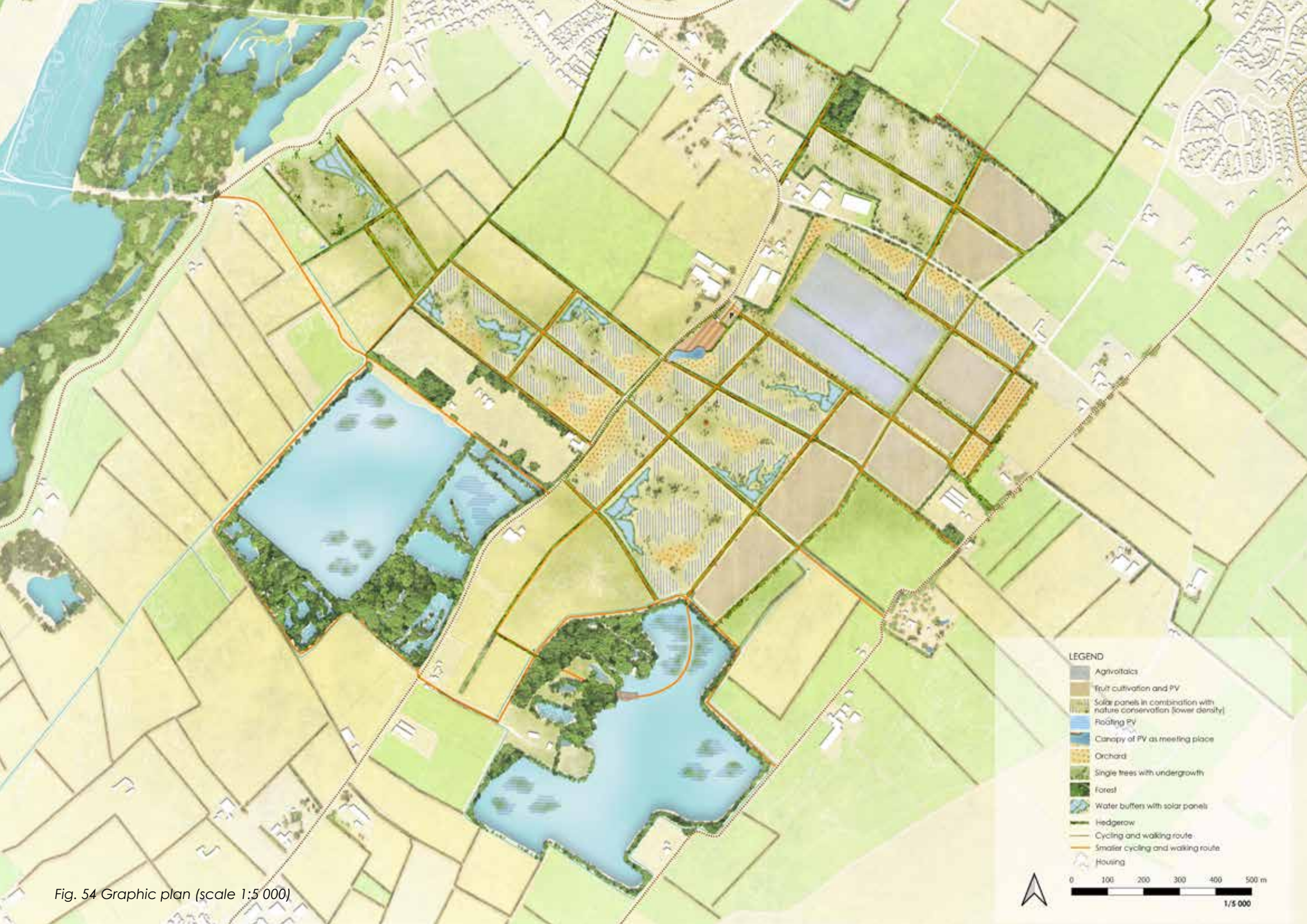


Fig. 54 Graphic plan (scale 1:5 000)

Fig. 55 Visualisation of the artistic PV canopy that covers a large public square where local markets can be held.

All these covered PV surfaces together create a solar landscape with approximately 290 000m² of panels that can potentially produce approx 40.650.000Kwh. This general calculation is based on the areas covered by solar panels, taking their density into account. For the bifacial panels, a higher energy output was calculated per area covered with solar panels.

Transformers are also part of a solar landscape. Therefore, design research is done on how transformers can fit within the Solar Synergy Landscape of Berg en Dal (Fig. 56).

7.4 NATURE PROVISIONING

Aside from the integration of the PV system, the design focuses on the development of new natural elements and the improvement of existing landscape elements. This focus is reflected throughout the plan. The largest part of the site, the Buffelse waard, is devoted to the combination of energy generation and nature provision. The small, scattered patches of solar panels in combination with extensive natural elements such as humid herb-rich grassland will stimulate the biodiversity within the area. At present the study area consists only of agricultural land with a low level of biodiversity in relation to the adjacent natural area. With the Buffelse Waard, the solar landscape becomes an extension of the Millingerwaard natural area. The Buffelse Waard will be a place where the panels are combined with extensive natural elements, such as wet meadows, flowery meadows, solitary trees, groups of trees, and hedges with a variety of species. In the current monofunctional landscape these natural elements will support the natural network for local insects and animals (e.g., bees), reinforcing the ecosystem service of pollination and habitat provision. Through different paths, visitors are able to experience nature from up close and admire the synergy between PV and nature. The solitaire tree groups will create different habitat zones with alternating sun and shade for people, flora and fauna.

Section A-A' shows the transition between the combination of solar panels with nature provision and agrivoltaics (soft fruit) (Fig. 57). The left shows a lower density to allow vegetation to develop sufficiently. The fields with PV are separated from the public paths by a hedgerow of various shrubs of 160 cm high allowing visitors to have an overview of the different fields. Target species are the beaver, the small 'parelmoer' butterfly and various bird species. Native and indigenous plants are used to target specific species. Furthermore, the use of native plants increases the number of native pollinators and enhances the ecosystem service of pollination while supporting terrestrial biodiversity. Native plants which have become accustomed to the landscape's features require minimal effort in order to thrive for several years (Danler & Langellotto, 2015). This is important to lower the maintenance costs.

7.6 CROP PRODUCTION/LIVESTOCK

The agrivoltaic fields are located in the Millingse Agrolandscape (e.g. fruit cultivation, arable farming, and cattle breeding, Fig. 63). Most of the current forms of land use remain in place but are augmented with translucent solar panels. The current farmers' expertise remains pertinent, which eases the transition. The agrivoltaic fields have a higher density than the PV fields combined with nature provision, except for solar grazing, which also has a low density of PV panels. Section B-B' shows the transition from solar grazing with vertical bifacial systems to agrivoltaics with stilt-mounted panels (Fig. 58). On the left side there is a lower density, so that livestock such as cows can find shelter between the panels. The focus is on extensive livestock farming where nature development is given a chance to thrive. The fields are separated from each other by a path bordered by varied hedges and vegetation. Since these fields are localized at the edges of the solar landscape, they are surrounded on the outskirts by groups of trees and vegetation. The PV structures are therefore less visible to nearby residents Where the agrivoltaic fields have a higher density or higher structures, the fields are alternated with extensive orchards and flowery meadows to break the view on the PV structures (Fig. 59: Section C-C' shows the transition from agrivoltaics (soft fruit) to an orchard with extensive grassland). The parcels are surrounded by medium-high hedges that refer to the past and to visually screen off

Surrounded by vegetation

A hedge on the side where recreation takes place

A fence planted with climbing plants

Artistic graffiti that characterises the area

Fig. 56 Various possibilities for integrating the transformers into the landscape

A-A'

Fig. 57 Section A-A'

B-B'

Fig. 58 Section B-B'

C-C'

Fig. 59 Section C-C'

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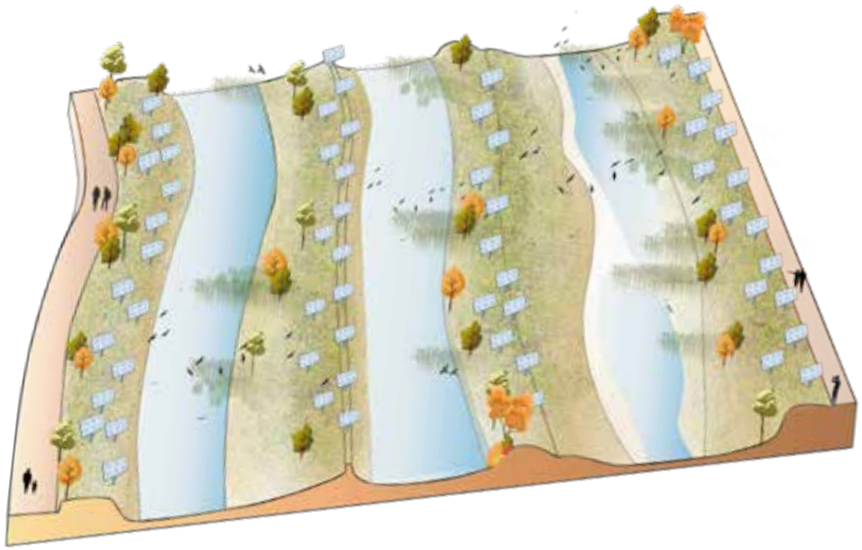

Fig. 60 Visualisation of the water buffers in normal situation.

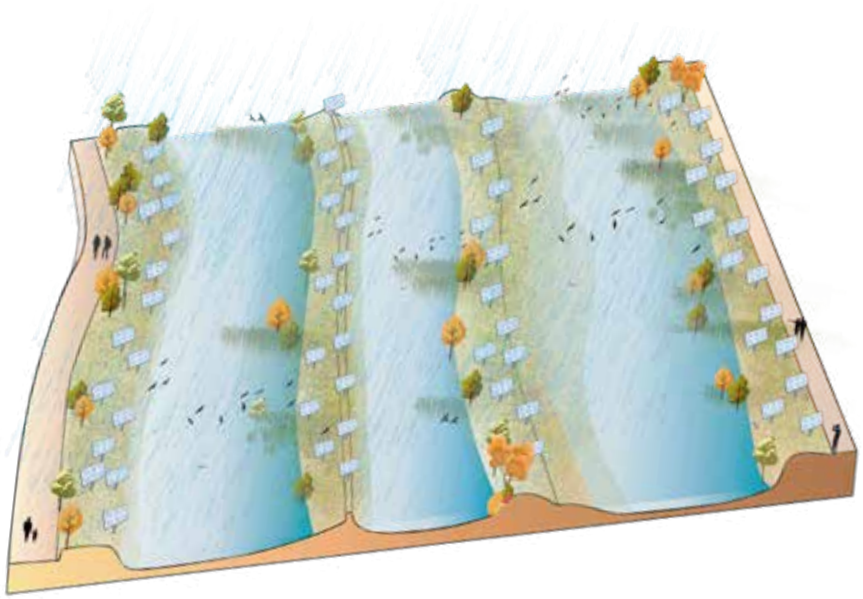

Fig. 61 Visualisation of the water buffers when there is heavy rainfall.

the technical appearance of the PV panels structures. Soft fruit (e.g. berries, strawberries) can be found under most panels due to high revenue and easy maintenance. The fields with fruit also refer to the many orchards and fruit cultivation that used to be in the region. The two fields in the middle are used to experiment with various crops such as lettuce and other leafy plants. These agrovoltaic systems have a heightened installation due to the need for machinery and are therefore surrounded by the other fields and vegetation.

7.5 WATER REGULATION

In the Buffelse Waard are several water buffers for slow water infiltration in combination with PV (Fig. 60). This is a solution to the problems of flooding and poor infiltration in the area (Fig. 61). During heavy rainfalls these buffers ensure that the surrounding agricultural lands can continue to function. The height differences of the buffers provide diverse habitats and greater biodiversity as moist to dry habitat types will develop in these low-lying areas. This is important since humid habitats are especially relevant in Berg en Dal such as the Millingerwaard area. These water buffers form therefore an important specific habitat extension of the Millingerwaard and its wetter habitats. They also refer to the many sand extractions that have slowly changed the area. The shape of the different buffers was chosen based on the already existing gully shapes of the Millingerwaard.

7.7 RECREATION, ACCESSIBILITY AND LANDSCAPE EXPERIENCE

The design includes recreational functions in addition to meeting the ecological objectives. Various cycling and walking paths wind through the area. They are linked to the existant bicycle network that bisects the area. Visitors can walk and cycle through the area and experience the different PV combinations. Along the hiking and biking trails are several public rest areas with picnic benches, lounge chairs, and an observation tower (Fig. 62). The observation tower provides a view of the entire solar landscape with its PV combinations and offers a view in the direction of the Millingerwaard. In order for the observation tower to fit within the solar landscape, a straight but playful shape was chosen. Along the paths there is a pattern of open and enclosed scenery that changes continuously, which creates an exhilarating journey for the visitor. The paths that have been made public or added to increase accessibility from all sides are seen in figure 47. The majority of the new paths are inspired by historical landforms or ditches. By planting medium-high hedges on both sides of the pathways, the lines and visual axes in the design will be strengthened. The hedges also ensure that visitors can always explore the solar landscape without harming the PV fields and its natural growth. Several fields are also accessible during the day (orange spots Fig. 64). Here the visitors can discover the various synergies with solar

Fig. 62 Visualisation of the observation tower and its surroundings.

energy using the mowed paths. Automatic gates allow the fields to be closed at night and during important breeding seasons.

The solar landscape can also be reached by car. A parking lot is located next to the community gardens. Visual nuisance is prevented by surrounding the parking lot with shrubs and trees. The location of the parking lot allows for easy access by residents to their community gardens and the solar landscape.

7.8 VISIBILITY

Shielding disturbing views is a regulatory ecosystem service called visual screening. Local communities are often concerned about observable trade-offs. For example, agrivoltaic systems are designed with stilt mounted PV installations reaching a height of at least five metres. This makes the PV systems stand out in the landscape. In the design, the visibility of the PV panels from outside the area is limited by using vegetation for screening or by altering the angle of the solar panels to reduce the height. The latter is only possible if high machinery is not required for the production. Figure 65 shows how the solar landscape is visible from 'Botsestraat'.

7.9 OTHER ECOSYSTEM SERVICES

Efforts were made within the design to enhance other ecosystem services such as education. Visitors can learn about the site's history, the solar energy transition, its ecological evolution, and the overall topic of renewable energy by reading the information panels placed in the observation tower and on the square under the artistic PV canopy. This will give visitors a new perspective on solar landscapes and the energy transition in general, impacting their view on their own energy use.

Beehives and the many extensive orchards boost the ecosystem service of pollination. Pollination is a critical service closely linked to habitat provisioning. Pollinators sustain wild vegetation species, maintain the stability of the ecosytem and its biodiversity, and contribute to the food security of the surrounding agricultural lands (Blaydes et al., 2021).

Floatovoltaics is used to a lesser extent within the area, only on the extraction lakes. This is because the combination received a very low score during the spatial quality survey. In the design, the floatovoltaic panels are combined with surrounding recreational uses. Between the floating panels, a bicycle and walking bridge crosses the lake. On a pontoon, visitors can take a relaxing pause on the long wooden bench. A spot where all age groups can come together to relax and experience the lake (Fig. 66). Further research into the application of floatovoltaics could provide new opportunities and would be particularly valuable considering the two large reclaimed lakes in the area.

Fig. 63 Millingse Agro Landscape

Fig. 64 Accessibility of the area (slow network)

Fig. 65 Visualisation of how the solar landscape from the road could look like.

Fig. 66 Visualisation of how the floatovoltaics on the extraction lakes could be combined with recreation.

7.10 SITE DESIGN

To give a better idea of the combination of solar panels with nature development, this area was chosen as site design (Fig. 67). The panels are playfully distributed in small patches with a 5.8 m gap between the rows to allow for sufficient vegetation development. The lenght of the PV rows varies to create a softer edge. Furthermore, the water buffers are illustrated with their slight height differences where several PV panels are placed at the highest points. The paths for walkers and cyclists are surrounded by hedges of different species or by ditches. During important vegetation or breeding seasons, the blocks of PV panels can be closed with automatic gates. Otherwise, people can walk along the PV panels via the mowed paths, and experience the lightly elevated flower fields that provide a colorful variety between the panels. Because these flower fields are elevated, wadis are provided near them to collect the water. On the right, a visualisation shows how the small patches of PV combined with nature could look like (Fig. 68).

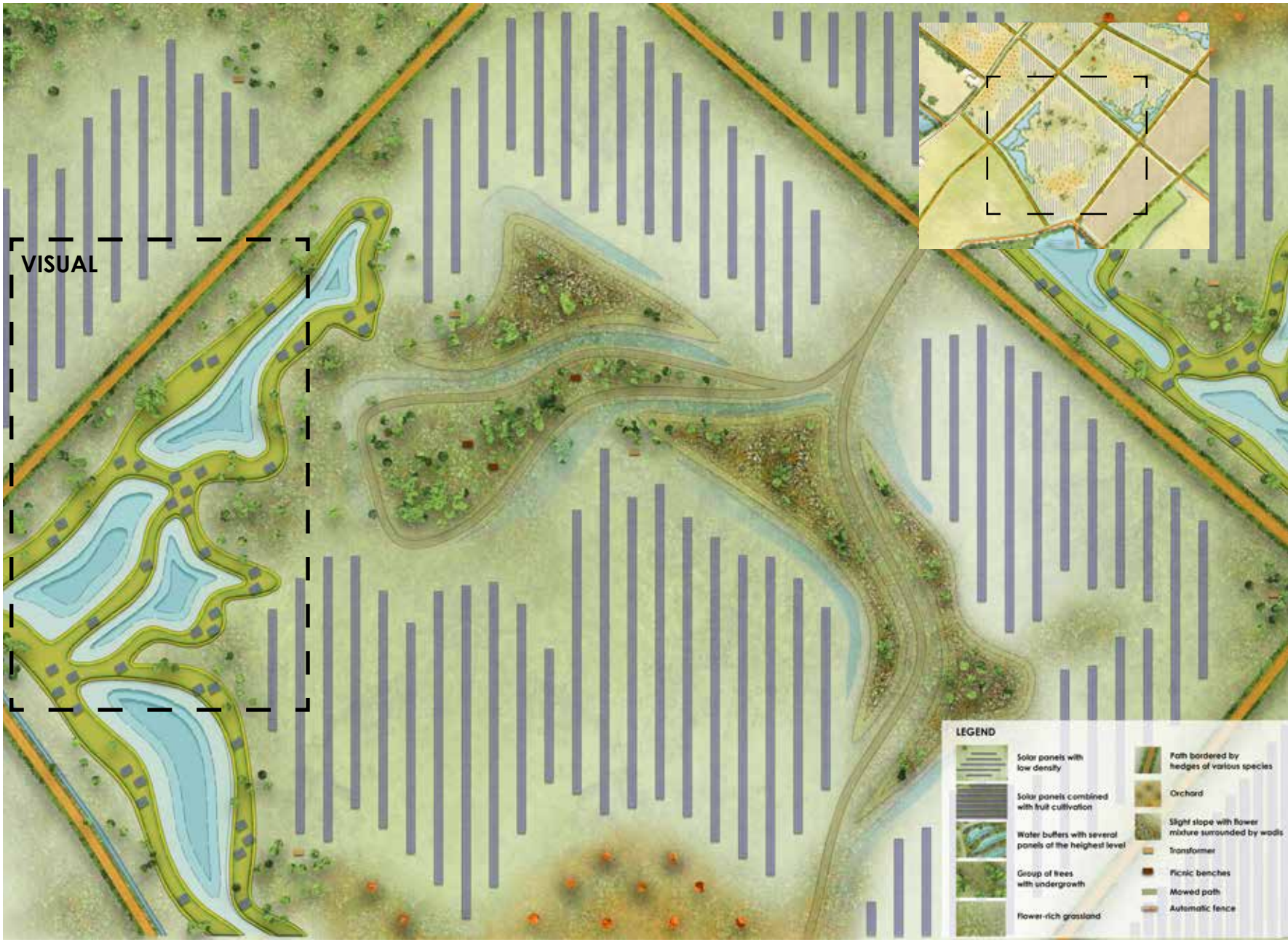

Fig. 67 Site design

Fig. 68 Visualisation of how the combination between PV and nature development could look like.

The water buffers are illustrated in this section (Fig. 69) with their low height differences where several PV panels are placed at the highest points. The height differences of the buffers provide diverse habitats and greater biodiversity as moist to dry habitat types will develop in these low-lying areas.

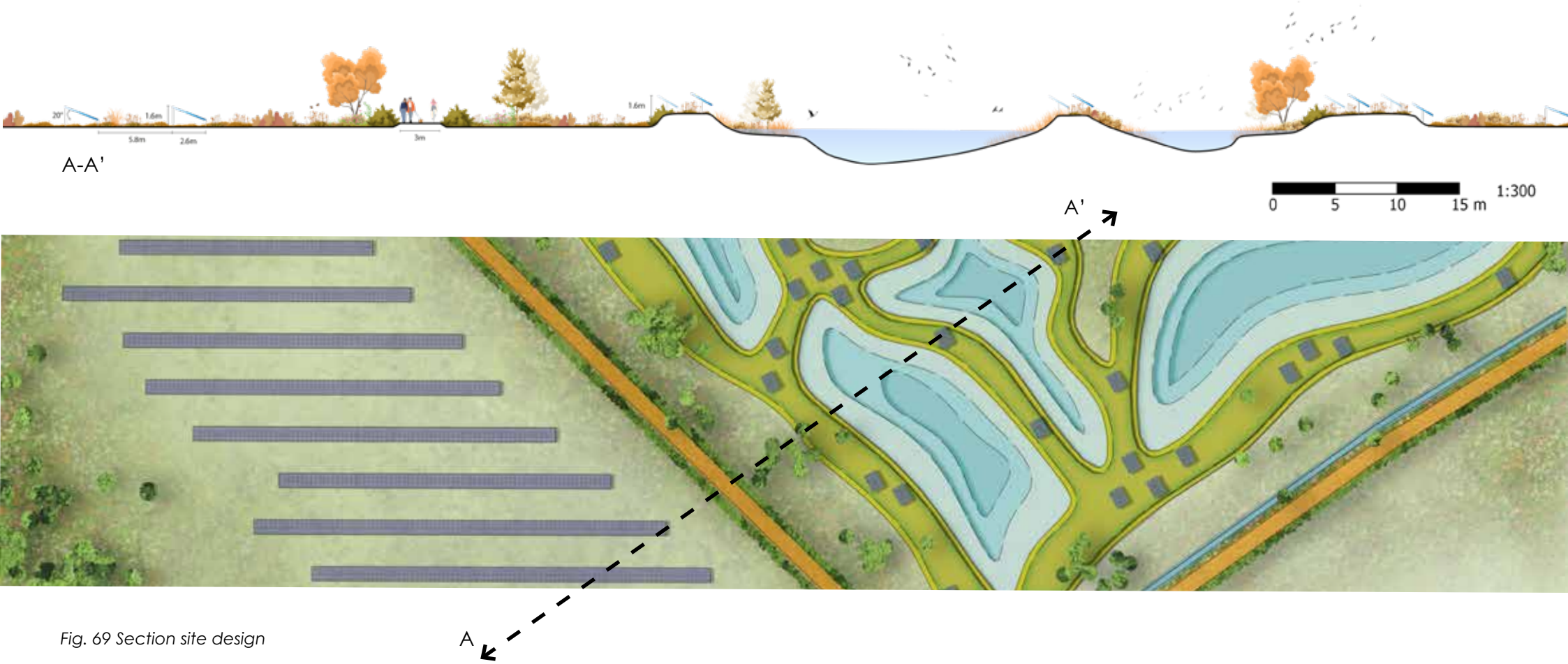

Fig. 69 Section site design

7.11 LONGTERM VISION

This section discusses how the Solar Synergy Landscape may develop in the future, in accordance with one of the principles derived from Chapter 3, namely 'the need to consider the temporal aspects of a solar landscape'. The goal is to enhance the landscape pattern, even further than the lifetime of the PV landscape itself.

Most current land uses in the area are monofunctional. In the future, they can be combined with solar panels to give the land a multifunctional use. It is necessary to reconsider what will happen to the solar landscape after 25 to 30 years, depending on the type of panels. Possible futures have been outlined for each combination of functions (Fig. 70-74). The first option is to return to their original monofunctional state. The second option is to prolong their life expectancy by replacing old panels with new ones without using more land or increasing the number of panels. The installation of these new and more efficient panels would not have a significant impact on the area. Biodiversity and the production of ecosystem services will continue to be stimulated. Another possibility is that now that the farmers are already engaged in renewable energy through the implementation of panels, they have the opportunity after 25 years to take another step in that direction. The ideal transition is to move towards more nature-inclusive agriculture such as row crop farming (with the possibility of combining it with solar panels).

From day one, nature development and renewable energy generation should go hand in hand through the extensive management of the solar landscape (Fig. 74). When the solar panels are removed after 25 years, the land can become available for

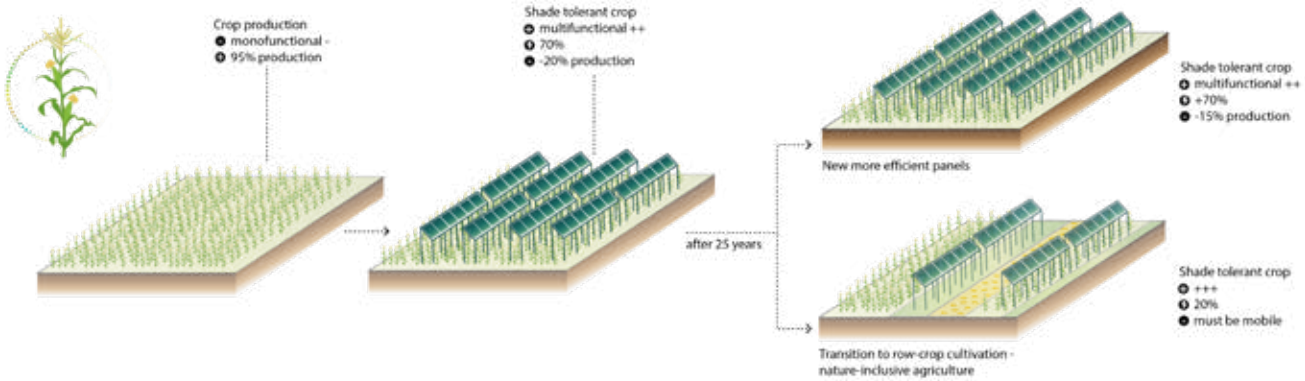

Fig. 70 Presentation of how arable land might evolve.

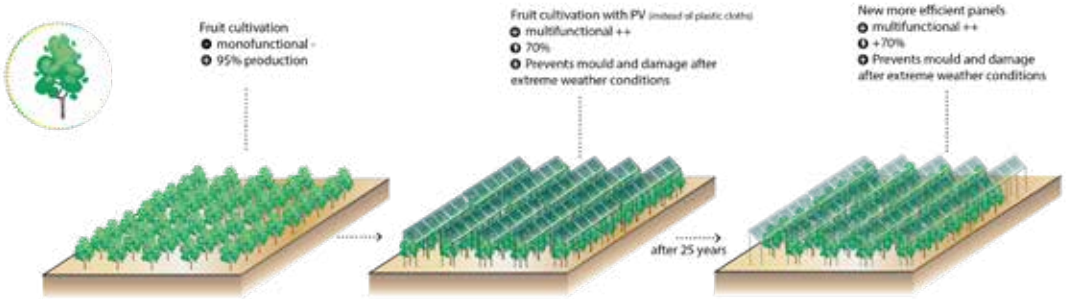

Fig. 71 Presentation of how fruit cultivation might evolve.

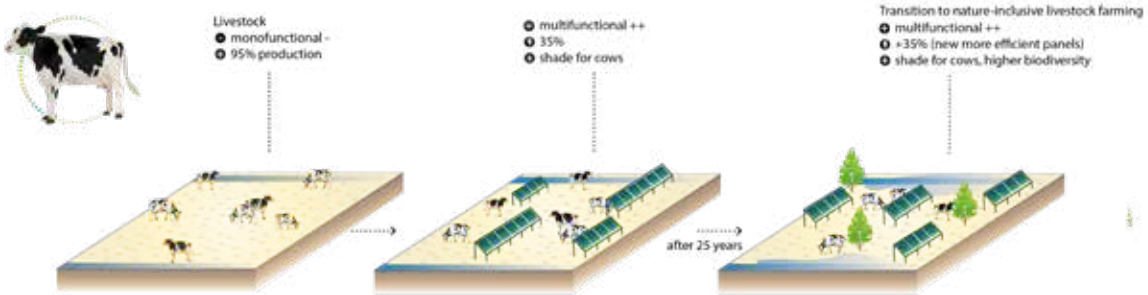

Fig. 72 Presentation of how livestock farming might evolve.

nature. Financial benefits from the development of the solar landscape can be used for co-financing to accelerate nature development along the Millingerwaard. The time span of the panels (25-30 years) is the ideal intermediate step to allow the first phase of succession and vegetation development to take place.

The municipality can continue to focus on its three pillars, namely nature, recreation and agriculture, by transforming the solar landscape into a new future perspective. Namely an experienceable landscape for cyclists and walkers where fruit cultivation is accompanied by solar panels as protectors against extreme weather conditions, where agriculture has been transformed into nature-inclusive agriculture, possibly focused on tourism, and where the development of nature takes place through succession and extensive management (Fig. 75).

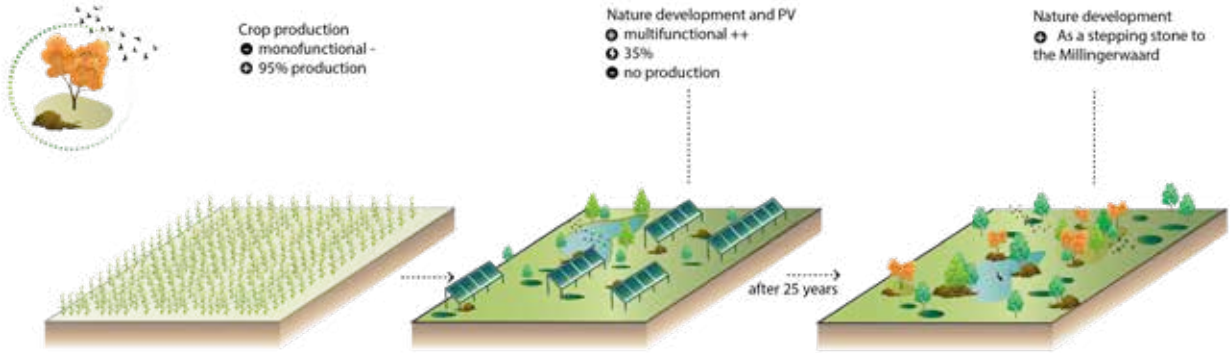

Fig. 74 Presentation of how arable farming can change into a nature-rich area.

The chosen scenario on which the design is based emphasizes nature development. Each half of the area is now given to agriculture and nature. However when nature inclusive agriculture is prioritised within the municipality, the ratio can be altered to assign 60% of the area to agriculture and 40% to nature development. In any scenario, the temporal aspects of energy transition must be considered from the start of the designing process to allow the social, ecological, and economic values in the area to continue to grow over time.

Fig. 75 Evolution of the area into a solar landscape (1) to a place where recreation, agriculture and nature come together through nature-inclusive farming and nature development that can be experienced (2).

7.12 REALISATION AND FINANCING

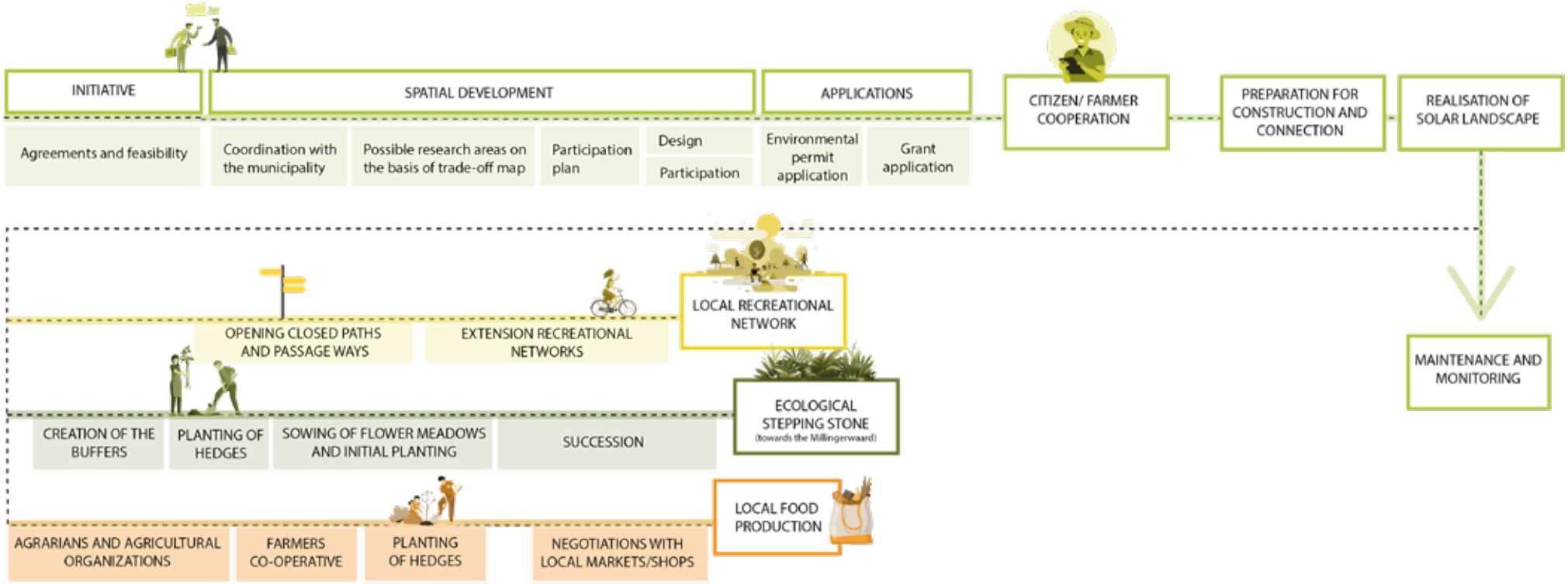

Fig. 76 Process of the Solar Synergy Landscape

The ideal scenario for the realization of this multifuncitonal solar park would be the establishment of a local energy cooperative as the intiative consisting of citizens, nearby businesses, farmers and other stakeholders. The chosen business form is often a cooperative because it fits the need for shared ownership and advocacy of the local community. The municipality of Berg en Dal could join this intiative. However, supporting the initiative can be done in several ways, without directly committing to the goals. Initiatives are limited in their resources, especially in the first years of their existence. Municipalities can facilitate support in the early stages by making available resources that the initiative itself cannot afford. For example, making technical, financial, environmental and other expertise available. Furthermore, the municipality can offer help in establishing contacts with other initiatives and knowledge providers (Klopstra and Schuurs, 2013). Further in the process when the municipality and the initiator have built a better relationship the municipality of Berg en Dal can become a member of the cooperative. By doing this the municipality gives a strong signal to the residents that it considers the initiative to be reliable and promising. The municipality can provide further support by exercising its powers, such as assisting in permit procedures and helping to set up the participation process with residents and stakeholders (Klopstra and Schuurs, 2013).

Before the different participation moment, it is important to see if the location for the realisation is most suitable. Clear opportunity and trade-off maps will make it easier to objectively discover the optimal location, allowing less

desirable initiatives to be abandoned at an early stage. In addition to choosing a location, it is critical to consider the future availability of connection and transmission capacity for the electricity generated (Dorrius, 2020). At the different participation moments, stakeholders, social actors and local people can all be actively involved in the process, in order to create support for the plan. Every local stakeholder plays a unique role in the area, and their expertise can be used for specific initiatives. In an initial participation moment, design sessions can be held by experts with local residents and intiators. Furthermore, an open dialogue about the process can take place. When a larger group of residents of Millingen, Leuth and Kekerdom has been reached, a second public participation event can take place where the first landscape plan is shown and where a dialogue can take place. After a few participation moments, the permit can be submitted. The permission process takes the longest. The municipality in question is an important partner for the developing party in this case.

The local energy cooperation can be used to fund the solar landscape in addition to subsidies. In the case of a cooperative, the solar landscape may be entirely funded locally by its members, which include private individuals, local foundations, and the municipality. The municipality could, for example, subsidize grid connection costs. A private limited company is commonly formed in the case of larger solar landscapes, such as the one in this plan, with greater financial interests and risks. A private limited company, is a type of privately held small business entity. This type of business entity limits owner liability to their shares. The cooperative then becomes a shareholder in the private company that houses the installation. Ownership is then often shared (HIER Opgewekt, 2020).

Construction and grid connection preparations can begin once everything is permitted and financially possible. The solar landscape final realization will be accomplished in several phases. The first phase is the installation of the fields with photovoltaic panels. When this is realized, the next step is to realize the recreational network by approaching local landowners and ask them to open up previously restricted paths to boost recreational connections. As a result, the area's existing roads can be utilised for recreational purposes, hence increasing recreational mobility. After these paths are openend, the recreational network can be expanded. Expansion will necessitate additional funding for infrastructure, primarily for the construction of cycling paths through the solar landscape and an observation tower to attract visitors. Along the pathways, there will also be needed benches and information boards.

When the PV panels are installed it is important to start immediately with the realization of the ecological connection towards the Millingerwaard. This will be realised by creating buffers, planting rows of hedges with different species and sowing flowery meadows, matching the existing habitat types of the area whenever possible. Together this will form a stronger physical, ecological connection between the existing natural elements. To finance this, some organizations can be involved such as ARK nature development.

Agrarian transitions to the usage of agrivoltaics should be realized through collaboration with agrarians and their associated interest groups. Next to the local energy cooperation, a specific agrarian cooperation should be developed with the purpose of sharing local knowledge and lowering the costs of the transition to agrivoltaics. This specific cooperation can ensure that all agricultural land is collectively converted to the use of PV panels resulting in greater cohesion across all plots. The local energy cooperative in which the farmers can also be shareholders can then perhaps focus more on recreation and ecology. Once this partnership has been established, it will be easier to plant hedges and extensive orchards along the agricultural land's borders. Negotiations with local markets and shops can begin after local production is up and running, with the goal of selling locally produced sustainable food.

7.13 EVALUATION OF THE DESIGN

The final design has been assessed according to the criteria used in SRQ3 and for the scenario study. Each criterion from the Spatial Quality Framework for Agricultural Landscapes (Bakx et al., 2021) was discussed and given a score from 1 to 4 by three landscape architects (table 7).

Diversity received a high score because many different applications for solar panels had been used in combination with other functions such as agriculture and recreation. Also, according to the three landscape architects, there were many different types of habitats that contributed to the diversity of the landscape.

Cohesion received a 2.6 since it is hard to imagine how all these different PV systems could fit well together in an open landscape. By using the straight blocks based on the historical landforms and ditches, the different PV systems already fit together quite well. Nevertheless, this solar energy transition will be a change from the surrounding landscape.

Naturalness received a good rating because the design emphasizes that the technical and natural no longer need to be separated, but can coexist and even complement each other. Positive remarks were the alternation between intensive fields and extensive orchards which reduces the view of the PV structures. Furthermore, it was appreciated that a large area has been given to the combination of nature provision and PV in which PV has a low density. Because these fields are situated closest to the Millingerwaard, a more natural transition is made to the agrovoltaic fields with a higher density. Yet, for the evaluaters it remains a solar landscape where solar panels are seen as a technical installation.

In terms of profitability, it was noted that by using multifunctionality, higher profits could be created. Also, by generating income in many different ways (livestock breeding, crop production, fruit farming, energy, etc.), a robust and sustainable economic model is created. However, it was questioned whether the cost of developing the solar landscape would outweigh the final profit achieved. This is, according to the experts, an important factor that needs to be examined in detail beforehand. Making the solar landscape public and experienceable was considered a priority over the pursuit of profit.

Recreational opportunities received a 3.3 because multiple prospective cycling and walking routes were carefully considered, allowing the solar landscape to be experienced from many perspectives. However, it was noted that more "landmarks" could be designed. Examples were works of art, colour codes, more viewpoints, story lines, etc.

Biodiversity received a high score of 3.3 out of 4. The score was given since biodiversity received a high priority in the design by viewing the solar landscape as an extesion of the Millingerwaard. Through the use of water buffers, flowery grassland, hedges and various groups of trees, the currently monofunctional agricultural area will receive a boost in terms of biodiversity. A detailed management plan has been proposed for the successful achievement of high biodiversity.

The design receives a relatively high score for sustainability because the land is mainly used multifunctional by combining different functions. Due to the lack of land, this is therefore a more sustainable option than, for example, cultivating fruit with plastic covers. Moreover, the amount of open space and the food market provided some flexibility for changing conditions, according to the evaluators. The flexibility of solar panels and the associated cabling and infrastructure were questioned. It was therefore recommended that more mobile solar panels that are not anchored to the ground should be used.

Table 7 Evaluation of the final design according to criteria from the Spatial Quality Framework for Agricultural Landscapes (Bakx et al., 2021)

EVALUATION FINAL DESIGN

CRITERIA	Expert 1	Expert 2	Expert 3	AVERAGE
Diversity	4	3	3	3.3
Cohesion	3	3	2	2.6
Naturalness	3	4	3	2.3
Profitability	2	3	2	2.3
Recreational opportunities	3	4	3	3.3
Biodiversity	3	4	3	3.3
Sustainability	4	4	2	3.3
	22/28	25/28	18/28	21.6/28

7.14 SUMMARY OF FINAL GUIDELINES

Several final guidelines emerged out of the spatial principles retrieved from the literature review and the design (table 8). One of the main guidelines are that in addition to the concept of ecosystem services, other dimensions must also be taken into account in order to obtain a sustainable design. These other important dimensions are the socio-cultural, sustainable technical, economical and environmental dimesion (Stremke, 2015). Furthermore, the methods used in this thesis have been transformed into guidelines for other designs. For example, the evaluation of the interactions in the area between the different current services and energy generation, resulting in a trade-off map which indicates the different trade-offs and synergies. A very important aspect that is relevant to any energy transition is the inclusion of the temporal aspects of an energy landscape. In addition to the design, further research is needed into how the landscape will evolve over time. Furthermore, some specific guidelines focused on the case study area have been developed. One of the most important guidelines of these are to respect the characteristics and history of the area. The various combinations of functions must fit into the landscape and its historical features. The case study area is a semi-open landscape provinding beautiful open views. Therefore it was a challenge not to surround all the solar fields with groups of trees but to use medium-high hedges. The hedges ensure that an overview of the landscape is still maintained, provide a habitat for fauna and refer back to the historical character of the area. Namely, the historic character of agricultural fields surrounded by hedges.

Table 8 General and specific guidelines that resulted out of the design.

SUMMARY GENERAL GUIDELINES
Combine the concept of ecosystem services with additional criteria that are not directly related to the concept but which are critical for the development of sustainable landscapes. Examples are the reuse of materials and landscape experience.
Identify the key ecosystem services in the area together with residents and stakeholders.
Evaluate the interactions in the area between the different current services and energy generation, resulting in a trade-off map which indicates the different trade-offs and synergies. This method is a helpful step towards a sustainable design.
Find out which multifunctional combinations with PV fit into the specific area by having residents and stakeholders evaluate the combinations using criteria based on the concept of spatial quality.
Take into account the temporal aspects of the energy transition, thereby increasing the ecological, social and economic values of the area.
The change and development occurring among the various ecosystem services can be monitored in order to learn from the effects of different function combinations with PV.

SITE SPECIFIC GUIDELINES
The low density and wide spacing (5.8m) between the rows of solar panels are a prerequisite allowing ecological processes to take place, but also require human involvement throughout the process as an interplay with the natural processes.
Make the solar landscape accessible, recreationally atractive and experienceable. A watchtower, shared bicycles, information boards and picnic tables can be helpful tools.
The solar landscapes should serve as a stepping stone or as an extension of the Millingerwaard nature reserve.
Respect the characteristics and history of the area and fit the various combinations of functions into it. The area must remain an important agricultural production landscape.

9 DISCUSSION & CONCLUSIONS

9.1 DISCUSSION

This section critically reviews and discusses the case study area, theories and methods used. It also addresses how further research can continue pursuing the questions examined in this study.

9.1.1 DISCUSSION OF METHODS

In this thesis, the theories spatial quality and ecosystem services have been drawn upon and brought together with the aim of creating a multifunctional solar landscape near the Millingerwaard. Although these theories can be interconnected, it was noticed during the process that there is a need for additional dimensions to supplement the concept of ecosystem services in order to achieve a sustainable energy landscape. To create a sustainable energy transition, ecosystem services must be provided sustainably while also including the socio-cultural, sustainable technical, economic and environmental dimensions (Stremke, 2015). How all these specific dimensions interact with the concept of spatial quality may be an interesting future research topic.

For the literature review was there prevalent scientific literature on multifunctional solar landscapes and, to a lesser extent, the use of ecosystem services in landscape architecture. However, there is limited discussion of the two subjects combined. When the combination of ecosystem services and renewable energy is mentioned, the focus is often on one ecosystem service such as habitat provisioning or food supply. The list of sixteen spatial guidelines that emerged from the literature review is not complete due to time constraints for this thesis. Further literature research could be done and more guidelines could then be found, leading to an even more informed design.

The collected list of current ecosystem services used for the survey to evaluate their importance value is incomplete as many services are intangible or invisible, making it difficult to collect them all. Furthermore, more general ecosystem services such as 'removal of air pollution' and 'production of oxygen', have been omitted to avoid complicating the study. As a result, the final trade-off map contains only a limited number of ecosystem services of this area. Moreover, the trade-off map may still be supplemented and updated, as only a small range of current data on ecosystem services in the area was available. The number of respondents of the survey was limited due to the obligation of confidentiality towards residents and recreational users and the limited number of experts familiar with the area. However, the selected number of experts (nine) in this thesis is sufficient for its purpose. Further research with residents and recreationists is an important step when continuing this project.

Thirty of the 34 landscape architects that responded to the survey to evaluate the function combinations were under the age of 35. As a result, the responses are possibly more favorable than if there was a sample with a wider age range. Since the younger generation grew up during a time when climate change gained more attention, they are often more concerned about it (Ballew et al., 2019). Furthermore, an extensive survey of residents and recreationists would have yielded valuable input based on their interaction with the area, this was impossible due to confidentiality obligations.

9.1.2 DISCUSSION OF RESULTS

The spatial context of Millingerwaard served as an ideal test bed for an experimental design study of a sustainable multifunctional solar landscape. The case study area is ideal because it currently provides few ecosystem service which can evolve in a multifunctional layered landscape. Another important reason for choosing this area, is one of the objectives of the municipality to transform the now monofunctional agricultural areas into a multifunctional landscape where recreation, nature and agriculture come together, which could ideally be combined in a solar landscape. Although this area was ideal, it features typical landscape types, therefore, the interaction between the theory of ecosystem services and spatial quality should also be examined for several other landscape types. A solar landscape in an open landscape will form different synergies than, for example, in a closed landscape or coulisse landscape, each carrying different additional values. The research was conducted on a case study basis, meaning that the results are highly context dependent. Indirectly, however, and with the necessary adjustments, the insights could potentially be applied to other solar transitions. The process used of different methods such as the trade-off map and the different surveys can easily be adjusted and used for other solar transitions where the goal is to enhance other ecosystems services besides energy generation.

The literature review revealed a list of sixteen spatial guidelines, most of which were applied to the design. Although they were often very general, they were of significant value since each guideline is aimed at improving specific ecosystem services. Together, the guidelines bring improvement to several ecosystem services that together enhance the landscape. Some principles have been adapted to the design because of their generality. Other principles belong to later steps, such as the planting and maintenance of the solar landscape. These guidelines are now used to a lesser extent for this thesis, but are of great importance for further realization. A list of the principles used for the design is shown in table 9.

The survey was of great importance in determining the value of current ecosystem services in the area. Each area has its own key ecosystem services. Crop production and nature provisioning are very important ecosystem services in the case study area, which therefore had to be integrated into the design in harmony.

The obtained trade-off map provided valuable output as it showed possible synergies between energy generation and other services and indicated possible conflicts to be avoided. This method has originated from the realm of the ecosystem services theory and has broadened the scope of the analysis beyond the solar landscape's layout.

The survey to evaluate the different function combinations with PV provided clear insights of how the different combinations affect the spatial quality. Surprising results emerged such as the poor scoring of floatovoltaics. Because of its poor scoring, little attention has been paid to floatovoltaics in the design phase. This combination, however, is viewed positively in literature. This suggests that further research into floatovoltaics is necessary. An effective application of this combination would be particularly valuable considering the two large reclaimed lakes in the area.

The process and methods used have ultimately served to answer the general research question: 'How can solar energy transition near the Millingerwaard improve the spatial quality by applying the concept of ecosystem multifunctionality?' By applying the different surveys and the trade-off map a sustainable multifunctional solar landscape has been created improving several ecosystem services through its multifunctionality. By focusing on improving the services of habitat provision, recreation, pollination, crop production, livestock and water regulation in combination with PV, the current monofunctional landscape has been improved into an area where many ecosytem services converge. As a result, the landscape has become more diverse, accessible, profitable, biodiverse and sustainable. These five aspects are five of the seven criteria for spatial quality. The other two criteria naturalness and coherence were determined later by design. The application of these two concepts has recently become even more important since the coalition agreement of 2021 states that solar panels on land will only be allowed if multifunctional use is possible (Van Gaste & De Jonge Baas, 2021; VVD et al., 2021). To ensure that these multifunctional solar landscapes do not harm spatial quality, it is necessary to carefully examine the various possible synergies and trade-offs in its specific landscape type. Therefore, applying the theory of ecosystem services can be used as a method to achieve this. The approach applied in this thesis can be expanded by using a multi-criteria assessment based on the spatial quality concept to include policymakers', experts', or citizens' preferences for the importance of various location conditions, function combinations, or trade-offs. Participation in such weighting exercises can be a powerful tool for including citizens.

Table 9 Evaluation of the retrieved spatial principles applied in the design

SPATIAL PRINCIPLES EVALUATION		
SPATIAL PRINCIPLE	USE IN THE DESIGN	NOTES
Nature and landscape must be the starting point for new energy transitions		
Energy landscapes should be multifunctional		
Consider the temporal aspects of energy transition		The agrivoltaic fields where lettuce and other leafy plants are grown will be an experiment since this has not yet been done in the Netherlands on this type of soil.
Create room for experimentation		
Take local needs and wishes into account when designing		Due to confidentiality obligations, it was difficult to find out the needs of local residents and recreational users.
Existing landscape infrastructure as a prerequisite for site selection		
Make the solar landscape accessible and experienceable		
Multifunctional solar landscape as stepping stone		
Preservation and restoration of existing landscape qualities		
Visual shielding of perceivable trade-offs		
Extensive management to improve pollination and habitat provision		It is already partly provided for, but it should also be included in the process later on.
Tailoring to specific target species as well as using native and endemic plants		Can eventually be applied through native flower meadows and trees.
Barrier as ecological habitat		
The adoption of floatovoltaics		
Solar energy on slopes		Adjusted: namely PV on the slopes of the water buffers.
Solar landscape as a buffer		

9.2 CONCLUSIONS

This chapter summarizes the answers to the SRQs. Combined they address the knowledge gap of the thesis and enable the main research question to be answered.

SRQ1: "What are the spatial principles in literature related to sustainable multifunctional solar landscapes and the theory of ecosystem services?"

The sixteen spatial principles obtained show a combined fusion between ecosystem services and multifunctional solar landscapes. The principles are a helpful instrument for the design phase to achieve a certain level of sustainability. This is because the highest level of sustainability can be achieved by creating multifunctional energy landscapes that maximise the production of ecosystem services. The various spatial principles obtained help to accomplish this (chapter 3). They are intended as a starting point, but must be complemented by site-specific features and local needs to make them relevant for the design process.

SRQ2.1: "How important are the current ecosystem services within and in the vicinity of the case study area?"

Crop production and habitat provisioning were rated as the two most important ecosystem services in the area and its surroundings. The services "Hydrological cycle and water flow regulation" and "landscape aesthetics, amenity, and inspiration" also rated highly (Fig. 25). By focusing on the key services, the design goes beyond energy transition and takes an integral approach that shows the potential for dual use.

SRQ2.2: "Do these current ecosystem services form a trade-off or synergy when combined with solar energy generation?"

The information from the trade-off map is used to enrich the spatial design. The trade-off map (Fig. 26) shows essential places where potential synergies are possible between different services and solar energy generation. Moreover, it avoids hard compromises to prevent losing valuable ecosystem services before the development of the solar landscape has taken place. Furthermore, it indicates hotspots where a wide range of ecosystem services come together. Identifying these valuable places is of value to include in the design process.

RQ3: "What are possible (new) design combinations between energy generation and other ecosystem services that contribute to the spatial quality?"

The results from the survey indicate that the combination of PV with community gardens and with habitat provision rates highest when it comes to their effect on spatial quality (Fig. 39). Other key results are that solar farming is believed to be the most profitable synergy and floatovoltaics is believed to have a rather negative effect on spatial quality, since this synergy is considered to be more disruptive in the landscape. The latter needs to be further explored for its opportunities. Most of the high scoring combinations are given the greatest focus in the design to maintain and improve spatial quality. Except for the combination of community gardens and solar panels, since this combination does not require much surface area and therefore receives a lower level of attention in the design compared to other function combinations.

MRQ: "How can solar energy transition near the Millingerwaard improve the spatial quality by applying the concept of ecosystem multifunctionality?"

In the design process, the concept of ecosystem multifunctionality was applied from the beginning in the analysis as an integrated design approach. As a result, the design was able to unfold as an energy-generating area, which also meets the various needs of humans, flora and fauna. The concept encourages the fusion of technical, functional and natural aspects creating an attractive landscape. The monofunctional agricultural fields near the Millingerwaard have been transformed into a multimayered landscape to be experienced. With the solar landscape, the Millingerwaard is getting an extension to its natural area. Surrounded by fields where PV and agriculture generate their goals in synergy.

The methods used focus on improving current ecosystem services while combining additional ecosystem services in synergy, creating a multilayered landscape that serves a variety of needs. By using the concept of ecosystem services in the designing process synergies are created rather than compromises, which ultimately benefits the spatial quality of the case study area near the Millingerwaard.

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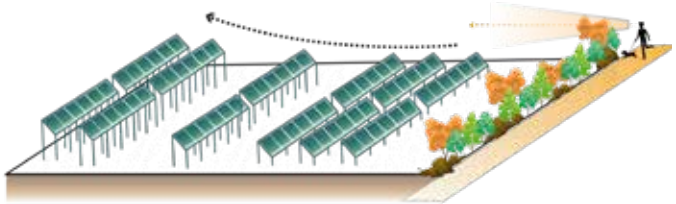
FIGURE LIST

Fig. 1 Growth scenarios of installed PV capacity in the Netherlands (NL Netherlands, n.d.).
Fig. 3 Criteria for spatial quality based on the Spatial Quality Framework for Agricultural Landscapes (Bakx et al., 2021)
Fig. 9 Landscape types of Berg en Dal (LOS stadomland, 2021)
Fig. 10 Three different landscape types in the case study are (LOS stadomland, 2021).
Fig. 11 Historical evolution of the case study area and the surrounding landscape (Topotijdreis, n.d.).
Fig. 12 Nature and biodiversity in Berg en Dal (LOS stadomland, 2021).
Fig. 14 Water on land after heavy rainfalls (Atlas voor de Leefomgeving, n.d.)
Fig. 15 Underground water storage capacity (Atlas voor de Leefomgeving, n.d.)
Fig. 16 Spatial vision for renewable energy generation in the municipality of Berg en Dal (LOS stadomland, 2021).
Fig. 17 Recreation and tourism in Berg en Dal (LOS stadomland, 2021).
Fig. 18 Accessibility in Berg en Dal (LOS stadomland, 2021).
Fig. 19 Elevation map (AHN, 2021)
Fig. 24 LGN 2020 (Wageningen University & Research, n.d.)
Fig. 28 Ground-mounted PV and crop zones (Toledo and Scgnamiglio, 2021).
Fig. 30 Vertical bifacial panels and livestock combined (Next2Sun, n.d.)
Fig. 32. Floatovoltaics (Lee et al., 2014)

TABLES

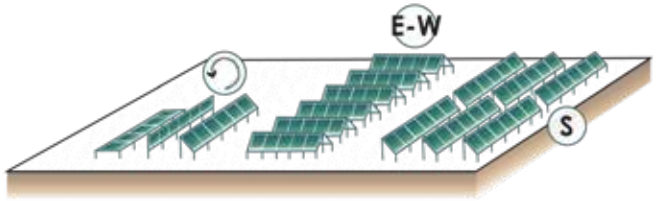
Table 2 "Barriers, opportunities and future research to the adoption of agrivoltaics" (Pascaris et al., 2020).
Table 3 "Barriers, opportunities and future research on combining solar panels and livestock" (Kochendoerfer and Thonney, 2021).
Table 4 "Barriers, opportunities and future research on combining solar panels, nature provision and pollination" (Blaydes et al., 2021; Randle-Boggis et al., 2020).
Table 5 "Barriers, opportunities and future research regarding the adaption of floatovoltaic technology and aquaculture" (Pringle et al., 2017; Sahu et al., 2016).

APPENDIX 1: GENERAL PRINCIPLES OF MULTIFUNCTIONAL SOLAR LANDSCAPES



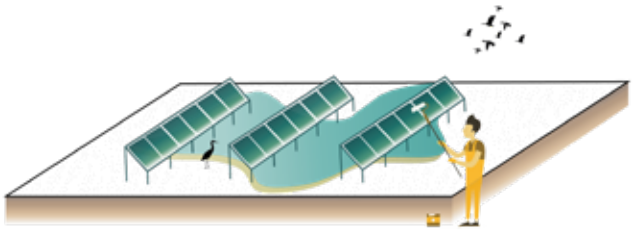
Arrays with a lower height need to be closest to where most observers will be expected. This is important to consider as local communities are more concerned with observable trade-offs. The visibility can be reduced with extra vegetation.

③



Most common arrangements is a south and east-west arrangement. Alternative array orientation may support maintaining existing landscape patterns and simultaneously reducing peak load on the electricity grid.

①③



Attractiveness of panels to water insects should be reduced by applying white stripes to the panels (small stripes or 1.8% of the surface is sufficient).

①

APPENDIX 2: IMPORTANT HABITAT TYPES AND THEIR SPECIES

Habitat type	Endangement	Rarity	Naturalness/ hemeroby	Presence of species of conservation concern	Habitat continuity	***Evaluation***
RESULTS OF TYPIFIED EVALUATION						
Softwood riparian forests	1	1	2	1	4	**1,80**
Dry hardwood riparian forests	1	1	2	1	5	**2,00**
Marslands	2	3	2	2	4	**2,60**
Herb and fauna rich grasslands	3	3	3	2	3	**2,80**
Shrubbery and fringes	2	3	3	3	3	**2,80**
Moist forest with production	3	3	3	2	5	**3,20**
Fres water lake	4	3	3	3	4	**3,40**
Orchard	4	3	3	4	4	**3,60**
Muddy riverbanks	4	3	4	4	4	**3,80**
Open grasslands	4	5	4	5	2	**4,00**
Cropland	5	5	5	5	2	**4,40**

Values for importance: 1 very high, 2 high, 3 medium, 4 low, 5 very low, X no data

Very important | *Important* | *Currently low importance*

Area required for a stable population (ha)	**Dispersion distance (m)**				
	<500	**< 2.000**	**< 5.000**	**< 10.000**	**< 50.000**
Softwood riparian forests, Dry hardwood riparian forests					
5	Kamsalamander, klein vliegend hert				
5-50	Boomkikker, knoflookpad	Sleedoornpage, muskusboktor	Keizersmantel		Boomklever
50-300			Boswitje, pauwoogpijlstaart	Grauwe vliegenvanger, blauwborst	Spotvogel, nachtegaal
300-1.000				Bever, matkop	Grote vos, buidelmees
1.000-7.500					Zwarte ooievaar, havik
> 7.500					Visarend, zwarte wouw

Area required for a stable population (ha)	Dispersion distance (m)				
	<500	< 2.000	< 5.000	< 10.000	< 50.000
Marslands					
5		Waterspitsmuis	Gevlekte glanslibel	Gevlekte witsnuitlibel	
5-50					
50-300				Blauwborst	
300-1.000				Grote zilverreiger, lepelaar, Bever	
1.000-7.500					
> 7.500					Otter
Herb and fauna rich grasslands					
5	Margriet	Bruin blauwtje	Kleine parelmoervlinder		
5-50					
50-300					
300-1.000					
Moist forest with production					
5					
5-50					Boomklever
50-300				Blauwborst, kleine bonte specht	Appelvink, nachtegaal, wielewaal
300-1.000					
1.000-7.500					
> 7.500					

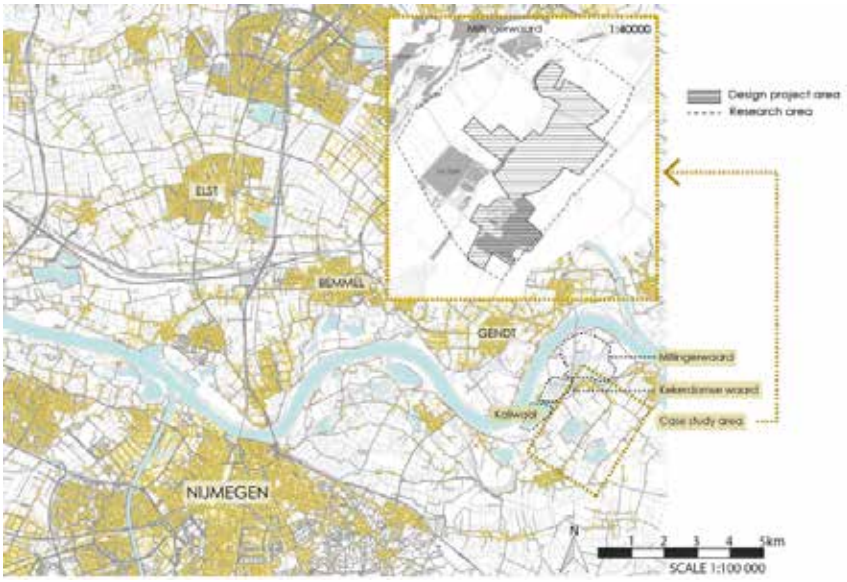
Area required for a stable population (ha)	Dispersion distance (m)				
	<500	< 2.000	< 5.000	< 10.000	< 50.000
Fresh water lake					
5		Kleine modderkruiper		Gevlekte witsnuitlibel	
5-50				Snoek	
50-300					
300-1.000					
1.000-7.500					
> 7.500					Otter

Huidige ecosysteemdiensten en landschapskenmerken in de gemeente Berg en Dal

Bij voorbaat dank voor uw anonieme deelname aan mijn onderzoek. Deze vragenlijst is onderdeel van een ontwerp/onderzoeksthesis over hoe een zonne-energietransitie langs de 'Millingerwaard' de omliggende ruimtelijke kwaliteit kan verbeteren door het concept van ecosysteem multifunctionaliteit toe te passen.

Aangezien hernieuwbare energie een ruimtelijke impact op het landschap zal blijven hebben, is het van essentieel belang uit te zoeken hoe de kritische trade-offs tussen verschillende ecosysteemdiensten kunnen worden verminderd. Aan de hand van deze survey zal aan de huidige ecosysteemdiensten binnen het gebied een belangrijkheidswaarde worden toegekend zodat kritische trade-offs en synergieën tussen de huidige ecosysteemdiensten en energie generatie duidelijker worden. Het invullen van deze vragenlijst zal ongeveer 5 tot 10 minuten in beslag nemen. Als u vragen heeft, aarzel dan niet om mij te contacteren via tine.lambert@wur.nl.

Het gebied binnen Berg en Dal dat belangrijk is voor deze survey is te zien op de foto hieronder. Het projectgebied ligt dicht bij de Kekerdomse waard en de Millingerwaard, die beide van ecologisch belang zijn.

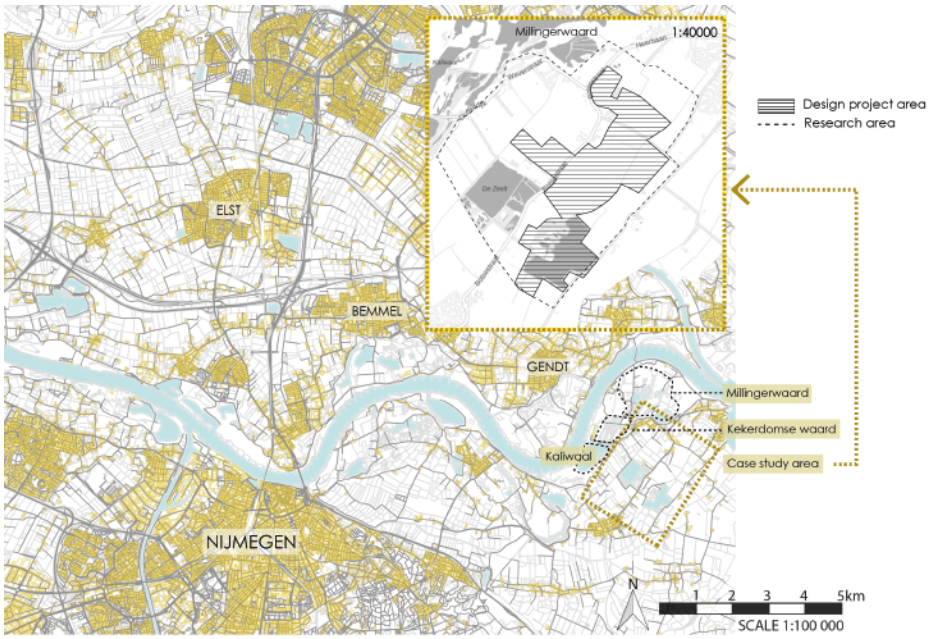


Huidige ecosysteemdiensten en landschapskenmerken in de gemeente Berg en Dal

1* Wat zijn volgens u de belangrijkste landschapskenmerken van het landschap in en rondom het projectgebied?

2* Hoe kunnen we volgens u de kwaliteit van het landschap verbeteren binnen dit gebied?

Beoordeel elk van de 13 opgesomde ecosysteemdiensten op een schaal van 1-4 (1= niet zeer relevant; 2= enigszins relevant 3= relevant; 4= extreem belangrijk voor dit onderzoeksgebied).



3* **Gewasproductie:**
Alle gewassen en vruchten die door de mens voor voedingsdoeleinden worden geteeld; voedselgewassen

1	2	3	4
Niet zeer relevant			Extreem belangrijk

3* **Gewasproductie:**

Alle gewassen en vruchten die door de mens voor voedingsdoeleinden worden geteeld; voedselgewassen

1	2	3	4
Niet zeer relevant			Extreem belangrijk

4* **Veeteelt:**

In stallen gehouden en/of in de wei gehouden dieren

1	2	3	4
Niet zeer relevant			Extreem belangrijk

5* **Hydrologische cyclus en regulering van het waterdebiet:**

Regulering van de waterstromen in het gebied

1	2	3	4
Niet zeer relevant			Extreem belangrijk

6* **Landschapsesthetiek, aantrekkelijkheid en inspiratie:**

Kenmerken van levende systemen die esthetische ervaringen mogelijk maken

1	2	3	4
Niet zeer relevant			Extreem belangrijk

7* **Instandhouding van populaties en habitats:**

Leefgebieden aanbieden voor wilde planten en dieren die nuttig kunnen zijn

1	2	3	4
Niet zeer relevant			Extreem belangrijk

8* **Massastabilisatie en beheersing van erosiesnelheden:**

Stabilisatie en beheersing van erosiesnelheden

1	2	3	4
Niet zeer relevant			Extreem belangrijk

9* **Natuurlijk erfgoed en natuurlijke diversiteit:**

Kenmerken van levende systemen die resoneren in termen van cultuur of erfgoed

1	2	3	4
Niet zeer relevant			Extreem belangrijk

10* **Ongedierte- en ziektebestrijding:**

Bestrijding van plagen, ziekten en invasieve soorten

1	2	3	4
Niet zeer relevant			Extreem belangrijk

11* **Ongedierte- en ziektebestrijding:**

Bestrijding van plagen, ziekten en invasieve soorten

1	2	3	4
Niet zeer relevant			Extreem belangrijk

12* **Fysiek gebruik van het landschap in verschillende omgevingscontexten:**

Kenmerken van levende systemen die activiteiten mogelijk maken die de gezondheid, het herstel of het plezier bevorderen door passieve of observerende interacties zoals wandelen of fietsen

1	2	3	4
Niet zeer relevant			Extreem belangrijk

13* **Bestuiving:**

Bestuiving van fruitbomen en andere planten

1	2	3	4
Niet zeer relevant			Extreem belangrijk

14* **Zaadverspreiding:**

Het verspreiden van de zaden van wilde planten

1	2	3	4
Niet zeer relevant			Extreem belangrijk

15* **Storm bescherming:**

Regulering van basisstromen en extreme gebeurtenissen

1	2	3	4
Niet zeer relevant			Extreem belangrijk

16* **Oppervlaktewater dat als materiaal wordt gebruikt (niet voor drinkdoeleinden):**
Oppervlaktewater voor niet-drinkdoeleinden, zoals zoetwatermeren

1	2	3	4
Niet zeer relevant			Extreem b

17 Zijn er momenteel essentiële ecosysteemdiensten in de regio Berg en Dal die vergeten zijn en daaror niet zijn opgenomen in de vorige vragen? Schrijf ze hieronder op en geef ze ook een belangrijkheidswaarde voor het gebied.

Dank u! We zijn er bijna. Alleen nog wat vragen over jou.

18* Wat is uw relatie tot het landschap van 'Berg en Dal'?

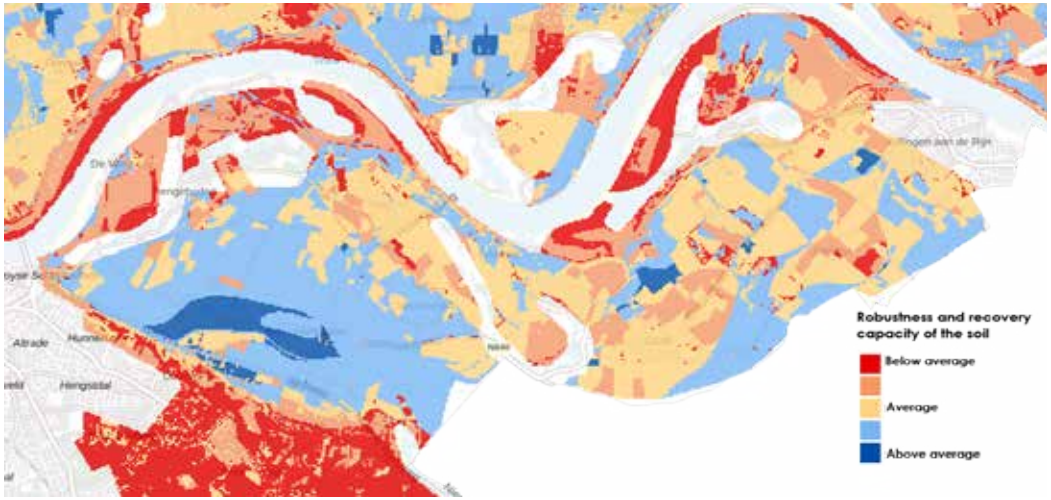
- [ ] Inwoner
- [ ] Recreant binnen het gebied
- [ ] Werkzaam bij de overheid (gemeente, provincie, enz.)
- [ ] Landbouwer
- [ ] Deskundige

19* Wat is uw leeftijdsgroep?

- [ ] 18 of jonger
- [ ] 19-24
- [ ] 25-34
- [ ] 35-44
- [ ] 45-54
- [ ] 55-64
- [ ] 65 of ouder

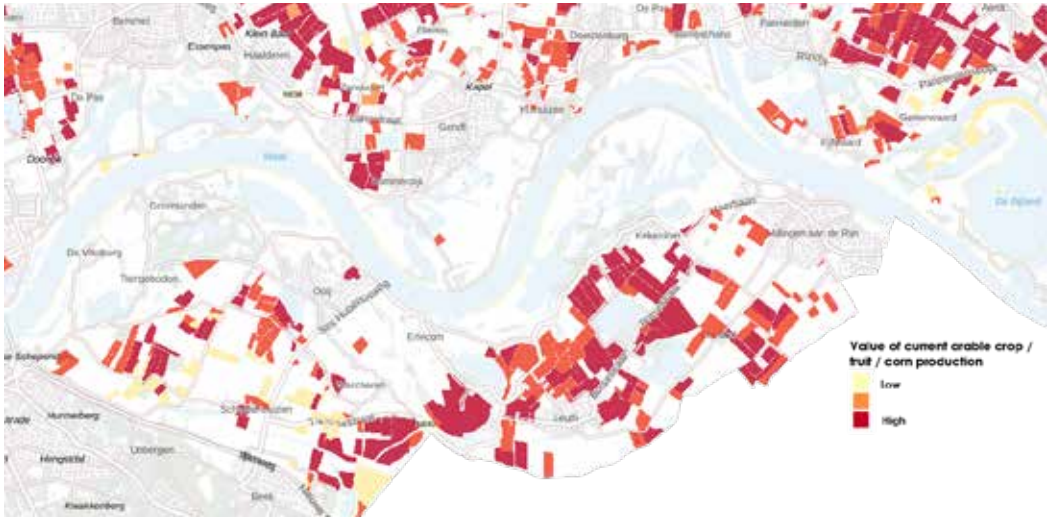
APPENDIX 4: DATA AND MAPS USED TO CREATE THE TRADE-OFF MAP

Robustness and recovery capacity of the soil (Atlasnatuurkapitaal, 2022)



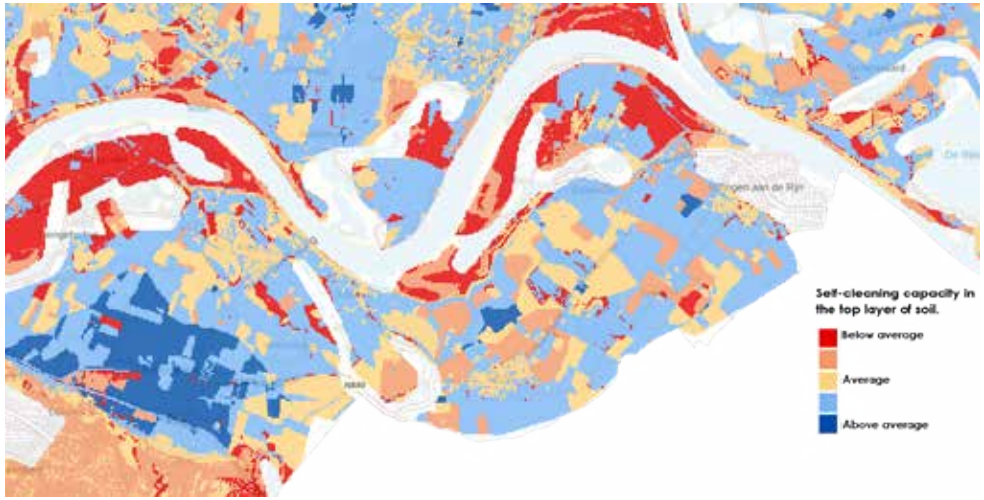
The robustness of soil to environmental stress and its ability to recover and adapt to changing land use.

Value of arable crop and fruit crop production (Atlasnatuurkapitaal, 2022)



This map shows the value of arable production and fruit cultivation. The map shows the yield of arable crops and fruit in euros per hectare per year.

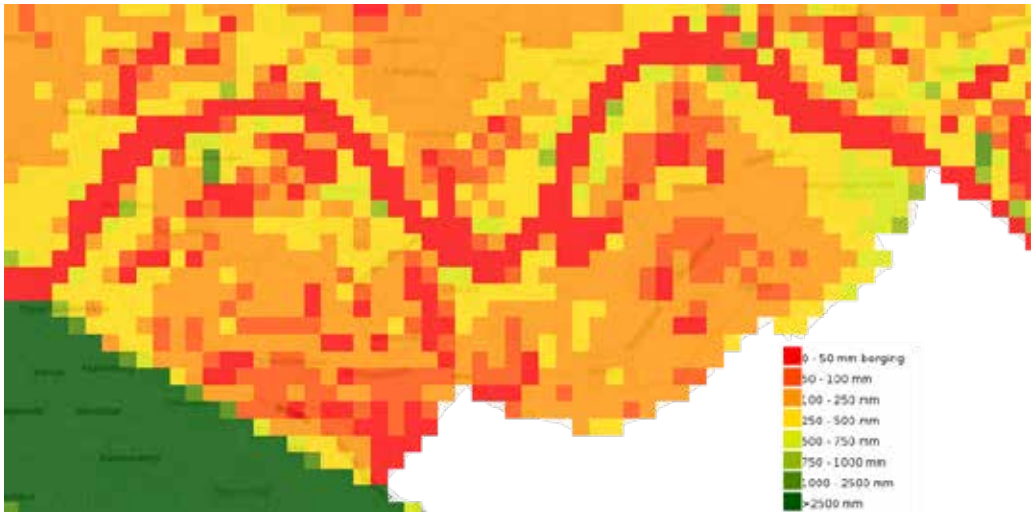
Self-cleaning capacity in the top layer of the soil (Atlasnatuurkapitaal, 2022)



The soil's self-cleaning ability ensures that problem substances (contamination) are rendered harmless and that system-specific substances are kept within harmless concentrations, and in particular that groundwater and surface water are cleaned up for extraction and nature purposes (Atlasnatuurkapitaal, 2022).

Value grassland (Atlasnatuurkapitaal, 2022)

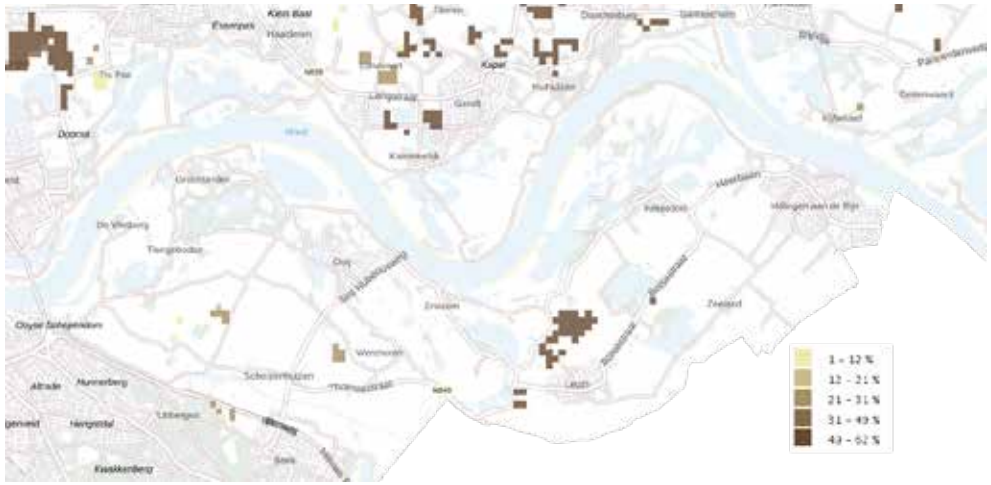
Water storage capacity underground (Atlasnatuurkapitaal, 2022)



The map maximum water storage in groundwater shows how much water (in mm) can still be stored in the ground compared to a current wet situation. (Atlasnatuurkapitaal, 2022).

Other maps used can be found at https://www.atlasnatuurlijkkapitaal.nl/kaarten.

Current pollination by pollinators (Atlasnatuurkapitaal, 2022)



Ruimtelijke kwaliteit van functiecombinaties met PV

Bij voorbaat dank voor uw anonieme deelname aan mijn onderzoek. Deze vragenlijst is onderdeel van een ontwerp/onderzoeksthesis. In de thesis wordt onderzocht hoe een zonne-energietransitie langs de 'Millingerwaard' de omliggende ruimtelijke kwaliteit kan verbeteren door het concept van ecosysteem multifunctionaliteit toe te passen.
Met zonnepanelen zijn veel functiecombinaties mogelijk. Door middel van deze studie zullen zes visualisaties van functiecombinaties worden beoordeeld op hun effect op de ruimtelijke kwaliteit. Elke visualisatie zal worden beoordeeld aan de hand van gekozen criteria uit het ruimtelijk kwaliteitskader. Het invullen van deze vragenlijst zal ongeveer 15 minuten in beslag nemen. U kunt bij het invullen altijd terugkeren naar de vorige vragen.

Als u vragen heeft, aarzel dan niet om mij te contacteren via tine.lambert@wur.nl.

Het is de bedoeling dat u de onderstaande vragen snel en intuïtief beantwoordt.

Beleeft u het landschap op de bovenstaande foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de bovenstaande foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Beleeft u het landschap op de tweede foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de tweede foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Veeteelt

Het opwekken van zonne-energie kan hand in hand gaan met het laten grazen van vee. Kleine dieren, zoals kippen, hebben een mix van zon en schaduw nodig, wat de panelen bieden. Bovendien kunnen de kippen gemakkelijk bij grassen en insecten komen. Zelfs grotere dieren, waaronder de meeste veerassen profiteren van zonnepaneelinstallaties. Koeien hebben meer comfort tijdens het grazen omdat ze toegang hebben tot schaduwrijke gebieden.

Ik beschouw de combinatie tussen veeteelt en zonnepanelen als divers.
(Is er volgens u een variatie aan visuele kenmerken binnen deze functiecombinatie. Bijvoorbeeld een variatie aan beplanting, landgebruik, activiteit, ...)

	1	2	3	4	
Divers					Eenvormig

Ik beschouw de combinatie tussen veeteelt en zonnepanelen als passend binnen het agrarisch landschap.
(Passen volgens u de verschillende landschapscomponenten bij elkaar of zijn er niet-passende of storende componenten die de eenheid van het landschap zouden kunnen verstoren?)

	1	2	3	4	
Passend					Storend

Ik beschouw de combinatie tussen veeteelt en zonnepanelen als natuurlijk/kunstmatig.

	1	2	3	4	
Natuurlijk					Kunstmatig

Ik beschouw de combinatie tussen veeteelt en zonnepanelen als winstgevend/nadelig.

	1	2	3	4	
Winstgevend					Nadelig

Ik beschouw de combinatie tussen veeteelt en zonnepanelen als geschikt voor recreatief gebruik.

	1	2	3	4	
Veel mogelijkheden					Ontoegankelijk

Ik beschouw de combinatie tussen veeteelt en zonnepanelen als geschikt voor de aanwezigheid van verschillende dieren- en plantensoorten in het landschap.

1	2	3	4
Rijk aan biodiversiteit			Geringe biodiversiteit

Ik beschouw de combinatie tussen veeteelt en zonnepanelen als iets duurzaam. Namelijk het makkelijk behouden en aanpassen van het systeem onder veranderende economische, ecologische, culturele en sociale omstandigheden.

1	2	3	4
Duurzaam			Niet-duurzaam

Beleeft u het landschap op de bovenstaande foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de bovenstaande foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Beleeft u het landschap op de tweede foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de tweede foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Agrivoltaics (Fruitkweek)

De bovenstaande visualisatie toont de combinatie tussen energieopwekking en fruitteelt. Deze toepassing komt tegenwoordig steeds vaker voor omdat de zonnepanelen niet alleen elektriciteit opwekken, maar ook de fruitgewassen beschermen tegen extreme weersomstandigheden. Zonnepanelen kunnen bijvoorbeeld de gespannen plastic zeilen vervangen die normaal bramen en frambozen beschermen tegen regen, hagel en wind.

Ik beschouw de combinatie tussen fruitkweek en zonnepanelen als divers.
(Is er volgens u een variatie aan visuele kenmerken binnen deze functiecombinatie. Bijvoorbeeld een variatie aan beplanting, landgebruik, activiteit, ...)

	1	2	3	4	
Divers					Eenvormig

Ik beschouw de combinatie tussen fruitkweek en zonnepanelen als passend binnen het agrarisch landschap.
(Passen volgens u de verschillende landschapscomponenten bij elkaar of zijn er niet-passende of storende componenten die de eenheid van een agrarisch landschap zouden kunnen verstoren?)

	1	2	3	4	
Passend					Storend

Ik beschouw de combinatie tussen fruitkweek en zonnepanelen als winstgevend/nadelig.

	1	2	3	4	
Winstgevend					Nadelig

Ik beschouw de combinatie tussen fruitkweek en zonnepanelen als natuurlijk/kunstmatig.

	1	2	3	4	
Natuurlijk					Kunstmatig

Ik beschouw de combinatie tussen fruitkweek en zonnepanelen als geschikt voor de toepassing van recreatie.

	1	2	3	4	
Veel mogelijkheden					Ontoegankelijk

Het is de bedoeling dat u de onderstaande vragen snel en intuïtief beantwoordt.

Beleeft u het landschap op de bovenstaande foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de bovenstaande foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Beleeft u het landschap op de tweede foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de tweede foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Gemeenschapstuinen

De toepassing van agrovoltaics (combinatie tussen PV en landbouw) kan ook op kleinere schaal worden toegepast, namelijk de combinatie van zonnepanelen en een gemeenschapstuin voor buurtbewoners. Zonnepanelen geïnstalleerd boven gemeenschapstuinen kunnen worden gebruikt om een waterpomp aan te drijven en elektriciteit te leveren voor verlichting. Hierdoor kunnen de gebruikers geld besparen. Met de vorm van de zonnepanelen kan worden geëxperimenteerd om bijvoorbeeld een artistieke gedeeltelijke overkapping te creëren.

Ik beschouw de combinatie tussen gemeenschapstuinen en zonnepanelen als divers.
(Is er volgens u een variatie aan visuele kenmerken binnen deze functiecombinatie. Bijvoorbeeld een variatie aan beplanting, landgebruik, activiteit, ...)

	1	2	3	4	
Divers					Eenvormig

Ik beschouw de combinatie tussen gemeenschapstuinen en zonnepanelen als passend binnen de overgang van landbouwgebied naar dorp.
(Passen volgens u de verschillende landschapscomponenten bij elkaar of zijn er niet-passende of storende componenten die de eenheid van het landschap zouden kunnen verstoren?)

	1	2	3	4	
Passend					Storend

Ik beschouw de combinatie tussen gemeenschapstuinen en zonnepanelen als natuurlijk/kunstmatig.

	1	2	3	4	
Natuurlijk					Kunstmatig

Ik beschouw de combinatie tussen gemeenschapstuinen en zonnepanelen als winstgevend/nadelig.

	1	2	3	4	
Winstgevend					Nadelig

Ik beschouw de combinatie tussen gemeenschapstuinen en zonnepanelen als geschikt voor de toepassing van recreatie.

	1	2	3	4	
Veel mogelijkheden					Ontoegankelijk

Ik beschouw de combinatie tussen gemeenschapstuinen en zonnepanelen als geschikt voor de aanwezigheid van verschillende dieren- en plantensoorten in het landschap .

1	2	3	4
Rijk aan biodiversiteit			Geringe biodiversiteit

Ik beschouw de combinatie tussen gemeenschapstuinen en zonnepanelen als iets duurzaam. Namelijk het makkelijk behouden en aanpassen van het systeem onder veranderende economische, ecologische, culturele en sociale omstandigheden.

1	2	3	4
Duurzaam			Niet-duurzaam

Beleeft u het landschap op de bovenstaande foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de bovenstaande foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Beleeft u het landschap op de tweede foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de tweede foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

PV on water

Drijvende zonnepanelen is een relatief nieuwe uitvoeringsvorm van grootschalige opwekking van zonnestroom. De belangrijkste motivatie voor deze toepassing is de schaarste aan geschikt en beschikbaar land voor zonneparken. Zonnepanelen op water kunnen een hogere elektriciteitsopbrengst opleveren. Aspecten die hierbij een rol spelen zijn: natuurlijke koeling van de panelen en een hogere instraling boven water in vergelijking met boven land.

Ik beschouw de combinatie tussen water en zonnepanelen als divers.
(Is er volgens u een variatie aan visuele kenmerken binnen deze functiecombinatie. Bijvoorbeeld een variatie aan beplanting, landgebruik, activiteit, ...)

1	2	3	4
Divers			Eenvormig

Ik beschouw de combinatie tussen water en zonnepanelen als passend binnen het landschap.
(Passen volgens u de verschillende landschapscomponenten bij elkaar of zijn er niet-passende of storende componenten die de eenheid van het landschap zouden kunnen verstoren?)

1	2	3	4
Passend			Storend

Ik beschouw de combinatie tussen water en zonnepanelen als natuurlijk/kunstmatig.

1	2	3	4
Natuurlijk			Kunstmatig

Ik beschouw de combinatie tussen water en zonnepanelen als winstgevend/nadelig.

1	2	3	4
Winstgevend			Nadelig

Ik beschouw de combinatie van water en zonnepanelen als geschikt voor recreatief gebruik.

1	2	3	4
Veel mogelijkheden			Ontoegankelijk

Ik beschouw de combinatie tussen water en zonnepanelen als geschikt voor de aanwezigheid van verschillende dieren- en plantensoorten in het landschap .

1	2	3	4
Rijk aan biodiversiteit			Geringe biodiversiteit

Ik beschouw de combinatie tussen water en zonnepanelen als iets duurzaam. Namelijk het makkelijk behouden en aanpassen van het systeem onder veranderende economische, ecologische, culturele en sociale omstandigheden.

1	2	3	4
Duurzaam			Niet-duurzaam

Het is de bedoeling dat u de onderstaande vragen snel en intuïtief beantwoordt.

Beleeft u het landschap op de bovenstaande foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de bovenstaande foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Beleeft u het landschap op de tweede foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de tweede foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Wateropvang en waterretentie

Het gebruik van een gebied als waterretentie blijft mogelijk in combinatie met zonnepanelen. De zonnepanelen zullen speciale microklimaatomstandigheden creëren waardoor het (nattere) gebied een bijzondere plek kan worden voor fauna en flora.

Ik beschouw de combinatie tussen een waterretentie gebied en zonnepanelen als divers.
(Is er volgens u een variatie aan visuele kenmerken binnen deze functiecombinatie. Bijvoorbeeld een variatie aan beplanting, landgebruik, activiteit, ...)

1	2	3	4
Divers			Eenvormig

Ik beschouw de combinatie tussen een waterretentie gebied en zonnepanelen als passend binnen het landschap.
(Passen volgens u de verschillende landschapscomponenten bij elkaar of zijn er niet-passende of storende componenten die de eenheid van het landschap zouden kunnen verstoren?)

1	2	3	4
Passend			Storend

Ik beschouw de combinatie tussen een waterretentie gebied en zonnepanelen als natuurlijk/kunstmatig.

1	2	3	4
Natuurlijk			Kunstmatig

Ik beschouw de combinatie tussen een waterretentie gebied en zonnepanelen als winstgevend/nadelig.

1	2	3	4
Winstgevend			Nadelig

Ik beschouw de combinatie tussen een waterretentie gebied en zonnepanelen als geschikt voor recreatief gebruik.

1	2	3	4
Veel mogelijkheden			Ontoegankelijk

Ik beschouw de combinatie tussen een waterretentie gebied en zonnepanelen als geschikt voor de aanwezigheid van verschillende dieren- en plantensoorten in het landschap.

1	2	3	4
Rijk aan biodiversiteit			Geringe biodiversiteit

Ik beschouw de combinatie tussen een waterretentie gebied en zonnepanelen als iets duurzaam. Namelijk het makkelijk behouden en aanpassen van het systeem onder veranderende economische, ecologische, culturele en sociale omstandigheden.

1	2	3	4
Duurzaam			Niet-duurzaam

Beleeft u het landschap op de bovenstaande foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de bovenstaande foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Beleeft u het landschap op de tweede foto eerder als positief of negatief?

1	2	3	4
Negatief			Positief

Heeft het landschap op de tweede foto volgens u een hoge of lage functionaliteit?

1	2	3	4
Lage functionaliteit			Hoge functionaliteit

Habitatvoorziening

Zonnepanelen in combinatie met extensieve natuur zoals vochtig kruidenrijk grasland, in combinatie met bijenkasten of als ecologische verbindingszone tussen natuurrijke gebieden kunnen heel wat positieve effecten geven aan natuur en biodiversiteit (afhankelijk van de al aanwezige natuurwaarden op de betreffende locatie). De visualisatie toont een mix van natuur, zonne-energie en kunst. Dieren kunnen de zonnepanelen als schuilplaats gebruiken op weg van het ene natuurrijke gebied naar het andere.

Ik beschouw de combinatie tussen natuurvoorziening en zonnepanelen als divers.
(Is er volgens u een variatie aan visuele kenmerken binnen deze functiecombinatie. Bijvoorbeeld een variatie aan beplanting, landgebruik, activiteit, ...)

	1	2	3	4	
Divers					Eenvormig

Ik beschouw de combinatie tussen natuurvoorziening en zonnepanelen als passend binnen het landschap.
(Passen volgens u de verschillende landschapscomponenten bij elkaar of zijn er niet-passende of storende componenten die de eenheid van het landschap zouden kunnen verstoren?)

	1	2	3	4	
Passend					Storend

Ik beschouw de combinatie tussen natuurvoorziening en zonnepanelen als natuurlijk/kunstmatig.

	1	2	3	4	
Natuurlijk					Kunstmatig

Ik beschouw de combinatie tussen natuurvoorziening en zonnepanelen als winstgevend/nadelig.

	1	2	3	4	
Winstgevend					Nadelig

Ik beschouw de combinatie tussen natuurvoorziening en zonnepanelen als geschikt voor recreatief gebruik.

	1	2	3	4	
Veel mogelijkheden					Ontoegankelijk

Ik beschouw de combinatie tussen natuurvoorziening en zonnepanelen als geschikt voor de aanwezigheid van verschillende dieren- en plantensoorten in het landschap.

	1	2	3	4	
Rijk aan biodiversiteit					Geringe biodiversiteit

Ik beschouw de combinatie tussen natuurvoorziening en zonnepanelen als iets duurzaam. Namelijk het makkelijk behouden en aanpassen van het systeem onder veranderende economische, ecologische, culturele en sociale omstandigheden.

	1	2	3	4	
Duurzaam					Niet-duurzaam

Dank u! We zijn er bijna. Alleen nog enkele vragen over jou.

Wat is uw leeftijdsgroep?

- [ ] 18 of jonger
- [ ] 19-24
- [ ] 25-34
- [ ] 35-44
- [ ] 45-54
- [ ] 55-64
- [ ] 65 of ouder

Wat is uw geslacht?

- [ ] Man
- [ ] Vrouw
- [ ] Anders

Hoe belangrijk is klimaatverandering voor u persoonlijk?

- [ ] Erg belangrijk
- [ ] Belangrijk
- [ ] Minder belangrijk
- [ ] Niet belangrijk

APPENDIX 6: GENERAL GRAPHS ABOUT THE RESPONDENTS

Table 15: Gender of respondents

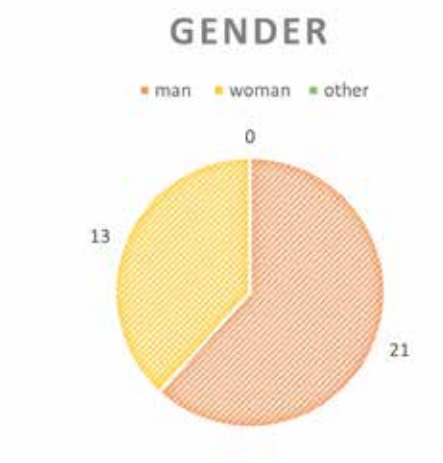


Table 15: Gender of respondents

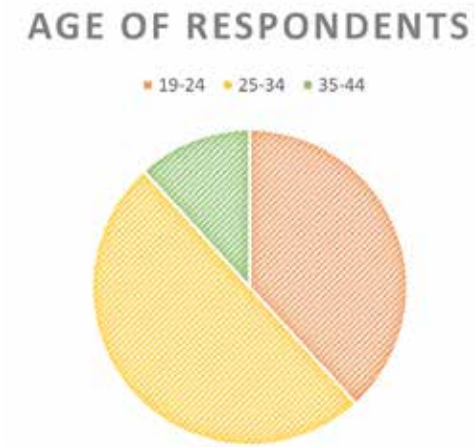


Table 16: Personal climate concern of respondents