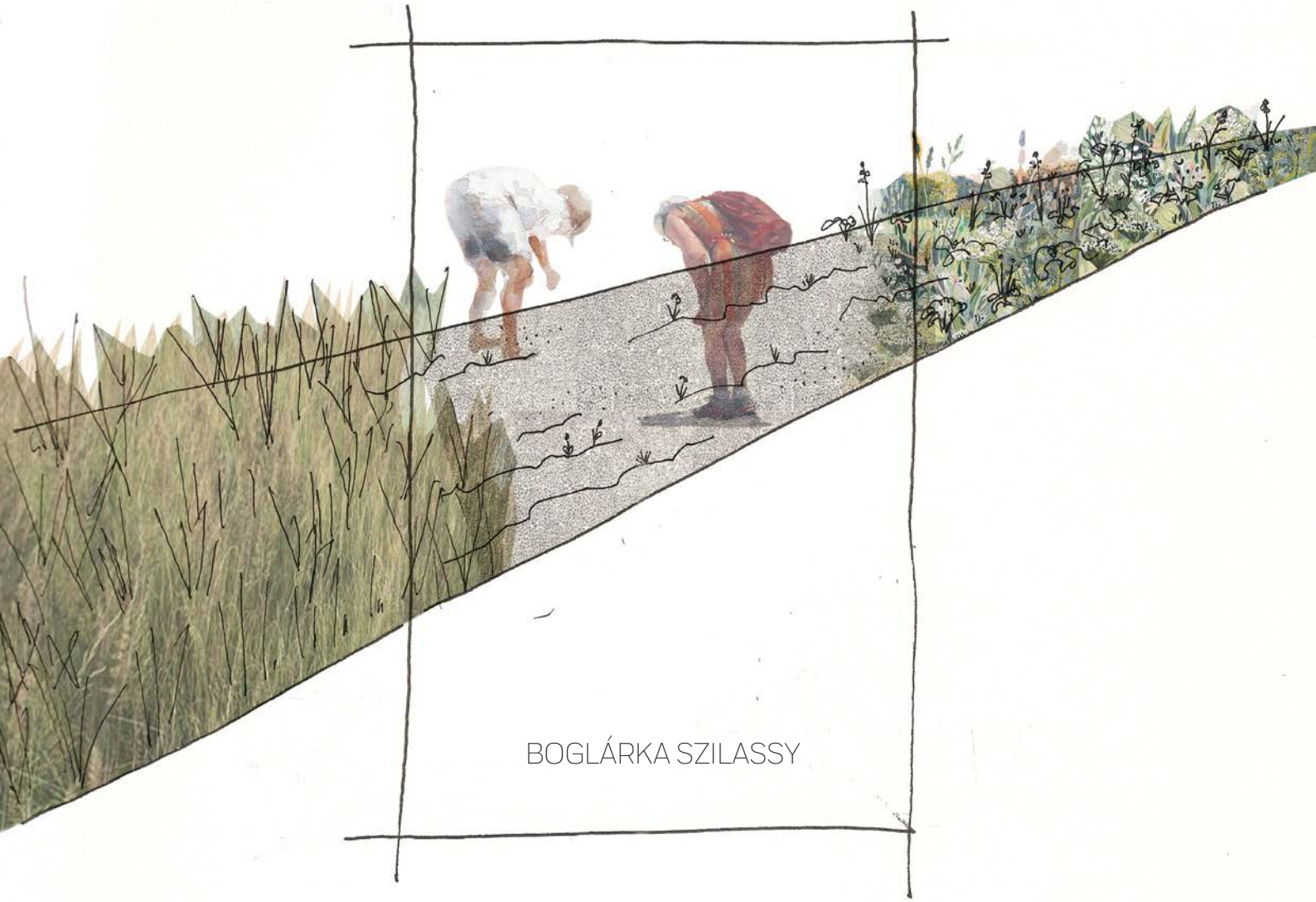
Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

**Faculty of Landscape Architecture,
Horticulture and Crop Production Science**

URBAN SANDY HABITATS

DESIGNING THROUGH NATURE CONSERVATION METHODS



BOGLÁRKA SZILASSY

Independent Project • 30 credits
Landscape Architecture – Master´s Programme
Alnarp 2019

Urban Sandy Habitats -
Designing through nature conservation methods

Author: Boglárka Szilassy
Supervisor: Karin Svensson, SLU, Department of Landscape Architecture, Planning and Management

Examiner: Mats Gyllin, SLU , Department of Work Science, Business Economics and Environmental Psychology

Co-examiner: Anna-Karin Ekwall, SLU, Department of Landscape Architecture, Planning and Management

Credits: 30
Project Level: A2E
Course title: Independent Project in Landscape Architecture
Course code: EX0852

Programme: Landscape Architecture – Master´s Programme
Place of publication: Alnarp
Year of publication: 2019
Cover art: Boglárka Szilassy
Online publication: http://stud.epsilon.slu.se

Keywords: sand, cultural landscape, sandy habitat, management, restoration, design, Tempelhofer Feld, prototype, native, grazing

SLU, Swedish University of Agricultural Sciences
Faculty of Landscape Architecture, Horticulture and Crop Production Science
Department of Landscape Architecture, Planning and Management

ABSTRACT

Sandy habitats carry an extreme diversity. They occur in many various types and forms from coast to inland. Also, there are landscape types that occur in sandy environments but are not exclusively sandy habitats. But what we can say about all for sure, is that they need disturbance to survive. They are sensitive and at the same time resilient systems. Therefore, the question raises: could we use them in cities too? How? This thesis is about figuring out how the systems of sandy habitats work and how models and knowledge from nature conservation could be lifted into the urban environment. Through the example of Tempelhofer Feld in Berlin, the research is set into context and some feasible solutions are suggested for this area. These are the “sand-themes”, the result of the thesis. The sand-themes are a way to use sandy habitats at Tempelhofer Feld but could be anywhere else too. They are designed as modular structures that can be repeatable and transformable throughout the landscape. For the pleasure of people, for the promotion of these declining habitats and for a more resilient cityscape.

TABLE OF CONTENTS

BACKGROUND 1
INTRODUCTION 2
OBJECTIVES & METHOD 4
SAND 5
Sand as a material 5
Sand and its influence on plants 7
Stress as an asset 7

SAND AND ECOLOGY 9
Sandy habitats and their value 9
Coastal sandy habitats 10
Inland sandy habitats 11
Life in sand 14

THE CULTURAL LANDSCAPE 16
Where grazing and cultivation happens 16
Linné's discovery and the implementation 16
Tourism and protection 17
Some treasures left 19
Outside of Sweden 19
Organizations for sand 19
Sand Life 19
SandAchse Franken 20

RESTORATION AND MANAGEMENT 20
Succession 20
The notion of disturbance 21
Succession-based model 22
Restoration and management methods 23
Cutting 23
Burning 24
Herbicides 25
Machine-driven soil disturbance 25
Direct human-made disturbance 27
Grazing 27
Approaches and outcomes 31
Examples of restoration projects 32

Leftover places 33

SAND AND DESIGN 35
Species introduction 35
Stirring the meadow composition 35
Seed mixtures 36
Landscape plugs 36
Nursery-grown pots 37
Design considerations 37
Design approaches 38
Kevin Benham 38
Peter Korn 39
Derek Jarman 40

SAND THEMES 40
Tempelhofer Feld 41
Flora and fauna 43
The central meadow area 44
Development of the themes 44
Spring & grazed prototype 45
Sand festival prototype 49
Sand heap prototype 51

DISCUSSION 54
CONCLUSION 59
REFERENCES 60
FIGURES 64

BACKGROUND

Hiking is my passion. Going around in South Sweden and its flat landscape always amazed me. At some of these occasions I became acquainted with the Sandlife organization and their recent restoration initiative and actions. Their projects were aiming for recreating (open) sandy habitats and promoting the survival of different plant, fungus and animal species. Their efforts also lead to environments being restored and turning them more attractive and accessible for people to experience nature. Drakamölla, Vitemölla, Revingefältet and Falsterbo were some of the places I have been around where these kind of restoration projects were carried out. I was completely amazed by those managed landscapes and how they started developing after the interventions.

Besides this input, also some of my Master's courses at SLU Alnarp, made me interested to work with sandy habitats and sandy plantings such as the Dynamic Vegetation Design course where we learnt about nature as a process and how to deal with the ever-changing nature of plants and an area as a whole in a design. In the Advanced Planting Design course my interest grew with knowing more about the horticultural aspect of planting design, creating habitats, suitable combination of plant species in suitable conditions.

The participation in the 'Skog' student competition in 2017 was also an antecedent to my thesis topic. For the competition you needed to pick a forest area wherever in Sweden and make a proposal for the improvement of the place in any way that you think it would contribute to the better. We, with my teammate, selected our design area in a forest that I passed by day by day on my way to school, in Habo Ljung (in Lomma municipality). It is a pine dominant forest with some glades and a bigger meadow-like opening with exposed sandy soil due to horse-riding activities. I found this second attribute of the place extremely intriguing and I started reading about the special qualities of sandy habitats. Such as the benefits of trampling and disturbance and how some specialist plant species prefer these conditions. I never have thought plants need to be stepped on to survive?! Seemed such a contradiction.

Moving to Brandenburg, often mentioned as the "sandpit" or "sandbox" of Germany in September 2018, was eventually the final push to choose this topic for my thesis. Once, in the first weeks of my stay, I went for a walk on the well-known Tempelhofer Feld in Berlin. I was overly impressed with what I experienced on the site. It is a naturally evolved sandy habitat, formerly a military field, later airport, functions now as an extensively managed public park in the middle of the city. It mainly consist of open areas of dry meadows that are framed with shrubberies on the edge. In a monitoring in 2005, many hectares of endangered and protected sandy dry grasslands and flat oat grasslands were detected. These are ecological treasures and should definitely be preserved in the future. If it was up to the

park users, Tempelhofer Feld would be saved like how it is at the moment. However, decisions makers have a slightly different view on the topic. In 2011 they launched an international competition for the Tempelhofer Feld where the master plan of the Scottish office GROSS.MAX got the prize. Interestingly, the design was criticized to be actually designed for bird's eye view – according to NABU Berlin (the nature protection alliance in Berlin). It means that the design was not formulated for the unique conditions of the place. On top of all, the public acceptance was not willing to agree with the winner design proposal either. The opposition was because the design wanted to change the character of the place (NABU 2014).

So based on these opinions, I actually wonder, what could be the solution for the future of this beautiful semi-urban park for plants, animals, fungi and people especially? At the moment, the near future of the park seems to be a little more stabilized, as a long-term extensive management plan has been released. In my opinion, the sand-based vegetation of the area holds a lot of potential in itself. Perhaps it is not an artificial mountain or a representative pool that was included in the 2011 competition that are needed. Perhaps already the sandy soil might be a bigger treasure than one could think…

I am interested to somehow merge all these points I mentioned above. To work with sandy habitats, follow the principals of those SLU courses and take the area, Tempelhofer Feld, where I live as a study example.

INTRODUCTION

Sandy habitats are versatile systems. As is sand, the material itself too. It is one of the end results of the slow processes that are ongoing permanently - when the bedrock slowly weathers into smaller and smaller elements (Länsstyrelsen 2018). It has little to no nutrient content, can be heated up quickly and filters through water very fast. It can be called the world of extremes (SandAchse Franken 2015), a harsh environment. The position of plants is not only determined by the availability of resources but by the lack of them too (Rainer & West 2015). So luckily, this extreme environment is an asset for some very special plant species.

Sandy habitats can be categorized in several ways. According to their location, but also according to environmental conditions, nutrient level, land use and land use history (SandAchse Franken 2004). They are unique and sensitive systems and unfortunately, their character can change easily with nutrient intake or the appearance of some competitive invaders.
The land use history of cultural landscapes can give a guide to how sandy surfaces evolved and what are ways to deal with them now. It is not a secret, humans have had and also nowadays, have a huge impact on sandy habitats. Through human activity, for example, fertilized agricultural lands, planned

afforestation, or abandoning previously grazed areas, many sandy habitats disappeared.
Since plant communities have a dynamic nature, they change over time. This long-term change is called succession. To keep and manage sandy habitats in a sustainable way succession should be a vital part and a base of landscape design and maintenance. A good example of this kind of management is used in nature conservation where the vegetation is treated as a whole. To keep sandy habitats in a desirable state you need to disturb them (Dunnett 2014). So they are sensitive but at the same time resilient systems. There are many ways to disturb them with different outcomes in accordance to the chosen disturbance regimes. Conservation and restoration of sandy habitats are already going on for decades. However, if these habitats are so resilient, diverse and easy to manage, why not bring them into cities? How about using conservation and restoration approaches to create urban sandy habitats? Sandy habitats could have a great potential to use in urban environment, for example when we think about climate change. But how to present a diverse sandy community in an urban environment? How to design a "sandy" place which is not only favourable from an ecological point of view but also people can enjoy and benefit from it? To create a more realistic ground for the research I chose a site as an example and attempt to apply the results of the thesis and make some suggestions for a design. This site is Tempelhofer Feld, a vast open green area in the heart of Berlin.

From an ecological perspective there are plenty of publications in this topic. But what can be achieved by merging these with design? What is the landscape architecture view on sandy habitats in urban conditions?

To understand the system of sandy habitats and planting design in poor environments we need to step back a little. Perhaps, there is a need to start the project from the smallest particle. To introduce a grain of sand first.

OBJECTIVES & METHOD

The main objective of the thesis is to study sandy habitats. See how they develop, work and transform. The second objective is to find out how to be able to use them in cities. Also, if there are existing examples that deal with similar situations, how do they do that? While the first objective is worked through a literature study, the second objective is processed through three design suggestion. This is done by applying the findings of the literature review onto an existing site and tayloring the research results to the existing site conditions in order to allow the ideal development of urban sandy habitats.

The main research questions that guided my thesis are:
- How do sandy habitats function?
- Could we use them in cities?
- Whhat can be some feasible ways to introduce them?

The thesis has been built up through four different steps. The first step precedes all strucural parts of the paper: this incorporates for example all hikes I took and where most of the photos have been made and I used in the chapters of the thesis. Some of these hikes were not intentionally centerred around material collection for the thesis, however, by proceeding with the literature study many of my photos started to make sense and I realized the ‘why’, the intention of for example some restoration interventions. The first real structural part of my thesis is the literature research. I have touched upon the main topics of the literature study in the Introduction but to clarify, I have five main sections in the review. Throughout the five chapters you can follow what sandy habitats are composed of, what types there are, how they evolved and how to manage them. And eventually, what existing ideas there are that could be used to lift the knowledge about sandy habitats into urban environment. After the research, a site is selected and as a result of the thesis, suggestions are made for how urban sandy habitats could exist.

SAND

SAND AS A MATERIAL

Sand is one of the end results of the slow processes that are permanently ongoing on Earth when the bedrock slowly weathers into smaller and smaller particles – gravel, sand and clay. The decomposed material is carried on by gravity, glaciers, wind and water. These are the processes that form different types of soil. For instance, the sandy soils and sandy coastal areas of Sweden (Länsstyrelsen 2018) and in Germany were formed in the last ice age period around 10,000 years ago. First, the larger and heavier grains of sand, then the smaller and lighter ones settled on the ground. By wind erosion, sand was driven inland building large dunes, then smaller and smaller inland dunes to just sand-blankets, only a few decimeters thick (SandAchse Franken 2015).

Particles smaller than 2 mm but bigger than 0,05 mm are defined as sand (See *Fig. 1*). These grains are normally visible to the naked eye. Their shape depend on their degree of weathering and abrasion but are usually rounded or angular in shape. These particles are nutrient poor, they have a very small amount of capacity for nutrient ion, water or gas adsorption therefore they contribute very little to soil fertility. Within the soil fabric the large (compared to silt or clay), sand particles have contact with other particles at several points due to their rounded shape, creating large gaps in between. This soil structure makes sandy soils less compact, aerated and loose. It also means that the water that they cannot hold, drains immediately. When you touch sand grains, they have a gritty feeling, and interestingly, this grittiness does not change whether the soil takes up moist or is dry, it only becomes somewhat looser (Weil & Brady 2017).

Property	**Sand**	**Silt**	**Clay**
Range of particle diameters in millimeters	2.0-0.05	0.05-0.002	Smaller than 0.002
Means of observation	Naked eye	Microscope	Electron microscope
Dominant minerals	Primary	Primary and secondary	Secondary
Attraction of particles for each other	Low	Medium	High
Attraction of particles for water	Low	Medium	High
Ability to hold chemicals and nutrients in in plant-available form	Very low	Low	High
Consistency when wet	Loose, gritty	Medium	Sticky, malleable
Consistency when dry	Very loose, gritty	Powdery, some clods	Hard clods

FIG. 1: *The general properties of sand, based on the table of general properties of soil particles from Weil & Brady (2017)*

There are different colors of sand. The main influencer of the shades is the mineral component. Coarse particles are built up primarily of quartz (originated from materials such as granite or sandstone) and other light minerals. Rock minerals have several colors such as quartz being gray or white, feldspars red, limestone gray or white, or sometimes even olive green. The color of the sandy soil could also be modified by the presence of clay and organic material (Craul 1992). Beach sands usually consist of quartz that withstands weathering while desert sands consist of quartz too but they may include a significant amount of other minerals as well. There are also some dramatic examples such as the White Sands desert in New Mexico (*Fig. 2)* where one can find dunes composed entirely of sand-sized gypsum. This is, compared to quartz, a weatherable mineral and even has the ability to dissolve in water (Weil & Brady 2017).

FIG. 2: *Bare gypsum sand dunes at White Sands National Monument, New Mexico, USA (photo by the author, 28.03.2018)*

Sand can be classified by qualities according to the origin of the decomposed material but also according to particle size. There are different classifications but the grain size of sand always falls between gravel and silt. For a sand bed, a recommended particle size by Peter Korn (2013) is 0-8 mm (which falls partly in the gravel category) but it also depends on the purpose or species of the bed. For example, really fine sand is challenging to use as it neither holds moisture nor drains well. “It is kind of like cultivating something on a rock”- says P. Korn (2013, p. 133). The fine sand grains seal up all the space between the coarser matter. The benefit is that you can create extremely dry beds where bulbs and some other plans thrive well that require summer drought- because of the lack of moisture from below. But there should be no extremely fine particles (below 0.02 particle diameter) in the sand like rock flour or silt since that tightens up and blocks the availability of air down in the bed (Korn 2013). An easy test to assess

the sand quality is described by P. Korn (2013) and Weil & Brady (2017) as well: the texture-by-feel method. It is when you take a handful of moist material, like sand and squeeze it together. When you release the grip, your material should just be holding together. However, if dirt remains on the palm it means the sand contains too many fine particles and it is less easy to work with.

SAND AND ITS INFLUENCE ON PLANTS

Sand is a world of extremes: hot, dry and low in nutrients (SandAchse Franken 2015). Sandy, well drained soils get heated up quickly and the excess water is drained away quickly and never stagnates in the upper layer. Due to this good permeability, more air is pulled down into the ground, more oxygen is provided and this is why the plant roots are enabled to develop much deeper down. So the plants in this way can adapt to the drier surface environment while their roots reach their way down to the moister and cooler soil level also trying to compensate for the nutrient-poor conditions. So one can say, that sand enables a deep root system, however this takes time. As a contrast when a soil mix has a high amount of nutrition in it, generally plant species grow faster. If that is not what certain plant species are used to, there is a risk that they lose their original, natural growth characteristics. They not only look oversized and floppy but they are also more prone to diseases and pest. On top of all, when they get too much nutrition they become a little less hardy (Korn 2013). Plants in sand, related to the growing substrate, cope with a major amount of stress. These stress factors are such as extreme temperatures, drought, low availability of nutrients, disturbance and substrate mobility (Martínez & Gallego-Fernández & Hesp, 2013).

STRESS AS AN ASSET

According to Grime (1977), plants have different survival strategies. The strategies are based on external factors which limit their biomass and influenced the evolution of the different kind of strategies. These two external factors are stress and disturbance. Stress can be defined as conditions that restrict biomass production of all or part of the vegetation. This is via for example light shortage, water or mineral nutrient limitation and temperatures suboptimal for species. Whilst, disturbance is when the biomass is partially or completely destroyed. Depending on the appearance and intensity of the factors there are 3 survival strategies: competitive, stress-tolerant and ruderal (*Fig. 3)*. We can talk about competitive strategist plants in low stress, low disturbance situations. The second type is ruderal strategy, this occurs under in low stress, high disturbance circumstances. Finally, plants with a stress-tolerant strategy live where there is a high stress, low disturbance situation experienced (Grime 1977). When we think about the floral inhabitants of these three different scenarios the following thing is important to know. Everything about how a plant looks and behaves is a response to a particular site. The shape, the root system, the leaves and the

reproduction strategy of the species are all responses to the site conditions. So, it is not just the availability of resources that determines the position of plants but the lack of the resources too (Rainer & West 2015).

		intensity of stress	
		low	high
intensity of disturbance	low	competitive strategy	stress-tolerant strategy
	high	ruderal strategy	no viable strategy

FIG. 3: *Based on Grime's table of viable strategies: the combination of environmental stress and disturbance creates three basic plant response strategies which are distinguished here (Grime 1977)*

What applies to plants in sand for sure is that they need to cope with a nutrient-deficient habitat where mineral nutrient stress arises from the poor nature of the habitat (Grime 1977). "It is remarkable that unrelated species growing in geographically separated parts of the world show very similar responses to the same sort of environmental pressures or constrains" (-Dunnett & Hitchmough 2014). Local factors can be extremely different (soil composition, vegetation management) but some common morphological features among plants can be found. Due to these stress factors, plants take up on a slow growth and on the long term they develop a fine, compact, steady character. This slow growth leads to both resistant, harder leaves that do not let insects attack them. It also contributes to make plants more long-lived (Korn 2013). Grasses can be narrow-leafed, creeping and forbs can have rosettes (Grime 1977) such as *Thymus spp., Eryngium bourgatii* and *Verbascum spp*. for example. The latter is also a good instance with its wooly leaves which is commonly a sign of drought tolerance as the hairs protect them from drying out (Hitchmough 2017). Woody species are characterized often coniferous trees and shrubs with evergreen, tiny, hard, thick, and leathery leaves. These three things: reduction in size, in leaf form and in potential growth rate are an adaption technique for surviving conditions of low mineral nutrient supply, in other words, with these attributes they require less mineral uptake and they limit their productivity. An additional feature of slow-growing plants on infertile soils is that their growth pattern cannot be strictly connected to a seasonal variation. They have often evergreen leaves that do not follow seasonal changes and therefore stay on the plant for a comparatively long time (Grime 1977). As a strategy group, stress tolerating species are in a continuous decline in today's world owing to agriculture and increasing soil productivity through intentional and unintentional human interventions. Numerous plant genera that are acknowledged and widely used in cultivation are sharing the features of stress tolerance such as *Eryngium, Euphorbia, Gentiana, Helleborus, Origanum, Penstemon, Scabiosa* and *Thymus* genuses (Hitchmough 2017).

However, many plants that also thrive in sandy soils, have another strategy categorized by Grime as ruderal strategy (competitive strategy in sand due

to the high stress factor is not typical). These species are often annual due to the high disturbance that occurs in sand. They have an early flowering period, before the heat wave in summer kicks in, and produce a high amount of seeds. Bare sand is important for these plants since the seeds have only a chance to grow if the plant cover is not completely closed or too dense (Länsstyrelsen 2018).

SAND AND ECOLOGY

SANDY HABITATS AND THEIR VALUE

What is a sandy habitat? Where can you find them? Why are they important? This chapter tries to answer these questions by showing some characteristics and special examples.
To start with the explanation of sandy habitats, it is important to mention that they can be categorized in several ways. One way is to define sandy areas according to their location. Whether it is in a coastal environment or it is an inland sandy area. These can be further divided into various characteristic habitat types, especially on the coast – from the sea towards inland (Länsstyrelsen 2018). However, besides the location, there are other factors that create every area to have their own special character. These can be environmental conditions like light availability, heat, exposure to wind, waves and currents, the nutrient and pH level of the sand, (for example calcareous) or the form of land use (meadow, field, forest) (SandAchse Franken 2004) and the land use history of the area such as grazing or agricultural activity (Länsstyrelsen 2018).

Only species that have evolved to adapt to these rough conditions can root down and survive in sandy habitats. However, species that are adapted to stress, do not have a chance to live anywhere else, they are basically tied to these conditions. In biotopes where the environmental factors are more balanced, for example more water supply, more nutrients are available these specialist species are displaced by other more competitive individuals. Sandy habitats therefore are sensitive systems. And their fragile nature is especially threatened in today's world. Land use changed into a direction where through intensified agriculture nutrients are leaching into the soil and the poor environment of these species is hard to maintain (SandAchse Franken 2004). More direct nutrient enrichment could be also connected to recreational activities. Too much disturbance related to trampling or for example leaving litter, leaving dog droppings on site contribute to the change of soil qualities. Other risks for sandy habitats can be also urban development. By having less sites available due to building and sealing of surfaces by non-permeable pavements. Next to this, problems such as plantings, sowing of non-native species and afforestation rise. They all prevent the settlement of open sand with typical plant species (Bresch Henne Mühlingshaus 2010).

Sand habitats are now among the most endangered biotope types (in Bavaria, Germany). At some places they are almost completely pushed back and can only exist on verges and roadsides. Many of their inhabitants have been registered on the Red List. Some are in acute danger of extinction or have disappeared already (SandAchse Franken 2004). You would not think, but poor areas might be a bigger challenge to keep than rich soil conditions.

COASTAL SANDY HABITATS

In the Baltic Sea - Western Europe region there are numerous different habitat types categorized by the Habitats Committee in the Interpretation Manual of European Union Habitats. These habitat types mentioned in the habitats directive are all declared as worthy of protection and conservation owing to wild animals, plant species and natural habitats. Coastal habitat types can be best described according to the illustration of common dune areas and the habitats directive of the European Union (*Fig. 4)* together.

name of the habitat type	habitat type code
(Embryonic) **shifting dunes**	2110
White dunes (Shifting dunes along the shoreline with *Ammophila arenaria)*	2120
Grey dunes (Fixed coastal dunes with herbaceous vegetation)	2130
Decalcified field dunes with *Empetrum nigrum* (dune heathland with crowberry)	2140
Dunes with *Salix repens ssp argentea*	2170
Wooded dunes (Wooded dunes of the Atlantic, Continental and Boreal region)	2180
Humid dune slacks	2190
Dry sand heaths with *Calluna* and *Genista*	2310
Dry sand heaths with *Calluna* and *Empetrum nigrum*	2320
Grassy sand dunes (Inland dunes with open *Corynephorus* and *Agrostis* grasslands)	2330
European dry heaths	4030
Sandy grasslands (Xeric sand calcareous grasslands)	6120
Siliceous grasslands (Fennoscandian lowland species-rich dry to mesic grasslands)	6270

FIG. 4: *Sandy habitat types based on the Interpretation Manual of European Union Habitats (European Commission DG Environment 2007)*

When you approach sea dunes of the Atlantic, North Sea and Baltic coast from the water side you find different dune formations (*Fig. 5*). Shifting dunes (habitat type code: 2110) are the first construction on the coast. These maritime sandy areas represent the first stages of dune creation (European Commission DG Environment 2007). Here you can experience the most powerful and dynamic changes: building, disappearing, re-building. Therefore, the vegetation is sparse and very specialized to these conditions. So are the insects and bird species. In the latter category belong the plover species (*Charadrius spp.*) that nest and forage on the beaches. After the so-called shifting dunes the habitat of white dunes come (habitat type code: 2120). It is defined by bare sand and undulating dune systems parallel to the shoreline. Here, the construction role of wind plays a big role and only a few species can thrive, which are adapted to the shifting environment (*Ammophila arenaria, Leymus arenarius, Eryngium maritimum)*. While grey dunes (habitat type code: 2130) are already colonized by more or less a closed carpet of herbaceous vegetation. It means that the open sand takes up only to 10-50%. The name of the habitat type, grey dunes can be a little confusing since this is the most flowery, colorful coastal situation

(with *Thymus serpyllum, Jasione montana, Lotus corniculatus* and *Viola* species). Decalcified (lime-deficient) dunes (habitat type code: 2140, 2170) with heather and crowberry are areas where various kinds of brushwood settle down and fixing the dunes such as the ones in the name of the habitat type. *Calluna* and *Empetrum nigrum* prefers drier sandy soils from which minerals have leached. On the contrary, *Salix repens ssp. argentea* (creeping willow) appears in moister conditions. These habitats (2140 and 2170) can appear in patches over the grey dunes or large mats can be formed with time and overgrow vast areas. This is a welcoming environment also for tree saplings that could eventually take over if left without any management. If this happens, wooded dunes (habitat type code: 2180) of various types can evolve. According to the habitat directive of the European Union (European Commission DG Environment 2007) a wooded dune is considered a wooded dune when the area has an overall of more than 30% tree coverage. They can be naturally evolved or plantings comprised of usually pine trees (Länsstyrelsen 2018). Eventually, the last typical habitat type of coastal sandy areas is called humid dune slacks (habitat type code: 2190). These are wet/ moist depressions of the dunal structures. Thanks to the high water table that reaches the surface, extremely rich and specialized habitats are able to develop under these circumstances, however, the creatures living here are also very vulnerable and threatened by the fluctuation of groundwater levels (European Commission DG Environment 2007).

FIG. 5: *Coastal sandy habitat types illustrated by Martin Holmer (Länsstyrelsen 2018)*

INLAND SANDY HABITATS

The distinction of inland sandy habitat types from one another is even harder than near the coast. Often, habitat types merge and transform due to the environmental conditions present on site. In order to explain inland sandy areas, the description of succession is inevitable to know. According to the SandAchse manual, succession is the change of different plant communities over time at one place. This can happen when humans no longer intervene in the development of the vegetation (more about succession in the Restoration and management chapter). Based on succession, it might be easier to understand that sandy ecosystems are often closely interlinked and it is a complexity of different biotopes together. For example in a sandy grassland one can find dispersed open sandy spots, and extremely poor, xeric grassland areas, all framed with a pine forest. Perhaps there are also some depressions in the terrain that create some humid

environments (SandAchse Franken 2004).

A major percentage of inland sandy areas are now occupied by woodlands, regularly sparsely dotted with pines. The remainder areas that are still partially or completely open are almost without exception, an outcome of human influence (Länsstyrelsen 2018). The development process is illustrated by *Fig. 8* that starts the "flowchart" of habitats with a nutrient-deficient open sandy soil.

Bare sand can exist with or without a sparse herbaceous vegetation. Naturally evolved open sandy areas are often closely linked to the forces of rivers, destruction of the bank or accumulation of sand, flood events, or uprooting of a tree and wild grazing activities. Even ants are capable of creates some patches of openness. However, larger surfaces are usually due to human interventions (e.g. sand mining, clear-felling). Since there is no or almost no vegetation, there are no significant plant species to mention but numerous insect species feel perfect in this environment. Open sandy areas if there are no forces to keep them open, become vegetated quite fast by various pioneer species such as for example the *Corynephorus canescens* (grey-hair grass) or population of lichens and mosses (SandAchse Franken 2004). If this pioneer process continues there is a high chance that it develops into a sandy grassland (habitat type code: 2330). Here, the dominant species are *Corynephorus canescens* and *Agrostis capillaris* alongside many annual plant companions (European Commission DG Environment 2007). This sandy habitat type can exist for a relatively long time in case of low nutrient supply or regular management. By the natural seeding of *Armeria maritima* and slightly more nutrients or mostly by grazing, a grassland dotted with *Armeria maritima* (sea pink) is able to develop (*Fig. 6*). It has a long flowering span from May until the autumn and it grows together with J*asionae montana, Festuca brevipila, Festuca ovina, Helichrysum arenarium, Thymus serpyllum* and *Dianthus deltoides*. As it was said for the previous habitat type, also sea pink grasslands can be sustained extensively for a long period with grazing or mowing.

FIG. 6*: Sandy Armeria maritima grassland in the park of Sanssouci, Potsdam, Germany (photo by the author, 19.10.2018)*

With a long-term continuous usage as pasture or hay meadow, poor (xeric) grasslands (habitat type code: 6120, 6270) appear. They are not typical sand habitats anymore. The dry, frequently open grasslands develop more or less on lime-rich soils, also on calcareous sandy soil and includes many different kind of plant communities. (European Commission DG Environment 2007). Xeric grasslands have an intermediate position between sandy grassland and farmland (agrarian sand field) and characterized by meadow species of grasses (*Arrhenatherum elatus, Anthoxanthum odoratum, Dactylis glomerata*) and some taller forbs like *Centaurea spp., Knautia spp., Salvia pratensis*, *Origanum vulgare* (*Fig. 7*) (SandAchse Franken 2004).

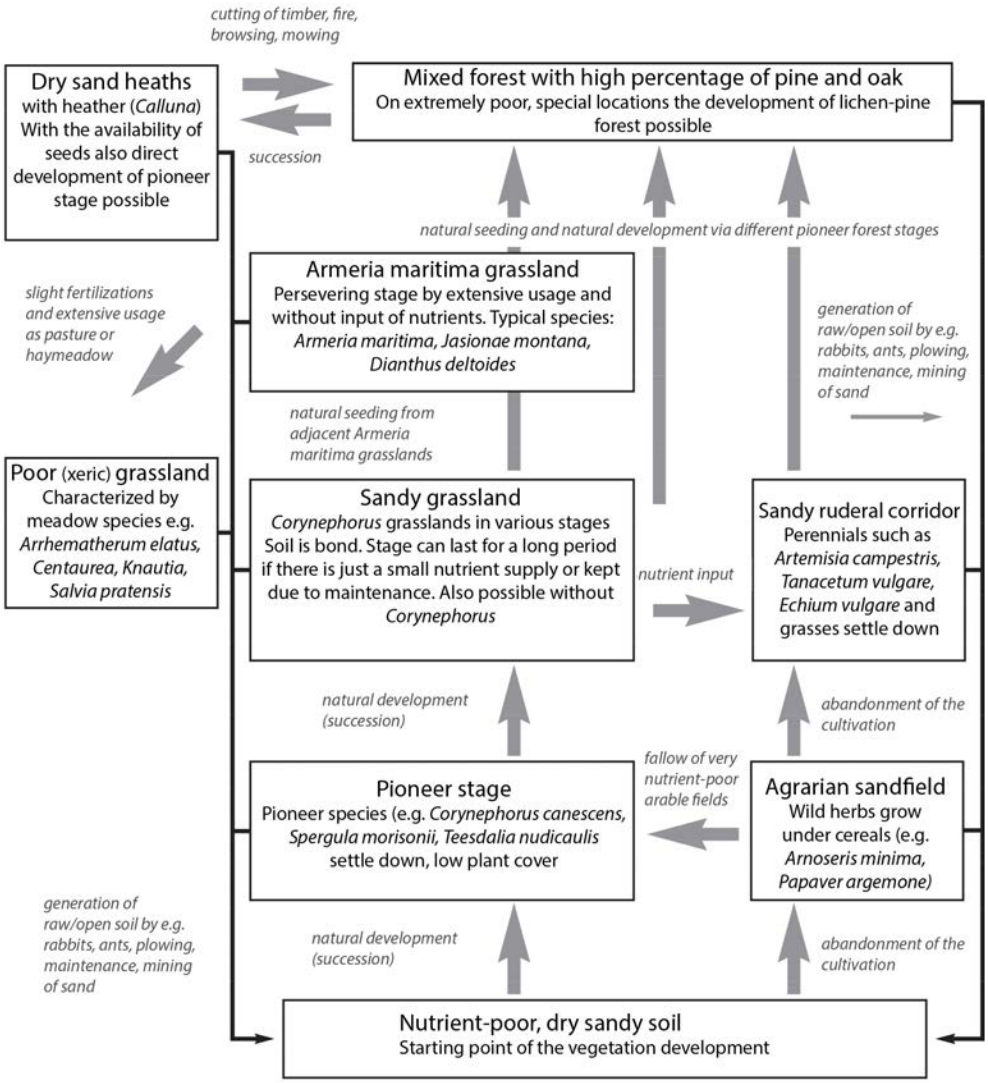
The last categorized habitat by the habitat directive is dry sand heaths (habitat type code: 2310, 2320, 4030). The term heath means a tree-free habitat dominated by dwarf shrubs mostly such as *Calluna vulgaris, Genista spp*. and *Empetrum nigrum*. Dwarf shrubs are woody plants, but they do not grow higher than about one meter. Dry sandy heaths have the ability to develop into a pioneer wooded area very quick and lose their open character. Therefore, today, most of these habitats, by the lack of sufficient management, are threatened by afforestation. In the long run, without further human influence, mixed forests of predominantly pine, oak and beech would replace the currently open sandy habitats (SandAchse Franken 2004).

Besides the categories in the Interpretation Manual of European Union Habitats, there are some other valuable habitat types, however, they do not receive a place in the classification. These are agrarian sand field or sandy agricultural field and sandy ruderal corridors. Due to the increasingly intensified agriculture, the agrarian sand field plant communities are almost completely pushed back and can only exist on the edge of cultivated fields as sandy ruderal corridors (SandAchse Franken 2004).

FIG. 7: *Salvia pratensis is a character species of xeric, lime-influenced grasslands; orchard at Lake Balaton, Hungary (photo by the author, 02.08.2017)*

Sandy habitats are livelier than they might seem. Every sandy habitat type has different benefits and give home to different specialist species. Moreover, how much the life of these sand-living plants and animals are dependent on one another is can be shown through an example of a symbiosis. One of the most dominant butterfly species you can find in the sandy soils of South Sweden is the *Maculinea arion* (Large Blue). This blue butterfly has a special connection to a plant species of *Thymus serpyllum* (Breckland thyme) and an ant species, *Myrmica sabuleti*. The story starts with that the butterfly lays its eggs in the flowers of the thyme. After a short time, the larvae finds its way down onto the ground, where it meets the ants. These ants are fooled by the look of the larvae, thinking that it is one of their own offspring. Therefore, the ants take the larvae into their ant nest. However, the butterfly larvae, instead of being thankful, grows by eating the real ant larvae around itself. Then it hibernates and pupates in the nest until it hatches and flies out as another Large Blue (Länsstyrelsen 2018).

Another example is about no unique "harmony" but to demonstrate the vulnerability of sandy habitats. The sand dunes of Oregon are one of the biggest in the United States and a big attraction to visitors. Unfortunately also to the *Ammophila arenaria* (European beach grass). In the early 1900s, big masses of grasses such as the European beach grass, were planted along the West coast of the United States. The reason was to stabilize sandy coastlines, protect roads and the people living on the coast (in a similar way how it happened in Europe). The European beach grass was proved to be successful in Europe with its large scale plantings so why not introduce it elsewhere too (Siuslaw National Forest 2019)? It thrived in its new surrounding and the people reached their goal, it made the sand's movement slow down and eventually much of the motion has stopped. However, the sand therefore stuck on the beach and piled up as a large fore dune along the shore. The environment behind the dune was a very favorable condition for plants (Save the Oregon dunes 2019). Just 50 years later, due to the efficient spreading of *Ammophila arenaria*, the open sand completely disappeared, leaving a dense carpet of vegetation behind. The European beach grass quickly took over the sand and threw the ecosystem out of balance so that nowadays, the lack of open sand leaves numerous plants and animals species, in struggle to stay alive. Since professionals realized the biodiversity loss and the aggressively spreading nature of the species, land managers are exploring the best ways to control *Ammophila arenaria* and to reverse the process. They work with measures from hand-pulling through bulldozing but also spraying herbicides. Nature conservationists are trying to bring the sand into motion again. As I mentioned above, the plover species lay their eggs and forage on the beaches, for example, *Charadrius alexandrinus nivosus*, the western snowy plover in the Oregon dunes. They need a dry environment with open sand. As the beach grass is invading their home, plovers lose nesting possibilities and the ability to hide in the sand (Siuslaw National Forest 2019).



Schematic overview of the developmental stages of sandy habitats

FIG. 8: *The habitats of inland sandy areas based on the table in the document of SandAchse Franken (2004)*

THE CULTURAL LANDSCAPE

WHERE GRAZING AND CULTIVATION HAPPEN

Historical descriptions of the Southern sandy areas of Sweden often miss to mention the beauty of the sandy heaths, farmlands and the coastline's pleasure for people and just refer to the past as a battle against drift sand (Länsstyrelsen 2018).

It is true that once these coastal areas had been wide and the sand whirled around on the open pasture. However, before 3000 BC, eastern Scania was mainly covered by forest. From around 3000 BC on, coppicing of the forests started opening up the landscape (Ödman & Olsson 2014), the first sandy areas had become under cultivation and grazing animals also started to roam around in the sand. Through farming, grazing and exploitation of the woodlands, the forests of the coastal sandy region, have begun to disappear piece by piece. The landscape was transformed into having a more and more open character. And even though the sandy ground was broken for cultivation, due to the low amount of nutrition, the soil was usually exhausted after a couple of years so the fields were frequently rotated (Länsstyrelsen 2018). This guaranteed the regularity of small disturbances and small-scale successions, important for a diverse plant community (Ödman & Olsson 2014). Other activities that kept the sand open (and created newer patched of exposed sand by disturbing the vegetation) was caused by residents in the vicinity of the sandy outfields, who regularly crossed the sand and travelled over or used the dunes for reasons such as transporting goods, shepherding grazing animals, tree felling, collection of wood and so on.

LINNÉ'S DISCOVERY AND THE IMPLEMENTATION

Carl von Linné on his journey to southern Sweden reports about the rich blossoming flora of the drift sands. He describes some wild flowers like *Thymus serpyllum, Helichrysum arenarium* and *Dianthus arenarius* that thrives on the open sandy soils. They even like it in the tracks of the wheels on the sandy paths (Länsstyrelsen 2018). Based on his observations, we can assume that xeric calcareous grasslands occupied an extensive area in eastern Scania in the 18th century (Ödman & Olsson 2014).

However, as problems of the sand drifts, like the moving dunes or sand blasts had been already a topic since the late 16th century, Linné also looked at plants with the angle of this issue. He observed that some plants have the qualities of preventing sand from being blown away. Some plants like *Ammophila arenaria, Carex arenaria, Avena strigosa* and *Leymus arenarius* grow an extreme root system deep down the terrain to ground themselves in the harsh conditions. After discovering this ability, he made

some suggestions on binding the whirling sand by building sand breaks on a large scale and populate it with plants that could be competent for this task such as the ones mentioned above (Länsstyrelsen 2018). In the meantime, open sandy areas had other growing threats too. The spread of agriculture and the increasing transformation of grassland into arable fields was only one factor. The thing that made the situation worse was the intensity of it. With fertilization of crops nutrients leached into ground. Moreover, with the intensification, the rotation of fields also became more frequent and fallow fields did not have time to recover. These made the contribution to the shrinking amount of sandy grassland in the nineteen hundreds (Berglund et al. 1991).

Not much later, as the situation of escaping sand was widely considered serious, the Swedish state ordered to control it and an act came into force. In 1826 activities to disturb or travel across drift sand field were all prohibited. No more firewood gathering, no more free grazing or good transportation across the fields were allowed. A great amount of open sandy soils that were not occupied by arable land, were stabilized with large-scale plantings of *Leymus arenarius* and *Ammophila arenaria (Fig. 9*) but also woody species were used such as *Pinus sylvestris* or *Pinus mugo* throughout the 18th and 19th century. A precious aim was to turn "useless" sand into productive land. Vast areas of Halland and Scania counties and Öland were converted into productive woodland stands. Lean sand heathlands disappeared piece by piece and were replaced by fertilized and irrigated farmlands (Länsstyrelsen 2018).

FIG. 9: *The re-vegetation of sand dunes in Ullahau, Foarö, photo was taken in 1907; Swedish University of Agricultural Sciences Historical forest images (Länsstyrelsen 2018)*

TOURISM AND PROTECTION

In 1936, the state declared that the battle against drift sand has been a

successful move. However, for safety reasons they announced the planted forests to become under protection. Also at this time, seaside tourism began to flourish. Country houses and cottages started occupying land and expanding along the water, more and more people were interested in spending leisure time in nature and visited destinations along the sea. Therefore, towards the second half of the 20th century, more and more sandy areas along the sea got the title of being nature reserves. Mainly to boost outdoor recreation and to limit development. But also, these nature reserves begun to serve as a tool to educate people and therefore for the sake of preserving natural habitats (e.g.: drift sand fields as a geological phenomenon) (Länsstyrelsen 2018).

Grassland ecosystems maintained by grazing and mowing activities still existed here and there, but they were limited to an ever shrinking area. These management methods are critical for the survival and establishment of the grassland species. Furthermore, regulated fires were intentionally prevented in this period too. The influence of grazing and coppicing of trees also diminished along with the usage of new fodder cultivation methods. In the middle of the 20th century these management techniques had a little impact and were not significant as landscape-forming processes. Since fire, browsing or coppicing was not of high importance in this period, secondary succession, such as recoveries after fire, or after a disturbance, decreased. The consequences of these led to a reduced biological diversity (Berglund et al. 1991).

With the expansion of vacation houses, huts and bathing houses the sand by the sea was aimed to be even more regulated to not cause a problem for holiday-makers. These newly formed nature reserves got strict maintenance plans and regulations. To conserve re-vegetated, fixed dunes and keep sand under control and not be blown away, they did not allow people to walk on them. Pedestrian traffic was channeled along trails and boardwalks and any new patches of bare sand were capped using seaweed or brushwood (e.g. *Calluna sp*.) (Länsstyrelsen 2018).

However, the millennial, the early years of the 2000s, did not bring any good results for these re-vegetated areas. Neither the effects of nitrogen precipitation and acidification accelerated the overgrowth of the decade-old aggressively spreading flora- the pine stands and the grass plantings. Having realized this, nature conservationists started putting a bigger emphasis on changing the situation. Maybe the aim of protecting nature has to receive another purpose? Focusing more on the situation, researchers suddenly recognized the exceptional natural value that exposed sandy soils carry. Out of the blue, not only the planted vegetation was the only issue anymore. It turned out, that among other species, *Anthus campestris* (tawny pipit) a bird breeding in open sandy habitats, has drifted into the verge of extinction. The concerned situation came to a real turn when Sweden become part of the European Union in 1995 (European Union 2019). As a member of the EU, countries with territories of the Natura 2000 network are obligated to protect valuable natural assets and endangered species. Therefore, Sweden had to begin taking actions and it re-evaluated the importance of sandy soils by starting action programs and initiatives (Länsstyrelsen 2018).

SOME TREASURES LEFT

Simultaneously, it became known that some spots of viable populations of rare sandy habitats still exist over the country. Drift sand fields and sand dunes were regarded for a long time as unproductive and problematic areas and sand was ordered to be kept under some kind of control. However, at some places the legislation of the Swedish state did not apply. Since the army has always been in need of open land for their military practices and inland sand heaths were never considered as profitable areas for cultivation they have acquired vast areas in the South of the country (Länsstyrelsen 2018). Here, as in other examples in Germany too, the threatening problems of the 19th and 20th century such as fertilization, dismantling and overbuilding did not take place (SandAchse Franken 2015). The usage of the area and a constant disturbance of the soil by stepping, driving and trampling resulted in a permanently high percentage of bare sand patches. And this gave refuge to a great species diversity having been preserved in inland sandy areas, somewhat how the South Swedish countryside could look before the 19th century. These military training grounds in Scania and Halland counties are the most flora and fauna-wise richest sandy habitats in the country (Länsstyrelsen 2018).

OUTSIDE OF SWEDEN

The notion of sand drifts had also been known in Germany, the UK and the Netherlands. Researches show that the dry sandy grasslands evolved thanks to the expansion of arable fields and intensive livestock grazing. These activities turned over soil therefore exposed bare sand, and sand drifts. Nowadays, just like in Sweden, these sandy grasslands do not receive the treatment they need. The areas' land use are changing, becoming afforested, abandoned or exploited (Ödman & Olsson 2014).

ORGANIZATIONS FOR SAND

Sand Life

Sand Life is a project that has focused on re-creating the once abundant open sandy soils and its flora and fauna but also to promote the survival of the species-rich habitats. At the same time, these efforts have also restored environments with the purpose of making them accessible to the general public so that people can experience these rare settings. Sand Life's work started in 2012 and ended in 2018, however, management will continue in the future as well. Over that six years an extensive amount of measures had been implemented across Skåne, Halland and Öland (Länsstyrelsen 2018). Sandlife's buzzword is to "stir in the sand" (Sand Life 2018), therefore, their restoration tasks "included everything from clearing trees and bushes to creating patches of exposed sand, burning unwanted vegetation and reintroducing grazing"(- Länsstyrelsen 2018). The areas where measures had been carried out have been under monitoring- how plant animal life,

have been affected and how the environments developed. The follow-up surveys and maps proved a success in reversing the trend of overgrowth and creating more open sandy habitats in the Sand Life project areas. The aim of the project was to raise awareness and understanding of sandy soils, to open a dialogue and to educate, inform people about the fascinating sandy habitats (outdoor museums, conferences, workshops) (Länsstyrelsen 2018).

SandAchse Franken

"Without immediate relief, the sand habitats in our landscape are on the verge of disappearance. More than 95 percent are already lost and the remaining sandy areas are also under threat" (- SandAchse Franken 2015). The SandAchse Franken is an organization that aims to protect and preserve the remaining sand habitats in Franken, Bavaria. Moreover, they also work on developing a biotope network in Bavaria, Germany. SandAchse Franken was founded by the Federal Nature Protection in Bavaria (BN), the German Association for Landscape Conservation (DVL) and the State Federation for Bird Protection in Bavaria (LBV) as well as seven districts and five cities of the federal state. Between 2000 and 2014 their association purchased valuable sandy habitats of many hectares in order to protect valuable habitats. In 2014, landscaping measures were carried out in the project area on at least 399 ha, mostly by landscaping associations. Lean grasslands are grazed or mowed by sheep or wild horses, emerging woods are cut back, occasionally the nitrogen-rich topsoil is deported and distributed to farmers for their other fields. They also developed their own seed mixture called "SandAchse Franken" with Rieger-Hofmann GmbH (see later) thus new sandy grasslands on sandy fields can be created. Besides the actual physical work, a significant part of their work is about educating and involving people into projects, especially pupils. Getting them acquainted with the topic of sandy habitats by games and fun exercises (SandAchse Franken 2015).

RESTORATION AND MANAGEMENT

SUCCESSION

The essay has touched the topic of succession already in the Ecology chapter. In order to talk about management and restoration, the concept of succession needs to be a little more unfolded.

Dunnett (2014) classifies different changes that happen over certain periods of time in dynamic plant communities. First, there is the phonological change, which is a change in a vegetation unit and it is about how this unit develops over a single growing season or year. Then there are fluctuations or cycles that are changes in the species composition according to abundance, performance or visual presence, or the overall biomass of the plant community year by year. However, the overall character of the vegetation

remains relatively constant (for example an area that had been a grassland still remains a grassland according to the species pool). Eventually, the third change he defines is the successional change that determines the long-term, directional changes in species composition and therefore the vegetation character (so the grassland changes to woodland) (Dunnett 2014). Succession in the plant community is influenced by competition, stress, and disturbance (Grime 1977). It alters the vegetation for the starting point and aims to reach to a final stage where the factors of competition, stress and disturbance can settle down and come to a balance on the site. However, if you want to have something other than a climax vegetation, you need maintenance.

As Dunnett (2014) says, succession is vital part and a base of landscape design and maintenance. While restoration's main point is to bring back a previous, more advantageous state of a natural area (Länsstyrelsen 2018), maintenance equals to activities done for manipulating, altering and guiding the changes of the area (Dunnett 2014).

THE NOTION OF DISTURBANCE

"The outcome of succession can be manipulated by altering the intensity of stress and disturbance operating on the system" (Dunnett 2014, p. 112). While stress has been mentioned before, disturbance is when the biomass is partially or completely destroyed. It arises from activities of herbivores (grazing), pathogens (diseases, pest), seasonal fluctuations, from natural catastrophes such as wind damage, frost, desiccation, flood, soil erosion and fire but also human activities (trampling, mowing, and plowing) play a role. In areas of high disturbance, such as arable fields, the ratio of living to dead plant material depend upon the balance between the processes of production and destruction (Grime 1977).

Regular disturbance of the soil provides constant access to bare sand. Disturbance also sets up a dynamic system of changes, growth, various stages of vegetation development which is also important for the species diversity (*Fig. 10*) (Länsstyrelsen 2018). Today, most of the movements in the sand are due to human activities (anthropogenic) and less to natural processes (SandAchse Franken 2004). The role of natural processes are at some places nearly eliminated and therefore it is not enough to achieve a regular maintenance of open soil. This is the reason, why a little human help of disturbance can be important. It can be done in several ways and each area has a different condition (degree of overgrowth, the thickness of biomass, the lime content of the sand, the level of the water table among others) and therefore the maintenance has to be tailored according to these factors and what is desired to be achieved (Länsstyrelsen 2018).

FIG. 10: *Disturbed grassland by horse-riding activities and the settlement of some flowering species on the edge, Galium verum in the picture; Habo Ljung, Sweden (photo by the author, 24.08.2017)*

SUCCESSION-BASED MODEL

Nigel Dunnett (2014) explains the concept of a succession-based management model (*Fig. 11*) developed by James O. Luken. It builts upon the process of succession and used as a basis for the creative management of designed urban vegetation. It has three components: designed disturbance, controlled colonization and controlled species performance. Designed disturbance is a human-induced disturbance and it comprises techniques that are renewing the vegetation (e.g. cutting, coppicing), creating ground for new succession or restoring the ground (e.g. top-soiling, soil inversion), set back (e.g. burning, cultivation) or slow down (e.g. herbicide spraying) directional changes, or simply manage cyclical changes (e.g. cutting) in the plant community. “Most cases it involves the removal of competition from existing vegetation and probably the creation of patches or areas of bare ground for seeding or planting” (- Dunnett 2014, p. 113). Controlled colonization is when you manipulate the composition of the vegetation. You bring in new species or alter the plant species’ availability. This can happen by directly sowing, planting species or encourage certain desirable species to establish or thrive even more. While controlled species performance is more about stirring the established disturbance and stress factors and methods by applying different operations on a regular basis (Dunnett 2014).

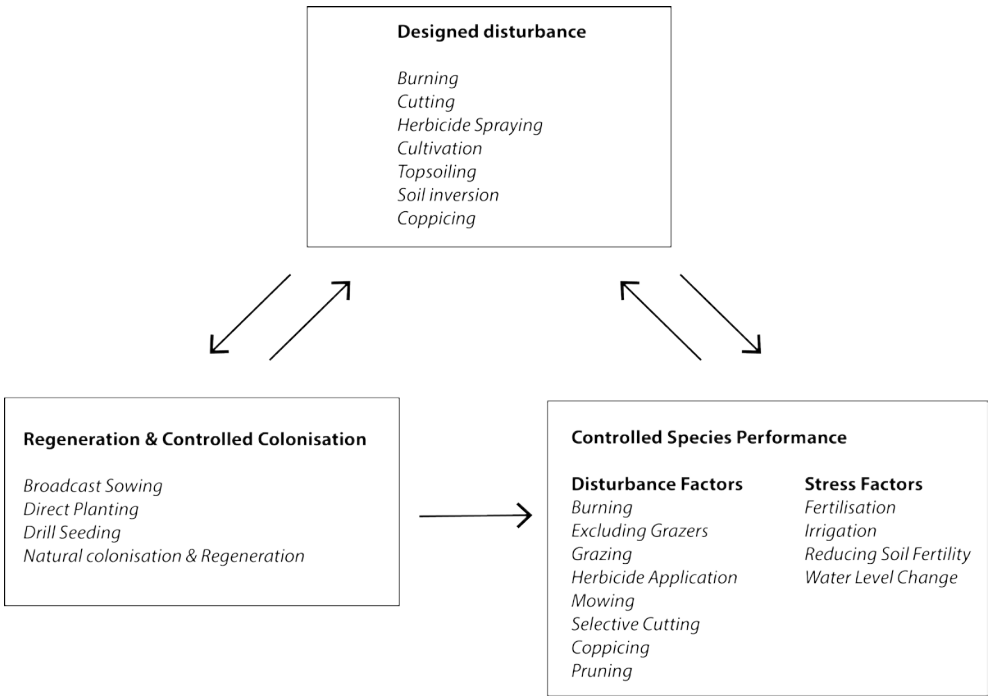


FIG. 11: *Succession-based management model based on the figure in Dunnett & Hitchmough (2014)*

RESTORATION AND MANAGEMENT METHODS

Hitchmough (Hitchmough 2014) categorizes management methods as selective management technique (e.g. weeding) and non-selective techniques applied to the plant community as a unit. These methods are originated from nature conservation practice and lifted into the management of naturalistic herbaceous plant communities, applied for example by Nigel Dunnett and James Hitchmough. There is a great need for using these methods because are "often relatively inexpensive to undertake and, more importantly, because they are applied to the vegetation as a whole, it is not necessary for practitioners to be able to distinguish between desirable and undesirable species" (Hitchmough 2014, p. 175).

Cutting

The non-selective management methods aim for the defoliation of the vegetation at critical times of the year. The most common way to achieve this is cutting. This is usually correlated with meadow management. It is mostly recommended to mow the meadows in summer and autumn. Cutting is important to slow down the competitive species and give growing space for the slower-growing species. For example from the early cut, forbs like low-growing rosette formers (e.g.: *Plantago spp.*) and wintergreens can benefit. Based on the composition of species in the meadow and the target on which species one wants to promote the cutting has to be set (Hitchmough 2014).

Burning

Another technique is burning, which is like a thorough cleaning procedure. When talking about burning it is important to note that the point in using fire is to care for the vegetation. It can be dangerous if not prepared carefully, however, when setting up the adequate control measures, it is a very useful tool (Hitchmough 2014). When a sandy grassland area is overgrown with grass and brushwood and the vegetation becomes thicker, the amount of dead plant mass increases and therefore the nutrient level as well. In this case, to help bring back the former, less fertile state, burning is the fastest and most effective way of eliminating unnecessary vegetation (*Fig. 12*). Compared to cutting, burning has some further benefits (Länsstyrelsen 2018). It darkens the soil's surface therefore that gets heated up faster and helps the germination of many species. Fire eliminates leaf litter and other debris, kills some invertebrates, seeds and annual weeds too (Hitchmough 2014). It creates space and environment for flowering plants. Although you need to review and take care of several factors, such as firebreaks, dry weather and wind to execute a safe burn, it gives better result, costs less and saves time than machinery work (Länsstyrelsen 2018). Prescribed burning is recommended between mid-March and mid-April. At this time, early in the season the foliage and species will still have time to recover. Species like *Linium narbonense* and *Origanum vulgare* among many other evergreen perennials tolerate this practice and recover quickly. This method is both a tool for habitat restoration but also can be used for regular maintenance. The practice is used in Central and Eastern Europe for steppe-like and dry meadow communities but in North America even some restored prairies in urban areas are managed by burning (Hitchmough 2014).

FIG. 12: *Burnt heather (in the front) in Drakamölla nature reserve (photo by the author, 17.03.2017)*

Herbicides

Herbicides in contrast to for instance cutting or burning do not only defoliate fully grown plants but cause harm or eliminate them. However, this is usually not done on a regular base but applied occasionally. Spraying is advised to be used when problems cannot be satisfactorily solved by other management methods since due to its toxicity, it is regarded to lie outside of sustainable practice (Hitchmough 2014). It is often for killing invasive, intensely growing plants that have aggressive root and rhizome systems and therefore probably the most efficient way to clear the undesired vegetation. Even though Roy Diblik (acknowledged American plant designer, owner of Prairie Nursery) occasionally in a garden's lifetime, he uses glyphosate, when eliminating unwanted vegetation, before the construction of new plantings. However, he is not promoting the chemical and advices to keep it to the minimum (Diblik 2014).

Machine driven soil disturbance

Soil disturbance has two major types. The excavation of the topmost layer is called plowing. This loses up and inverts the upper layer of the soil. A deep excavation is when you work with a bigger landmass because there is a lot more organic material that has to be removed. This unwanted layer can be transported away, burnt or piled up into heaps that create special dry micro-living environments. Or you simply invert the soil. It goes in a way that you invert soil and so that a clean, nutrient-poor sand is lifted up to the surface from lower layers. Then the topsoil you wanted to get rid of, goes back under the newly brought not fertile sub-layer. For this method you need a study and sampling of the existing soil conditions first how much and how the excavation should be conducted (Länsstyrelsen 2018).

FIG. 13: *Plowing activity to open up the soil in Drakamölla nature reserve (photo by the author, 17.03.2017)*

FIG. 14: *Disturbed soil by means of scraping of the topsoil. Here you can already observe the settlement of new species, e.g. Sedum spp. in Vitemölla nature reserve, Sweden (photo by the author, 23.06.2017)*

When you only disturb the topmost soil layer, there are two common methods used, described by Schnoor & Olsson (2010). Rotavation crushes the grass and mixes the topsoil layer approximately in a 10 cm depth. Plowing works within a 30 depth range and overturns the soil so that it leaves no visible clumps of grass (*Fig. 13*). In their study they researched what method would be feasible for the restoration of a calcareous grassland. Their result showed that both disturbance types had a positive influence in the increase of number of species and both maintenance method were optimal for the site. While rotavation produced a more heterogeneous vegetation, plowing with more soil disturbed had a patchier result. Since these methods set back the succession to an earlier stage or create new ground for succession (succession-based model- designed disturbance (Dunnett 2014)) species that are considered pioneers/ early colonizers can be associated with these kind of disturbance methods. These methods also transport chalk or other subsoil from lower soil layers to the top therefore promoting a development of a less fertile plant community. Interestingly, "rotavation which resembles old disturbance forms i. e. when plowing devices were less powerful than today was the method that most favored plant diversity" (Schnoor & Olsson 2010, p. 718). There is also a way to simply remove the topsoil (*Fig. 14*). It is a good way when you would like to restore a site or establish something new. Topsoil removal leads to a drastic reduction of organic matter. Depending on how much topsoil you remove, for example 30 or 50 centimeter will have an impact on the result, the growing vegetation (Hölzel & Otte 2003).

Direct human-made disturbance

When the point is to create open sandy areas, the Sand Life Organization (Länsstyrelsen 2018) names a basic rule of thumb as an optimal condition for open sandy habitats. It says that at least one-third of the area that is part of the site should be opened up.

According to Sand Life, every action that helps to create bare sand is important- and there are some unusual ways to do this. One example is when one of the world's biggest orienteering competitions, O-ringen, was held in a Swedish nature reserve (Friseboda) in summer 2014. On that warm and dry day 20,000 runners trampled and helped to stir up the sand to fight succession (Länsstyrelsen 2018). Another outdoor activity which is widely practiced, is to allow OHVs (Off-Highway Vehicles) or motorcycles (*Fig. 15*) onto sand dunes or sandy areas. Besides that they are an enjoyable activity to many, are used as a tool against having the vegetation grown together (Oregon Dunes 2015). And another joyful way to promote open sand is allowing sand sledding how they do it at White Sands National Monument in New Mexico as a management method (White Sands 2018).

FIG. 15: *The pattern of cross-motor activities at Jüterbog nature reserve, Germany (photo by the author, 17.03.2019)*

Grazing

Many grasslands, heaths and sand habitats have traditionally been grazed and can therefore best be preserved if this action is maintained. Alternative forms of use, for example with regard to the grazing animal, the time of grazing and the intensity of use, are usually associated with changes in the species spectrum or the frequency of individual species (Zahn 2014). Ödman & Olsson (2014) make a difference between grazing types when they categorize maintenance/ disturbance methods. In the sites they studied, these sorts of browsing occur: ungulate grazing (e.g.: sheep, goat), horse

grazing and wild grazers (e.g. rabbits) (Ödman & Olsson 2014). For grazing of dry open land sheep, cattle, yaks, donkeys, horses, goats, pigs, llamas or alpacas are recommended. For a preservative management, a short-term grazing with high stock density makes sense, while at productive and ruderal areas grazing should rather take place several times in a year with long breaks in-between. In nitrogen-rich sand habitats a longer and intensive browsing is important. Grazing schedules are beneficial for bigger areas also to keep track of the fauna (Zahn 2014).

With sheep, grazing can be spatially and time-wise uneven, in order to keep a diverse species spectrum since a continuous browsing would result in lower diversity. Short time grazing in an interval of more than 6 weeks, if really poor meadows or open sandy spots are desired. The grazing should happen for one or just a few days with high amount of animals. It can be repeated 2 or 3 times to disturb the ground and free up sand (However, Dr. Andreas Zehm's personal experience suggest that sheep grazing tends to lead to a closed sod and not to a reactivation of open sands). Usually April, May, June, perhaps July and autumn is an option to prevent organic material to cover the ground. Around 10-40% of the area should not be grazed in a year. Sheep grazing is very selective and it is widely used in nature conservation. In the first few days sheep target especially nitrogen-rich plants (ruderal species) (Zahn 2014). Other plant patterns occur when some species are a not palatable to animals, such as Euphorbia rigida is not eaten by goats in Sicily (Hitchmough 2017). A similar situation is shown in *Fig. 17*, where bisons do not graze *Euphorbia cyparissias*.

FIG. 16: *Grazed landscape by cattles – the difference is visible between the landscapes on the two sides of the stone wall; Öland, Sweden (photo by the author, 20.05.2017)*

Complementary grazing by goats is recommended when woody plants have to be kept at bay but these animals not sufficient alone. An interesting fact that Zahn (2014) notes is that sheep and goats are recommended to be kept

outside of highly valuable nature protection areas at night. At this time of the day they have an increased amount of feces production- and having them out of the grazed area keeps it nutrient-poor (Zahn 2014).

Cattle, horses and goats can be a cheap alternative for big areas (Fig. 16), however the vegetation will change (no “preservative” grazing). At small areas probably a loss of flora will happen. The suitability of cattle for the care of sand habitats is not yet sufficiently clarified, but there are some documented cases where a sandy grassland vegetation was preserved by grazing (2x one-week) of young cattle. Similar results with all year around grazing are seen with przewalski horses at Tennenloher Forst in Germany where also goats are used for “after-grazing”. As well as at Oraninenbaumer heide (*Fig. 18*) where cattle and horses are used together for grazing all year around. At these large areas it is expected that only summer grazing would be not enough to keep only small-growing and less competing plants. Also the all year round grazing has a good impact on insects and bird species (Zahn 2014).

FIG. 17: *Flowering Euphorbia cyparissias at the territory of the bisons, which is left ungrazed; Őrség National Park, Hungary (own photo, 22.04.2019)*

Islands with woody plants are important and should be protected. Locally higher grazed areas could be good for specialist species and warm-loving species. Those areas could be created by higher intensity of grazing in spring and during the year or by installing salt licking stones or water supplier or mobile sheds at places that should be more frequented (Zahn 2014).

FIG. 18: *Horse-grazing activity and impact on the vegetation at Oranierbaumer Heide, Germany (own photo, 22.03.2019)*

Nature conservation with donkeys? They have actually proved to be quite a helpful tool, for high-value dry grasslands in particular. However, their "service" is nearly unknown in landscape management. Their kind of selective grazing is quite effective in restoring and preserving dry grassland habitats. With their feeding and the disturbance patterns (trampling, wallows) they create a desirable damage, open up the ground and eat dominant grass species, (like *Calamagrostis epigejos*). Horses are also adapted to dryness, however, donkeys reduce woody plants more efficiently than horses or cattle would do and promote small growing plants. While a flock of sheep for a certain area could be of 100 animals, you only need 1-2 donkeys for the same size (Zehm & Fölling & Reifenrath 2015). However, on vast areas they are often used only supplementary since it is rarely possible to bring a larger herd of donkeys for grazing. The donkeys are used so far mainly in the after-grazing part. A combination with sheep grazing is optimal since even after highly grazed areas by sheep rural grasses and rhizomes still remain. This system is also feasible for mono-dominant *Calamagrostis epigejos* grasslands that could be turned into open and species rich sand vegetation (Zahn 2014).

According to Zahn (2014) the aim with grazing should be to keep the diversity of landscape types without promoting the initial or pioneer state. And keeping this in mind and following this principle results can be reached that sandy meadows get richer in herbs and flowers already in the second year after the introduction of grazing animals to the site.

To lead grazing, there are several tools to consider, as it was mentioned above, you can influence browsing animals by placing out mineral stones or some sort of bait to shepherd them. Moreover, sometimes it is also beneficial not only to bring them to a certain area but also define places where they

cannot enter. Fencing is an effective action where grazing happens or to actually prevent grazing and exclude them from some spots. With some enclosures of areas, with “non-grazing”, you can save flowering species that do not tolerate browsing, and with that you can create areas with different characteristic. In *Fig. 19* placed out by the Sand Life project the aim was to support the bloom of *Anthericum liliago* by closing down an plot from animals (Länsstyrelsen 2018).

FIG. 19: *Fenced-in area to support the flowering of sand lily (Anthericum liliago) in Drakamöllan nature reserve (own photo, 19.03.2017)*

APPROACHES AND OUTCOMES

An interesting approach to restoration and management techniques is to call them as different sort of “filters” as Halassy et al. (2016) do in their research. These interventions so-called filter the vegetation, in other words the application or treatments on units of areas end up with different results. In their research they talk about three methods: the dispersal filter (seeding), the abiotic filter (carbon amendment to lower nitrogen availability) and the biotic filter (mowing) (Halassy et al. 2016). “The aim of restoration interventions is the manipulation of filters to achieve a restoration target.” (Halassy et al. 2016, p. 765)

However, it is always important to note that “similar ecological restoration techniques, when applied in different contexts, do not lead to uniform outcomes” (Grman & Bassett & Brudvig 2013). Instead, “restoration outcomes are contingent on factors such as landscape context, historical land uses, weather events, and the chance arrival of organisms” (Matthews et al. 2017, p. 972)
It goes the same way when we talk about designed but naturalistic herbaceous vegetation. The goal of the management is to achieve a satisfactory balance between maintenance costs and the appearance and persistence of the vegetation. The managers of the naturalistic vegetation need to recognize that some plants will succeed and thrive, some will fail, and some of the successful will take over territories (by seeding or vegetative means) vacated by the vanished ones. You have to accept change

and the vegetation as a whole, it is not about single species. “Management becomes the art of defining the limits to acceptable change. Judgements on this will depend not just on the values of the manager but also on their perception of how site users feel about the vegetation, which, in return, will be dependent upon the site’s context and role” (Hitchmough 2014, p. 173).

The different approaches have different impacts, and change the amount of biomass in different ways. The certain management approach is strongly connected to the biodiversity and the evolution of the area.
Fig. 20 is based on the research and the author’s own experience of the different management methods mentioned in this chapter and provides a summary for an easier understanding. It defines the method by showing their influence on the soil and the vegetation. Also, how often the management is done approximately and how much effort is needed for their execution.

EXAMPLE OF RESTORATION PROJECTS

Since the early 1990s and 2000s, numerous successful sand restoration projects have taken place. They were initiated to partly conserve disappearing species-rich habitats, partly as compensation projects for development or even as a tool to educate people. Some, in Bavaria, Germany were initiated under the lead of the SandAchse Franken organization.

One project was for example at the highway exit- intersection to North Bavaria. A sandy grassland was created as a compensation measure for the development of the infrastructure. Sandy grass dunes were created at the embankments of the highway and at the interchange of two highways of Nürnberg and Schwabach. Another interesting instance is the headquarters of the Deutsche Telekom in Bamberg. Here the 2 hectares area around the premises was turned into a sandy habitat. A regular management includes plowing of the sandy grasslands and visitor information is also provided by information boards of the significance and management of the area for the public (SandAchse Franken 2015).

For the richness of sandy habitats the instance of Baden airpark is a good example. A former NATO airbase was planned to be turned into a regional airport and industrial park in Söllingen, Southwest Germany. Since the establishment of these infrastructure caused damage to the vegetation, a restoration project had to be initiated. The restoration was executed by a German planning and landscape architecture office Bresch Henne Mühlinghaus. The process of the restoration of the species-rich grassland and heath at Baden Airpark started with 7 years of monitoring. Within this period and within the project area they detected numerous species that are worthy of protection. 34 endangered species of plants and more than 400 endangered animal species were noted. Furthermore, a very special plant association called Polygalo-Nardetum was found too. To compensate for the loss of areas and restore the damaged sites the project at Söllingen airport tried several kind of restoration and management techniques. Their aim was to bring back a species-rich grassland and heath after the damage of converting an airbase to the regional airport. They began with soil studies

and ecological site evaluation such as defining the type of predominant vegetation, species richness, abundance of rare species, vegetation coverage and height. And then carried out the restoration. First the soil preparation happened: they moved the humus-rich and fertile topsoil from the site. At some other places, close to buildings and roads sand was dispersed on top to turn the soil content less poor. Then the different vegetation-recovering methods started. One way was hay mulching. After the recreation of a vegetation map the best vegetation types were localized. After cutting the vegetation, the fresh hay was taken and used from these sites. The mowing happened early morning because in this way the morning dew ensured that seeds would stick to the transported hay. The hay was then spread onto the chosen site and mixed more than one time to increase the fallout of the seeds. In this way they had a bigger chance that the seed bank moved onto the site, could settle and sprout. Another method was topsoil transportation. Here, not only the vegetative parts of the plants were brought but also the nutrient-poor soil with its diaspora bank. A third way to restore habitats was the transportation of sod rolls. This actually turned out to be the most successful implementation while the upper soil layer of 2-4 cm with vegetation was one to one taken with the least disturbance and rolled out onto the new site (Bresch Henne Mühlinghaus 2006).

LEFTOVER PLACES

It is also essential to work with the sandy areas that perhaps get less attention, found along the edges of roads, embankments and developed areas (Länsstyrelsen 2018). As Peter Korn mentions, some plant species can even benefit new man-made surroundings. “Roadsides with their gravelly well-drained environments, often create very good growing conditions for these specialized plants, and may aid their spread” (Korn, 2013, p. 174). These environments tend to be even more species-rich then what is around. This could be because “today’s maintenance of these roadsides is often similar enough to natural grazing to meet the native meadow plant’s needs” (Korn, 2013, p. 174). However, roadsides cannot function as real biotopes, but still they can serve as stepping stones (SandAchse Franken 2015) or corridors between larger areas of sandy soils with high natural values and make it possible for vegetation to spread around (Länsstyrelsen 2018). These leftover places are often nothing, people are amazed of, no one really cares about them. They just exist and are tolerated where they are. However, they are actually a good example for urban low maintenance spaces where specialist can thrive. Perhaps this could be a starting point to talk about and think about a design for urban sandy habitats.

scale: * (little)-***** (much)

method	selectiv/ non-selective	effort			loss of biomass	soil disturbance	frequency	what do you filter?
		organisation	educated staff	machinery				reduce or eliminate/want to have
trampling	none	*	*	-	**	***	every year, many times	ruderal and dominant plant species, overgrown vegetation/ stress tolerators
grazing	partly selective, can be influenced	***	**	*	****	*(*)	every year, continuously or more times	woody and herbaceous dominant plant species/ less biomass
cutting trees	seletive	*****	**	*(*)	**	*	every year	woody species/ more openness
mowing	none	***	**	**	***	-	every year, once or twice	overgrowth of competitive species/ less biomass, stress
burning	none	*****	*****	*	*****	**	2-5 years or every spring	unnecessary vegetation, annual weeds/
plowing	none	**	**	*****	*****	****	depends on	dominant species, fertile plant community/ annuals, stress tolerators
rotavation	none	**	**	****	**	***	depends on	dominant species, fertile plant community/ specialists, stress
excavation/removal of topsoil layer	none	***	****	*****	*****	*****	restoration? Every 20 year?	organic material
herbicides	none	*****	***	**	*****	-	once in a lifetime	agressive plants, but kills everything/ establishment of new vegetation

FIG. 20: *Summary of management methods based on the research and own experience*

SAND AND DESIGN

After taking the ecological approach of sandy habitats, this chapter aims to deal with the design aspects. What are ways to introduce species and why is it important? How can you make a restoration project accepted in an urban area? How can you design a sandy habitat? And what makes a designed area designed?

SPECIES INTRODUCTIONS

In today's modern fragmented landscapes the restoration of species-rich grasslands is often a challenge. These grassy meadows tend to be seed-limited due to their depleted seed bank. Furthermore, they are limited of receiving new species through seed dispersal from other places because of the fragmentation of the landscape. However, the regional biodiversity of a certain landscape can be only conserved with restoration when they use species of local origin in the meadows. When restoring sites, there are some near-natural techniques to introduce desired plant species. These consist of for example seeding of site-specific seed mixtures, fresh seed-containing hay brought to and spread on site (mentioned before), vacuum harvesting, and transfer of turfs or seed-containing soil (mentioned before). According to Kiehl et al. (2010) the most successful result of the establishment of species-rich grasslands are reached when "seeds, seed-containing plant material or soil are spread on bare soil of ex-arable fields after tilling or topsoil removal, or on raw soils." (Kiehl et al. 2010).

Stirring the meadow composition

Meadows are not typically sandy habitats but sandy habitats can also appear as meadows (SandAchse Franken 2004). When it is about the improvement of an area, in general, it is quite a hard work to transform the composition of massively grass-dominated urban meadows in a short time. However, it is much easier to integrate plants into the meadow by management strategy in a longer term. One option is to reduce the grass species by introducing hemi-parasites or the other is to bring in desirable forbs that has not been in the meadow composition before. Hemi-parasites contain genuses such as *Castilleja, Pedicularis* and *Rhinanthus.* With the latter, *Rhinanthus*, you can achieve the best results in terms of biomass reduction since their strategy is to attach to adjacent plants' roots and take over their carbohydrates in order to produce *Rhinanthus* biomass. As this conversion of energy is not efficient at all, the result is that way less *Rhinanthus* is grown compared to how much meadow biomass there would be otherwise. Also, interesting to mention that even though this plant is often known as aiming for attacking grasses, it simply targets every species that finds around itself without being picky. It reduces grasses in a heavily grass dominated meadow, since there, often grasses are its neighbors. But if they need to choose among plant genera, they are likely to attach themselves to nitrogen-fixing plants, like clover first (Hitchmough 2017).

When you try to enrich your meadow with some target species that are absent from the species composition, you need even more patience. Grass-dominant meadows are tough and it is a very competitive environment for most of the forbs. The process of change is expected to be very slow and also a very low chance that sown seeds actually survive, grow and reproduce. Therefore, often nursery-grown potted plants are recommended to use instead (however, still not a guarantee). Forbs that can achieve a greater success are for instance ones that produce a higher biomass (*Geranium spp.)*, have long leafy stalks (*Knautia spp., Centaurea spp., Malva spp.*) or have shade-tolerant evergreen rosettes (*Primula veris, Succisa pratensis*) (Hitchmough 2017).

Seed mixtures

Rieger-Hofmann GmbH deals with European regional native plant communities (Hitchmough 2017). They have mapped 22 source areas in Germany. These 22 seed banks are then remodeled in their eight different production rooms. The conditions in these production rooms resemble to the conditions found naturally. Rieger-Hofmann is famous for selling seed mixtures (of native forbs and native grasses) that are native to each region and main environmental conditions in Germany. They promote the re-creation of natural habitats in urban areas by creating balanced species compositions that thrive as their natural habitat "sisters". For example, they have a seed mixture category called 'Lean and sandy grasslands. This mixture is available for every main region of Germany with alterations in the seed mix according to the specific regional characteristics. They also created an own special seed mixture for the organization "SandAchse Franken" But there are also different mixes for city environments such as for example for road embankments, green roofs or traffic islands (Rieger-Hofmann GmbH).

Seed mixtures can also be generated by simply taking the cut hay from a sandy meadow habitat and transport it to the new site. This was one method used at the restoration project at Baden Airpark that was mentioned earlier. Before you transport hay, you carefully need to choose the origin. According to what plant community you would want to bring to the site you select an area where this vegetation type grows. So did Bresch Henne Mühlinghaus, a German planning office in the restoration project in Darmstadt too. Based on the site conditions of the areas in need of restoration the source materials were brought from different sandy habitats (Bresch Henne Mühlinghaus 2017).

Landscape plugs

Smaller plant size saves time and money, especially at large scale interventions and functional plantings. A good alternative to consider compared to container-grown plants is the use of landscape plugs (Rainer & West 2015). These plants have "the minimum plant size to successfully transition nursery-grown plants into the landscape" (-North Creek Nurseries 2016). These plugs have a different root-leaf ratio than usual. They have long, deep roots and grown in trays of usually thirty or more. The deep roots (thirteen-centimeter-deep root systems) are designed to be planted

directly in the landscape (Rainer & West 2015). They establish quickly due to less soil media in the chambers (these are the cells in the tray) - the roots can quickly make connection with the surrounding soil and due to the deep roots- reach water and nutrients faster. North Creek Nurseries in Pennsylvania, USA is one of the nurseries offering plugs and having much experience in the field. The nursery uses two kind of tray systems with different roots growing aids. The tray chambers have guides that prevent root circling therefore contribute to the quicker establishment at planting as well as less plant damage and losses during the establishment phase (North Creek Nurseries 2016).

Nursery-grown pots

According to European standards, pots are available in specified sizes. The most common standard pots are P 0,5 (9 x 9 x 9,5 cm) and P 1 (11 x 11 x 12 cm) . The pot size depends on the morphology and root system of the plants. As well as the target group of the nursery: private customers or landscapers. Big perennials and grasses are often grown in containers. These are called C2 (2 liter size), C3 (3 liter) and C5 (5 liter) depending on their volume (Bouillon 2013).

DESIGN CONSIDERATIONS

When designing a plant community it is recommended to follow some overall design considerations. After getting acquainted with some methods of how species could be introduced, the upcoming thoughts are essential elements to think of in the design process.

A designed plant community differs from a natural plant community. Designed plant communities are a hybrid, a representation of both horticulture and ecology (Rainer & West 2015). It is because they not only provide ecological functions but their key role is to create meaning and pleasure for people. In urban areas where people are surrounded by so many stimuli, designed plant communities are proven to be more accepted and more desired (Hitchmough 2014). And since human beings are the target of the design, the aim is to provoke an emotional response with the planting. For example, people always seek to find recognizable motives, pictures, characters, patterns. But in order to find these leading motives you need a reference first. Perhaps a natural landscape type helps. When you start to design a plant community, you often use natural archetypes[1]. The aim in using these archetypes is to find and understand their character, a sort of structural pattern and apply the interpreted nature in your design as a motive to trigger human emotions. A designed plant community is a translation of a wild habitat into a cultural language (Rainer & West 2015). This translation can happen through distilling the archetype into its most elemental forms. It can be a help to set up a structural framework for the design. For example working with forms, patterns (such as shapes, or a rhythm) or plants from the wild plant community. Moreover, to reach a visually more dramatic

1 An archetype is a sort of universal prototype. Archetypes are an inspiration for design and are able to build a connection between an actual plant community and our human emotions, memories, interpretations and associations. Landscape archetypes can be for example a forest or a grassland.

effect than natural habitat stereotypes, repetition and exaggeration are suitable tools. It gives structures and helps to be more attractive for humans. Structure can be also reached with creating some strict, crisp edges such as paths and shortly mowed surfaces between naturalistic planting areas. However, one thing to remember about natural landscape inspirations is that habitat stereotypes are only a guide in a design. Using stereotypes do not mean a mere habitat restoration. Nature should rather be interpreted than imitated (Hitchmough 2014).

When it comes to aesthetics and acceptance, there are several other key components to take into account. The flowering period of the plant community is one of them. With maximizing the flowering impact you maintain the support of the public audience. For example leaving out grasses or reducing their percentage is a way to reach a greater flowering effect (Hitchmough 2014). At the time of choosing plant species another key factor to consider is whether to use native or non-native plants in the design. It goes without saying, there are some good reason to start designing a plant community based on native species. First of all, when you are aiming to design a community, you need plants that thrive at the location. Natives to this areas and locations have perhaps already proven to be right since they most probably survive similar environmental conditions (similar stress situations and disturbance regimes) as given at the planning site. And secondly, native species are also compatible with each other regarding their competitive strategies. “Native plant communities- simply put- plants that grow together in the wild will likely go together in a similar landscape setting” (- Rainer & West 2015). But plants of different origin can have a good ecological performance together too and give important features to a plant design such as a longer flowering period. The latter, that native species do not necessary are able to provide. Furthermore and more from a design perspective: the role of native species is precious for one more reason. These communities, even designed, have a value in conserving native species and they also give the site a sense of authenticity (Rainer & West 2015).

DESIGN APPROACHES

The following examples show how people have been dealing and designing with sand (or other nutrient-poor habitat types) in an extreme and unique way that serve as a model for the hereinafter.

Kevin Benham

In 2018 Kevin Benham, artist and landscape architect created “Broken Kilometer” in Harlösa, Sweden. “Broken Kilometer” is an installation for a military base and it is a kilometer long cut into the soil broken into ten sections along the road. It is a combination of a landart[2] project and restoration initiative supported by the Swedish Sand Life Organization. With the cuts in the soil it behaves as a temporary art installation. At the same time the act of disturbing the ground with scraping off the topsoil

2 Land art is a type of art that is created directly in the landscape. For example using the land for sculpturing by using earthworks or constructing structures in the landscape by natural materials such as rocks, branches or other plant material (Tate Museum 2019)

also created growing space for rare plant species. Moreover, fostered the influx of insects and bird species too. These stripes of exposed sandy soils and their little diverse community are a reminder of the time when military tank maneuvers left traces in the surface and the same special habitats could formed (*Fig. 21*) (Kevin Benham 2018).

FIG. 21: *Kevin Benham's Broken kilometer half year after the creation of the soil stripes, in blossom on the 10th of October, 2018. (photo by the author)*

Peter Korn

Peter Korn is famous for experimenting growing plants in pure sand. He treats the garden as a situation of different temperature zones where one is able to create many kinds of growing environments. His philosophy is that by amplifying and taking advantage of the pre-existing dominant conditions of the landscape, some more extreme plant communities are possible to be implemented (ranging from Mediterranean to Himalayan). And these could be growing conditions where plants from any climates or habitats can thrive in. His assumption is that "there aren't any plants that are hard to grow, only environments hard to recreate" (-Korn 2013). He uses sand-only beds particularly for cultivating alpine plants of dry habitats but recently also for many of his perennial beds. "If however you want plants that look like they do in nature," - not as in conventional fertile garden soil – "where the environment and the climate shape their appearance, then sand is a very good solution" (-Korn 2013). On poor soil one can grow all sorts of vegetation (Korn 2013). According to Hitchmough (2017) when dealing with the idea of cultivating on especially unproductive soil to create highly contrasting plant communities Korn's garden in Sweden is a must-see. He probably has created the most interesting garden landscape where he implemented the idea of poor-exotic habitats (Hitchmough 2017).

Derek Jarman

Derek Jarman's well-known Prospect cottage garden in Dungeness is a leading example for plant specialist and landscape architects. He created an outstanding design of plant communities growing in poor conditions. The prospect cottage is nested in a brutal landscape. A landscape of power poles, flashing lights, a nuclear power plant. And then there are the harsh natural elements of exposed sunshine and salty winds sweeping across the landscape. To start with, it is interesting to know that the garden actually happened from some pure experimenting. His attempts began with seeding something in the gravely soil. One might not think, but the pebble desert welcomed the experiments of Jarman so he continued introducing new species. The planting of Rosa canina was another successful try and step by step he was able to add more and more until he created a flourishing designed plant community. He put together his elements piece by piece as he discovered that the nutrient-poor soil supported a wide array of plant species. The gravely-sandy soil is quickly heated up by the sun from the top but staying cool and humid below that. Some of the first colonizers were *Santolina spp., Crambe maritime* and *Valeriana officinalis*. Especially annuals and self-seeding plants favored these conditions and soon they became an important feature of the artist's garden. These are such as *Echium, Digitalis, Silene*, poppies, *Tagetes* or some *Helichrysum* species that create some wow-effects in the summer. "The planting serves many functional purposes: ornament, a nectar source for his honey bees, and an ecological solution for a harsh site" (-Rainer & West 2015). What made this place so famous is more than just the combination of these plants. The garden and its surroundings have sort of an unnoticeable transition in between. Moreover, the designed vegetation is actually an amplified version of the environment around - Jarman was aiming to select "plants that would accentuate the desolate beauty of the place" (-Rainer & West 2015) And yet, it responds to the site so suitably with a choice of plant species and an arrangement that brings playfulness and sharp contrast to its surroundings (Rainer & West 2015).

SAND THEMES

With the following design phase I am trying to seek answers for design solutions and to create something that reflects my research. My intention is to work with sandy habitats and seek ways how it can be integrated into an urban environment. To bring sandy habitats closer to people, we can use the tool of design. As I see, it is important to create something that visitors need, understand and enjoy. For this reason in this chapter I come up with three prototypes that could be used, called the "sand themes". Furthermore, they could contribute to the multi-functionality of a green space. It is not only a "simple" restoration project but something that can be visually and by participation interpreted by humans. Something that makes people passing

by stop, and watch and be fond of a designed sandy habitat. And through that, perhaps they open their eyes and rediscover natural habitats or the subtle beauty of "simple" restoration projects too.
These sand-themes or sand prototypes are suited for Tempelhofer Feld in Berlin. In the case of this urban park area, as I see, was important to improve the vegetation without changing the character of the landscape as a whole. The aim is to add a layer of increased aesthetics and diversity.
But to not proceed so far ahead, I would like to start by introducing the site. and its qualities first and then move on to the detailing of the sand-themes.

TEMPELHOFER FELD

Tempelhofer Feld is an expansive green area in the heart of Berlin, Germany (*Fig. 22*). It is famous for its 303 hectares of vast open spaces in the densely built-up city used for recreational purposes. The existence of such an extensive area (*Fig. 23*) was thanks to its former function as an airport, shut down in 2006 and the followed initiatives of inhabitants to keep the space untouched by real estate investors. Therefore, the main characteristics of the site are the functional structures of the former airport. It consist of runways, taxiways and large greenery in between, which are now meadows that provide a wide range of usage possibilities for park users. It attracts over three million visitors a year for leisure time and sport. Tempelhof is now once again what it was used for before everything else: it is a diverse and unique recreational area for the inhabitants of Berlin as well as for visitors (from all over the world). Furthermore, it is an identical place for residents of Berlin carrying a rich and diverse history. It is regarded as a place of the oppression and monumental power representation of the National Socialism. However, it is also celebrated as a place of freedom and a "gateway to the West" as it later was an American Air Base supplying the West Berlin inhabitants with everything during the era of blockade during the time the two German parts has been divided. (Tempelhofer Feld 2016).

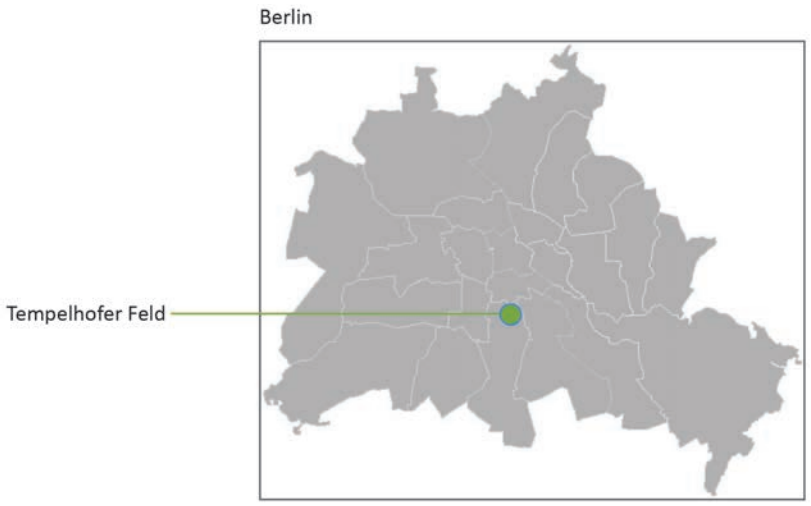


FIG. 22*: The location of Tempelhofer Feld in Berlin, Germany (work of the author)*

FIG. 23*: Today's look of the Tempelhofer Feld (photo of the author; 26.10.2018)*

The future of Tempelhofer Feld was in a debate for a long time. In 2011 they launched an international competition for the Tempelhofer Feld where the Master plan of the Scottish office GROSS.MAX got the first prize. However, the design was criticized to be actually designed for bird's eye view - unnecessary, irrelevant design elements not formulated for the unique conditions of the place - according to NABU (Naturschutz Bund- Nature protection Alliance) Berlin (2014). On top of all, the public acceptance was not willing to agree with the winner design proposal either. The opposition was because the design wanted to change the character of the place (NABU 2014). It became clear that the involvement of Berlin's inhabitants is essential into the project of Tempelhofer Feld. In 2014 a significant population of the city decided in a referendum to keep the field in its current condition and preserve its qualities. Along a participatory planning process, a conservation and development plan was worked out to ensure the desired evolution of the green space (Grün Berlin GmbH 2017). Throughout the dialogue they defined five different levels of access and usage zones. These were also used as a guide in the creation of the vegetation management plan (Tempelhofer Feld 2016).

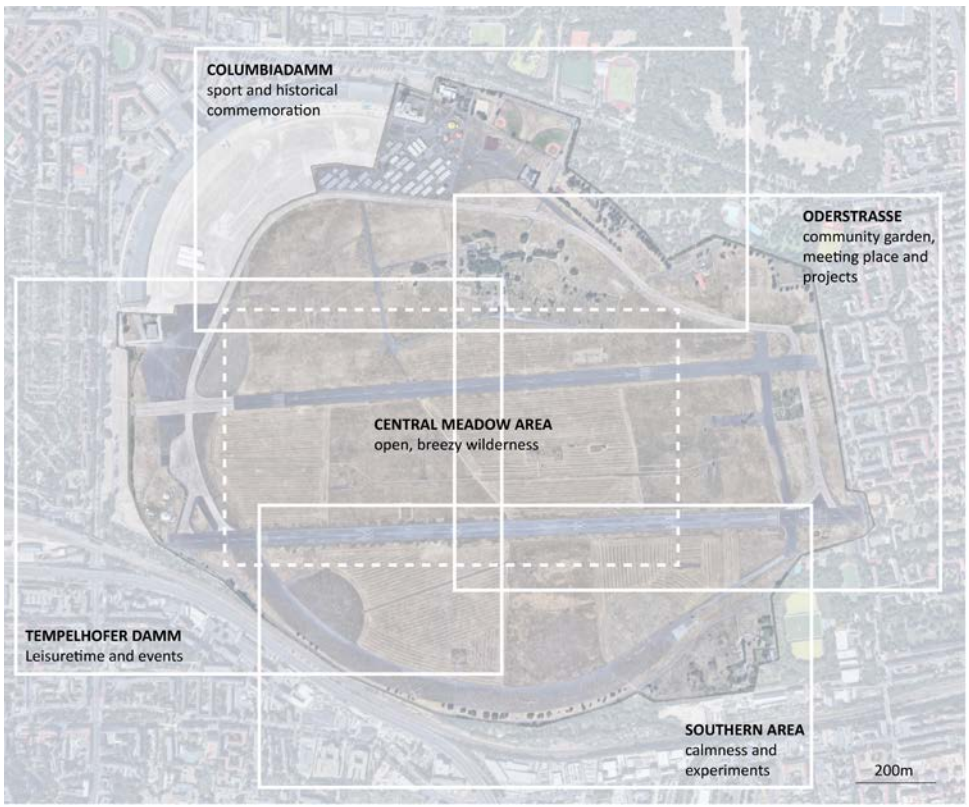


FIG. 24: *Defined usage zones according to the open public hearing process based on the figure from Tempelhofer Feld's development plan (Tempelhofer Feld 2016)*

FLORA AND FAUNA

Tempelhofer Feld's most appreciated feature is its vast, pure landscape. And the open meadows are not only significant for recreational purposes. The total of 303-hectare land consist of open areas of dry meadows that are valuable biotopes with species worthy of protection (Grün Berlin GmbH 2017). In a monitoring in 2005, 20 hectares of endangered and protected sandy dry grasslands as well as 27 hectares of flat oat grassland were detected. According to the usage zones, these habitats lie both in the Central and South parts (*Fig. 24*). Most of these sensitive flora and fauna habitats are mainly located in the middle area though, between the runways (Tempelhofer Feld 2016). These ecological treasures in the opinion of the NABU Berlin should definitely be preserved, especially because the field is one of the only large habitats for species in the Berlin region. In the park there are 329 wild-growing species of plants, also some such as *Dianthus arenarius* (sand pink) and *Helichrysum arenarium* (sandy everlasting). The animal life cannot be neglected either (*Fig. 25*), Tempelhof is providing an important habitat for a nationwide endangered species, *Alauda arvensis* (the skylark) (Seebauer- Wefers & Partner Gmbh 2010).

FIG. 25*: Skylark area (photo of the author; 26.10.2018)*

THE CENTRAL MEADOW AREA

As it was mentioned previously, the central meadow area holds most of the valuable habitat types in it. In the document Tempelhofer Feld (2016) it is described as the place of openness, wind and wilderness. The existing biotopes here are protected and the character of the place is not allowed to be changed. The priority actions encompass the compatibility of grazing and wind sports as well. This part of the field is also important as it has a cooling quality in the summer that helps to balance the hard surfaces in the residential neighbourhoods.

All in all, we can say that Tempelhofer Feld is a unique field where a multitude of actions and features appear. Since 2014 it is sort of a field of experimentation, a field for valuable nature, exciting temporary and permanent projects, and creative and cultural uses such as a variety of sport and leisure activities.

DEVELOPMENT OF THE THEMES

In my design I am aiming to develop some elements that could be used in the example area, at Tempelhofer Feld. To be more specific, to the area in between the two runways, where an open, grassy meadow dominates the scenery, the central meadow area (*Fig. 24*).
These design elements or modules can also be called prototypes or schemes that are repeatable and transformable throughout the landscape. The modules are useful because they give freedom to the people for

implementing the design and making it easier to fit to a specific site. Before I created the prototypes, based on the design considerations of the design chapter, I set up some features that dominate in these modules.

Eventually, I collected five main guidelines for the schemes:
- simple, understandable but call for attention
- work with native[3], stress-tolerant species
- open-end designs (the time aspect plays an important role in the transformation of the elements)
- managed by methods lifted from nature conservation: the vegetation should be treated as a whole, a "blanket" (plant community level), not species individually, with non-selective management methods.
- education and involvement of people either or both in the design and in the management of the prototypes

The prototypes/ sand-themes are based on the research part of the thesis. In the followings I will explain the three themes: the "spring & grazed", the "sand festival" and the "sand heap".

SPRING & GRAZED PROTOTYPE

Design idea:

The first theme is called "spring and grazed" (*Fig. 26*). The name tells a lot, the concept here is the creation of a designed sandy habitat with increased spring effect. And at the same time use browsing animals and some character species to shape the landscape the prototype aims for. In my research I found out that grazing and different animals have not the same impact on the vegetation. They "select" different plant species by eating or leaving them and therefore "stir" the vegetation composition. Animals unintentionally create patterns. I was interested if these patterns can be exaggerated in a way. Based on this and my own observations the theme contains character species that grazing animals do not feed on. Therefore, species, such as *Euphorbia cyparissias* and *Eryngium campestre* have a striking position in this landscape. The idea of using *Euphorbia cyparissias* was strengthened by a visit of mine in the Western part of Hungary end of April 2019. A Hungarian national park called Őrség started keeping a formerly also Hungarian-native bison species at one spot of the park. They seemed to graze most of the herbaceous plants within their territory but the poisonous *Euphorbia*. The vegetation was kept short and these lime colored flowers were beautifully dotting the landscape. They were not disturbed by the animals.

How to develop:

I also found that a common restoration tool to start re-creating a sandy

3 In this context I define native as being included in the Rieger-Hofmann Catalogue as native for Brandenburg or Berlin, or it is already present at Tempelhof (based on the Tempelhofer Feld monitoring). Or it is mentioned by the SandAchse Franken Organization as being a sand-loving species native to Germany.

habitat is topsoil removal. In a favorable situation with a high biodiversity, like at Vitemölla nature reserve in the Eastern coast of Scania or at the area where Kevin Benham created his "Broken Kilometer" perhaps you do not even need more. With scraping off the upper centimeters you can activate the seed bank and some sand loving, stress-tolerant species can grow. To be certain of having a better result, topsoil removal can be paired up with hay transportation (from some flora and fauna-wise valuable area). In this way, as it was mentioned in the species introduction part, you can enrich the limited, segregated seed bank of the urban area. At Tempelhof probably the combination of the two would give the best result. As *Fig. 27* shows, there are numerous potential sites in Brandenburg with sandy, dry meadows from where hay could be brought. The topsoil removal here, based on Hitchmough's (2017) words about introducing new species into a meadow composition: if new plants were just simply planted into or sown over the vigorous grassy meadow, there would be a high chance that nothing would be able to compete with the grasses and survive. The imported hay would desirably contain a larger diversity of forbs. Perhaps this hay mixture would also contain forbs that animals do not eat. Additionally, with the introduction of some spring flowering plants and bulbs the area could have an expanded blossoming period with for example: *Primula veris, Pulsatilla vulgaris* and *Anthericum liliago* that are all sand-loving species and mentioned in the Rieger-Hofmann seed mixture catalogue. A possibility would be to use a scheme for the planting to ease the implementation (*Fig. 28*). The introduction (planting, sowing) of these forbs and also the other character plants could be important in a way too since it could be organized as a community action involving people in the process.

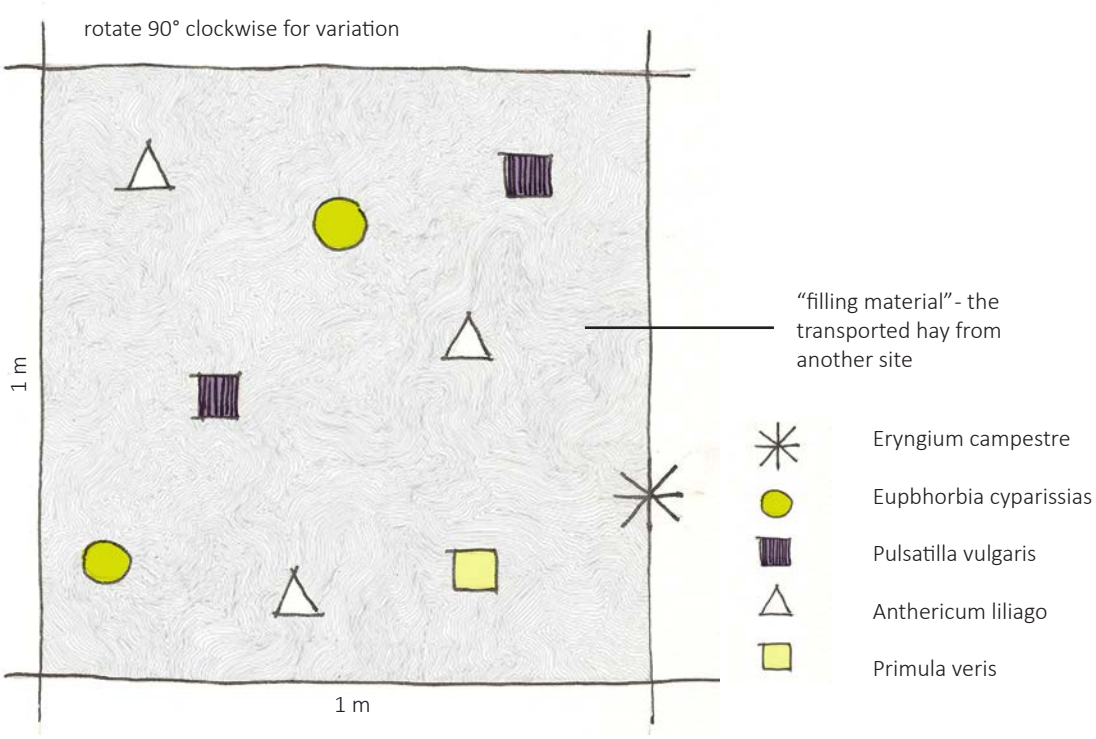


FIG. 28: *This is a mixed or matrix planting of a 1 m2 area. It shows an example how the character species could be implemented on the area (work of the author).*

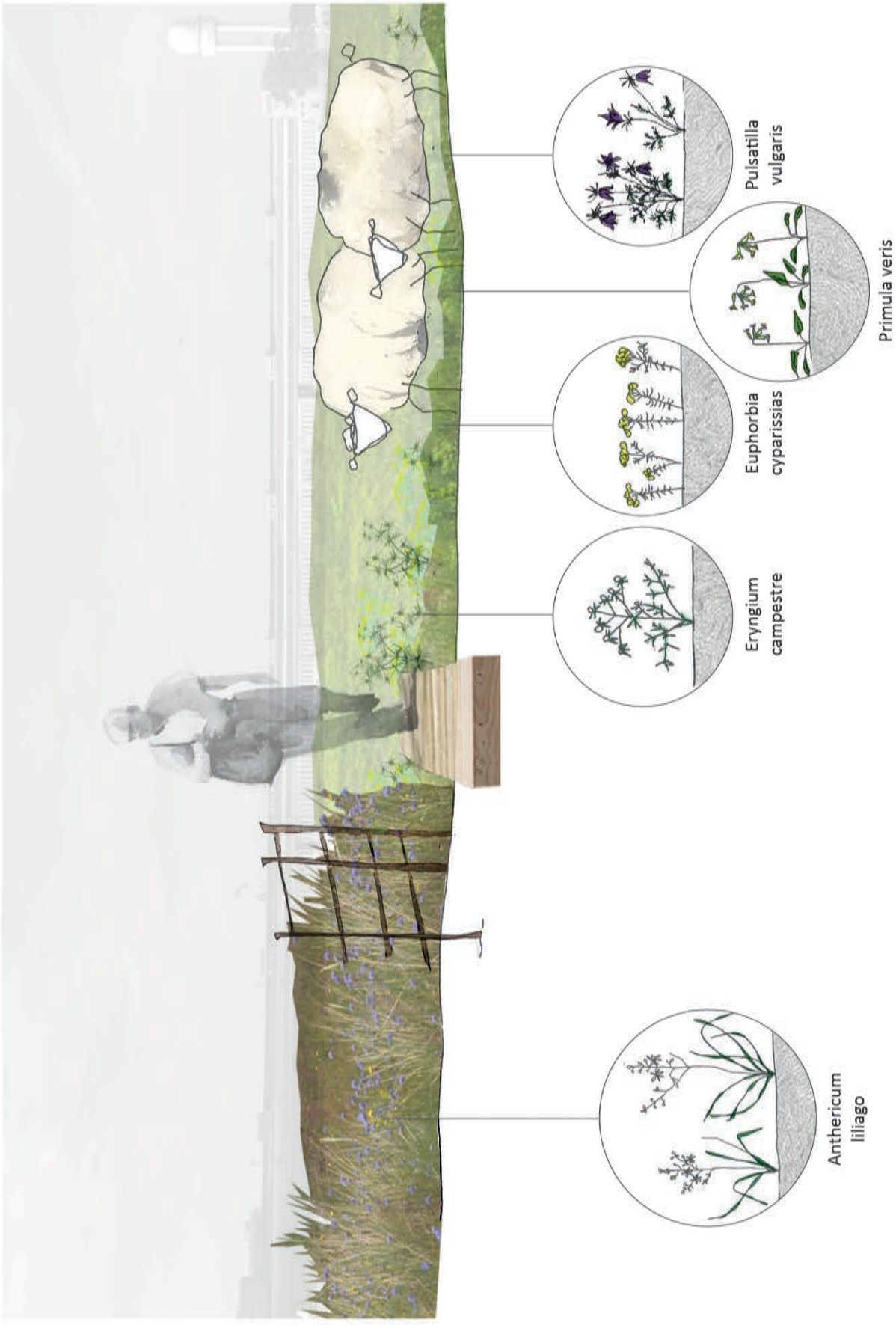


FIG. 26: *Section of spring & grazed prototype: In the right side of the picture you can see the fenced off area where Anthericum liliago can grow. In the middle the boardwalk leads through and on the left side the grazed area is shown (work of the author).*

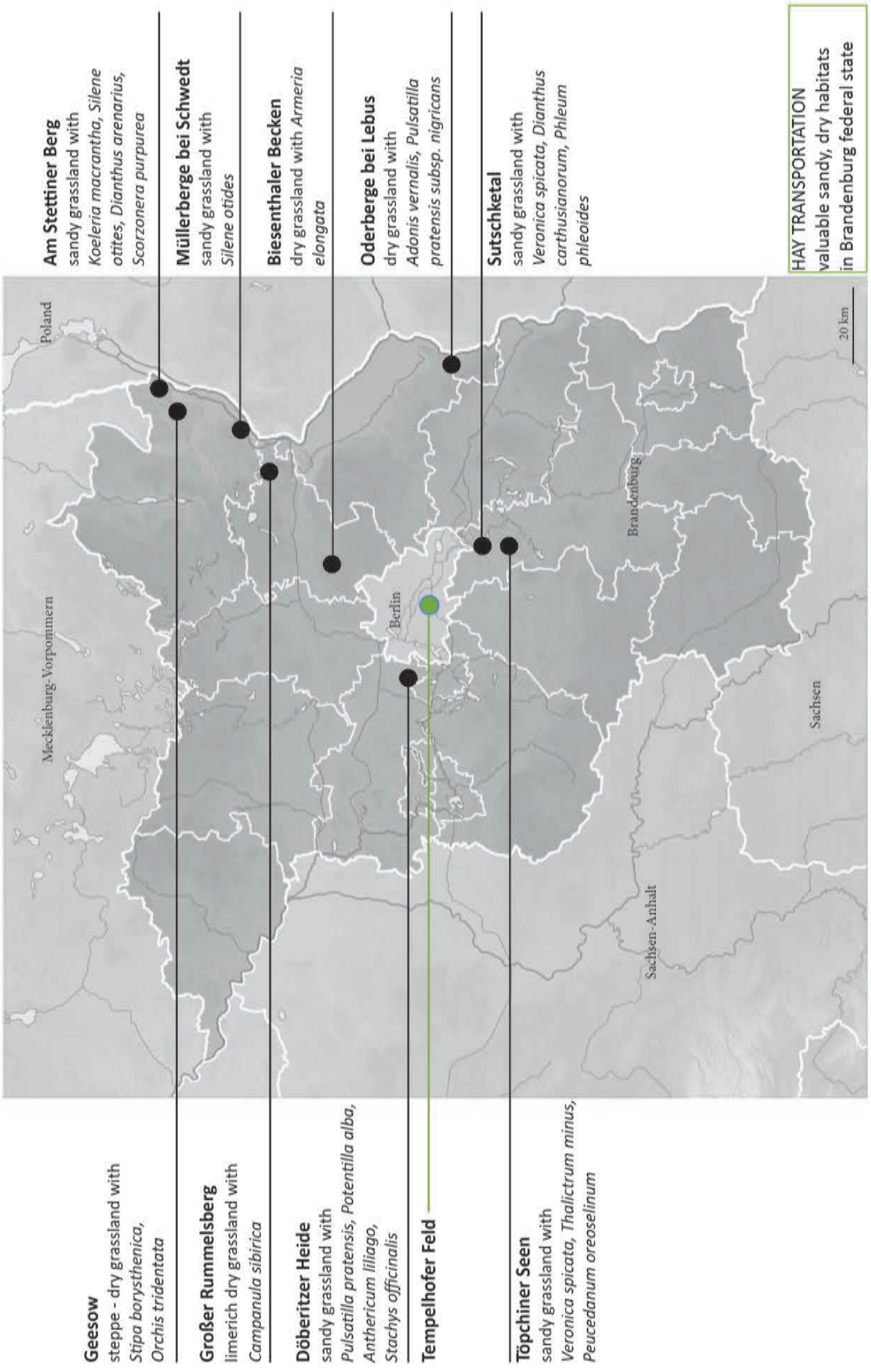


FIG. 27: *This map shows where the „filling material", the hay could be coming from. The black points in the map are valuable sandy or dry habitats in Brandenburg federal state (work of the author). The location, the habitat types and some species that are characteristic to the areas are based on Land Brandenburg (2019), Döberitzer Heide (2019) and Life Sandrasen (2019).*

How to manage:
The grazing management paragraph talks about advantages and disadvantages of certain animal species. For example donkeys and goats need more care and are usually recommended to have them for "after-grazing". On the contrary, sheep are quite bulky and undemanding. Furthermore, Tempelhofer Feld's management plan says that the meadows are approved as sheep "compatible" areas. At the moment, the green areas of Tempelhofer Feld are all managed by cutting, however, in my opinion, a more diverse regime could be introduced. On top, grazing could be a joyful tool for education and entertainment for children too.

Based on the fact that walking or crossing of humans and pets and other recreational activities can bring in nutrition, the sandy habitat can be threatened. To keep the area "clean" of nutrient-input, the commuting of people across the area should be regulated. This could be reached with for example some boardwalks. They could lead from one runways to the other through the theme area. It would not only be beneficial to keep out unwanted nutrients from the sandy area but also could provide a fun way for people to explore the area. It would also allow skylarks to still freely nest on the ground without fencing away a large part of the park.

SAND FESTIVAL

Design idea:
The landscape of the sand festival theme is a patchy sandy habitat with short wild herbs implemented through a community based effort. It is called festival once because of the action of coming together and implementing it together but also because you can by no fear step on these plants and they will survive. In this prototype there are two important features. One of the main points is to create an aesthetically pleasing half-open sandy area. The species would mostly be from the ones that have already been registered at some parts of Tempelhofer Feld. Such as D*ianthus arenarius, Helichrysum arenarium* and *Armeria maritima subsp. elongata*. This would promote species already settled in the park. Plus, the sand festival would introduce some other sand-loving species that are recommended by Rieger-Hofmann for sandy and lean areas for Berlin and Brandenburg and also by Sandachse Franken. Like *Thymus serphyllum, Jasione montana, Sedum acre and Origanum vulgare amongst others.*

How to develop:
This mixture would concentrate herbs that are stress and trampling tolerant to enhance the limited seed bank therefore increase biodiversity. Moreover, to enhance the presence of these strategist species (based on the sand chapter's last paragraph by Hitchmough, that the number of stress-tolerant species are declining). Based on the example of the symbiosis of *Thymus serpyllum* and the Large Blue butterfly one can assume the importance of these sandy species. As I mentioned in the Restoration and management chapter, trampling can have a positive effect as well (not only the threat of nutrient input) to disturb plants and drive back competitive species that are

FIG. 29: *Invitation poster for the sand festival - a potential way to advertise the event among residents (work of the author).*

sensitive to disturbance. Therefore, in this mixture of "festival" plants I tried to aim for choosing species that can cope with some footsteps. Hopefully, at some areas they could create a denser mat and withstand footsteps while at other places the soil would remain completely open. This could be regulated and some areas could be kept vegetation-free already when planted. These bare-soil areas would be made to facilitate the settlement of some insects and random plants species. These areas could be a great place to observe how and what kind of plants and animals conquer the place without any special intervention. People could also see some different stages of succession as at Kevin Benham's Broken Kilometer. So with selecting some nicely flowering, fragrant plants and exaggerating the look of a sandy habitat people could possibly find it more attractive.

How to manage:

One thing is the design of the area and the composition of the species, the other thing is the way of creating it, by involving the inhabitants of the city. As I mentioned in the design chapter, education has a key role to acceptance. With helping in the implementation of this sand theme, people could not only be convinced by the aesthetics but understand the significance of sandy habitats a little better. *Figure 29* is an idea on how to involve residents, an invitation poster for the event.

As I imagined, the whole process would start with scraping off the topsoil to remove competing species and biomass. The sub-sandy-soil would be a more suitable growing ground for the stress-tolerant species as the Sand chapter mentions. The seeds or pots of the different stress-tolerant species would be prepared and the ratio and amount would be pre-determined. People would just need to participate in the planting/ seeding process. They could freely decide where and which species to use from the ones that are provided. With this, they would basically create a random distribution of the plants. Perhaps moving across the space and trampling the seeds would help the process too. The open sandy patches would be marked ahead to be avoided. After a few years of implementation, new areas could be included and the process of the "festival" could be repeated at other plots.

SAND HEAPS

Design idea:

Actually the prototype is called sand heap but to be more precise, this theme is about forms of heaps and their "negatives", depressions in the landscape (*Fig. 30*). These heaps actually resemble or interpret a semi-open dune setting. The shapes are in one way temporary art installations sculpting the open meadow. However, the heaps and hollows can also provide habitat for stress tolerant species, a little lifted away or (sunken down) from the vigorous grassland species around.

How to develop:

As Hitchmough (2017) says, grassy meadows are not easy to improve with other species because the grasses tend to be quite competitive. This is one reason to shape these forms. To sort of provide a refuge for the species that

cannot settle in the meadow because the competitors supersede them based on the strategies of Grime. With the creation of these little mounds more draught and warm loving species can have a chance to live. Because with the creation of heaps you can invert the soil. You bring up clean, nutrient-poor sandy soil and flip the grassland, the organic material to the bottom, as it was said in the machine driven soil disturbance part. The regular oval or round shapes structure the landscape and as mentioned before, provide an experience for people. The habitats lifted away from the surface are calling for attention and passengers are able to observe them better as they walk around the heaps.

There is also a technical aspect of the positive and negative forms. In order to create heaps, the material is needed to be taken from somewhere. Therefore, the easiest way is to take the material from the same site, creating shallow holes in the meadow. And what is the purpose of the depressions? First of all, after going through the ecology of sandy habitats, it became clear for me that these depressions are quite diverse flora and fauna-wise. They keep the moisture longer and they give the possibility for completely other species to settle down. This approach is similar to how Peter Korn uses his garden. According to every fold, crack, crevice, heap or anything in the landscape he sets his plants, taking into account spots where different plants could thrive. Another thought in these shapes I could also underline with an observation of mine at Oranierbaumer Heide. At this nature reserve the sandy habitats are managed by wild horses and cattle. Horses seemingly enjoy weltering in the dust since you could see a pattern of depressions scattered in the landscape. So these hollows are an interpretation of these disturbance patterns. I believe that these depressions are also a fun experience for people. Running around, sitting down into it, seeking for a shelter from the breeze… It could provide a tempting spot for children especially.

How to manage:

At the beginning of the prototype description I said that these are temporary installations. Tempelhofer Feld's central meadow area is a very open space. Therefore, wind can easily glade through the landscape. It also means that therefore the installations can be subject to degradation by wind erosion and also rainwater. However, the natural processes make these shapes change and become more exciting. The sand that is blown away or carried a few meters further also help to make the area a little "poorer" so that species from the top of the mound have a chance to thrive in the surrounding landscape too and not be segregated anymore.

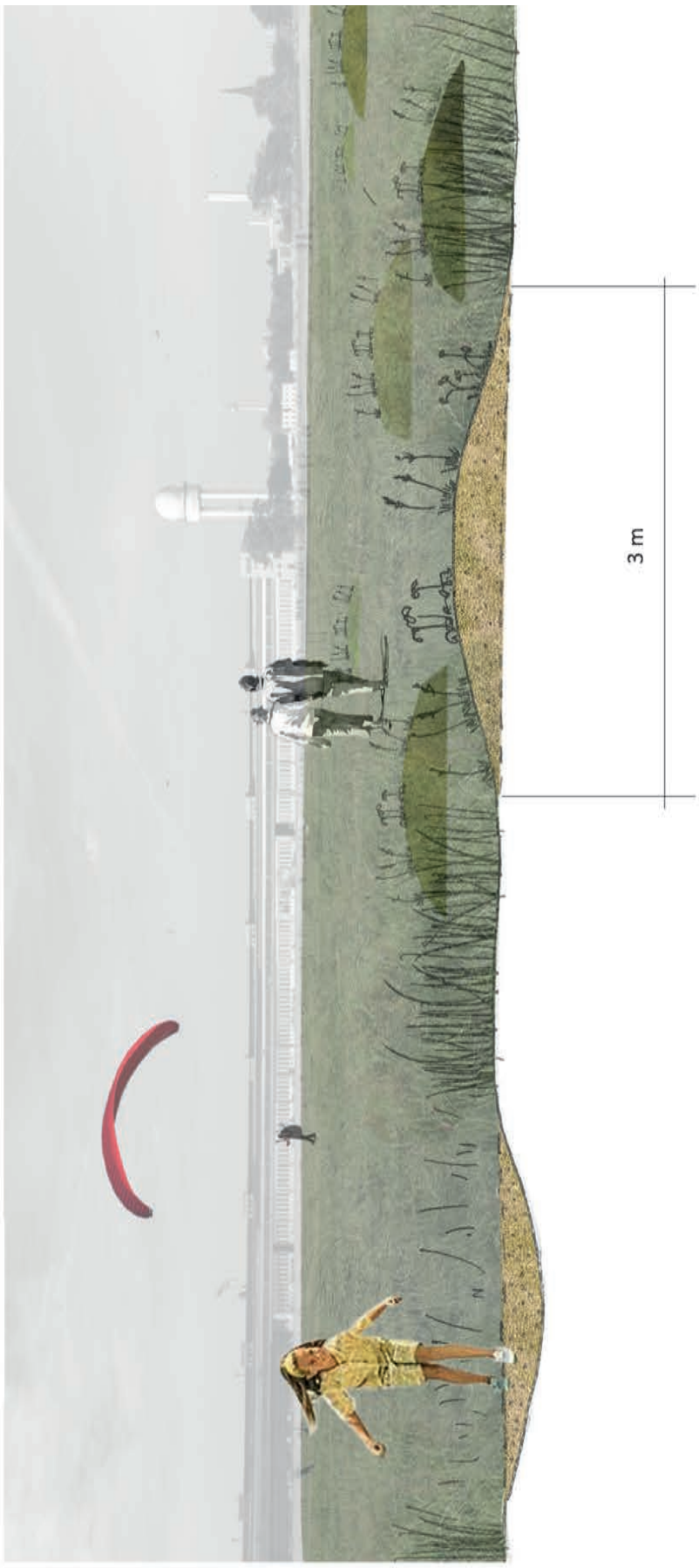


FIG. 30: *Sand heaps and negative forms (work of the author).*

DISCUSSION

While working on my thesis topic my aim was to seek answers for my questions about how sandy habitats work, if and how they could be used in cities. This chapter is a discussion and an evaluation of the research and the result of the thesis. Eventually, it leads to the summary of the essay.

That one sand grain I started rolling at the beginning of the thesis ended up in a diverse sand landscape. Perhaps while reading the literature study, you also realized that sandy habitats are not something, we can take for granted. It is not often that large inland sandy habitats are created on their own, as the history of Southern Scania depicts, and for sure not, continued to be sustained without human interventions. This becomes clear when you see all the different management methods listed in the Restoration & management chapter. I found numerous carefully researched and executed restoration project of sandy habitats. However, I encountered barely any examples that deal with the intersection of city environment, sandy habitats and the design aspect. I only found suggestions on how to design a sand bed by the SandAsche organization (2004) and by Peter Korn (2013) that can be considered the closest to man-made sandy habitats.Therefore, according to my findings, sandy habitats are not so popularly interpreted into planting design yet.

Why not? Perhaps because the management of sandy habitats in nature conservation generally needs big machines. According to the different management techniques, machines are used for for example rotavation, plowing or topsoil removal that Schnoor & Olsson (2010) mention. Large agricultural machineries would be simply too much effort to work with in urban situations. Another reason why sandy habitats are perhaps not widely used, could be what Korn (2013) mentions. That due to the stress factor of the sandy substrate, plants take up on a slow growth and they develop in a slow rhythm. Therefore, the combination of sand and stress-tolerant species might be less favoured in a buzzing city environment where the tool of exaggeration or the maximization of the flowering effect are a priority to attract people's eyes.

So if we translate what Korn (2013) says, the main point is that sand grains do not only give the structure of the soil but they have a great impact on the conditions of what can settle there. The qualities of sand allow and embrace a more limited palette of plants, the so-called stress-tolerator species to grow there, as Grime (1977) classifies them. This theory of the survival strategies was quite a base for my thesis. Additionally, Grime puts it into a framework: he identifies the background, the different strategic qualities of plants. And also, these qualities do not let other more competitive plants outcompete the fragile sand-loving species easily. But are these places, the sandy habitats, important, special, and needed? The ecological aspects provided some answers. I took the chance to introduce the main types of sandy habitats that can occur and show how different these are. The Interpretation Manual

of European Union Habitats from 2007 lists all habitat types worthy of protection. Therefore I had to make a selection with the focus on the main sandy habitat types myself.
The idea to show the versatility and vulnerability of these landscapes occurred to me because of an educative experience: to be present at the Oregon Sand Dunes in the summer of 2018 and see it with my own eyes how the European beach grass took over the landscape. This is a very specific, personally experienced example but the problem of the invasive grass is fought by the members of the Siuslaw National Forest (2019) in Oregon, as well as a similar situation of bound sand in South Sweden fought by Sand Life (Länsstyrelsen 2018). The instance of the European beach grass is something that tells how fragile these sandy systems in general are and how much we need to take care of them. Moreover, it shows that the situation of poor environment being equivalent to no competitors is not so black and white.
The research about the history and the evolvement of sandy habitats is a part that gives the thesis a good ground, in my opinion. This part was not especially possible to use one to one in the design phase but it was more like transitioning into why design is needed. From this chapter I got the first idea of working with grazing and trampling in the sand-themes. The history of Southern Scania helped to understand and made it very clear: sandy habitats can be very much dependent on people (Länsstyrelsen 2018). So here, the question raised: how do they now depend on us? As a way to research this, I took some hikes and observed. Sometimes I did not understand why processes happened, managements that were executed in certain ways, so the literature study about succession, disturbance and the management methods gave me some good hints. Also, to assemble a summary table of the management methods and to compare them helped to understand the methods and their impact on the vegetation. However, the certain management types did not help to comprehend how they can be applied together and how they can be used in the long term. This is why I reached out and got in contact with a German planning office called "Bresch Henne Mühlinghaus". They have dealt with several sand based restoration projects in Germany before. Their examples were a useful tool to see and show how restoration in an urban or semi-urban environment can be like. For example, the restoration project at Baden Airpark was a required step to balance-out the destroyed, built-in areas. This was something that was had to be done. As part of the SandAchse organization (2015), the example of the Telekom Headquarters and its sandy habitat idea was basically the only one I came across that was the closest to my thesis results. However, the little information about it did not allow me to study the project in details. My findings about restoration projects show that at the moment, restoration projects are already a widely applied way to bring back declining sandy flora and fauna communities.

However, in dense, populated urban areas, these restoration projects should look a little different in my opinion. Perhaps there is no need for an actual restoration in an urban area because there is nothing to be restored as well as the restored habitat would not be able to survive under so much pressure. There is a need for multifunctional green spaces that withstand the city

environment easily.
Therefore, I wondered, how you can make a restoration project more acceptable in an urban area. What makes a designed sandy habitat different from a restored habitat? What can a landscape architect do different in a city than landscape planners in open, large-scale landscapes or at abandoned industrial areas? As you can read it out from the Design considerations paragraph in the Sand and design chapter, landscape architects think about design. But design not only from the plants but also from the people's perspective. Perhaps that is something that makes them different from planners. These were my questions when I moved into the design phase of the project.

Unfortunately, literature about this specifically complex field is very scattered. Therefore, I researched different approaches of planting design that assemble some knowledge of designing plant communities in poor, urban environments. These design approaches involve for example sandy, gravelly locations, self-seeding, experimenting, or different, unconventional management regimes. The work of the designers Benham and Jarman and plantsman Korn influenced my design choices in different ways. I was inspired by the temporary installations of Benham and how he merged art and ecology with such simple interventions. He basically presented sandy habitats as an art piece but in a very subtle way. The garden of the Prospect Cottage also includes art, specifically art in a way of experimentation. I thought that the process of creation was very important here, how he built up the garden layer by layer via sowing, planting and experimenting with self-seeding plants. I also wanted to think about my themes this way. However, I could not take the approach how he reflects to the surrounding landscape in his design because that could not have been part of the prototype design. As Jarman, Peter Korn also reacts to the given conditions of the place. He pays attention to every fold of the landscape and builds his garden accordingly. I liked that he works with these given conditions. However, unlike Derek Jarman, he imports soil, (pure sand) as a soil media, not that he uses the one on site. His main point is different to the one at Prospect Cottage, he is creating his own botanical garden. He rather experiments with individual rare plant species than putting the emphasis on assembling a nice-looking plant community. So when I moved onto Tempelhofer Feld, I made an attempt to merge these approaches on the field.

To implement the findings of my research I chose a specific site, Tempelhofer Feld and worked with its given conditions. At my site visit, my impression was that it is a very unconventional, outstanding "urban park" area. I was impressed that the vast field has such a diversity in functions, history and users. The reason why I chose to work with Tempelhof is not because the vegetation needed a restoration. The vegetation is in good conditions and they have set up a long-term management program. The point in applying my design into this area was because I think Tempelhofer Feld is a good ground for changes. I found out, that there is a constant active participation going on from the residents' side. The Management and Development document (Tempelhofer Feld 2016) shows a clear picture of how the stakeholders work together and stir the development of the area.

Also, the field is a good ground for the design simply, because it has already sandy soil and already existing sandy grasslands. Without those preconditions it would be much harder to realize the sand themes explained in the design part and would need much alteration in the landscape. Based on the Management and Development document (Tempelhofer Feld 2016) I assumed and realized that Berlin is a good place to introduce something new. Already the transformation process of the airfield to a public open area shows how much the residents are open for something new and unconventional. My findings about the area showed me that the place has the potential to function as an exhibition place for designed sandy habitats and perhaps there would be an interest in a participatory planning process too.

The development of the prototypes for Tempelhofer Feld, as I see, could be a starting point. One option would be to take it further and present it to the directorate of Tempelhof, to figure out their statement and the opinion of the public. Maybe it is possible to start a negotiation process with the board of the park commission and collaborate. In this case, the sand themes could be developed further together with the users of the airfield. This could be a very exciting process.

Even though the schemes are suited for Tempelhofer Feld, it is possible to apply those ideas elsewhere. The modules are made for extensive usage and management and they are feasible to use at other places. There are some limitations though to every prototype. The "spring- grazed" type is limited to areas where grazing could be allowed by law, as well as where the area provides the special needs for keeping animals. This prototype is based on browsing as a selective management method since another method, such as cutting or burning would not sort out the character species (the Euphorbia, the Eryngium) but would cut them with the rest as it is mentioned in the Management and Restoration chapter. In this way the sense of the prototype would be more or less lost. The "festival" theme is limited to large areas and to places where a big amount of people could be involved in it, in order to call it a festival. Also, a too high amount of people trampling on this theme, using it too intensively would make loose its character as Bresch Henne Mühlinghaus (2010) wrote in the document for Darmstadt. The "sand heaps" are also a matter of area size. The heaps and hollows have a diameter of at least 3 meters and in ideal case there is always a positive and a negative form to deal with the balance of the earthwork. Ideally, this is executed at a site where the subsoil is sandy, that there has to be no extra sand transported to the site. Another thing that should be kept in mind about the sand themes is, that even though they would be applied similarly, when applied in different context, they will not have uniform outcomes. They will always depend on factors such as landscape context, historical land uses, climate, weather, different organisms, seed bank and usage. So, even though someone is willing to apply the sand themes I proposed in my thesis at another site, outcomes will always depend on the site circumstances.
However, in spite of the limitations, there are plenty of possibilities. The project of the Telekom headquarters in Bamberg proves that private firms can have an innovative approach to landscape design. Also, rooftop gardens could be suitable for hosting designed sandy habitats. For example, the

German seed mixture producer company, Rieger-Hofmann sells their own mixes for green roofs. Some more “slack” places, based on the text about road edges and leftover places have a high potential too. Moreover, this spring, after researching more about this part of the topic, I have been continuously keeping an eye on spontaneous road side vegetation. And places that are part of the road infrastructure and could be aesthetically improved. For example roundabouts are a place where cars need to slow down. Therefore it is worth considering to give them a more representative look, as it has been already a trend in the past decade. Could be a suitable place for something like the “sand heap” theme.

To think further, climate change with more draughts and heavy rains needs more resilient plantings. As for example Hitchmough and Dunnett aim for it. But it is also a chance for designed sandy habitats. With more dry periods and irregular rain events, the resilience of sandy habitats could be a way to adapt to the changing climate. As it was figured out in the first chapter, sandy soil profile can take and filter through an immense amount of water in a short time. Yet, the low capillarity let moist stay in lower layers. What if designed sandy habitats can be viewed as the urban surfaces of the future? No irrigation, resilient plant societies, low budget non-selective management methods and a great biodiversity.

CONCLUSION

Sandy habitats are needed because they carry an extreme diversity of our nature. They are important because they are resilient. Sandy habitats occur in so many various types and forms: coastal types, inland types, types that are not especially sandy habitats but can occur in sandy environments too… However, one thing is for sure, altogether they need disturbance to be able to survive. At some places natural forces can keep the sand open, whereas some others are actually a cultural product of our landscapes and are connected to human activities. But natural systems continuously evolve. They change all the time due to succession so management can keep them in a desirable state. With different management methods you are able to filter/ keep different things.

This thesis in not a handbook on how to design sandy habitats. This thesis is basically an introduction to sandy habitat design. It gives you an orientation on designing sandy habitats in an urban environment. Therefore, the result of my thesis are the "sand themes". Based on my research I took an attempt and proposed these modular structures as a design for sandy habitats. With these themes I tried to find a way to combine protecting and presenting sand communities with a design thought.

The sand themes are a way to introduce sandy habitats into cities. They have been developed for Tempelhofer Feld however, the modular system can be re-interpreted according to the site conditions and ready to be implemented at other places too. It would be amazing seeing the sand themes be planted.

REFERENCES

Benham, K. (2018). Broken Kilometer. Retrieved 02 13, 2019, from https://www.kevinjonbenham.com/broken-kilometer

Berglund, B., Larsson, L., Lewan , N., Olsson, E., & Skansjö, S. (1991). Cultural Landscape Periods: Patterns and Processes. Ecological Bulletins, No. 41, The Cultural Landscape during 6000 Years in Southern. Retrieved 03 05, 2019, from https://www.jstor.org/stable/20113089

Bouillon, J. (2013). Handbuch der Staudenverwendung : aus dem Arbeitskreis Pflanzenwerwendung im Bund deutscher Staudengärtner ; Empfehlungen für Planung, Anlage und Managment von Staudenpflanzungen. Stuttgart: Ulmer.

Bresch Henne Mühlinghaus. (2006). Restoration of species-rich grassland and heath at Baden Airpark (Germany). Retrieved 04 04, 2019

Bresch Henne Mühlinghaus. (2010). Konversionsgelaende Darmstadt West: Sandrasenkonzeption. Retrieved 04 05, 2019

Craul, P. (1992). Urban Soil in Landscape Design. New York: John Wiley & Sons Inc.

Diblik, R. (2014). The Know Maintenance Perennial Garden. Portland, Oregon: Timber Press.

Döberitzer Heide. (2019). Naturschutzgebiet “Döberitzer Heide” [in German]. Retrieved 05 09, 2019, from https://www.doeberitzerheide.de/

Dunnett, N. (2014). The Dynamic Nature of Plant Communities - Pattern and Process in Designed Plant Communities. In Dunnett, N., & Hitchmough, J. (Eds.), The Dynamic Landscape (pp. 97-114). Routledge: London.

European Comission DG Environment. (2007). Interpretation Manual of European Union Habitats - EUR27. European Comission DG Environment.

European Union. (2019). EU member counties in brief - Sweden. Retrieved 23 06, 2019, from https://europa.eu/european-union/about-eu/countries/member-countries/sweden_en

Grime, J. (1977). Evidence for the Existence of Three Primary Strategies in Plants and Its Relevance to Ecological and Evolutionary Theory. The American Naturalist, Vol. 111, No. 982, pp. 1169-1194.

Grman, E., Bassett, T., & Brudvig, L. (2013). Confronting contingency in

restoration: management and site history determine outcomes of assembling prairies, but site characteristics and landscape context have little effect. Journal of Applied Ecology, 50:1234–1243.

Grün Berlin GmbH. (2017). Tempelhofer Feld. Retrieved 03 01, 2019, from https://gruen-berlin.de/en/tempelhofer-feld/about-the-park/projects

Halassy, M., Singh, A., Szabó , R., Szili-Kovács, T., Szitár, K., & Török, K. (2016). The application of a filter-based assembly model to develop best practices for Pannonian sand grassland restoration. Journal of Applied Ecology, 53, 765–773.

Hitchmough, J. (2014). Naturalistic Herbaceous Vegetation for Urban Landscapes. In Dunnett, N., & Hitchmough, J. (Eds.), The Dynamic Landscape (pp. 97-114). Routledge: London.

Hölzel, N., & Otte, A. (2003). Restoration of a species-rich flood meadow by topsoil removaland diaspore transfer with plant material. Applied Vegetation Science, 6, 131-140. Retrieved 05 11, 2019, from https://www.staff.uni-giessen.de/~gh1912/ee/paper/paper4.pdf

Kiehl, K., Kirmer, A., Donath, T., Rasran, L., & Hölzel, N. (2010). Species introduction in restoration projects – Evaluation of different techniques for the establishment of semi-natural grasslands in Central and Northwestern Europe. Basic and Applied Ecology, 11, 285-299.

Korn, P. (2013). Giving plants what they want. Mölndal, Sweden: Peter Korn.

Land Brandenburg. (2019). Liste der in Brandenburg vorkommenden Lebensraumtypen [in German]. Landesamt für Umwelt. Retrieved 05 09, 2019, from https://lfu.brandenburg.de/cms/detail.php/bb1.c.315320.de

Länsstyrelsen. (2018). Restoration and Mangament of Sandy Habitats in Southern Sweden. Skåne: Taberg Media Group. Länsstyrelsen. Sand Life. Retrieved 11 15, 2018, from http://sandlife.se/?page_id=785

Life Sandrasen. (2019). Sandrasen in Brandenburg [in German]. Retrieved 05 09, 2019, from https://www.sandrasen.de/projekt/

Martínez, L. M., Gallego-Fernández, J. B., & Hesp, P. A. (2013). Restoration of Coastal Dunes. Berlin/Heidelberg: Springer-Verlag.

Matthews, J. W., Molano-Flores, B., Ellis, J., Marcum, P. B., Handel, W., Zylka, J., & Phillippe, L. (2017). Impacts of management and antecedent site condition on restoration outcomes in a sand prairie. Restoration Ecology, Vol. 25, No. 6, 972–981.

NABU. (2014). Akte Tempelhof- Einmal Freiheit und zurück. Berlin: Landesverband. Retrieved October 15, 2018, from https://berlin.nabu.de/stadt-und-natur/stadtentwicklung/tempelhofer-feld

North Creek Nurseries. (2016). Landscape Plug Specification Manual LP32 | LP50. Retrieved 03 24, 2019, from https://docslide.net/documents/landscape-plug-specification-manual-615.html

Oregon Dunes Restoration Collaborative. (2019). Save the Oregon Dunes. Retrieved 04 06, 2019, from https://www.saveoregondunes.org

SandAchse Franken. (2004). SandGestöber – Aktionsmappe. Erlangen: Bund Naturschutz Service GmbH.

SandAchse Franken. (2015). Sandlebensräume zwischen Weißenburg und Bamberg (Sandy habitats between Weißenburg and Bamberg). Bavaria, Germany: Bayerischen Naturschutzfonds.

Schnoor, T. K., & Olsson, P. A. (2010). Effects of soil disturbance on plant diversity of calcareous grasslands. Agriculture, Ecosystems and Environment 139 (2010) 714–719.

Seebauer- Wefers und Partner Gmbh. (2010). Naturschutzfachliches Monitoring. Berlin Tempelhofer Feld. Retrieved October 10, 2018, from https://www.berlin.de/senuvk/umwelt/stadtgruen/aktuelles/downloads/projekte/naturschutz_monitoring_2010.pdf

Siuslaw National Forest. (2019). Oregon Dunes. https://www.fs.usda.gov/siuslaw: Forest Service United States Department of Agriculture.

Hitchmough, J. (2017). Sowing Beauty. Portland, Oregon: Timber Press.

Tate Museum. (2019). Landart. Retrieved 04 13, 2019, from https://www.tate.org.uk/art-terms/l/land-art

Tempelhofer Feld. (2016). Entwicklungs- und Pflegeplan Tempelhofer Feld (Development and Managementplan Tempelhofer Feld). Berlin, Germany: www.tempelhofer-feld.berlin.de.

Weil, R., & Brady, N. (2017). The Nature and Properties of Soils. Harlow, England: Pearson Education Limited.

West, C., & Rainer, T. (2015). Planting in a Post-Wild World: Designing Plant Communities for Resilient Landscapes. Portland, Oregon: Timber Press.

White Sands. (2018). Sledding. Retrieved 02 08, 2019, from www.nps.gov/whsa

Zahn , A. (2014). Beweidung von trockenem, nährstoffarmem Offenland. – In: Burkart-Aicher, B. et al., Online-Handbuch “Beweidung im Naturschutz”, Akademie für Naturschutz und Landschaftspflege (ANL) (In German). Retrieved 03 14, 2019, from https://www.anl.bayern.de/fachinformationen/

beweidung/6_1_1_offenland_trocken.htm

Zehm, A., Fölling, A., & Reifenrath, R. (2015). Nature conservation with grazing donkeys – conclusions and management implications (Esel in der Landschaftspflege – Erfahrungen und Hinweise für die Beweidungspraxis). ANLIEGEN NATUR, 55-66. Retrieved from www.anl.bayern.de

Ödman, A., & Olsson, P. (2014). Conservation of Sandy Calcareous Grassland: What Can Be Learned from the Land Use History? PLOS ONE www.plosone.org, Volume 9, Issue 3.

FIGURES

FIG. 1: *Boglárka Szilassy after Weil, R., & Brady, N. (2017). The Nature and Properties of Soils. Harlow, England: Pearson Education Limited; p. 39*

FIG. 3:*Boglárka Szilassy after Grime, J. (Vol. 111, No. 982 (Nov. - Dec., 1977)). Evidence for the Existence of Three Primary Strategies in Plants and Its Relevance to Ecological and Evolutionary Theory. The American Naturalist, p. 1170*

FIG. 4: *Boglárka Szilassy after European Comission DG Environment. (2007). Interpretation Manual of European Union Habitats - EUR27. European Comission DG Environment.*

FIG. 5: *Martin Holmer from Länsstyrelsen (2018). Restoration and Mangament of Sandy Habitats in Southern Sweden. Skåne: Taberg Media Group. Länsstyrelsen. Sand Life. Retrieved 11 15, 2018, from http://sandlife.se/?page_id=785, p. 32*

FIG. 8: *Boglárka Szilassy after SandAchse Franken. (2004). SandGestöber – Aktionsmappe. Erlangen: Bund Naturschutz Service GmbH., p. 39*

FIG. 9: *Swedish University of Agricultural Sciences Historical forest images from Länsstyrelsen (2018). Restoration and Mangament of Sandy Habitats in Southern Sweden. Skåne: Taberg Media Group. Länsstyrelsen. Sand Life. Retrieved 11 15, 2018, from http://sandlife.se/?page_id=785, p. 16*

FIG. 11*: Boglárka Szilassy after [edited by] Dunnett, N., & Hitchmough, J. (2014). The dynamic landscape: naturalistic planting in an urban context. Routledge: London., p. 113*

FIG. 2, 6, 7, 10, 12–19, 21, 23, 25: *photos taken by Boglárka Szilassy*

FIG. 24: *Boglárka Szilassy after Tempelhofer Feld. (2016). Entwicklungs- und Pflegeplan Tempelhofer Feld (Development and Managementplan Tempelhofer Feld). Berlin, Germany: www.tempelhofer-feld.berlin.de., p. 27*
base map accessible at: Google maps [15.05.2019]

FIG. 22*: Boglárka Szilassy; base map accessible at: https://upload.wikimedia.org/wikipedia/commons/6/64/Germany_divided_Berlin_East.png [14.05.2019]*

FIG. 27: *Boglárka Szilassy; base map accessible at: https://upload.wikimedia.org/wikipedia/commons/1/17/Brandenburg_relief_location_map.png [08.05.2019]*
Information for the making of the map:
Land Brandenburg. (2019). Liste der in Brandenburg vorkommenden Lebensraumtypen [in German]. Landesamt für Umwelt. Retrieved 05 09, 2019, from https://lfu.brandenburg.de/cms/detail.php/bb1.c.315320.de
Döberitzer Heide. (2019). Naturschutzgebiet "Döberitzer Heide" [in German]. Retrieved 05 09, 2019, from https://www.doeberitzerheide.de/
Life Sandrasen. (2019). Sandrasen in Brandenburg [in German]. Retrieved 05 09, 2019, from https://www.sandrasen.de/projekt/