THE FUTURE OF INTERURBAN FOREST STRUCTURES ?!

A PROPOSAL FOR A NEW CRITICAL APPROACH TOWARDS THE DESIGN OF DROUGHT ADAPTIVE INTERURBAN FOREST STRUCTURES.

CONTENT

ABSTRACT

THIS GRADUATION PROJECT PROPOSES A NEW CRITICAL APPROACH TOWARDS THE DESIGN OF DROUGHT ADAPTIVE INTERURBAN FOREST STRUCTURES. THE INCREASING DROUGHT DURING THE SUMMER IS CURRENTLY NEGLECTED IN THE DESIGN (AND MANAGE-MENT) OF GREEN STRUCTURES IN THE NETHERLANDS.

SEVERAL STUDIES UNDERPIN THE IMPORTANCE OF TAKING DROUGHT STRESS IN CONSIDERATION FOR THE FUTURE WELL-BEING OF TREES AND FORESTS. GERRITS (2010) PROVIDES INSIGHT INTO THE CAUSE OF DROUGHT STRESS IN ACCORDANCE WITH THE HYDROLOGICAL CYCLE OF TREES. DE VRIES ET AL. (2000) GIVES AN OVERVIEW OF THE INDIRECT FACTORS THAT CAN CONTRIBUTE TO THE LEVEL OF DROUGHT STRESS THAT TREES PERCEIVE. THE RESEARCH OF BRUNNER (2010) REVEALS THE RESPONSE MECHANISM OF TREES. ZADWORNY ET AL. (2014) AND PRETZSCH ET AL. (2012) SHOWED THAT CHANGING THE CURRENT FORESTRY PRACTICE CAN RESULT IN MORE DROUGHT ADAPTIVE FOREST. HOWEVER, THESE STUDIES DO NOT LOOK INTO THE SPATIAL IMPLICATIONS OF THE DROUGHT-STRESS. SINCE, THEY DO NOT CONSIDER FORESTS AS PART OF A SPATIAL STRUCTURE WHICH IS EMBEDDED IN A LANDSCAPE THAT IS DEFINED BY ITS PALIMPSEST, SCALE-CONTINUUM.

THE UTRECHTSE HEUVELRUG SERVES AS A CASE TO MAP THE SPATIAL IMPLICATIONS OF TRANSFORMING THE CURRENT FOREST STRUCTURE INTO AN EXPANDING DROUGHT ADAPTIVE INTERURBAN FOREST STRUCTURE. THE DESK ANALYSIS OF THE UTRECHTSE HEUVELRUG PROVIDED MORE INSIGHTS IN ABOUT CURRENT FUNCTIONING OF INDIRECT FACTORS. THE SOIL CONDITIONS, WATER CYCLE APPEARS, AND HUMAN INTERFERENCE APPEARS TO MAKE CURRENT VEGETATION LESS CAPABLE OF DEALING WITH INCREASING EXTREME CLIMATE CONDITIONS. FURTHERMORE ANALYSES THE FOREST STRUCTURE SHOWS THAT IT CONTAINS FOUR TREE CONSTELLATIONS: LANES, ESTATES, FOREST PLANTATIONS AND NATURE RESERVES.

A NEW FRAMEWORK IS PROPOSED THAT INCLUDE THESE NEGLECTED SPATIAL ASPECTS. THE FRAMEWORK COMBINES THE DROUGHT STRESS CYCLE WITH SCALES OF URBAN FORESTRY. THE FRAMEWORK IS APPLIED TO DEVELOP A VISION UTRECHTSE HEUVELRUG WHICH IS ELABORATED IN REGIONAL DESIGN FOR THE AREA BETWEEN AUSTERLITZ AND WOUDENBERG. THE VISION PROPOSED A NEW FOREST STRUCTURE WHICH WILL BE REALIZED IN TWO STAGES. THE FIRST STAGE IS THE TRANSFORMATION OF THE STRUCTURE, WHICH CONSISTS OF THE ADDITION OF SEASONAL BUFFERS IN BETWEEN THE FORESTRY, AGRICULTURAL AND URBAN CORES. THE SECOND STAGE CONSISTS OF THE EXPANSION OF THE FOREST IN PATCHES BETWEEN THE FORESTRY, AGRICULTURAL AND URBAN CORES.
THE REGIONAL DESIGN PROPOSES A NEW GREEN AND BLUE SYSTEM THAT ADAPTS THE CURRENT GRID TO MAKE IT DROUGHT ADAPTIVE. MOREOVER, THE ADAPTED GRID WILL FACILITATE FURTHER EXPANSION OF THE FOREST. THE CENTRAL ELEMENT IS REGIONAL WATER BODIES. THEY BUFFER EXCESSES OF RAINWATER AND DIMINISH THE AMOUNT OF WATER THAT DRAINED INTO THE RIVER EEM AND RIVER RHINE THROUGH THE REGIONAL CANAL 'VALLEIKANAAL'. TWO DIFFERENT SUBSYSTEMS ARE CONNECTED TO THESE REGIONAL WATER BODIES. THE PURPOSE IS TO RETAIN WATER AND DISTRIBUTE IT LATER.

LASTLY, THE DIFFERENT CORRESPONDING CONSTELLATIONS WHICH ARE NEEDED TO TRANSFORM AND EXPAND THE CURRENT GRID ARE DESCRIBED. THIS INCLUDES SEVEN DIFFERENT CONSTELLATIONS. TRANSFORMING A NEW FOREST STRUCTURE CONSISTS OF FOUR TYPES OF TREE CONSTELLATION. THE CATCHMENT VALLEYS AND NETWORK OF DITCHES ARE TWO PRIMARY CONSTELLATIONS THAT WILL BE CONSTRUCTED TO PREVENT EXCITING FOREST OF FURTHER DETERIORATING FROM DROUGHT STRESS. THE SPRENGBEEK AND THE ZIGZAG ARE CONSTELLATIONS MAINLY LET CIRCULATES THE RETAINED WATER. THE SPRENGBEEK IS RESPONSIBLE FOR DISPOSAL WHEREAS THE ZIGZAG TAKE CARE OF THE (EMERGENCY) SUPPLY OF WATER. THE CONSTELLATION OF EXPANSION CONTAINS FOUR TYPES OF TREE CONSTELLATION. THESE TREE-CONSTELLATIONS ARE THE BACKBONE OF BOTH DEVELOPING AGRICULTURE AND URBAN PATCHES. THE FOOD CLEARING CONSISTS OF WOODED BANKS AND SWAMP FORESTS. THE LIVING CLEARINGS IS THE LAST CONSTELLATION WHICH IS PART OF DENSE FOREST PATCHWORK WHICH WILL DEVELOP IN BETWEEN FOOD CLEARINGS.

ALL THINGS CONSIDERED, THIS GRADUATION PROJECT RESULTED IN THE DESIGN OF SEVEN TREE-CONSTELLATIONS. THEY ILLUSTRATE SPATIAL IMPLICATIONS WHICH ARE NECESSARY TO DESIGNING DROUGHT ADAPTIVE INTERURBAN FOREST STRUCTURE IN THE UTRECHTSE HEUVELRUG.

FIGURE 1: THE AVERAGE YEARLY AMOUNT OF RAIN IN THE NETHERLANDS

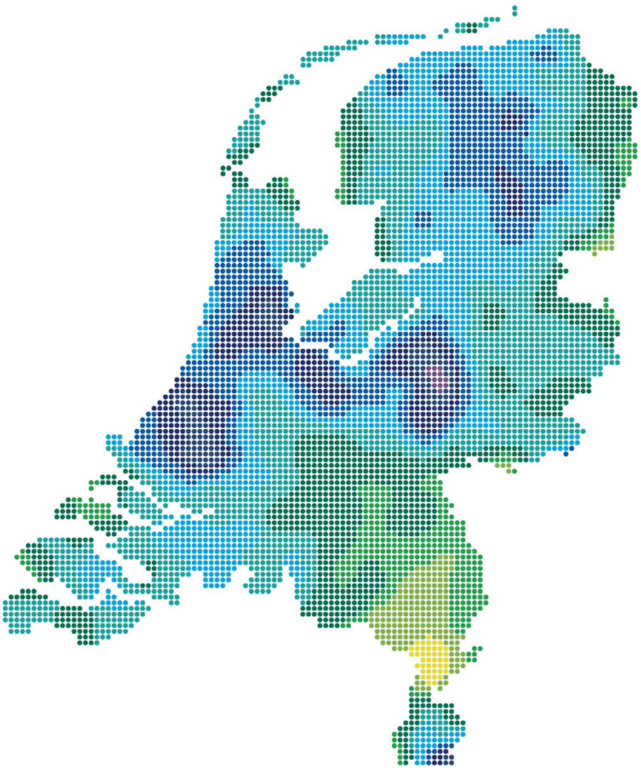


FIGURE 2: THE SHORTAGE OF RAIN AT THE END OF THE SUMMER IN THE NETHERLANDS

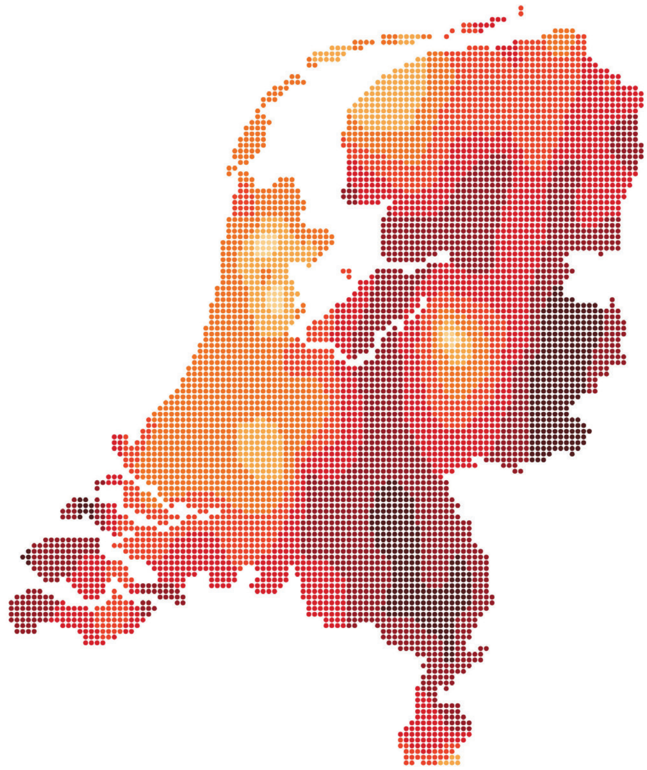


FIGURE 3: THE SPATIAL CHALLEGES IN THE REA OF THE UTRECHTSE HEUVELRUG AND THE VELUWE

INTRODUCTION

THE INCREASING DROUGHT DURING THE SUMMER IS CURRENTLY NEGLECTED IN THE DESIGN (AND MANAGEMENT) OF FOREST STRUCTURES IN ESPECIALLY THE ELEVATED SANDY AREAS OF THE NETHERLANDS.

The increasing drought during the summer is currently neglected in the design (and management) of forest structures in especially the elevated sandy areas of the Netherlands. The changing weather patterns due to climate change results in an increasing amount of rainfall that precipitates more and more irregularly (fig. 1 & 2). It seems that winters will become wetter and the summers dryer in the Netherlands. This development influences the structure of forests and the species growing and living in the forests.

The increment in both the intensity and the frequency of seasonal droughts will affect the functioning of forest structures and their ecosystem services. Providing these ecosystem services have become more and more critical in spatial strategies and policies that supposedly make our society more sustainable. However, the performance of these forest structures is at risk due to these drought events. Drought compromises, for instance, the CO2 storage, cooling-capacity, recreational use and wood production. Furthermore, the envisioned expansion of these forests will possibly be in vain because their implementation neglects drought stress.

Recent studies to drought stress show that most of the knowledge to address it is available. However, it appears that current spatial developments in landscape architecture do not implement this specialized knowledge. Therefore, a holistic landscape architectural approach is proposed to look into especially the spatial implications of the drought stress. This implies that these trees or forests need to be regarded as spatial structures. They are namely embedded in the landscape by its palimpsest, scale-continuum and processes.

It also means that the relationship between forests and cities needs to be reconsidered. It implies the replacement of the traditionally dualistic view by reconsidering these forest structures as the interurban forests. This means that forests and cities are henceforth regarded as intertwined systems that need to be designed as a whole. In this way, the complexity and interdisciplinary character of the problem statement can be addressed.

The primary purpose of this graduation project is mapping the spatial implications which are necessary to transform the current forest structure of the Utrechtse Heuvelrug into an expanding drought adaptive interurban forest structure. This project is, therefore divided into two parts. The first part contains a literature study and site analysis of the case. The case is the area of the Utrechtse Heuvelrug because of its remarkable spatial structure which faces different challenges (fig. 3). The objective of the theoretical part is to generate a theoretical overview of the current understanding of drought (stress) for the case of the Utrechtse Heuvelrug. This resulted in a proposed framework that uses two axes to combine current knowledge of drought stress and urban forestry. Element, constellation and structure form the horizontal axis that contains the scales of the interurban forest. The four lenses of hydrology, ecology, forestry and urban planning are the vertical axis that generates principles to design drought adaptively. The framework is used in the second part of the graduation project as a method to design in a drought adaptive way.

The second part of the graduation project consists of research by design for the sub-area of the Utrechtse Heuvelrug. This part shows a range of different options that can be implemented as part of a broader vision to build drought adaptive interurban forest structure. Therefore it focuses mainly on designing new tree constellations. Its scale is ideal for showing the spatial component of these interventions.
Moreover, it comes all together as these tree constellations translate spatially the design principles into interventions which will contribute to the envisioned functioning of the more overall structure. This lead to a design that consists of an overall vision for the Utrechtse Heuvelrug. The vision is subsequently elaborated in a regional design for the sub-area between Austerlitz and Woudenberg. The last part of the chapter shows a series of detail designs of the tree constellations that are used to realize the regional design.

The graduation project ends with a discussion and sums it all up in an overall conclusion. It discusses the limitations and dilemmas of the project from a landscape architectural point of view. Moreover, it recommends future possibilities for research and design to drought stress.

THEORY

THIS CHAPTER LOOKS INTO THE THEORICAL BACKGROUND OF DROUGHT STRESS BASED ON A LITERATURE STUDY. IT IS SUPPLEMENTED BY A CASE STUDY SINCE SITE-SPECIFICNESS OF THIS ISSUE. SEVERAL FACTORS PLAY A ROLE IN DROUGHT STRESS CYCLE. SITE CHARACTERISES AND NATURE MANAGEMENT APPEARED TO ESSENTIAL SPATIAL FACTORS. DROUGHT SENSITIVITY OF THESE TWO FACTORS ARE MAPPED IN CASE STUDY. THE CASE STUDY LOOKS INTO THE DS OF THESE FACTORS. ESPECIALLY SITE CHARACTERISES DEPEND ON THE SOIL, WATER, ECOLOGY CONDITIONS. MOREOVER, URBANIZATION CONDITIONS ARE MAPPED TO SHOW THE DS OF NATURE MANAGEMENT. IN CONCLUSION, THE MAPPING OF DROUGHT SENSITIVITY AND THEORICAL UNDERSTANDING OF DROUGHT STRESS ARE COMBINED INTO A MATRIX. THE DROUGHT ADAPTIVE MATRIX SERVES AS A UNDERLAY FOR DROUGHT ADAPTIVE DESIGN OF LANDSCAPES.

DDROUGHT STRESS IS A PROCESS THAT VEGETATION STARTS TO PERCEIVE WHEN THEIR GROWTH RATE BECOMES CONSTRAINED DUE TO A TEMPORALLY RESTRICTED UPTAKE OF WATER BY ITS ROOT SYSTEM. THE LENGTH OF THE PROCESS AND THE OCCURRING FREQUENCY DETERMINE THE SEVERITY OF DROUGHT STRESS.

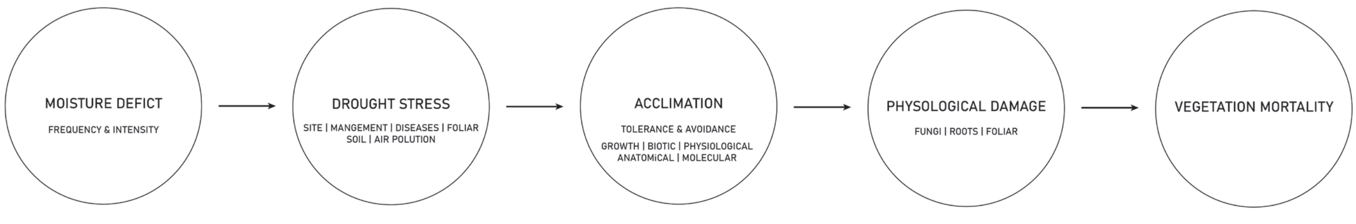
THIS MOISTURE DEFICIT THAT TREES EXPERIENCE IS THE RESULT OF TWO PRIMARY REASONS. THE FIRST REASON IS, ACCORDING TO GERRITS (2010), DEFICIENT PRECIPITATION IN THE HYDROLOGICAL CYCLE OF THE VEGETATION. THE HYDROLOGICAL CYCLE SHOWS THAT RAINFALL CAN BE DIVIDED INTO THREE FLOWS. THE FIRST FLOW IS THE PART OF THE PRECIPITATION, WHICH WILL BE INCEPTED AND SUBSEQUENTLY EVAPORATED BY THE SOIL AND CANOPY. THE SECOND FLOW CONSISTS OF THE THROUGHFALL AND STEMFLOW, WHICH WILL INFILTRATE AND PROVIDES (PARTLY) WATER FOR THE ROOTS OF VEGETATION. A THIRD FLOW IS THE RUN-OFF OF WATER ON TOP OF THE SOIL, WHICH OCCURS WHEN THE SOIL IS TEMPORALLY SATURATED. THIS FLOW RESULTS IN SOIL EROSION WHICH CAN BE A PROBLEM IN RELIEF-RICH AREAS.

THE LONG-TERM AVERAGE RAINFALL IS 851 MM. HOWEVER, THE RAINFALL IS UNEVENLY DISTRIBUTED THROUGHOUT THE YEAR. ON THE ONE HAND, MORE RAIN PRECIPITATES THAN EVAPORATION OF WATER DURING WINTER. THIS OVERFLOW OF RAINWATER WILL RECHARGE THE GROUNDWATER LEVEL. THE AVERAGE IS 300 MM/YEAR. HOWEVER, IT DEPENDS ON THE TYPE OF VEGETATION. PINE FOREST HAS, FOR EXAMPLE, A LOW SURPLUS OF 100-200 MM/YEAR. THE SURPLUS OF THE DECIDUOUS FOREST IS 250 MM/YEAR. HEATHLANDS HAVE A HIGH SURPLUS OF 375 MM/YEAR. ON THE OTHER HAND, MORE MOISTURE EVAPORATES THAN THE AMOUNT OF RAINFALL DURING THE SUMMER. THIS SEASONAL DEFICIT IS COMMON FOR TEMPERATE CLIMATES LIKE IN THE NETHERLANDS. BETWEEN APRIL AND OCTOBER, THE AVERAGE DEFICIT CAN BE UP TO 144 MM DEPENDING ON THE GROUNDWATER LEVEL AND SOIL TYPE. HOWEVER, THE STATISTICS ABOUT FIVE PER CENT DRIEST SUMMER SHOWN THAT IS SHORTAGE REACH A DEFICIT OF 300-400 MM. THE SECOND REASON IS THE RESTRICTED ACCESS TO GROUNDWATER. THIS RESTRICTION IS USUALLY THE RESULT OF A LOWERED GROUNDWATER LEVEL DURING SUMMER. THE GROUNDWATER MAP SHOWS, THEREFORE, THE AVERAGE GROUNDWATER TABLE DURING BOTH WINTER (GHG) AND SUMMER (GLG). MOREOVER, THIS IS STRENGTHEN BY THE EXTRACTION OF GROUND WATER FOR DRINKING WATER AND IRRIGATION OF AGRICULTURAL AREAS. THE CONSEQUENCE OF GRADUALLY LOWERING OF THE GROUNDWATER TABLE IS THAT ROOTS OF TREES CANNOT TAKE UP GROUND WATER ANYMORE.

FURTHERMORE, RESEARCH TO STRESS MECHANISM OF TREES SHOWED THAT SIX INDIRECT STRESS FACTORS INFLUENCE THE DEGREE OF DROUGHT STRESS. DE VRIES ET AL. (1999) DESCRIBES THE DIFFERENT TYPES OF STRESS THAT TREES HAVE TO DEAL WITH. THE TREE AGE, ALTITUDE, SOIL AND ITS DRAINAGE CLASS ARE FACTORS THAT DETERMINE THE POTENTIAL STRESS WHICH RELATES TO THE STAND AND SITE CHARACTERISTICS OF THE TREES. ALSO, THE WEATHER CONDITIONS DETERMINE THE EXTENT OF STRESS THAT TREES ENDURE THROUGH THEIR TRANSPIRATION RATE AND AIR TEMPERATURE.

THE SOIL COMPOSITION IS ANOTHER FACTOR WHICH IS DETERMINED BY PH, C/N-RATIO AND PRESENCE OF METALS AND NUTRIENTS IN THE SOIL. TWO PROCESSES IN SOIL COMPOSITION INCREASE THE VULNERABILITY OF VEGETATION TO DROUGHT STRESS. THE FIRST PROCESS IS THE EUTROPHICATION BY NITROGEN. THE EXCESS OF N CAUSES AN INCREASE OF ESPECIALLY THE CANOPY OF THE TREES. THIS LEADS TO THE FURTHER IMBALANCE OF NUTRIENTS AND WATER . THE TREES CONSUME MORE WATER AND NUTRIENT TO MAINTAIN THEIR ENLARGED CANOPIES. THE SECOND PROCESS IS THE ACIDIFICATION OF THE SOIL. THIS PROCESS IMPLIES A DECREASED CAPACITY OF THE SOIL TO NEUTRALIZE ACIDS. IT IS THE RESULT OF LOADING OF BASE CATIONS LIKE CALCIUM, MAGNESIUM, POTASSIUM AND

FIGURE 4: DROUGHT STRESS CYCLE ILLUSTRATES THE FIVE STAGES OF DROUGHT STRESS THAT TREES PRECEIVE.



SODIUM. THIS PROCESS COMPLICATES THE UPTAKE OF NUTRIENTS WHICH IS IMPORTANT FOR THE RECOVERY OF TREES AFTER A DROUGHT EVENT.
`THE MANAGEMENT OF VEGETATION IS ANOTHER STRESS FACTOR WHICH IS INFLUENCED BY PLANTING AND TRIMMING OF VEGETATION. ZADWORNY ET AL. (2014) SHOWED THAT THE TYPE OF FORESTRY INFLUENCES THE RESPONSE OF TREES TO DROUGHT STRESS. THREE DIFFERENT PRACTICES WERE INVESTIGATED: SOWN, PLANTED AND COPPICE. IT APPEARS THAT THE ROOT SYSTEM OF PLANTED TREES AND COPPICE TREES DO NOT DEVELOP TAPROOTS. THESE TREES DEVELOP USUALLY A SHALLOW ROOT SYSTEM. ONLY SOWN TREES DEVELOP AN UNDISTURBED TAPROOT SYSTEM. THEIR ROOTS GROW FIRST VERTICAL TAPROOTS BEFORE IT DEVELOPS HORIZONTAL LATERAL ROOTS. THIS RESULT IN A ROOT SYSTEM THAT CAN REACH DEPTH BETWEEN 4 AND 23 METRES DEPENDING ON THE USED TREE SPECIES AND ITS CONSTELLATION (STONE & KALISZ, 1991).
A SIMILAR RESULT CAME FORWARD IN TSAKALDIMI ET AL. (2009). IN HIS RESEARCH HE COMPARED THE ROOT ARCHITECTURE BETWEEN SEEDLINGS OF QUERCUS ILEX. NATURALLY GENERATED SEEDLINGS SHOWED THAT THEY HAVE A MORE BALANCED SHOOT-ROOT RATIO AND LONGER TAPROOT. THEREFORE THESE TYPE OF SEEDLINGS GENERATES TREES WHICH ARE BETTER ADAPTED AGAINST MOISTURE AND NUTRIENTS DEFICIT. LOW RAINFALL ADAPTED SPECIES HAVE A MORE STRAIGHTFORWARD ROOT SYSTEM. MOREOVER, THEY INCREASE THE DEPTH OF THEIR ROOTS.
PEST AND DISEASES ARE THE LAST FACTORS THAT GENERATE STRESS FOR TREES. THE TREES BECOME MORE SENSITIVE FOR PEST INFESTATIONS AND FUNGI ATTACKS AFTER THE DROUGHT PERIOD. THIS LEAD TO FURTHER DETERIORATION OF THE HEALTH OF THE TREES. THE TREE DIAGRAM (FIG. 5) COMPARES THESE CHARARCTICS OF THE TEN MOST COMMON TREE SPECIES OF THE UTRECHTSE HEUVELRUG.

DROUGHT STRESS RESPOND MECHANISM

THE DROUGHT STRESS CYCLE (FIG 4.) SHOWS THE RESPONSE MECHANISM THAT TREES USE TO DEAL WITH DROUGHT STRESS. ACCORDING TO BRUNNER (2015), TREES USE TWO STRATEGIES TO ACCLIMATE THEMSELVES AGAINST DROUGHT STRESS. TREES WILL START FIRST AVOIDING DROUGHT STRESS BY APPLYING MECHANISMS WHICH REBALANCES ITS WATER LOSS AND WATER UPTAKE. THE WATER LOSS OF TREES CAN BE ADJUSTED BY STOMATAL CLOSURE AND LIMITING ITS SHOOT GROWTH. ENHANCING OF THE WATER UPTAKE CAN BE ACHIEVED BY THE FORMATION OF DEEP TAPROOTS, THE GROWTH OF FINE ROOTS AND ACCUMULATION OF SOLUTES IN THE ROOT SYSTEM. SUBSEQUENTLY, TREES WILL PROTECT THEIR ROOT SYSTEM AGAINST DAMAGE WHEN THE DROUGHT STRESS BECOMES TOO SEVERE.

THIS IS ACHIEVED BY THE ACTIVATION OF SOLUTES AND PROTEINS WHICH THEIR PROTECTIVE FEATURES WILL ENABLE THE TREE TO TOLERATE DEHYDRATION. THEREFORE, IT WILL ADJUST ITS GROWTH RATIO, BIOTIC FEATURES, PHYSIOLOGICAL PROCESSES, ANATOMICAL PROCESSES AND MOLECULAR CONFIGURATION.

HOWEVER, THESE MECHANISMS ARE LIMITED DEPENDING ON THE FREQUENCY AND INTENSITY OF DROUGHT STRESS. THE THIRD STAGE OF PHYSICAL DAMAGE STARTS WHEN THESE MECHANISMS REACH THEIR LIMITS. FIRST FUNGI WILL DIE IN THE ROOT SYSTEM. THE SYMBIOSES BETWEEN THESE MYCORRHIZAS AND ROOT SYSTEM IMPROVES THE HYDRAULIC CONDUCTIVITY OF THE ROOTS. AFTER THIS, IT WILL ALSO REPEL PARTS OF THE ROOT SYSTEM AND FOLIAR STRUCTURE. THE TRANSPORTATION OF WATER IN XYLEM TISSUES OF THE TREE GETS, FOR INSTANCE, DISRUPTED. THIS IS THE RESULT OF CLOGGING UP OF TRANSPORT VESSELS BY AIR. THE PREMATURE DEATH OF FUNGI AND ROOTS WILL MAKE TREES MORE VULNERABLE TO DROUGHT STRESS IN THE PERIOD FOLLOWING A DROUGHT EVENT. IT BECOMES HARDER FOR TREES TO RECOVER SINCE IT IS LESS CAPABLE OF TAKING UP WATER AND NUTRIENTS. THE LAST PHASE IS THE MORTALITY OF THE TREE. THIS PROCESS OCCURS WHEN THE TREE ACCUMULATES ENOUGH PHYSIOLOGICAL DAMAGE OVER A MORE EXTENDED PERIOD. HOWEVER, THE MORTALITY PROCESS IS STILL INSCRUTABLE IN RECENT STUDIES.

THE DROUGHT STRESS CYCLE EXPLAINS THIS PROCESS IN GENERAL. HOWEVER, MOST FACTORS APPEAR TO DEPEND ON THE CONTEXT OF TREE. THEREFORE A CASE IS CHOSEN TO ANALYSE IT AND SUBSEQUENTLY PROPOSE A DESIGN. THE NEXT CHAPTER CONTAINS AN ANALYSE THE SOIL, WATER CYCLE, ECOLOGY AND URBANISATION FOR THE STUDY AREA.

FIGURE 5: THE TREE DIAGRAM COMPARES FOUR DIFFERENT FEATURES OF TREES TO SHOW THEIR DROUGHT SENSITIVENESS.

	SCOTS PINE	OAK	DOUGLAS	BEECH	BIRCH	LARCH	NORWAY SPRUCE	NORTERN RED OAK	ALDER
ROOT DEPTH	DEEP	MEDIOCRE	SHALOW	MEDIOCRE	SHALLOW	DEEP	MEDIOCRE	MEDIOCRE	SHALLOW
HYDROLOGY	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
ECOLOGY	172	423	?	98	334	38	70	12	141
WOOD PRODUCTION	6.2	6.2	13.9	7.2	4.6	8.9	12.2	7.9	6.7
	75	-	50	-	-	45	60	-	-

Figure 6: The Pleistocene and Holocen landscape of the Netherlands

Figure 7: The areas coverd by ice during the Saale and Weichesalien glacation.

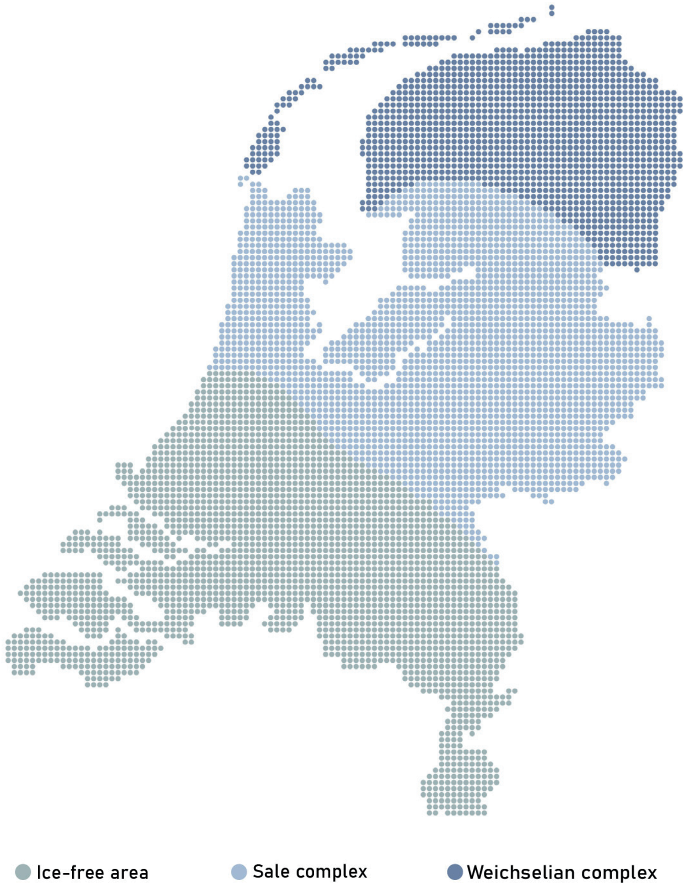
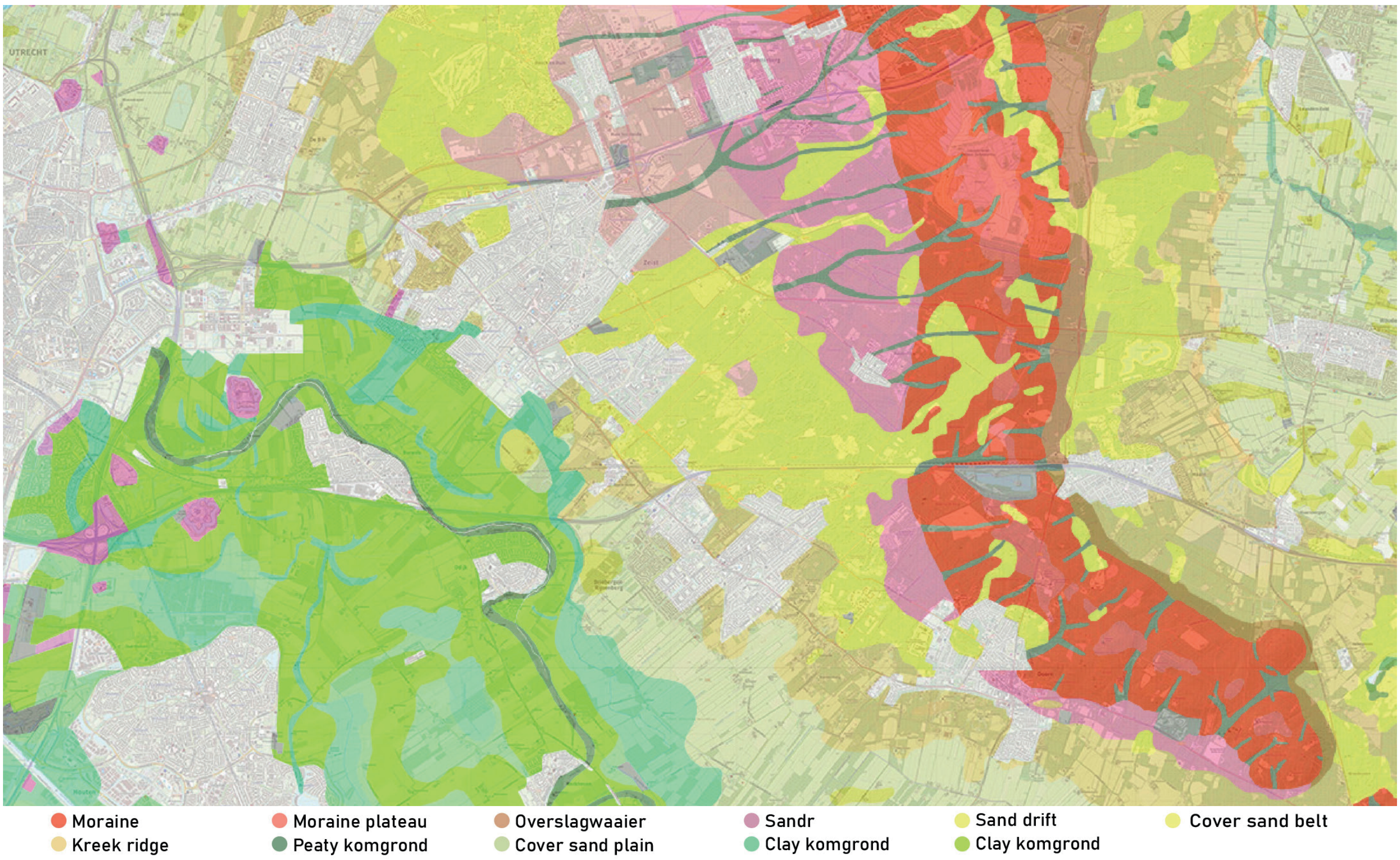


Figure 8: Geomorfological map of National Park the Utrechtse Heuvelrug



SOIL ANALYSIS

THE SOIL OF THE NETHERLANDS CAN BE DIVIDED BASED ON SURFACE GEOLOGY INTO THREE CATEGORIES (FIG. 6). THE FIRST CATEGORY IS YOUNG SOILS WHICH THEIR SURFACE GEOLOGY DATE FROM HOLOCENE. THESE ARE USUALLY SITUATED IN LOWER AREAS. THE SECOND CATEGORY IS OLDER SOILS WHICH DATE BACK FROM THE PLEISTOCENE. THESE ARE SITUATED MOSTLY IN THE EAST AND SOUTH OF THE NETHERLANDS. LASTLY, A LIMITED NUMBER OF BOTH PRE-TERTIARY AND TERTIARY SOILS REMAIN IN THE FAR EAST AND SOUTH OF THE NETHERLANDS (DE JAGER ET AL. 2007).

THE NETHERLANDS USED TO BE PART OF A MARINE BASIN SYSTEM WHICH WAS CHARACTERIZED BY A HIGH SEA LEVEL AND MARINE AND FLUVIAL DEPOSITIONS. DURING THIS PERIOD, THE CIRCUMSTANCES STARTED TO FLUCTUATE BETWEEN COLD TERRESTRIAL CONDITIONS AND WARM DELTAIC CONDITIONS. ICE SHEETS COVERED THE NORTHERN HALF OF THE NETHERLANDS (FIG. 7) DURING COLD TERRESTRIAL PERIODS. THESE ICE SHEETS LED TO THE FORMATION OF GLACIOLOGIC STRUCTURES. THESE STRUCTURES ARE MORAINES THAT CONSIST OF SIGNIFICANT ACCUMULATIONS OF UNCONSOLIDATED SEDIMENTS. THE UTRECHTSE HEUVELRUG IS PART OF A COMPLEX OF THESE MORAINES. THIS COMPLEX WAS DEVELOPED AT THE SOUTHERN EDGE OF THE ICE SHEET AND RAN TILL GERMANY AND POLAND (BAKKER & VAN DER MEER, 2003).

LAND FORMING PROCESS DURING HOLOCENE

THE SOIL HAS CHANGED SINCE THE START OF HOLOCENE. THE LOWER SOILS WENT THROUGH TRANSGRESSIONAL PROCESS DURING THE FIRST HALF OF THE HOLOCENE. INUNDATIONS LED TO SEDIMENTATION THE PERIGLACIAL VALLEYS WHICH WERE FORMED DURING THE PLEISTOCENE. A SEQUENCE OF SOIL MAPS THROUGH TIME SHOWS THE DEVELOPMENT THAT THE ' UTRECHTSE HEUVELRUG' AND ITS SURROUNDING LANDSCAPE UNDERGONE (VOS, 2015).

MOREOVER, HUMANS STARTED TO INFLUENCE THE SOIL AS THEY INTRODUCED AGRICULTURAL PRACTICES. THESE NEW PRACTICES ENHANCED EROSION DUE TO DEFORESTATION. MOREOVER, PEOPLE STARTED TO DRAIN PEAT TO CULTIVATE CROPS AND STOCK. THIS LEAD TO SUBSIDENCE OF SOIL WHICH IS STILL A SIGNIFICANT ISSUE FOR FARMERS AND CITIZENS DUE TO SALINIFICATION AND THE SINKING OF BUILDINGS. LASTLY, PEOPLE STARTED TO EMBANK THE LANDSCAPE BY BUILDING OF TERPS, DYKES AND CANALS TO PROTECT THEMSELVES AGAINST FLOODS, TO TRANSPORT (EASIER) GOODS AND ENLARGE THEIR AGRICULTURAL GROUNDS.

THE FIRST MAP (FIG. 9) SHOWS THE LANDSCAPE IN 5500 BC. SOUTH OF THE MORAINES IS BORDERED BY MEANDERING RIVER SYSTEM OF THE RHINE. THE COASTAL TIDAL LANDSCAPE MARKS THE NORTH SIDE OF THE MORAINE. IN BETWEEN THE COASTLINE AND THE MORAINES AN AREA DEVELOPED OF KWELDERS AND CLAY IN WHICH THE LOWER AREA PARTIALLY FLOODED EVERY DAY, AND THE HIGHER AREA CLAY HAS BEEN DEPOSED PERMANENTLY. THE VALLEYS BETWEEN THE MORAINES CONSIST OF A SYSTEM OF STREAMS THAT DRAIN THE (RAIN)WATER. PEAT GROWS ONLY IN LIMITED AREAS WITH A WEAK DRAINAGE SYSTEM.

THE SECOND MAP (FIG. 10) SHOWS THE LANDSCAPE IN 3850 B.C. THE FORMER TIDAL COASTAL LANDSCAPE HAS CHANGED INTO A PEAT LANDSCAPE WITH ONE LARGE WATER BODY. THE RIVER SYSTEM DEVELOPED A BRANCH TO THE NORTH. MOREOVER, PEAT COVERS MOST OF THE VALLEYS (IJSSEL- AND GELDERSE VALLEY) BETWEEN THE MORAINES.
THE FOURTH MAP (FIG. 12) SHOWS THE SITUATION IN 800. THE RIVER IJSSEL BECOMES A FULL-ON RIVER BRANCH OF THE RHINE. THE WATERBODY NORTHERN OF THE MORAINES ALSO OBTAINS ITS FINAL FORM. THE FORMER RIVER BRANCH IN UTRECHT ALREADY DISAPPEARED AND LEFT AN ONLY DEPOSIT OF CLAY. THE LANDSCAPE IS MOSTLY COVERED BY PEAT IN THIS PERIOD. FINALLY, THE TWO SETTLEMENTS HAVE DEVELOPED NEXT TO THE RIVERS.

THE LANDSCAPE (FIG. 13) AROUND THE MORAINES STARTS TO BECOME CULTIVATED IN THIS PERIOD. PEOPLE START TO DRAIN PEAT AND CLAY AREAS TO CULTIVATE THE SOIL FOR AGRICULTURE PURPOSES. THE FIRST SIGNS OF HARVESTING PEAT BECOME VISIBLE. THE AMOUNT OF WATER BODIES INCREASES AS A RESULT OF PEAT EXTRACTION. LASTLY, THE LANDSCAPE BECOMES MORE URBANIZED. AN INCREASING AMOUNT OF VILLAGES AND CITIES ESTABLISH THEMSELVES IN THIS PERIOD.

FIGURE 9: SOIL RECONSTRUCTION OF THE UTRECHTSE HEUVELRUG IN 5500 BC.

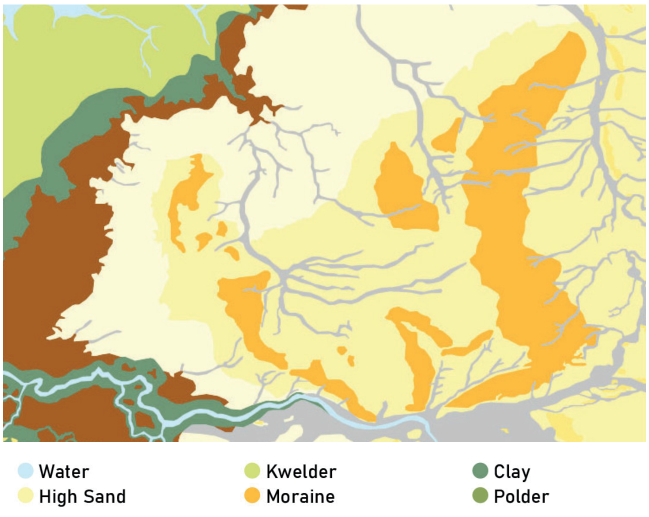
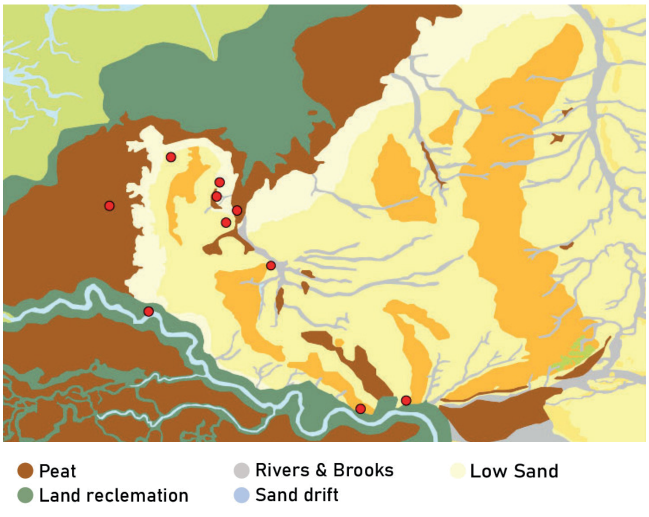


FIGURE 10: SOIL RECONSTRUCTION THE UTRECHTSE HEUVELRUG IN 3850 BC.



The last map (fig 14) of the sequence shows the situation around 1850. Larger cities are expanding due to the industrial revolution in that century. Moreover, land reclamation has been introduced. A part of the ancient lakes in the peat landscape is reclaimed as lakebed polders. Moreover, less and less of the peat landscape remains visible as more and more peat is extracted till the beginning of the 20th century. Lastly, only development on top of the moraines occurred. Large parts of the sand landscape start to drift due to wind erosion. This is the result of overgrazing and extraction of heather for agriculture purposes.

Contemporary soil of the Utrechse Heuvelrug

The soil map (fig. 8) shows that the soil of the 'Utrechtse Heuvelrug' consists of sand. The sand soil contains podzol soils and vague soils. Also, sandy earth soils and vague soils are common at the transition from the moraine to its surrounding landscape (De Bakker & Schelling, 1986).

Podzol soils consist of sandy soils in which a specific soil formation process has occurred (de Bakker et al., 1982; van Trikt & Ahrens 2020a). Vegetation has deposited humus in the topsoil layer. Infiltrating rainwater dissolves these organic materials gradually, whereby the dissolved organic material and iron particles precipitate in the deeper soil layer. This results in the formation of two subsoil layers underneath the topsoil layer. A bleached, ash-grey coloured soil layer is the result of the removal of iron particles. Underneath this soil layer, a dark brown soil layer is formed by the discharged of the dissolved particles. The reduced permeability of this layer prevents that this soil formation process influences further the soil underneath it.

Three types of podzols are common in Utrechtse Heuvelrug: moder podzol soils, xeropodzol soils and of ordinary hydropodzol soils. Xeropodzol soils (haarpotzol) developed on more on the higher northern grounds. Moder podzol soils (holtpotzol) are common in the southernmost part of the Utrechtse Heuvelrug. At the edges of the moraine, the soil consists of ordinary hydropodzol soils (veldpotzol) with a sand cover.
Another common soil type is vague soils (Bakker et al., 1982; van Trikt & Ahrens 2020a). These mineral soils distinguish themselves through the absence of any soil formation processes. Therefore, the soil typology did not develop sublayers due to its younger age or a lack of organic materials.

Sandy xerovague soils (duinvaaggronden) form the sand dunes in the Utrechtse Heuvelrug. This soil type is the result of wind erosion during the Weichselien. Prevailing tundra climate caused sand drifting. This resulted in a layer of sand that covered parts of the moraine. This layer of sand started to drift again during the Middle Ages due to lodging and agricultural practice. It formed subsequently sand dunes of this drift sand soil (stuifzandgrond).

The soil at the southern edge of the Utrechtse Heuvelrug consists of clayey xerovague soils (ooivaaggrond of poldervaaggrond). It consists of cumulative layers of clay minerals which rivers (used to) deposited once or twice a year. The clay formed an impermeable structure due to the fineness and flattened shape of these minerals. This is reinforced by the (slightly) negatively-charged characteristic of these minerals. Therefore, water can hardly infiltrate vertically.

At the edge of the moraine and in the adherent valley developed earth soils (Bakker et al., 1982). These mineral soils are characterised by their dark, humic or peaty topsoil layer. A small fraction of the soil is 'enk' earth soils (enkeerdgrond). This soil type is the result of agricultural practice that transformed former podzols into these earth soils. These soils were fertilised by use of sheep manure and heather. By doing so, these soils became suitable for arable farming. These soils are

Figure 11: Reconcrustion of soil in 500 BC

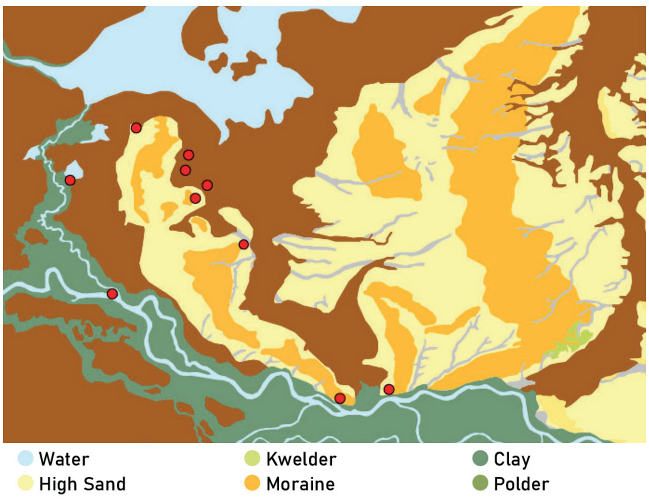
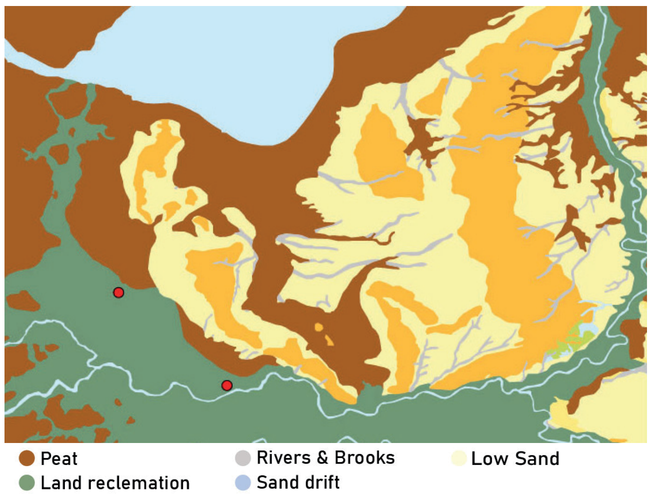


Figure 12: Reconcrustion of soil in 800



USUALLY SITUATED AROUND VILLAGES.
THE SOIL IN THE ADHERENT VALLEY IS SANDY HYDRO-EARTH (BEEKEERDGROND). THE SOIL CONSISTS OF TWO LAYERS. A DARK LAYER OF ORGANIC MATERIAL DEVELOPED ON TOP OF THE MINERAL LAYER. THESE SOILS ARE USUALLY MEADOWS.

THE ANALYSE OF SOIL STRUCTURES OF THE UTRECHTSE HEUVELRUG EXPLAINS THEIR LIMITED WATER HOLDING CAPACITY. ONLY AT LIMITED PLACES, THE SOIL WAS ABLE TO DEVELOP AN IMPERMEABLE LAYER WHICH EXPLAINS THE PRESENCE OF HIGHER LOCATED WATER PONDS (VENNEN). THE LIMITED WATER HOLDING CAPACITY IS THE REASON THAT THESE TYPE OF AREAS ARE VULNERABLE TO DROUGHT STRESS.

FIGURE 13: RECONCRUSTION OF SOIL IN 1500

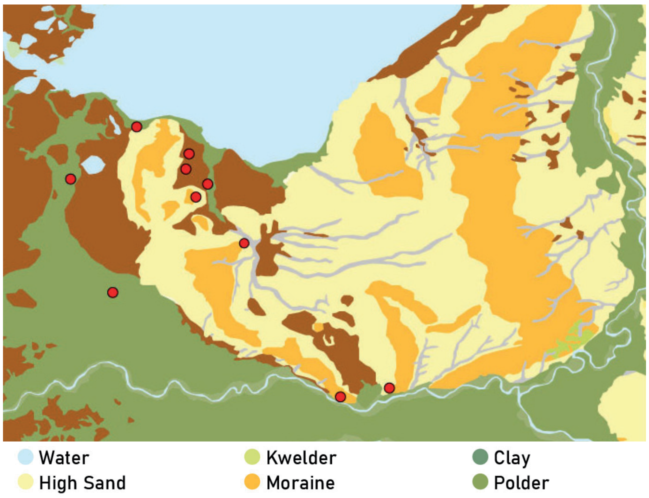


FIGURE 14: RECONCRUSTION OF SOIL IN 1850

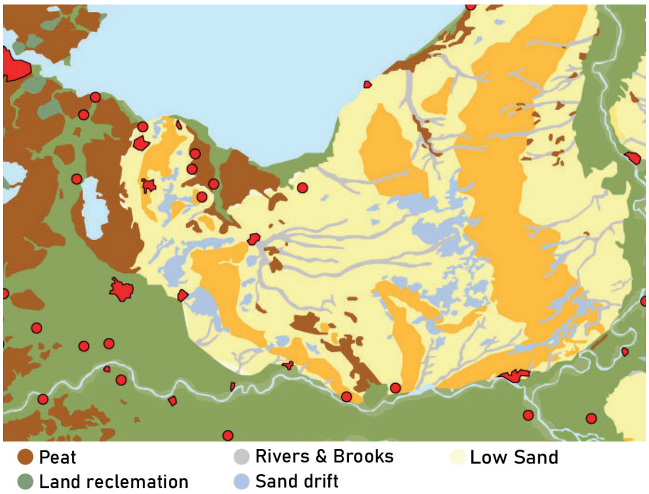


FIGURE 15: THE SEEPAGE AND INFILTRATION AREAS IN THE UTRECHTSE HEUVELRUG

FIGURE 16: PROTECTED AREAS FOR THE EXTRACTION OF GROUND WATER

Protected area
Extraction of water

WATER CYCLE ANALYSIS

THE DEVELOPMENT OF THE SOIL HAS SHOWN THAT IT HAS HARDLY CHANGED SINCE ITS FORMATION DURING THE PLEISTOCENE. THE WATER SYSTEM IS THEREFORE DETERMINED BY THE GEOMORPHOLOGICAL PROCESSES THAT PREVIOUSLY FORMED TOPOGRAPHY OF THE UTRECHTSE HEUVELRUG.

THE GEOMORPHOLOGICAL MAP SHOWS THREE PROCESSES WHICH ARE RELEVANT FOR THE WATER CYCLE OF THE UTRECHTSE HEUVELRUG.
FIRST OF ALL, THE UTRECHTSE HEUVELRUG IS PART OF A COMPLEX OF MORAINES IN THE NETHERLANDS. IT IS THE RESULT OF GLACIAL PROCESSES DURING THE SALE GLACIATION PERIOD. DURING THIS PERIOD A GLACIER COVERED THE NORTHERN PART OF THE NETHERLANDS. THE MASS OF THE MOVING ICE ELEVATED DEPOSITS WHICH FORMED RIDGES IN THE LANDSCAPE.

SECONDLY, THESE ICE SHEETS ALSO FORMED DRY VALLEYS. A RESULT OF THE TUNDRA CLIMATE WAS THE FORMING OF PERMAFROST IN THIS PERIOD. THE FROZEN SOIL DID NOT LET INFILTRATE MELTING WATER FROM THE TOPSOIL LAYER. THE MELTING WATER ERODED THE DRY VALLEY PERPENDICULAR TO THE SLOPE OF THE MORAINE.

THIRDLY, MELTING WATER OF ICE SHEET DEPOSITED HORIZONTAL LAYERS OF MINERALS. GRAVEL AND COARSE SAND WERE DEPOSED ON THE MORAINE. FINE SAND AND LOAM ENDED UP AT THE EDGE OF THE MORAINE. THESE DEPOSITS FORMED OUTWASH PLAINS (SANDRS).

THE RESULTING TOPOGRAPHY OF THESE THREE LAND FORMING PROCESSES AND CAPILLARY EFFECT OF THE WATER CAUSES THE HIGHER GROUNDWATER TABLE OF THE AREA. THE GROUNDWATER IS ACCUMULATED IN AN UNCONFINED AQUIFER WHICH HAS AN OPEN CONNECTION WITH EXISTING OPEN WATER BODIES. THIS RESULTS IN A FLOW OF WATER IN THE SUBSOIL. IT CREATES SEEPAGE AT THE EDGES OF THE MORAINES AND OUTWASH PLAINS (FIG. 15).

THE MAP OF THE GROUNDWATER TABLE IN THE UTRECHTSE HEUVELRUG SHOWS THAT MOST OF THE MORAINE IS CLASSIFIED IN THE LOWEST LEVEL (VIII). THE LEVEL OF GROUNDWATER IS LARGER THAN 140 CM DURING WINTER (GHG) OR 160 CM DURING SUMMER (GLG).
FURTHERMORE, THE GROUNDWATER TABLE IS GRADUALLY LOWERING DUE TO TWO HUMAN INFLUENCES. THE PLANTATION OF CONIFEROUS FOREST DIMINISHED THE AMOUNT OF RAINWATER EXCESS. HUMANS HAVE ALSO EXTRACTED GROUNDWATER FOR THEIR SUPPLY OF DRINKING WATER SINCE THE 19TH CENTURY (FIG. 16).

SOESTDUINEN WAS THE FIRST AREA WHICH WAS USED TO SUPPLY THE SURROUNDING TOWNS OF DRINKING WATER. THEREFORE A WATER SUPPLY SYSTEM OF PIPES AND WATER TOWERS WAS BUILT. TOWNS LIKE AMERSFOORT, ZEIST, DOORN, LEERSUM AND BILTHOVEN ALSO BUILT THEIR DRINKING WATER INFRASTRUCTURE AT THE BEGINNING OF THE 20TH CENTURY. LOCAL ENTREPRENEURS STARTED COMPANIES WHICH BECAME RESPONSIBLE FOR THE EXTRACTION AND SUPPLY OF DRINKING WATER. CENTRALISATION OF THE DRINKING WATER SUPPLY SYSTEM LEADS TO SEVERAL FUSIONS OF THESE COMPANIES LIKE UTRECHSCHE WATERLEIDING MAATSCHAPPIJ, NV BRONWATERLEIDING DOORN AND VENENDAALSCHE WATERLEIDINGMAATSCHAPPIJ. THIS RESULTED IN THE CURRENT WATER SUPPLY COMPANY, VITENS.

THE EXTRACTION OF GROUNDWATER LED TO THE PROTECTION OF THESE NATURAL AREAS. ACTIVITIES WHICH ENDANGERED THE QUALITY OF DRINKING WATER ARE FORBIDDEN IN THESE PROTECTED GROUNDWATER EXTRACTION AREAS. MOREOVER, AN AREA SURROUNDING THESE PROTECTED AREAS IS ALSO PROTECTED AGAINST ANY DRILLINGS THAT PUNCTURE THE CONFINING CLAY BED OF THE AQUIFER.

THE WATER ANALYSIS SHOWS THAT THE AREA LACKS THE ABILITY TO BUFFER WATER. THE CONDITIONS GENERATED BY THE SOIL PREVENTS THE FORMATION OF NATURALLY FORMED BUFFERS. MOREOVER, THERE WAS NO REASON FOR HUMANS TO MANAGE THE WATER SYSTEM ARTIFICIALLY IN THE PAST. A DEFICIENT IN THE PRECIPITATION CAN ONLY BE SOLVED BY DEVELOPING THESE BUFFERS. THIS PREVENTS THE FURTHER DETERIORATION OF THE WATER BALANCE.

FIGURE 16: THE DISTRIBUTION OF DECIOUS, MIXED AND CONIFEROUS FORESTS.

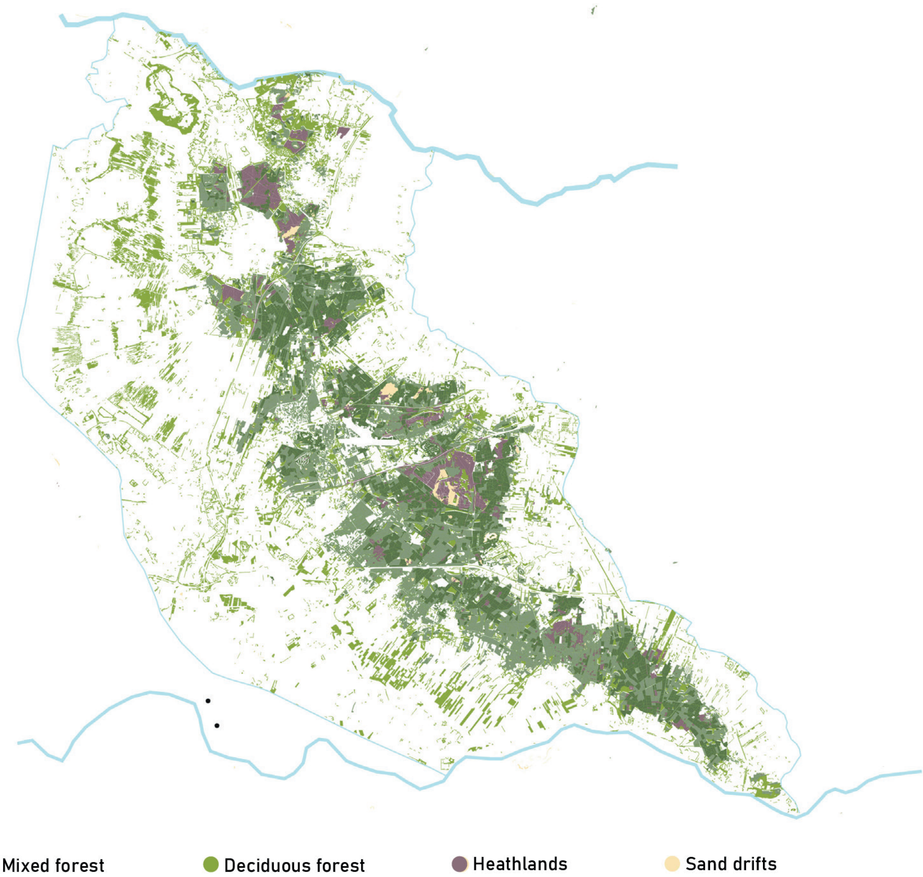
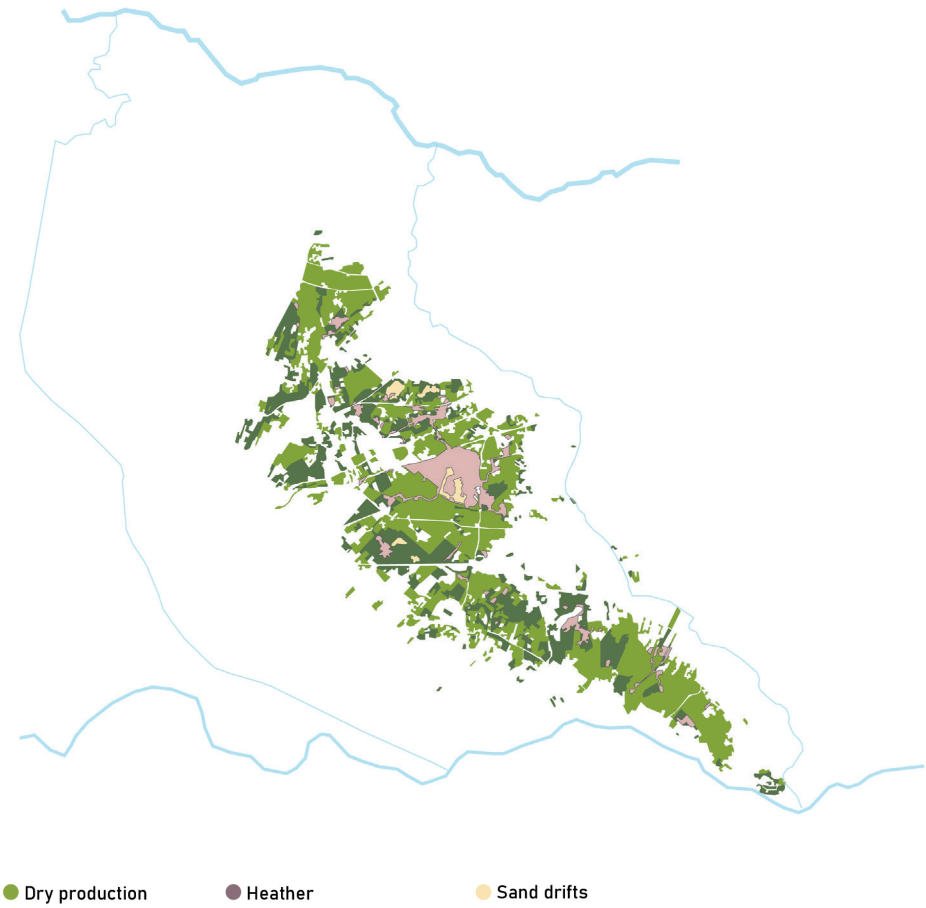


FIGURE 17: THE VEGEATATIONTYPES OF OF THE FOREST STRUCTURE IN THE UTRECHTSE HEUVELRUG



ECOLOGY

THE ECOSYSTEM IN THE UTRECHTSTE HEUVELRUG IS A SEASONAL FOREST WHICH CONSISTS OF FIVE TYPES OF VEGETATIONS: DECIDUOUS FOREST, MIXED FOREST, CONIFEROUS FOREST, HEATHLAND AND SAND DRIFT (FIG. 16). THE VEGETATION MAPS SHOW THE SPATIAL STRUCTURE OF THESE VEGETATION TYPES (FIG. 17). FURTHERMORE, IT APPEARS THAT THREE OTHER VEGETATION TYPES GROW ALONG THE EDGES OF THE MORAINE.

TTHE ANNUAL PRECIPITATION AND AVERAGE ANNUAL TEMPERATURE CLASSIFY THE ECOLOGICAL ZONE OF THE UTRECHTSE HEUVELRUG AS A TEMPERATE SEASONAL FOREST. HOWEVER, HUMAN EXISTENCE HAS RESULTED IN A LANDSCAPE WHICH CAN BE DESCRIBED AS A PATCHWORK OF DIFFERENT NATURAL AND MANAGED ECOSYSTEMS. NATURAL TERRESTRIAL ECOSYSTEMS ARE FOR EXAMPLE CONIFEROUS FORESTS, TEMPERATE DECIDUOUS FORESTS AND HEATHLANDS. THE MANAGED TERRESTRIAL ECOSYSTEMS ARE MANAGED GRASSLANDS, FIELD CROPS AND URBAN ECOSYSTEMS. LASTLY, THE SURROUNDING LANDSCAPE ALSO CONTAINS AQUATIC ECOSYSTEMS LIKE RIVER AND STREAMS AND MANAGED AQUATIC ECOSYSTEM.

THE FOREST CONSISTS FOR THE MOST PART OF DRY PRODUCTION FOREST (KENNISNETWERK OBN, 2020E). IT GROWS ON SANDY SOILS WHICH ARE DRY, NUTRIENT-POOR AND ACIDIC. COMMON TREES ARE PINE (PINUS SYLVESTRIS), OAK (QUERCUS ROBUR/QUERCUS PETRAEA), BEECH (FAGUS SYLVATICA), DOUGLAS (PSEUDOTSUGA MENZIESII), LARCH (LARIX KAEMPFERI/LARIX DECIDUA) AND NORWAY SPRUCE (PICEA ABIES). PINE, OAK AND BEECH ARE USUALLY PLANTED ON POORER SOILS. WHILE, BEECH, DOUGLAS, LARCH AND NORWAY SPRUCE WERE ALSO PLANTED ON RICHER SANDY SOILS.
THE SECOND VEGETATION TYPE IS OAK, BEECH & PINE-FOREST (KENNISNETWERK OBN, 2020D), WHICH IS SLIGHTLY DIFFERENT FROM DRY PRODUCTION FORESTS (FIG. 19) SINCE WOOD PRODUCTION IS NOT THE DOMINANT REASON BEHIND THE MAINTENANCE OF THESE FORESTS. VEGETATION CONSISTS, FOR INSTANCE OF AT LEAST 80% OF NATIVE SPECIES LIKE OAK, PINE, BEECH, BIRCH (BETULA PENDULA) AND ROWAN (SORBUS AUCUPARIA). THE REST OF THE VEGETATION CONSISTS OF EXOTIC SPECIES LIKE DOUGLAS AND RED OAK (QUERCUS RUBRA). THE DEPOSITION OF ACIDIC LEAVES FROM OAK AND BEECH TREES LIMITS THE GROWTH OF GROUND VEGETATION UNDERNEATH THE TREES. THIS RESULTS IN THE TYPICAL OPEN FOREST STRUCTURE.
THE PRESENCE AND SPREAD OF FAUNA LIKE BIRDS AND COMMON FLORA IS AN INDICATOR OF THE BIOTIC QUALITY OF THESE FORESTS. THESE FORESTS FORM THE HABITAT OF BIRDS LIKE HAWFINCH (COCCOTHRAUSTES COCCOTHRAUSTES), EURASIAN NUTHATCH (SITTA EUROPAEA), WOOD WARBLER (PHYLLOSCOPUS SIBILATRIX), YELLOWHAMMER (EMBERIZA CITRINELLA), GREEN WOODPECKER (PICUS VIRIDIS), BRAMBLING (FRINGILLA MONTIFRINGILLA), LESSER SPOTTED WOODPECKER (DRYOBATES MINOR), MIDDLE SPOTTED WOODPECKER (DENDROCOPTES MEDIUS), COMMON RAVEN (CORVUS CORAX), EURASIAN SISKIN (SPINUS SPINUS), COMMON FIRECREST (REGULUS IGNICAPILLA), COMMON HONEY BUZZARD (PERNIS APIVORUS), GOLDEN ORIOLE (ORIOLUS ORIOLUS) AND BLACK WOODPECKER (DRYOCOPUS MARTIUS). THE WOODLARK (LULLULA ARBOREA), YELLOWHAMMER (EMBERIZA CITRINELLA), MIDDLE SPOTTED WOODPECKER AND GOLDEN ORIOLE ARE SPECIES OF CONCERN. THEY ARE RARE OR ENDANGERED KEY SPECIES IN DE NETHERLANDS.

THE THIRD VEGETATION TYPOLOGY IS HEATHLAND (FIG. 20), WHICH CAN BE DIVIDED INTO TWO TYPES OF HEATHLANDS. DRY HEATHLANDS ARE THE FIRST TYPE OF HEATHER. IT COVERS MOST OF THE HEATHLANDS IN UTRECHTSE HEUVELRUG. THIS VEGETATION TYPOLOGY CONSISTS OF PIONEER SPECIES WHICH FORM FIRST SUCCESSION STAGE OF ALKALI-POOR, SANDY AND LOAMY SOILS. THEREFORE THE CONSERVATION OF THIS VEGETATION DEPENDS ON GRAZING. MOREOVER, THE NUTRIENT-POOR CONDITIONS MAKE IT VULNERABLE TO NITROGEN DEPOSITION (KENNISNETWERK OBN, 2020B). DRY HEATHLANDS CONTAIN FOR AT LEAST 60 % OF HEATHERS LIKE COMMON HEATHER (CALLUNA VULGARIS), CROWBERRY (EMPETRUM NIGRUM), BLUEBERRY (VACCINIUM MYRTILLUS), WAVY HAIR-GRASS (DESCHAMPSIA FLEXUOSA) AND PURPLE MOOR GRASS (MOLINIA CAERULEA). SMALL GROUPS AND SOLITARY SHRUBS AND TREES GROW ALSO IN THESE HEATHLANDS. EXAMPLES OF THESE SHRUBS AND TREES ARE COMMON JUNIPER (JUNIPERUS COMMUNIS), SCOTCH BROOM (CYTISUS SCOPARIUS) AND BIRCH (BETULA PENDULA). BARE SAND SOILS ARE ALSO COMMON TO A LIMITED EXTEND.

DRY HEATHLAND IS THE HABITAT FOR BIRDS LIKE WOODLARK (LULLULA ARBOREA), RED-BACKED SHRIKE (LANIUS COLLURIO), EUROPEAN STONECHAT (SAXICOLA RUBICOLA), WHEATEAR (OENANTHE OENANTHE), COMMON CURLEW (NUMENIUS ARQUATA). MOREOVER, THIS VEGETATION TYPE IS HOME FOR SOME RARE OR ENDANGERED SPECIES LIKE NORTHERN WRYNECK (JYNX TORQUILLA), GREAT GREY SHRIKE (LANIUS EXCUBITOR), BLACKCOCK (LYRURUS TETRIX) AND EURASIAN SKYLARK (ALAUDA ARVENSIS). LASTLY, IT IS ALSO THE HOME FOR REPTILES AND INSECTS LIKE COMMON ADDER (VIPERA BERUS), SAND LIZARD (LACERTA AGILIS), GRIZZLED SKIPPER (PYRGUS MALVAE), BLUE-WINGED GRASSHOPPER (OEDIPODA CAERULESCENS), TWO-SPOTTED GROUND-HOPPER (TETRIX BIPUNCTATA), SMALL HEATH (COENONYMPHA PAMPHILUS) AND STRIPE-WINGED GRASSHOPPER (STENOBOTHRUS LINEATUS).

FURTHERMORE, IT IS THE HABITAT FOR SOME RARE/ENDANGERED SPECIES LIKE YELLOWHAMMER (EMBERIZA CITRINELLA), TWO-SPOTTED GROUND-HOPPER (TETRIX BIPUNCTATA), NIOBE FRITILLARY (FABRICIANA NIOBE), DARK GREEN FRITILLARY (SPEYERIA AGLAJA), ROCK GRAYLING (HIPPARCHIA SEMELE), HEATH BUSH-CRICKET (GAMPSOCLEIS GLABRA), SILVER-SPOTTED SKIPPER (HESPERIA COMMA), LESSER MOTTLED GRASSHOPPER (STENOBOTHRUS STIGMATICU), WART-BITER (DECTICUS VERRUCIVORUS) AND SADDLE-BACKED BUSH CRICKET (EPHIPPIGER EPHIPPIGER).
THE SECOND TYPE OF HEATHER GROWS IN (SEASONALLY) WET CONDITIONS (KENNISNETWERK OBN, 2020A). THE TEMPORAL PRESENCE OF WATER IS USUALLY THE RESULT OF A LOCAL SUPERFICIAL CONFINING BED OF LOAM OR PODZOLIC LAYER. THE MAJORITY CONSIST OF SMALL SHRUBS LIKE CROSS-LEAVED HEATH (ERICA TETRALIX), COMMON HEATHER, CROWBERRY AND PURPLE MOOR GRASS. MOREOVER, IT CONTAINS SMALLER PATCHES OF BARE

SOILS, SMALL STAGNANT PONDS, GRASSES, SHRUBS AND SMALL TREES. WET HEATHLANDS ARE A TYPICAL HABITAT FOR BIRDS AND INSECTS LIKE WHINCHAT (SAXICOLA RUBETRA), EUROPEAN STONECHAT (SAXICOLA RUBICOLA, WHEATEAR (OENANTHE OENANTHE), GRASSHOPPER WARBLER (LOCUSTELLA NAEVIA), EURASIAN SKYLARK (ALAUDA ARVENSIS), COMMON CURLEW (NUMENIUS ARQUATA), ALCON BLUE (MACULINEA ALCON), GREEN HAIRSTREAK (CALLOPHRYS RUBI), LARGE SKIPPER (OCHLODES SYLVANUS), SILVER-STUDDED BLUE (PLEBEJUS ARGUS), BOG BUSH CRICKET (METRIOPTERA BRACHYPTERA), LARGE MARSH GRASSHOPPER (STETHOPHYMA GROSSUM) AND TATRA GRASSHOPPER (PSEUDOCHORTHIPPUS MONTANUS). LASTLY, THIS VEGETATION TYPE IS HOME FOR RARE SPECIES. THIS INCLUDES, FOR INSTANCE, YELLOWHAMMER (EMBERIZA CITRINELLA), GREAT GREY SHRIKE (LANIUS EXCUBITOR) AND WHEATEAR (OENANTHE OENANTHE).

THE FOURTH VEGETATION TYPE IS SANDS DRIFTS (FIG. 21), WHICH ARE SIMILAR TO HEATHLAND. HOWEVER, IT HAS A HIGHER DEGREE OF BARE SAND SOILS COMBINED WITH COVER VEGETATION OF MOSSES, LICHENS AND (BUNT) GRASSES. THIS IS THE RESULT OF OVERGRAZING WHEREBY HEATHER DISAPPEARED, AND BARE SOIL STARTED DRIFTING. REMAINING VEGETATION CONSISTS OF PATCHES OF HEATHER AND GRASSLAND ON WHICH SMALL GROUPS OF SHRUBS AND SOLITARY TREES GROW.
THE SOIL CONTAINS HARDLY ANY ORGANIC MATERIALS, AND IT IS NUTRIENT- AND ALKALI-POOR. MOREOVER, IT HAS A LIMITED CAPACITY TO RETAIN MOISTURE. THEREFORE THIS VEGETATION TYPE IS VULNERABLE TO THE DEPOSITION OF NITROGEN WHICH ACCELERATES THE VERTICAL SUCCESSION INTO DRY GRASSLANDS AND FORESTS. CHARACTERISTIC FAUNA IS TREE GRAYLING, GRIZZLED SKIPPER, BLUE-WINGED GRASSHOPPER, SHORE EARWIG, TAWNY PIPIT, WOODLARK AND SAND LIZARD.

AT THE EDGE OF MORAINE AND SURROUNDING VALLEY, THREE OTHER VEGETATION TYPES ARE COMMON. COPPICE LED TO TWO TYPES OF VEGETATION DEPENDING ON WET OR DRY CONDITIONS OF THE SOIL. THESE PLOTS OF FOREST ARE THE RESULT OF THE FORMER WAY OF SILVICULTURE IN WHICH ONLY THE TOP PART OF THE TREE WAS CUT DOWN EVERY 4-15 YEARS. THE WOOD AND BARK WERE USED FIREWOOD, PRODUCTION OF TOOLS AND LEATHER. THIS METHOD WAS CONSIDERED AS A PROFITABLE WAY OF SILVICULTURE UNTIL THE BEGINNING OF THE 20TH CENTURY. HOWEVER, THESE FORESTS HAVE FALLEN IN DISREPAIR SINCE IT BECAME TOO LABOUR-INTENSIVE TO MANAGE THEM. DRY COPPICE IS SITUATED NEAR THE VILLAGES ON DRY SANDY SOILS. THESE ANCIENT PRODUCTION FORESTS USUALLY CONSIST OF OAK, BIRCH OR BEECH. THESE FORESTS ARE THE HABITAT FOR FLORA LIKE HYPERICUM AND MOSSES AND FAUNA LIKE WOODLARK (LULLULA ARBOREA), TREE PIPIT (ANTHUS TRIVIALIS), YELLOWHAMMER (EMBERIZA CITRINELLA) REDSTART (PHOENICURUS PHOENICURUS), GREENFINCH (CHLORIS CHLORIS) AND GOLDFINCH (CARDUELIS CARDUELIS).

WET COPPICE DIFFERENTIATES A BIT SINCE THESE FORESTS GROW ON MORE FERTILE AND MOIST SOILS. THE FOREST PRODUCED WOOD OF TREE SPECIES WHICH PREFER MOIST CONDITIONS LIKE ALDER (ALNUS GLUTINOSA), ASH (FRAXINUS EXCELSIOR), HAZEL (CORYLUS AVELLANA), HORNBEAM (CARPINUS BETULUS) AND OAK (QUERCUS ROBUR/ QUERCUS PETRAEA). THESE WET FORESTS ARE IDEAL HABITAT FOR BIRDS LIKE BLUETHROAT (LUSCINIA SVECICA), TREE PIPIT (ANTHUS TRIVIALIS), REDSTART (PHOENICURUS PHOENICURUS), NORTHERN GOSHAWK (ACCIPITER GENTILIS), WILLOW TIT (POECILE MONTANUS), NIGHTINGALE (LUSCINIA MEGARHYNCHOS), GOLDFINCH (CARDUELIS CARDUELIS), ICTERINE WARBLER (HIPPOLAIS ICTERINA), GOLDEN ORIOLE (ORIOLUS ORIOLUS) AND HAWFINCH (COCCOTHRAUSTES COCCOTHRAUSTES).

FLORA AND FAUNA OF THE UTRECHTSE HEUVELRUG ARE PRIMARILY INFLUENCED BY HUMANS. THE NATURAL FOREST HAS DISAPPEARED. MOREOVER, RESEARCH TO POLLEN HAS SHOWN THAT VEGETATION HAS EVOLVED DURING THE LAST CENTURIES. THE DIAGRAM SHOWS THE CHANGING PRESENCE OF DIFFERENT NATIVE TREE SPECIES DURING THE LAST TEN CENTURIES (JANSSEN & VISSCHER, 1974).
HUMANS HAVE, FOR INSTANCE, BEEN INTRODUCING NEW EXOTIC SPECIES SINCE ROMAN TIMES. THE ROMANS INTRODUCED SPECIES LIKE ORIENTAL PLANE (PLATANUS ORIENTALIS), SWEET CHESTNUT (CASTANEA SATIVA), BOXWOOD (BUXUS SEMPERVIRENS) AND GRAPEVINE (VITIS VINIFERA). FURTHERMORE, A LOT OF TREE SPECIES ORIGINATES FROM NORTH-AMERICA AND EAST-ASIA. THEY WERE INTRODUCED BETWEEN THE 17TH AND 20TH CENTURY. EXAMPLES OF THESE TREES SPECIES ARE THE RED OAK (QUERCUS RUBRA) AND DOUGLAS (PSEUDOTSUGA MENZIESII) WHICH WERE PLANTED DUE TO THEIR GROWTH RATE AND HIGH REVENUE (MAES ET AL., 1991, P14-20).

FIGURE 18: A EXAMPLE OF AN OAK,BEECH, PINE FOREST IN SPEULDERSBOS

FIGURE 19: DRY FOREST IN KOOTWIJKER BOS

Furthermore, humans are also responsible for the reintroduction of native species which were (almost) extinguished. The Scotch pine is a specie which disappeared in the Netherlands due to the changing climate after the last ice age. Since the 16th century, Scotch Pine has been planted in the Netherlands. These trees originated mostly from Germany. The broad usability of wood, especially in the mining industry and their ability to grow fast on poor sandy soils lead to large plantations of these trees. Nowadays, it is the most common tree in the Netherlands. Small-leaved lime (Tilia cordata) and Large-leaved lime (Tilia platyphyllos) used to be a common native in the Netherlands. However, it has gradually made a place for cultivars (Tilia × europaea). Not all these (re)introductions appeared to be successful as some species become invasive due to a lack of natural enemies or too ideal conditions. Trees like Black cherry (Prunus serotine), Red oak (Quercus rubra) and Black locust (Robinia pseudoacacia) appeared to be invasive after their introduction in the Netherlands. Current policy is to remove these invasive species as much as possible.

The introduction of non-native species became undesirable by the end of the 20th century. Their added value to the ecosystem appeared to be limited. The species diagram shows that native tree species attract much more insects than exotic species. This lead to a favouring of native species. However, Staatsbosheer started to introduce non-native species which appeared in research to be drought resistant (Hensels, 2020). According to Grundmann & Roloff (2009), the most drought-resistant tree species appear to be trees like Norway maple (Acer platanoides), walnut (Juglans regia) and hazel (Corylus avellane). The replacement of native trees have reservations from both an ecological and cultural point of view. It can conflict with nature values and the conservation of cultural landscape elements like old lanes and estates. This is the reason that this measure can only be limited applied for the most extreme cases.

Improvements

Improving the ecological value of these vegetation typologies can be achieved by taking five measures. First of all these forests are usually characterized by its large plantation of monocultures. Mixing these monocultures with other common trees is the first measure to improve these forest. Secondly, native species need to prevail over the exotic trees. This results in thinning of plots which are planted with Douglas, Lark, Spruce and Sessile oak. The third measure is retaining an adequate amount of dead vegetation. Forth provision is the establishment of clearings for two reasons. The clearings enhance the development of well-developed vertical vegetation structure in the edges of the forest. Moreover, the rotation of these clearing will improve the degree of horizontal succession through time. By doing so, the forest develops plots with a variety of different vegetation stages (BIJ12, 2020a; BIJ12, 2020b).

The presence of clearings, death material and well-develop edges are essential for increasing its diversity (and nature value). The clearing creates the perfect conditions for Rowan, Buckthorn and Bramble thickets. Moreover, the degree of homogeneity and the multi-tiered stages are essential factors.
The ecological analysis of the Utrechtse Heuvelrug shows its typical types of vegetation. These types appear that they all are already adapted to poor and dry conditions of the soil. Moreover, they are the result of constant human intervening since they started to reforest the area. However, these ecosystems appear to reach (soon) their limits to deal with arid conditions. Therefore these conditions need to be better managed to conserve current flora and fauna. The introduction of new species is only preferable if these conditions cannot further be managed.

Figure 20: Dry heather in Kootwijk

Figure 21: Sanddrift in the Utrechtse Heuvelrug

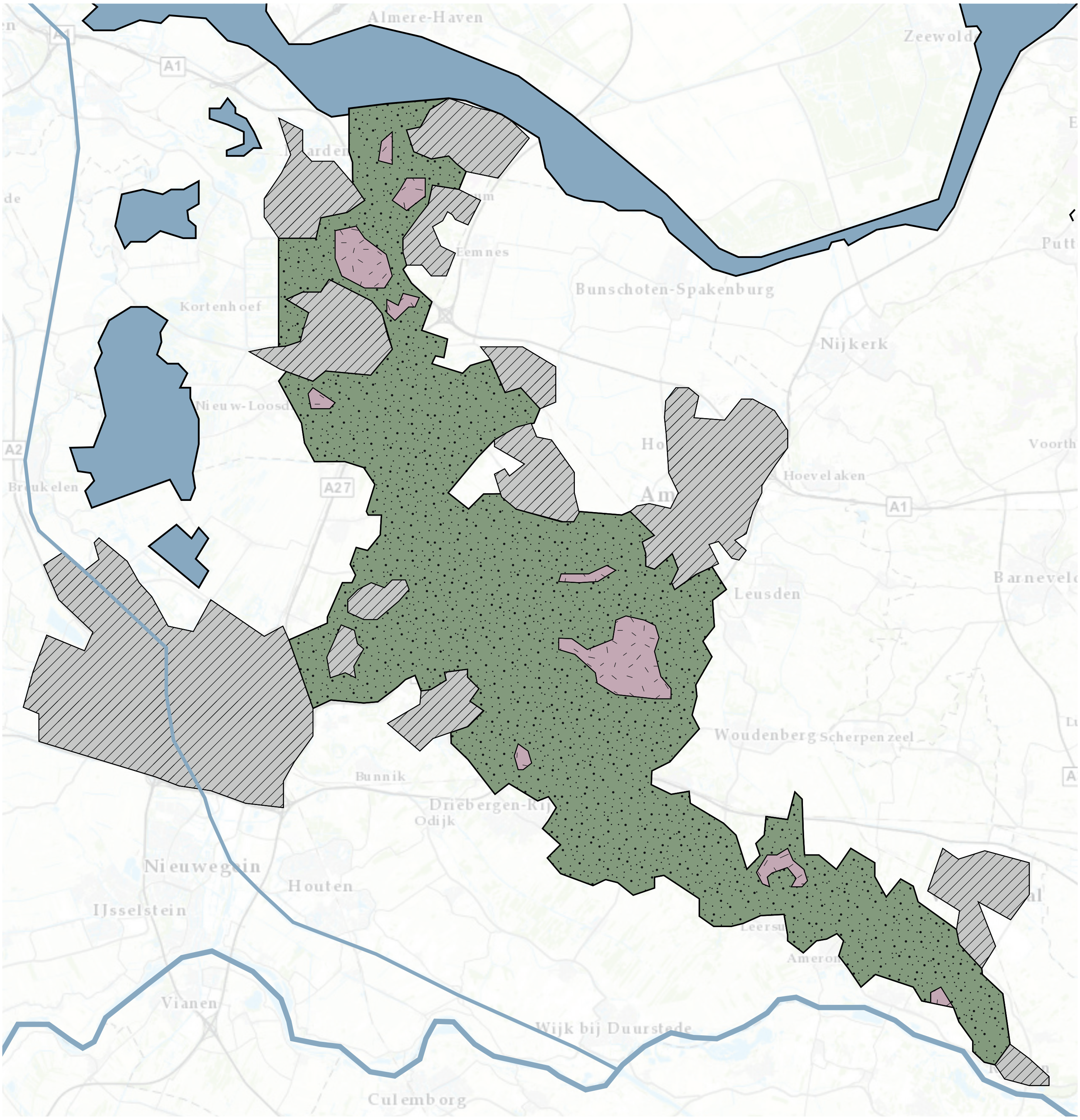


FIGURE 22: THE CURRENT URBANISATION OF THE UTRECHTSE HEUVELRUG CONCENTRATES IN THIIRTEEN URBAN CORES.

URBANISATION

THE URBANISATION HAS PLAYED AN ESSENTIAL ROLE IN THE ESTABLISHMENT OF THE CURRENT FOREST STRUCTURE. THESE URBAN AREAS WERE THE STARTING POINTS OF REFORESTATION OF THE UTRECHTSE HEUVELRUG (BLIJDENSTIJN ET AL., 2015, P.28-42). THEREFORE, THE URBANISATION OF THE AREA IS FURTHER ANALYSED.

The map (Fig. 22) shows the urban development in the area. Urbanisation is mostly concentrated in cities. The oldest types of cities which were founded before the 12th century. Utrecht is one of these Dutch cities which developed an administrative centre along trade routes. The second type of cities was founded as strategical outposts which were used to protect the territories of the Bishop of Utrecht. These cities include Amersfoort, Rhenen and Wijk bij Duurstede, Amersfoort and Rhenen. They were all founded during the 13th century. The last type of cities is founded along the rivers Eems, Hollandse IJssel and Kromme Rijn during the 14th century. However, their regional importance and urban growth stayed limited until the 19th century. Austerlitz is the last city which earned its city rights during French domination.

These cities were connected through a network of regional roads and rivers. Along these roads and rivers, smaller villages developed. Two types of villages developed in linear structure or surrounding agricultural common land. First of all, brinkdorpen with surrounding collective arable lands (engen) developed on top of moraines. Secondly, flankdorpen appeared at the edge of the moraine. These villages are situated between the higher arable lands and heather areas, and the lower meadows.

Expanding municipalities

The introduction of municipalities vanished the distinction between cities and villages in 1851. This lead to the first expansion of both these cities and villages. The industrialisation, which introduces new modes of faster transportation, lead to the first period of urban expansion. New urban settlements were established to house rising commuters and workers along with these new infrastructures. An example is Villapark Vogelzag (Fig. 24).

The third stage of urban development is the period after the Second World War. The stage consists of a period of vast planned urban expansions. Estates lost, for instance, their revenue model due to economic crises. This lead to the transformation of these estates in post-war residential districts. Subsequently, the rise of nature- and culture conservation policies led to the limitation of urban expansion in the area. This led to the current policy in which densification became the norm in existing urban areas at the beginning of the 21st century.

The urban analysis shows that urban sprawl has a tradition in which it goes hand-in-hand with the development of green outdoor spaces. Corresponding tree constellations characterise each of these stages. Cities used to have surrounding green belt (Fig .2£). Orchards and coppice-fields for their supply of food and wood. Trees were planted in villages surrounding their common lands or next to roads and railways. Moreover, trees were an integral part of the design of urban expansion like the first villa parks, and subsequently post-war garden city expansions. This topic will be further elaborated in the next chapter as it uses the landscape biography with an overview of these trees constellations. They form the foundation for the vision and design of drought adaptive interurban forest.

A final comment on these constellations is that they are sensitive to drought stress. They have to deal with more extreme conditions because the micro-climate of the urban areas differentiate due to the urban heat effect. Local municipalities and nature associations who are responsible for the management of these constellations need to improve its drought resistance by paying attention to it in their management regime.

Figure 23: The surrounding of urban settelments used to be forested

Figure 24: Villapark Vogelzang is a example of expansion of villages

DROUGHT ADAPTIVE MATRIX

THE THEORETICAL FRAMEWORK IS THE RESULT OF COMBINING THE URBAN FORESTRY MATRIX WITH DROUGHT STRESS CYCLE. IN THIS WAY, A MODEL IS PROPOSED THAT ADDRESSES DROUGHT STRESS ON THREE SCALES OF URBAN FOREST. THE MODEL INCLUDES THE SCALE OF THE TREE ITSELF, CONSTELLATIONS OF TREES AND THE OVERALL GREEN STRUCTURE.

THE THEORETICAL FRAMEWORK (FIG. 25) IS THE RESULT OF COMBINING THE URBAN FORESTRY MATRIX WITH DROUGHT STRESS CYCLE. IN THIS WAY, A MODEL IS PROPOSED THAT ADDRESSES DROUGHT STRESS ON THREE SCALES OF THE URBAN FOREST. THE MODEL INCLUDES THE SCALE OF THE TREE ITSELF, CONSTELLATIONS OF TREES AND THE OVERALL FOREST STRUCTURE. FOUR DIMENSIONS OF THE URBAN FORESTRY ARE USED TO ANALYSE AND DESIGN URBAN FORESTRY STRUCTURES: ECOLOGY, FORESTRY, HYDROLOGY AND URBAN PLANNING. THESE DIMENSIONS ARE ANALYSED TO UNDERSTAND THE CURRENT FUNCTIONING OF THE INTERURBAN FOREST.

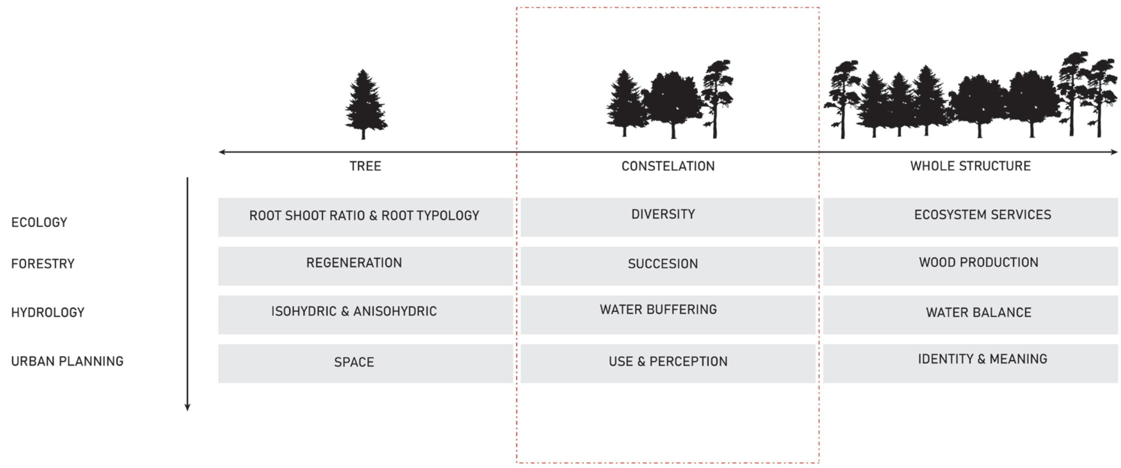
THE FIRST DIMENSION IS THE PERSPECTIVE OF ECOLOGY. IT APPEARS THAT THE CONSTRAINTS OF THE UTRECHTSE HEUVELRUG CHARACTERISE CURRENT VEGETATION. MAINLY THE DRY, POOR AND ACID CONDITIONS OF THE AREA LEAD TO CHARACTERISTIC VEGETATION WHICH ALREADY SUITED FOR THESE CONSTRAINTS. HOWEVER, THE ROBUSTNESS OF GREEN STRUCTURE APPEARS TO DIMINISH. THE VEGETATION SEEMS NOT ABLE TO ADAPT THEMSELVES AGAINST THE MORE AND MORE EXTREME CONDITIONS THAT DROUGHT GENERATES.
THE SECOND DIMENSION LOOKS INTO THE DEVELOPMENT OF FORESTRY IN THE AREA. IT APPEARED MOST OF NATIVE OAK AND BIRCH-FORESTS WHICH GREW AFTER THE LAST ICE AGE (WECHSELIEN) DISAPPEARED DUE TO LODGING AND AGRICULTURAL PRACTICE BETWEEN 10TH AND 17TH CENTURY. THE EFFORT OF LOCAL AND NATIONAL AUTHORITIES HAVE LED TO THE FORMATION OF FORESTRY. THE CURRENTLY FORESTED AREAS ARE THE RESULT OF THIS EFFORT, ALTHOUGH THE APPROACH HAS CHANGED DURING THE LAST FOUR CENTURIES. THE DIFFERENT APPROACHES HAVE LED TO AN EVER-EVOLVING PATCHWORK OF DIFFERENT TREE CONSTELLATIONS.

THE THIRD DIMENSION CONTAINED A HYDROLOGICAL ANALYSIS SHOWED THAT THE AREA IS CHARACTERISED BY THE ABSENCE OF HUMAN-DRIVEN MANAGEMENT OF WATER. THE UTRECHTSE HEUVELRUG RELIES ON THE NATURAL INFILTRATION SYSTEM THAT FUNCTIONS AS A RECHARGE AREA FOR GROUNDWATER. THE AREA BECAME ALTHOUGH NECESSARY FOR THE SUPPLY OF DRINKING WATER. LARGE PARTS OF THE UTRECHTSE HEUVELRUG ARE PROTECTED AS DRINKING WATER SUPPLIES. THE EXTRACTION OF GROUNDWATER HAS THE DOWNSIDE THAT NATURE AREAS ON THE MORAINE BECOME MORE VULNERABLE FOR DROUGHTS. MOREOVER, VEGETATION RELIES MOSTLY ON RAINWATER SINCE IT IS HARDLY CAPABLE OF RETAINING IT. THIS MAKES IT MORE VULNERABLE TO LONG-LASTING DROUGHT PERIODS.

THE LAST DIMENSION ANALYSED THE URBAN DEVELOPMENT OF THE AREA. THE HUMAN PRESENCE IN THE LANDSCAPE WAS LIMITED FOR AN EXTENDED PERIOD. THE POOR SANDY SOIL MADE THE AREA NOT SUITABLE FOR AGRICULTURE. THE DEVELOPMENT OF CITIES WAS VERY LIMITED DUE TO INADEQUATE RESOURCES AND CONNECTIVITY OF THE AREA. THEREFORE ONLY SMALL SETTLEMENTS DEVELOPED. THE COMING OF INFRASTRUCTURES LIKE RAILWAYS AND HIGHWAYS IMPROVED THE CONNECTIVITY OF THE AREA. THIS MADE WAY FOR URBAN EXPANSION OF THESE VILLAGES. MOREOVER, ESTATES LOST THEIR REVENUE MODEL AFTER THE SECOND WORLD WAR. THIS LEAD TO THE TRANSFORMATION OF THESE ESTATES INTO POST-WAR RESIDENTIAL DISTRICTS. THE RISE OF NATURE CONSERVATION POLICIES LED TO THE LIMITATION OF URBAN EXPANSION IN THE AREA. THIS LED TO THE CURRENT POLICY TO DENSIFY WITHIN THE BOUNDARIES OF CURRENT URBAN SETTLEMENTS.

THE THEORETICAL FRAMEWORK WILL SUBSEQUENTLY BE USED AS A METHOD TO A DESIGN DROUGHT ADAPTIVE INTERURBAN FOREST IN THE NEXT CHAPTER. THE VISION PROPOSES A NEW FOREST STRUCTURE. THE VISION IS FURTHER ELABORATED IN A REGIONAL DESIGN FOR WOUDENBERG. IT MAPS, BY DOING SO, THE SPATIAL IMPLICATIONS OF DROUGHT ADAPTIVE STRATEGIES. THE DESIGN SHOWS A SYSTEM OF DIFFERENT TREE CONSTELLATION, WHICH IS NECESSARY TO ESTABLISH THIS OVERALL STRUCTURE. LAST PART OF THE DESIGN EXPLAINS IN DETAIL THE DESIGN OF ALL SEVEN TYPES OF PROPOSED TREE CONSTELLATIONS..

FIGURE 25: DROUGHT ADDAPTIVE MATRIX SERVES AS A FRAME WORK FOR DROUGHT ADDATIPVE DESIGN IN LANDSCAPEARCHITECTURE



VISION

TTHE FOREST STRUCTURE OF THE UTRECHSE HEUVELRUG IS CONSIDERED TRADITIONALLY AS A PROTECTED GREEN CORE WHICH IS SURROUNDED BY AGRICULTURAL AND URBAN CORES (FIG. 26). THE VISION SHIFTS FROM THIS NOTION TO A VISION IN WHICH THE LARGER GREEN STRUCTURE IS REGARDED AS AN INTERURBAN FOREST. BY DOING SO, THE STRUCTURE CAN DEVELOP FURTHER IN A DROUGHT ADAPTIVE WAY THAT ALLOWS ROOM FOR BOTH SOCIETAL AND ENVIRONMENTAL CHALLENGES. THIS CONCERNS ISSUES LIKE AN ENVISIONED FOREST EXPANSION OF 10.000 HECTARES AND THE BUILDING OF CIRCA 30.000 DWELLINGS IN THE AREA.

THE INTERURBAN FOREST CONSIDERS ITSELF AS A PATCHWORK OF SMALLER FORESTRY CORES. THESE CORES WILL EACH INCORPORATE ADJACENT AGRICULTURAL AND URBAN CORES AS THE STRUCTURE EXPANDS (FIG. 29). THE FURTHER DEVELOPMENT OF THESE PATCHES INVOLVES TWO STAGES. THE FIRST STAGE (FIG. 27) IS THE TRANSFORMATION OF THE CURRENT FOREST STRUCTURE. IT INCLUDES THE ADDITION OF SEASONAL BUFFERS IN BETWEEN THE FORESTRY, AGRICULTURAL AND URBAN CORES. THESE BUFFERS CONSIST OF GULLIES WHICH CATCH EXCESS OF RAINWATER AND SEEPAGE AND STORES IT TEMPORALLY IN BASINS. DURING DROUGHT EVENTS, THESE BASINS WILL DISTRIBUTE THE RETAINED WATER THROUGH THE SAME SYSTEM OF GULLIES.

THE SECOND STAGE (FIG. 28) CONSISTS OF THE EXPANSION OF THE PATCHWORK. NEW FORESTED PATCHES WILL BE PLANTED BETWEEN THE AGRICULTURAL AND URBAN CORES. THEREFORE, HYBRIDS BETWEEN THESE CORES WILL BE INTRODUCED. THESE HYBRIDS ARE CLEARINGS WHICH HOUSE DIFFERENT MIX-USES LIKE FOOD-PRODUCTION, HOUSING, RECREATION AND WATER BUFFERING. LASTLY, THE VEGETATION WILL BE GRADUALLY REPLACED BY DROUGHT ADAPTIVE CONSTELLATIONS INSIDE THESE FORESTRY, AGRICULTURAL AND URBAN CORES.

THE VISION IS FURTHER ELABORATED IN A DESIGN FOR THE SUB-AREA OF UTRECHT HEUVELRUG. THEREFORE THE FOREST STRUCTURE OF SUB-AREA IS ANALYSED. THIS IS THE AREA IN BETWEEN DRIEBERGEN-ZEIST, AUSTERLITZ, DOORN, LEERSUM LEUSDEN AND WOUDENBERG. FURTHERMORE, THE DESIGN ZOOMS IN ON THE AREA BETWEEN AUSTERLITZ AND WOUDENBERG.

FIGURE 26: CONCEPTALISATION OF THE CURRENT FOREST STRUCTURE

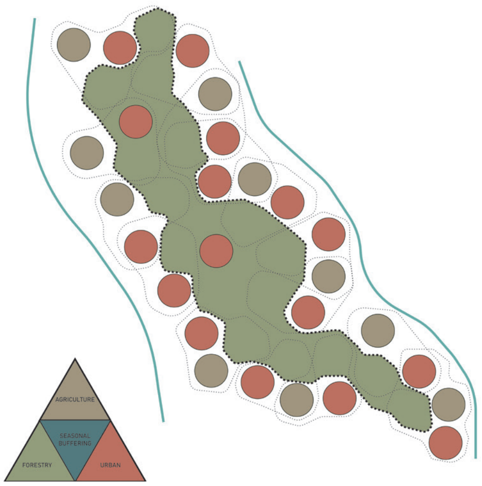


FIGURE 27 THE FIRST PHASE OF THE VISION: TRANSFORMATION OF THE STRUCTURE

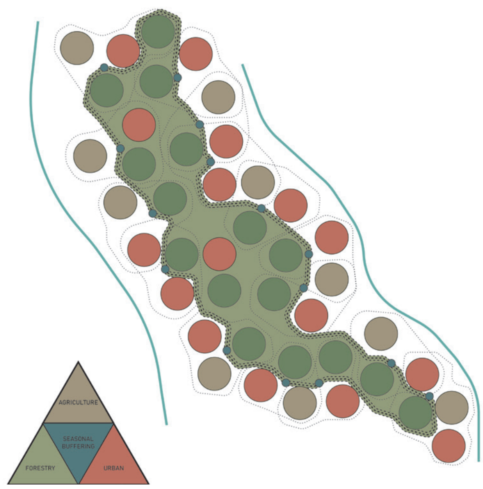


FIGURE 28: THE SECOND PHASE OF THE VISION: EXPANSION OF OF THE STRUCTURE

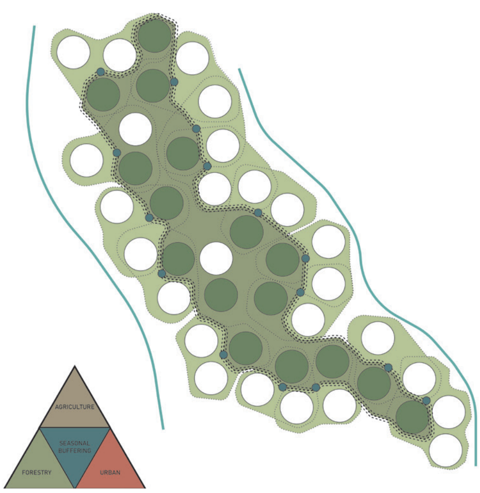
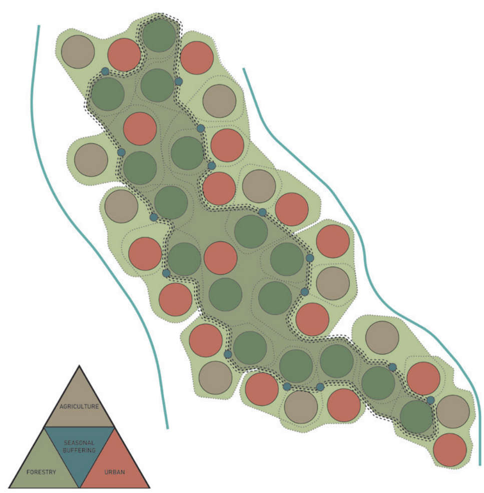


FIGURE 29: CONCEPT FOR THE FUTURE DROUGHT ADDAPTIVE INTERURBAN FOREST



Current Forest · Forest Cores · Forest Expansions · Urban Cores · Argicutural Cores · Circular Watersystem

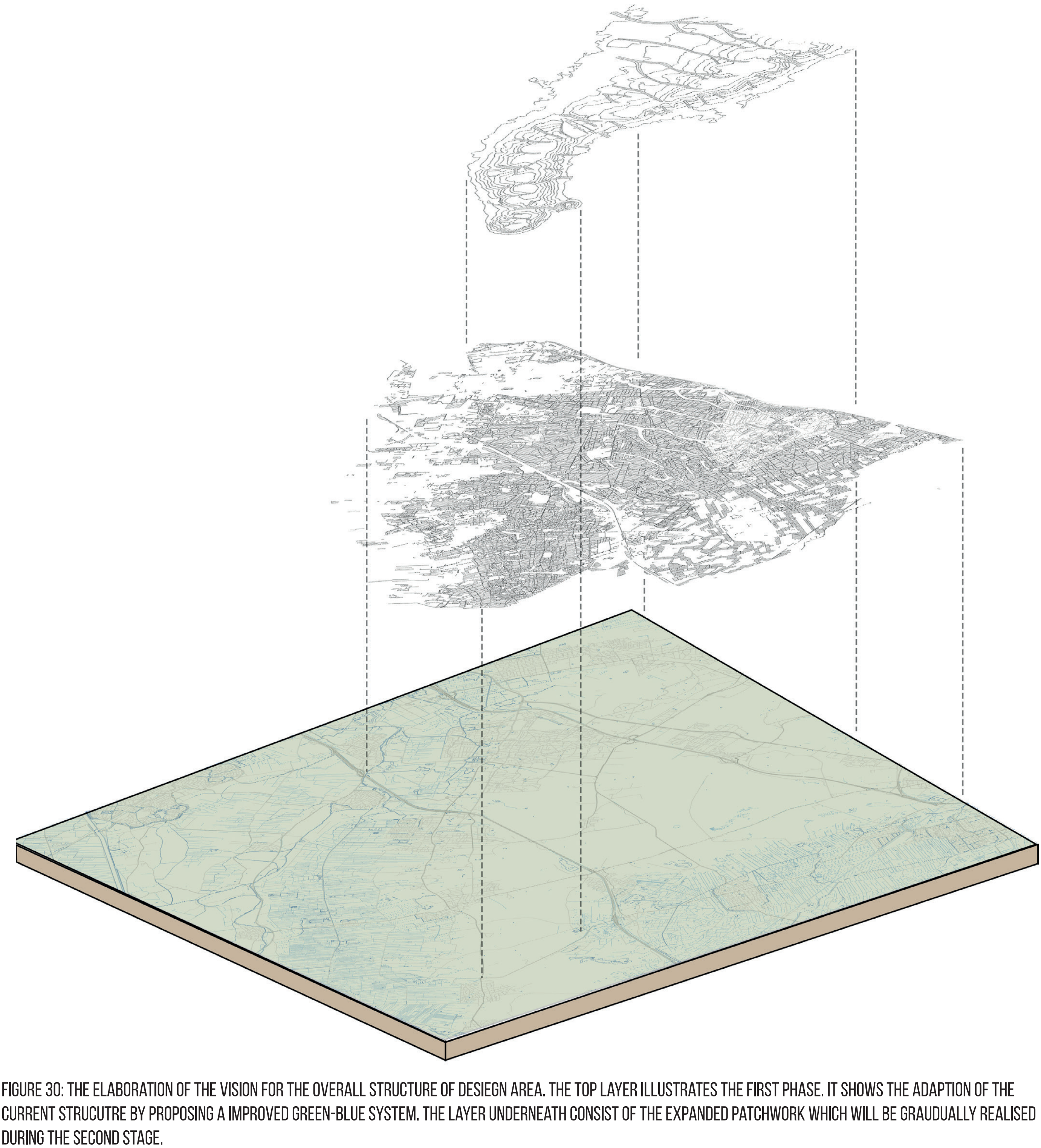


FIGURE 30: THE ELABORATION OF THE VISION FOR THE OVERALL STRUCTURE OF DESIEGN AREA. THE TOP LAYER ILLUSTRATES THE FIRST PHASE. IT SHOWS THE ADAPTION OF THE CURRENT STRUCUTRE BY PROPOSING A IMPROVED GREEN-BLUE SYSTEM. THE LAYER UNDERNEATH CONSIST OF THE EXPANDED PATCHWORK WHICH WILL BE GRAUDUALLY REALISED DURING THE SECOND STAGE.

THE OVERALL FOREST STRUCTURE

THE DESIGN OF DROUGHT ADAPTIVE INTERURBAN FOREST STRUCTURES CONSIDERS THEM AS A PATCHWORK THAT IS HELD TOGETHER BY A GRID OF AXES (FIG. 30). THE EXISTING SITUATION OF THESE STRUCTURES IS THE STARTING POINT OF THE DESIGN. THEREFORE THE ESTABLISHMENT OF THE CURRENT STRUCTURE IS ANALYSED IN GREATER DETAIL. SUBSEQUENTLY, THE FUTURE DEVELOPMENT OF THIS STRUCTURE IS DISCUSSED IN ITS ENVISIONED DESIGN. LASTLY, THE DIFFERENT CORRESPONDING CONSTELLATIONS WHICH ARE NEEDED TO TRANSFORM THE CURRENT GRID ARE DESCRIBED. THIS INCLUDES SEVEN TREE-CONSTELLATIONS.

THE DESIGN OF DROUGHT ADAPTIVE INTERURBAN FOREST STRUCTURES CONSIDERS THEM AS A PATCHWORK THAT IS HELD TOGETHER BY A GRID OF AXES. THE EXISTING SITUATION OF THESE STRUCTURES IS THE STARTING POINT OF THE DESIGN. THEREFORE THE ESTABLISHMENT OF THE CURRENT STRUCTURE IS ANALYSED IN GREATER DETAIL. THE HISTORICAL DEVELOPMENT OF THE CURRENT STRUCTURE SHOWS THAT IT CONSISTS OF FOUR CONSTELLATIONS (FIG. 33 & FIG. 34).
SUBSEQUENTLY, THE FUTURE DEVELOPMENT OF THIS STRUCTURE IS DISCUSSED IN ITS ENVISIONED DESIGN. THE DESIGN CONSISTS OF AN ADAPTED GRID BASED ON A NEW PROPOSED GREEN AND BLUE SYSTEM. IN THIS WAY, THE GRID WILL FACILITATE FURTHER EXPANSION OF THE FOREST. LASTLY, THE DIFFERENT CORRESPONDING CONSTELLATIONS WHICH ARE NEEDED TO TRANSFORM THE CURRENT GRID ARE DESCRIBED. THIS INCLUDES SEVEN DIFFERENT TREE-CONSTELLATIONS.

INTRODUCING FIRST WOODED COMMONS

THE FIRST REFORESTATION APPEARED TO BE THE ESTABLISHMENT OF COPPICE PLANTATIONS NEAR VILLAGES AND THE PLANTING OF TREES ALONG THE CONNECTING ROADS (BLIJDENSTIJN ET AL., 2015, P.205 - 230). THEY WERE CONSIDERED AS LONG TERM INVESTMENTS IN THE 17TH AND 18TH CENTURY DUE TO ITS WOOD YIELD. THE DOMINANT TREE SPECIES WERE OAK AND BEECH DUE TO ITS MEANING AND GROWTH-RATE. DIFFERENT CONSTELLATIONS OF LANES WERE PLANTED IN THIS PERIOD. A DIFFERENT NUMBER OF ROWS WERE PLANTED ACCORDING TO THE IMPORTANCE OF THE ROAD. MOREOVER, ALSO THE TYPE OF MOVEMENT DETERMINED THE PATTERN IN WHICH THE TREES WERE PLANTED. TREES WERE PLANTED, FOR INSTANCE IN A TRIANGULAR PATTERN ALONG ROADS WITH FAST TRAFFIC. CONVERSELY, SQUARE PLANTING OF TREES WAS CONVENTIONAL ALONG ROADS FOR SLOW TRAFFIC. THE LANE-DIAGRAM (FIG. 37) PROVIDE A OVERVIEW OF THE DIFFENRENT LANE TYPOLOGIES.

THE PRECURSOR OF REGIONAL ROAD N225 WAS VIA RIGIA. THIS ROAD (FIG. 30) CONNECTED THE UTRECHT AND KOHL. THE CONNECTION CONSISTED OF THE DUAL ROAD SYSTEM. THE MAP OF DE ROY (1696) SHOWS THAT TREES ARE PLANTED NEXT TO THESE TWO ROADS. DURING THE FOLLOWING CENTURY, THIS ROAD BECAME AN ALONG WHICH ESTATES AND URBAN AREAS DEVELOPED.
THE CONSTRUCTION OF AMSTERFOORSTEWEG (FIG. 31)I S AN EXAMPLE OF THIS TYPOLOGY. JACOB VAN CAMPEN DESIGNED THIS ROAD AS THE STRAIGHT AXIS TO IMPROVE THE CONNECTION BETWEEN TWO MAJOR CITIES IN THE REGION. FURTHERMORE, THIS ROAD WAS DESIGNED ACCORDING TO THE PREVAILING FORMAL IDEALS. THIS RESULTED IN AN IDEAL PROPORTIONED GRID THE RECTANGULAR PLOTS OF LANDS WERE GRANTED FOR THE DEVELOPMENT OF ESTATES TO FINANCE THE CONSTRUCTION OF THE ROAD. TREES WERE PLANTED NEXT TO THE PRINCIPAL AND SOME OF THE SIDE ROADS ACCORDING TO THE MAP OF THE PROVINCE OF UTRECHT (DE ROY,1696) AND MAP OF KAMP ZEIST (1853).

SHIFTING FROM EXCLUSIVE TO INDUSTRIAL REFORESTATION

THE SECOND TYPE OF REFORESTATION IS THE DEVELOPMENT OF ESTATES (FIG. 38). THE POLITICAL AND ECONOMIC CONTEXT OF THE 17TH AND THE 18TH CENTURY LED TO THE FIRST TRANSFORMATION OF THE UTRECHTSE HEUVELRUG INTO AN ESTATE LANDSCAPE (BLIJDENSTIJN ET AL., 2015, P.174-177). THESE ESTATES WERE BUILT AS SUMMER RESIDENCES FOR (EXCLUSIVE) LEISURE IN THE COUNTRY. THESE ESTATES ARE SITUATED MOSTLY IN THREE AREAS: SOEST, STICHTSE LUSTWARANDE AND AMERFOORSTSEWEG.

THE DEVELOPMENT OF ESTATES TOOK PLACE IN THREE PHASES. THE FIRST PHASE CONSISTS OF FORMAL ESTATES WHICH WERE BUILT ON THE TRANSITION BETWEEN RIVER CLAY AND SAND SOIL. THESE ESTATES WERE BUILT ACCORDING TO THE FORMAL PRINCIPLES IN WHICH CONTROL OF NATURE IS CENTRAL. THE COMPOSITION OF THE ESTATES MADE USE OF ONE OR MORE VIEW AXES. THE MAIN BUILDING WAS SITUATED ON A VIEW AXIS PERPENDICULAR TO THE HILLSIDE. THE AXIS USUALLY ENDED WITH A VIEWPOINT. ZEISTERBOS AND ESTATE SPARRENDAAL ARE TWO EXAMPLES.

FIGURE 31: AMERFOORSTE WEG IS EXAMPLE FORMAL LANE THAT FORESTED THE LANDSCAPE

FIGURE 32: THIS MAP SHOWS THE FIRST ESTATED THAT REFORESTED THE LANDSCAPE

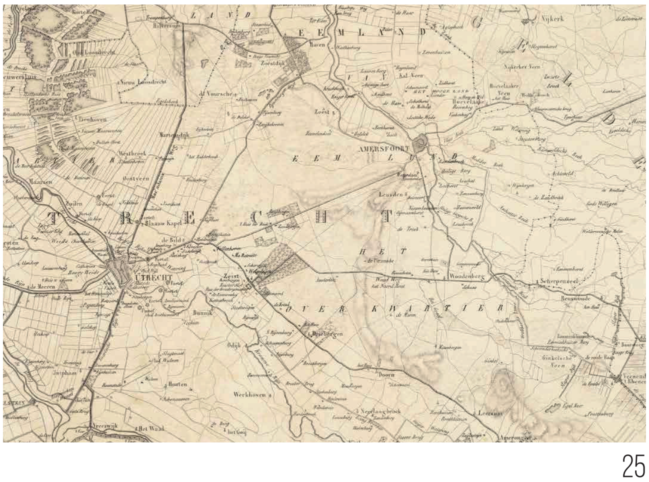
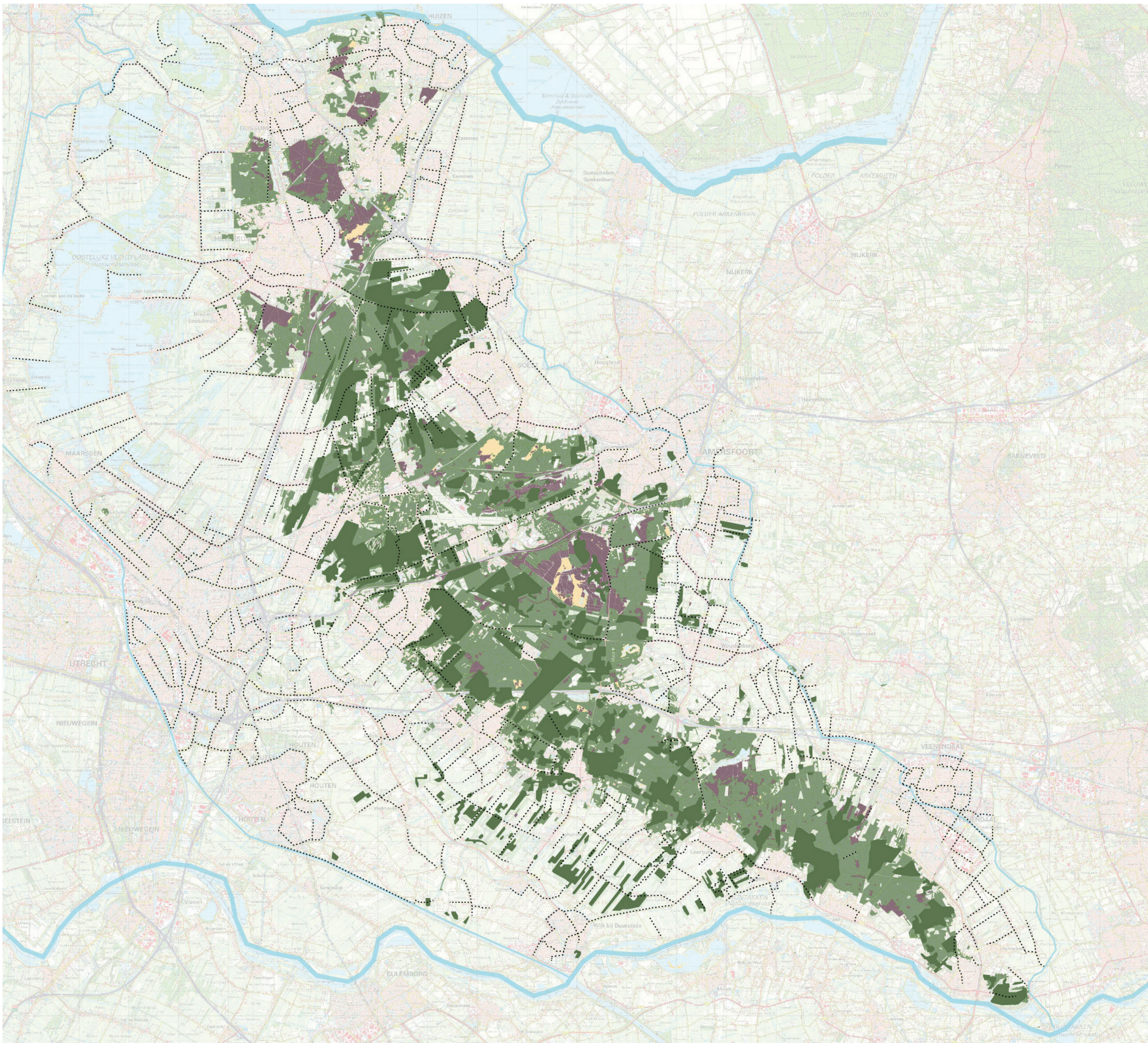
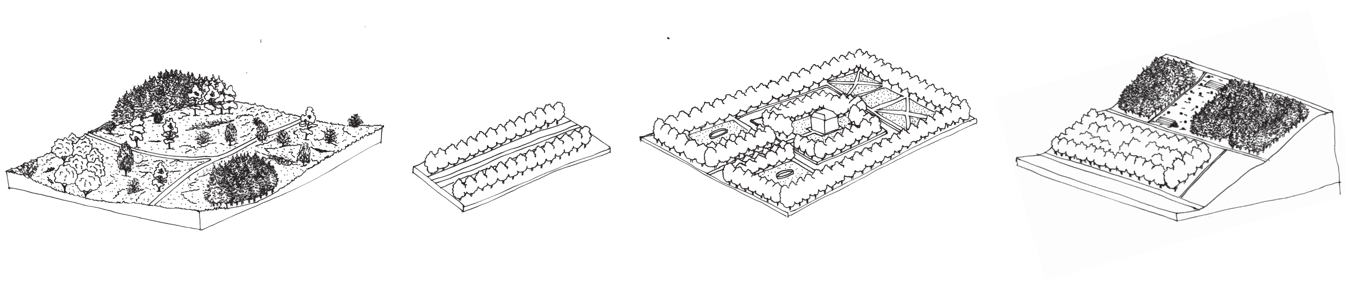


FIGURE 33: THE CURRENT FOREST STRUCTURE OF THE UTRECHTSE HEUVELRUG SEEMS TO CONSIST OF FOUR TREE CONSTALLATIONS: LANES, ESTATES, PLANTATIONS AND NATURE RESERVES.



● Row of Trees ● Forested before 1850 ● Forests Plantations ● Heather ● Sand Drifts ● Area delimitations

FIGURE 34: THE TIME SHOWS WHEN THE FOUR DIFFERENT TREE CONSTELLATIONS WHERE USED TO REFOREST THE UTRECHTSE HEUVELRUG.



150 000 BC: SALE GLACATION

800 - 1700 : DEFORESTATION

1700 -1850: FOREST DEVELOPMENT ALONG ROADS AND ESTATES

1850 -1960 : HEATHER RECLAMATION THROUGH PRODUCTION FORESTS

1960 - NOW : NATURE CONSERVATION & DEVELOPMENT

An example of this type is the Zeisterbos in Zeist (Feijen, 2010a). This forest was originally planted as part of two estates. The forest consists of a series of lanes which were planted on the common heathland of Zeist. The Slotlaan is the principal axis of the first estate 'Slot Zeist' (fig. 35). An axis diagonally to the central axis was used as the main axis for the second estate 'Beek & Royen'. This axis was designed as a patte d'oie, which consisted of three axes. These lanes were built as an infinite axis that had a visual connection with the church tower of the surrounding villages Amersfoort and Leusden. They were planted with oak, beech and pine trees. Furthermore, a grand canal was built along one axis of the patte d' oie. Subsequently, the plots of heather were transformed into (star-shaped) forests which were dominantly planted with pine trees. A part of the forest was replaced with a landscape park during the first half of the 19th century. The grand canal changed into two organic shaped ponds which were connected with a small stream. Copijn designed this park forest in an English landscape-style.

Local authorities bought the forest as a public forest for citizens of Zeist. Therefore some attractions and amenities were built like a deer park, two playgrounds and benches. However, the three stands became unilateral at the beginning of the 20th century. A fifth of the forest consisted of oak coppice plantation. The rest of the forest only consisted of pine forests. The thinning of Scotch pine forest led to natural regeneration of younger groups of deciduous and coniferous trees. This resulted in the current mixed forests which contain Scotch pine (Pinus sylvestris), Douglas (Pseudotsuga menziesii), oak (Quercus robur & Quercus rubra), beech (Fagus sylvatica), birch (Betula pendula). It still contains a large variety of monumental trees. The oldest trees are currently pine trees that were planted in 1795.

Moreover, the treestands contain small numbers of coniferous trees like black pines (Pinus nigra, Pinus contorta, Pinus strobus), spruce (Picea abies, Picea sitchensis, Picea omorika, Picea pungens), larch (Larix kaempferi/Larix decidua), fir (Abies grandis, Abies nordmanniana), cypress (Chamaecyparis lawsoniana), hemlock (Tsuga heterophylla) and cedar (Thuja plicata). Also small numbers of maple (Acer pseudoplatanus & Acer platanoides), black locust (Robinia pseudoacacia), chestnut (Castanea sativa, Aesculus hippocastanum), popular (Populus tremula), hornbeam (Carpinus betulus), lime (Tilia). Currently, nature management of this forest focuses on the facilitation of native species through thinning and removal of Douglas and red oak. Moreover, it involves the conservation of lane structure, former oak coppice plantation and exotic monumental trees.

Landgoed Sparrendaal (fig. 38) is a typical example of a formal estate (Blijdenstijn et al., 2015, p.224). The estate was built on a former road which was used to transfer sheep from the village to the heather fields (schapendrift). This formed the central axis, which ended in a star-shaped coniferous forest. A rectangular grid of lanes was planted along the central axis. During the 19th a part of estate transformed into a landscape park. The estate became partially urbanised after it fell in decay. The star-shape forest was, for example, demolished for the building of a new neighbourhood.

The second generation of estates (fig. 38)was built between the higher and lower situated road. The estates were built in the English landscape style. Contemporary landscape architects like H.Copijn, J.D. Zocher and L. Springer often designed these estates (Blijdenstijn et al., 2015, p.227-229).
An example is Hydepark which was designed by Hendrik Copijn. The vegetation is characterised by mixed forests with great variety including some exotic species. Most of these estates lost its original function and became offices and rental locations for weddings and conferences. This lead also to the loss of original landscape elements.

The third generation of estates were usually 19th century-expansions of exercising estates. They started to reforest these newly acquired heathlands for wood production purposes as the result of the industrialisation of the Netherlands. These forest plantations anticipated on the growing demand for wood in the (mining) industry.

Figure 35: This bird-eye shows the surrouding forest of the estaste Zeister Slot

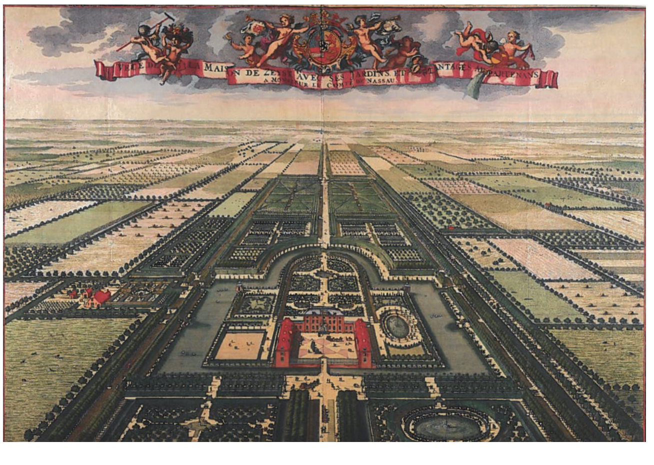


Figure 36: The reforestation of heather during the interbellum

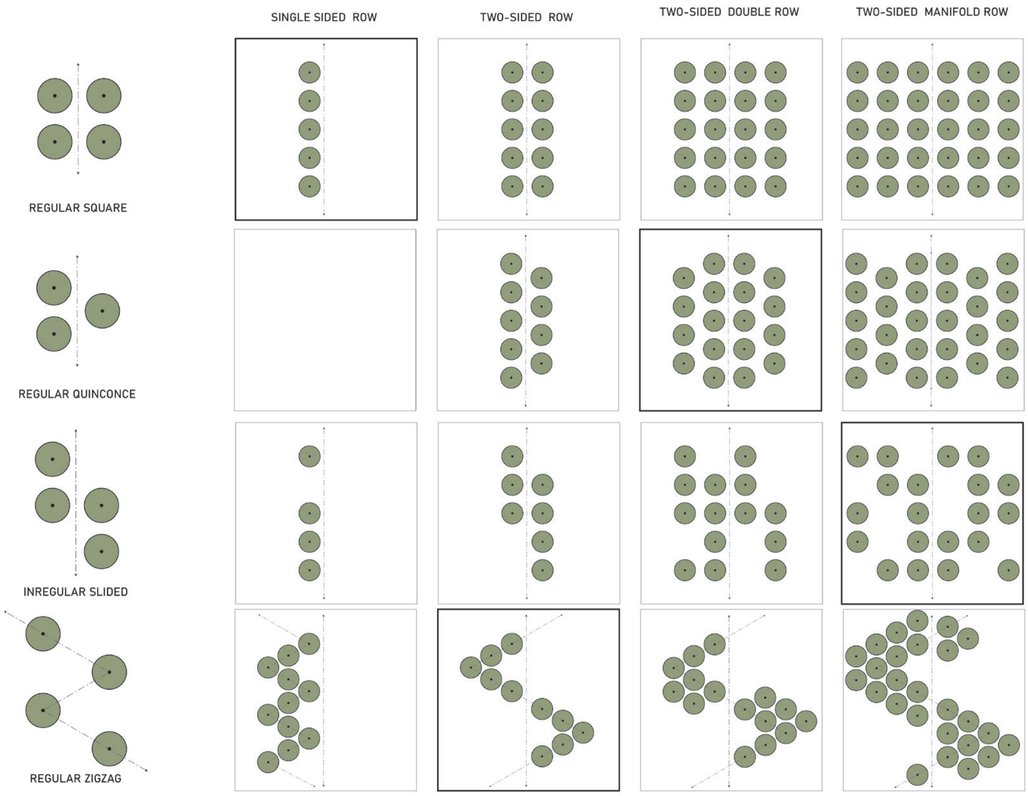
Heathlands appeared to be the perfect place for (local) governments to facilitate this type of reforestation. They lost their importance in the agricultural system due to the introduction of chemical fertilisers and the abolishment of collective agricultural practices. This allowed private initiatives to expand their estates. Moreover, they can be regarded as the precursors of governmental-driven organisations like Staatsbosbeheer and Heidemij. These organisations were assigned to reforest especially heathlands and sand drifts during the beginning of the 20th century (fig.36).
Commercial forestation was primarily determined by wood production and the idea of generating jobs for unemployed people during depressions. This resulted in the plantation of monocultural coniferous forests with shorter rotation cycles. Moreover, it leads to the introduction of exotic species with higher yield and shorter rotation cycles. Especially Douglas and Larch appeared suitable for commercial forestation in the Netherlands. The mechanisation of forestry practice also changed the spatial structure of these forests. Esthetical plantation of (park) forests made place for rational forest plantations. These forests were less determined by the topography of its subsoil. The well-connected rectangular grid of these forests ensured an efficient way of yielding and removal of wood. Two examples of these forest plantations are the extension of the estate 'Ten Treek-Henschoten' (Boosten et al., 2009) and the expansions of 'Zuilenstijlse bos'.

Nature reserves: the rise of nature conservation

The commercial forestation by governmental-driven organisations and private individuals gave way to nature conservation from the '60 onwards. Reclamation of the remaining heather areas became prohibited. Nature conservation organisations like 'Utrechtse landschap' and 'Natuurmonumenten' became more and more important since they started to buy and maintain valuable forested areas. The Ministry of Agriculture and Fishery designated 60 forests as reserves which represent the different types of woodland areas in the Netherlands. Two forest reserves were appointed in the Utrechtse Heuvelrug. Staatsbosheer became responsible for the management and conservation of these reserves. Lastly, the establishment of national parks and the Dutch Nature Network (NNN) strengthen this movement. The use of the forest changed from wood-production towards recreational and environmental purposes.

Noordhout is an example of a nature reserve which is maintained by 'Het Utrechtslandschap' (Feijen, 2010b). The deciduous forest used to be part of a hunting forest (warande) in the 18th century. It is probably used as oak coppice plantation in the following centuries. Coniferous trees partially replaced the oak forest during the 19th century. In 1980 the forest became a nature reserve which links the southern part of the National Park with the northern heather fields.

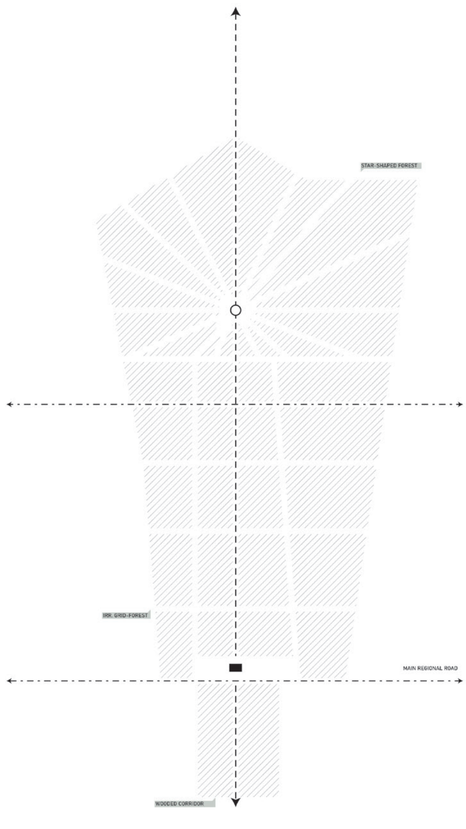
Figure 37: This sheme illustrates the different types of lanes which were used to reforested the area along the road network. The four types in a frame are used in the design of the adaptation of the grid.



Initially, most exotic species like red oak, American mountain ash and coniferous trees were removed. Moreover, paths were demolished to make the forest inaccessible. Subsequently, the forest ought to be left in peace for the last forty years. The further development of the forest depends entirely on natural succession processes. In this way, it facilitates the development of native forests. Monitoring of the forest has shown that beeches and oaks are becoming more and more dominant.

De Galgenberg is the second forest reserve. It represents a typical dry oak-beech forest which is common for the 'Utrechtse Heuvelrug' (Knoppersen, 1995). Staatsbosbeheer came into the possession of the area in 1973. The forest became designated as a forest reserve in 1983. The reforestation of the former heather area started at the end of the 18th century. The current vegetation consists of both deciduous and coniferous forests. The coniferous forest was planted with (exotic) species like scotch pine, black pine, larch and sitka spruce between 1885 and 1906. A small part scotch pine forest became mixed with birches which grow as a result of natural succession. The deciduous forest is naturally regenerated birch oak forests. The two forests distinguish themselves spatially by the grid of the path. The coniferous forest was planted in a rational (rectangular) grid as opposed to the organic-shaped plots of deciduous forests.
The most recent designated forest reserve is De Heul (Clerkx, 2001). The forest is originally a result of reforestation of the former wet heather area. Most of the coniferous forest was planted in a rectangular grid between 1885-1906. The contain monocultures of scotch pine. The expansion of the forest leads to the introduction of exotic species. Douglas, larch and spruce were planted between 1941 until 1960. The most recent new-planted trees were planted between 1974 and 1977. This forest is envisioned as moisture birch-oak forest due to the high water table in the area. Therefore, a part of scotch pine and Douglas trees are thinned in the '90. By doing so, the succession of natural regenerated birches, oaks and beeches will be facilitated. However, this process has still taken a limited place.

Figure 38: The two most common tree constellation which were used at estates. The left sheme shows the prevailing constrallion for the first generation estates. The right sheme shows the constallation that was used for the second genereation estates.



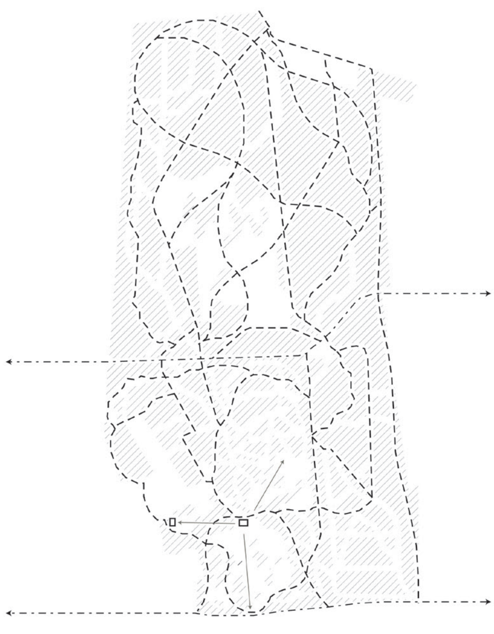


FIGURE 39: THE MASTEPLAN FOR THE REGIONAL DESIGN. IT SHOWS THE ADAPTATION OF THE THE GRID AND THE EXPANSION OF THE FOREST.

REGIONAL DESIGN: EXTENDED NATIONAL PARK

THE BASIS OF THE REGIONAL DESIGN IS THE CURRENT PATCHWORK OF ESTATES, FOREST PLANTATIONS, NATURE RESERVES. THE GRID OF THE PATCHWORK NEED FIRST TO BE ADAPTED AND THEN EXPAND THE PATCHWORK IN THE NEXT STAGE. THIS RESULTED IN THE DECISION THAT THE REGIONAL DESIGN OF AREA BETWEEN AUSTERLITZ AND WOUDENBERG (FIG. 39) FOCUS FIRST ON THE ADAPTATION OF THE GRID AND SUBSEQUENTLY SHOWS HOW THE PATCHWORK WILL BE EXPANDED BY USING CERTAIN TREE CONSTELLATIONS.

THE DESIGN FOR ADAPTION OF THE GRID PROPOSES A NEW GREEN AND BLUE SYSTEM (FIG. 40 & 41). ALONG WITH THE BLUE SYSTEM, FOREST CONSTELLATIONS ARE BUILT TO IMPROVE ITS DROUGHT ADEPTNESS. THE CENTRAL ELEMENTS ARE TWO REGIONAL WATER BODIES. THEY BUFFER EXCESSES OF RAINWATER AND DIMINISH THE AMOUNT OF WATER THAT DRAINED INTO THE RIVER EEM AND RIVER RHINE THROUGH THE REGIONAL CANAL 'VALLEIKANAAL'. MOREOVER, THESE WATERBODIES HAVE A REGIONAL RECREATIONAL FUNCTION AS PEOPLE CAN SPORT AND RELAX AT THESE PLACES. ON TOP OF THAT, THESE WATER BODIES ARE PLACES WHERE MORE SIGNIFICANT QUANTITIES OF PEOPLE CAN COOL OFF DURING HOT SUMMERS. TWO DIFFERENT SUBSYSTEMS ARE CONNECTED TO THESE REGIONAL WATER BODIES. IN THIS WAY, WATER CAN BE TRANSFERRED FROM ONE SYSTEM INTO THE OTHER AND VICE VERSA.

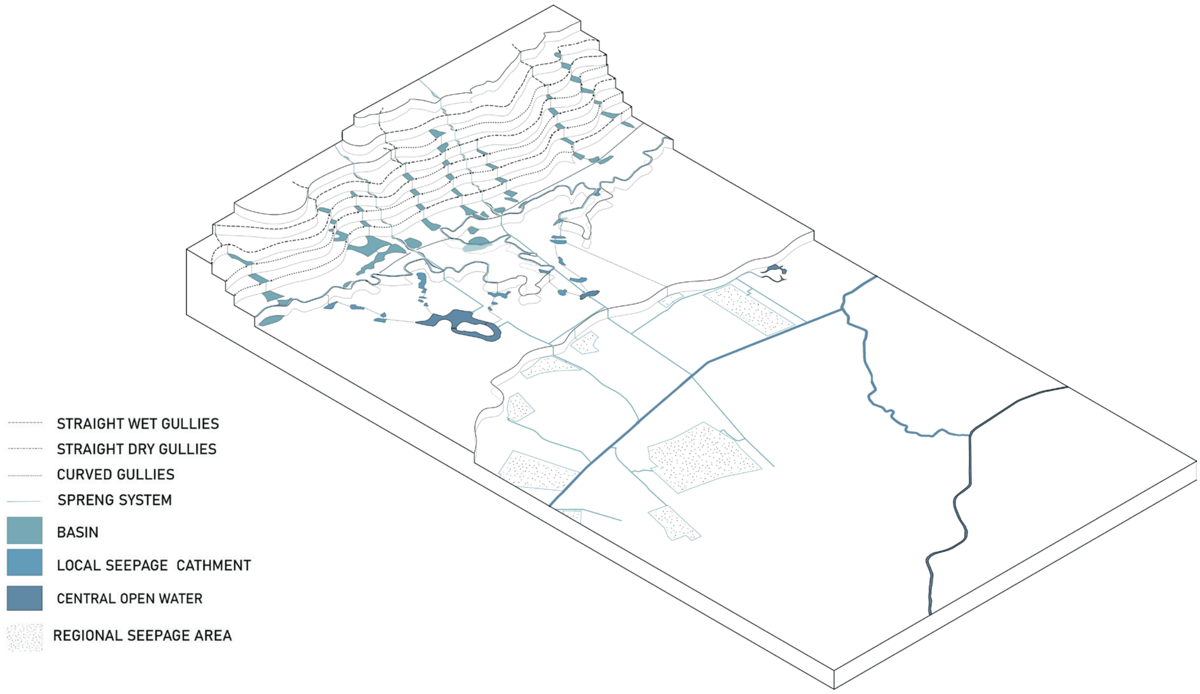
THE FIRST SUBSYSTEM COMPRISES THE INTERVENTIONS WHICH ARE NECESSARY TO TRANSFORM THE GRID. IT CATCHES EXCESSES OF RAINFALL ALONG THE SLOPE OF THE MORAINE. THEREFORE A NETWORK OF CURVED AND STRAIGHT DITCHES ARE CONSTRUCTED. THE STRAIGHT DITCHES ARE BUILT TO CATCH RAINWATER QUICKLY AND DRAIN IT INTO THE LOCAL BASINS. THE WATER IS TEMPORALLY RETAINED IN THE FORMER DRY VALLEYS OF THE MORAINE. THESE ARE TRANSFORMED IN CATCHMENT VALLEYS BY CONSTRUCTING A CASCADING SYSTEM OF WATER BASINS. ANOTHER WAY AROUND THE SYSTEM DISTRIBUTES RETAINED WATER DURING DROUGHT EVENTS. THE WATER FLOWS FROM THE BASIN INTO LOWER DITCHES. THE CURVED DITCHES ARE DESIGNED FOR THIS PURPOSE. THEY DISTRIBUTE SLOWER WATER TO A LARGER SURFACE THAN THE STRAIGHT DITCHES.

A RESIDUAL FLOW OF WATER ENDS UP IN THE ARTIFICIAL BROOK 'SPRENGBEEK'. IT CONNECTS THE CATCHMENT VALLEYS TO THE MAIN REGIONAL WATERBODY. ALONG THE BROOK ALSO CATCHMENT AREAS ARE SITUATED THAT CATCHES STAGNATED STORMWATER AND SEEPAGE. LASTLY, THE ZIGZAG IS A DITCH WHICH IS BUILT ALONG REGIONAL ROADS. IT FUNCTIONS AS A BACK-UP FOR THE DISTRIBUTION OF WATER IN THE CATCHMENT VALLEYS. IT PUMPS WATER FROM THE TWO LOWER SITUATED REGIONAL WATERBODIES TO THE HIGHEST DITCH ALONG THE MORAINE. THE DITCH DISTRIBUTES THE WATER BETWEEN THE CATCHMENT VALLEYS. THIS RESULTS IN A SEMI-CIRCULAR SYSTEM THAT IS ABLE TO REPLENISH SHORTAGES OF WATER WITH EXCESSES OF WATER OVER TIME.

THE SECOND SUBSYSTEM IS SITUATED IN THE LOWER AREA ALONG THE MORAINE. IT FOCUSES ON FACILITATING THE EXPANSION OF THE FOREST. IT ALSO FUNCTIONS AS A SYSTEM THAT RETAINS SEEPAGE IN SMALLER LOCAL WATER BODIES. IT WILL REPLACE FORMER PRACTICE TO DRAIN THE EXCESS OF SEEPAGE THROUGH THE SYSTEM OF DITCHES AND CANALS. THEREFORE NEW DITCHES AND SWAMP FOREST ARE BUILT. FARMERS CAN USE THIS SYSTEM TO WATER THEIR CROPS DURING DROUGHT EVENTS WITHOUT PUMPING GROUNDWATER.

MOREOVER, SMALL FORESTED AREAS WILL BE IN THE LONG RUN BE URBANISED. THESE SMALL URBAN EXTENSIONS CONTRIBUTE TO THIS SYSTEM BY ALSO CATCHING RAINFALL. THE WATERBODIES LINK THE TWO SUBSYSTEMS WITH EACH OTHER. MOREOVER, THEY ALSO WILL PROVIDE COOLING AMENITIES FOR RECREATIONAL PURPOSES.

FIGURE 40: THIS SCHEME ILLUSTRATES HOW THE GREEN-BLUE SYSTEM FUNCTIONS DURING THE WINTER. IT CONSIST OF CENTRAL WATERBODIES THAT CONNECT TO TWO SUBSYSTEMS. THE MORAINE-SUBSYSTEM WORKS TRANSFORMS THE CURRENT FOREST STRUCTURE INTO A RAINWATER RETAINING FOREST. IT USES A SYSTEM OF DITCHES AND CATCHEMENT VALLIES. THE VALLEY-SUBSYSTEM FOCUS ON DIMISHING THE AMOUNT OF DRAINED WATER BY CIRCULATING THE SEEPAGE IN A SYSTEM OF (WINDINGO DITCHES AND SMALLER WATER BODIES.



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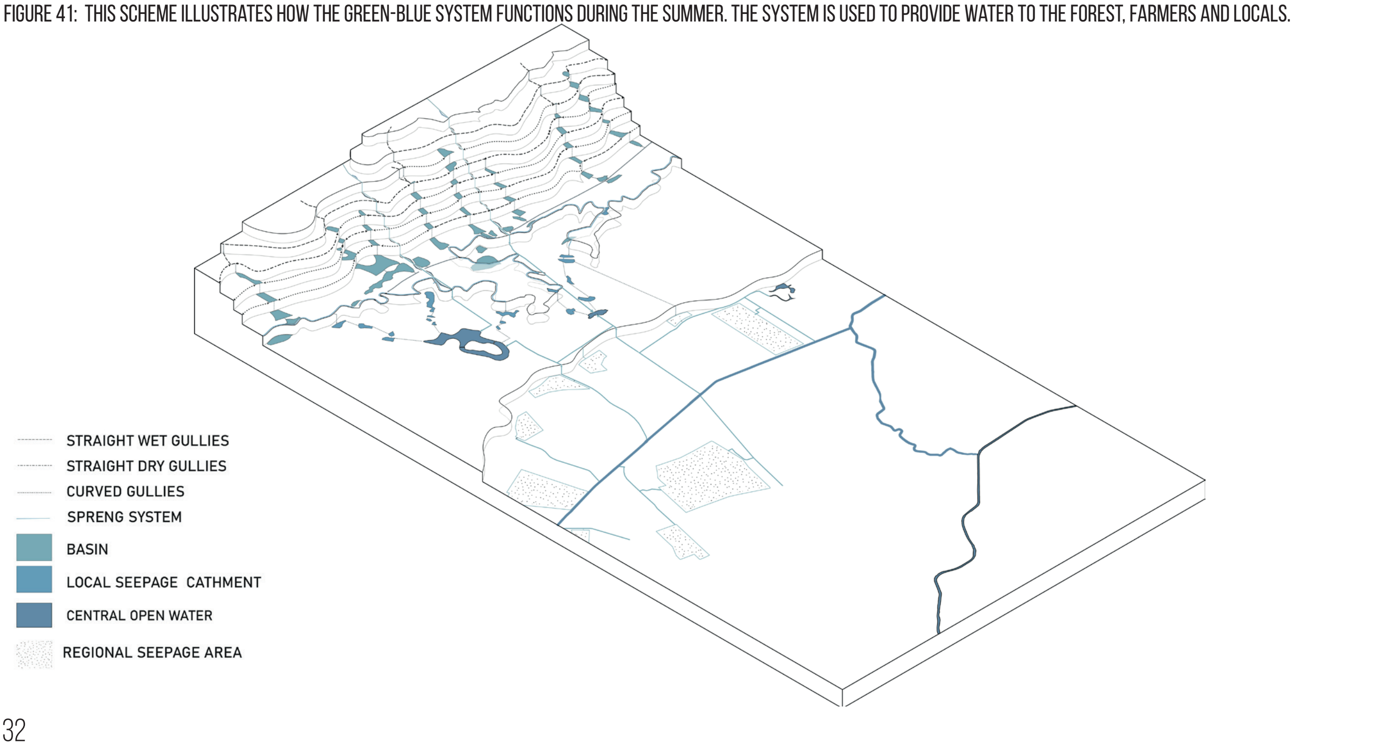
EXPANDING THE PATCHWORK

THE PATCHWORK CONSISTS OF DIFFERENT FOREST CONSTELLATIONS. EACH OF THE PATCHWORKS SORTS WITH ONE OF THE FOUR SINGLE FUNCTIONS OR A CROSS BETWEEN THESE FUNCTIONS (FIG. 42).
THE FIRST CATEGORY IS FORESTRY. A LARGE PART OF THE GREEN CONSTELLATIONS IS THE RESULT OF AUTHORS WHO PLANTED TREES FOR RECREATIONAL OR EVEN WOOD PRODUCTION PURPOSES. CROSS-OVER WITH URBAN ARE ESTATES WHICH WERE COMMISSIONED BY WEALTHY DWELLERS WHO WANTED TO FLEE (TEMPORALLY THE CITY AND RECREATE IN RURAL AREAS. THE BUILDING OF THESE ESTATES INCLUDED THE PLANTATION OF FORESTS WHICH SERVED AS REVENUE. ANOTHER CROSS-OVER IS AGROFORESTRY WHICH IS A TENDENCY WHICH OFFERS AN ALTERNATIVE TO INDUSTRIALIZED AGRICULTURAL PRACTICE. THE PRODUCTION OF MONOCULTURES IS REPLACED BY A COMPLEX SYSTEM THAT IS INSPIRED BY THE STRUCTURE OF FORESTS.
AGRICULTURE IS THE SECOND CATEGORY OF FARMERS WHO CULTIVATED PLOTS OF THE LANDSCAPE BY USING IT FOR ARABLE OR PASTURE FARMING. A CROSS-OVER WITH FORESTRY ARE ORCHARDS SINCE THEY CAN BE CONSIDERED AS PRODUCTIVE FORESTS. HORTICULTURE IS CROSS OVER WITH THE

FIGURE 41: THIS SCHEME ILLUSTRATES HOW THE GREEN-BLUE SYSTEM FUNCTIONS DURING THE SUMMER. THE SYSTEM IS USED TO PROVIDE WATER TO THE FOREST, FARMERS AND LOCALS.



URBAN CATEGORY BECAUSE THE BUILDING OF GLASSHOUSES RESEMBLES IN A WAY THE URBANIZATION OF THE LANDSCAPE.

THE URBAN CATEGORY INVOLVES DIFFERENT PEOPLE WHO CONTRIBUTED TO THE VAST EXPANSION OF THE FORMER RURAL COMMUNITIES. A CROSS-OVER WHICH WAS A DIRECT RESULT OF THIS TENDENCY IS A VILLA PARK. ANOTHER CROSS-OVER IS URBAN FARMING WHEREBY LOCALS (COLLECTIVELY) PRODUCE FOOD IN THEIR ALLOTMENT GARDENS.

LASTLY, WATER CAN BE SEEN AS AN ESSENTIAL CATEGORY OF THE AUTHOR IN THE CURRENT LANDSCAPE. AN EXAMPLE IS THE COMPANIES THAT BECAME RESPONSIBLE FOR DRINKING WATER. ALSO, WATERBOARDS IS STILL A VITAL AUTHOR RESPONSIBLE FOR THE WELL-FUNCTIONING OF THE WATER SYSTEM. THIS INCLUDED THE BUILDING OF ARTIFICIAL STREAMS (GRIFTEN) WHICH WERE NECESSARY FOR DRAINAGE OF VALLEYS.

THE EXTENSION OF THIS PATCHWORK CONTAINS TWO NEW PATCHES THAT WILL BE ADDED TO THE CURRENT PATCHWORK. THE PROPOSED PATCHES CONTAIN THE LIVING CLEARING AND THE FOOD CLEARING. THE FOOD CLEARING IS AN AGRICULTURE VARIANT THAT CONTRIBUTES TO THE DROUGHT ADEPTNESS OF THE OVERALL INTERURBAN FOREST STRUCTURE. SECONDLY, THE LIVING CLEARING IS AN URBAN VARIANT OF FOREST CONSTELLATION THAT COMBINES THE EXPANSION OF FOREST WITH A SMALL-SCALE URBAN EXPANSION.

FIGURE 42: THIS SCHEME ILLUSTRATES TYPES OF CONTELLATIONS WICH CAN BE DEVELOPPED AS EXPANSIONS OF THE PATCHWORK.

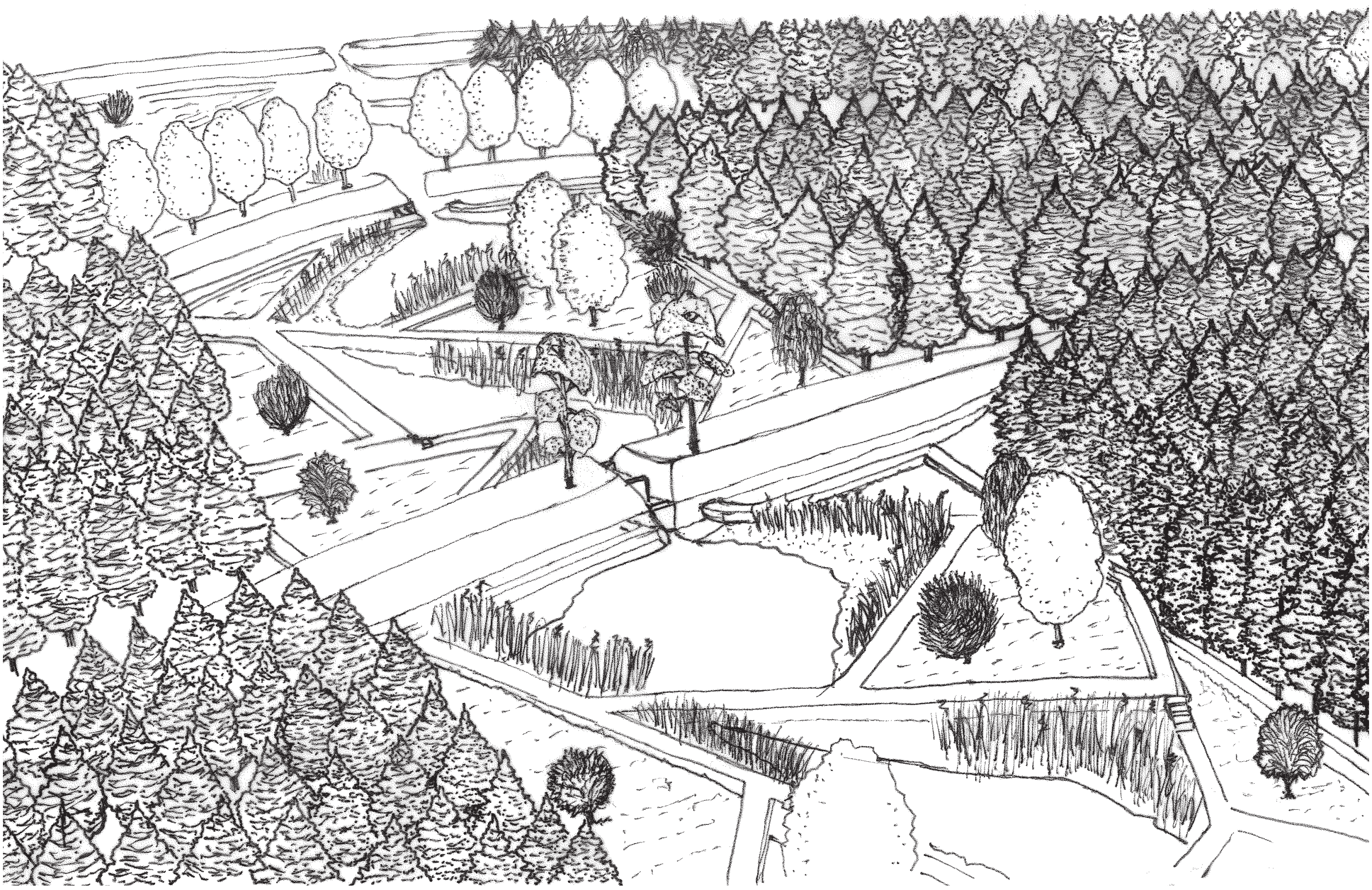


FIGURE 43: BIRD-EYE VIEW OF PROPOSED TREECONSTALLATION OF ADDAPTATION. THESE CONSTELLATION S TRANFORM THE CURRENT FOREST STRUCTURE INTO A DROUGHT ADDAPTIVE FOREST.

CONSTELLATIONS OF TRANSFORMATION

THE REALISATION OF THE IMPROVED GRID AND EXPANDED PATCHWORK CONSISTS OF SMALL-SCALE INTERVENTIONS. THESE ARE DETAIL DESIGNS OF DIFFERENT TYPES OF TREE CONSTELLATIONS. ALL THESE INTERVENTIONS WILL DIRECTLY OR INDIRECTLY CONTRIBUTE TO DROUGHT ADEPTNESS OF THE OVERALL STRUCTURE.

TRANSFORMING THE NEW FOREST STRUCTURE CONSISTS OF FOUR TYPES OF TREE CONSTELLATION. THE CATCHMENT VALLEYS AND NETWORK OF DITCHES ARE TWO PRIMARY CONSTELLATIONS THAT WILL BE CONSTRUCTED TO PREVENT EXCITING FOREST OF FURTHER DETERIORATING FROM DROUGHT STRESS. THE SPRENGBEEK AND THE ZIGZAG ARE CONSTELLATIONS THAT MAINLY LET CIRCULATES THE RETAINED WATER. THE SPRENGBEEK IS RESPONSIBLE FOR DISPOSAL WHEREAS THE ZIGZAG TAKE CARE OF THE (EMERGENCY) SUPPLY OF WATER.

CATCHMENT VALLEY

THE CATCHMENT VALLEY (FIG. 44) IS AN OPENING IN THE EXISTING FOREST. THEY ARE PROPOSED AS HUMAN-MADE STRUCTURES THAT RESEMBLE NATURALLY FORMED WATERBODIES (VENNEN). VENNEN ARE SMALL WATER BODIES THAT ARE SPORADICALLY FOUND IN THE SAND LANDSCAPE. THEY ARE USUALLY THE RESULT OF THE LOCALLY ELEVATED GROUNDWATER TABLE. THESE OPENINGS ARE SITUATED IN FORMER DROUGHT VALLEYS OF THE MORAINE. THE CONSTRUCTION OF THE CATCHMENT VALLEYS STARTS WITH THE EXCAVATION OF THE TWO METERS OF SOIL FOR THE WATER BASINS. THE WATER BASIN IS THE FIRST FIELD TYPE THAT IS SURROUNDED BY A PATH. THESE PATHS ARE BUILT ALONG AN IRREGULAR GRID. ALL THE PATHS CONSIST OF TWO VERTICAL CONCRETE SLABS WITH ON TOP A WOODED DECK. THE SLABS SURROUNDING THE WATER BASINS ARE TALLER AND LIE SUNK IN THE GROUND SINCE THEY FUNCTION SIMULTANEOUSLY AS THE RETAINING WALLS OF THE WATER BASINS.

TWO IMPERMEABLE LAYERS OF CLAY LOAM WITH A TOTAL THICKNESS OF 250 MM ENSURES THAT THE PROPOSED BASINS WILL RETAIN WATER. ON TOP OF THE IMPERMEABLE LAYER, A LAYER OF EXCAVATED SOIL IS LAID DOWN. THE THICKNESS OF THIS LAYER IS AT LEAST 1000 MM IN THE MIDDLE OF THE WATER BASIN. TOWARDS THE CONCRETE SLABS, THE THICKNESS OF THIS LAYER WILL INCREASE GRADUALLY TILL 1500 MM. IN THIS WAY, THE ROOT VEGETATION WILL NOT PENETRATE THE LOAM LAYER AND CREATE LEAKAGES. IT ALSO CREATES THE SOFT EDGES OF WATER BODIES. THE VEGETATION WILL GROW IN A GRADIENT BETWEEN MOIST AND WET CONDITIONS. THE CROSS-LEAVED HEATHER (CALLUNA VULGARIS), WHICH GROWS AT THE EDGES OF THE BASIN WILL GRADUALLY CHANGE INTO BOG PLANTS AND MARGINAL PLANTS.
AN ELEVATION MADE OF LEFTOVER EXCAVATED SOIL SEPARATES THE WATER BASINS INTO TERRACES. EACH TERRACE HAS AN ALTITUDE THAT DIFFERENTIATES RELATIVELY FROM THE OTHER TERRACES. A DAM IN THE MIDDLE OF THE ELEVATION WILL REGULATE THE FLOW OF WATER BETWEEN THE BASINS. THE WATER LEVEL VARIES BETWEEN THE MINIMUM OF 200 MM BY THE END OF THE SUMMER AND A MAXIMUM 1200 MM OF WATER BY THE END OF THE WINTER. THE TREES ARE PLANTED ON TOP OF THE ELEVATIONS. THEY FUNCTION, DEPENDING ON THE CONSTELLATION OF TREES, LIKE DIVISION OR A FOCAL POINT. A ROW OF OAK TREES CREATES THE DIVISION. ON THE OTHER HAND, ONLY TWO SCOTCH PINE IS PLANTED NEXT TO THE DAM. THE TWO TREES WILL BECOME A FOCAL POINT.

THE SECOND TYPE OF FIELDS CONTAINS HEATHLAND. THESE FIELDS ARE RELATIVE OPEN. ONLY PERENNIALS AND SOME SMALL SHRUBS GROW IN A GRADIENT BETWEEN THE MOIST CONDITIONS NEXT TO THE WATER BASINS AND DRY CONDITIONS AT THE EDGES OF THE EXISTING FOREST. THE VEGETATION CONSISTS OF PLANTS LIKE COMMON HEATHER (CALLUNA VULGARIS), CROWBERRY (EMPETRUM NIGRUM), BLUEBERRY (VACCINIUM MYRTILLUS), WAVY HAIR-GRASS (DESCHAMPSIA FLEXUOSA) AND PURPLE MOOR GRASS (MOLINIA CAERULEA). AT THE MORE MOIST SIDE OF THE FIELD GROW, FOR INSTANCE, MORE MOISTURE-LOVING PLANTS LIKE CROSS-LEAVED HEATER (ERICA TETRALIX).

THE LAST FIELD TYPE CONTAINS PARTIALLY CONSERVED OLDER VEGETATION AND DYING VEGETATION. THESE ARE USUALLY REMAINING TREES LIKE SCOTCH PINE, DOUGLAS AND OAK AND SOME SHRUBS LIKE COMMON JUNIPER (JUNIPERUS COMMUNIS) AND SCOTCH BROOM (CYTISUS SCOPARIUS). THESE TREES AND SHRUBS PLAY AN IMPORTANT ROLE IN HORIZONTAL AND VERTICAL LAYERS OF THE VEGETATION. BY DOING SO, IT PROVIDES SHELTER AND FOOD FOR THE LOCAL FAUNA.

NETWORK OF DITCHES

TWO TYPES OF DITCHES (FIG. 44) ARE BUILT ALONG THE MORAINE. THE DITCHES HAVE FIVE-METER OF HEIGHT DIFFERENCE FROM EACH OTHER. THEY BOTH FOLLOW THE CONTOUR LINES OF THE MORAINE. THEIR PRIMARY FUNCTION IS TEMPORARILY CATCHING RAINWATER AND DISTRIBUTING IT AT A LATER MOMENT.
THE STRAIGHT DITCHES FOCUS ON CATCHING EXCESSES OF RAINWATER AND DRAIN IT AS SOON AS POSSIBLE TOWARDS THE BASIN IN THE CATCHMENT VALLEYS. THE DITCH IS DUG OUT IN BETWEEN A STEEP SLOPE UP-HILL, A PATH AND GENTLE SLOPE DOWN-HILL. THE STEEP SLOPE WILL INCREASES THE AMOUNT OF RUNOFF THAT THE DITCH WILL CATCH. THE FUNCTIONING OF THE DITCH IS STRENGTHENED BY ITS EDGES, THE PATH AND TREES WHICH ARE PLANTED AND SOWED NEXT TO IT. THE SURFACE OF THE HARD PAVED PATH CATCHES RAINFALL. BIRCHES (BETULA PENDULA) ARE PLANTED ALONG THE STEEP SLOPE. IN THIS WAY, THE DITCH WILL MAKE USE OF THE PRECIPITATION THAT TREE CATCHES, AND FLOWS ALONG THE TREE TRUNK INTO THE DITCH. BIRCHES ARE USED SINCE THEY APPEAR TO GENERATE A HIGHER STEMFLOW.
THE CURVED DITCHES FOCUS ON THE DISTRIBUTION OF RAINWATER WHICH FLOWS FROM THE BASIN IN THE CATCHMENT VALLEYS. THE WATER IS DISTRIBUTED AT A SLOWER RATE TROUGH THE CURVED FORM OF THE DITCH AND REPEATEDLY BRANCHING OF THE GULLIES INTO TWO SMALLER GULLIES. IN THIS WAY, THE DITCH CAN DISTRIBUTE THE WATER OVER A LARGER SURFACE. THESE GULLIES CONTAIN ELEVATED OPENINGS. THE WATER WILL FLOW OVER AND FLOW IN THE SOIL. A DIAGONAL TUBE WILL BE DISTRIBUTED FURTHER UNDERNEATH THE SLOPE. SESSILE OAK (QUERCUS PETRAEA) ARE PLANTED IN BETWEEN THE GULLIES. IN THIS WAY, LESS WATER WILL EVAPORATE IN THE GULLEY DURING DROUGHT EVENTS.
SPRENGBEEK

SPRENGBEEK
THE SPRENGBEEK (FIG. 44) IS AN ARTIFICIAL BROOK. THE SOURCES OF THE BROOK ARE THE CATCHMENT VALLEYS. IT IS ALSO CONNECTED WITH SEVERAL STORMWATER CATCHMENT AREAS THAT SITUATED AT THE FOOT OF THE MORAINE. IN THIS AREA RAINWATER ACCUMULATES IN SMALL PEDDLES ON TOP OF THE SOIL. THIS IS THE RESULT OF TEMPORAL SATURATION OF THE SOIL DURING HEAVY RAIN SHOWERS DUE TO THE RELATIVE HIGH GROUNDWATER TABLE. IN EXTREME CIRCUMSTANCES WHICH OCCUR EVERY FIVE YEARS OR AFTER CONSECUTIVE SERVAL DAYS OF RAINFALL THIS WILL LEAD A MAXIMUM OF 300 MM OF STAGNATED WATER.
THE CONSTELLATION OF THE STORMWATER-FOREST IS AN ADAPTATION OF A RABATTEN-FOREST. THIS FOREST TYPOLOGY USED TO BE A COMMON SILVICULTURAL PRACTICE IN WET AREAS. IT CONSISTS OF EXCAVATED ISOSCELES TRAPEZOID-SHAPED LOWERINGS IN THE TERRAIN. THESE LOWERINGS ARE ALTERNATED WITH UNREGULAR SQUARE FURTUM-SHAPED ELEVATIONS. THESE ARE CONSTRUCTED WITH THE RESIDUAL SOIL OF THE EXCAVATION OF THE TERRAIN. ON TOP OF THE ELEVATION MIXTURE OF TREES LIKE OAK (QUERCUS ROBUR), WHITE BIRCHES (BETULA PUBESCENS) AND ALDER (ALNUS GLUTINOSA) ARE SOWED. IN THIS WAY, THE TERRAIN WILL CONTROL THE FLOW OF RAINWATER THAT IS CATCH AND DRAINED INTO THE SPRENGBEEK. THE FORESTED ELEVATIONS CONTRAST WITH OPEN LOWERING IN WHICH ONLY GROUND COVERING VEGETATIONS GROW. MOWING IN STAGES OF THE LOWERINGS ENSURES THAT THEY MAINTAIN THEIR ABILITY TO CATCH STORMWATER.
THE BROOK IS, THEREFORE, BUILD AS STRAIGHT GULLEY THAT TRANSFERS WATER AS FAST AS POSSIBLE INTO THE REGIONAL WATER BODIES LIKE 'HENSHOTERMEER' AND 'VEENPLAS'. THE EDGES OF THE BROOK ARE SOFT IN CONTRAST TO EDGES OF BOTH TYPES OF DITCHES. THE DIFFERENT FUNCTION OF THE BROOKS ALSO MANIFESTS ITSELF BY THE SEPARATION OF THE PATH ALONG THE BROOK. THIS IS BECAUSE OF THE CONSTELLATION FOCUS ON TRANSFERRING WATER RATHER THAN THE CATCHMENT OF WATER.
THE SPACE IN BETWEEN THE PATH AND THE GULLY FUNCTIONS AS A CORRIDOR. IT LINKS THE BIOTOPES OF OPENINGS IN THE FOREST WITH EACH OTHER. SMALLER WATER BODIES THAT CATCH LOCAL SEEPAGE INTERRUPTS THE GULLIES OF THE BROOK. THESE WATER BODIES ARE SITUATED IN PLACES WHERE THE LARGER CONCENTRATION OF VASCULAR SPECIES GROW LIKE WATER VIOLET (HOTTONIA PALUSTRIS). THESE BODIES REGULATE THE AMOUNT OF WATER THAT FLOWS INTO THE REGIONAL WATERBODY. FURTHERMORE, THEY FUNCTION AS ADDITIONAL WATER BUFFERS.

ZIGZAG
THE ZIGZAG (FIG. 42) IS A CONSTELLATION THAT SITUATED ALONG ROADS ACROSS THE MORAINE. A CONCRETE GULLY IS BUILT IN A ZIGZAG SHAPE TO TRANSFER WATER UP-HILL DURING DROUGHT EVENTS. A CENTRIFUGAL PUMP HANDLES THE DISPLACEMENT AND DISTRIBUTION OF WATER. THEREFORE A PUMPING STATION IS BUILT ON THE HIGHEST POINT OF THE ROAD. IN THIS WAY, THE CATCHMENT VALLEYS WILL NOT RUN OUT OF WATER. FURTHERMORE, THE GULLY CAN WATER THE EXISTING ROW OF TREES ALONG THE ROAD.

CONVERSELY, THE ZIGZAG CATCH ALSO RAINFALL THAT ENDS UP ON THE ROAD DURING THE WINTER. A GRILLE BUILT IN THE ROAD DRAIN THE WATER INTO THE OPEN PIPE UNDERNEATH IT. THESE OPEN PIPES LINK ALL THE GULLIES ALONG THE ROAD. IT ALSO FUNCTIONS AS AN UNDERPASS FOR LITTLE ANIMALS LIKE TOADS. THE WATER CAN BE STORED IN THE LOWER-LYING SECONDARY GULLY THAT IS USED TO WATER TREES ALONG THE ROAD. LASTLY, BIRCHES (BETULA PENDULA) ARE PLANTED NEXT TO THE TWO GULLIES. THESE TREES WILL PROVIDE SHADOW FOR THE BEECHES (FAGUS SYLVATICA) THAT ARE SOWED IN BETWEEN. THIS IS DONE TO DISTINGUISH THE CONSTELLATION BY GENERATING A DIFFERENT SPATIAL EXPERIENCE.

FIGURE 44: DETAIL DESIGN FOR THE THE DROUGH VALLEY. MOREOVER IT SHOWS THE NETWORK OF DITCHES, ZIHZAG AND THE SPREGBEEK.

FIGURE 45: EXPANSION OF THE FOREST STRUCTURE

CONSTELLATIONS OF EXPANSION

THE REALISATION OF THE IMPROVED GRID AND EXPANDED PATCHWORK CONSISTS OF SMALL-SCALE INTERVENTIONS (FIG 45). THESE ARE DETAIL DESIGNS OF DIFFERENT TYPES OF TREE CONSTELLATIONS. ALL THESE INTERVENTIONS WILL DIRECTLY OR INDIRECTLY CONTRIBUTE TO DROUGHT ADEPTNESS OF THE OVERALL STRUCTURE.

FOOD CLEARING

THE MORAINE IS SURROUNDED BY BOCAGE-LANDSCAPE, WHICH IS THE RESULT OF SIMPLE FARMING SYSTEM IN THE GELDERSE VALLEY (FIG. 47). THE PASTURES AND FARMLAND APPEAR TO CONSIST OF TWO TYPES OF LAND PARCELLATION (BLIJDENSTIJN ET AL., 2015, P. 406). MOST OF THE VALLEY IS DIVIDED BY AN IRREGULAR SQUARE PATTERN (KAMPVERKAVELING). THE MORE PEATY SOILS DEMANDED A DIFFERENT WAY TO CULTIVATE THE LAND. THIS RESULT IN A REGULAR RECTANGULAR PATTERN (COPEVERKAVELING). THE LANDSCAPE NORTH-WESTERN OF WOUDENBERG CONSIST MOSTLY OF THIS PATTERN.

HOWEVER, THE INDUSTRIALISATION OF THE AGRICULTURAL PRACTICE LED TO THE LOSS OF MANY FAMILIAR WOODED CONSTELLATIONS (FIG. 48) THAT ARE TYPICAL FOR THE BOCAGE LANDSCAPE. FARMERS USED, FOR INSTANCE, WOODED BANKS AND HEDGES TO BOUND THERE PLOTS OF LAND. THESE ELEMENTS DISAPPEARED GRADUALLY AFTER THE REPARCELLATION OF THE AGRICULTURAL AREAS IN THE SECOND HALF OF THE 20TH CENTURY. MOREOVER, COPPICING BECAME TOO LABOUR INTENSIVE WAY TO MANAGE WOODLANDS IN THE NETHERLANDS.

A PART OF THE EXPANSION OF THE FOREST PROPOSED TO RESTORE PART OF THIS FORMER FORESTED STRUCTURE (FIG. 47). MOREOVER, PART OF THE QUITTING FARMS IS TRANSFORMED INTO DENSE FOREST ZONES. IN THIS WAY, FOOD CLEARING AND DENSE FOREST PATCHES ALTERNATE IN THE RESTORED BOCAGE-LANDSCAPE. FOREST ZONES ARE BUILT MOSTLY TO PRODUCES WOOD AND COMPENSATE EMISSIONS. IT ALSO CONTAINS TEMPORAL FORESTS WHICH ARE USED FOR DEVELOPING SMALL-SCALE URBAN EXTENSIONS. THIS IS FURTHER ELABORATED IN THE NEXT PARAGRAPH.

THERE IS CURRENTLY A TENDENCY TO TRANSFORM AGRICULTURAL AREAS IN NATURE IN ORDER TO COMPENSATE FOR EMISSIONS. THIS TENDENCY IS STRENGTHENED BY A GROWING AMOUNT OF FARMERS THAT ARE QUITTING. THE SIZE OF THE AGRICULTURAL BUSINESSES HAS BECOME LARGER AND LARGER SINCE THE SECOND WORLD WAR.

HOWEVER, THERE IS AN OPPOSED TENDENCY AT THE SAME TIME IN WHICH THE AMOUNT OF BUSINESSES HAS DECLINED VASTLY. CURRENTLY, 54.7% OF 97000 AGRICULTURAL BUSINESSES IN 2000 ARE STILL OPERATIONAL (CENTRAL BUREAU FOR STATISTICS [CBS], 2020). THIS MEANS THAT AGRICULTURAL PRACTICE NEEDS TO TRANSFORM IN ORDER TO MAINTAIN SIGNIFICANT IN THE FUTURE. THE AGRICULTURAL PRACTICE NEEDS, THEREFORE, TO BECOME MORE CIRCULAR ORIENTATED.

MIXED FARMING MIGHT BE THE SOLUTION. HOWEVER, IT LACKS THE EFFICIENCY THAT FARMERS NEED TO RUN THEIR BUSINESSES. THEREFORE ANOTHER SOLUTION IS PROPOSED. FARMERS NEED TO WORK TOGETHER TO MAKE THEIR BUSINESS CIRCULAR. THE FOOD CLEARING (FIG. 46) IS A PLACE WHERE THESE GROUPS FARMERS CAN RUN THEIR BUSINESSES COLLECTIVELY. THE FARMS ARE CONCENTRATED IN THE CORE OF THESE FOOD CLEARINGS. THE CORE CONTAINS FOUR TO SIX BUILDING BLOCKS THAT ARE USED FOR A HIGHLY AUTOMATED WAY OF VERTICAL AGRICULTURE. THE SURROUNDING LANDSCAPE USES SMALL-SCALE AGROFORESTRY TO MAKE THEIR PRACTICE CIRCULAR. IT FOCUSES ON THE DIMINISHING THE LOSS OF NUTRIENTS AND THE ABSTRACTION OF GROUNDWATER.

TWO TYPES OF TREE CONSTELLATION ARE PROPOSED TO BOTH EXPAND THE FOREST STRUCTURE, RESTORE THE SPATIAL IDENTITY OF BOCAGE-LANDSCAPE AND SIMULTANEOUSLY MAKE THESE BUSINESSES CIRCULAR.

FIGURE 46: THIS SCHEME SHOWS HOW THE DIFFERENT CONSTALLAIONS OF EXPANSION WORK TO GETHER TO RETAJN THE WATER BY CIRCUCULATING IT IN EXTENSOVE NETWORK OF DITCHES , SMALL EN LARGES WATERBODIES .

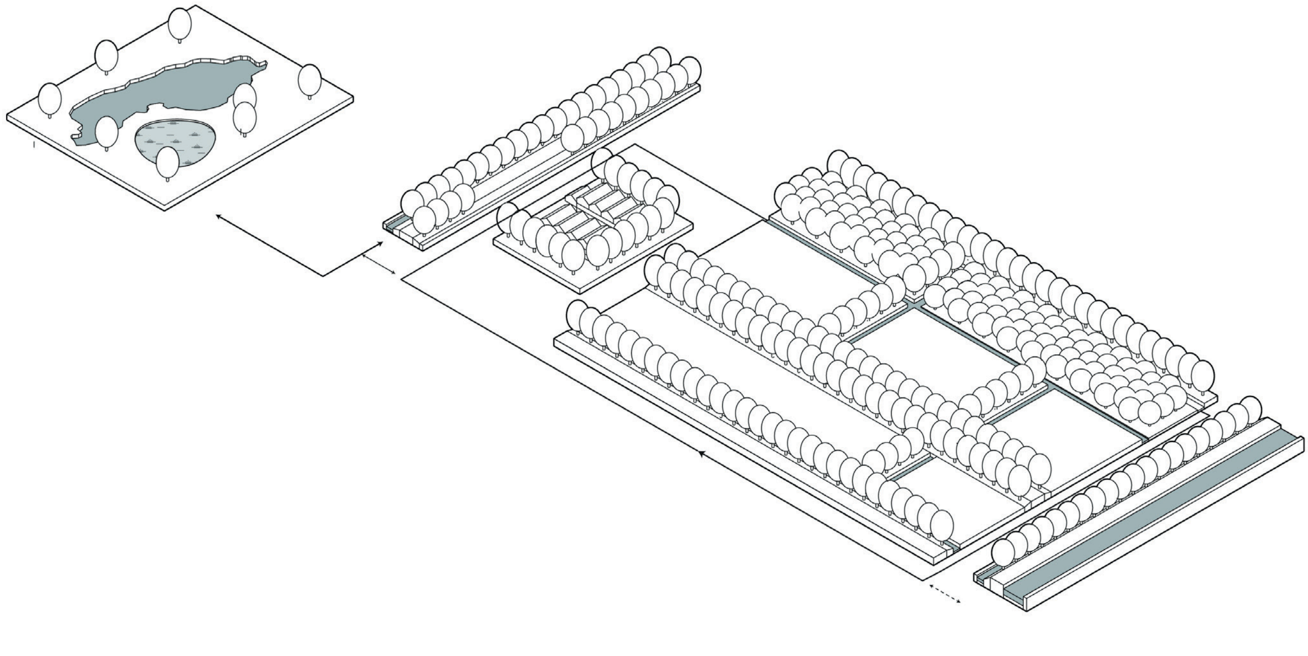


FIGURE 47: THE IS AXOMETRY SHOWS THE FOREST STRUCTURE AT THE EDGE OF THE MORAINE BEFIRE THE SECOND WOLD WAR. . THE STRUCTURE USED TO BE EXTENSIVE NETWORK OF WOOD BAKS AND SMALL-SCALE WET FORESTS.

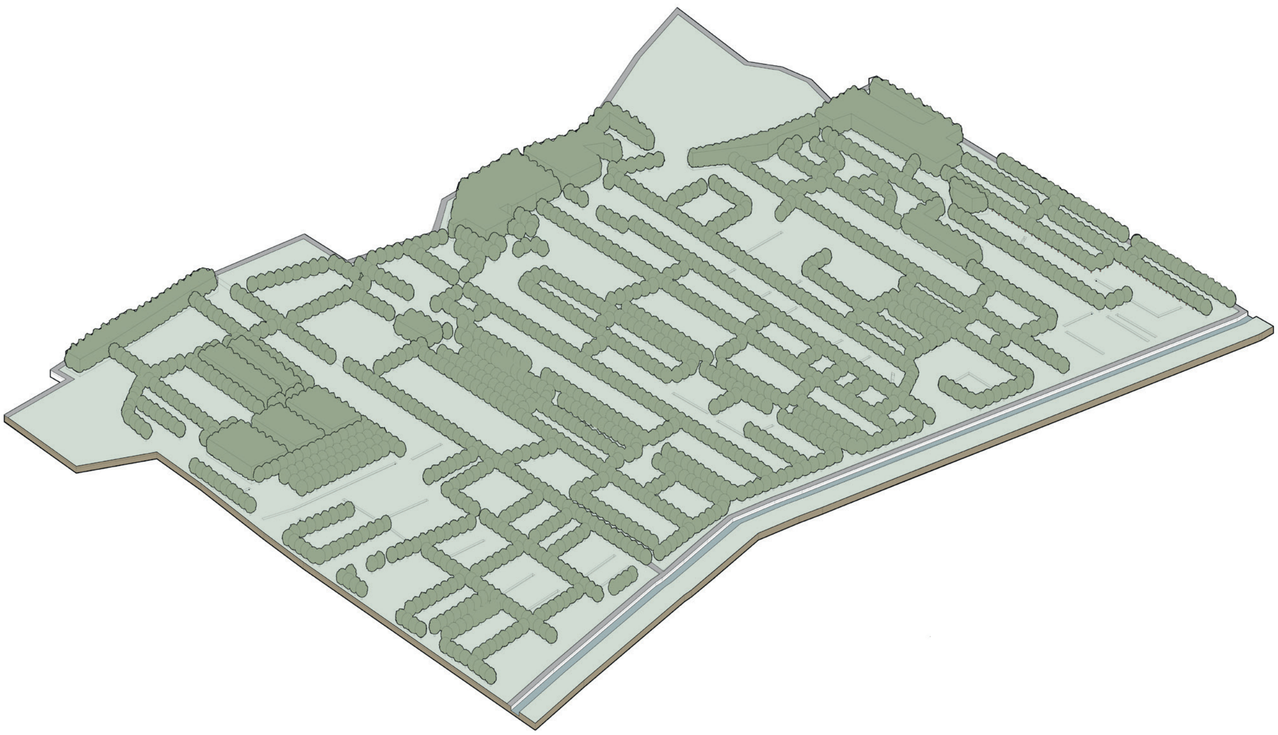
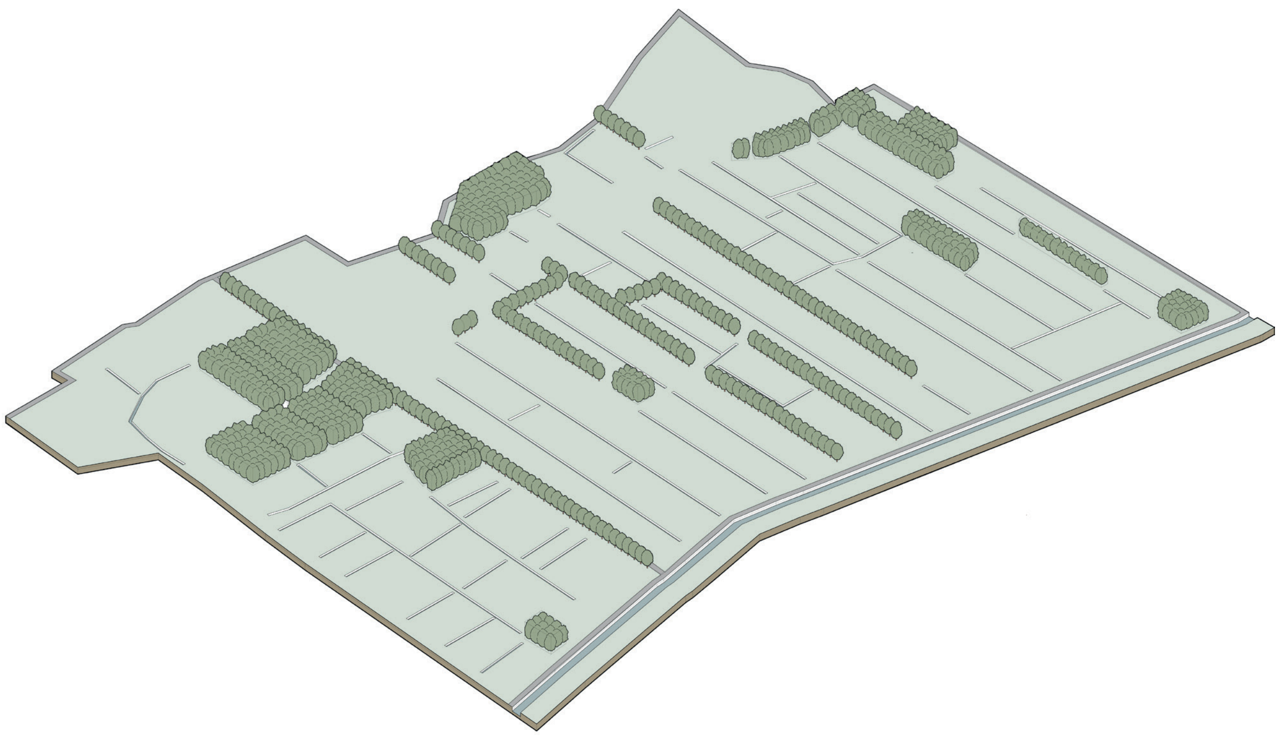


FIGURE 48: THE IS AXOMETRY SHOWS THE CURRENT FOREST STRUCTURE AT THE EDGE OF THE MORAINE. A LARGE PART OF THE STRUCTURE DISAPPEARED AFTER THE SECOND WOLD WAR.



THE FIRST CONSTELLATION IS WOODED BANKS WHICH ARE PLANTED NEXT TO THE EXCITING DITCHES. THE HOLDING CAPACITY OF THE DITCHES IS ENLARGED. THE WOODED BANKS ARE THE BACKBONE OF THE FOREST LAYER, WHICH PRODUCES FOODS LIKE HAZEL (CORYLUS AVELLANA) AND BEECH (FAGUS SYLVATICA).
MOREOVER, FAST-GROWING TREES LIKE WILLOW (SALIX CAPREA & SALIX TRIANDRA) AND ALDER (ALNUS GLUTINOSA) PROVIDES RAW MATERIALS LIKE WOOD CHIPS. THESE MATERIALS CAN BE USED FOR THE CULTIVATION OF FUNGI, AND AS A BUILDING MATERIAL. FURTHERMORE, WOODED CHIPS AND REEDS ARE USED FOR COMPOSTING MANURE. THIS IS NECESSARY SINCE IT REDUCES NITROGEN-EMISSION DURING THE SPREADING OF MANURE (SANDERS & WESTERINK, 2015). LASTLY, HOG FARMERS CAN BE INCLUDED IN THE MANAGEMENT OF THE SURROUNDING SOWED DENSE MIXED FORESTS.

THE SECOND CONSTELLATION IS THE SWAMP FORESTS WHICH IS PRIMARILY USED TO CLEAN THEIR CIRCULATING WATER. COMMON TREES ARE WILLOW, ALDER AND ASH. LARGE PARTS OF SWAMP FOREST GROW BOG AND MARGINAL PLANTS LIKE THE REEDS (PHRAGMITES AUSTRALIS), REED CANARY GRASS (PHALARIS ARUNDINACEA), CAREX (CAREX), BULRUSH (SCHOENOPLECTUS) AND SWAMP SAWGRASS (CLADIUM MARISCUS). THE REEDS AND WILLOWS CLEAN THE CIRCULATING WATER INDIRECTLY. THIS PREVENTS EXCESSES NUTRIENT-RICH WATER IS TRANSFERRED TO THE REGIONAL WATER BODIES AND THE CATCHMENT VALLEYS. FURTHERMORE, THESE SWAMP FOREST STORE WATER THAT FARMERS CAN USE FOR IRRIGATING THEIR CROPS DURING DROUGHT EVENTS. THIS WILL DIMINISH THE EXTRACTION OF GROUNDWATER IN THE REGION.

LIVING CLEARING

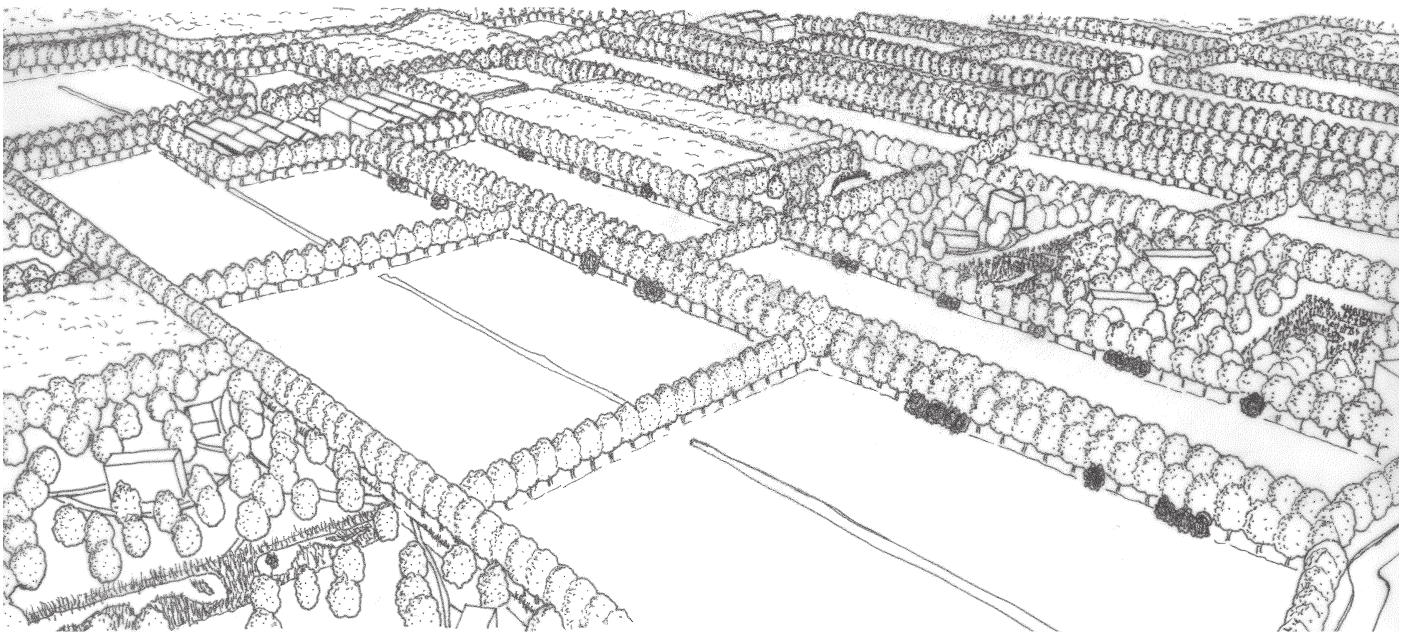
THE LIVING CLEARINGS IS TREE CONSTELLATIONS THAT ARE USED TO URBANISE IN FUTURE SPECIFIC PARTS OF IN THE EXPANDING FOREST. THE CURRENT TENDENCY TO DENSIFY IN URBAN AREAS WILL ULTIMATELY REACH ITS LIMIT. THEREFORE THE EXPANSION OF FOREST NEEDS TO ANTICIPATE THIS TENDENCY BY DEVELOPING FOREST WITH LIVING CLEARINGS. THESE FORESTS ARE FORMER PASTURES AND FARMLANDS THAT SITUATED IN SEEPAGE AREAS. IN BETWEEN THESE FORESTS, WET ZONES ARE CONSTRUCTED IN WHICH THE SURROUNDING DITCH STARTS WINDING.
THIS INCREASES THE AMOUNT OF WATER THAT THE DITCH CAN RETAIN. THE DITCH SYSTEM IS SUPPLIED WITH WATER THAT COMES FROM A LOCAL WATER BODY THAT IS CONTINUOUSLY FILLED BY THE FLOW OF SEEPAGE. THE CIRCULAR DITCH SYSTEM IS ALSO LINKED TO ONE OF THE MAIN WATER BUFFERS IN THE REGION. NATURAL SUCCESSION WILL TRANSFORM THESE AREAS INTO THE YOUNG FOREST OF OAK (QUERCUS PETRAEA), ASH (FRAXINUS EXCELSIOR), WHITE BIRCHES (BETULA PUBESCENS), HORNBEAM (CARPINUS BETULUS), HAZEL (CORYLUS AVELLANA) AND HAWTHORN (CRATAEGUS MONOGYNA).

THE URBAN CONCEPT FOLLOWS THIS SUCCESSION PROCESS BY DENSIFYING THIS FOREST IN THREE STAGES. THE FIRST STAGE STARTS IN 15 YEARS AS THE NECESSITY FOR URBAN EXPANSIONS BECOMES INEVITABLE. THIS STAGE CONTAINS THE CONSTRUCTION OF THE FIRST GENERATION OF BUILDING BLOCKS. THE MAXIMUM HEIGHT OF THE BUILDING BLOCKS IS DEFINED BY THE HEIGHT OF THE SURROUNDING YOUNG FOREST. THE BUILDING BLOCK HAS TO BE DESIGNED IN A WAY THAT IT IS EASY TO TRANSFORM IT AFTER THIRTY YEARS. THESE BUILDING BLOCKS ARE BUILT ON TOP OF THE ELEVATIONS THAT ARE MADE OF EXCAVATED SOIL. THESE ELEVATIONS FUNCTION AS A HA-HA, WHICH DIVIDES THE PUBLIC SPACE AND THE COLLECTIVE SPACE. THE BUILDINGS AND PATHS BECOME PART OF SURROUNDING DITCH-SYSTEM THAT CIRCULATES WATER. THEY ARE USED TO CATCH AND DRAIN RAINFALL INTO THIS CIRCULATING SYSTEM. LASTLY, THE PUBLIC SPACE OF THE FOREST CONTAIN AMENITIES THAT LOCALS CAN USE COLLECTIVELY WHEN THEY ARE SEEKING COOLING. THE LOCAL WATERBODY IS ALSO USED TO PROVIDE THESE AMENITIES PUBLICLY. BY DOING SO, EXCESS USE OF DRINKING WATER IS LIMITED.

IN THIRTY YEARS STARTS THE SECOND STAGE OF URBANISATION. THE THINNING OF THE FOREST MAKES PLACE FOR NEW OPENINGS THAT ARE USED TO FURTHER URBANISE THE FOREST HORIZONTALLY. THE BUILDING BLOCKS WILL BE SLIGHTLY HIGHER SINCE THE TREES HAVE BECOME TALLER.

THE THIRD STAGE STOPS HORIZONTAL URBANISATION AND REPLACES IT WITH DENSIFYING VERTICALLY. THE 30-YEAR OLD BUILDING BLOCKS WILL BE TRANSFORMED INTO HIGHER BUILDING BLOCKS. THIS PROCESS IS FACILITATED BY LIMITING THE TYPE OF OWNERSHIP FOR THE FIRST AND SECOND-GENERATION BUILDING BLOCKS. THIS RESTRICTION LAPSES WHEN THE BUILDING BLOCKS ARE TRANSFORMED. THIS WAY OF URBANISATION HAS THE ADVANTAGE THAT DWELLING ADAPTED IN EACH STAGE TO EVOLVING DEMAND FOR DIFFERENT DWELLING TYPOLOGIES.

FIGURE 45: BIRD-EYE VIEW OF PROPOSED TREECONSTALLATION OF EXPENSION. THESE CONSTELLATION S TSTRUCTURE INTO A DROUGHT ADDAPTIVE FOREST.



DISCUSSION

THIS GRADUATION PROJECT STARTED WITH A FASCINATION FOR NATURE FIRES. HOWEVER, THE RESEARCH AND DESIGN DID NOT RESULT IN ANSWER TO QUESTION IF SPATIAL INTERVENTIONS CAN LEAD TO PREVENTION OF THESE DEVASTATING EVENTS. THE FOCUS OF THE GRADUATION TOPIC MOVED TO AN UNDERLYING ISSUE WHICH APPEARED MORE EXTENSIVE AND COMPLEX. BY DOING SO, IT GRADUALLY EVOLVED INTO A SPATIAL INVESTIGATION OF DESIGNING WITH THE CONSEQUENCES OF AN EMERGING LACK OF WATER.

THE FIELD OF LANDSCAPE ARCHITECTURE DEVELOPED DESIGN APPROACHES WHICH FACILITATE EXCESSES OF WATER IN THE LAST DECADES. NEVERTHELESS, THESE APPROACHES APPEARED TO HAVE ONE DRAWBACK AS THEY ALL RELY ON THE ASSUMPTION THAT THE SUPPLY OF WATER IS GUARANTEED. THIS RESULTED IN DESIGNS WHICH OVERLOOK THEIR FUNCTIONING IN CONDITIONS WITH A LIMITED AMOUNT OF WATER. CONSEQUENTLY, THEY RUN THE RISK THAT SPATIAL INTERVENTIONS WHICH ARE USED TO MEET CONTEMPORARY SOCIAL AND CLIMATE GOALS BECOME IN VAIN DUE TO DROUGHT STRESS.

ADDRESSING DROUGHT STRESS WAS NOT A STRAIGHTFORWARD PROCESS. FIRST OF ALL CURRENT UNDERSTANDING OF DROUGHT STRESS APPEARED FRAGMENTED IN DIFFERENT FIELDS OF SCIENCE. THE LACK OF OVERVIEW AVOIDED THE DEVELOPMENT OF A METHOD TO DESIGN IN A DROUGHT ADAPTIVE WAY. SECONDLY, THE IMPLICATION OF THESE METHOD REQUIRES A DIFFERENT PERSPECTIVE ON NATURE DEVELOPMENT DUE TO THE GROWING SCARCITY OF SPACE. ALTOGETHER, A HOLISTIC APPROACH HAS PROPOSED A SOLUTION. HOWEVER, THIS APPROACH HAS ALSO ITS LIMITATIONS. THE DISCUSSION OF THESE LIMITATIONS FORMS THE BASIS OF RECOMMENDATIONS FOR FUTURE RESEARCH AND DESIGN TO DROUGHT STRESS.

EVALUATION OF THE DESIGN PROPOSAL
THE GRADUATION PROJECT CONSISTS OF RESEARCH AND A DESIGN PROPOSAL. THE RESEARCH RELATES AS IN INPUT FOR THE DESIGN PROPOSAL. BOTH PARTS DISTINGUISH THEMSELVES THROUGH THE DIFFERENT SUB-QUESTION THEY ANSWER. THE RESEARCH IN THIS PROJECT FOCUSES ON HOW TO DESIGN WITH DROUGHT STRESS. THEREFORE IT IS USED TO CREATE A METHOD TO DESIGN IN A DROUGHT ADAPTIVE WAY. THE LITERATURE STUDY AND DESK ANALYSIS RESULTED IN A COMPRESSIVE THEORETICAL FRAMEWORK. THE METHOD CAN BE USED VICE VERSA AS A WAY TO ANALYSE THE DROUGHT SENSITIVITY OF EXISTING AND FUTURE GREEN STRUCTURE. ON THE OTHER HAND, THE DESIGN SHOWS WHAT KIND OF SPACES ARE NEEDED TO REALISE A DROUGHT-ADAPTIVE DESIGN. IT MAPS THE SPATIAL IMPLICATIONS OF DROUGHT ADAPTIVE STRATEGIES. THIS RESULTED IN A SERIES OF NEW CONSTELLATIONS OF FOREST TYPOLOGIES WHICH PROPOSED TO TRANSFORM THE CURRENT FOREST INTO A DROUGHT ADAPTIVE INTERURBAN FOREST.

DROUGHT ADAPTIVE DESIGN IN LANDSCAPE ARCHITECTURE
THE GRADUATION PROJECT USES URBAN FORESTRY THEORY FROM THE GRADUATION LAB IN BOTH THE RESEARCH TO DROUGHT STRESS AND DROUGHT ADAPTIVE DESIGN. IT USES URBAN FORESTRY MATRIX LENS TO DESIGN THE RELATIONSHIP BETWEEN CITIES AND FORESTS. THE REVISED DIMENSIONS OF URBAN FOREST ARE USED TO DEFINE THE RELEVANT LENSES TO SOLVE DROUGHT STRESS. THE SCALE OF THE URBAN FOREST IS, FOR INSTANCE, USED TO STRUCTURE DIFFERENT TREE ELEMENTS OF THE DESIGN METHOD.
A HOLISTIC LANDSCAPE ARCHITECTURAL APPROACH IS PROPOSED TO LOOK INTO ESPECIALLY THE SPATIAL IMPLICATIONS OF THE DROUGHT ADAPTIVE STRATEGIES. THIS IMPLIES THAT THESE TREES OR FORESTS NEED TO BE REGARDED AS SPATIAL STRUCTURES THAT ARE EMBEDDED IN THE LANDSCAPE BY ITS PALIMPSEST, SCALE-CONTINUUM AND PROCESSES. THE LANDSCAPE BIOGRAPHY IS USED TO REFLECT ON THE LAYERS AND COMPLEXITY OF THE SITE. FURTHERMORE, THIS APPROACH TRIES TO ENVISION THE CONSEQUENCES OF THE DROUGHT ADAPTIVE STRATEGY ON EYE-LEVEL BY LINKING THREE SCALES IN THE PROJECT.

THE LAST REMARK OF THIS APPROACH IS THAT IT NEEDS TO BE REGARDED AS A FRAMEWORK WHICH WILL BE FURTHER SPECIFIED BY URBANISTS, FARMERS, DEVELOPERS AND MUNICIPALITIES. THEREFORE THE DESIGN OF THESE LIVING CLEARINGS AND FOOD PROGRAMME DOES NOT DEFINE A SPECIFIED BUILDING PROGRAMME OR COMPLETE BLUE-PRINT FOR THE FUTURE FARM OR FOREST PLANTATION. THE POSITION OF LANDSCAPE ARCHITECTURAL DESIGNER RESTRICTS ITSELF TO PLOT THE DESIRED PATH. HOWEVER, IT IS THESE OTHER PROFESSIONS THAT, IN THE END, WILL COLOURISE THEIR PATCHES.

SCOPE AND RELEVANCE
THE RESEARCH USES TWO METHODS TO UNDERSTAND DROUGHT STRESS. THE FIRST METHOD WAS A LITERATURE STUDY WHICH ENABLES TO DEVELOP AN OVERVIEW OF THE QUANTITATIVE REQUIREMENTS OF DROUGHT ADDITIVE DESIGNS. THE RESULT OF THE RESEARCH CONSIDERS AS A SUPPLEMENT TO THE CURRENT UNDERSTANDING OF DROUGHT STRESS. NEVERTHELESS, THIS METHOD BEARS THEORETICAL LIMITATIONS AS IT DEPENDS ON THE OBTAINED KNOWLEDGE THAT PREVIOUS STUDIES HAVE GENERATED. MOREOVER, THE BROADNESS OF THE OVERALL THEORY IS AT THE EXPENSE OF THE DEPTH-RELATED ASPECTS OF DROUGHT STRESS.

SECONDLY, THE COMPLEXITY OF DROUGHT STRESS APPEARED TO DEPEND ON ITS SPATIAL CONTEXT. THEREFORE A DESK ANALYSIS IS ADDED TO UNDERSTAND THE FURTHER SPATIAL IMPLEMENTATION OF THE THEORY. THIS ENABLES THE RESEARCH TO TRANSLATE THE GENERIC STRATEGY INTO DROUGHT ADAPTIVE DESIGN PROPOSALS. THE SPATIAL CONSTRAINTS FORM THE SECOND LIMITATION WHICH THIS RESEARCH AND DESIGN ENCOUNTERED. THE DESK ANALYSIS LIMITS ITSELF GEOGRAPHICALLY TO THE REGION OF THE UTRECHT HEUVELRUG. THE DESIGN STARTING POINT OF THE DESIGN IS

GLACIAL PROCESSES WHICH FORMED THE CURRENT LANDSCAPE OF THE UTRECHTSE HEUVELRUG. THIS MEANS THAT SPATIAL IMPLICATIONS OF THE STRATEGY DO NOT INCLUDE A DIFFERENT GEOGRAPHICAL REGION WHICH IS DEFINED BY OTHER LAND FORMING PROCESSES.
MOREOVER, THE SPATIAL CONSTRAINTS RESULTED IN LEAVING OUT SOME THEORETICAL ASPECTS WHICH APPEARED LESS RELEVANT FOR THE PERCEPTION OF THE LANDSCAPE. NATURE FIRES, PEST AND DISEASES WERE FOR INSTANCE LEFT OUT ALTHOUGH SEVERAL STUDIES UNDERPIN THEIR INTEREST IN THE FUTURE WELL-BEING OF TREES AND FORESTS

DEALING WITH SCARCITY
SOCIAL AND ENVIRONMENTAL RELEVANCE OF THIS PROJECT LIES MAINLY WITH DIFFERENT WAYS THE STRATEGY USES DROUGHT ADEPTNESS DESIGN AS A SPATIAL SOLUTION FOR DEALING WITH SCARCITIES LIKE WATER, WOOD, FOOD AND DWELLINGS. MOREOVER, THE GROWING TEMPORAL SCARCITY OF WATER CREATES TENSIONS BETWEEN NATURE CONVERSATION, FOOD PRODUCTIONS AND URBANISATION. THE PROHIBITION OF EXTRACTING OF GROUNDWATER OR SURFACE WATER CREATES ECONOMIC DAMAGE FOR FARMERS AS THEIR YIELDS DECREASES. ON THE LONG-RUN FOOD SECURITY COME UNDER PRESSURE AS LESS FOOD IS AVAILABLE FOR COUNTRIES/ COMMUNITIES WHO RELY ON THE IMPORT OF FOOD. THE RELEVANCE MAINLY APPEARS TO BE THE PROTECTION OF PERFORMATIVE LANDSCAPE

ETHICAL ISSUES AND DILEMMAS
THE THIRD TYPE OF LIMITATION CONCERN ETHICAL ISSUES AND DILEMMAS WHICH SPATIAL STRATEGIES NEED ALWAYS TO DEAL WITH DUE TO CONTRADICTORY INTERESTS. THE INTERNATIONAL, NATIONAL AND REGIONAL INTERESTS CAN POTENTIALLY CONTRADICT WITH EACH OTHER DURING THE IMPLEMENTATIONS OF THESE STRATEGIES. CURRENT POLICIES AND AVAILABLE SUBSIDIES SUPPORT THE EXTENSION INTERURBAN FOREST STRUCTURE BY TRANSFORMING FORMER AGRICULTURAL AREAS INTO FORESTS AND WETLANDS. HOWEVER, THIS SUPPORT ON A NATIONAL LEVEL DOES NOT AUTOMATICALLY IMPLY LOCAL SUPPORT FOR THE STRATEGY. A PRIME EXAMPLE IS THE IMPASSE OCCURRED WHEN NATIONAL POLICYMAKER STARTED TO IMPLEMENT THE ENVISIONED DEPOLDERISATION OF THE HEDWIGEPOLDER. LOCAL AUTHORITIES AND INHABITANTS STARTED A MOVEMENT WHICH HAS OPPOSED THIS DEVELOPMENT FOR SERVAL YEARS. CONSIDERING THE RISK OF RUNNING A DEADLOCK IS, THEREFORE, NECESSARY IN BOTH THE STRATEGY AS THE DESIGN. THE DESK ANALYSIS MAPPED, FOR INSTANCE, THE DIFFERENT LANDOWNERS IN THE STUDY AREA. THE PHASING OF THE VISION ANTICIPATES THIS UNCERTAINTY SINCE IT IS IMPOSSIBLE TO PREDICT IN A DESK ANALYSIS OR LANDSCAPE BIOGRAPHY WHICH FARMERS WILL STOP FARMING. ALSO, THE ENVISIONED URBANISATION IS PLANNED IN THE WAY THE CURRENT EXPANSION ALSO CAN HOUSE FUTURE DEMAND FOR HOUSING. THE ENVISIONED EXPANSION ALREADY ANTICIPATES TO FUTURE DENSIFICATION OF THESE LIVING CLEARINGS. THESE RESEARCH METHODS APPEARED, HOWEVER, TO ADDRESSES LIMITED THIS TOPIC.
THE LAST ETHICAL ISSUE WHICH HAS TO BE CONSIDERED IS FOOD SAFETY. IT REMAINS TO BE SEEN HOW LONG IT IS DESIRABLE THAT MORE AND MORE FARMER STOPS WITH FARMING IN THE NETHERLANDS. THIS DEVELOPMENT CAN LEAD TO A LOSS OF FOOD PRODUCTION, WHICH CAN HARM FOOD SAFETY AROUND THE WORLD. THE NETHERLANDS, AS THE SECOND-LARGEST EXPORTING COUNTRY, FORMS AN IMPORTANT LINK IN THE SUPPLY OF FOOD OF MANY IN COUNTRIES. THE DESIGN ALSO ADDRESSES THIS ISSUE FROM A DROUGHT PERSPECTIVE. THE ENVISIONED FOOD CLEARINGS ARE, FOR INSTANCE, DESIGNED THAT REMAINING FARMERS' EXPERIENCE AS LITTLE AS POSSIBLE LOSS OF FOOD PRODUCTION THROUGH DROUGHTS.

FUTURE RECOMMENDATIONS
THE REFLECTION OF THE LIMITATIONS OF THIS GRADUATION PROJECT SHOWS THE DIFFERENT RECOMMENDATIONS FOR FUTURE RESEARCH AND DESIGN TO DROUGHT STRESS.

FIRSTLY, THE GEOGRAPHICAL LIMITS OF THIS PROJECT OFFER OPPORTUNITIES FOR FUTURE RESEARCH. THE SCOPE OF THIS RESEARCH AND DESIGN IS LIMITED TO A SPECIFIC SAND LANDSCAPE IN THE PROVINCE OF UTRECHT. HOWEVER, THE RELEVANCE OF DESIGNING WITH DROUGHT OR WATER SCARCITY SEEMS TO BE GLOBAL. A COMPARATIVE STUDY IS A POSSIBLE WAY TO ANALYSE DIFFERENT DROUGHT ADAPTIVE GREEN STRUCTURES DEPENDING ON THE DIFFERENT TYPES OF LANDSCAPES (AND THEIR UNDERLYING LAND FORMING PROCESSES). ESPECIALLY COUNTRIES LIKE THE UNITED STATES, PORTUGAL OR AUSTRALIA SEEM INTERESTING FROM A DROUGHT ADAPTIVE POINT OF VIEW.

SECONDLY, THE THEORETICAL LIMITATIONS CAN BE INCORPORATED INTO FUTURE RESEARCH AND DESIGN. THE OVERVIEW OF CURRENT THEORIES ABOUT DROUGHT STRESS SHOWED THAT STILL UNDERSTANDING OF IT IS STILL INCOMPLETE. FOR INSTANCE, THE HYDROLOGICAL FEATURES OF TREES SPECIES ARE STILL LARGELY UNKNOWN AT THIS MOMENT. RESEARCH IN CLIMATE ARBORETA IS CURRENTLY EXECUTED TO DEVELOP NEW INSIGHT ABOUT TREE SPECIES-SPECIFIC REACTIONS TO ENVIRONMENTAL FACTORS (LIKE DROUGHT STRESS). THIS RESEARCH CAN BE INPUT FOR NEW VARIETIES WHICH DO NOT UNDERMINE THE IDENTITY OR SPATIAL FEATURES OF THE SPECIE. THIS HAPPENED WITH NEW VARIETIES WHICH USUALLY WERE RESISTANT TO DISEASES OR PLAGUES LIKE ASH AND ELM TREES. MOREOVER, CLIMATE ARBORETA OFFER THE OPPORTUNITY TO RESEARCH WITH DIFFERENT CONSTELLATIONS. CURRENT KNOWLEDGE GIVES INSIGHT INTO THE QUANTITATIVE REQUIREMENT FOR DROUGHT ADAPTIVE LANDSCAPE DESIGNS. MONITORING OF TREE CONSTELLATION CAN GIVE INSIGHT INTO THE QUALITATIVE REQUIREMENTS OF DROUGHT ADAPTIVE DESIGNS.

LASTLY, THE ETHICAL LIMITATIONS SHOWED THAT OTHER RESEARCH AND DESIGN METHODS ARE REQUIRED FOR FURTHER REALISATION OF DROUGHT ADAPTIVE DESIGN. ESPECIALLY THE MANY INTERESTS OF STAKEHOLDERS AND ACTOR CHALLENGE THE REALISATION OF THE PROPOSED DESIGN. A MANAGEMENT-GAME IS A POSSIBLE WAY TO INCLUDE THEM IN THE DESIGN PROCESS.

CONCLUSSION

THE INCREASING DROUGHT DURING THE SUMMER IS CURRENTLY NEGLECTED IN THE DESIGN (AND MANAGEMENT) OF GREEN STRUCTURES IN THE NETHERLANDS. RECENT STUDIES TO DROUGHT STRESS SHOW THAT MOST OF THE KNOWLEDGE TO ADDRESS IT IS AVAILABLE. HOWEVER, IT APPEARS THAT CURRENT SPATIAL DEVELOPMENTS IN LANDSCAPE ARCHITECTURE DO NOT IMPLEMENT THIS SPECIALIZED KNOWLEDGE. THEREFORE, A HOLISTIC LANDSCAPE ARCHITECTURAL APPROACH IS PROPOSED TO LOOK INTO ESPECIALLY THE SPATIAL IMPLICATIONS OF THE DROUGHT STRESS. THE MAIN OBJECT OF THE GRADUATION PROJECT IS HENCE THE MAPPING OF SPATIAL INVENTIONS WHICH ARE NECESSARY TO TRANSFORM THE CURRENT FOREST STRUCTURE UTRECHTSE HEUVELRUG INTO AN EXPANDING DROUGHT ADAPTIVE INTERURBAN FOREST STRUCTURE.

THE PROJECTED STARTED WITH A LITERATURE STUDY AND SITE ANALYSIS OF THE CASE. THE CHOICE FELL ON THE AREA OF THE UTRECHTSE HEUVELRUG BECAUSE OF ITS REMARKABLE SPATIAL STRUCTURE WHICH FACES DIFFERENT CHALLENGES. THE LITERATURE STUDY GAVE INSIGHTS INTO THE CURRENT UNDERSTANDING OF DROUGHT STRESS. THE FIVE STAGES OF THE DROUGHT STRESS CYCLE ILLUSTRATE HOW TREES RESPONSE TO THE CAUSES OF DROUGHT STRESS. DROUGHT STRESS IS THE RESULT OF A MOIST DEFICIT THAT IS CAUSED BY THE LACK OF PRECIPITATION OR ACCESSIBLE GROUNDWATER. THE CHARACTERISTICS OF SITE, VEGETATION AND NATURE MANAGEMENT IMPACT INDIRECTLY THE SEVERITY AND FREQUENCY OF THE DROUGHT STRESS. THE TREES APPEARED TO HAVE FIVE METHODS TO ACCLIMATE THEMSELVES AGAINST DROUGHT STRESS BEFORE THEY START TO DIE.

THE DESK ANALYSIS OF THE UTRECHTSE HEUVELRUG SHOWED THE CURRENT FUNCTIONING OF THE INDIRECT FACTORS. THE UTRECHTSE HEUVELRUG FUNCTIONS AS A WATER INFILTRATION AREA WHICH IS USED FOR THE SUPPLY OF DRINKING WATER. THE VEGETATION IS PRIMARILY DEFINED BY THE DRY, POOR, ACIDIC CONDITIONS OF THE AREA. THE VARIETY OF DIFFERENT TYPES OF VEGETATION OF THE AREA IS THE RESULT OF HUMAN INTERFERENCE THAT HAVE REFORESTED THE AREA FOR MORE THAN TWO CENTURIES. URBAN DEVELOPMENT SHOWED THAT IT IS AN ESSENTIAL DRIVER OF THE FORMATION OF THE FOREST STRUCTURE. HOWEVER, THE SITE ANALYSIS SHOWS THAT THE AREA IS VULNERABLE TO DROUGHT STRESS. THIS CAUSED BY THE LACK OF RETAINING RAINFALL AND EXTRACTION OF GROUNDWATER. THE CURRENT VEGETATION REACHES CURRENTLY THEIR LIMITS TO DEAL WITH DROUGHT STRESS.

THE THEORETICAL FRAMEWORK IS THE RESULT OF COMBINING THE DROUGHT STRESS CYCLE WITH URBAN FORESTRY MATRIX WITH. IN THIS WAY, A FRAMEWORK INCLUDES THE SPATIAL COMPONENT OF DROUGHT STRESS USING THE THREE SCALES OF THE URBAN FOREST. THESE SCALES CONTAIN THE SCALE OF THE TREE, CONSTELLATIONS OF TREES AND THE OVERALL FOREST STRUCTURE. ECOLOGY, FORESTRY, HYDROLOGY AND URBAN PLANNING FUNCTION AS THE FOUR LENSES WHICH ARE USED TO UNDERSTAND AND PREVENT DROUGHT STRESS.

THE SECOND PART OF THE GRADUATION PROJECT CONSISTS OF RESEARCH BY DESIGN FOR A SUB-AREA OF THE UTRECHTSE HEUVELRUG. THE DESIGN SHOWS A RANGE OF DIFFERENT INTERVENTIONS THAT CAN BE IMPLEMENTED AS PART OF A BROADER VISION TO BUILD DROUGHT ADAPTIVE INTERURBAN FOREST STRUCTURES.

THE VISION PROPOSED A NEW FOREST STRUCTURE WHICH WILL BE REALIZED IN TWO STAGES. THE STRUCTURE CONSIDERS ITSELF AS A PATCHWORK OF SMALLER FORESTRY CORES WHICH EACH WILL INCORPORATE ITS ADJACENT AGRICULTURAL AND URBAN CORES. THE CURRENT FOREST STRUCTURE APPEARS IT CONSISTS OF S OF FOUR TYPES OF TREE CONSTELLATIONS: LANES, ESTATES, PLANTATIONS AND NATURE RESERVES. THE FIRST STAGE IS THE TRANSFORMATION OF THE STRUCTURE, WHICH CONSISTS OF THE ADDITION OF SEASONAL BUFFERS IN BETWEEN THE FORESTRY, AGRICULTURAL AND URBAN CORES. THE SECOND STAGE CONSISTS OF THE EXPANSION OF THE FOREST IN PATCHES BETWEEN THE FORESTRY, AGRICULTURAL AND URBAN CORES.

THE VISION IS ELABORATED IN REGIONAL DESIGN. THE DESIGN PROPOSES A NEW GREEN AND BLUE SYSTEM THAT ADAPTS THE CURRENT GRID TO MAKE IT DROUGHT ADAPTIVE. MOREOVER, THE ADAPTED GRID WILL FACILITATE FURTHER EXPANSION OF THE FOREST. LASTLY, THE DIFFERENT CORRESPONDING CONSTELLATIONS WHICH ARE NEEDED TO TRANSFORM AND EXPAND THE CURRENT GRID ARE DESCRIBED. THIS INCLUDES SEVEN DIFFERENT CONSTELLATIONS.
TRANSFORMING AN EXISTING FOREST STRUCTURE CONSISTS OF FOUR TYPES OF TREE CONSTELLATION. THE CATCHMENT VALLEYS AND NETWORK OF DITCHES ARE TWO PRIMARY CONSTELLATIONS THAT WILL BE CONSTRUCTED TO PREVENT EXISTING FOREST OF FURTHER DETERIORATING FROM DROUGHT STRESS. THE SPRENGBEEK AND THE ZIGZAG ARE CONSTELLATIONS THAT MAINLY LET CIRCULATES THE RETAINED WATER.
THE CONSTELLATION OF EXPANSION CONTAINS FOUR TYPES OF TREE CONSTELLATION. THESE TREE-CONSTELLATIONS ARE THE BACKBONE OF BOTH DEVELOPING AGRICULTURE AND URBAN PATCHES. THE FOOD CLEARING CONSISTS OF WOODED BANKS AND SWAMP FORESTS. THE LIVING CLEARINGS IS THE LAST CONSTELLATION WHICH IS PART OF PATCHES OF DENSE FOREST. THESE PATCHES ARE DEVELOPED IN BETWEEN FOOD CLEARINGS.

IN SHORT, THIS GRADUATION PROJECT RESULTED IN THE DESIGN OF SEVEN CONSTELLATIONS, WHICH ILLUSTRATES SPATIAL IMPLICATIONS WHICH ARE NECESSARY TO DESIGNING DROUGHT ADAPTIVE INTERURBAN FOREST STRUCTURE IN THE UTRECHTSE HEUVELRUG.

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