

**DESIGNING
AN
ATTRACTIVE BIOMASS PRODUCING
CITY
OF
WAGENINGEN**



Minmin Gao
Master Thesis Landscape Architecture
Wageningen University and Research Centre

cover image
<http://www.aperfectworld.org/clipart/plants/planting.png>

© Minmin Gao & Wageningen University, Landscape Architecture Group, 2012

Minmin Gao [860201250090]
kittyme0201@gmail.com

Supervisors:

Dr. Ir. I. (Ingrid) Duchhart (WUR)

Ir. R. (Renée) de Waal (WUR)

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means without the permission of the author. This publication is written as a final master thesis at the chairgroup of landscape architecture at Wageningen University.

Landscape Architecture Group
phone: +31 317 484 056
fax: +31 317 482 166
E-mail: office.lar@wur.nl
www.lar.wur.nl

Postal address
Postbus 47
6700 AA, Wageningen
The Netherlands

Prof. Dr. ir. A. (Adri) van den Brink (Examiner)

Ir. R. (Rudi) van Etteger MA (Examiner)

Dr. ir. I. (Ingrid) Duchhart (Supervisor)

Ir. R. (Renée) de Waal (Tutor)

Wageningen, October 2012

Wageningen University and Research Centre
Master Thesis Landscape Architecture LAR-80436



PREFACE

During the first and half year studying in Wageningen University, I get to know some landscape issues through lectures and books. I found I am interested in sustainable energy landscape. I was very curious about how landscape architects could save and provide energy meanwhile beautify our world. I believe this topic is the one that I would like to learn and dedicate. When I come back to my hometown, China, I can make a contribution to solve problems by using the knowledge which I have studied in the Netherlands. With all these expectations I started my research.

There are some approaches of sustainable energy landscape had been developed and widely applied, however they are suitable for researching all renewable energy sources (e.g. wind, solar, biomass, geothermal and etc.) in general. Therefore I developed my own approach to deal with the suitability of biomass vegetation specifically. Furthermore analyzing visual qualities of biomass vegetation inspired from theories is aiming for creating an attractive environment in Wageningen.

To successfully complete this thesis, I highly appreciate the inspirations, wise and critical advice from my supervisors, Ingrid Duchhart and Renée de Waal. They offered lots of patience, support and encouragement to an eastern student who was doing a western project during the whole process. And I would like to thank Rudi van Etteger, my green light examiner as well. He gave new comments in the presentation. It was an inspiring interview with Lex Hoefsloot who is one of the aldermen of Wageningen municipality. He helped me in the beginning with understanding the energy status and target of Wageningen, and provided me very useful energy data. Dr. Zhanguo Bai, a senior researcher from ISRIC – World Soil Information, kindly provided me many websites and information about soil.

I would like to thank my college students and friends for their positive support and critical suggestion. Last but not least, I would like to thank my parents for all the supporting and encouragement.

In the process of writing this thesis, I was being a board member of International Exchange Erasmus Student Network Wageningen for half year. This part-time job enriched my student life experience in the Netherlands, and helped me

integrate into Dutch culture as well.

This thesis was a long and complicated process, and it enabled me to understand a bit more of my surrounding world, which is indeed valuable experience.

SUMMARY

This thesis focused on the productivity and visual quality of biomass vegetation, aiming to achieve an optimal productiveness and an attractive environment. First of all landscape status and energy system of Wageningen is analyzed. Five biomass species which all fit to grow in my study area were selected. Secondly three criteria were established to find out the most suitable location of each species. In order to make a different composition of biomass vegetation as a design tool for later design, analysis of the biomass visual characteristics was accomplished from both time and space aspects. At last, the plan and design were created based on the design concepts which derived from visual landscape quality theory.

Starting with the global issue of renewable energy and the energy target of Wageningen municipality, the knowledge gap, purpose and research question of thesis are introduced.

Chapter 1 Introduction

Research context and framework is discussed in chapter 2. Research context contains my understanding of landscape, biomass and visual landscape quality theories, while research model, framework and method are included in research framework.

Chapter 2 Research Context and Framework

Landscape process from history to present is stated in this chapter, which assisted a better understanding of my study area.

Chapter 3 Landscape Development and Analysis of Wageningen

For analyzing energy status of Wageningen, components of energy system, i.e. energy consumption, provision, transportation network and storage facility are studied in this chapter.

Chapter 4 Current Energy System of Wageningen

With the aim of achieving a suitability analysis and productivity of species, knowledge in relation to biomass vegetation on soil types, drought resistance, planting and harvesting technology, and energy value are collected and elaborated. Further on, biomass vegetation is classified by time and space analysis in aspect of visual characteristics, and then made compositions.

Chapter 5 Production and Visual Quality of Biomass Vegetation

Chapter 6 discovered design concepts, model and guideline from visual landscape quality theory, which is the foundation of design and plan for Wageningen.

Chapter 6 Design Concept, Detail Design and Plan

Conclusion and discussion of the research and design is discussed, which includes the evaluation of biomass productivity and visual landscape quality, the answers of research questions and recommendations for the further study.

Chapter 7 Conclusion and Discussion

TABLE OF CONTENT

Preface	7
Summary	9
1 Introduction	13
1.1 Orientation of Thesis and Knowledge Gap	15
1.2 Purpose and Research Question	17
2 Research Context and Framework	19
2.1 Research Context	20
2.1.1 landscape and landscape architecture	20
2.1.2 biomass	22
2.1.3 visual landscape quality	28
2.2 Research Framework	30
2.2.1 research model	30
2.2.2 thesis framework and method	32
3 Landscape Development and Analysis of Wageningen	37
3.1 Historical Development	39
3.2 Social Analysis	46
3.3 Present Landscape Analysis	52
4 Current Energy System of Wageningen	69
4.1 Energy Consumption	70
4.2 Energy Provision	73
4.3 Transportation Network	73
4.4 Storage Facility	75
4.5 Possible Biomass Sources	77

5	Production and Visual Quality of Biomass Vegetation	81
	5.1 Five Types of Biomass Species to be Applied in Wageningen	82
	5.2 Suitability Analysis of Biomass Species	96
	5.3 Productive of Species	104
	5.4 Visual Quality of Five Biomass Species	105
6	Design Concept, Detail Design and Plan	127
	6.1 Theory on Visual Landscape Quality	128
	6.2 Sequence	129
	6.2.1 concept	129
	6.2.2 model & guideline	129
	6.2.3 plan & visualization	130
	6.3 Control	142
	6.3.1 concept	142
	6.3.2 model & guideline	142
	6.3.3 plan & visualization	143
	6.4 Coherence	146
	6.4.1 concept	146
	6.4.2 guideline	146
	6.4.3 site selection and analysis	147
	6.4.4 detail design	149
	6.5 Plan	157
7	Conclusion and Discussion	161
	7.1 Answering the Research Questions	162
	7.2 Discussion	166
	7.3 Conclusion	167
	Appendix	169

Chapter 1

Introduction

- 1.1 Orientation of this thesis and Knowledge Gap
- 1.2 Purpose and Research Question

Energy transition is a highly dynamic topic in sustainable landscape recently. Human interventions and innovation should always be taken long-term planning and better life quality into consideration. Nowadays we are trying to shift the traditional energy sources (coal, oil and natural gas) to renewable sources (solar, wind and biomass), shift the underground hidden sources to the over ground visible sources. As a result, landscape architects feel the need to involve into this topic because energy transition starts to change our landscape.

My thesis aims to link the concerns for enhancing an attractive environment to the local citizens by providing renewable energy only from biomass sources in the city of Wageningen. It proposes that to gain insight into how biomass can be a source for renewable energy and how to create an attractive environment by exploring the theoretical possibilities and practical implementations of making biomass a substantial renewable energy source in Wageningen.

In recognizing the role of landscape in the process of providing biomass renewable energy, visual landscape quality and multifunctional landscape are the notions that I consider to be as the core theoretical study of making an attractive landscape. Biomass sources and their visual beauty are another key knowledge to be studied and developed significantly.

Following these theoretical consequences, the city of Wageningen will be better analyzed and designed both from landscape and biomass perspective. In the end my thesis will show the visual consequence of an attractive landscape combining renewable energy generation by means of biomass within the municipal border of Wageningen.



Figure 1.2~1.5: the photos against wind energy
 source: http://cdn.radionetherlands.nl/data/files/imagecache/must_carry/images/lead/earth-beat-nimby-650.jpg
http://r1v.zcache.com/anti_wind_farm_not_in_my_backyard_button-p145455018185374071z745k_400.jpg
<http://www.cartoonstock.com/newscartoons/cartoonists/cgo/lowres/cgon6431.jpg>
<http://www.tradebit.com/usr/stock-photos/pub/9002/900134.jpg>

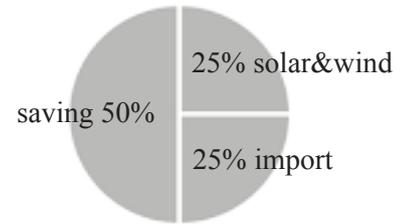


Figure 1.1: Wageningen municipality goal

1.1 ORIENTATION OF THESIS AND KNOWLEDGE GAP

As illustrated in official document ‘voor de Routekaart naar Wageningen klimaatneutraal in 2030’, Wageningen municipality set a goal to save, provide renewable energy inside and import green energy from outside. First, in terms of Energy Saving 50%, all buildings will be fitted with good insulation (floor, roof and wall insulation) and 90% dwellings in 2030 will be replaced a durable heat installation. Second, for the purpose of generating renewable energy 25%, it was chosen that solar and wind energy will provide most of them. Solar panels will be installed on most roofs and three wind turbines will be built in the agricultural lands in Binnenveld. Third, importing 25% of the energy demands in the form of green power and gas from outside can help Wageningen to achieve the goal (Fig. 1.1).

Wageningen target

However, modern wind turbines arouse controversy in the Netherlands because many people believe they are harmful to human (Fig. 1.2-1.5). A ‘Not in my backyard’ (NIMBY) reaction often occurs when residents oppose a proposal for wind power plants close to them. As minister Maxime Verhagen (Economic Affairs) said to Telegraaf, one of the most read newspaper in the Netherlands, everyone wants to have a good supply but then are against those activities when they are planned to close to his or her home place (Telegraaf Media Nederland, 2011). People’s complaints range from visual pollution to noise to potential magnetic fields. People find unacceptable if they can see a mega turbine in sight when they enjoy the sunshine in their backyard. They

Controversy on wind power

experience noise pollution in the day and night when they are at home. And the fields around wind turbines will become magnetic which are harmful to people (<http://anamericaninamsterdam.com/2011/09/28/wind-turbines-in-holland-not-in-their-back-yard-2/>). Furthermore, huge wind turbines has not been accepted by Wageningen municipality.

Apart from setting up wind turbines, more renewable energy could be provided by biomass sources. Vegetation, being a form of biomass, can add to the landscape quality of greening the city, which is often perceived positively. Furthermore, it is also important to take all local available sources into consideration when creating a safe and renewable energy system (Dobbelsteen, Broersma & Stremke, 2011). In the city of Wageningen, there is lots of green vegetation and space which could be potentials of biomass sources. Biomass mainly consists of different fast growing vegetation that can provide renewable energy in the process of combustion. This vegetation is the tool of landscape architects building livable environment, healthy life and attractive landscape.

Knowledge gap

Wageningen municipality did not consider biomass as one option of renewable energy sources so far, although it has the potential to be a valuable contribution to the energy generation and an attractive environment. Since few literature is available on the subject of biomass as renewable energy resource and means to add to spatial quality, it is addressed in this thesis.

Furthermore, the productivity and visual quality of biomass species have rarely been researched. These are the reasons why I will study biomass vegetation for the city of Wageningen.

As for my thesis, it requires a strong design strategy on various biomass sources in order to make an attractive landscape. In Wageningen, different neighborhoods have different conditions and characters, such as soil types and patterns. Biomass production should be adapted to it. Consequently it needs dissimilar design strategies to well satisfy requirements both from landscape quality visuality and landscape multifunctionality.

1.2 PURPOSE AND RESEARCH QUESTION

Purpose

The purpose of this thesis is to gain insight into biomass vegetation in order to produce renewable energy in Wageningen and to enhance the visual attractiveness of the environment by making biomass a substantial renewable energy source in Wageningen.

Research Question

Q 1: What percentage of energy consumption can be provided with this design?

Q 2: How does biomass vegetation create a visual attractive environment in the city of Wageningen?

REFERENCE

Botman Ine. Gemeente Wageningen. 2011. *voor de Routekaart naar Wageningen klimaatneutraal in 2030*. Wageningen: Wageningen municipality.

Van Den Dobbelsesteen, A., Broersma, S. & Stremke, S., 2011. Energy potential mapping for energy-producing neighborhoods. *International Journal of Sustainable Building Technology and Urban Development*, 2, 170-176.

Telegraaf Media Nederland, 2011. Verhagen deelt zorg 'niet in mijn achtertuin'. http://www.telegraaf.nl/binnenland/10971687/___Niet_in_mijn_achtertuintuin___html

<http://anamericaninamsterdam.com/2011/09/28/wind-turbines-in-holland-not-in-their-back-yard-2/>

Chapter 2

Research Context and Framework

2.1 Research Context

2.1.1 Landscape and Landscape Architecture

2.1.2 Biomass

2.1.3 Visual Landscape Quality

2.2 Research Framework

2.2.1 Research Model

2.2.2 Thesis Framework and Method

2.1 RESEARCH CONTEXT

This part will discuss the theories which are relevant to this thesis topic. Fundamentally, since there is no single definition of landscape and landscape architecture that is agreed on by all landscape architects, I will choose the terms of landscape and landscape architecture which is suitable for this thesis to clarify whom I am and what I shall cope with.

2.1.1 Landscape and landscape architecture

Landscape There are different perspectives about landscape in different conditions. Landscape has the capacity to deal with territories, networks, infrastructure as well as energy transition. Prof. Kerkstra and Ir. Vrijlandt, who were related to the Wageningen University landscape architecture group in 1980s, define landscape as follows:

“Landscape is the visible result on the surface of the earth of the interactions between man and nature” (Kerkstra & Vrijlandt, 1988, cited by Duchhart, 2007, p.16).

My thesis is for researching spatial quality and productivity of renewable energy plants interfering in local landscape, which means the new visible man-made interventions on the surface of the earth interacting on ‘nature’ (the current landscape). Therefore their definition will be appropriate for my thesis.

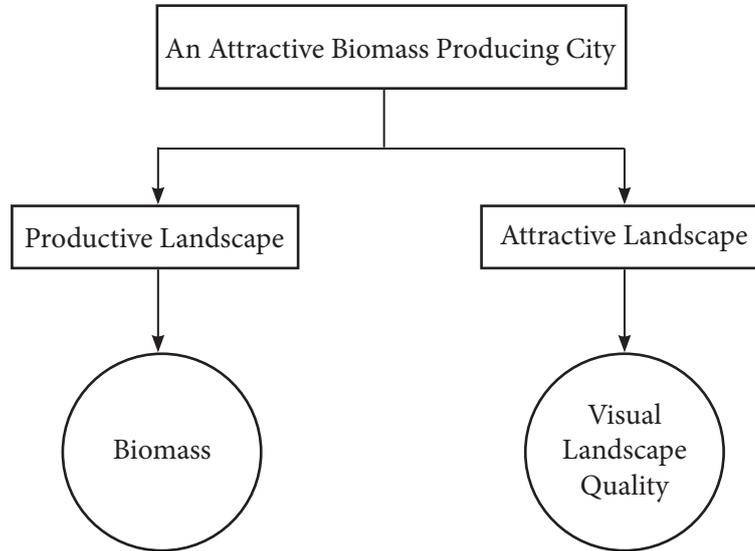


Figure 2.1: theoretical framework

Various descriptions of landscape architecture are defined in different point of views and circumstances. The following definition is closely relevant to this thesis because it states that design for space plays an important role and landscape form is concerned to enhance sensory delights and meaning (Vroom, 1983 cited by Duchhart, 2007).

Landscape architecture

“Landscape architecture is one of the activities dealing with the mutual adjustment of human activities and the space available. A landscape architect adapts new development to that which already exists and created new forms required for new types of use” (Vroom, 1986; Vroom & Steiner, 1991, cited by Duchhart, 2007, p.15).

Afterwards, as Figure 2.1 illustrated, attractive landscape and biomass producing landscape will be the main part of my theoretical framework because my thesis aims to generate electricity and heat by means of biomass sources for local Wageningen citizens, and in the meantime design an attractive landscape.

Theoretical framework

PRODUCTIVE LANDSCAPE

2.1.2 Biomass

biomass definition

Biomass is an organic material that consists of waste and residues derived from plants and animals. It is used for non-food applications, especially as a replacement to fossil fuels, for example in the form of wood chips, agricultural residues, urban waste, and animal manure. It is a raw material (feedstock) for the production of heat, electricity, transportation fuels, chemicals and products (Elbersen, 2005).

Biomass has been very significant importance for energy purpose for thousands of years since mankind discovered fire. Biomass provides food, construction materials, paper and chemicals as well. Later on, we found green biomass sources such as vegetation has other functions that beautify human environment.

Recently, biomass is one of the hottest topics in renewable energy domain. We are not only shifting the traditional energy sources to renewable sources, but also taking better living environment into consideration. Therefore, landscape architects can contribute their knowledge to combine biomass and environmental beautification.

The effects of implementing biomass are predicted by lots of researchers are competitions with food production, forest and other land use because biomass needs large-scale application (see for instance Pimentel & Pimentel, 2008). They believe biomass production which takes up too much space will reduce the amount of land available for food production and forest, in the result of driving up food price and environmental disruption. This is the basic argument against biomass production. However, recently, UK Energy Research Centre (2011) published a report to state “up to a fifth of global energy could be provided by biomass without damaging food production.” This finding is based on reviews of over 90 global studies. They conclude that, first scientists working on biomass and food production should cooperate more closely; second more investments should contribute to technological advances for increasing food and energy crops production; third we should make the best use of agricultural residues, energy crops and waste materials. Then biomass will not be harmful for food production. Ecologically, biomass production on large-scale is not good for biodiversity. There are only a few biomass species and they are either grasses, shrubs or

trees. Considering landscape, most biomass is only obtained one function, energy generation. However vegetation is a basic and traditional tool for landscape architects creating beautiful and sustainable environment. Furthermore in highly density of built area like urban area there is rarely space for biomass. That's why biomass is hardly to implement in cities.

However from another perspective, biomass is an indispensable renewable energy source in the way of making a sustainable landscape. The following reasons can be distinguished.

Reason 1: The importance of biomass among all renewable energy sources

why biomass is important

“Biomass is the most important energy source in the world after fossil fuels. In Europe, biomass conversion is considered a renewable, environmentally-sound way to produce energy” (Twidell & Weir, 2006, p.1). In the Netherlands, renewable energy sources provided 3.84% of total primary energy supply (TPES) in 2010. The share more than 85% comes from biomass, mainly co-firing in coal plants, with smaller volumes used in small combined heat and power plants (CHP). Wind is the second important renewable-based supply provides almost 13%. The rest comes from solar and hydro (IEA, 2008).

Reason 2: Diversity in energy provision

Perhaps one renewable energy source can satisfied the internal demands on a small scale, but it cannot achieve on regional or even larger scale and it is not a resilient and secured system. A highly diversified energy system can cope with possible periodic and unexpected change of the single source (Smil, 2008). Therefore, the local energy system must be diversification of sources and technologies in order to create a sustainable and secured energy system (Sven, 2010). Biomass is one of the most important renewable sources. All energy systems which are resilient, secured and sustainable should take biomass into consideration if they have this local source.

Reason 3: Plenty of sources in Wageningen circumstance

The municipality of Wageningen offers potential for harvesting biomass as energy source. Agriculture area is one option of implementing renewable energy sources. There are some arable lands in Wageningen, however these

lands cannot grow biomass crops because of food production competition, but they are options for agricultural waste and residues. Furthermore, much meadow lands make planting biomass crops being reality, but still need to do some research about growth conditions.

Overview and new classification of biomass

Biomass consists of various sources from both plants and animals. Concluding from the other literatures, there are many ways of biomass classifications for distinguishing different types of biomass materials, but generally it can be split to woody biomass and non-woody biomass, including herbaceous crops. Rosillo-Calle et al. (2007) classified biomass into eight categories: Natural forests/woodlands, Forest plantations, Agro-industrial plantations, Trees outside forests and woodlands, Agricultural crops, Crop residues, Processed residues, Animal wastes. They state that this is attractive because it can be assessed and measured by similar methods. I agree with it and this system is professional and well-organised, however I think this classification is difficult for non-biomass experts to understand and remember, moreover I found it has a gap because it did not include municipal waste. Therefore inspired by them I will lay out a concise classification of biomass sources especially for landscape architects better and easier understanding.

In terms of object properties, everything on the earth can be divided into three types: solids, liquids and gases. Amongst all biomass sources, no liquid material has been used for producing bioenergy, only solids and gases have been studied. In all solid biomass sources, wood, crops and garbage are classified again. Wood means all trees and shrubs, crops contain all kinds of grasses, garbage mainly contains the refuse from municipal solid waste. Gas is from animal manure, municipal solid waste and sewage, generally named landfill gas. To sum up, four categories of biomass source are: wood, crops, garbage and landfill gas (Tab. 2.1).

Biomass sources

Linking up with biomass classification, this section will follow that structure to summarize different kinds of biomass sources from the books of Twidell & Weir (2006) and Rosillo-Calle et al. (2007).

Table 2.1: New biomass classification, source, conversion technology and production (proposed by author based on Twidell & Weir, 2006 and Rosillo-Calle et al., 2007)

Location	Category	Sources	Pretreatment	Conversion technology	Production
urban area	wood	street tree/shrub	cut down & dry	combustion	heat & electricity
	garbage	urban refuse from MSW*	-	combustion	heat
	landfill gas	landfill gas from MSW*	-	anaerobic digestion	biogas
	landfill gas	sewage gas	-	anaerobic digestion	biogas
sub-urban area	crops	energy crops	dry	combustion	heat & electricity
	crops	energy crops	heat	fermentation	bioethanol
	crops	energy crops	dry	esterification	biodiesel
	wood	forest residues	dry	combustion	heat & electricity
	wood	forest logging	dry	combustion	heat
	wood	wood from timber mill residues	dry	combustion	heat
	wood	wood from fuel lot cropping	dry/heat	pyrolysis	oil
	landfill gas	farm animal manure	heat	anaerobic digestion	biogas

*MSW: municipal solid waste

Wood: In Oxford dictionary, wood is the hard fibrous material that forms the main substance of the trunk or branches of a tree or shrub, used for fuel or timber. This includes all trees and shrubs generally. Specifically, it can be natural forests, urban trees or shrubs, commercial plantations (paper or furniture), energy plantations (trees dedicated to energy production), agro-industrial plantations (coffee, rubber trees or coconut palms) or all woody residues from above (sawdust or sawmill off-cut).

Crops: This consists of agricultural crops and crop residues. These agricultural crops grow for food, fodder, fiber or specifically energy production. Crop residues means all residues from crops and plant produced in the field, such as cereal straw, leaves and plant stems.

Garbage: This comprises refuse from municipal solid waste, such as old paper, cardboard, organic household waste (vegetable, garden and fruit waste, or GFT in Dutch)

Landfill gas: This includes gas from animal manure, gas from municipal waste and sewage gas.

Biomass conversion technologies and productions

These various sources are converted to the certain types of energy by different technologies.

Combustion: heat and electricity are the products of biomass combustion which is one of the major energy conversion techniques. Energy crops (e.g. switchgrass or miscanthus), forest residues (e.g. branches), forest logging and wood logging residues (e.g. woodblock or wood sawdust) are burnt to provide heat for cooking, space heat, crop drying, factory process and raising steam for electricity production and transport. Steam process heat is commonly to use steam first to generate electricity before the heat temperature degrades. The efficiency of generating electricity from biomass sources is only about 20-25% because of low temperature combustion, so the rest of the energy remains as heat.

Pyrolysis: pyrolysis is a general term for all processes of heating or combusting organic material to produce secondary fuels and chemical products. Wood, biomass residues, municipal waste and coal can be the sources which provide gases, condensed vapors (e.g. liquids, tars and oils), and solid residue as char (charcoal) and ash (Fig. 2.2).

Esterification: oil is extracted from plants such as seeds (e.g. sunflower and soya bean), nuts (e.g. oil palm and coconut copra), fruits (e.g. olive), leaves (e.g. eucalyptus), tapped exudates (e.g. rubber latex) and by-products of harvested biomass (e.g. oleoresins from pine trees). However, it is difficult to use this oil direct to diesel engines due to high viscosity and combustion deposits especially at low temperature ($\leq 5^{\circ}\text{C}$). Both difficulties are overcome by converting the oil to the corresponding ester which is a debated fuel better suited to diesel engines than petroleum-based diesel oil.

Fermentation: bioethanol is produced by certain micro-organisms from sugars (e.g. sugarcane, sugar beet, starch crops and cellulose) under acidic conditions. It is concentrated up to 95% by distilling and fractionating (Fig. 2.3).

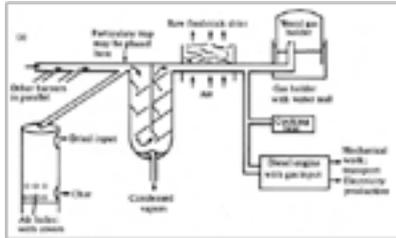


Figure 2.2: small-scale pyrolysis system (Twidell & Weir, 2006, p.371)

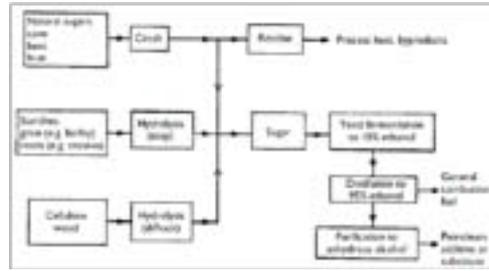


Figure 2.3: ethanol production (Twidell & Weir, 2006, p.375)

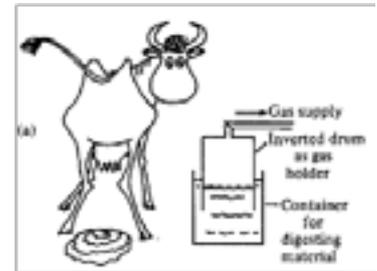


Figure 2.4: simple oil drum batch digester (Twidell & Weir, 2006, p.380)

Anaerobic digestion: anaerobic digestion means biomass sources such as municipal solid waste, sewage and animal manure can be digested in a closed condition without oxygen. During the process of biogas generation, nutrients, micro-organisms, temperature, pH value and water content are the important fabrication requirements. Micro-organisms need nutrients such as carbon, nitrogen, water and minerals for digestion. The normal temperature, between 10°C and 30°C, and pH value between 6.5 and 7.5 is the best conditions of decomposition.

To sum up, the new biomass form of classification, source, conversion technology and production is giving an overview and checking out later during design. For this thesis, I only focus on biomass vegetation, because vegetation has an advantage of greening city, which is perceived positively. It is the tool of landscape architects implementing accurately for creating a livable environment.

Location	Category	Sources
urban area	wood	street tree/shrub
	garbage	urban refuse from MSW*
	landfill gas	landfill gas from MSW*
	landfill gas	sewage gas
sub-urban area	crops	energy crops
	crops	energy crops
	crops	energy crops
	wood	forest residues
	wood	forest logging
	wood	wood from timber mill residues
	wood	wood from fuel lot cropping
landfill gas	farm animal manure	

ATTRACTIVE LANDSCAPE

In this section, the primary assignment is to figure out what an attractive landscape is. There is rarely article or book to discuss about the definition of attractive landscape, because it is a highly subjective topic which cannot make one definition of an attractive landscape. Moreover, there are many publications on attractiveness of landscape, which could imply the meaning although one definition cannot be given. Therefore I try to clarify the definition of attractive landscape for this thesis.

In Oxford dictionary, the definition of attractive is

“pleasing or appealing to the senses:

- (of a person) appealing to look at; sexually alluring
- having qualities or features which arouse interest
- relating to attraction between physical objects”

(source: http://oxforddictionaries.com/definition/attractive?q=attractiveness#attractive__7)

Obviously, the second explanation would apply to the theme of my thesis. An attractive landscape should arouse visitors' interests and make them sensorial pleasure. Therefore, be appropriate for this thesis, my definition of attractive landscape is the visible results of interacting between man and nature, which have qualities or features on the earth can arouse human interests and appeal to their senses.

However, what landscape are people interested in? Which criteria can make

them enjoy the landscape? In my opinion, a landscape attracting people needs to meet visual beauty requirement firstly and satisfy different users' demands secondly. This is an attractive landscape. Of course human has five senses, however I deem vision is the most important sense and landscape is the visible result on the earth like my definition said. So I will research on visual landscape quality for building an attractive landscape.

2.1.3 Visual landscape quality

In my opinion visual landscape quality is the basic criterion of landscape attractiveness. "Our sight is the most perfect and most delightful of all our senses; it fills the mind with the largest variety of ideas..." wrote by Joseph Addison (1672-1719) who was an English essayist, poet, playwright and politician (<http://publicquotes.com/quote/10495/our-sight-is-the-most-perfect-and-most-delightful-of-all-our-senses.html>). Vision is the most important human sense that receives approximately 80% of all information (<http://www.vision1to1.com/EN/HomePage.asp?BGColor=1&Category=6&Article=122>) and offers the broadest range of possibilities for stimulation. Furthermore everyone likes beautiful objects and visual stimulation is the most direct and effective way to influence human psychology. As Ulrich (1979) summarized that outdoor visual environment can influence people's psychological well-being, therefore should be given more attention in planning and design determination. Last but not least, there is few research to show the consequence of combining visual landscape quality and biomass sources. For these reasons I recommend visual landscape quality is a fundamental criterion of creating an attractive landscape by providing biomass energy.

Landscape designers cope with the problem of human intervention on the earth (refer to 'landscape definition' p.20). In design not all demands can be met because human-beings have so many different demands and wishes. Visual quality is one of the common requests. Carlson (1999, p. xvii) states that "Aesthetics is the area of philosophy that concerns our appreciation of things as they affect our senses, and especially as they affect them in a pleasing way". In Saito's (2007) book "*Everyday Aesthetics*", she states that some hold that "the aesthetic" refers to a set of sensory qualities; others contend that "the aesthetic" appoints a special kind of experience; and yet others claim that it is a specific attitude renders an experience aesthetic. However Saito includes that "the aesthetic are any reactions we form toward the sensuous and/or design qualities of any object, phenomenon, or activity" (Saito, 2007, p. xix). This means, first of all, aesthetic consists of all sensory, not only vision but also taste, touch, smell and sound. Second, aesthetic reacts all positive and negative emotion, not only pleasant, but also unpleasant. Third, aesthetic reaction can be insignificant and automatic response to our daily life and phenomena. Obviously, visual quality is one part of aesthetics.

2.2 RESEARCH FRAMEWORK

2.2.1 Research Model

Layer approach

Landscapes are complex entities. To reduce the complexities it is worthwhile to separate layers to analyze. In the 1980's Prof. Kerkstra and Ir. Vrijlandt of Wageningen University developed the triplex model which is a practical analysis tool for the total environment. It can be very helpful when I try to find the specific characteristics for the city of Wageningen. Furthermore, as a landscape architectural student of WUR, it is important to study what works teachers did and put it into practice. In this model a complicated landscape can be distinguished by three layers: abiotic (geomorphology), biotic (nature) and anthropogenic (occupational, human) layer. It is a classical approach as an analytical tool contributes to spatial planning methodology.

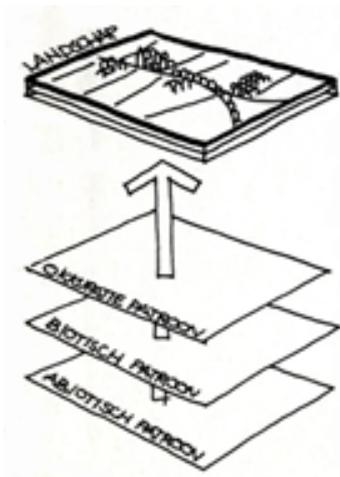


Figure 2.5: Layer approach
(Kerkstra & Vrijlandt, 1988)

This model helps to dissect landscape into understandable parts. But the most important step is to link the different layers and to understand dependencies between patterns in the layers.

Abiotic layer: its components are climate, geology, physiography, hydrology and soil (Steiner, 2008). They are the structure bearers of space use. Abiotic substratum is a large and long time formative system which is mostly beyond our control. The natural resilience and dynamic and self-regulation processes must become decisive in the design and allocation of the other two layers: biotic and anthropogenic layers (Priemus, 2004).

Biotic layer: it consists of vegetation and wildlife (Steiner, 2008).

Anthropogenic layer: People responded to nature consisting of abiotic and biotic patterns and have adapted these patterns creating their own patterns. It contains land use, patterns of dwelling, agriculture, roads, villages and cities.

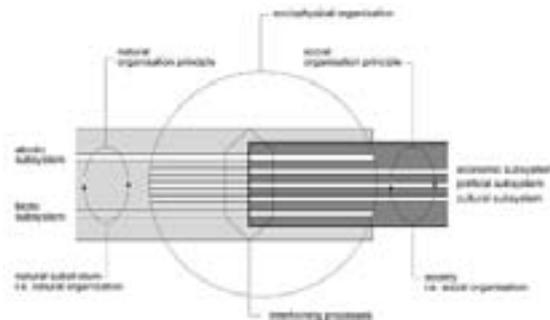


Figure 2.6: Sociophysical-organisation model adapted from Kleefmann's model (Duchhart, 2007, p.18)

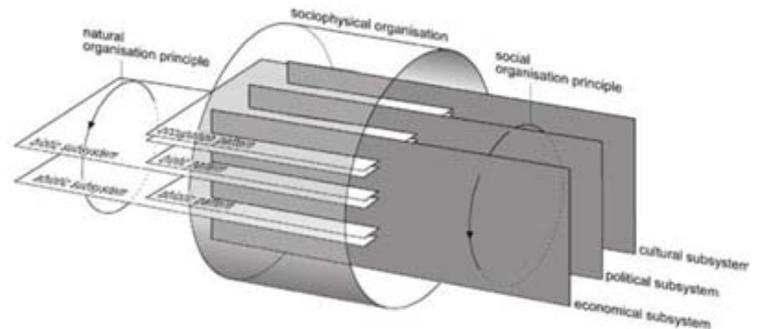


Figure 2.7: Intertwining the triplex model and the socio-physical model (Duchhart, 2007, p.194)

Intertwining the triplex model and the socio-physical model

Prof. Kleefmann in Wageningen University modified this model and provided another one called sociophysical-organization model. "This model is based on the reciprocal relationships between man and nature and should be seen as an abstract notion of the functioning and co-ordinating of human activities required for living a meaningful life" (Duchhart, 2007, p.18). Kleefmann elaborated that natural organization is one of the critical factor in landscape development. Consisting of abiotic and biotic subsystem, it is well resembled in layer approach. The other factor is social organization which is divided as economic (organization of production), political (intermediary between the two foregoing subsystems) and cultural (shared pattern of norms and values) subsystem. They all belong to anthropogenic layer, however using different classification and reflecting more sophisticated to define. The three subsystems are all together with abiotic and biotic subsystem determine the appearance of the landscape.

The sociophysical-organization model regards the relationship between natural environment and social influence. It emphasizes that landscape is a complex system focuses mainly on exploring the driving forces behind the factors that form the landscape (Duchhart, 2007).

Intertwining the triplex model and socio-physical model, Duchhart (2007) demonstrated her model will be a new integrated layer generated implying problems and constraints of studying landscape. As a landscape architect, it is necessary to try our best to think over every aspect carefully while affected by everything happening in this planet. This model guides a clear instruction that landscape architects can follow to do analysis and design from both human control and uncontrolled circumstances.

2.2.2 Thesis framework and method

Framework of this thesis

This thesis focuses on the knowledge of biomass energy at first and later on exploring the visual landscape quality theoretically and integrating with biomass vegetations. Design principles will be made after bringing together all these informations. It is a difficult task to gather, select, summarize and integrate them because visual attractiveness relates to human-environment reflection. The design process turn out to be the way that brings these information into implementation. The evaluation and conclusion assess, emphasize and the findings of my research.

Table 2.2: Thesis Framework

Purpose	Knowledge/theory	Approach	Result/Concept	Plan/Design	Conclusion	
Gain insight into biomass for producing renewable energy	- soil type - drought resistance	- soil analysis - groundwater analysis - near future development analysis(political desicion)	Biomass suitability	Plan	- Calculate the percentage of energy provision by biomass	
	- yield & energy value	Data calculation	select most productive species			
	- planting technology - harvest	time analysis	visual composition			
	visual charecteristics of vegetation	space analysis				
Enhancing visual attractiveness	visual landscape quality	reading and selecting	- sequence		Plan/Design	- evaluate attractiveness
			- control			
			- coherence			

Methods used in this thesis

Based on Creswell's (2009) book, a mixed research methods is chosen for this thesis. Mixed method is the combination of quantitative and qualitative methods. In this thesis, I use qualitative methods, such as literature study, to study the theoretical knowledge. Both quantitative and qualitative methods are very important for exploring current situation. Literature study like maps, GIS data collection and sketches and field work are the qualitative methods for landscape characteristics. CBS database research, municipal energy documents collection and statistical analysis are the quantitative methods which help me figure out existing energy situation in the city of Wageningen. In design section, I use the results from both qualitative and quantitative methods of previous phase to draw a conceptual and detail design. In the end, I use quantitative methods, statistic calculation to evaluate how much renewable energy can be generated from the design which is the result of qualitative methods.

Table 2.3: Methods and Expectations

Processes	Methods	Expectations
Site analysis (including current landscape characteristics and energy system analysis)	Literature study (maps, GIS data, CBS database, municipal energy documents and website); fieldwork (observation and photos); desktop (sketches); statistical analysis and interpretation (electricity and heat and biomass sources numerical measures); Fieldwork (observation and photos)	<ul style="list-style-type: none"> - To analyze current situation for better understanding study area and estimating future potentials - Being a base of designing
Theory (biomass and visual landscape quality)	Literature study (books, articles and website)	To make criteria and design principles for an visual attractive biomass landscape
Design (including concept and detail design)	Fieldwork (observation and photos); desktop (sketches and visualization)	To gain visual impression of both providing energy and creating landscape by biomass
Conclusion (including attractiveness evaluation and biomass calculation)	Statistic valuation and interpretation (electricity and heat calculation)	Figure out how much biomass energy is provided

REFERENCE

Carlson, A., 1999. *Aesthetics and the environment: the appreciation of nature, art, and architecture*. London [etc.]:Routledge.

Creswell, J. W., 2009. *Research design: qualitative, quantitative, and mixed methods approaches*. Los Angeles, CA [etc.]: Sage.

Daniel, T. C., 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning* 54(1-4): 267-281.

Duchhart, I., 2007. *Designing sustainable landscape: from experience to theory: a process of reflective learning from case-study projects in Kenya*. PhD thesis.

Elbersen, W., 2005. *Switchgrass and miscanthus as energy crops – agricultural aspects*. Lecture. Wageningen University and Research Center.

IEA (International Energy Agency), 2008. *Energy policies of IEA countries: Netherlands 2008 review*. Paris: IEA publications.

Lothian, A., 1999. Landscape and the philosophy of aesthetics: is landscape quality inherent in the landscape or in the eye of the beholder? *Landscape and Urban Planning* 44(4): 177-198.

Pimentel, D. & Pimentel, M., 2008. *Food, energy, and society*, Boca Raton, FL, CRC Press.

Priemus, H., 2004. *Spatial memorandum 2004: A turning point in the Netherlands' spatial development policy*. Tijdschrift Voor Economische En Sociale Geografie, 95, 578-583.

Rosillo-Calle et al., 2007. *The biomass assessment handbook*. London: Sterling, VA.

Saito, Y., 2007. *Everyday aesthetics*. Oxford [etc.]: Oxford University Press.

Smil V., 2008. *Energy in nature and society: general energetic of complex systems*. MIT press: Cambridge.

Steiner, F. R., 2008. *The living landscape: An ecological approach to landscape planning*, Island Pr.

Stremke, S., 2010. *Design sustainable energy landscapes: concepts, principles and procedures*. PhD thesis.

Twidell, J. & Weir, T., 2006. *Renewable Energy Resources*. 2nd ed. Abingdon: Taylor & Francis.

http://oxforddictionaries.com/definition/attractive?q=attractiveness#attractive__7

<http://publicquotes.com/quote/10495/our-sight-is-the-most-perfect-and-most-delightful-of-all-our-senses.html>

<http://www.vision1to1.com/EN/HomePage.asp?BGColor=1&Category=6&Article=122>

Chapter 3

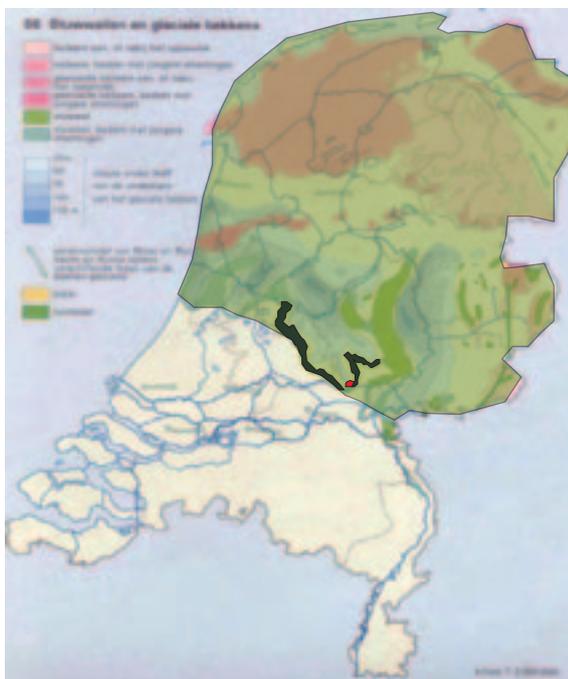
Landscape Development and Analysis of Wageningen

- 3.1 Historical Development
 - 3.1.1 geology evolution
 - 3.1.2 urban growth
- 3.2 Social Analysis
 - 3.2.1 demographic development
 - 3.2.2 economic distribution
 - 3.2.3 cultural dynamic
 - 3.2.4 political decision
- 3.3 Present Landscape Analysis
 - 3.3.1 abiotic landscape
 - 3.3.2 biotic landscape
 - 3.3.3 anthropogenic landscape

Introduction The city of Wageningen is a historical town in the province of Gelderland in the Netherlands. It is situated on the north bank of the River Rhine. It has 37,575 inhabitants 31st of December in 2010 (CBS, 2011). The total area is 32.35 km², land takes up 30.47 km², the water is 1.88 km² (CBS, 2009). Wageningen is well-known for Wageningen University and Research Center (WUR) which specializes in life science.

The research about this entire chapter has been done is significant important to me, a non-native designer, and the readers who are from abroad. It is helpful for understanding physical geographic change, social development and current landscape situation.

Figure 3.1 glacial deposit in the Netherlands (Lenzholzer, 2009, p.17)



3.1 HISTORICAL DEVELOPMENT

In order to study how the spatial and social aspects of Wageningen take shape as today's status, it is necessary to know the transformation of geology, urban pattern and demography from past. With the information showing below, we can better understand the current situation of Wageningen city, better design the future development of Wageningen city and better find the energy solution for Wageningen.

3.1.1 Geology evolution

General

The Pleistocene period started from 2.5 million years BP and ended up in 10,000 years BP. During early this period ice covered the northern part of the Netherlands which took up more than 50% of the country territory including my study area. The ice-sheet movement gouged out deep basins and pushed up high ridges on their flanks (Fig. 3.1). Such push-moraines, in Dutch called 'stuwwallen' have occasional summits exceeding 100m NAP (Normaal Amsterdams Peil, the mean summer high-water level in Amsterdam harbor), while the basins underlying the valleys of the Gelderse IJssel, Eem, and

Dutch geological development



Figure 3.2 glacial valleys in Gelderse Vallei (Lenzholzer, 2009, p.14)

IJ reach similar depths below sea-level (Audrey, 1985, p.13). These push-moraines form the basic structure part of today's Dutch landscape.

The study area

Geological status of Wageningen

Around Wageningen municipality which is my study area, a large plain agricultural land is sandwiched between two moraines, the Utrechtse Heuvelrug (Grebbeberg) and the Veluwe (Wageningse Berg) (Fig. 3.2). These two moraines almost form as one sandy hill. They starts at Hattem in the northeast, extend to south until Dieren. It is beside the Neder Rijn through Renkum and Wageningen to Leersum, and northwards to Hilversum and Bussum in Gooiland (Fig. 3.3). Currently the highest peak of Grebbeberg is 68.9 meter NAP (Fig. 3.4) and for Wageningse Berg is 51.4 meter NAP (Fig. 3.5), which were both formed by ice-sheet movement, and they are keeping decreasing slightly. Currently, Wageningen city is bordered by several local roads on the north perpendicular to National road N781, and the bottom is through the Lower Rhine (Fig. 3.6).

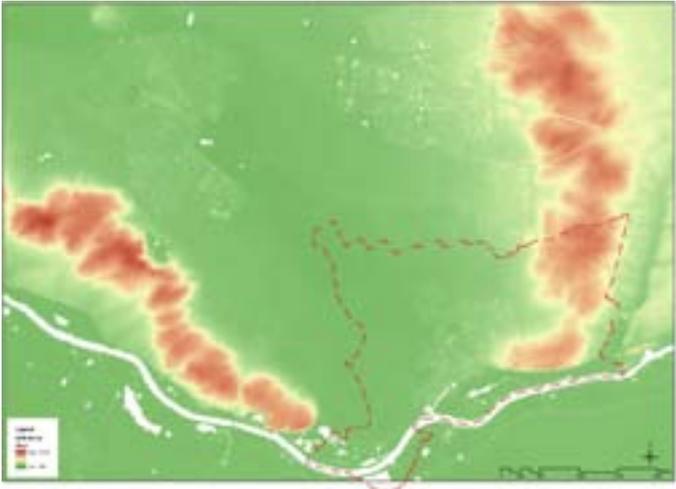


Figure 3.3 Height map in study area (illustrated based on GIS, 2011)



Figure 3.4 Grebbeberg and agricultural land



Figure 3.5 Wageningse Berg

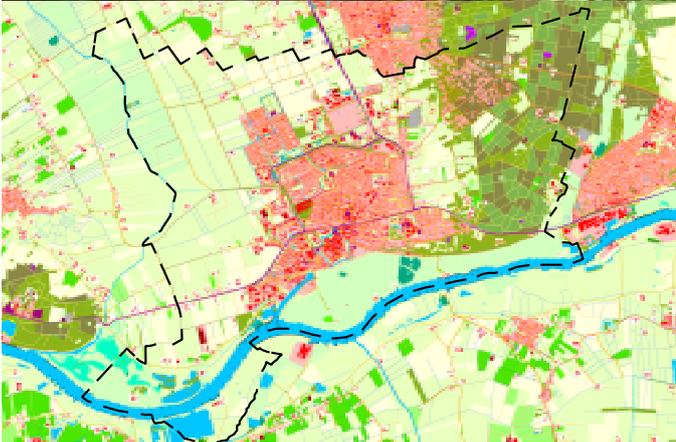


Figure 3.6 Wageningen Municipality Border Map (illustrated based on GIS, 2011)

3.1.2 Urban growth

Wageningen in 19 century

Wageningen was a small town in the map of 1868 compared with today's dimensions (Fig. 3.7). The shape of the fortified town can be seen very obviously at that time, and 1885 as well, protected by a canal and wall. The fortified town is the first urban pattern in Dutch urbanism history, which derives from Middle Age. Wageningen was part of the Roman defensive line. It was the major military center for this region. Size was not so much the factor, but location was much more critical because it is along the lower Rhine. The structure of Wageningen fortified town was one main street through from southwest to northeast and several by-pass crossing it. The church is closed to the main street. The wall surrounded and protected the whole town and the canal encircled the wall for keeping the distance of fire.

In 1885, people started moving, towards Wageningse Berg and Bennekom, to the northeast of Wageningen fortified town as their settlements. Farmers settled their dwellings and farmsteads next to the main roads and arable lands (Fig. 3.8). In decades years after that, towards north, Wageningen city became triple larger than that of 1868. More and more settlers came to live here (Fig. 3.9).

Wageningen in 20 century

Currently, the old fortified town area maintains its significance and centrality in the city of Wageningen at present, in which it contains the most important constructions like Wageningen church, city hall, market square and shopping

street. The new developments expanded towards all round except south because of lower Rhine. In 1918, Wageningen University was established and was the successor to the Agricultural School founded here in 1876. The campus is in northwest of and quite closed to the old fortified city. Later on city of Wageningen is becoming well known because of Wageningen University and Research Centre (WUR). Nowadays, the total area (including both land and water) of Wageningen city has 32.35 km² which is just in the left corner of the cross between highway N225 and N781 (Fig. 3.10).

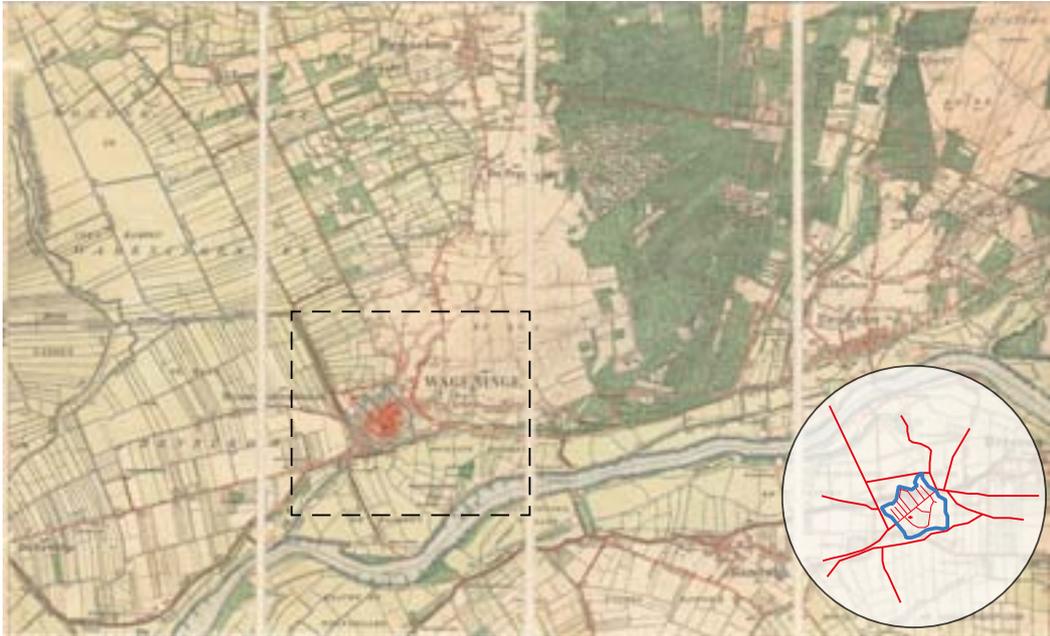


Figure 3.7 Wageningen 1869 (background map scan from WUR library)



Figure 3.8 Wageningen 1885 (background map scan from wur library)



Figure 3.9 Wageningen 1954 (background map scan from WUR library)

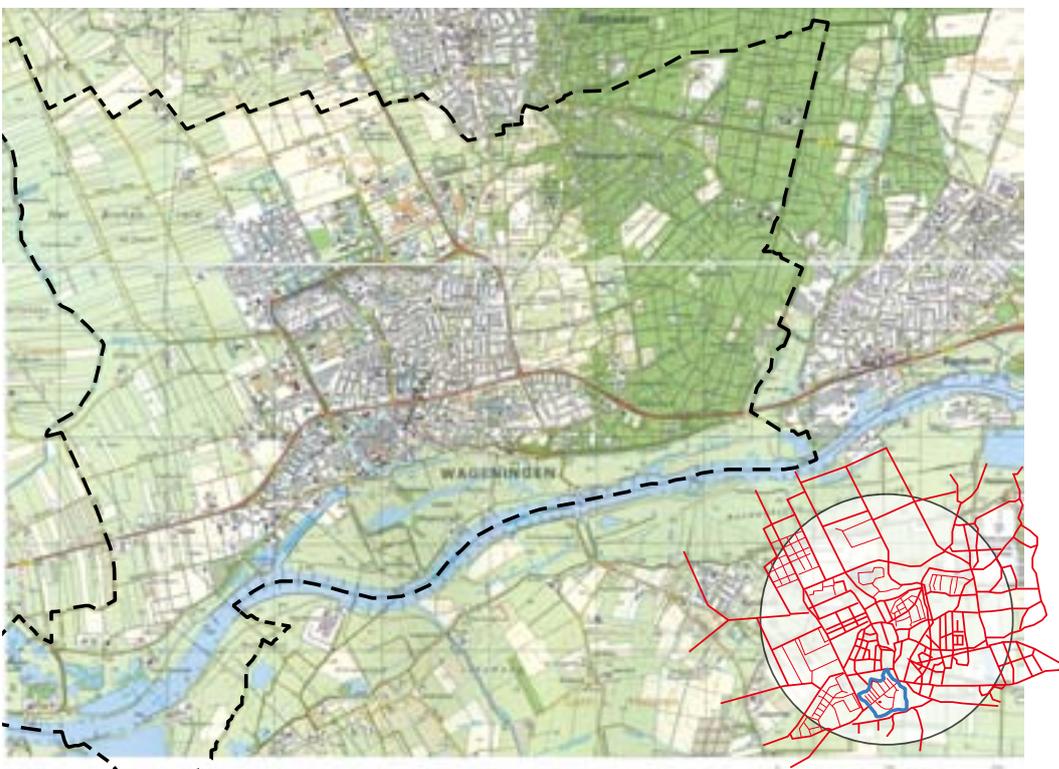


Figure 3.10 Wageningen 2000 (background map scan from WUR library)

Table 3.1 The Population Development of Wageningen Municipality (information based on CBS, 2011)

Periods	Live born Children	Deaths	Natural Increase	Arrivals in Municipality	Departures from Municipality	Population Growth	Population on 31 December
1960	470	138	332	1391	-	200	22904
1970	455	186	269	2325	-	478	27050
1980	356	260	96	2208	-	204	30651
1990	341	308	33	2779	2486	326	32818
2000	364	323	41	2911	2566	386	33826
2005	364	376	-12	2989	2893	96	35315
2009	352	404	-52	3593	2954	664	37359
2010	340	423	-83	3943	4551	-717	36642

3.2 SOCIAL ANALYSIS

3.2.1 Demographic development

population growth

Demography is the statistical study of human population. In Oxford dictionary, the definition is “The composition of a particular human population”. In order to determine the human influence on landscape development and energy consumption, population change is necessary to be discussed.

The population of Wageningen Municipality is not available before 1960, and it is not necessary to trace the data from those earlier years as well. Therefore the table below (Table 3.1) shows the population trend of city Wageningen that occurred over the last fifty years.

Through the first three rows of data, in general the new born baby number is slightly going down from 470 person/year in 1960 till 340 person/year in 2010. However, the deaths population is sharply increasing in fifty years, which causes the natural increase amount become minus by the year of 2005 as a result (Table 3.2). Every year more and more people came to Wageningen mainly because of new students’ arrival. In the mean while, lots of people left from Wageningen. The number of them went up slowly from 1990, but it increased suddenly in 2010. These unexpected left people together with the minus natural increase people is the reason why the population of city Wageningen went down in the year of 2010 (Table 3.3).

Table 3.2 The natural population trend of Wageningen Municipality (information based on CBS, 2011)

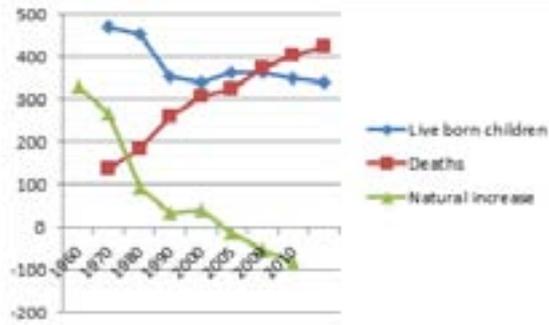


Table 3.3 The population of Wageningen Municipality on 31ST December (information based on CBS, 2011)

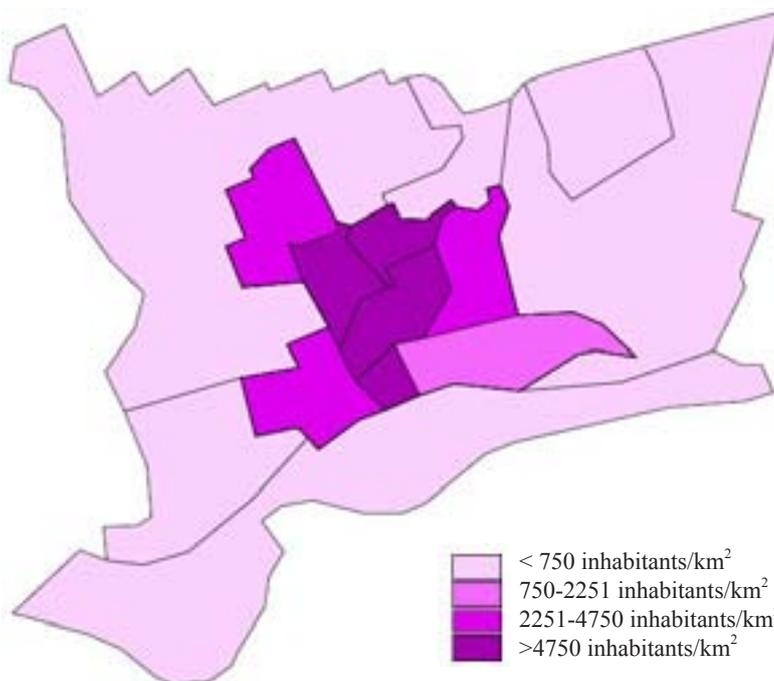
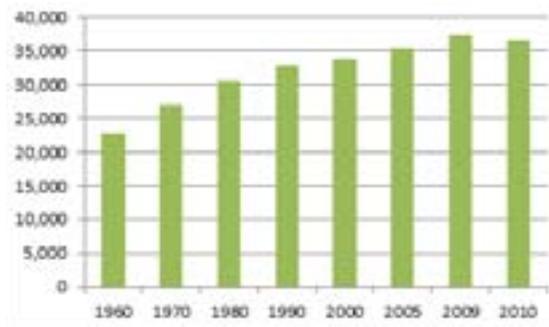


Figure 3.11: population density (information based on CBS, 2011)



Figure 3.13 Rich Villa (photo by author)



Figure 3.14 Normal house (photo by author)



Figure 3.15 Rented house (photo by author)

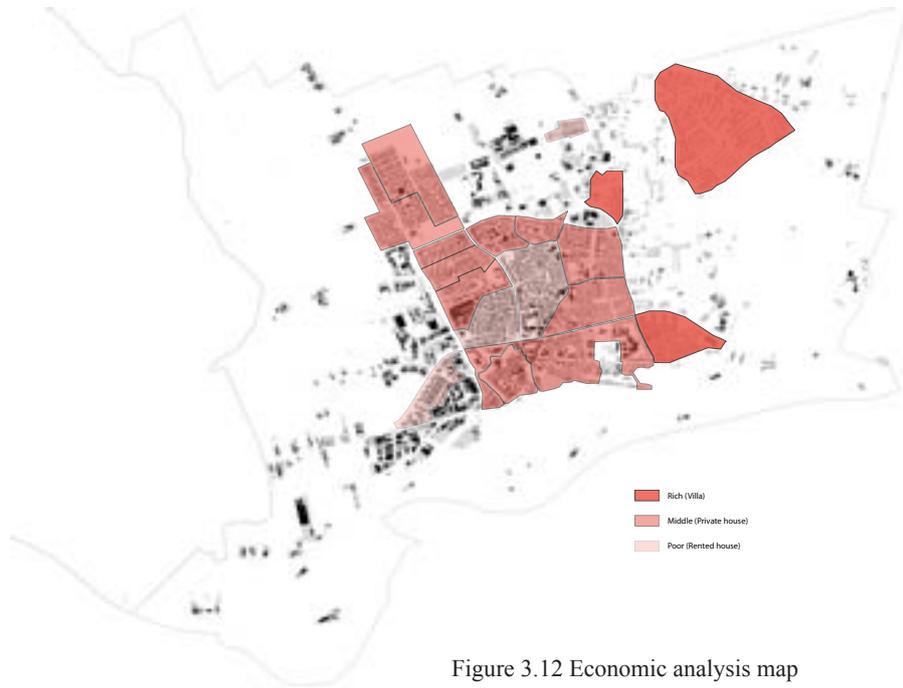


Figure 3.12 Economic analysis map

3.2.2 Economic distribution

In the city of Wageningen, living in villa, normal house or rented house/apartment are three kinds of way to assess economic level (Fig. 3.12). Moreover, according to CBS database (2010), the average housing price classified different areas either. In the east of Wageningen, close to Veluwe, lots of villas which are single family houses are situated here (Fig. 3.13). In this area the private garden extraordinary decorated and the greening rate is higher than the rest of the city. Normal houses take up large amount of the gross. Two families share one house, or several families share one longitudinal building (Fig. 3.14). The last kind of living style is renting house or apartment, such as students, younger or poor people (Fig. 3.15). These information might be helpful for finding biomass potential area, because rich area has larger private garden and more public green space. In neighborhoods scale, the distribution in figure 3.12 indicates the average housing price and the neighborhood which consists of the most building type, so it does not mean only one type of building existing in this neighborhood.

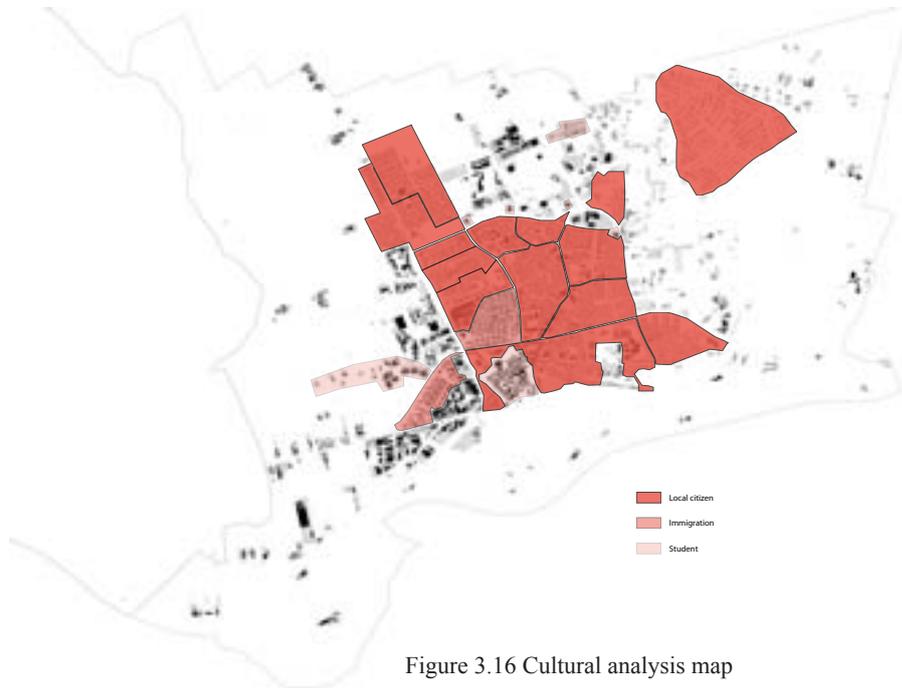


Figure 3.16 Cultural analysis map

3.2.3 Cultural dynamic

Wageningen is a dynamic cultural city which contains more than one hundred nationalities. Most of them are the students of Wageningen university and research center (WUR). Local citizens or Dutch people are the major cultural determination. Immigrants have been living here decades of years however they keep their cultural traditions partly (Fig. 3.17). Indonesians, Turks, Surinamese and Moroccans are the main immigrants in the Netherlands (CBS, 2010). Student apartment buildings contain four high buildings around campus, three dormitory areas and lots of separated apartments which are rented by Dutch students in the city centre (Fig. 3.18). In neighborhoods scale, the distribution in figure 3.12 indicates the average housing price and the neighborhood which consists of the most building type, so it does not mean only one type of building existing in this neighborhood. These information are the potential analysis aspect which shows the consideration and acceptance of renewable energy, because people from different cultural background have different point of view for understanding landscape.



Figure 3.17 Immigration area
(photo by author)



Figure 3.18 Student building
(photo by author)

3.2.4 Political decision

Wageningen is a city of life sciences stands for quality of life. In recent years, following the Dutch Environment Policy (IEA, 2008), like the many other municipalities in the Netherlands will also try to work hard for the sustainable energy, the city of Wageningen in July 2008 set a goal 'Wageningen Klimaatneutraal in 2030'. It is recorded that is chosen for two tracks: directly on concreting CO2 reductions while developing the roadmap to climate ambitions in 2030.

In Initial Document 'voor de Routekaart naar Wageningen klimaatneutraal in 2030' it proposes two principles of roadmap as follow:

“Uitgangspunt 1:

Er wordt gekozen voor de actorenbenadering.

Uitgangspunt 2:

- We hebben de ambitie om klimaatneutraal te worden wat betreft ons gas-, elektriciteits- en brandstofgebruik (directe emissies);

- De indirecte emissies proberen we wel zoveel mogelijk te verminderen, maar ze tellen niet mee voor klimaatneutraal.” (Botman, 2011, p.6)

English translation¹:

“Principle 1:

Determining who are involved in energy consumptions, for example

¹: Translated by Danny Hamers

municipality, companies and households.

Principle 2:

- Ambition to become climate neutral concerning gas, electricity and fuel consumptions (by decreasing direct emissions)
- Decreasing the amount of indirect emissions as much as possible even though they do not count towards climate neutrality.”

To find out how to achieve carbon neutral city by 2030, Wageningen sustainability and Climate Policy Office did three studies towards gas and electricity use, mobility and indirect energy. Based on these researches, municipality concluded that amounts to the following objectives:

- Energy Saving 50% which means half energy consumption reduction from 2010 level.
- Renewable 25% which means renewable energy generation in Wageningen municipality border takes up one fourth of total energy consumption.
- Green Power and Gas 25% which is purchased from the rest of the Netherlands.

In this thesis, I will only focus on produce renewable energy by biomass for the city of Wageningen instead of a carbon neutral city.



Figure 3.19 Temperature map (KNMI, 2008)

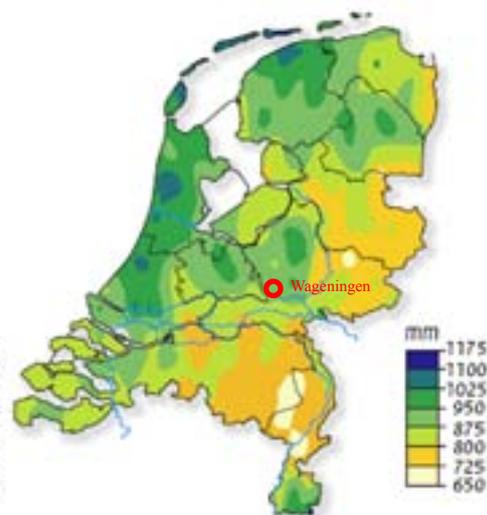


Figure 3.20 Precipitation map (KNMI, 2008)

3.3 PRESENT LANDSCAPE ANALYSIS

The analysis of present conditions shows the current situation of Wageningen landscape from biomass related point of view. Landscape is a complex entity. In order to better understand it, this chapter uses layer approach from abiotic, biotic and anthropogenic substratum to research as method. These layers depend on each other, though there is no hierarchy.

3.3.1 Abiotic landscape

Abiotic components are climate, geology, physiography, hydrology and soil (Steiner, 2008. P.15). In this section we will discuss three out of five except geology and physiography, because in Chapter 3.1.1 we have elaborated geology from antiquity till now. After that in Wageningen the physiography does not have that big difference in slope or elevation, and does not have relevancy of biomass energy neither. Therefore it will only analyze climate, soil and hydrology.

Climate

Climate is a very important element for plants that can directly determine



Figure 3.21 Sunshine map (KNMI, 2008)

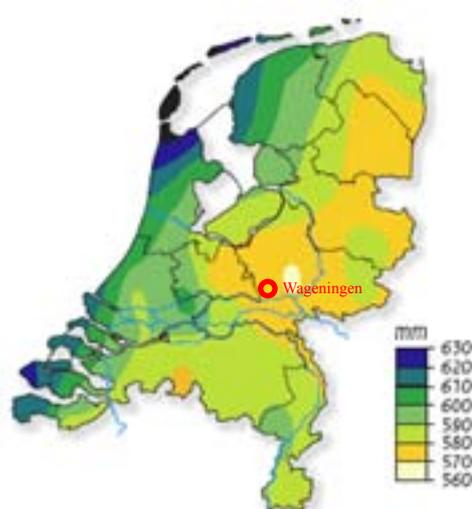


Figure 3.22 Evaporation map (KNMI, 2008)

if the plant is suitable growing in the certain place or not. It contains temperature, sunshine, precipitation and evaporation. In CBS, some information can be traced from 1880. It shows the average temperature, year precipitation and year sunshine. The general trends will be discussed. And in KNMI, the recent climate report is 2008 which includes more detail information. The information deriving from two sources can be contrasted and combined. They will be very useful for vegetation selecting in later chapter.

climate situation of
Wageningen

Soil types

Within Wageningen municipality area, there are several different kinds of soils such as sand, clay, peat and loam. Most of sandy soil and clay soil mixed areas locate in flooding buffers and recreation space where are along the Lower Rhine. Some of them are ingredients of agricultural lands. Peat soil is the component of the agricultural land which is around Utrecht and Gederland province border. At the Veluwe, it consists of different sandy soils like coarse and loamy sandy soil. The four main soil types will be explained below. After figuring out the characteristics and geographical distributions of different soil types, which kind of vegetations can grow in Wageningen is a rational and traceable question later on.

soil types of Wageningen



Figure 3.23 Sandy soil

(<http://www.dreamstime.com/black-hand-on-sandy-soil-thumb7671875.jpg>)

Figure 3.24 Clay soil

(<http://www.motherearthsfarm.com/MotherEarthsNotes/wp-content/uploads/2010/07/clay-soil-impressions.jpg>)

Sandy soil

character of sandy soil

In the Land and plant nutrition management service, sandy soil is defined as followed: “Sandy soils are the soils in which a coarse texture dominates the problems related to agricultural land use. Sandy soils are characterized by less than 18% clay and more than 65% sand in the first 100 cm of the solum.” (<http://www.fao.org/ag/AGL/agll/prosoil/sandy.htm#top>) In the Netherlands, sandy soil is derived from arid to (pre)humid and from cold to hot climates. It forms vary from recent dunes, beach ridges and sandy plains. Sandy soil is not the most suitable soil type for agriculture; however mixed arable cropping and grazing is practiced and it probable needs supplemental irrigation during dry season. Sandy soil structure is very weak and unstable because it is selected by wind and water. Therefore a low water holding capacity, low inherent fertility status and high infiltration rate is the main constrains of sandy soil as a productive land. (<http://www.fao.org/ag/AGL/agll/prosoil/sandy.htm#top>)

Clay soil

character of clay soil

Clay is sticky and plastic-like to handle when wet. Clay soil is fine-textured and it is the oldest materials for building (<http://gardenline.usask.ca/misc/soil.html>). It is typically comprised of approximately 0-45% sand, 0-45% silt and 50-100% clay by volume. Clay soil is not well draining, and takes a long time to infiltrate of water. When wet, it is easy to allow all water to run-off. When dry, it is heavy and different to work on (<http://www.rain.org/global-garden/soil-types-and-testing.htm>).



Figure 3.25 Peat soil

(<http://www.greenleafsupply.com/images/Screenedpeatb.jpg>)

Figure 3.26 Loamy soil

(<http://inlinethumb53.webshots.com/42548/2312312220056376852S425x425Q85.jpg>)

Peat soil

Peat is found in wetland areas such as bogs, muskegs, mires, and peat swamp forests. It is composed of marshland vegetation like trees, grasses, fungi, and other types of organic remains. Peat grows very slow, at the rate of approximately one millimeter per year (<http://westerlyvisions.com/peat.php>). Peat is the source of fossil fuel in the Netherlands many years ago. Today peat bog is the material to block carbon and decrease the greenhouse effect. When peat starts to decompose, the carbon will be released. Therefore saving and refusing to use peat bogs are something we can contribute to our earth (<http://www.wildlifetrust.org.uk/facts/peat.htm>).

character of peat soil

Loamy soil

Loam is soil that consists of sand, silt and clay in relatively equal amounts, but contains more nutrients and humus than sandy, has better infiltration and drainage than silty, is easier to till than clay soils. It is comprised of about 25-50% sand, 30-50% silt and 10-30% clay by volume (<http://www.rain.org/global-garden/soil-types-and-testing.htm>). Loam is gritty, moist, and retains water easily, but also drain well so that sufficient air can reach the roots. Therefore it is ideal soil for most garden plants.

character of loamy soil

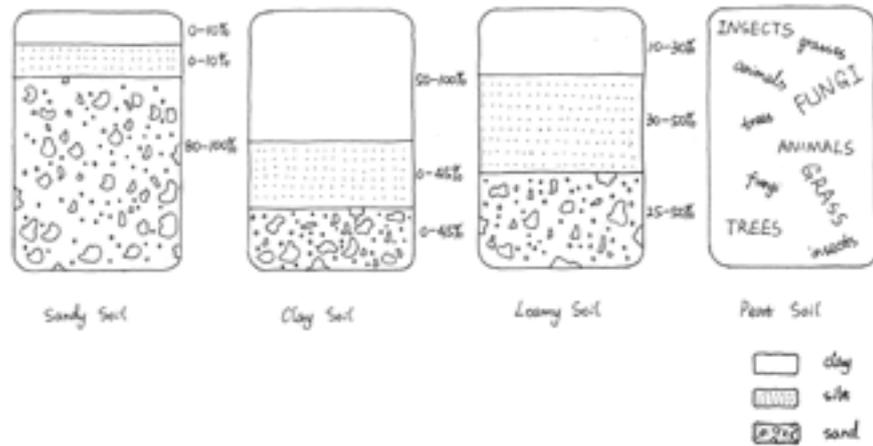


Figure 3.27: Proportion of soil texture (information based on the text above, p.54-55)

In the city of Wageningen, the flooding area which is along the lower Rhine is consist of sandy clay, and heavy and light clay loam.

soil distribution in Wageningen

In most of agricultural land, soil consists of heavy clay, sandy and light clay. Moreover, in agricultural land near Bennekom, they are comprised of sandy and light clay, loamy fine sand, weak loamy sand leemarm, and loamy fine sand and weak leemarm. Along province border, soil contains peat bog, meadow and sandy.

In Wageninse Berg, coarse sand, and weak loamy sand leemarm are the main soil types (Fig. 3.28). In general it is called podzol soil which is the typical soil type of coniferous forest. Most podzol are poor soil for agriculture. It is one kind of sandy soil.

For the specific percentages of different soil texture, fig. 3.29 shows the data. This is a soil texture triangle which is widely applicated for soil texture classification.

Figure 3.30 indicates the rough soil types in the city of Wageningen. There is no soil information in the built area which is located in the middle of Wageningen. However soil under constructions is needed to secure for foundations. Therefore I assume the soil type is sandy soil.

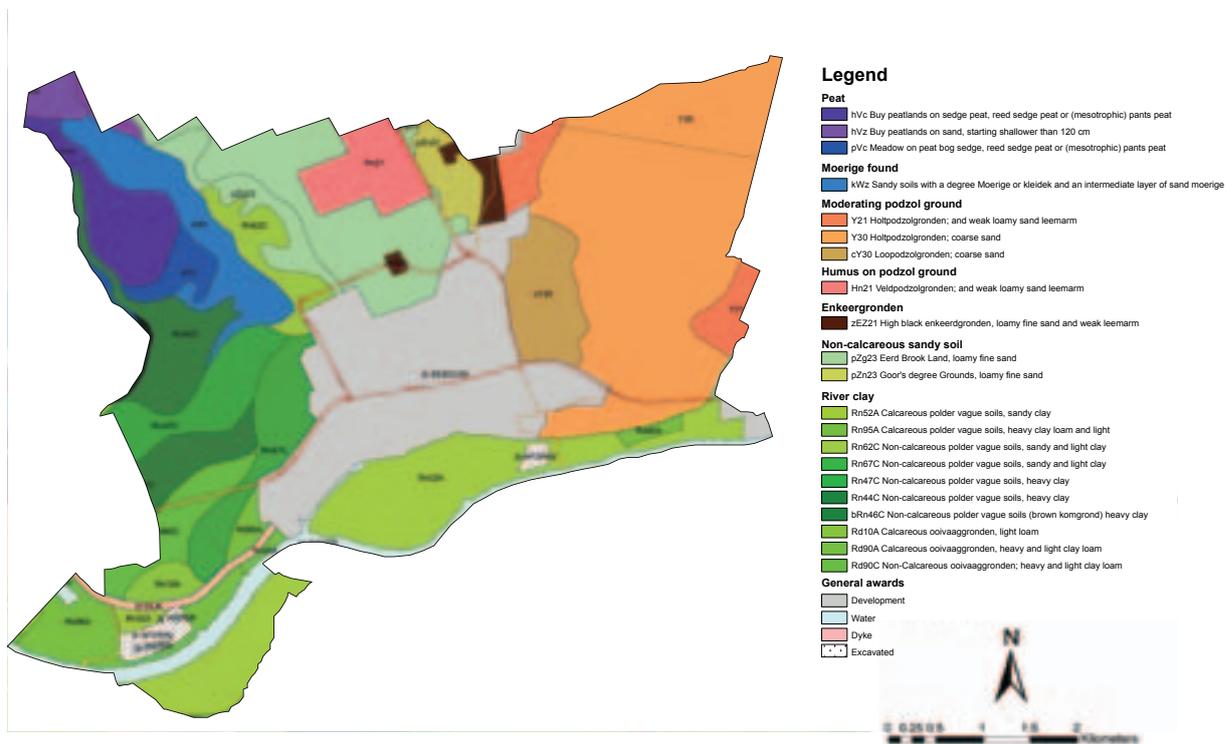


Figure 3.28: Detail soil type map (Wageningen UR Alterra, 2006)

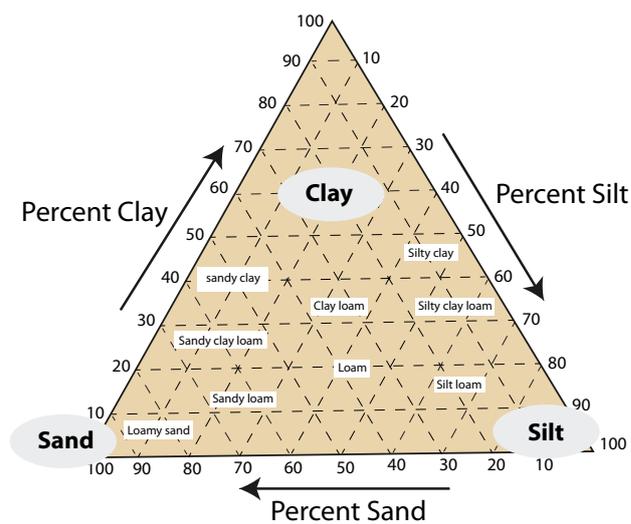


Figure 3.29: Soil texture triangle (information based on Miller, et al., 1990)

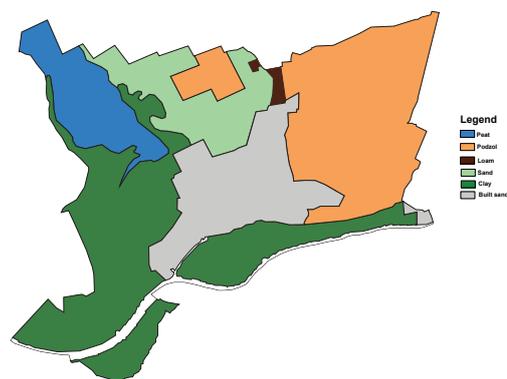


Figure 3.30: Rough soil type map (information based on Fig. 3.28)

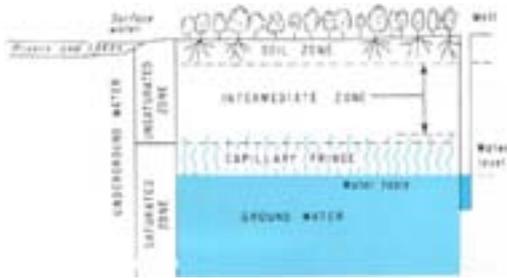


Figure 3.31 Profile from soil to groundwater (Heath, 1983, p. 4)

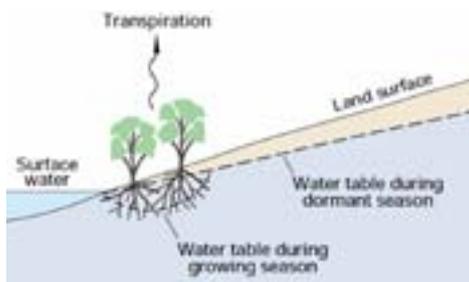


Figure 3.32 Water table in wet season (Winter et al., 1998)



Figure 3.33 Surface water map (GIS database, 2010)

Water

Water is one of very important ingredients for vegetation growth, ecosystem, and landscape design. It can be classified as atmospheric water, surface water and groundwater. Soils are hydrologically linked to groundwater and surface water systems. Only surface water and groundwater what are closed related to biomass plants will be discussed in this section.

Surface water

character of surface water

Surface water refers to water occurring in ocean, lakes, rivers, streams, wetland, or other fresh water sources opened to atmosphere (<http://www.historyofwaterfilters.com/ground-surface-water.html>). The most visible surface water in Wageningen is Rhine River that is the reason why the clay soil occurs in the south of Wageningen. This area is occupied by meadow lands and not allowed to plant much vegetation or build constructions because of flooding risk.

Ground water

All water beneath the land surface is called underground water, which consists of two different zones. Shallower zone, which immediately below

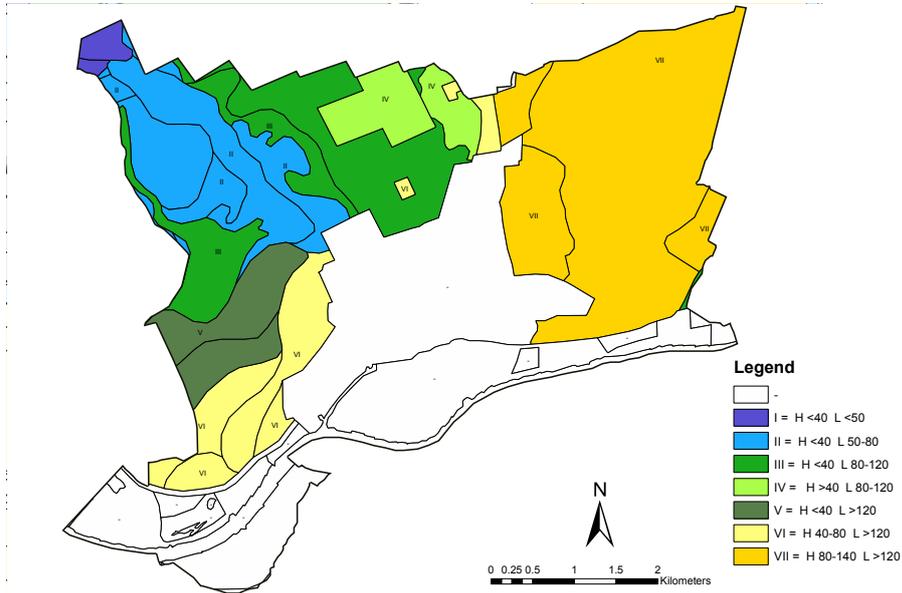


Figure 3.34 Groundwater level map (GIS database, 2006)

the land surface, contains soil, intermediate and upper part of capillary fringe zone. This zone is named unsaturated zone. The depth of soil zone from land surface to a maximum one or two meters. The growth of vegetation is supported by soil zone. The thickness of intermediate zone is different depending on the depth of soil zone and capillary fringe (Heath, 1983).

character of ground water

The other zone is referred to as the saturated zone. It includes capillary fringe and groundwater. Groundwater refers to any subsurface water that occurs beneath the water table in soil and other geologic forms (Rail, 2000). The water table is the level at which hydraulic pressure is equal to atmospheric pressure (Heath, 1983). During the wet season, it is possible that water table is closed to land surface at the edge of surface water, and the plants roots can reach the saturated zone (Winter et al., 1998). Fig. 3.32 shows the section of this situation.

Fig. 3.34 indicates the groundwater level in the city of Wageningen. H means the depth of water table from the land surface is in the highest level, L means it is in the lowest level. The depth of groundwater is classified to seven ranks and variable from 40 cm to 120 cm. The depth of groundwater decrease from east to west because Veluwe is in the eastern part, flat agricultural lands are in the western. If hilly area has the same depth with flat area, the water table requires more hydraulic pressure from groundwater.

groundwater level in Wageningen

3.3.2 Biotic landscape

Biotic landscape consists of vegetation and wildlife. However in this thesis, studying wildlife in Wageningen like fishes, reptiles, birds or mammals is not helpful for biomass energy topic at all. Therefore it will only discuss native plants in Wageningen, to figure out which biomass plants growing here.

main vegetation species in
Wageningen

Vegetation is divided into groundcover, shrubs and trees. In the city of Wageningen, groundcover contains some kinds of flowers such as bellflower, speedwell or primrose. None of them are biomass species, and they cannot produce energy by combustion. Shrubs consist of hazelaar and red elder. They all can provide heat, however non-biomass species cannot produce much. Oak, Pine tree, Beech, Douglas fir, Poplar and willow are the main tree species in Wageningen. Their annual increment is the source of renewable energy production. Poplar is another important biomass plant in terms of generating heat and electricity. Willow is one kind of broad applied biomass species, which could be used as shrub or tree. It is planted both in neighborhood's districts or rural area appreciated close to water.

In Appendix A, detailed information of other vegetation growing in Wageningen can be found. This information includes exposure, height, growth rate, pH value, flowering period and flower color.

GROUNDCOVER



Bellflower



Speedwell



Primrose

SHRUB



Hazelaar



Red elder

TREE



Oak



Pine tree



Beech



Douglas fir



Poplar



Willow



Figure 3.35: The Anthropogenic landscape

3.3.3 Anthropogenic landscape

As Fig. 3.35 shows, in Wageningen municipality boundary, the anthropogenic landscape is simple and easy partition. In one side, infrastructure contains two levels, big infrastructure and local road. Big infrastructure consists of national road 225 and 781 which make direct and fast way get through Wageningen city. The local roads form small infrastructure which are used more often by citizens and indicates part of urban pattern. On the other side, three sub-areas are comprised of urban area, agricultural land and forest. In the center of the map is urban area contains old town, new residential area, WUR campus and students houses. Around these built areas, agricultural land mainly concentrates in the west of the city and natural forest is in the east. They are the potential biomass energy sources for producing electricity and heat.

Three sub areas

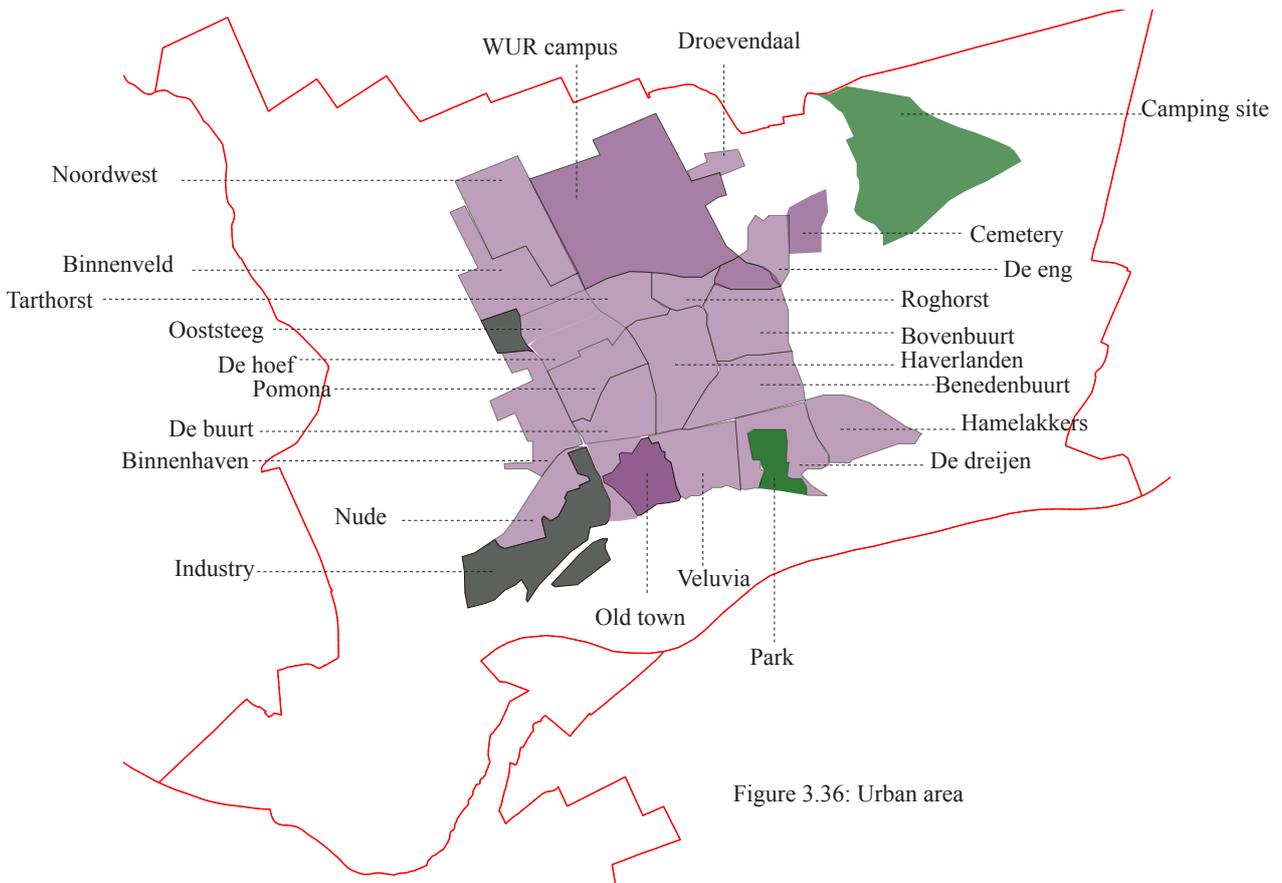


Figure 3.36: Urban area



Figure 3.37: Neighborhood (Ooststeeg) (photo by author)



Figure 3.39: Industry area (photo by author)



Figure 3.38: WUR campus - Forum (photo by author)



Figure 3.40: Camping site (Google Map, 2009)

Urban area

In the urban area of Wageningen, there are four types of land use, neighborhoods, industry area, Wageningen University campus and camping site.

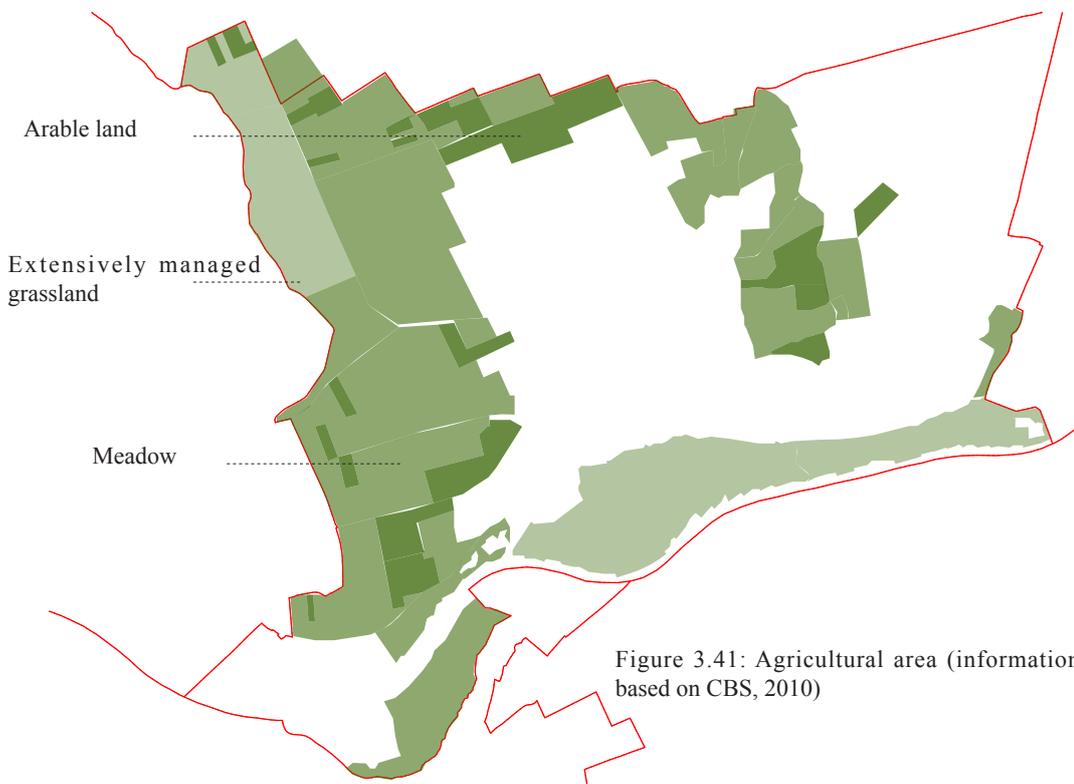


Figure 3.41: Agricultural area (information based on CBS, 2010)



Figure 3.42: Extensively managed grassland (photo by author)



Figure 3.43: Meadow land (photo by author)



Figure 3.44: Arable land (photo by author)

Agricultural area

Arable land, meadow land and extensively managed grassland are taken up the agricultural area in the city of Wageningen.

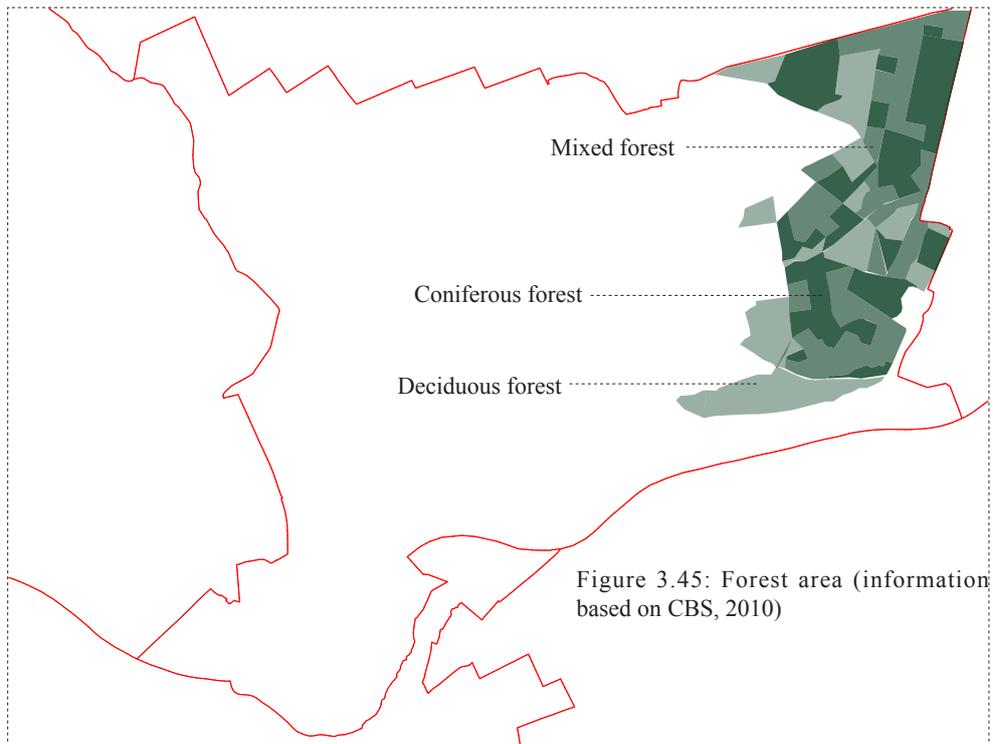


Figure 3.46: Deciduous tree (Google Map, 2009)



Figure 3.47: Coniferous tree (Google Map, 2009)

Forest area

The forest area in the city of Wageningen is part of Veluwe. It is mixed by deciduous and coniferous trees.

REFERENCE

Audrey, M. Lambert. 1985. *The Making of the Dutch Landscape: An Historical Geography of the Netherlands*. Academic press.

Botman Ine. Gemeente Wageningen. 2011. *Voor de Routekaart naar Wageningen klimaatneutraal in 2030*. Wageningen: Wageningen municipality.

GIS, 2012. ArcGIS Desktop: Release 10. Wageningen, the Netherlands. Geo Information System.

Heath, Ralph C., 1983. Basic ground-water hydrology: U.S. *Geological Survey Water-Supply Paper 2220*, 86 p.

IEA (International Energy Agency), 2008. *Energy policies of IEA countries: Netherlands 2008 review*. Paris: IEA publications.

Lenzholzer, S., 2009. *The genesis of Dutch landscapes*. Lecture. Wageningen University and Research Center.

Miller, R. W., Donahue, R. L. & Miller, J. U., 1990. *Soils : an introduction to soils and plant growth*. London [etc.], Prentice-Hall International.

Rail, Chester D., 2000. *Groundwater contamination, volume 1: Contamination, sources, & hydrology*. Lancaster, Pennsylvania: Technomic Publishing Company, Inc.

Steiner, F., 2008. *The living landscape: an ecological approach to landscape planning*. New York: McGraw Hill.

Twidell, J. & Weir, T., 2006. *Renewable Energy Resources*. 2nd ed. Abingdon: Taylor & Francis.

Winter, T. C., Harvey, J. W., Franke, O. L. & Alley, W. M., 1998. *Ground water and surface water: a single resource*. U.S.: Prentice-Hall International Inc.

<http://www.fao.org/ag/AGL/agll/prosoil/sandy.htm#top>

<http://gardenline.usask.ca/misc/soil.html>

<http://www.rain.org/global-garden/soil-types-and-testing.htm>

<http://westerlyvisions.com/peat.php>

<http://www.wildlifetrust.org.uk/facts/peat.htm>

http://www.nirov.nl/Home/Projecten/De_Nieuwe_Kaart/Website.aspx

<http://www.historyofwaterfilters.com/ground-surface-water.html>

<http://www.cbs.nl>

<http://www.knmi.nl>

Chapter 4

Current Energy System of Wageningen

- 4.1 Energy Consumption
- 4.2 Energy Provision
- 4.3 Transportation Network
- 4.4 Storage Facility
- 4.5 Possible Biomass Sources

The present energy system consists of energy consumption, provision, transportation network, conversion and storage facility. I found the data by interviewing the alderman, searching on Centraal Bureau voor de Statistiek (CBS) and other sources, however some information is not available such as conversion and storage facility. Some part I will use the average number of the whole Netherlands for estimation.

4.1 ENERGY CONSUMPTION

Household calculation

For better understanding the current energy system in the city of Wageningen, I got the energy document '*E-atlas: Inzicht in het energieverbruik van de gemeente Wageningen 2008*' from municipality. It contains electricity consumption of household, company and industry by districts partition. However there is no information about heat in Wageningen. Therefore the average heat consumption is calculated by the total Dutch private household heat consumption and Dutch population of 2010. Furthermore the population of each district is available on CBS too. Combining them, the estimation of heat consumption of Wageningen emerges (Table 4.2). In that case, the volume of electricity expense of households is approximately four times higher than that of heat in the city of Wageningen (Fig. 4.1).

Industry and company calculation

In CBS only the industrial consumption of electricity and heat of the whole Netherlands is available. The electricity is 124 PJ and the heat is 72 PJ of 2010. So industry expenses electricity almost twice of heat.

About company consumption, no data can be found. I estimate the rate of electricity and heat consumption is the same with industry.

Table 4.1: Electricity consumption in Wageningen in 2008 (information based on Liander, 2010)

District	Household consumption (MJ)	Company consumption (MJ)	Industry consumption (MJ)	Education consumption (MJ)	
De Buurt	23,987,189	24,468,159	-	19,992,738	
Veluvia - Hamelakkers	13,179,473	68,907,471	657,445		
Nude	11,339,753	44,445,489	1,002,650		
De Weiden - Boomgaarden	13,219,503	27,342,376	-		
Tarhorst - Roghorst - Haverlanden	11,974,094	11,592,852	-		
Bovenbuurt - Benedenbuurt	17,858,881	17,144,178	-		
Noordwest	20,147,590	13,789,352	-		
Wageningen Hoog	6,893,411	7,437,014	-		
De Born Zuid en Oost / Grindweg	853,219	49,412,805	-		
Vroegere Nudegebied	953,992	28,828,266	10,393,333		
Binnenveld	311,696	73,816,286	-		
Wageningse Berg, De Eng eo	723,452	12,083,435	-		
Uiterwaarden	573,425	50,748,293	41,803,854		
Centrum	7,366,656	30,062,634	-		
Total	129,382,334	460,078,611	53,857,283		19,992,738

Table 4.2: Heat consumption of household (CBS, 2012)

	Population	Total consumption (MJ)	Average Consumption/capita (MJ)
The Netherlands	16,575,000	11,360,000,000	685.37
Wageningen	37,360	25,605,423	

Table 4.3: Electricity and heat consumption of industry in the Netherlands (CBS, 2012)

	Consumption (PJ)	Ratio
Electricity	124	1.7
Heat	72	1

Table 4.4: Heat consumption in Wageningen in 2008 (Estimation)

District	Household consumption (MJ)	Company consumption (MJ)	Industry consumption (MJ)	Education consumption (MJ)	
De Buurt	4,797,438	14,393,035	-	No data	
Veluvia - Hamelakkers	2,635,895	40,533,806	386,732		
Nude	2,267,951	26,144,405	589,794		
De Weiden - Boomgaarden	2,643,901	16,083,750	-		
Tarhorst - Roghorst - Haverlanden	2,394,819	6,819,324	-		
Bovenbuurt - Benedenbuurt	3,571,776	10,084,811	-		
Noordwest	4,029,518	8,111,384	-		
Wageningen Hoog	1,378,682	4,374,714	-		
De Born Zuid en Oost / Grindweg	170,644	29,066,356	-		
Vroegere Nudegebied	190,798	16,957,804	6,113,726		
Binnenveld	62,339	43,421,345	-		
Wageningse Berg, De Eng eo	144,690	7,107,903	-		
Uiterwaarden	114,685	29,851,937	24,590,502		
Centrum	1,473,331	17,683,902	-		
Total	25,876,467	270,634,477	31,680,754		No data

Table 4.5: Electricity and heat consumption in Wageningen in 2008

	Electricity	Heat	TOTAL
Consumption	663,300 GJ	328,200 GJ	991,500 GJ

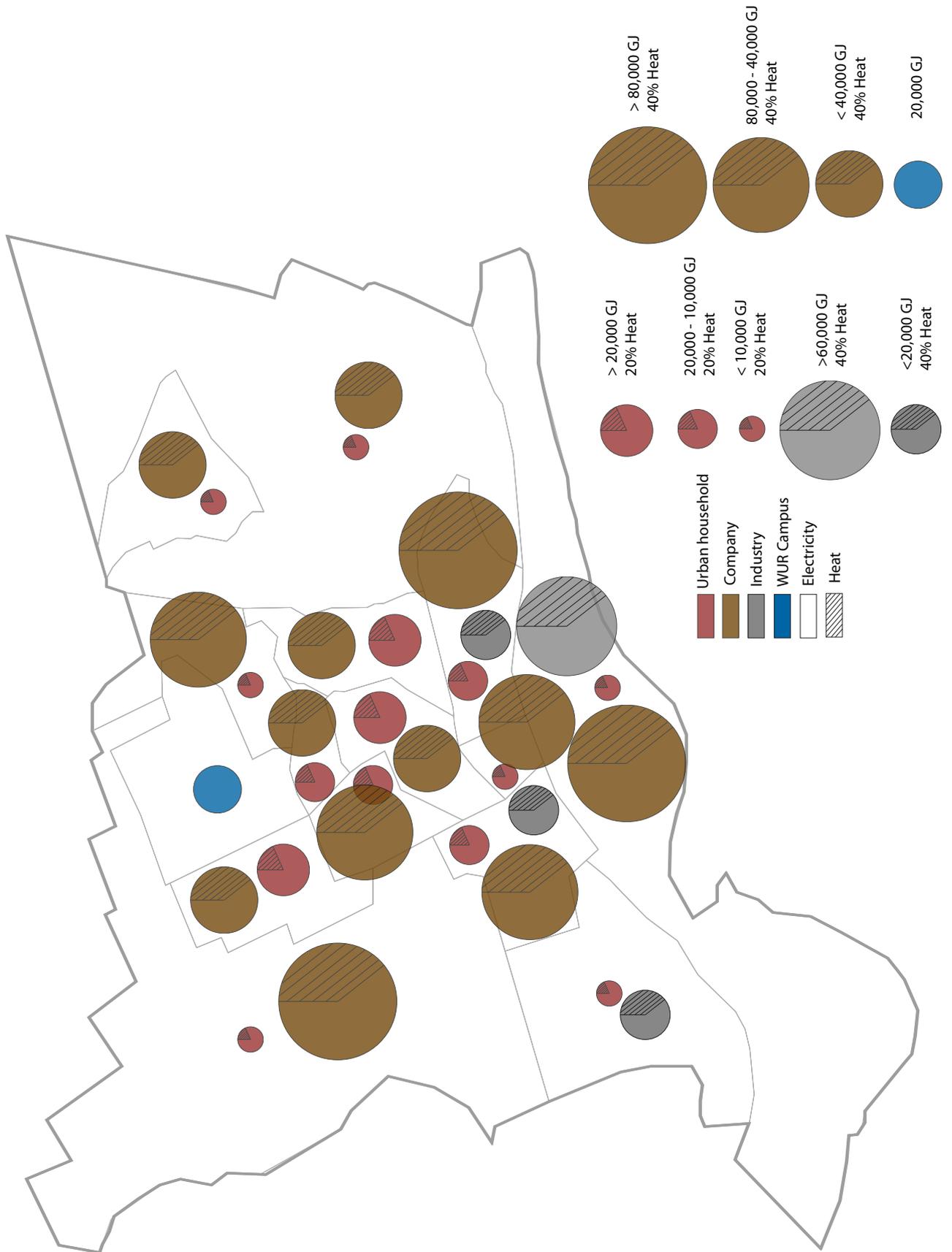


Figure 4.1: electricity and heat consumption in Wageningen in 2008 (illustrated based on my calculation)

4.2 ENERGY PROVISION

There is no data available about where and which source generates electricity, heat or gas for local citizens within the city of Wageningen, only the energy supply number of the Netherlands in 2010 can be accessed through CBS.

no local energy provision

After research there is no electricity energy is produced within Wageningen municipal border. Neither is heat in large scale, but maybe small scale. For example the swimming pool of De Bongerd creates its own heat. Natural gas extracts off-shore largely, but Wageningen locates in the middle of Netherlands. So it is impossible to generate massive natural gas in Wageningen as well.

4.3 TRANSPORTATION NETWORK

In GIS database of the Netherlands, high voltage powerlines is one of the layers in topography map. As Fig. 4.2 indicates there are three high voltage powerlines crossing Wageningen municipal area in the agricultural lands from north to south. They are the providers of Wageningen electricity power which connects to national electricity grid. In the future they will become the receivers of electricity that is generated by Wageningen local renewable energy sources such as wind turbines, solar panels and biomass.

three high voltage powerlines

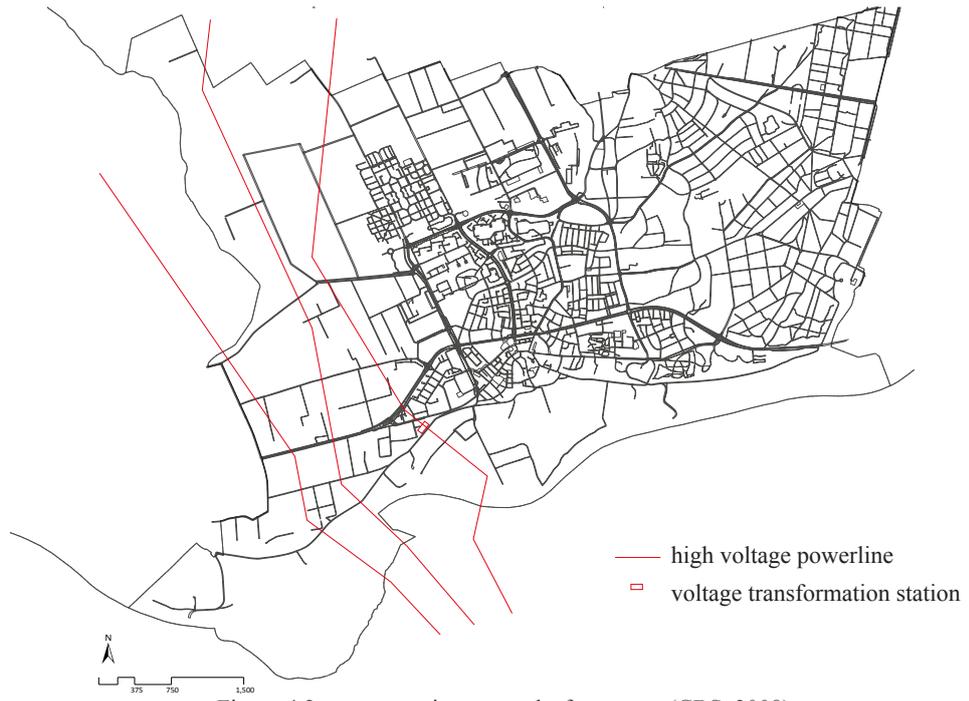


Figure 4.2: transportation networks for energy (CBS, 2008)



Figure 4.3: high voltage powerline (photo by author)



Figure 4.4: three high voltage powerlines (photo by author)



Figure 4.5: voltage transformation station (photo by author)

4.4 STORAGE FACILITY

Several storage tanks locate in the west of Wageningen (Fig. 4.6), mostly in Nude and Binnenveld area. They are the private tanks to storage fodder for cow which are named silo up to about 10 meters high and 2 meters diameter. Some tanks are animal manure tank which are 3 meters high and 20 meter wide. Only one oil company named oilinmotion in Wageningen. Besides these, Forum building and Atlas building of Wageningen university and Research center have their own heat and cold storage system.

no public storage facility



Figure 4.6: storage facility (CBS, 2009 & Google Map)

4.5 POSSIBLE BIOMASS SOURCES

Within Wageningen municipal boundaries a few possible biomass sources which would be used directly as raw materials for renewable energy production are significant worthful to estimate. However, currently they are not utilized as biomass sources. In figure 4.7, three types of biomass renewable energy sources present in the urban and sub-urban area of Wageningen, which are agricultural residue, forest residue and urban trees/shrubs/grass. These renewable sources can be converted to energy, such as heat and electricity by implementing combustion technology.

three types of greeneries could be biomass sources

Agricultural residue

Arable land takes up small proportion of the whole agricultural space. It can be the source of agricultural residues. In the sub urban area of Wageningen, maize is the main agricultural crop. Therefore maize straw is the agricultural residue which is the major potential biomass source in this area.

maize straw is the main agricultural residue in sub urban area

The arable lands takes up 262 ha (calculated based on Dutch GIS database, 2009) which is only 18% of the agricultural lands in total. The energy content of the maize straw is 18 odt/ha/y (Pimentel & Pimentel., 2008) and every ton of straw can generate 13.3 GJ renewable energy (ECN & WUR,

produce 62,700 GJ/y



Figure 4.7: All the possibilities of biomass sources in the city of Wageningen

2006). Therefore all maize straw in Wageningen will provide 62,700 GJ if they become the raw material of renewable energy (Table 4.6).

Forest residue

Forest can be divided into deciduous, coniferous and mixed forest because they are growing as different woody species have different logging potentials. Camping site is classified as part of forest because the location closed to forest and it is mainly woody species.

The average annual increment of the forest in the Netherlands is 8 m³/ha/y in 2002. About 65% of the annual increment is harvested, 25% of increment is added to standing stock, and dead wood takes up about 10% (Mohren G. M.J. & Vodde F., 2006). So the total annual logging is 2,460 m³. The main species of the Dutch forest is Scots pine (*Pinussylvestris*), Pseudotsugamenziesii, oak (*Quercusrobur*), common beech (*Fagussylcatica*), poplar (*Populus*) and willow (*Salix spp.*). In Wood Density Database, the average of wood dry density is about 0.6 tons/m³ (<http://www.worldagroforestry.org/sea/Products/AFDbases/wd/index.htm>). Therefore the annual wood quantity of the forest within the Wageningen municipal boundaries is approximately 1,476 tons dry matter per year. The gross of energy is 15,000 GJ which is provided by Wageningen forest (Table 4.6).

main tree species in Dutch forest

produce 15,000 GJ/y

Table 4.6: the existing biomass renewable energy production value

Location	Arable Land	Forest Area	Urban Green Area
Source	agricultural residue ¹	forest residue	trees/shrubs/ grasses
Energy content	18 odt/ha/y ²	3 odt/ha/y ³	3 odt/ha/y ⁴
Energy value	13.3 GJ/ton ⁵	10.2 GJ/ton ⁵	10.2 GJ/ton ⁵
Area	262 ha ⁶	473 ha ⁶	28 ha ⁶
Gross of Energy	62,700 GJ	15,000 GJ	900 GJ
Maximum Energy Quantity	78,600 GJ		

1 agricultural residue in Wageningen mainly are maize straw

2 Pimentel & Pimentel., 2008, p.30

3 calculated by author based on Mohren G. M.J. & Vodde F., 2006, p. 2

4 assume the data is the same with forest residue's

5 ECN & WUR, 2006, p. 38

6 calculated by author, information based on Dutch GIS database and Google earth

Urban trees/shrubs/grass

In the built area within Wageningen municipal boundaries green can be distinguished into trees, shrubs, grass. Trees consist of biomass species (poplar and willow) and non-biomass species (oak, beech, ash and pine etc.) Shrubs contains hazelaar, red elder, mistletoe and willow etc. Grasses growing in the city is not biomass species which are capable to convert to bio-energy. Different trees and shrubs have different energy values, it is hard to estimate an average value. I use forest residue logging data to do a calculation. I estimate urban trees and shrubs is 28 ha (information based on Google Earth, 2009), so the total annual logging is 146 m³. The annual renewable energy is 900 GJ (Table 4.6).

estimate urban green by using forest residue data

produce 900 GJ/y

In a conclusion, all the biomass sources which are estimated above can generate 78,600 GJ per year (Table 4.6).

produce 78,600 GJ/y in total

REFERENCE

ECN & WUR, 2006. *Biomass in the Dutch energy infrastructure in 2030*. S.l. s.n.

Google Inc. 2009. Google Earth (Version 6.1.0) [software].

GIS, 2009. ArcGIS Desktop: Release 10. Wageningen, the Netherlands. Geo Information System.

Liander, 2010. *E-atlas: Inzicht in het energieverbruik van de gemeente Wageningen 2008*. (Unpublished document)

Mohren G. M.J. & Vodde F., 2006. *Forests and Forestry in the Netherlands*. s.l. s.n.

Pimentel, D. & Pimentel, M., 2008. *Food, energy, and society*, Boca Raton, FL, CRC Press.

<http://www.worldagroforestry.org/sea/Products/AFDbases/wd/index.htm>

<http://www.cbs.nl>

<http://www.map.google.com>

Chapter 5

Production and Visual Quality of Biomass Vegetation

- 5.1 Five Types of Biomass Species to be applied
in Wageningen
- 5.2 Suitability Analysis for Biomass Vegetation
- 5.3 Productive of Species
- 5.4 The Visual Quality of Five Biomass Vegetation
 - 5.4.1 Time analysis
 - 5.4.2 Space analysis
 - 5.4.3 Composition

5.1 FIVE TYPES OF BIOMASS SPECIES TO BE APPLIED IN WAGENINGEN

the species I will apply

The city of Wageningen is not suitable for growing oil plants and sugar plants like sunflowers or sugarcane due to climate and soil conditions (refer to chapter 3.3.1, p. 52). Sugar beet fits the growing conditions, however bioethanol and biodiesel are the subsidiary products in the process of producing sugar. There is no sugar production in Wageningen. To sum up, table 5.1 indicates all biomass sources are current available or can be implemented which I am going to study detail for this thesis and apply them as a tool to provide bioenergy and create a visual attractive landscape for my studying area.

Five biomass species which can be implemented in Wageningen contains poplar, willow, miscanthus, switchgrass and traditional agricultural crop (maize). I collect the information and summarize them due to different purpose. Exposure, soil type, pH value and drought resistance are the basic information of flora. Height, growth speed, bloom period, flower color and root depth are vegetation habitus which are the significant important visual quality elements for seasonal and annual landscape cycle. Planting period, propagation method, planting dimension, plantation scale and water demand are the planting technology. They are the professional technique support for designing and productive calculation. Harvest age, period, method, coppice

Table 5.1: the biomass species I will study and apply

Source	Pretreatment	Conversion technology	Product
Poplar	harvest & dry	combustion	heat & electricity
Willow	harvest & dry	combustion	heat & electricity
Miscanthus	harvest & dry	combustion	heat & electricity
Switchgrass	harvest & dry	combustion	heat & electricity
Maize	harvest & dry	combustion	heat & electricity

cycle and productive lifespan change the landscape change visually. Yield and energy content are significant necessary information during the process of renewable energy estimation and evaluation.

Following by text, a table summarized all information of these five biomass vegetation which I select.

POPLAR

POPLAR

Latin name: *Populus* spp.

Exposure: sun

Soil type: Poplar is tolerant of a wide range of soil conditions. Light clay, sand, loam and humus soils are all acceptable for poplar. Heavy clay or those with poor drainage soils are not appreciated (EL Bassam, 2010).

pH value: Poplar grows well in both slightly acidic as well as slightly alkaline soil. The best range is between 6.0 and 8.0 (EL Bassam, 2010).

Drought resistance: Moderate. Poplar should avoid summer flooding. Water table is 0.45 to 0.9 meters below soil surface (http://hybridpoplar.com/home/sr1/growing_main.html).

Habitus

Height: 15 – 50 meter (EL Bassam, 2010).

Growth speed: does not grow as fast as willow in first few years (<http://www.folkecenter.net/gb/rd/biogas/biomass-energy-crops/energy-poplar/>).

Bloom period: March – April (Braun Blanquet & Pavillard, 1930).

Flower color: yellow, red or purple (Braun Blanquet & Pavillard, 1930).

Root depth: can be very deep, depends on soil thickness

Planting Technology

Planting period: early spring, February to March (<http://www.tsec-biosys.ac.uk/index.php?p=8&t=1&ss=3>).

Propagation method: poplar is easily established using unrooted cuttings made from one-year-old material (Mitchell, Stevens & Watters, 1999). They can be planted as 1.5 meter rod cuttings (http://mammothwillow.co.uk/store/index.php?main_page=page&id=5). Planting hole is created to a depth of 750 mm (<http://www.trc.govt.nz/assets/Publications/information-sheets-and-newsletters/land-management-information-sheets/soil-conservation-information-sheets/15poplarwillowguide.pdf>).

Planting dimension: The 1.0 * 1.0 meter spacing permits two-way cultivation (http://mammothwillow.co.uk/store/index.php?main_page=page&id=5). The total number of plants per hectare is around 10,000 trees/ha.

Plantation scale: On land less than five hectares energy poplar is better suited

POPLAR

than willow (<http://www.folkecenter.net/gb/rd/biogas/biomass-energy-crops/energy-poplar/>).

Water demand: high (Jansson, Groover, & Bhalerao, 2010)

Harvest

Harvest age: 5 years old (<http://www.extension.umn.edu/agroforestry/biomass/schmidt.pdf>)

Harvest period: winter

Harvest method: Harvest technique depends largely on the scale of the plantation and the end-use specification of the wood, however they can be broadly grouped into two systems: single pass cut and chip, and whole stem. Single pass cut and chip involves a higher capital cost and output than the coppice stem which require secondary handling and chipping operations. (Mitchell & Stevens & Watters, 1999)

Coppice cycle: once per 2-5 years

Productive lifespan: at least 30 years (<http://www.tsec-biosys.ac.uk/index.php?p=8&t=1&ss=3>)

Bio-energy Production Data

Yield: 12 odt/ha/y

Energy content: 18.4 GJ/ton (De Wit & Faaij, 2010)

WILLOW

WILLOW

Latin name: *Salix* spp.

Exposure: sun

Soil type: sandy loams, light or medium clays and even heavy clays are suitable for willow cultivation. Sandy soils may also be suitable if the plants have access to water or organic nutrients can be applied to provide moisture retention (Larsson et al., 2007).

pH value: 5.5-7.7 (Larsson et al., 2007).

Drought resistance: high (Wickberg, 2006)

Habitus

Height: 10–30 meter

Growth speed: fast

Bloom period: early spring (Braun Blanquet & Pavillard, 1930).

Flower color: yellow (Braun Blanquet & Pavillard, 1930).

Root depth: minimum 0.6 meter (www.thegrowspot.com)

Planting Technology

Planting period: mid-March until mid-June, ideally start as early in the spring (Larsson et al., 2007).

Propagation method: one-year-old willow rods (1.8 – 2.4 meters long)

Planting dimension: willow is planted in a twin row formation. The dimension between the rows is 75 and 150 cm respectively which is the distance adapted to harvesting machines to cut two rows at a time. The distance between the plants in the rows is approximate 59-65 cm. The total number of plants per hectare is around 13,000 (Larsson et al., 2007).

Plantation scale: the applicable willow plantation scale is larger than five hectares, because willow requires specialized machinery that is too expensive on smaller pieces of land. (<http://www.folkecenter.net/gb/rd/biogas/biomass-energy-crops/energy-poplar/>)

Water demand: high water availability such as river banks (IEA Bioenergy, 2011)

WILLOW

Harvest (Larsson et al., 2007)

Harvest age: Willow harvest age is 3-4 years old when the diameter of the trunk at the base of the thickest shoots exceeds 6 cm.

Harvest period: willow is harvested in winter when the plants have shed their leaves.

Harvest method: The harvest machine, which is for the raw material of electricity generation, both cuts the rods and processes them directly into wood chips.

Coppice cycle: at least once per 3 years

Productive lifespan: 20-30 year

Bio-energy Production Data

Yield: 8 - 10 odt/ha/y

Energy content: 18.4 GJ/ton (De Wit & Faaij, 2010)

MISCANTHUS

MISCANTHUS

Latin name: *Miscanthus giganteus*

Exposure: sun

Soil type: Miscanthus tolerant of a range of soils, from sands to high organic matter soils (Defra, 2007). Sands and sand loams consisting of up to 10 percent of clay shows the preferred soil types. The good yield is well drained soils with high humus (EL Bassam, 2010).

pH value: It is also tolerant of a wide range of pH, but the optimum is between pH 5.5 and 7.5.

Drought resistance: high (Clifton-brown, Chiang & Hodkinson, 2008)

Habitus

Height: up to 4 meter (Elbersen, 2005)

Growth speed: fast (Elbersen, 2005)

Bloom period: may not bloom in northern latitudes (http://heritagemiscanthus.com/miscanthus_giganteus.php)

Flower color: yellow

Root depth: depend on different soil thickness and water table

Planting Technology

Planting period: March to April (Defra, 2007)

Propagation method: Rhizomes should be purchased from dedicated nursery fields of Miscanthus, and be of a young age class (Defra, 2007).

Planting dimension: working margins are required larger than 3 meters to allow for machinery to turn. Rides are 4 to 6 meters wide every 500 meters. (Defra, 2007) Planting density is about 10,000 plants per hectare (1 meter spacing) (Scurlock, 1999).

Plantation scale: no requirement

Water demand: low (Elbersen, 2005)

MISCANTHUS

Harvest

Harvest age: Miscanthus is harvested in the third year after it is established.

Five years on marginal sites is also possible.

Harvest period: from late February to early May, early spring. The fallen leaf material and the rhizome mat below the soil surface provide very stable ground conditions for harvesting.

Harvest method: a chopping forage harvest may be used (Scurlock, 1999).

Coppice cycle: once per year

Productive Lifespan: 15 years (Elbersen, 2005)

Bio-energy Production Data

Yield: 12 - 35 odt/ha/y (Elbersen, 2005)

Energy content: 17.8 GJ/ton (De Wit & Faaij, 2010)

SWITCHGRASS

SWITCHGRASS

Latin name: *Panicum virgatum* L.

Exposure: sun

Soil type: Switchgrass is broadly adapted and perform well in a wide range of soil types. It prefers finer texture soils such as loam and sandy soils than dense clay soils. The key establishment requirements are warm temperature and moisture of soil (Christensen & Gary eds., 2010).

pH value: The optimum soil pH between 6.0 and 8.0, but it can grow with pH as low as 5.0 (Christensen & Gary eds., 2010).

Drought resistance: high (Roth et al., 2005)

Habitus

Height: 2.0–3.0 meter

Growth speed: fast

Bloom period: Fall (Elbersen, 2001)

Flower color: Brown

Root depth: often more than 2 meters (Elbersen, 2001)

Planting Technology

Planting period: in the spring

Propagation method: seeding rates of switchgrass average 5.6 kg/ha. (Christensen & Gary eds., 2010).

Planting dimension: the growing space of switchgrass is one plant per square foot (Christensen & Gary eds., 2010). In general 107,527 plants per hectare.

Plantation scale: no requirement

Water demand: low (Elbersen, 2005)

Harvest

Harvest age: Switchgrass yields achieve full productivity in the third year. In the second year it is typically 70 – 80% of mature stand yields.

Harvest period: early spring (Elbersen, 2005)

Harvest method: switchgrass can be mowed and baled like *Miscanthus* with

SWITCHGRASS

standard hay equipment. When harvesting, switchgrass is suggested to leave 10 – 15 cm of stubble preferably (Christensen & Gary eds., 2010).

Coppice cycle: once per year

Productive Lifespan: 15 year (Elbersen, 2005)

Bio-energy Production Data

Yield: 10 – 30 odt/ha/y (Elbersen, 2005)

Energy content: 17.8 GJ/ton (De Wit & Faaij, 2010)

MAIZE

MAIZE

Latin name: *Zea mays*

Exposure: sun

Soil type: a clay content of less than 10% sandy or in excess of 30 % clay and clay-loam. High demands of nutrients (Du Plessis, 2003).

pH value: 5.8 - 7.0 (<http://www.pda.org.uk/leaflets/17/leaflet17-3.html>)

Drought resistance: low

Habitus

Height: 1.0–5.0 meter (Du Plessis, 2003).

Growth speed: fast

Bloom period: August

Flower color: yellow

Root depth: up to 2.0 meter (Du Plessis, 2003).

Planting Technology

Planting period: April to May

Propagation Method: direct drilled (with a direct-drilling machine) or sown into a cultivated soil bed. The depth of the seed is about 2.5 – 4.0 cm (Garcia, 2008).

Planting dimension: a well-established maize crop sown at 65 cm between rows and about 95,000 plants/ha (Garcia, 2008).

Plantation scale: no requirement

Water demand: high (Wriedt et al, 2009).

Harvest

Harvest age: the first year

Harvest period: Autumn

Harvest method: machinery

Coppice cycle: once per year

Productive Lifespan: 120 - 150 days (<http://www.ksgains.com/corn/CornClass04.pdf>)

MAIZE

Bio-energy Production Data

Yield: 12 – 18 odt/ha/y (Gerin, Vliegen & Jossart, 2008)

Energy content: 16.3 GJ/ton (De Wit & Faaij, 2010)

CONCLUSION

For summing up the previous information, Table 5.2 presents in order. In general, these five biomass species all require sunshine and pH value between 5.5 and 8.0, however they have own preferences on soil types and drought resistance.

Biomass tree species are generally different from grasses and traditional agricultural crops in habitus such as height and bloom period. Poplar and willow are much higher than the rest ones, and they bloom in spring rather than in summer or autumn. The same habitus are fast growing speed, and four out of five bloom yellow flower. Root depth is the most uncontrollable property amongst all of them because it depends on plant form, soil properties, availability of water and nutrients. It is a complicated system.

The five biomass species concentrate their planting periods from spring lasting till early summer. The planting dimensions are designed diversely but planting densities are all approximate 10,000 plants/ha. Propagation methods are different as well. Switchgrass and maize are seeding, the rest are rod or rhizome. Plantation scales are no requirement in general, only that of willow requests larger than five hectares, because specialized machinery is too expensive on smaller pieces of land.

They have the similar harvest ages and periods except maize due to its half year lifespan. Their different harvest methods are taken into account in time of propagation. Furthermore coppice cycle of tree species are longer than grasses and traditional agricultural crops.

The the yeild of poplar and willow are much higher than the rest ones due to their coppice cycles. However energy content have no big gap among them all.

Table 5.2: Summarized information table of five biomass species

Biomass Species	Poplar	Willow	Miscanthus	Switchgrass	Maize
Latin Name	<i>Populus</i> spp.	<i>Salix</i> spp.	<i>Miscanthus giganteus</i>	<i>Panicum virgatum</i> L.	<i>Zea mays</i>
Exposure	Sun	Sun	Sun	Sun	Sun
Soil Type	light clay, sand, loam and humus soil are suitable. heavy clay or poor drainage soil are unsuitable.	sandy loams, all clays are suitable. sandy soil with moisture retention may be suitable as well.	sand and sandy loam consist of 10% of clay are the best soil types	prefer finer texture soil such as loam and sandy soils	clay contains less than 10% sandy or excess of 30% clay and clay loam are suitable
pH Value	6.0-8.0	5.5-7.5	5.5-7.5	6.0-8.0	5.8-7.0
Drought Resistance	Moderate	High	High	High	Low
Height	15-50 m	10-30 m	up to 4 m	up to 2.5 m	1.0-5.0 m
Growth Speed	fast	fast	fast	fast	fast
Bloom Period	March - April	early spring	may not bloom in northern latitudes	Fall	August
Flower Color	yellow, red or purple	yellow	yellow	brown	yellow
Root Depth	depends on soil thickness and water table	minimum 0.6 m	depends on soil thickness and water table	often more than 2.0 m	up to 2.0 m
Planting Period	February - March	March - June	March - April	Spring	April - May
Propagation Method	1.5m unrooted rod cuttings from one-year-old material	one-year-old willow rods (1.8 – 2.4 m long)	rhizome from young age class, the length is about 10 cm	seed seeding rate average 5.6 kg/ha	seed
Planting Dimension	1.0 × 1.0 m 10,000 plants/ha	twin row formation. 75cm×(59-65 cm) 150cm×(59-65cm) 13,000 plants/ha	working margins are larger than 3 m rides are 4-6m every 500m 10,000 plants/ha	one plant per square foot 107,527 plants/ha	65 × 65 cm 95,000 plants/ha
Planation Scale	no requirement	no less than 5 hectare	no requirement	no requirement	no requirement
Water Demand	High	High	Low	Low	High
Harvest Age	5 years old	3-4 years old	3 years old	3 years old	the first year
Harvest Period	winter	winter	February to May	early spring	Autumn
Harvest Method	1. single pass cut and chip 2. whole stem	harvest machine which is cuts the rods and process them into wood chips together	chopping forage	mow and bale like Miscanthus leave 10-15cm of stubble	machinery
Coppice Cycle	once per 2-5 years	at least once per three years	once per year	once per year	once per year
Productive Lifespan	at least 30 years	20-30 years	15 years	15 years	120-150 days
Yield	12 odt/ha/y	8-10 odt/ha/y	12-35 odt/ha/y	10-30 odt/ha/y	12-18 odt/ha/y
Energy Content	18.4 GJ/ton	18.4 GJ/ton	17.8 GJ/ton	17.8 GJ/ton	16.3 GJ/ton

5.2 SUITABILITY ANALYSIS FOR BIOMASS VEGETATION

Before planning or design, the important step needs to be figured out is the places where are suitable for which species. Therefore I choose near future development, soil type and groundwater level as criteria for suitability selection.

As being the first criterion of selecting suitable area for biomass species which are chosen in the previous section, near future development is the alternative decision made by government. These new developments are being built currently or will be built in the future, therefore these places cannot be entirely used by other land use purpose.

Soil type is another important criterion for suitability selection. Different vegetations require different kinds of agrotypes. It is hard to change all soils of Wageningen. It is the essential factor which determines plants growth.

Groundwater level is closely relevant to drought resistance. In books or literatures, there is rarely information indicate which biomass species suit certain depth of groundwater table, because root system is complicated. Therefore this criterion is an assumption.

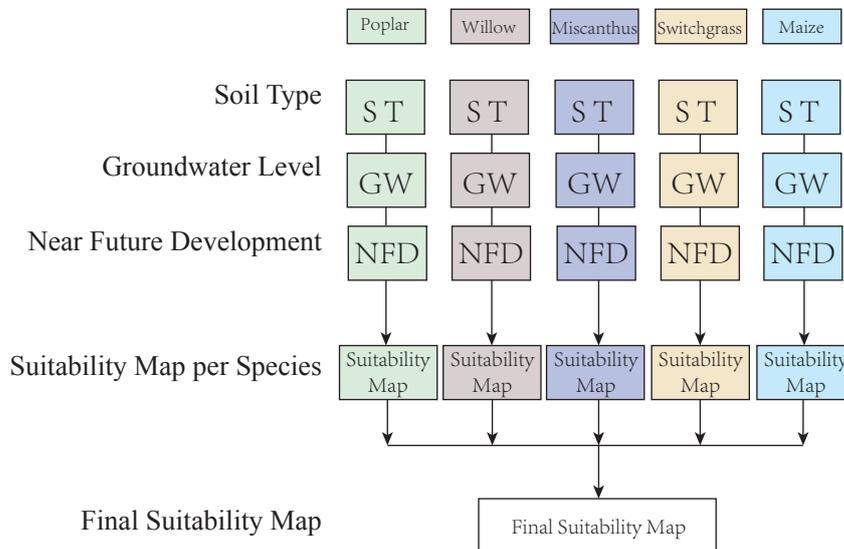


Figure 5.1: Strategy of suitability analysis

In chapter 3.3.1 (p.52) I did research about the physical characteristics of Wageningen including soil types and groundwater level, and in chapter 5.1 (p.84) knowledge of five biomass species includes soil types and drought resistance. Combining them with near future development together, suitable location of each biomass species is confirmed. Overlapping all of five suitable maps, the final suitability map in the city of Wageningen can be generalized (Fig. 5.1).

Criteria one: near future development

In the Binnenveld area, a new office area and a new neighborhood is being established. This neighborhood is the first sustainable district in the city of Wageningen which contains at least 520 homes and started to build from 2010 (http://www.nirov.nl/Home/Projecten/De_Nieuwe_Kaart/Website.aspx). Near them, another new students housing area started from 2012 in order to solve the housing shortage problem for the students of Wageningen University. Moreover, the campus of Wageningen University is constructing new buildings for students (Fig 5.2).

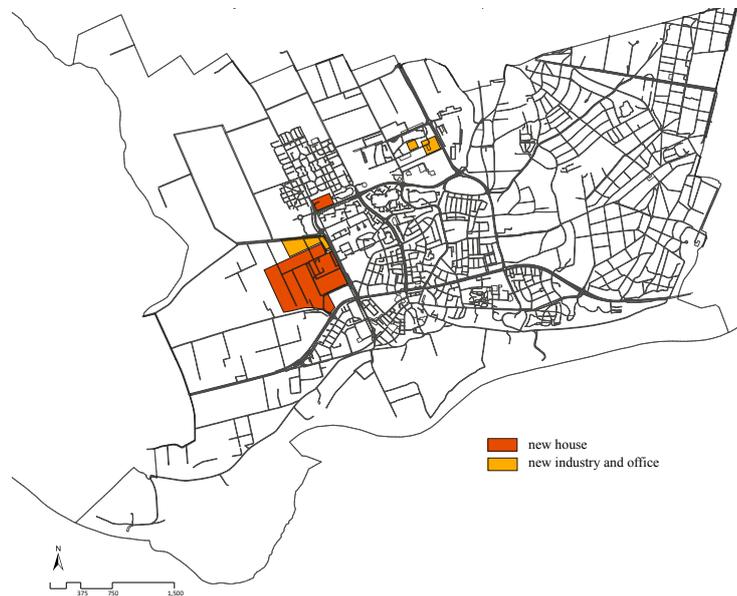


Figure 5.2: near future development (http://www.nirov.nl/Home/Projecten/De_Nieuwe_Kaart/Website.aspx)

Criteria two: soil type

According to chapter 5.1 (p.84), Poplar, Miscanthus and Switchgrass all prefer finer texture soil and well drainage soil types such as sandy and loamy soils. Willow prefers sandy loam with moisture retention, but all clay soils are suitable as well. Maize grows better in clay soil (Tab. 5.3). So poplar, miscanthus and switchgrass are suitable in the north or east of Wageningen, willow and maize are suitable in the south or west of Wageningen (Fig. 5.3). Suitable is colored as green, medium is orange, and unsuitable is red.

Criteria three: groundwater level

In chapter 5.1 (p.84), I summarized that Willow, Miscanthus and Switchgrass have high drought resistance capacity, however maize cannot bare drought (Tab. 5.3). Combining the groundwater level of Wageningen, Willow, Miscanthus and Switchgrass are suitable for most area in the city of Wageningen. And poplar is suitable in the west and north, maize is only suitable in the northwest (Fig. 5.3).

Table 5.3: Criteria of give biomass species

Criteria		Poplar	Wilow	Miscanthus	Switchgrass	Maize
Near Future Development	New Neighborhood	-	-	-	-	-
	New Student Apartment	-	-	-	-	-
Soil Types	Sandy	***	**	**	***	-
	Loamy	***	***	***	***	***
	Light Clay	***	***	***	-	***
	Heavy Clay	-	***	-	-	***
	Pent	-	**	-	-	**
Groundwater Level	I = H <40 L <50	**	***	***	***	***
	II = H <40 L 50-80	**	***	***	***	***
	III = H <40 L 80-120	***	***	***	***	**
	IV = H >40 L 80-120	***	***	***	***	-
	V = H <40 L >120	**	***	***	***	**
	VI = H 40-80 L >120	**	***	***	***	-
	VII = H 80-140 L >120	**	***	***	***	-

Overlying the three criteria maps of each species together, the suitability maps present in page 102 and 103. In these maps, red area means one of the three maps is not suitable for certain species in this area. Orange means this place are medium suitable in both soil and groundwater maps. Yellow green means this vegetation is suitable for either soil or groundwater criterion. Green color means this area is suitable for all criteria. And then overlapping these five suitability maps, the final suitability map of biomass species for Wageningen is displayed in fig. 5.5. In legend, three asterisks indicate vegetation is suitable for growing in this area, two asterisks mean medium suitable, one asterisk means a little bit suitable, and dash means unsuitable.

POPLAR

WILLOW

MISCANTHUS

SWITCHGRASS

MAIZE



Figure 5.3: near future development, soil type and groundwater suitability map per source

Suitability Map

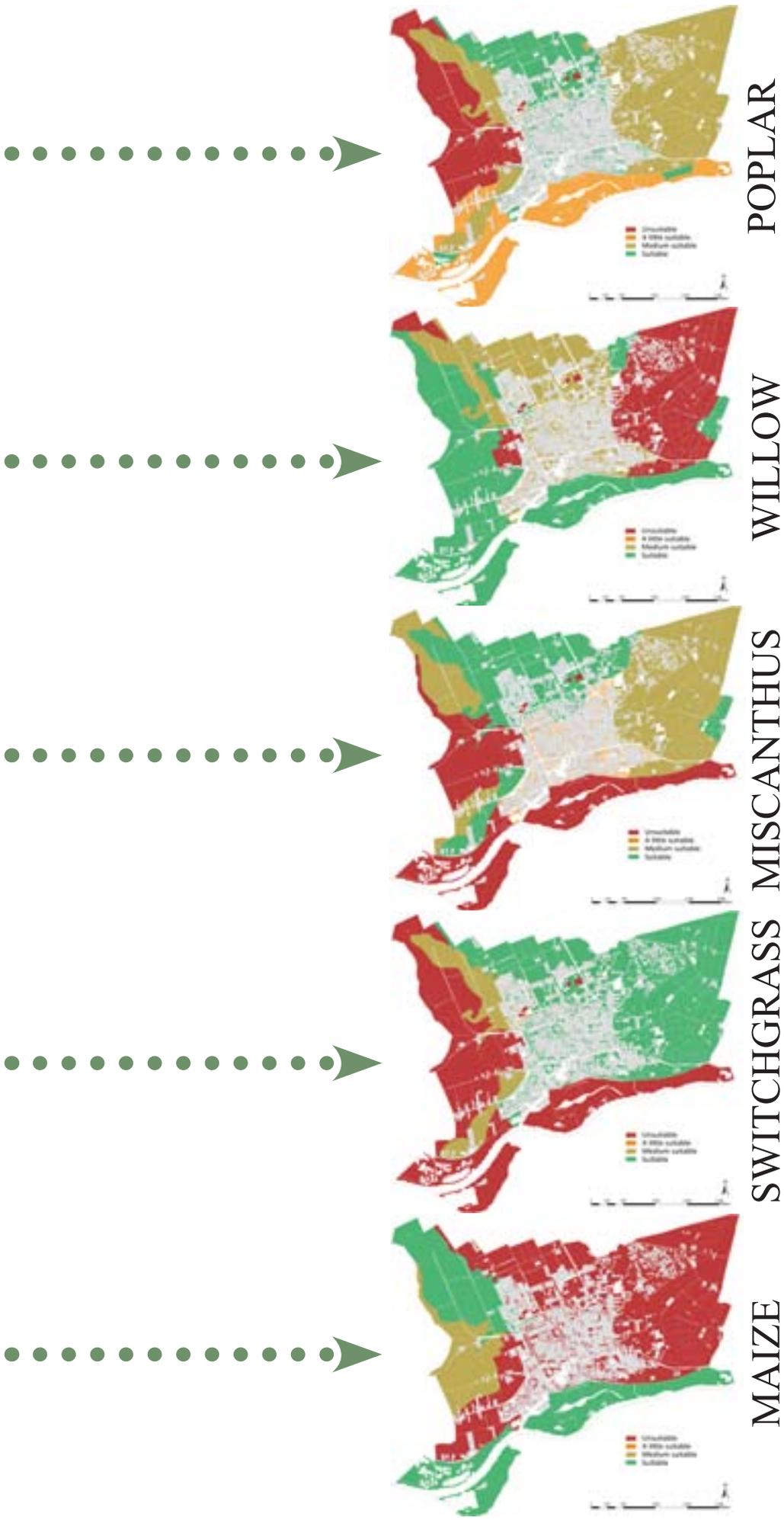


Figure 5.4: Suitability map per source

Final Suitability Map



Figure 5.5: Final suitability map for Wageningen

Final Suitability Map



LEGEND	Poplar	Willow	Miscanthus	Switchgrass	Maize
	***	***	***	**	***
	***	***	***	**	**
	***	***	—	—	***
	***	**	***	***	—
	***	**	***	**	**
	***	**	*	***	—
	**	***	***	***	—
	**	***	***	**	***
	**	***	***	**	—
	*	***	—	—	***
	—	***	**	—	***
	*	***	**	—	—
	—	***	—	—	**
	**	**	***	**	***
	**	—	**	***	—
	—	—	**	—	***
	—	—	—	—	—

5.3 PRODUCTIVE OF SPECIES

In the same area which has the same color, several biomass vegetations are all suitable for growth. In this case, I will firstly select the most productive one. According to yield and energy content of biomass species, the most productive one is Miscanthus which could produce 623 Giga Joules per hectare per year. The lowest one is willow (Tab. 5.4).

Table 5.4: Energy value of five biomass species

Ranking	Biomass Species	Energy Value
1	Miscanthus	623 GJ/ha/y
2	Switchgrass	534 GJ/ha/y
3	Maize	293.4 GJ/ha/y
4	Poplar	220.8 GJ/ha/y
5	Willow	184 GJ/ha/y

5.4 THE VISUAL QUALITY OF FIVE BIOMASS SPECIES

In order to analyze visual quality of biomass vegetation, I compare some characteristics of them which are plants' growing process, height, seasonal variations and visual characteristics. Sum them up, I found that first three elements could be named time analysis, because the visual consequences depends on time variation. Secondly, the visual characteristics of plants could be called space analysis due to the difference spatially. At last, combining time and space analysis I make several compositions which fit my thesis requirement well.

5.4.1 Time analysis

Vegetation Growing Process

Poplar & Willow: they are both planted in spring and harvested in winter, but poplar is harvested in the fifth year and willow is harvest in the fourth year (Fig. 5.6). The coppice cycles of them are between 2-4 years.

Miscanthus & Switchgrass: they are both planted in spring as well, and harvested in the early spring in the fourth year (Fig. 5.6). The coppice cycles of them are once per year.

Maize: maize is not the perennial vegetation. It is seeded every year in the spring and lifespan only last half year (Fig. 5.6). Therefore maize is harvested once per year as well.

Height Comparison and Seasonal variation of mature biomass plants

As Fig. 5.7 displays poplar can grow till 7 meters before harvesting, willow can reach 5 meters, miscanthus is almost 4 meters, switchgrass is only 2.5 meter which is the lowest biomass species of five, and maize can grow till 3 meters. In Fig. 5.8, the different seasonal change is shown.

I simplify and group these five types of biomass vegetation for analyzing their visual quality better. From time analysis, because of different harvest season and coppices cycle, poplar and willow are in the same group, miscanthus and switchgrass are in the same group, maize is another group.

Vegetation Growing Process

Year 1

Year

Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sept. Oct. Nov. Dec.

Cuttings

three-month-old



POPLAR

Cuttings

three-month-old

Cut back

Regre



WILLOW

Cuttings

three-month-old



MISCANTHUS

Seed

three-month-old



SWITCHGRASS

Seed

three-month-old



Harvest



MAIZE

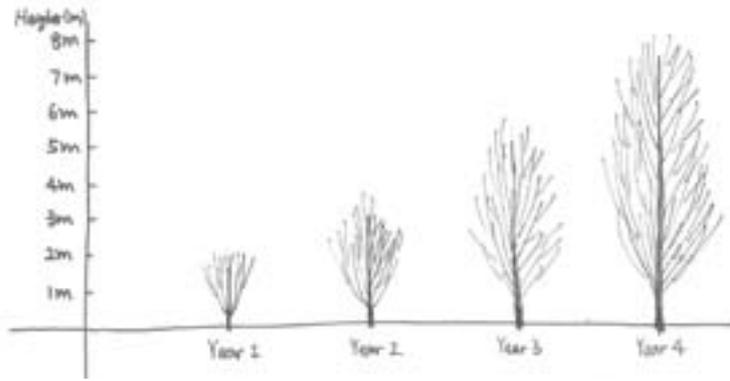
Vegetation Growing Process



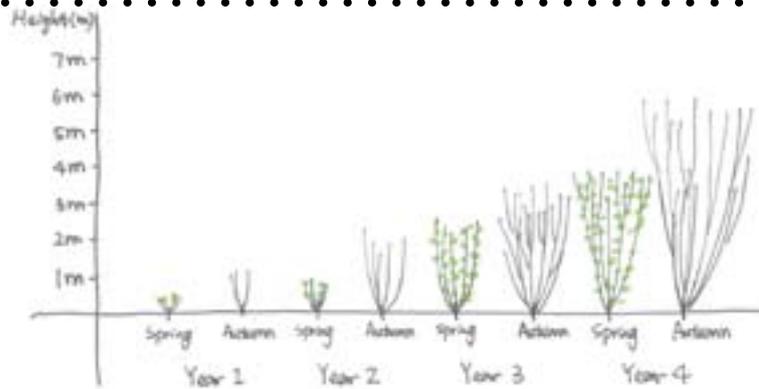
Figure 5.6: Vegetation growing process of five biomass species

Height Comparison

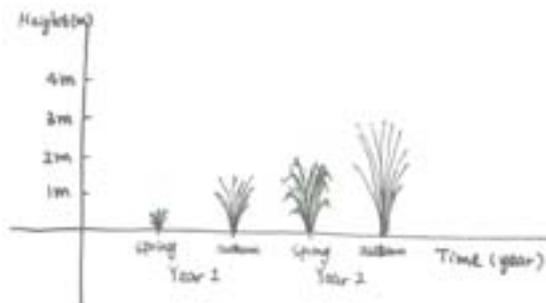
POPLAR



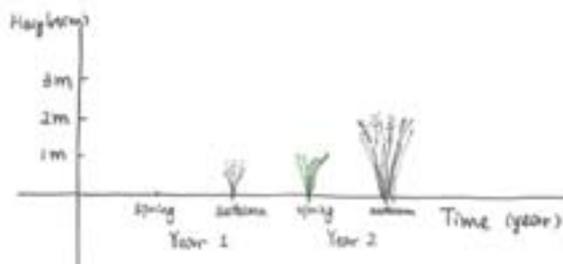
WILLOW



MISCANTHUS



SWITCHGRASS



MAIZE

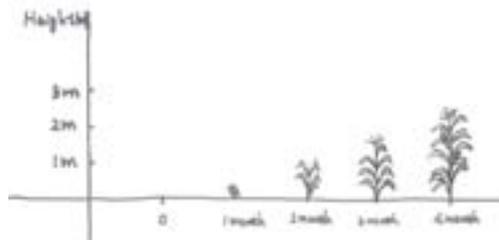


Figure 5.7: Height comparison of five biomass species (drew by author)

Seasonal Variation of Mature Biomass Plants

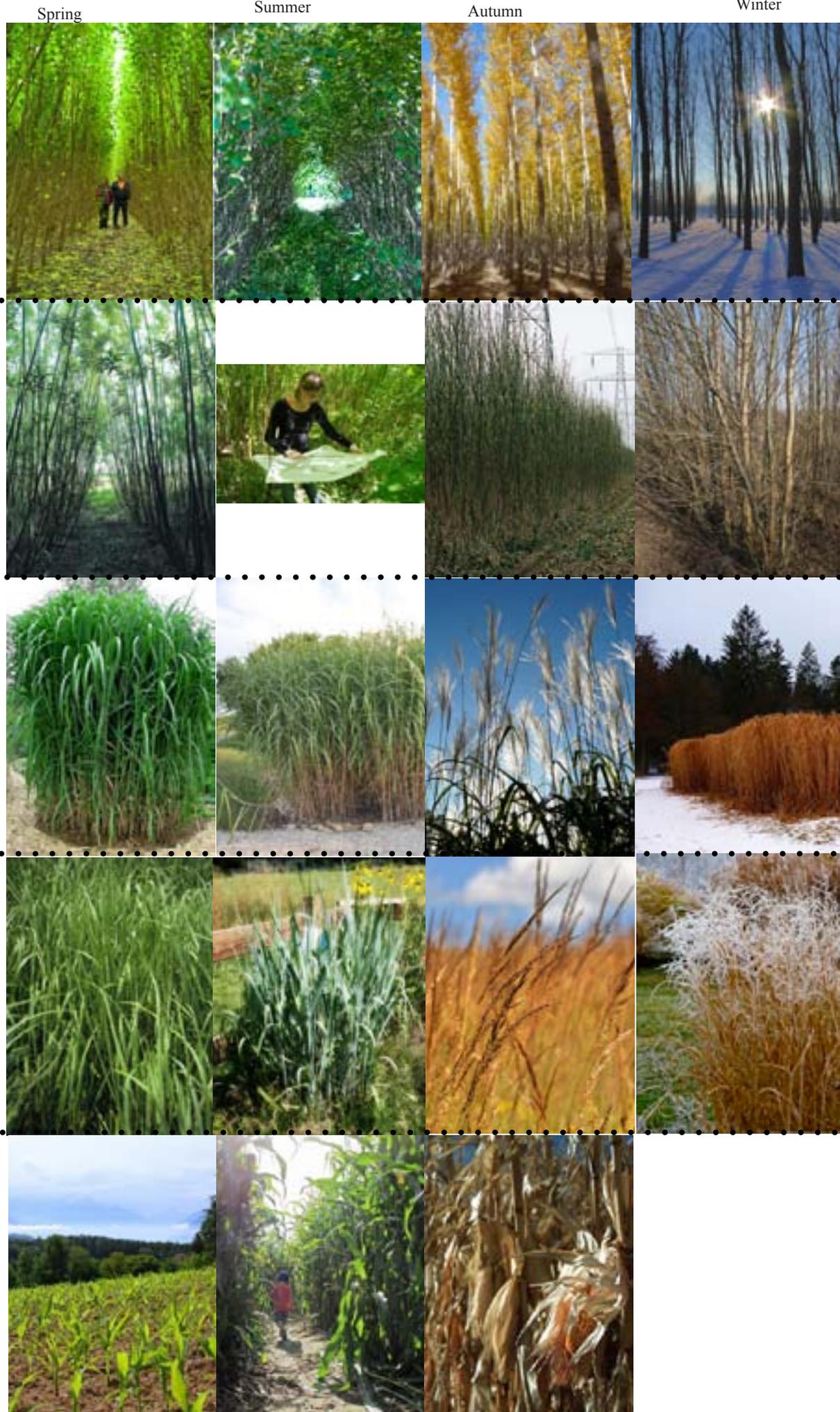


Figure 5.8: Seasonal variation of five biomass species

Vegetation growing process

POPLAR

<http://www.extension.umn.edu/distribution/naturalresources/images/3-planted-unrooted.jpg>
http://www.sciencephoto.com/image/340103/large/T1220020-Close-up_of_poplar_cutting_in_fuelwood_plantation-SPL.jpg
<http://cfs.nrcan.gc.ca/assets/file/1457>
<http://cfs.nrcan.gc.ca/assets/file/1453>
 Video: <http://wn.com/Taglio del pioppo short rotation>
 Video: <http://wn.com/Biobaler1>
<http://www.flickr.com/photos/widnr/6582815565/>
<http://www.extension.umn.edu/distribution/naturalresources/images/5-stump.jpg>

WILLOW

<http://cfs.nrcan.gc.ca/assets/file/1436>
 Defra 2004. Growing short rotation coppice. Defra Publications, London
 Defra 2004. Growing short rotation coppice. Defra Publications, London
http://www.sciencephoto.com/image/340099/large/T1220016-Farmer_in_willow_fuelwood_plantation_in_Clanfield-SPL.jpg
<http://www.poplar.ca/images/Swewill.jpg>
http://northernwoodlands.org/images/articles/KNOT_WILLOW.jpg
 Video: <http://wn.com/Taglio del pioppo short rotation>
http://jamestwhats.com/BackPackBlog/wp-content/uploads/2011/12/coppicedwillow_001.jpg

MISCANTHUS

http://farmersguide.co.uk/content/img/2010/11/pp24-2_Miscanthus.jpg
http://www.ukagriculture.com/crops/images/miscanthus_young_plants.jpg
http://www.ukagriculture.com/crops/images/miscanthus_plants.jpg
<http://biomassmagazine.com/uploads/posts/magazine/2011/01/12959747217854.jpg>
http://envplan240.pbwiki.com/f/miscanthus_harvesting.jpg
<http://www.rightplants4me.co.uk/admin/Photos/Miscanthus%20sinensis%20'Silberfeder'~cut%20back%20regrowth.jpg>

SWITCHGRASS

<http://www.noble.org/imageFactory?f=/Global/ag/research/Articles/Switchgrass/switchgrass.jpg&w=315&bw=0>
<http://www.flickr.com/photos/usdagov/6853616290/>
<http://i41.photobucket.com/albums/e288/dbltree/Switchgrass/switchgrass8-24-09038.jpg>
<http://www.monticellolive.com/wp-content/uploads/2011/08/Pelkki-with-2-yr-switchgrass-plot-at-Pine-Tree-133x200.jpg>
<http://www.switchgrass.nl/photos/Netherlands,%20harvest%201999.jpg>
<http://cses.uark.edu/switchgr.gif>

MAIZE

<http://bbs.jrhot.com/data/attachment/forum/201205/13/190137fnenjrrj8jnfj8uh.jpg>
<http://www.flickr.com/photos/anyhoo/998881643/>
 photo by author, 6th of August 2011, Wageningen
http://www.flickr.com/photos/panorama_paul/3404061647/in/photostream/
<http://www.g-can.net/images/managed/Harvesting%20maize%20St%20Peter%20Port%20311007%201459%20RLLord%20GCAN.jpg>

Seasonal variation of mature biomass plants

POPLAR

<http://cfs.nrcan.gc.ca/assets/file/1452>
<http://www.flickr.com/photos/glbrc/5954973959/>
<http://3.bp.blogspot.com/-2kdy1tWld-c/Td69YRyGJYI/AAAAAAAAHRI/tl7zWtlzfHc/s1600/Zechem+hybrid+poplar.jpg>
<http://i1.treknature.com/photos/10988/pioppi.jpg>

WILLOW

Defra 2004. Growing short rotation coppice. Defra Publications, London
<http://cfs.nrcan.gc.ca/assets/file/1441>
 Leen Kuiper. Handout Excursion 'Short Rotation Coppice in the Netherlands' August 16th, 2011
http://www.silvanusforestry.com/gallery/images/gallerypic_1_39.jpg

MISCANTHUS

http://media-cache5.pinterest.com/upload/94083079685014929_pE3NPY9q_b.jpg
http://www.willowaynurseries.com/gallery/photos/Miscanthus_floridulus_Giganteus.JPG
<http://foxhollowfarmsga.webs.com/miscanthus%20002.JPG>
http://farm4.static.flickr.com/3120/3156017431_0bae31be98.jpg

SWITCHGRASS

<http://hayandforage.com/images/switchgrass-cellulose.jpg>
<http://www.flickr.com/photos/ginkyhackle/5931162565/>
<http://www.flickr.com/photos/mully410/4895641634/in/photostream/>
<http://www.thegardenerseden.com/wp-content/uploads/2010/12/Switch-Grass-with-Ice-%E2%93%92-Michaela-at-TGE.jpg>

MAIZE

<http://www.flickr.com/photos/50718005@N08/5800115044/>
<http://www.flickr.com/photos/joneew/6217587046/>
<http://www.flickr.com/photos/erfahrungsraum/6898807857/>

5.4.2 Space analysis

In our environment, mountains, water, vegetation, buildings and other landscape objects can be analyzed in a fundamental manner to aid understanding the visual qualities. According to Bell (1999), Daniel (2001) and Robinson (2004), shape, line, texture and color are the basic elements of visual composition. The visual characteristics of plants can be analyzed by the four elements. Although they are more abstract than the appearance of plants, these properties are helpful understanding visual composition fundamentally and professionally. It needs to be clarified that the four elements are analyzed in the circumstance of single plant. A group of plants could form infinite types of shapes depending on the way of combination, as well as line. Therefore in this section I will only explore the visual characteristics of individual plant.

Shape

The shape of plants is one of the most important and powerful varieties that effects on our feelings when we perceive. There are various kinds of shapes and it is three-dimension form. In the book of Robinson (2004), he summarized types: prostrate and carpeting, hummock, dome and tussock, ascending, arching, palm, succulent and sculptural, oval upright, conical, fastigate and columnar, tabulate and level spreading, open irregular and trained shapes. These types contain all plants completely, not only trees but also shrubs and grasses. In terms of them, I analyze the shapes of five biomass species and human feelings that reacted on.

Oval Upright Shape - Rising & Contained

Hybrid poplar trees in biomass plantation are in the shape of oval upright. This form of plants has a generally erect habit of growth but a crown also spreads laterally. Because of its upright trunk and rounded crown, it brings a feeling of rising and contained. It is seen more often in selected cultivars (Robinson, 2004). Oval form makes a clear stop to a mixed planting. The canopy of oval upright form is less closely associated with the ground. Poplar is restricted spread, therefore it is convenient for planting next to roads. However it needs to mix with other plants if visual weight is required.

Poplar

Ascending Shape - Forceful & Assertive

Hybrid willow trees in biomass plantation are in the shape of ascending. Their characteristics are a majority of vertical or sharp-angled main stems and

Willow

branches. These branches draw up towards the light. This kind of shape can be forceful and assertive element in composition (Robinson, 2004).

Miscanthus & Switchgrass
& Maize

Arching Shape - Mild & Compromised

Miscanthus, switchgrass and maize are in the shape of arching. This shape is not common among trees, because their lateral branches arch over under their own increasing weight after erect stems. They play a similar role though with a little less contrast because they have a rather looser habit. They bring a feeling of mild and compromised.

Line

Line is closely related to shape which is the two-dimensional effect of edges. Lines are created by edges of a whole massive plants, or different materials, colors or shadows. It could be curved or bent but the essence of line is direction, being the result of movement. Line can be generalized as ascending, pendulous, horizontal and diagonal line (Robinson, 2004).

Poplar & Willow

Vertical Line - Forceful, Assertive

Vertical line is expressed in the outlines of plants with oval upright shapes, like poplar and willow. Vertical lines define height. Since they are perpendicular to the earth, growing against the gravity, they assertion of the force of life.

Miscanthus & Switchgrass
& Maize

Pendulous Line - Peacefulness & Restfulness

Pendulous line is the plants hanging leaves or flowers like miscanthus, switchgrass and maize. This type of line brings peacefulness and restfulness to the scene, because it reveals letting go with gravity and wind (Robinson, 2004).

Texture

Texture has the visual distinctiveness of roughness and smoothness of any part of plants. A plant is commonly referred to as having coarse, fine or medium texture. Texture depends on viewing distance. From a moderate distance, the texture of plants is the result of its leaves and twigs. If we move far away, the canopy will be visual domain. I will discuss the textural effects from medium distance which is about 2-20meters, because it is the distance most planting is appreciated (Robinson, 2004).

Coarse Texture - Striking & Focal

Plants with large foliage or stems often strongly draw viewers' attention because of their size and visibility from a distance, for example maize. This

makes them prominent as advantage. Such large leaves of coarse-textured plants provide big shadows and create striking patterns through the light.

Maize

Medium Texture - Transition

The other four biomass plants are all belongs to medium texture. This type of texture is between fine and coarse texture. Lots of plants can be described as medium texture. It has a function of progression, and it is easy ignored by people.

Poplar & Willow &
Miscanthus & Switchgrass

Since the most biomass species which are selected for growing in Wageningen are medium texture. This type of visual characteristics could leave out.

Color

The differences of colors are caused both by the nature of the light source and reflection, refraction and absorption of the light before it reaches our eyes. Color theory develops in a systematic way. It can be described as hue, lightness and saturation (Bell, 1996; Robinson, 2004). Being a small section of plants' visual characteristics I will only discuss the effects of color hues perceived by observer, because it is one of the aesthetic materials. Colors provide emotional responses, for example red/orange/yellow are known as 'warm' and advancing color, rather than blue appears to 'cool' and recede color. It brings physical and visual sensations (Bell, 1996).

Green - Sooth & Balance & Stimulate

Magenta, cyan and yellow are three primary colors. Green is a neutral color which is neither warm nor cool, because green is mixed by yellow and blue. Green could be warm or cool depended on the proportion of the two colors. It is soothing and balancing, but also stimulating (Robinson, 2004). Similar colors tend to harmonize with each other.

Poplar & Willow &
Miscanthus & Switchgrass
& Maize

After analyzing shape, line, texture and color, only miscanthus and switchgrass can be grouped together, because the four characteristics are all the same. Texture of maize is different with miscanthus and switchgrass, however texture is an important distinguish element. Poplar and willow are the same in three plant characteristics, only shape is different.

Shape

Line

POPLAR



Oval Upright Shape
Rising & Contained



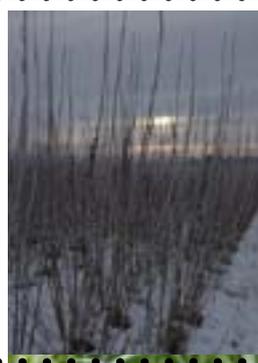
Verticle Line
Forceful & Assertive



WILLOW



Ascending Shape
Forceful & Assertive



Verticle Line
Forceful & Assertive



SWITCHGRASS/MISCANTHUS



Arching Shape
Mild & Focal



Pendulous Line
Peaceful & Restful



SWITCHGRASS/MISCANTHUS



Arching Shape
Mild & Focal



Pendulous Line
Peaceful & Restful



MAIZE



Arching Shape
Mild & Focal



Pendulous Line
Peaceful & Restful



Texture

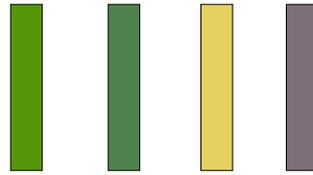
Color



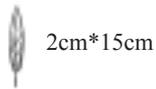
Medium Texture
Transition



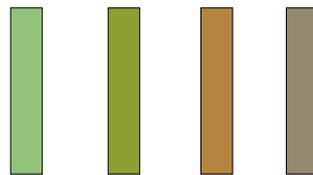
Green
Sooth & Balance & Stimulate



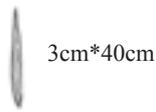
Medium Texture
Transition



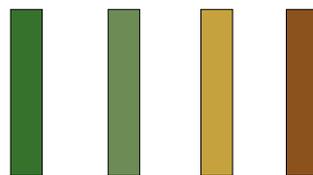
Green
Sooth & Balance & Stimulate



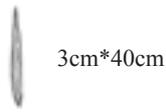
Medium Texture
Transition



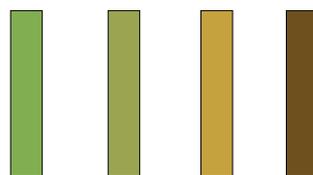
Green
Sooth & Balance & Stimulate



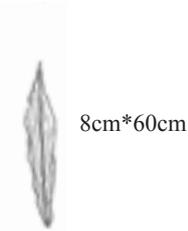
Medium Texture
Transition



Green
Sooth & Balance & Stimulate



Coarse Texture
Striking & Focal



Green
Sooth & Balance & Stimulate

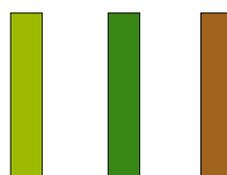


Figure 5.9: Visual characteristics of five biomass species

reference of pictures

POPLAR

<http://www.flickr.com/photos/valter/7326439474/in/photostream/>

<http://www.flickr.com/photos/graniteroad/2066621/>

http://www.worldpaulownia.com/assets/images/hybrid_poplar_leaves.jpg

WILLOW

http://www.sciencephoto.com/image/178999/large/E7680440-Willow,_Salix_sp._-SPL.jpg

http://www.flickr.com/photos/paul_jones_london/5340942160/

http://www.extension.iastate.edu/forestry/iowa_trees/tree_id_photos/WILLOW_SANDBAR2_leaves.jpg

MISCANTHUS

<http://www.bluestem.ca/miscanthus-giganteus.htm>

<http://www.blueskynursery.ca/index.php?/products/detail/227/>

http://4.bp.blogspot.com/-_wbU_S1uqho/TxYLndGCA_I/AAAAAAAAAFa0/IYcgKO4LuRM/s1600/IMG_0341.JPG

SWITCHGRASS

[http://nybioenergy.org/generalInformation/biomass/PublishingImages/switchgrass%20\(Small\).JPG](http://nybioenergy.org/generalInformation/biomass/PublishingImages/switchgrass%20(Small).JPG)

http://ecx.images-amazon.com/images/I/617VfE2btcL._SL500_AA300_.jpg

<http://www.ok.gov/ocast/images/switchgrass.jpg>

MAIZE

<http://world.edu/wp-content/uploads/2012/01/maizeplants.jpg>

http://www.cccmkc.edu.hk/~kei-kph/Gardening/Growing%20maize/Maize_leaf_image/maize%20leaf_dorsal%20view_800.jpg

http://www.vcbio.sci.kun.nl/public/Final-Images/PL_Final1512z_301-350/PL0316_512zMaizeLeafMacro.jpg

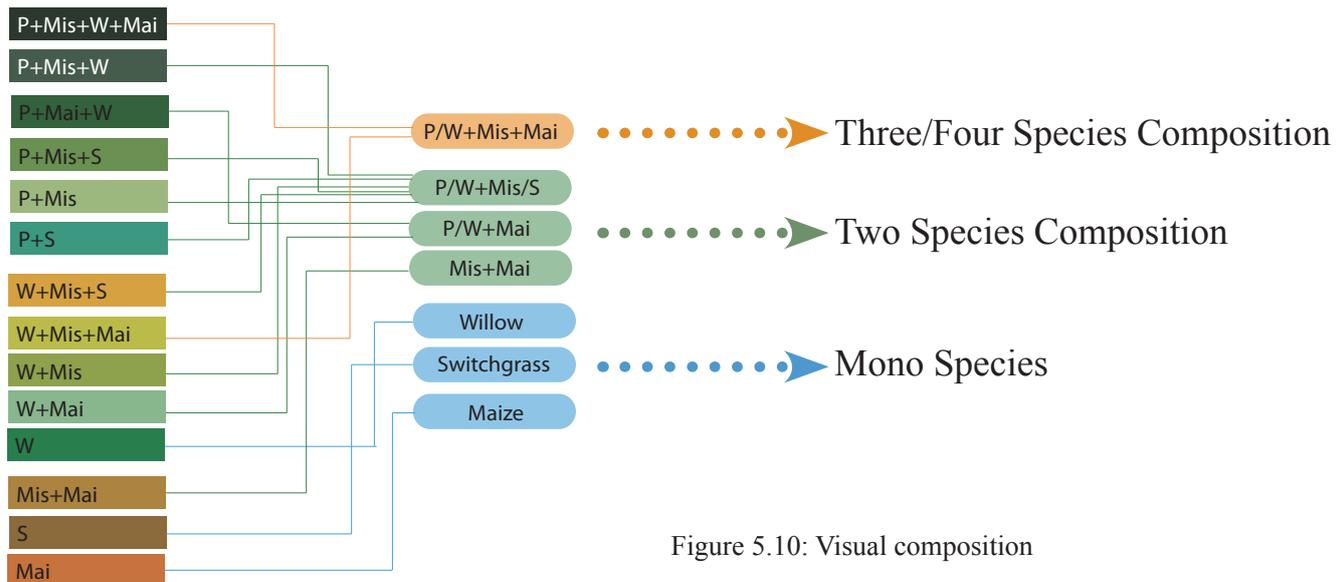


Figure 5.10: Visual composition

5.4.3 Composition

Plants are used in defining open space and integrating the buildings to the surrounding environment. Plants can create walls, canopies or floors of intimate outdoor spaces. They create landscape variation through varying colors, textures and shapes (Robinette, 1972; Robinson, 2004). According to time and space analysis of five individual biomass vegetation (chapter 5.4.1 & 5.4.2), I conclude that maize could give a different visual effect with the rest. Miscanthus and switchgrass are almost same in both time and space analysis. Poplar and willow are similar in visual impact of time change, however they are distinct in space analysis. Therefore in different situation, poplar and willow could be observed as the same kind of vegetation, could be also observed as different.

In final suitability map (p. 102-103), there are 17 categories which indicate variety of suitability. Simplified by time and space analysis, they can be generalized to seven categories. And these seven categories are classified as three types of visual compositions (Fig. 5.10).

First type is mono-species. It consists of willow, switchgrass or maize. One type of vegetation grows in one unit. It brings a feeling of continuous and control (Fig. 5.11 - Fig. 5.16). Second type is two species combination which are made of poplar/willow and miscanthus/switchgrass, poplar/willow and maize, or miscanthus and maize. They could create a hierarchy view for people (Fig. 5.17 - Fig. 5.22). The last type is three/four species combination. They are poplar/willow, miscanthus and maize. This is the most complex one, because it contains all types of vegetation even after simplifying. They could create many visual effects, both negative and positive ones. In my thesis I prefer to design a harmony environment for Wageningen people (Fig. 5.23- Fig. 5.24).

Maize



Figure 5.11: Mono-species - Maize

Switchgrass

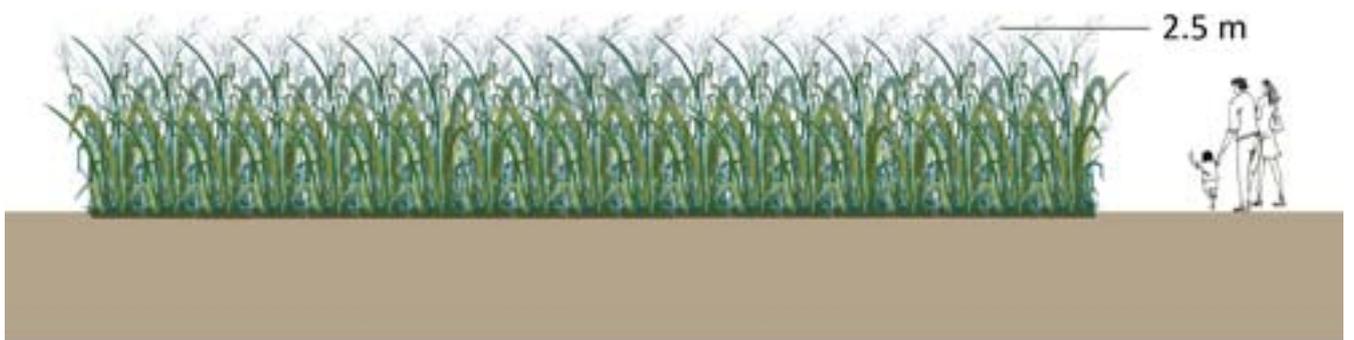


Figure 5.12: Mono-species - Switchgrass

Willow

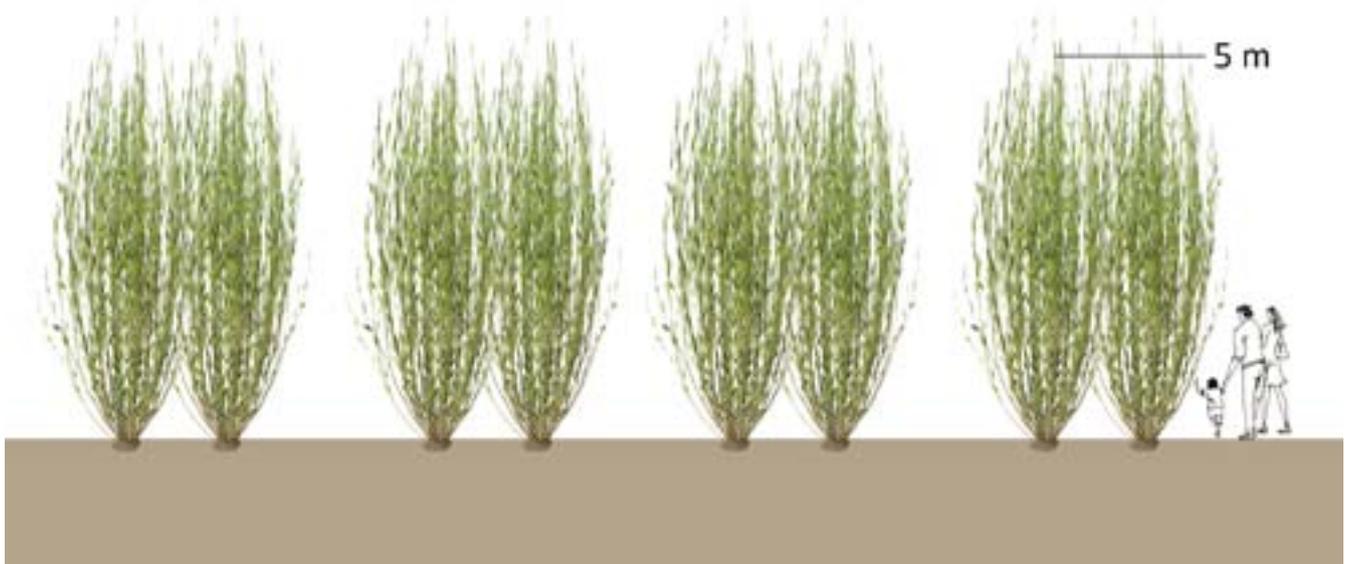


Figure 5.13: Mono-species - Willow



Figure 5.14: Mono-species - Maize picture



Figure 5.15: Mono-species - Switchgrass picture



Figure 5.16: Mono-species - Willow picture

Poplar & Miscanthus

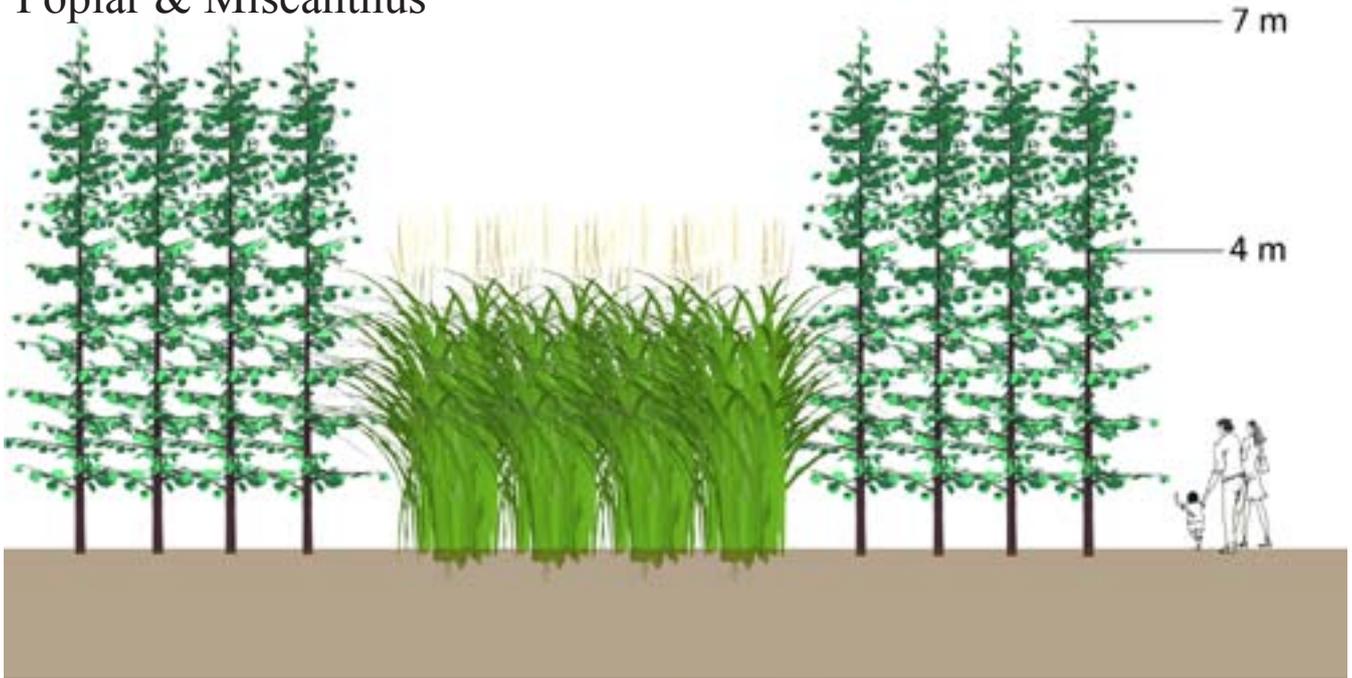


Figure 5.17: Two species combination - Poplar & Miscanthus

Willow & Maize

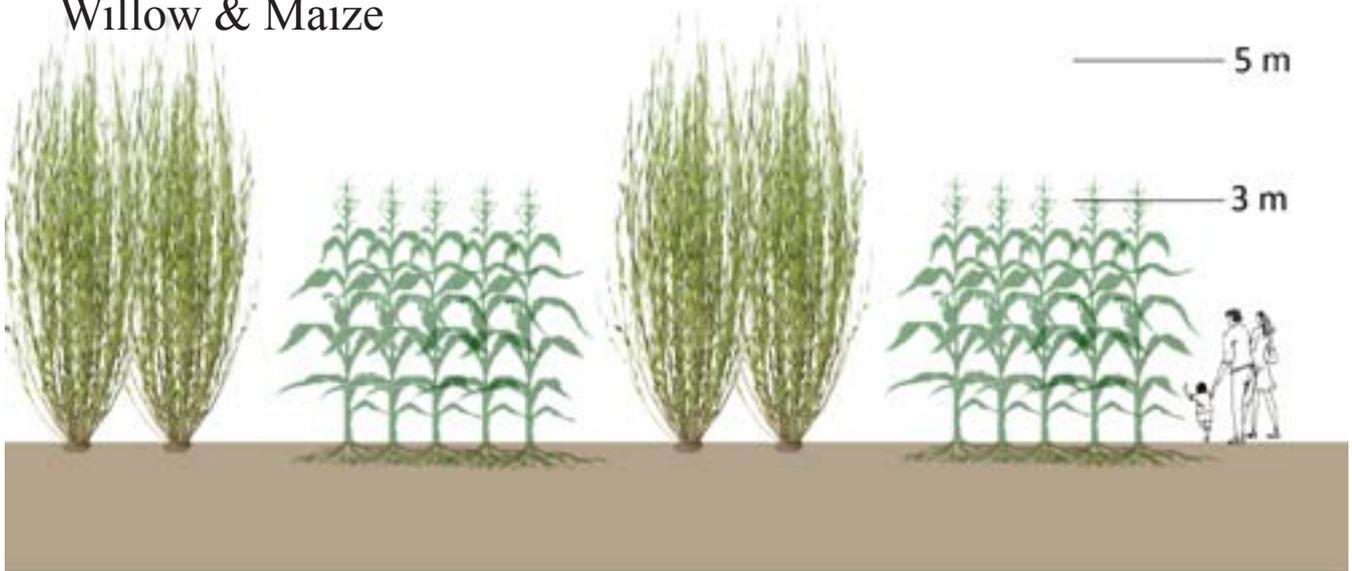


Figure 5.18: Two species combination - Willow & Maize

Miscanthus & Maize



Figure 5.19: Two species combination - Miscanthus & Maize



Figure 5.20: Two species combination - Poplar & Miscanthus picture



Figure 5.21: Two species combination - Willow & Maize picture



Figure 5.22: Two species combination - Miscanthus & Maize picture

Miscanthus & Maize

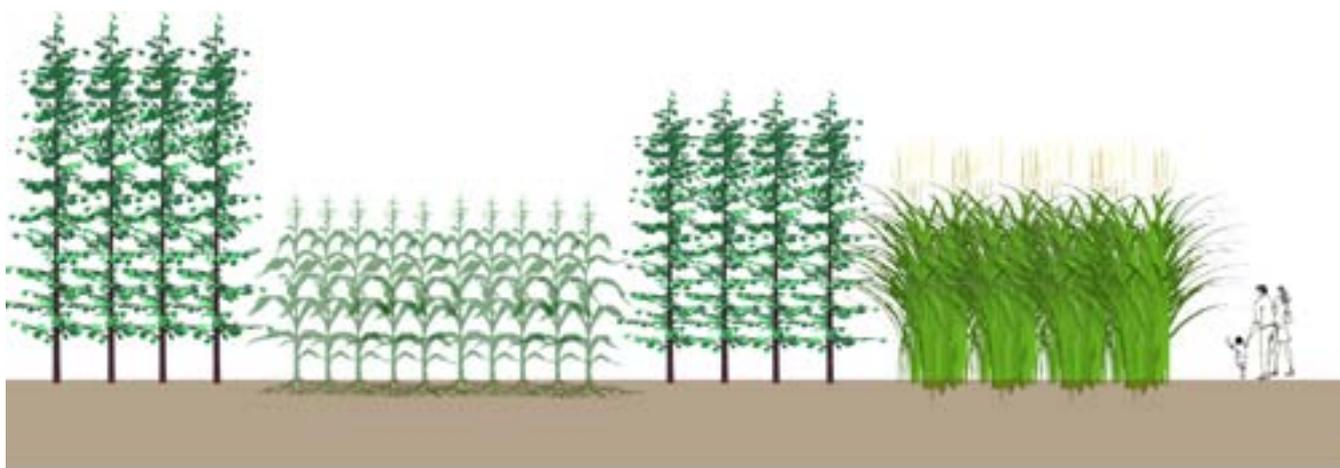


Figure 5.23: Three species combination - Poplar & Miscanthus & Maize



Figure 5.24: Three species combination - Poplar & Miscanthus & Maize picture

REFERENCE

Bell, S., 1996. *Elements of visual design in the landscape*. London [etc.], Spon.

Bell, S., 1999. *Landscape pattern, perception and process*. London, E & FN Spon.

Braun Blanquet, J. & Pavillard, J., 1930. *Vocabulair der plantensociologie*. [S.l.], Instituut voor Vegetatie-onderzoek van Nederland.

Christensen, Cory A. & Gary Koppenjan, eds., 2010. *Planting and Managing Switchgrass as a Dedicated Energy Crop*. 2nd ed. Blade Energy Crops.

Clifton-brown, J., Chiang, Y. C. & Hodkinson, T. R., 2008. Miscanthus: genetic resources and breeding potential to enhance bioenergy production. *Genetic improvement of bioenergy crops*, 273-294.

Daniel, T. C., 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning*, 54 (1-4): 267-281.

Defra, 2007. *Planting and growing Miscanthus: best practice guidelines*. Defra Publications.

De Wit, M. & Faaij, A., 2010. European biomass resource potential and costs. *Biomass and Bioenergy*, 34, 188-202.

Du Plessis, J., 2003. *Maize Production*. Directorate of Agricultural Information Services, Department of Agriculture South Africa.

EL Bassam, N., 2010. Handbook of bioenergy crops : a complete reference to species, *Development and Applications*, London [etc.], Earthscan.

Elbersen, W., 2001. *Switchgrass (Panicumvirgatum L.) as an alternative energy crop in Europe Initiation of a productivity network*. s.l. s.n.

Elbersen, W., 2005. *Switchgrass and miscanthus as energy crops – agricultural aspects*. Lecture. Wageningen University and Research Center.

Garcia, Y., 2008. *Growing maize for silage: a guide for dairy farmers*. Future dairy forages.

Gerin, P. A., Vliegen, F. & Jossart, J.-M., 2008. Energy and CO₂ balance of maize and grass as energy crops for anaerobic digestion. *Bioresource Technology*, 99, 2620-2627.

IEA Bioenergy. 2011. *Quantifying environmental effects of Short Rotation Coppice (SRC) on biodiversity, soil and water*. s.l. s.n.

Jansson, S., Groover, A. & Bhalerao, R., 2010. *Genetics and Genomics of Populus*. New York, NY, Springer Science+Business Media, LLC.

Larsson S., Nordh, N.-E. & Farrel, J., 2007. Tweddle P. Manual for SRC willow growers. Örebro, Sweden: LantmännenAgroenergi AB.

Mitchell, C. P., Stevens, E. A. & Watters, M. P., 1999. Short-rotation forestry – operations, productivity and costs based on experience gained in the UK. *Forest Ecology and Management*, 121, 123-136.

Robinson, N., 2004. *The planting design handbook*. Aldershot, Hants, England ; Burlington,VT, USA, Ashgate.

Robinette, C., 1972. *Plants, people and environmental quality*. Department of the Interior. National ParkService, Washington DC

Roth, A. M., Sample, D. W., Ribic, C. A., Paine, L., Undersander, D. J. & Bartelt, G. A., 2005. Grassland bird response to harvesting switchgrass as a biomass energy crop. *Biomass and Bioenergy*, 28, 490-498.

Scurlock, JMO., 1999. *Miscanthus: a review of European experience with a novel energy crop*. Oak Ridge, TN, USA: Oak Ridge National Laboratory

Wickberg J., 2006. *Water relations in Salix with focus on drought responses*. Ph.D. Dissertation, Swedish University of Agricultural Sciences, Umea, Sweden.

Wriedt, G., Van der Velde, M., Aloe, A. & Bouraoui, F., 2009. Estimating irrigation water requirements in Europe. *Journal of Hydrology*. 373, 527-544.

http://hybridpoplar.com/home/sr1/growing_main.html

<http://www.folkecenter.net/gb/rd/biogas/biomass-energy-crops/energy-poplar/>

<http://www.tsec-biosys.ac.uk/index.php?p=8&t=1&ss=3>

http://mammothwillow.co.uk/store/index.php?main_page=page&id=5

<http://www.trc.govt.nz/assets/Publications/information-sheets-and-newsletters/land-management-information-sheets/soil-conservation-information-sheets/15poplarwillowguide.pdf>

<http://www.extension.umn.edu/agroforestry/biomass/schmidt.pdf>

www.thegrowspot.com

http://heritagemiscanthus.com/miscanthus_giganteus.php

<http://www.pda.org.uk/leaflets/17/leaflet17-3.html>

<http://www.ksgains.com/corn/CornClass04.pdf>

http://www.nirov.nl/Home/Projecten/De_Nieuwe_Kaart/Website.aspx

Chapter 6

Design Concept, Detail Design and Plan

6.1 Theory on Visual Landscape Quality

6.2 Sequence

6.2.1 Concept

6.2.2 Model & Guideline

6.2.3 Plan & Visualization

6.3 Control

6.3.1 Concept

6.3.2 Model & Guideline

6.3.3 Plan & Visualization

6.4 Coherence

6.4.1 Concept

6.4.2 Guideline

6.4.3 Site Selection and Analysis

6.4.4 Detail Design

6.5 Plan

6.1 THEORY ON VISUAL LANDSCAPE QUALITY



Figure 6.1: relationship between landscape and visual landscape quality

Landscape quality arises from the integration between characteristics of biophysical and judgment of human viewers. It is a junction of landscape visible features and psychological reaction from human observers (Fig. 6.1). Through the years, researches of visual landscape quality have been developed by lots of experts. The history of landscape quality has been divided into two point cuts. One is expert aspect which devotes to landscape quality from an objective feature. The other is perception-based aspect which focus on subjective experience from landscape viewers (Daniel, 2001).

I will choose expert aspect to study visual landscape quality of biomass plants. Expert aspect are normally determined by a single person which might not be proven reliable, however based on classical design parameters they are more related to “true aesthetic values” than the perception from the unsophisticated public (Carlson, 1977 cited by Daniel, 2001).

There are lots of principles, concepts or assessments of visual landscape composition or quality illustrated by landscape architects and experts from other disciplines. I summarized them in Appendix B. These principles are applicable for most of the visual landscape designs.

However designs do not have to reach the whole list of concepts. It depends on the objectives. For my thesis, designing a biomass landscape, sequence, control and coherence are significant important to be design concepts (Tab. 6.1). Sequence is the concept of road, control is for sub-urban area, and coherence is for urban area. These concepts are a way of doing design, but not the only way.

Table 6.1: Design concepts

Design Concepts	Synonyms	References
Sequence	rhythm and change	Spirn, 1988; Kaplan, R. & Kaplan, S., 1989; Bell, 1996; Daniel, 2001; Robinson, 2004
Control	order and care	Nassauer, 1995; Bell, 1996; Dee, 2001; Saito, 2001
Coherence	harmony and balance	Nassauer, 1995; Bell, 1996; Bell, 2001; Daniel, 2001; Dee, 2001; Robinson, 2004

6.2 SEQUENCE (RHYTHM AND CHANGE)

6.2.1 Concept

Sequence is the most distinguish advantage of biomass vegetation could be used for design, because biomass vegetation fast grow, and be harvested and re-grow in certain short period, rather than normal plants. Their seasonal and annual changes are easily observed by people. Therefore landscape architects could put them to use for enhancing the visual quality and drawing layfolks' attention. It provides temporal hierarchy to the composition. Sequence is essential to the dynamic qualities of composition. It is linked to rhythm and change in visual composition. Rhythm is used as an important structure and brings a design to life. Simply repeat man-made forms create rhythm, as well as irregular natural forms. They could be simple or complex (Bell, 1996). Moreover it is useful for further enhancing a design relying on visual forces such as agricultural margin lands, both sides of paths or any edges. Direction and speed of human movement strongly effects on rhythm.

6.2.2 Model & Guideline

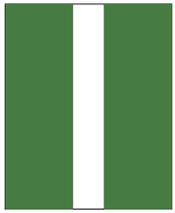
In current situation, only one type of tree grows along streets (Fig. 6.1). After design, two types of vegetations are planted in same distance (Fig. 6.1). I choose 15 seconds as time dimension. Different types of roads and vehicles have different speed limits. In the city of Wageningen, three regional roads are the fastest roads with 80 km/h speed limitation by car, because car is the main vehicle. So in these roads, one kind of biomass vegetation can keep continue grow 330 meters, and then change other species. Other two types of roads are the same with the first one. Their time dimensions are 15 seconds as well. The distances are 200 meters and 125 meters (Fig.6.3). The entrance model is showing in Fig. 6.2. Moreover, roadside rhythm changes every years, because two species have different grow speed, harvest time and coppices cycle. Sometimes the rhythm is shallower, sometimes is deeper (Fig.6.4).

Guidelines:

- Unifying roadside rhythm (Lyhn, 1960)
- Enhancing rhythm of the main entrance

Sequence

current situation
single hirarchy
no change



fast movement
roadside rhythm
two speices

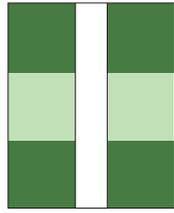
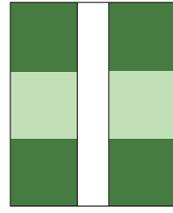


Figure 6.1: design model of roadside sequence

fast movement
roadside rhythm
two speices



fast movement
entrance rhythm
two speices

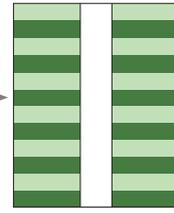


Figure 6.2: design model of entrance sequence

same time dimension = 15 seconds

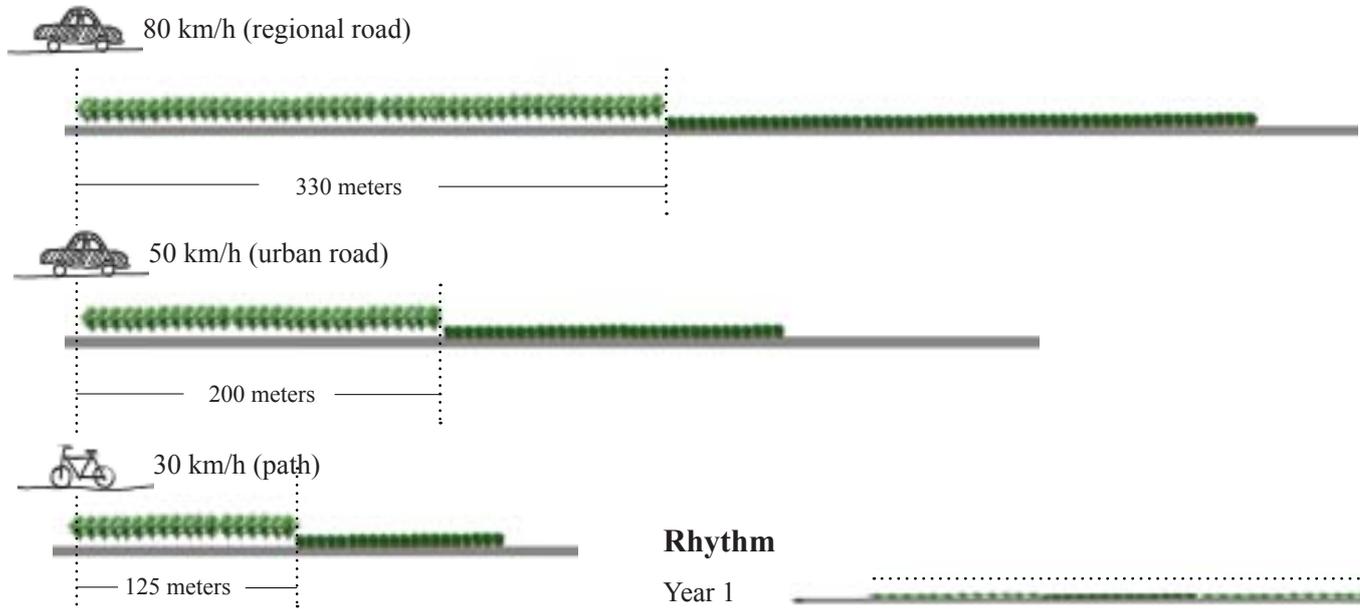


Figure 6.3: design model of time dimension

Rhythm

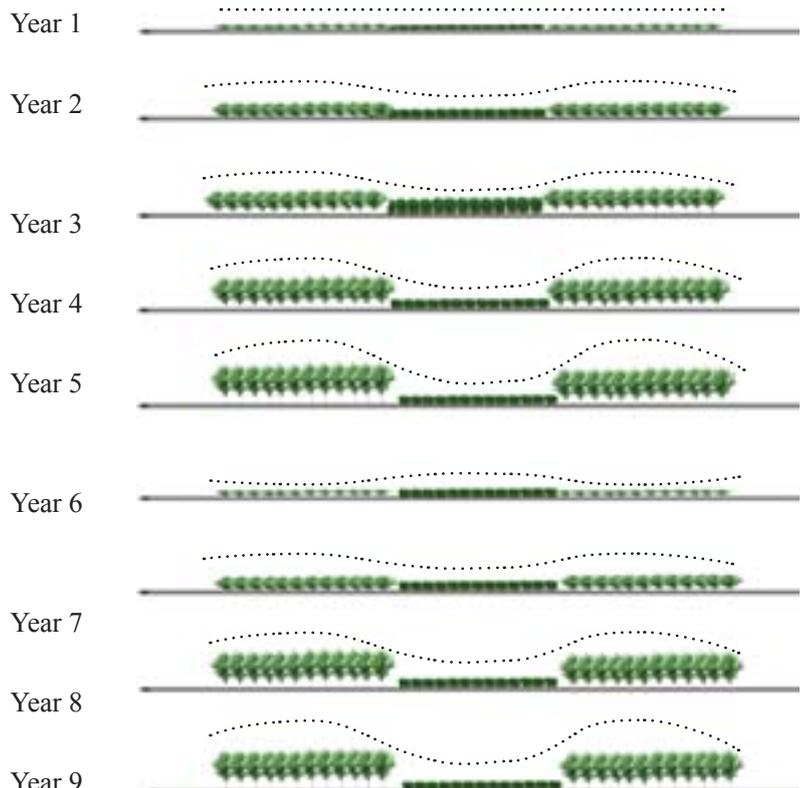


Figure 6.4: design model of sequence degree

6.2.3 Plan & Visualization

Model of sequence is shown in Fig. 6.5 which is guided by design model and guidelines. The traffic system and main vehicle types are taken into consideration as well. Combining with suitability map (chapter 5.2, p.102-103) and productive selection (chapter 5.3, p. 104), sequence plan is presented in Fig. 6.6.

I select four kinds of typical biomass sequence as to show the visualizations (Location A, B, C and D).

Location A is in the entrance of Wageningen, so the vegetation distance is shorter than other regional road, which is 80 meters. In suitability map, this area is suitable for growing poplar, miscanthus and switchgrass. For the purpose of productivity, I should choose miscanthus as the primary choice. However for the sake of visual quality, which is required two different visual types of vegetation to establish roadside rhythm, I choose poplar besides miscanthus.

Location B is in the built area, the vegetation distance is 200 meters. In suitability map, it is suitable for poplar and switchgrass. Either for productive or visual quality, I use both of the two vegetation for design.

Location C is in the regional road, so the vegetation distance is 330 meters. In the suitability map, there are two categories in this area: willow, or willow and miscanthus. Currently several houses are situated along the road. And in a quite long distance, only willow suits for growth. As a result, in location C, roadside sequence is built by willow and houses. These two landscape elements are totally visual different, bringing a soft and hard intertwining sequence.

Location D is chosen in the boundary of Wageningen. This boundary is in the form of nature river separates two cities. In suitability map, this area is only suitable for planting willow. The vegetation distance is 125 meters, because this path is only accessible for pedestrian and cyclist, with the limited speed of 30 km/h. Moreover, this area is nature conservation area in the characteristic of natural openness. I only design half of the roadside taken up by willow, because I would like to keep this openness for visitors. It is combined biomass sequence and productive function with natural openness.

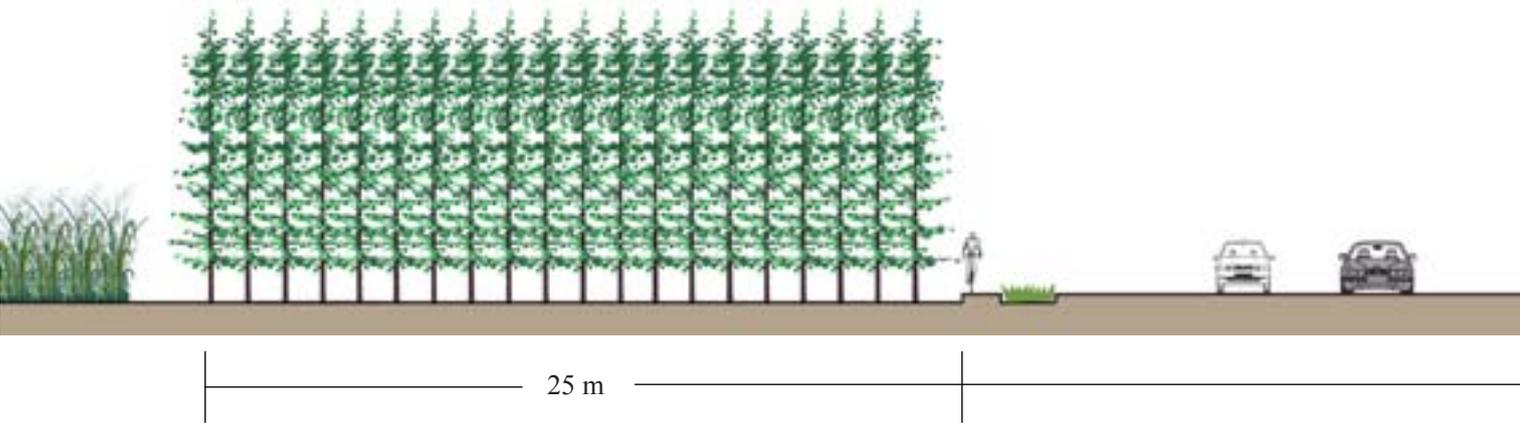


Figure 6.5: Model of roadside rhythm



Figure 6.6: Plan of roadside rhythm

Sequence - Location A (entrance)



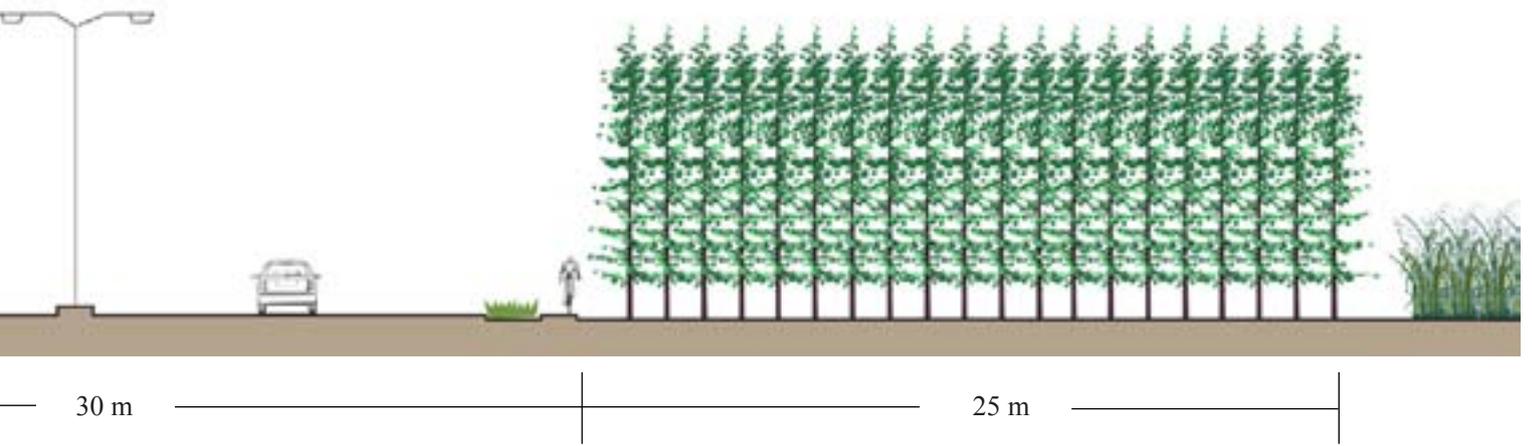


Figure 6.7: Section A - entrance



Figure 6.8: Visualization A - entrance

Sequence - Location B



Figure 6.9: Current situation B - urban built area (google map, 2009)

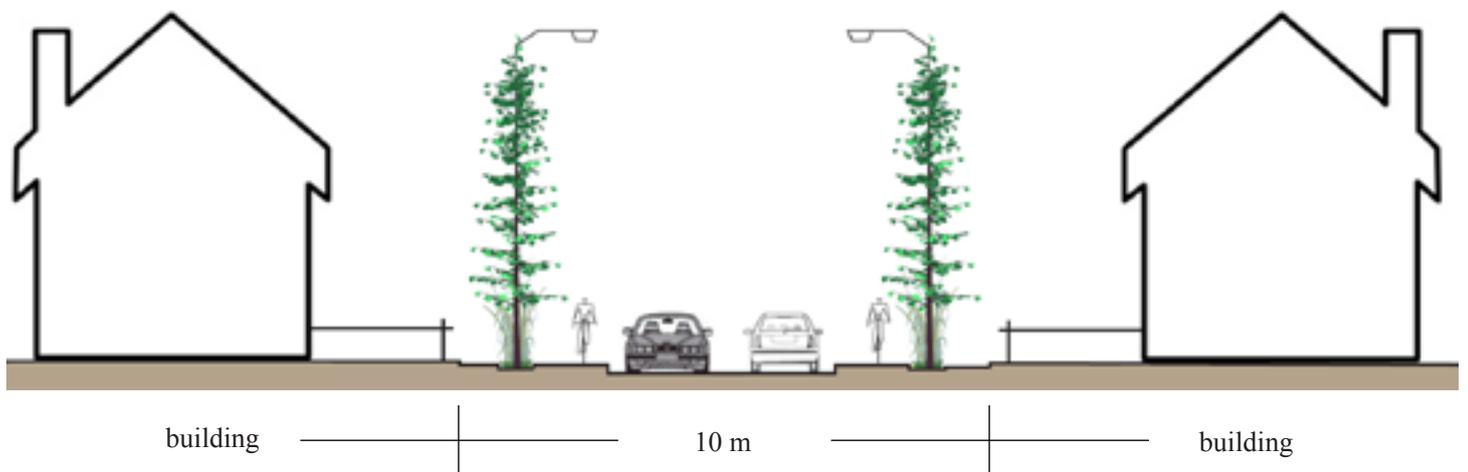


Figure 6.10: Section B - urban built area

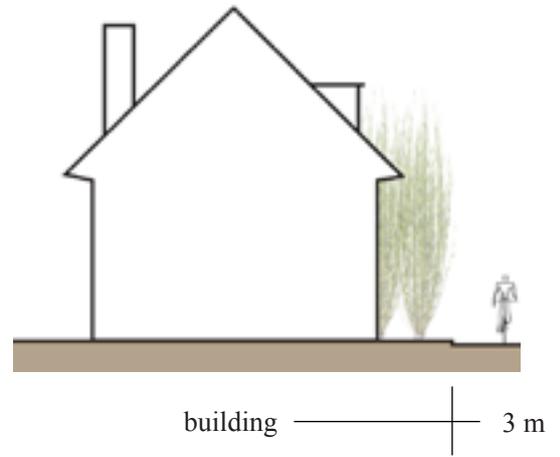


Figure 6.11: Visualization B - urban built area

Sequence - Location C



Figure 6.12: Current situation C - regional road (google map, 2009)



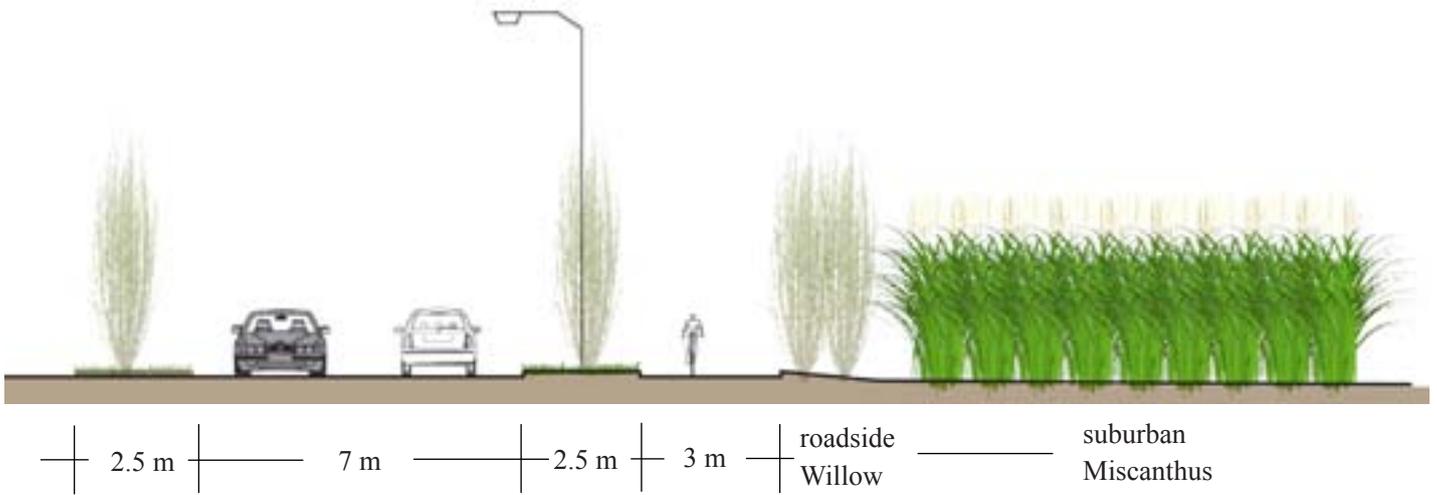


Figure 6.13: Section C - regional road



Figure 6.14: Visualization C - regional road

Sequence - Location D



Figure 6.15: Current situation D - boundary (photo by author)

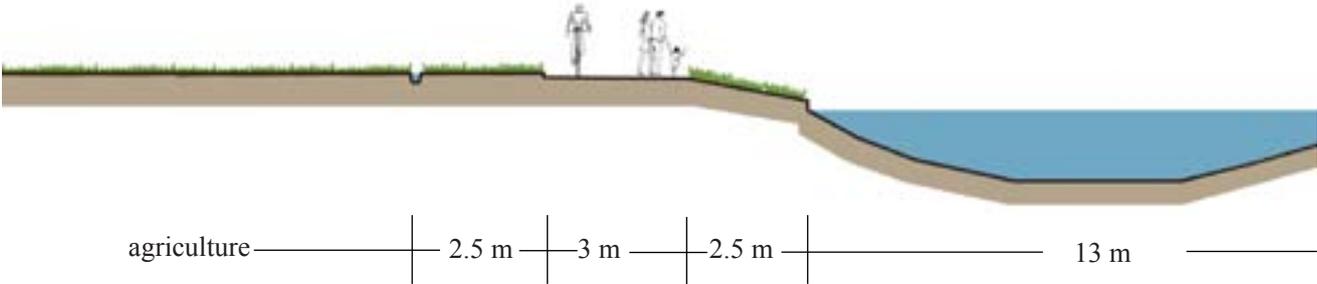
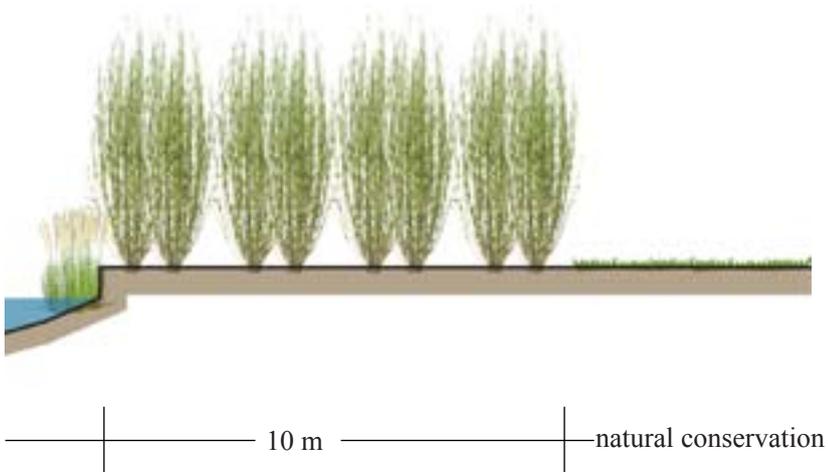


Figure 6.16: Section D - boundary



Figure 6.17: Visualization D - boundary



6.3 CONTROL (ORDER AND CARE)

6.3.1 Concept

Control reflects a sense of order and care, contributing to a human neat situation. Orderly landscape is a sign of neighborliness, hard work and pride (Nassauer, 1995). An orderly design not only forms a landscape which uses space effectively, but also expresses human control over nature (Saito, 2007). It completely matches the requirement of biomass production as well. Nassauer (1995) indicates that cues to human care expressions of neatness. People are generally familiar with these cues. Cues tell people whether the landscape is well looked after or not (Tveit et al., 2006). They include mowing fences, trimming edges and harvesting crops.

6.3.2 Model & Guideline

In the sub-urban area of Wageningen, agricultural land and forest are the main compositions (chapter 3.3.3, p. 64). Forest is a part of Veluwe (chapter 3.1.1, p. 39) which is an important mountain in the Netherlands, because it is a large natural habitat for flora and fauna. Therefore I only use agricultural land for biomass production.

This controlled biomass landscape displays the whole process of biomass vegetation from seeding, growing, harvesting, baling till transporting to biomass plants (e.g. CHP center = Combined Heat Power Center), and then converting to heat and electricity which are delivered to households (Fig. 6.17). It is a typical biomass landscape providing an alternative opportunity for citizens or visitors to get insight into biomass vegetation and its working process, and meanwhile join the beautiful landscape. For the purpose of productivity, in each land unit only mono biomass vegetation is planting. However in the whole agricultural area, different land grows variety vegetation. The reason is that the greater the homogeneity of agricultural landscape, the lower its perceived visual beauty, due mainly to the lack of color contrast (Arriaza, M., J. F. Cañas-Ortega, et al., 2004).

Guidelines:

- Display the whole process of generating biomass energy in sub-urban area

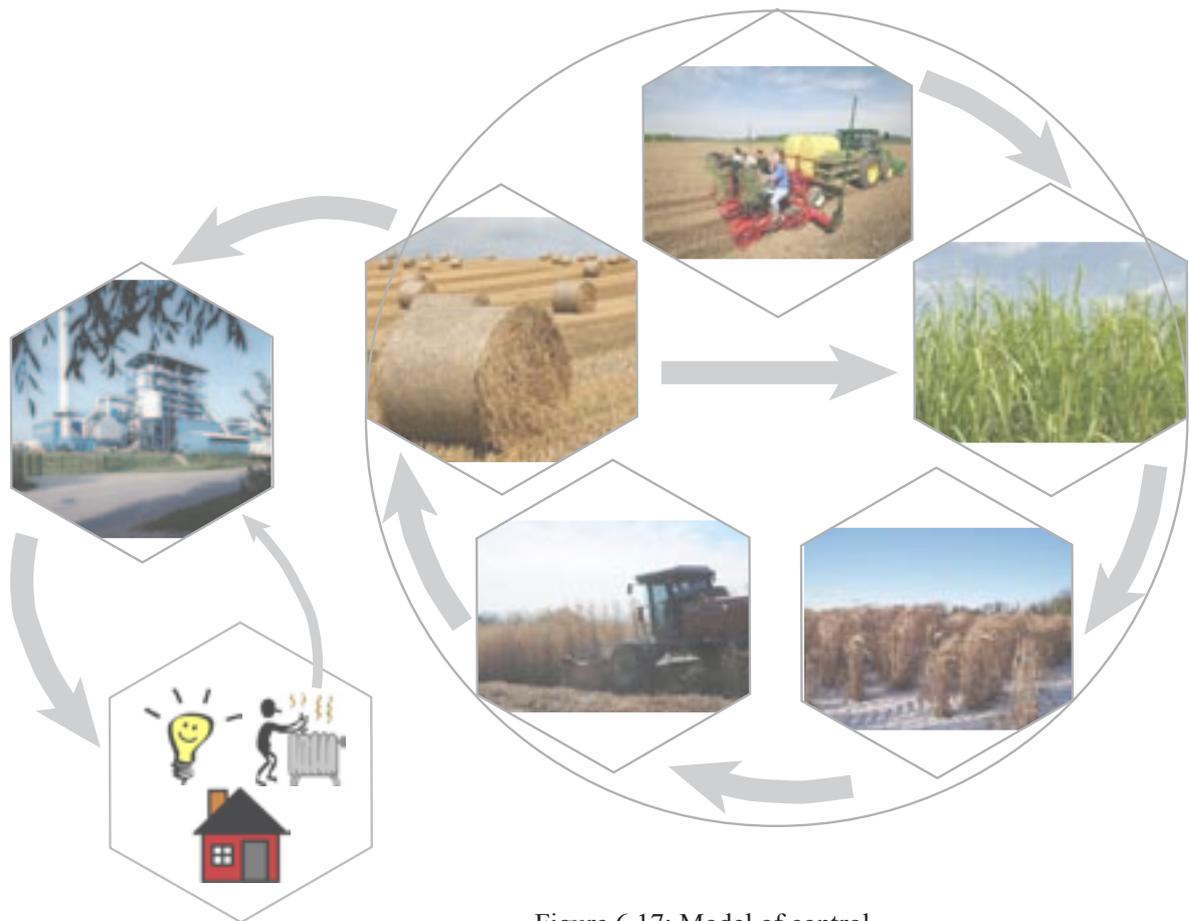


Figure 6.17: Model of control

- Planting only mono species in the same land unit
- Planting diverse biomass species (Arriaza, M., J. F. Cañas-Ortega, et al., 2004)

6.3.3 Plan & Visualization

As showing in Fig. 6.18, plan of biomass landscape in sub-urban is presented. Closed to the river, natural conservation field is kept to be open, for respect of its characteristic. Overlying with plan of sequence, I choose location E to display the controlled landscape by human care (Fig. 6.19). In suitability map, this area is suitable for growing willow and maize. Therefore the roadside rhythm consists of willow and maize. In terms of productiveness this land unit is cultivated with maize. Visualization E shows citizens are cycling in a sunny autumn day, for seeing the harvesting machinery and beautiful maize and other biomass vegetation (Fig. 6.20).



Figure 6.18: Plan of control



Figure 6.20: Visualization E



Figure 6.19: Plan of sequence and control

Control - Location E



6.4 COHERENCE (HARMONY AND BALANCE)

6.4.1 Concept

Coherence is a reflection of the harmony and balance of a scene. It also reflects the correspondence between land use and natural conditions in an area. It should reflect its basis geomorphology (vertical coherence), and interconnected of its elements as a whole (horizontal coherence) (Tveit et al., 2006). Bell (1999) explains coherence is understood by us that the comprehension of the whole is more significant than that of the individual parts. Harmony and balance have quality of relatedness. They can be created between similar plants' shapes, textures, lines and colors. The closer relationship between the visual characteristics of associated plants, the greater the harmony (Robinson, 2004). By repeating similar spaces or patterns landscape can achieve harmony as well. However harmony would be lost its identity because it depends on both similarities and differences. Contrast may contribute to differences through varying size or shape of space (Dee, 2001). Contrast does not necessarily mean conflict. It may be an attractive, if harmony and contrast balanced well. Designers must make a balance about how much contrast and harmony are required in the process of seeking coherence.

6.4.2 Guideline

Followed the coherence concept, variety of biomass vegetation are planted in same land unit. In urban area, each land has different functions for neighbours. The status of urban area is much more complex. Design needs to be done after land use analysis. In general, the guidelines of coherence are presented below.

- Choose similar biomass vegetation with similar visual characteristics (shape, line, texture or color) (Robinson, 2004)
- Planting in symmetric or asymmetric balanced pattern (Bell, 1996; Robinson, 2004)

Site Selection of Detail Design



Figure 6.22: suitability map of Ooststeeg

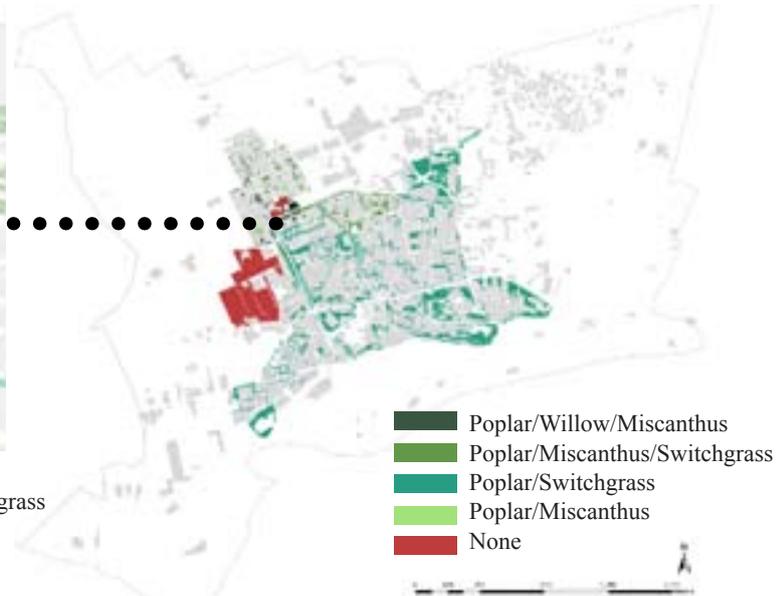
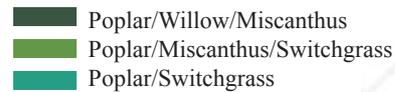


Figure 6.21: suitability map in urban area



Figure 6.23: current situation (google map, 2009)

6.4.3 Site selection and analysis

In the urban area of Wageningen, it includes four categories of suitable area from suitability map (Fig. 6.21). I choose the neighbourhood named Ooststeeg for detail design, because it contains three categories out of four (Fig. 6.22).

Site Analysis

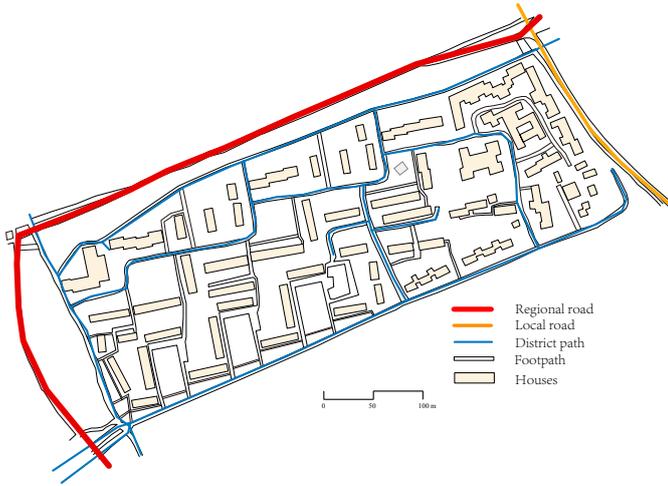


Figure 6.24: Traffic analysis

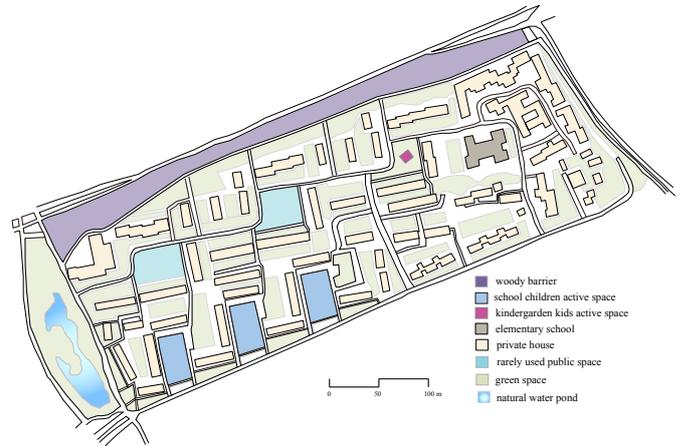


Figure 6.25: Human activity analysis

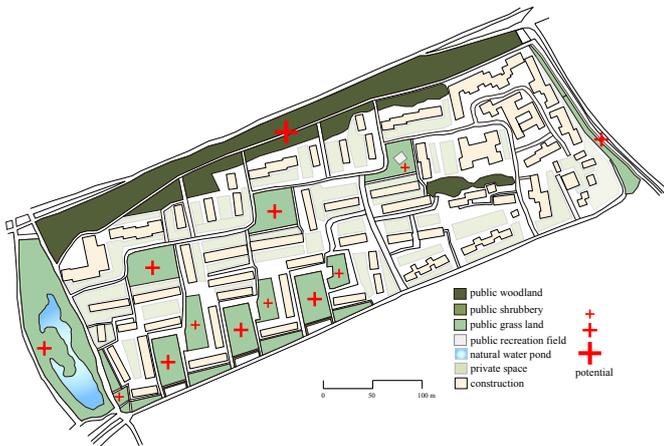


Figure 6.26: Potential green space analysis

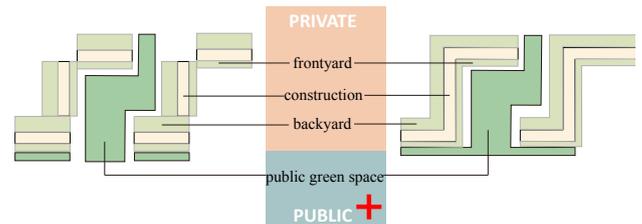


Figure 6.27: Building pattern analysis

Traffic Analysis (Fig. 6.24)

Ooststeeg is easy accessible because of an adjacent regional road.

Human activity analysis (Fig. 6.25)

There is an elementary school in the west of Ooststeeg. One baby recreation field which is colored dark purple locates near the school. Three fields in blue are the main space for children activity. Two light blue fields are rarely used by neighbors.

Potential green space analysis (Fig. 6.26)

All public green space is the potential area for biomass vegetation. According to area, location and function, each public green space has different potential degree. Between regional road and concentrated households, a long woody land is the largest potential area in Ooststeeg. Baby and children recreation field, and rarely used land are the second choices. A natural pond next to Ooststeeg is surrounded by green space as well.

Building pattern analysis (Fig. 6.27)

The typical buildings form in Ooststeeg is long building blocks. They formulate semi-open green space.

6.4.4 Detail Design

Figure 6.28 is the detail design of Ooststeeg which is on the basis of design concept, model and guideline. In the north, a large woody barrier consists of poplar and willow which not only have the function of providing renewable energy, but also block noise and sight line from regional road. Two rarely used green fields are created to symmetric patterns by poplar, willow, miscanthus and switchgrass. Next to woody boundary, a district combine heat power centre (CHP centre) is situated for convert vegetation to energy. CHP centre supplies electricity during whole year but only provide heat in winter. All residues from public space and private garden waste will be collected and sent to storage centre. This is the process will be accomplished by neighbors. This storage centre has another function of displaying various biomass vegetation sources. All local vegetation sources go to storage centre and convert to energy in CHP centre. CHP centre supply electricity and heat to each household. Water, as transmitter of heat, needs to return to CHP centre after warming up houses (Fig. 6.29).

Utilizing this process, an artificial water pond is established. It may create an exotic landscape in winter especially facing a natural water pond. In winter, waste water flows to artificial pond displaying the feeling of hot spring, while natural pond is probably frozen (Fig. 6.36). This landscape is not made of biomass vegetations, but an indirect energy landscape. Through the same landscape feature (water) combining different energy sources (natural and artificial), it shows a coherence landscape which contains both harmony and contrast visual landscape quality. This is one of three locations (location F, G and H) which I am going to show visualizations because they are the most interesting designs of Ooststeeg.

Location F



miscanthus and switchgrass
mixed baby playground



biomass leisure field



biomass leisure field

Location G



switchgrass labyrinth



biomass storage centre



biomass playground

Location H



artificial water pond



district combined heat
power center



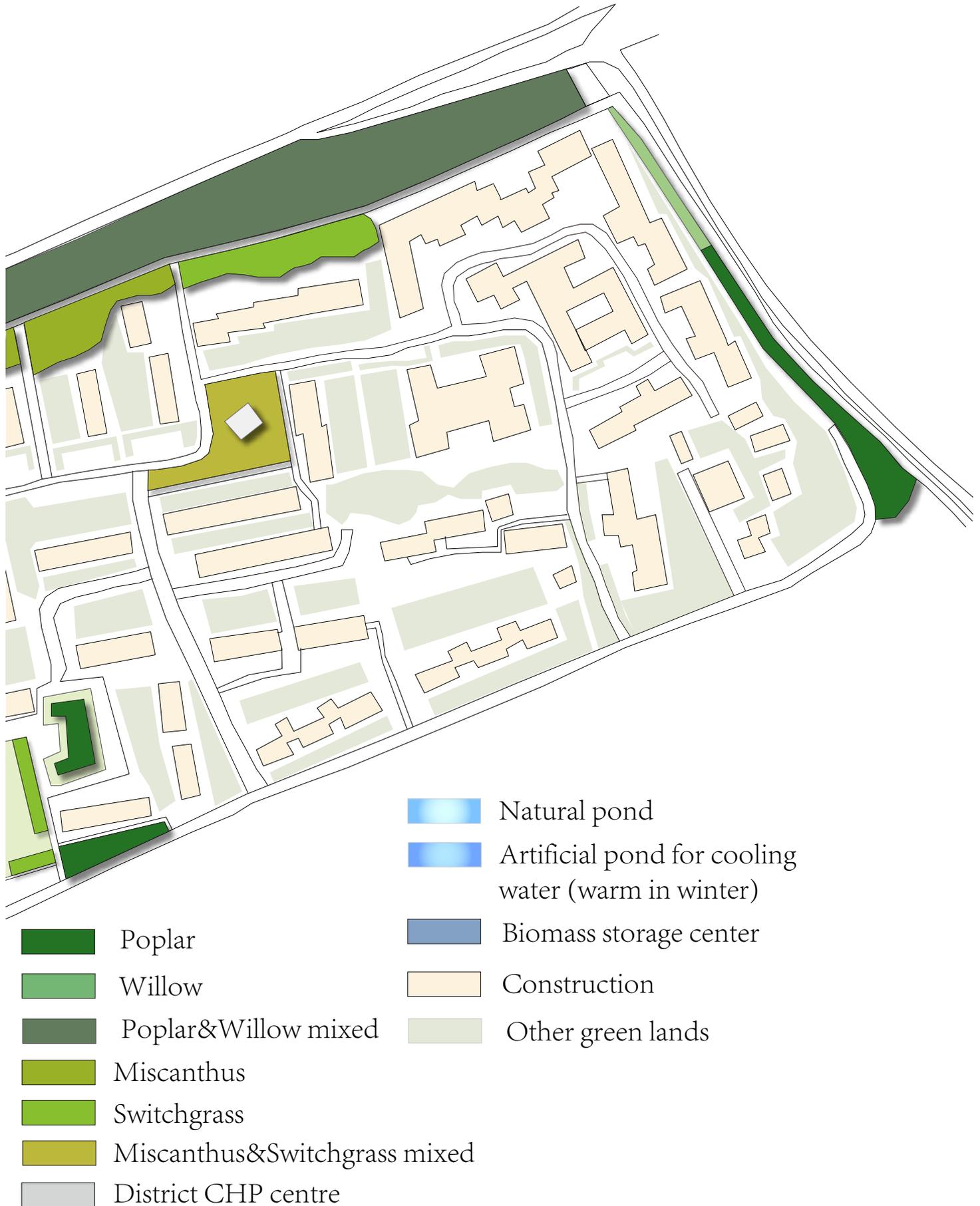


Figure 6.28: Detail design of Ooststeeg

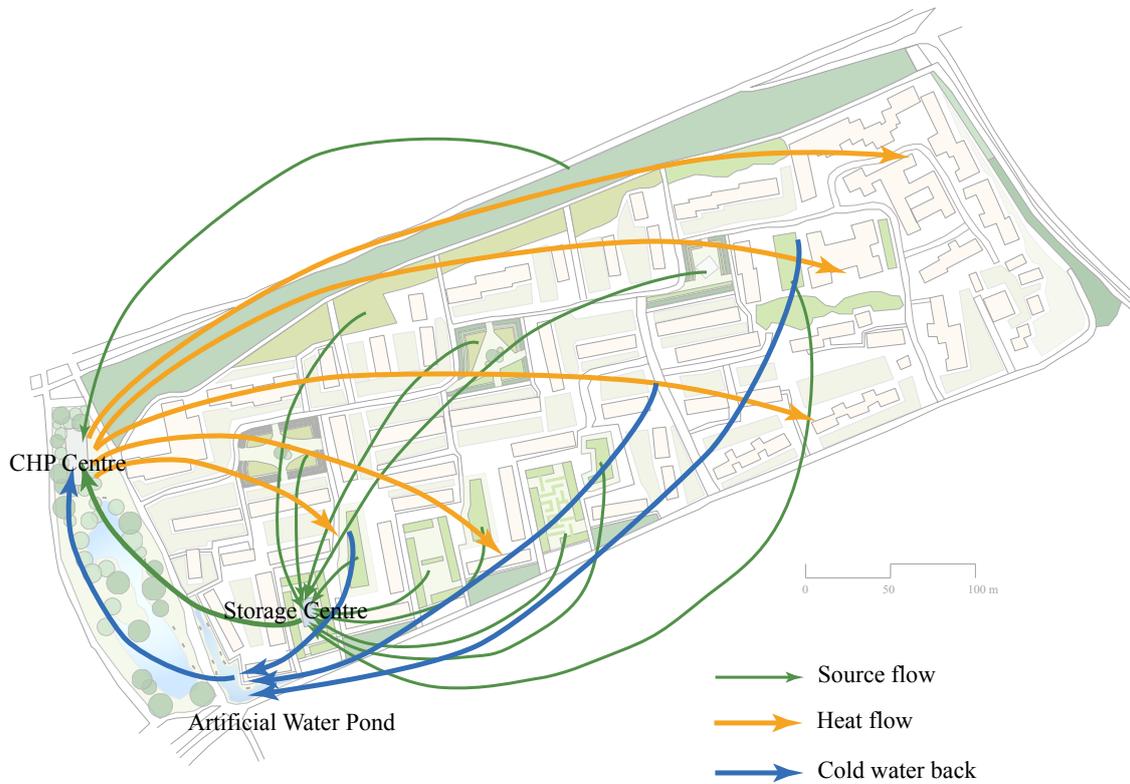


Figure 6.29: Energy flow map

Location F, in the east of Ooststeeg, miscanthus and switchgrass are chosen by suitability analysis. They are mixed planted for a feeling of harmony according to design guideline (Fig. 6.31). Location F is named switchgrass labyrinth (Fig. 6.34). This is not only the strongest landscape intervention by biomass vegetation, but also the most attractive view in Ooststeeg. Switchgrass labyrinth reveals the growing process of biomass vegetation. Neighbors could observe the fast growing speed and visual variety in different seasons (Fig. 6.33). It demonstrates to people that biomass vegetation could beautify our environment, make life variety and provide renewable energy as well.

Coherence - Location F

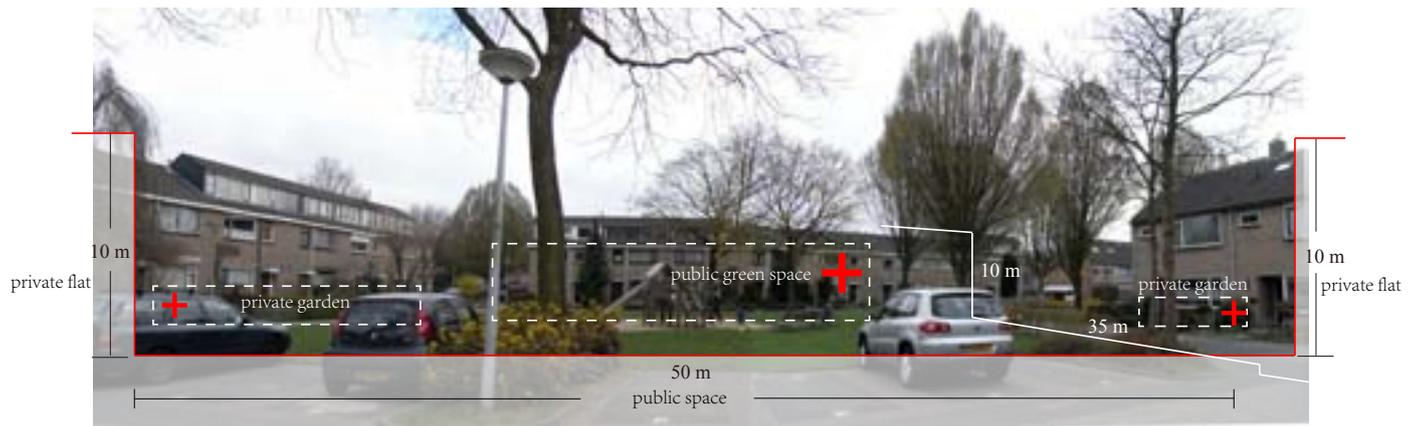


Figure 6.30: Current situation of location F (large green space between perpendicular blocks)



Figure 6.31: Visualization F

Coherence - Location G

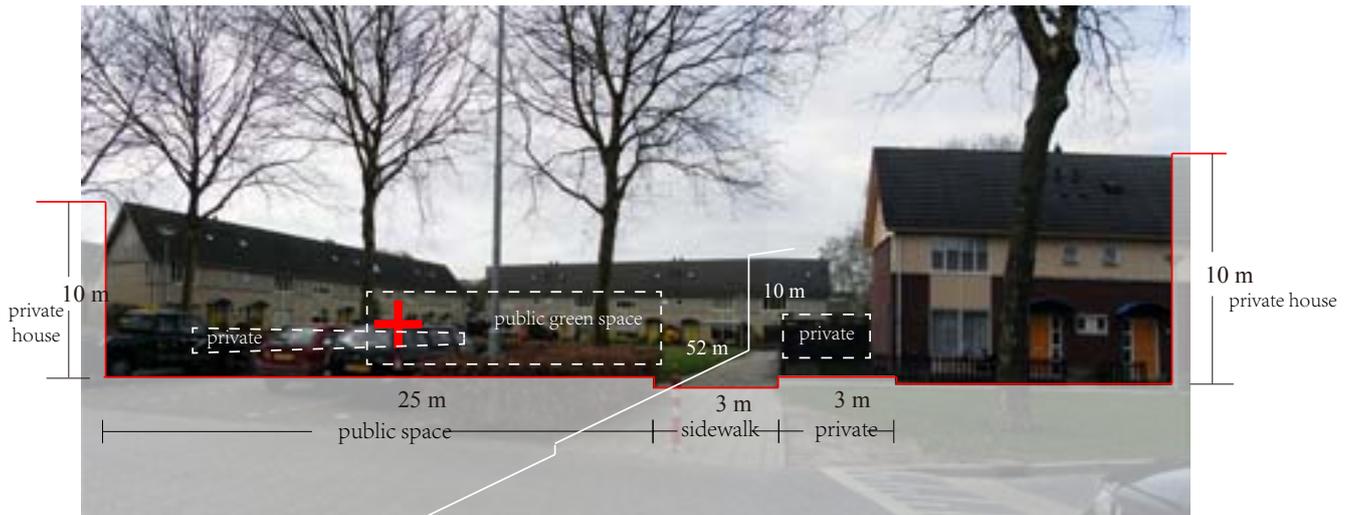
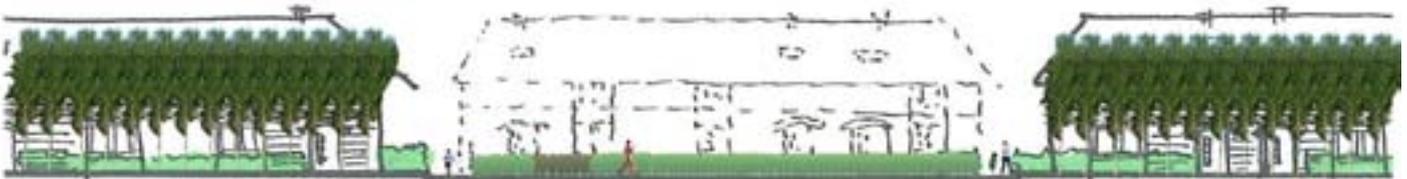
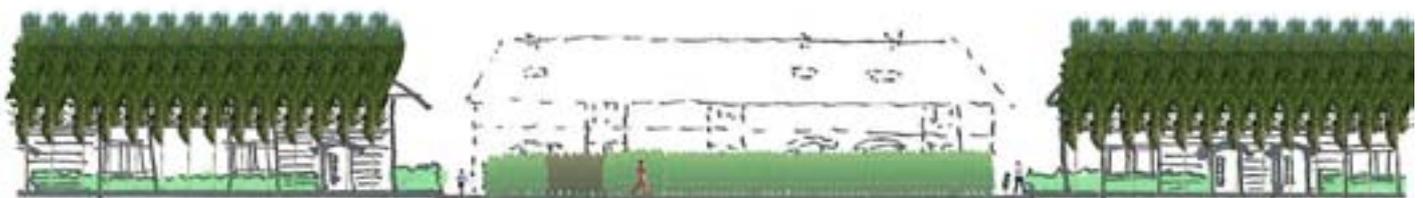


Figure 6.32: Current situation of location G (large green space between perpendicular houses)

Summer (switchgrass 1.0 m)



Autumn (switchgrass 2.0 m)

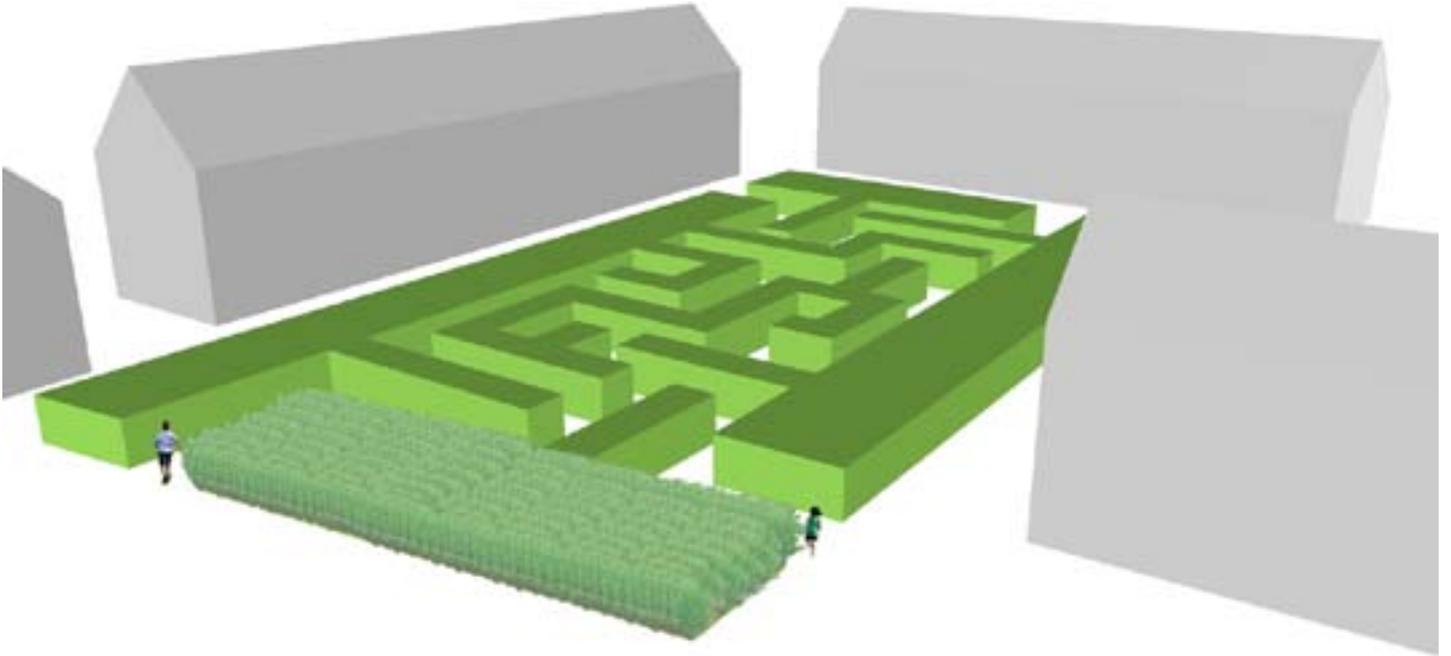


After harvest in early spring (switchgrass 0.15 m)

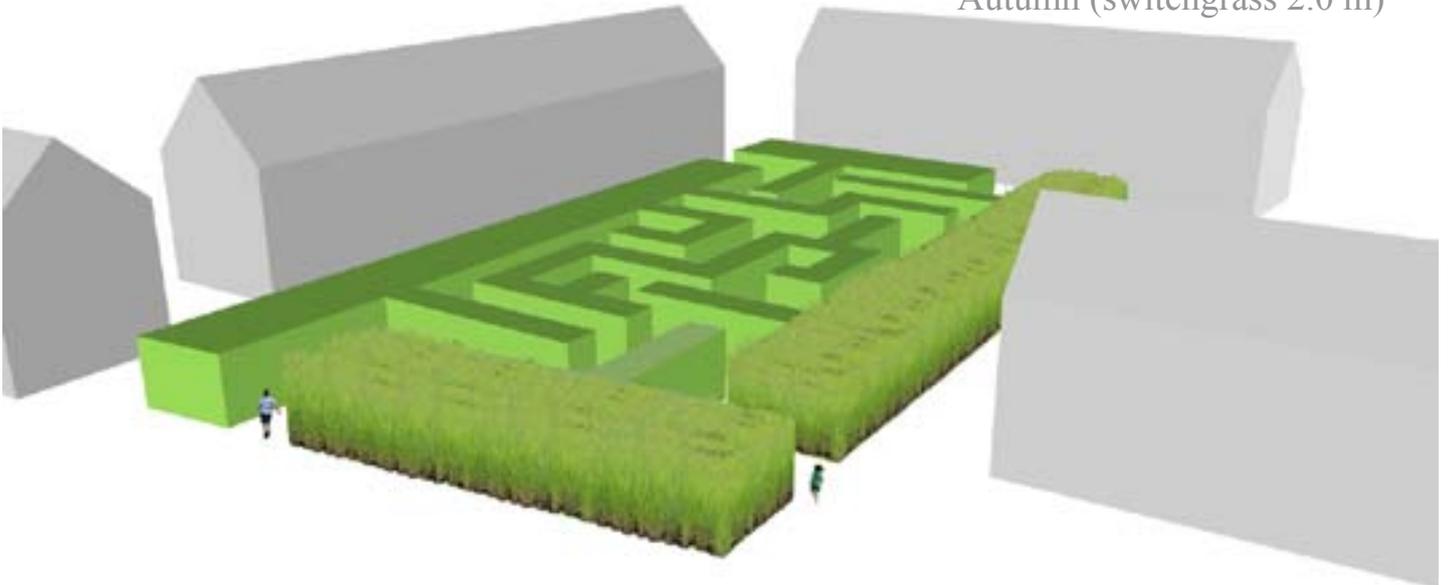


Figure 6.33: Design section of location G (summer, autumn and early spring)

Summer (switchgrass 1.0 m)



Autumn (switchgrass 2.0 m)



After harvest in early spring (switchgrass 0.15 m)

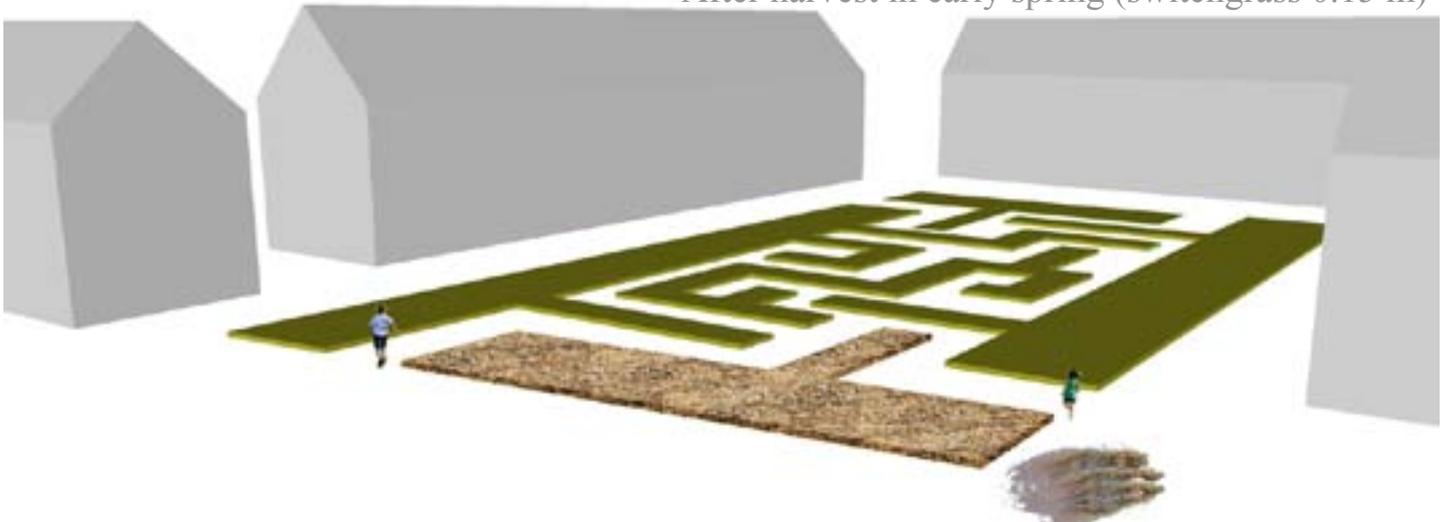


Figure 6.34: Visualization G (summer, autumn and early spring)

Coherence - Location H



Figure 6.35: Current situation of Location H



Figure 6.36: Visualization H

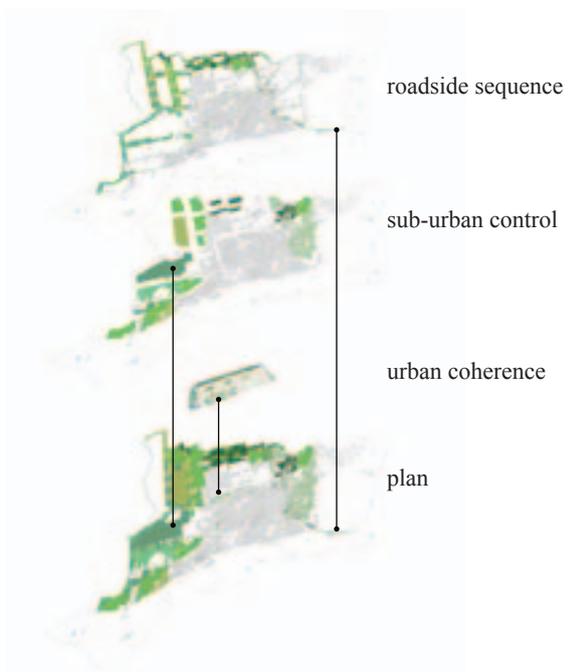


Figure 6.37: overly three concepts together

6.5 PLAN

Overlying roadside sequence, controlled sub-urban and coherence Ooststeeg, the plan is displayed here.



Figure 6.38: plan

REFERENCE

Arriaza, M., J. F. Cañas-Ortega, et al., 2004. Assessing the visual quality of rural landscapes. *Landscape and Urban Planning* 69(1): 115-125.

Bell, S. 1996. *Elements of visual design in the landscape*. London [etc.], Spon.

Bell, S. 1999. *Landscape: pattern, perception and process*. London, E & FN Spon.

Carlson, A., 1999. *Aesthetics and the environment: the appreciation of nature, art, and architecture*. London [etc.], Routledge.

Daniel, T. C., 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning*, 54(1-4): 267-281.

Dee, C., 2001. *Form and fabric in landscape architecture: a visual introduction*. London [etc.], Spon.

Jakobsen, P., 1977. Shrubs and Ground Cover, in Clouston, B. (ed.) *Landscape Design with Plants*. London: Heinemann.

Kaplan, R. & Kaplan, S., 1989. *The experience of nature: a psychological perspective*. Cambridge; New York, Cambridge University Press.

Lynch, K., 1960. *The image of the city*. Cambridge Mass., Technology Press.

Spirn, A. W., 1988. The poetics of city and nature: Towards a new aesthetic for urban design. *Landscape Journal*, 7, 108-126.

Nassauer, J. I., 1995. Messy ecosystems, orderly frames. *Landscape Journal*, 14, 161.

Robinson, N., 2004. *The planting design handbook*. Aldershot, Hants, England; Burlington, VT, USA, Ashgate.

Robinette, C., 1972. *Plants, people and environmental quality*. Department of the Interior. National ParkService, Washington DC.

Saito, Y., 2007. *Everyday aesthetics*. Oxford [etc.], Oxford University Press.

Tveit, M., Ode, A. & Fry, G., 2006. Key concepts in a framework for analysing visual landscape character. *Landscape Research*, 31, 229-255.

Tyrväinen, L., Pauleit, S., Seeland, K. & de Vries, S., 2005. Benefits and uses of urban forests and trees. *Urban forests and trees*. Springer-Verlag, Berlin Heidelberg, 81-114.

Chapter 7

Conclusion and Discussion

- 7.1 Answering the Research Questions
- 7.2 Discussion
- 7.3 Conclusion

After the whole process, I need to check if this design is fulfilling the purpose that I formulate in the beginning of this thesis. Therefore, I will give the answers of the research questions, evaluate visual landscape quality of my design and give some further recommendations.

7.1 ANSWERING THE RESEARCH QUESTIONS

Question 1:

What percentage of energy consumption can be provided with this design?

According to my design, I calculate the numbers of hectares of each biomass species in agriculture and roadside area, and then times their energy value. I get the result that the agricultural lands and roadside area can produce 336,880 GJ per year (Tab. 7.1).

Ooststeeg produces 710 GJ per year (Tab. 7.2). This neighborhood contains three categories (dark green, grass green and viridis) in suitability map (chapter 6.3.3). These categories are in the most neighborhoods of urban area. Therefore I calculate biomass energy of Ooststeeg by each category. Firstly, I count the occupied area of each vegetation per category, and calculate their percentage of total category area. Secondly, by using these percentages, I estimate other urban area which I did not design. Moreover, one category (light green) does not involve into design in Ooststeeg, however the suitability status of light green is similar with viridis color. They are both suitable for poplar and biomass grass (switchgrass or miscanthus), so visually the two types of grass could be observed as the same. According to this, I use the percentage of viridis to calculate the production of light green area. The biomass production of the rest urban area excludes Ooststeeg is presented in Table. 7.3.

Summing them up, biomass vegetation can produce 350,900 GJ per year in the city of Wageningen.

The total consumption of Wageningen is 991,500 GJ including electricity and heat (chapter 4.1, p.71). 35.4% is the result that my thesis has been seeking for (Fig. 7.2). In the future, Wageningen municipality is going to save 50% of current energy consumption (Fig. 7.1). That means my design reaches a much higher goal which supplies 70.8% energy of 'future' consumption after saving 50% (Fig. 7.3).

Table 7.1: Biomass energy produced by agricultural and roadside area

Agricultural Lands and roadside (calculate)			
Species	Energy Value (GJ/ha/y)	Area (ha)	Energy provision (GJ/y)
Miscanthus	623	230	143,290
Switchgrass	534	125	66,750
Maize	293	160	46,880
Poplar	220	100	22,000
Willow	184	315	57,960
Total	336,880 GJ / y		

Table 7.2: Biomass energy produced by Ooststeeg

Ooststeeg (calculate)			
Species	Energy Value (GJ/ha/y)	Area (ha)	Energy provision (GJ/y)
Dark green color: poplar/willow/miscanthus			
Poplar	220	0.4	90
Willow	184	0.35	65
Miscanthus	623	0.3	185
Grass green color: poplar/miscanthus/switchgrass			
Poplar	220	0.33	70
Miscanthus	623	0.04	25
Switchgrass	534	0.14	75
Viridis color: poplar/switchgrass			
Poplar	220	0.3	65
Switchgrass	534	0.25	135
Total	710 GJ/y		

Table 7.3: Biomass energy produced by other urban area exclude Ooststeeg

Species	Ooststeeg (calculate)		Other urban area (estimate)		
	Area (ha)	Percentage	Area (ha)	Energy Value (GJ/ha/y)	Energy provision (GJ/y)
Dark green color	1.6		1.4		
Poplar	0.4	25%	0.35	220	75
Willow	0.35	22%	0.31	184	55
Miscanthus	0.3	19%	0.27	623	170
open space	0.55	34%	0.47	0	0
Grass green color	0.53		11		
Poplar	0.33	62%	6.82	220	1500
Miscanthus	0.04	8%	0.88	623	550
Switchgrass	0.14	26%	2.86	534	1525
open space	0.02	4%	0.44	0	0
Viridis color	0.86		39		
Poplar	0.3	35%	13.7	220	3015
Switchgrass	0.25	29%	11.3	534	6035
open space	0.31	36%	14	0	0
Light green (estimate)			1.5		
Poplar		35%	0.525	220	115
Miscanthus		29%	0.435	623	270
open space		36%	0.54	0	0
Total				13,310 GJ/y	

Table 7.4: Biomass production in Wageningen

Energy provision in Wageningen	
Location	Energy provision (GJ/y)
Agricultural lands and roadside	336,880
Ooststeeg	710
Other urban area	13,310
Total	350,900 GJ/y

The total consumption of Wageningen: 991,500 GJ

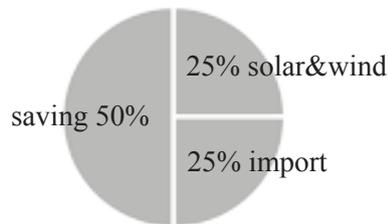


Figure 7.1: Wageningen municipality goal

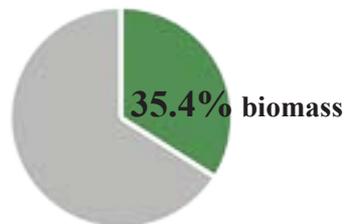


Figure 7.2: the percentage of current consumption provided by biomass

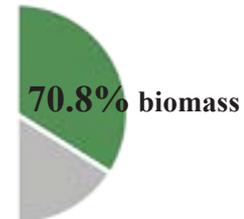


Figure 7.3: the percentage of 'future' consumption provided by biomass

With this design, biomass vegetation provides 35.4% of present energy consumption and 70.8% of energy consumption when saving 50%.

Question 2:

How does biomass vegetation create a visual attractive environment in the city of Wageningen?

Firstly, finding out what biomass species fit the local conditions and where are the best suitable places for these plants. Secondly, analyzing the visual characteristics of each biomass vegetation individually and then make combinations. Thirdly, selecting design concepts which is applicable for the site. Finally, according to the context, suitable locations and visual characteristics of biomass vegetation, and design concepts a visual attractive Wageningen is created.

7.2 DISCUSSION

Expert/design approach has been chosen to be the research orientation of visual landscape quality in this thesis. The assessment of visual landscape quality has only three classes of quality typically: low, medium and high, often with a substantial proportion of areas classified as medium (Daniel, 2001). As a consequence visual landscape quality will tend to remain in the same level over a quite range of area. This is the disadvantage. Moreover, expert assessment is determined by a single person, the reliability of individual landscape quality judgments is important (Daniel, 2001). However this design is created by me, I do not think assess my own work is reliable. I suggest evaluating the design by perception-based approach.

For the realistic practices and further researches, a few suggestions and statements elaborate below.

There is no information about soil types in the urban area of Wageningen, so I estimate it is sandy soil (chapter 3.3.1, p.57). That is why the plenty of urban area only presents the same suitability. For the future research this is the point could be improved before implementation.

In the section of biomass energy value calculation, I choose the highest productive number of each species to evaluate. However I am not sure whether these vegetations can reach the highest value in Wageningen. It needs to be tested in practice.

The first design concept is roadside sequence. I designed variety of biomass vegetation along streets and then calculate how much energy could be provided from them. However the production from roadside vegetation in urban and sub-urban land will probably lower than the calculation. The reason is the edge effect by human will make these lands different with other interior lands on productivity especially in urban area. Children may cross edges when the plants are under their knee.

In the neighborhood of Ooststeeg, I project a district combined heat power center closed to it. This district CHP center can supply heat and electricity to each household through energy system. However I am not sure about the relationship between the plant scale and its output. This could be a technical point for doing further research in depth.

I am aware of balancing biomass productivity and visual quality will cost extra time and more money, in the process of seeding, harvesting and transporting. This is the thing government should make a decision.

7.3 CONCLUSION

With this design, 35.4% of current energy consumption will be generated. After saving 50% of present energy consumption, Biomass vegetation will produce 70.8% of renewable energy for Wageningen, although I am not sure if these species can reach the highest value in geographic environment of Wageningen. I am proud of my design which I believe to create an attractive landscape, however attractive is such a subjective judgement. It cannot accept by everyone.

REFERENCE

Daniel, T. C., 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning*, 54, 267-281.

Twidell, J. & Weir, A. D., 2006. *Renewable energy resources*. London; New York, Taylor & Francis.

Appendix

Appendix A
Appendix B

Appendix A: Local vegetation in the city of Wageningen

○ ● ● Exposure (sun | semi-shade | shade)
10-20cm | damp Height | Soil type
■ ■ ■ Growth rate (slow | moderate | rapid)
■ ■ ■ pH value (acid | medium | alkaline)
■ ■ ■ ■ Flowering period (spring | summer | fall | winter)
white Flower color

GROUNDCOVER

Allium ursinum (Ramson)
25-45cm | damp



○ ● ●
■ ■ ■
■ ■ ■
■ ■ ■ ■
 white

Asplenium scolopendrium (Hart's tongue fern)
up to 100cm | damp



○ ● ●
■ ■ ■
■ ■ ■
■ ■ ■ ■
 no data

Campanula glomerata (Clustered bellflower)
20-60cm | range from sand to loam



○ ● ●
■ ■ ■
■ ■ ■
■ ■ ■ ■
 dark blue,
 purplish-blue

Campanula persicifolia (Peach-leaved bellflower)
60-90cm | moist soil



○ ● ●
■ ■ ■
■ ■ ■
■ ■ ■ ■
 white, sky blue

Campanula rapunculus (Rampion bellflower)
40-80cm | well-drained sandy, loamy



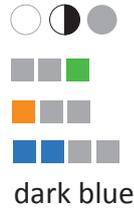
○ ● ●
■ ■ ■
■ ■ ■
■ ■ ■ ■
 light purple

Cirsium dissectum (Meadow thistle)
15-50cm | peat bogs

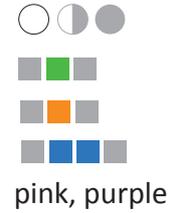


○ ● ●
■ ■ ■
■ ■ ■
■ ■ ■ ■
 dark red,
 purple

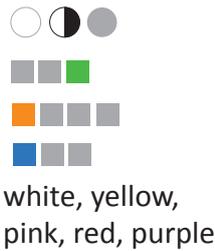
Gentiana pneumonanthe (Marsh gentian)
15-60cm | wet heath, peat bogs



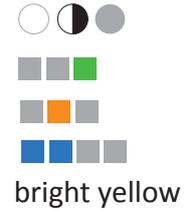
Origanum vulgare (Wild marjoram)
20-80cm | fairly dry soil



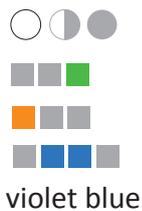
Primula vulgaris (Primrose)
10-30cm | moist meadow



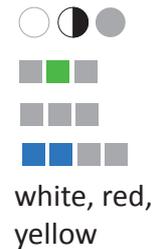
Pseudofumaria lutea (Yellow Corydalis)
30-38cm | no data



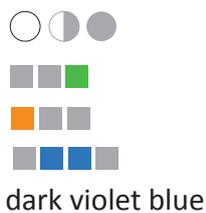
Salvia pratensis (Meadow clary)
100-150cm | limestone



Saxifraga stolonifera (Saxifrage)
7-10cm | loam



Veronica longifolia (Long-leaf speedwell)
70-100cm | moist soil



SHRUBS

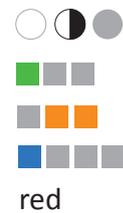
Corylus avellana (Hazelaar)

up to 6m | loam, sand



Crataegus laevigata (Midland hawthorn)

up to 12m | loam, clay



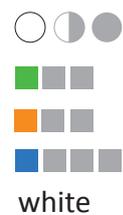
Michelia figo (Banana shrub)

3-4.5cm | well-drained sand



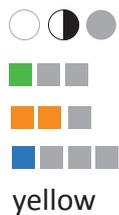
Salix caprea (Goat willow)

up to 10m | loam, sand



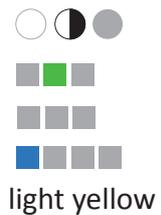
Sambucus racemosa (Red elder)

up to 3m | dry sandy



Viscum album (Mistletoe)

30-80cm | grow attached to the branch



TREES

Abies (Firs)

20-30m | sand



dark violet blue

Acer pseudoplatanus (Sycamore maple)

20-35m | loam, clay, sand



no data

Alnus glutinosa (European black alder)

15-30m | loam, clay, peat



no data

Betula pubescens (Downy birch)

10-20m | loam, wet sand, peat



no data

Carpinus betulus (Hornbeam)

15-20m | loam



no data

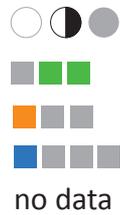
Castanea sativa (Sweet chestnut)

25-30m | loam, sand

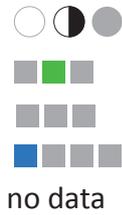


no data

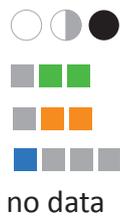
Chamaecyparis lawsoniana (White cedar)
up to 30m | loamy, sandy



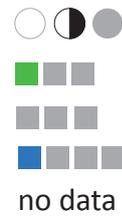
Fagus sylvatica (European beech)
50m | loamy, clay, sandy



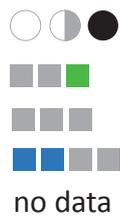
Fraxinus excelsior (European ash)
15-40m | loamy, clay



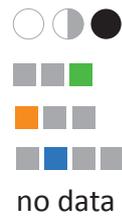
Ilex aquifolium (Holly)
8-20m | no data



Larix decidua (European larch)
15-30m | loamy, sandy



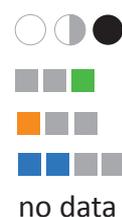
Picea abies (Norway spruce)
up to 35m | sandy



Picea omorika (Serbian spruce)
25-30m | sandy



Pinus strobus (Weymouth pine)
20-30m | loamy, sandy



Populus (Poplar)

15-50m | clay



pale yellow,
red, purple

Prunus avium (Wild cherry)

15-20m | loamy, sandy, limestone



white

Pseudotsuga menziesii (Douglas fir)

30-50m | loamy, clay, sandy



no data

Pyrus communis (Cultivated pear)

15-25m | loamy



white, pink

Quercus rubra (Red oak)

20-30m | dry sandy, loamy



no data

Robinia pseudoacacia (Robinia)

15-30m | sandy, loamy



white

Salix fragilis (Crack willow)

up to 30m | sandy, loamy



yellow

Salix pentandra (Bay willow)

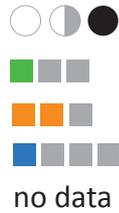
up to 10m | no data



yellow

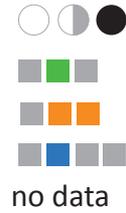
Taxus baccata (Yew)

10-20m | no data



Tilia cordata (Small leaved linden)

10-35m | loamy, sandy, clay



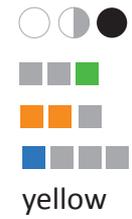
Tilia x vulgaris (Common European linden)

20-35m | loamy, clay, sandy



Ulmus minor (European field elm)

up to 20m | loamy



Appendix B: Design concepts of visual landscape quality

Concepts	Synonyms	References
Control	order; care; maintenance	Nassauer, 1995; Bell, 1996; Dee, 2001; Saito, 2001
Coherence	unity; balance; harmony	Nassauer, 1995; Bell, 1996; Bell, 2001; Daniel, 2001; Dee, 2001; Robinson, 2004
Historicity	historical continuity; cultural significance	Bell, 1996; Daniel, 2001; Dee, 2001
Visual scale	enclosure; openness	Bell, 1996; Bell, 1999; Dee, 2001; Robinson, 2004
Genius loci	spirit of place; uniqueness; distinctiveness; vividness	Lynch, 1960; Bell, 1996; Bell, 1999; Daniel, 2001
Complexity	diversity; variation; complexity of patterns and shapes	Lynch, 1960; Bell, 1996; Bell, 1999
Naturalness	intactness; wildness; natural; ecologically robust	Kaplan, R. & Kaplan, S., 1989; Nassauer, 1995; Daniel, 2001
Sequence	change; dynamic; rhythm	Spirn, 1988; Kaplan, R. & Kaplan, S., 1989; Bell, 1996; Daniel, 2001; Robinson, 2004

REFERENCE

Bell, S. 1996. *Elements of visual design in the landscape*. London [etc.], Spon.

Bell, S. 1999. *Landscape: pattern, perception and process*. London, E & FN Spon.

Carlson, A., 1999. *Aesthetics and the environment: the appreciation of nature, art, and architecture*. London [etc.], Routledge.

Daniel, T. C., 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning*, 54(1-4): 267-281.

Dee, C., 2001. *Form and fabric in landscape architecture: a visual introduction*. London [etc.], Spon.

Kaplan, R. & Kaplan, S., 1989. *The experience of nature: a psychological perspective*. Cambridge; New York, Cambridge University Press.

Spirn, A. W., 1988. The poetics of city and nature: Towards a new aesthetic for urban design. *Landscape Journal*, 7, 108-126.

Lynch, K., 1960. *The image of the city*. Cambridge Mass., Technology Press.

Nassauer, J. I., 1995. Messy ecosystems, orderly frames. *Landscape Journal*, 14, 161.

Robinson, N., 2004. *The planting design handbook*. Aldershot, Hants, England; Burlington, VT, USA, Ashgate.

Saito, Y., 2007. *Everyday aesthetics*. Oxford [etc.], Oxford University Press.

