

Exploring a communicative tool for community-based planning and design

Case study: Hoeksche Waard

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Abstract — In a society in which the role of the citizen becomes more and more important the procedures that design and plan the rural environment are changing. The community that resides in the area is no longer only a user of the space but also a stakeholder in development procedures. An important aspect of these latest procedures is adequate communication between stakeholders. In order to facilitate the communication this thesis explored the possibilities of a planning and design tool that creates mutual understanding between stakeholders by transferring knowledge and thus tries to eliminate conflicts by determining mutual benefits. Through a systematic approach towards the organization of the landscape the social and ecological processes in the landscape are dissected and simplified. Consequently the processes are more suitable to model and easier to understand. Although a community-based planning and design tool would need substantial more research and geospatial data before it would be fully operational, facilitating communication in community-based planning and design procedures with the conceptualized demonstrator of a Landscape Information Modelling Tool appears to be promising.

Keywords— Communication tool, Community-based planning, Geographical Information System, Interface design, Landscape functions, Landscape services, Landscape values, Social Ecological Systems.

1. INTRODUCTION

1.1 Problem and Objective

Within the field of the built environment the current trend in computer aided design (CAD) is combining three-dimensional models of buildings with other available information such as use of materials and use in order to create a building information model (BIM). These models contain the information needed to virtually built and 'use' the building in order to indicate where problems might arise so that these problems can be dealt with before actually building the structure (Verbaan, 2011). The term landscape information model (LIM) was introduced by Marc Goldma (2011) to address the fact that in landscape architecture and land use planning a BIM like system is also possible. As is the case with BIM concerning single buildings an important part of LIM would be the view of a landscape as a system. According to Jonkers (2011) society consist of networks that interact with each other in order to transfer material and immaterial services. Apart from society Jonkers states that the physical environment in which society exists can also be seen as a living system that consists of many subsystems. Jonkers states that any area is a network of systems through which value streams submits capital to the area (van Rooy, 2011). The notion that the spatial network facilitates the social networks is supported by Hillier (2007). He elaborates on this by stating that space is more than a static framework for social and cultural interactions. All kind of interactions, human as well as natural, do not only occur in space, they define the space. These interactions come in many different forms; there are passive interactions like the perception of the landscape but also more active interactions like cultivating the land in order to use the landscape for food supply. However, in order to optimize the use of the landscape for its use for society the ecology of the landscape will sometimes be altered. These alterations are imposed by changes to the physical landscape and because

of the connection between the physical landscape and the ecological subsystem of the environment the ecological subsystem changes too (Termorshuizen en Opdam, 2009).

Some of these subsystems are already modelled but these are mainly monodisciplinary and confine themselves to one of the subsystems (Geertsema, Van der Heide and Blaeij, 2007). An example of such a subsystem model is LARCH, which focussed on ecological networks. The model of LARCH is therefore confined to workings of the ecological subsystem (Pouwels, et al., 2002). Another example is the CLUE-S modelling tool that is used in the analysis of land-use in small regions. Through the analysis of several scenarios CLUE-S helps to identify specific locations that could be endangered through environmental change (Verburg and Mastura, 2002). This tool is limited to the impact of environmental changes and does not take human induced changes into account. Furthermore, according to Geertsema, Van der Heide and Blaeij (2007) many modelling tools are not interactive, the models are capable of modelling the current status and the consequences of that status to the respective subsystem. However, it is not possible to change spatial characteristics in the LARCH and CLUE-S models in order to visualize the changes caused by spatial alterations to the respective subsystems.

The problem this thesis addresses is the absence of an adequate interactive interdisciplinary tool (Geertsema, Van der Heide and Blaeij, 2007) that combines multiple subsystems into one model and visualizes the interrelations between the variables in the several subsystems. Because of this absence the question whether or not such a tool could facilitate communication in community-based planning and design procedures in a rural environment arises. When changes are made to the rural environment in order to improve the functioning of one or more aspects other aspects are also influenced. In order to manage the land use

and facilitate the communicative processes of planning and design an interactive BIM-like tool could enable planners and other stakeholders to foresee the impact of changes. Since the development of a complete LIM-tool will not be possible in a thesis of this magnitude the objective of this research is to explore the criteria for a simplified demonstrator version of the proposed LIM-tool in order to show the possibilities for the concept of landscape information modelling.

1.2 Case Study

The Hoeksche Waard is a suitable case study for this thesis since the area has been the subject of other studies by Geertsema, et al. (2004; 2006) on the impact of spatial properties on the use and management of the landscape. These previous studies collected information on the area, the stakeholders, the desired future for the area and community-based planning within a rural environment. As depicted in figure 1 the Hoeksche Waard is located in the south of the province of South Holland between the harbour city of Rotterdam and the provinces of North Brabant and Zeeland the Hoeksche Waard borders to the natural reserve the Biesbosch. Because of the low building density of the area several more parts of the area are designated as natural reserves. The Hoeksche Waard is mainly arable land, which is cultivated by several local farmers. However, the Southside of the Hoeksche Waard offers the possibility for ecologic developments. The foremost function is that of water retention of excess river discharge. On an organisational level the Hoeksche Waard is divided in six municipalities that all have a say in the future developments in the area (Hajer, 2001). Other stakeholders in the region are the Commissie Hoeksche Waard (CHW), which is collaboration between multiple municipalities in the Hoeksche Waard, the ministry of Infrastructure and the Environment, the ministry of Economic Affairs, Agriculture and Innovation and the province of South Holland. Furthermore the farmers, livestock and agricultural, some of which are organised in local associations, and the individual inhabitants play a role in the development of the area (Geertsema, et al., 2004).



Fig. 1 Hoeksche Waard in the Netherlands (de Koe, 2013)

From the inhabitants and farmers perspective the attachment with the Hoeksche Waard landscape is strong. Distinctive for the region are the spacious polders that are being used for agricultural activities. These polders are being separated by robust inner dikes, which are planted with multiple tree rows. Together with the private yard planting the dikes and creeks form the most important aspects of the landscape identity. These green (e.g. dikes, road verges etc.) and blue (e.g. creeks, ponds etc.) aspects are also the main carriers of the ecological networks of the area (Geertsema, et al., 2004).

1.3 Methodology

In order to realize the objective the first step was to specify the necessary planning theory in order to justify the need for an innovative communication tool in community based planning. Thereafter the theories on a systems approach towards understanding the landscape were researched. With these theories on the social physical organisation and social ecological system the relations between the physical environment and society will be justified. The next step was to dissect the landscape into several different subsystems each consisting of multiple processes. During this phase the quantity of information is almost limitless since the number of processes within the landscape are numerous and the connected variables are a multitude of that. The key, and most of the research of this thesis, is related to making well-argued choices regarding the most relevant and explicit landscape processes and their respective variables in order to conceptualise an operative and understandable demonstrator. When the interrelations of the relevant variables are dissected the complexity of the demonstrator will probably be too great. Again choices will have to be made to integrate only a select number of variables that were needed for creating an adequate demonstrator. The next step is to conceptualise an interface for the demonstrator that is shaped to the capabilities of the intended users and their needs regarding communication within community based planning procedures. Finally, several criteria for a LIM-tool will be determined through experiences from other tools. The demonstrator will in turn be addressed on its performance concerning the determined criteria and its capabilities.

2. COMMUNITY-BASED PLANNING

2.1 Trends and Definition

Paradigms within every sector are changing. Due to the financial, energy and climate crises civilisations are losing trust in the central, bureaucratic and hierarchical ordered society. Citizens want to participate in procedures that are shaping the world around them. The planning discipline will also be affected by this global trend and a shift from top-down to a more bottom-up procedure is eminent (Rotmans, 2012). The decentralisation of responsibility and growing importance of local decision-making, because of the previously mentioned trend of changing paradigms concerning governance, are both aspects that are of value in community-based planning and design creates the need for a (new) framework for collaborative planning procedures. (Lane, 2003). Conventional spatial planning is an expert driven model that somewhat patronizes the community in a sense that the planners will tend to assume they know what is best for the community (Watson, 2006). According to van Assche & Duineveld (2005) projects that involved the community did so often only on a superficial level where the communities' opinion was heard but not necessarily used. The fact that the community becomes more and more important within the planning discipline makes for a growing sense of social responsibility. According to van Assche & Duineveld (2005) governments and spatial experts increasingly involve the citizens and their communities in planning processes in order to create more public support for their plans. This form of planning is called community-based planning. Glover, Stewart & Gladdys (2008) state that

community-based planning needs democratic methods to represent the values of all stakeholders. Only by doing so will the planners be able to plan with sensitivity for the lives and values of the people for whom the plan is being made.

A pressing issue within community-based planning is the difference between the stakeholders. These differences vary from the desired futures to perceptions but most problematic is the difference in knowledge. In planning there are two kinds of knowledge. There is local knowledge, which is the knowledge of citizens or communities based on their social and historic experiences with the area and expert knowledge, which is a more scientific knowledge based in theory and planning concepts. The subjective local knowledge will often be perceived as less valuable in relation to expert knowledge (van Assche & Duineveld, 2005). This hierarchy complicates the planning procedure and a measure to counteract this is by facilitating knowledge transfer between stakeholders. By doing so all stakeholders will have similar knowledge, local as well as expert, and understanding between stakeholders rises. Cash, et al. (2003) argue that in order for knowledge transfer to be effective the transferred knowledge should be reliable, relevant and valid, which means that the information must be shared through adequate channels so that the information is not subject to change or out-dated because of a communication delay. Still, communication seems to be of vital importance in community-based planning procedures and should be facilitated as best as possible in order to plan an adequate environment for the stakeholders.

2.2 The Importance of Communication in Community-based Planning

Allmendinger (2009) states that community-based planning is a form of collaborative planning. According to Forrester (1989) collaborative planning must be seen as a communicative process. By communicating about things such as a common vision and prioritising the current problems the tension between private and public interest reduces. Moreover, understanding between stakeholders and governmental planners and experts is crucial to the development of a community-based planning model (Cheng, Kruger & Daniels, 2003). Hence the need for the proposed LIM-tool that makes the consequences of interventions visible in order to support the transfer of knowledge between the stakeholders and thus create mutual understanding between the stakeholders (Al-Kodmany, 2002).

According to Simão, Densham & Hakley (2009) the advancement of communication methods makes it much easier to communicate. Electronic methods of communication like the Internet makes it possible to distribute and exchange maps and texts documents over large distances. Making all information available for all stakeholders facilitates the procedures since the actors do not have to arrange special visits to public facilities for information such as libraries or travel to the project area in order to see the area for themselves. Additionally, with current communication techniques a wider audience can be reached what in turn makes for a more complete collaboration. Lastly, time constraints could be removed and the financial gain that could be reached by such efficiency would also be a noteworthy benefit (Simão, Densham & Hakley, 2009).

2.3 Current Community-based Planning Tools

The philosophy behind making a tool for collaborative planning procedures is the fact that people tend to be more willingly to adapt when they are consulted (Bressers, 2007). Furthermore, every stakeholder wants to maximize his own utility and by involving the stakeholders a balance between their utilities can be reached (van der Heide, de Blaeij & Heijman, 2008). As stated above, there are multiple GIS-based planning and design tools. However, most of the tools that have the possibility to facilitate collaborative planning procedures are challenging to use and rely on a certain level of expertise from its users (Planning Tool Exchange, 2013). Since most of these tools are specialized in one or two processes within the planning discipline the tools are inadequate for most of the stakeholders since they do not act within those specific processes. The need for a tool that operates within and between multiple disciplines is an important aspect for community based planning since mutual understanding of each others driving factors is needed regarding all processes in the landscape (Boroushaki & Malczewsk, 2010).

A similar preceding tool has been developed by van der Heide, de Blaeij & Heijman (2008). This tool is called RITA, which is a Dutch acronym for spatial explicit interactive interdisciplinary trade-off method. The focus of this tool is the ecological and economical value of the green-blue veining of an area. However, there are restrictions to the number of variables that can be taken into consideration according to Geertsema, van der Heide & Blaeij (2007) since RITA operates on the basis of the choices of stakeholders. Therefore there has to be data on what stakeholders want before creating the model. The proposed LIM-tool should not have these restrictions since it operates on the basis of a systems approach towards the landscape in which the subsystems in the landscape are being modelled. The interrelations between the subsystems will be apparent even though the stakeholders' desired futures have not been specified.

2.4 Conclusion

Because of the low population density in the Hoeksche Waard (Geertsema, et al., 2004) the number of actors is small but their incentives still differ, especially among farmers who have business interests and personal interests. With a community-based planning procedures for determining the green-blue veining in the Hoeksche Waard the interests of all stakeholders could be taken into account because the community at large could determine the interventions needed to achieve their desired future as stated in Geertsema, et al. (2004). The individual owners could in turn resolve in what way they can assist to achieve this. According to the case study reports this procedure took a significant amount of time and multiple session in order to achieve this level of cooperation. The LIM-tool demonstrator could greatly reduce this period with a clear representation of the status quo and the relations between certain aspects of the landscape. The proposed interactivity of the LIM-tool concerning the alteration of the landscape and the information the tool should give makes it possible for the stakeholders to make virtual interventions in order to assess the consequences and by doing so finding an adequate solution.

3. SYSTEMS APPROACH TO UNDERSTANDING THE LANDSCAPE

3.1 Social Physical Organisation

In order to understand the workings of the system that is present in the rural environment Kleefmann (1989) introduced a model of the social-physical organisation referred to with the Dutch acronym (MFO) in which the system of an area is divided in several subsystems as depicted in figure 2. Initially Kleefmann poses that our environment is grounded in a natural organisation that has been formed by a biotic and an abiotic subsystem. The biotic subsystem consists of all flora and fauna and the abiotic subsystem consists of geological systems such as soil and rock formations.

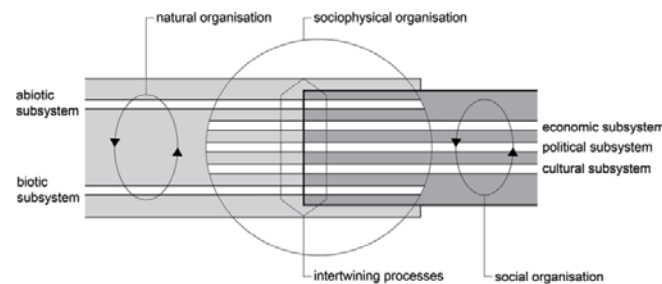


Fig. 2 Social Physical Organisation model (Kleefman, 1989)

Within these physical conditions the social organisation operates. The social organisation consists of economic, political and cultural subsystem. Kleefmann defines the whole as the social physical organisation. Within all these systems there are several values that can be influenced by the other systems since the whole social-physical organisation is intertwined (Hidding, 2006). This MFO concept can be equated with the People, Planet, Profit theory of Elkington (1998) which states that sustainable development can only occur when social, ecologic and economic aspects of development are in balance with one and another.

3.2 Social Ecological System

The notion of an interdependent linkage between the several aspects of our life world is also underwritten by the Social Ecological System (SES) theory of Berkes, Colding, and Folke (2001). The SES-theory considers a landscape as a two-sided interaction between the human society and the physical system. The most evident interdependencies of the SES model are (1) human use and valuation of landscape services and (2) human interventions to the physical system and therewith changing the landscapes spatial characteristics. This valuation of landscape services can be valued from the several perspectives that are present in the natural organisation of the MFO model; economic value, political value and cultural value.

According to Termorshuizen en Opdam (2009) a landscape has the potential to provide several landscape services. Every landscape has its own spatially explicit characteristics e.g. plains, hills, ditches, hedgerows, water features, etc. These characteristics determine the possible functions of the landscape. The function of the landscape is derived from the interaction between the physical structures in the landscape,

which are at the base of natural processes and human interference. The fact that stakeholders in an area can value or appreciate the landscape functions justifies the term landscape service since it provides a service to the stakeholders. Figure 3 depicts a schematic representation of this theory called the structure-function-value chain. This scheme will be the bases on which the several landscape services used in this thesis will be dissected in order to understand the processes of the landscape services. According to the SES-theory the users and stakeholders in an area take benefit of these services and will try to improve the level of service by making interventions in the landscape.

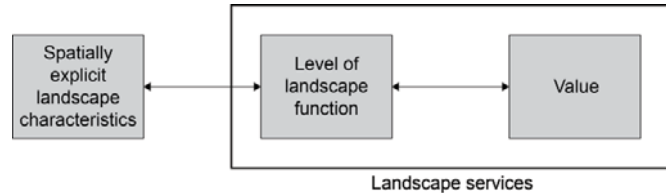


Fig. 3 Structure-Function-Value chain (Termorshuizen & Opdam, 2009)

From the SES-theory scheme three definitions have to be clarified. Landscape- function, service and value are important principles for the rest of this thesis so a clear definition is vital. Termorshuizen & Opdam (2006) define the terms as follows; a **landscape function** is defined as a performance of the landscape such as shelter from the elements. This performance should also exist without interference of humanity. A **landscape value** is defined as a specific function of the landscape, onto which an economical, political or cultural value can be attached by the society that utilizes it. A **landscape service** is by defined as the combination of a landscape function and the attached value by the society. The level of service is determined by the need for this landscape function by society and the manner to which this need is met.

3.3 Conclusion

With the MFO theory presented in previous sections it becomes possible to dissect the landscape of the Hoeksche Waard into several subsystems and processes, natural and social, which operate in order to fulfil the landscape functions. By doing so it becomes possible to model the landscape one process at the time in order to prevent the complexity of the landscape system of becoming unmanageable, which could not only be beneficial for the working of the model but also for the understanding of the landscape. Because the case study focuses on the green-blue veining the SES-theory serves its purpose. The green-blue veining within the Hoeksche Waard is an important factor of the landscape according to Geertsema, et al. (2006) since it does not only fulfil ecological functions but also social functions such as attractiveness of the landscape, which are both valued by the stakeholders in the Hoeksche Waard. The SES-theory makes it clear how to connect specific spatial characteristics to a landscape function and the attached value. By doing so changes to the spatial characteristics can be connected to the corresponding changes to the value that is given to the level of landscape function and thus the landscape service. In the next sections several processes that are present in the

landscape of the Hoeksche Waard are to be dissected according to the SES-theory in order to illustrate its potential.

4. VARIABLES AND INTERRELATIONS OF THREE LANDSCAPE SERVICES

4.1 Landscape Services

Within the Hoeksche Waard the landscape, like every other landscape, has multiple landscape services are present (Termorshuizen & Opdam, 2009). These landscape services are the starting point of the demonstrator. The landscape services that are going to be used in the demonstrator have to be relevant to the desired future for the Hoeksche Waard because the demonstrator should be a tool that assists with the procedure of achieving this future. According to Geertsema, et al. (2004) the desired future of the stakeholders concerning the spatial characteristics in the area is the conservation of the open, with streams intersected polder landscape divided by dikes and/or rows of trees. Concerning landscape functions sustainable agriculture should be developed and the area could use additional functions such as tourism. Moreover, since the previous studies of the Hoeksche Waard focused on the green-blue veining of the area the chosen landscape services for this thesis are also relevant to that aspect of the landscape.

Because of its relation with sustainable agriculture the first chosen service is **Natural Pest Regulation**, which is the use of natural enemies to challenge the harmful species to the crops and other important fauna. With a significant relation to the biodiversity in an area, natural pest regulation is one of the most important aspects in the case study of Geertsema, et al. (2004) and an important factor for sustainable agriculture. The second service is that of **Water Purification** because the green-blue veining is another important spatial factor of the case study. The ability to purify the water is strongly related to the water quality, which is an important factor for the biodiversity. Apart from that the use of pesticides, when natural pest regulation lacks, partly determines the water quality. This relation makes water purification a suitable service to use in the demonstrator. **Landscape Identity** will be the third landscape service because the explicit mention of the conservation of the current landscape identity and simultaneously making the landscape positively perceived by tourists (Geertsema, et al., 2004). The mentioned concepts in this paragraph are further explained in Appendix A

Related to the MFO model the chosen landscape services are further justified since all subsystems are being covered. Natural pest regulation exists primarily in the biotic subsystem of the MFO model since it is a product of an adequate biodiversity. Nonetheless, biodiversity is also of influence to the attractiveness of an area and thus part of the cultural subsystem. Concerning water purification the abiotic subsystem of the MFO model is the most relevant although it also connects with the other systems. A good water quality has positive consequences for the flora and fauna in and around the water and thus the biotic subsystem. With less contaminated surface and ground water because of fewer pesticide use the costs of purifying the water for consumption could be lowered which is of

value for the economical and political subsystem. Furthermore, as landscape elements water bodies play an important role, it can enhance the attractiveness of areas for residents and visitors and thus has value for the cultural subsystem. Landscape identity in turn exists because of the interaction in the MFO model between the cultural subsystem and the physical organisation embodied by the biotic and abiotic subsystem. According to Stobbelaar & Pedroli (2011) landscape identity emerges out of the interaction between that what people perceive as specific for that area in the context of culture, usually also influenced by historic characteristics or occurrences, and the spatial shapes and sizes of the landscape elements. Furthermore, users and especially inhabitants of the area also appreciate and identify themselves with this specific landscape identity, which could have implications for the entire social organisation within the area since the cultural system within the MFO model is closely connected to the economic and political system of the MFO model (Hidding, 2006).

4.2 Relevant Variables

In appendix A and B the definition and formation of all three chosen landscape services related measurable variables are asserted. Per landscape service the measurable variables should determine a value of that certain landscape service. However, the complete package of interrelations between the variables within one landscape service and with variables of other landscape services would form a complex whole that could not be illustrated within this thesis. Therefore the demonstrator will consist of the most relevant variable of each of the three chosen landscape services in order to illustrate the interrelations of the landscape services.

One group of variables that has significance to the landscape services presented in Appendix A are the **Spatial Properties**. Therefore, these variables form an important part of the demonstrator. These properties can be divided into three variables that according to Geertsema, et al. (2004) are significant for a landscape element. **(1)** The spatial dimension, related to the width of a landscape element, **(2)** the spatial arrangement, related to the distance between similar landscape elements and **(3)** the surface area of the landscape element. The significance of these variables is twofold. First, all three landscape services are dependent on the space that is available and its location. Secondly, The spatial properties are the variables that communities are most able to change. Geertsema, et al. (2004) states that the spatial properties of the landscape elements are measured in meters or square meters. Consequently, this is a quantitative variable since it is measured numeric.

For the landscape service natural pest regulation the most relevant quantitative variable according to Geertsema, et al. (2004) is that of the **Vegetation Structure** of landscape elements. The importance of vegetation structure lies in the two functions of the landscape concerning natural pest regulation, which are the accommodation of species that is called the source area and the area that is being used by the species for their survival that is called the living area. From the living areas the species go into the nearby lots to find their nourishment but the source area is the place from which they are being distributed. When vegetation structure

of the landscape elements is inadequate the species cannot develop to their full potential. Too low vegetation does not provide enough shelter and only large trees prevents sheltering bushes to receive sunlight and therefore will not grow. (Geertstema, et al., 2004) The vegetation structure is measured as the height of the vegetation and is divided into four classes. Each class defines a vegetation layer, the layers are; (1) moss layer (unto 0.25 meters), (2) herb layer (unto 1.35 meters), (3) bush layer (unto 8 meters) and (4) tree layer (8 meters and higher). Because of the interval scale for the classification this variable is a quantitative variable.

According to Delago, Periago & Vigueira (1995) a practical variable for determining water purification abilities of an area is **Soil permeability**. Concerning the soil permeability two aspects are of importance; filtration of ground water and precipitation run off into surface water. The texture of the soil should be open enough to let precipitation water percolate into the ground water instead of running over the soil into a nearby creek but dense enough to purify the water in order to prevent high levels of harmful substances in the ground water. On the other hand the slope of the soils should not be to great otherwise the water will not have time to percolate the soil (Delago, Periago & Vigueira, 1995). In order to make a classification within soil permeability several properties are of relevance; the soil type, such as clay or sand, and the amount of organic deposits determined by the amount of loam. These characteristics lead to a classification consisting of a combination of soil type and the loam value in the soil which all have a average value of permeability displayed in centimetres an hour. Following the classification of the Food Agricultural Organization of the United Nations (1997) six adequate soil classes are; (1) Clay (0.05 cm/h), (2) Silty loam (0.25 cm/h), (3) Clay loam (0.8 cm/h), (4) Loam (1.3 cm/h), (5) Sandy loam (2.5 cm/h) and (6) Sand (5.0 cm/h). The interval scale for the classification makes this a quantitative variable.

Concerning the landscape identity the case study of Geertsema, et al. (2004) describes a desired future in which the landscape identity should be maintained but at the same time the landscape should be more attractive for tourists by boosting quality of nature combined with walking and cycle paths to facilitate the potential tourists. The **Naturalness** variable of BelevingsGIS, translated into ExperienceGIS, method of Roos-Klein Lankhorst, et al. (2005) would therefore be an adequate variable for the landscape identity service of the landscape. Roos-Klein Lankhorst, et al. (2005) makes use of square grid cells varying in size depending on the scale, within which the surface area of nature and grassland is measured. Roos-Klein Lankhorst, et al. (2005) defines nature as deciduous forests, coniferous forests and mixed forests. Also surfaces consisting of open sand, heath, marshes, open and closed dune vegetation, reed vegetation, peat land, open overgrown nature and bare soil in nature is defined as nature. The total of nature and grassland is then related to the total surface of a grid cell in order to calculate a percentage. This percentage indicates the degree of naturalness and therefore the strength of the desired landscape identity in the Hoeksche Waard. Roos-Klein Lankhorst, et al. (2005) classified this indicator in 5 classes; (1) <0.1% nature and <50% grassland, (2) 0.1-5% nature and >50% grassland, (3) 5-10% nature and <50%

grassland, (4) 10-50% nature and (5) >50% nature. Additionally classes 0 through 3 will increase a class when any form of surface water exists in the grid cell. This variable is also quantitative since it contains an interval scale for the classification.

4.3 Interrelations

In order to have a functioning LIM-tool demonstrator the relations between the three chosen variables and the spatial dimension needs to be specified, these relations will all be quantitative since all variables are quantitative. When the correlation between the chosen variables is defined the impact of spatial or policy related interventions and demands on the several variables can be modelled and visualized in the LIM-tool demonstrator.

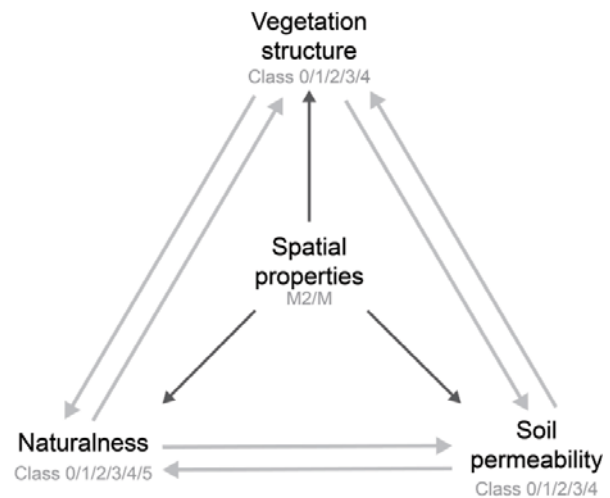


Fig. 4 Interrelation of the selected variables (de Koe, 2013)

The most distinctive variables are the spatial properties. In figure 4 the relations between the spatial properties and the other variables is a one sided relation since the properties only influence the value of the other variables. These relations are the backbone of the demonstrator since spatial interventions will influence the three relevant variables of the landscape services, which in turn influence each other. The extent to which the several variables influence each other and thus function within the model depends on the exact correlation between the variables.

Concerning the vegetation structure there is an interrelation with spatial properties. When a desired vegetation structure of a landscape element is multiplied with the spatial dimension of the related landscape element surfaces the greater dimension makes for more desired vegetation. The spatial arrangement is also relevant since the distance to the green-blue veining, the source area of natural enemies, influences the level of natural pest control (Geertsema, et al., 2004). Concerning water purification the spatial properties, as part of the spatial properties, are of importance since the soil permeability is measured by multiplying the soils surface with the volume of water that it can percolate in a given timespan, more space therefore influences the permeability of a landscape element (Delago, Periago & Vigueira 1995). The distance to the green-blue veining is also of importance since with a water body nearby the run off water will reach it easier, which could have

negative consequences for the water quality (Koelmans and de Klein, 2012). The same is true for naturalness since the more space is defined as natural, the higher the naturalness variable will be. Furthermore, since water is valued as naturalness the distance to the green-blue veining is also of relevance. Lastly, the larger the natural landscape element the higher the naturalness perception. (Roos-Klein Lankhorst, et al., 2005).

Apart from the relations with the spatial properties every landscape service variable is also related to the other landscape services and thus the most relevant variable of those landscape services as depicted in figure 4. Vegetation structure is influenced by the soil permeability since a well-drained soil accommodates healthy plant roots (Hillel, 2004). Naturalness also influences vegetation structure since according to Roos-Klein Lankhorst, et al. (2005) more natural landscape elements will generally have more upright growth and thus a higher vegetation structure class. Soil permeability in turn is influenced by the vegetation structure because deep roots create a less permeable soil and the higher the vegetation the deeper the roots go in order to keep the vegetation stable. However, when the perennial vegetation such as trees and bushes is removed for crops for example the vegetation no longer protects the soil, which makes it more permeable (Hillel, 2004). This phenomenon indicates the influence of naturalness on soil permeability. Lastly, naturalness is influenced by the vegetation structure since more upright vegetation makes for a more natural environment according to Roos-Klein Lankhorst, et al. (2005). The relation between soil permeability and naturalness is illustrated by the fact that the land-uses and vegetation types defined as natural by Roos-Klein Lankhorst, et al. (2005) are mostly present on permeable sandy or peat soils so the more naturalness the more permeable the soil probably is.

4.4 Conclusion

With the three landscape services, the corresponding variables and the relations between the variables the model will have adequate input to illustrate the workings of the proposed LIM-tool. The data that is needed to make the demonstrator realistic will need to consist of data on all variables. The data on spatial properties are relatively simple to attain. The data on the three key variables for the landscape services however are more difficult since this data needs to be obtained from other institutions that have data on the height of the vegetation and the geological conditions of the soil. In order to operate the model with reliable and valid information sharing data with other is an important issue. So-called Open-data could be a solution for data issues since all relevant data will be available for whoever needs it. According to Taylor and Ives (2010) the need for data sharing is obvious and not only in spatial planning, means to share and collaboratively edit data are being developed en masse in every sector and again reliability and validity are an important aspect of such developments.

5. CONCEPTUALISING A MODEL

5.1 Model Content

In order to model the landscape not only the processes but also the space should be dissected into different parts in

order to prevent the complexity of the landscape system to be unmanageable. According to the theory of visual understanding (Jakle, 1987) landscapes consist of three basic landscape elements; points, lines and planes. The point embodies specific and spatially isolated elements in the landscape. Lines or linear elements are part of the physical network in a landscape, which can connect, divide other landscape elements or facilitate transport of goods, persons or animals. Planes are surfaces or areas that are bounded by lines and have a specific function or determine a certain zone or district. Obviously this phenomenon is applicable to multiple scales.

The spatial properties of the landscape elements are the most important aspect of the interactive use in a LIM-tool. However, there are many types of interactivity so a clear definition for this thesis is needed. Smuts (2009) defines five types of interactivity of which the theory related to interactive art of Saltz (1997) seems the most adequate for the proposed LIM-tool. He states that in order to be interactive three criteria are to be met; **(1)** a input device must translate aspects of the subject into digital form that a computer can understand, **(2)** the model outputs data that are systematically related to the input, **(3)** The output data are translated back into information that the user understands. Key in this process concerning the LIM-tool demonstrator is that input for the computer could be data on the plan area, requirements of the stakeholders and spatial interventions put in by users. Furthermore the interactivity of the model itself is also divided into navigation, as in movement to the virtual space, which is useful for creating the interface, and manipulation. Manipulation in turn is divided into object change, object position, object properties change. These changes can be natural or by human interference (van Lammeren, et al., 2001). The interrelation between variables can be observed by changing one object and perceive the changes to the other variables.

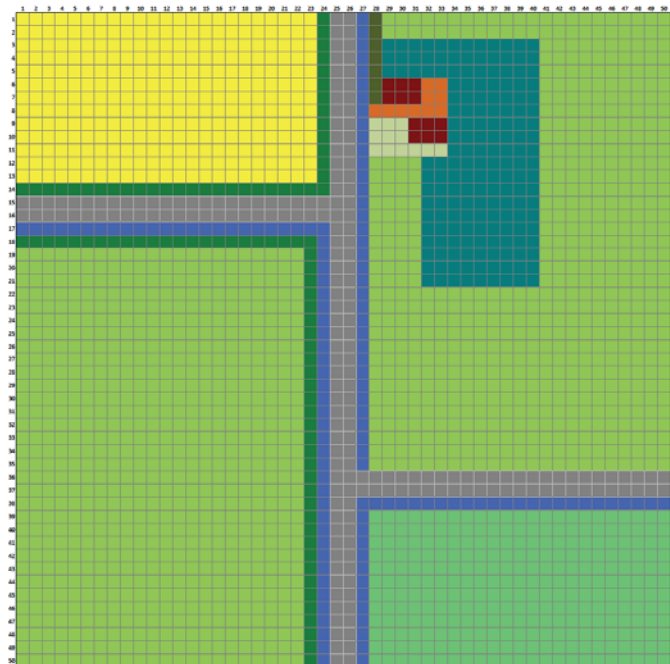


Fig. 5 GIS raster model of the Hoeksche Waard (de Koe, 2013)

The demonstrator in this thesis will be composed with the six variables as stated in section 4.2. The demonstrator is based on a Raster GIS that in effect divides the area into a grid in which every grid cell has the same surface area. By combining several cells together to form a landscape element or several landscape elements the average value of a certain landscape service can be calculated for a specific part of the area for example of one owner or all adjacent landscape elements of a part that is planned to change in order to see what is the influence on these adjacent landscape elements. The possibilities are endless since every grid cell has its own value and any number of cells can be combined to calculate the average value. A Raster GIS has proved to be a valuable tool in the computer-based modelling of processes according to Stock & Wise (2000). The strength of a Raster GIS lies in the fact that it can bring together various forms of raw spatial data into one spatial reference format with the same scale. In a similar method of Tomlin (1990) the chosen variables will be represented in different layers. The data of each variable is represented in a layer, since six variables have been determined in section 4.2 the demonstrator will have six data layers. These six different data layers are then scaled, weighted, and combined in order to visualize the level of biodiversity or other value. When using a raster GIS, the separate data layers are linked to different criteria used in the model are usually transformed into factors or constraints. According to Holroyd and Bell (1992) a factor is a condition that influences the value of a cell. A constraint is absolute in its inclusion or exclusion of the outcome for the model. Factors will be used within the data layers and constraints will be part of the analytical layers since the outcome of the analysis will be reflected against the desired value that comes forth out of the desired future of the case study area.

Translating the above to the demonstrator of this thesis makes for a GIS raster model. In figure 5 a part of the Hoeksche Waard is modelled in order to make each cell a specific geographical location to which data can be attached. The demonstrator consists of six data layers each representing one of the relevant variables for the demonstrator: **(1)** The surface area layer, **(2)** The landscape element width layer, **(3)** The spatial arrangement layer, **(4)** The vegetation structure layer, **(5)** The soil permeability layer and **(6)** The naturalness layer. However, since the three chosen landscape services needs to be calculated the demonstrator will also consist of three analytical layers: **(1)** The natural pest regulation layer, **(2)** The water purification layer and **(3)** The landscape identity layer. The six data layers will provide the input for these layers. In every layer the same cell (geographical location) will have a different meaning since in every layer another variable is represented. In the analytical layers every cell presents the level of the specific landscape service in that grid cell. In Appendix C the several layers are depicted in a spreadsheet with fictional values in the grid cells. The 50x50 grid represents a company scale in which each grid cell represents an area size of 6.25 m². The 5x5 grid represents a community scale in which the each grid cell represents an area size of 625 m² and the cell value shows the average of the values of each 100 cells block. The reason for these two scales in the fact that the LIM-tool demonstrator is a communicative tool for community-based planning and design, by using these two scales the influence

of changes by one individual company or lot on the community can be visualized. Apart from that the desired value of a landscape service can also differ considering the scale. A farmer desires a sufficient level of natural pest regulation to keep his company running whereas the community as a whole could desire the same level from a sustainability perspective.

5.2 Model Processes

Within the surface area layer every grid cell has a value of 6.25 since this is the spatial dimension of that cell. The landscape element width layer is determined by the width of the landscape element of which the cell is a part. The spatial arrangement layer shows the distance from that cell to the nearest green-blue veining element. All these numeric values are of influence on the level of a landscape service. Concerning the three landscape service variables the vegetation structure layer consists of cells with a value between 0 and 5 where 0 represents no vegetation and 1 to 4 indicates the values as explained in section 4.2. Concerning the soil permeability layer the value in the grid cell lies between 0 and 6 where 0 represents no permeability and 1 to 6 indicates the values as explained in section 4.2. The naturalness layer consists of cells with a value between 0 and 5 where 0 represents no naturalness and 1 to 5 indicates the values as explained in section 4.2. Moreover, as depicted in figure 6, the model also adds a colour to the different classes in order to visualize the difference in classes within the area. Although these classifications are reliable the meaning of the classes are only defined as positive or negative for the other variables since data on the exact influence is insufficient.

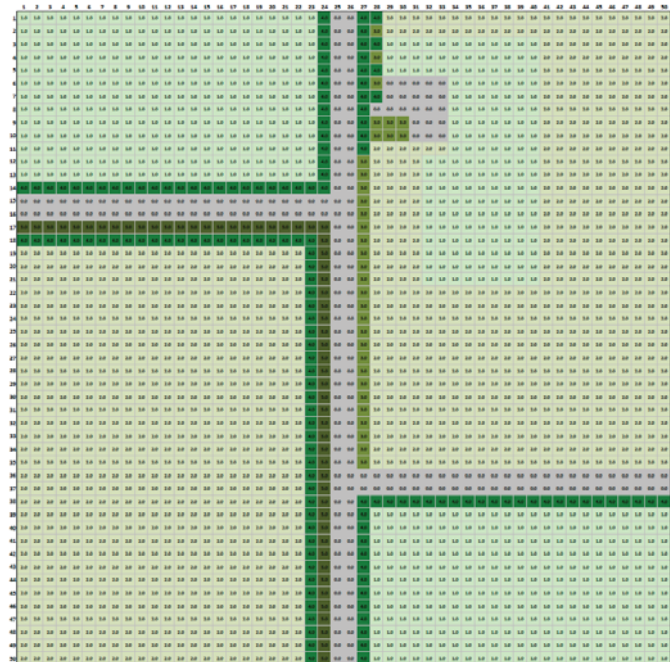


Fig. 6 GIS raster model of the Naturalness layer (de Koe, 2013)

Concerning the analytical layers the correlation of the chosen variables becomes an issue of discussion. Since this thesis explores the concept of a LIM-tool the amount of research needed to find the exact correlations between all

variables is unattainable within this thesis. However, as stated in section 4.3 the interrelations between the variables have been researched and form an important part of the processes of the model. Although the influences on each other are defined, the exact correlations between the variables and landscape service values have not been defined since there is insufficient data on these correlations. The three analytical layers, as shown in appendix C, are devised by the combination of the values in the six variable layers. The formulas for these values are assumed since the available data does not justify a reliable formula. However, the analytical layers do give an insight in how the model would operate when provided with accurate formulas. As depicted in figure 7 the value of each grid cell shows the level of natural pest regulation; water purification or landscape identity in that cell and the icon that has been linked to that value gives a quick impression of the meaning of that value. Since this thesis has insufficient data on the correlations between the variables of the attached values and the scaling of the icons are assumed.

Within the model as depicted in appendix C every grid cell has a value derived from the interrelation between the variables. The formula of each analytical layer is therefore different since the impact of each data layer variables on the analytical layer is different. As stated this thesis does not

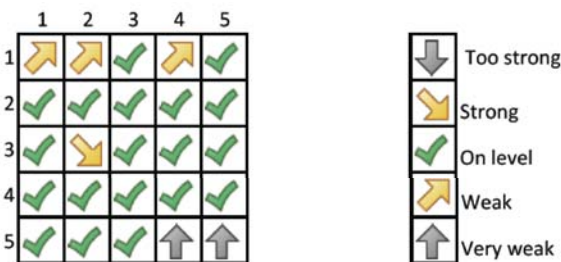


Fig. 7 Indication icons for the level of landscape identity (de Koe, 2013)

address the exact correlations of the interrelations, nonetheless the analytic layers have a formula consisting of the several attributes related to the positive or negative impact of the variable of the analytical layer as stated above. When a relation is positive the value is added to the calculation and with negative relations the value is subtracted from the calculation. Concerning the attributes the abbreviations are as follows; TOPOMAP relates to the surface area, attribute_RS relates to the surface area of related landscape elements, attribute_SA relates to the spatial arrangement of landscape elements, attribute_VS relates to the vegetation structure, attribute_SP relates to the soil permeability an attribute_N relates to the naturalness. The formula in cell A1 of the analytical layer of Natural Pest Regulation would be as follows:

$$=((((TOPOMAP!A1 + attribute_RS!A1) + attribute_SA!A1) + attribute_VS!A1) + attribute_SP!A1) - attribute_N!A1)$$

for Water Purification the formula would be:

$$=((((TOPOMAP!A1 + attribute_RS!A1) + attribute_SA!A1) + attribute_VS!A1) - attribute_SP!A1) - attribute_N!A1)$$

for Landscape Identity the formula would be:

$$=((((TOPOMAP!A1 + attribute_RS!A1) + attribute_SA!A1) + attribute_VS!A1) + attribute_SP!A1) + attribute_N!A1)$$

When exact correlations are known it would be relatively easy to incorporate them in the formula by adding the correlation coefficient to the data layer value. Since the correlation coefficient already has a negative or positive value the current relevance of that relation in the formula as stated above would fall due. On a community level a single grid cell represents the average value of 100 cells. The formula for the cell that takes A1 into account would be:

$$=AVERAGE(A1:J10)$$

Since the outcome of this formula is the average level of landscape service for 100 grid cells the community scale can only be able to illustrate this level, when the user wants to know in what landscape element an intervention is needed the company scale should be used to determine this. The user can also use the same formula to calculate the average of a specific landscape element by selecting the relevant grid cells. In effect the community would check the levels of the plan area and would zoom in on the problematic areas in order to see what the companies or other form of land owners could do to facilitate solving the problematic issue in that part of the plan area.

However, there are some issues concerning every model that cannot be disregarded. According to Loucks & van Beek, (2005) models are simplified representations of reality because the complexness of reality is too great. Because of this simplification the proposed LIM-tool demonstrator model contains multiple assumptions that might be inaccurate. The outputs and conditions of the model are therefore uncertain. According to Loucks & van Beek, (2005) some these uncertainties could be reduced by more data collection and analysis. Usable data exists all over the world and although the data might not be totally relevant it can be combined or homogenized in order to make it relevant. According to Reichman, et al. (2011) the heterogeneous and dispersed nature of data needs more than the standardisation of methods and metadata. Reproducibility of analyses and executable workflows will enable researchers everywhere to collect and analyse data in the same manner in order to create reliable homogeneous data. Furthermore, the sharing of this data should be enabled but even more importantly

stimulated by adequately rewarding for shared data. This concept of Open Data is spreading into the world according to Reichman, et al. (2011) but is nowhere as efficient as it can possible be and therewith the level of certainty of model such as the proposed LIM-tool demonstrator remains debatable.

6. AN INTERFACE TO COMMUNICATE

6.1 The Users

In order to design a proper interface for the proposed LIM-tool demonstrator the potential users will first have to be clear according to Stappers, et al. (2007). Furthermore the nature of the activities that the interface is going to be used for is important. Since this thesis focussed on a community-based planning and design tool, the activities for which the interface is needed are communication, planning and design. Concerning the Hoeksche Waard the users will consist of residents, farmers, entrepreneurs, government officials and several experts in relevant field of expertise. (Geertsema, et al., 2004). This composition is likely to be the same in most of the cases concerning community-based planning. According to Stappers, et al. (2007) the design of an interface should also take into account what are the strengths and weaknesses of the users. Assumingly residents are good at determining their desired living conditions but more or less unaware of the ecological systems and spatial policies. Farmers on the other hand will probably reason from their companies' perspective and should know much about the landscape but less about desired living conditions. Government officials will presumably know a lot about spatial policies but less about the ecological subsystem and desired living conditions. Lastly, the experts ought to know a lot on their field of expertise. According to Stappers, et al. (2007) the interface should facilitate the weaknesses of every user, which means that the interface should clearly visualize the used concepts in order to be understandable. Kunze, et al. (2012) states that visualisations will help create the mutual understanding because the visual aids will help a layman to understand complex issues. And this mutual understanding is an important requirement for successful community based-planning as stated in section 2.3.

6.2 The Interface

Concerning the appearance of the interface, three-dimensional visualisations are becoming more and more important. Google Streetview© and examples like the three-dimensional design programmes that are being used in many industries are numerous. In figure 8 a conceptual interface is depicted, a full size image is available in Appendix D. Every screen in this interface will have a function. Screen A will consist of a topographic map such as Google Earth© onto which the GIS raster is to be laid out. Because of the fact that the land uses and landscape elements do not all form a perpendicular whole the GIS raster will need to consist of hexagons since they are easier to combine into different shapes (Zhao & Zheng, 2013). Screen B of the interface is a graphic representation of Google Earth© top view of the selected area. This screen has the function of being able to change the spatial properties of the landscape elements. This usability goal makes it necessary that the screen is graphic because

changes should be visualized and the interface of a viewer like Google Earth© would be insufficient in this case (Stapper et al., 2007). The C screen has the functionality to illustrate the street level perspective of the area. Especially for the less expert stakeholders it is hard to imagine a three dimensional view from a two dimensional representation like screen A and B. According to Kim & Mahler (2008) a three dimensional view of the situation helps the user to perceive more spatial relationships and thus creates more understanding. Therefore the added value of a perspective screen is the fact that stakeholders can recognize the influences of the interventions on their perception of the area before they take place.

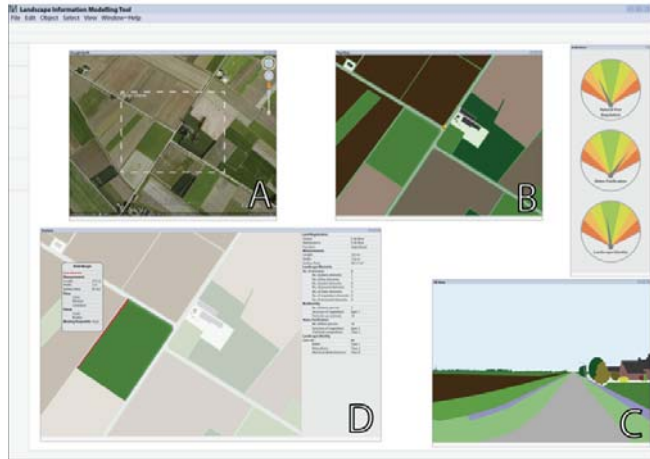


Fig. 8 Impression of the LIM-tool demonstrator interface (de Koe, 2013)

Screen D will be have the function of analysis. Every landscape element has different values for the several variables that are relevant in the area. When selecting a landscape element this element will light up in order to confirm selection. According to Marchenko, et al. (2011) such smart selection visualisation makes complicated structures easy to understand. By selecting the landscape elements that are of significance for a certain analysis the values of the selected elements can be read in a textbox as seen in figure 9. This separation of geometric visualization of elements and attached data on variables improves data organization and flexible updates on changes in the model (Yan, Culp & Graf, 2010).

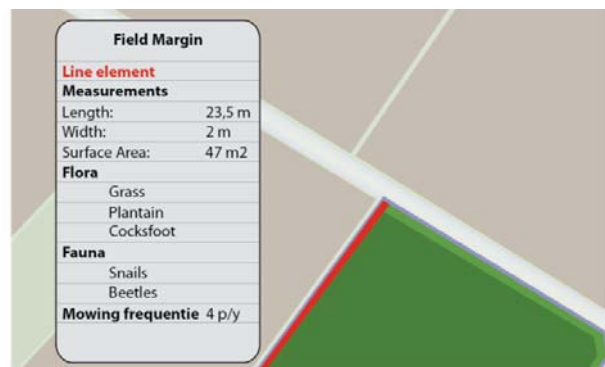


Fig. 9 Landscape element values textbox (de Koe, 2013)

The most important aspect of the interface are the indicators that illustrate the value of the chosen landscape services.

The indicators visualize the value of the landscape services in order to illustrate whether or not the value is on the desired level. However, this value has little meaning without the knowledge about the desired levels of the landscape services.

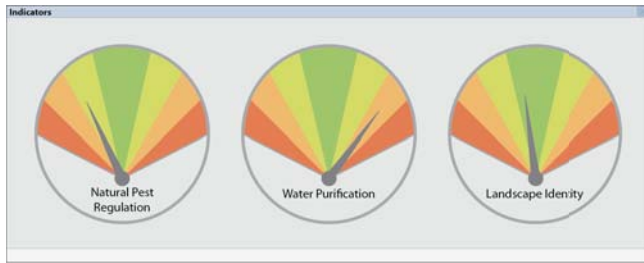


Fig. 10 Landscape service gauges of the demonstrator (de Koe, 2013)

In figure 10 the gauges of the interface are depicted. In the case of the Hoeksche Waard these values and thus the meaning of the colours in the gauges are related to the research of Geertsema, et al. (2004). For the natural pest control the desired level is connected to the wish of the Hoeksche Waard community to have a more sustainable pest regulation. Therefore the value should be higher than the current value. The current value could for example be indicated in orange and the desired value would then be indicated by the upright position of the dial in the green zone. When changes are made to the landscape elements in the model the values are altered. The ideal level of water purification is also related to the wish for a more sustainable pest regulation since the less pesticides are used the lower the necessary level of water purification. Consequently an increase of the level of natural pest regulation will cause an increase in the level of water purification. This interrelation as described in section 4.3 is possible to instigate different changes and instantly visualize what the impact of the changes are to the selected landscape services. When implementing a purification marsh connected to the creeks in the area for example the level of water purification will rise. However, as stated before the values could also rise to an undesired level. Therefore the indicators also indicate when a landscape service level has surpassed the desired future. With the level of landscape identity the desired level is connected to the desire of the Hoeksche Waard community to create a more natural landscape identity. In the case the changes to the landscape creates a multitude of natural elements in a way that the overall landscape becomes too natural in the perception of the stakeholders who formed the desired future. The gauge of the level of landscape identity will set the dial beyond the ideal upright positions in order to indicate that the landscape identity would be too natural with the proposed changes that were made in the model via screen B, C or D. The tool is most useful for the potential user by making different changes to the spatial environment that translated into landscape service levels. By making several scenarios by different stakeholders without the use of multiple drawings and time-consuming communication processes the most adequate scenario can be easily modelled and possibly developed.

The final property of the interface that is of significance is the manner in which the demonstrator can be used. In essence there are two forms in which the demonstrator could be made available; a software package and a web-

based interface. According to Stapper, et al. (2007) a web-based interface would be the most suitable for a demonstrator as explored in this thesis because of the fact that users will not have to purchase or install software on their devices. This makes the use of the interface more accessible and easy to distribute. Potential users would be provided with an account and are able to use the interface. However, Stapper, et al. (2007) points out that the web-based interface has pitfalls. Apart from the necessity of a web connection the capabilities of the servers and download and uploading speeds are of vital importance for the usability of the demonstrator. The use of a web-based interface also has advantages since the model is not only accessible from everywhere but also always up to date for every user since changes and interventions are immediately changed on the server (Chen & Hou, 2012). Before engaging in collaborative planning procedures the number of users and the potential size of the model should be assessed in order to adequately provide suitable hardware.

7. LESSONS LEARNED

During the course of this research the objective to develop a simplified version of the LIM-tool demonstrator led to a multitude of criteria that the demonstrator should meet. These criteria varied from conceptual criteria to usage qualities and operational necessities. The exploration of these criteria implies that a LIM-tool would indeed be a valuable asset in collaborative planning procedures. Boroushaki & Malczewsk (2010) studied the implementation of a participatory GIS-based system that facilitates decision-making processes in collaborative planning. According to their research the level of consensus reached with the use of such a tool was significantly higher and even better, the preferences of the stakeholders became similar instead of compromising on several issues. Another outcome was that the level of engagement in spatial decision making rose, not only in number but also on the public participation ladder of Arnstein (1969) which facilitates the shift to a more bottom-up development procedure.

The most relevant lessons concerning the proposed model are related to the conceptual criteria of the LIM-tool demonstrator. As stated in section 5.2 the simplified reality presented in the model makes the outcome of the tool not exactly accurate. According to Cresswell (2009) it is therefore important to cross reference findings concerning variables, indicators and other data that has been used in devising the model. Another conceptual criterion is the use of two scales in the tool as stated in section 5.1. Since the LIM-tool demonstrator is proposed as a communicative tool it should facilitate the communication between stakeholders in the plan area. The role of information in this process is significant. According to Innes (1998) the fact that there are many products in the world that give information on how to use them or when to clean them is an interesting analogy to the embeddedness of information in planning. Related to the two scales the LIM-tool provides individuals in the plan area with information on the measures that can be taken in their land-use in order to assist in the realisation of the desired future of the community. Although in the end the choice lies with the individual whether or not action will be taken since it might not be in the best interest of the individual the knowledge how you can contribute to the common needs

seems to be additional motivation to do so according to Innes (2009). Also the consequences for the community of actions by individuals taken from a private or commercial motivation can be visualized. In turn the community could decide to alter specific landscape elements to facilitate an individual stakeholder or level out the consequences. Eminent for this criterion is the possibility for input by users, section 5.1 already states that in order to be interactive the LIM-tool demonstrator must facilitate input for the model. The criterion above acknowledges the need for the possibility of data input by an individual or group of users that represent their desired future and/or (proposed) interventions.

Concerning the usage qualifications, Geertman & Stillwell (2004) who studied the then existing inventory of planning support systems stated several criteria that where of importance for an innovative communicative planning and design tool. According to their research such a tool should take the interdisciplinary perspective into account and take the user seriously. Furthermore the users' characteristics should be taken into account. With the interdisciplinary approach as proposed in section 2.3 and an adequate interface that is fitted to the perceived users these criteria could be met. Since the proposed LIM-tool demonstrator interface provides multiple visual representations that aims at giving adequate information to its specific users in order to facilitate the procurement of knowledge. Another criteria according Geertman & Stillwell (2004) states that the tool should be focused at the wishes of the participants. Since the desired future is made explicit in the desired levels of landscape services that in turn have an important role in the usage and interface of the LIM-tool demonstrator this would be the case.

The two final criteria of Geertman & Stillwell (2004) concern the role of the tool in the planning and design process. The tool should be an integral part of the process and it should be able to function within the context of the process. Concerning the context the tool has the required qualifications since it's interdisciplinary approach the integral part is feasible and all stakeholders should be able to go through the planning procedure with the proposed LIM-tool. However, this aspect asks for a cooperative paradigm with all stakeholders that might not always be present since it requires trust between public and private parties, which is not always apparent (Mansuri & Rao, 2003). This trust on the other hand can be established by mutual understanding according to Blomqvist, Hurmelinna and Seppänen (2005) and as mentioned in section 2.3 the proposed LIM-tool demonstrator should be capable of creating this mutual understanding by the transfer of knowledge.

With regard to the operational criteria for a working LIM-tool the research discovered that the landscape system and subsystems are so complex that the whole of variables and correlations between the variables proved to be very difficult to model. According to Holling (2001) this complexity is instigated by the dependant and hierarchal nature of the system and together with the adaptive and regulative capabilities makes it subject to change. Holling (2001) states that this complexity can be managed when one devises the model by making it as simple as possible for communication and understanding and keeping the model dynamic and

perceptive in order to keep on developing the model. But above all one must embrace the uncertainty that is eminent in a model. The simplification of the landscape system into a model could be possible but the level of detail that was proposed in this research will be difficult to reach.

Furthermore, should the proposed LIM-tool for community-based planning and design be realised for certain landscape services the SES-theory appears to be able to systematically approach landscape processes in order to give insight into the working of the system. However, with the three landscape services covered in this thesis the multitude in variables proved to be complex enough to the extent that in an operational demonstrator the number of services should be minimal in order to keep the system understandable. Furthermore, the raster GIS-based model appears to be a adequate choice for implementing the model not only because its proven ability to represent spatial reality so sufficient but also because of its spatial data handling and geo-processing operations that reduce the need for a software developer (Stevens, Dragicevic & Rothley, 2007).

Lastly, research implies that there are limitations concerning the procurement of necessary data for the realisation of the LIM-tool demonstrator. According to Schilling, Neubauer & Zipf (2010) the amount of data needed for every larger level of detail is a multitude of the previous level of detail. Within this research a division between community level and company level was made. The company level will not be realistic for the demonstrator since the data needed on that level would not be accessible because private properties are not always open to be measured. However, on a community scale the demonstrator could be feasible since data on the public accessible landscape should be adequately measurable. Moreover, as stated by Gustafson (1998) and recognized by Wu (2013) the use of a larger scale makes the spatial environment subject to spatial heterogeneity and the correlation between variables can be sufficiently argued by theoretical relations. In conclusion, the lessons learned within this thesis are valuable and offer perspective for the use of interactive interdisciplinary community-based planning and design tools within rural planning and design procedures. Even though the present utility of the demonstrator would be limited, it seems to be possible to realise a LIM-tool demonstrator on a community level scale with the researched variables in combination with the use of reference data from other similar landscape systems.

8. DISCUSSION

At the start of this thesis the absence of an interactive interdisciplinary tool to support communication between stakeholders within in spatial planning procedures was the main reason for the question whether or not such a tool could facilitate community-based planning and design procedures. This research tried to validate that the proposed LIM-tool could indeed facilitate communication in the community-based planning and design. According to research by Cope, Lafferty and Rhoads (2011) the visual language of maps and three-dimensional visualisations assist users in gaining knowledge of the space and setting of their everyday life. Furthermore Cope, Lafferty & Rhoads (2011) describe the construction of spatial narratives between stakeholders because of a model that functions as

a reference for these narratives. In extension of these statements the value of the interdisciplinary aspect of the proposed LIM-tool in terms of implementation of multiple subsystems of the landscape in the model seems essential. In other sectors the use of information technology and virtual reality modelling this interdisciplinary and systematic approach proved to be valuable (Sokolova & Fernández-Caballere Gómez, 2011).

The research for this thesis was focussed on three landscape services that were dissected according the SES-theory. The vast amount of variables that are of some sort of relevance for these three landscape services proved to be too great. However, within the research the demarcation of variables gives insight in the process of the chosen landscape services. The theories of measuring the several variables are part of several different monodisciplinary tools.

Concerning the operational aspects of the LIM-tool demonstrator the fact that it seems possible to combine the analytic aspects of the landscape service indicators with the experiential aspects of the interactivity of the tool and the possibilities to make spatial interventions in the virtual model together in a interdisciplinary tool is of relevance. The combining of analytic and experiential methods has already proven itself in a study of Vervoort, et al. (2012) with the development of scenarios for spatial planning and design. Within this research the use of scenarios as a form of communication proved valuable for analytic as well as experiential communication. The use of a desired future as a part of the LIM-tool demonstrator could therefore be interpreted as a valuable attribute if the demonstrator. Still, the interactive input opportunities of the LIM-tool demonstrator, which makes it possible to alter spatial properties and determine the effects, is an essential addition to the development of a working interdisciplinary planning and design tool for collaborative planning procedures. With the proposed interactivity the users of the tool are able to experience what the consequences are of spatial interventions or which interventions are needed to reach a certain landscape service level.

Because of the fact that the methods and theories used in the conceptualisation of the LIM-tool demonstrator consist of many more variables than used in the tool the landscape system model could be expanded. However, although the gained knowledge about the working of the subsystems seems sufficient the collection of data has an even higher priority for the development of a working LIM-tool demonstrator. As stated above spatial data on specific geographical locations such as a project or plan area need the most attention concerning further research. Apart from obtaining data by measurements and research the aspect of sharing this data is also an important issue for further research. Although in the Netherlands and thus the Hoeksche Waard spatial related data on ownership situation becomes more and more public on Dutch websites such as <https://kadasterdata.nl> and <https://data.overheid.nl> the bulk of the data stored in government databases is not open for the public and thus unusable in a spatial decision tool. Although not necessary linked to spatial planning research on adequate open government data and linked web data is important for the further development of the LIM-tool demonstrator. According to Shadbolt et al. (2012) research

on this issue will consists of locating data sources, integrating the data and making browsing and querying the data possible and easy to link.

Although Shadbolt, et al. (2012) focus on governmental data the relevant issues will also be applicable for spatial data measured and analysed by independent institutions. Conclusively, a model in which the system is represented in the most accurate manner will not function properly without an input of sufficient data for the variables. Therefore the crux of a successful LIM-tool demonstrator is and will be adequate and reliable data.

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Appendix A: The Related Variables of the Three Chosen Landscape Services.

Natural Pest Regulation

Several different pests such as weeds, fungi and insects threaten crops in de Hoeksche Waard. Conventional agricultural methods are relying on chemical pesticides to counter these pests. Case study and scientific research indicates that in a perfect environment the respective natural enemies should eliminate the pest organisms; this concept is called natural pest regulation (Geertsema, et al., 2004) and needs an adequate biodiversity in order to function.

In order to visualize the influence of spatial interventions in the landscape, first the processes concerning natural pest regulation and the relevant variables of natural pest regulation have to be defined. By ascribing the relevant aspects to the corresponding columns of the structure-function-value chain of natural pest regulation in appendix B of Termorshuizen and Opdam (2009) the system of natural pest regulation can be dissected. The SES-theory first identifies several landscape characteristics. For natural pest regulation the relevant landscape elements are specified in the research on natural pest regulation in the Hoeksche Waard of Geertsema, et al. (2004). They define a difference between robust landscape elements and fine landscape elements. Robust elements contribute to natural pest regulation on an area scale and are divided in; dikes, creeks, small bushes yard planting and wide road verges. Fine elements contribute to natural pest regulation on a lot scale and are divided in brook edges, trenches, field margins and small road verges.

The second column of the chain identifies the landscape functions that are relevant to natural pest regulation. Geertsema, et al. (2004) define two functions of the landscape which are the accommodation of natural enemy species which is called the source area and the area which is being used by the natural enemy species for their survival which is called the living area. From the living areas the natural enemy species go into the nearby lots to find their prey but the source area is the place from which the natural enemy species are being distributed over larger distances. The third column consists of the landscape value of natural pest regulation on which the structure function value chain above is based. Furthermore the landscape service is defined at the bottom of the scheme and exists as an interaction between the function and the value that has been defined as biodiversity because the more natural enemies the higher level of natural pest regulation can be reached.

The next step to create a model of the processes concerning natural pest regulation is ascribing measurable specifications to the different relevant variables. Geertsema, et al. (2004) have defined five measurable specifications for the fine and robust elements. Furthermore Levitan (2000) defines a measurable unit for pesticide use as the volume of pesticide used for a specific harvest. These six specifications are divided in; **(1)** Spatial properties, consisting of space or width requirements measured in square meters or meters and the related landscape element surface area, and the spatial arrangement requirements measured in distance in meters to the green blue veining, **(2)** Pesticide use related to the crop production, i.e. litre of pesticide per kilogram crops, **(3)** The species composition of vegetation, measured in number of different species, **(4)** The species composition of fauna, measured in number of different species of fauna and **(5)** Structure of the vegetation, which can be divided in horizontal and vertical (van de Brink, Stumpel and Jansman, 2008). In this research we use the vertical structure that can be measured in vegetation height. The height is ranked in four layers; **(1)** moss layer (unto 0.25 meters), **(2)** herb layer (unto 1,35 meters), **(3)** bush layer (unto 8 meters) and **(4)** tree layer (8 meters and higher).

Following the measurable specifications, the relations between the relevant variables need to be clarified. The most adequate way to do is a scheme as depicted hereunder in figure 1 where the variables are depicted in black and the units in grey.

The spatial properties affect the vegetation and fauna composition. It is important to recognize these relations because the spatial dimensions, related dimensions and spatial arrangement of the landscape elements influence the vegetation species, the more space the vegetation has and the more room between the landscape elements the more potential different species have to develop. The same line of reasoning makes that the spatial properties of the landscape elements also influences the number of fauna species and makes this relation quantitative. The structure of the vegetation influences the number of fauna species since the structure determines the potential to accommodate fauna species. The interrelation between the number of vegetation species and fauna species

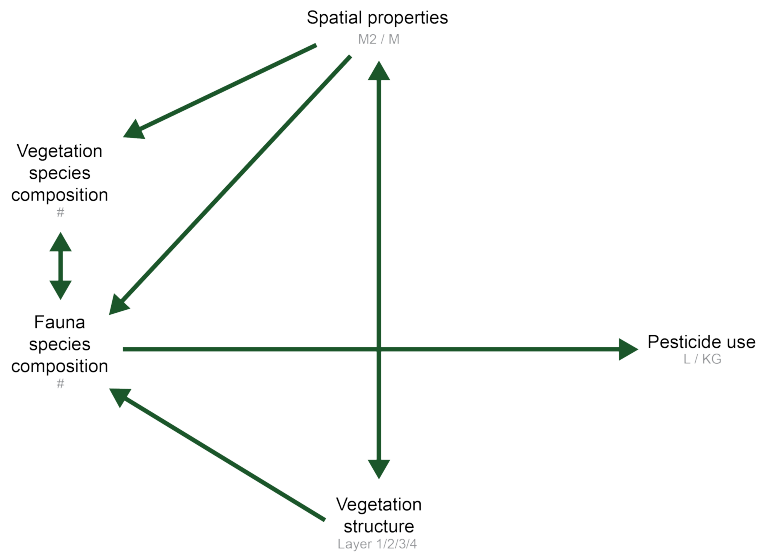


Figure 1 Relations between natural pest regulation variables (De Koe, 2013)

is established by the potential of fauna to facilitate the reproduction process of certain vegetation species and certain vegetation species facilitate fauna species in their existence (van Maarsel, 2004). Lastly the relation between the number of fauna species and pesticide use is explained by Geertsema, et al. (2004), the more natural enemies that are present in the landscape elements the higher the level of natural pest regulation is and thus the farmers will not need to use as much pesticides to maintain their crops and the volume of pesticide used to grow the same amount of crops will therefore be lower.

Water Purification

A sufficient landscape service such as water purification leads to a desired level of water quality. The chemical composition of the water is significant for the water quality. Furthermore the biological activity in the water is an important aspect. This quality can be influenced by several spatial characteristics as shown in first column structure-function-value chain of water purification in Appendix B. According to Ietswaart & Breure (2000) the spatial possibilities for water in the rural area of the Hoeksche Waard are all addressed within line shaped elements, lakes and rivers. For the land related purification possibilities de Haan, et al. (2011) defines five different forms of wetland that can be of importance for water purification. These wetlands are divided in flow fields, Horizontal purification marshes of reed or straw and brook supporting flow fields designed to filter phosphate or nitrogen.

The relevant landscape functions that are related to water purification are depicted in the second column and consist of the drainage of water from the surface which should be on a certain level in order to prevent either a high concentration of chemicals in the water because the filtration is not sufficient or a too wet surface since the drainage is underperforming. The other function is the retention of water during heavy precipitation in order to take the pressure of other parts of the aquatic network (Geertsema, et al., 2006). The third column depicts the value water quality on which the structure-function-value is based as society attaches value to the quality of the water.

The next issue is defining the measurable specifications within the realm of water purification. As with natural pest regulation four specifications, spatial properties / vegetation structure / vegetation species / fauna species, of Geertsema et al. (2004) are also applicable for water purification. In addition the soil permeability is a relevant variable. According to Delgado, et al. (1995) soil/vegetation subsystems offer effective processes of removal of excess substances and chemicals from wastewaters but more importantly run-off water from precipitation. Apart from the purifying capabilities of the vegetation filters, the soil itself also has the potential to purify water that runs through it. Furthermore, the quantitative specification for water purification is the chemical composition of the water. These can be divided into phosphate and nitrogen, also called nutrients. High levels of nitrogen can cause harm to the fish and other aquatic animals and phosphate fuels algae growth and too many algae clouds the water, which causes aquatic plants to produce less oxygen through photosynthesis and thus diminishing aquatic animal life (Koelmans & de Klein, 2012). The levels of these two elements and oxygen are of importance for determining the water quality. Phosphate levels are related to the organic processes in the water and nitrogen. Oxygen levels are of vital

importance for the fauna in the water. Furthermore, the concentration of heavy metals and drugs is an indicator for the water quality, the higher the concentration of these exotic substances the lower the water quality (Ietswaart & Breure, 2000).

Next, the relations between the relevant variables need to be clarified. In figure 2 the variables are depicted in black and the corresponding measurable units in grey. As shown the relations do not differ that much from the biodiversity scheme. Another key aspect of the relations within water quality is the influence of the chemical composition in the water related to landscape elements. The composition of chemicals is influenced by the vegetation structure since the depth of the water directly influences the structure of the vegetation in the water, which influences the capability of purifying the water. Soil permeability also has influence on the composition of chemicals since precipitation that infiltrates the ground is usually cleaner than water that runs off the soil into the surface water because some nutrients are filtered by the soil before the water joins the surface water through the groundwater (Delago, Periago & Vigueira, 1995).

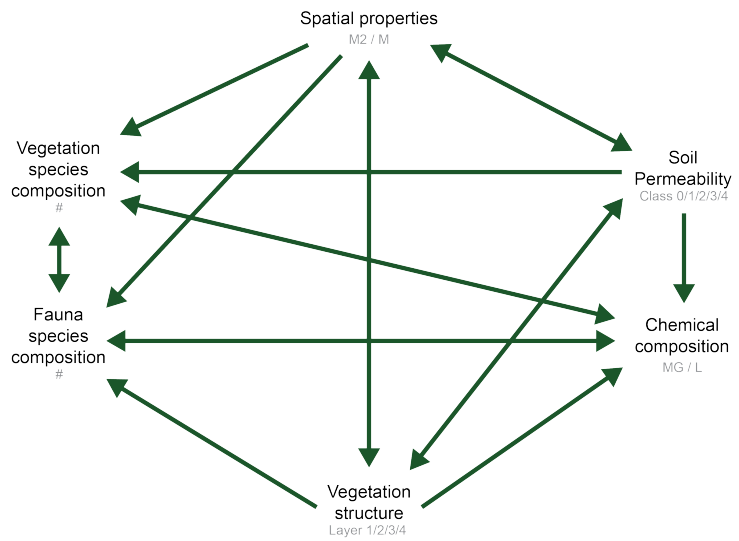


Figure 2 Relations between water purification variables (De Koe, 2013)

The concentrations in turn influence the number of flora and fauna species in and around the water since not all species can survive in water that is for example oxygen poor. The aquatic subsystem is a delicate process of organic decomposition in the form of nitrates that function as a source of food for other plants and animals, the plants in turn provide oxygen for the animals in the water. Other chemicals such as phosphorus and heavy metals in the water influence this balance and should therefore be managed in order to maintain the balance (Ietswaart & Breure, 2000).

Landscape identity

The final landscape service that has to be dissected is that of landscape identity. Since the identity of a place has to be experienced by the user of the area the five landscape elements as described by Lynch (1960) in his theory on user experience of public space are used in the first column of the structure-function-value chain of landscape identity in appendix B. Although the theory of Lynch was originally devised for the urban public space the five elements can also be utilized in a rural environment. Districts within the city define a specific area that is generally homogeneous, in a rural area this can also be recognizable. Edges in a city are usually visual or spatial boundaries that define a district such as a park or waterway. In the rural setting this is also the case. Paths are routes through the area and places where paths cross are defined as nodes. These two elements are obviously also equipped for the rural area. The last of Lynch's elements are the landmarks in an area. In the city these can be high buildings or cultural historic structures and the same can be said for the rural area. The second column consists of the landscape function that is relevant to the landscape identity. The function of landscape distinctiveness within the structure-function-value chain is that users need specific landscape characteristics to perceive and give meaning to the landscape (Alumäe, Printsman & Palang, 2003). The third column consists of the value that is given by the user to the landscape function. This value is determined by past experience, knowledge, expectations and the socio-cultural context of the user. In other words, it is about the perception of the user. Therefore the use of landscape perception is the most adequate terms to describe this aspect of the structure-function-value chain (Zube, Sell & Taylor, 1982).

Because of the sociological and physiological nature of the service of landscape identity the measurability of the variables is a difficult issue. An important factor is that of perception and within perception there are several paradigms according to Zube, Sell and Taylor (1982). Within this research the experiential paradigm will be used, which focuses on the interaction between humans and the landscape in order to understand the development of the landscape. However as Appleton (1975) pointed out; "in collecting value-judgements, however objectively, and converting them into the basis of scientific conclusion, we should not deceive ourselves into believing that this can be done without making assumptions about the fundamental nature of aesthetic experience and its relationship to enjoyment of the landscape.." With Appleton's statement in consideration the BelevingsGIS concept will be used for the perception related variables.

Several Dutch institutes that deal with spatial issues in the broadest sense developed BelevingsGIS that translates into ExperienceGIS.

Based on several literature studies and validated on multiple occasions Roos-Klein Lankhorst, et al. (2005) devised six variables of which three are positive; Naturalness, Relief and Historical distinctiveness, so the higher the value of these indicators the better the experience of the landscape. The three negative variables are Visual pollution, Urbanity and Sound pollution and the higher these values the more worse the experience. The ExperienceGIS divides the landscape into a grid with square grid cells. Four of these indicators are classified and assessed within these grid cells and are therefore qualitative. Sound pollution and Urbanity are calculated values and are thus quantitative.

Naturalness will be defined as the composition of vegetation that is present in a certain grid cell and a distinction has been between nature, as in forests, heath and marshes, and grasslands as in meadows and water banks. Cultivated land has no part in either and will therefore diminish the score for an area. This indicator is classified in 5 classes; **(0)** <0.1% nature and <50% grassland, **(1)** 0.1-5% nature and >50% grassland, **(2)** 5-10% nature and <50% grassland, **(3)** 10-50% nature and **(4)** >50% nature. Additionally classes 0 through 3 will increase a class when any form of surface water exists in the grid cell. Relief is also a indicator with 5 classes and each class will stand for a certain amount of relief that exists in the landscape; **(0)** Garbage heap, Plains, Dikes and vantage points **(1)** mounds and bulged, **(2)** Sloping, **(3)** undulating, **(4)** Hilly. The third positive indicator of historical distinctiveness has close ties with area and place identity. It measures the presence of landmarks and other visible features that illustrate the history of a certain area. Again 5 classes are devised; **(0)** No historical landmarks in sight, **(1)** Historic landmarks between 0,5 and 1 kilometre, **(2)** Historic land- or cityscape within 1 kilometre, **(3)** Historic land- or cityscape within 500 meter, **(4)** Historic land- or cityscape within 250 meter (Roos-Klein Lankhorst, et al., 2005).

From the negative indicators only Visual pollution is classified. Visual pollution focuses on the presence of visible manmade structures in that pollute an otherwise rural landscape such as transmission towers and electricity pylons. Four classes are defined; **(1)** No visual pollution within 2,5 kilometre, **(2)** Pylons or towers between 1 and 2,5 kilometre, **(3)** Pylons or towers within 1 kilometre, **(4)** Grid cells with 0,05 percent high-rises. The value of Urbanity is calculated by the percentage that has been build upon per grid cell also known as density. Although Sound pollution is measured in decibel there still is a classification in order to simplify the assessment. Five classes have been devised **(0)** less that 35 decibel: quiet, **(1)** 35-45 decibel: relatively quiet, **(2)** 45-55 decibel: sound pollution, **(3)** 55-65 decibel: much sound pollution, **(4)** more than 65 decibel: noisy (Roos-Klein Lankhorst, et al., 2005).

As with the previous landscape services the relations between the several indicators needs to be clarified. In figure 3 these relations are depicted the variables are depicted in black and the corresponding measurable units in grey. Although there are not as many relations between the indicators Urbanity has the most relations since it is the opposite of a rural landscape. As depicted the higher the urbanity the higher the visual- and sound. Moreover, there are also relations between the both kinds of pollution because of the two as being related to urbanity. However, the historical distinctiveness will also rise since buildings tell a better story for the average user than a landscape. The next relation is that of naturalness and visual pollution, which is an obvious one since the more visual pollution the lower the perception of nature. And the final relation between relief and visual pollutions is fairly evident since a hilly landscape takes away the view at may lead to visual pollution (Roos-Klein Lankhorst, et al., 2005).

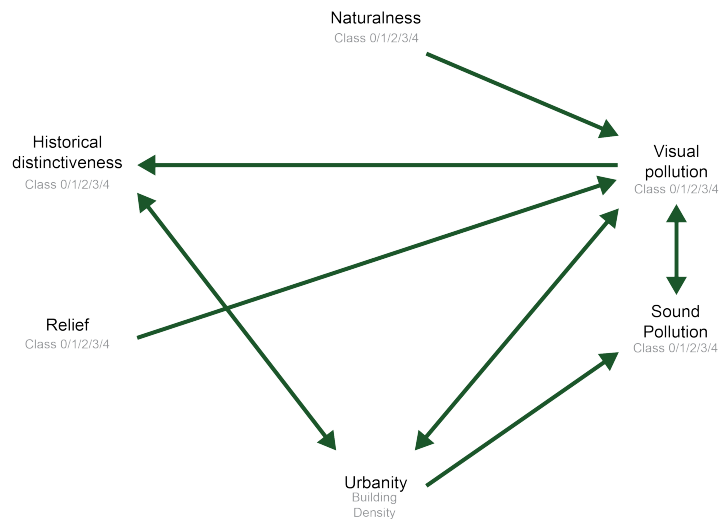


Figure 3 Relations between landscape identity variables (De Koe, 2013)

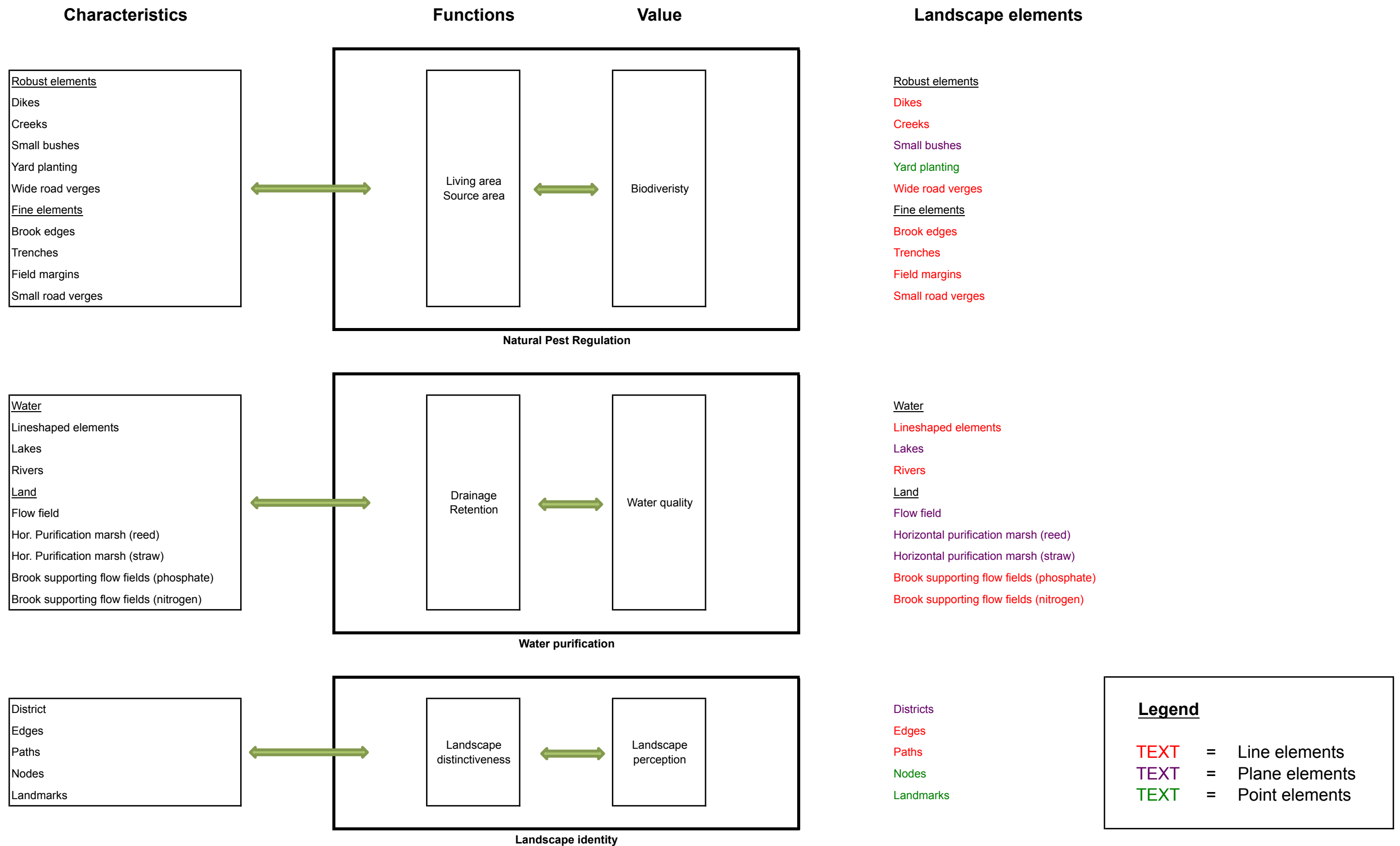
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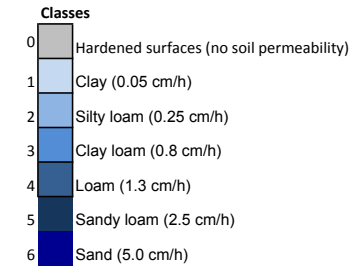
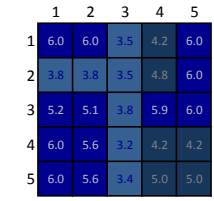
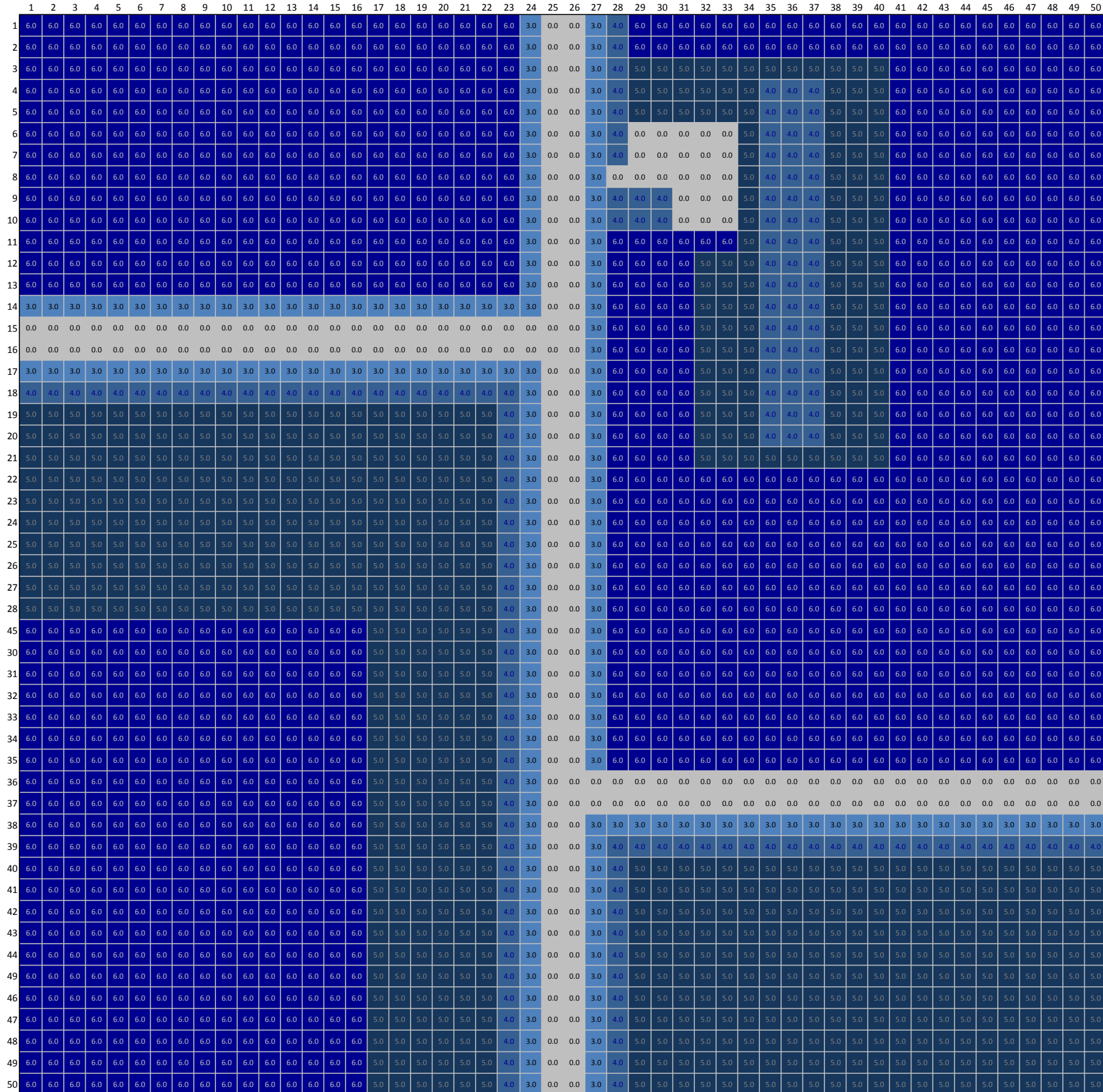
Appendix B: Structure-Function-Value Chain of The Three Chosen Landscape Services



SOIL PERMEABILITY

Company scale (Grid cells 2.5x2.5m) Value: Classes

Community scale (Grid cells 25x25m)



Appendix D: Mock-up Landscape Information Model Demonstrator Interface

