Ecological Value Restoration: a demo SEA for the island of Schiermonnikoog, the Netherlands

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May, 2012

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by

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Thesis submitted to the University of Twente , Faculty of ITC in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation, Specialisation: Environmental Modelling and Management.

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Disclaimer

To my dearest, Soheil. With all my love!

Abstract

In order to have a demonstration of strategic assessment of the management plan of Schiermonnikoog National Park (BIP+) from environmental point of view (SEA), one of the programs of this plan named desired development of the Westerplas lake has been considered in this research. According to the plan, water quality of the lake is very poor due to eutrophication. The consultative body of the park has determined three alternative improving measures (scenarios) for the core problem: "declining Westerplas naturalness".

To shape a common understanding between the stakeholders and the university party, a conceptual model around the mentioned issue is built. The concepts around the core problem and their relationships behaviour are identified systematically. They are obtained through participatory modelling exercise, in which the stakeholders' local knowledge and their experience about the ecological system of the lake are exploited to build the problem tree and Fuzzy Cognitive Map (FCM).

Having applied a preliminary analysis on the created cognitive map, the most important concept in the map was "maintenance practises". The result of the analysis is in line with the stakeholder's initial opinion about the main problem, and the related scenarios they had been suggesting with regard to maintenance practices. The similarity shows that the constructed conceptual model is representing the understanding of the stakeholder's about the system well enough. This common conceptual model allows us to discuss and present our further results in a known frame work to stakeholders.

"Connecting the lake to Wadden Sea" was the selected scenario for this research (among the suggested scenarios) to be developed. For the sake of the simplicity, 'free access of Wadden Sea to Westerplas area' was assumed. Based on this assumption, a base quantitative model for the system including 3D spatial model of the area, inundation frequency map, inundation duration map and the envisaged salt marsh vegetation zonation was developed.

Spatial modelling of the bounded system (the Westerplas area), is obtained using the combination of DEM and a topographic map of the lake bottom. Albeit, the integrity of the two data sets were checked in prior to the combination. This has been done using height difference check, removing systematic effects and check the normality of the height differences' distribution.

To generate inundation frequency and inundation duration maps, analysis of the tidal regime of the Wadden Sea was necessary. The water height measurements of Schiermonnikoog within the past 12 years were extracted from Rijkswaterstaat database. This data set has 10min temporal resolution. The function of water height with respect to time, and the function of water level durations were calculated and analysed, and the frequency of inundation for each elevation were calculated.

The inundation frequency map is calculated using the generated spatial model and calculated inundation frequencies. This map provides both frequency and the extent of inundation for each elevation in the lake area. Similar map is generated using the spatial model and calculated inundation duration.

Having calculated the inundation frequency, different vegetation types in five zones were determined. These are the vegetation types which are going to grow in each particular elevation, provided the scenario is deployed. The zonation types are adopted for our study area from the existing ecological literature of the Dutch salt marshes.

Through these maps, the stakeholders can see the simulation of the effect of deploying the scenario. This gives them the opportunity to analyse the ecological and environmental effects of implementation of such a scenario and support their management decisions. Although only one scenario is developed, the provided information (the spatial model and inundation maps) is essential for other possible scenarios as well.

Key words: Westerplas Lake, Fuzzy Cognitive Map, participatory modelling exercise, SEA demonstration, spatial modelling, inundation frequency and duration, salt mash zonation

Acknowledgements

My very first appreciation goes to the Education and Culture DG, European Union because of providing a valuable opportunity for me to pursue such a special experience graduate program (GEM) in two European countries.

I owe my deepest gratitude to faculty members of NATEKO, Lund University Dr.Karin Larsson and Dr.Petter Pilesjö.

I am very thankful to my supervisors, Dr. Alexey Voinov and Drs. Henk Kloosterman, for their valuable guidance throughout the thesis phases especially during the workshops performance.

I would like to express my deep gratitude to the consultative body of the Schiermonnikoog National Park for their friendly cooperation: Mr. Jan van der Velde , Dr.Theo Claassen ,Mr. Otto Overdijk , Mr. Erik Jansen, Mr. Arjen Kok, Ms. Mia Michels and Ms.Francine Venselaar.

I would like to thank Dr.ing. T.H.M. Rientjes, Dr. ir. Mhd. Salama Dr. J. Joris Timmermans and Mr. Gokmen from department of Water Resources of ITC for their precious advices.

I would like to show my gratitude to Ms. Ir. E.M.C. Groenendijk, Ms. Alejandra Larrazabal from department of Urban and Regional Planning and Geo-information Management of ITC, Dr.Michael Weir, Ms. Ir. L.M. van Leeuwen, Mr.Babak Naimi and Ms. Mitra Shariati Najafabadi from department of Natural Resources of ITC for their great spiritual and scientific support.

I am indebted to my lovely classmates in GEM course for their unforgettable friendship and support. Your company enriched my life! Thanks a lot Speeder and Abel for all your scientific cooperation and sympathetic help.

I offer my special deep regards and blessings to my beloved Dr. Soheil Sotoodeh from department of Earth Observation Science of ITC. Without your encouragement and valuable scientific advices it would have been impossible for me to finish this work. Thanks for your kind support and untiring help during my difficult moments.

Lastly, I appreciate my lovely parents, my sweet sister and brother for all their continuous encouragement and deep kind support to complete this work. You are the precious treasure of my life.

Table of Contents

List of figures

List of tables

1 Introduction

1.1 Background

In order to choose the best scenario for the restoration of ecological value of Westerplas area, located in the Schiermonnikoog National Park, a demonstration of a Strategic Environmental Assessment (SEA) approach for the third Management and Development Plan of the park(Beheer en Inrichtingsplan 'Plus') which covers the period from 2011 to 2022, is formed and the most probable scenario is developed.

Environmental assessment of the policies, plans and programs (PPP) named as SEA is now used by many administrations in the world at various scales and for different sectors and problems (Rauschmayer et al., 2005) to incorporate environmental concerns into policies, plans and programs and evaluate their inter relations with economic and social considerations (Commission for Environmental Assessment, 2009).

In recent years, almost all of the SEA and ecological management efforts are performed with stakeholder participation to be more effective (Voinov et al., 2010), since the key principles of SEA are public participation, clearness and good quality information (Commission for Environmental Assessment, 2009).

Stakeholders are regarded as "those that are both affected by and affecting the problem and are, at the same time, participating in the process of formulating and solving it." (Rauschmayer, et al., 2005).

The knowledge of stakeholders can be formalized by the aid of modelling tools. The models need to be transparent and sufficiently flexible to be able to show how the system responds to different parameters inputs related to various scenarios (Spang, 2007).

In the case study of this research, the major objectives for the management of the park, which leads to some general consideration (programs), has been considered with regard to nature restoration and conservation, water management, recreation, education, protection of the coast and research. The desired development of the Westerplas lake located in the western part of the island and the measures for its poor quality is one of these general considerations (Consultative body, 2011).

This study can be divided into two main sections: 1) Qualitative modelling which obtained from the stakeholders opinion and 2)

Quantitative modelling. The second includes spatial modeling of the system parameters which is obtained by using GIS analysis. This is required to inform the stakeholders about the condition of ecological system of the Westerplas after applying different scenarios.

In the following section, the ecological value of the lake and why it is necessary to take care of it, are explained. Then the actual problem this thesis is trying to address is stated, followed by this research's objectives.

1.2 Ecological value of Schiermonnikoog

Schiermonnikoog is one of the Frisian Islands located in the northern coast of the Netherlands. The Wadden Sea separates these islands from the main land. The islands attract many tourists because of their unique riches of natural vegetation which form a perfect breeding place for numerous birds (Beukeboom, 1976).

Based on the Ramsar Convention on Wetlands, which is an intergovernmental agreement of its member countries to sustain the ecological character of their Wetlands of International Importance in their territories, the 'Waddeneilanden, Noordzeekustzone, Breebaart' site was designated as a Ramsar site in 2000. The site covers the sand dune area of five Wadden Sea islands included Schiermonnikoog and the adjacent North Sea coastal zone (Ramsar Convention Bureau, 2002).

Schiermonnikoog is famous for its spectacular nature, with variation in landscape that includes salt marshes, dunes, forest, the Westerplas, one of the widest beaches in the Wadden region, the 'Strandvlakte', sandbanks and tidal flats, causes it to be the first to receive official National Park status in 1989 (de Vleet, 2011).

In the Netherlands, a national park is defined as "a contiguous area of nature of at least 1,000 hectares, with a characteristic landscape and special plants and animals which also present good opportunities for recreational use" (Consultative body, 2011). Based on the above definition, the major part of Schiermonnikoog island, except the village and the polder, falls under protection of the National Park Schiermonnikoog(de Vleet, 2011).

1.3 problem statement

In 1960, the Westerplas salt marsh area in Schiermonnikoog island was isolated from the sea by constructing artificial dunes (dike) to make a buffer zone against brackish water and to increase safety against flooding, as well as making new pasture land for farmers. The dike blocks the inflow of sea water to the Westerplas and there is no entrance of sea water to the Westerplas since then. The entire Westerplas area, with area of 36 hectares, is bounded on the east side by the dike around the polder area and in the west by a dune complex.

In order to keep water balance of the island and diminish the desiccation of dune valleys and to conserve the ecological value of the island e.g. conservation of the vegetation like Orchids which need wetness to be alive, extraction of water for drinking water usage from Hertenbos valley was reduced by 50% through extraction the ground water nearby the Westerplas.

Potable water has been gained from Westerplas by three wells (pumps) in the dike from ca. 20 m under the dike in the northern zone of the Westerplas from 1997 onwards. The abstraction is from the thick fresh water bubble below the region. That bubble is stable (within a certain range) and fresh water from the dunes is added to this bubble constantly.

To compensate this extraction, additional fresh water from the polder was pumped into the Westerplas during the period 1997 till 2006. Periodic samplings of Wetterskip Friesland (water Board Company) from 1993 indicated strong eutrophication of the water in the lake which is most likely a mainly caused by intake of polder (from 1997 till 2006) which contains higher levels of phosphate, bicarbonate and sulfate compared with water in the lake. The inlet phosphate-rich water from polder has contributed to the increased nutrient loading of the lake. This has resulted in a decline of the ecological value of the Westerplas. The population size of Hippuris vulgaris and Littorella uniflora has decreased. The water has also become fresher. The Westerplas currently has poor water quality, high turbidity and absence of significant aquatic vegetation. The riparian vegetation in the form of a broad zone of reed (Phragmites australis (common reed)) almost disappeared in a relatively short time.

Since pumping of water collected in the polder into the Westerplas has led to eutrophication, intake was stopped in October 2006, while extraction of drinking water continues.

Since 2006, there is no input of nutrients into the lake, but still there is phosphorus in the water that is because of releasing from sediments due to internal eutrophication. Sulphate and bicarbonate stimulate this release. Phosphate seems to accumulate in the sediment on the bottom of the lake during winter and there seems to be an increased release of phosphate during summer. Climate change resulting in higher temperatures during recent summers may have stimulated this release of phosphate.

Disappearance of aquatic plants over the past decade is the result of this eutrophication. The missing large reeds around the pond (in 2008 only one remained stubble under water) is possible due to this increased eutrophication, but initiated and strengthened by the predation of Greylag geese and changes in the water inlet of polder. Greylag geese, especially in the period moulting, are able to eat much water reeds, close to the water. That population has increased considerably over the last decade. That reinforces and accelerates the dying process (water) reed.

1.4 Research objectives

1.4.1 General objective

The general objective of this research is the development of management scenarios for restoration and improvement of the ecological value of Westerplas Lake.

1.4.2 Specific objectives

I. To identify the effective parameters of the problem regarding the ecological value of Westerplas Lake and build the conceptual model of the system concerned the defined problems

II. To define scenarios for the restoration of the Westerplas degradation through participatory decision making process

III. To provide base quantitative models for supporting participatory decision making

1.4.3 Research Questions

The research questions related to each specific objective mentioned above are as follows:

1.4.3.1.I. What is the problem of the lake? What are the causes and effects of that problem?

1.4.3.2.I. Who are the relevant stakeholders?

1.4.3.3.I. What are the variables/concepts of the system and how are the relationships between them?

1.4.3.4.II. What are management scenarios for lake ecological restoration and which one is applicable for this study?

1.4.3.5.III. What is the boundary of the system to be modelled?

1.4.3.6.III. What will be the proper tools for modelling?

1.4.3.7.III. What aspects should be considered to make a base model and which data is needed?

1.5 Overview of the thesis content

To tackle the mentioned problem, obtained the research objectives and answer the research questions, this research is conducted. First an introduction, the statement of the problem and objectives of the research are presented in this chapter. They are followed by reviewing the available literature and getting an overview about the current state of the research and practice about similar subjects, in Chapter 2. Chapter 3 provides information the geographical and environmental properties of the island.

Chapter 4 explains about concepts and approaches used to cope with the stated problem. It guides the reader through all the taken steps to get to the research objectives. Chapter 5 presents the available data around the problem and the results of applying the methods, mentioned in Chapter 4, to these data. An extensive discussion about the obtained results is provided in Chapter 6 and the last chapter, 7, presents the conclusions of the research and tells about any further ideas of the writer.

2 Literature review

2.1 *System qualitative modelling*

2.1.1 Strategic Environmental Assessment (SEA)

Environmental assessment of the policies, plans and programs is now used by many administrations in the world at various scale and for different sectors and problems (Rauschmayer, et al., 2005). According to Netherlands Commission for Environmental Assessment, Strategic Environmental Assessment (SEA) is defined as a group of approaches that try to incorporate environmental concerns into policies, plans and programs (PPP) and evaluate their inter relations with economic and social considerations. So, the key principles of SEA are public participation, clearness and good quality information (Commission for Environmental Assessment, 2009).

Some of the advantages of public participation in SEA, are : increasing clearness in decision-making; proposing different options and mitigating measures; promoting expertise sharing and raising the credibility of selected PPPs (Rauschmayer, et al., 2005).

Noble and Christmas (2008) presented a methodological framework for a stakeholder-based strategic environmental assessment (SEA) application in greenhouse gas (GHG) mitigation policy options in Canadian agriculture. In this study, five competing GHG mitigation options against 13 valued environmental components (VECs) as different alternatives were evaluated by agricultural producers and non-producers as stakeholders(Noble, et al., 2008).

2.1.2 Participatory modeling exercise

The process of integrating stakeholders with local knowledge to scientific knowledge in the form of analytic system modeling process to support ecosystem-based management is called participatory modeling. There are different participatory modeling include Shared Vision Planning, Mediated Modeling, Participatory Action Research (PAR), participatory Integrated Assessment (PIA), and Participatory Integrated Planning (PIP) (Gaddis et al., 2008).

The basic assumption in participatory modeling approaches is that the participants have fairly high knowledge about the system. This assumption is the reason to involve the stakeholders within the process(Gaddis, et al., 2008).

It is a valuable research approach in resolving challenging questions in watershed management, resource extraction and ecosystem protection (Gaddis, et al., 2008).

In recent years, almost all of the environmental assessment and ecological management efforts are performed with stakeholder participation to be more effective. With stakeholder engagement, the decision-making process is executed with less argument and more success especially when stakeholders have sufficient knowledge and understanding of a system and its dynamics under different conditions (Voinov, et al., 2010).

The stakeholders' engagement in as many of the decision making process stages as possible and as early as possible will improve the modeling result (Voinov et al., 2008).

In order to identify the problem clearly, the system structure should be studied and the conceptual model, which is a qualitative description of the system must be created. The required temporal, spatial and structural resolutions for the system dynamic modeling will be determined in designing the conceptual model (Voinov, 2008).

The social relations between stakeholders, their communication ability and the technical and modeling tools and softwares used to enhance the exchange of information are some important factors that affect the efficiency of the participatory process (Voinov, et al., 2010).

There are some variations of participatory modeling such as shared vision planning, mediated modeling, participatory action research which are different in whom the process initiated by, the way of stakeholders engagement in the process, the wideness of research questions addressed and the mechanism of incorporation the modeling results to decision making (Gaddis, et al., 2008).

Rauschmayer and Risse (2005) presented five different methods of participatory approaches used in land-use planning and environmental disagreement resolution which were divided based on stakeholder involvement and with the involvement of the general public (Rauschmayer, et al., 2005). One of these methods is called Mediated modeling which is a process of understanding the dynamics of a complex problem, improved with cooperation of people working together to create a common image of a problem in form of face-to-face discussions (Antunes et al., 2006).

Another study that showed the application of strategic stakeholder dialogues was executed in 2010 in National Park Schiermonnikoog. The problem was the prohibition of large-scale cockle fishing in the Wadden Sea which produced confliction between the islanders on the one hand and the professional bodies on the other hand. All the Stakeholders were committed equally in this decision-making process (Franssen, 2010).

The participatory modeling generates the proper information for a broad SEA by concentrating on the physical-technical performance of the system and the strategic decision making problem (Nardini et al., 2005).

2.1.3 Fuzzy Cognitive Mapping (FCM)

The cognitive map is a qualitative model of a system with its variables and the causal relationships between them(Ozesmi et al., 2003).

The term fuzzy cognitive map (FCM) was invented by Kosko in 1986 to describe a cognitive map model with two significant characteristics: Firstly causal relationships between concepts are fuzzified and secondly the system is dynamic involving feedback (Shamim Khan et al.).

F.Hobbs et al.(2002) used FCM modeling process to define management objectives for the Lake Erie ecosystem by participation of many experts and some members of the public. The FCM was generated with 160 variables which could be grouped into three general categories: management actions, physical/chemical ecosystem variables, and biotic ecosystem variables. The stakeholders were asked to weigh the interactions between these variables within the range of -100 to 100 which then were divided by 100 to yield the final weights.

Ozesmi et al. (2003) developed a participatory ecosystem management plan for Uluabat Lake, Turkey through interviews with stakeholders who belonged to six different groups. The stakeholders represented their opinion about the most important goal to design the management plan with FCM .In the management plan, lake pollution reducing was considered as the main goal since lake pollution considered as the central problem for the lake system which had effects on all variables.

The similar research was done by Ozesmi et al. (2004) in order to determine the opinion of different stakeholders for resettlement of people displaced by a large scale dam project through construction social FCMs .In both researches the relative strength of the relationships between variables in the FCM was considered between 1 and -1. At the end of these researches some policy options run to see what would happen in the system under implementation of different policy options.

Markinos et al.(2007) introduced FCMs to model a decision support system for precision agriculture (PA) in which the problem of crop development and spatial unpredictability of cotton yield was addressed. The concepts (nodes) in this model consisted of the main factors effecting on cotton crop yield such as texture, pH, K, and P of the soil. In this work, the FCM model was designed by one experienced cotton farmer and two experienced soil scientists who considered eleven main factors-concepts for this model .The weight of influence from one concept to another was done by using IF-THEN rules among factors and yield.

Fuzzy Cognitive Maps was applied by Nasserzadeh et al.(2008) as a decision making tool to represent and model the factors affecting customer satisfaction in banking industry and the relationships among them. The model included 31 variables with 34 relationships weighted based on linguistic fuzzy weights according to the data collected form 70 experts of 30 branches of Mellat bank through questionnaires was constructed by using the fuzzy toolbox in MATLAB software.

2.2 System quantitative modelling

In participatory modeling process, modeling tools especially simulation modeling is determined as the major tool for decision making which can answer the questions determined by the stakeholders and formalize their knowledge. One of these tools is system dynamics which is a method for learning and managing the feedback relationships and determining the behavior of the system in complex systems like social or environmental systems (Antunes, et al., 2006) through computer models. The models need to be transparent and sufficiently flexible to be able to show how the system responds to different parameters inputs while running various scenarios (Spang, 2007).

The temporal dynamics and spatial relationship are both important in modeling of physical, biological and socioeconomic dynamics of an ecosystem. There are some soft wares such as Stella, Simile or Madona, which are applicable for simulating the system processing with a series of connected stocks, flows and converters. However the process modelings are generally useful for understanding and analyzing the non- spatial structure of the system (Sandker et al., 2010).

Sandker et al. (2010) combined the system dynamics software STELLA with the spatial simulation software GEOMOD (IDRISI) to explore environmental and social impacts of large scale plantation investments for reducing emissions from deforestation in Kaimana district in Indonesia under different scenario in a participatory manner (Sandker, et al., 2010).

In order to analyze and visualize the fate of nitrogen produced in different anthropogenic sources, which led to eutrophication in Solomons harbor watershed in Maryland, two modeling tools were used. One of them was dynamic model of a septic tank by using STELLA software and the second one was the spatially explicit landscape modeling frame work (LMF) to estimate the relative impact of various nutrient sources on water inflow to a watershed(Voinov, et al., 2008).

In FLORES international program for developing policy to improve livelihoods of people at the forest margin in developing countries, Flores models have been developed using Simile in a process of participatory model development in order to enhance understanding the interaction between people and their natural resources. The Flores model represents a very specific view of rural communities in terms of different submodels. Participants with little or no modeling experience can be involved in modeling process with Simile's visual modeling (Muetzelfeldt et al., 2003).

Regarding lake management, Håkanson et al.(2003) used holistic lake ecosystem model, LakeWeb, to discuss practically useful management criteria such as PER (the Potential Ecosystem Risk number), in order to illustrate two scenarios which discusses changes in nutrient loading in Lake Batorino, Belarus. The first scenario describes the agricultural changes after 1990 when there was a drastic reduction in the use of fertilizers and the second scenario describes the possible changes in the lake foodweb related to global climatic changes.

GIS package especially ArcGIS can be a useful tool in modelling when spatial aspects are more important than temporal aspects.The spatial connectivity of the system variables can be modeled by using Geographic Information Systems (GIS) which are not strong in simulation of temporal dynamics of the system (Voinov, et al., 2010).

The tendency to use GIS in spatial decision making situations causes that designing and developing participatory GIS (PGIS) becomes a fundamental issue in decision making procedure. PGIS combines both quantitative and qualitative methods and relates them through community development processes. The Participatory Approaches implemented in Agriculture and Forestry project in Shanxi province of China in pilot village to monitor and to evaluate their benefits for restoring the environment and reducing the poverty is a case study for using PGIS(Tane et al., 2007).

2.2.1 Salt marsh inundation and vegetation

Salt marshes are a transitional zone between the sea and land formed by flooding, sedimentation and erosion. This highly specialized zone is characterised by a close interaction of physical and biological processes(Erchinger 1995). In the Netherlands part of the Wadden Sea, 3.6% of the total tidal area is salt marsh, divided into a barrier island-type and a mainland-type of salt marsh. In the past, embankments have far exceeded the natural accretion rate of the mainland-type of salt marsh. Therefore, the total salt marsh area decreased. Salt marsh plants play an essential role in the interaction between hydrodynamical and biological factors. In general, salt marsh development is possible on locations with a gently sloping coastline, low wave energy and low water velocity. Therefore, salt marshes are absent on exposed rocky coastlines, but they are usually present along flat coasts and in sheltered bays(Dijkema et al., 2007).

The relationship between vegetation zonation, shore height, and inundation frequency and inundation time for three dominant plant species on the Dutch Barrier Island of Schiermonnikoog was investigated over one year(Bockelmann et al., 2002).The survey was done on three study sites in the eastern part of the island (1110 plots of 2m2 in a grid on 1650 ha salt marsh to check whether inundation is a better explanatory variable than shore height for the occurrence of dominant salt marsh plant species.A custom made computer program (MultiTrace) was used to calculate MHT and inundation frequency which was measured by inundation meters. At higher shore heights inundation became a rare event, and frequencies changed slowly with shore height. The study showed that inundation frequency and time are superior to shore height in predicting marsh plant zonation(Bockelmann, et al., 2002).

Two major aspects of tidal inundation and exposure, j,e., frequency and duration, were examined by Elellterills et al. (1979)in relation to the abrupt demarcation between adjacent monotypic zones of Spartina alternijlora and Juiicus roemerianus of salt marsh in Davis Bay, Mississippi. These two zones were compared based on the range of elevation(comparing to mean low water (MLW)) that they occupied and their flooding frequency. The results showed, while major portions of the two monotypic stands have extremely different tidal relationships, frequency and duration of tidal flooding could not be related to the line of abrupt delineation between the plant zones, suggesting that factors other than the tide are involved(Elellterills, et al., 1979).

The frequency and duration of inundation analyses are part of a total analysis package named inundation program that includes long-term sea level and seasonal variation comparisons with a nearby long-term tide station. The necessary data input for the program is 6-minute water level data and the tabulated high tides over the desired time period for the inundation study, relative to a desired tidal datum or user-specified datum. The program calculates the amount of time the water level is higher than a given elevation, and to what height the high tide rises. Although this program was originally developed for marsh restoration activities, the analyses have broader applications for the coastal engineering and mapping community and for use in designing coastal infrastructure.(Stolz, 2005).

Chormański et al. (2009) applied the hydrodynamic 1D unsteady model for calculating hydro-ecological flood characteristics in the Lower Biebrza River Basin located in northeastern Poland. The model was combined with the Digital Elevation Model for determining of flood extent. Also, the relations of flood characteristics to particular generalized groups of vegetation of the riparian wetland were analyzed for vegetation season (February- September) daily time series (1961-1996).The results show a significant congruity between the type of vegetation and calculated flood characteristics. The hydrodynamic model was confirmed to be a useful tool for calculating flood characteristics(Chormański, et al., 2009).

A spatial analysis tool on the GIS-raster system in ILWIS software included Neighborhood operation and iteration model have been applied in order to calculate the encroachment of the tidal inundation on the coastal area in Indonesia. The resulting inundation map showed that the tidal flood spreads to the lowland area and caused the inundation of coastal settlement, infrastructure, as well as productive agricultural land. The monitoring of the vulnerable area due to the tidal inundation under the scenario of extended land subsidence plays an important role in long-term coastal zone management in Semarang (Marfai et al., 2008).

3 General description

3.1 Study area

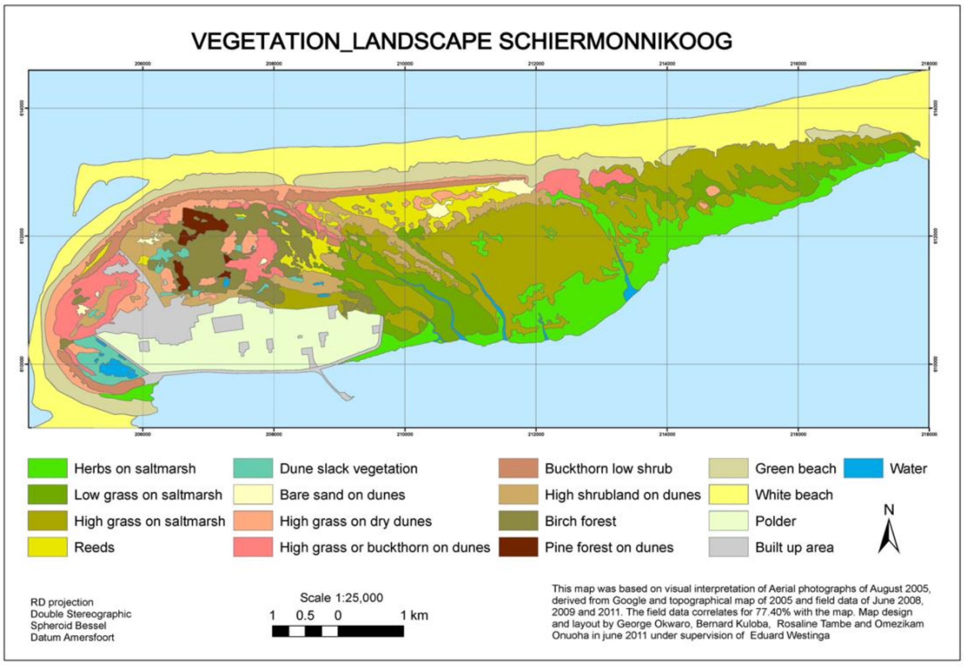
Schiermonnikoog, with a length of 16 km and a width of 4 km located at 53º 29´ 0´´ N and 6º 10´ 0´´ E is the most easterly inhabited Dutch Wadden Island, in the North of The Netherlands. Since 1500, the island has shifted around three kilometers eastward. Schiermonnikoog became the site of the Netherlands' first national park in 1989. Schiermonnikoog National Park has an area of 5,400 hectares, which is managed largely by Natuurmonumenten ("National Park Schiermonnikoog," 2004).

The only village on the island has just 1,000 permanent residents, making the municipality of the island the least densely populated in the Netherlands. Yearly, up to 300,000 people visit the island, making tourism become the main source of income for the island("National Park Schiermonnikoog," 2004). Figure (3.1) shows the location of study area in The Netherlands.

Figure 3-1- location of the study area in the Netherlands (Google map, 2011)

3.1.1 Flora and fauna

Schiermonnikoog is an excellent example of a nature island included eight landscape types i.e. salt marsh, dunes, forest, water bodies, polder, village, beach and tidal flats cause an abundance of plants and animals("National Park Schiermonnikoog," 2004). The various landscapes and the related vegetation distribution have been shown in figure (3.2).



This map was based on visual interpretation of Aerial photographs of August 2005, derived from Google and topographical map of 2005 and field data of June 2008, 2009 and 2011. The field data correlates for 77.40% with the map. Map design and layout by George Okwaro, Bernard Kuloba, Rosaline Tambe and Omezikam Onuoha in june 2011 under supervision of Eduard Westinga

Figure 3-2- landscape and vegetation distribution in Schiermonnikoog

The vegetation of Schiermonnikoog is also relatively unusual particularly in the moist dunes e.g. mushrooms and Orchids. During recent years, these dune valleys have become increasingly overgrown with birch and creeping willow caused by enrichment of the soil by fertilizers and reduction of the rabbit population. Some rare species such as the 'honey orchid' Herminium monorchis had disappeared ("National Park Schiermonnikoog," 2004).

The woods on Schiermonnikoog have coniferous as well as deciduous trees. The coniferous trees are almost one hundred years old. In the shelter of the coniferous woods, more and more deciduous trees began to grow, such as alder and birch("National Park Schiermonnikoog," 2004).

The dominant species of the distinguished vegetation types in different elevation of salt marsh on Schiemonnikoog are as following. Typical for Schiermonnikoog, however, are the large areas covered by Juncus maritimus(Bakker, 1978).

The Puceinellia maritima vegetation type is found on the lowest parts of the salt-marsh, partly along the creeks, partly in local depressions. It is surrounded by a vegetation of Festuea rubra, often somewhat higher situated.Farther away from the tidal flat a Juncus gerardii vegetation occurs in depressions with poor drainage, enclosed by low dunes. On levees bordering the tidal flat towards the salt-marsh and on creek bank levees a vegetation is found with Artemisia maritima as a dominant. On the highest parts of the salt marsh, low dunes have developed, covered with a vegetation of Ammophila arenaria. On the transition of the latter towards lower parts of the marsh generally a vegetation of Juncus maritimus, Elytrigia pungens, or a combination of these two species is found(Bakker, 1978).

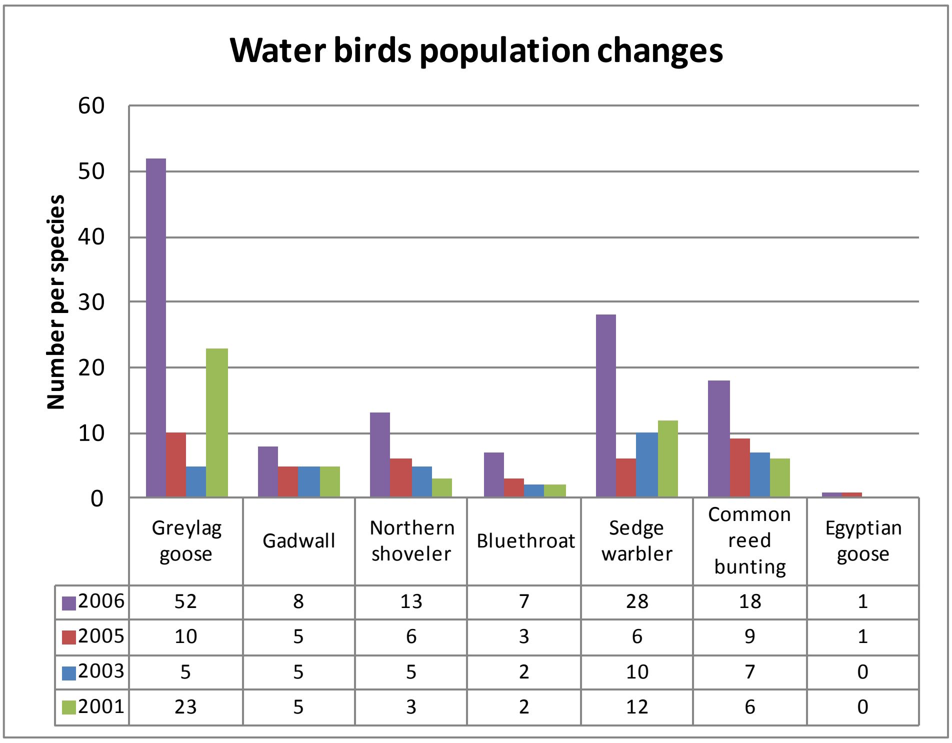
Schiermonnikoog is an attractive location for birds all year round. Besides the tidal flats with their many birds searching for food, the salt marsh with its colonies of gulls, terns and spoonbills, and the dunes with their abundant population of songbirds, also the polder with food richness often attract a large number of birds especially large groups of Brent geese and Barnacle geese in the winter ("National Park Schiermonnikoog," 2004).

The figure(3-3) show the water birds population changes from 2001 to 2006.As the figure shows, the number of graylag geese has been doubled since 2001 and Egyptian goose has been introduced since 2005(Natuurmonumenten Organization, 2011).

3.1.2 Hydrological condition

In the island, annual average rain fall rate is more than evaporation rate, so the fresh water thickness below the surface of the island is permanent and high. Generally, in the center of island, especially the dunes region, the thickness of the fresh water layer is higher than at the edges. Under the polder the fresh water depth is very shallow(Wetterskip Fryslân, 2011).

The fresh water thickness under Hertenbos valley which is near the center of the dunes on the island is high about 60-80 m and because of this, the valley has been chosen for potable water extraction and supply. The fresh water thickness under the Westerplas Lake is about 30 m in the northern part to only a few m at the southern border(Wetterskip Fryslân, 2011).



	Greylag goose	Gadwall	Northern shoveler	Bluethroat	Sedge warbler	Common reed bunting	Egyptian goose
🟪2006	52	8	13	7	28	18	1
🟥2005	10	5	6	3	6	9	1
🟦2003	5	5	5	2	10	7	0
🟩2001	23	5	3	2	12	6	0

Figure 3-3- Water birds population changes from 2001 to 2006 in Schiermonnikoog

The ground water table decreases gradually from north to the south toward the Wadden Sea at the southern border and to the North Sea at north of the island. Under the Westerplas located in the western part of the island, ground water table is around 2 m and in the polder, groundwater table is a little lower (under mowing fields about 0.5 m above sea level and 1 to 2 meters above sea level at the higher parts of the polder) (Claassen et al., 2010).

The polder has the lower elevation (around 1.5 m, in mowing field about 1 to 3 meters above sea level) compared to dunes so there is seepage of fresh water from dunes to polder. The additional water from rainfall and the seepage are collected in ditches of the polder and goes to Wadden Sea. If the water level in the ditches becomes higher, surplus water will be discharged (by low tide) to the sea. If water level decreases (too much) the opening to the sea will be closed(Claassen, et al., 2010).

3.1.3 Population

Based on the Statistics Netherlands in 2011, total population in Schiermonnikoog had been increasing from 1960 as 783 until 2003 as 1000 (Table 3.1). The only village on the island has just 1,000 permanent residents, making the municipality of the island the least densely populated in the Netherlands ("National Park Schiermonnikoog," 2004).

Yearly, up to 300,000 people visit the island, making tourism become the main source of income for the island("National Park Schiermonnikoog," 2004). According to municipality of Schiermonnikoog data, the number of tourists has been increasing from 2000 to 2003 and after that till 2009 that data is available-the number of tourist had a reduction.

Table 3-1- Total population in Schiermonnikoog since 1960 (CBS (Centraal Bureau voor de Statistiek), 2012)

Periods	Population	No. of tourists*
1960	783	NA
1970	814	NA
1980	875	NA
1990	921	NA
2000	1000	300,170
2001	1017	311,080
2002	1025	303,442
2003	1000	310,968
2004	992	279,042
2005	997	273,613
2006	986	290,000
2007	946	276,700
2008	951	287,900
2009	946	294,700
2010	942	NA

* ***Source: municipality of Schiermonnikoog***

4 Methods

The general workflow of this research is shown in Figure 4.1. This workflow has been divided in two main sections: system qualitative (conceptual) and quantitative modelling. The methods used for each of these sections will be explained separately.

The system qualitative modelling section includes stakeholders selection and organization, problem identification and making a conceptual model for the system by using Fuzzy Cognitive Mapping approach.

General steps of the quantitative modelling of this research are scenario selection and building a base quantitative model for the preliminary assessment of the scenario.

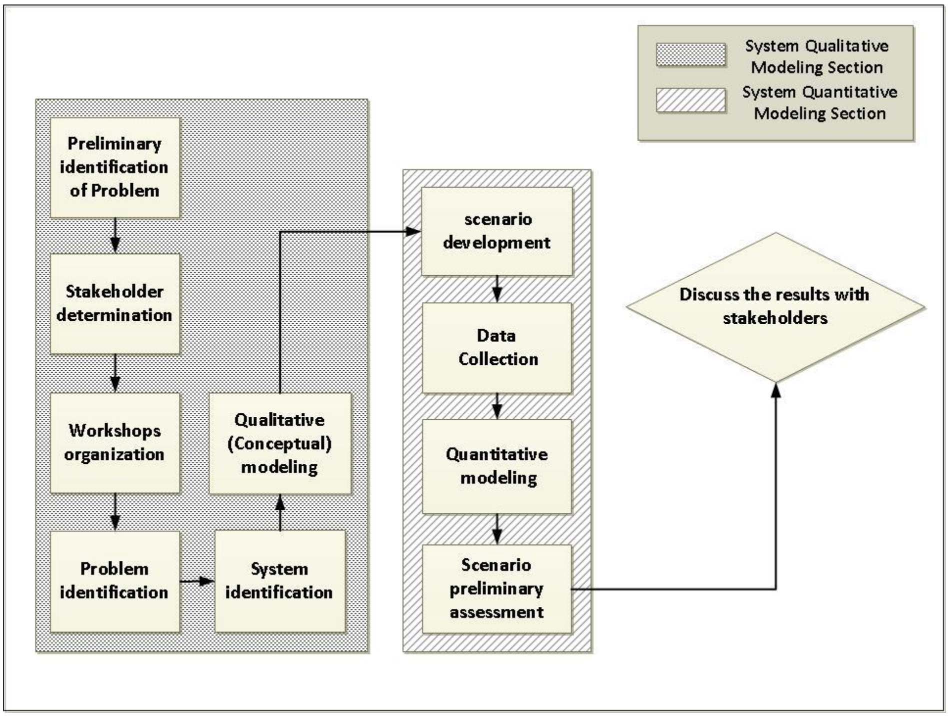


Figure 4-1- Research general workflow

4.1 System Qualitative Modelling

The aim of system qualitative modelling section (figure 4-1) is creating a conceptual model of the ecological system of the Westerplas through participatory modelling exercise with stakeholders' engagement.

Stakeholders engage in the participatory modelling process at different stages, with various level of involvement. The level of contribution is based on the type of the selected participatory modelling approach, and the aims and the time frame of the project.

To have an effective engagement of stakeholder, two preliminary important issues which should be considered are selection and organization of stakeholders.

4.1.1. Stakeholder selection and organization

All the stakeholders in a National Park sit on a Consultative Body. The consultative Body of the National Park included the owners, site managers and other parties within a National park who work together closely to develop a common vision for the area as management and development plan. The provincial authorities are responsible for running the secretariat of the Consultative Body. ("National Parks in The Netherlands," 2005).

Based on Franssen (2010) and ("National Parks in The Netherlands," 2005), the consultative body of Schiermonnikoog National Park are consisted of nine sub groups which are mentioned in Table 4.1. National Forest Service, Educational and recreational organizations (Royal Dutch Touring Club, regional recreation boards), Vitens which is responsible for the drinkining water on Schiermonnikoog, Rijkswaterstaat which has the responsibility for management of the position of the coast line and dikes in the island and also local businesses can be determined as the other stakeholders in this research.

For this research, a group of stakeholders were selected, in consultation with Natuurmonumenten Association, from Consultative Body of National Park Schiermonnikoog who have a high knowledge about the island and are interested in the problem. They were organized and involved in system conceptual modelling process through several workshops supported by university researchers.

Table 4-1 - Stakeholders composition in the consultative body of National Park Schiermonnikoog(Franssen, 2010; "National Parks in The Netherlands," 2005)

No.	**Consultative body and partners composition**	
1	**Consultative Body**	Friesland Provincial Authority
2		Schiermonnikoog Municipality
3		Ministry of Agriculture, Nature and Food Quality-Management of North sector
4		Natuurmonumenten Association
5		Rijkswaterstaat
6		Friesland Water Board
7		Schiermonnikoog Entrepreneurs Association(Islanders)
8		Schiermonnikoog Natural and Bird watching(Islanders)
9		Schiermonnikoog Farmer Interest(Islanders)
10		National Forest Service
11		Educational organizations
12		local businesses
13		Vitens company
14		recreational organizations (Royal Dutch Touring Club, regional recreation boards)

4.1.2. Workshop arrangement

Initially three workshops were planned which all could not be held due to agenda conflicts of the stakeholders. Finally, two workshops were arranged.

The aim for the first workshop was to build a conceptual model for the system by using two main methods considered as problem tree method and fuzzy cognitive map. In the second workshop, getting the feedback on the results of the first workshop, analyze the weights of concepts and scenario definition based on the results of the concepts ranking were the main objectives.

4.1.3. Problem identification

The problem tree method was used to find out what the core problem of the research is and to specify and investigate the causes and effects of the problem and to highlight the relationships between them. The problem tree as a visual problem-analysis tool resembles a tree. The roots of the tree represent the causes of the main problem. The tree trunk at the centre of the drawing represents the main problem and the tree branches, on the upper side of the drawing, provide a visual representation of the effects of the main problem (Anyaegbunam et al., 2004).

Based on the defined method, for this research in the first step, the core problem that the research seeks to overcome should be identified by discussing with stakeholders. In the next step, the problem tree was developed by demonstrating the cause-and-effect relationships between the issues regarding the core problem. The problem tree was completed and any necessary adjustments was made based on stakeholders' opinions (Refer to the method presented in Groenendijk, 2003).

4.1.4. Conceptual model creation

The conceptual model consisting of concepts of the system and causal relationships between them, was created using Fuzzy Cognitive Mapping method. The Fuzzy Cognitive Mapping methodology is a symbolic representation for the description and modeling of different aspects of the behavior of a system in terms of concepts (Papageorgiou et al., 2012)

The basic idea of the method was based on Özesmi et al (2004) in which a cognitive map described as a qualitative model of how a given system operates. The concepts were defined based on the results of the problem tree in which all the problems considered as main concepts of the system regarding the Westerplas naturalness. In the map, the directed lines between the concepts labelled with fuzzy values between -1 (strongly negative related) and 1 (strongly positive related) showing the strength of the causal relationships between them.

The system network has been analysed by using FCMapper software to calculate the Outdegree which is summing up the absolute values of all out going arrows, Indegree as summing up the absolute values of all ingoing arrows and Centrality which is a measure for the importance of a variable and calculated by summation of the in- and outdegrees (Bachhofer et al., 2009).

The most central concept can play a significant role in defining suitable scenarios to solve the core problem. Then, to realize the future of the implementation of the selected scenario(s), a base quantitative modelling regarding some related aspects is provided in order to help the decision makers for assessing the scenarios.

4.2 System quantitative modelling

The objective of the system quantitative section is to make an assumption on one of the selected scenario and provide a base quantitative model of some selected aspects of the system to facilitate the scenario(s) assessment by decision makers.

The quantitative modelling is done in three stages:

- Construction a 3D spatial model of the catchment area by using the available spatial data,
- Calculating the extent of inundation, in addition to the frequency and the duration of the inundation,
- Providing a basic model of the envisaged salt marsh vegetation zonation in the area

4.2.1 Scenario development

Based on the BIP+ (National Park Schiermonnikoog, Management plan 2011-2022), three scenarios mentioned in are the proper alternatives for Westerplas ecological restoration. These scenarios are:

- Connecting the lake to Wadden sea
- Dredging to remove the sediments as a cause of the lake eutrophication
- Leaving the lake without any change and just mowing the area

Among the three scenarios mentioned above, the focus of this research is going to be on the first scenario “Connecting the lake to Wadden Sea”. One assumption which is free access of the Wadden Sea to the Westerplas has been considered for this study. By constructing spatial model of the area and then an inundation frequency model, including the envisaged vegetation zonation based on this assumption, various scenarios can be visualized later in other studies, through the adaptation of the model.

4.2.2 Data requirement and availability

Two types of data are used in the quantitative modeling: ground elevation data and tide height data.

- Elevation data

There are two sources of the ground elevation data. The first set is a topographical point map measured on 1993. Seems this map is obtained via regular surveying methods, since it covers the ground under the fresh water. The second elevation set is the DEM with the vertical accuracy 15cm, Vertical resolution 5 cm and cell size as 5m*5m. It has been measured using LiDAR technology in 2002 (Swart, 2009).

These two elevation (surface) models are not identical, particularly, over the fresh water areas. It seems that the DEM have measured all the fresh water area with the same height, indicating that the LiDAR had measured the surface of the fresh water, rather than the bottom of the lake. However, the TOPOMAP has a complete topography of the Westerplas lake bottom. It is expected that both elevation models are quite similar in the areas that the surface of the ground is not covered by fresh water.

- Tidal regime data

The data of tide height and duration for Schiermonnikoog Island was obtained from Rijkswaterstaat website[1], Ministry of Infrastructure and the Environment.

The data from this website is ”water height in cm from Normal Amsterdam Level Peil surface”.

It includes 42 years of water level measurement at Wadden Sea, Schiermonnikoog (1971-2012). The temporal resolution of the measurements is 10 min. For this study 12 years of the data from 2000 to 2011 is used.

4.2.3 3D spatial modelling

To produce the spatial model for the study area using both elevation data sets (DEM and TOPOMAP) is essential. The catchment (Westerplas) area was defined based on the DEM contour lines. The initial boundary for the catchment area is roughly a polygon close to

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[1] *http://live.waterbase.nl/waterbase_dbh.cfm?loc=SCHIERMNOG&page=start.locaties.databeschikbaarheid&taal=nl&loc=&wbwns=1%7CWaterhoogte+in+cm+t.o.v.+normaal+amsterdams+peil+in+oppervlaktewater&whichform=2*

390cm contour line which is almost the elevation of the dike in the eastern part of Westerplas area.

As explained in the previous section, the DEM data does not show the height of the bottom of the water area. For these areas TOPOMAP should be used. Before integration of the data sets, the differences of the data sets should be examined.

4.2.3.1 Data sets comparison

The general idea is to compare DEM, 2002, and the point map (TOPOMAP), 1993, in the overlapping areas, when they are in the same format. If the height difference between the two data sets is less than a certain threshold, then the data is consistent and can be integrated. The consistency threshold was considered based on the DEM accuracy, equal to 15cm, since the accuracy of the digitized TOPOMAP was not known.

First, the data sets should be converted into a similar format; in this case the vector data (the point map) was converted to raster. A raster surface was interpolated from point map data using the Kriging method. After that, both raster data were subtracted from each other to prepare a (heat) map of the elevation differences, regarding each cell in the data sets.

The height differences were calculated for the areas that two data sets overlapped. These areas defined by considering a barrier as the lowest continuous contour line, calculated over raw DEM data, above 200cm (height of water surface in DEM data). All point elevation data above the defined barrier (225 cm contour line) were compared with the elevation data of the laser DEM and if no height differences the two data sets are compatible.

4.2.3.2 3D spatial modelling

Having assured the data sets are compatible, the 3D topographic model for the catchment area is processed.

The detail procedure to obtain the model is shown in Figure 4-2. Following the procedure, the integrated point map is transferred to a contour line map (topography map), ranging from the deepest point in the lake to the highest point of the area, limited to the catchment.

According to the obtained spatial model, the lowest elevation of Westerplas area (in the catchment) is 75cm which is considered as the starting elevation for the inundation frequency map (refer to section 4.2.4).

Having the spatial model, the other aspect of inundation is the study of the tide regime of the Wadden sea. This is needed to model the extent, frequency and duration of inundation.

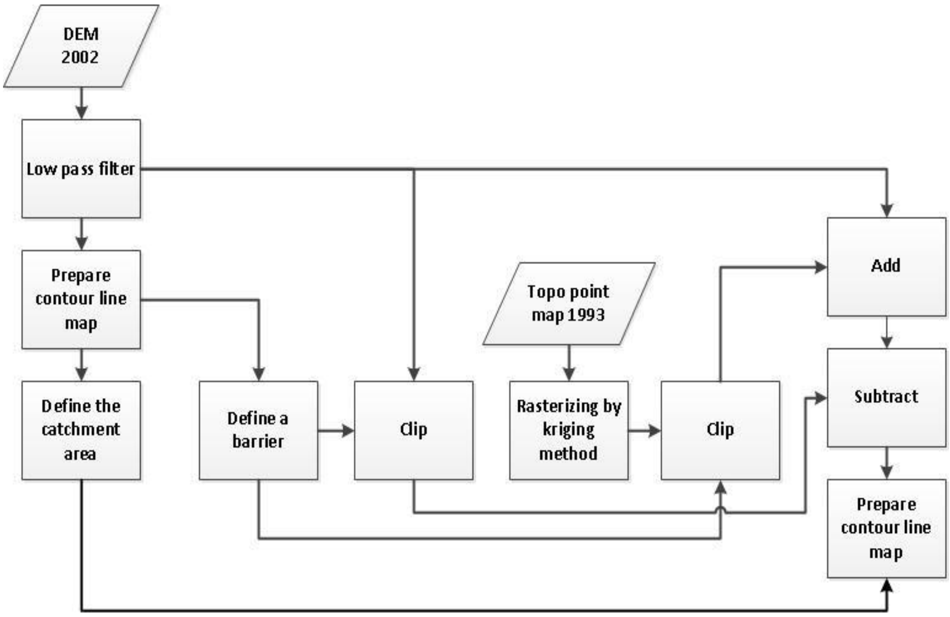

Figure 4-2– flow chart of preparing 3D spatial model for the Westerplas area

4.2.4 Inundation characteristic

To find out the tide regime for the Westerplas area, 12 years data of water level measurement with 10 min temporal resolution at Wadden Sea was analyzed. The datum of the sampled data (height = 0) is NAP (Rijkswaterstaat website mentioned in item 4.2.2, footnote 3).

Four parameters were extracted out of these data: MHW (Mean High Water), MHHW (Mean Higher High Water), duration of high waters and frequency of high water occurrence.

High water is when water level is above zero. In this study water levels below zero are not considered, since the minimum depth of the catchment is already 75 cm above NAP.

MHW was calculated by averaging all the high water heights over all measured data. MHHW was obtained by averaging the height of maximum high tide for each day over 12 years.

For an average daily tidal cycle also the inundation duration was calculated. Inundation duration shows the period which an elevation is covered by water, which in turn is a function of high tide duration.

To calculate the duration of high tide for certain tide level, periods over which the height of the tide is above that certain level was summed for each year and then averaged over 12 studied years.

The flood frequency of a tidal level, which is an essential parameter to obtain the inundation frequency, is calculated by counting the number of higher high water occurrence over a year. This is calculated using the histogram of the measured HHW of each day along each year, averaged over the 12 years. The range of the bins of histogram is considered the same as the height interval of contour lines, to ease the data alignment (Based on the function of Inundation Analysis Tool mentioned in the website of (Center for Operational Oceanographic Products and Services)).

The inundation frequency percent for each elevation range is the summation of the frequency of a height range and its above ranges, guarantee that the elevation is fully covered by water.

Using the inundation frequency for each elevation, we can assign the vegetation type which is going to grow in that particular elevation based on existing ecological literature of the Dutch salt marshes.

4.2.5 Zonation of salt marsh vegetation

Salt marshes are a transitional zone between the sea and land formed by flooding, sedimentation and erosion. Plant community distribution is sensitive to elevation, and how often and how long it is inundated (Dijkema, et al., 2007).

There are several factors which should be determined for the vegetation zonation such as soil type, shore height, salinity, interaction between the plants and environmental factors. However, the focus of this study is the frequency and duration of inundation.

Different studies around Wadden Sea define the salt marsh zones differently depending on inundation frequency and duration as well as water height.

Figurative relation between salt marsh zones, elevation and flooding is illustrated in Figure 4-3 which is summarized in Table 4-2. They show the characteristics of four salt marsh zones in the coasts of Netherlands with different plant community based on elevation to MHT, flooding frequency and duration (J.A.M.Janssen, 2001).

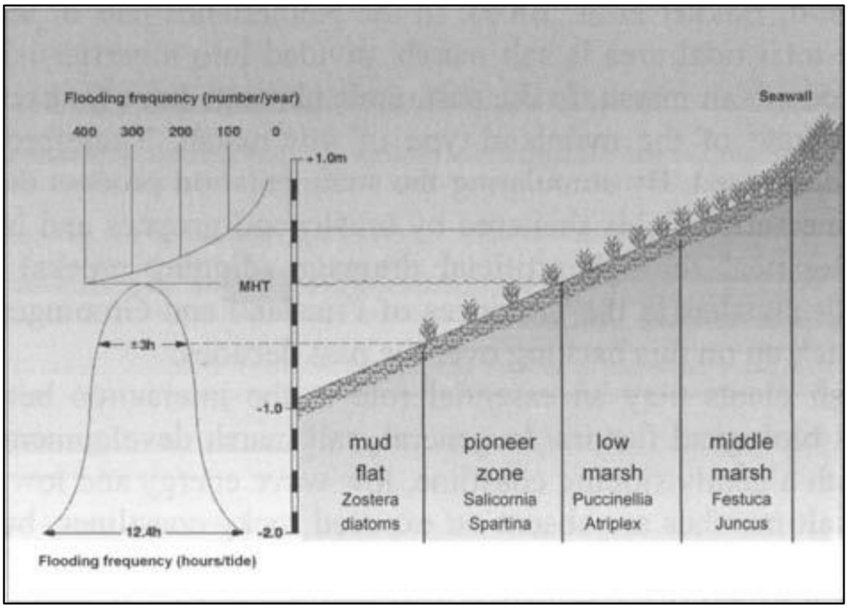

Figure 4-3 -Schematic overview of the vegetation zonation in a typical salt marsh as a consequence of water height variations, flooding frequency and duration in the coast of Netherlands(J.A.M.Janssen, 2001 inspired byErchinger, 1985).

Table 4-2 - relation between salt marsh zone, plant community with flooding frequency and duration and elevation(Erchinger, 1985).

No.	**Salt marsh zone**	**Plant community**	**Flooding frequency ($N\,yr^{-1}$)**	**Flooding duration (hr/tide)**	**Elevation (cm)**
1	Mud flat	*Zostera*	-	±3	MHW-95 to MHW-50
2	Pioneer zone	*Salicornia Spartina*	-	-	MHW-50 to MHT(=0)
3	Low marsh	*Puccinellia Halimione*	100-400	-	MHT(=0)to MHT+42cm
4	Middle marsh	*Festuca Juncus*	Less than 100	-	MHT+42cm to MHT+83

Another study by J. P. Bakker (1993) , shows the relation between salt marsh zones and a beach plain along the Netherlands coast with inundation frequency and plant community (Table 4-3).

Table 4-3 -relation between salt marsh zones and a beach plain along the Netherlands coast with inundation frequency and plant community(J. P. Bakker, 1993).

No.	**Salt marsh zone**	**Plant community**	**Inundation frequency ($N\ yr^{-1}$)**
1	Pioneer zone	*Salicornia europaea*	350-600
		Spartina anglica	350-600
2	Lower salt marsh	*Puccinellia maritime*	130-350
		Halimione portulacoides	130
3	Mid salt marsh	*Juncus gerardii*	40
		Artemisia maritime	30-160
4	Upper salt marsh	*Juncus maritimus*	12-60
		Elymus pycnanthus	20-40
		Festuca rubra	12-30
		Armeria maritime	30-80
5	Beach plain	-	2-5

Average inundation frequencies and MHT of three dominant salt marsh species (*Elymus athericus*,*Festuca rubra*, *Artemisia maritima*) at three sites (Kobbeduin, Fourth Creek, Willemsduin) on Schiermonnikoog island was measured over 1 year by (Bockelmann, et al., 2002). The result of this work has been mentioned in Table 4-4.

Table 4-4 -Average annual inundation frequency and MHT relation with three dominant salt marsh species measured at three sites on Schiermonnikoog island (Bockelmann, et al., 2002).

Plant community	**Inundation frequency ($N\ yr^{-1}$)**	**Elevation**
Festuca rubra	52–274	122 to 197 cm +NAP
Armeria maritime	82 -303	120 to 186 cm +NAP
E. athericus	1–204	131 to 274 cm +NAP

A literature review on the vegetation types of salt marsh of Wadden sea island was done by J.A.M.Janssen (2001). The abstract of the review is shown in Table(4-5) including the plant community of 5 salt marsh zones on Dutch salt marshes.

The relative elevation compared to MHT for defining the salt marsh zones is mentioned in Table 4-5(Bakker, 1989).

Table4-5-plant community(J.A.M.Janssen, 2001) and elevation(Bakker, 1989) related to salt marsh zones on Dutch salt marshes

No.	**Salt marsh zone**	**Plant community**[1]	**Elevation**[2]
1	Tidal flat	*Zosterion,Zosteretum noltii* on low levees and *Zosteretum marinae* in depressions	MHW-40 cm
2	Pioneer zone on tidal flats	*Salicornietum dolichostachyae, Spartinetum townsendii*	MHW+10cm
3	Lower salt marsh	*Puccinellion maritimae, Puccinellietum maritimae, Halimionetum portulacoidis,Plantagini-Limonietum*	MHW+35cm
4	Middle salt marsh	*Armerion maritimae,Juncetum gerardi, Armerio-Festucetum, Artemisietum maritimae, Atriplici-Agropyretum pungentis*	MHW+75cm
5	High salt marsh		MHW+150cm

[1] Source: (J.A.M.Janssen, 2001)

[2] Source:(Bakker, 1989)

For this study, vegetation zonation is determined based on the data mentioned in table 4-3 which shows the relation between salt marsh zones along the Netherlands coast with inundation frequency by J. P. Bakker (1993).

5 Results

5.1. System qualitative modelling

5.1.1 Workshop arrangement

In this research, the total number of invitations were 18 including different number of the representative of each sector of consultative body and partners of the park according to the level of their engagement to the problem (table 5.1).The final number would depend upon their willingness to participate.

Table 5-1- List of participants invited to the workshops

No.	List of Participants
1	Friesland Provincial Authority
2	Rijkswaterstaat
3	Schiermonnikoog Municipality
4	Ministry of Economic Affairs, Agriculture and Innovation
5	Schiermonnikoog Entrepreneurs Association
6	Schiermonnikoog Natural and Bird watching
7	Schiermonnikoog Farmer Interest
8	VVV Schiermonnikoog (recreational organization)
9	Visitors' centre Schiermonnikoog
10	Wetterskip Fryslân (Regional Waterboard)
11	Natuurmonumenten
12	Vitens (drinking water Company)
13	ITC, University of Twente

5.1.2 First Workshop result

From 18 invitations sent to the stakeholders, 10 people from Natuurmonumenten, Schiermonnikoog Farmer Interest, Wetterskip Fryslân, Vitens, Schiermonnikoog Entrepreneurs Association, recreation and tourist office, Schiermonnikoog Natural and Bird watching participated in the workshop.

The aim for this workshop was to build a conceptual model for the system. To achieve the aim, two main methods considered as problem tree method and Fuzzy Cognitive Map (FCM). In order to build the tree, the core problem was determined, related concepts had been listed and the inter-relation between the concepts and the core problem were identified. Then a FCM approach was used to create the cognitive map of the causality relationship between these concepts.

5.1.2.1 Problem tree

The participants identified 42 problems concerning the core problem as "Westerplas Degradation" as shown in Figure 5-1. Most of them were written in Dutch, which were translated at that moment. The list of the mentioned problems is mentioned in the Appendix.

Considering the listed concepts, some of them were similar or highly correlated. Therefore, a grouping step followed by name generalization were applied which were inspired mainly by the stakeholder's opinions. Having the generalized concepts and the initial core problem, Westerpls degradation, the problem tree was implemented with 9 causes and 15 effects and two which weren't identified if cause or effect.

Figure 5-1- preliminary problem tree concerning the core problem as "Westerplas Degradation"

During the build process of the problem tree, it became clearer that the core problem was not Westerplas degradation, but the decrease of its naturalness. It was because the subject is a natural park and degradation refers to a degradation of a natural reserve (according to the stakeholders' opinion).

Finally, the core problem was changed to "decrease in Westerplas naturalness including biodiversity, natural dynamics and landscape".

Therefore, the generalization of the problem tree concepts was changed accordingly.

The figure 5.2 shows the final problem tree with 7 causes, 7 effects and two problems, internal water quality and many birds to look at, are not exactly identified if they are causes or effects. The problem tree is without hierarchy consideration to show which cause/ effect produced the next ones. The number mentioned in each box shows how many times the problem repeated by stakeholders and generalized.

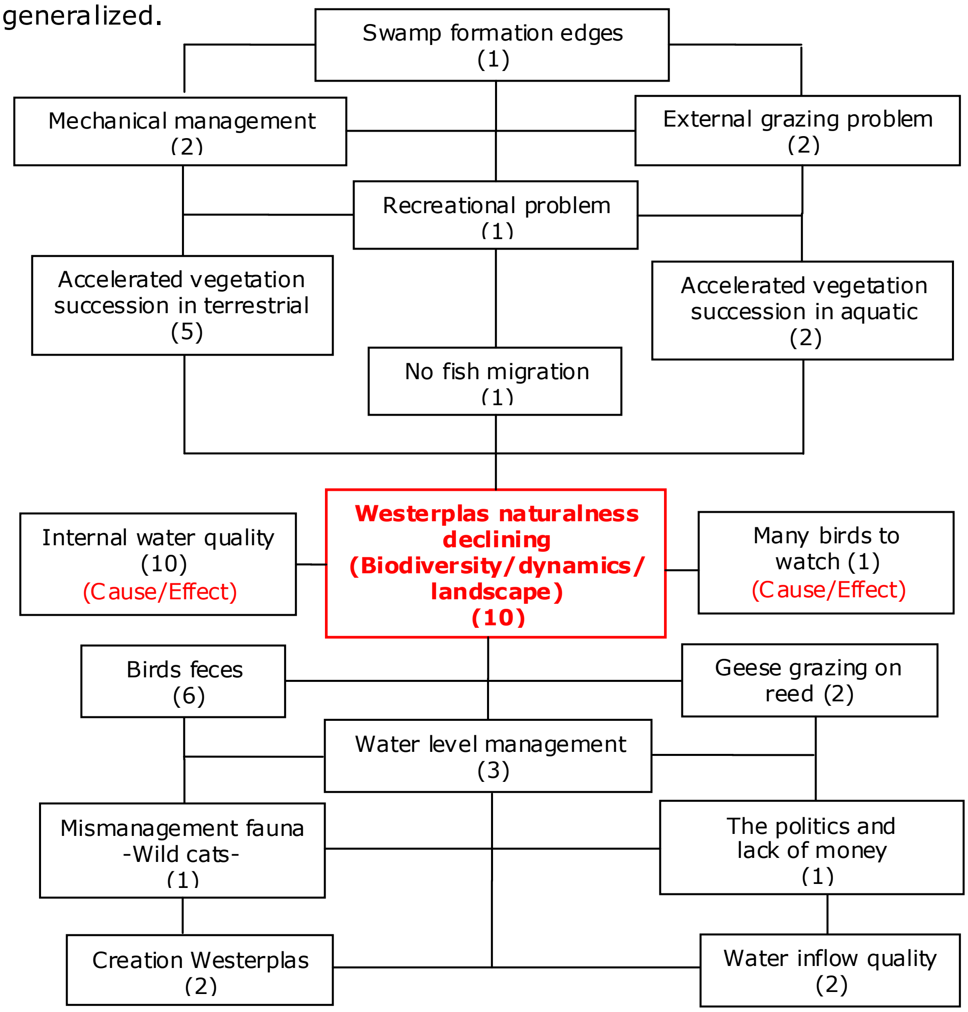

Figure 5-2- final problem tree concerning the core problem as "decrease in Westerplas naturalness including biodiversity, natural dynamics and landscape".

Figure 5.3 shows the importance of each concept according to the number of times it has been mentioned by the stakeholders. According to the figure, the "water quality" is the most important problem among the others which mentioned by 10 people and the “fish migration” is the least just mentioned one time.

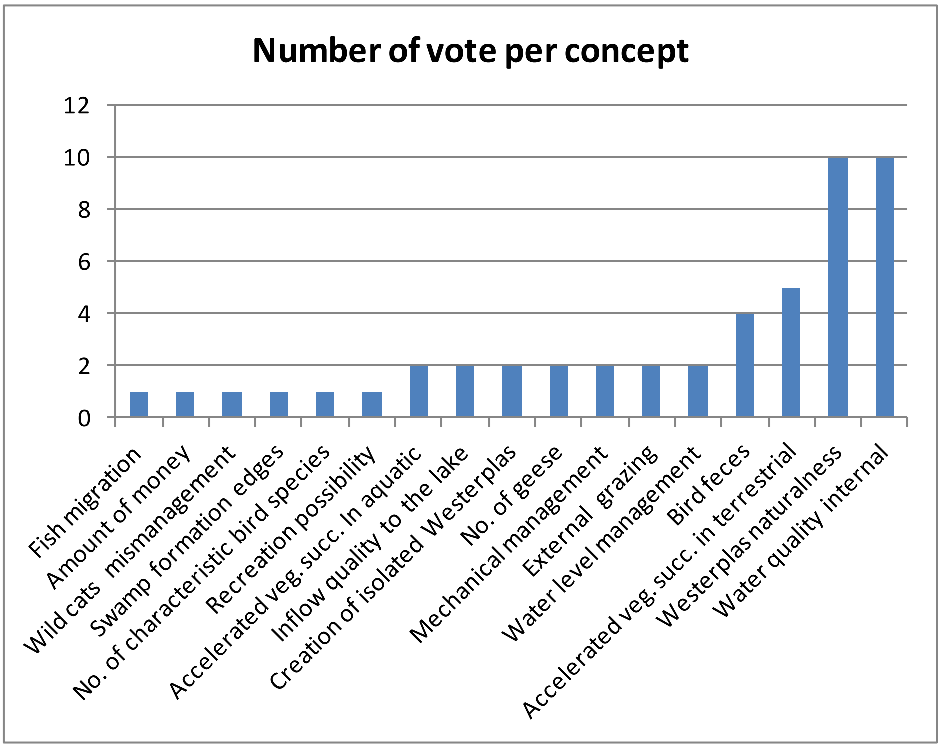

Figure 5-3- number of vote by the stakeholders for each concept of the system

5.1.2.4 Fuzzy Cognitive Map (FCM)

In order to build a FCM, the concepts and core problem which have been identified in the problem tree process were used.

Firstly, the stakeholders were asked to connect the remaining 17 concepts to each other to show their interactions.

In the second step, they were asked to assign a weight to each relation. This weight had to be in a range of [-1, +1]. The more weight of an interaction shows more strength of the corresponding casual-effect relation. The final FCM is shown in figure (5.4).

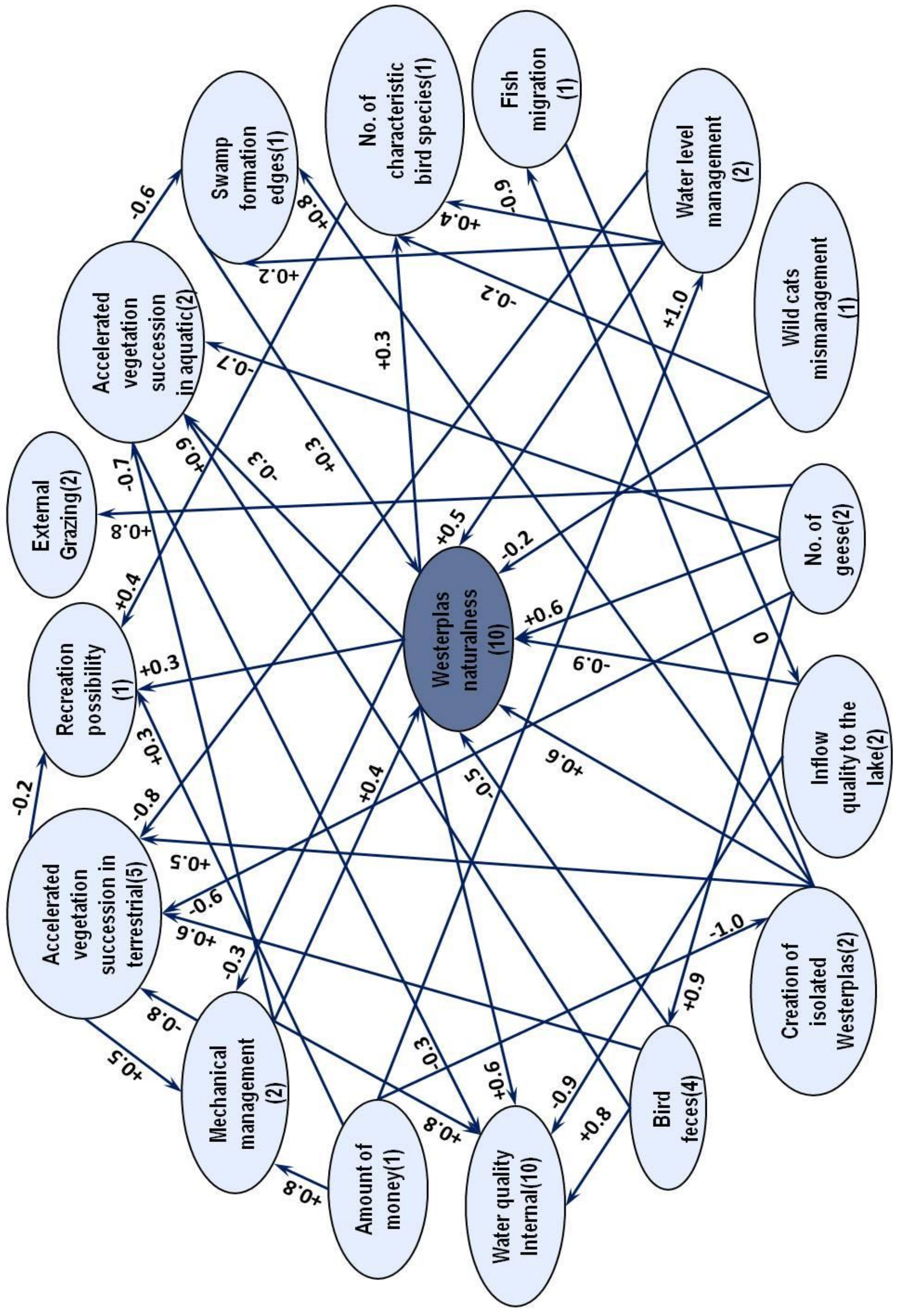

Figure 5-4- Fuzzy Cognitive Map included 17 concepts and the weighted interactions

5.1.3 Second Workshop result

The second workshop held on 6th of Dec. 2011 with presence of 8 of the 18 invitations. The aim of the workshops was to get the feedback on the results of the first workshop, analyze the weights of concepts, scenario identification and selection of the most important processes for further analysis and dynamic modeling.

5.1.3.1 FCM revision

The concepts and their connections obtained from the previous workshop were revised and the number of concepts decreased from 17 concepts to 10 concepts. Since the stakeholders developed a common understanding about the system after more discussions which lead to a more precise and focused definition of the concepts pertaining to the core problem.

The new Fuzzy Cognitive map for these new concepts was designed. There were 24 connections between these 10 concepts as depicted in Figure 5.5.

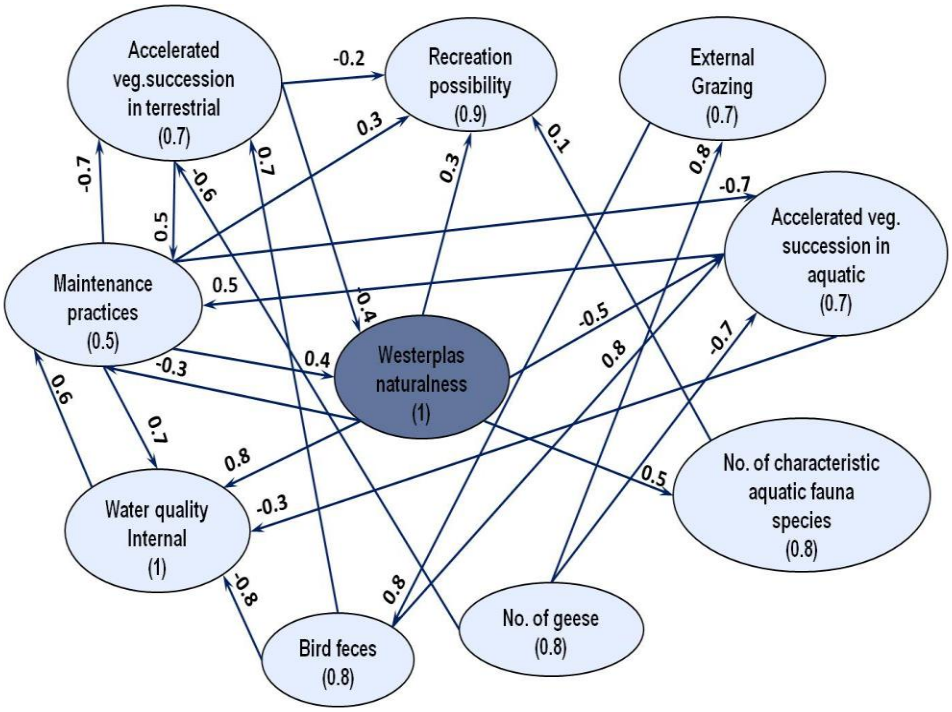

Figure 5-5- new Fuzzy Cognitive Map included 7 concepts and the weighted interactions

In the first workshop the score of the concepts were calculated based on the number of votes the stakeholders had considered for each concept. (For example, "water quality" was listed 10 times and therefore is weighted as 1.0, while "number of geese" was mentioned twice and got the weight of 0.2).

In the second workshop, due to the generalization of some of the concepts, the stakeholders had to change the score of the concepts. "Water quality internal" and "Westerplas naturalness" are two common effective (with highest votes) concepts in both workshops from stakeholders' point of view regarding the Westerplas ecological problem.

The weights of connections were transformed to the adjacency matrix in order to do the analysis for centrality calculation.

The centrality of the variables calculated in the FCMapper software based on the above matrix. The results of figure 5.6 show that the most central concept-with the highest amount of out degree and in degree - in the new FCM is the "Maintenance practices"which is in line with three scenarios mentioned in BIP$^+$.

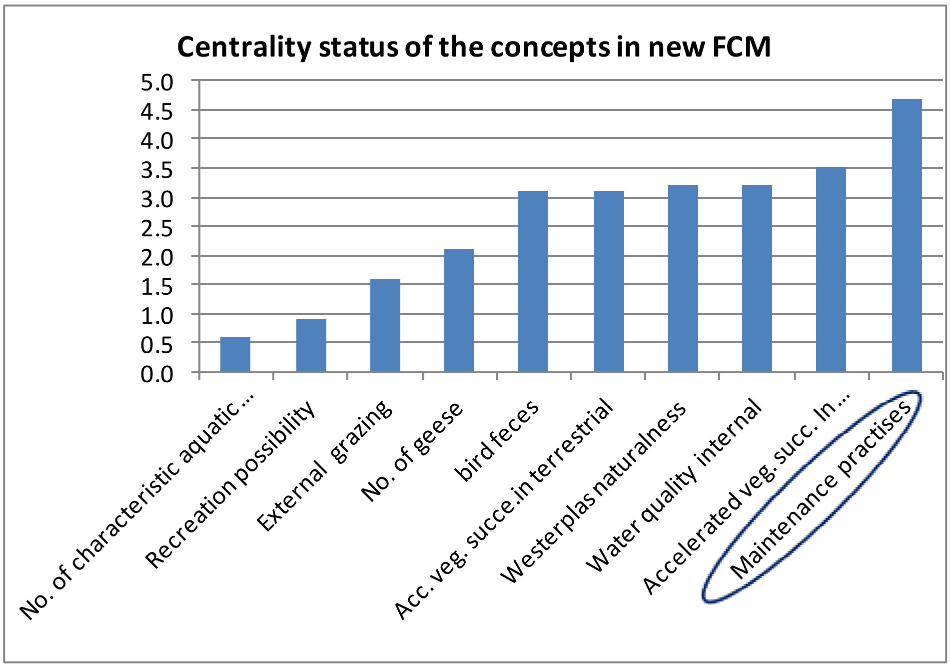

Figure 5-6- centrality status of each concepts in new FCM

Among the three maintenance practices management scenarios, the focus of this research is on the first scenario "Connecting the lake to Wadden Sea". For the sake of the simplicity, 'free access of Wadden

Sea to Westerplas area' is assumed for assessing this selected scenario by developing a basic quantitative model.

5.2. System quantitative modelling

5.2.1 Spatial modelling

The result of data set comparison and making a 3D spatial model for the catchment area are mentioned in the following sections.

5.2.1.1 Data sets comparison

There are 173 points outside the 225cm contour line (the lowest continuous contour line in the laser DEM) which was considered as the barrier between DEM data and point map data. The height differences between the two data sets were compared. Since the accuracy of the laser DEM is known (+/- 15 cm), all values < -15 and >15 can be considered significant.

Figure (5-7) shows the spatial distribution of errors between two data sets. The figure shows three categories including blue for height difference less than -15cm and red for differences more than +15cm. The points within the green category show differences in the range of -15 to +15cm.

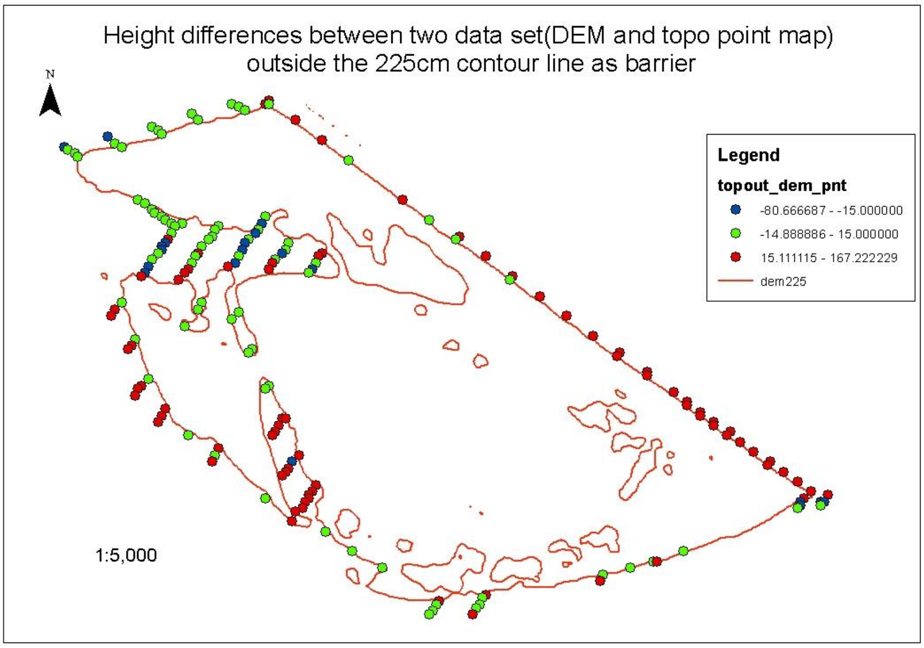

Figure 5-7- Height differences between two datasets at selected points, above the threshold of 225 cm.

Considering +/-15cm threshold, some systematic patterns are visible in Figure (5-7) which can also be seen in the distribution of height differences shown in Figure (5-8).

The test of normality in SPSS16.0 with confidence interval 95%, Shapiro-Wilk test, shows the height difference distribution of points is not matching a normal distribution.

A primary analysis on the height differences of points in Figure (5-8) shows 10% of the 173 points are in the category of less than -15, 45% of them are in the category of more than 15cm, meaning that 55% of the errors are significant and 45% are within the DEM accuracy range and therefore not significant.

Looking at the distribution of the points/errors in figure (5-7), it is obvious that some of the points are following some systematic patterns. For example, most of the points in the eastern part of the area are aligned along a line and having height differences all above 15 cm.

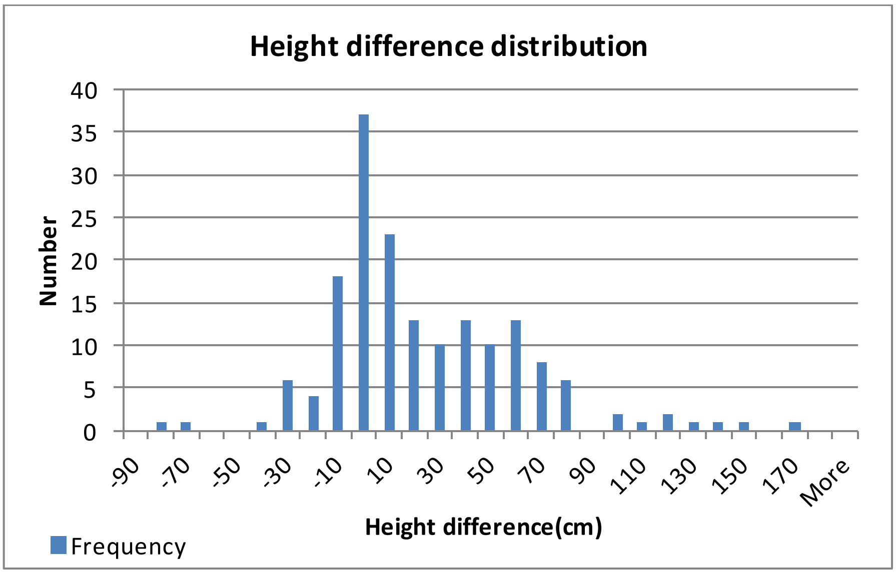

Figure 5-8 - Distribution of the height differences over the points, above the threshold of 225 cm.

Figure (5-9) shows all the points with systematic errors, containing 70 points (40% of all the points outside the red boundary).

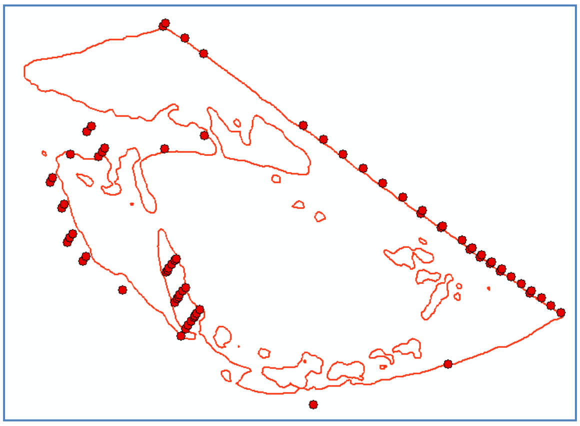

Figure 5-9-systematic distribution of errors

After removing the points with systematic errors, the remaining points (60% of all the points, equal to 103 points) seem to have random error distribution (Figure 5-10). The result of Shapiro-Wilk normality test, with 95% confidence interval, complies this hypothesis. In this point set, 40% are in the category more than 15cm (red points) or less than -15cm (blue points), and 60% of the points are in the category of +/- 15cm which are not significant. The average of height differences for these points is 2.28cm which is in the acceptable range (< 15cm).

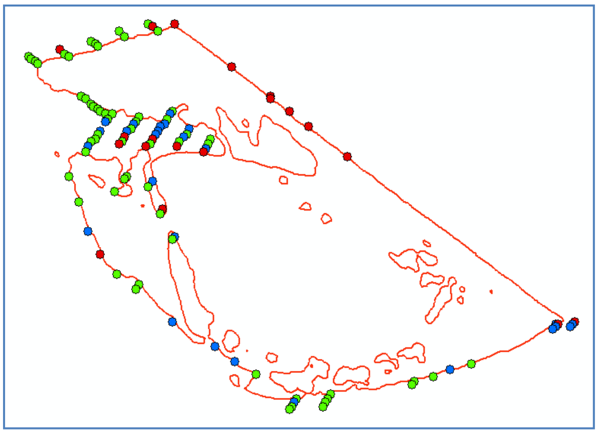

Figure 5-10- random distribution error

Height difference between the two data sets, DEM and TOPMAP over the selected points (103 points), is following a normal distribution (Figure 5-11), and the average difference is less than the measurement accuracy (2.3cm < 15 cm).

Moreover, these test points are well distributed over the area (Figure 5-10). Therefore, we can conclude that the data sets are consistent and we can combine them.

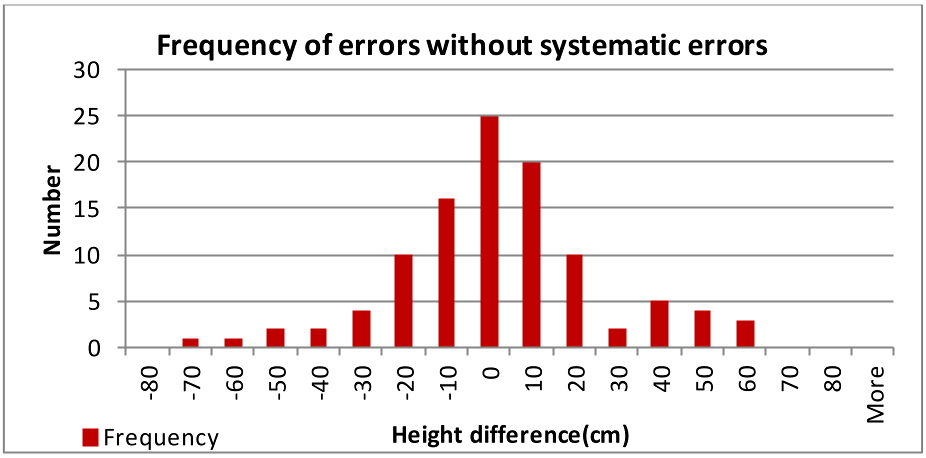

Figure 5-11- frequency of errors without systematic errors

5.2.1.2 Contour line map

Figure 5-12 shows the obtained 3D spatial model for the catchment area inside the contour line of 390cm based on the integration of two elevation data sets. The lowest height is 75cm and the highest one is 390cm.

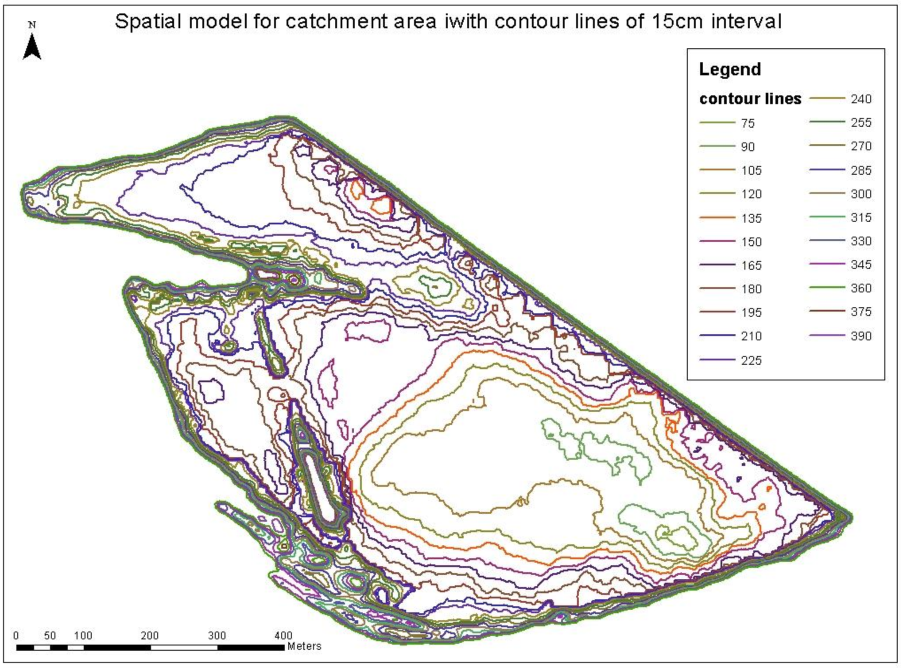

Figure 5-12 - 3D spatial model for the Westerplas area with the contour lines of 15cm interval

The steep gradient along the edge of the catchment is due to the nature of the original laser DEM. It's the place that the ground meets the higher elevation ground.

5.2.2 Tide regime

The result of primary analysis on the data of tide height for the studied period (12 years), including the values of MHW, MHHW and maximum height of HHW, are shown in Table 5-5. The majority of maximum heights of HHW during the 12 studied years are less than 270cm. The highest value of HHW is 356cm in 2006. The mean value of MHW is 68.511 cm and MHHW is 116.7276cm in the studied period.

Table 5-2- values of MHW, MHHW and maximum height of HHW for the studied time period (2000 to 2011)

Year	MHW (cm)	MHHW (cm)	Max HHW (cm)
2000	69.5	118.2	311
2001	68.8	116.8	234
2002	68.0	116.4	250
2003	67.6	115.7	271
2004	70.1	119.5	257
2005	67.2	116.5	266
2006	69.7	121.9	356
2007	73.3	126.5	353
2008	70.0	119.1	304
2009	65.9	114.2	251
2010	66.2	114.7	238
2011	65.9	101.4	242
Mean	68.5	116.7	277.8

5.2.3 Inundation area extent

The following figure (5-13) shows the inundation maps for tide heights 75 cm, 90cm, 105cm and 120 cm (MHHW level) as some examples based on the 3D spatial model of the catchment area.

The lowest point in the 3-D model of the Westerplas is 75 cm above NAP. This means that the inundation map is started at 75 cm above NAP.

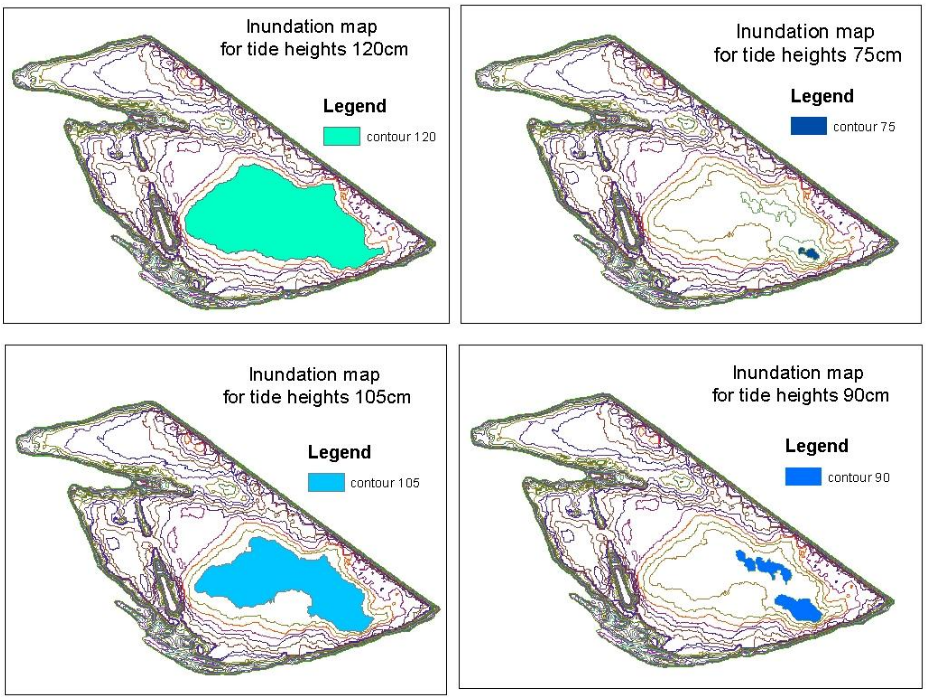

Figure 5-13-inundation map for tide heights 75 cm, 90cm, 105cm and 120 cm

5.2.4 Inundation duration

Duration of high tide for some certain levels e.g. NAP, MHW and MHHW is calculated by the daily average of summation of period over which the height of the tide is above those certain levels. The function of inundation duration versus tide height (elevation of area) is shown in Figure 5-14 which states a reverse relation between these two parameters.

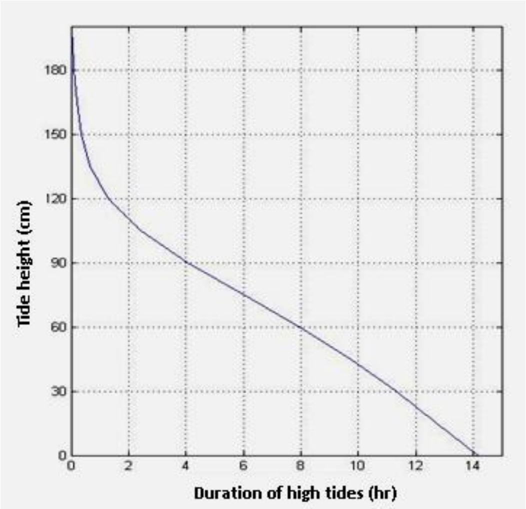

Figure 5-14 -function of inundation duration (hr/day) versus tide height (cm) over 12 years of the study (2000-2011)

The average of inundation duration for 12 years in three levels: zero level (NAP), MHW and MHHW are shown in Table (5-6). For example the average duration that elevations equal to MHHW are inundated is almost 1.5 hour per day.

Table 5-3- the average of inundation duration for 12 years in three levels: zero level (MSL), MHW and MHHW

Tide level	inundation duration (hr/day)
0	14.180
MHW	6.818
MHHW	1.477

The inundation duration map (figure5-15) for the catchment area is obtained based on the above analysis and the inundation extent. It shows the inundation duration for the elevation range between 75 cm to 240 cm in Westerplas area considering the assumption of free access to Wadden Sea. The elevation more than 240cm was ignored to illustrate, since the inundation duration is less than 1 min per day which is negligible.

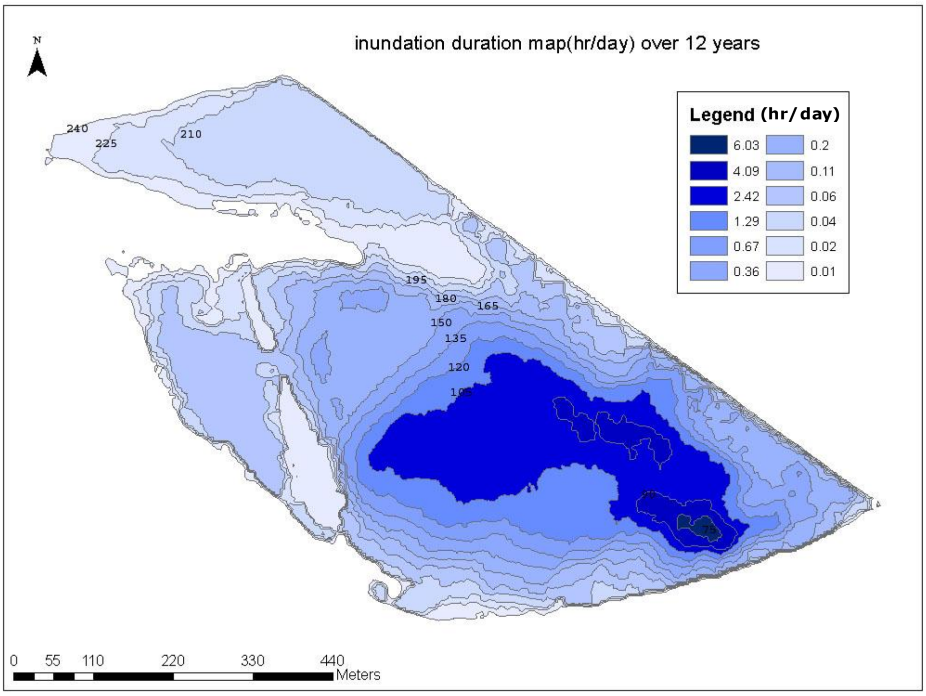

Figure 5-15- inundation duration map for the Westerplas area averaged over 12 years (2000-2011)

5.2.5 Inundation frequency

Figure (5-16) shows the histogram of yearly average of higher high tide frequency over the 12 years. The highest frequency (~85 times per year) belongs to the tide within the height range of 35 to 50 cm (above MHW) in which MHHW is also occurs. For the elevation ranges more than 110 cm (above MHW), the frequency is going lower around just 5 times per year. For the elevation range 155 to 170cm, the frequency is near zero.

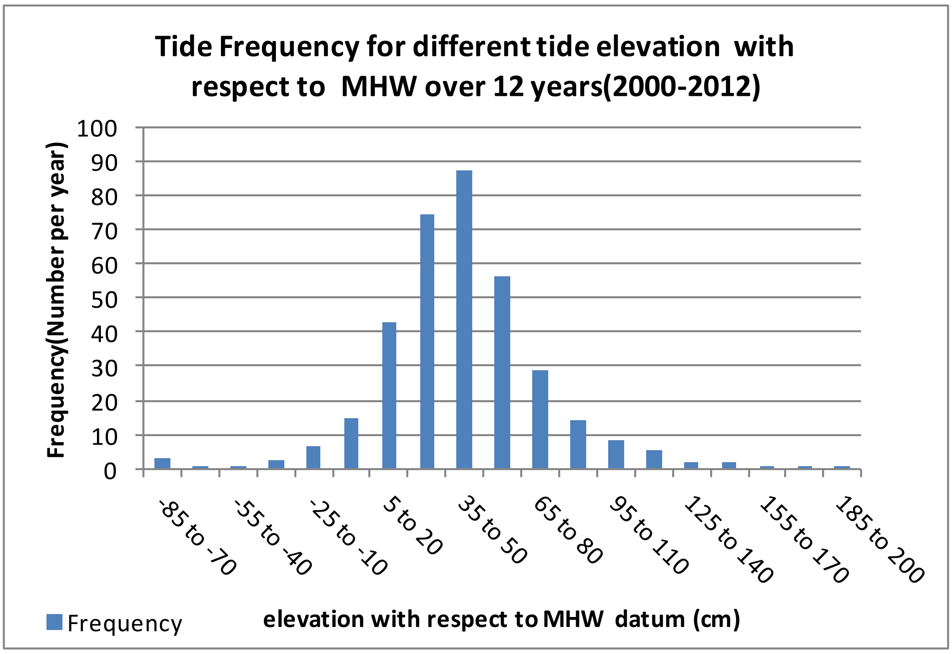

Figure 5-16- flood frequency for HHWs with respect to MHW datum over 12 study years (number per year)

Figure 5-17 shows the inundation frequency (red) of the range of elevations in the studied period in percentage. As the figure shows, the inundation frequency shows how many days of the year (in percentage) the corresponding elevation range is inundated. For example, for the elevation range 5 to 20cm (with respect to MHW), the inundation frequency is about 90 percent. It means 90 percent of the year (~ 317 days) this elevation range is covered totally by water and the rest of the days the water height is less than this elevation.

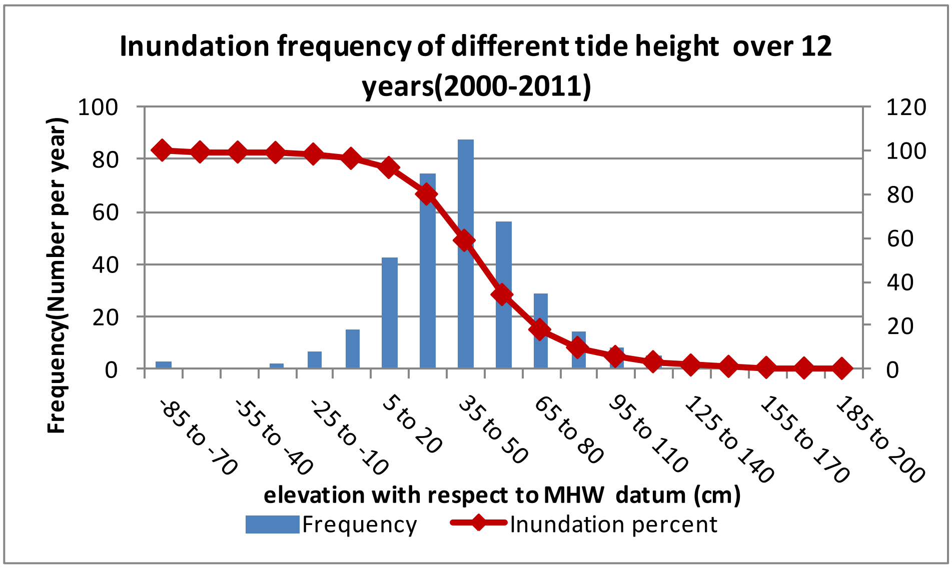

Figure 5-17- Yearly inundation frequency for the elevation ranges of the catchment area over 12 years

The inundation frequency percent can be converted to number per year based on the total number of tide occurrences which is 352 times per year. The figure (5-18) shows the number of inundation frequency related to different tide elevation above MHW over 12 years on average.

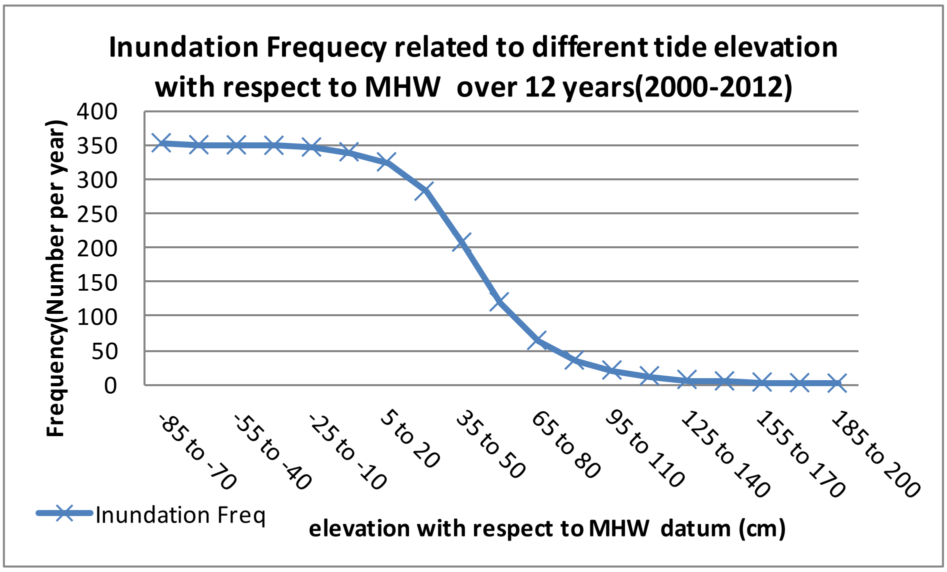

Figure 5-18- Yearly inundation frequency for the elevation ranges of the catchment area over 12 years

The figure (5-19) shows the inundation frequency map for Westerplas area considering the assumption of free access to Wadden Sea. Since the lowest elevation part of the studied area is 75cm, the focus is on the frequency for height tide more than that. The elevation more than 240cm was ignored to illustrate, since the flood frequency for the elevation more is less than 1 time per year which is negligible.

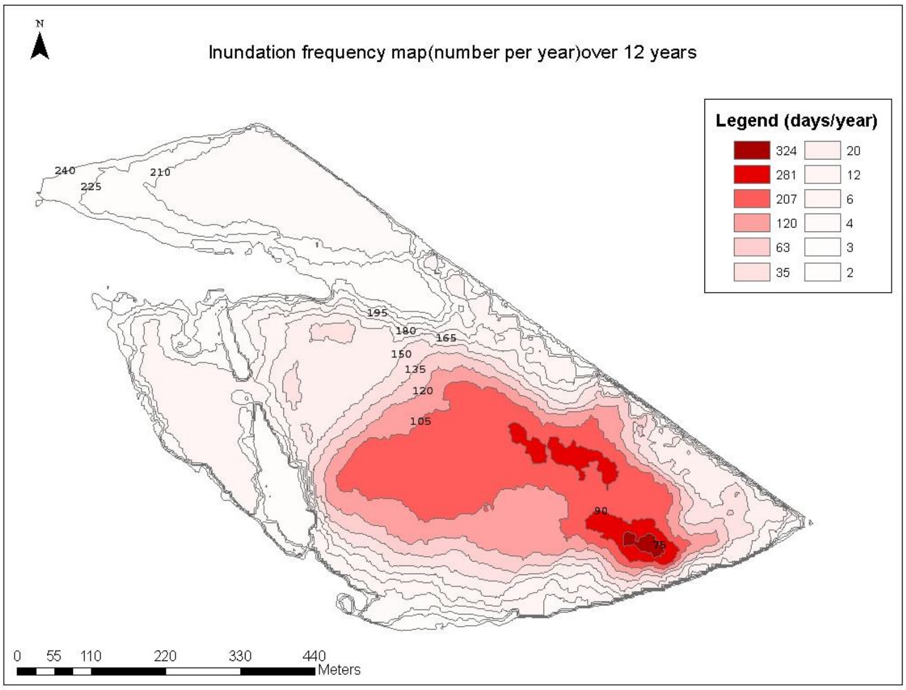

Figure 5-19 –Yearly inundation frequency map for the Westerplas area over 12 years (2000-2011)

5.2.6 Vegetation zonation in salt marshes

Comparing the inundation duration and frequency of the Westerplas area while applying the assumption of free access to Wadden Sea obtained in the previous steps with the selected source (table 4-3 mentioned in chapter of method), the envisaged vegetation zonateion is illustrated (figure5-20).

Table(5-7) shows the result of inundation frequency for different elevation above MHW comparing the results for the salt marshes along the coast of Netherlands by J. P. Bakker (1993). Four vegetation zones can be envisaged for the Westerplas area based on the inundation frequency data while applying the assumption of free access to Wadden Sea as pioneer, lower, mid and upper salt marsh with special plant community. The elevations lower than -85cm (almost equal to elevations 17cm below NAP) are considered mud flat.

Table 5-4-comparison between the analysis result of inundation frequency and related elevation with the published source data by J. P. Bakker (1993).

Published source data				Analysis result	
No.	**Salt marsh zone**	**Plant community**	**Inundation frequency (N/yr)**	**Elevation above MHW (cm)**	**inundation frequency (N/yr)**
1	Pioneer zone	*Salicornia europaea, Spartina anglica*	350-600	-84	352.0
2	Lower salt marsh	*Puccinellia maritime, Halimione portulacoides*	130-350	-69	349.2
				-54	348.9
				-39	348.3
				-24	345.8
				-9	338.8
				6	324.1
				21	281.3
				36	206.9
3	Mid salt marsh	*Juncus gerardii, Artemisia maritime*	30-160	51	119.7
				66	63.4
				81	34.6
4	Upper salt marsh	*Festuca rubra*	12-30	96	20.1
				111	11.7

The diagram of inundation duration can be roughly fitted to the obtained vegetation zonation map due to different scale (figure 5-20). It can be resulted from the diagram that according to inundation duration image, the inundation duration for the pioneer zone is around 15 hr, for the lower zone it is around 1.2-15 hr, 1.2 to 0.2 hr for mid zone and from 1.2 to almost 0 is the duration of inundation for upper zone. Based on this graph we can simply say, the tidal flat is the area with inundation duration almost less than 15.3 hr. The pioneer zone and mud flat are two zones that located under NAP and in low tide are applicable for the study area. After

125cm above MHT, tide, has no influences on the vegetation distribution and the main effect of tide is in lower elevation of salt marsh.

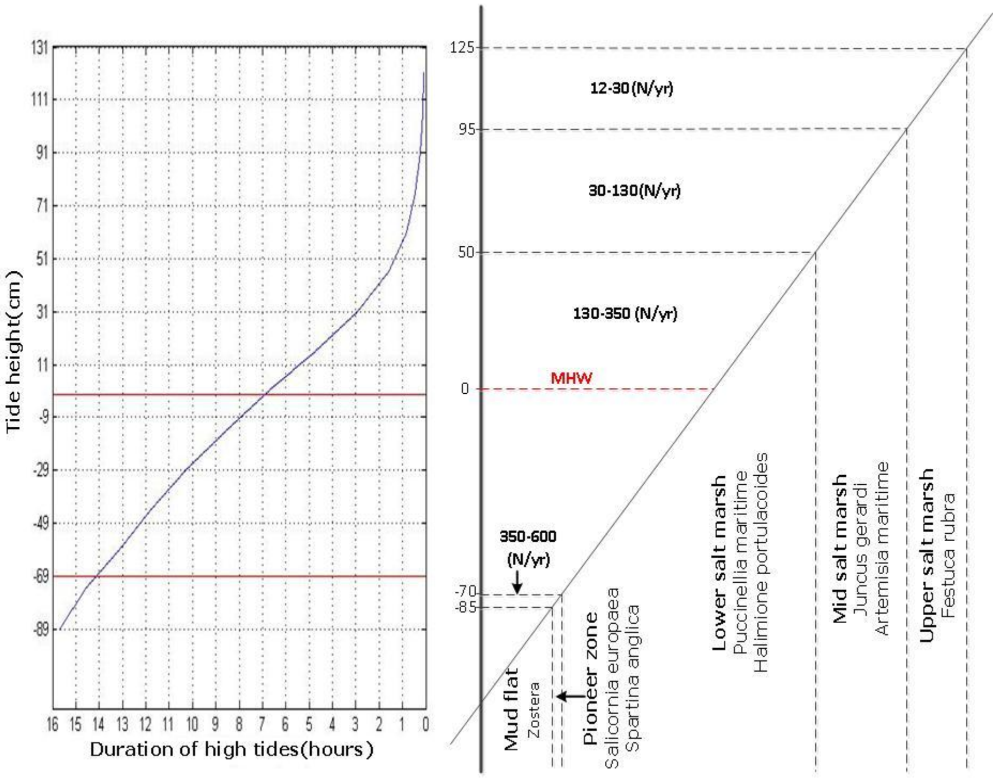

Figure 5-20- relation between salt marsh vegetation zones, elevation (with respect to MHW) and inundation duration concerning the tide regime data. The definition of the zones is inspired by the work of (J. P. Bakker, 1993).

6 Discussion

6.1 System qualitative modelling

In this research the ecological problem of the Westerplas lake is identified and essential information for the assessment of the suggested solution scenarios are provided through participatory modeling exercise in which local sufficient knowledge of the stakeholders are integrated with scientific knowledge. So the selection of proper stakeholders was very key factor to have a more success research process. The stakeholders were mainly selected from the ones who participated in the development of the park management plan and had high understanding of the system.

Since in face to face discussion all the stakeholders would engage more effectively in the process, participatory modeling exercise was planned to be done through some workshops in dates when most of the stakeholders could participate. The most challenging part was the lack of mutual understanding due to different languages (Dutch for stakeholders and English for scientific consultants). Through this problem some of the invitees didn't participate in the workshops and during the workshops most part of the discussions between the participants were in Dutch and the summary of them was translated to English.

Having the core problem identified, the relationships between the concepts around the core problem and their weights were determined using a cognitive map. In order to show the strength of the relationships in FCM, the numerical range was used which was easy for the stakeholders to work with and more precise while analysing, contrary to (Papageorgiou, et al., 2012) who found it difficult for the experts to assign a real number in order to express their beliefs with regard to the strength of relationships.

Generally, we found FCM a fairly simple and suitable graphical tool for organizing, representing and exploiting the stakeholders' local knowledge and their experience of the system's behavior. But since it is a process that mainly relies on the input from the stakeholders and the way they perceive the system, the results greatly depends on the stakeholders' opinion and may not be a right representative for the real system.

Having applied a preliminary analysis on the created cognitive map, the most important concept in the map was "maintenance practises". The result of the analysis is in line with the stakeholder's initial opinion about the main problem, and the related scenarios they had been suggesting with regard to maintenance practices.

Actually, these three scenarios were defined as different ways in which restoring the naturalness of the Westerplas can be perceived based on two main ideas:

1. A salt/fresh gradient

Corresponding maintenance/restoration practice:

- Connecting the lake to Wadden Sea.

2. A nutrient poor fresh water dune lake.

Corresponding maintenance/restoration practice:

- Dredging/draining to remove the sediments which are thought to be the main cause for eutrophication of the Westerplas.
- Reduce/slow down the declining naturalness by mowing the vegetation.

The mentioned similarity shows that the constructed conceptual model is representing the understanding of the stakeholder's about the system well enough. This common conceptual model allows the scientific party to discuss and present further results in a known frame work to the stakeholders.

Considering that the writers of the BIP+ are largely the same as the participants of the workshops, the results of the FCM analysis has a large overlap with the results that the BIP+ writers got from their internal meetings. Of course this was what we were expecting. However when the conceptual model compiles that, it is a sign that the conceptual modelling approach, if applied properly, is practical and in line with the management ideas.

In order to understand the behaviour of the system in reality, more analysis on FCM should be done by assigning the value for each concept and finding out the activation level of concepts in interaction with other concepts in the system network. In this research due to lack of time, the concepts didn't take value and basic analysis with considering the weights for the interconnection arcs was done. Considering a vector of initial states of variables on FCM by assigning unequal weights with respect to the number of the stakeholders' votes for the importance of each concept (Figure 5-3 in Section 5.1.2.1) would be a good option. The comparison between the rankings of the concepts after running the network with these different initial states helps us to choose the suitable scenarios based on the highest ranked.

6.2 System quantitative modelling

Among the three management scenarios mentioned in National Park Schiermonnikoog, Management plan 2011-2022, the focus of this research was on the first scenario "Connecting the lake to Wadden Sea". It is perceived as the preferred option, since in terms of naturalness, the Westerplas area was originally a saline ecosystem until the dike closed it off from the Wadden See. Also the park manager had more emphasis on this scenario.

For the sake of the simplicity, 'free access of Wadden sea to Westerplas area' was assumed for assessing this selected scenario. This allowed us to develop a basic quantitative model for the system from which various scenarios can be visualized later on through the adaptation of the corresponding topography.

The 3D spatial modelling was done by ArcGIS10 which is a user friendly and proper software to analysis and visualize the spatial aspects of the data but is not strong in analyzing the temporal aspects.

In the process of the spatial modelling of the lake, since we have elevation data sets from different measurement schemes, we need to make sure that the two elevation sources are consistent (Section 4.2.3.1 and 5.2.1.1). The analysis on the height differences of two data sets in the overlapped area outside the defined barrier (Section 5.2.1.1), shows 40% of all the studied points have systematic errors.

The reason of such height differences errors, for the eastern part of the study area, maybe is that these points, which are very close to the dike, seem higher than the actual ground due to interpolation errors in DEM calculations. In the Western part, there are some points with systematic error as well. It is related to a high ground (maybe a sandy hill) which seems to be measured in DEM but not measured in TOPOMAP.

After removing the points with systematic errors, the remaining points seem to have random error distribution with average height difference less than the measurement accuracy (2.3cm < 15 cm). The result of Shapiro-Wilk normality test, with 95% confidence interval, complies this hypothesis. Shapiro-Wilk Test is more appropriate for small sample sizes (< 50 samples) but can also handle sample sizes as large as 2000, so it is applicable for this study according to the SPSS tutorial.

By the way, the measurement error related to point map and digitizing error have not been considered in the consistency check procedure. If we consider the error related to the topo point map, we can expand the range of non- significant error to +/- 30 which would increase the percentage of non-significant random error.

Having the consistency between two data sets, the spatial model of the catchment area obtained with the lowest elevation as 75cm. Since this research just focuses on the free access of the Westerplas area to sea without any concern about the connection method, the study is mainly based on the elevations of the topography model. Implementing different sub scenarios depending on how high the elevation of the dike will be removed, causes changing in topography and the 3D spatial model in the connecting area.

In tide regime study, the low tide wasn't considered since the study area is already 75 cm above the NAP. To obtain the flood frequency the histogram of the yearly average of higher high tide frequency over the 12 years was calculated, since for inundation, the higher high tide is the most important factor. For the elevation more than 240cm the flood frequency is less than 1 time per year with the inundation duration less than 1 min per day which is negligible. Therefore, the significant range of elevations to study for our purpose is from 75 to 240 cm above NAP.

Within the 12 years study period, the majority of HHW is lower than 270cm (above NAP) which is lower than the highest elevation of the Westerplas area (390cm). Also the MHW is 68.5cm (above NAP) which is lower than the lowest elevation of the area (75cm). Therefore, the possibility of entrance of salt water to the Westerplas area depends on how the implementation of the scenario changes the topography. However in reality, it seems that even at MHHW (116.7cm), the area hardly gets covered with salt water even with an open access to the sea. This issue was also the concern of the water board experts.

The inundation frequency (number per year) was calculated based on the total number of tide occurrences which is 352 times per year according to the lunar day which is 24 hr and 50min.

In order to determine the plants community in new situation regarding the implementing the scenario, several factors should be considered such as soil type, shore height, salinity, interaction between the plants weather condition, seasons and other environmental factors. However in this research, the duration and frequency of flooding the area are key factors for determination of vegetation zonation. Since in the studied articles regarding salt marsh vegetation zonataion, the zonation of a salt marsh is determined by inundation frequency rather than inundation duration, we focused on inundation frequency factor.

In one schematic overview of the vegetation zonation relation with tide height, flood frequency and duration in a typical salt marsh of the Netherlands coast by (Erchinger, 1985), the flood duration for mud flat stated as ±3 hr, which corresponds to MHW-95 to MHW-50 cm, height range. In comparison to my result, 3 hr of high tide durations belongs to elevations in the range of MHW+5 to MHW+20 cm. Therefore, that source couldn’t be used because of the incompatibility with our results.

Also, the data from different sources which show the relation between different salt marsh zonation and elevation, inundation frequency and duration are not compatible, perhaps due to different measurement methods, different years of study or different areas of study.

7 Conclusion and Recommendation

7.1 Conclusion

Within the course of this project, we have provided the necessary information for demonstration of strategic assessment of the management plan of Schiermonnikoog National Park (BIP+). The provided information is supposed to give the management of the park the opportunity to analyse the environmental effects of implementing maintenance practice scenarios and support their management decisions. Although only one scenario is developed in this research, the provided information (the spatial model and inundation maps) are essential basis for further possible scenarios as well.

Through a participatory modeling exercise about the Westerplas area, we have constructed a conceptual model (cognitive map) of the study area with 10 concepts and 24 connections regarding the naturalness declining of Westerplas as a core problem. After analysis of the map, the most important concept of the map is maintenance practice. This result complies with the initial opinion of the stakeholders of the park and confirms the suggested scenarios for one of the general programs of the third Management and Development Plan of the Schiermonnikoog National park. This common conceptual model allows us to discuss and present our further results in a known frame work to the stakeholders. It implies that using such a conceptual model provides the means to level different party's knowledge and understating, and subsequently develop a common language for further discussions.

Although there were different discussed scenarios for ecological restoring of the mentioned lake, e.g. dredging the sediments of the lake and mowing the vegetation, we kept our focus on one of the scenarios, connection of the lake to the sea. However, we have used all the available information, maps, tidal data and the knowledge of the park management, to make sure that the provided information has the essential integrity for supporting development of other scenarios. For example provided spatial model, gives the fundamental means for developing the dredging or mowing scenarios.

Having two sources of spatial data, DEM and a topographic map, consistency of the data had to be checked before any further process. This was necessary due to the different approach of data surveying (aerial versus ground surveying), time difference (~10 year) in data capturing and various spatial resolution. We should note that the combination of data sets was needed since DEM data had a higher spatial resolution and more up-to-date; however it did not contain under water areas. The data integrity is checked against their coordinate system and height values in common areas. By removing systematic effects, and further statistical tests, the final results showed that the two data sets were consistent.

The water height measurements obtained via Rijkswaterstaat database is a rich source of data and very helpful for studying the tide regime of the target area. Although 10min temporal resolution provides detail information, the required data for the inundation frequency and inundation duration maps needed further processing and extraction of more general factors (for example the average of the durations of a specific water heights per year). Moreover, to reconstruct a reliable tide function we have extracted such information over the data of the past 12 years.

We have provided inundation frequency and inundation duration maps. These maps allow us to visualize the inundation frequency and the duration of inundation for each elevation. Not only the frequency or duration, but the extent to which inundation happens is demonstrated in these maps. It is worth mentioning that the height resolution of the maps (contour line distances) is set with respect to the height resolution of the data source (DEM), and so is the inundation spatial resolution.

Having calculated the inundation frequency, different vegetation types in five zones were determined. The zonation types are adopted for our study area from the existing ecological literature of the Dutch salt marshes. This information can demonstrate the vegetation figure of the vegetation types which are going to grow in each particular elevation, provided the studied scenario is deployed.

ArcGIS, version 10, was an essential tool in the spatial modelling and visualization processes. It provides the necessary tools to combine different layers of spatial information, calculate height difference maps and cartographic tools by which we could present the maps properly. However, we could not easily integrate other source of information like water heights. We had to use some external tools and even develop some codes to calculate the statistics we needed for tide analysis.

7.2 Recommendation

Although we have tried our best to hold as much meetings as possible to capture and map the conceptual model properly, more communication via workshops would be necessary in participatory modeling exercise.

Further analysis of the cognitive map (Fuzzy analysis) was supposed to be done in this research, however due to the lack of time and long gaps between meetings, the research was restricted. Therefore, any further study which can use the gathered information by this research and analyse the map for more concrete results can extend this work. Particularly considering the temporal aspect in the analysis of the conceptual model, assigning proper values to the concepts and finding the activation level of the variables in interaction with other variables with different initial states, and the calibration and validation of the designed FCM by stakeholders, based on the real data.

Although we had very accurate and recent tidal information, the spatial modelling was done using our available data sets which were outdated. This means the inundation maps are created with respect to the spatial state of the lake at that time. Therefore, to have an up-to-date extent of the inundation we require having more recent spatial information of the lake.

Moreover, considering other environmental and ecological factors such as edaphic conditions and possibly biotic interactions for modelling the vegetation distribution after applying scenarios will help gaining more reliable results.

Glossary

Flood Frequency: the occurrence of high waters for different elevations above the marsh surface(Stolz, 2005)

High Water (HW): Maximum height reached by a rising tide(Voigt, 1998).

Higher High Water (HHW): The higher of the two high waters of any tidal day(Voigt, 1998).

Inundation duration: the amount of time that the marsh surface is inundated by water(Stolz, 2005).

Marsh: Soft, wet area periodically or continuously flooded to a shallow depth, usually characterized by a particular subclass of grasses, cattails and other low plants(Voigt, 1998).

Mean High Water (MHW/MHT): The average elevation of all high waters recorded at a particular point or station over a considerable period of time (Voigt, 1998).

Mean Higher High Water (MHHW): The arithmetic average of the elevations of the Higher High Waters of a mixed tide over a specific 19-year period (Voigt, 1998) .

Mean Low Water (MLW): The average height of the low waters over a 19-year period(Voigt, 1998).

Mean Lower Low Water (MLLW): The average height of the lower low waters over a 19-year period(Voigt, 1998).

Mean Tide Level (MTL): The arithmetic mean of mean high water and mean low water (Center for Operational Oceanographic Products and Services).

Mean Sea Level: The average height of the surface of the sea for all stages of the tide over a 19-year period(Voigt, 1998).

Normal Amsterdam Level: All heights in the Netherlands both the water height as the height of the country are measured relative to the same level, the Normal Amsterdam Level (NAP). A NAP-height of 0 meters is roughly equal to mean sea level (Rijkswaterstaat (Ministry of Infrastructure and Environment)).

Tidal datum: a standard elevation defined by a certain phase of the tide.(Center for Operational Oceanographic Products and Services).

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Appendix

The list of the 42 problems concerning the core problem as "Westerplas Degradation" defined by the participants is as follows.

1. No fish migration
2. The politics
3. No recreation possible, people can't get to the water to swim, fish, boat, skate
4. Fauna mismanagement of fauna-wild cats
5. Pioneer plants disappear
6. Not many water plants, it seems dead water
7. More phosphate in the water
8. Standing water makes it dirty, no fresh water can get in
9. Swamp formation at the edges
10. Grazing geese and feces of geese
11. Geese produce dung in Westerplas
12. Birds faeces in the water
13. Increasing woodland, less sight on the water
14. Vegetation succession
15. Weakly PH buffering nutrient poor vegetation
16. Encroachment of woody plants and coarse grasses
17. More bushes, willows, etc.
18. Becoming more fresh
19. No natural process it looks, gardening
20. No human maintain act but natural process
21. Eutrophication
22. Closure of the Westerplas from the Wadden sea
23. No problem, lots of birds , nice to look at
24. Decreasing nature values
25. Biodiversity decline
26. Decrease reed birds
27. Big landscape change in last 20 years.
28. View on the lake disappears
29. Bad quality of surface water
30. Deterioration chemical quality of the water , turbid water
31. Big landscape change
32. Increase nesting geese
33. Breeding grey leg geese
34. Water polluted with nutrients
35. Increase geese
36. More breeding greylag geese
37. Increase nesting geese

38. Lake filled with mud, sediments
39. Dynamics are gone, too static, stable
40. Becoming more wet
41. The area changes from a varied area for the tourist in a dull and uninteresting area
42. Water level changes due to inlet water (more stable) bad for water quality