POSSIBILITIES FOR FOREST DEVELOPMENT IN A ZONE OF CONTROLLED INUNDATION IN KRUIBEKE (EASTERN FLANDERS) BY MEANS OF A GEOGRAPHICAL INFORMATION SYSTEM

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Abstract

As an area of 750 hectares is going to be constructed as a controlled inundation zone of the river Scheldt, a preliminary study of the environmental changes and the possible shifts in forest types was done by the Laboratory of Forestry and the Laboratory of Hydrology and Water Management, both of the University of Ghent. Based on a digital elevation model and the relation between water height in the river and the amount of water entering the area for a given height of the dikes, for each place in the inundation zone the frequency of inundation was determined.

These frequencies, in combination with the data layers soil texture, soil drainage, substrate, current land use and historical vegetation data allowed to determine the potentially natural vegetation according to Van Der Werf (1991) and to do a prediction of the forest communities most likely to occur now and for the inundation scenario. Because the very common use of poplar cultivars, also the future possibilities of these trees were considered. As a synthesis, a number of management suggestions could be worked out.

Key words: forest community, forest development, inundation zones, land information system

1. Introduction

After the dramatic inundations of 1976, which proved the vulnerability of the Flemish dike system of the river Scheldt, the decision was made to work out a safety plan for this river, in analogy to the Dutch Deltaplan. This plan, called the Sigmaplan, was based on three main strategies: rising and strengthening the dikes, creating inundation zones to lower the water level in case of extremely high water levels and the construction of a storm surge.

At present all the improvements to the dikes are accomplished and 12 of the 13 foreseen inundation zones are in use. The construction and the configuration of the last and biggest zone is now to be done. Since the importance for agriculture will be strongly reduced, a study was done to search for the future possibilities for afforestation of the inundation zone.

2. Site description

The future inundation zone is situated in the lowest part of the village Kruibeke, near Antwerp in the North of Belgium. It comprises the alluvial part between the dikes of the river Scheldt and the sandy paracuesta on which fertile eolic loam is found (Fig. 1).

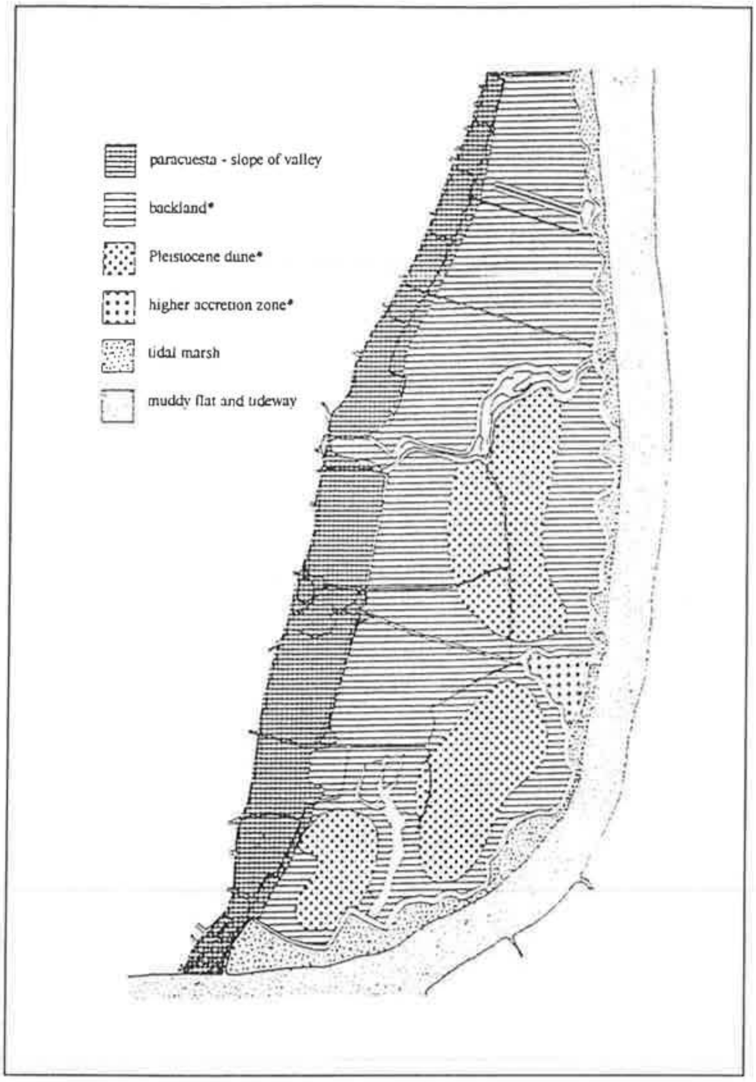

Figure 1: Physical patern of the study area

This future inundation zone can be considered as three main compartments (Fig. 2).
Most downstream the smallest (135.7 ha) and also lowest (average height is 1.28 m) compartment is situated (Kruibeke). Most of the soil is wet to very wet clay with often a shallow peat layer. The main land uses are meadows, fields and poplar fields. The next compartment (161.5 ha) is dominated by a higher (3.5 m) central zone of eolic sandy loam parallel to the river (Bazel). The lowest part is the very wet clayey part on peat between this elevation and the paracuesta.

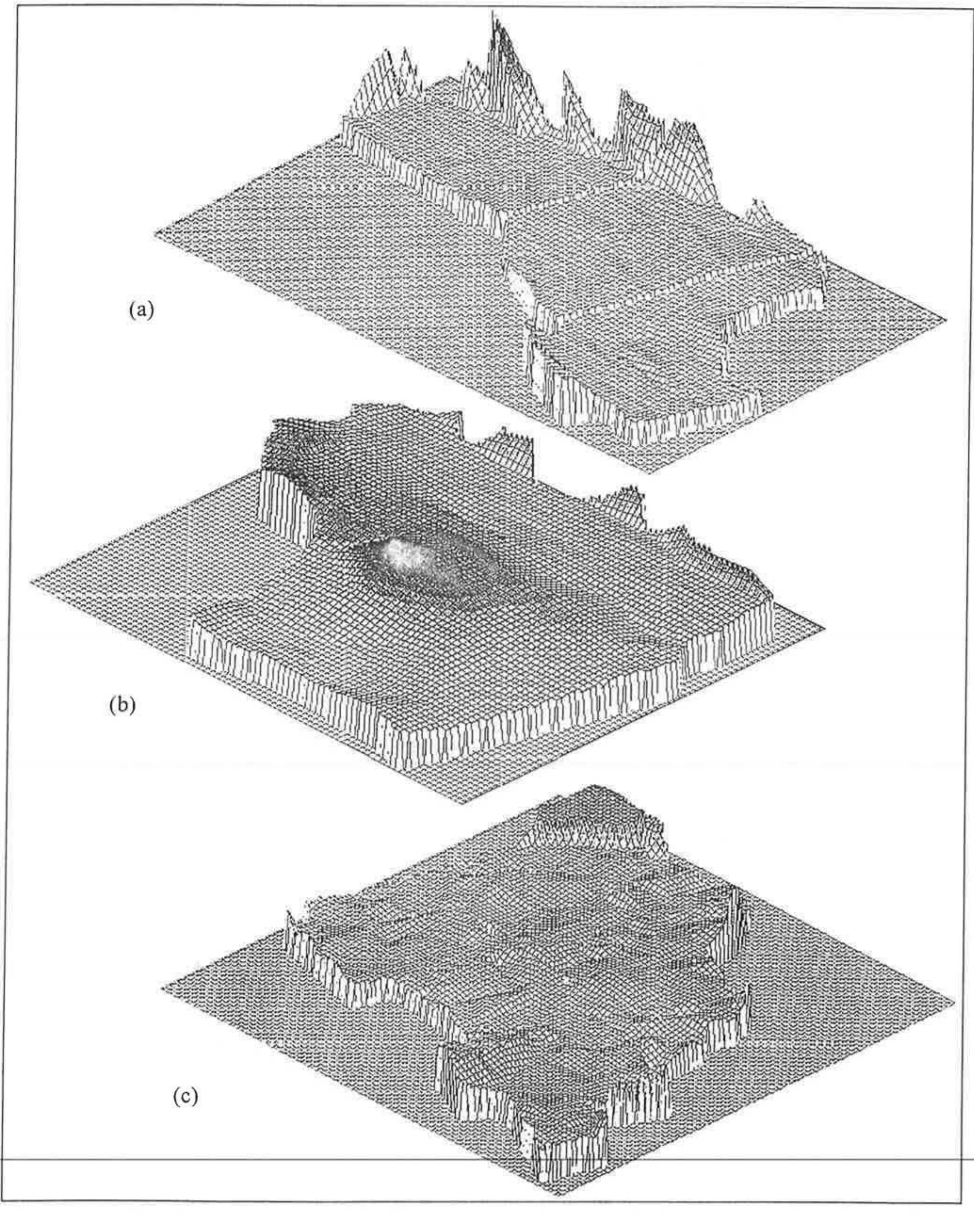

Figure 2: *Overview of the compartments of Kruibeke (a), Bazel (b) and Rupelmonde (c)*

This obviously groundwater dependent zone is covered by Mesothropic Alder swamp forests (Noirfalise 1984) and wet meadows.
The wet part between the sandy ridge and the dikes is partly clay and partly light sand loam under meadows and fields.
The most upstream compartment is the biggest (218 ha) and the most heterogeneous (Rupelmonde). In the wettest part near the paracuesta the landscape is dominated by mesotrophic to eutrophic alder swamp forests with poplar in the upper tree layer. Nearer to the Scheldt lower clayey and higher sandy zones alternate.

3. Material and method

For the construction of a GIS of the study area, an Intergraph Workstation was used in which the CAD applications were done by means of Microstation 32 and the GIS applications within MGE (Modular GIS environment) with MGE System Nucleus, MGE Analyst for vector applications, MGE Terrain Modeler and MGE Grid Analyst for grid applications. For the database management ORACLE, a relational database, was chosen. The communications with this database happened by means of the Relational Interface System (RIS).
The vegetation of the entire zone was digitised from analogous cards with a 1/5000 scale. Soil maps were digitised based on the Soil Map of Belgium (scale 1/20000) as well as a web of height measuring points on a scale of 1/2500. Further data layers contained tree rows, canals and dikes (scale 1/5000).
In a next step, these vector data were converted into grid files with a resolution of 10 by 10 meter. Via the interpolation of a triangulated irregular network (TIN), the height points were translated into a digital elevation model (DEM). This DEM was used for visualisation and for combination with other grid files, the TIN was used to compute volumes of water in the study area.

3.1 Determination of the inundation frequency

Because the relation between the volume of water entering the inundation zone and the level of the water in the river as well as the chance of occurrence of each water height were available (Waterbouwkundig Laboratorium Borgerhout), it was possible to work with the chance of occurence of a certain amount of water in the study area. By means of the digital elevation model and an option within the Intergraph GIS allowing the calculation of the volume between a DEM and a plane on a chosen height (i.e. the water level), a zonation for inundation frequency could be build (Table 1). This frequency was taken as representative for the duration of the inundation because the exact dimensions and the capacity of the sluices were not yet known.

***Table 1:** The volume of water that enters the area according to the calculations of the Waterbouwkundig Laboratorium te Borgerhout (Volume 1) with a return period of once every X years (Frequency) and the best approximation of Volume 1 based on the DEM (Volume 2) by which the inundation height (Height) as well as the inundated surface (Area) were found*

Compartment	Volume 1 (m^3)	Frequence (year)	Volume 2 (m^3)	Height (cm)	Area (ha)
Bazel	107100	4	105457	168	54.2
	612000	8	600318	223	113.8
	1377000	17.5	1357950	283	146.3
Kruibeke	98700	4	96594	140	67.2
	606300	8	606446	188	121.0
Rupelmonde	120000	4	119214	162	68.0
	780000	8	778157	215	170.0
	1860000	17.5	1869240	274	196.3

3.2 Change of the physical factors of the area

On the above described manner, zones were delineated with different inundation frequencies and duration. Because the inundations occur only during the period from November to March, and because the inundated area has got to be emptied as fast as possible (from several days to a few weeks), in the first place the level of the soil water during the winter will be affected.
Most of the soils have a winter groundwater level that is just below or even reaches the surface. So the winter groundwater level of these soils is not very likely to change considerably. In the drier parts though, the alternations can be important. Changes in the summer groundwater level were not considered as being relevant. This way an approximation was obtained of the scale on which changes in drainage classes can be expected and the places most likely to undergo changes. As a result, a map of the new drainage situation was build.
Apart from this, an estimation was made of the deposition of sludge in the inundation zone. Therefore the calculation was done for the amount of sludge that would have been deposited if the area should have been used as an inundation zone during the period of 1960 to 1984.
Using a density of 2.25 g/cm³ for the sediment, a concentration of 100 mg sediment in a litre of water (MER 1986) and in the assumption of total sedimentation, at maximum 0.42 mm of sludge would have been deposited in the most frequently inundated zones. In the further study, this change was not taken into account.

3.3 Selection of forest communities and quantification of the demands of the different forest types

The first step of this selection was an extensive literature study to find all suitable forest communities. For transparency reasons the forest communities were chosen as much as possible from the same author. A difficulty in this was the fact that most authors do not describe the primary site characteristics but only secondary characteristics like vegetation or profile types: an existing forest is described and not the places where such a forest could develop.
The decision was made to use the potentially natural vegetation according to Van der Werf (1991), completed with data from mostly Noirfalise (1984).

The selected communities can roughly be classified into four large groups, based on the pedologic entities of the area: communities of dry, light sandloam soils (P) or loamy sand soils (S), of wet P and S soils, of drier clay soils (E and U) and those of wet clay soils.
Further division is done by confrontation with factors as presence of certain substrate types, the amount of peat, the situation of the drainage system, elevation, nutritional state and pH. This way the following communities were found (Van der Werf 1991):

drier P and S soils:
- Fago-Quercetum petraeae typicum
- Endymio-Carpinetum typicum

wetter P and S soils:
- Fago-Quercetum petraeae molinietosum
- Lysimachio-Quercetum
- Stellario-Carpinetum typicum

drier clay and heavy clay soils:
- Fraxino-Ulmetum typicum
- Fraxino-Ulmetum alnetosum

wet clay soils:
- Filipendulo-Alnetum
- Alnetum glutinosae filipenduletosum
- Alnetum glutinosae symphyto-cirsietosum
- Salicetum albae
- Salicetum triandro-viminalis

The choice was made to interpret the site conditions for natural forest communities rather than for their possibilities for the distinct tree species. This way the choice of tree species is not only best in relation to the site (Van Slijcken, 1992) but it also gives the best idea of the possible mixtures of species. It also gives the best idea of what silviculture is most sustainable, which is the first of all conditions. Because of the heterogeneous geological composition of the area (young alluvial soils), this way of working will also guarantee a high diversity. The composition is such that the areas where forest communities could develop is large enough to allow an evolution to a representative form with all stages present and with several transition zones between the communities (Londo 1991). The decision to work with site adapted communities instead of only tree species was also made to obtain a more complete picture of the possible shifts in the forest dynamics. A rise in dynamic can be expected, certainly if the inundations could happen in an ecologically solid manner, that is with a regular, more or less predictable frequency to which forest ecosystems can adapt (Hermy 1989).
Next the site demands for the information layers substrate, texture and drainage class of all forest types were quantified in a numerical appreciation. By combination of these information or appreciation layers for each forest type a map was obtained with the suitability of the locations. After this one map was composed in which all the communities were brought together. For each community in this map, also the potential for production was determined of the most important species. This was done by means of the tables of Baeyens (1992) from the Institute of Forest and Wild management, completed with data from Le Fichier Ecologique de Essences (1991).

3.4 Minimal Structure Area

In order to check whether the area assigned to each forest type is large enough to conserve all chances for a good development of each community, the area was confronted with the minimal structure area. This is the supposed surface that each forest community needs to occur in its typical form and with all stages present and in a dynamic equilibrium. This size depends on the forest type, border influences and the scale of mesogradients (by openings in the canopy layer) (Londo 1991).

3.5 Poplar

Because at present a considerable part of the area is used for the cultivation of poplars, also the future suitability was investigated for poplar cultivars of the group of the old Euramerican clones and of the group of the new Euramerican and interamerican clones, and the West American Balsam poplars that have only recently appeared on the market. The results were also confronted with the map of forest communities in order to get an idea which communities would be most threatened.

3.6 Mud flats and tidal marshes

In each compartment the influence of daily inundations to a reduced height was considered. By means of sluices a tidal entrance of water over one third of the surface could be arranged, ensuring a highly dynamic, but regularly inundated ecosystem to install.

3.7 Grazing

A last part of the study was to check to possibilities for grazing as a management strategy for the future forests. This type of management is often chosen to rise the structural diversity of complexes of grassland and forest. Differences in grazing intensity between different locations and different plant species, differences in trampling intensity and amount of faeces (latrines or not) at each spot all have their impact. Each animal species has its own way and preferences of grazing: gnawing or ripping of herbs or branches, browsing, grazing, ...
A first condition to consider is the number of animals per ha. As maximal numbers, Londo (1991) gives the following numbers in bcu (big cattle units):

- forest on rich grounds: 1 bcu for 10 ha
- forest on poor grounds: 1 bcu for 20 ha
- rich grassland: 1 bcu for 1 ha
- poor grassland or heather: 1 bcu for 5 ha

Adult cows and horses are 1 bcu, young cows 0.5, calves 0.3 and sheep 0.2 bcu's.
Furthermore, the area to be grazed should be at least 30 ha and at least two thirds should be forest. Forest zones with an extremely shallow groundwater level will hardly be visited by the animals but should not be excluded from the forest reserved for grazing (Londo 1991).
A last consideration to make is that also the grassland should be as divers as possible, that is, the grassland should be spread over as many different growing conditions (gradients) as possible. For this study this condition was translated in "as many forest communities as possible".

4. Results

For each compartment a synthesis map with the forest communities was produced. Because the differences between the compartments are considerable, the results will be discussed separately.

4.1 Compartment 1: Kruibeke

After the spatial division of the forest types, the future inundation zone of Kruibeke appeared to be best fit for Filipendulo-Alnetum (61 ha), Alnion glutinosae (40.5 ha) and Lysimachio-Quercetum (21.5 ha). These communities are little fragmented but nevertheless have large zones of mutual contact. The evaluation of their surface was done by checking it with the minimal structure area of each community (Table 2). Only for the Lysimachio-Quercetum there is serious doubt whether this community would be able to develop to what is called a potential natural vegetation. Because the area reaches 20 ha though, and because it is embedded in a larger forest complex with mostly the same tree species, it should certainly be able to grow to a rather typical Lysimachio-Quercetum forest, but probable not with all phases present at all times. In literature, transitions between these forest types are also well documented (Van der Werf 1991)

When these communities are confronted with suitable soils for poplar, it is clear that they coincide largely with certain forest types. For the group of old clones (91.5 ha), the entire Lysimachio-Quercetum and Filipendulo-Alnetum area is suitable, for the new clones (27.5 ha) only the Lysimachio-Quercetum zone. Both groups of clones are not suitable for the Alnion glutinosae area.

If we consider the possibilities for grazing in this compartment, we leave out the 40.5 ha of Alnion glutinosae because they are to wet to be fully used for grazing. The total grazing area then becomes 95.5 ha of which 63 ha should be forest and at maximum 32 ha grassland. Since the Lysimachio-Quercetum ought to be conserved as much as possible, 20 ha of Filipendulo-Alnetum and 12 ha of the category "others" were chosen. At maximum 36 bcu could then be used. Because of the high inundation risk during winter and the lack of higher sheltering places, seasonal grazing might be the best solution.

Table 2: *Minimal structure area of the different forest communities (Van der Werf 1991, Koop in prep.)*

Forest community	Minimal Structure Area (ha)
Fago-Quercetum petraeae typicum	40
Endymio-Carpinetum typicum	?
Fago-Quercetum petraeae molinietosum	40
Stellario-Carpinetum typicum	10
Lysimachio-Quercetum	40
Fraxino-Ulmetum typicum	10
Fraxino-Ulmetum alnetosum	15
Filipendulo-Alnetum	20
Alnetum glutinosae filipenduletosum	20
Alnetum glutinosae symphyto-cirsietosum	20
Salicetum albae	25
Salicetum triandro-viminalis	25

4.2 Compartment 2: Bazel

The more heterogeneous structure of this compartment is reflected in a wider range of forest communities. Again Lysimachio-Quercetum (33 ha), Filipendulo-Alnetum (40 ha) and Alnion glutinosae (28.5 ha) are found, but now also Fraxino-Ulmetum typicum (19 ha) and endcapt/Fago-Quercetum petraeae typicum (36 ha) find suitable grounds. Except for Lysimachio-Quercetum their surfaces all meet the minimal structure area. Concerning this fact, the same remarks as for the Kruibeke compartment can be made, with the available area being even bigger.
The area of the old poplar clones (107 ha) took the complete zones of Lysimachio-Quercetum, Fraxino-Ulmetum typicum and Filipendulo-Alnetum, and half of the endcapt/Fago-Quercetum petraeae typicum. The new clones (46.5 ha) coincided only with the complete Lysimachio-Quercetum.
In this compartment 132 ha could be used for grazing of which 40 ha of grassland. This might be composed of 15 ha of Filipendulo-Alnetum, 10 ha Fago-Quercetum petraeae typicum, 5 ha Fraxino-Ulmetum typicum and 10 ha of category "others". Since there are enough places for shelter, grazing could be tested for the whole year. This way 49 bcu could be used.

4.3 Compartment 3: Rupelmonde

In this compartment, eight forest types have an important area. Fraxino-Ulmetum typicum (33 ha), Lysimachio-Quercetum (55 ha), Filipendulo-Alnetum (24 ha), Alnion glutinosae (50 ha), Stellario-Carpinetum typicum/Fago-Quercetum petraeae molinietosum (16.5 ha) and Fraxino-Ulmetum alnetosum (15 ha) all meet their minimal structure area. Except for Alnion glutinosae they all coincide with the group of old poplar clones (149 ha). The new poplar clones (91.7 ha) coincide with Stellario-Carpinetum typicum/Fago-Quercetum petraeae molinietosum and Lysimachio-Quercetum, partly with Fraxino-Ulmetum typicum and Fraxino-Ulmetum alnetosum. Grazing could be done over 168 ha, of which at maximum one third being grassland chosen as 15 ha of Lysimachio-Quercetum, 13 ha of Fraxino-Ulmetum typicum, 4 ha of Filipendulo-Alnetum and 5 ha of Stellario-Carpinetum typicum.

5. Conclusions and suggestions for management

This case study proved that common GIS techniques are very efficient tools for the study of changing environmental factors as caused by the implementation of different inundation regimes. By using GIS it was/is possible to consider rapidly the expected consequences of several types of inundations. The inundation frequency can be translated into changes of soil physical characteristics, even in rather heterogeneous situations as the study area. Also the numerical expression of the demands of forest communities proved to give good results for the prediction of the future shifts in species composition and concurrence between species. The same technique can be used to verify the possibilities for single tree species.

In general we can conclude that the study area has considerable troeven for forest and nature development
For the compartment of Kruibeke the alternative of daily inundations was considered as being the most suitable. Because it is very flat, slight variations in water level have a high effect on the number of inundated hectares, which makes it easier to work out a well balanced inundation regime. The fact that for the moment it is geophysically seen the most homogeneous part, is largely corrected by the rise in dynamic of this system, guaranteeing a future heterogeneity. Furthermore, this compartment is

poorest in possible forest communities, and the forests that is present at the moment is also the less valuable. This daily inundation regime can be combined with summer grazing.
For the compartment of Bazel grazing was suggested. The area is heterogeneous enough to ensure diversity in the forest as well as in the grassland types. It also has got a higher and drier part were the animals can shelter. For a regime of daily inundations, not only the future but also the present richness of forests has got to be sacrificed.
The compartment of Rupelmonde was seen as the most suitable for forest development. In each case the present forests ought to be protected from daily inundations.

7. Aknowledgement

I would like to thank the Laboratory of Hydrology and Water Management of the University of Ghent for the use of the GIS environment and their guidance. I would also like to thank the Laboratory of Forestry of the University of Ghent for their help in selecting the forest communities.
Finally I have to thank Dr. P. Meire of the Institute of Nature Conservation for the enormous efforts he is doing to work out the ecological structure for the basin of the river Scheldt, which was the outline of this study. I hope he and his team succeed in realising their project.

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