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RANKING OF WATER-TABLE DEPTHS FOR PURPOSES OF ECOSYSTEM MANAGEMENT IN THE COASTAL DUNES OF BELGIUM

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(5 figures, 2 tables)

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ABSTRACT. Integrated monitoring was conducted to evaluate the result of nature development actions to increase the biodiversity. During the first year, the natural fluctuation of the piezometric level has been determined based on existing data and newly gathered data. From these data, the groundwater table classes following a classification, developed in The Netherlands, have been deduced. However, the result does not correspond with the observed vegetation. To predict the natural habitats and ecosystems in the coastal dunes of Belgium, a new classification adapted to natural conditions in the area is required. Advantages of existing approaches are integrated in the classification, combined with new elements, to represent the relationship between groundwater regimes and ecosystems.

This new classification, consisting of 4 codes, provides information about the mean high water table depth, the mean low water table depth, mean spring water table depth and whether inundation can take place or not. It also gives an indication of the variability of the seasonal fluctuations of the water table and the importance of the fluctuation of the water table between years. With this new classification, a fine breakdown by ecotypes is possible. The new classification has been applied to the existing data in the study area.

KEYWORDS: groundwater dynamics, classification, inter-yearly variability, seasonal fluctuation, groundwater statistics, monitoring

1. Introduction

EC "Life Nature" projects at the Belgian coast aim to increasing biodiversity. To reach this goal, four "Life-Nature" projects are established along the Belgian coast. The project: the "Fossil Estuary of the Yzer Dunes Restoration Action" (FEYDRA) is one of them. Deforestation of 6 ha of artificial Elder- and Poplar-woodland and dredging a dune river, are the main activities of the management plan to reach the goal of restoration of threatened habitats and species of the annexes 1, 2 and 4 of the European Habitat Directive that are typical for the coastal dunes (Herrier & Van Nieuwenhuyse, 2005). To evaluate these actions, a four year monitoring programme is executed. Existing data and new field experiments are used to define the reference situation before the evaluation of the nature restoration actions started. The results, considering the hydrologic characteristics of the groundwater reservoir related to fauna and flora, are discussed in the following. It was found that, based on literature and existing classification approaches to predict certain ecotopes at a certain place, the determined groundwater class based on the measured depth of the groundwater table does not correspond with the observed vegetation. This statement is not only valid in the study area, but widely in Flanders. In parallel to this project, a model "NICHE Flanders" has been developed, based on an existing model in the Netherlands. To increase the applicability, the NICHE Flanders model is converted to the Flemish conditions and soil moisture, pH, availability of nutrients can be calculated to predict the possibility of development of some vegetation types (Huybrechts et al., 2007). At the moment, the coastal area is not included in the model, due to the difference in soil characteristics compared with the rest of Flanders (Callebaut et al., 2007 in Huybrechts et al., 2007).

Whether a certain ecotope develops or not at a certain place will depend, amongst other factors, on the variability of the groundwater table level. Several methods exist to present the groundwater regimes to deduce which natural habitats and ecosystems can occur under these circumstances. These methods, such as frequency of exceedence graphs, and groundwater table depth statistics which lead to groundwater table classes, are among the most widely applied methods and have their specific advantages and disadvantages. These methods have been applied to the available data in the study area and, depending on the applied method, or period of time-series, this results in different conditions for different ecosystems. The existing water table class was developed in the Netherlands where the water table level is kept artificially stable and varies between 0 and 2 m below surface (Knotters & Bierkens, 2001). A more extended approach is the database "Waternood" of Runhaar & Hennekens (2006) with integration of different vegetation types related to MSW and, if available, indication of MLW with a differentiation in soil types when desired. But, this database has also been developed in the Netherlands. So, to predict the natural habitats and ecosystems at the coastal dunes of Belgium, a classification adapted to natural conditions in the area is required. Advantages of existing approaches to represent the relationship between groundwater regimes and ecosystems are considered to develop the classification, combined with new elements.

2. Study area and dataset

The study area is located in the dune belt of the north-western part of Belgium, in the western coastal plain at Oostduinkerke, and includes the nature reserves Ter Yde and Hannecartbos. Also the plots in between make part of the study area to form one entity. The northern part of the study area consists of medium to high dunes with dune slacks, while in the southern part a dune river "Beek zonder Naam" divides the flat valley in two similar parts. The elevation ranges from +5 up to more than +20 m T.A.W.

The shallow groundwater reservoir consists of Quaternary sediments and can be considered as one phreatic aquifer: three pervious units separated by two less pervious units. At the bottom of the groundwater reservoir, at ca. –20 m T.A.W., bluish grey heavy clay (Kortijk Formation, Tertiary) occurs. This structure is representative for a part of the groundwater reservoir in the western part of the Flemish coastal area (Denys et al., 1983; Mahauden et al., 1982; Walraevens et al., 1993; Walraevens et al., 2002; Van Camp et al., 2002).

Prior to this study, a network of piezometers has been installed. These are evenly distributed throughout the study area. Depending on the property of the land, they are supervised by the Intermunicipal Water-Supply Company of Veurne-Ambacht (IWVA) or by the Flemish Community. With the aim to identify the relation between groundwater depth and vegetation, a set of these piezometers are selected with screens located in the upper part of the phreatic aquifer, close to the water table. The location of the selected piezometers is presented in Fig. 1.

The piezometers of the Intermunicipal Water-Supply Company of Veurne-Ambacht (IWVA) have been measured weekly from March 1993 onwards. Since 1998, the piezometers in the nature reserves of the property of the Flemish community have been measured bi-weekly by the Flemish Community. Because of the objective to define the natural groundwater dynamics in relation with the existing vegetation, the considered dataset has been limited up to the 24th of September 2004. At that moment, the nature restoration activities have started. For four selected piezometers (SB20, SB21, 553 and 559), the piezometric level is plotted and represented in Fig. 2.

3. Groundwater table depth classification

3.1. Existing approaches

The categories of vegetation classes find their origin in groundwater dynamics. Independent of the approach for the presentation of results (frequency of exceedence graphs, or groundwater table classes deduced from

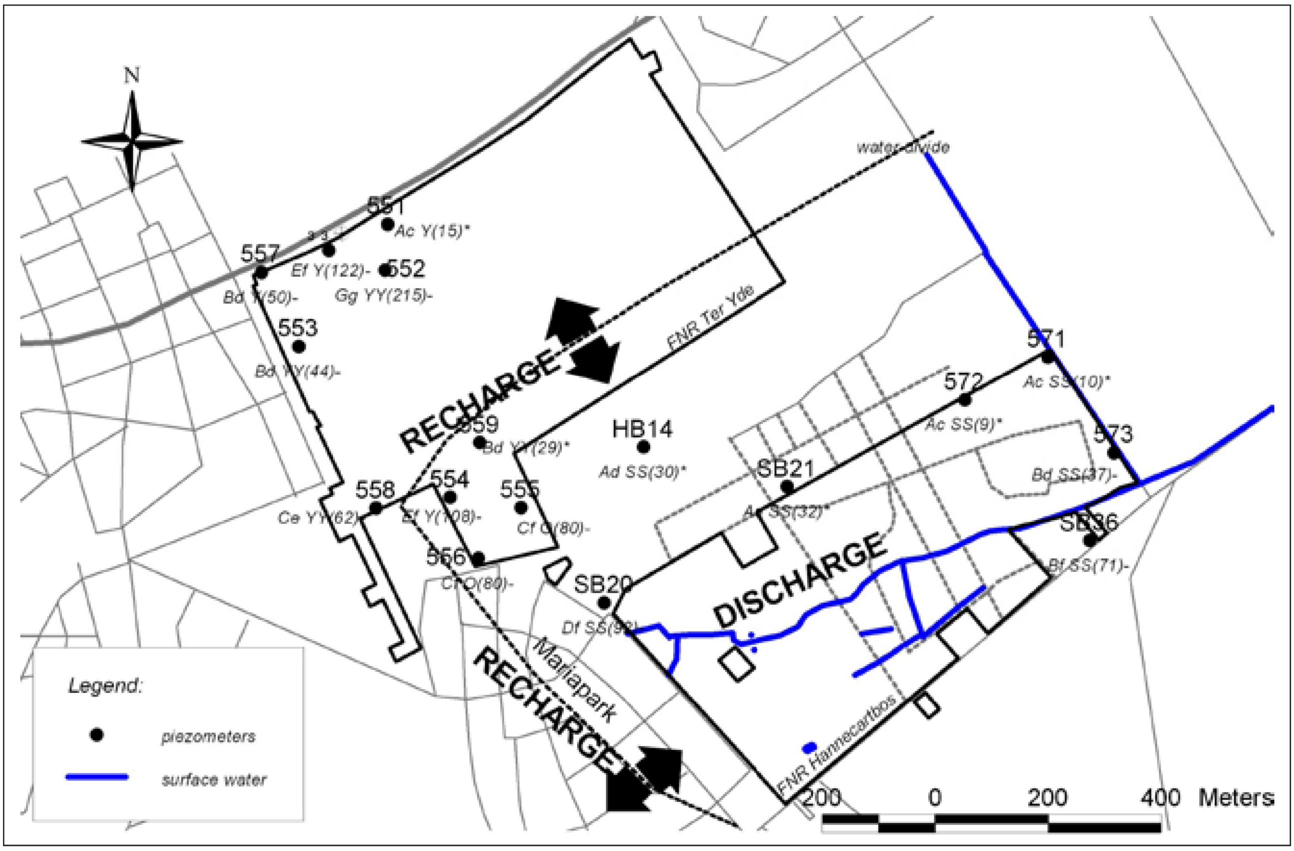

Figure 1. Study area with indication of piezometers with long time-series, the groundwater class according to the new classification, the groundwater recharge area in the high dunes, and the discharge area in the dune river valley.

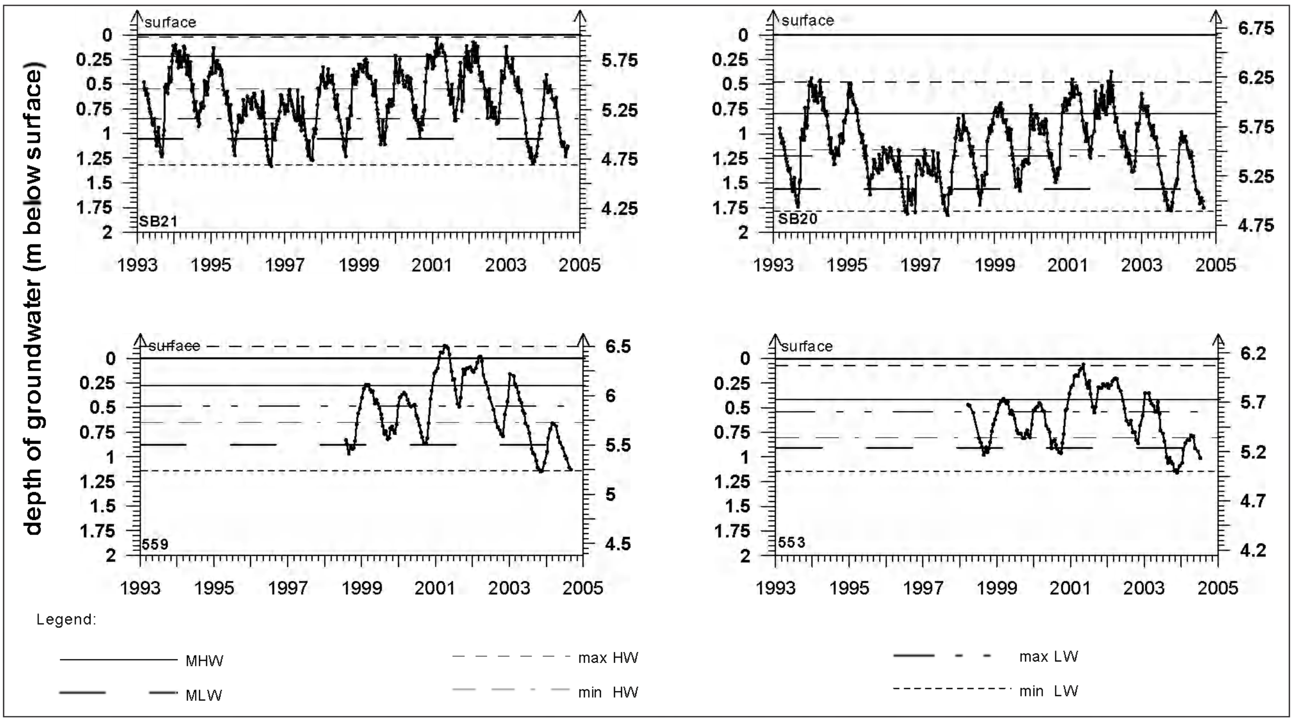

Figure 2. Fluctuation of the groundwater level in 4 selected piezometers (SB20, SB21, 553 and 559)

groundwater table depth statistics) the importance of long time series with regular measurements is emphasized (Bierkens & Hoogland, 2002; von Asmuth & Knotters, 2004; Finke et al., 2004). With these time series, frequency of exceedence graphs can be drawn. They express the percentage of measurements that the groundwater table occurs above or below a specific depth (Fig. 3). The longer the time series and the more frequently measured the water levels are, the more reliable are the results, because of the integration of climatological influences on the variability of the depth of the groundwater table. A period of at least 30 years is needed to calculate a reliable mean groundwater level, representative of climatological conditions (Knotters & van Walsum, 1997 in Finke et al., 2004 and in Bartholomeus et al., 2008a). Due to limited time series, the existing approach considers time series over a period of 8 years with bi-weekly measurements representative to apply the groundwater table depth

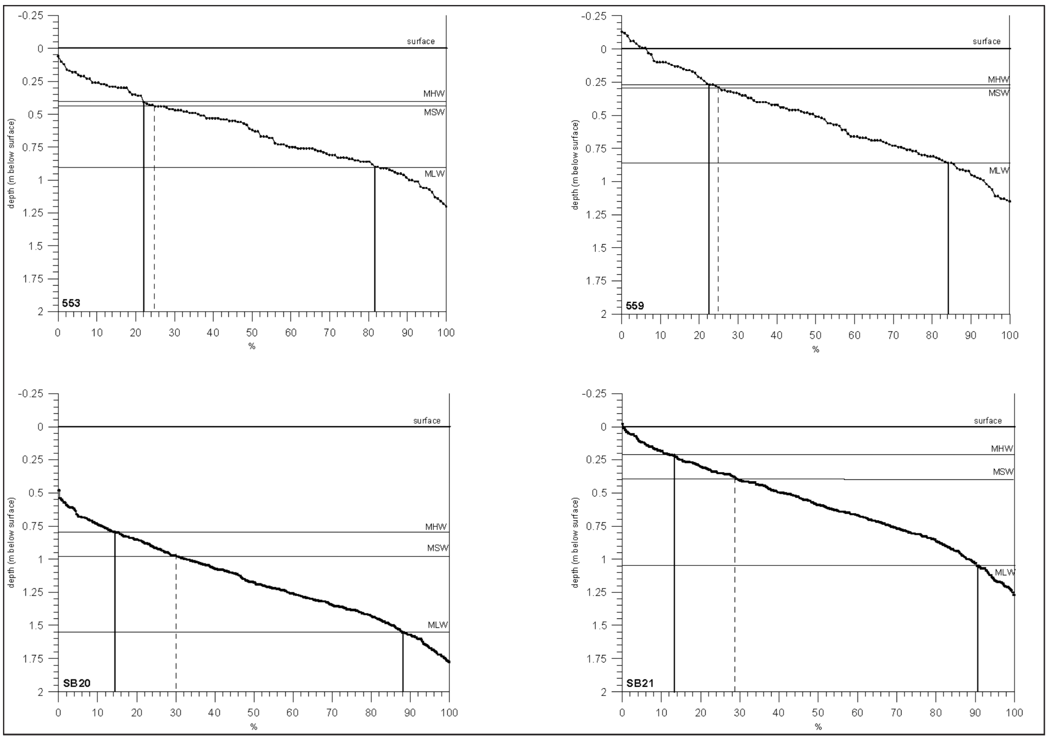

Figure 3. Frequency of exceedence graphs for piezometer 553, 559, SB20 and SB21

statistics (Mean Highest, Mean Lowest or Mean Spring Water table depth) from which groundwater classes are deduced (Fig. 4) (Van der Sluijs & Gruijter, 1985; Van der Sluijs, 1990; Knotters & Bierkens, 1999; Finke et al., 2002; Mekkink, 2003; Finke et al., 2004; Finke et al., 2005). The Mean Highest Water table (MHW) is defined as the mean value of the three shallowest groundwater depths measured in one year (in cm from soil surface), averaged over the whole time series. The Mean Lowest Water table (MLW) is defined likewise with the deepest groundwater depths. The groundwater depths measured at three dates nearest to April 1, serve for calculation of the Mean Spring Water table (MSW). Depending on the author, the period to calculate the MHW and MLW can differ. In Finke et al. (2002) the MHW is defined between October 1st and April 1st, while Bierkens & te Stroet (2007) reduce the MHW to the months December and January, while the MLW is calculated for July and August. The approach of MHW and MLW filters out the extreme groundwater levels (von Asmuth & Knotters, 2004), while they are often of great interest because they will affect the vegetation, especially when the period is reduced to two months. To eliminate this shortcoming and enhance the groundwater table depth statistics, the average of the three shallowest and deepest groundwater depths of each year are included and are called HW and LW in this paper.

3.2. New classification

With the new approach, a classification has been developed to reflect the fluctuation of the water table based on long time series. It is an easy and cost effective method, providing valuable information which can be used to correlate with water dependent vegetation. The new classification focuses only on the depth of the water table, while it is understood that soil type, nutrient availability, acidity,… also determine whether a vegetation occurs or not.

The purpose of the new classification is that from the code, the depth of MLW, MHW and MSW can be easily deduced. The classification consists of four codes. The conditions for the application are the same as for the groundwater classes: at least 8 years of measurements that are done bi-weekly.

3.2.1. Code 1: MHW and MLW

A new classification is developed composed of two symbols referring to MHW and MLW. The first symbol of the code (a capital letter) refers to MHW, while the second (a lower-cast letter) corresponds with MLW. Although the soil type is not included in the classification, the code for MLW indicates the depth of the water table during summer and can be indirectly related to drought stress. The MLW

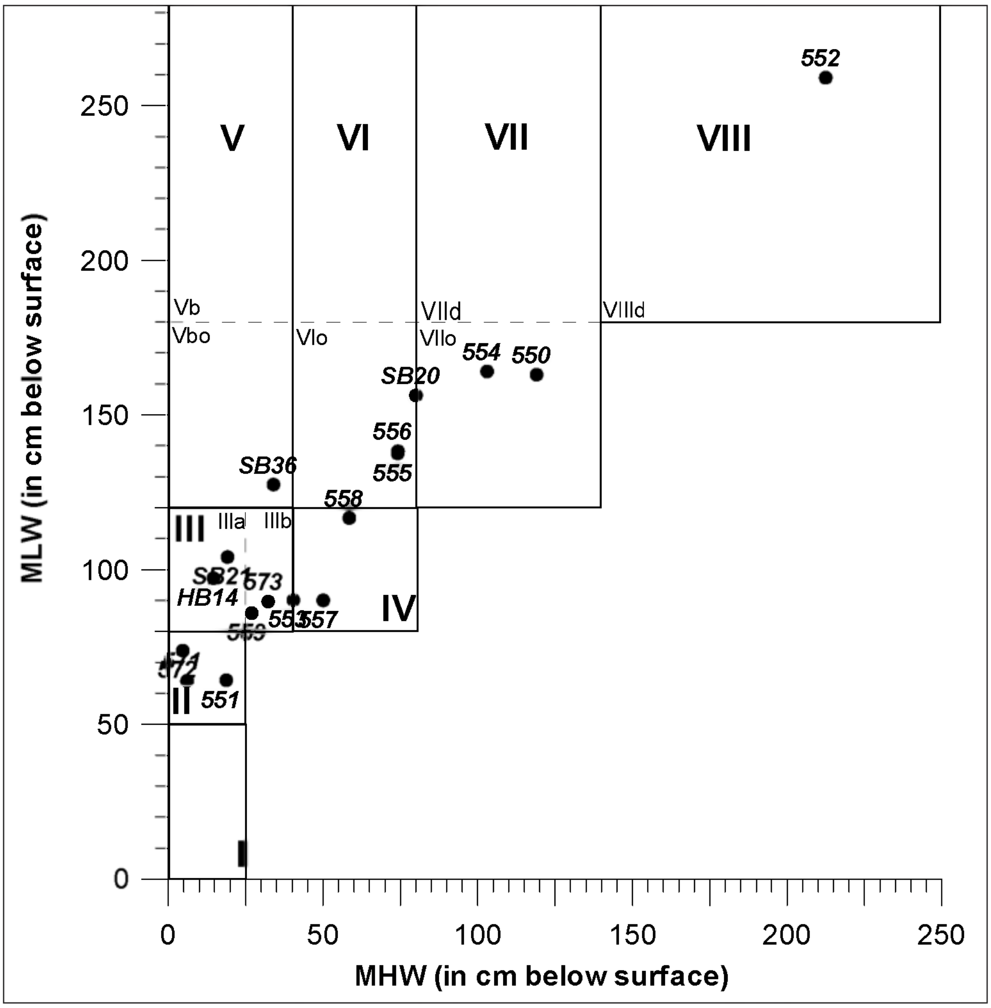

Figure 4. Water table classes in relation with MHW and MLW applied for the piezometers in the study area (after Knotters & Bierkens, 1999)

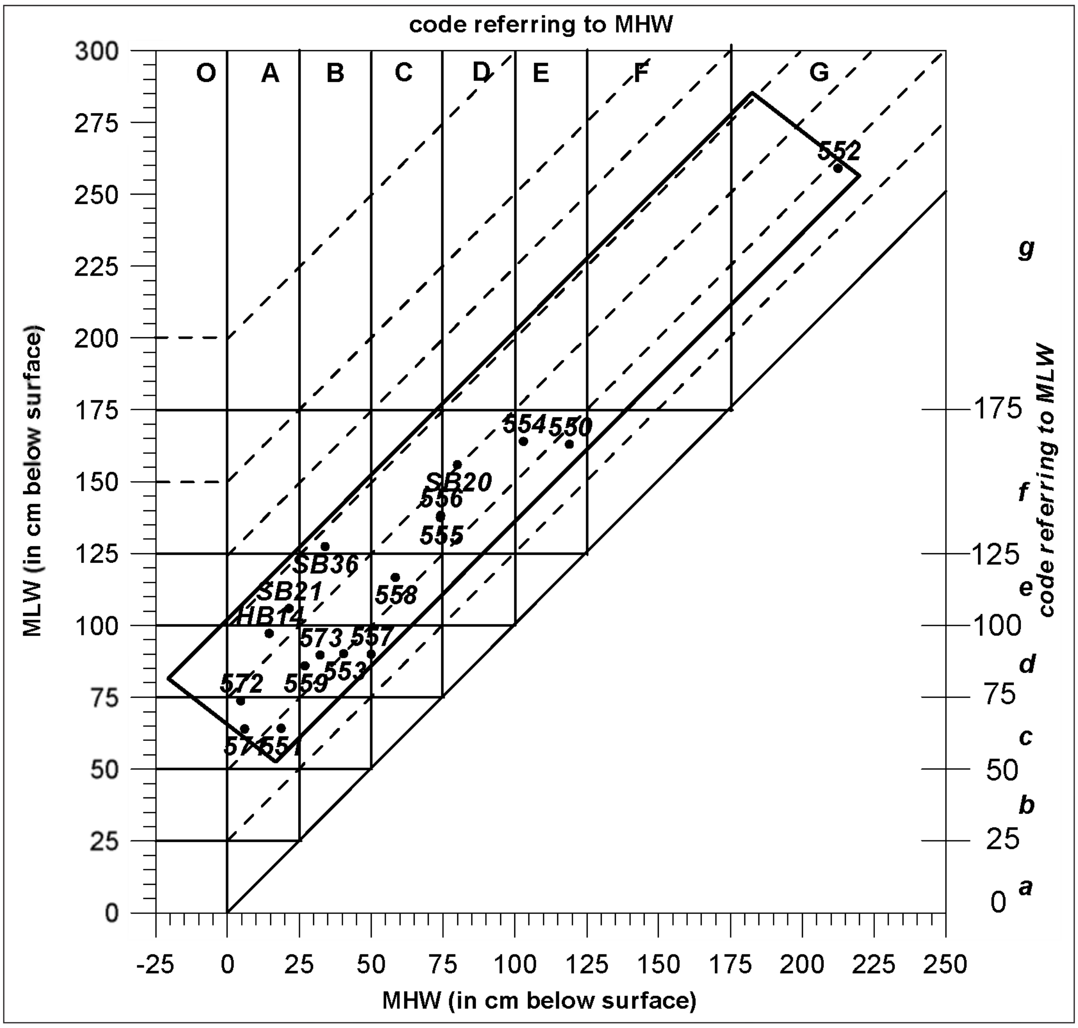

Figure 5. New water table classes in relation with MHW and MLW applied for the piezometers in the study area

also determines the range of mineralisation of organic material (Runhaar & Hennekens, 2006). A deep water table promotes mineralisation of organic material. With a stable water table close to the surface, mineralisation will be hindered with an accumulation of organic material as a result.

The earlier the letter comes in the alphabet, the higher the water table. The new water table classification is illustrated on Fig. 5. It is obvious that MLW can not be smaller than MHW. This shortcoming of the existing classification is eliminated by bounding the classes at the base by the 1:1 line. The interval between two consecutive classes is regular: 25 cm. From 125 cm below surface, the interval is 50 cm. When the water table levels are deeper than 175 cm, one code is foreseen, because a further subdivision is not relevant for groundwater dependent vegetation. A depth of 1.3 m is considered as the limit from which the vegetation has no causal relationship with groundwater level (Witte & von Asmuth, 2003). The symbol (O) is added to indicate that MHW is above soil surface. In the existing water table classification, this clear reference is missing.

For the interpretation of the figure, MHW and MLW can be read from the axes and the corresponding code is deduced. Additional information can be deduced from the dotted lines. They indicate the difference between MHW and MLW, representing the seasonal fluctuations of the water table. They should be read from the number on the y-axis opposite to the intersection of the relevant dotted line with the x=0 line. A limited seasonal variability can be concluded when the difference between MHW and MLW is small. In the opposite case, significant seasonal fluctuations occur with big differences between MHW and MLW. This information can also be deduced from the code.

MHW and MLW are reflected in the first code, but the variability of HW and LW between years is missing. Yet, the latter provides information about the depth of the water table in "dry" and "wet" years. For this reason a second code is included, which reflects the relative importance of seasonal and inter-yearly fluctuations.

3.2.2. Code 2: Relative importance of seasonal and inter-yearly fluctuations

In Table 1 the range of MHW and MLW (MLW-MHW), as well as the range between the minimum and maximum of LW over the years, respectively of HW are added. The ranges of HW and LW give an indication of the fluctuation of the water table over the years. This is important for the chances of adaptation of the vegetation.

As an example, the time series for four selected piezometers are presented in Fig. 2 with indication of

Table 1. Groundwater statistics with indication of the water table class and new classification

nr.	MHW	MLW	MSW	MLW-MHW	HW (in cm)			LW (in cm)			WTclass (Knotters & Bierkens, 1999)	new approach
	(cm)	(cm)	(cm)	(cm)	min	max	range	min	max	range		
550	119.00	163.00	121.83	44.00	92.00	150.00	58.00	133.00	180.67	47.67	VII_o	Ef Y(122)-
551	18.67	64.19	22.00	45.52	-11.00	50.67	61.67	34.00	82.67	48.67	II	Ac Y(15)*
552	212.48	259.00	214.78	46.52	179.00	248.67	69.67	223.67	280.33	56.67	VIII	Gg YY(215)-
553	40.38	90.14	43.67	49.76	9.33	80.00	70.67	51.00	114.67	63.67	IV	Bd YY(44)-
554	103.00	164.00	108.00	61.00	67.67	142.00	74.33	120.00	190.67	70.67	VII_o	Ef Y(108)-
555	74.10	137.52	79.67	63.43	40.33	111.67	71.33	99.00	162.67	63.67	VI_o	Cf O(80)-
556	74.19	138.24	81.50	64.05	43.67	111.00	67.33	98.67	164.00	65.33	VI_o	Cf O(80)-
557	50.00	90.00	52.61	40.00	23.33	77.33	54.00	63.00	105.33	42.33	IV	Bd Y(50)-
558	58.43	116.67	59.28	58.24	16.33	98.33	82.00	68.00	144.00	76.00	IV	Ce YY(62)-
559	26.95	85.95	29.61	59.00	-11.67	67.33	79.00	45.00	114.00	69.00	III_b	Bd YY(29)*
571	5.99	63.99	16.80	58.00	-1.53	14.47	16.00	50.13	86.80	36.67	II	Ac SS(10)*
572	4.63	73.77	16.03	69.14	-0.80	11.20	12.00	59.87	97.87	38.00	II	Ac SS(9)*
573	32.28	89.70	41.36	57.43	25.47	38.47	13.00	72.80	117.47	44.67	III_b	Bd SS(37)-
HB14	14.53	97.21	32.00	82.68	-8.80	50.70	59.50	66.70	116.03	49.33	III_a	Ad SS(30)*
SB20	80.00	156.32	96.00	76.32	54.00	117.83	63.83	122.83	179.17	56.33	VII_o	Df SS(92)-
SB21	19.06	104.01	38.00	84.96	-0.50	51.17	51.67	76.00	123.33	47.33	III_a	Ae SS(32)*
SB36	33.94	127.44	77.00	93.50	17.33	60.83	43.50	105.67	146.50	40.83	Vb_0	Bf SS(71)-

Legend:
MHW = mean high water level; MLW = mean low water level; MSW = mean spring water level
HW = high water level; LW = low water level; WTclass = water table class

MHW, MLW, minimum and maximum of LW, minimum and maximum of HW to visualise the importance of the seasonal variability within years and the inter-yearly variability. It will be clear that the latter information in the classification provides information about the possible fluctuation of HW or LW due to dry or wet years.

The code consists of 5 possibilities, and should be obtained by the following scheme:
Average seasonal fluctuation s:
(MHW – MLW) = s
Inter-yearly variation of high and low water table y:
((min HW - max HW) + (min LW – max LW))/2 = y
Finally, both s and y must be compared:
s - y = x

The obtained value of x determines the code (Table 2). The codes SS and S represent the piezometers where seasonal fluctuations are dominant compared to inter-yearly fluctuations. That means that the fluctuation of HW and/or LW stay more or less stable compared to the inter-yearly fluctuations and is not influenced a lot by a succession of several dry or wet years. In the case of dominance of inter-yearly fluctuations, YY and Y, the difference between the minimum and maximum of HW (and/or LW) is more important. It could be possible that during successive dry years, HW is lower than LW during successive wet years. So, the observed vegetation must be adapted to important fluctuations between years.

In the transition zone, the fluctuations between years are of the same order as the seasonal fluctuations, which are indicated by the code 0.

3.2.3. Code 3: MSW

MHW and MLW indicate average high and low water table, but the time of the year at which they occur can not be deduced. The highest/lowest water table will occur at different times in different places depending on, besides the precipitation, the thickness and lithology of the unsaturated zone. Because of the importance of the availability of oxygen for plants during the spring period, at the start of the growing season (Runhaar & Hennekens, 2006), the MSW is included in the classification which is relevant to differentiate the hydrophytes from the meso- and xerophytes. The limit between both is a water table at 25 cm below surface (Wamelink & Runhaar, 2000). The definition of MSW was given before. MSW is representative for the depth of the groundwater level at April 1st. From Fig. 3, it can be deduced that, for the study area, the calculated MSW corresponds on the average with 25% on the frequency of exceedence graphs. So, to reduce formulas, which are basically the main reason for mistakes, and to simplify the application, the 25% of the frequency of exceedence graphs will be taken to identify MSW. This depth (in cm below surface) will be used as the number, figuring between brackets as code 3 in the new classification.

Table 2. Inter-yearly or seasonal fluctuation

x	Code
$x \leq -15$	YY
$-15 < x \leq -5$	Y
$-5 < x \leq +5$	O
$+5 < x \leq +15$	S
$+15 \leq x$	SS

3.2.4. Code 4: inundation

The code for inundation can be deduced from minimum of HW, the negative value of which indication that water table will rise above the surface. If the groundwater level some times may appear above soil surface, the code "*" will be given; if not, the code is "–". Another method to define the code of inundation can be applied by simply reading from the frequency of exceedence graphs. This code delivers additional information, next to the first code, where "O" indicates the MHW is negative, pointing to inundation. Indeed, a negative MHW will represent regular inundation during winter, while occasional inundations may occur at positive MHW, and still be relevant for vegetation.

4. Results and discussion

The new methodology has been applied for the 17 piezometers and the result is added in Table 1, together with the groundwater statistics and the groundwater classes according to the existing method. The first 3 columns refer to MHW, MLW and MSW, followed by the columns representing the minima and maxima of HW and LW together with the range between them. Also the results of the existing water table classification (Knotters & Bierkens, 1999) applied for the 17 piezometers is included and visualised in Fig. 4. From this figure, it can be deduced that piezometers 559 and 573 have the same water table class (IIIb) after Knotters & Bierkens (1999), and according to these authors the groundwater level of this class is a result of the increased intensive drainage of originally wet soils. Regarding the location of piezometer 573, close to a ditch, it corresponds to the theory. However, this is not the case for piezometer 559, which is situated in the dunes without any ditches in the surroundings and artificial drainage is absent. This example illustrates that one groundwater class may correspond with different hydrodynamical conditions and, as a result, different associations of vegetation types can occur. In the current water table class, this differentiation is not possible.

The inconsistency of these groundwater table classes is also reflected by the vegetation. The vegetation in the study area has been mapped (Zwaenepoel, 2009) and compared with groundwater dynamics. It can be concluded that the corresponding water table class is not in agreement with existing vegetation such as *Parnassia, Triglochino agrostietum, Epipactis palustris* and *Herminium monorchis* (Zwaenepoel, 2009). In general, MHW and especially MLW are too deep compared with the existing vegetation in the study area. For example, the desired MLW for *Triglochino Agrostietum* is a few decimetres below surface (Sykora et al., 1996 in Zwaenepoel, 2009; Zwaenepoel et al., 2002 in Zwaenepoel, 2009) while it is observed at more than 50 cm below surface. Other factors, however, may play a role in the preservation of species. Many authors (Ensign et al., 2006; Dekker & Ritsema, 2000; Lammerts et al., 2001) have emphasized the importance of rainfall and moisture regime. Besides the former site factors, it was recently found that the consequences of oxygen stress are underestimated (Bartholemeus et al., 2008b; Bartholomeus, 2009). However, all these arguments are unlikely to be valid for all cases in the study area where the vegetation is in apparent contradiction to the water table class. The existing water table classification (Van der Sluijs & Gruijter, 1985) is developed in The Netherlands where the water table level is kept artificially stable, which is not the case in Belgium. So, a methodology with respect to natural conditions as prevailing in the Belgian coastal dunes is required.

The new classification is applied to the 17 piezometers in the study area. Fig. 5 is used to deduce the first code (two symbols) reflecting MHW and MLW. The variation between MHW and MLW, or the average fluctuation between high and low groundwater level, is between ca. 40 and 95 cm, illustrates the variability within the study area. As explained before, the second code indicates the importance of seasonal and inter-yearly fluctuations and can be deduced from Table 1. Generally, the climatological circumstances have more effect on the depth of the groundwater inter-yearly fluctuations. The existing vegetation should be resistant to these extremes. Because of the deep water table, drought stress can appear, and the following year, a high water table can occur because of a wet period. The new classification reflects the differentiation of hydrological conditions, allowing a more accurate differentiation in vegetation types.

The frequency of exceedence graphs provides information to deduce codes 3 and 4. The results are included in Table 1, along with the water table class according to the existing classification (Knotters & Bierkens, 1999). The code for the inundation provides no specific information about the frequency, duration nor water quality. The water might be groundwater rising above the surface or derived from a local surface water due to flooding.

To illustrate the advantage of the new classification, piezometers 559 and 573 are used, because of the same code considering the existing groundwater class. At first sight, based on MHW and MLW, no difference can be made. Both piezometers (559 and 573) are situated in the class Bd, with MHW between 25 and 50 cm and MLW between 75 and 100 cm below soil surface. Besides, as can be deduced from Fig. 5, the differences between MHW and MLW (diagonal lines) are comparable and rather small: ca. 60 cm. But, considering the code representing the relative importance of seasonal and inter-yearly fluctuations, a first difference can be noticed. Piezometer 573 has the code SS which indicates that HL and LW are more or less stable and that the groundwater table fluctuations are independent of a succession of several dry or wet years. An artificial ditch close to piezometer 573 is responsible for this behaviour. During high water levels, the ditch drains the water out of the area with a low variability in HW as a result. Although this piezometer is located near a ditch, no inundations take place. On the other hand, for piezometer 559, the inter-yearly fluctuations dominate the seasonal fluctuations, as is represented by the code YY. In this case, the vegetation must be adapted to variable water table fluctuations between years. In the case of Y, and certainly for YY, drainage by ditches is out of the question, although inundation can take place (for example at 559). In this case, inundation is temporal and is caused by the locally lower topography (the dune slack or a wallow).

To illustrate the relation of the code with the general groundwater dynamics in the study area, the results of the new classification are plotted in Fig. 1. A contrast between the recharge area and discharge area is reflected in a different code: Y and YY are located in the recharge area, while code S and SS are located in the discharge area. It can be concluded that piezometers with a code S or SS are located in an area where it is most likely that an upward groundwater flow occurs, while the piezometers with the code Y and YY are located in a zone with a downward vertical groundwater flow. The advantage of the code is that, without the knowledge of the general groundwater flow pattern in the case of a limited number of piezometers, an indication of recharge or discharge area can be deduced. It is known that water dependent vegetation also relies on the groundwater quality, which is influenced by the location in a recharge or discharge area. It is believed that the new classification of water table depths provides additional information that can contribute to a more meaningful classification of environmental conditions linked to different vegetation types.

A next step is to link vegetation types to the codes. Although other abiotic site factors are not included, it is believed that this new classification is useful because of the additional information about possible inundations and information about inter-yearly and seasonal fluctuations.

5. Conclusions

The natural fluctuations of the groundwater dynamics have been defined and a clear distinction between recharge and discharge areas can be made based on the fluctuation of the water table. This information indirectly supplies indication as to the quality of the groundwater. In the recharge area, the groundwater quality will be associated with infiltrated rain water, while in the discharge area the groundwater has a higher mineralisation. The recharge/discharge differentiation is also reflected in a difference of vegetation types. The implementation of the existing water table classification (Knotters & Bierkens, 1999), based on MHW and MLW, is not consistent with the observed vegetation in the study area. It is also shown that different hydrodynamics can correspond with one class. The classification is developed in The Netherlands with an artificial stable groundwater level, and does not correspond with the situation at the Belgian coast. A new classification is proposed based on the groundwater dynamics, by means of groundwater statistics in combination with the frequency of exceedence graphs. The new classification reflects MHW and MLW, the relative importance of seasonal and inter-yearly fluctuations, the depth of MSW, and whether inundation occurs or not. This information meets the needs to identify the association of vegetation types. Depending on the code to indicate the importance of seasonal and inter-yearly fluctuations, it provides an indication as to whether it is likely that seepage occurs or not.

This classification has been applied in the study area and reflects very well the spatial variation of groundwater table fluctuations. It is recommended to examine the application in other coastal areas and other shallow groundwater systems to verify the conclusions and performances. The most important condition for a successful application of the classification is that the groundwater reservoir is not disturbed by anthropogenic activities, such as pumping. Influences on the groundwater regime caused by changing the drainage level of surface water will hinder the interpretation of the variability of groundwater levels and the application of the classification.

In many nature reserves, the monitoring network has been implemented recently, with consequently short time series. Although it is known that long time series (30 years) give more reliable values of mean high, mean low and mean spring water levels, the length of the available time series in the nature reserves are in many cases too short. Yet a management of the nature reserve is desired, and can only be based on the short time series. The new classification gives information of the MHW and the MLW. On the other hand, also the MSW is included. The MSW is directly related to the soil moisture (Bartholomeus et al., 2008a). The lack of long time series can be compensated by the third code of the classification which indicates the importance of inter-yearly and seasonal fluctuations of the water table. Although information on the soil type is missing, the MLW gives indirectly information on drought stress.

With this classification, an integration of the variability of hydrodynamics is turned into a code for a clear understanding of the relation with vegetation. Additional information in the classification might be necessary in order to include further ecological boundary conditions.

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