Abstract

An overview is given of the history of vegetation mapping in the Netherlands. This history started with a map of *Zostera noltii* in 1860, while from 1937 the first phytosociological maps were made. Applications of vegetation mapping are discussed, as well as the comparison of sequential maps of the same area for monitoring purposes. The paper ends with an overview of developments in remote sensing, which are used for vegetation mapping, and the recent start of habitat mapping for Natura 2000.

Vegetation mapping in the Netherlands

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Introduction

Vegetation mapping in the Netherlands has a long and interesting tradition. The first vegetation map dates from almost one and a half century ago and surely belongs to the oldest records of this kind in Europe. It refers to a map of *Zostera marina* compiled by Oudemans in 1869, commissioned by the State on behalf of the exploitation of eelgrass fields (for dike construction and as filling of mattresses) in the Wadden Sea and the northern parts of the former Zuiderzee. Although, strictly spoken, it is not a vegetation map, it can be regarded as such, because the *Zostera* fields stand synonymous for the *Zostera* community (*Zosteretum marinae*). In the following decades several maps have been produced, but they hardly received any attention: they have remained unpublished or must be searched for in obscure reports. Conform the well-known, large-scale vegetation maps of GRISEBACH (1872) and SHIMPER (1898), the mapping units are based on physiognomic characteristics and dominant plant species.

This situation changed from the early nineteen thirties onwards, after the introduction of the Braun-Blanquet approach in the Netherlands. The first Dutch vegetation relevés were made in 1929 by Josias Braun-Blanquet and Carel Willem de Leeuw (SCHAMINÉE *et al*. 1995). Within a very short period, this method of vegetation analysis became very popular in the Netherlands. Already in 1937, the first syntaxonomical outline was published, presenting an overview of alliances and listing the most important associations. This publication by VLIEGER (1937a) is in French language (Apercu sur les unités phytosociologiques supérieures des Pays-Bas), illustrating the strong liaison of the first generation of Dutch phytosociologists and Braun-Blanquet. In the same year, Vlieger published the first vegetation map that is based on phytosociological fieldwork. The map describes the vegetation of a small forest area along the southern border of the Veluwe near Wageningen; the mapping units include syntaxon names like *Alnetum glutinosae* and *Querceto-Betuletum* (figure 1).

A first overview of mapping approaches, techniques and their application was presented by WESTHOFF (1954). In the period 1962-1982, several attempts have been made to give a review of all vegetation maps in the Netherlands. In 1974, Nijland reported 635 maps, of which 525 maps were interpreted as real vegetation maps (NIJLAND 1974) ; the other 110 maps are dealing with pasture management, in the framework of re-allotments. In 1982, the number of registered vegetation maps exceeded one-thousand, 1,003 to be accurate (KLEES 1982). There are no exact figures of the last three decades, but surely hundreds of new vegetation maps have been compiled (figure 2).

It is beyond the scope of this article to summarise the vegetation maps that have been produced in the Netherlands over the last one and a half century. What we want to present is an outlook of the enormous variability of maps in this small, lowland country, resulting from different scales, different goals, and (ever-changing) different survey approaches and techniques. Mapping (actual or potential natural) vegetation, mapping on behalf of nature management or for the purpose of land use planning, mapping a small nature reserve or a much larger area, one-time or sequential vegetation mapping, it all has its specific demands, whereas relatively new tools like geographic information systems (GIS) and remote sensing (RS) have opened new and unexpected possibilities.

In the following, we will – more or less chronologically – describe some of the many purposes and methods of vegetation mapping. The following applications will be discussed: (1) scientific purposes, mostly phytosociological and synecological, (2) agriculture and silviculture, (3) nature management, (4) environmental impact assessment, and (5) sequential mapping for monitoring purposes. Although we distinguish these fields of application, they are not always strictly separable in individual mapping projects. Furthermore, we will discuss two approaches that have been used additional to traditional phytosociological field mapping: (1) landscape-ecological mapping and (2) the use of digital remote sensing techniques. Finally we will describe the recent increase of the number of vegetation maps because of the implementation of Natura 2000. The paper ends with a short review on the contribution of Dutch scientists to the international scene of vegetation mapping and with some perspectives on vegetation mapping in the Netherlands. An overview of key moments for vegetation mapping in the Netherlands is given in figure 3.

In 2014, an overview of vegetation mapping in several countries in Europe was published (EUROPEAN ENVIRONMENTAL AGENCY, 2014), in which a description for the situation in the Netherlands was lacking. This paper can be considered as an addition to that overview.

Scientific purposes

In general vegetation maps describe the biodiversity and its arrangement in space of a certain area, at a certain time. A measure of biodiversity that can be extracted from vegetation maps is the number of vegetation types that are recorded. Many vegetation maps (still) have this general purpose. Early examples comprise the map of forests in a diluvial sand area near Losser by DE JONG (1959 ; map drawn in 1949 and published in 1959) and the map of the St. Pietersberg, a limestone hill near Maastricht (BECKING *et al*. 1950 *in* WESTHOFF 1983). The latter was made for the purpose of biocoenological knowledge, in the framework of an inventory of the fauna.

In the early days of vegetation mapping, the field work often included a thorough investigation of the site conditions of the vegetation. Such maps can be summarised as synecological vegetation maps. One of the first was compiled by ADRIANI (1945), dealing with salt-marshes. This classical study is still of importance for understanding the ecology of salt-marsh communities. Other examples are the maps of the Wageningse Eng (ZANDSTRA 1950), Nieuwland van Heusden en Altena (ZONNEVELD & BANNINK 1958), both concerning weed communities, the Verbrande Pan (HOFFMAN & WESTHOFF 1951), concerning dunes and dune slacks, the salt marshes of Lake Veere (BEEFTINK 1967) and Het Zwin (MÖRZER BRUIJNS *et al*. 1953), the Brabantsche Biesbosch (ZONNEVELD 1960), a fresh water tidal area, the Savelsbosch (VAN DEN BROEK & DIEMONT 1966) and the Speulderbos (LEYS 1964), concerning forest communities, the Kralose Heide (HOEKSTRA & TJALINGII 1963) and Kalmthoutse heide (ZONNEVELD & BANNINK 1966), both heathlands, the Loosdrechtse Plassen (DE VRIES 1962), Tienhovense Plassen (VISSER 1972), and the Weerribben (VAN ZON-VAN WACHTENDONK 1969), all three wetland areas, and the grassland surveys of De Vries and co-workers (see under : Agriculture and silviculture).

A specific type of vegetation maps are those dealing with historical geography. An example is the map of ROORDA VAN EYSINGA (1952), concerning a forest area in the south-western part of the Veluwe. The map was used to explain the interaction between vegetation development and human occupation.

Agriculture and silviculture

During the first period of vegetation mapping in the Netherlands, the main focus was on site evaluation for silviculture and agriculture, sparsely also for other economical purposes (like the *Zostera marina*-map by OUDEMANS, 1870). Numerous maps are made for the evaluation of forest stands. Main objective of most of these forest maps is the determination of the suitability of the sites for cultivating different tree species. An example of such a map is the already-mentioned first Dutch vegetation map on a phytosociological basis (VLIEGER 1937b). Vlieger came to the conclusion that in the highly urbanised landscape of the Netherlands forest management could not use a map solely based on associations, but additional mapping of artificial forest communities was needed. In the following years several maps were used for recommendations on growing of tree species, for example De Jong (map drawn in 1949, published in 1959) for country estate Egheria and VAN DEN BROEK & DIEMONT (1966) for the Savelsbosch. In both maps, the legend exists of associations and lower syntaxa. In a later stadium, forest maps were also used for the restoration of natural broad-leaved forests, for instance the map of Doorwerth (Reijnders 1955) and the map of Middachten (WESTHOFF 1957). The legend of the latter map contains only local vegetation types. A spin-off from this kind of silvicultural vegetation maps was the publication of a general guideline for planting of indigenous tree and scrub species (VAN LEEUWEN & DOING-KRAFT 1955).

By far the most important investigator of agricultural grasslands was Prof. dr. D.M. de Vries, who developed a mapping method which has been used for several decades (DE VRIES 1954). DE VRIES (1949) considered his labour-intensive method as applied phytosociology. On more than 1500 grassland parcels throughout the Netherlands, the species assemblage and the environmental conditions were surveyed. The floristic composition was assessed by samples – approximately 100 per parcel – of which the mean dry weight of the different plant species was measured. For this analysis all individual species had to be sorted out by hand. Based on the correlation between species composition and site conditions, the grasslands were mapped (DE VRIES *et al*. 1949, DE VRIES & KOOPMAN 1949, DE VRIES & DE BOER 1949, DE BOER 1956). Later, also ditch sides, road verges, dykes and grasslands in nature reserves were mapped in this way. In total more than 520 000 hectares were mapped between 1949 and 1988. This is almost 50 % of the Dutch grassland area and approximately 26 % (!) of the total area in agricultural use (SIKKEMA & KRAAK 1989).

Nature management

Already in the early years of vegetation mapping in the Netherlands, maps with a focus on management were made. As has been described above, silvicultural maps for economical purposes gradually evolved towards vegetation maps for the purpose of nature management. The first vegetation maps for management purposes were published in the 1930s by Rijkswaterstaat (the Water Management Department of the Government), aiming at surveying the diversity of sites along the coast. However, these maps were not published officially. In the 1950s and 1960s the number of vegetation maps that was made for the benefit of nature management grew rapidly. Some examples are the map of the Gerritsfles, a fen near Kootwijk (SCHIMMEL & MÖRZER BRUIJNS 1952), the Zeyerstrubben, an ancient forest remnant near Zeyen (STAPELVELD 1955) and the Ilperveld, a peatland area north of Amsterdam (BLOK 1958, VAN DER TOORN 1958). These days, all major nature conservation agencies use vegetation maps as a basis for their management. The maps are used as an inventory of nature values and followed by management plans and activities. The total number of these maps made until now can hardly be counted, but Staatsbosbeheer, the largest nature management organisation in our country, alone produced more than 400 vegetation maps of nature reserves between 1990 and 2000.

A special case of vegetation maps for nature management purposes are the maps of military ranges. The first maps of these areas were made to assess the capacity for the use of tanks (WARTENA *in* VAN DER

KNAAP 1957a, 1958a ; DE SMIDT *in* VAN DER KNAAP 1957b, 1958b). Although soil maps formed the basis for this assessment, vegetation maps were made to mark spots of biological interest, which should be saved from destruction by military use. Recently, most of the military areas have been mapped once or several times, for the sake of nature management, on scales ranging from 1:2 500 to 1:10 000, depending on the size of the area. Most of the training ranges are heathland areas, with large areas of the *Calluno-Genistion anglicae*, like the Oldebroekse Heide (HORNMAN *et al*. 2002), one of the largest heathland areas in the Netherlands, Havelte (PAHLPLATZ *et al*. 2003) and Oudemolen (VAN DER BERG 2014). Other noteworthy examples are the vegetation maps of the calcareous dune areas like De Kom (DE RONDE & HAVEMAN 2012) and Uijlenbosch (DE RONDE & HAVEMAN 2014), both with large areas of natural grasslands of the *Cladonio-Koelerietalia* and scrubs of the *Rhamo-Prunetea*. The last mentioned map was in fact a sigma-sociological map in which vegetation complexes were defined and mapped, resembling a more landscape ecological approach (see below). Military airbases contain the largest areas in the Netherlands with moist and dry, semi-natural grasslands of the *Plantagini-Festucion*, as a result of many years of continuous grass cutting, but also extensive grasslands of the *Arrhenatherion elatioris* can be found, especially on clay-ground. An example of such an airbase is the Marine Aircamp Valkenburg near The Hague (HAVEMAN & HORNMAN 2002).

Environmental Impact Assessment

A special case in which vegetation maps are used for the description of biodiversity are the vegetation maps that are realised in the framework of so-called EIAs (Environmental Impact Assessments). These EIAs are carried out preceding human interventions (road or dike construction, farm enlargement...) in order to assess the effects of the intended intervention on the environment. Two examples of maps made within an EIA framework are the one from the Ederheide by HARKINK *et al.* (1990) and a vegetation map of a large part of the Dutch coastal dunes that was made by compiling numerous local vegetation maps and their typology, which was used for the assessment of effects of the construction of an airport in the North Sea (SANDERS *et al*. 2002).

Monitoring

One of the main applications nowadays is the use of a series of vegetation maps for monitoring, in such a way that changes in vegetation can be calculated and quantified. The background for monitoring may be nature management, scientific reasons, impact assessment.... The oldest example of sequential vegetation mapping are the maps of the small isle of Griend in the Wadden Sea made by VAN DIEREN (1932) and a few years later repeated by FEEKES (1936, 1941), all published in BROUWER *et al.* (1950). The vegetation of this island was studied because impacts were expected from the construction of the Afsluitdijk, the large dyke that in 1932 closed off the Zuider Sea which became Lake IJssel. The constructed maps contained physiognomic characteristics of dominant plant species, but in the species poor salt-marsh area, most of these map units can be translated to phytosociological units. A few years later (from 1942 till 1946) FEEKES & BAKKER (1954) studied the development of pioneer vegetation in the Noordoostpolder, an embanked area, by compiling a sequence of vegetation maps.

Four other classical examples of vegetation monitoring with sequential maps are addressed here: the studies of Londo (Kennemer Dunes), Van der Maarel and others (dunes near Oostvoorne), Leemans & Verspaandonk (Saeftinghe) and Zonneveld (Biesbosch). LONDO (1974) studied vegetation succession in an artificial lake in the Kennemer Dunes, comparing maps of 1956 (VAN DER MAAREL 1959), 1963 (SEGAL 1960) and 1968 (LONDO 1971). He developed a succession scheme for the vegetation by comparing the successive maps and by analysing vegetation development in permanent plots (PQs). One of his conclusions is that the combination of vegetation maps and PQs provides the best insight in the vegetation succession. Besides he gives some criteria for successive mapping, in order to provide a maximum amount of information about succession.

Van der Maarel and others studied vegetation succession in the dunes near Oostvoorne by comparing vegetation maps of 1959 and 1980 and by analysing old aerial photographs, the oldest from 1934 (VAN DER MAAREL & WESTHOFF 1964, VAN DER MAAREL *et al*. 1985, VAN DORP *et al*. 1985, BOOT & VAN DORP 1986). The compared vegetation maps were made at the same scale and using the same system of vegetation types, which enabled analysis of changes. The analysis showed a strong decrease of pioneer and grassland vegetation in the dry dunes and dune slacks, and an increase of shrubland and forest during 50 years. The study was an important source for theories about vegetation succession in the coastal dunes in our country.

The salt-marsh vegetation of the Verdronken Land van Saeftinghe (the largest salt-marsh area in the Netherlands) was the subject of one of the first phytosociological studies in the Netherlands (VAN LANGENDONCK 1931). Already since 1935 the vegetation patterns in this area have been recorded in a sequence of surveys. The comparison of these maps by LEEMANS & VERSPAANDONK (1975, 1980) resulted in a good insight in vegetation succession in this area. It appeared that, due to a decrease of the tidal processes in the estuary, the relatively old succession stages strongly increased, while pioneer vegetation disappeared from most parts of the salt-marsh.

Zonneveld recorded the vegetation development in the Biesbosch, a fresh water tidal area in the south-west of the country, over a period of 50 years (ZONNEVELD 1999). This study contains several series of 48 small maps of the same site that were compiled between 1950 and 1997. These maps were based on aerial photographs that Zonneveld took by climbing into a high tension pylon from which he could overview the area. The maps illustrate the gradual changes from a high dynamic tidal area with large bare spots and *Bolboschoenus maritimus* and *Scirpus triqueter* stands into a less-dynamic marsh area with dense tall-herb vegetation and shrubs.

The introduction and fast implementation of Geographical Information Systems in the early 1990s resulted in a boom of map comparisons. Many series of sequential vegetation maps already existed and now could be digitised and compared in an easy way. Again, many examples are from coastal areas, like the salt marshes along the mainland Wadden Sea coast (DIJKEMA 2001), the island of Schiermonnikoog (DE LEEUW *et al*. 1993; OLFF *et al*. 1997; VAN DER VEEN *et al*. 1997; VAN WIJNEN *et al*. 1997), the island of Ameland (EYSINK *et al*. 1995; JANSSEN & VAN GENNIP 1999; JANSSEN 2001) and the Amsterdam Water Supply Dunes (APPLEMAN *et al*. 1990; EHRENBURG *et al*. 1988; VAN TIL & MOURIK 1999). In some of these cases vegetation succession was studied in a retrospective way by combining vegetation maps with landscape and vegetation structure maps based upon old aerial photographs (like was done before by Van der Maarel and others for the dunes near Oostvoorne). Other examples come from young, embanked areas that formerly were part of the sea, like the Oostvaardersplassen (JANS & DROST 1995) and the Krammer-Volkerak (VAN GENNIP & KNOTTERS 2002). Examples from less dynamic and less quickly changing ecosystems are the studies of heath and mire vegetation (VAN LEEUWEN 1997) and a chalk grassland study (VERMEER & WEIJS 1974).

GIS has had an enormous stimulating impact on the use of vegetation maps for monitoring: it nowadays is rather easy to draw, edit and present a map and to compare differences between sequential maps. However, the latter has also an important disadvantage: if the change analysis is done without knowing the backgrounds of the used maps, the results may be interpret in a wrong way. Often the methods, legends and scales of compared maps differ and this causes large uncertainties in the results of a change analysis. Several studies have focussed on this problem and proposed methods to reduce these uncertainties (VAN TIL & LOEDEMAN 1987; MIDDELKOOP 1991; PUNTER & KLOOKER 1991; JANSSEN & VAN GENNIP 2000; JANSSEN 2001, 2004). One should know the detail level, mapping method, purpose and uncertainties of the original map before evaluating changes. A general guideline for a reliable analysis of vegetation changes is consistency in the boundaries of the map units (scale, detail level) and the vegetation typology of the original maps (JANSSEN & VAN GENNIP 2000, JANSSEN 2001, 2004). HOLTLAND *et al*. (2010) developed a method for comparison of sequential vegetation maps using indicator values for abiotic conditions of the vegetation types. In this way changes in abiotic conditions may be studied, and uncertainties by differences in mapping methods (boundaries or typology) are partly overcome, as the change analysis is carried out on a higher, generalized detail level.

Landscape-ecological mapping

In the Netherlands the rise of landscape ecology as a field of study since the late 1960's (see ZONNEVELD 1995b) resulted also in the development of a landscape-ecological approach to vegetation mapping. In this approach information about the vegetation is integrated with information about other aspects of the landscape, like soil, geomorphology, hydrology and land use. These maps are most times made at a relatively smaller scale (in general from scale 1:600,000 to 1:25,000) than 'pure' vegetation maps (the latter in general range from scale 1:25,000 to 1:1,000). One of the advantages of landscape-ecological maps, compared to single-feature maps, is that the relationship between vegetation and other aspects of the landscape are made clear. Therefore the maps form a good basis for predictions and effect studies. Two important methods of landscape-ecological mapping will be shortly addressed here: the landscape approach of the International Institute for Geo-Information Science and Earth Observation (ITC) in Enschede, developed by Isaak Zonneveld c.s. (ZONNEVELD *et al*. 1979, ZONNEVELD 1979, 1988, 1995a) and the dune landscape mapping method of Henk Doing (DOING 1974, 1988). Furthermore an important application of landscape-ecological mapping is discussed.

Zonneveld and others developed a method for landscape ecological mapping based on aerial photographs, in which vegetation is one of the main features of the maps. The method is called the landscape approach to vegetation mapping. Aerial photographs form the basis for the maps, together with field observations. The photographs are used for both delineation of land units (in a hierarchical way) and for determining a stratified random field sampling scheme. In the legend of the maps several aspects of the landscape, that could be distinguished from aerial photographs or have been recorded in the field, are integrated. The legend units are often presented as ecological diagrams, which provide insight in the ecological position of the legend units in the landscape. The method is suitable for surveying large and inaccessible areas; it is also relatively cheap. Students of the ITC have applied this approach in many countries throughout the world. In the Netherlands this method has been used mainly in coastal areas. Examples are the maps of the Meyendel Dune Area (VAN DER MEULEN & VAN HUIS 1985), the Middel- and Oostdunes of Goeree (WESTINGA & VAN WIJNGAARDEN 1985) and the Verdronken Land van Saeftinghe (LEEMANS & VERSPAANDONK 1975, 1980). The method forms the basis for the coastal vegetation monitoring by the Ministry of Water Management (KLOOSTERMAN 1991; KERS 2006); nowadays in this institute the method has been adapted in order to make the vegetation maps more suitable for monitoring (JANSSEN & VAN GENNIP 2000; KERS 2006). The sequential mapping of salt-marshes has resulted in several overviews of developments in these coastal areas (a.o. DIJKEMA *et al*. 2005, BAKKER *et al*. 2005), which formed the basis for reporting for the Water Framework Directive and Natura 2000.

Doing developed a second important way of landscape ecological mapping for the Dutch dune landscape. He constructed a landscape ecological system of dune units and a mapping method in which these units are assigned to areas in the field and map units are delineated, sometimes using aerial photographs. His work resulted in a landscape map of the whole Dutch coast (DOING 1988). Although the maps provide much insight in the landscape ecological processes, the method has not been followed by many persons. The reason is that it is relatively difficult to learn this method, as it has to be taught in the field. One of the students of Doing used the method in the Amsterdam Water Supply Dunes and compared the vegetation map with the older map of Doing in order to analyse vegetation changes (EHRENBURG 1994), and also the Ministry of Defence made sequential landscape ecological maps (HAVEMAN *et al*. 2014). The approach of Doing has also been applied in the brook landscape of the Drentsche Aa in the North of the Netherlands by EVERTS *et al*. (1984).

A third application, that also arose in the late 1960's and 1970's, was the use of landscape-ecological maps in the sphere of physical planning. These maps were amongst others used as a basis for environmental impact assessment. An overview of this kind of projects at a local and regional scale is given by VAN DER MAAREL & STUMPEL (1974). For the whole country a map of the actual and potential natural vegetation was made at a scale of 1:200.000 using generalised spatial units from soil maps and field descriptions of vegetation, soil and ground water regime from 600 stratified randomly chosen sites (KALKHOVEN *et al*. 1976; STUMPEL & KALKHOVEN 1978). The legend of this map consists of (complexes of) ecotope types, that are characterised by the actual and potential vegetation and other aspects of the landscape.

One specific example of a more-or-less landscape ecological map is the vegetation map of the Veluwe made by Van der Werf and others in the 1970's and 1980's (VAN DEN BRINK & VAN DER WERF 1977). Although never officially published, this is a classic example of a map, as it covers the largest terrestrial nature area in the Netherlands (app. 220,000 ha) and it combines information on soil, geomorphology, species distribution, actual vegetation and potential vegetation.

Remote sensing

While aerial photographs have been used as a basis for mapping since the 1970's, nowadays several studies focused on the use of digital remote sensing images as a basis for vegetation maps (a.o. VAN KOOTWIJK 1985; DROESEN 1999; SANDERS 1999; JANSSEN 2001; SCHMIDT 2003; ASSENDORP 2010). Automatic digital image processing is often seen as an alternative for traditional mapping as it is possible to make vegetation maps in a more consistent and objective way using these techniques, an advantage when aiming at change analysis. However, until now, the number of applications of digital remote sensing in vegetation monitoring is low. This is partly due to the shortcomings of the techniques. In spite of the high expectations often the implementation of the techniques fails on a large scale (see for instance KLOOSTERMAN 2000). The automatic distinction of different vegetation units from digital images is often a problem (especially for fuzzy classes like vegetation types), whereas very detailed units are in many cases needed from the point of view of the nature site manager.

An example in which automatic processing of digital remote sensing worked well is the study of DROESEN (1999). He mapped vegetation structure in a dune area in the Amsterdam Water Supply Dunes by applying a fuzzy classification algorithm on high-resolution airborne digital images. Based on a low number of legend units he could analyse and quantify changes in vegetation structure over different years. The method was further developed by ASSENDORP (2010).

Amongst the most recent developments in applying digital remotely sensed imagery for vegetation mapping are examples of vegetation structure mapping using laser data from LiDAR (light detection and ranging; FICETOLA *et al*. 2014) and of combining canopy height models, derived from LiDAR, with high resolution satellite imagery for mapping habitats in the Natura 2000 site Veluwe (MÜCHER *et al*. 2014).

Although nowadays digital aerial photographs are available with high frequency for the whole country, for most vegetation mapping purposes the visual interpretation of these digital images is more widely used over automatic procedures. VANDEN BORRE *et al*. (2011) provide an overview of challenges and possibilities for using digital remote sensing in monitoring obligations for Natura 2000.

Mapping for Natura 2000

In the last 10 years a new boost of vegetation mapping activities took place, because of the implementation of the Natura 2000 legislation. At present for all Natura 2000-sites in the Netherlands habitat maps have been prepared or are under construction. Examples are the maps of the Nieuwkoop fen area (DAMM & VAN 'T VEER 2010), the Botshol fen area (RAMAEKERS *et al*. 2010) and the bog area Witterveld (JANSSEN & BIJLSMA 2010). These maps serve as a baseline for monitoring, inform management plans and are used for assessing the impacts of activities in and around the Natura 2000 sites. In the beginning in several cases maps of the, relatively broadly defined, European habitat types (of the Annex 1 of the Habitats Directive) were drawn in the field, using aerial photographs as a geographical reference. However, nowadays in most cases traditional vegetation maps are made, and the local vegetation types are translated into the Annex 1 habitat types. The latter method has two advantages over the (quicker and cheaper) direct mapping of Annex 1-types. In the first place the vegetation types and underlying relevés provide important information on the quality of the Annex 1-types. In the second place, in the case of discussion on the presence or absence of Annex 1-types within a site, the vegetation types and relevés form the proof for the presence or absence of the protected habitat types. Finally, the vegetation map may be used for other purposes, as the typology can be translated into other types, for instance the national typology of 'nature types' used for providing subsidies for nature management costs.

Conclusions and perspectives

Vegetation mapping in the Netherlands not only has a long tradition, but also from the very beginning many people were involved. This resulted in a huge number of vegetation maps, surely in comparison with the size of the country. The same applies to other aspects of vegetation science, as is shown by the more than 600 000 of relevés (SCHAMINÉE *et al*. 2009) and 7 000 permanent plots in our small country (SMITS *et al*. 2002). Influences from different European schools and traditions resulted in a large variation in approaches and applications. The high detail level of many vegetation maps is remarkable, a result of the relatively small size of the nature reserves. The two above-mentioned landscape-ecological approaches of Doing and Zonneveld have clearly contributed to the international methodology. The latter, often referred to as the ITC method, has been exported to many countries all over the world, especially to the tropics.

Recently many of the historical data have been digitised and made available in computer databases. The 600 000 vegetation relevés, for instance, have been brought together in the National Vegetation Database and made available for application in the field of nature conservation, nature restoration and spatial planning via the information system SynBioSys (SCHAMINÉE & HENNNEKENS 2001, 2003). In SynBioSys the information on vegetation is related to information on the level of species and landscape, including soil characteristics, hydrology and topography. The system incorporates a GIS-platform for the visualisation and analysis of the different types of information. As an example, SynBioSys has been used for the selection and description of special protected areas under the Habitats Directive of Natura 2000. A large part of the Natura 2000-network is covered already by vegetation maps, which will serve as a basis for the planned monitoring.

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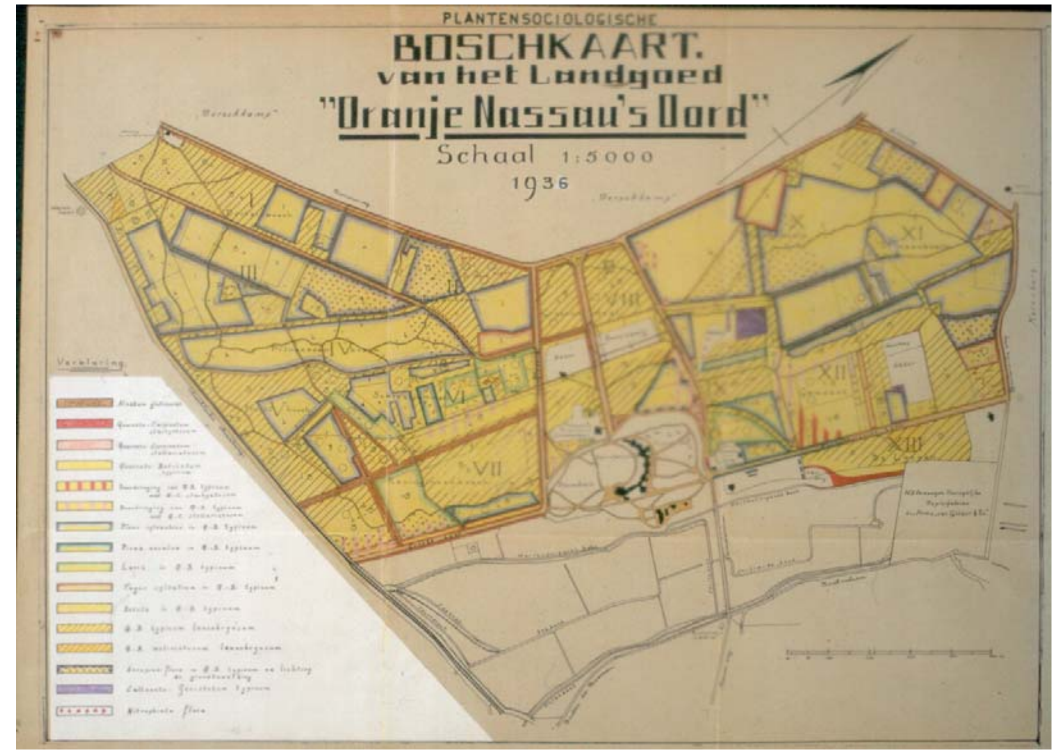

Figure 1
First phytosociological map of the Netherlands, by Vlieger (1937)

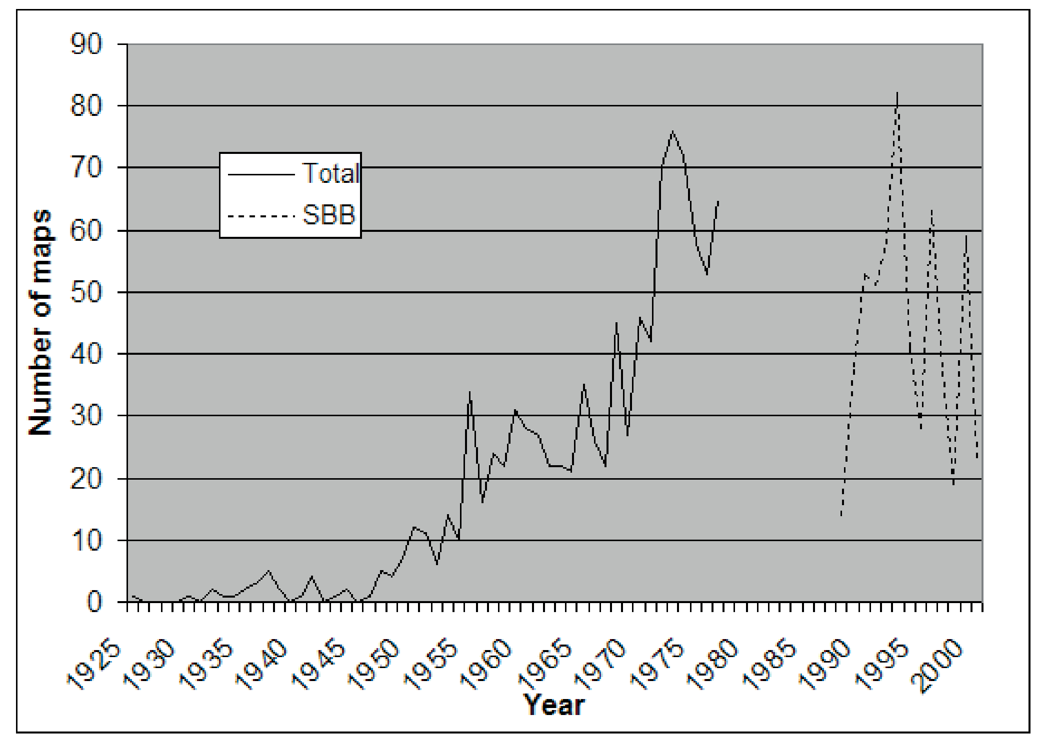

Figure 2
Number of vegetation maps compiled in the Netherlands in the period 1925-1977 (total number; based upon Nijland 1974 and Klees 1982) and 1988-2003 (number of maps made by Staatsbosbeheer (SBB), the largest nature conservation organisation; SBB approximately produces 30-60 % of all maps in the country).

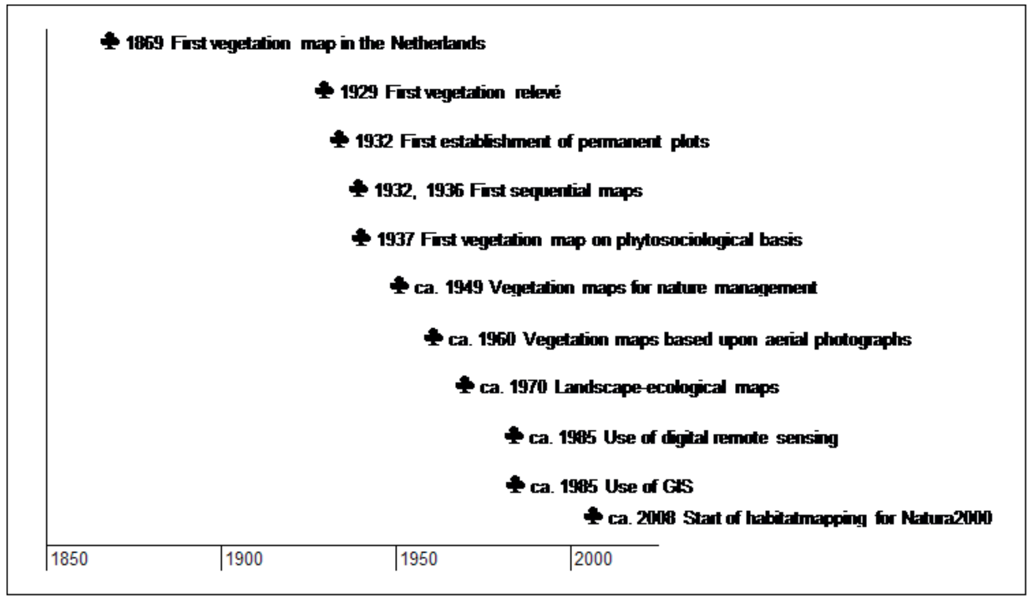

Figure 3
Key moments in the history of vegetation mapping in the Netherlands