7 TERRESTRIAL ECOLOGY OF LOWLAND STREAMS

J. Runhaar & P.C. Jansen

7.1 Introduction

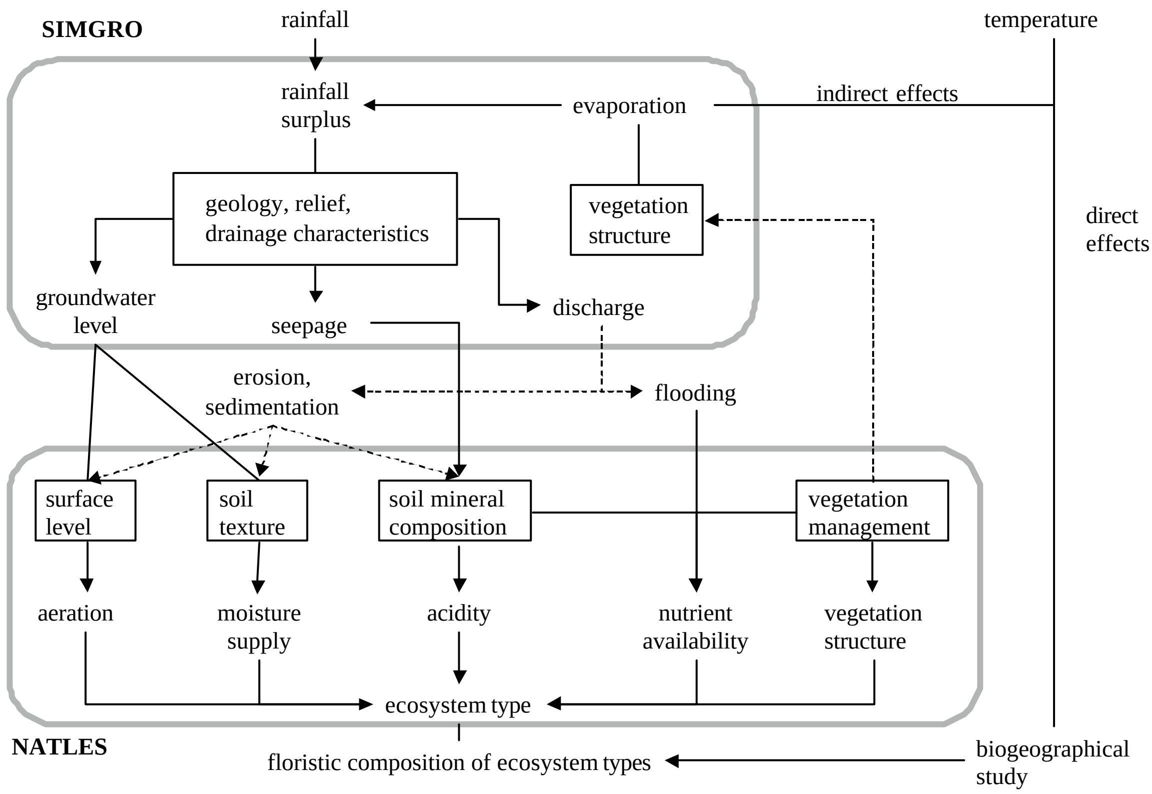
In this study a distinction is made between indirect and direct effects of climatic changes. The *indirect effects* are a result of changes in hydrology, and do not only depend upon climatic conditions such as rainfall and evaporation, but also on characteristics of the area such as soil texture, relief and drainage. The main indirect effects distinguished in this study are (see Figure 7.1):

- changes in aeration and moisture supply due to changes in watertable and evaporation
- changes in base regulation and acidity due to changes in upward seepage intensity
- changes in nutrient status and dynamics due to changes in flooding frequency and sedimentation

Changes in floristic composition as a result of increased temperature are seen as *direct effects*, because they are independent of the abiotic characteristics of the area. These effects are described in Section 10.2.

To determine the indirect effects we made use of the model NATLES (NATure oriented Land-Evaluation System), that has been developed to evaluate the effects of hydrological measures and changes in land use on the distribution of ecosystem types and associated vegetation types (Runhaar et al. 1999). In this model ecosystems are classified in terms of vegetation structure and abiotic site factors such as aeration, moisture supply, acidity and nutrient supply, using a limited number of classes per site factor.

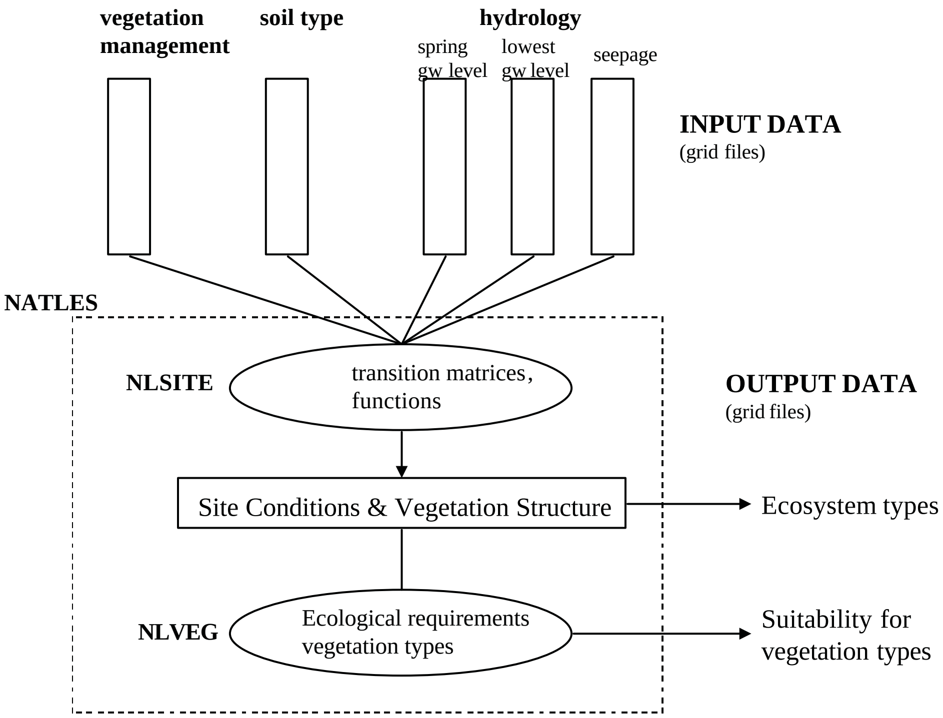
Figure 7.1 Direct and indirect effects of climate. Indirect effects depend upon characteristics of the area such as geology and soil texture. To predict these effects the models SIMGRO and NATLES are used. Direct effects, mainly effects of changes in temperature, are independent of area characteristics. Dotted lines represent relationships not modelled in this study.



7.2 Calculation of effects with the NATLES model

The NATLES model used in this study is a model meant for use in land-evaluation studies and in hydro-ecological modelling. It can be used to determine the suitability of sites for the maintenance or development of certain ecosystem types and associated vegetations. It is an ArcView application written in the AVENUE language (ESRI 1996). The input consists of ArcView grid files with geographical data on soil type, hydrology and vegetation management. The output consists of maps with the distribution of predicted ecosystem types, and the suitability for the development of certain vegetation types (Figure 7.2).

Figure 7.2 Conceptual framework of the Natles model.



The ecosystem types are defined in terms of vegetation structure and abiotic site conditions. The site conditions are predicted as a function of soil type, management and hydrology, using transition matrices that have been compiled on the basis of simulation experiments with models such as SWAP (Van Dam *et al*. 1997) en SMART (Kros *et al*. 1995), empirical data and expert judgement. Predictions are made for situations where vegetation and site conditions are more or less in equilibrium with hydrology and management, which is assumed to be the case after a period of approximately 10-30 years.

The detail of the produced maps depends upon the detail of the input data, but in general the model is meant for use in studies on a 1:10.000 to 1:50.000 scale. In this study grid cells with a size of 25 x 25 m were used. The NATLES version used in this study (1.2) is similar to the version 1.1 described by Runhaar *et al*. (1999), but for the prediction of the effects of climatic change the moisture regime classification has been modified (see next section).

The site factors that are considered most relevant for vegetation development are chosen to serve as ecosystem classification characteristics. They are moisture regime, acidity and nutrient availability. Salinity is equally important, but has not yet been incorporated in the model and is less relevant for inland situations where fresh water prevails. To characterize the ecosystems the site factors have been classified into discrete classes. The site factor classification is basically the same as in the classification of ecotopes by Stevers *et al*. (1987) and Runhaar *et al*. (1987, 1994, and 1999) but some classes have been added to increase the detail. In the following a short description will be given of the classification of site factors and it will be indicated how the classes are predicted as a function of soil type, hydrology and management.

7.2.1 Moisture regime

The term 'moisture regime' is used to indicate a complex of factors that are all in some way linked to the amount of water available. It is used to describe differences in medium (aquatic versus terrestrial systems), aeration and moisture supply (Table 7.1).

Table 7.1 Classification according to moisture regime.

MSW (cm b.s.s.)	MLW (cm b.s.s.)	Potential moisture stress (d)	Description of the classes
< -50	-	-	Permanent deep water
-50 – -20	< 0	-	Permanent shallow water
-50 – -20	= 0	-	Non-permanent shallow water
-20 – 0	-	-	Very wet
0 – 25	-	-	Wet
25 – 40	-	-	Very moist
> 40	-	<14	Moist
> 40	-	14-30	Moderately dry
> 40	-	>30	Dry

MSW: Mean Spring Watertable *MLW*: Mean Lowest Watertable
Potential moisture stress: average number of days the soil moisture potential is less than -12.000 cm at a depth of 12.5 cm, assuming a standard grass layer

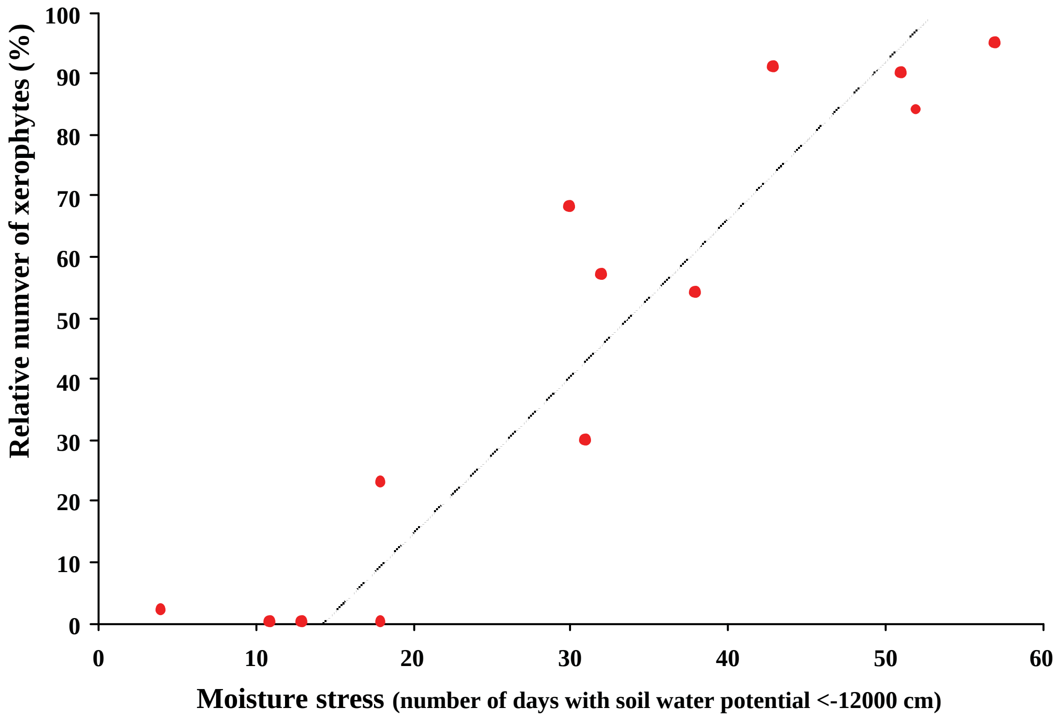
As shown by Runhaar *et al.* (1996) the relative abundance of hygrophytes[1] is most directly related to the watertable in spring, probably because the aeration in spring – when most species sprout or germinate – is most critical for the competition of hygophytes and non-hygrophytes. The boundary between sites dominated by hygrophytes and sites dominated by

[1] For definition of hygrophytes, mesophytes and xerophytes see table 7.2

Table 7.2 Comparison of the grouping of species as to moisture regime by different authors. Unless otherwise stated in this study the classification according to Runhaar *et al*. 1987 is followed.

	Classification according to moisture regime		
Author	Hygrophytes	Mesophytes	Xerophytes
Runhaar et al. 1987	Species characteristic for wet sites	Species characteristic for moist sites	Species characteristic for dry sites
Klapp (1965)	7-10	4-6	1-3
Ellenberg (1992)	7-9	4-6	1-4
Londo (1988)	Obligate phreatophytes (W,F)	Facultative phreatophytes (V, K, P, D)	-
Iversen (1936)	Polyhygroob	Oligohygroob	Xeroob
Schimper (1909)	Hygrophyte	Mesophyte	Xerophyte
Reed (1988)	Obligate wetland	Facultative	Upland

Figure 7.3 Relation between relative number of xerophytes in the vegetation and moisture stress. Source: Jansen *et al*. 2000.



mesophytes and xerophytes coincides with a Mean Spring Watertable (MSW; defined as average watertable in March-April) of about 25 cm below soil surface. Therefore this level has been used as the boundary between the classes ‘wet’ and ‘very moist’. The difference between moist and dry sites is based on the moisture supply of the soil, with dry sites defined as sites with large moisture deficits during the growing season, dominated by obligate xerophytes[1]. Jansen *et al*. (2000) found that the potential moisture stress[2] is a good predictor for the number of xerophytes found in grassland vegetations (Figure 7.3). At a potential moisture stress of more than 30 days obligate xerophytes dominate the vegetation, whereas at a moisture stress of less than 14 they are absent. Although the number of observations in this research was rather small (n=17), the relation found is the rather clear (R=0.9). Since other data on this relationship are scarce, the data of Jansen *et al*. were used to define the classes moist, moderately dry and dry.

In this classification it is implicitly assumed that moisture stress will only occur on sites with low watertables (MSW more than 40 cm below soil surface). In the present climatic conditions, with moderate summer temperatures and rainfall equally distributed over the year, this assumption is valid for most situations. However, with changing climatic conditions situations might come to exist with high watertables and aeration problems in winter, and moisture stress in summer. Therefore the classes ‘very wet’, ‘wet’, and ‘very moist’ have been subdivided on the basis of moisture stress (Table 7.3). Especially in situations with more extreme climatic conditions it is assumed that sites with multiple stress (both anaerobic conditions and moisture stress) will increase.

The potential moisture stress depends upon the soil type, watertable and precipitation excess. In the study of Jansen *et al*. (2000) calculations were made with the model SWAP (Belmans et al. 1983, Van Dam *et al*. 1997, Van Dam 2000). However, because of the large number of grid cells for which calculations have to be made it is impossible to use this model for every single grid cell. Instead SWAP was used to derive functions that predict the moisture stress as a function of soil type, precipitation excess and the number of consecutive days that the groundwater is below a critical level for sufficient moisture supply to the rooting zone. Section 5.4 describes in more detail how the moisture stress was calculated with the SIMGRO hydrological model and the functions derived from SWAP.

---

[2] calculated as the number of consecutive days the soil moisture potential is less than -12.000 cm at a depth of

Table 7.3 Subdivision of the classes ‘very wet’, ‘wet’, and ‘very moist’ on the basis of moisture stress.

Subclass	Code	Moisture Stress (days)
No moisture stress	-	< 3
Little moisture stress	*	3-13
Moderate moisture stress	**	14-30
Large moisture stress	***	> 30

7.2.2 Acidity

Table 7.4 shows the acidity classes used in the NATLES model. The acidity is predicted on the basis of soil type, management and hydrology. In the study area only non-calcareous soils occur, which means that except for agricultural areas, where lime is applied, the soils are predominantly acid. In the river valleys younger and more mineral-rich soils occur with a relatively high base-saturation, which are only moderately acidic. In the nature areas weakly acidic to neutral conditions can be found in upward seepage areas, where carbonate in the groundwater forms a buffer against acidification. Flooding with carbonate-rich river water forms an additional buffering mechanism, but has not been taken into account in the NATLES calculations because of the lack of sufficient data to predict the effects.

In non-seepage area the acidity of the soil in non-limed conditions was estimated on the basis of average carbonate-content and base-saturation of the soil. To calculate the acidity in upward seepage areas use has been made of the soil acidification model SMART (Kros *et al*. 1995). As with the prediction of moisture stress, dose-effect functions calculated with SMART were used instead of the model itself. These functions give the pH as a function of upward seepage intensity, spring watertable, soil type and groundwater composition. In the SMART model five soil types are distinguished, of which two types commonly occur in the study area: ‘poor sands’ and ‘rich sands’ (see Kros *et al*. 1995 for soil classification used). The upward seepage intensity is calculated with SIMGRO as the gross amount of upward seepage (in mm/d, averaged over the year) reaching the upper soil layer (20 cm). Section 5.3 describes how these calculations were made. As to groundwater composition distinction is

12.5 cm, assuming a standard grass layer

Table 7.4 Classification as to acidity. Source: Runhaar *et al*. 1999.

PH-H_2O	Description of the classes
< 4,5	Acidic
4,5-5,5	Moderately acidic
5,5-6,5	Weakly acidic to neutral
> 6,5	Basic

made between soft water (Ca ca 7.5, HCO3 ca 27 mg/l), moderately alkaline water (Ca ca 15, HCO3 ca 55 mg/l) and alkaline water (Ca ca 40, HCO3 ca 146 mg/l). The groundwater composition has been derived from the study by Van Ek *et al*. (1998), in which the type of groundwater in upward seepage areas has been estimated on the basis of available chemical data and geohydrological information.

7.2.3 Nutrient availability

As there are hardly any quantitative data on the relationship between nutrient availability (N,P and K) and vegetation composition, and because of the lack of knowledge on the precise relationship between nutrient supplies, nutrient availability and productivity, the classification as to nutrient availability is by necessity of a qualitative nature. Because of the scarce information only three classes have been distinguished: poor, moderately rich and rich. These classes are primarily defined on the basis of species occurring on the sites, defining ‘poor’ sites as sites dominated by species classified as indicative for poor conditions and ‘rich’ sites as sites dominated by species classified as indicative for rich conditions. The classification of species is according to Runhaar *et al*. 1987 (Table 7.5).

For grassland vegetations the sites can be described more quantitatively in terms of productivity and mineralization. Table 7.7 gives a description of the classes according to

Table 7.5 Comparison with the classification of species as to nutrient availability by Runhaar *et al*. with the classifications by Clausman *et al*. (1987), Ellenberg *et al*. (1992) and Klapp (1965).

	species indicative for poor sites	species indicative for moderately rich sites	species indicative for rich sites
Ellenberg N	1-3	4-7	7-9
Klapp N	1-3	2-4	4-5
Nutrient indication Clausman	0-40	40-60	60-100

Blokland and Kleijberg (1997). However, these data are of a tentative nature. Productivity, for example, is not only limited by nutrient availability but also by management, amount of solar radiation and moisture supply and therefore can only be used as an indicator for nutrient availability within a certain range of climate and management conditions. In dry grasslands, where soil moisture supply is a limiting factor, productivity may be less than indicated in Table 7.6. The amount of nitrogen or phosphorous present is only representative for the nutrient availability in situations where these elements are limiting the productivity. As shown by Runhaar (1989) and Boeker (1954) there is only a very weak relationship between amounts of available N and P and the species composition and productivity of sites.

Table 7.6 Characterization of nutrient-availability classes according to Blokland and Kleijberg (1997).

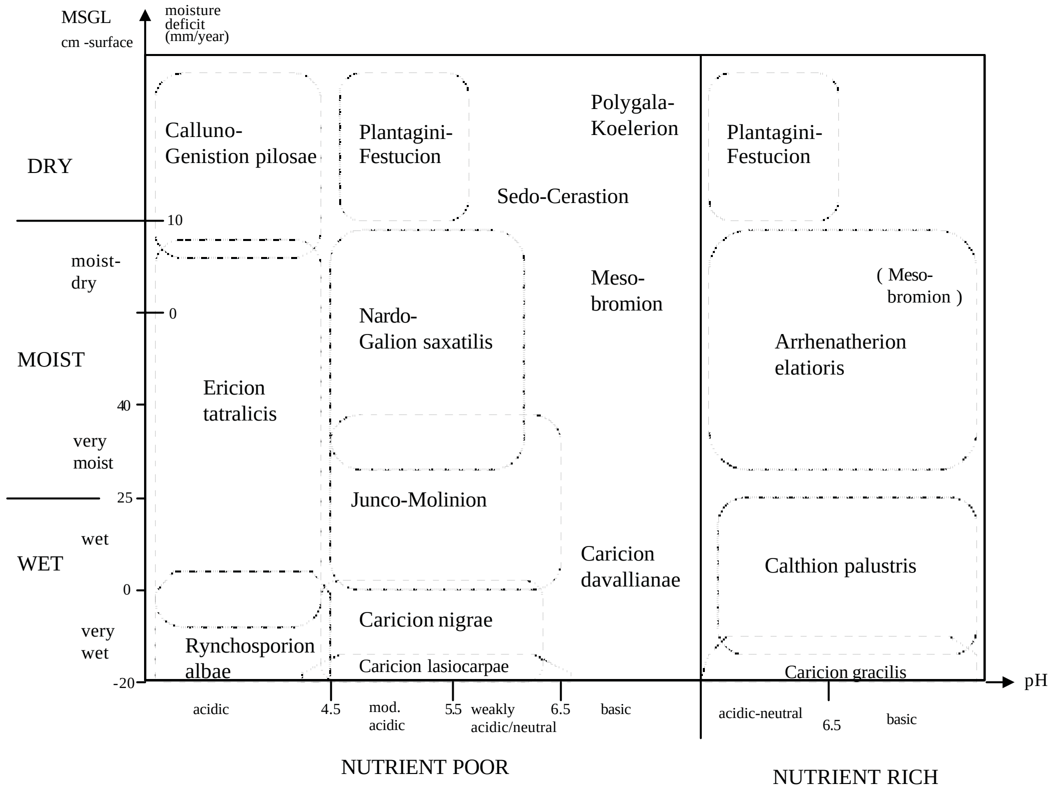
	In groundwater and surface water		In soil				
	NO3 (mg/l)	PO4 (mg P/l)	C/N	C/P	N-min	Ellenberg N	Productivity (dry yield in kg/ha x 1000)
Nutrient poor	< 1	< 0.04	> 35	> 750	< 60	1-4	< 4
Mod. nutrient rich	1-2	0.04-0.10	20-35	300-700	60-180	5-6	4-8
Nutrient richt	2-3	>0.10	<20	<300	> 180	7-9	>8

In the NATLES model the nutrient availability status is predicted as a function of vegetation management (fertilized versus non fertilized sites) and mineralization of organic matter. Because of the lack of a precise quantitative definition of the nutrient availability classes no attempts have been made to predict the classes on the basis of mechanistic models. Instead estimates have been made of the nutrient availability status per combination of management type, soil type (amount and type of organic matter), pH (predicted on the basis of soil type, management and hydrology; see previous section) and groundwater (Mean Lowest Watertable predicted with SIMGRO). Nutrient rich sites are predicted for fertilized agricultural land only, whereas moderately nutrient rich sites are predicted mainly on sites rich in organic matter and a high pH. In other situations mainly nutrient-poor conditions are predicted. In the model fertilization with flooding nutrient-rich river water has not been taken into account. In Section 10.2 the implications of this omission will be discussed.

7.3 Relevant ecosystem types and associated vegetations

In this study attention is focused on those ecosystem types that are most characteristic for small river systems: species-rich mesotrophic wet grasslands with vegetations belonging to the alliances *Junco-Molinion*, *Caricion nigrae* and *Calthion palustris*. Figure 7.4 gives an overview of the ecological position of these alliances in terms of site conditions, using the classification to site conditions used in the NATLES model (Section 7.2). In this scheme they are represented with other alliances that are characteristic for Pleistocene sandy regions. Only alliances comprising grassland and heathland vegetations are shown: woody vegetations, tall herb vegetations and pioneer vegetations are not represented.

Figure 7.4 Ecological position of Junco-Molinion, Calthion palustris and Plantagini-Festucion vegetations in comparison with other alliances. Nomenclature according to Schaminée *et al*. 1995b, 1996.



7.3.1 Junco-Molinion

Wet grasslands of the alliance *Junco-Molinion* grow on wet and moist soils with a low availability of nutrients. They are found in areas influenced by Ca-rich groundwater, as well as by surface water from a local origin and rainwater. They tolerate only a limited flooding with nutrient-rich surface water, and therefore are often limited to the edges of the brook valleys. The groundwater is relatively acid: a pH of 4.7-5.6 is commonly found for *Junco-Molinion* grasslands in the Netherlands (Jalink & Jansen 1996). The proportion of the different water types that influence the vegetation has an impact on the species composition (Grootjans 1985; Everts & De Vries 1991; Jalink & Jansen 1995). During winter, these grasslands are very wet. The watertable is above or just below surface level for several months. From spring onwards, the watertable falls below surface level. Due to seepage, the watertable does not fall lower than 50-60 cm beneath soil surface for most of the summer period. Ellenberg (1968) mentions 35 and 5 cm below surface level as the highest watertable for respectively moist and wet *Junco-Molinion*. The lowest watertable is 70 and 55 cm below soil surface for moist and wet *Junco-Molinion*, according to Ellenberg (1968).

Character species of the alliance of *Junco-Molinion* are *Succissa pratensis* and *Juncus conglomeratus*. *Luzula multiflora* and *Valeriana dioica* (character species of the order *Molinietalia*) have their optimum in this alliance. For the Netherlands, one association is distinguished: *the Cirsio dissecti-Molinietum* (Schaminée *et al*. 1996). Character species are *Cirsium dissectum*, *Carex panicea*, *Carex hostiana*, *Carex pulicaris* and *Cirsium x forsteri*.

Junco-Molinion meadows used to be widespread in river valleys and other low-lying areas. Nowadays only a few have remained (e.g. Grootjans 1985; Bakker 1990; Everts & de Vries 1991, Runhaar *et al*. 1996). Their decline is caused by drainage, resulting in a replacement of groundwater by rainwater and by an increasing mineralization. Only a small decrease in watertable in nature reserves (a decrease in mean groundwater table in spring from 20 to 40 or 50 cm below soil surface) can have a great impact on species composition. Sensitive species are replaced by dominant, less rare species (Van Beusekom et *al*. 1990; Runhaar 1996). As described above, the change in species composition is caused by a changing pH in the top soil as well as a change in base saturation as a result of a higher impact of rain water compared to Ca-rich groundwater and an increasing mineralization. Moreover, the use of fertilizers has increased, changing nutrient poor meadows into nutrient rich ones. Also, the abandoning of meadows has led to litter accumulation and an increase of tall herbs. And finally, much meadows have been lost because of a change in land use. In the Beerze-Reusel area *Junco-Molinion* vegetations have become very rare. Small patches of *Junco-Molinion* vegetetations are still present at the Smalbroeken area.

7.3.2 Calthion palustris

This ecosystem type used to be widespread in NW Europe on wet soils with a relatively good nutrient availability (Grootjans 1985; Ellenberg 1968). It can be found in situations influenced by calcium-rich groundwater. It is found in relatively base rich, meso- to slightly eutrophic situations. Compared with the *Junco-Molinion*, *Calthion palustris* vegetation is found on more nutrient-rich soils, which may be more frequent flooded with surface water. The hydrological regime is comparable to that of the *Junco-Molinion*: very wet in winter and moist in summer.

Character species of the *Calthion*-alliance are *Lycnhis flos-cuculi*, *Rhinanthus angustifolius*, *Dactylorhiza majalis*, *Caltha palustris*, *Lotus unliginosus* and *Carex disticha* (Schaminée et al. 1996). Six associations are distinguished for the Netherlands. Four of them are potentially found in the higher sand region of the Netherlands: the *Crepido-Juncetum acutiflori* (character species: *Scutellaria minor* (weak)), *Ranunculo-Senecionetum aquatici* (character species: *Senecio aquaticus*), *Scirpetum sylvatici* (character species: *Scirpus sylvaticus*) and *Angelico-Cirsietum oleracei* (character species: *Crepis paludosa*, *Cirsium oleraceum* and locally *Polygonum bistorta*).

During the last decades most of the *Calthion* meadows have been transformed into high-productive pastures through drainage and additional use of fertilizers. In the Netherlands, *Calthion* meadows are nowadays only found in nature reserve areas where the use of fertilizers is restricted. In spite of the conservation status of the *Calthion* meadows, many of them are still affected by drainage from adjacent agricultural areas, as is mentioned above for the *Junco-Molinion* grasslands. In the Beerze-Reusel area *Calthion* vegetations are still present at the Smalbroeken, Helsbroek and Westelbeerse Broek areas.

7.3.3 Related vegetations

Because of the lack of free carbonate in the soils that occur in the study area, *Junco-Molinion* and *Calthion* vegetations are restricted to the river valleys where bicarbonate in ground- and surface water and a higher base-saturation form a buffer against acidification. In wet places where infiltration of rainwater prevails, the lack of carbonates in the soil and the percolation with rain water results in acidic conditions. In these sites wet heath vegetations, belonging to the *Ericion tetralicis*, occur (Figure 7.4). Because of the lack of calcareous sediments the pH is normally too low for *Caricion davallianae* vegetations, that prefer more basic conditions. Where conditions are slightly drier and more acidic, *Nardo-Galion* vegetations may occur. They often form a transition zone between the vegetations belonging to the *Junco-Molinion* and the *Ericion tetralicis* alliances. In slightly wetter and more acidic conditions, less species-rich *Carion-nigrae* vegetations occur. In the study area they occur occasionally in nature reserves on places where rainwater stagnates, causing a superficial acidification of the soil.

7.3.4 Ecosystem classification used in presentation of results

The number of ecosystem types distinguished in NATLES is too large to give a good overview of the effects of climate change and changes in water management. For this purpose, a simplified ecosystem classification is used as indicated in Table 7.7. The ‘target’ ecosystem types in these study are wet and very moist riverine grasslands, that are characteristic for upward seepage areas in the river valleys. For comparison purposes wet and dry heathland ecosystems, characteristic for the infiltration areas, have also been distinguished.

Table 7.7 Simplified ecosystem classification used in presentation of modelling results. Site factor classes as described in Section 7.2. Target ecosystem types indicated in bold.

simplified ecosystem classification used to present result predictions	moisture regime	nutrient avaliability	acidity	associated vegetation types
wet riverine grassland	very wet	poor	mod. acid-basic	Caricion nigrae
		mod.rich		Caricion gracilis
	wet	poor	mod. acid-basic	Junco-Molinion, Caricion davallianae
		mod.rich		Calthion palustris
very moist riverine grassland	very moist	poor	mod. acid-basic	Junco-Molinion, Caricion davallianae
		mod.rich		Calthion palustris
moist riverine grassland	moist	poor	mod.acid-neutral	Nardo-Galion saxatilis
		mod.rich		Arrhenatherion elatioris
wet heath	wet	poor	acid	Ericion tetralicis
very moist heath	very moist	poor	acid	Ericion tetralicis
moist heath	moist	poor	acid	Ericion tetralicis
moderately dry heath	mod. dry	poor	acid	Ericion tetralicis/Calluno genistion
dry heath	dry	poor	acid	Calluno-Genistion pilosae