Documentation and terms of usage

This subset of the NOVANA database (Nielsen *et al.*, 2012) is maintained and quality assured to the best of my knowledge. The data may be used for any purpose. However, I find it natural that I am invited to be a co-author if the data are used in a publication. I may or may not choose to accept such an invitation.

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The documentation is still incomplete, so please ask me

# General information

* Files with “cover” contain cover data. Files with “frekvens” contain probability of occurrence data (in a cirkel with a radius of 5 meter), Files with “abiotiske” contains other data (not only abiotic data). Plant trait data are either cover-weighted and marked with “p”, or not weighted and marked with “f”. The first three columns in the files are identical and denotes place and year of the sample.
* The columns "sekhabtype" og "terhabtype" are the designated habitat type for the plot (EU, 2013), either as determined in the field, or further quality assured by an analysis of the observed plant species in the 5 meter circle {Nygaard, 2009 #1026}, respectively.
* The species codes “ArtID” are explained in the file “artsliste”.
* The entry “mv” denotes a missing value

Below is relevant M&M text that I have used in my publications :

# Sites and plots

Danish dry heathland sites were monitored from 2004 to 2009. At each site, 20-60 plots were placed randomly, and in each plot the plant cover of higher plants was measured by the pin-point method in frames of 50 × 50 cm with 16-grid point (Nielsen *et al.*, 2012).

The vegetation types of all plots were classified according to the habitat classification system used in the European Habitat Directive (EU, 2003), which is a somewhat broader habitat definition than the Calluna – Deschampsia vegetation type (Rodwell, 1991), where the two species are known to co-occur. The classification of the habitat type was based on the vegetation in a circle with a 5 meter radius around the plot, i. e. it will not be uncommon that a plot is classified as a dry heathland plot without either Calluna or Deschampsia is being hit by a pin in the pin-point frame.

Only a subset of the possible heathland sites was used in the analysis. In order for a site to be selected, it should have more than 30 plots that were classified as dry heathland (EU habitat type 4030) and *Calluna vulgaris* or *Deschampsia flexuosa* should be observed in at least one of the plots. Seventeen sites met these criteria and were used in the present analyses.

Danish acid grassland sites have been monitored since 2004 as part of the Danish National habitat monitoring program, NOVANA (Nielsen *et al.*, 2012). The vegetation structure is recorded using a random stratified sampling process in 20, 40 or 60 plots per site, depending on its size. At each plot, vegetation data of vascular plants is recorded by pin-point measure (n = 16) in a 0.25 m2 quadrate and a complete species list in a 78.5 m2 circle (radius = 5 m) centered on the sample quadrate. Additionally, a number of physio-chemical soil properties, vegetation structural properties , and other ecological indicators were measured (Nielsen *et al.*, 2012).

The vegetation types of all plots were classified according to the habitat classification system used in the European Habitat Directive (EU, 2003) and only plots that were classified (Ejrnæs *et al.*, 2004) as acid grassland (EU habitat type 6230; species-rich *Nardus* grasslands) and monitored after 2007 were used in the analysis. Some plots were monitored several times, in those cases only the last monitoring event was used in the analysis. A total of 2262 plots from 103 sites were used in the analysis.

# Pin-point

The pin-point cover data was sampled using a square frame of 16 grid points that were equally spaced by 10 cm (Nielsen *et al.*, 2012) in the period from 2007 to 2012. The used cover data is a small subset of the ecological data that is collected within the Danish terrestrial habitat monitoring programme NOVANA (Nielsen *et al.*, 2012).

The pin-point cover data from 179 sites with a total of 2526 randomly placed plots was used in an analysis of the spatial variation of the complementary vegetation classes at dry heathlands sites (Fig. 1). In 29 of the 179 sites (Fig. 1), the plots were resampled with GPS-certainty (< 10 meters), and only the first observation of these resampled plots was used in the analysis of the spatial variation. However, in the time series analysis all 1928 observations from the 29 sites where the plots were resampled several years in the period from 2007 to 2012 (108 combinations of sites and years) were used in the analysis.

# Plant traits

The selected plant traits used in the analysis are listed in Table 1. The investigated species specific plant traits were either measured characters (e.g. specific leaf area), life history characters (e.g. age at the first flowering event), or index values assessed by experts. The quantitative traits include leaf-height-seed (LHS) traits (Westoby, 1998), Ellenberg indicator values (Ellenberg, 1979) Grime’s plant species CSR strategies (Grime, 2001), and life history traits. To avoid unnecessary correlation among traits the analyses were split in sub-groups of traits that were analysed independently. We find that it is meaningful to base the investigation on these groups although some of them are based on expert opinion rather than measured traits. The leaf, height and seed mass traits implied by the LHS strategy are basic plant traits that are simple to measure. This contrasts to the Ellenberg ecological indicator values (EIV), which are semi-quantitative composite traits that cannot be strictly understood as basic plant traits. Rather they represent an assembly of structural and physiological traits that together improve tolerance to soil acidity, salinity, drought tolerance etc. A nine point scale is applied for each of six gradients: soil acidity (Ell-R), soil productivity or fertility (Ell-N), soil humidity (Ell-F), soil salinity (Ell-S), light availability (Ell-L) and climatic continentality (not included in this investigation) (Ellenberg, 1979). The interpretation of the Ellenberg indicator values is not always simple (Ertsen *et al.*, 1998, Schaffers & Sýkora, 2000); for example, the moisture indicator Ell-F, indicates a combination of high groundwater table and soil ability to retain water, and correlation is strongest to the soil moisture content in a dry period (Schaffers & Sýkora, 2000). Likewise, the CRS-strategies suggested by Grime (2001) are also composite plant traits. The CSR-triangle theory predicts that the degree of competition, stress and disturbance characterizing a habitat will determine which species will occupy the habitat. In this scheme, the plant species have values in the three dimensions Competition, Stress and Ruderal (disturbance). Generally, Grime’s C and Ellenberg’s N indicators are positively correlated and an increase in both indicators suggests an increase in plant biomass and general competitive ability (Timmermann et al., unpublished). Like EIV’s, the CSR-triangle theory has been subject to criticism, e.g. for the lack of obvious tests to apply to validate the values (Wilson & Lee, 2000). CSR- and EIV-values have been treated as traits in comparable analyses by some authors (e.g. Pywell *et al.*, 2003), and we have chosen to follow the example of Pywell et al. (2003) in this study.

The species specific plant trait values were found either in the LEDA database (Kleyer *et al.*, 2008), or in a Danish database of plant traits (Nielsen *et al.*, 2012). All qualitative characters were transformed to ordered index values to allow calculations of average values. The trait values of plant height, seed mass, and specific leaf area (SLA) were log-transformed.

# Other variables

## Nitrogen deposition

Nitrogen deposition at each plot was calculated for each year using a spatial atmospheric deposition model in the period from 2005 and 2014 (Ellermann *et al.*, 2012). The mean site nitrogen deposition ranged from 7.34 kg N ha-1 year to 21.68 kg N ha-1 year-1, with a mean deposition of 13.37 kg N ha-1 year-1.

## Soil samples

The uppermost 5 cm of the soil (four samples composited into a single sample) were sampled from randomly selected plots. The soils were passed through a 2mm sieve to remove gravel and coarse plant material.

### pH in soil

pHKCl was measured on a 1 M KCl-soil paste (1:1).

### C in soil

The total carbon content in the soil was measured in mg/g

### N in soil

The total nitrogen content in the soil was measured in mg/g

### P in soil

Phosphor in soil (fosfortal) was measured using the Olsen method in units of mg/100g.

## Plant leaves chemistry

Leaves were sampled for a few selected plants species.

### N in leaves

Nitrogen in leaves were measured in percent.

### P in leaves

Phosphor in leaves were measured in percent.

## Thickness of moor layer

The thickness of the moor layer is measured in cm.

## Soil type

The predicted texture of the top soil type for each site was obtained from a raster based map of Danish top soils (Greve *et al.*, 2007). The classification of the soil is ordinal with 1: coarse sandy soil, 2: fine sand soil, 3: coarse loamy soil, being the relevant soil classification types for wet heathlands. There were some records with other soil types but they were treated as missing values. The mean soil type was 1.32.

## Precipitation

Site specific precipitation was measured by the average annual precipitation in the period 2001 to 2010 with a spatial resolution of 10 km (DMI, 2014). The annual precipitation ranged from 620 mm and 974 mm, with a mean of mean precipitation of 830 mm.

## Grazing

Grazing was observed at each plot for each year as a binary variable (yes = 1 or no = 0). The mean grazing at the site level was 0.13.

# Statistics

The model was parameterized using numerical Bayesian methods, where the joint posterior distribution of the parameters and the latent variables were calculated using Markov Chain Monte Carlo (MCMC), Metropolis-Hastings, simulations with a multivariate normal candidate distribution and using a MCMC run of 50,000 iterations with a burn-in period of 10,000 iterations.

The prior distributions of all parameters were assumed to be uniformly distributed either as improper priors or in their specified domain, except and, which were assumed to be inverse gamma distributed. The prior distributions of the latent variables were assumed to be uniformly distributed within, where *g* is the number of pins in a pin-point frame.

Plots of the sampling chains of all parameters and latent variables were inspected in order to check the mixing properties of the used sampling procedure. Additionally, the overall fitting properties of the model were checked by inspecting the regularity and shape of the marginal distribution of all parameters as well as the distribution of the deviance. The efficiency of the MCMC procedure was assessed by inspecting the evolution in the deviance.

Statistical inferences on the parameters were based on the marginal posterior distribution of the parameters.

All calculations were done using *Mathematica* version 9 (Wolfram, 2013). The data as well as the *Mathematica* procedures and calculations are available as Supplementary Information.

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