

Vegetation data access and taxonomic harmonization

version 0.6-7

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Abstract

An example session to show functionality and usage of R library `vegdata`. After installation of `vegdata` you can invoke this PDF with

```
vignette("vegdata")
```

1 Preliminary notes

Some `vegdata` functions expect an installation, or more precisely the main directory structure, of the vegetation database program Turboveg for Windows (see '<http://www.synbiosys.alterra.nl/turboveg/>' and Hennekens & Schaminee (2001). If the package can not find a Turboveg installation it will use the directory within the package installation path. If you want to use function `taxval` for taxonomic harmonization you will need to have GermanSL or an equally structured reference list. If you do not specify any, the most recent version of GermanSL will be used and if it can not be found within the specified path, it will be downloaded from <http://geobot.botanik.uni-greifswald.de/reflist>.

Turboveg uses dBase database format for storage. The package tries to deal with the limitations of that format but it is essential, that you use "Database -> Reindex" in Turboveg every time you delete something in your Turboveg database. Otherwise it will not be deleted immediately in the dBase file, instead it is only marked for deletion, i.e. it is still there when you access this file with R and will not be recognized as deleted until you reindex your Turboveg database.

2 Provided functionality

2.1 Database access

At the moment `vegdata` provides direct access to two different vegetation database formats:

Turboveg is a desktop program, written in VisualBasic. It provides basic functions to enter, import, maintain and export vegetation data. From the 2 000 000 vegetation plots registered in <http://www.GIVD.info> approximately 1.5 million are stored in Turboveg databases format.

VegetWeb is the German national vegetation database. VegetWeb is developed as a MySQL-Server database at the Federal Agency for Nature Conservation (BfN) and can be used via a PHP framework at <http://www.floraweb.de/vegetation/vegetweb/RechercheView.php>.

2.2 Taxonomic harmonisation

One of the most important steps in using vegetation data (from different sources) for statistical analysis is to take care about the taxonomic content of the names existing in the database. That is, to make sure, that exactly one (correct and valid) name defines one biological entity. Most researchers remember to convert synonyms to valid names but in many cases the care about e.g. monotypic subspecies or ambiguous taxonomic

levels is lacking (Jansen & Dengler, 2010). The package offers the function `taxval` with different options for the adjustment of synonyms, monotypic taxa, taxonomic levels, members of aggregates and undetermined species.

2.3 Cover standardization

Turboveg provides different abundance codes and all kinds of user defined cover codes can easily be added. For vegetation analysis a unique species performance platform is needed which will in most cases be the percentage cover of the observed plot area. Therefore, for every abundance code class the mean cover percentage is defined in Turboveg. Since different scales can occur in a database and the storage format of the code table in Turboveg is somewhat strange, the function `tv.coverperc` provides automatic conversion for convenience.

2.4 Layer aggregation

The most frequently used sample unit in vegetation science is a plot based vegetation relevé (Dengler *et al.*, 2011). A Braun-Blanquet relevé is a sample of names and coverage (abundance) of species in a specified area (usually between 1 and 1000 m^2) at a specific time. It contains (at least is intended to contain) a *complete* list of photo-autotrophic plants (or a defined subset) in that plot. This information can be stored in a three-column list of relevé ID, Taxon ID and performance measure (e.g. cover code).

Often additional information about the kind of occurrence is wanted. In Turboveg one additional column for the most widespread attribute is included by default: growth height classes. E.g. in a forest it is of interest, if a woody species reaches full height (tree layer) or occurs only as a small individual (herb layer). Other attributes like micro location (hummock or depression, rock or dead wood), development stage (juvenile or not, flowering status etc.) or the month of survey in a multi-seasonal survey could also be of interest and can be added in Turboveg. For analysis you may want to differentiate species with different species-plot attributes (e.g. growing in different layers). Function `tv.veg` provides possibilities for species-plot attribute handling.

2.5 Vegetation matrix

Turboveg stores relevés as a dataframe of occurrences (s. below) but almost all functions and programs for vegetation analyses use plot-species cross-tables with a 0 value for non-occurrence = observed absence. Function `tv.veg` inflates the Turboveg list to matrix format with plots in rows and species in columns. Column names can be either species numbers, species letter-codes (default) or full names (with underscores instead of blanks to match the R naming conventions).

3 Preparations

The best way to introduce the functionalities of the package is a session with example code.

We load the library as usual into our R environment.

```
library(vegdata)

Loading required package: foreign
This is vegdata 0.6-7
```

Many functions use the directory structure of Turboveg. The first time such a function is called, the internal function `tv.home` tries to find your Turboveg installation path. Depending on whether you have Turboveg installed on your computer or not, it will give you a message about the Turboveg installation path or the path to the Turboveg directory structure of package `vegdata`.

```
tv.home()

No Turbowin installation path found.
```

```
Should I use
1) the vegdata package path (recommended), or
2) a temporary folder?

#####
Turboveg root directory is set to "/tmp/Rtmpm555CJ"
If you want to change this use: options(tv_home="<path_to_your_Turboveg_root>")
#####
```

If you want to change this, declare manually by setting option "tv_home":

```
# options(tv_home='path_to_your_Turboveg_root_directory')
```

4 Service functions

```
tv.db()
```

will give you a list of possible database names (directories within the Turboveg Data directory).

```
tv.refl()
```

```
[1] "GermanSL 1.2"
```

GermanSL is the default Taxonomic reference list in package `vegdata`. However, whenever you use a Turboveg database name in a function, the Reference list will be read from the database configuration file "tvwin.set" if possible.

Package `vegdata` contains several service functions to query the taxonomic information contained in the reference list.

```
tax("Achillea millefolium")
```

```
Reference list used: GermanSL 1.2
```

Taxonomic list (species.dbf) of reflist (version) GermanSL 1.2 not available.

	TaxonUsageID	LETTERCODE	TaxonName	VernacularName
18	27	ACHI#MI	Achillea millefolium agg.	Artengruppe Wiesen-Schafgarbe
20	31	ACHIMIL	Achillea millefolium	Gew+Ähnliche Wiesen-Schafgarbe
21	32	ACHIM-M	Achillea millefolium subsp. millefolium	Gew+Ähnliche Wiesen-Schafgarbe i.e.S.
22	33	ACHIM-S	Achillea millefolium subsp. sudetica	Sudeten-Wiesenschafgarbe
8680	20096	ACHICOL	Achillea millefolium subsp. collina	<NA>
8681	20097	ACHIPAN	Achillea millefolium subsp. pannonica	<NA>
8682	20098	ACHIPAN	Achillea millefolium var. lanata	<NA>
13222	26082	ACHIMIL	Achillea millefolium var. firma	<NA>
26250	90019	ACHI*AB	Achillea millefolium agg. x nobilis	<NA>
26251	90020	ACHIM*P	Achillea millefolium x pannonica	<NA>
	SYNONYM	TaxonConceptID		
18	FALSE	27		
20	FALSE	31		
21	FALSE	32		
22	FALSE	33		
8680	TRUE	29		
8681	TRUE	34		
8682	TRUE	34		
13222	TRUE	31		
26250	TRUE	90028		
26251	FALSE	90020		

The GermanSL is not included in `vegdata` to keep the R package small. Instead the reference list will be automatically downloaded into the `tv_home` directory (see `tv.home()`) or a temporary folder, if it is not installed but needed. If you want to use a different list, specify `refl=<Name of your list>` according to

the directory name in the Turboveg directory *Species*. Function `tax` can use the given species name (with option `strict=FALSE` also name parts), or 7 letter abbreviation or the TaxonUsageID (called SPECIES_NR in Turboveg) to look for all (partially) matching species names within the reference list.

```
tax("Achillea millefolium", strict = TRUE, verbose = TRUE)
```

Reference list used: GermanSL 1.2

TaxonUsageID	LETTERCODE	TaxonName	AUTHOR	SYNONYM	TaxonConceptID	TaxonConcept
20	31	ACHIMIL Achillea millefolium	L.	FALSE	31	Achillea millefolium
		VernacularName TaxonRank GRUPPE FAMILIE	IsChildTaxonOfID		IsChildTaxonOf	
20		Gewöhnliche Wiesen-Schafgarbe	SPE S Asteraceae		27	Achillea millefolium agg.
		NACHWEIS	AccordingTo	HYBRID	BEGRUEND	EDITSTATUS
20		BfN(Wisskirchen u. Haeupler 1998)	BfN(Wisskirchen u. Haeupler 1998)	<NA>	<NA>	BfN

```
tax("Achyilleus x millefoliae", simplify = TRUE, hybrid = TRUE)
```

Reference list used: GermanSL 1.2

TaxonUsageID	LETTERCODE	TaxonName	VernacularName	SYNONYM
18	27	ACHI#MI Achill millefol agg.	Artengruppe Wiesen-Schafgarbe	FALSE
20	31	ACHIMIL Achill millefol	Gew+Ähnliche Wiesen-Schafgarbe	FALSE
21	32	ACHIM-M Achill millefol subsp. millefol	Gew+Ähnliche Wiesen-Schafgarbe i.e.S.	FALSE
22	33	ACHIM-S Achill millefol subsp. sudetic	Sudeten-Wiesenschafgarbe	FALSE
8680	20096	ACHICOL Achill millefol subsp. collin	<NA>	TRUE
8681	20097	ACHIPAN Achill millefol subsp. panonic	<NA>	TRUE
8682	20098	ACHIPAN Achill millefol var. lanat	<NA>	TRUE
13222	26082	ACHIMIL Achill millefol var. firm	<NA>	TRUE
26250	90019	ACHI*AB Achill millefol agg. nobil	<NA>	TRUE
26251	90020	ACHIM*P Achill millefol panonic	<NA>	FALSE
TaxonConceptID		originalTaxonName		
18	27	Achillea millefolium agg.		
20	31	Achillea millefolium		
21	32	Achillea millefolium subsp. millefolium		
22	33	Achillea millefolium subsp. sudetica		
8680	29	Achillea millefolium subsp. collina		
8681	34	Achillea millefolium subsp. pannonica		
8682	34	Achillea millefolium var. lanata		
13222	31	Achillea millefolium var. firma		
26250	90028	Achillea millefolium agg. x nobilis		
26251	90020	Achillea millefolium x pannonica		

Additional to the Turboveg standard fields comprehensive information for every taxon is stored in an extra file (tax.dbf) which can be used with option `verbose=TRUE`.

`tax` will give you all matching names by default. If you set option `strict=TRUE`, only the species with exact match to the given character string will be returned.

`syn` will give you all taxon names within the swarm of synonyms. The valid name is marked in column SYNONYM with FALSE.

```
tax("Elytrigia repens")$TaxonName
```

Reference list used: GermanSL 1.2

[1]	"Elytrigia repens subsp. arenosa"	"Elytrigia repens"	"Elytrigia repens var. caesia"
[4]	"Elytrigia repens var. littoralis"	"Elytrigia repens var. repens"	

```
syn("Elytrigia repens")
```

Name swarm of Elytrigia repens :

TaxonUsageID	TaxonName	SYNONYM	EDITSTATUS
4078	6541 Agropyron repens subsp. caesium	TRUE	BfN
4081	6544 Elymus repens subsp. repens s. l.	TRUE	Korrektur
4791	10260 Elymus repens subsp. caesium	TRUE	BfN
8714	20143 Agropyron caesium	TRUE	BfN
8732	20167 Agropyron repens subsp. repens	TRUE	BfN
9890	21639 Elytrigia repens	TRUE	BfN
12066	24393 Triticum repens	TRUE	BfN
13916	27778 Elymus repens	FALSE	BfN
14008	27914 Agropyron repens	TRUE	BfN

The reference list contains information about the taxonomic hierarchy which can be used with *childs* or *parents*.

```
childs(27, quiet = TRUE)$TaxonName

[1] "Achillea collina"           "Achillea millefolium"
[3] "Achillea pannonica"        "Achillea roseoalba"
[5] "Achillea setacea"          "Achillea pratensis"
[7] "Achillea lanulosa"          "Achillea collina x millefolium"
[9] "Achillea collina x pannonica" "Achillea collina x pratensis"
[11] "Achillea collina x roseoalba" "Achillea collina x setacea"
[13] "Achillea millefolium x pannonica" "Achillea pratensis x roseoalba"
[15] "Achillea millefolium subsp. millefolium" "Achillea millefolium subsp. sudetica"

parents("ACHIMIL")

Parents of Achillea millefolium (31):
  TaxonUsageID      TaxonName TaxonRank IsChildTaxonOfID GENERATION
        27 Achillea millefolium agg.      AGG          60728          1
        60728      Achillea      GAT          60463          2
        60463      Asteraceae      FAM          60415          3
        60415      Asterales      ORD          60079          4
        60079      Asteridae      UKL          60071          5
        60071      Magnoliopsida      KLA          60049          6
        60049      Magnoliophytina      UAB          60000          7
        60000      Spermatophyta      ABT          94419          8
        94419      "Gefaesspflanze"      AG2           0          9
           0      "Gruenliches etwas"      ROOT           0         10
```

If you want to learn more about the taxonomic reference list *GermanSL* for Germany, please look at Jansen & Dengler (2008). You can download the list manually from '<http://geobot.botanik.uni-greifswald.de/portal/reflist>'.

5 Taxonomic harmonisation

Care about the taxonomic content of the datasets is crucial for every analysis. Some of these steps can be automated with an appropriate taxonomic reference. For background and details see (Jansen & Dengler, 2010).

```
db <- "taxatest"
```

Defines the vegetation database name according to the name of the Turboveg database directory name

```
tv.metainfo(db)
```

Metainformation, i.e. information about the kind of available information should always be given for every database. Since Turboveg does not ask and provide such information, write a simple text file called metainfo.txt and save it within the database folder. Turboveg does not provide any metadata handling. Database *taxatest* is an artificial dataset to show functionalities and necessary steps for taxonomic harmonization.

Let's have a look at the Turboveg data structure.

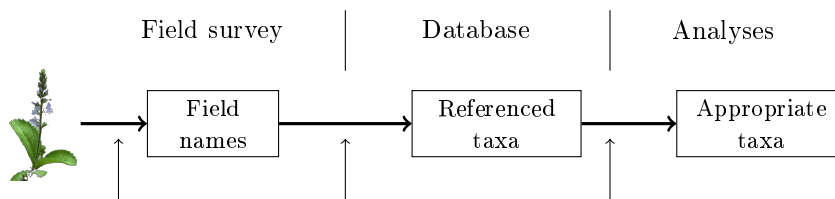
```
obs.tax <- tv.obs(db)

reading observations ...

# Adding species names
species <- tax("all")

Reference list used: GermanSL 1.2

obs.tax$TaxonName <- species$TaxonName[match(obs.tax$TaxonUsageID, species$TaxonUsageID)]
head(obs.tax[, c("RELEV_NR", "TaxonUsageID", "COVER_CODE", "LAYER", "TaxonName")])
```



1. Field interpretation

- document your source(s) of taxonomic interpretation (Flora)
- specify determination certainty
- collect herbarium specimen

2. Database entry

- document field records / original literature
- reference as conservative as possible to a taxonomic reference list with all relevant taxa (synonyms, field aggregates, horticultural plants, ...)
- document your interpretations

3. Preparation for analyses

- convert synonyms
- summarize monotypic taxa
- clean up nested taxa
- clean up taxonomic ranks
- ...

Three steps of taxonomic interpretation

- need of appropriate tools (software, reference lists)
- standards
- threefold attention

Figure 1: Steps of taxonomic interpretation

RELEVE_NR	TaxonUsageID	COVER_CODE	LAYER	TaxonName
1	2	27	2b	0 Achillea millefolium agg.
2	2	4685	4	1 Quercus robur
3	2	4685	1	2 Quercus robur
4	2	4685	1	6 Quercus robur
5	1	31	3	6 Achillea millefolium
6	1	20096	+	6 Achillea millefolium subsp. collina

This condensed format shows only presences of species observations. Every species observation is stored in one row and the membership to a specific vegetation plot is given in column *RELEVE_NR*.

5.1 Function taxval

We are using the taxonomic reference list GermanSL (Jansen & Dengler, 2008) which contains not only information about synonymy of species names, but also about the taxonomic hierarchy. This enables several semi-automatic enhancements of the taxonomic information stored in your vegetation database. If your

database is not referenced to GermanSL (and can not be converted), you have to dismiss function `taxval` (option `tax=FALSE` in `tv.veg`) and do the taxonomic harmonization by hand (function `comb.species`).

```
obs.taxval <- taxval(obs.tax, db = db, mono = "lower", sink = FALSE)
```

Original number of names: 21

4 Synonyms found in dataset, adapted

TaxonUsageID	TaxonName	Freq.1	TaxonConceptID	TaxonConcept
20096	Achillea millefolium subsp. collina	1	29	Achillea collina
20583	Armeria maritima subsp. bottendorffensis	1	20585	Armeria maritima subsp. halleri
25203	Abies alpestris	2	4269	Picea abies
27309	Armeria bottendorffensis	1	20585	Armeria maritima subsp. halleri

Freq.2
0
0
0
0

Check for monotypic taxa: 1. round.
2 monotypic taxa found in dataset, set to lower rank.

AGG_NR	AGG_taxonR	MEMBER_NR	MEMB_NAME	MEMB_taxon
61329	GAT	69	Acorus calamus	SPE
66142	FAM	61329	Acorus species	GAT

Check for monotypic taxa: 2. round.
1 monotypic taxa found in dataset, set to lower rank.

AGG_NR	AGG_taxonR	MEMBER_NR	MEMB_NAME	MEMB_taxon
61329	GAT	69	Acorus calamus	SPE

No taxa higher than ROOT found.

5 child taxa found in dataset, adapted

TaxonUsageID	TaxonName	Freq.1	IsChildTaxonOfID	IsChildTaxonOf	Freq.2
29	Achillea collina	NA	27	Achillea millefolium agg.	1
31	Achillea millefolium	1	27	Achillea millefolium agg.	1
33	Achillea millefolium subsp. sudetica	1	31	Achillea millefolium	1
27	Achillea millefolium agg.	1	60728	Achillea species	1
2923	Hieracium pilosella	1	12273	Hieracium subg. Pilosella	1

2 child taxa found in dataset, adapted

TaxonUsageID	TaxonName	Freq.1	IsChildTaxonOfID	IsChildTaxonOf	Freq.2
31	Achillea millefolium	1	27	Achillea millefolium agg.	1
27	Achillea millefolium agg.	1	60728	Achillea species	1

1 child taxa found in dataset, adapted

TaxonUsageID	TaxonName	Freq.1	IsChildTaxonOfID	IsChildTaxonOf	Freq.2
27	Achillea millefolium agg.	1	60728	Achillea species	1

Number of taxa after harmonisation: 12

Warning: Potential pseudonyms in dataset, please check.

	to_check	check_No	check against	TaxonUsageID
Galium mollugo	2555	Galium mollugo auct.	27395	BfN(Wisskirchen u. Haeupler 1998)

Warning: Critical species in dataset, please check

	to_check	check_No	check against	TaxonUsageID	AccordingTo
Dactylis glomerata	1843	Dactylis glomerata s. l.	26585	BfN(Wisskirchen u. Haeupler 1998)	
Galium mollugo	2555	Galium mollugo s. l.	26777	BfN(Wisskirchen u. Haeupler 1998)	

Number of taxa after validation: 12

The database contains 20 different names in the beginning.

Synonyms 4 of the species names are synonyms and are therefore transferred to legal taxon names, respectively numbers (see option `syn='adapt'`). If you want to preserve synonyms, choose option `syn='conflict'` or `'preserve'`.

Monotypic species within the area Monotypic taxa are valid taxa which are the only child of their next higher taxonomic rank within the survey area. By default they will be converted by `taxval` to the higher rank. For instance *Poa trivialis* is in Germany only represented by *Poa trivialis subspecies trivialis*. Both taxa are valid, but for most analysis only one name for these identical entities must be used. By default a list of monotypic taxa within the GermanSL (whole Germany) is considered (see `tv.mono('GermanSL 1.2')`).

The default is to set all monotypic species to the higher rank (because many monotypic subspecies can occur in vegetation databases).

If necessary, the procedure has to be repeated through the taxonomic

Trimming the hierarchy If your database contains the taxon *Asteraceae spec.*, the taxval code explained in the next chapter will aggregate occurrences of all your *Asteraceae* to the family level. To prevent this you can delete all observations above a certain taxonomic level. The default is not to trim the hierarchy (ROOT = "Greenish something" is the toplevel).

Solving the nestedness If your database contains *Achillea millefolium* but also *Achillea millefolium agg.* for most analysis it will be necessary to coarsen the first (option `ag='conflict'`) because *A. millefolium agg.* will probably include further occurrences of *Achillea millefolium*.

The procedure has to be repeated until all occurring taxonomical levels are considered.

Especially with aggregates and their members the coarsening to the higher level can be a sad fate. If you have 100 occurrences of *Achillea millefolium* but a single one with *A. mill. agg.* you might want to clean your observational dataframe beforehand or do the aggregation afterwards manually with `tv.veg(db, ag='preserve')` and a manual correction with function `comb.species` (see below).

I confess that it is a strange and complete artificial example. Starting with 25 names in the beginning only 13 taxa survived the valuation. All others had to be converted.

```
obs.taxval$TaxonName <- species$TaxonName[match(obs.taxval$TaxonUsageID, species$TaxonUsageID)]
obs.taxval$OriginalName <- obs.tax$TaxonName
obs.taxval[, c("RELEV_NR", "COVER_CODE", "TaxonName", "OriginalName")]
```

	RELEV_NR	COVER_CODE	TaxonName	OriginalName
1	2	2b	Achillea	Achillea millefolium agg.
2	2	4	Quercus robur	Quercus robur
3	2	1	Quercus robur	Quercus robur
4	2	1	Quercus robur	Quercus robur
5	1	3	Achillea	Achillea millefolium
6	1	+	Achillea	Achillea millefolium subsp. collina
7	1	1	Achillea	Achillea
8	1	1	Acer pseudoplatanus	Acer pseudoplatanus
9	1	2	Acer pseudoplatanus	Acer pseudoplatanus
10	1	1	Picea abies	Abies alpestris
11	1	1	Achillea	Achillea millefolium subsp. sudetica
12	3	1	Armeria maritima subsp. halleri	Armeria maritima subsp. bottendorffensis
13	3	1	Armeria maritima subsp. elongata	Armeria maritima subsp. elongata
14	3	1	Armeria maritima subsp. halleri	Armeria maritima subsp. halleri
15	1	1	Picea abies	Abies alpestris
16	3	1	Acorus calamus	Acoraceae
17	1	1	Galium mollugo	Galium mollugo
18	1	1	Dactylis glomerata	Dactylis glomerata
19	1	1	Adonis aestivalis	Adonis aestivalis
20	1	1	Agrostis stolonifera var. palustris	Agrostis stolonifera var. palustris
21	2	1	Hieracium subg. Pilosella	Hieracium pilosella
22	2	3	Armeria maritima subsp. halleri	Armeria bottendorffensis
23	3	1	Hieracium subg. Pilosella	Hieracium subg. Pilosella
24	2	1	Picea abies	Picea abies
25	2	2m	Acorus calamus	Acorus

Critical Pseudonyms Taxon misapplication is maybe the greatest danger in using survey data. Known misapplications of names (.auct) are embedded within GermanSL. Please pay attention, if these might also be relevant for your dataset.

Completely independent from the questions of correct taxonomic naming of a specific specimen, the boundary of a taxon interpretation can differ much Jansen & Dengler (see 2010). This should be adequately solved during data entry. Nevertheless these warnings gives you a last chance to rethink the correctness of your taxon assignments.

Coarsening to a specific taxonomic level If you want only taxa of e.g. level "species" in your analyses but no other taxonomic level, use `taxval(obs, ag='adapt', rank='SPE')`. All hierarchical levels below the species level (including the above specified monotypic subspecies) are set to species level in this case.

```
tmp <- taxval(obs.tax, refl = "GermanSL 1.2", ag = "adapt", rank = "FAM", sink = FALSE)
tmp$oldTaxon <- tax(obs.tax$TaxonUsageID, refl = "GermanSL 1.2")$TaxonName
tmp$newTaxon <- tax(tmp$TaxonUsageID, refl = "GermanSL 1.2")$TaxonName
```

```
head(tmp[, c("oldTaxon", "newTaxon")], 10)
```

	oldTaxon	newTaxon
1	Achillea millefolium agg.	Asteraceae
2	Quercus robur	Fagaceae
3	Quercus robur	Fagaceae
4	Quercus robur	Fagaceae
5	Achillea millefolium	Asteraceae
6	Achillea millefolium subsp. collina	Asteraceae
7	Achillea	Asteraceae
8	Acer pseudoplatanus	Aceraceae
9	Acer pseudoplatanus	Aceraceae
10	Abies alpestris	Pinaceae

Check `?taxval` and `args(taxval)` for more options.

5.2 Implementing other taxon views

If you wish to use another taxonomic concept (Berendsohn (1995)) than the default, you can use a conversion table to change synonymy etc. to catch your needs.

```
newconcept <- taxval(obs, db = db, concept = "korneck1996", sink = FALSE)
```

However, writing files which contain the necessary changes is tedious and other taxon concept based systems have to be developed and used to cover the challenges of different taxon views.

6 Vegetation matrices

At the moment there exists no formal class for vegetation data in R. But most functions in `vegan`, `ade4` or other packages expect vegetation data to be stored in a matrix with species in columns and plots in rows. Therefore, we need to inflate the `Turboveg` format (where zero occurrences are missing) to such a matrix.

`tv.veg` is a wrapper for the above mentioned functions and produces a vegetation matrix with relevés as rows and species as columns. Additionally care about species-plot attribute differentiation and combination, and the handling of species codes is provided.

6.1 Performance measures

At least in Europe most vegetation plots have information about the performance of a species within the survey area, often given in some kind of alphanumeric code for cover percentage within the survey plot. Different code systems are combined by using the mean cover percentage per cover code class. Function `tv.coverperc` will do this job according to the definitions in *Turboveg/Popup/tvscale.dbf* and the entries in the header data column `COVERSCALE`.

```
obs <- tv.obs(db)

reading observations ...

obs <- tv.coverperc(db, obs)
```

```

[1] WARNING! Values less than -100,000. \n
[2] WARNING! tvhabita.dbf may be corrupt. \n
[3] WARNING! Please correct by im- / exporting e.g. with OpenOffice.

The following columns contain no data and are omitted
[1] REFERENCE TABLE_NR NR_IN_TAB PROJECT AUTHOR SYNTAXON UTM ALTITUDE EXPOSITION MOSS_IDENT
[11] LICH_IDENT

The following numeric columns contain only 0 values and are omitted
[1] COV_TOTAL COV_TREES COV_SHRUBS COV_HERBS COV_MOSSES COV_LICHEN COV_ALGAE COV_LITTER COV_WATER COV_ROCK
[11] TREE_HIGH TREE_LOW SHRUB_HIGH SHRUB_LOW HERB_HIGH HERB_LOW HERB_MAX CRYPT_HIGH

The following numeric fields contain 0 values:
[1] X_COORD Y_COORD
Please check if these are really measured as 0 values or if they are not measured
and wrongly assigned because of Dbase restrictions.
If so, use something like:
site$Column_name[site$Column_name==0] <- NA
summary(site[,c('X_COORD','Y_COORD')])
Cover code used: 01 Braun/Blanquet (old) SCH1 SCH2 SCH3 SCH4 SCH5 SCH6 SCH7
code r + 1 2 3 4 5
perc 1 2 3 13 38 68 88
Cover code used: 02 Braun/Blanquet (new) SCH1 SCH2 SCH3 SCH4 SCH5 SCH6 SCH7 SCH8 SCH9
code r + 1 2m 2a 2b 3 4 5
perc 1 2 3 4 8 18 38 68 88

tail(obs)

RELEV_NR TaxonUsageID COVER_CODE LAYER DET_CERT SEASON MICRORREL FLOWER COVERSCALE COVER_PERC
20 1 10024 1 6 0 0 <NA> 0 01 3
21 2 2923 1 0 0 0 <NA> 0 02 3
22 2 27309 3 6 0 0 <NA> 0 02 38
23 3 12273 1 6 0 0 <NA> 0 01 3
24 2 4269 1 1 0 0 <NA> 0 02 3
25 2 61329 2m 6 0 0 <NA> 0 02 4

```

A few simple possibilities for percentage cover transformations are directly included in the `tv.veg` code, e.g. to use only presence-absence information you can choose option `cover.transform = 'pa'`.

6.2 Pseudospecies

How to account for different vegetation layers or other kinds of species differentiation?

The next step is the separation of pseudo-species. "Pseudo-species" are all kind of taxa split according to species-plot information beyond the performance measure which will be used within the matrix. At this point you have to decide which information should be preserved and which should be aggregated. For instance layer separation must be defined at this step. The default is to differentiate tree, shrub and herb layers but to combine finer layer specifications within them.

If we have more than one occurrence of the same species in a plot, e.g. because tree species growing as young stands and adult specimens were differentiated according to growth height classes, we have to create either pseudo-species which differentiate the occurrences in the resulting vegetation matrix or to combine species occurrences from different layers. For the latter we can use different calculations e.g. to sum up all cover percentages of different layers (`lc='sum'`) or the maximum value (`lc='max'`), mean value (`lc='mean'`). If we assume an independent occurrence of a species in different vertical layers, we can do the calculations with option `lc = 'layer'` (the default). This results in a probability sum: A species covering 50% in tree layer 1 and 50% in herb layer will get a combined cover of 75% because both layers will overlap 50% ($1 - 0.5 \cdot 0.5$).

If you want to specify pseudo-species by other species-plot differentiation you can define a combination dataframe. Two example dataframes are included in the package (`lc.0` and `lc.1`). Option `comb` has to be given as a list with first element naming the column name holding the grouping variable and as second element the name of the combination dataframe. Try

```
data(lc.0)
tv.veg(db, pseudo = list(lc.0, c("LAYER")), lc = "layer")
```

and check the column names:

```
reading observations ...
Taxonomic reference list: GermanSL 1.2
converting cover code ...
[1] WARNING! Values less than -100,000. \n
[2] WARNING! tvhabita.dbf may be corrupt. \n
[3] WARNING! Please correct by im- / exporting e.g. with OpenOffice.

The following columns contain no data and are omitted
[1] REFERENCE TABLE_NR NR_IN_TAB PROJECT AUTHOR SYNTAXON UTM ALTITUDE EXPOSITION
[10] MOSS_IDENT LICH_IDENT

The following numeric columns contain only 0 values and are omitted
[1] COV_TOTAL COV_TREES COV_SHRUBS COV_HERBS COV_MOSSES COV_LICHEN COV_ALGAE COV_LITTER COV_WATER
[10] COV_ROCK TREE_HIGH TREE_LOW SHRUB_HIGH SHRUB_LOW HERB_HIGH HERB_LOW HERB_MAX CRYPT_HIGH

The following numeric fields contain 0 values:
[1] X_COORD Y_COORD
Please check if these are really measured as 0 values or if they are not measured
and wrongly assigned because of Dbase restrictions.
If so, use something like:
site$Column_name[site$Column_name==0] <- NA
summary(site[,c('X_COORD','Y_COORD')])
creating pseudo-species ...
combining occurrences using type LAYER and creating vegetation matrix ...
replacing species numbers with short names ...
Reference list used: GermanSL 1.2
[1] "AGRTS;P.6" "HIERSUG.6" "ACERPSE.5" "ACERPSE.6" "DACYGLO.6" "ACHICOL.6" "ARMEM-H" "ARMEM-E"
[9] "ARMEM-H" "PICEABI.2" "PICEABI.3" "GALUMOL.6" "ACHI#MI" "ARMEM-H.6" "HIERPIO" "ACHIMIL.6"
[17] "ACHIM-S.6" "PICEABI.1" "QUERROB.1" "QUERROB.2" "QUERROB.6" "ACHI-SP.6" "ACOU-SP.6" "ACOR-SP.6"
[25] "ADONAES.6"
```

Separated by dots and layer numbers you can see the preserved layers. For meaning of layer numbers see Turboveg help.

Check (`data(lc.1)`) for the default layer combination.

Beside layers you can use any kind of species-plot attributes to distinguish between occurrences, for instance in a multi-temporal survey.

```
comb <- list(data.frame(SEASON = 0:4, COMB = c(0, "Spring", "Summer", "Autumn", "Winter")), "SEASON")
names(tv.veg(db, tax = FALSE, pseudo = comb, quiet = TRUE))

reading observations ...
Taxonomic reference list: GermanSL 1.2
converting cover code ...
[1] WARNING! Values less than -100,000. \n
[2] WARNING! tvhabita.dbf may be corrupt. \n
[3] WARNING! Please correct by im- / exporting e.g. with OpenOffice.

The following columns contain no data and are omitted
[1] REFERENCE TABLE_NR NR_IN_TAB PROJECT AUTHOR SYNTAXON UTM ALTITUDE EXPOSITION
[10] MOSS_IDENT LICH_IDENT

The following numeric columns contain only 0 values and are omitted
[1] COV_TOTAL COV_TREES COV_SHRUBS COV_HERBS COV_MOSSES COV_LICHEN COV_ALGAE COV_LITTER COV_WATER
[10] COV_ROCK TREE_HIGH TREE_LOW SHRUB_HIGH SHRUB_LOW HERB_HIGH HERB_LOW HERB_MAX CRYPT_HIGH

The following numeric fields contain 0 values:
[1] X_COORD Y_COORD
Please check if these are really measured as 0 values or if they are not measured
and wrongly assigned because of Dbase restrictions.
If so, use something like:
```

```

site$Column_name[site$Column_name==0] <- NA
summary(site[,c('X_COORD','Y_COORD')])
creating pseudo-species ...
combining occurrences using type LAYER and creating vegetation matrix ...
replacing species numbers with short names ...
Reference list used: GermanSL 1.2
[1] "AGRTS;P"      "HIERSUG"      "ACERPSE.Spring" "ACERPSE.Summer" "DACYGLO"      "ACHICOL"
[7] "ARMEM-H"      "ARMEM-E"      "ARMEM-H"      "PICEABI"      "GALUMOL"      "ACHI#MI"
[13] "ARMEM-H"      "HIERPIO"      "ACHIMIL"      "ACHIM-S"      "PICEABI"      "QUERROB"
[19] "ACHI-SP"      "ACOU-SP"      "ACOR-SP"      "ADONAES"

```

```

data(lc.1)
veg <- tv.veg(db, lc = "sum", pseudo = list(lc.1, "LAYER"), dec = 1, quiet = TRUE)

```

```

4 Synonyms found in dataset, adapted.
2 monotypic taxa found in dataset, set to species rank.
1 monotypic taxa found in dataset, set to species rank.
5 child taxa found in dataset, adapted.
2 child taxa found in dataset, adapted.
1 child taxa found in dataset, adapted.
Warning: Potential pseudonyms in dataset, please check.
Warning: Critical species in dataset, please check
Information is written to /tmp/Rtmpm555CJ/file2ce1d72c0ftxt.

```

```

veg[, 1:10]

```

	AGRTS;P	HIERSUG	ACERPSE	ACERPSE.Shrub	DACYGLO	ARMEM-E	ARMEM-H	GALUMOL	PICEABI.Tree	QUERROB
1	3	0	3	13	3	0	0	3	6	0
2	0	3	0	0	0	0	38	0	3	3
3	0	3	0	0	0	3	6	0	0	0

6.3 Combine species manually

Beside semi-automatic taxon harmonization with function `taxval` there are two possibilities to change Taxonomy manually. If you decide to interpret a certain species name in your database different than stored in the standard view of the taxonomic reference you can replace species numbers within the observational dataframe and run `taxval` later on.

```

obs.tax$TaxonUsageID[obs.tax$TaxonUsageID == 27] <- 31

```

will replace all occurrences of *Achillea millefolium* *agg.* with *Achillea millefolium* which might be adequate for your survey and will prevent a too coarse taxon grouping. For a longer list of replacements you can use a dataframe.

```

taxon.repl <- data.frame(old = c(27), new = c(31))
obs.tax$TaxonUsageID <- replace(obs.tax$TaxonUsageID, match(taxon.repl$old, obs.tax$TaxonUsageID), taxon.repl$new)

```

The second possibility is to use function `comb.species` on vegetation matrices.

```

veg <- tv.veg("taxatest", quiet = TRUE)

reading observations ...
Taxonomic reference list: GermanSL 1.2

Original number of names: 21

4 Synonyms found in dataset, adapted.
2 monotypic taxa found in dataset, set to species rank.
1 monotypic taxa found in dataset, set to species rank.
5 child taxa found in dataset, adapted.
2 child taxa found in dataset, adapted.
1 child taxa found in dataset, adapted.
Warning: Potential pseudonyms in dataset, please check.
Warning: Critical species in dataset, please check

```

Number of taxa after validation: 12

Information is written to /tmp/Rtmpm555CJ/file2ce31fd2c56tat.

converting cover code ...

[1] WARNING! Values less than -100,000. \n

[2] WARNING! tvhabita.dbf may be corrupt. \n

[3] WARNING! Please correct by im- / exporting e.g. with OpenOffice.

The following columns contain no data and are omitted

[1] REFERENCE TABLE_NR NR_IN_TAB PROJECT AUTHOR SYNTAXON UTM ALTITUDE EXPOSITION
[10] MOSS_IDENT LICH_IDENT

The following numeric columns contain only 0 values and are omitted

[1] COV_TOTAL COV_TREES COV_SHRUBS COV_HERBS COV_MOSSES COV_LICHEN COV_ALGAE COV_LITTER COV_WATER
[10] COV_ROCK TREE_HIGH TREE_LOW SHRUB_HIGH SHRUB_LOW HERB_HIGH HERB_LOW HERB_MAX CRYPT_HIGH

The following numeric fields contain 0 values:

[1] X_COORD Y_COORD

Please check if these are really measured as 0 values or if they are not measured and wrongly assigned because of Dbase restrictions.

If so, use something like:

```
site$Column_name[site$Column_name==0] <- NA
```

```
summary(site[,c('X_COORD','Y_COORD')])
```

creating pseudo-species ...

combining occurrences using type LAYER and creating vegetation matrix ...

replacing species numbers with short names ...

Reference list used: GermanSL 1.2

```
comb.species(veg, sel = c("QUERROB", "QUERROB.Tree"))
```

The following names are combined to the new name: QUERROB

[1] "QUERROB" "QUERROB.Tree"

	AGRTS;P	HIERSUG	ACERPSE	ACERPSE	Shrub	DACYGLO	ARMEM-E	ARMEM-H	GALUMOL	PICEABI.Tree	ACHI-SP	ACOUCAL	ADONAES
1	3	0	3		13	3	0	0	3	6	43	0	3
2	0	3	0		0	0	0	38	0	3	18	4	0
3	0	3	0		0	0	3	6	0	0	0	3	0

QUERROB

1 0

2 72

3 0

will use the first name ('QUERROB') for the replacement column with the sum of the selected columns.

7 Site data

tv.site will load the site (header) data and does some basic corrections caused by Turboveg dBase format.

```
site <- tv.site(db)
```

[1] WARNING! Values less than -100,000. \n

[2] WARNING! tvhabita.dbf may be corrupt. \n

[3] WARNING! Please correct by im- / exporting e.g. with OpenOffice.

The following columns contain no data and are omitted

[1] REFERENCE TABLE_NR NR_IN_TAB PROJECT AUTHOR SYNTAXON UTM ALTITUDE EXPOSITION
[10] MOSS_IDENT LICH_IDENT

The following numeric columns contain only 0 values and are omitted

[1] COV_TOTAL COV_TREES COV_SHRUBS COV_HERBS COV_MOSSES COV_LICHEN COV_ALGAE COV_LITTER COV_WATER
[10] COV_ROCK TREE_HIGH TREE_LOW SHRUB_HIGH SHRUB_LOW HERB_HIGH HERB_LOW HERB_MAX CRYPT_HIGH

The following numeric fields contain 0 values:

[1] X_COORD Y_COORD

Please check if these are really measured as 0 values or if they are not measured

```
and wrongly assigned because of Dbase restrictions.
If so, use something like:
site$Column_name[site$Column_name==0] <- NA
summary(site[,c('X_COORD', 'Y_COORD')])
```

The function is quite straightforward. After loading the file *tvhabita.dbf* from the specified database folder, warnings are given for plots without specified relevé area or date and fields are checked if they are empty (a lot of predefined header fields in Turboveg are often unused) or contain probably mistakable 0 values in numerical fields, due to dBase deficiencies (dBase can not handle NA = not available values reliably). It is stated in the output, if you have to check and possibly correct 0 values.

8 Additional functions

Use `help(package='vegdata')` for a complete list of available functions and data sets in *vegdata*.

8.1 Combine different taxonomic reference lists

If you have to combine different taxonomic reference lists, functions `tv.compRef1` might be a starting point, comparing species numbers and/or species names of both lists.

```
tv.compRef1("taxref1", "taxref2")
```

8.2 Frequency tables

`syntab` produces a relative or absolute frequency table of a classified vegetation table with the possibility to filter according to threshold values. To exemplify the function we use the second dataset implemented in the package. It is the demonstration dataset from Leyer & Wesche (2007), a selection of grassland relevés from the floodplains of the river Elbe.

```
elbaue <- tv.veg("elbaue")

5 Synonyms found in dataset, adapted.
1 monotypic taxa found in dataset, set to species rank.
Warning: Critical species in dataset, please check
        Information is written to /tmp/Rtmpm555CJ/file2ce499e26b4tat.

elbaue.env <- tv.site("elbaue")

clust <- vector("integer", nrow(elbaue.env))
clust[elbaue.env$MGL < -50 & elbaue.env$SDGL < 50] <- 1 # dry sites, low deviation
clust[elbaue.env$MGL < -50 & elbaue.env$SDGL >= 50] <- 2 # dry sites, high deviation
clust[elbaue.env$MGL >= -50 & elbaue.env$SDGL >= 50] <- 3 # wet sites, high deviation
clust[elbaue.env$MGL >= -50 & elbaue.env$SDGL < 50] <- 4 # wet sites, low deviation
levels(clust) <- c("dry.ld", "dry.hd", "wet.hd", "wet.ld")
```

We can e.g. look at the relative frequency of all species with more than 40% at least in one column, according to the height of the groundwater table (low or high) and the amplitude of the groundwater table fluctuations (high or low deviations from the mean). Additionally we can use the affiliation of species to abiotic clusters with the help of package *indicspecies*, which calculates species indicator values for one or several cluster (De Cáceres *et al.*, 2010) to order the syntaxonomical table. Together with Ellenberg indicator values with will get a comprehensive view into our data.

```
require(indicspecies)

Loading required package: indicspecies
Loading required package: permute
```

```

traits <- tv.traits()

Changing character fields into logical, integer or numericals if appropriate:
Dat format of OEK_L changed to integer
Dat format of OEK_T changed to integer
Dat format of OEK_K changed to integer
Dat format of OEK_F changed to integer
Dat format of OEK_R changed to integer
Dat format of OEK_N changed to integer
Dat format of OEK_S changed to integer
Dat format of Mahdvertra changed to integer
Dat format of Weidevertr changed to integer
Dat format of Trittvertr changed to integer
Dat format of Futterwert changed to integer
Dat format of Futter.Dam changed to integer

trait <- data.frame(EIV_F = traits$OEK_F, EIV_N = traits$OEK_N)
rownames(trait) <- traits$ABBREVIAT
st <- syntab(elbaue, clust, mupa = TRUE, fullnames = TRUE)

Number of clusters: 4
Cluster frequency 7 10 5 11
Reference list used: GermanSL 1.2

print(st, limit = 30, trait = trait)

Number of clusters: 4
Cluster frequency 7 10 5 11

```

	dry.ld	dry.hd	wet.hd	wet.ld	index	stat	p.value	EIV_F	EIV_N
Cirsium arvense	43	.	.	9	1	0.64	0.010	NA	7
Deschampsia cespitosa	57	.	.	18	1	0.72	0.015	7	3
Euphorbia esula	43	.	.	.	1	0.65	0.025	4	NA
Galium verum agg.	71	20	.	.	1	0.83	0.005	4	3
Lathyrus pratensis	43	.	.	9	1	0.59	0.020	6	6
Vicia tetrasperma	57	10	.	.	1	0.71	0.005	5	5
Alopecurus geniculatus	.	20	60	9	3	0.65	0.035	8	7
Rorippa amphibia	.	.	60	9	3	0.77	0.010	10	8
Caltha palustris	.	.	.	36	4	0.60	0.040	9	6
Agrostis canina	.	.	.	36	4	0.60	0.025	9	2
Carex vesicaria	.	.	.	55	4	0.74	0.010	9	5
Carex acuta	14	.	40	82	4	0.87	0.010	9	4
Ranunculus flammula	.	.	.	55	4	0.74	0.005	9	2
Carex praecox	43	70	.	.	5	0.77	0.005	3	4
Elymus repens	57	90	.	.	5	0.87	0.005	NA	7
Alopecurus pratensis	71	90	20	36	5	0.88	0.005	6	7
Rumex thyrsiflorus	43	60	.	.	5	0.73	0.005	3	4
Taraxacum sect. Ruderalia	57	60	.	18	5	0.72	0.025	5	8
Cardamine pratensis	43	10	.	55	7	0.69	0.030	6	NA
Glyceria maxima	.	.	80	45	10	0.75	0.020	10	9
Sium latifolium	.	.	40	45	10	0.66	0.045	10	7

9 Vegetation analyses

The package *vegdata* serves mostly as a helper for the analysis of vegetation data. Several powerful R packages like *vegan* and others exist, to provide a very broad range of possibilities.

9.1 Multivariate Ordinations

With the functions shown above we are now ready to do some example analyses in the wide area of vegetation analyses.

We can do, for instance, a “Nonmetric Multidimensional Scaling with Stable Solution from Random Starts Axis Scaling and Species Scores” which is a wrapper for Kruskal’s Non-metric Multidimensional Scaling (Cox & Cox, 1994, 2001) from Jari Oksanen (Oksanen *et al.*, 2008).

```
## Data analyses
library(vegan)

Loading required package: lattice
This is vegan 2.0-10

veg.nmds <- metaMDS(elbaue, distance = "bray", trymax = 5, autotransform = FALSE, noshare = 1, expand = TRUE, trace = 2)
mT.F <- meanTraits("OEK_F", elbaue)
mT.N <- meanTraits("OEK_N", elbaue)
env <- envfit(veg.nmds, data.frame(mT.F, mT.N))
```

To show the result in comparison with environmental measurements in a nice graphic we do some plotting magic.

```
library(labdsv)

Loading required package: mgcv
Loading required package: nlme
This is mgcv 1.8-3. For overview type 'help("mgcv-package")'.
Loading required package: MASS
Attaching package: 'labdsv'
The following object is masked from 'package:stats':
  density

library(akima)
color = function(x) rev(topo.colors(x))
nmds.plot <- function(ordi, site, var1, var2, disp, plottitle = "NMDS", env = NULL, ...) {
  lplot <- nrow(ordi$points)
  lspc <- nrow(ordi$species)
  filled.contour(interp(ordi$points[, 1], ordi$points[, 2], site[, var1]), ylim = c(-1, 1.1), xlim = c(-1.4,
  1.4), color.palette = color, xlab = var1, ylab = var2, main = plottitle, key.title = title(main = var1,
  cex.main = 0.8, line = 1, xpd = NA), plot.axes = {
    axis(1)
    axis(2)
    points(ordi$points[, 1], ordi$points[, 2], xlab = "", ylab = "", cex = 0.5, col = 2, pch = "+")
    points(ordi$species[, 1], ordi$species[, 2], xlab = "", ylab = "", cex = 0.2, pch = 19)
    ordisurf(ordi, site[, var2], col = "black", choices = c(1, 2), add = TRUE)
    orditorp(ordi, display = disp, pch = " ")
    legend("topright", paste("GAM of ", var2), col = "black", lty = 1)
    if (!is.null(env))
      plot(env, col = "red")
  }, ...)
}
```

The first axis of our NMDS plot show the influence of mean groundwater level on the patterns of the dataset. *Glyceria maxima* is marking the wet side of the gradient, whereas *Cnidium dubium* *Agrostis capillaris* or *Galium verum* agg, occur only at low mean groundwater level. The second axis can be assigned to the fluctuation of water levels measured as standard deviation of mean groundwater level. Species indicating high water fluctuation are *Agrostis stolonifera* or *Alopecurus geniculatus* whereas *Carex vesicaria* occurs only in more balanced situations.

References

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- Dengler, J., Jansen, F., Glöckler, F., Peet, R., De Cáceres, M., Chytrý, M., Ewald, J., Oldeland, J., Lopez-Gonzalez, G., Finckh, M. & Others (2011). The Global Index of Vegetation-Plot Databases (GIVD): a new resource for vegetation science. *Journal of Vegetation Science*, 22, 582–597.


```
nmds.plot(veg.nmds, elbaue.env, disp = "species", var1 = "MGL", var2 = "SDGL", env = env, plottitle = "NMDS of Elbaue floodp
```

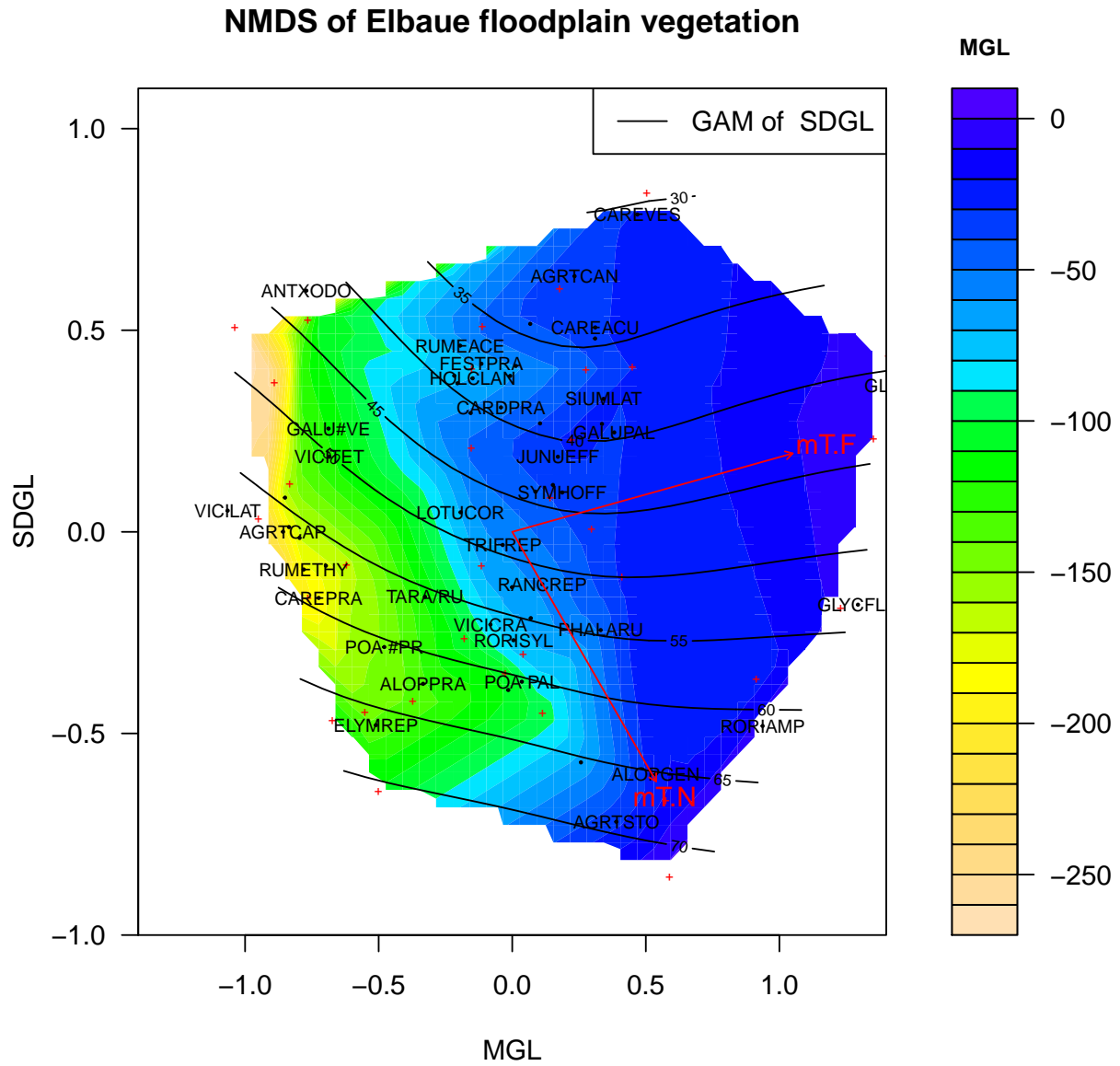


Figure 2: Non-metric multidimensional scaling of the elbaue vegetation data with an overlay of mean groundwater table (colors) and standard deviation of groundwater level fluctuations (lines). Arrows show direction of increasing mean Ellenberg F resp. N

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