User Manual

LandS Model Documentation

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1 Introduction

The purpose of the LandS model is to illustrate and predict vegetation succession in semi-natural landscapes for small-scale applications such as a national park. Therefore, the model simulates vegetation dynamics in a landscape mosaic and includes competition among herbaceous species as well as early successional encroachment. At its core, plant-environment interactions are mediated by the inverse use of Ecological Indicator Values (EIVs) from the phytosociological literature (Dierschke & Briemle, 2002; Ellenberg & Leuschner, 2010).

Vegetation in the model differs in the way it is modeled: grasses and forbs as compartments, and trees as individuals. For each group, different processes and approaches to growth, reproduction, dispersal, and competition are implemented in the model. Compartments are used for grasses, forbs, and shrubs like brambles and blackthorn and hence referred to as "Grasslikes" and "Shrublikes". They are modeled per cell and are characterized in particular by their vegetative reproduction. Trees and other shrubs, such as broom or elder, are modeled as individuals and referred to as "Treelikes" and "Bushlikes". They can occur several times in a cell or occupy more than one cell, depending on the cell size. In addition, different seed dispersal is implemented for individuals. A more detailed description of the model concept can be found in the ODD.

To make the model applicable to different landscapes, the plant species modeled are interchangeable and require pre-calibration. The model can be used to develop different management scenarios for situations where the landscape has changed or where changes are imminent. Examples include intended/planned changes in land management in protected areas, or action plans following severe storms that have created windthrow areas in forests. Ultimately, the model is intended as a decision support system (DSS) for stakeholders involved in the management of these landscapes.

The current version of the model has been fully overhauled. Previous versions of the model have been published as the GraS model (Siehoff et al., 2011) and the WoodS model (Hudjetz et al., 2014).

2 System requirements

The executable file of the model runs on Windows, no programming environment needs to be installed. Further it is advised to leave the folder architecture as it is, as default input settings saved in text files use relative paths to input files.

3 Getting started

There are two possibilities to run the model: through the Graphical User Interface (GUI) or as an inline program. The inline application uses a text files (*.gras, see below) to start the model with all necessary settings and parameters. The same text files can also be used to synchronize the GUI with saved values.

Model run with the GUI:

A) Open the executable that is located in /bin/.
B) Load a *.gras file to synchronize the GUI settings (middle section to the right).
C) Click "Start" in the bottom right corner of the screen to run the simulation.

Model run as inline program:

As inline program the model is run with two additional parameters, the path of the run file (*.gras) and the path to a desired output folder. The command prompt should look like this: "Path\to\Modell.exe" "Path\to*.gras" "Path\for\OutputFolder"

3.1 Run files (*.gras)

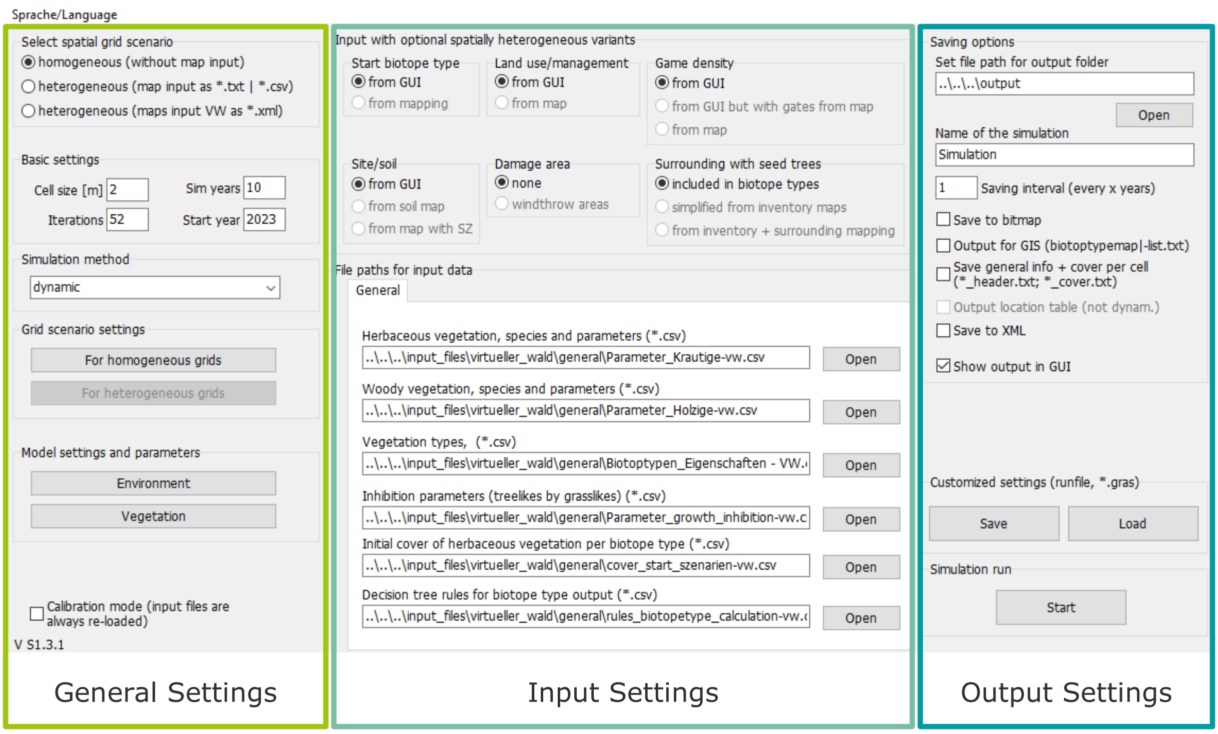
The so called run files (*.gras) are simple txt files that contain values for settings and edit fields in the GUI that are essential to run a simulation. Each line contains a value for one GUI element.

Run files are used to start the model as inline program or they can be used to synchronize the GUI with settings from previously saved run files and vice versa to save the current GUI settings to rune files for later usage. Do not edit run files manually, as this is error-prone, but use the "Save" run file button in the GUI.

3.2 GUI

The GUI comes with two language settings, English and German. The top ribbon allows changing between languages. The main interface guides the user through all other settings.

It is divided into the sections left, middle and right. The left section contains the general settings for the simulation, the middle part navigates the user through different input files options and the right section is used to specify the output options and start the simulations.



3.3 User input and Input files

In general the user input and all input files use "." as decimal separator. Additionally the input files use ";" as column separators. Microsoft EXCEL interprets CSV text files (*.csv) different dependent on system settings. The standard setting for English countries is "," as column separators and "." as decimal separator. In German language setting it is ";" as column separators and "," as decimal separator. If your EXCEL does not display the input files correctly you can change your setting in EXCEL, use the import from text files option in EXCEL to view input files or use other text editors to edit input files.

The number of input files for the initialization depends on the chosen grid scenario. We distinguish between homogeneous and heterogeneous spatial grid scenarios. In the former it is possible to run the model with a minimal set of input files, which only contain the necessary information about the vegetation and its entities. Otherwise in a heterogenetic grid scenario, additionally to the minimal set of input files the environment can be specified by a multitude of different raster files.

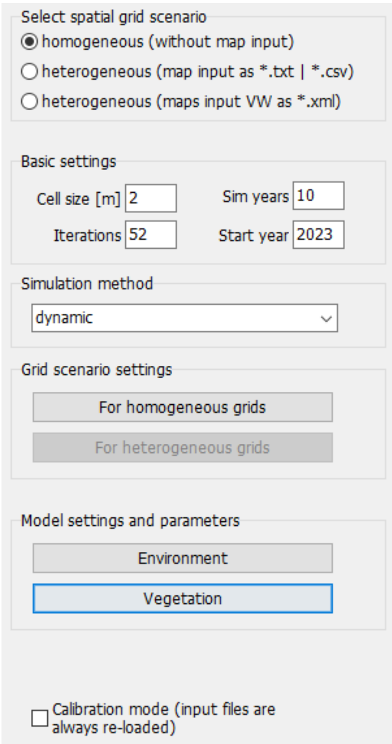
Minimal set of input files:

- Vegetation types with parameters
- Herb and grass entities with parameters
- Tree and bush entities with parameters
- Initial cover, specifying herbs/grasses cover in different vegetation types
- Rule based decision tree for model output, converting species cover into vegetation types

4 Model settings

4.1 General settings

In general, simulations differ in the source of available landscape data: On the one hand there is the possibility to create a simple homogeneous raster directly in the model (homogenous grid) and on the other hand rasterized data can be loaded from GIS (heterogeneous grid). Depending on the source and availability of additional information, there are then various optional settings that can be made in the user interface of the model.



Spatial grid scenario - homogenous grid

In this case the user defines the environment in the GUI settings. It is only possible to create cells with identical environmental conditions, in other words the drawn grid will be homogeneous.

Spatial grid scenario - heterogeneous grid

Here the user is free to choose a combination input options for different factors of the environment. E.g. the site and soil conditions can be provided in raster files but the land use is specified in the GUI equally for all cells. Generally raster maps are loaded into the model as *.txt or *.csv files (option 2). Only for specific projects the *.xml format was developed (option 3).

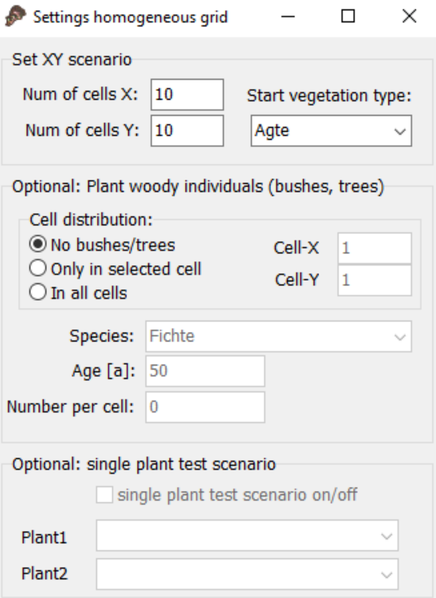
Basic settings

The basic settings consist of cell size in meters, number of simulation years, number of iterations per year, e.g. 365 or 52 for days or weeks, and the displayed start year in the output graphs.

Simulation method

The main method is the "dynamic" simulation, other simulation methods had been used in previous developments stages (Single plant scenario; Downhill Simplex) but are currently not functional.

Grid scenario settings – For homogenous grids

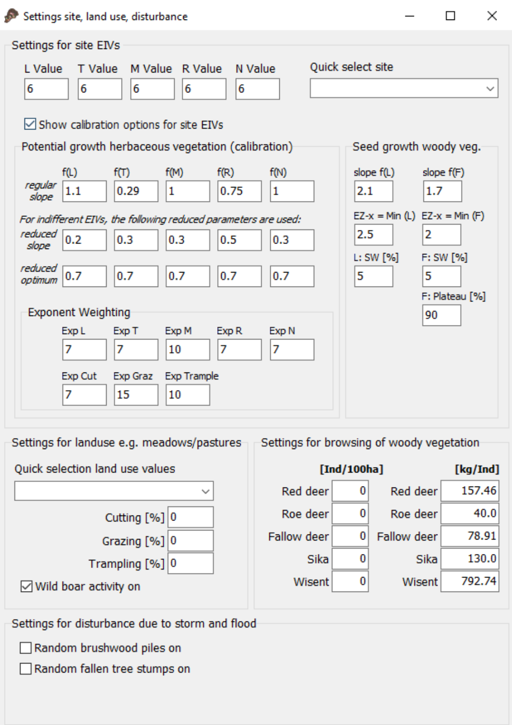


This button opens a window that allows specifications for the uniform grid such as number of cells and initial vegetation type of the cells. Further the user has the possibility to "plant" woody vegetation from the list of available bush and tree species in a specific cell or all cells. The single plant test scenario is currently not functional.

Grid scenario settings – For heterogeneous grids

The second button opens a window that lets the user select a bounding box with in larger raster files, this is currently only supported for xml input files. Further the user is provided with a test grid – button that will create the grid from specified import files. It allows users to check if the grid is correctly generated in the model without running a full simulation.

Model settings and parameters – Environment



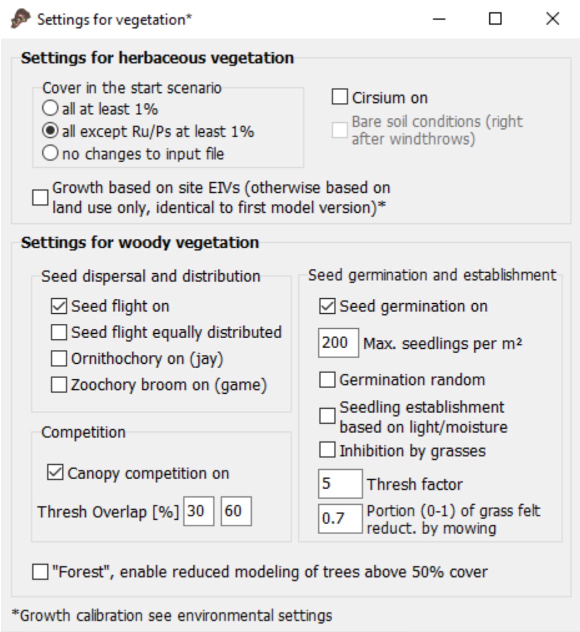
This button opens the environment window. The model contains two types of environmental factors: site properties such as light availability, temperature, soil moisture reaction (soil pH) and soil nutrients, as well as land use factors, i.e., cutting intensity, grazing intensity and trampling intensity. Site factors are implemented as ordinal scale from 1-9, while land use uses a relative intensity scale from 0-100. Both factor types correspond with plant EIVs of Ellenberg and Briemle respectively and are therefore called site EIVs. If a homogeneous grid scenario is selected or when no raster data for the factors are available, the user can specify the values for each factor.

By checking the check box "show options for calibration", further model parameters are reveled. These are essential for calibrating new landscapes. During calibration the user can here change how strong influence of a single factors is compared to others. The ecological reasoning for this is that depending on the landscape there are different environmental factors that dominate a specific landscape. E.g. in forests light availability is an essential factor for species growth and distribution where as in open grassland light availability is generally high and other factors like moisture or land use are more important to differ between grassland types. For further details on how to obtain values for site EIVs see ODD section 5, initialization.

In addition, the user can specify here the browsing pressure by game on the woody plants. The density is indicated by individuals per ha. Browsing pressure on herbaceous vegetation needs to be indicated by the site EIVs Grazing and Trampling.

Ultimately the user can switch on stochastic process such as brushwood piles and fallen tree stumps on when vegetation development after disturbances such as storms are modelled.

Model settings and parameters – Vegetation



This button opens the vegetation settings window. To explore the model behavior different mechanisms can either be turned on and off or be replaced with simpler versions for simulations. E.g. plant growth can depend on all site EIVs or only on land use which corresponds to the first model version.

Settings for herbaceous vegetation:

The selection box "Cover in start scenario" is used to manipulate the read-in start covers:

The option "all at least 1%" increases the initial cover of all Grasslikes to 1%, which had been initialized with a cover below 1%. The option "all except Ru/Ps at least 1%", is similar to the first option with the exception of not raising the cover of bramble and blackthorn. The default option “no changes to input file” leaves the initial species cover at the defined values in the input file.

This selection box is in particular useful to mimic a general seed availability for herbaceous species. While a plant species might not be originally present in a vegetation type it could start growing if the cover is set to 1% and the environmental conditions are favorable.

The following checkboxes have been developed for special use cases and are not necessary generally applicable. By unselecting "Cirsium on" it is possible to revert the initialized *Cirsium arvense* and set it to 0%. The checkbox "bare soil conditions" overrides the vegetation types from a vegetation mapping with bare soil conditions, and was used to mimic the vegetation conditions after windthrow events.

Settings for woody vegetation - Seed dispersal and establishment

The user can choose whether seed dispersal for woody vegetation is active and whether it seeds are distributed equally or according to a double exponential seed dispersal algorithm.

Further the seed germination can be turned on and off. It can also be specified if the seeds should germinate randomly or if germination probability should depend on the on the environmental factors light availability and soil moisture.

For the dispersal of seeds by animals two different mechanisms are implemented in the model, both can be turned on and off. First there is the oornitochory mechanisms where birds, such as jay, are spreading certain seeds. If a species has seeds that could be spread by birds is specified in the woody species parameters by a Boolean. Second there is mammaliochory that has so far only been implemented for broom seeds, which are spread by game.

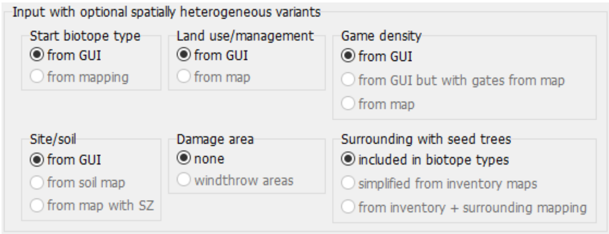
Settings for woody vegetation - Competition

The competition of trees with trees in neighbor cells can be turned on and off. Additionally two thresholds for overlapping are specified. The first threshold defines a growth stop for the inferior tree, the second to death of the inferior tree. The competition of grasses and trees comes into play when tree seeds germinate. If this competition is enabled, the grass felt can reduce the proportion of germinating seeds. This mechanism has two parameters: a threshold factor that modulates the interval at which the inhibition starts to be reduced gradually, and a factor that modulates the felt density also influencing the strength of the germination inhibition.

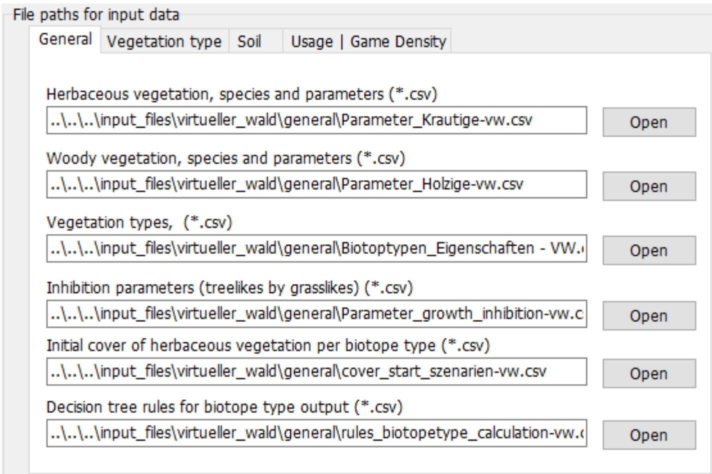
Checkbox calibration mode

In normal simulation runs, the model only reloads input data with different file paths (and file names) to previous input. While this saves memory in normal application runs, it leads to incorrect simulation if data in utilized files is changed. As this is the usual case during calibration this checkbox can be selected to always reload all input date.

4.2 Input Settings



As mentioned before in 4.1 for the spatial grid scenario, simulations can use different means of input. In the heterogeneous grid scenario the user has the option to initialize the model with a variety of spatially explicit raster data to create a landscape in the model that reflects the reality, alternatively environmental data can be specified in the GUI. In that case all cells are initialized for that factor with the same values. The various selection boxes guide the user through the different input options.



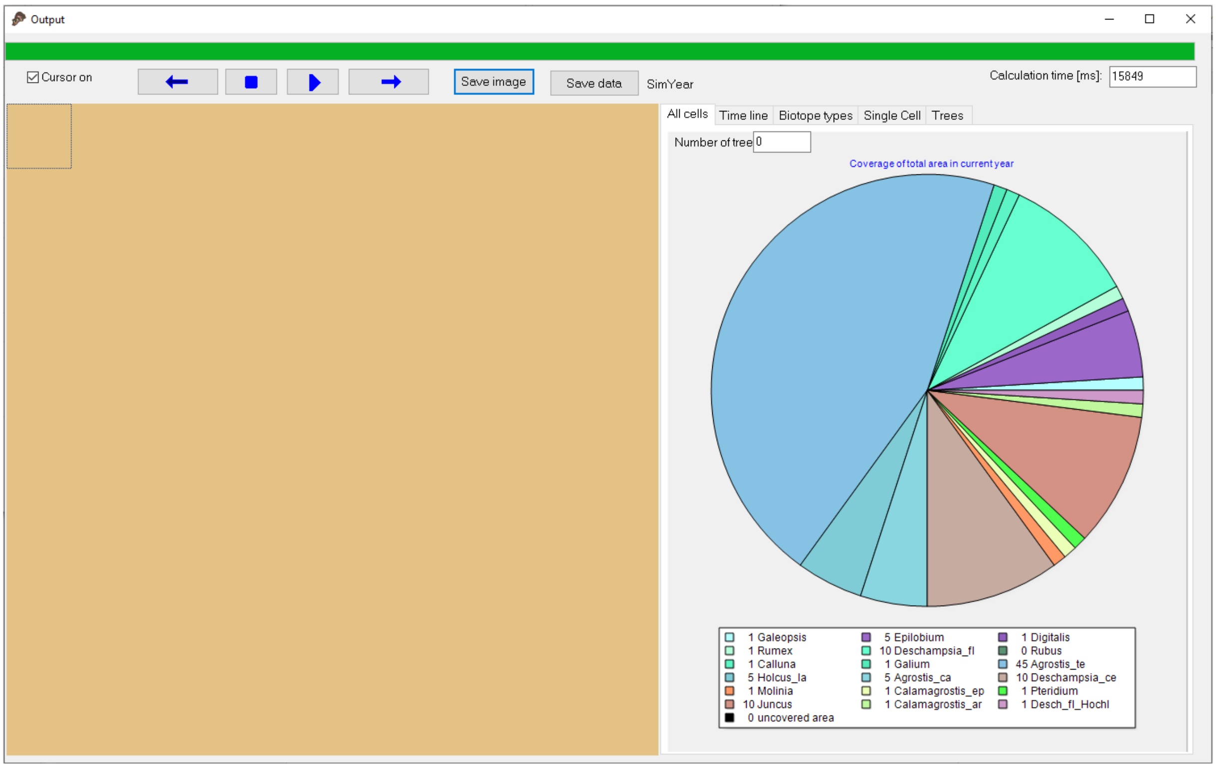
Depending on the selections made, corresponding paths for input data must be specified in the tabs below the selection boxes. The first tab contains the minimal set of input data, which needs to be specified even in homogeneous grid scenarios. The following tabs correspond to the selection boxes. The system will guide the user by making Edit fields only available if the input is necessary based on the user prior selection.

4.3 Output Settings

In the saving options the user can choose between different output options and specify output path as well as file names. The runfile import and export is located below the saving options followed by the simulation start button. Beware that the load runfile dialog only accepts files with the ending "*.gras".

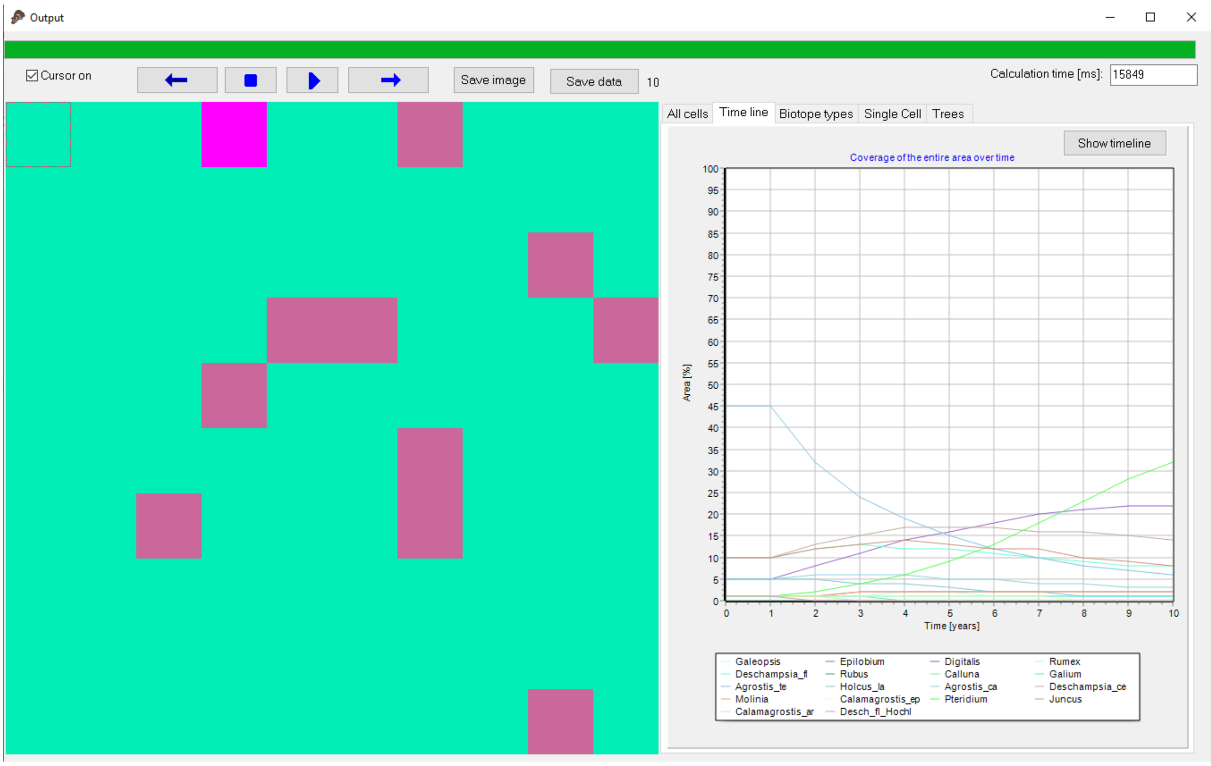
5 Model output

Once the simulation is started the output window opens. The green bar at the top of the window shows the progress of the simulation. When a simulation is finished the user can navigate through the simulated years by clicking on the arrows.



On the left side of the output window the simulated landscape is shown, on the right side tabs with different data. The tab "All cells" shows the relative cover of all plants within the landscape and the number of trees in the landscape. In the tab "Time line" a graph can be generated, which shows the course of the cover of each species over the simulation time.

The tab "Biotope types" shows the proportion of different vegetation types in the landscape. In the tab single cell the user can view the environmental values of a selected cell as well as the relative cover and the course of cover over time in that specific cell. The tab trees shows the width, height and age of trees in a cell. Each tree is represented by a separate column in the chart.



6 Example applications

The repository is equipped with two example application. These stylized tests are designed to test the model behavior. The first test uses a heterogeneous patchy landscape with different environmental conditions and a selection of very different herbaceous species, with one species fitting to each patch. The second test contains a calibrated community with runfiles for three homogenous landscapes: a fertilized meadow, an unfertilized meadow, and a transition experiment from fertilized to unfertilized meadow. For further details on the example application please refer to the upcoming publication (Rumohr et al., LandS Model).

7 References

Dierschke, H., & Briemle, G. (2002). *Kulturgrasland: Wiesen, Weiden und verwandte Staudenfluren; 20 Tabellen*. Ulmer.

Ellenberg, H., & Leuschner, C. (2010). *Vegetation Mitteleuropas mit den Alpen: In ökologischer, dynamischer und historischer Sicht; 203 Tabellen* (Freds Büro; 6., vollst. neu bearb. und stark erw. Aufl). Ulmer.

Hudjetz, S., Lennartz, G., Krämer, K., Roß-Nickoll, M., Gergs, A., & Preuss, T. G. (2014). Modeling Wood Encroachment in Abandoned Grasslands in the Eifel National Park – Model Description and Testing. *PLOS ONE*, *9*(12), e113827. https://doi.org/10.1371/journal.pone.0113827

Siehoff, S., Lennartz, G., Heilburg, I. C., Roß-Nickoll, M., Ratte, H. T., & Preuss, T. G. (2011). Process-based modeling of grassland dynamics built on ecological indicator values for land use. *Ecological Modelling*, *222*(23), 3854–3868. https://doi.org/10.1016/j.ecolmodel.2011.10.003

8 Appendix

8.1 Rule based decision tree for model output (detailed description)

In the model, the vegetation types are derived based on the cover of the different plants prevailing in a cell.

8.1.1 Rules for woody vegetation

Two simple, logical queries are implemented in the model for Treelikes and Bushlikes:

- If > 10% cover of a species per cell, the associated vegetation type (see input table Biotope Type Properties) is appended to the existing biotope type.
- At > 50% cover of a species per cell, the existing biotope type is overwritten with the associated vegetation type.

Limitation: mixed forests/mixed tree groups cannot be output with this process at this time.

8.1.2 Rules for herbaceous vegetation

For both Grasslikes and Shrublikes, query trees (=cascades) of logical conditions must be initialized via the input table. It should be noted that 3 cascades are distinguished in the model:

- Grasslikes in the dynamic simulation
- Shrublikes in the dynamic simulation
- Grasslikes/Shrublikes together in the non-dynamic simulation

I.e. in dynamic simulations the cascade for Grasslikes is called first, followed by the cascade for Shrublikes (see also: Notes on the input table). For non-dynamic simulations there is only one (mixed) query tree for Grass- and Shrublikes.

Special feature of the Grasslike cascade in dynamic simulations: It is only invoked if the total coverage of Grasslikes is >= 50%. In addition, the proportional cover factor of the Grasslike layer is calculated here (Grasslike cover / total cover * 100). In the Grasslike cascade, this factor is multiplied by the threshold values from the input table in the cascade. This may need to be taken into account when developing new conditions.

Implemented logical conditions to determine vegetation type:

Type	Condition	Result	Dynam. Sim	Not dynam. Sim
type 0	No condition	Overwrite old with new vegetation type	[x]	[x]
type 1	All conditions with >, AND conjunction	Overwrite old with new vegetation type	[x]	[]
type 2	All conditions with <, AND conjunction	Overwrite old with new vegetation type	[x]	[]

type 3	First condition > AND second condition <	Overwrite old with new vegetation type	[x]	[]
type 4	First condition > AND NOT second condition >	Overwrite old with new vegetation type	[x]	[]
type 5	condition > AND vegetation type not already present in current name	New vegetation type is amended to old	[x]	[]
winner1	One condition: species with highest cover	Overwrite old with new vegetation type	[]	[x]
winner2	Two conditions: species with highest cover and species with second highest cover	Overwrite old with new vegetation type	[]	[x]

Type 0 does not include any conditions, here the cell is overwritten with the selected biotope type. This is suitable e.g. at the beginning or end of a sequence to specify not grab of the condition cascade with a special biotope type (e.g. N.D. in the VW project).

In type 5, next to the coverage, it is checked if the biotope type name to be added is already included in the present name. If not, it is added at the end, otherwise no action is performed. This was used e.g. in the NP project to indicate the distribution of blackberry/sloe in the name of the biotope type from a certain cover. This notation is also used for Treelikes at coverages of 10-49%. For Treelikes, however, this is implemented in the code and cannot be flexibly adjusted via an input table).

The condition classes' winner1/winner2 are only implemented for non-dynamic simulations. In this simulation method, the species with the highest and second highest potential growth are calculated and reused here in the biotope type calculation (see chapter on non-dynamic simulations, if applicable). In the condition class winner1 only one species is given, in the class winner2 two species are given, this is especially meant that if a less informative pioneer/disturbance vegetation type is most abundant, the cells can be given to the second most abundant vegetation type if necessary.

Structure of the input table for different column names:

- dynamic: Boolean, values: 0 or 1; indicates for which simulation method the condition is valid (dynamic or non-dynamic)
- biotopetype_class: 'grasslike' or 'shrublike'; must be given for dynamic simulations to determine which cascade the line belongs to
- calc_type: 'type 0', 'type 1', 'type 2', 'type 3', 'type 4', 'type 5', 'winner1', 'winner2'; types of logical linkage (see table above);
- species1, species2: Name of the species, must match the other input tables
- cover1, cover2: cover between 0-100; if empty, 0 must be specified
- biotopetype: name of the derived vegetation type, must match the specification in the other input tables

Example screenshot:

	A	B	C	D	E	F	G	H
1	dynamic	calc_type	biotopetype	species1	cover1	species2	cover2	biotopetype
2	1	type 1	grasslike	Juncus	40		0	Juef
3	1	type 1	grasslike	Epilobium	40		0	Epan
4	1	type 1	grasslike	Pteridium	40		0	Ptaq
5	1	type 1	grasslike	Calamagrost	40		0	Caep
6	1	type 1	grasslike	Deschampsia	40		0	Dece
7	1	type 1	grasslike	Rumex	10		0	Ruac
8	1	type 1	grasslike	Galeopsis	20		0	Gate
9	1	type 3	grasslike	Deschampsia	25	Deschampsia	70.1	Defl
10	1	type 1	grasslike	Deschampsia	50		0	Defl-D
11	1	type 1	grasslike	Desch_fl_Ho	50		0	Defl-D