This project has received funding from the European Union´s Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 289437

ARANGE Deliverable D5.4

Documentation of DSToolBox applications in selected case study regions

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Document Properties

Document number	FP7-289437-ARANGE / D5.4
Document title	Documentation of DSToolBox applications in selected case study regions
Author(s)	Lexer MJ, Rammer W, Schauflinger C, Irauschek F
Date of last revision	30.09.2015
Status	Final
Version	1.0
Dissemination level	PU
Relation	D5.4 is closely related to other DSToolBox deliverables, especially D4.4, D4.5.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 289437.

Keywords:

AFM ToolBox, ARANGE case study, Vulnerability assessment tool, Landscape assessment tool

Abstract:

This deliverable demonstrates the utility of the AFM ToolBox approach for real-world analysis questions. It includes two applications of tools that are part of AFM ToolBox: first, the vulnerability assessment tool is used to study the climate sensitivity of forests in the Bulgarian case study, and second, the landscape assessment tool is used to learn about the effects of management alternatives on a variety of landscape level indicators in the Austrian case study.

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1 Introduction

The ARANGE AFM ToolBox is a (mostly) web-based collection of interactive data-driven tools for data analysis and visualization as well as a “knowledge-base” covering adaptive forest management, ecosystem services and case study examples. The ToolBox is described extensively in the Deliverables D4.4 and D4.5.

This deliverable documents two applications of tools of the ARANGE ToolBox. The examples use the data of two selected ARANGE case study regions. The first application focused on the climate sensitivity of mountain forest ecosystems. In this exercise the effects of climate change on business-as-usual and alternative management were analysed from the point of view of different stakeholder (types). For this example the Bulgarian case study in the Rhodopian Mountains was used.

The second application focused on landscape level effects of different forest management alternatives, particularly analysing their influence on standing stock, species composition and protection against natural hazards. For this analysis the Austrian case study in the Montafon valley was employed.

Both application examples do not only reveal the potential of the data generated within the ARANGE project, but are also showcasing the tools itself, representing typical workflows and, in the case of the second example, touching also advanced analysis options.

2 Exercise 1: Climate sensitivity of mountain forest management

2.1 Introduction

This demonstration application of the ARANGE ToolBox explores the climate sensitivity of the ecosystems in the Bulgarian case study region Shikora Laka. The analysis approach is quantitative and is based on the simulations conducted within the ARANGE project. For the case study a number of climate change scenarios for both historic and adapted forest management strategies were simulated. The resulting alternative ecosystem trajectories were stored in the ARANGE ToolBox data base. The interactive vulnerability assessment tool from the AFM ToolBox was then used to analyse the data set applying a multi-criteria analysis approach. The main questions addressed in this application were (a) to assess the expected impacts of climate change on the provisioning of ecosystem services, and (b) to explore the potential of alternative management regimes to mitigate negative impacts. In order to gauge the sensitivity of the results to stakeholder preferences, the analysis was conducted for three stakeholder types, from timber oriented to biodiversity oriented forest managers.

2.2 Material and Methods

2.2.1 The Case study region Shiroka Laka, Rhodopes, Bulgaria

The case study region is located on the northern slopes of the Mount Perelik – the highest mountain of Western Rhodopes (South Bulgaria). The climate on its northern slopes is much less influenced by the Mediterranean Sea compared to surrounding territories, especially those located in the Greek part of the Rhodopes. Average annual precipitation (Shiroka Laka station, 1 km from the study area at 1050 m a.s.l.) for the years 1960−2010 is 850 mm, with precipitation being evenly distributed through most of the year. The driest period is August −October (165 mm precipitation). The mean annual temperature at 1050m a.s.l. for the same reference period is 6 °C, with a July mean temperature of 15.5 °C and a January mean temperature of minus 3 °C.

The case study region contains two study landscapes: the landscape 1 (coordinates 41°40′ N and 24°32′ E) includes six representative stand types (RSTs 1–6). The 736 ha landscape has an elevation range from 1000 to 1450 m a.s.l., and is characterized by a variety of site conditions and mixed forests (Table 1). Representative landscape 2 (RSTs 7–10; coordinates 41°37′N and 24°35′E) is larger (1001 ha), is dominated by mountainous and subalpine spruce forests, and includes an elevation range from 1550 to 2100 m a.s.l.

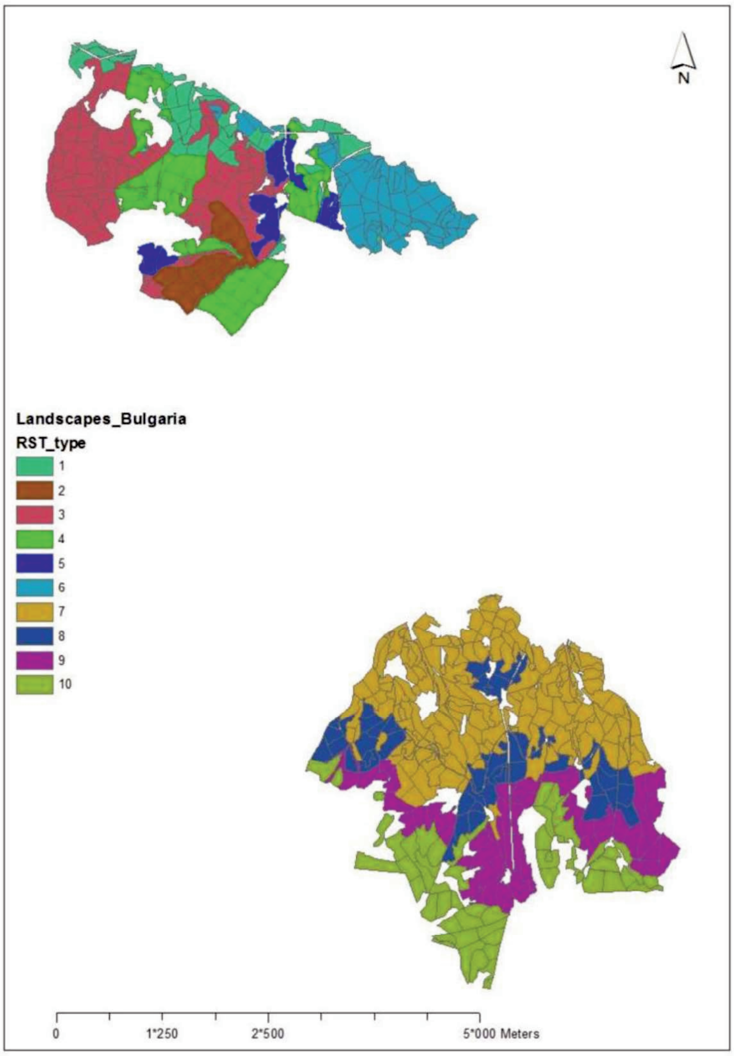

Figure 1. The Bulgarian Case Study (CSA7) in Shiroka Laka. The total area of the landscape is about 1,740 ha and comprises of the Depicted are the representative stand types on landscape 1 (top left) and landscape 2 (lower right).

2.2.1.1 Forest and site data

Table 1 gives an overview over the representative stand types (RSTs) that were used in the case study. The RSTs of landscape 1 are mainly mixed forests (mainly Beech, Black pine, Scots pine, and Spruce), while landscape 2 is by and large dominated by Norway spruce.

Table 1. Description of the RSTs of the Bulgarian case study. The representative stand types 1-6 are found on landscape 1, RSTs 7-10 are located on landscape 2 (see also Figure 1).

RST ID	RST name	Species composition	Stand development stage	Altitude [m a.s.l.]	Soil type *	Soil nutrient supply *	Soil water regime *
1.	Beech forests on mesotrophic mesic sites	European Beech (*Fagus silvatica* L.)	Pole and mature	1000–1150	Cambisol	intermediate	moderately moist
2	Black pine forests on oligotrophic xeric sites	Black pine (*Pinus nigra* Arn.)	Pole and mature	1200–1450	Rendzina	poor	dry
3	Black pine dominated forests on submesotrophic subxeric sites	Black pine, Norway spruce and European beech	Thicket, pole and mature	1200–1450	Rendzina	moderately poor	moderately dry
4	Mixed forests on Mesotrophic mesic sites	Black pine, Norway spruce and European beech	Pole and mature	1200–1400	Cambisol	intermediate	moderately moist
5	Scots pine dominated forests on submesotrophic subxeric sites	Scots pine (*Pinus sylvestris* L.), black pine, Norway spruce and European beech	Pole and mature	1100–1300	Cambisol	moderately poor	moderately dry
6	Spruce-fir forests on permesotrophic mesic sites	Norway Spruce and Silver fir (*Abies alba* Mill.)	Thicket, pole and mature	1200–1350	Cambisol	rich	moist
7	Mountainous spruce forests on permesotrophic mesic sites	Norway Spruce	Thicket, pole and mature	1550–1850	Cambisol	rich	moist
8	Mountainous spruce forests on mesotrophic mesic sites	Norway Spruce	Thicket, pole and mature	1550–1850	Cambisol	intermediate	moist
9	Subalpine spruce forests on mesotrophic mesic sites	Norway Spruce	Mature	1900–2050	Cambisol	intermediate	moist
10	Subalpine spruce forests on former pastures	Norway Spruce	Thicket and pole	1900–2100	Cambisol	rich	moist

2.2.1.2 Climate scenarios

A baseline climate (C0) and five transient climate change scenarios (C1 to C5), each consisting of a 100-year time series of daily temperature, precipitation, radiation and vapor pressure deficit, were evaluated. The baseline climate was generated from grid cell data of the E-OBS dataset and bias corrected for temperature and precipitation with empirical data from the weather station Shiroka Laka. The base climate data set was adjusted for representative site types within the case study area regarding altitude, slope and aspect.

Projected temperature and precipitation anomalies under the five climate scenarios are shown as the deviation from the baseline climate in Figure 2.

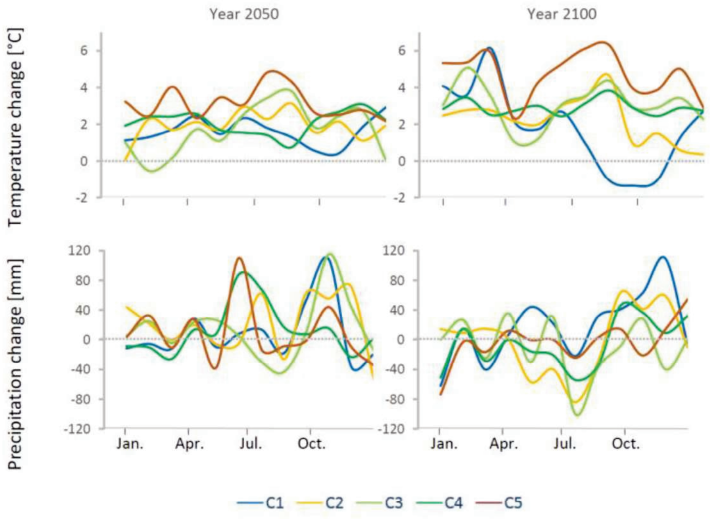

Figure 2. Deviation from the four climate change scenarios C1 – C5 compared to the baseline scenario C0.

2.2.1.3 Forest management

Table 2 gives an overview about management scenarios simulated for the Shiroka Laka case study in Bulgaria. The BAUM1 represents a "No-management" approach without active interventions, which is currently practiced in low productive black pine stands (RST 2) and high elevation spruce stands (RST9+10).The remaining stands are simulated under BAUM2,an even-aged business as usual forest management. In addition, a number of alternative managements were simulated: All stands were simulated following two different scenarios (AM2, AM3): AM2 is an irregular shelterwood system with patch sizes between 0.2 and 0.25ha, and AM3 is a group selection system. For those stands that are currently not managed, AM4 management is simulated, which follows principles of BAUM2, while the remaining stands are simulated under AM1, to achieve simulation without management interventions for all occurring stands.

Table 2. Overview about simulated management scenarios in the CSA7 case study. BAUM1 represents a No-management scenario, and BAUM2 an evenaged business as usual forest management. Alternative managements are AM1 (a no management scenario) to AM4.

Scenario	FM Code	Shape of regeneration fellings:	Rotation period [years]	Browsing pressure	Regeneration mode:
BAUM1	80_01_BAU	n.a.	n.a.	current	Natural
BAUM2	10_01_BAU	Patches (from 0.15 to 0.25ha) enlarged in 2-step shelterwood approach for 20–30 years	120–130	current	Natural
AM1	80_01_AM	n.a.	n.a.	current	Natural
AM2	70_01_AM	Few patches (from 0.15 to 0.25ha) enlarged in narrow strips in 2-step shelterwood manner for at least 80 years period.	n.a.	current	Natural
AM3	70_02_AM	Patches (from 0.05 to 0.24ha)	n.a.	current	Natural
AM4	10_01_AM	Patches (from 0.15 to 0.25ha) enlarged in 2-step shelterwood approach for 20–30 years	120–130	current	Natural

2.2.2 Data flow and data generation

The simulations were conducted using the forest model PICUS. For each RST the relevant forest management regimes were simulated, facilitating the spatially explicit and very fine grained management sub system of the forest model. The simulation runs were repeated for all five climate scenarios. In a post processing step, the outputs of the forest models were aggregated and converted to the ARANGE triplet format. Those indicators that were not directly available from PICUS were calculated externally. The resulting indicators followed the definitions given in the ARANGE Deliverable 2.2: "Models and linker functions (indicators) for ecosystem services".

The thus produced data triplet files were uploaded to the ARANGE DataBase (see ARANGE Deliverables D4.4, D1.5), which enables further analysis of the data using the tools of the ARANGE ToolBox.

2.2.3 Vulnerability tool

Assessing the vulnerability of ecosystem services under climate change calls, inter alia, for full consideration of climate variability and uncertainty, high degree of stakeholder involvement, integration of ecological and social dimensions, and a focus on adaptation strategies. This is well in line with the holistic systems view advocated by emerging management paradigms such as sustainable forest management (SFM). Several conceptual approaches to vulnerability are reported in the literature (e.g. Füssel and Klein 2006, Luers 2005). For the AFM ToolBox we have used the approach as introduced by Seidl et al. (2011). The vulnerability surface is conceptualized over a rectangular space defined by the dimensions sensitivity and exposure of the system (x-dimension) as well as the systems state regarding adaptive capacity (y-dimension) (Figure 3). Both dimensions are characterized by a set of indicators. The sensitivity indicators represent a set of ecosystem services and are directly retrieved from the data base for each available management alternative. For sensitivity indicators the difference between indicator value under baseline climate and the respective value under climate change conditions is used to assess the impacts of a changing climate. The indicators for adaptive capacity are qualitative. The user has to assess the relevance of each indicator on a scale of 3-5 predefined qualitative ordinal categories depending on the analysed problem setting (i.e. none to negligible/ moderate/ strong for "institutional support").

The two-dimensional vulnerability surface can be collapsed to a one-dimensional sensitivity index and thus the need to provide user input on adaptive capacity is dropped. To evaluate the sensitivity indicators on a dimensionless scale [0-1] thresholds for recognition and tolerance of an impact must be defined for all indicators. In the manager variant these thresholds are fixed while the analyst variant of the Vulnerability Assessment Tool allows access to advanced features of the tool where thresholds and underlying preference functions which transfer the original measurement scale of the sensitivity indicators into a dimensionless index [0-1] can be adjusted according to specific stakeholder needs. Applying additive value functions from multi-criteria methodology the indicators can be aggregated at the level of ecosystem services, or across all involved services to yield an overall "multifunctional" vulnerability index. For details we refer to Seidl et al. (2011) and Lexer and Seidl (2009).

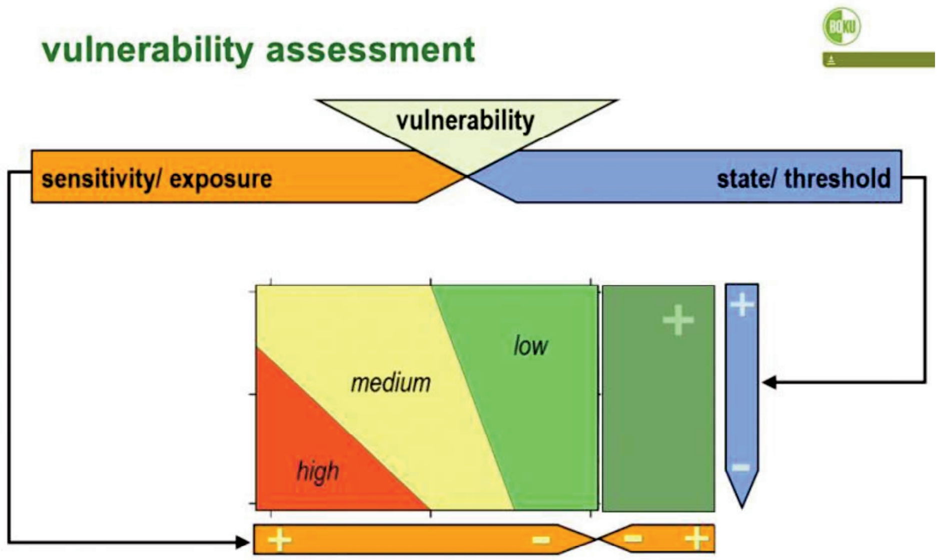

Figure 3. Conceptual representation of the vulnerability surface. The total perceived impact is aggregated from impacts on indicators that are available from forest ecosystem simulations. Values on the y-axis (adaptive capacity) are derived from user input.

The application of the vulnerability assessment tool (VA-Tool) is split into three general steps: First, the cases for analysis are selected. Secondly, the value-based preferences of the user or user group are defined, and the third step is the interactive analysis of the results.

The cases for analysis can be selected based on the available metadata in the database. For instance, a user may be interested in forest stands that are dominated by beech at sites with a poor water supply. The selection can be further explored in geographical or in biophysical space using an integrated map or via diagrams.

The available indicators in the database are grouped into ecosystem services (e.g., timber production, biodiversity, risks). In the second step, the task of the user is to select relevant ecosystem services and assign weights reflecting the relative subjective importance of the indicator/ ecosystem service.

Step three, the analysis of results, is organized along four pre-defined questions, such as "What is the predicted impact of climate change under current management (BAU – business as usual)?" or "What is the effect of switching to alternative management under climate change?". The results which are then presented show the expected impact on the provisioning of ecosystem services under climate change for the selected cases. The underlying preference information (Step 2) is used to calculate these impacts. See also the concepts sections. In the "ADVANCED" (Analyst) version the tool provides additional features to analyse individual cases.

2.2.4 Scenarios/patterns

In order to demonstrate the significant effect of stakeholder preferences on the overall analysis results, a set of contrasting stakeholder preference patterns was designed that represents a typical range of stakeholder preferences. While the specific patterns used for this exercise were not elicited from a real stakeholder interaction, the used patterns deem, based on previous experiences with stakeholder processes, as being realistic.

The following patterns were defined (Figure 4):

- Timber production: The timber oriented manager is mainly interested in timber production, expressed by a high importance of the indicators for timber increment and forest harvest.
- Multifunctionality: The managers interested in multifunctional forests attribute similar importance to all ecosystem services.
- Biodiversity and Carbon: The Biodiversity & Carbon managers have a strong emphasis on biodiversity indicators and to a lesser degree on carbon related indicators. Within the carbon indicators a strong focus is on deadwood.

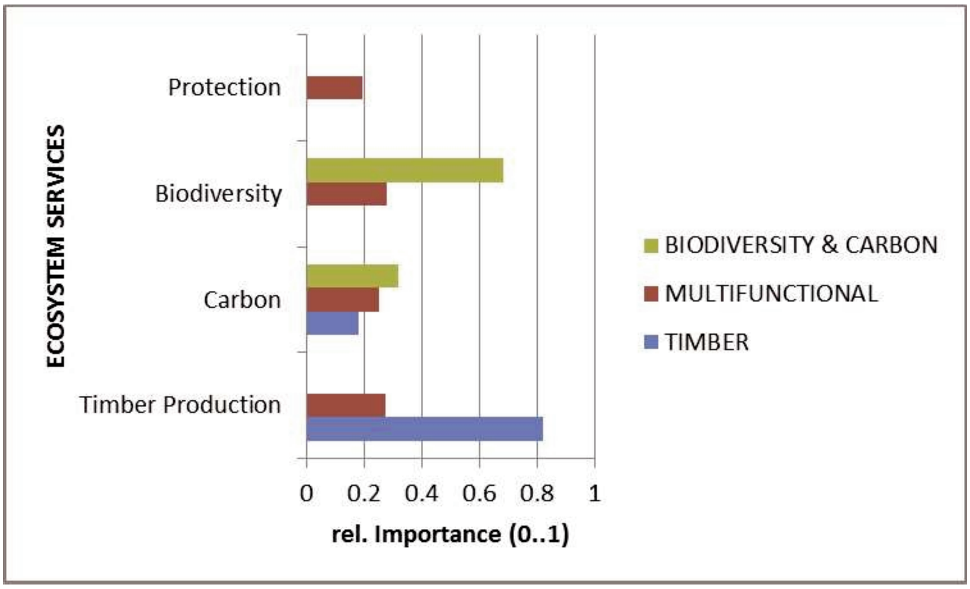

Figure 4. Weights on the level of ecosystem services for the three distinguished manager types.

2.3 Results

2.3.1 Interactive analysis

The vulnerability analysis tool has been specifically designed for interactive analysis of climate change impacts on ecosystem services provisioning, and the exploration of management effects on these impacts. It combines functions allowing a broad overview of results, and also possibilities to focus on single cases with a high level of detail. The following screen shots can only provide a limited glimpse on the user experience provided by the tool.

2.3.1.1 Selection of cases

In the first step the user selects cases from the underlying data base that he/she wants to analyse. Selection can be based on various meta data properties such as location, soil and initial stand conditions (e.g., species composition), climatic information, et cetera. This allows for example to select those stands that are on poor soils located on an elevation > 1500m and are dominated by Norway spruce. In this exercise all cases that are available in the Bulgarian case study are selected.

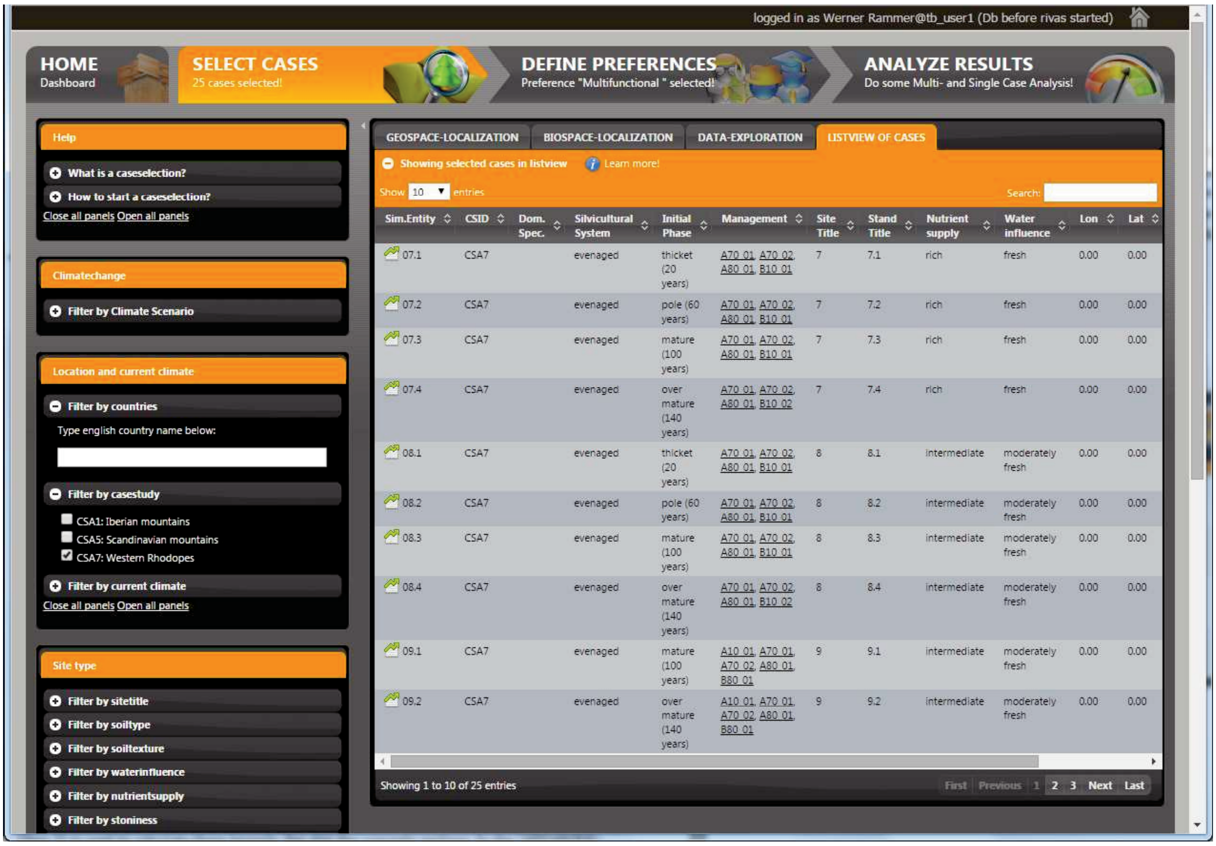

Figure 5. The selection of cases – the first step in using the vulnerability tool.

2.3.1.2 Definition of preferences

In order to being able to jointly analyse different ecosystem services (using a variety of quantitative indicators), the multi-criteria algorithm requires preference information from the user. This means, that the user defines per ecosystem service or per indicator the relative importance of the respective service/indicator. Advanced users can edit for each indicator the levels of recognition and full preference that express the sensitivity of the user to differences in a given indicator between the cases that are to be compared. The tool allows the definition of several "preference patterns" that can stand for different stakeholder groups (e.g., timber oriented vs. multifunctionality oriented forest owners).

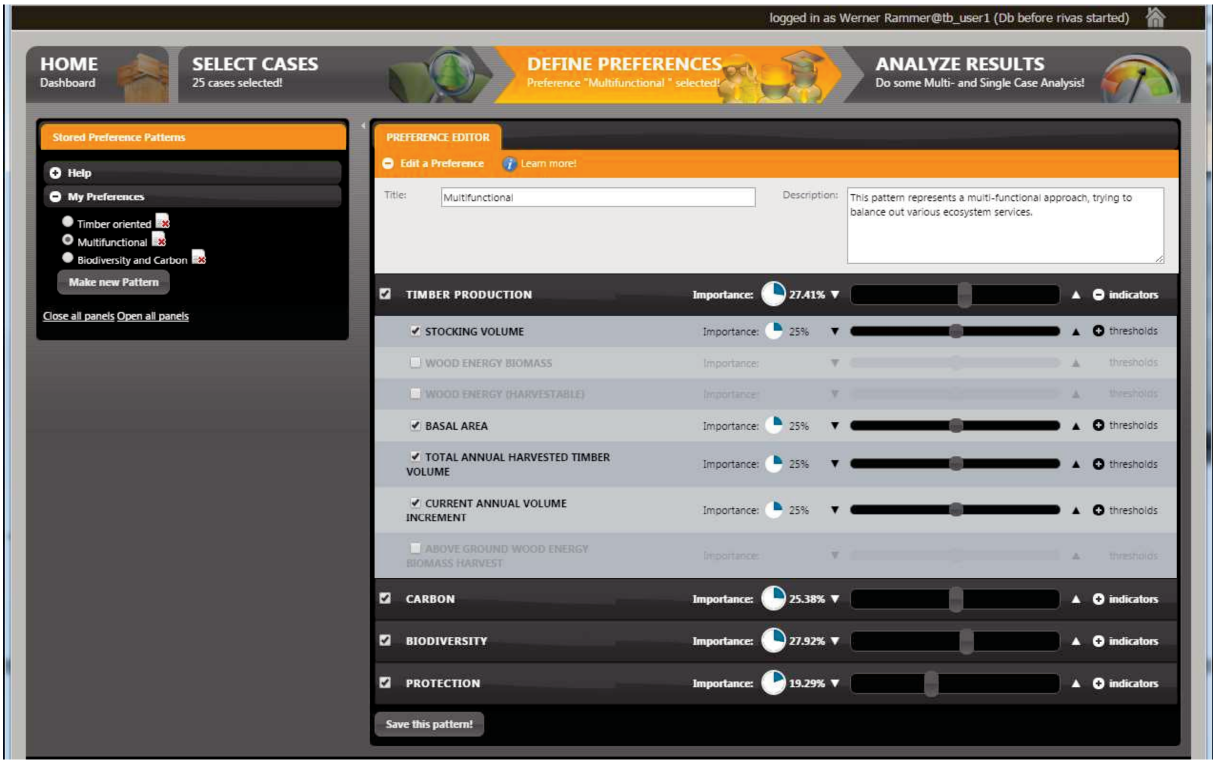

Figure 6. The definition of preference pattern is the second step in using the vulnerability assessment tool. The sliders indicate the "importance" of an ecosystem service (dark grey) / indicator (grey). The small pie-charts show the relative importance.

2.3.1.3 Analysing results

Selecting questions

The first step in the analysis section is to select the question that the tool should try to answer. The selected question determines what elements are compared within the VA-Tool (Table 3).

Table 3. Overview of analysis options in the VA-Tool. BAU=business as usual scenarios, AM=alternative management scenarios.

Question	What is compared?
Impact of climate change for BAU-management?	BAU-runs under climate change (c1-c5) are compared to runs with baseline climate (c0).
Impact of climate change for AM management?	AM-runs under climate change (c1-c5) are compared to runs with baseline climate (c0).
Impact of switching to AM (under climate change)?	AM runs are compared with runs under BAU management (for the same climate change scenario)
Impact of switching to AM when the climate does not change?	AM runs are compared with runs under BAU management (for the baseline climate)

The selection of the main analysis question can be changed any time on the "Analysis home" tab of the analysis section of the tool (Figure 1).

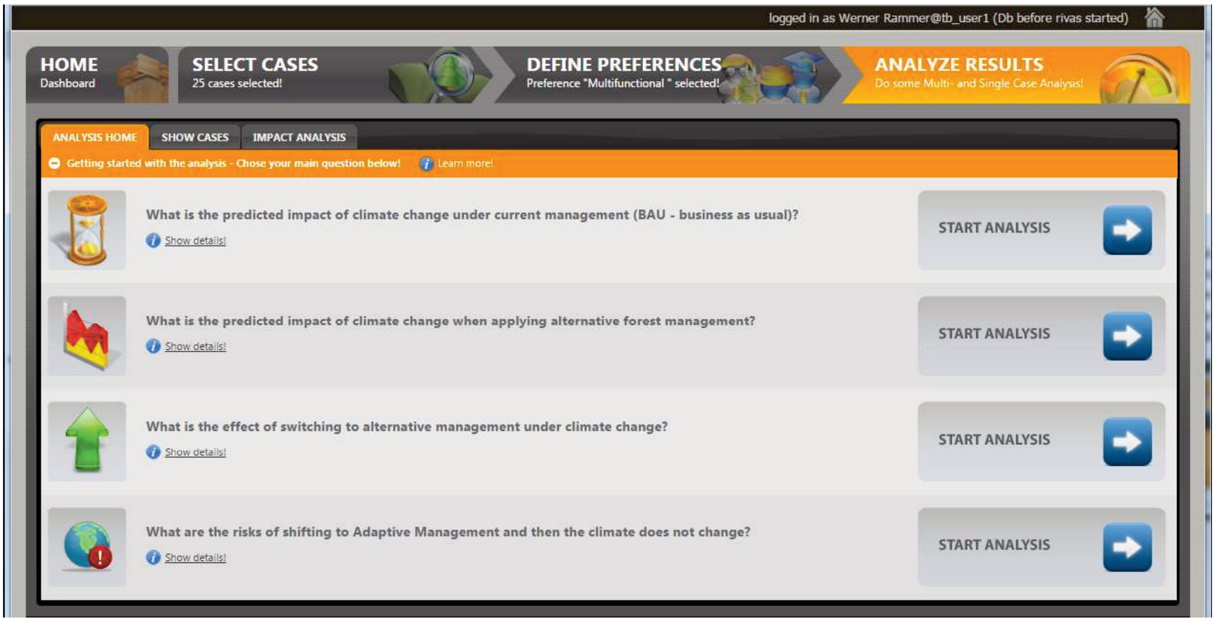

Figure 7. Selection of the analysis question.

Overview (multiple cases)

The "Impact analysis" tab is the main hub for the analysis of results. The upper part of the screen is taken up by the "multiple case" view that shows the results for all selected cases and a given combination of time period, forest management scenario and selected ecosystem service (or the total aggregated impact) (Figure 8).

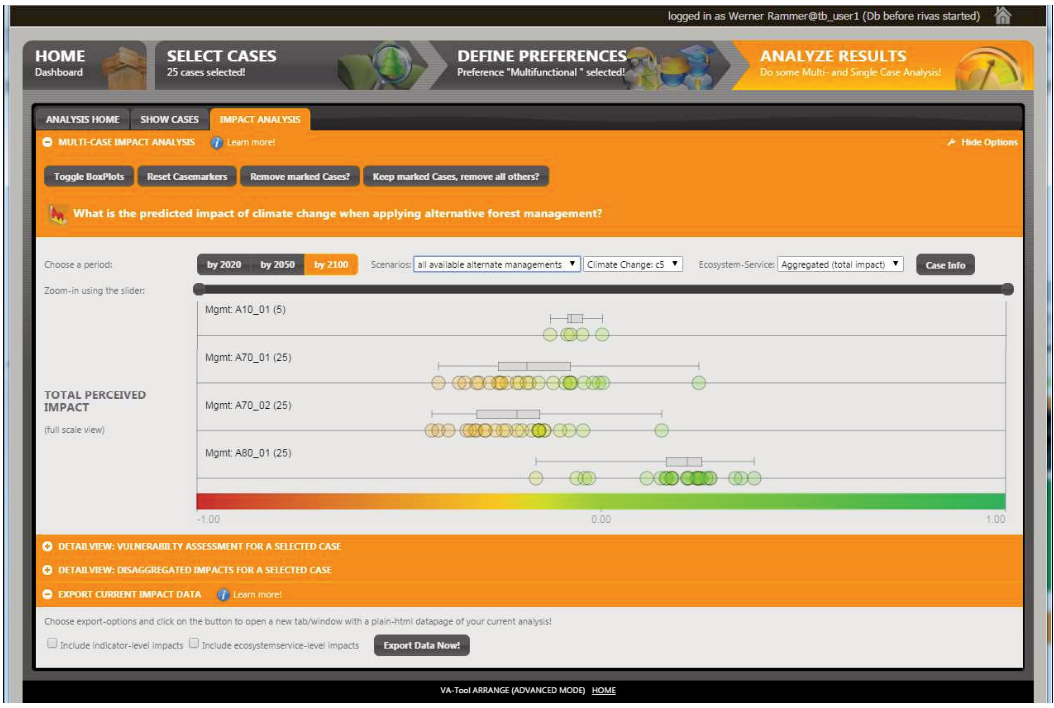

Figure 8. The multiple cases result view of the VA Tool. This example shows the expected climate change impact (aggregated over all ecosystem services) of alternative management scenarios for the time period 2051-2100 for the climate scenario c5. Each dot is a simulated case (RST).

The user has various options to fine-tune the central multiple-case diagram (Figure 9): he/she can select the time period (short-term, mid-term, long-term perspective), select the management scenario, the climate scenario, and can select a specific ecosystem service (e.g., timber production), or the total aggregated impact. The diagram shows the individual cases as semi-transparent dots. The impact is shown on a range from -1 to +1, where +1 means that the shown alternative is for every indicator fully preferable over the compared alternative (which depends on the selected question). A value of 0 means either that the compared alternatives show no recognizable differences (or that the differences of the indicators cancel each other out). The semi-transparency of the dots allows a very intuitive understanding of the distribution of the data, which is further hinted at by the box-plots above the dots. Whenever the user changes the selection (e.g., by switching between time horizons), then dots follow animated, given a clear indication on trends and behavior over time.

Figure 9. Magnified image of the central diagram. See text for further explanations.

Detail view

Whenever a single case is selected (by clicking on one of the cases), additional analysis options for single cases are available (Figure 10). Figure 10b shows the "vulnerability surface" (see chapter 2.2.3), combining the "impact" on the x-axis with the "adaptive capacity" on the y-axis. The latter is assessed by a small "questionnaire" above the diagram. The lower part of the screen (Figure 10c) is occupied by additional single-case analysis diagrams. These diagrams show a profile that of impacts over ecosystem services (or on indicator level) for several periods (shown), or for several management scenarios, or climate change scenarios (not shown).

a)

b)

c)

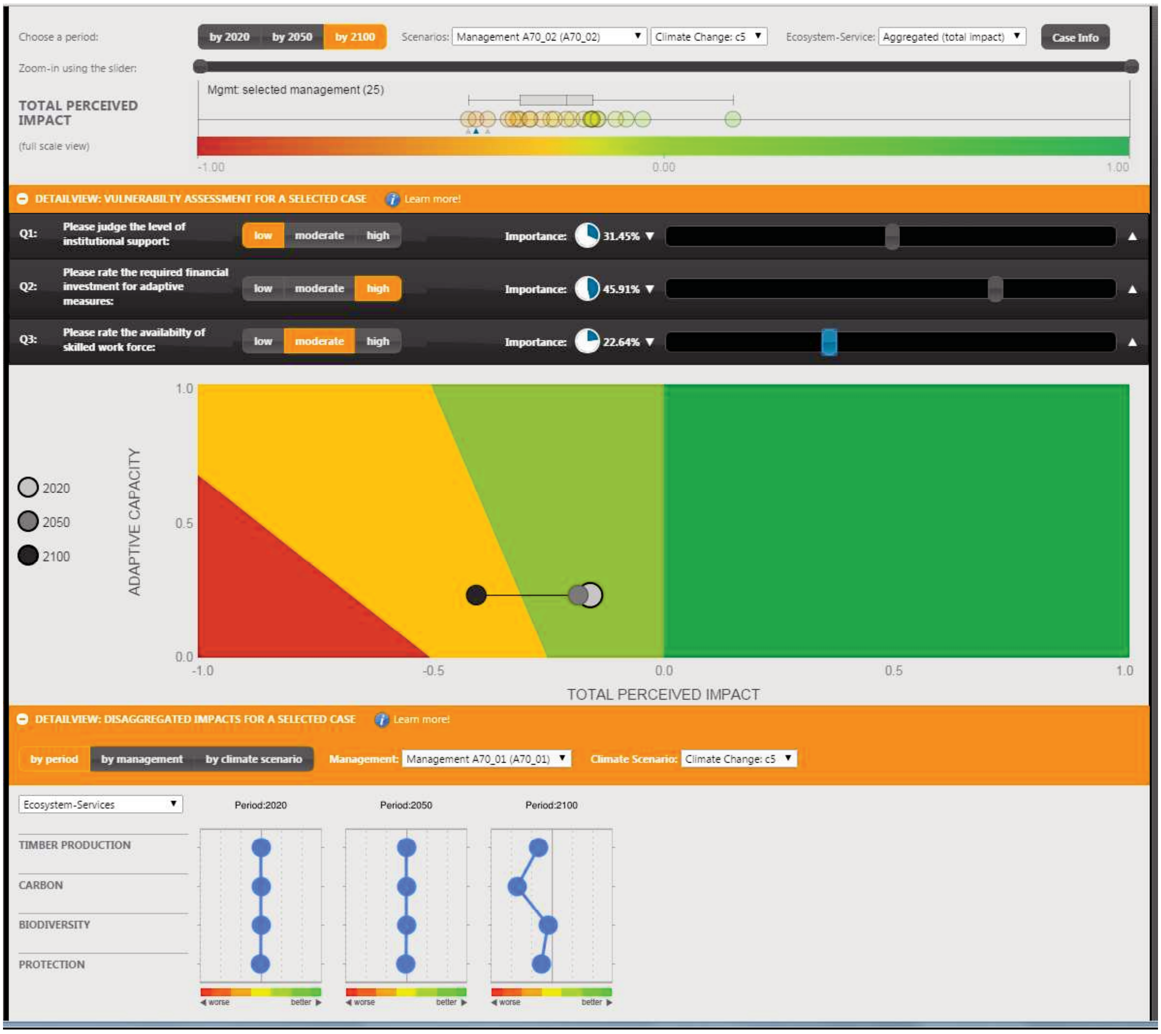

Figure 10. The detail view of the VA-Tool. The screen is split in three distinct areas: a) is the multiple case view, b) the vulnerability surface view for a single case, and c) are detailed diagrams for a single case.

Further options for analysis are available: the tool allows inspecting the underlying data for each case (i.e., time series of simulated data such as stocking timber), and also the export of the numerical results of the analysis for subsequent processing in spreadsheet programs or statistical software packages.

2.3.2 Sensitivity to climate change of current management practices

The previous section covered in some detail the available features of the user interface of the vulnerability tool. This section focuses again more on the actual results for the given exercise. All data shown below were generated with the VA Tool.

An obvious question is the expected impact of climate change on ecosystem services when the forest management is not changed, i.e. a business as usual approach (BAU) is continued. Figure 11 shows the expected climate change impact for the different manager types. Quite apparently, impacts are predominantly negative and the magnitude of changed increases with time. The timber-oriented manager suffers for the period 2050-2100 the largest negative impact (mean: -0.12, multifunctional: -0.11, biodiversity: -0.06).

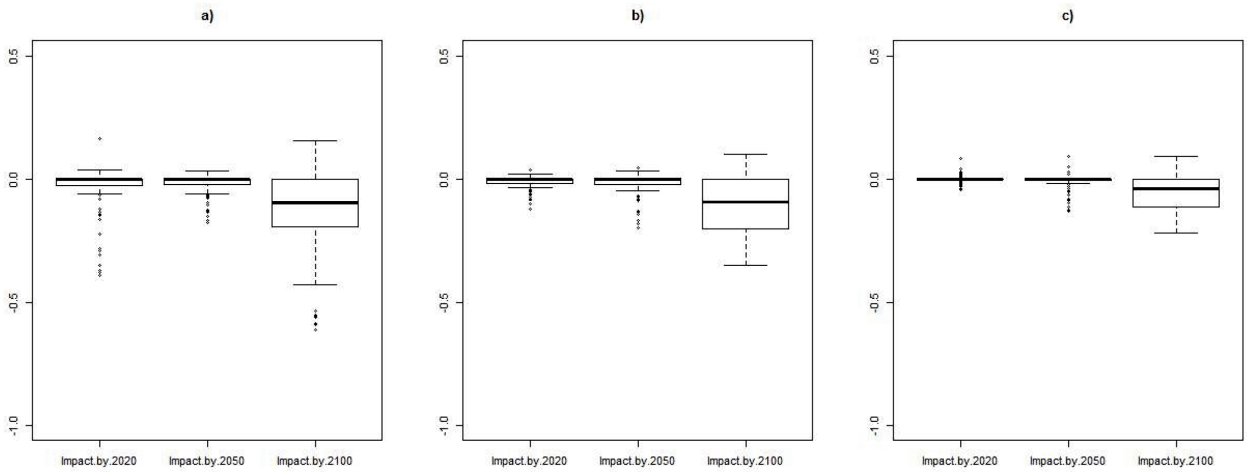

Figure 11. Impact of climate change for three time periods for BAU scenarios (all climate scenarios) for a) the timber oriented, b) the multifunctional, and c) the biodiversity oriented manager.

Given the large uncertainties linked to the unknown climate future, it is informative to scrutinize the results of the analysis with regard to the climate scenario assumptions (Figure 2). As shown in Figure 12, the results vary considerably with the assumed climate. The largest negative impacts are yielded by the scenarios c3 and c5, which are either the warmest (c5), or show a strong decrease in precipitation in the summer month (c3).

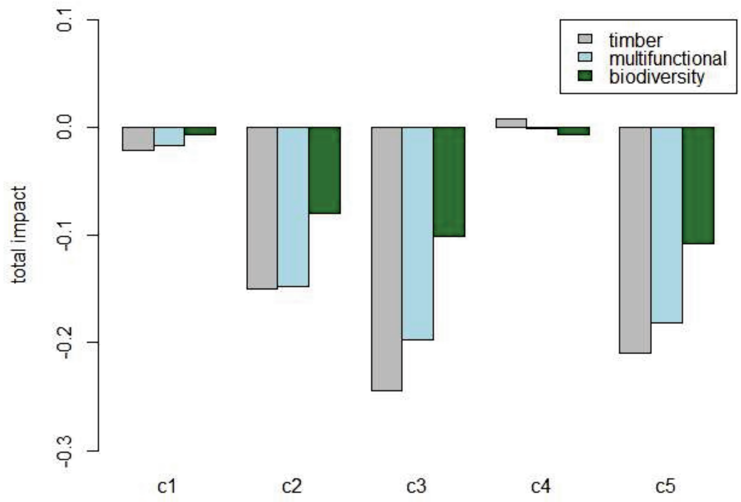

Figure 12. Sensitivity of the total impact for the period 2051-2100 to the climate scenario. Simulations using the scenarios c3 and c5 show consistently the largest negative impacts over all preference types.

2.3.3 Effect of switching to alternative management

The predominantly negative effects of climate change (shown in the previous section) lead to the question, whether alternative management approaches are able to alleviate the negative impacts of climate change.

Figure 13 provides some insight into this question: shown is the impact of two alternative management scenarios (AM2 and AM3 in Table 2), for the period 2051-2100: interestingly, the expected impact of switching forest management depends strongly on the preference pattern: while the biodiversity oriented manager finds positive impacts for both alternative managements, both the timber-oriented and the multifunctionality-oriented manager would strongly prefer AM2 (A70_01) over AM3 (A70_02).

The design of both AM2 and AM3 tried to integrate requirements for management according to Natura 2000, by setting aside 10% of the stand area in patches of 0.2ha size, which remains permanently uncut. Accordingly these old-growth-patches result in more suitable stand structures under both AM-scenarios.

Both AM2 and AM3 reduce rotation periods compared to BAU management from 120 to 100 years and have the goal of achieving unevenaged stand structure. Main differences between AM2 and AM3 are harvesting interval and intensities: AM3 has return intervals of 10 years and per entry initially harvests 20% which decreases down to 5%. AM4 undergoes harvests each 20 years and has constant area undergoing final harvesting operations throughout the 100 years of simulation (up to 20%). This explains why a timber oriented manager would prefer scenario AM2 if only period 2051-2100 is considered. AM2, as a 2 step shelterwood management approach, furthermore provides a more inhomogeneous stand structure with constant intensity of management activities, favouring this scenario over AM3 for the multifunctionality-oriented manager.

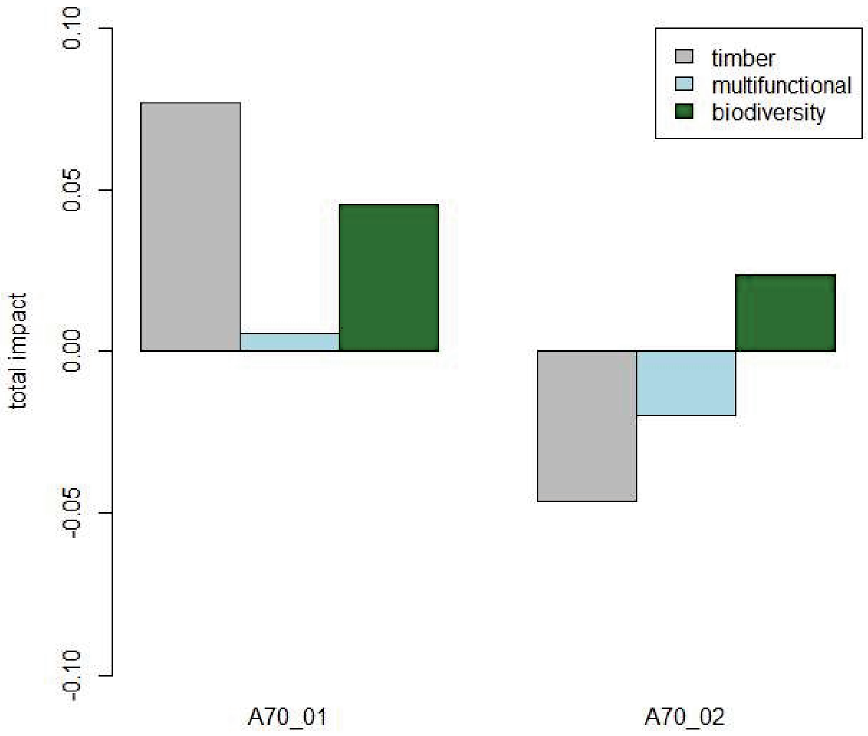

Figure 13. Effect of alternative management (compared to BAU) under the climate change assumption for the last period of the century (2051-2100) and for all climate change scenarios. A70_01=AM2, A70_02=AM3.

The effect of switching to alternative management scenarios was also dependent on the assumed climate scenario (

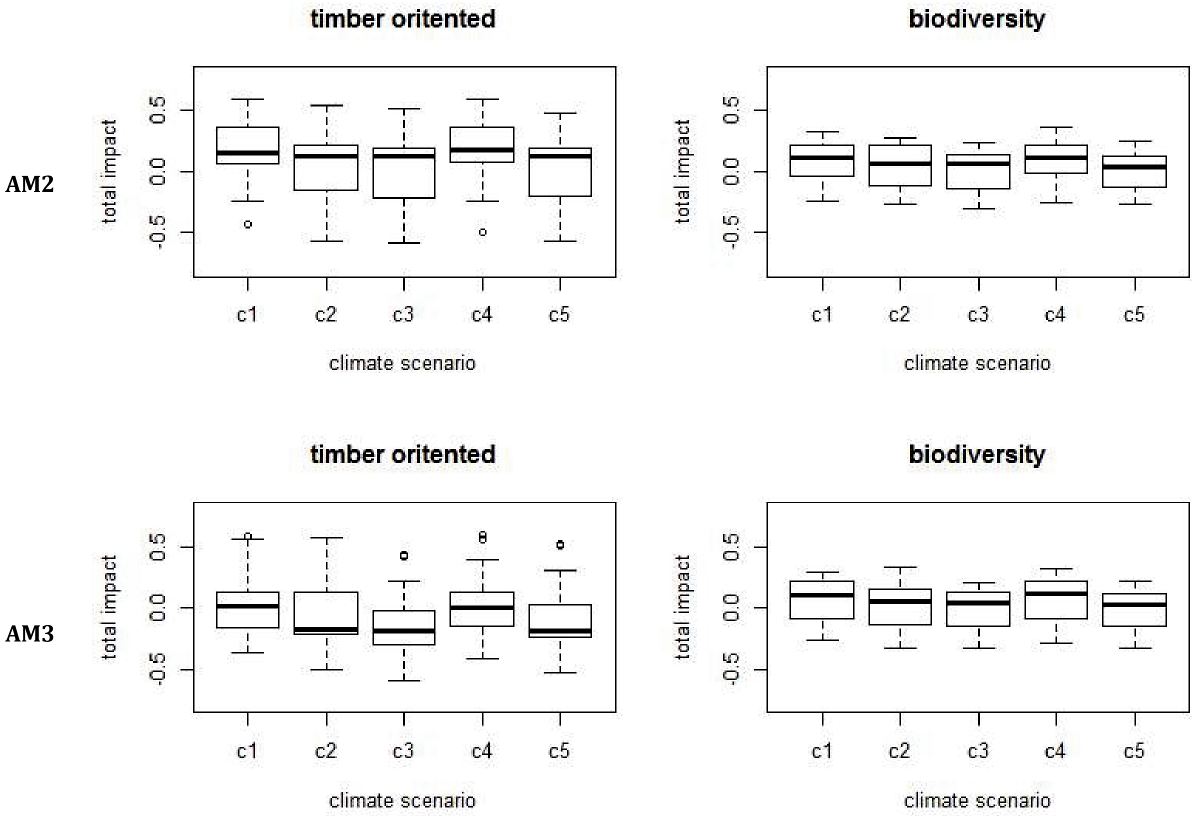

Figure 14). Shown is the expected change for the contrasting preference types “timber oriented” and “biodiversity & carbon oriented”. The differences between AM2 and AM3 were most pronounced for the timber oriented manager: while AM2 was positive for all climate scenarios, AM3 had clear negative impacts especially for the most severe climate change scenarios c3 and c5. One reason for this behavior could be increased resilience of stands, because the shelterwood management system AM2 harvests patches in two successive cuttings (seeding cut removing 60% of volume, and final cut removing the residual overwood 20 years after the seeding cut). Reduced density in forest areas undergoing the seeding-cut may lead to reduced mortality during drought periods, occurring under c3 and c5.

For the climate scenarios c1 and c4 switching to AM had the most positive impact for both analyzed manager types.

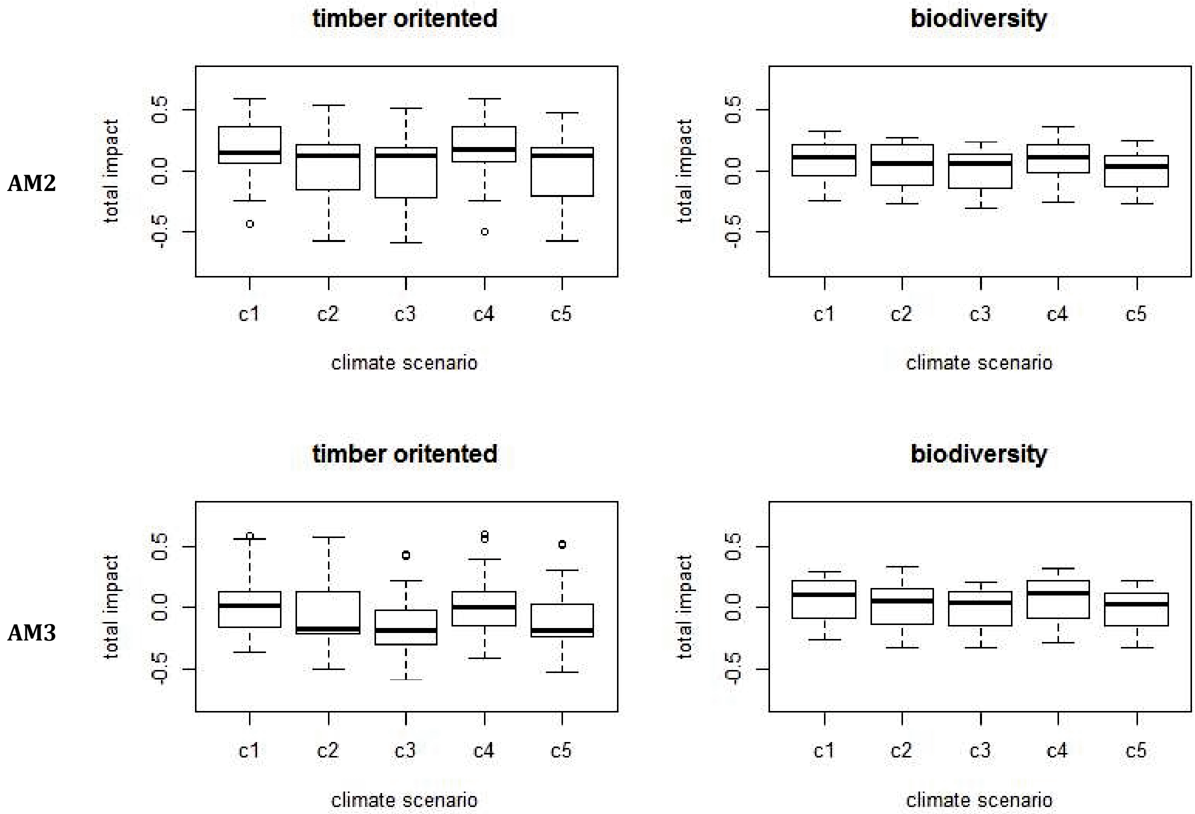

Figure 14. Climate scenario effect of switching to the alternative managements AM2 (upper row) and AM3 (lower row) and for the timber oriented (left) and biodiversity oriented manager (right). Data is shown for the period 2051-2100.

2.4 Conclusions

This application of the vulnerability tool of the AFM ToolBox demonstrated the suitability of the ToolBox approach for forest management decision support. The tool provides quick and intuitive insights in potential patters hidden in the large amount of data, but includes the necessary options for going deeper into the analysis of single cases. It has to be noted, though, that such an analysis scheme requires in the first place the (quantitative) projections of forest development that is derived from simulation modelling, i.e. the multi criteria analysis is also limited to the range of climate change and management options that can be simulated with forest models. In this respect, the available tools for data management and the compatibility of the ToolBox approach with a variety of ecosystem models (as successfully demonstrated within the ARANGE project) alleviates the necessary efforts of raw data production.

This exercise reveals interesting insights into expected climate change impacts and adaptation potential for the forests in the Rhodopian Mountains. Climate change is projected to have generally negative impacts on the forests of this region. Particularly negative impacts can be expected when precipitation – which already is a limiting factor in the region – is further decreased. Switching to alternative forest management has a clear potential to reduce the negative impacts - at least as far as the biodiversity and carbon oriented forest manager is concerned. From a timber oriented point of view, however, one alternative forest management (AM2) is more preferable as the BAU approach, while the other management alterative (AM3) is even less attractive than BAU. These results clearly demonstrate the importance of including stakeholders and stakeholder preferences when investigating long-term ecosystem service provisioning in strongly managed ecosystems.

3 Exercise 2: Effect of management scenarios on landscape scale indicators

3.1 Introduction

3.2 The case study region Montafon, Eastern Alps, Austria

The study area is located in the Province of Vorarlberg in Austria, close to the Swiss border in the Rellstal valley (N 47.08°, E 9.82°). Landowner is the Stand Montafon Forstfonds (SMF), which owns about 6.500 ha forest land in total. Depending on bedrock the soils are rendzinas, rankers, podzols and rich cambisols. The terrain is steep, with slope angles from 30-45°, which makes forest management difficult and underlines the protective function against gravitational natural hazards (snow avalanches, rockfall, landslides and erosion). The case study area is a catchment of 250ha total area (234 ha forest area) at altitudes between 1060 m and 1800 m (a.s.l.). Forest management has been practiced since more than 500 years. The current management objectives of the owner are income generation from timber production and securing sustainable protection against snow avalanches and landslides. In addition, major shares of the forest area are under Natura 2000 regulations with a focus on bird habitat protection for Black Woodpecker (*Dryocopus maritimus*) and Three-toed Woodpecker (*Picoides tridactylus*).

3.2.1 Forest

The forests in the case study area are dominated by Norway spruce (*Picea abies*, 96% of growing stock) with minor shares of silver fir (*Abies alba*, 3%), European beech (*Fagus sylvatica*, 1.6 %) and other broadleaved species (e.g., *Acer pseudoplatanus, Fraxinus excelsior*, 1%). Historic forest management has led to mostly uneven-aged patchy stand structures with a considerable share of large old trees. The current mean standing stock in the case study area is 455 m^3 ha^{-1}. Game management has favored high densities of ungulates and consequently the browsing pressure on Silver fir and broadleaves is high.

3.2.2 Climate Scenarios

A baseline climate represented by the historic climate of the period 1961-1990 (c0) and five transient climate change scenarios (c1 to c5) based on regional simulations from the ENSEMBLES project (www.ensembleseu.org) were prepared for the model simulations. The baseline climate was generated from available daily instrumental data of the historical period 1961-1990 from the meteorological station Feldkirch (9.6° long, 47.27° lat). Climates where adjusted for representative site types within the case study area regarding altitude, slope and aspect using the algorithms in Thornton and Running (1999). Mean historic climate at 1000 m a.s.l. is characterized by 6.2°C mean annual temperature and 1150mm annual precipitation with

840mm during summer season from May to September. In all climate change scenarios temperature increased (+2.6°C in c1, +3.0°C in c2, +3.5°C in c3, +4.3°C in c4, +6.0°C in c5). In all climate change scenarios except c1 there was a relative shift of precipitation from summer (May-September) to winter with a reduction in summer by -7% in c2, -32% in c3, -19% in c4 and -14% in c5.

3.2.3 Forest management

The currently practiced management regime (BAU) is aiming at uneven-aged, structurally diverse forests. Due to steep terrain, timber harvesting is bound to motor-manual felling, delimbing and cutting the stems to length. The logs are extracted to forest roads at the base of the slopes by cable yarding with skyline systems. Current management features irregular patch cuts along the skyline track. The skyline track of 5m width is cleared of all trees (>10m height). Size and shape of the patches is variable with a typical maximum width of 50m (i.e. maximum lateral skidding distance) and a mean length of 40-50m along the skyline (compare Figure 15). All trees (>20cm DBH) on the patches are harvested. No tending and thinning operations are carried out in the rejuvenated patches and current management relies fully on natural regeneration. The general silvicultural aim is to maintain and further develop the heterogeneous uneven-aged forest structure in order to guarantee high protective functionality while generating income from high value timber production. Overall, the implemented BAU management results in a complete area turnover of the case study catchment of 250 years. The influence of high ungulate densities on regeneration was considered via species specific annual browsing probabilities (Abies alba seedlings 0.78, Fraxinus excelsior 1.0, Acer pseudoplatanus 0.51 and Fagus sylvatica 0.70). Tree mortality due to bark beetle infestations was calculated by the PICUS bark beetle disturbance module.

To test adaptation of current management regime alternative scenarios where designed utilizing (i) different (i) different harvesting patterns (see Fig 1), (ii) shortened rotation period (150 years) by reducing the return reducing the return interval to a skyline working field and (iii) artificial regeneration in harvested areas. harvested areas. Additionally, one scenario (AM1) was simulated without management interventions and interventions and scenario AM13 was mimicked sanitary management, by annually cutting down trees died down trees died by European spruce bark beetle (*ips typographus*) and subsequently planting of Acer Acer pseudoplatanus. In this scenario browsing probabilities were reduced to 50% of current values. A values. A tabular overview of AMs is given in Table 4. The management options simulated in the case study region comprised of one BAU scenario (business as usual) and 14 alternative management scenarios.

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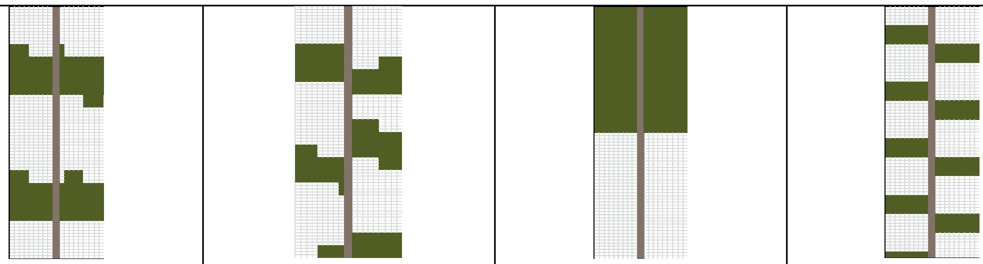

irregular big patches size 1500m^2 (BAU)	Irregular small patches size 600m^2	strip cuts size 5000m^2	slit cuts size 333m^2

Figure 15 Different harvesting patterns along a skyline track. Green area depicts harvested area per regeneration cut. Grey area depicts skyline track

Table 4. The management options simulated in the case study region comprised of one BAU scenario (business as usual) and 14 alternative management scenarios.

Scenario	Shape of regeneration fellings:	Rotation period [years]	Browsing pressure	Regeneration mode: when planted shares in 1/10 area
BAU	Irregular big patches	250	current	Natural
AM1	n.a.	n.a.	current	Natural
AM2	Irregular big patches	150	current	Natural
AM3	Strip cut	250	current	spruce
AM4	Strip cut	250	current	RSTs <1500m a.s.l.: 4 spruce, 3 larix, 3 acer RSTs >1500m a.s.l.: 4 spruce, 4 larix, 2 acer
AM5	Irregular big patches	250	current	RSTs <1500m a.s.l.: 2 spruce, 3 larix, 4 acer, 1 fir RSTs >1500m a.s.l.: 4 spruce, 2 larix, 2 acer, 2 fir
AM6	Irregular small patches	250	current	Natural
AM7	Slit	250	current	Natural
AM8	Strip cut	150	current	10 spruce
AM9	Strip cut	150	current	RSTs <1500m a.s.l.: 4 spruce, 3 larix, 3 acer RSTs >1500m a.s.l.: 4 spruce, 4 larix, 2 acer
AM10	Irregular big patches	150	current	RSTs <1500m a.s.l.: 2 spruce, 3 larix, 4 acer, 1 fir RSTs >1500m a.s.l.: 4 spruce, 2 larix, 2 acer, 2 fir
AM11	Irregular small patches	150	current	Natural
AM12	Slit	150	current	Natural
AM13	only sanitary fellings	n.a.	50 %	10 acer
AM14	Strip cut	250	Current	natural

3.3 Analysis

3.3.1 Data retrieval

The data for this application exercise is stored in the ARANGE ToolBox data base. The data was originally generated by simulations with the PICUS forest ecosystem model. The output data was then transformed into the common file format used in ARANGE, and uploaded to the ARANGE ToolBox database. For this application the complete data packages was downloaded from the ARANGE ToolBox DataBase.

3.3.2 Landscape assessment tool

The goal of the landscape assessment tool (LAT) is to provide the means landscape level analysis, for instance regarding the habitat quality or protective functions of forested landscapes. The tool specifically addresses indicators that require a spatial scale well beyond the stand scale, which are typically out of scope of stand-level simulation tools. LAT includes forest structures not by running actual forest simulations on the landscape scale, but rather by putting together stand level results on a common landscape. The LAT tool (and all its sub-tools) is covered in detail in the ARANGE deliverable D4.5.

For this application, the “Landscape level analysis” tool is used, which allows the joint analysis of data available in the ARANGE file triplet format on landscape scale.

The LA Tool is a software running on the local PC and not as a web tool, which is due to its powerful 3d visualization and its built-in high-performance calculation algorithms. Since a more technical description (also regarding the configuration) is given in D4.5, we show here only briefly the main steps of the analysis process.

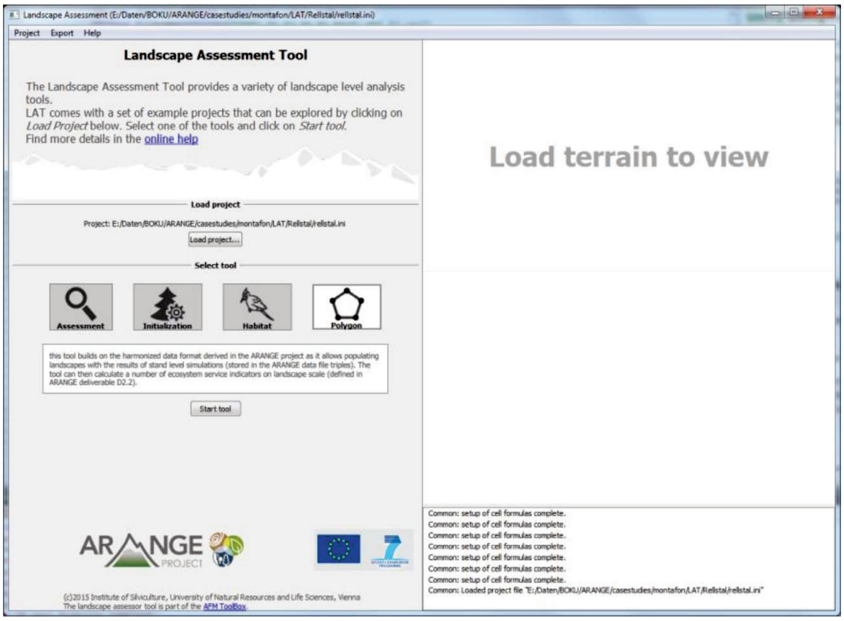

Figure 16. The start screen of the LA Tool. After loading a project file, one of the available tools can be started.

The software can be downloaded from the AFM ToolBox website and needs to be installed on the client PC. A downloaded version runs on Microsoft Windows only; additional version for Mac and Linux can be created on demand. The first step after starting the software is loading a project file (see Deliverable D4.5 for details) and then engaging one of the tools (Figure 16).

The main screen of the "Landscape level analysis" tool is depicted in Figure 17. Table 5 provides an overview over the UI elements of the software.

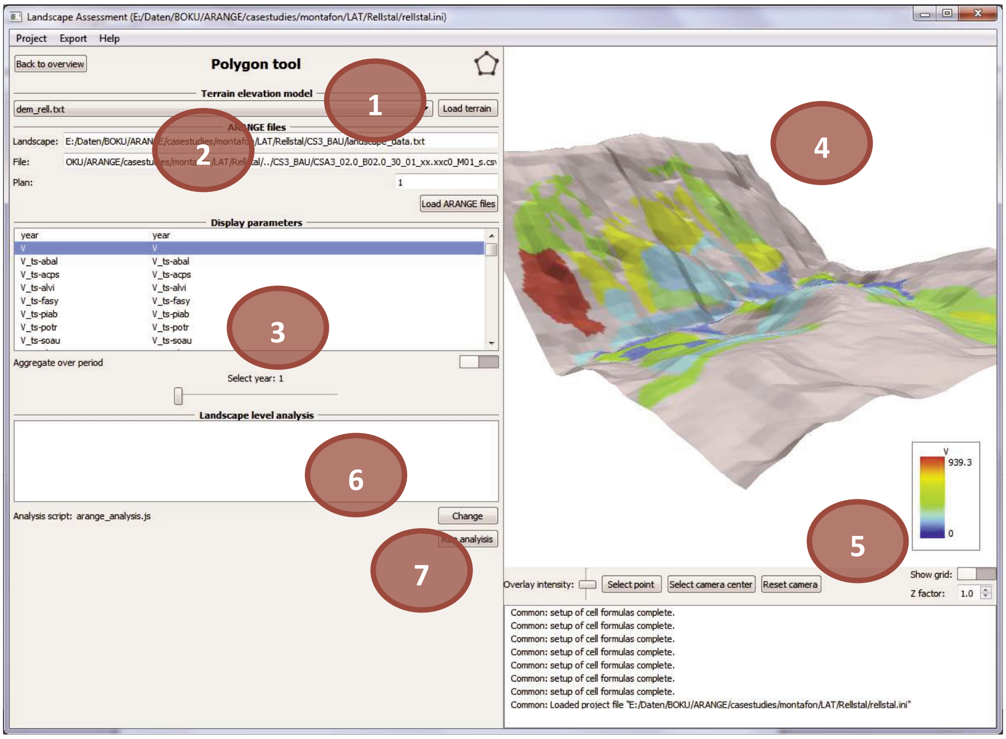

Figure 17. Main screen of the Landscape level analysis tool. The main UI options are related to which data to load (1, 2), which data to view (3, 4, 5), and additional analysis based on Javascript (6,7). See also the main text.

Table 5. UI options of the Landscape level analysis tool. Compare Figure 17.

Code	Description
1	Select a digital elevation model (if available) or a flat terrain.
2	The path to the landscape-description file, and the file mask for the RST-file triplets. The landscape-description file is a table linking the polygon-ids of the GIS stand-grid to RSTs (representative stand types) as defined in the ARANGE project. The mask for the file triplets is an easy way to alter the climate and management scenario that should be loaded. Facilitating the file mask and the landscape-description file, the tool can load for each polygon the correct data file.
3	The table view lists the content of the data files (i.e., the available data columns). Clicking on a column updates the 3d landscape view (4). Using the slider below the table view, the time code of the data to be shown can be selected (i.e., the year). When the "Aggregate over period" option is selected, aggregates over a user-

	defined period are drawn.
4	3d landscape view. Numerical data values are (see 3) automatically mapped to colors and drawn on the landscape.
5	Options to fine-tune the 3d visualization. For example, the center point of the view can be changed, or a z-factor amplifying elevation differences can be selected.
6	Output area of user-defined analysis scripts.
7	Buttons for selecting user-defined analysis scripts and for running the analysis. LAT supports Javascript scripts and provides an API for targeted data access.

For this exercise we focused on the effect of forest management scenarios on landscape level state indicators. In order to gauge the effect of climate change on the performance of forest management strategies, all analysis was done for the baseline climate (c0) and the most extreme climate scenario within the ARANGE project (c5). See also section 3.2.2.

If, as in this case, a large number of scenario options and indicators are to be analysed, automation in form of Javascript code can ease the analysis process enormously. For instance, the semi-automated analysis was iterating over only few steps: First, management and climate scenario, which should be loaded, were selected (by modifying the triplet-file mask). Then the data was loaded, and a custom automation script was executed. The Javascript code processed all indicators (for all years) and wrote the output to a CSV file for further processing (in Excel or R).

To further demonstrate the potential of extending the analysis capabilities with user defined scripts, an assessment of the effect of random sampling on landscape level aggregates was implemented in Javascript and performed: 10 replicates of a random point sampling (with 200 points for each replicate) were conducted. For each replicate, landscape aggregates were calculated for all sample points that fell into a valid stand polygon on the landscape (the random pattern remained the same within a replicate). The resulting landscape level aggregates (standing volumes, protection indicators) were compared.

3.4 Results

3.4.1 Data retrieval

The ARANGE data base serves also as an efficient means for data exchange between the partners of the ARANGE project (see also Deliverable D4.4). Access to raw data is, however, restricted and valid user credentials have been distributed within the participants of the ARANGE project. Figure 18 shows the process of downloading the raw data file triplets (for a specific case study region and a particular forest model). The download consists of a ZIP file containing the data triplet files.

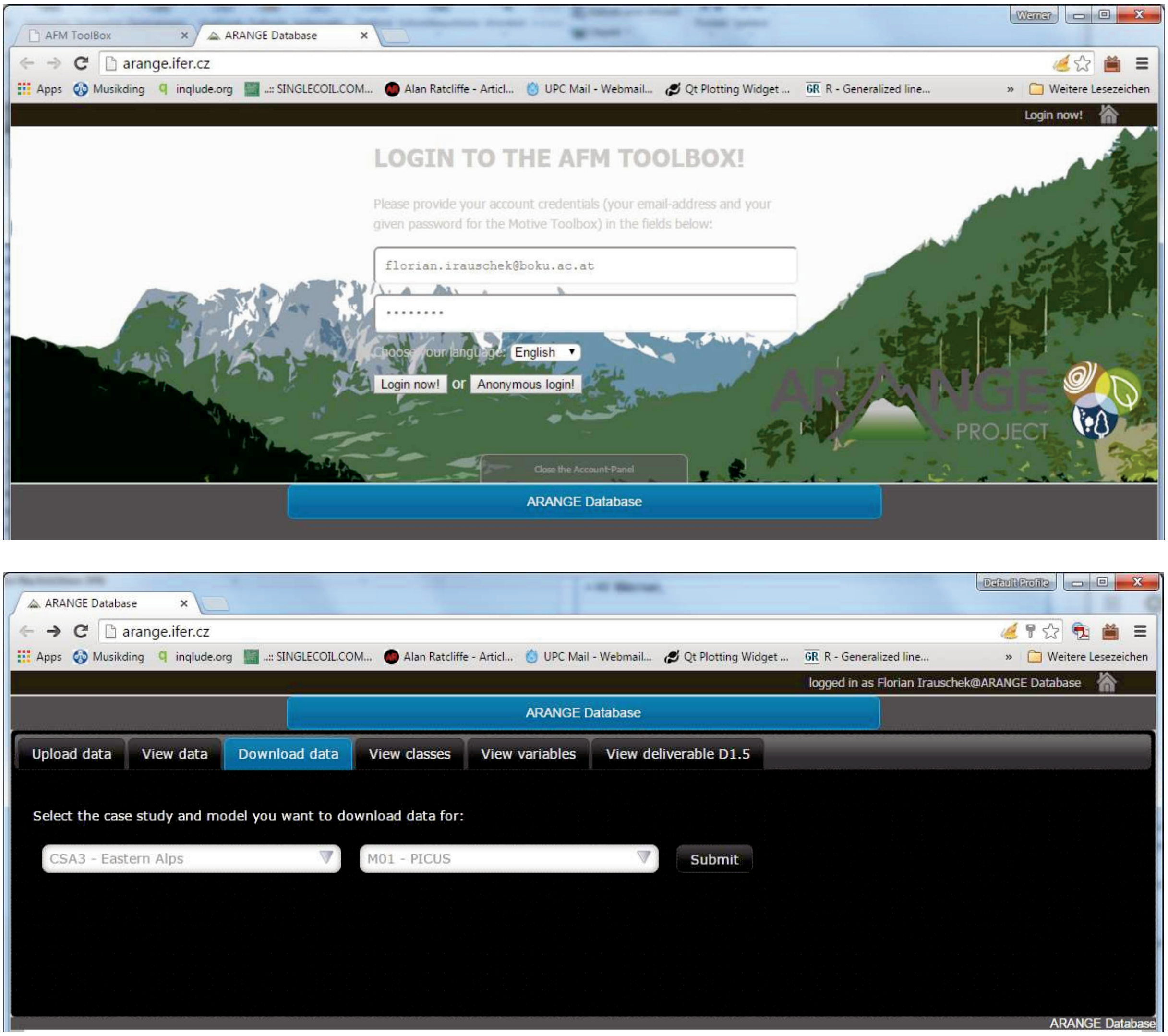

Figure 18. Retrieving data from the ARANGE database.

The data thus retrieved from the ARANGE data base can then be used for further analysis, either by working directly with the raw-data (e.g. using a spreadsheet software or a statistics software package), or by using tools capable of directly digesting ARANGE data triplets such as the LA tool (which was used in this exercise). Since raw data without sufficient meta data is only of limited use, detailed description of the indicators is very important. In case of the ARANGE data triplets this information is provided in ARANGE deliverables (mainly D1.5: "ARANGE DataBase: Data model and technical implementation of the ARANGE DataBase", and D1.2: "Catalogue of harmonized environmental variables").

3.4.2 Automation script

The data processing/ automation script that was used for the analysis is given in Box 1. It iterates over all the available indicators and all points in time and calculates then landscape level averages (weighted with the polygon area). The results are written to a CSV file for further analysis.

Box 1. Javascript function to automate the processing of landscape level analysis.

```
function landscape_aggregate() {
        var myres = data.params() ;
        for (var year = 1; year < 100; ++year) {
                var myline=year;
                for (var p=1;p<data.params().length;++p) {
                        var param = data.params()[p];
                        var weighted_sum = 0;
                        var vs = data.get(param, year);
                        var total_area = 0;
                        for (var poly_idx = 0; poly_idx < vs.length; poly_idx++) {
                                var x = vs[poly_idx];

                                var area = data.getArea(data.getPolyId(poly_idx));
                                total_area += area;

                                weighted_sum += x * area;
                        }
                        myline = myline + ", " + (weighted_sum/total_area).toFixed(5);
                }
                myres = myres + "\n" + myline;
        }
        results.saveToFile("e:/temp/test.txt", myres);
}
```

3.4.3 Standing volume and species composition

The simulation of the various forest management scenarios over 100 years (2000-2100) led to distinctly different levels of standing volume at the end of the century. Figure 19 shows the mean standing volume (m^3/ha) in the period 2070-2100. AM1 and AM13 (no management, and only sanitary fellings, respectively) had the highest standing volume.

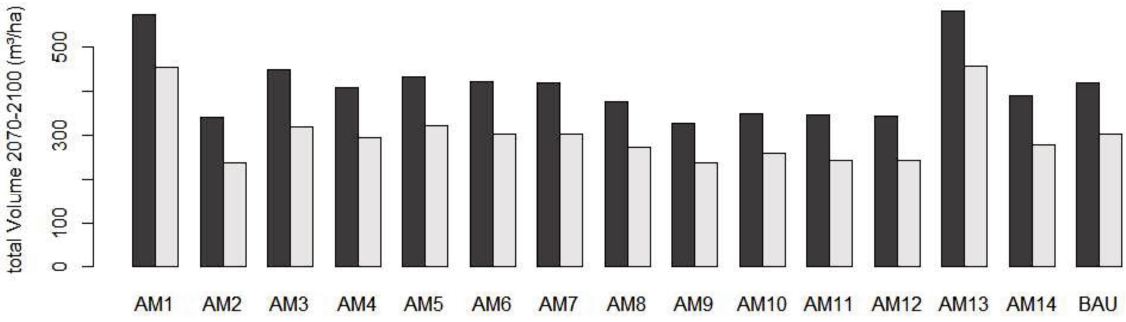

Figure 19. Total standing volume in the period 2070-2100 for the 14 AM and the BAU scenarios. Dark bars indicate the baseline climate c0, light grey bars the climate change scenario c5.

The AM scenarios yielded on average a mean standing volume of 412 m^3/ha for the baseline climate and 302 m^3/ha under climate change (BAU: 419 m^3/ha, and 304 m^3/ha under climate change). The difference between the two climate change scenarios was distinct (Figure 20).

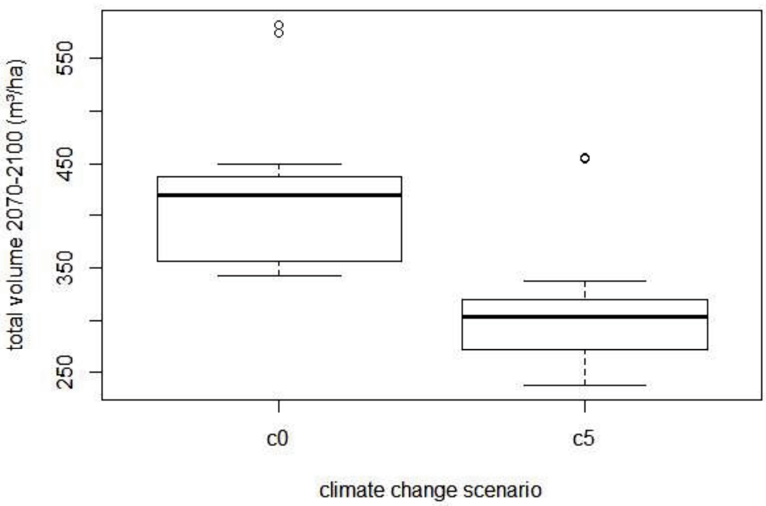

Figure 20. Total standing volume in the period 2070-2100 for all management scenarios for the baseline climate c0 (left), and the climate change scenario c5 (right).

One of the main goals of alternative management strategies was to increase the share of other species than the dominating Norway spruce. Figure 21 informs about the success in introducing other species. The highest share of other species was reached by the AM10 scenario (9%) and the AM5 scenario (7%) – both rely on big patches with additional planting of larch and maple.

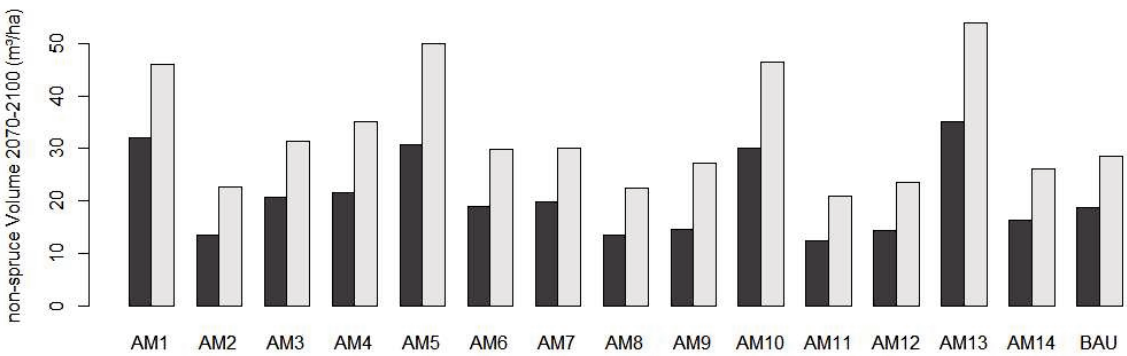

Figure 21. Total standing volume (2070-2100) of all species except Norway spruce in 2070-2100. Darkgrey=baseline climate c0, light gray bars: climate change scenario c5.

3.4.4 Biodiversity and protection indices

The tree species diversity *D* and the tree size diversity *H* are direct measures for biotic and structural diversity in the forest. *D* is expressed as the exponential of the classical Shannon index (see also Deliverable D2.2 for details), and *H* is a post-hoc Shannon-like index that is calculated from fixed DBH and height classes (also calculated as the exp(shannon), see also Deliverable D2.2). It has to be noted, that upscaling to landscape scale was done by area-weighted averaging of stand-level *D* and *H* values, and not by applying the more advanced methodologies discussed in the aforementioned deliverable.

Figure 22 shows the development of *D* and *H* over time for all management scenarios and the two climate scenario c0 and c5. The tree species diversity was generally higher for the climate change scenario c5, where broadleaved species are increasingly able to expand into higher elevations. Especially high values were brought forth by the scenarios AM4, AM5, AM9, and AM10 which rely not only on natural regeneration. Unsurprisingly, the lowest *D* was found for the scenario with the planting of 100% spruce (AM8). Trends in the structural diversity index *H* were less clear, but generally the c5 climate change scenario showed less structural diversity than the baseline climate. The lowest values for H were generated by the 100% spruce scenarios AM3 and AM8.

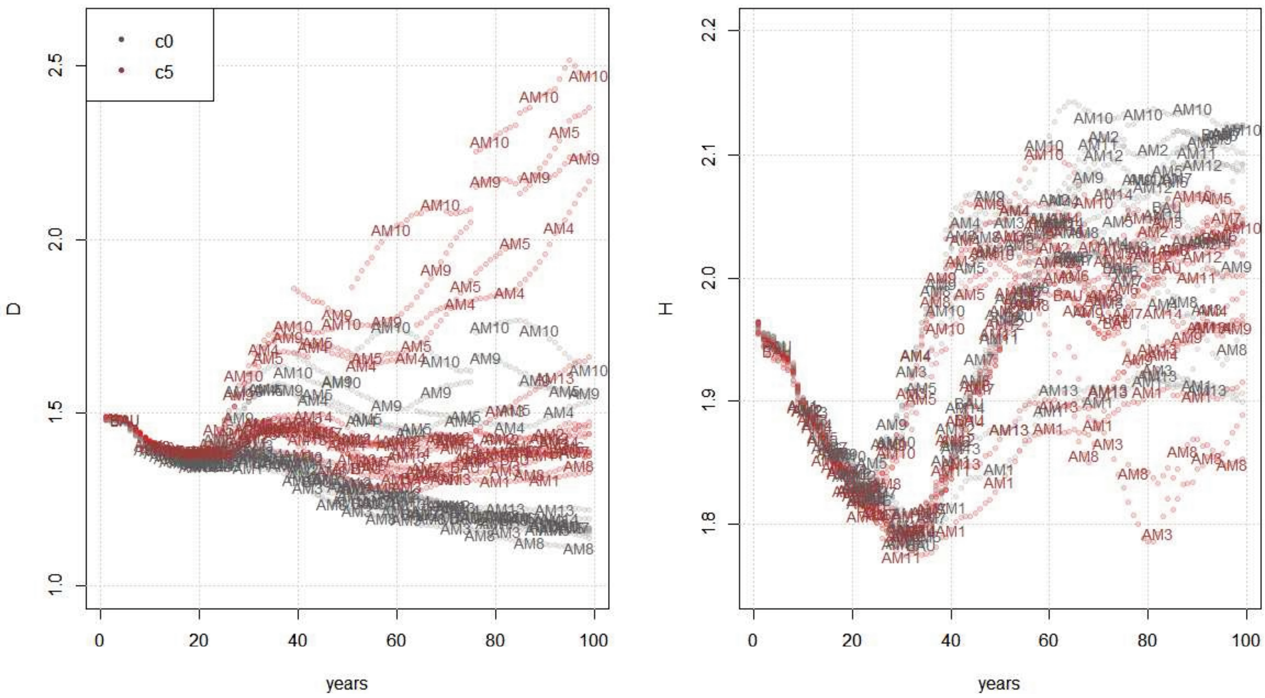

Figure 22. Diversity indices mean for baseline climate (c0, grey) and climate change scenario c5 (red). Left: *D*, the Tree Species Diversity (exp(Shannon)), Right: *H*, the Tree Size Diversity. Labels indicate management scenario.

Additional insight into the relationship and potential trade-offs of structural and species-diversity can be gained from Figure 23. Interestingly, the variation in *H* was distinctly larger for the baseline climate compared to c5. High values for both dimensions were again realized by scenarios that include the planting of additional tree species (AM4, AM5, AM9 and AM10).

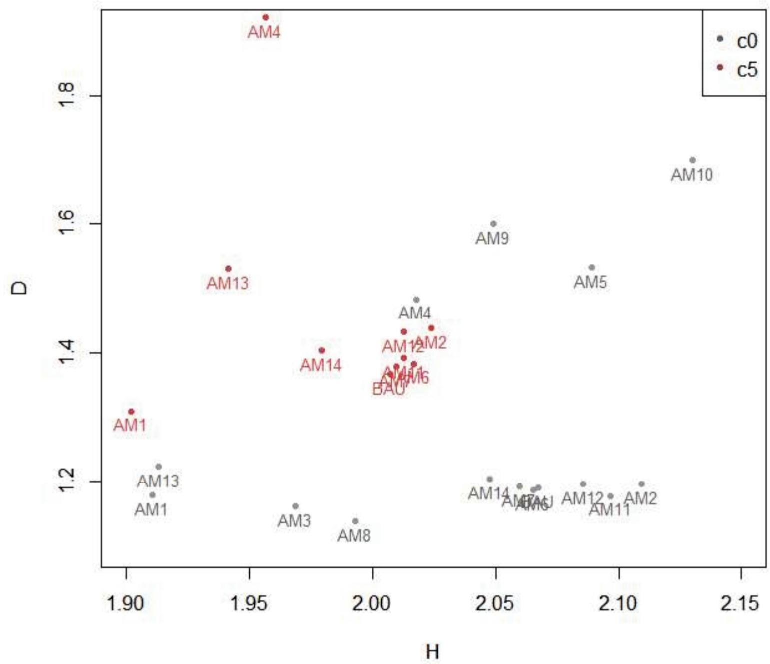

Figure 23. Diversity indices mean for 2070-2100 for baseline climate (c0) and climate change scenario c5. D: Tree species diversity (exp(Shannon)), H: Tree Size Diversity. Labels indicate management scenario.

The Landslide Protection Index (LPI) is a protection function indicator that is strongly dependent on the density of the forest cover (see Deliverable D2.2). The development of the landscape scale LPI over time for c0 and c5 is shown in Figure 24. The LPI tends to increase generally, but reaches higher values in the baseline climate scenario c0. The best performance with regard to the LPI was realized by scenarios including artificial regeneration: AM10 (2.85), AM9 (2.71), AM8 (2.65), AM13 (2.59), AM5 (2.52) (mean 2.33, period 2070-2100, climate scenario c5).

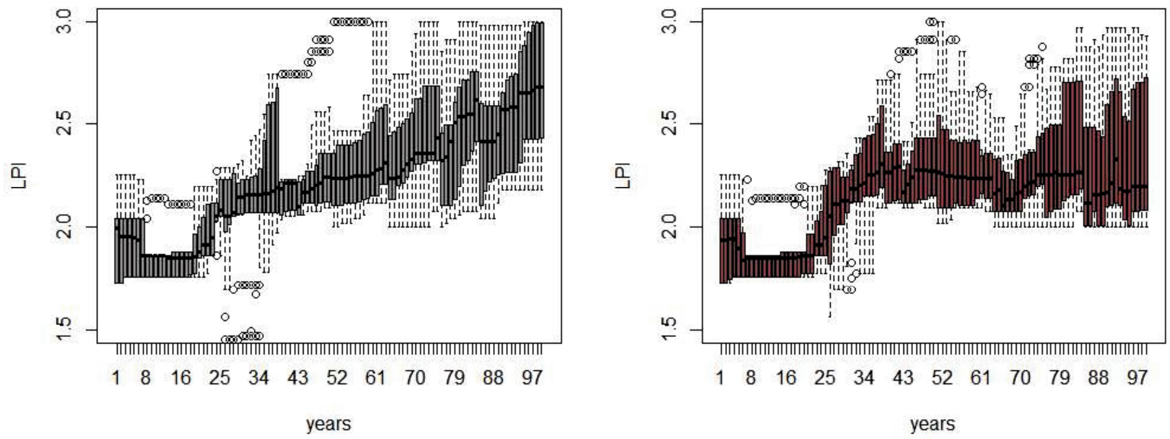

Figure 24. The Landslide Protection Index over time for all management scenarios in base line climate (c0, left), and climate change scenario c5 (right). The LPI per stand is a ternary variable encoded with 1=poor, 2=medium, and 3=high. A numerical landscape value of three means therefore good protection for the whole landscape. For each year a box plot indicates the variability within the management scenarios.

3.4.5 Effect of random sampling in the landscape

3.4.5.1 The analysis script

The Javascript code for the random pattern analysis is given in Box 2: The random positions within the landscape are stored in a list, and then re-used for the calculation of mean values over all indicators and all years.

Box 2. Javascript function to automate the processing of landscape level analysis.

```
function sample_test()
{
        var n_samples = 200;

        var poly_list = [];
        for (var i = 0; i<n_samples; ++i) {
                var poly_id = data.getPolyIndex(data.getPolyFromXY( Math.random()*1900,
                                                Math.random()* 2700) );
                if (poly_id>-1) {
                        poly_list.push(poly_id);
                }
        }
        results.add(poly_list.length);
        if (poly_list.length==0)
                return "no samples found";

        var myres = data.params();
        for (var year = 1; year < 100; ++year) {
                var myline=year;

                for (var p=1;p<data.params().length;++p) {
                        var param = data.params()[p];
                        var weighted_sum = 0;
                        var vs = data.get(param, year);
                        for(var poly_id = 0; poly_id < poly_list.length; poly_id++) {
                                var x = vs[poly_list[poly_id]];
                                weighted_sum += x;
                        }
                        weighted_sum /= poly_list.length;
                        myline = myline + ", " + weighted_sum.toFixed(5);
                }
                myres = myres + "\n" + myline;
        }
        results.saveToFile("e:/temp/test_sample.txt", myres);
}
```

3.4.5.2 Results

For ten replicates of randomly selecting 200 points within the project area rectangle a number of indicator values were calculated. On average, 77 times of 200 samples hit a valid forest stand (standard deviation: 6.8 hits). Figure 25 shows the variation of the indicators already used in this example.

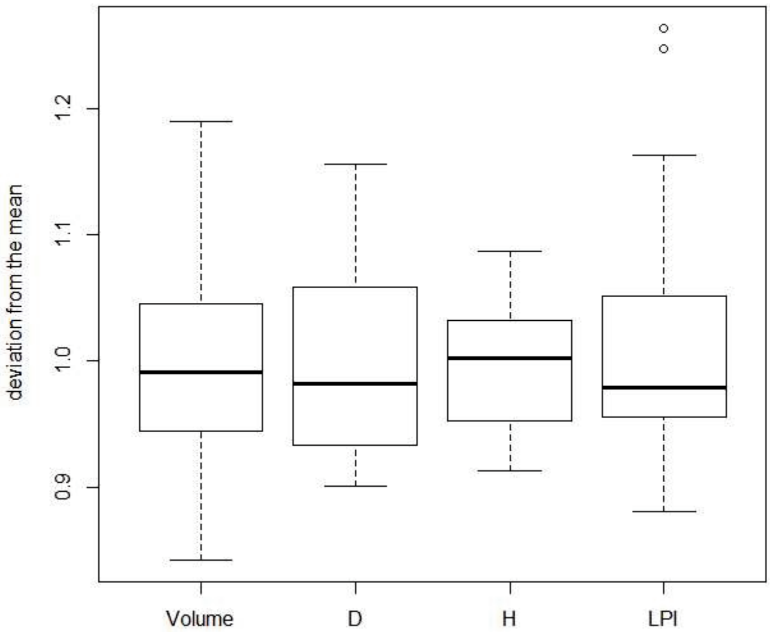

Figure 25. Variability within 10 replicates of random sampling on the landscape for the variables total standing volume, the species diversity index D, the structural diversity index H and the landslide protection index LPI (data shown for the entire simulation period 2000-2100). Shown is the distribution of mean values for each replicate relative to the total mean.

3.5 Conclusions

This application exercise demonstrated an application of the Landscape Assessment Tool on data of a case study region of the ARANGE project. The LA Tool proved an efficient means for the landscape level analysis of complex data from simulation modelling. Especially powerful were the extended opportunities for extending the functionality of the tool with user defined analysis code. Compared to other tools of the ToolBox (see for example exercise 1 in this document), the LA-Tool requires more expert knowledge and also more computer skills. This renders the LA-Tool as a tool for more advanced users. However, the tool could also be efficiently used for the visualization of complex data that is particularly valuable in stakeholder communication processes.

The analysis of the simulation results covered in this brief example application of the ToolBox did not fully explore the rich data-set developed within the ARANGE frame. It yielded, however some interesting results. A relatively consistent picture valid for all types of indicators is the good performance of management alternatives that rely on relatively large gaps and rely not only on natural regeneration. Protection indices did not profit distinctively from reducing gap sizes, and larger harvesting patterns resulted in higher values for diversity. The extreme climate change scenario scrutinized in this application showed distinct effects when compared to the baseline climate: standing volume decreased remarkably, but the share of non-spruce tree species (and, in parallel, the tree species diversity index D) increased. Generally, the tree species diversity increased with climate change, while the landslide protection index (LPI) decreased with climate change. This response complexity calls for approaches that include stakeholders to incorporate stakeholder preferences in order to reaching succinct results.