SIXTH FRAMEWORK PROGRAMME
PRIORITY 8.1
Scientific Support to Policies (SSP)

Deliverables 4.1, 4.2, 4.3   **Exploring European land use change scenarios: thematic downscaling and regional variability**

Project acronym: **COCONUT**

Project full title: **Understanding effects of land use changes on ecosystems to halt loss of biodiversity due to habitat destruction, fragmentation and degradation**

Proposal/Contract no.: **044346**

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Project home page: **www.coconut-project.net**

Comment:

The deliverables 4.1 “A set of probability distribution functions (PDFs) per storyline of the key input variables for land use modelling”, 4.2 “Conditional probabilistic land use projections for the case study areas”, and 4.3 “Land use projections for the EU25” have been merged into one report.

Understanding effects of land-use changes on ecosystems to halt loss of biodiversity due to habitat destruction, fragmentation and degradation

Proposal/Contract no.: 044346

Exploring European land use change scenarios: thematic downscaling and regional variability

– DELIVERABLE report –

IMPORTANT

There have been a number of problems in achieving the originally envisaged objectives of WP4. Consequently the WP4 work plan had to be revised several times and several of the original deliverables were no longer meaningful for the COCONUT project. This reports describes the deviations from the original objectives and our efforts to explore alternative methods of downscaling European land use change scenarios that were explored (part 1). In addition, in part 2 of the report the conditional probabilistic approach is discussed and an analysis of the variability in land use change projections across Europe is included.

Deliverable number:	Combined report for deliverables 4.1, 4.2, and 4.3
Deliverable titles:	D4.1 A set of probability distribution functions per storyline of the key input variables for land use modelling D4.2 Conditional probabilistic land use projections for case study areas D4.3 Land use projections for the EU25

Lead contractor for this deliverable: University of Edinburgh

Partners involved:	University of Edinburgh, SYKE, Helmholtz Centre for Environmental Research – UFZ
Researchers involved:	Marc Metzger, Mark Rounsevell, Sophie Rickebusch, Guancai Xu, Risto Heikkinen, Juha Pöyry, Ingolf Kuehn

Abstract

The main objectives of WP4 were (a) to develop statistical biodiversity models that relate biodiversity parameters to landscape change (including fragmentation) and (b) to develop land use changes scenarios exploring future fragmentation based on existing European land use scenarios and detailed data on regional historic land cover change (COCONUT DoW, pg 31). In addition, WP4 would explore a new land use scenario approach my creating conditional probabilistic land use change scenario, which would provide a formal representation of the uncertainties within the alternative scenario futures.

Unfortunately, there have a number of problems in achieving the originally envisaged objectives. Statistical downscaling approaches proved unsuitable for achieving the required spatial and thematic detail for the biodiversity modelling, while at the same time detailed local data for the landscape matrix around the COCONUT field sites was unavailable. Consequently, the WP4 work plan had to be revised several times and several original objectives were no longer meaningful to the project.

Part 1 of this report describes how alternative methods to downscale European land use change scenarios for the COCONUT biodiversity modelling were explored. In the end, the adopted approach is introduced, which is described in more detail in D4.4. Given the obstacle encountered and the altered work plan that was adopted the conditional probabilistic approach that was described in the DoW became meaningless to the COCONUT project. Instead, part 2 provides an analysis of regional variability in European land use change scenarios.

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Part 1 - Exploring methods for downscaling European land use change scenarios

Introduction

The main objectives of WP4 were (a) to develop statistical biodiversity models that relate biodiversity parameters to landscape change (including fragmentation) and (b) to develop land use changes scenarios exploring future fragmentation based on existing European land use scenarios and detailed data on regional historic land cover change (COCONUT DoW, pg 31).

European trends of land use change would be derived from existing land use change models (Ewert et al. 2005; Rounsevell et al., 2005; Rounsevell et al 2006; Schroeter et al., 2005; Settele et al., 2005), and would be downscaled to account for local land use characteristics relating to biodiversity. Statistical biodiversity models (cf Heikkinen et al. 2004, Kivinen et al. 2006) would then be developed to relate land use variables to species richness data from the Coconut field sites. Subsequently, these parameterised models could be used to construct predictions of patterns of species traits, abundance and richness in the case study areas as well as in larger spatial scales according to the future land use scenarios.

Unexpectedly, and unknown at the time of writing the COCONUT proposal, several tasks outlined in WP4 were also included in the FP7 IP EcoChange (http://www.ecochange-project.eu/). WP4 lead Mark Rounsevell was asked to participate in the EcoChange project *after* it had been funded to develop statistical, downscaling methods for the ALARM land use change scenarios and to explore conditional probabilistic approaches in land use scenario modelling. These unforeseen developments have meant that COCONUT could benefit from synergies and insights from ECOCHANGE.

One important insight relates to the possibility to use statistically downscaled land use scenarios in COCONUT. In order for the scenario results to be useful for assessing impacts on biodiversity, the scenarios must provide variables (e.g. on land use types or landscape metrics) that are significant in the biodiversity modelling. Dendoncker et al. (in press) have shown that there are methodological constraints in the number of land use classes that can be included. Only currently existing land use types can be spatially disaggregated using statistical rules. Consequently, the ALARM land use classes for bio-energy crops and abandoned land, which are important in relation to biodiversity, cannot be included. The remaining 6 land use classes (built-up, arable, permanent crops, grassland, forest and others) provide only very limited thematic detail and lack any incorporation of landscape level processes (e.g. fragmentation), as illustrated in Fig. 1 for one of the Finnish COCONUT field sites. It is therefore apparent results from top-down of pan-European land use change modelling are not appropriate as input for landscape level biodiversity assessment.

For COCONUT it was therefore important to explore alternative approaches of interpreting the trends that are projected by European land use change scenarios, providing appropriate land use variables for landscape scale biodiversity modelling.

This report gives an overview of the various approaches that were explored. The final method is elaborated in more detail in a separate report (D4.4). There are also consequences for the conditional probabilistic approach that was described in the DoW, which is discussed in the second part of this report.

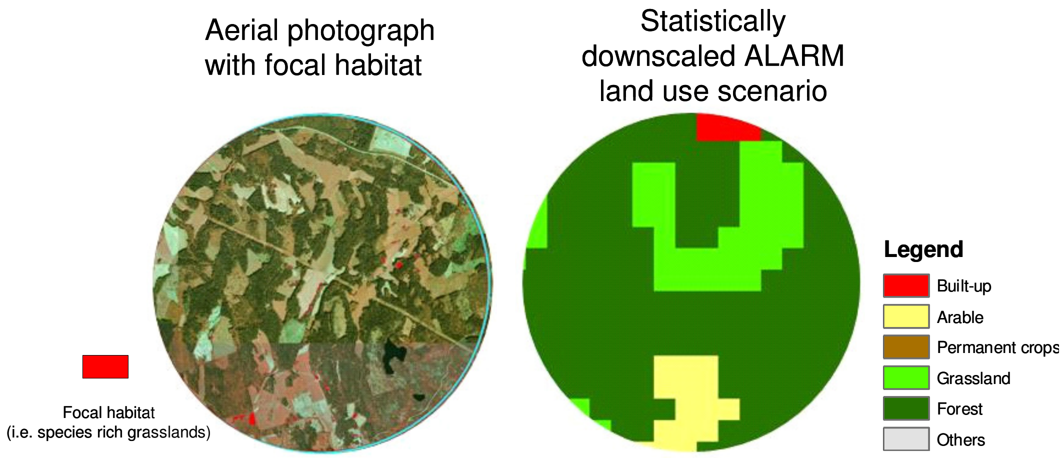


Figure 1. Aerial photograph and downscaled ALARM land use for a Finnish COCONUT field site (#33).

Work plan revision 1

Instead of using statistical algorithms to provide a spatial disaggregation of the pan-European ALARM land use scenarios it would be possible to construct a rule base to allocate regional land use change. The trends of these changes could then be derived form the European scenarios (e.g. amount of grassland change, pressures from land abandonment, urbanisation, afforestation, population growth). In addition, the ALARM scenarios also provide socio-economic storylines that could be used to interpret willingness to protect landscapes / biodiversity and negative effects of agriculture. Table 1 gives an example of such rules.

The initial plan was therefore to extract general trends from the ALARM scenarios that would be further interpreted for the COCONUT field sites using detailed local data and expertise from regional experts. Most importantly, we would rely on detailed digitised aerial photographs of the landscape matrix surrounding the focal grasslands, and the historic changes that had occurred between 1950 and 2000. For each case study region it would then be possible to extract trends for relevant local land use variables that could feed into statistical biodiversity models.

After initial delays in digitizing the aerial photographs of the field sites, in October 2007 it became clear that the consortium would not have access to the digitized aerial photographs of the entire the case study regions, but only for the small patches of grassland (cf Fig 1). As such there was no baseline data available on the landscape matrix surrounding the grasslands, which made it impossible to derive local trends of land use indicators from the European scenarios.

Table 1. Example of rules that could be used to allocate land use change trends.

Land use (change)	**Rule**
Grassland	
Abandonment of permanent	Small, remote sites abandoned first. These are surrounded by forest

grassland	and are far from the farm house. Use forest density as a proxy for 'remoteness' and/or the grassland neighbourhood density. Distance to roads is a measure of accessibility. Municipality cattle numbers could be an indicator of grassland importance (low numbers = higher probability of abandonment). Grassland abandonment more prevalent on small farms.
Grassland type x to grassland type y	Not thought to be important, except a) dry grassland may convert to mesic grassland under climate change and b) future N deposition could change species composition (and grassland type)
Grassland to cropland (food and energy crops)	Only improved grasslands could be used for cropland
Forest	
Deforestation	Urban expansion. Conversion to cropland in places that are next to existing cropland areas.
Afforestation	Stoniness and slopes are not an obstacle to forest plantation. Poor quality land in remote places is forested first, except where this land is protected. Then cropland.
Bio-energy crops	
	Improved grassland are the most likely land use to be converted to bio-energy crops
Croplands	
Abandonment of cropland	Cropland with serious physical constraints, or remote accessibility may be abaondoned

Work plan revision 2

Despite these setbacks, it would still be possible to make some projections about the changes in the focal grasslands. For example, the ALARM scenario trends for grassland and the storyline assumptions about nature conservation and farmer's subsidies could be used to project changes in the size and connectivity of the focal habitat patches. In addition, it might be possible to use the European Corine Land Cover 2000 (CLC2000) map (EEA, 2000). Although the pan-European1:1000 000 CLC2000 vector map was thought to be too coarse for regional application, it was felt that the option should not be ruled out. Furthermore, for several counties a more detailed 25m CLC2000 was available (e.g. Finland and Sweden). Figure 2 gives an illustration of the CLC2000 map at the two resolutions.

An analysis of the differences between the detailed and the coarser CLC2000 dataset for Sweden and Finland illustrated how in the coarser dataset small patches get lumped into more generic categories. For example, patches of broadleaf and coniferous forest get lumped into mixed forest and urban and agricultural land cover classes get lump tint he the category 'land principally occupied by agriculture with significant natural vegetation' (Fig. 3).

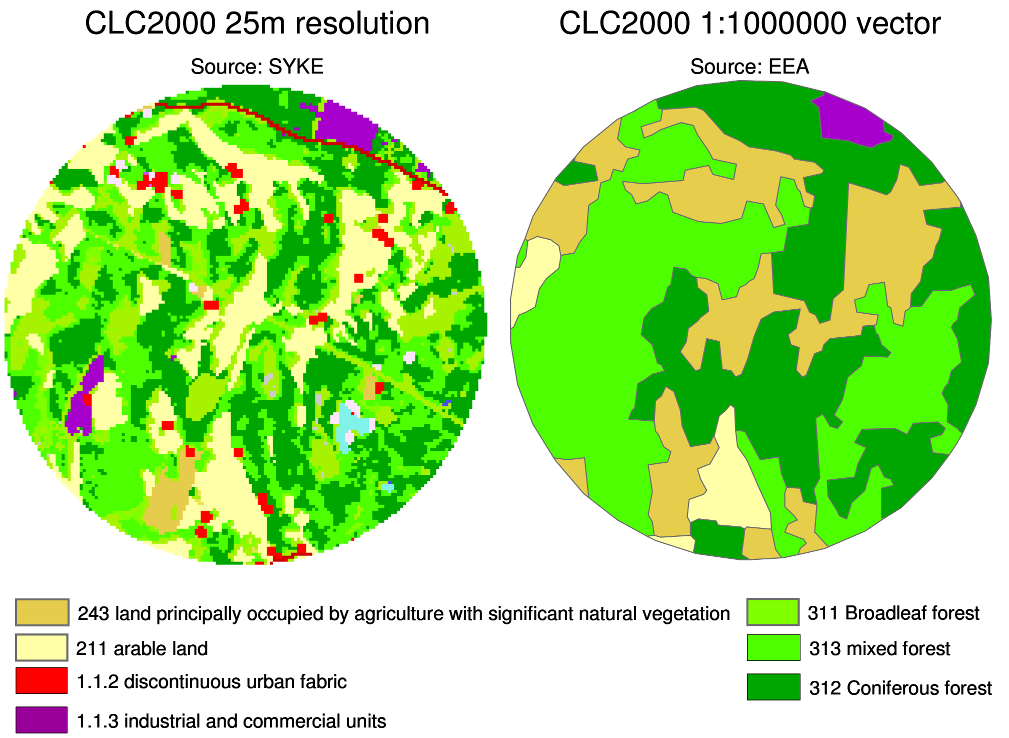


Figure 2. CLC2000 land cover maps for Finnish field site #33 at the 25m and 100m resolution.

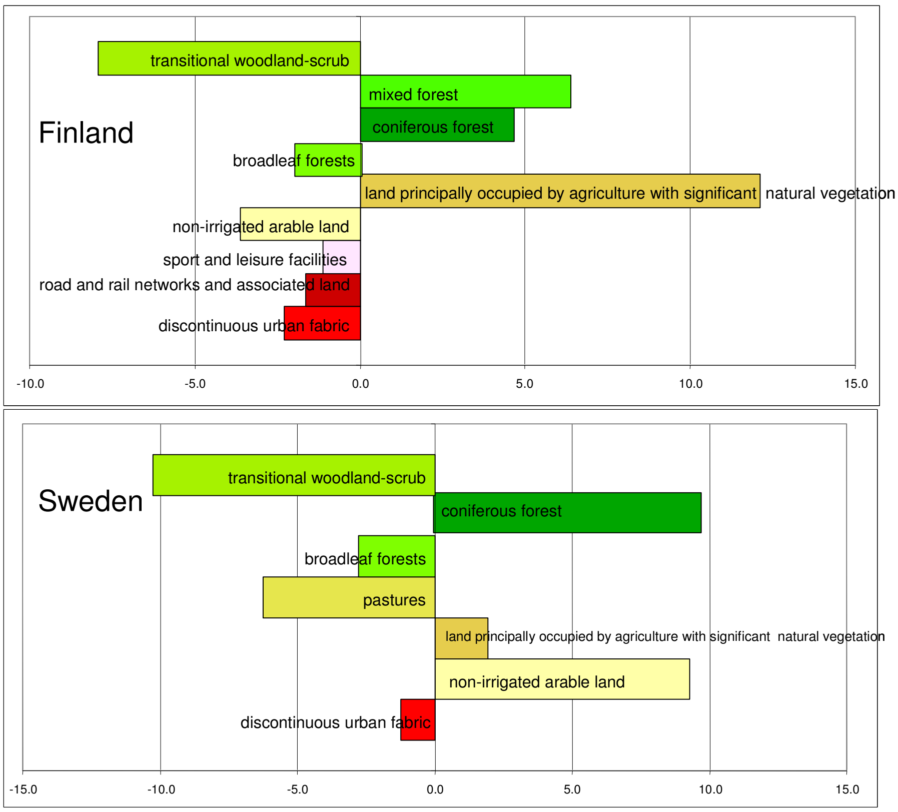


Figure 3. Comparison between the area of the CLC2000 land cover types at 25m and 1:1 000 000 resolution (i.e. 100m). Negative values indicate less coverage in the 100m EU data than in the 25m national data while positive values indicate more coverage in EU data than in 25m national data.

It was decided to explore the relation between current biodiversity (obtained though Coconut field work) and four potential indicators that could be linked to the European scenarios:

1. the area of the focal habitat patch
2. the area of the focal habitat in the circle
3. the area of the aggregated CLC types
4. landscape fragmentation measures based on CLC

Analysis
Exploring the tasks 1 and 2, i.e. the usability of the area of the focal habitat patch and the area of the focal habitat in the 2-km circle surrounding the focal patch as predictors of the present-day richness of grassland vascular plant and butterfly species, was a key research target in COCONUT WP1 and thus decision whether these might be useful options in the biodiversity modelling in WP4 was based on the experience gathered in WP1. Unfortunately, the modelling exercises including data from the five COCONUT study countries in WP1 showed that the development of predictive models for species richness was extremely difficult and producing of predictions for future trends of species richness rather unreliable. Instead, a multimodel approach to explore only the explanatory power of the focal habitat patch and the area of focal habitat in the circle were ultimately used in analysis related to tasks 1 and 2, and no predictive biodiversity models could be produced.

The modelling exercises conducted in WP4 focussed in investigating the potentiality of the variables derived from the European / national CORINE 2000 land cover data to provide useful predictors for the grassland species richness. The results of these modelling exercises are discussed more in depth in Appendix 1. The usefulness of CLC land cover classes in modelling the grassland plant and butterfly species richness were tested for Finland and Sweden, where both the national CLC data with 25m resolution and European CLC data with 100m resolution was available. Using generalized additive models (GAMs) (Hastie and Tibshirani 1986), as implemented in GRASP (Lehmann et al. 2003), the total number of vascular plant species and butterfly species, and the number of grassland specialist plant and butterfly species in the focal grassland patch were related to the cover of different CLC land classes in the 2-km circles at the two spatial resolutions. The selected significant CLC land cover variables in the GAM models are shown in Table 2.

Overall, the GAM results showed that the CORINE land cover data, both at the resolution of 25 meters and 100 meters, appear to provide very seldom potentially useful and ecologically plausible explanatory variables, and when logical correlations are discovered the proportion of explained variation in species richness patterns are so low (e.g. the percentage of explained variation by the area of pastures 15-17%), that they prevent the reliable use of these data in scenario-based or other types of predictive modeling. Thus the further use of CORINE land cover data as the basis of biodiversity models in WP4 was abandonment.

Table 2. CLC2000 land cover variables that were statistically significantly related to the species richness of grassland plants and butterflies in the focal grassland patch. D2= proportion of explained deviance to the total deviance in species richness (see Lehmann et al. 2003). Only those variables that were statistically significantly related with species richness in univariate GAMs are shown.

	Total richness of vascular plants	Species richness of grassland specialist plants	Total richness of butterflies	Species richness of grassland specialist butterflies
Finland				
25-m resolution CLC2000 land cover data	none	none	water courses (p=0.05, D2=0.16)	coniferous forest (p=0.05, D2=0.15)
100-m resolution CLC2000 land cover data	industrial and commercial units (p=0.05, D2=0.27) transitional woodland-scrub (p=0.05, D2=0.29)	transitional woodland-scrub; p=0.05, D2=0.29)	- CLC class 1.3.1. - mineral extraction sites (p=0.05, D2=0.31)	none
Sweden				
25-m resolution CLC2000 land cover data	green urban areas (p=0.05, D2=0.36) bare rocks (p=0.05, D2=0.24)	industrial and commercial units (p=0.05, D2=0.17) green urban areas (p=0.05, D2=0.39)	none	mixed forest (p=0.05, D2= 0.16)
100-m resolution CLC2000 land cover data	none	discontinuous urban fabric (p=0.05, D2=0.21) pastures (p=0.05, D2=0.15)	broadleaf forests (p=0.05, D2=0.31)	discontinuous urban fabric (p=0.05, D2=0.20) pastures (p=0.05, D2=0.17)

In addition to relating species richness patterns of plants and butterflies to CORINE land cover data, responses of individual plant and butterfly species to the patch area and regional connectivity of the focal habitat type of semi-natural grasslands was explored. This was done in order to find out whether there are any consistent patterns between abundance and occurrence of plants and butterflies and habitat area. If such patterns were discovered, these data could be used as a basis for projections relating changes in habitat area to changes in abundance and occurrence of plants and butterflies. This modelling exercise was conducted only with data from Finland for WP1, using generalized additive models (GAM) in S-PLUS version 6.1. Abundances of individual plant species, and occurrence and abundance of individual butterfly species, were related to focal habitat patch area and regional connectivity of grassland network within a 2-km radius from the focal patch.

Results of modeling individual species are shown in Table 3. Overall, about half of the plants and about two thirds of the butterflies were abundant enough that they could be modeled with GAMs. However, only less than 15% of plant species showed an expected positive relationship with habitat area. In butterflies, slightly over 20% of the species showed a positive abundance-habitat area relationship and less than 5% showed a positive occurrence-habitat area relationship. Therefore, it was concluded that responses of individual species were not consistent enough that they could be used in developing models which predict impacts of the focal habitat area change to biodiversity.

Table 3. Summary of generalized additive models (GAM) for individual plant and butterfly species in relation to habitat patch area and regional habitat connectivity of semi-natural grasslands.

	Plants (abundance)	Butterflies (abundance)	Butterflies (occurrence)
Species in total	37	22	22
Species modeled	19	16	15
Species related to habitat area or regional connectivity	17	7	3
Species with positive relation ship	5	5	1

Heterogeneity index

Finally, we explored the possibility of constructing a generic landscape heterogeneity index for the field sites based on the CLC2000 land cover classes in the landscape matrix. Landscape heterogeneity was thought to be an important land cover variable affecting biodiversity (Benton et al. 2003; Heikkinen et al. 2004). By assigning different heterogeneity scores to the CLC2000 land cover categories it would be possible to calculate a landscape heterogeneity score for each filed site. Table 4 gives an example of a heterogeneity scores for an aggregation of CLC2000 land cover category.

Table 4. Example of possible landscape heterogeneity scores for CLC2000 land cover types. A higher number indicates a greater landscape heterogeneity.

Corine code	**Corine class name (i)**	**Heterogeneity score (H)**
1.0	Artificial surfaces	
2.1	Arable land	2
2.2	Permanent crops	2
2.3	Pastures	2
2.4	Heterogeneous agricultural areas	5
3.1.1	broad-leaved forest	3
3.1.2	coniferous forest	2
3.1.3	mixed forests	3
3.2.1	natural grassland	4
3.2.2	moors and heathland	4
3.2.3 & 3.2.4	sclerophyllous vegetation & transitional woodland-scrub (Scrub)	4
3.3	open spaces with little or no vegetation	2
4.1	inland wetlands	3
4.2	coastal wetlands	2
5.0	Water bodies	1

Unfortunately it proved impossible to derive a generic heterogeneity index. The descriptions of the land cover classes[1] are very broad, frequently making it impossible to assign a single heterogeneity values to a land cover class. For example, Pastures 2.3.1 includes both large expanses of intensive *Lolium perenne* monocultures and small mosaics with significant natural vegetation and up to 25% arable land. Furthermore, this approach would be difficult to apply consistently across Europe because of inconsistencies in the definitions of the classes and contrasting interpretations between European countries.

Given the fact that the land use variables that we could derive had no significant input in the biodiversity models, we reached the conclusion in June 2008 that it would not

[1] http://etc-lusi.eionet.europa.eu/CLC2000/classes

be possible to adapt trends from the European ALARM scenarios to provide meaningful indicators for the Coconut biodiversity models. This was quite a disappointment, because this meant that both objectives of WP4 could not be met.

Work plan revision 3

In the mean time, WP2 had made considerable progress in its attempts to evaluate historic land use impacts on biodiversity in and around N2k sites. They used detailed digitised aerial photographs for 1950, 1990 and 2000 for selected 2x15km transects, which were available through the EU FP5 BioPress project (Olschofsky et al. 2006; http://www.biopress.ceh.ac.uk/). Land cover was classified following the CLC legend, but the spatial accuracy is considerable greater (minimum mapping unit of 0.5ha instead of 25ha in CLC2000).

A spatial and thematic downscaling of the ALARM scenarios would provide WP2 with the possibility to extend the historic analysis by also providing an exploration of future changes in habitat quality. It would also be possible to compare the extent of the projected land use change with the observed changes in recent decades. Given the outlined problems in providing meaningful input to the biodiversity modelling, it was decided during the Coconut general project meeting in September 2008 that WP4 would focus on providing input to WP2.

Unfortunately, the adopted method for providing the spatial and thematic downscaling of the European scenarios for the BioPress transect was labour intensive and could not be automated. Furthermore, time was running out as the WP4 results would require further processing by WP2. As a result, the downscaling had to be restricted to only four UK transects. Fig. 4 gives an example of three alternative scenarios for one transect. A full description of the method, the result for the four UK transects, and suggestions for future work are described in detail in deliverable D4.4.

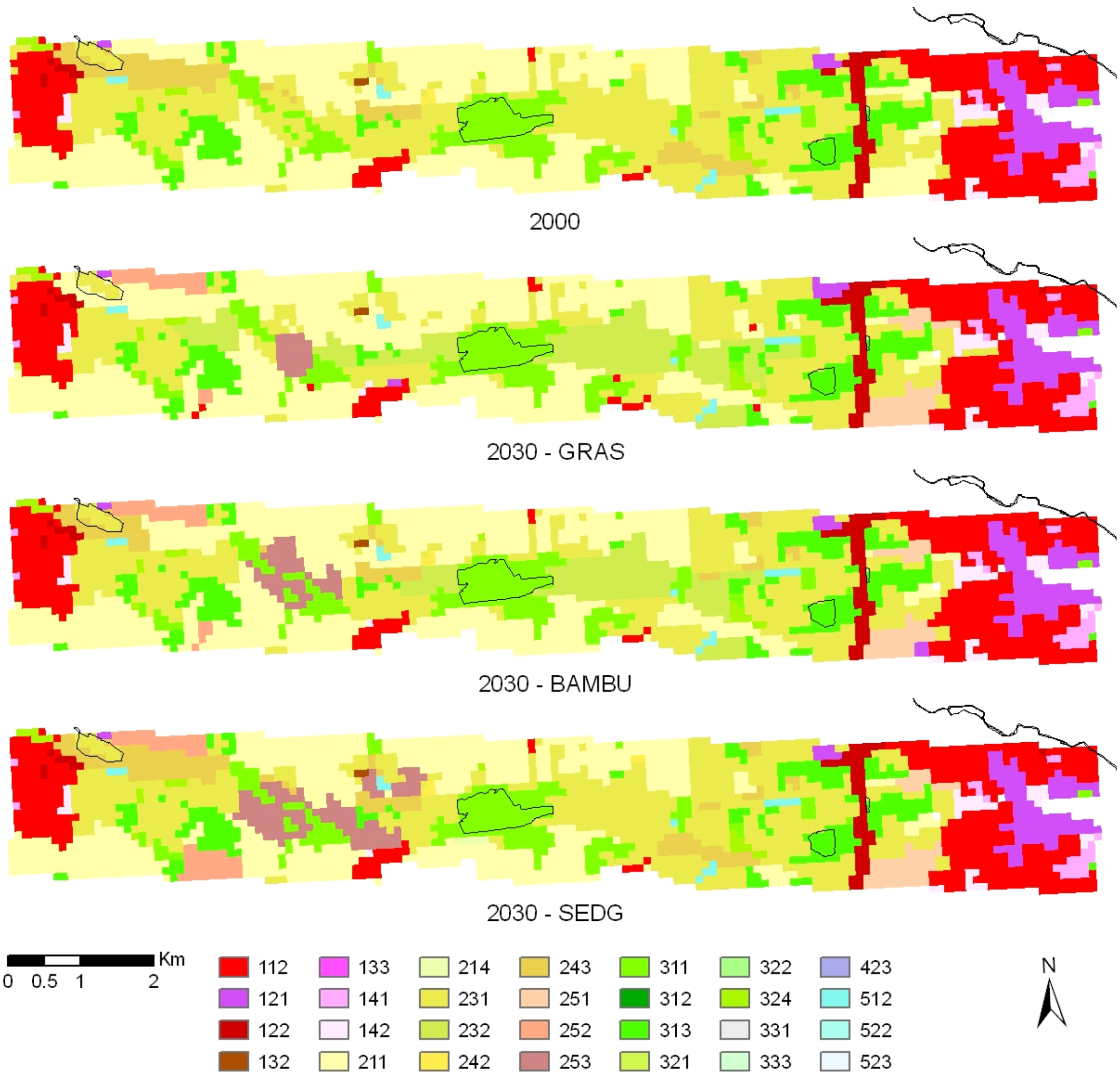


Figure 4. Transect UK1 (Kennet Valley Alderwoods). Current (2000) land-cover and projections for 2030 according to three scenarios. The categories correspond to CORINE land-cover level 3, except for the new categories: 214 (abandoned arable land), 232 (abandoned pastures), 251 (liquid biofuels), 252 (non-woody biofuels) & 253 (woody biofuels). The black lines are the perimeters of the protected areas.

Part 2 – An analysis of the variability in land use projections for 12 European environmental zones

Introduction

As outlined in the first part of this report, the state of the art pan-European land use change model MOLUSC is inappropriate for landscape level biodiversity assessment. Although there are methods to improve the spatial accuracy, thematic relevance is limited (cf Fig. 1). Consequently, it does not make sense within the context of COCONUT to allocate resources to a further analysis of the MOLUSC model uncertainties within the different scenarios, especially since this work is also being carried out as part of the ECOCHANGE project (www.ecochange-project.eu).

However, it is still very interesting to explore uncertainties in the scenarios projections. One approach would be to construct probability density functions (PDFs) for the input variable of the biodiversity models. These models could then be run using a Monte Carlo sampling of the PDFs of the input variables to explore conditional probabilistic biodiversity projections. However, as explained already, in the end it proved impossible to link land use variable to the biodiversity models.

Instead, a more detailed analysis of the variability of the ALARM scenarios was carried out. The variability in the ALARM scenario projections were compared for 12 principal environmental zones of Europe (Metzger et al. 2005). These results provide insights in the differences in main land use change trends in different part of Europe, as well as quantifying uncertainties in these general trends. Although it would be possible to present these results as PDFs, it was decided to use Box plots to graphically provide a simplified representation of the distribution of land use change.

Methods

Quantifying land cover change requires insight in the relative change compared to the present situation. However, because the ALARM bio-energy and 'surplus' land categories are not present in the baseline situation, it is not possible to calculate relative change figures for these categories. To overcome this problem, the relative change was calculated for aggregated categories, which incorporate the bio-energy crops, as listed in Table 5. These same categories are used in the final thematic downscaling of the ALARM scenarios for four UK trasect, as described in D4.4.

The relative change change compared to the 2000 baseline was calculated in ArcGIS, so that 100 refers to no, 75 a reduction of 25% and 200 a doubling of the land use type. These change figures were then summarized for 12 principal European environmental zones (Fig. 5.) using the zonal statistics function in the GIS software.

Table 5. Aggregation of ALARM land use categories.

Aggregated category	ALARM categories
total crops	cropland permanent crops liquid bio-energy crops non-woody bio-energy crops
total forest	forest woody bio-energy crops
grasslands	grasslands
built-up area	Built-up area

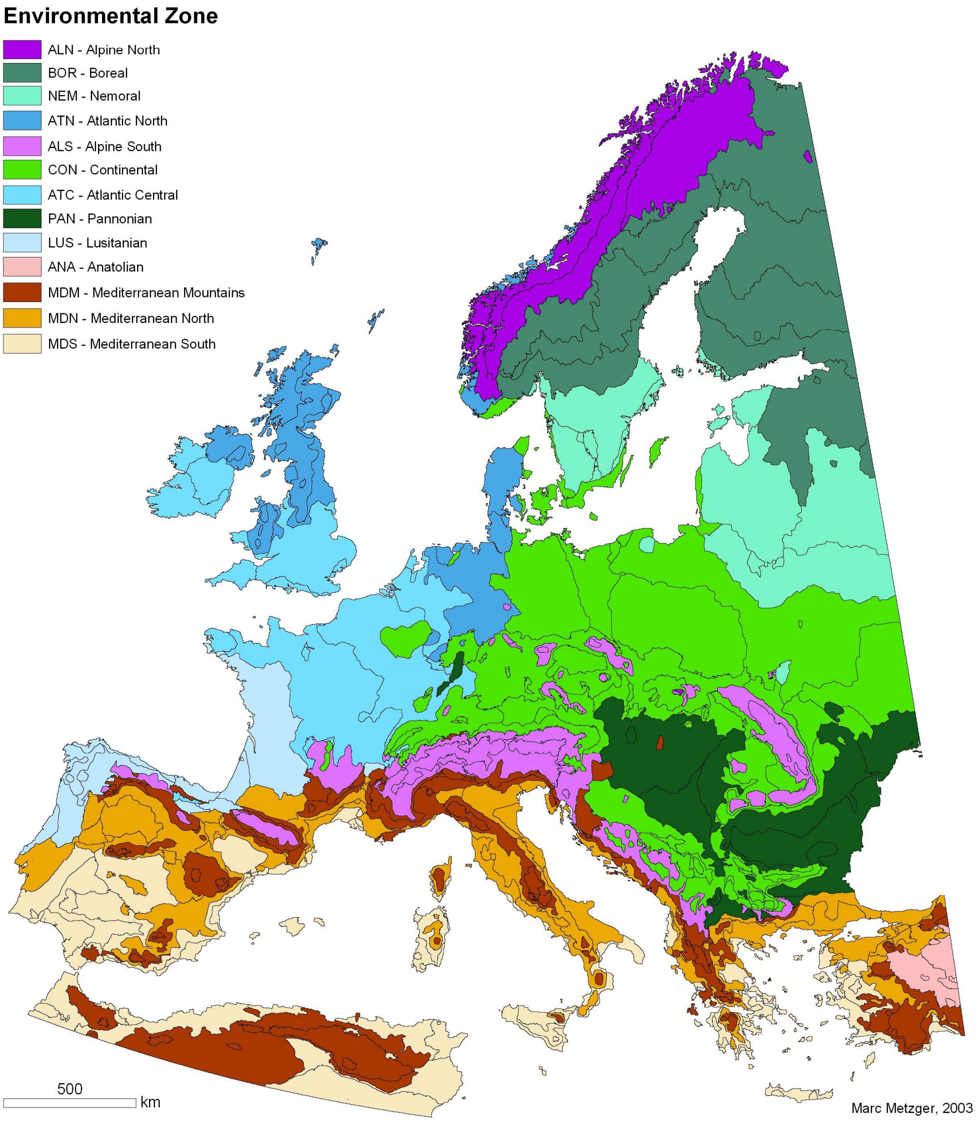


Figure 5. The twelve European Environmental Zones (Metzger et al., 2005) used for summary reporting of the land use change.

The environmental zones (EnZs) form an appropriate division of the variability in principal European environmental gradients. The dataset forms an aggregation of the Environmental stratification of Europe, a dataset set constructed based on tried-and-tested statistical procedures so that strata are unambiguously determined and, as far as possible, independent of personal bias. Principal Components Analysis (PCA) was then used to compress the variation of twenty mainly climatic input variables into three dimensions, which were subsequently clustered using a multivariate clustering routine. The classification procedure is described in detail by Metzger et al. (2005) Fig. 5 shows the first principal component values for the five central European countries of this study. The EnS has a 1km2 resolution, and consists of 84 strata, which have been aggregated into 12 Environmental Zones (EnZs). Appendix 2 gives more information about this dataset, including examples of other studies that have used the EnZs for summary reporting.

For the graphic representation of the variability in land use changes we used Box (also known as a box-and-whisker diagram or plot) as a convenient way of graphically depicting groups of numerical data through their six-number summaries (the smallest observation, lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation and mean. Box plots are useful to display differences between populations without making any assumptions of the underlying statistical distribution: they are non-parametric. The spacings between the different parts of the box help indicate the degree of dispersion (spread) and skewness in the data, and identify outliers. Fig. 6 gives an example of a Box plot for a normal distribution, while Fig. 7 gives an explanation of the graphs used in this report.

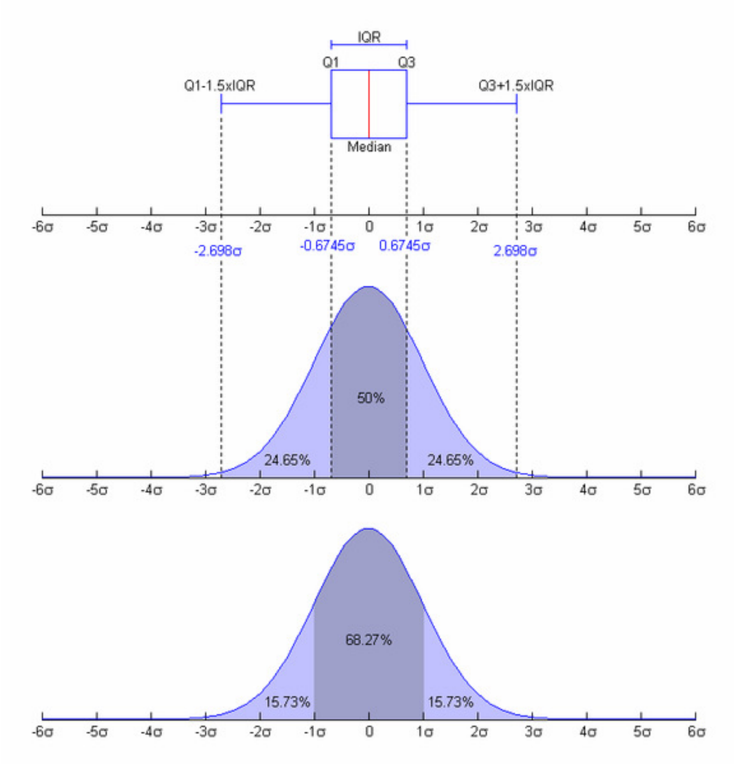


Figure 6. Box plot and a probability density function (pdf) of a Normal N(0,1σ2) Population (source: Wikipedia)

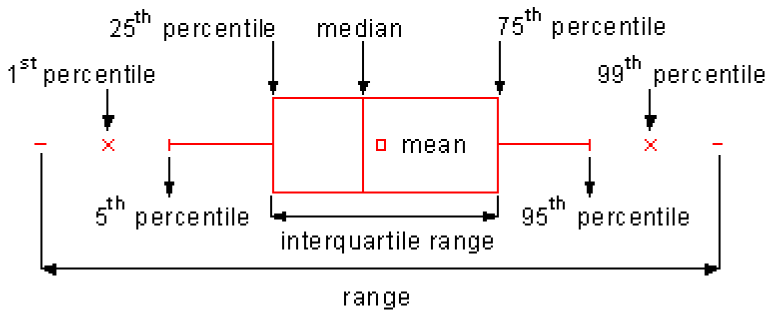


Figure 7. Values represented in this report's Box Plot (source: OriginLab.com)

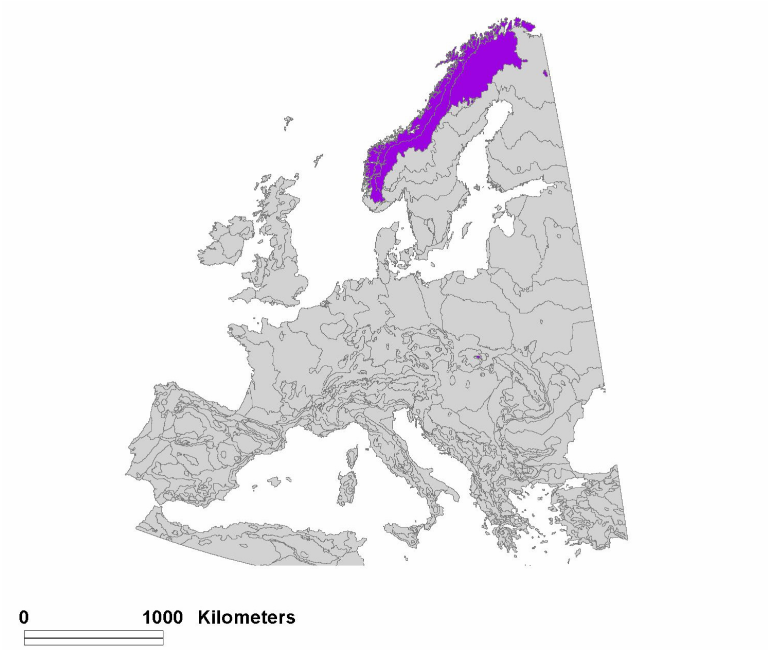
Results and conclusions

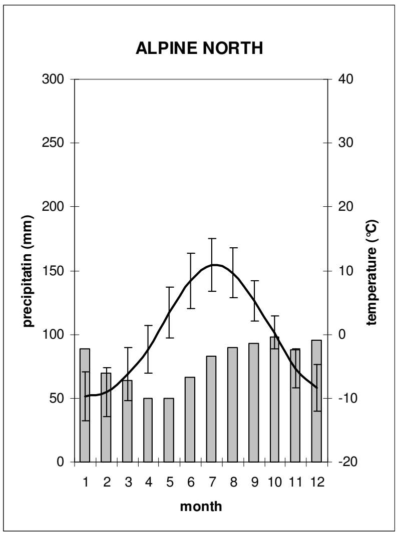
The Box plots are presented on pages 18-41 alongside a general description of the EnZ and a bar chart illustrating the current land cover in the region. Although there are general European trends, including a decline in grasslands and an increase in built-up areas, the Box plots show that there are considerable differences in the projected land use change between the regions and between the scenarios.

One notable difference is the variability in projected changes between regions, which are depicted by large boxes in the graphs. This will partly be due to differences in the current land use patterns. For example, in the Alpine North and Boreal zones agriculture is currently very limited. Small absolute increase in the extent of cropland in a given ALARM 10arcmin grid cell can therefore result in very large relative changes. Nevertheless, this variability does suggest that in such cases projected land use changes value should be treated with caution and further investigation in to regional trends may be required. A further consequence of this variability becomes apparent when the mean and the median values of the projections are compared. Frequently, the mean value is influenced by outlier and differs greatly from the median.

Conversely, the results also show that in many regions the variability in land use change projection is small and consistent between scenarios. In these regions that land use change projections are fairly robust and can be used confidently to explore further the regional impacts on biodiversity.

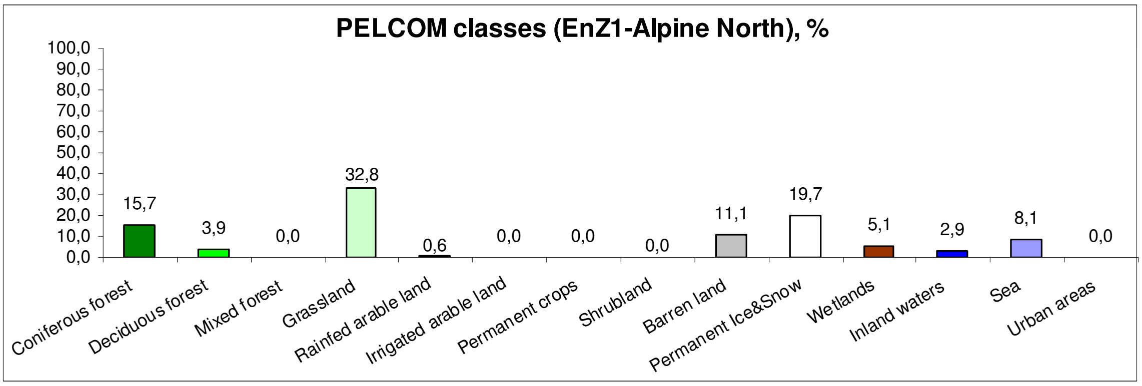
Alpine North (ALN – EnZ1)



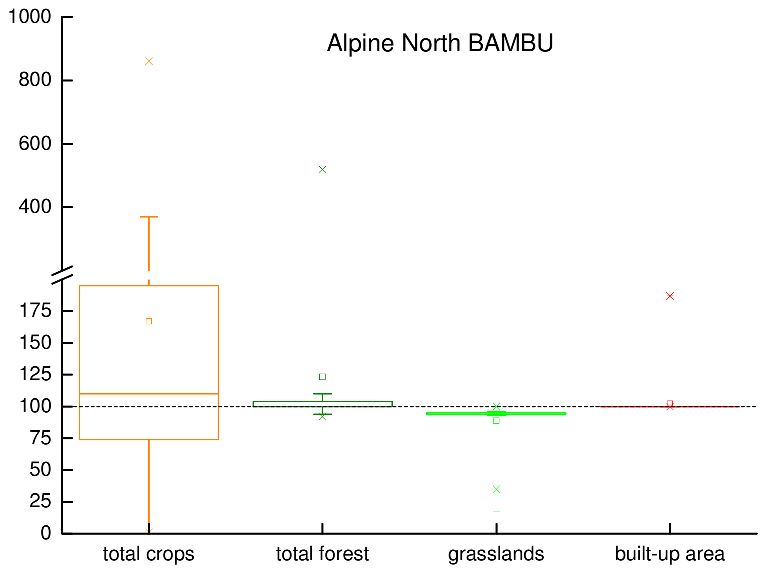


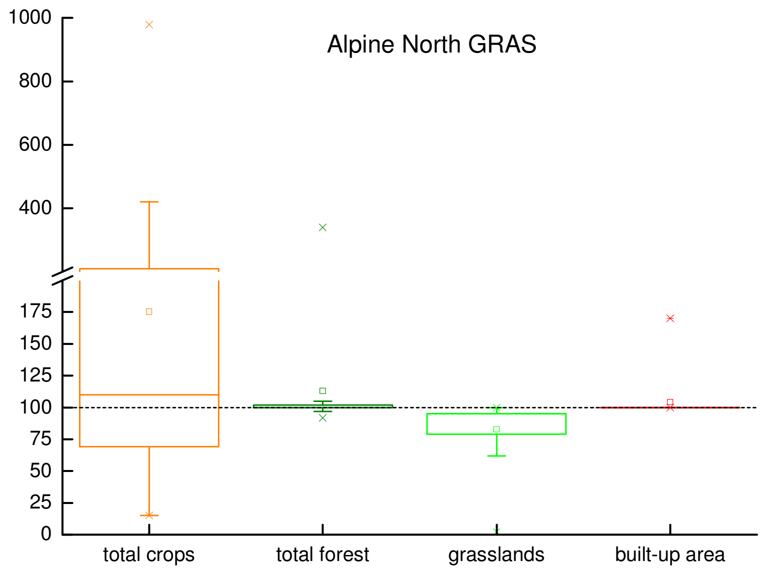
The Environmental zone Alpine North covers medium and low mountains and uplands in Scandinavia. Climate of western slopes is modified by the North-Atlantic current, meanwhile eastern uplands are influenced by continental air masses. The growing season lasts 130 days (low); sum of active temperatures is 1416° (low). Landscapes are dominated by arctic tundra (uplands in the north), arctic-alpine tundra (high mountain regions) and various forest and dwarf-scrub tundras changing on the southern uplands and less elevated eastern plateaus to sparse coniferous forests. Relief bears fresh traces of the last glaciation.

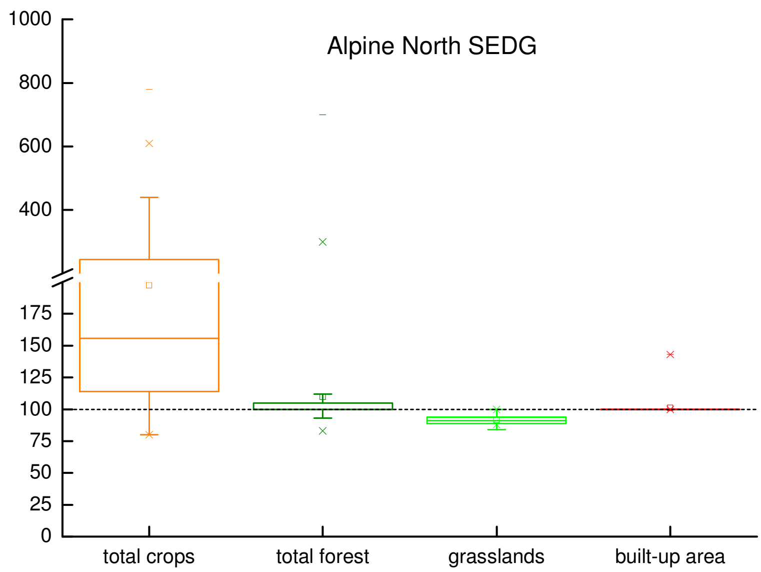
PELCOM land cover:



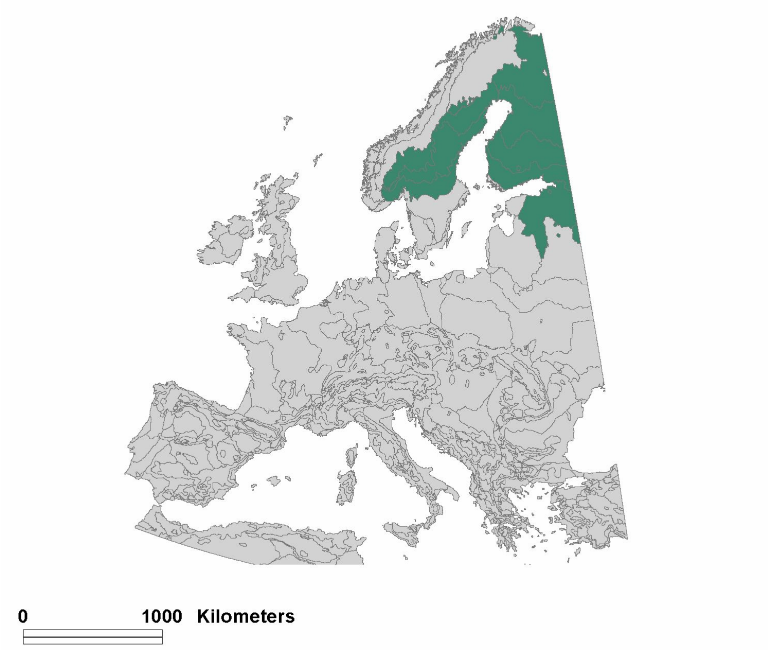
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	167	112	123	100	89	95	102	100
GRAS	175	110	113	100	83	95	104	100
SEDG	197	156	110	100	92	91	101	100

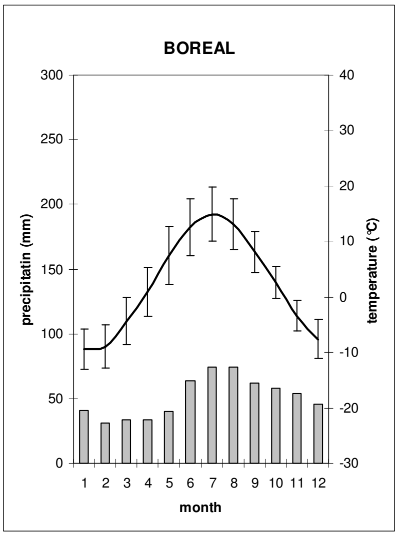

Alpine North BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Alpine North GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Alpine North SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

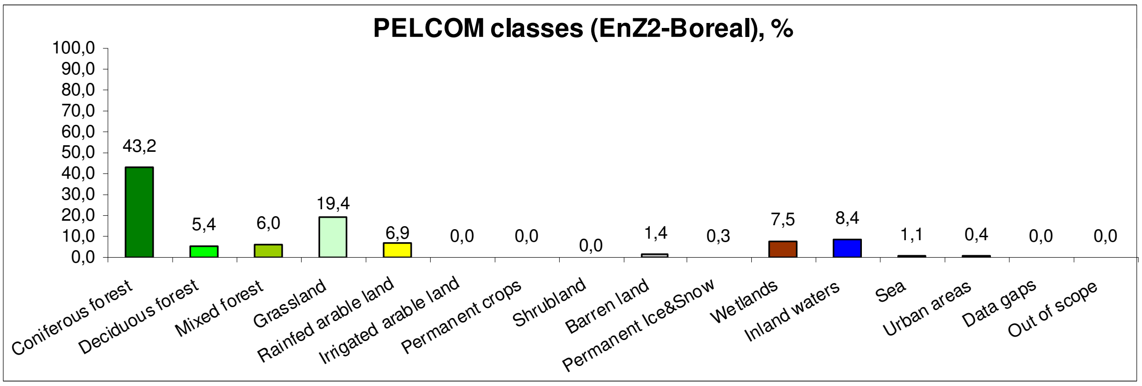
Boreal (BOR – EnZ2)



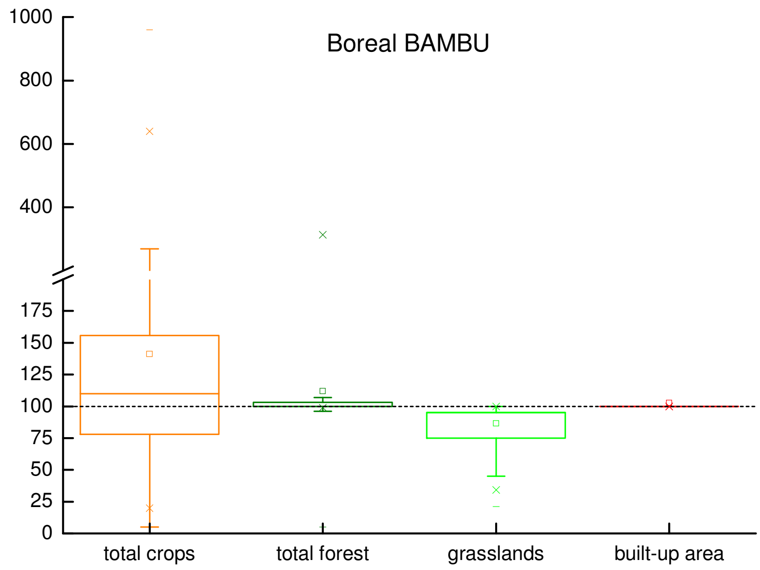


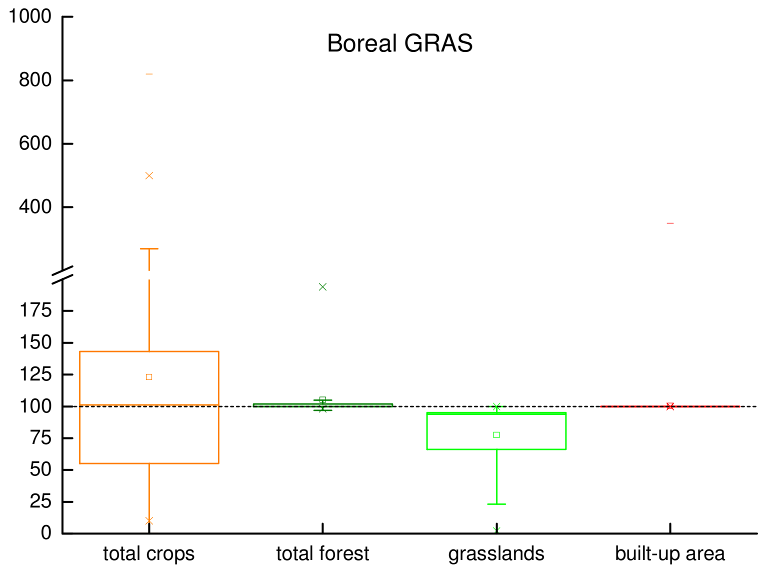
The environmental zone Boreal occupies low plateaus, undulating plains and lowlands of North-East Europe. The climate is continental. The growing season lasts 157 days, sum of temperatures above +10° is 1966° (both values are in the low category). The same as EnZ ALN, most of the zone was an arena of Quaternary glacial abrasion, as revealed by roches moutonnées and other types of ice-moulded surfaces in Scandinavia, Finland and Karelia. The most typical habitat is taiga composed by evergreen coniferous trees. Bogs are very common. The agricultural lands are dominated by grasslands. The main crop is barley; the North of the region is used mainly for forestry and grazing.

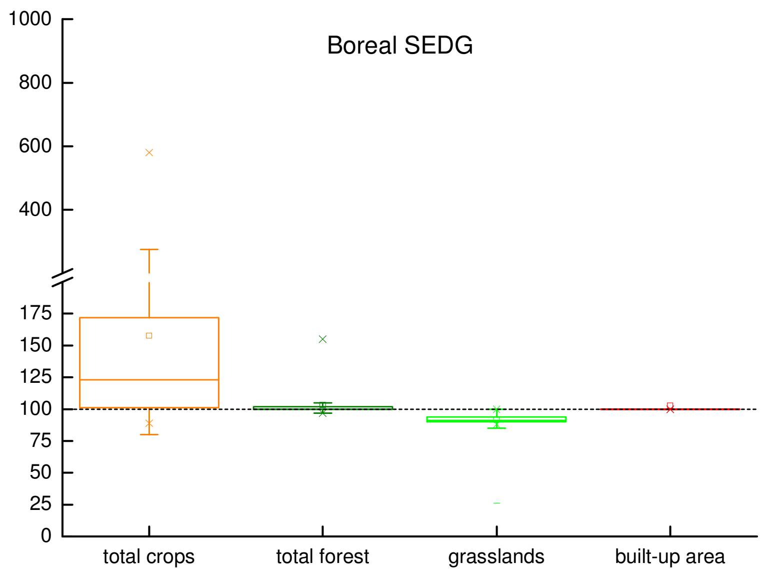
PELCOM land cover:



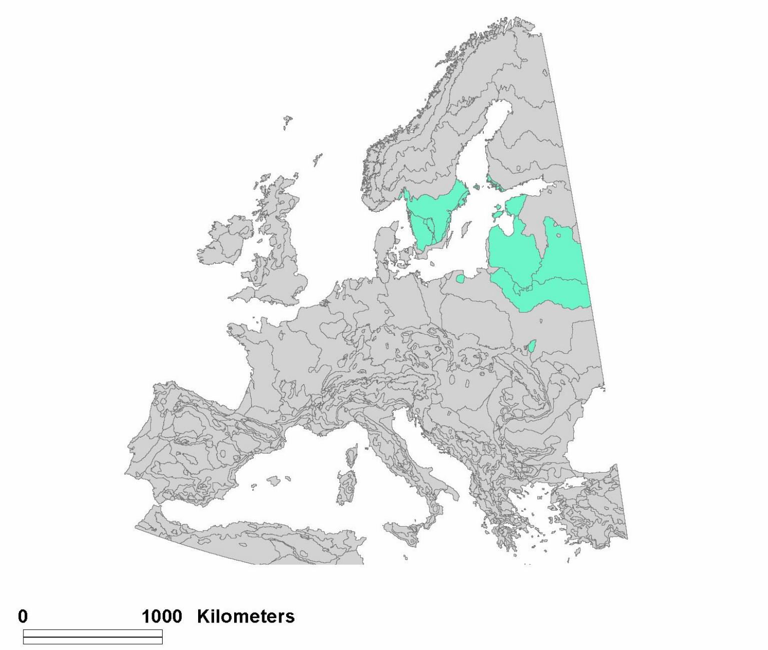
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	141	110	112	100	87	95	103	100
GRAS	123	101	105	100	78	94	100	100
SEDG	158	123	103	100	92	91	103	100

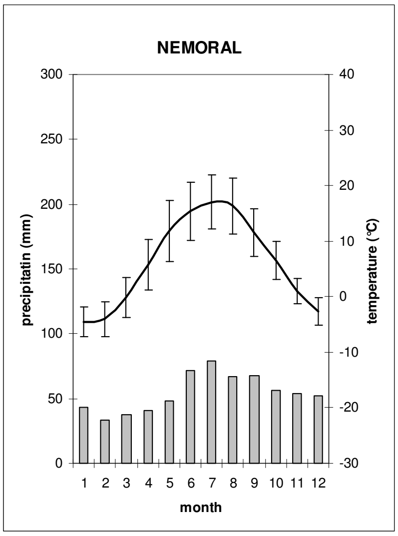

Boreal BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Boreal GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Boreal SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

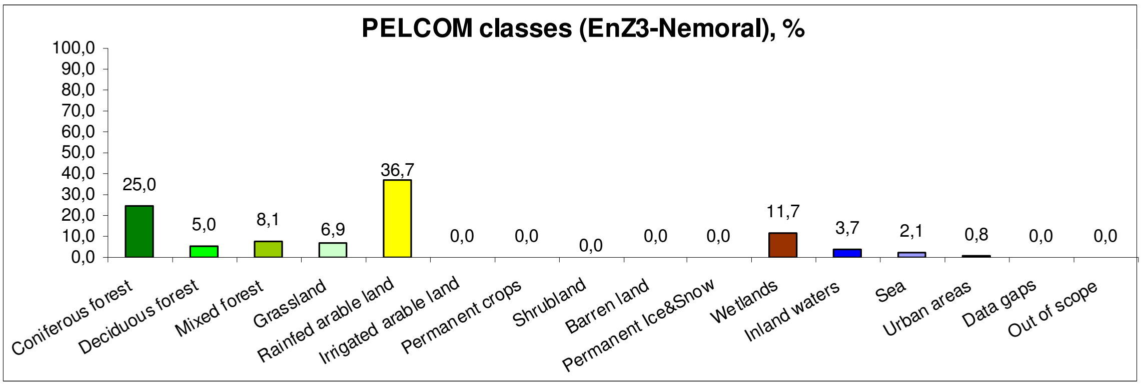
Nemoral (NEM – EnZ3)



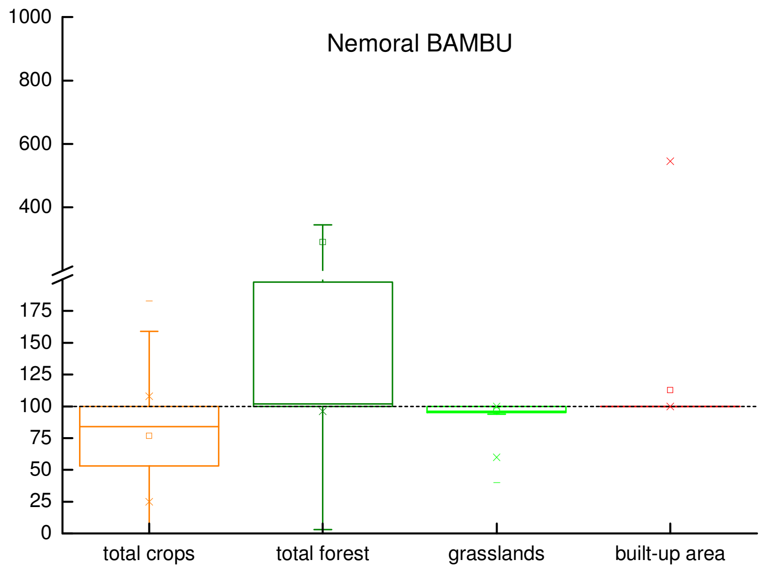


The environmental zone Nemoral is present in the lowlands and undulating plains of South Scandinavia and in the north-west of the Russian Plain. The growing season lasts 196 days, the sum of temperatures above +10° is 2716,5° (values are in the low category). The most characteristic in the Nemoral zone are well developed forms of glacial accumulation (moraine and fluvioglacial) and mixed and evergreen coniferous forests. Most of the natural forests have been converted into agricultural lands or into production forests (in particular in Scandinavia). The main crops are barley and wheat. Bogs and large floodplain marches are very common.

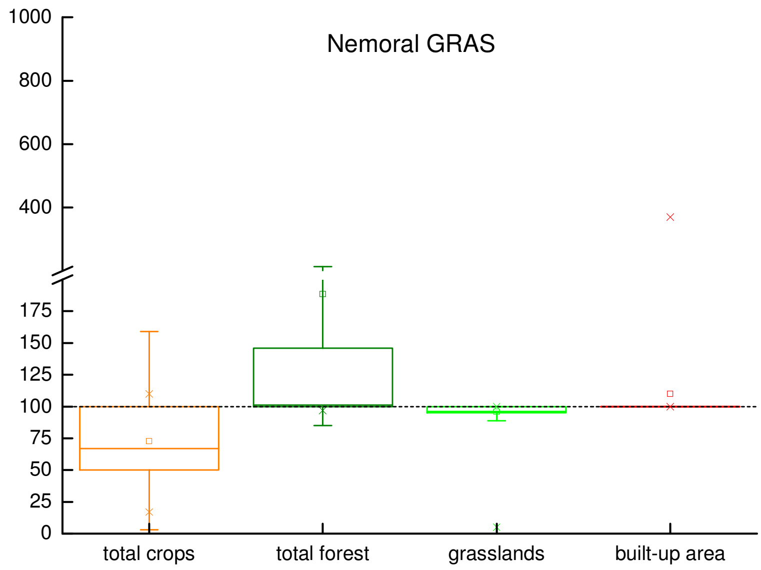
PELCOM land cover:



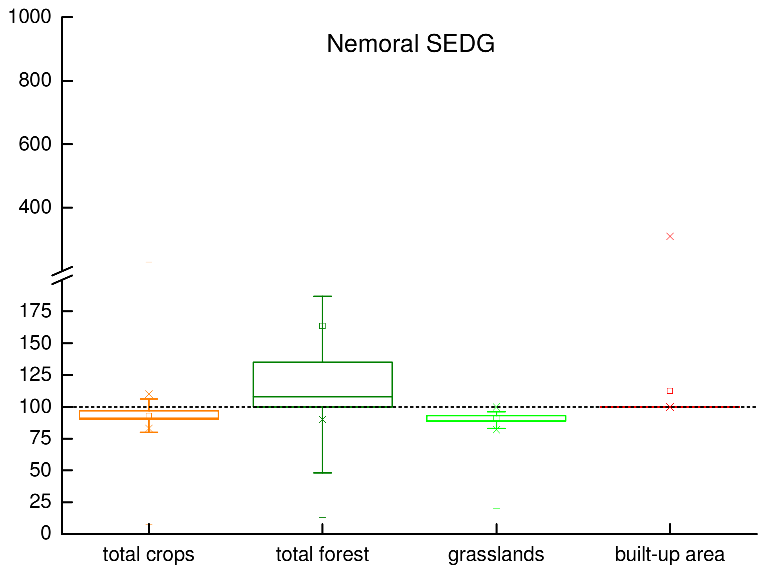
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	77	84	291	102	97	96	113	100
GRAS	73	67	189	101	96	96	110	100
SEDG	93	91	164	108	91	89	112	100



Nemoral BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

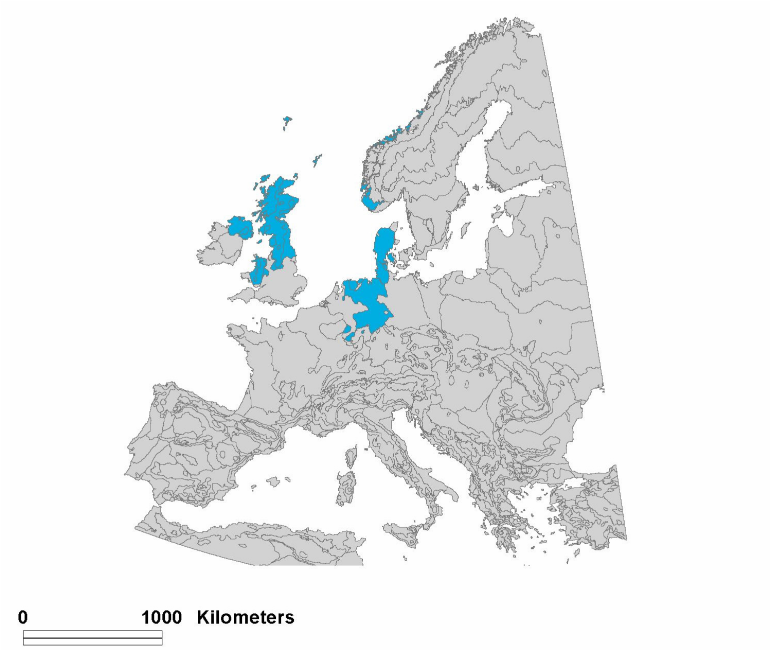


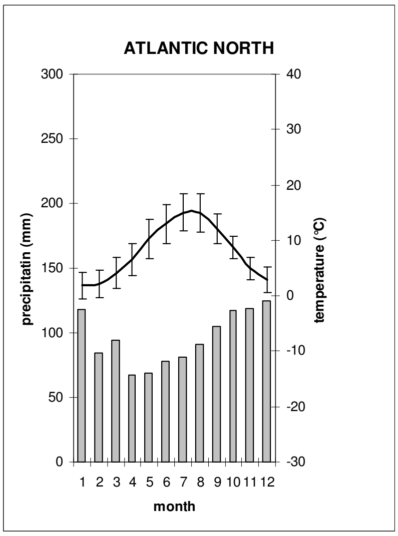
Nemoral GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area



Nemoral SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

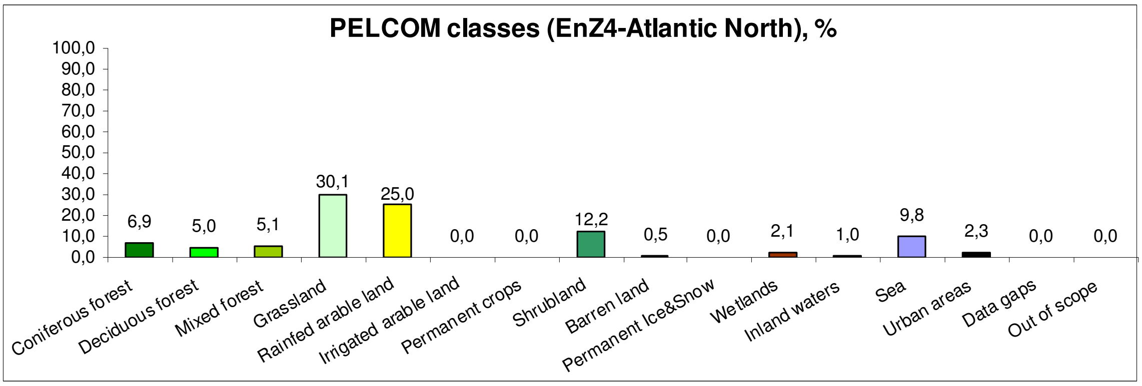
Atlantic North (ATN – EnZ4)



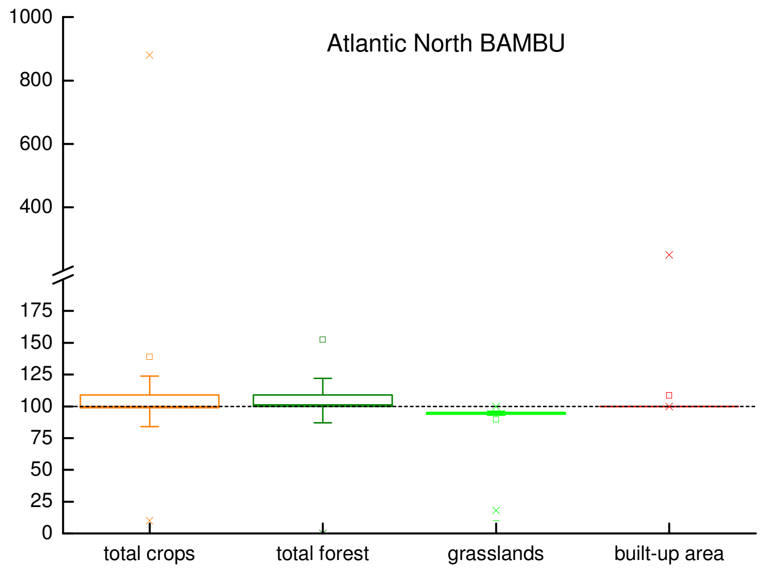


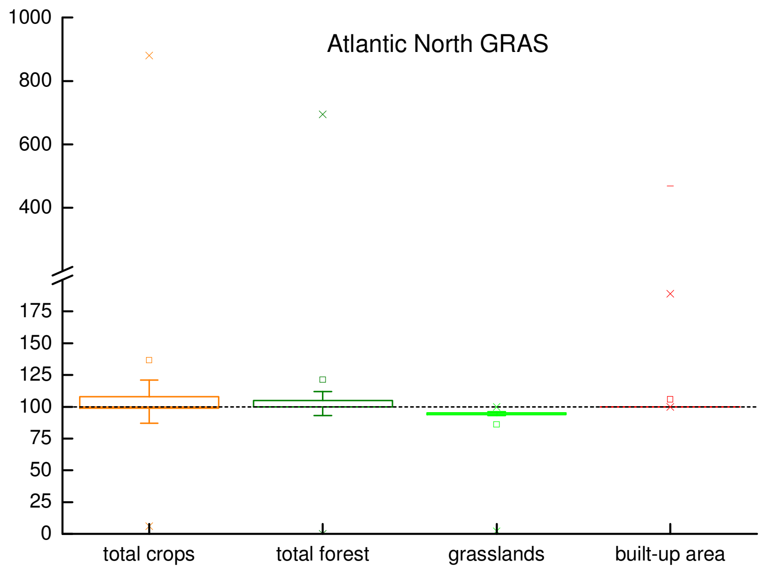
The Environmental zone Atlantic North covers uplands and low mountains in Central and Northern Britain, Northern Ireland and Western coast of Scandinavia, and lowlands and plains of Jutland and North Germany. The growing season lasts 255 days, the sum of temperatures above +10° is 3198,1° (both values are in the middle category). The natural vegetation consists of deciduous forests, except Scandinavia dominated by coniferous and mixed formations. Agricultural lands occupy most of the area. They are mostly crops in the densely populated continental segment, and grasslands in much emptier North Britain and Scandinavia.

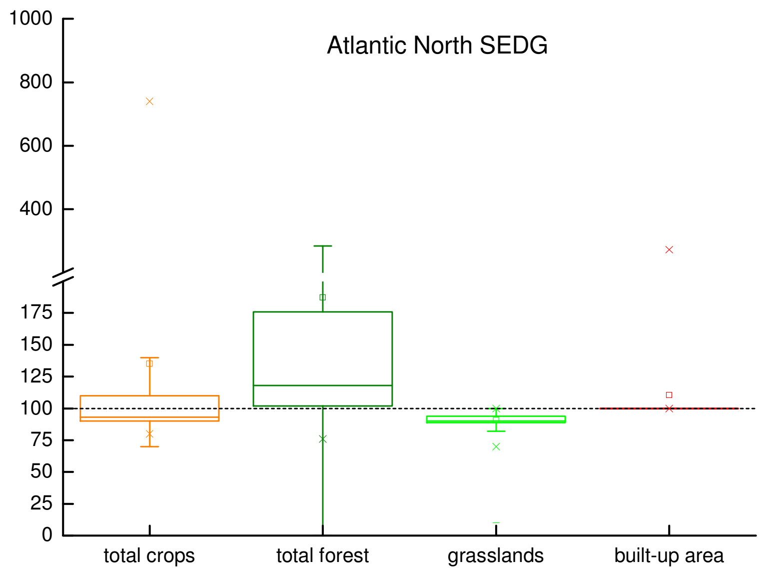
PELCOM land cover:



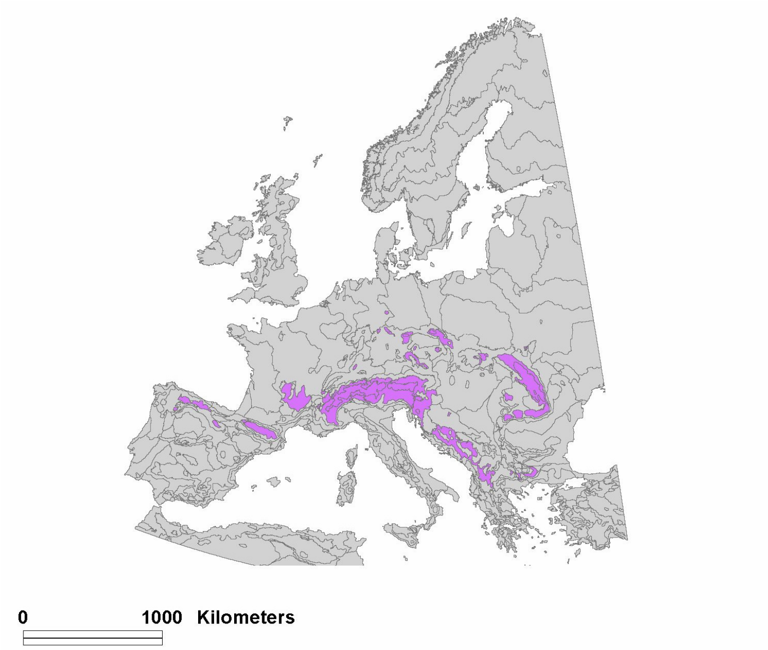
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	139	100	152	101	90	95	108	100
GRAS	137	100	121	100	86	95	106	100
SEDG	135	93	187	118	91	90	110	100

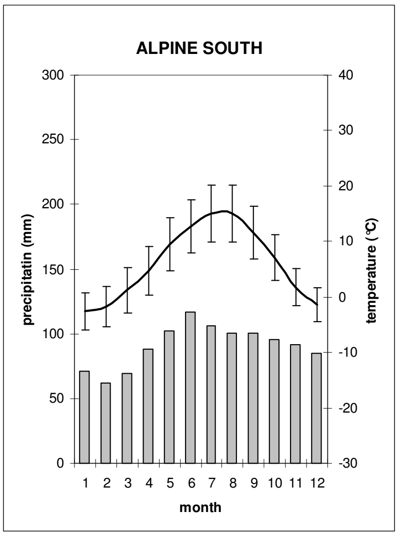

Atlantic North BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Atlantic North GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Atlantic North SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

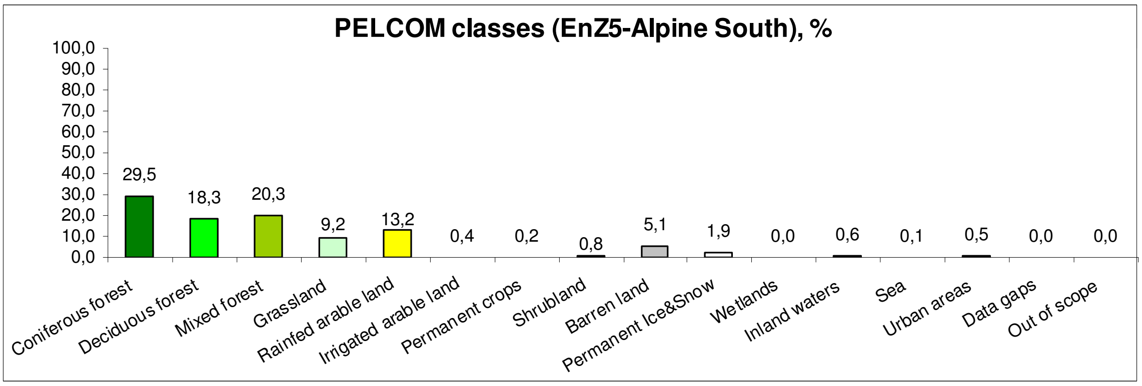
Alpine South (ALS – EnZ5)



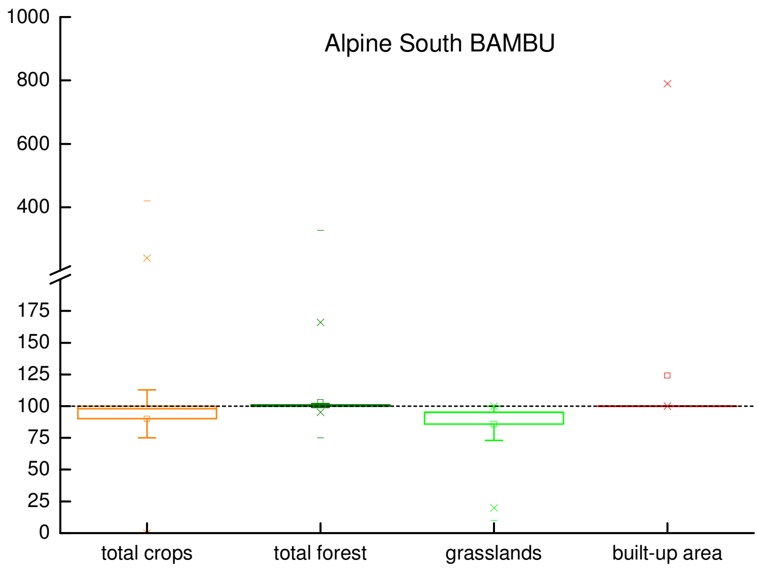


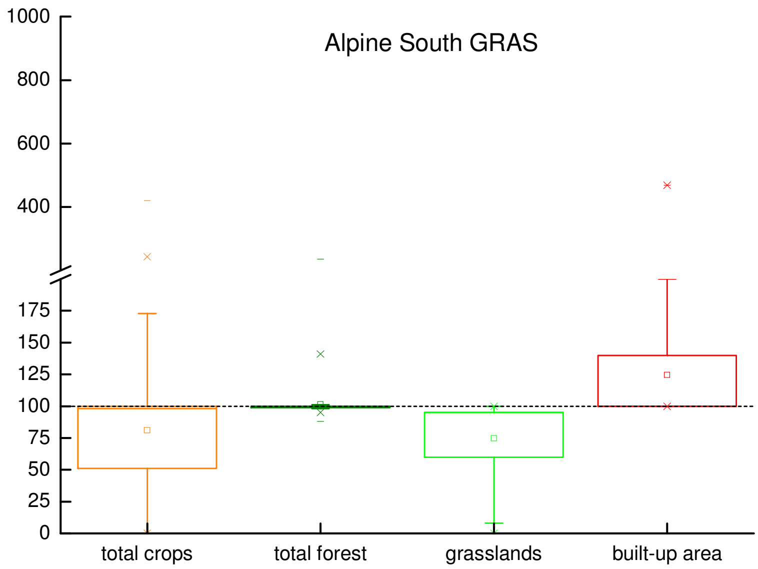
The Environmental zone Alpine South covers high, medium and low mountains of Central and Southern Europe. Most of them belong to the Alpine orogenic belt (Pyrénées, Alps, Carpathians, Tatr and mountains of the Balkan peninsula) or to Hercynian Europe (Schwarzwald, Thüringer Wald, Harz, Etzgebirge and Sudety) and, respectively, are classic Alpine landscapes with deep, relatively inaccessible valleys and permanent snow cover on the highest peaks, or low mountains and uplands. The climate and vegetation vary greatly from west to east and also depend on the orientation of slopes. The growing season lasts 220 days (middle), the sum of temperatures above +10°C is 3005°C (low).

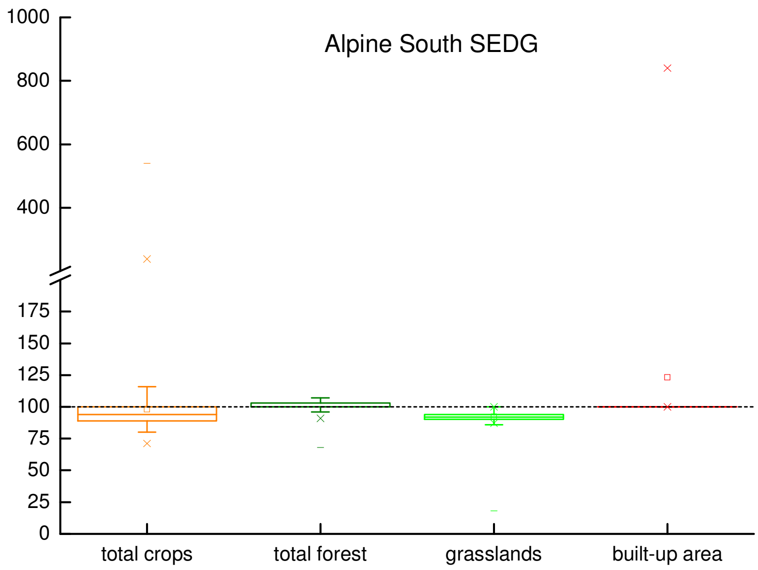
PELCOM land cover:



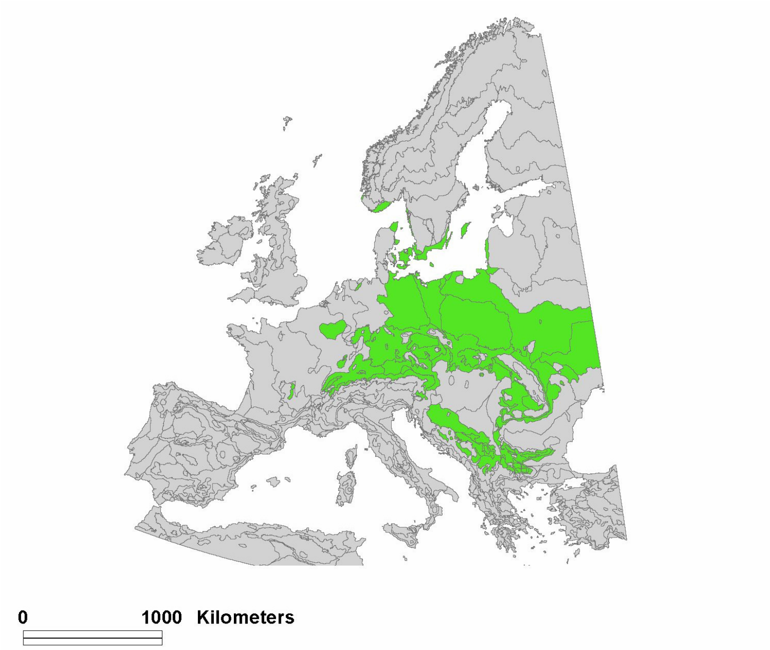
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	90	98	103	100	86	95	124	100
GRAS	81	98	102	100	75	95	125	100
SEDG	98	94	1861	100	92	92	123	100

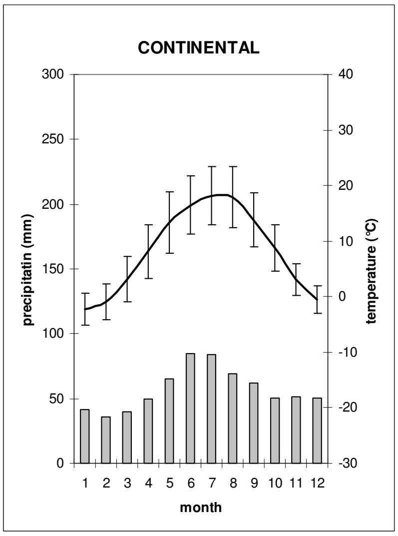

Alpine South BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Alpine South GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Alpine South SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

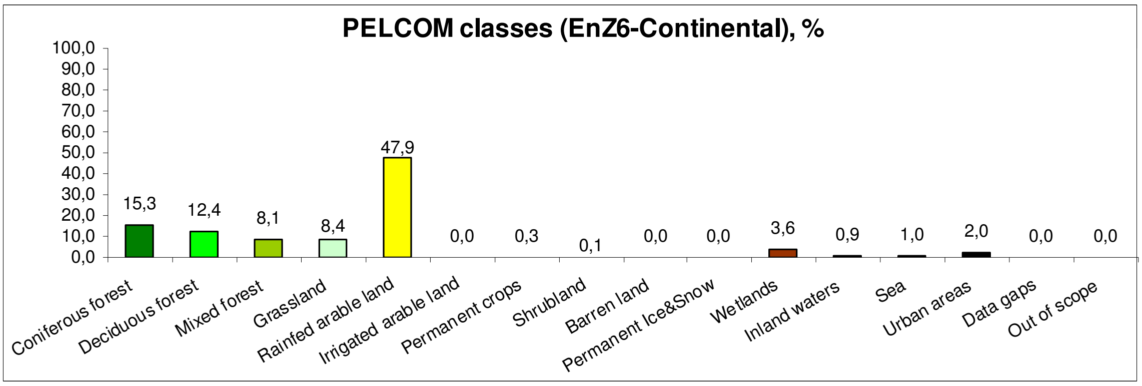
Continental (CON – EnZ6)



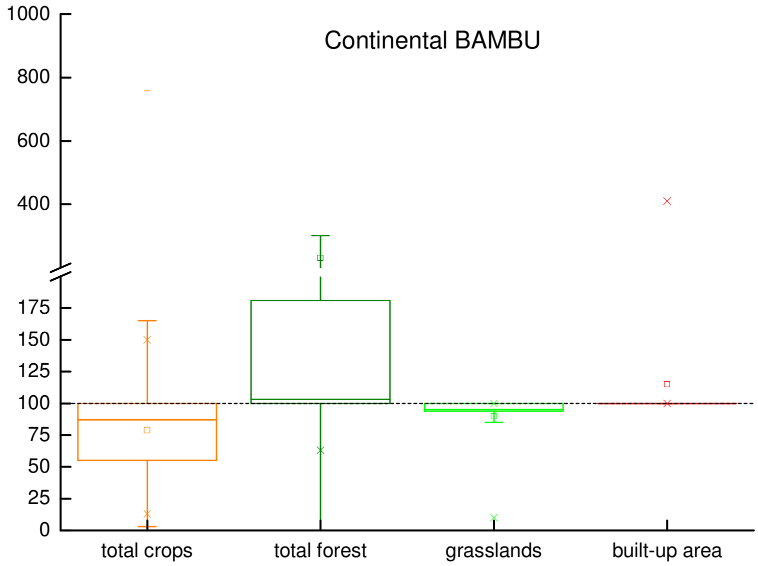


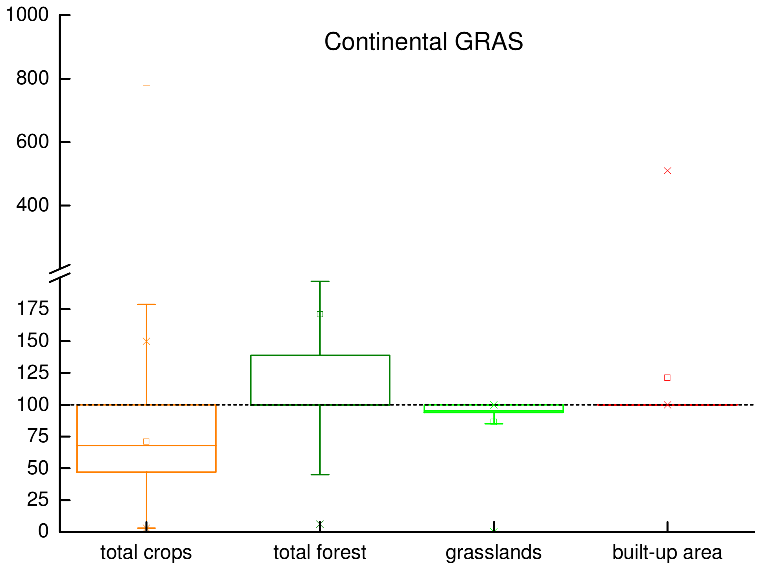
The Environmental zone Continental is mostly on the plains and lowlands of Central and Eastern Europe and uplands and low mountains of the Balkan peninsula. The climate is continental, with clear summer maximum of precipitations and 15-20° difference in the average monthly temperatures. The growing season lasts 227 days, the sum of active temperatures is 3294° (middle). The potential vegetation consists of deciduous forests in the west, mixed and coniferous forests in the central areas, sparse deciduous forests and steppic vegetation in the east and south-east. Most of the area are agricultural lands, however in some districts in Poland and Belarus up to 30-40% of the area are forested.

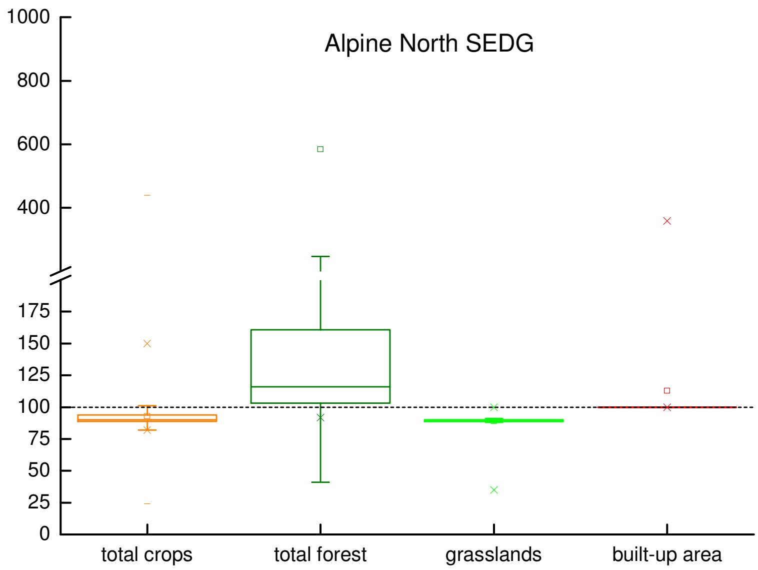
PELCOM land cover:



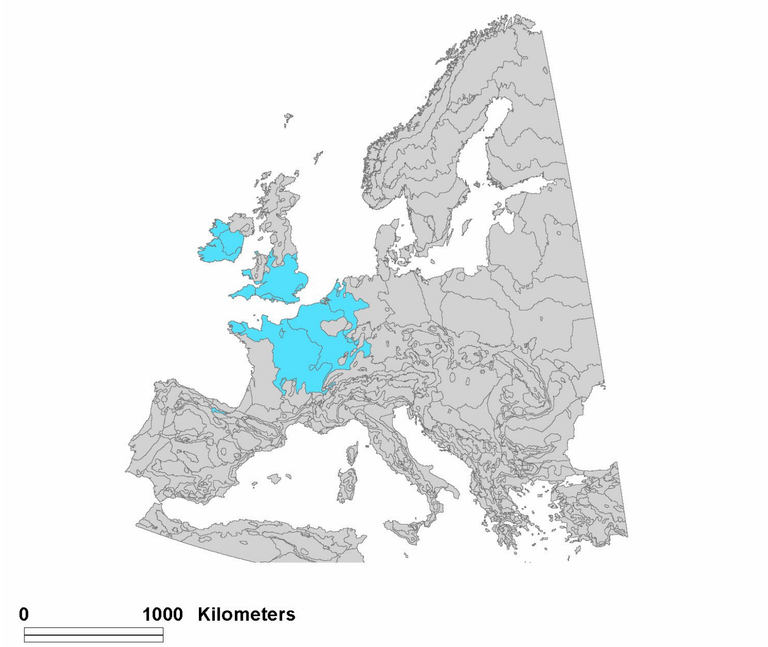
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	79	87	232	103	90	95	115	100
GRAS	71	68	171	100	86	95	121	100
SEDG	93	90	584	116	89	89	113	100

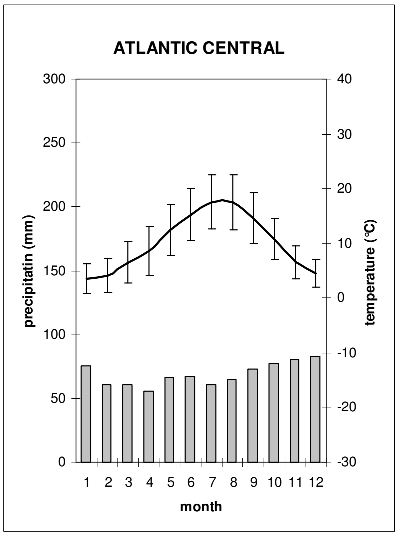

Continental BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Continental GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Alpine North SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

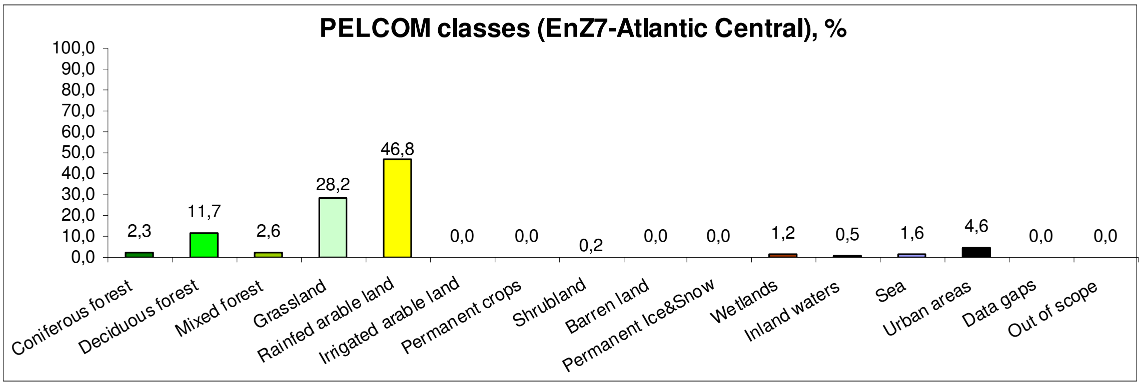
Atlantic Central (ATC – EnZ7)



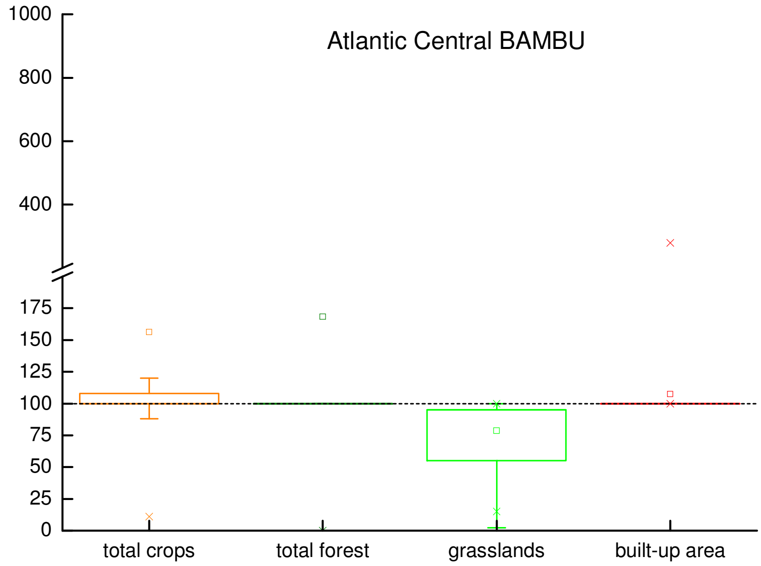


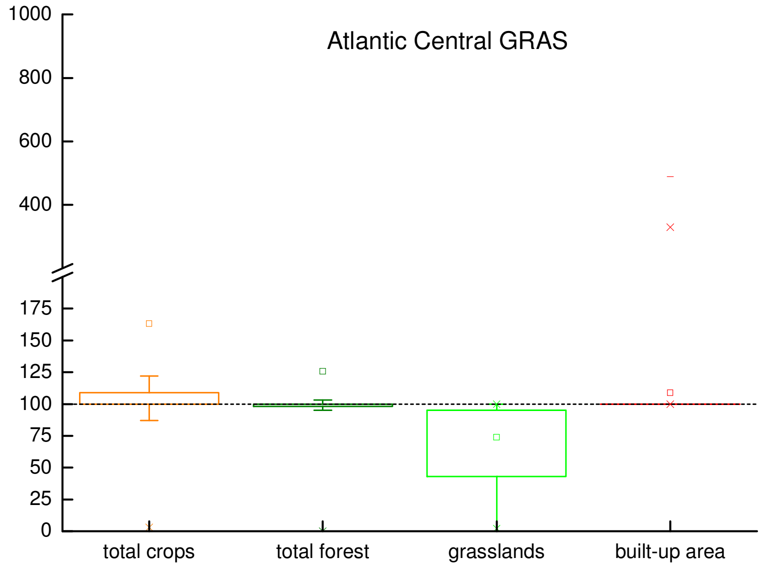
The Environmental zone Atlantic Central is situated in Ireland, South Britain, North and Central France, Belgium, the Netherlands and West Germany. The climate is modified by the Atlantic: the sum of precipitations does not vary much during a year; the contrast in average monthly temperatures is usually within 10°. The growing season lasts 296 days and the sum of active temperatures is 3849°. The area is flat, except the uplands and low mountains of Bretagne and Cornwell. The potential vegetation consists of deciduous forests. The agriculture is intensive and still intensifying. Most of the area is occupied by crops (wheat, barley, sugar-beet, potatoes and vegetables).

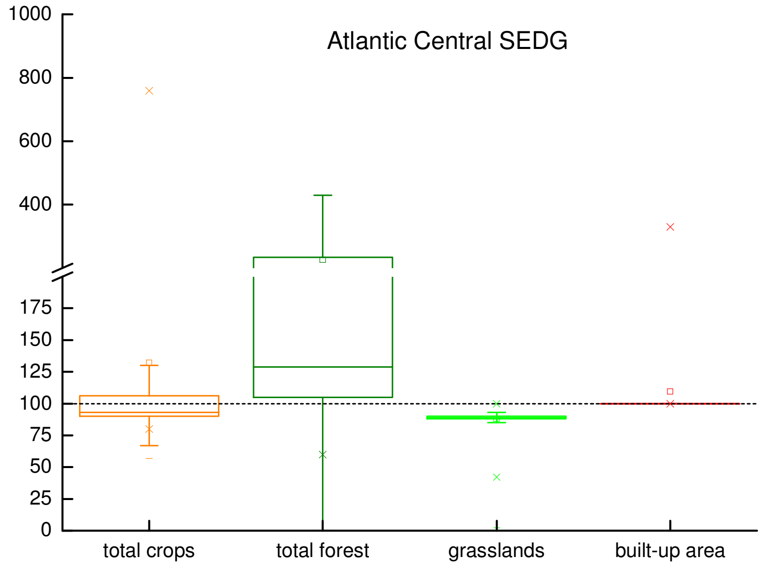
PELCOM land cover:



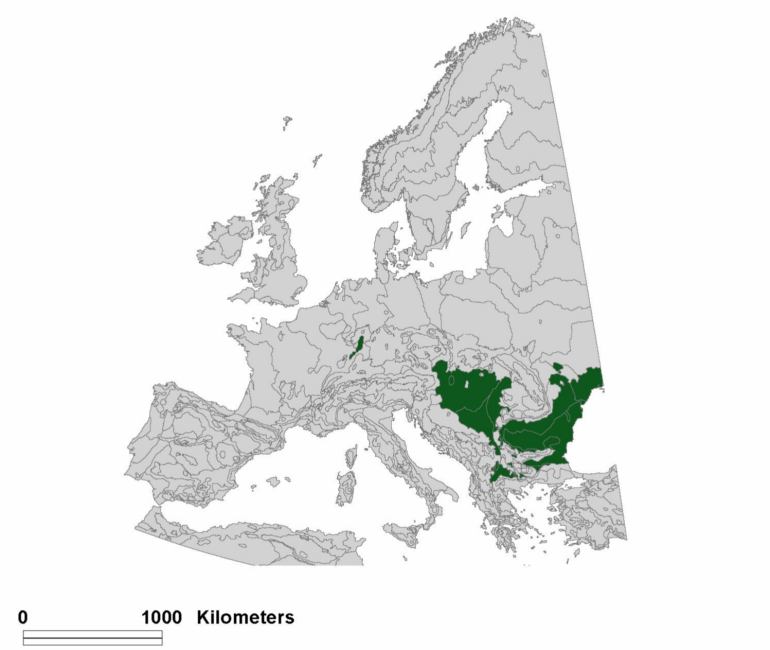
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	156	100	169	100	79	95	108	100
GRAS	163	100	126	100	74	95	109	100
SEDG	132	93	227	129	88	89	109	100

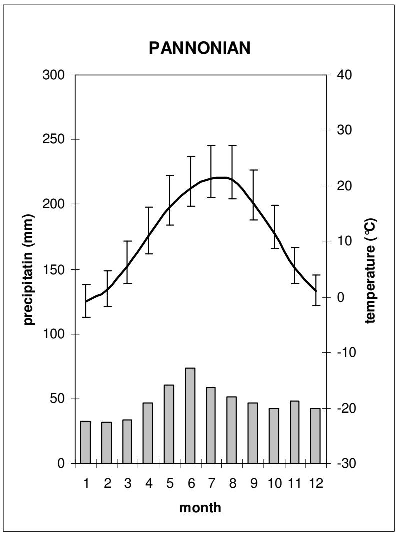

Atlantic Central BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Atlantic Central GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Atlantic Central SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

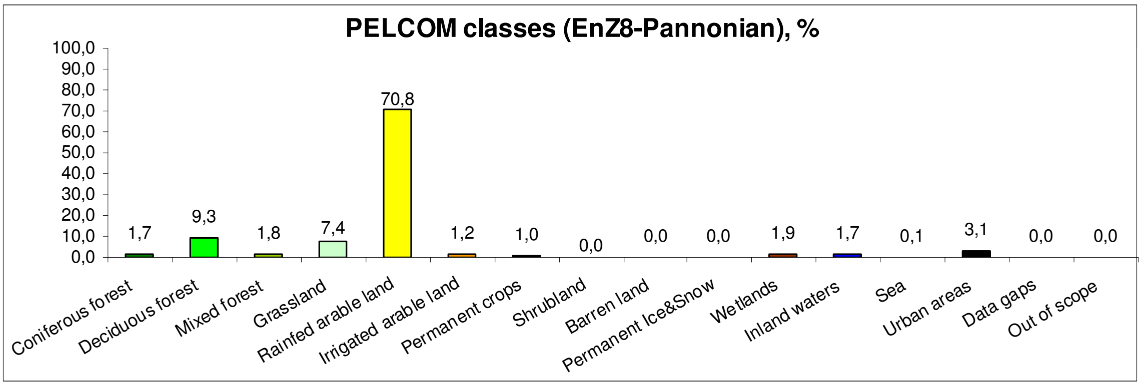
Pannonian (PAN – EnZ8)



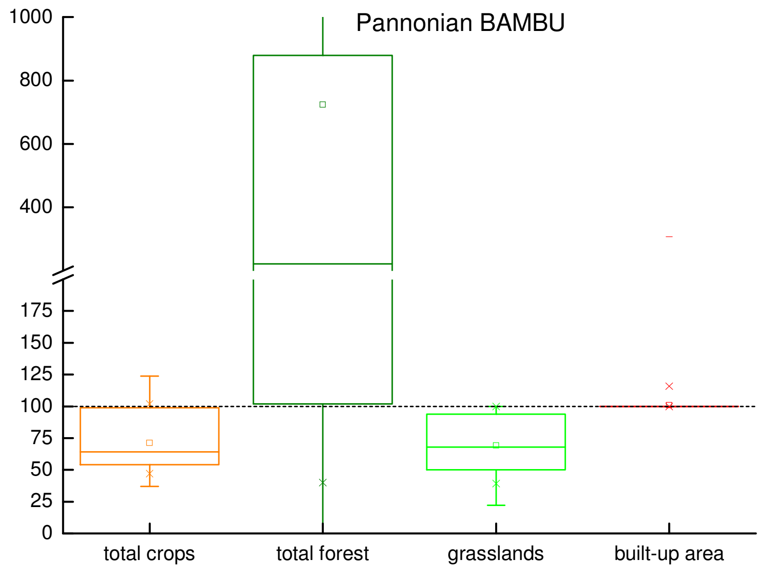


The Environmental zone Pannonian occupies lowlands, valleys and mountain peripheries on the Middle- and the Lower-Danube Plains, the Rein Valley and the Black-Sea Lowland. The area is characteristic for the flat relief, dry continental climate (maximum of precipitations in summer, the yearly amplitude of temperature is 20°) and steppe-like natural vegetation. The formations dominated by threes grow only along the rivers (willow, black poplar) and in the mountain peripheries (oak). The growing season lasts 250 days (both values are in the middle category), the sum of temperatures above +10° is 4098,8°. Historically the area is dominated by grassland farming; nowadays many areas are converted into crops.

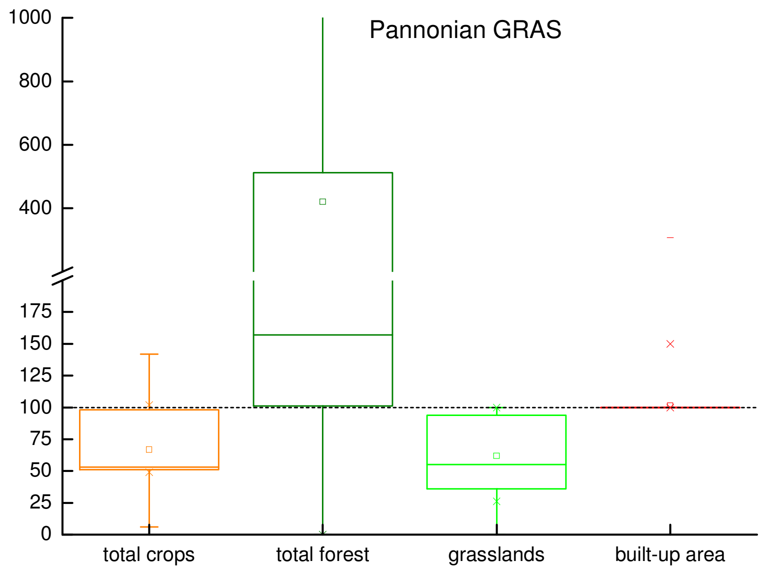
PELCOM land cover:



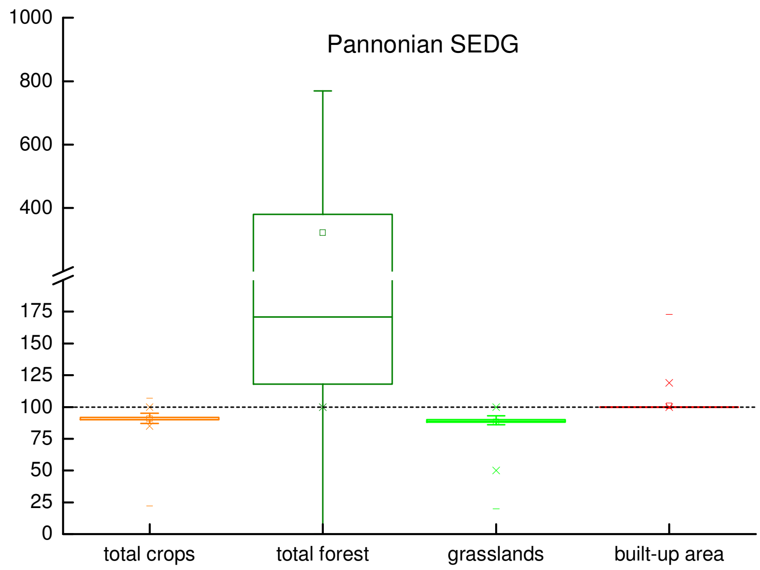
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	71	64	724	223	69	68	101	100
GRAS	67	53	421	158	62	55	102	100
SEDG	91	90	322	172	88	89	101	100



Pannonian BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

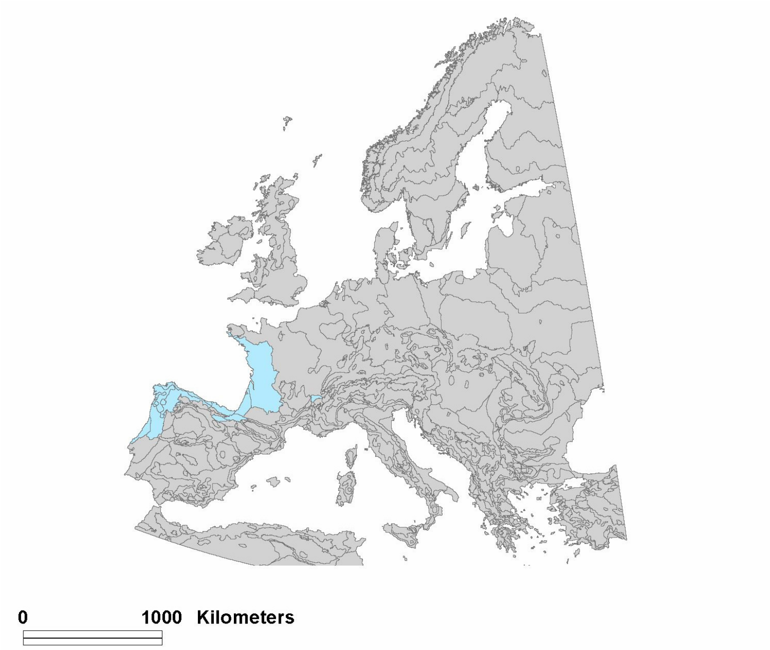


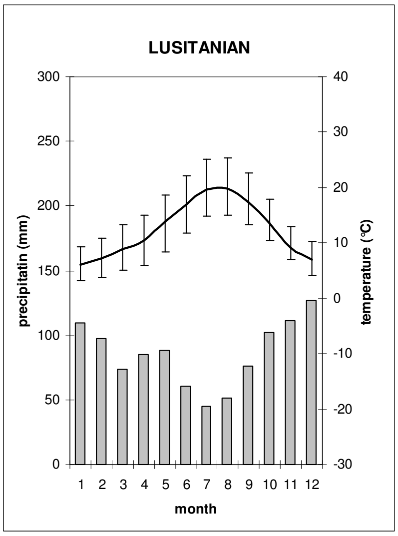
Pannonian GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area



Pannonian SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

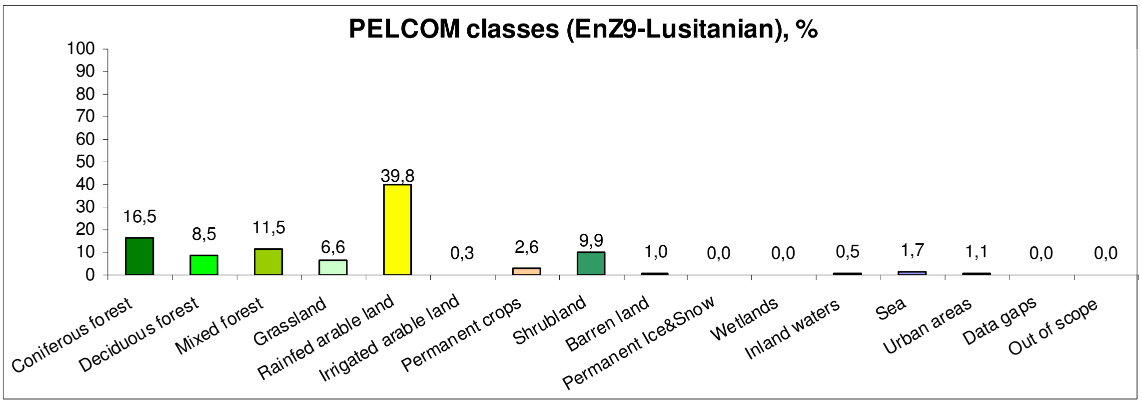
Lusitanian (LUS – EnZ9)



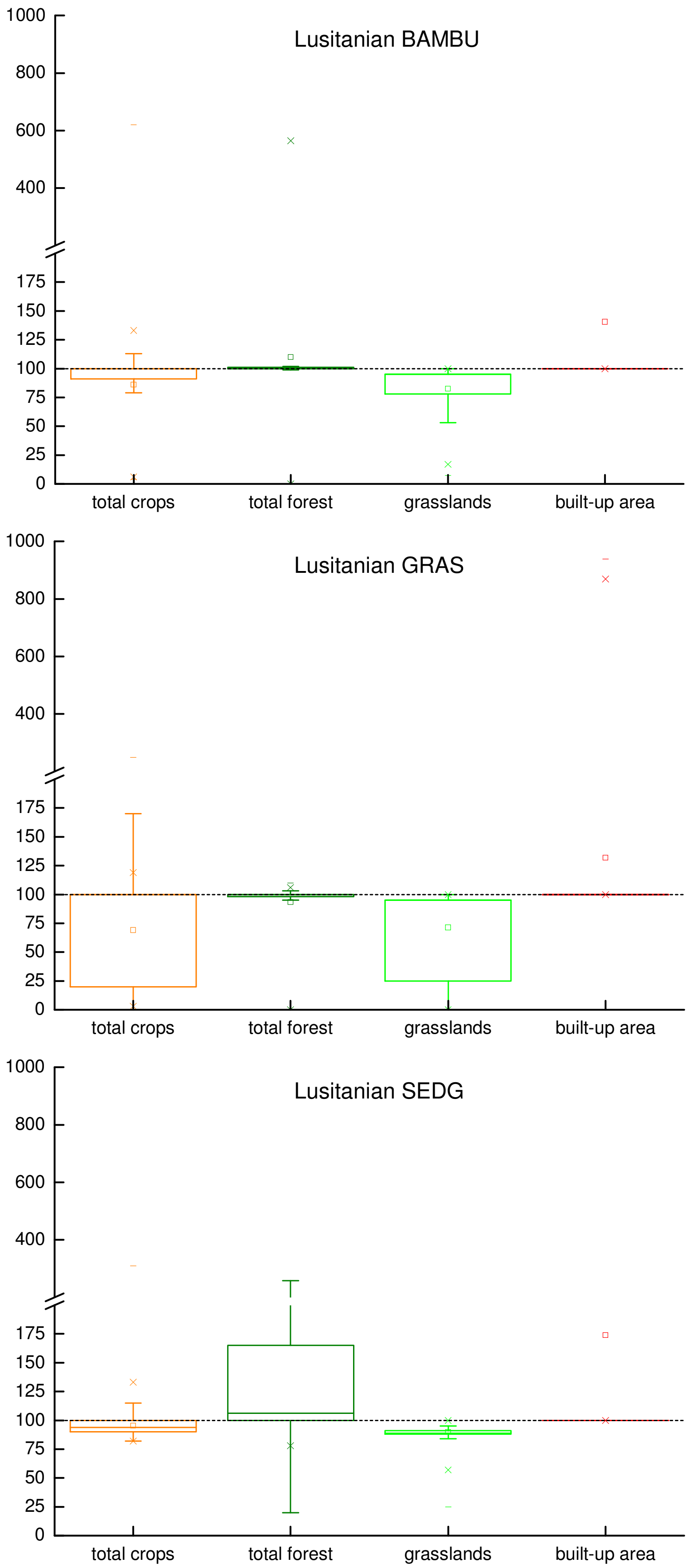


The most characteristic in the environmental zone Lusitanian is the relatively humid climate with Mediterranean-like distribution of precipitation within a year (maximum in winter). The growing season lasts 353 days, the sum of temperatures above +10° is 4749℃ (respectively in the high and middle categories). The relief is very diverse, varying from the lowlands of Les Grandes Landes to the low mountain ranges of Galicia and Serra da Estrela. The potential vegetation consists of deciduous forests; flora is dominated by Atlantic species, rather than Mediterranean. A large proportion of land is used for rainfed crops. The main agricultural products are wheat and wine.

PELCOM land cover:

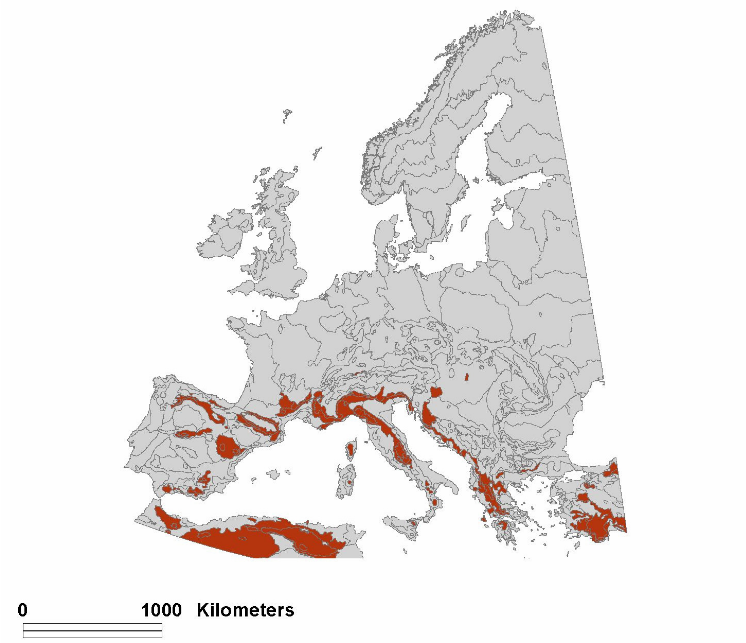


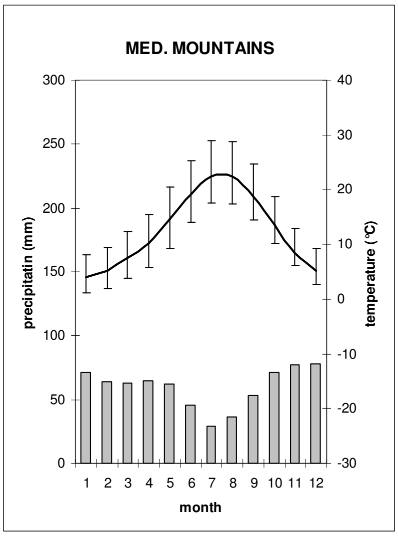
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	86	100	110	100	83	95	141	100
GRAS	69	100	93	100	71	95	132	100
SEDG	95	94	2439	106	90	89	174	100



Lusitanian BAMBU
Lusitanian GRAS
Lusitanian SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

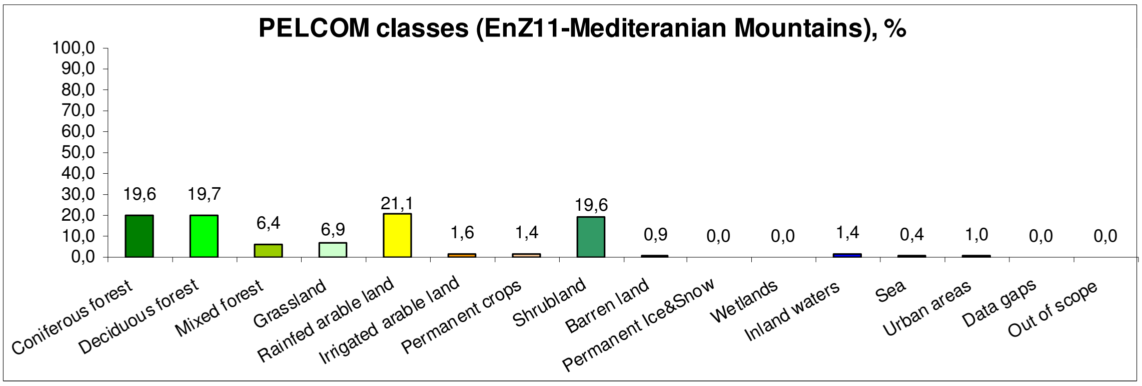
Mediterranean Mountains (MDM – EnZ11)



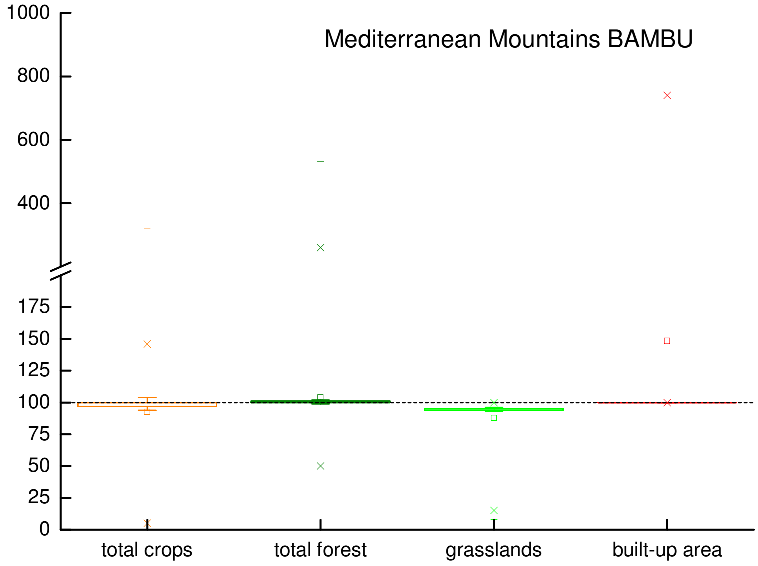


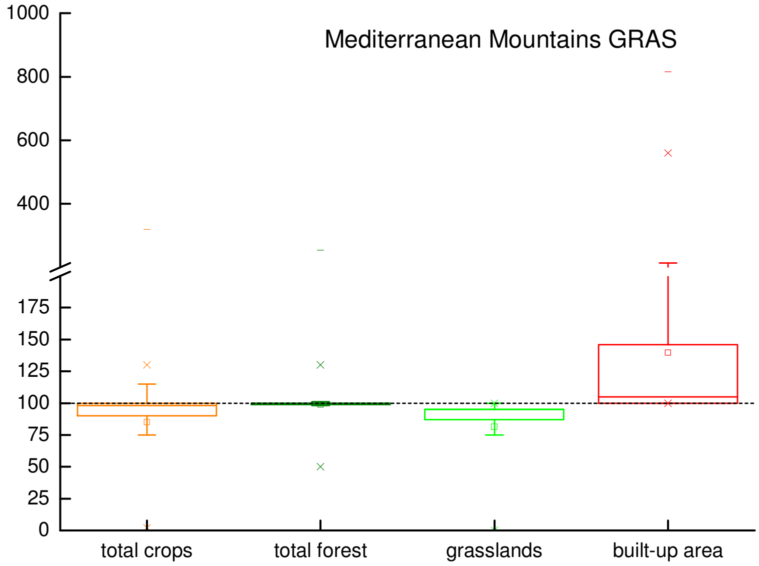
The Environmental zone 11 Mediterranean Mountains covers low- and medium mountains in the north Mediterranean and high mountains in the south. Unlike the Alpine classes, glacial abrasion is not important or nonexistent in MDM; instead the relief is severely affected by water erosion. Compared to other Mediterranean classes, Mediterranean Mountains receive more precipitation. This and difficult access to the mountains preserve the natural vegetation of the region – deciduous and coniferous forests. Primary and secondary (various stages of degradation) shrub formations (e.g. maquis, garriga, carrascal, phrygana, shibliak) are also very common. The growing season lasts 298 days, the sum of temperatures above +10℃ is 4547,8° (values are respectively in the high and the middle categories).

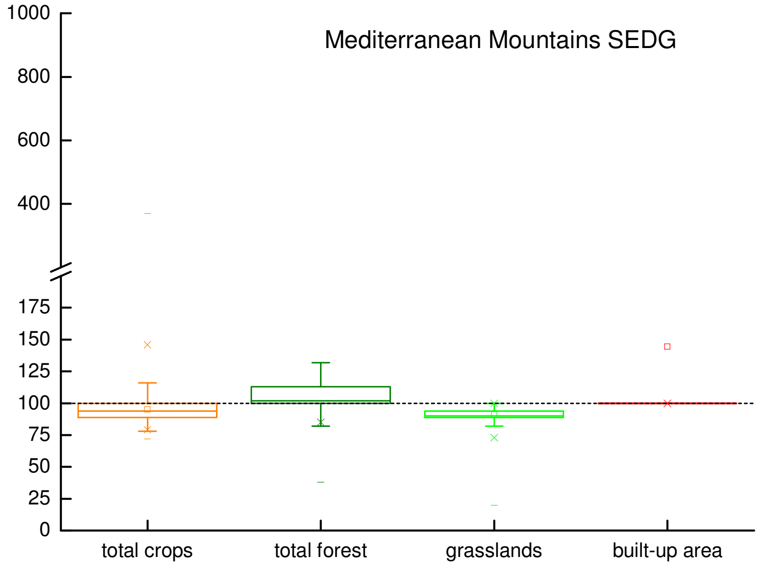
PELCOM land cover:



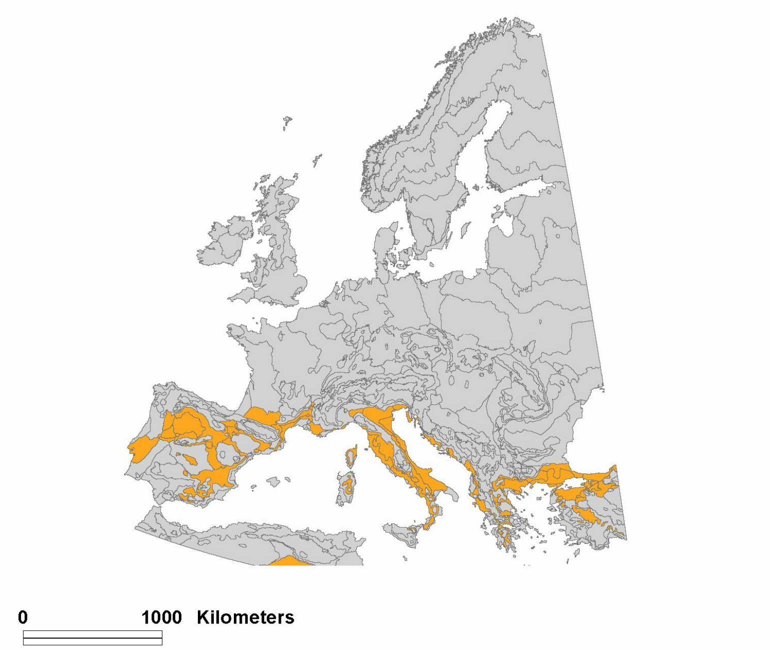
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	93	100	104	100	88	95	148	100
GRAS	85	98	99	100	81	95	140	105
SEDG	95	94	1992	102	91	90	145	100

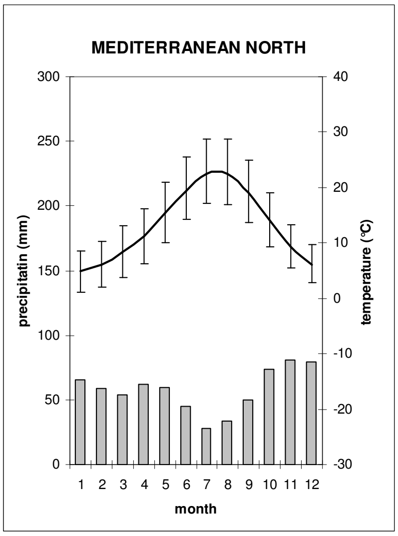

Mediterranean Mountains BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Mediterranean Mountains GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Mediterranean Mountains SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

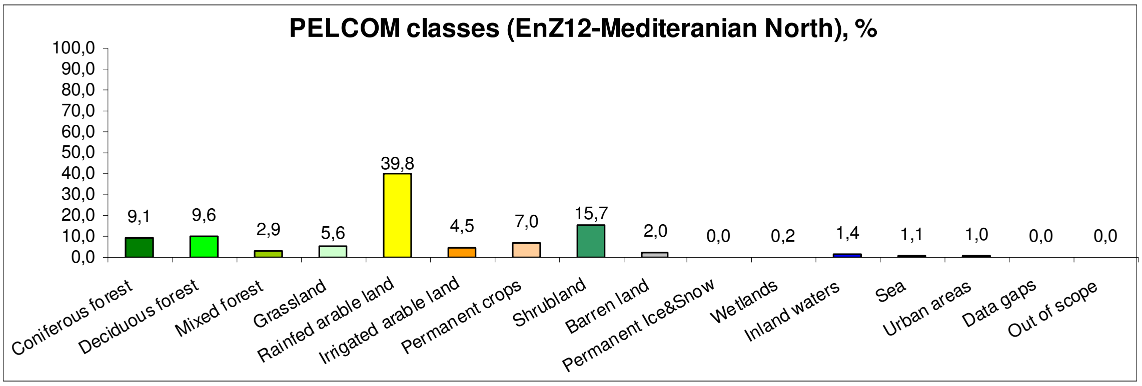
Mediterranean North (MDN – EnZ12)



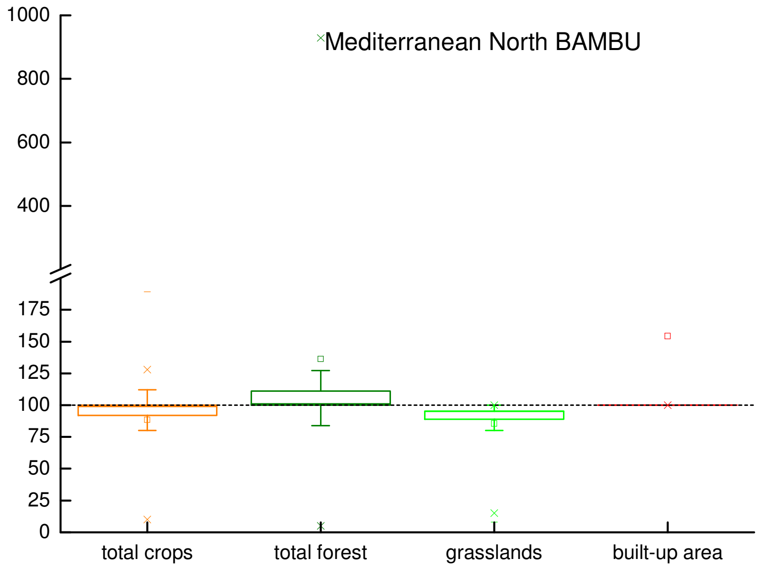


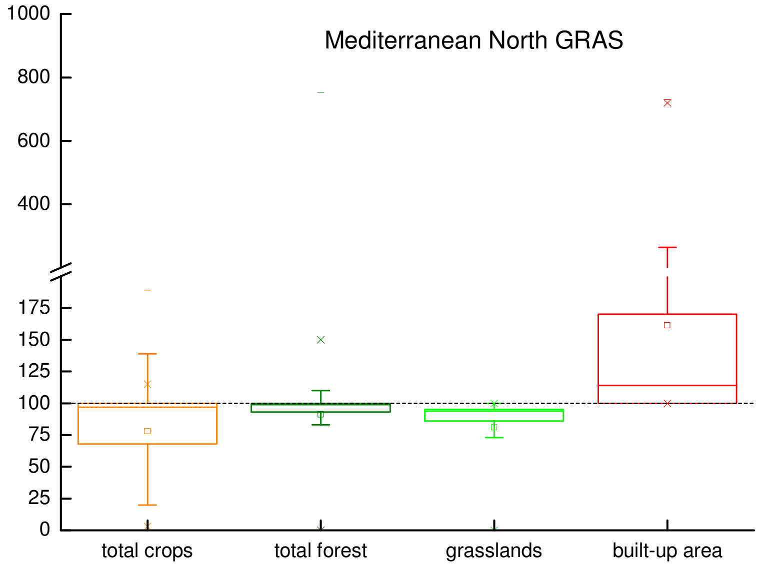
Environmental zone Mediterranean occupies lowlands in northern, uplands and low mountains in southern Mediterranean. Common landforms are lowlands of intermountain troughs and coastal plains, plateaus with isolated mountains, mountain piedmonts, low mountains and uplands. Climate is Mediterranean, typical for the winter maximum of precipitations and dry summer. Growing season lasts 335 days, sum of active temperatures is 5104,2°. The vegetation consists mostly of scrub formations (e.g. maquis, garriga, phrygana); most of them are successions of originally dominating forests. Agricultural lands dominate the region; major products are wheat, wine, olives and fruits.

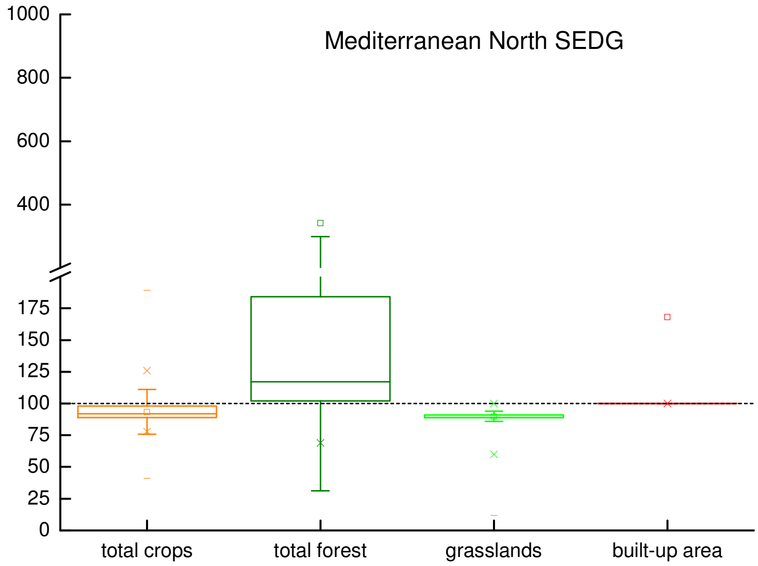
PELCOM land cover:



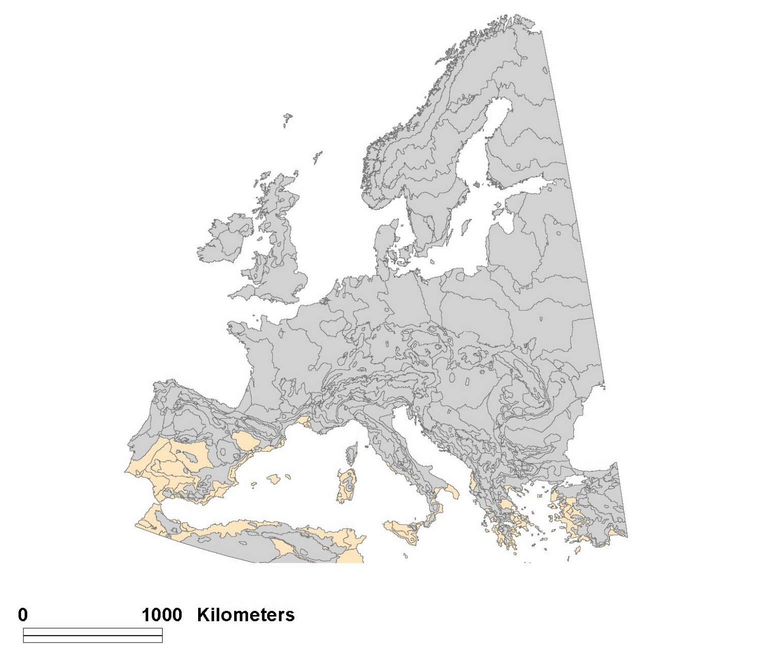
Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	89	99	136	101	85	95	154	100
GRAS	78	97	91	99	81	94	161	115
SEDG	93	92	342	117	90	89	168	100

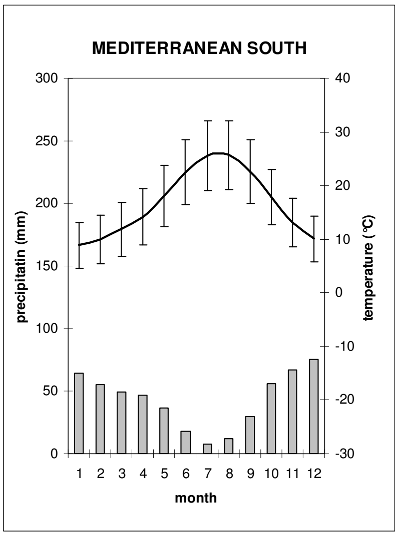

Mediterranean North BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Mediterranean North GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Mediterranean North SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

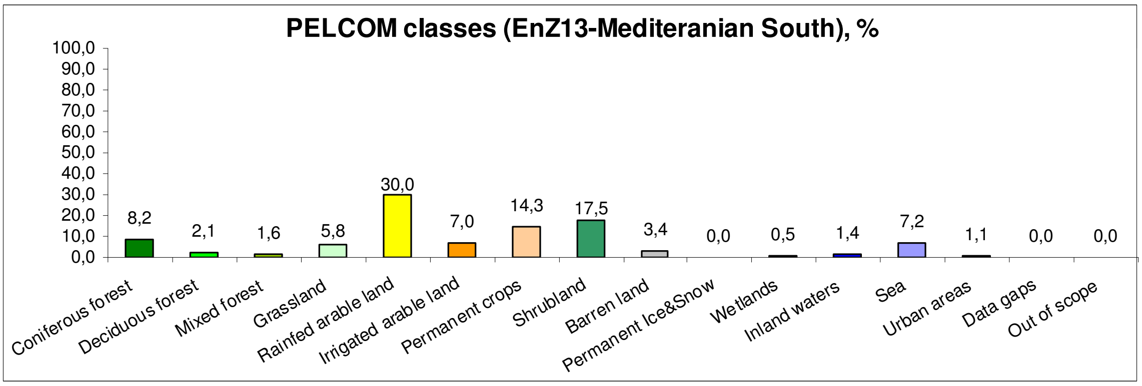
Mediterranean South (MDS – EnZ13)



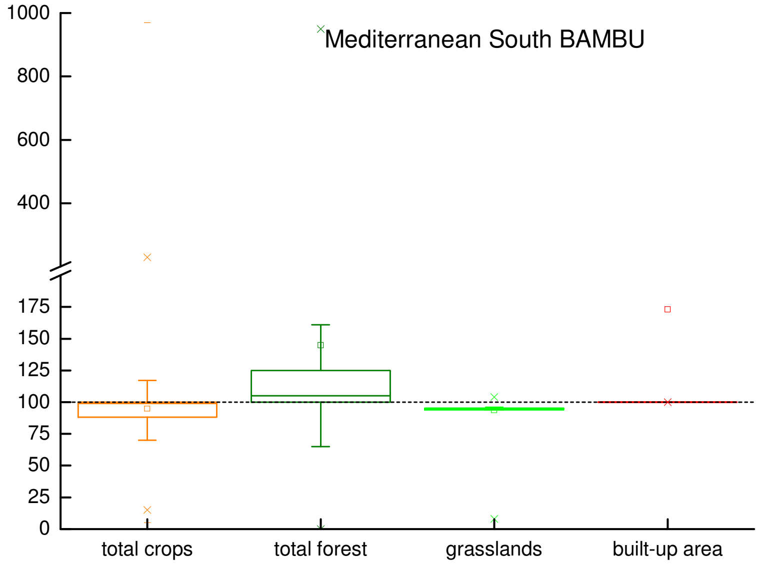


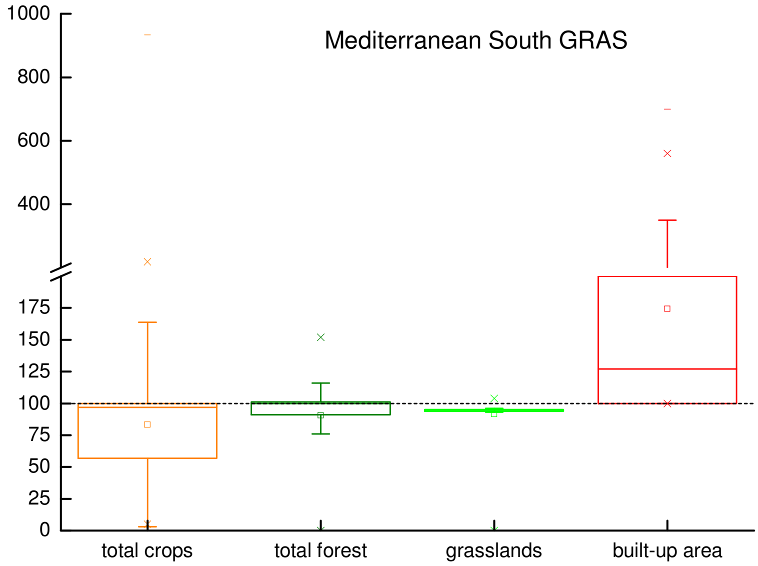
Environmental zone Mediterranean South occupies plains and uplands in southern Mediterranean and some lowlands in the northern. Most of the zone is in the Iberian peninsula, where relief consists of plateaus with residual mountains, denudational plains and accumulative lowlands. Climate is Mediterranean with hot and dry summer and maximum of precipitations in winter. Growing season lasts 363 days, sum of active temperatures is 6021,4°. Vegetation is dominated by a variety of scrub formations. Agriculture is partly in a phase of abandonment, partly intensifying. Major products are wheat, wine, olives and fruits.

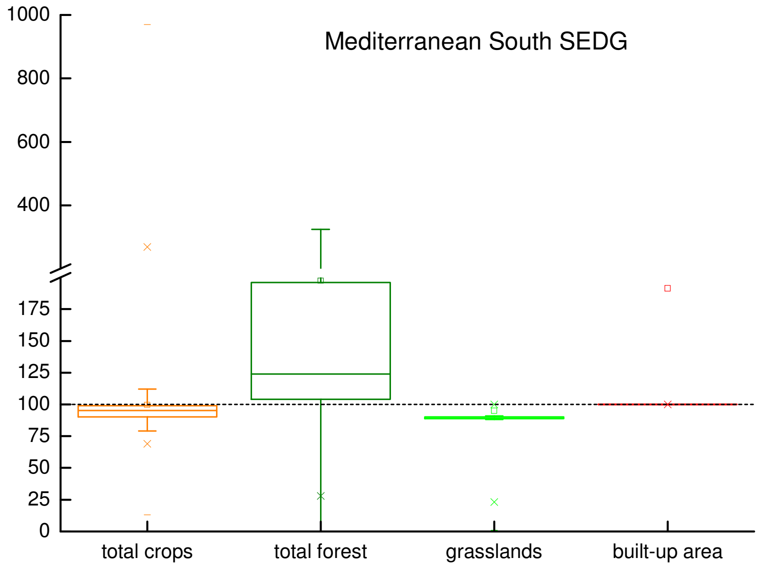
PELCOM land cover:



Scenario	Total crops		Total forest		Grasslands		Built-up area	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BAMBU	95	99	145	105	94	95	173	100
GRAS	83	97	91	100	92	95	174	127
SEDG	99	95	197	124	95	89	191	100


Mediterranean South BAMBU
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Mediterranean South GRAS
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area


Mediterranean South SEDG
1000
800
600
400
175
150
125
100
75
50
25
0
total crops
total forest
grasslands
built-up area

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Appendix 1 – Statistical analysis work plan revision 2

The capability of CLC land cover classes to provide useful and ecologically plausible predictors for grassland plant and butterfly species richness were tested for Finland and Sweden, where both the national CLC data with 25m resolution as well as European CLC data with 250m resolution was available. The total number of vascular plant species and butterfly species, and the number of grassland specialist plant and butterfly species in the focal grassland patch were related to the cover of different CLC land classes in the 2-km circles, first using the 25m-resolution CLC data and then 250m-resolution CLC data. All the models were built using generalized additive models (GAM), as implemented in GRASP (Generalised Regression Analysis and Spatial Prediction) user interface developed for the statistical package S-PLUS (version 6.1 for Windows, Insightful Corp.) (Lehmann et al. 2003).Generalized additive models are flexible data-driven non-parametric extensions of generalized linear models (Hastie and Tibshirani 1986) that allow both linear and complex additive response curves to be fitted (Wood and Augustin 2002). GAMs have proven to provide a useful and reliable modelling tool for different biodiversity attributes in recent studies (see Austin 2002, Austin et al. 2006). The goodness of fit in the GAM/GRASP models were measured by proportion of explained deviance to the total deviance in the response variable (D2; ranging from 0 to 1, higher values indicating that the predictors capture more of the variation in the response variable), and p-values derived from the associated F-tests (see Lehmann et al. 2003).

For Finland, in the 25m-resolution CLC data, 19 CORINE land cover classes were recorded to occur in the 28 study landscapes included in the modelling. Most of these land cover classes had, on average, a low cover in the 2-km circles in the study landscapes, only land cover classes non-irrigated arable land (CLC class 2.1.1) (25.3%) and coniferous forests (CLC class 3.1.2) (23.9%) showed a higher coverage. The cover of pastures (CLC class 2.3.1) was below 1.0% on average based on the CLC 25m-resolution data, and natural grasslands (CLC class 3.2.1) were not recorded in the database from the study landscapes. These 19 CLC land cover classes did not provide useful predictors for the richness patterns of vascular plants or butterflies recorded in the focal grassland patches in the study landscapes.

For total species richness of butterflies, only one CORINE land cover type was selected in the models as a statistically significant predictor, i.e. CLC class 5.1.1 - water courses (P=0.05, D2=0.16). However, this variable explained only a minor part of the variation in the butterfly species richness, and was also highly unreasonable as an explanatory variable. For the total richness of plant species in the focal grassland patches, the results were even less encouraging, because none of the 19 CORINE 25m-resolution land cover classes provided a statistically significant predictor. As regards the richness of grassland specialist species, same patterns appeared in the results. For grassland specialist butterflies, only CLC class 3.1.2 - coniferous forest (p=0.05, D2=0.15) provided as a statistically significant (but ecologically doubtful and less useful) predictor. For grassland specialist plants, again none of the 19 CORINE 25m-resolution land cover classes provided a statistically significant predictor.

In the 250m-resolution CORINE land cover data, 14 land cover types were recorded from the 28 study landscapes in Finland. In the GAM models based on this data, only one CORINE land cover type appeared as a statistically significant predictor for total species richness of butterflies: CLC class 1.3.1. - mineral extraction sites (p=0.05, D2=0.31). For the total richness of vascular plants, two CLC classes appeared as statistically significant predictors: land cover class 1.2.1. - industrial and commercial units (P=0.05, D2=0.27), and land cover class 3.2.4 - transitional woodland-scrub (p=0.05, D2=0.29). The explanatory power of all these predictors was only moderate (leaving majority of the variation in species richness unexplained). Moreover, from ecological perspective, results related to especially mineral extraction sites and industrial and commercial units were very likely artifacts as neither of these variables is plausibly linked with variation in the richness of grasslands species.

As regards the grassland specialist plant species, only one CLC class (3.2.4 - transitional woodland-scrub; p=0.05, D2=0.2956124) was selected as a statistically significant (but again ecologically doubtful and in practice unuseful) explanatory variable for the GAM models for these species. Moreover, none of the fourteen 250m-resolution land cover classes provided a statistically significant predictor for the species richness of grassland specialist butterflies in Finland.

Similar tests were carried out also using the CLC 25m-resolution and CLC 250m-resolution data available from Sweden. When modelling the total richness of butterflies using finer-scale 25m-resolution CLC data, none of the CORINE land cover classes was selected in the GAM models as a statistically significant explanatory variable. For total richness of vascular plants, two CLC classes appeared as significant predictors:CLC class 1.4.1 – green urban areas (p=0.05, D2=0.36) and CLC class 3.3.2 - bare rocks (p=0.05, D2=0.24). Neither of these was considered as a highly logical and useful predictor for grassland species, especially when included in the models on their own. In the case of species richness of grassland specialist butterflies, one Corine land cover type provided a significant predictor, namely class 3.1.3 – mixed forest. Although this variable was more realistic than the variables reported above, the amount of explained variation in the richness patterns by it was low (p=0.05, D2= 0.16). For grassland specialist plants, two variables were statistically significant, i.e. CLC land cover class 1.2.1 - industrial and commercial units (p=0.05, D2=0.17) and CLC class 1.4.1. - green urban areas (p=0.05, D2=0.39), but neither of them were ecologically plausibly linked with the species richness patterns in the focal grassland patches.

In the models based on the CORINE data from Sweden recorded at 250m-resolution, one of the CLC land cover classes, 3.1.1 - broadleaf forests, appeared as a significant explanatory variable for the total richness patterns of butterflies (p=0.05, D2=0.31), while species richness of grassland specialist butterflies was not significantly correlated with any of the CLC land cover variables recorded from the studied 2-km circles.

In the corresponding GAMs developed for the total richness of vascular plant species, two statistically significant variables were selected. First one of the, CLC class 1.1.2 - discontinuous urban fabric (p=0.05, D2=0.21) was not ecologically plausible, but the second one was: CLC class 2.3.1 – pastures (p=0.05, D2=0.15). However, the amount of explained variation in richness patterns was so low that developed model appeared to have rather much uncontrollable uncertainty elements in the predictions it might provide, and thus it was not consider being reliable enough in predictive purposes. Similar results were obtained for the richness of grassland specialist plants, where again two CLC classes were significantly correlated with the richness patterns: CLC class 1.1.2 - discontinuous urban fabric (p=0.05, D2=0.20), and CLC class 2.3.1 – pastures (p=0.05, D2=0.17).

Overall, these tests showed that the CORINE land cover data, both at the resolution of 25 meters and 250 meters, appear to provide potentially useful and ecologically plausible explanatory variables very seldom, and when logical correlations are discovered the proportion of explained variation in species richness patterns are so low that they prevent the reliable use of these data e.g. in scenario-based predictive modeling. Moreover, most of the derived significant relationships were from the perspective of studied species biology artifacts, which thus did not reveal logical ecological links. Thus the further use of CORINE land cover data as the basis of biodiversity models in WP4 was abandonment.

In addition, it proved difficult to derive a generic heterogeneity index based on CLC2000 classes because of inconsistencies in the definitions of the classes and contrasting interpretations between European countries.

We therefore reached the conclusion in June 2008 that it would not be possible to adapt trends from the European ALARM scenarios to provide meaningful indicators for the Coconut biodiversity models.

In addition, it was decided in June 2008 to test whether individual species of plants and butterflies would show expected positive relationships with area or regional connectivity of the focal habitat type, semi-natural grasslands. This modelling exercise was restricted at first stage to plant and butterfly data collected from Finland (30 focal sites and landscapes) for WP1. The analysis was implemented using generalized additive models (GAM) in the S-PLUS version 6.1 statistical environment. Abundances of individual plant species were related to focal habitat patch area and regional connectivity of grassland network within a 2-km radius from the focal patch. Occurrence and abundance of individual butterflies species were related in a similar manner as in plants to focal habitat patch area and regional connectivity.

Of grassland-specialised plants 37 species were included in the analysis, and 19 species were found to be appropriate for modelling with GAM whereas 18 species were either too rare or too common to be modelled. Of the 19 tested species, 17 species showed a significant relationship to habitat patch area or regional connectivity. Of these 17 species, 9 species showed a positive relationship to either habitat patch area or regional connectivity. Of these 9 species, only 5 species exhibited a model that could be considered reliable based on cross-validation statistics (area under curve (AUC) of the receiver operating characteristic plot (ROC) > 0.7).

Of grassland-specialised butterflies 22 species were included in the analysis of the relationship between the occurrence of individual species and habitat patch area and regional connectivity. Of these species 15 could be modelled with GAMs. Of the modelled species only 3 showed a statistically significant ($p < 0.05$) relationship with either habitat patch area or regional connectivity, and for only one species this relationship was positive.

As with the above analysis of butterfly occurrence, 22 butterfly species were included in the analysis of the relationship between the abundance of individual species and habitat patch area and regional connectivity. Of these species 16 were abundant enough that they could be modelled with GAMs. Of the modelled species 7 showed a significant relationship ($p < 0.05$) with either habitat patch area or connectivity. With 5 species this relationship was positive as expected.

In conclusion, although some individual plant and butterflies showed expected positive relationship to habitat patch area and regional connectivity of the habitat network, a majority of species did not do so. Thus, there were no consistent relationships between occurrence and abundance of plants and butterflies and these landscape variables.

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Appendix 2 - Environmental Stratification of Europe

Objectives and background
The Environmental Stratification of Europe (EnS) was developed to provide a high-resolution stratification of the principal European environmental gradients. In existing maps (e.g. for biogeography (EEA, 2002) or ecoregions (Olson et al., 2001)) classes were not defined statistically, but depend on the experience and judgement of the originators and rely upon the intuition of the observer in interpreting patterns on the basis of personal experience. These classifications, while important as descriptions of environmental regions, are not suitable for statistical stratification (Metzger et al., 2005a).

The EnS aimed to delineate relatively homogeneous regions suitable for strategic random sampling of ecological resources, the selection of sites for representative studies across the continent and the provision of strata for modelling exercises. The dataset provides a generic classification that can be adapted for specific objective, as illustrated in this paper, as well as forming a suitable zonation for environmental reporting.

Construction
The EnS was created using tried-and-tested statistical procedures so that the strata are unambiguously determined and, as far as possible, independent of personal bias. The EnS covers a 'greater European window' (11∘W–32∘E, 34∘N–72∘N), extending into northern Africa. This wider extent was needed to permit the statistical clustering to distinguish environments that have their main distribution outside the European continent.

Twenty of the most relevant available environmental variables were selected, based on those identified by statistical screening (Bunce et al. 1996). These were (1) climate variables from the Climatic Research Unit (CRU) TS1.2 dataset (Mitchell et al. 2004), (2) elevation data from the United States Geological Survey HYDRO1k digital terrain model, and (3) indicators for oceanicity and northing. Data were analysed at 1-km2 resolution. Principal component analysis (PCA) was used to compress 88%of the variation into three dimensions, which were subsequently clustered using an ISODATA clustering routine. The classification procedure is described in detail by Metzger et al. (2005a).

The EnS consists of 84 strata, aggregated into 13 environmental zones (EnZs), Fig. 1. These were constructed using arbitrary divisions of the mean first principal component score of the strata, with the exception of Mediterranean mountains, which were separated on altitude. Within each EnZ, the EnS strata have been given systematic names based on a three-letter abbreviation of the EnZ to which the stratum belongs and an ordered number based on the mean first principal component score of the PCA. For example, the EnS stratum with the highest mean principal component score within the Mediterranean South EnZ is named MDS1 (Mediterranean South one).

Robustness
Bunce et al. (2002) have shown that statistical environmental classifications have much in common, identifying the major gradients and assigning classes in similar locations despite differences in statistical clustering techniques or input datasets. Kappa analysis of aggregations of the EnS strata shows they compare well with other European classifications (Metzger et al. 2005a, b). In addition, the EnS shows strong statistical correlations with European environmental datasets (e.g. for soil, growing season and species distributions (Metzger et al. 2005a) and habitats (Bunce et al. 2008)).

Despite distinguishing 84 strata there can still be considerable environmental heterogeneity with a stratum, especially in regions with many regional gradients, e.g. in topography or soil types. For example, the stratum ALS1 covers a range of altitude from mountain valleys at 630m to summits at 4453m. In such cases regional subdivisions can be constructed based on ancillary datasets such as altitude regional soils (Jongman et al., 2006).

*Application*s
Over the last few years the dataset has been used in numerous studies. In the most simple form, the EnZs have been used to describe broad European environmental context (e.g. Holland et al. 2009; DiFilippo et al. 2008) and as units for summary reporting (e.g. Thuiller et al. 2005; Metzger et al., 2008a; Smit et al. 2008). The European Commission has used the EnZs as the basis to assess High

Nature Value farmland (Paracchini et al., 2008) and the potential bio-energy crop production (EEA, 2007). Bunce et al. 2008 have illustrated how the EnS can be used as a sampling framework for assessing stock and trends in European habitats, which will now be developed further under the EU project EBONE, which aims to develop a European Biodiversity Observation Network (http://www.ebone.wur.nl). In addition, by fitting climate function to the strata the EnS could be linked to climate changes scenarios, providing insights in broad environmental shifts (Metzger et al. 2008b) as well as the basis for projection of future crop yields (Ewert et al. 2005; Hermans et al, in press) and shifts in biodiversity (Verboom et al., 2007). Finally, the EnS has been used as a core data layer in a number of more specific European classifications, including four other datasets described in the manuscript.

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