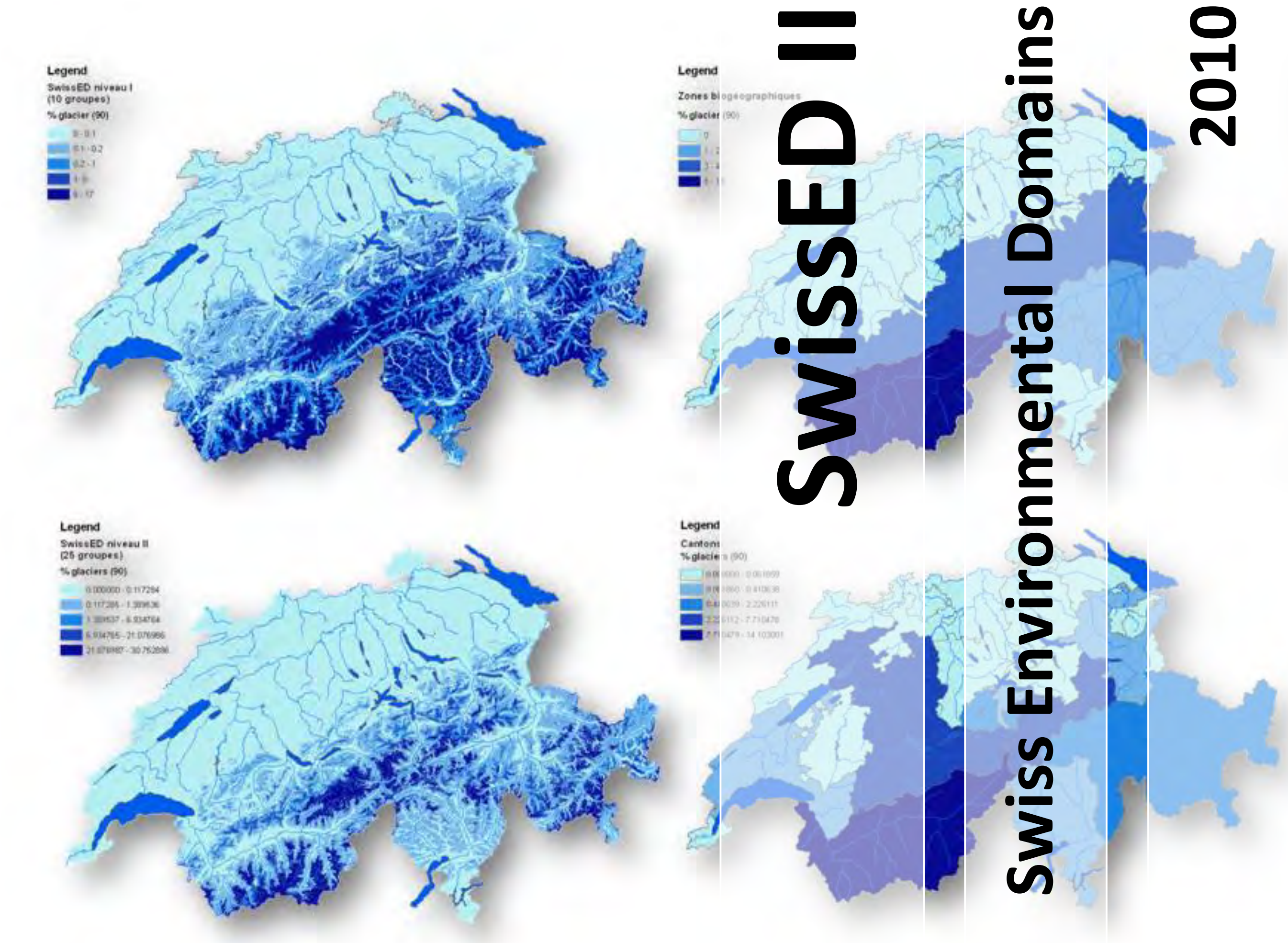
SwissED II

Swiss Environmental Domains

2010



APPLICATIONS

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Summary

Swiss Environmental Domains (SwissED) is an environmental classification of key climatic, geologic and topographic variables influencing both natural and anthropogenic processes at various scales. It represents a new spatial framework to analyse data about our environment (e.g. biodiversity, land cover, demography, agriculture, economical activities) that is not replacing existing ones but simply complementing them.

SwissED was inspired from several similar initiatives developed in Australia, New Zealand, USA and Europe. It follows a quantitative and reproducible approach composed of two phases: i) first a non-hierarchical classification to group a sample of pixels representing Switzerland into a 120 domains, ii) second a hierarchical classification of these 120 domains into 100, 50, 25 or 10 domains. These domains can be coloured following the result of a PCA analysis where red corresponds to a gradient of temperature, green a gradient of calcareous content and blue a topography gradient. The first 10 domains were named according to their environmental characteristics: calcareous reliefs, molassic flats and hills, quaternary hills and valleys, crystalline slopes, dry quaternary flats, calcareous midslopes, calcareous upper slopes, crystalline crests, crystalline quaternary slopes and calcareous crests.

SwissED represents the natural potential of the landscapes independently of human activities. It can serve therefore as spatial framework to analyse any environmental statistics according to classes that are defined based on environmental conditions. SwissED would be particularly well suited to represent sustainable development statistics based on the principle that the economy depends on the society, and the society depends itself on the environment. Examples from other countries and regions prove that SwissED can bring a new, complementary and useful spatial framework to underpin environmental research and management in Switzerland at various scales. Possible applications are:

- providing a framework for reporting on the state of the environment;
- identifying the most efficient use of limited financial resources for biodiversity conservation;
- management, including management of protected natural areas and other areas of land with high biodiversity values;
- identifying sites where similar problems are likely to arise in response to human activities, or where similar management activities are likely to have a particular effect;
- identifying the geographic extent over which results from site-specific studies can be reliably extended; and
- designing stratified sampling strategies.

The main conclusions that we can derive from this work are:

- The strong climatic, geologic and topographic gradients found in Switzerland represent the ideal pre-conditions for building environmental domains;
- When compared to traditional spatial frameworks, the maps produced when representing statistics (e.g. land cover) on SwissED return more realistic spatial patterns and surface areas;
- SwissED does not replace previous spatial framework but can bring a valuable complementary tool to represent environmental data;
- SwissED are in line with similar developments made across the world at continental, regional or national levels; and
- SwissED were developed for general purposes analyses without trying to weight the input variables, they could therefore be improved by targeting a specific need (e.g. biodiversity, land cover, agriculture).

Introduction

Swiss Environmental Domains (SwissED) is an environmental classification of key climatic, geologic and topographic variables influencing both natural and anthropogenic processes at various scales. It represents a new spatial framework to analyse data about our environment (e.g. biodiversity, land cover, demography, agriculture, economical activities) that is not replacing existing ones but simply complementing them. SwissED brings a new paradigm in environmental data interpretation that needs to be adequately understood before any possible applications. Swiss Environmental Domains are contiguous groups of pixels that are close together in an environmental space defined by a selection of key variables. Spatial frameworks presently in use (e.g. bio-geographical regions, administrative limits) are defined rather as contiguous groups of pixels that are close together in the geographical space defined by X, Y and Z coordinates.

This study was inspired from a similar work named Land Environment of New Zealand (LENZ: Leathwick et al. 2003) that was achieved by Dr. John Leathwick from Landcare Research. Thanks to an ongoing collaboration, the methods used for LENZ could be transferred entirely and adapted to carry out this study. LENZ was itself inspired from pioneer studies developed in the nineties in Australia (e.g. Kirkpatrick & Brown, 1994) and the United States (Hargrove and Hoffman, 1999, 2005). Altogether these methods share the same goal that is to use modern data-driven techniques to build objective and reproducible classifications of the environment. These classifications create an adapted spatial framework to underpin the management of natural resources and biodiversity. Indeed, the joint development of spatially explicit descriptions of our environment at finer and finer scales, together with the improvement of computer technologies, made it possible to envisage such classifications on larger and larger datasets (e.g. Switzerland at 25m resolution = 64 million pixels).

This work is therefore the fruit of several years of development and experiences made across the world and brought together by John Leathwick in LENZ, and then adapted here for Switzerland. SwissED represents therefore a new and interesting paradigm to look at our environment through a different angle, the angle given by key environment drivers of most natural phenomenon as well as human activities.

Swiss Environmental Domains

In the following figures (19 to 22), SwissED are represented at the four different levels in order to represent first the level of details (random colors) and second the environment gradients underpinning them (RGB).

Level I: 10 groups

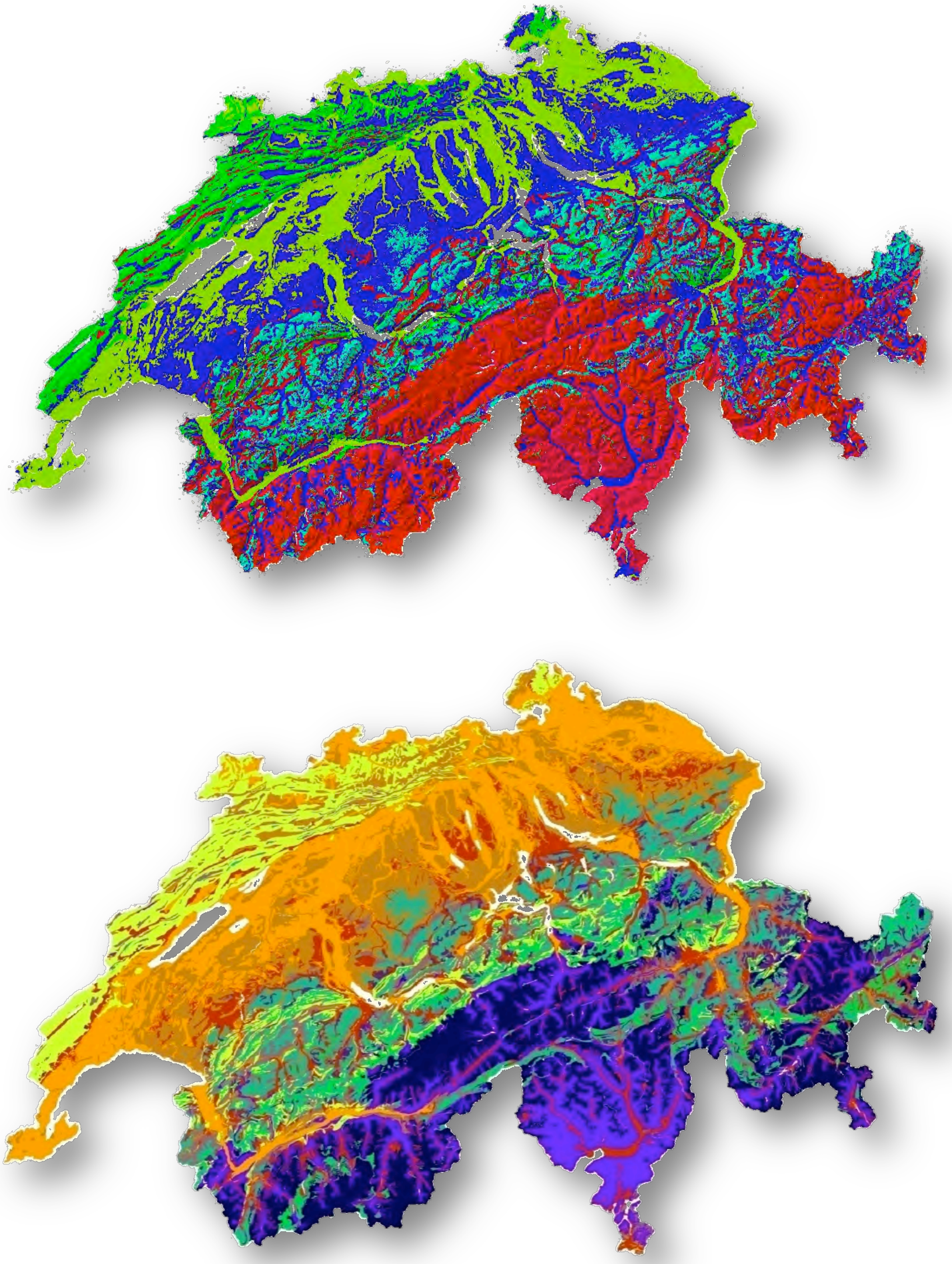


Figure 1 Randomly and RGB colored Swiss Environmental Domains at level I (10 groups)

Level II: 25 groups

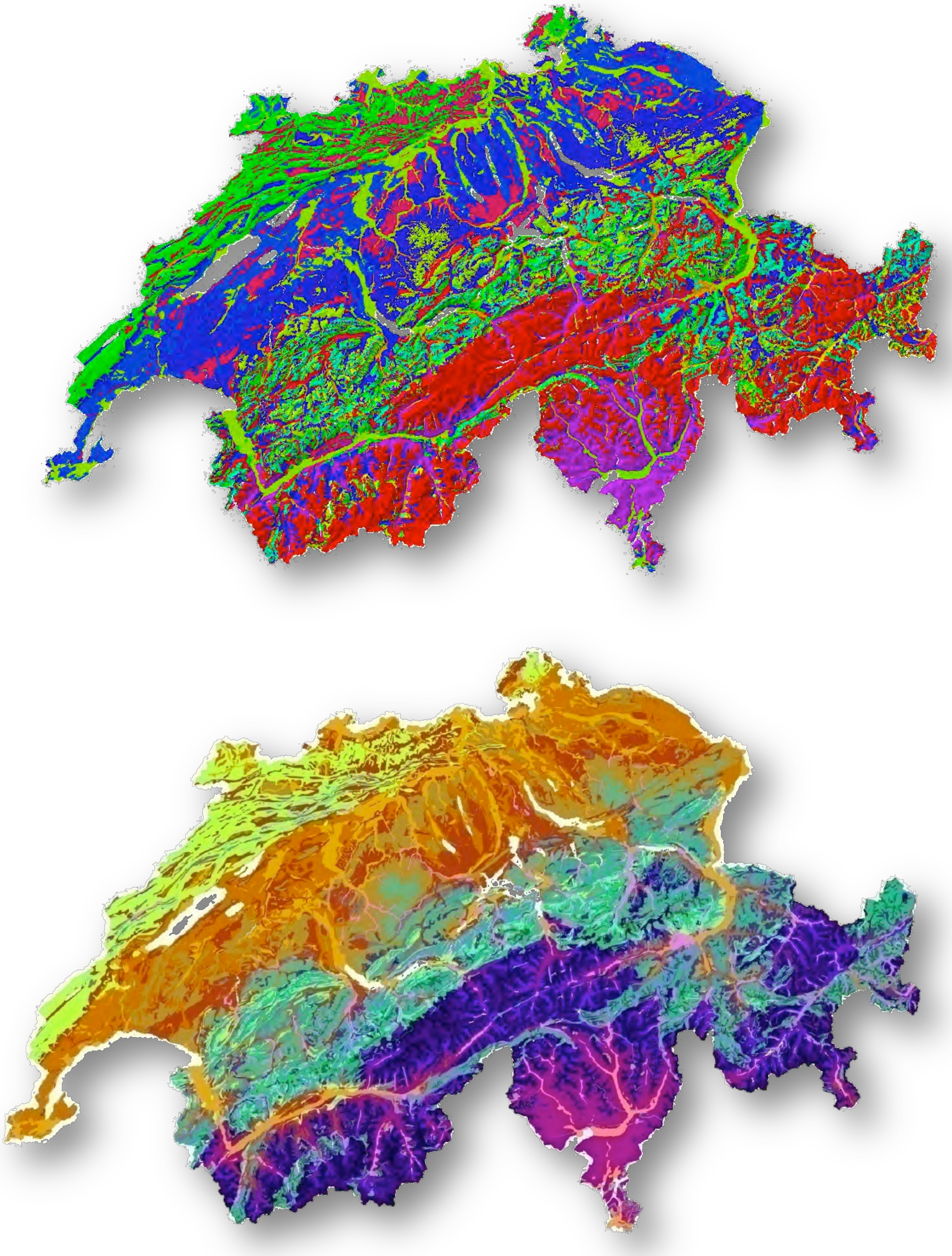


Figure 2 Randomly and RGB colored Swiss Environmental Domains at level II (25 groups)

Level III: 50 groups

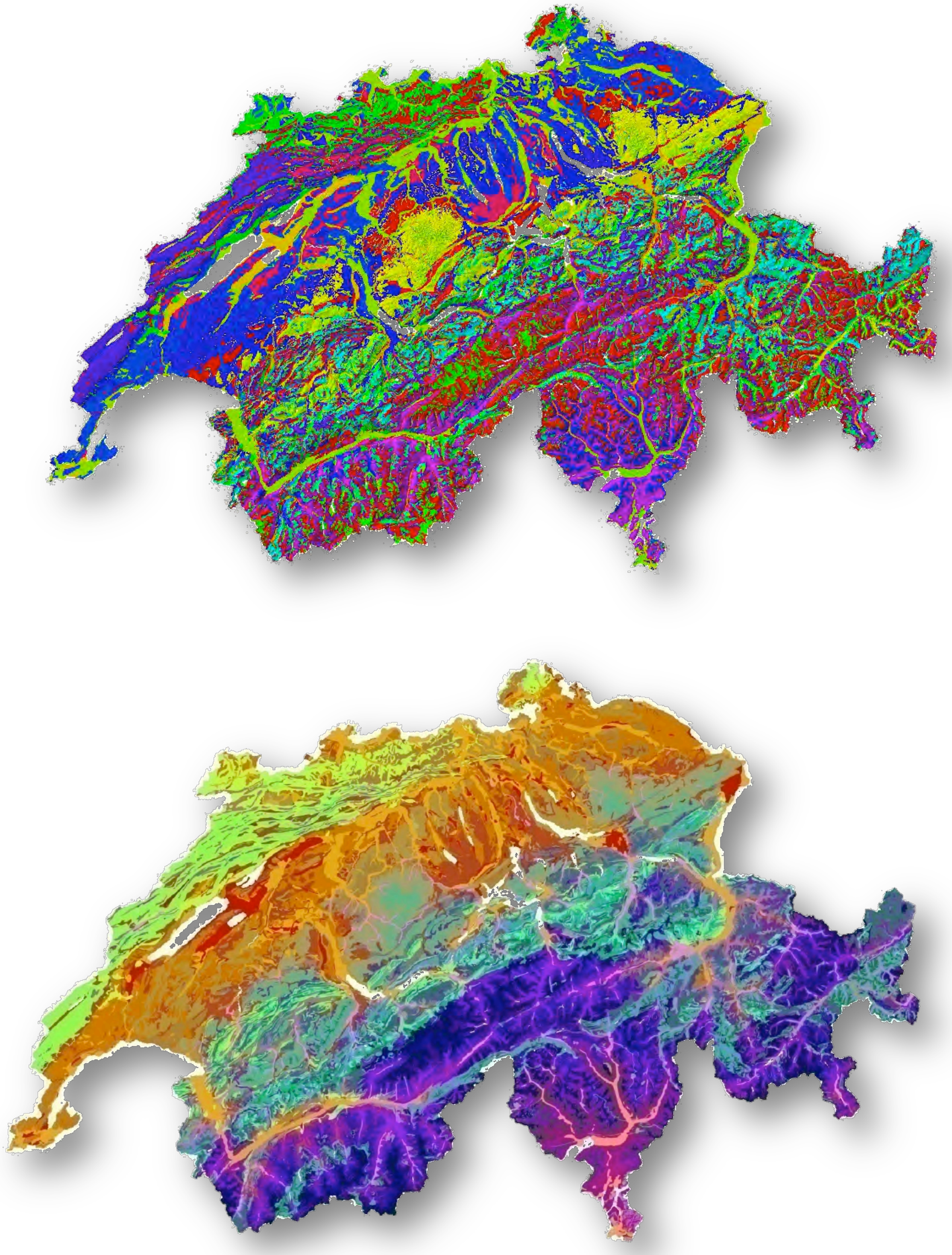


Figure 3 Randomly and RGB colored Swiss Environmental Domains at level III (50 groups)

Level IV: 100 groups

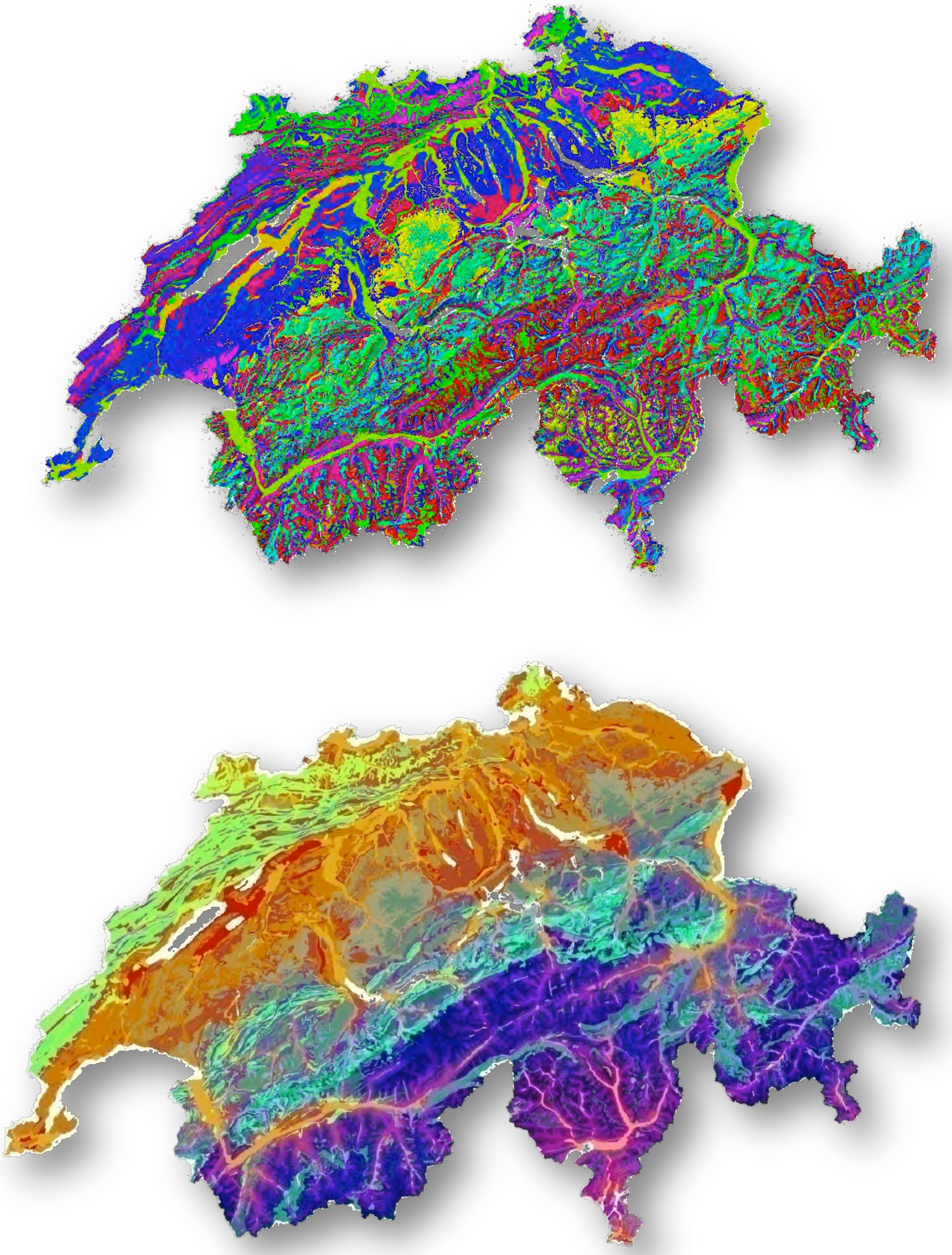


Figure 4 Randomly and RGB colored Swiss Environmental Domains at level IV (100 groups)

Levels and scales

With its hierarchical classification, SwissED was developed at four different levels (
Figure 6) that in practice correspond to different scales for which they are better suited:

- Level IV : 100 groups: 1:100’000
- Level III : 50 groups: 1: 250’000
- Level II : 25 groups: 1: 500’000
- Level I : 10 groups: 1: 2’000’000

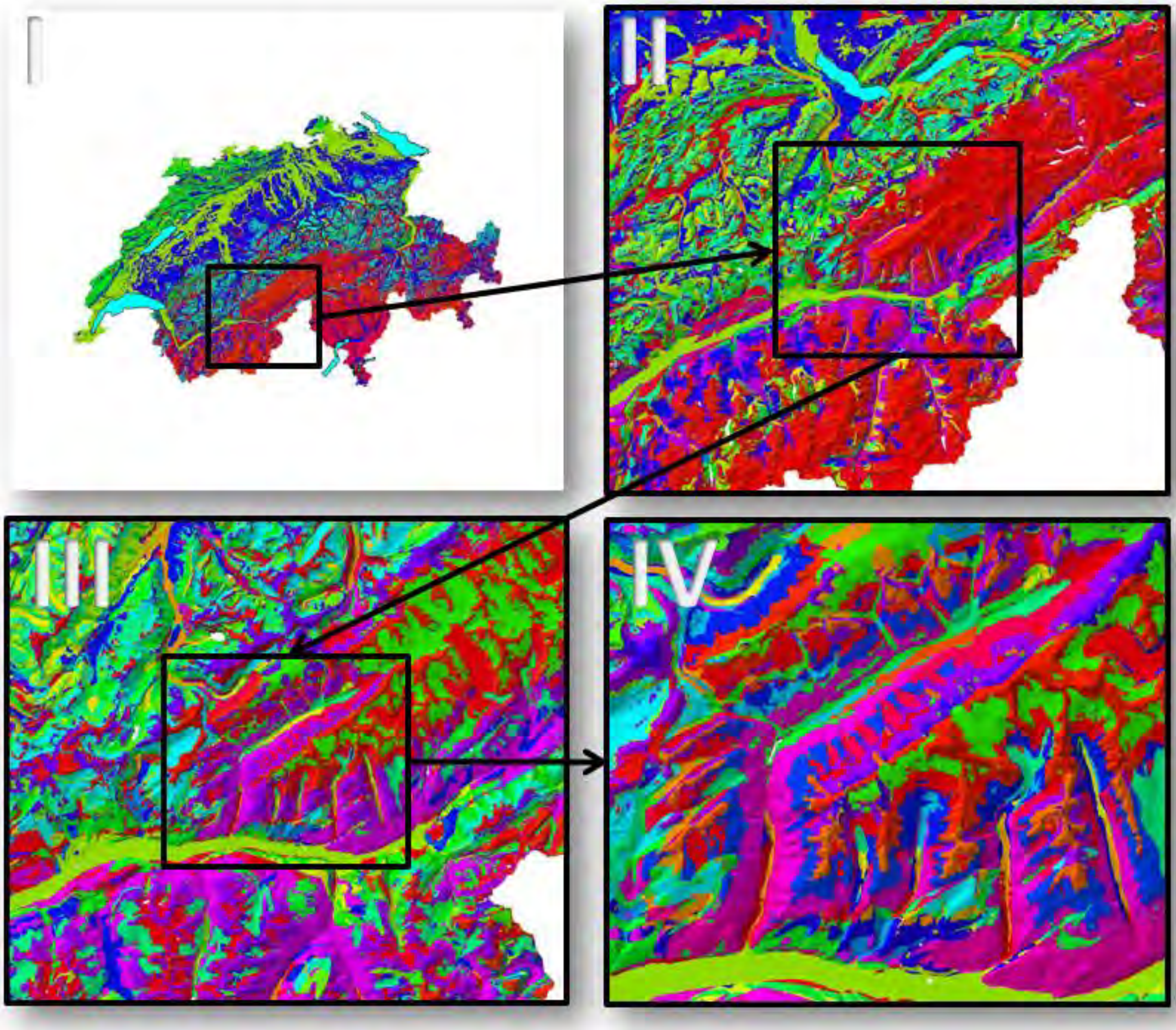


Figure 5 Relative scales at which SwissED are thought to be used from level I (1:2’000’000) to level IV (1:100’000)

If we zoom on a given region (Figure 6), we can assess the quantity of details provided by each level.

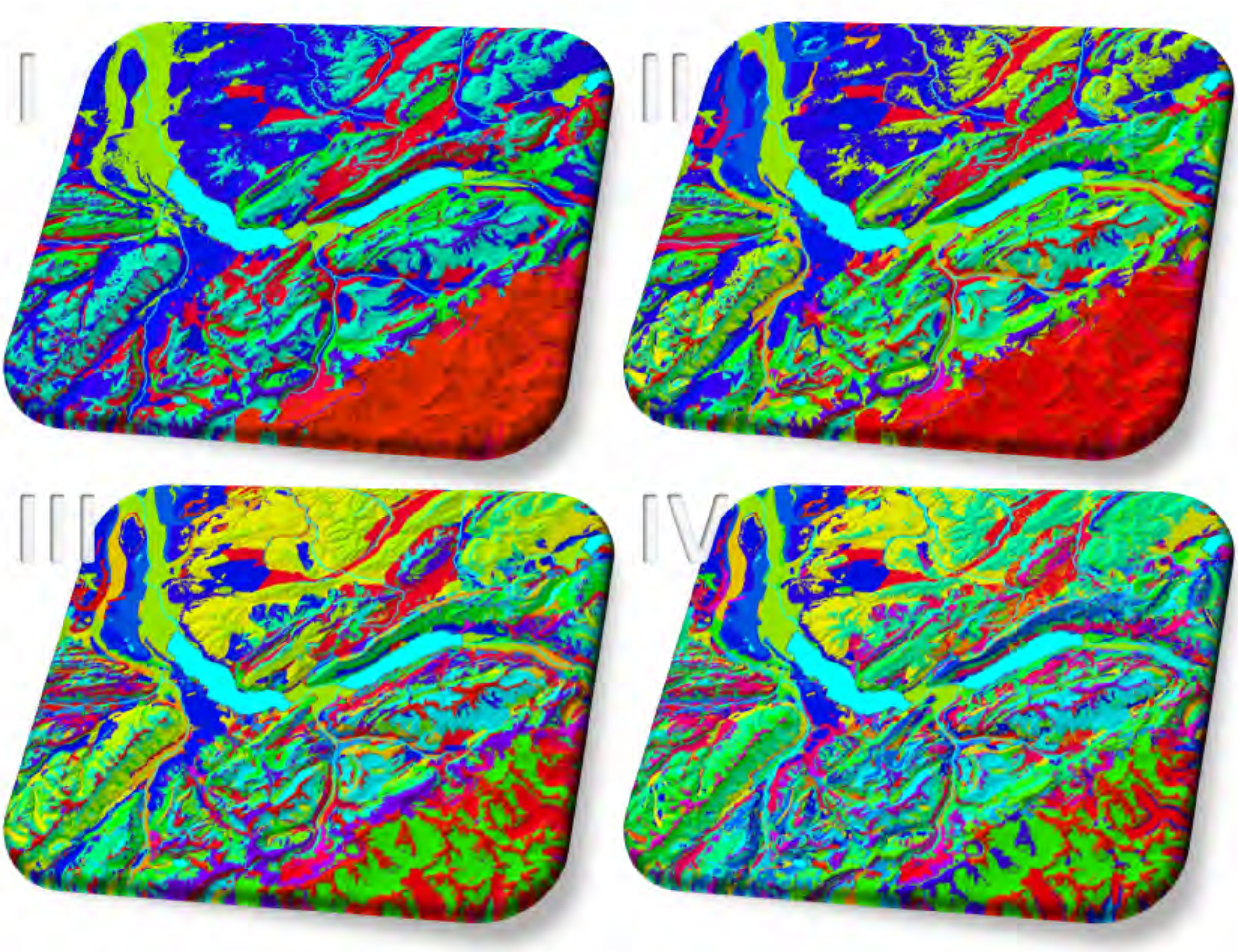


Figure 6 Zoom on the Interlaken region to visualize the amount of details provided by the 4 different levels of SwissED randomly colored.

Possible applications

The examples from other countries and regions prove that SwissED can bring a new, complementary and useful spatial framework to underpin environmental research and management in Switzerland at various scales.

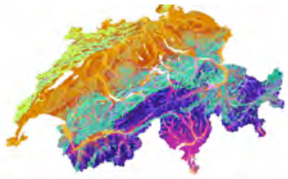
Future applications could be:

- providing a framework for regulatory activities and reporting on the state of the environment (see Figures 24 and 25);
- identifying the most efficient use of limited financial resources for biodiversity;
- management, including management of protected natural areas and other areas of land with high biodiversity values;
- identifying sites where similar problems are likely to arise in response to human activities, or where similar management activities are likely to have a particular effect;
- identifying the geographic extent over which results from site-specific studies can be reliably extended; and
- designing stratified sampling strategies.

Reporting on the state of the environment

The themes of the following factsheets are:

- Biodiversity:
  - B1 - Birds richness and diversity per Environmental Domains
  - B2 - Animal species richness per Environmental Domains
- Land cover:
  - L1 - Land cover distribution per Environmental Domains
  - L2 - Land cover evolution per Environmental Domains
- Socio-economic data
  - S1 - Population densities per Environmental Domains
  - S2 - Evolution of farms number per Environmental Domains
  - S3 - Employment by sectors per Environmental Domains



Theme: BIODIVERSITY

Breeding bird richness and diversity in Switzerland

Purpose

A customary framework in order to report biodiversity for Switzerland are biogeographical regions (Gonseth et al., 2001), themselves based on the sectors defined by Welten and Sutter (1982). Biogeographical regions subdivide the Swiss territory into 6 or 10 main regions according to the patterns of distribution of flora and fauna. Patterns are thus defined by ecological factors but also account for historical aspects such as the postglacial recolonisation.

Biogeographical regions are surely a first very effective cut-off of the Swiss territory but remain too coarse for detailed ecological reporting. A single biogeographical region encompasses several habitat types which support different species and degrees of biodiversity. As a valuable alternative we propose to use the environmental domains (SwissED; Allenbach et al., 2008). Since SwissED are defined in the environmental space, they are more likely to support a limited number of habitats sharing similar characteristics. Reporting biodiversity statistics according to SwissED would thus be more ecologically meaningful. Moreover, when projected into the geographic space, SwissED delineate much finer zones than biogeographical regions and thus more precisely identify the zones where managers should concentrate their actions.

As an application, we will evaluate the effectiveness of SwissED in reporting the biodiversity of breeding birds in Switzerland. Species richness and species diversity (combination of number and abundance of the species) will be reported using SwissED at different levels of classification (10, 25, 50 and 100 groups) and compared to other customary reporting frameworks.

Data Description

Data used for the analysis are data of the 2nd atlas of breeding birds of Switzerland (Schmid et al. 1998) relative to the 125 more widespread species recorded in the 1 x 1 km squares. Fieldwork for the atlas was carried out between 1993 and 1996 and the number of territories, which represents the number of breeding pairs, was recorded in a total of 2943 squares distributed across Switzerland, Liechtenstein and nearby foreigner territories.

Data are semi-quantitative, i.e. the number of breeding pairs was recorded only up to a certain value, beyond which the species was considered as “abundant”. The limit value depends on the species. As an example, the limit was set to 11 (=more than ten) for species with high densities such as the blackbird, to 6 for species with lower densities like the goldfinch and to 2 for species with very low densities like the common buzzard.

For our analysis we selected only squares that have their centre within the Swiss boundaries (2671 squares). For each square we calculated the total number of species observed (species richness) and the species diversity (Shannon index). In order to overcome the problem posed by the semi-quantitative data, all abundances were stretched between 0 and 10 before calculating a Shannon index (species richness weighted by their abundance). As an outcome, rare species have here the same weight as widespread species in the calculation of species diversity.

Results and interpretation

The total number of species of breeding birds recorded in each 1-km square is represented in Fig.1. Mean richness calculated over the 2671 squares having their centre within the Swiss territory is of 35.2 species per square kilometre. Species richness is particularly high in the Plateau and the Jura regions, relatively important in the Northern slopes of the Alps and at the bottom of the main alpine valleys, moderate South of the Alps and within the rest of the Alps as summarized by the graph in Fig.2.

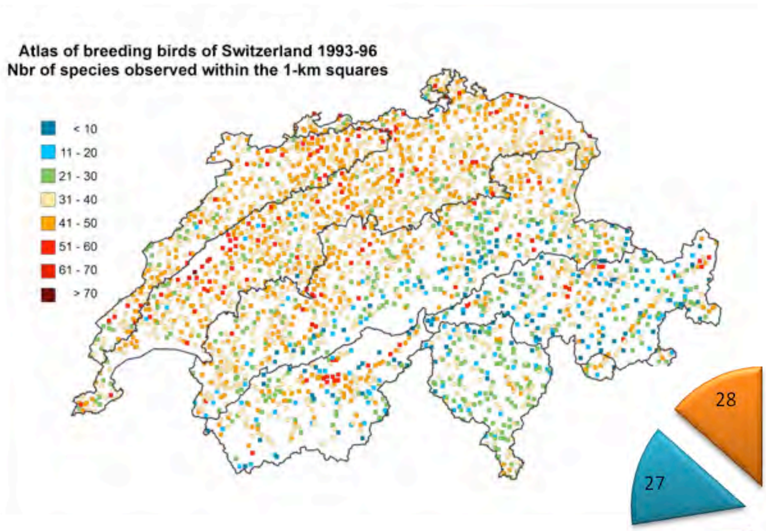


Figure 1 Total number of species recorded in the 1-km squares of the atlas of breeding birds 1993-96 within the Swiss territory.

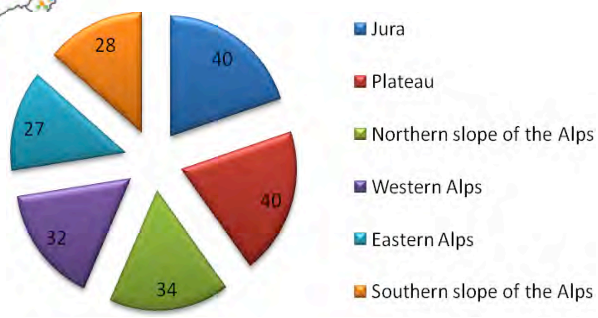


Figure 2 Mean number of breeding bird species per square kilometer and per biogeographical zone (6 main regions) based on the data of the 2nd atlas of breeding birds of Switzerland (1993-1996).

Figure 3 represents the mean species richness according to different frameworks: the biogeographical regions, the administrative boundaries of the cantons and the corresponding levels of the environmental domains (10 and 25 domains respectively). The definition of the biogeographical regions has an ecological background and therefore better represents the distribution of the breeding bird richness in comparison to the arbitrary administrative cut-off represented by the cantons. However, best representations are those derived from the environmental domains. Even at the first level (10 groups) their cut-out of the territory is much finer and allows a better localization of the hotspots.

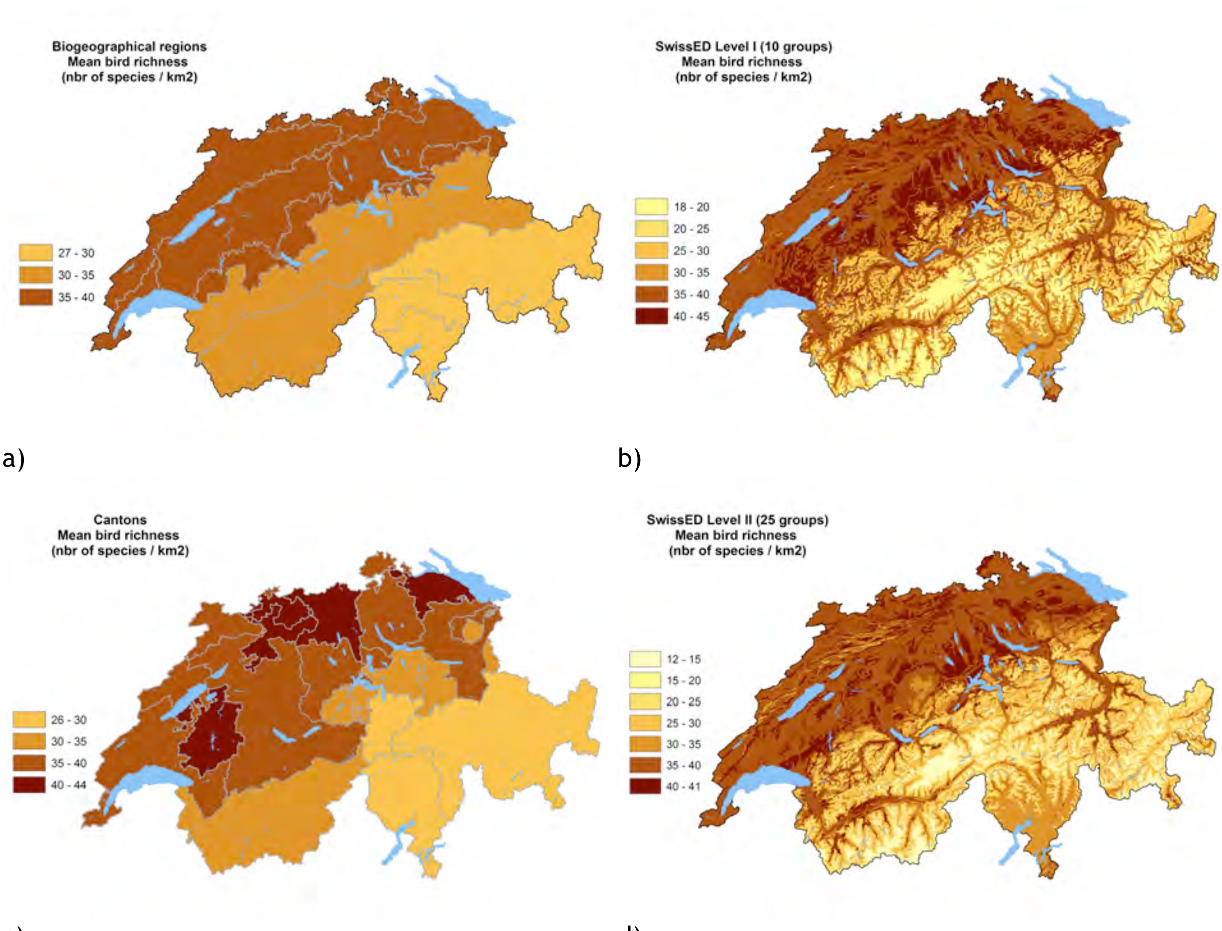


Figure 3 Mean breeding birds' richness per square kilometre of a) biogeographical region (10 groups), b) environmental domain (10 groups), c) canton (26), d) environmental domain (25 groups).

Figure 4 shows other possible cut-off of the Swiss territory and their corresponding breeding bird richness. Fig.4c shows the cut-off based on the Welten & Sutter sectors. These are the base sectors used in order to define the biogeographical regions, they thus have the same ecological baseline but have a much finer resolution. However, sectors are still relatively large and breeding bird richness seems to be better represented by the altitudinal slicing of the territory (Fig.4a). Indeed, the 46 altitudinal bands of 100 m allow a better discrimination of the real favourable zones within the sectors which correspond to the bottom of the valleys and midslopes. The hotspots identified by the altitudinal slicing are very similar to those designated by the analysis with a corresponding number of environmental domains. Note that domains are not defined using altitude but incorporate a highly correlated variable which is temperature.

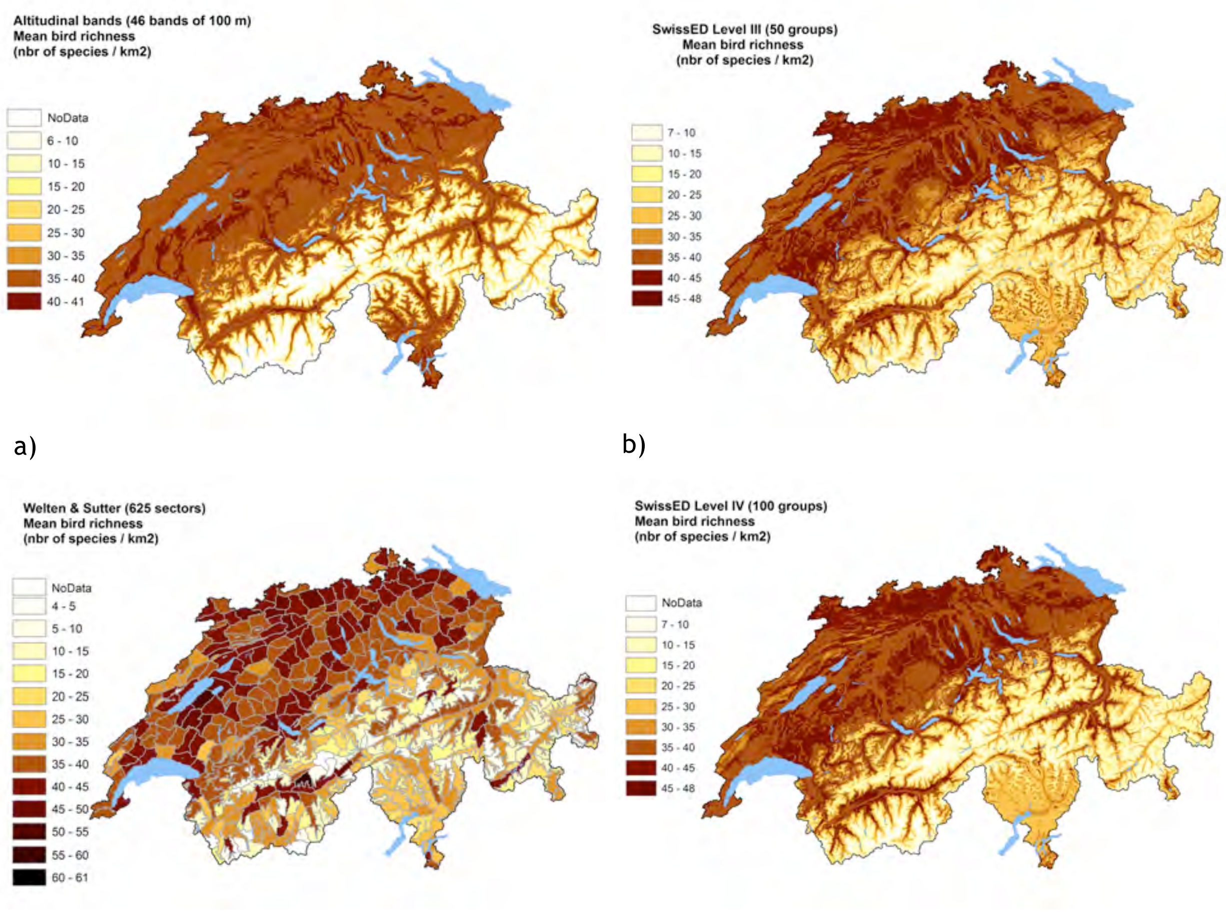


Figure 4 Mean breeding birds' richness per square kilometre of a) altitudinal band (46 bands of 100 m), b) environmental domain (50 groups), c) Welten & Sutter sector (625 sectors), d) environmental domain (100 groups).

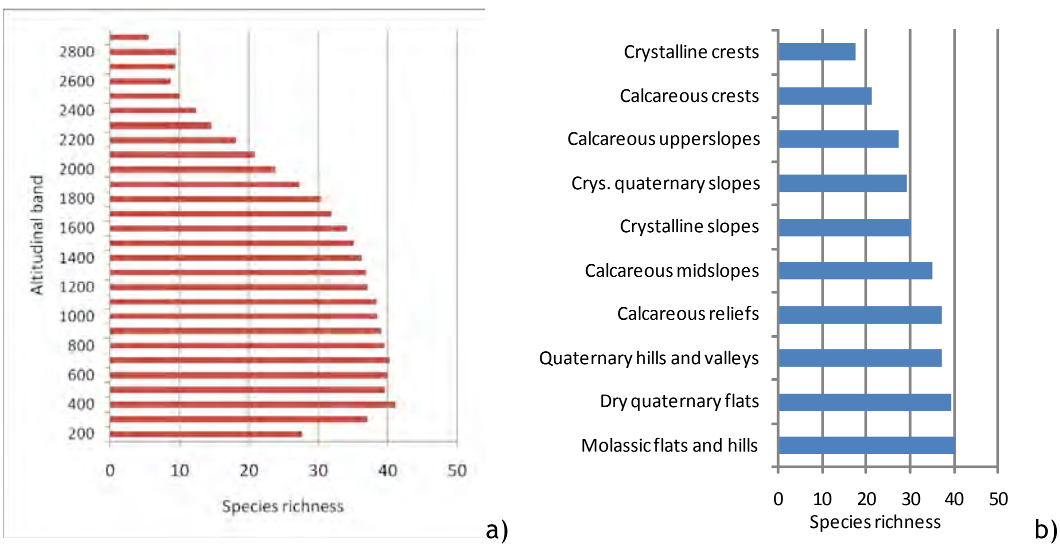
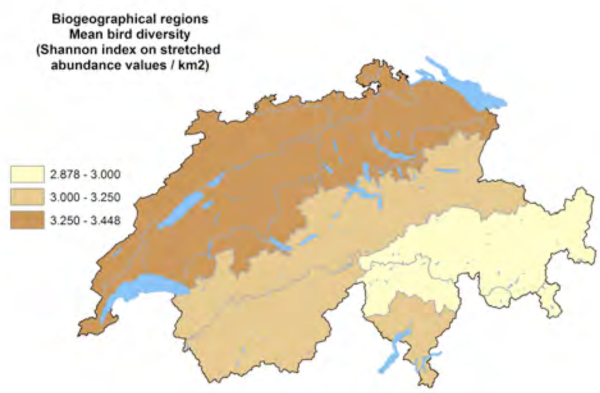


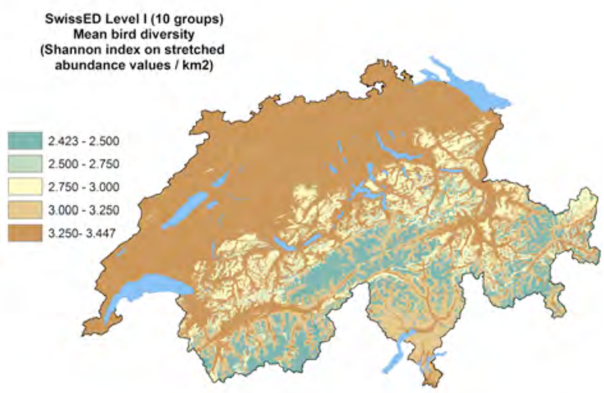
Figure 5 Mean species richness per a) altitudinal band (100 m) and b) per main environmental domain (10 groups).

Graphs in Fig. 5 confirm that mean species richness is higher at lower altitudes. Fig. 5a shows that the mean species richness decreases as a function of altitude and drop to zero above the altitudinal belt corresponding to 2900m. Fig.5b, reporting the mean species richness by the main environmental domains, shows that richness is higher in flat and midslope regions, in contrast to mountain upperslopes and crests.

Figure 6 shows results concerning the breeding bird diversity (Shannon index). Level I or II of environmental domains (10 and 25 groups respectively) give very similar patterns that globally follow the richness patterns. Differences between the higher richness classes become however blurred. Once again, representation by environmental domains is much closer to our understanding of species ecology (e.g. less diversity on cold mountain tops) than representation by coarse biogeographical regions or arbitrary administrative cut-offs.



a)



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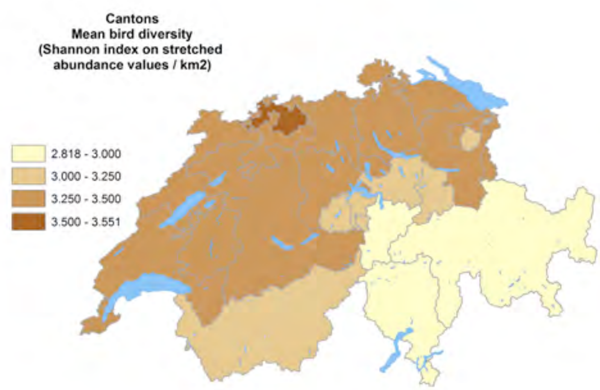
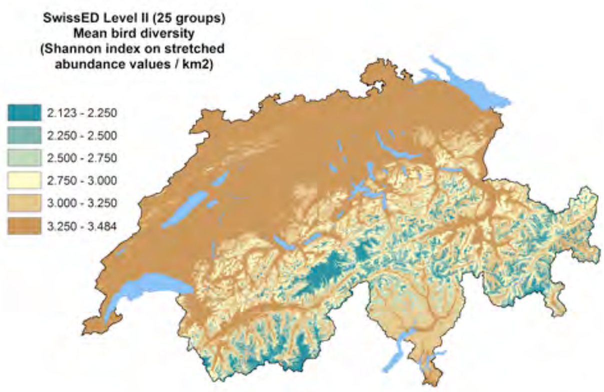


c)



d)

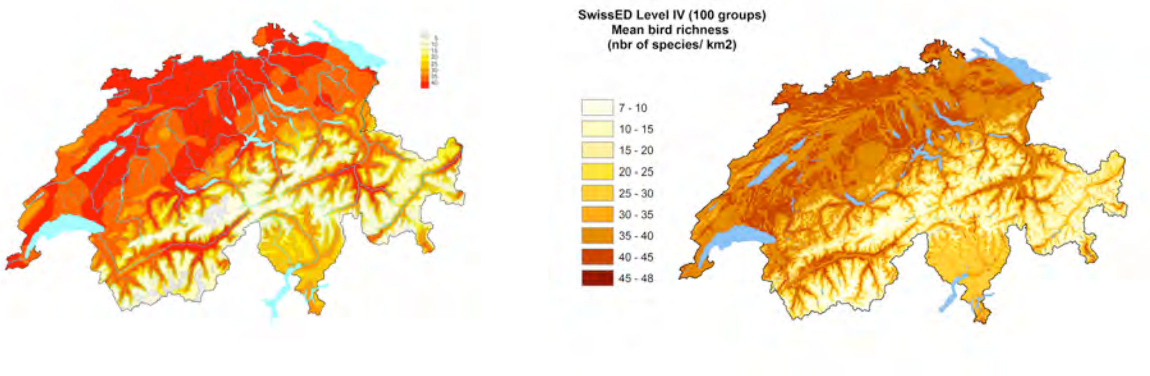
Figure 6 Species diversity (Shannon index) of breeding birds per square kilometre of a) biogeographical region (10 groups), b) environmental domain (10 groups), c) canton (26 regions), d) environmental domain (25 groups).

Expert evaluation

Consulted experts: Dr Niklaus Zbinden and Hans Schmid, Swiss Ornithological Institute, Sempach, Switzerland.

Figure 7a shows the map resulting from the interpolation of the number of species of breeding birds sampled in the 2943 square kilometres of the Atlas 1993-1996. Interpolation was performed as a function of altitude using the squares in a radius of 20 km and in an altitudinal interval of ± 200 m from the focal one. This is the original map presented in the Atlas 1993-1996 (Schmid et al. 1998). For comparison, Fig. 7b shows the map representing the mean breeding bird richness per square kilometre and per environmental domain at level IV (100 groups).The resulting patterns are very similar to those represented in Fig. 7a. A similar accuracy could certainly not be reached by an analysis by biogeographical region or any other administrative zonation.

Environmental domains therefore prove to be an effective support in order to report biological data and breeding bird richness in this specific case. Indeed, they are mainly defined according to abiotic variables belonging to three main categories, namely topography, geology and climate. These abiotic variables contribute to define unique environmental conditions that support different types of flora, fauna and ultimately different degrees of biodiversity.



a) b)

Figure 7 a) Map resulting from the interpolation of the number of breeding bird species sampled per square kilometre; b) Mean breeding bird richness per environmental domain (100 groups).

A particular advantage of a classification based on abiotic data is that the resulting zonation is fixed trough time and can therefore be used as a support in order to identify temporal changes in the distribution of biotic data. As an example Fig.8 shows the evolution of species richness per environmental domain (100 groups) between the 1st and 2nd atlas of breeding birds in Switzerland (analysis based on atlas squares of 10 x 10 km).

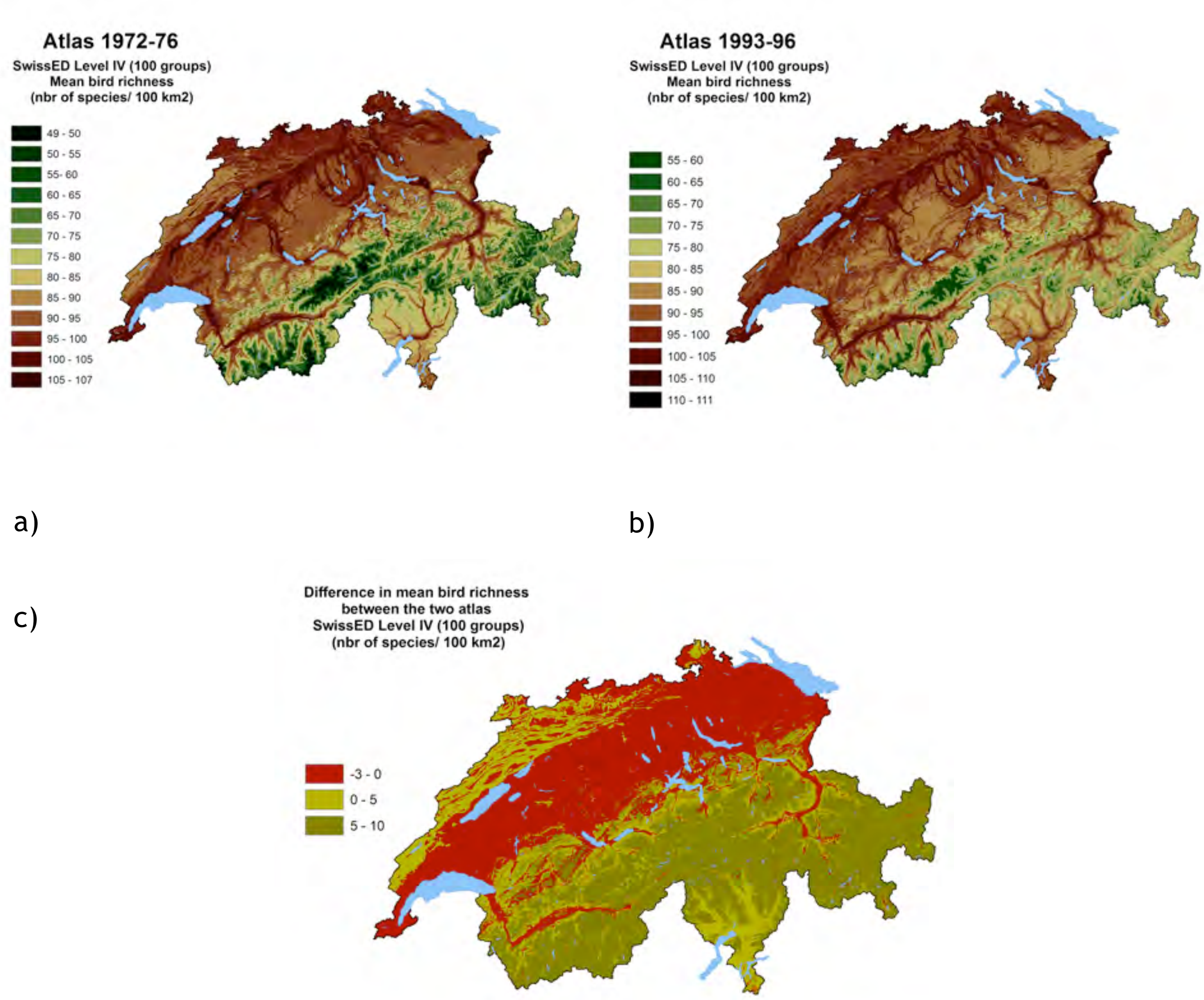


Figure 8 Mean breeding bird richness per square kilometre and per environmental domain (100 groups) a) for the first atlas (1972-76), b) for the second atlas (1993-96) and c) the difference between the two periods.

As shown by Fig.8c between the two periods of atlas the number of species increased mainly in the elevated regions (Prealps, Alps). This is not only related to an intensification of the sampling efforts and to an improvement of the access roads, but also to a real advance of the species towards elevated regions due at least in part to climate change. On the other hand, a clear decrease occurred in the low land regions where species related to agricultural areas were mainly affected.

Perspectives

Swiss Environmental domains are not only an ecologically meaningful spatial framework but also a simple and effective tool in order to downscale data from coarse to fine spatial resolution. As an example we have here downscaled bird data sampled at a 1km resolution down to the resolution of the domains which is 25 m. Without having recourse to modeling techniques, domains therefore allow to make a first approximation at fine scale of the distribution of the statistic in consideration.

Domains can further be improved by fine tuning them for a specific purpose. This can be achieved by selecting meaningful subsamples of input variables or by weighting the variables according to their relevance for the target purpose when defining the domains. Convincing attempts have been made in this direction that were published by Snelder et al. (2009).

Target Audience

Ornithologists, conservation managers, the Federal Office for the Environment (FOEN)

Links

http://www.vogelwarte.ch/

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Acknowledgments

We would like to kindly acknowledge the Swiss Federal Office for the Environment (FOEN) for their support and for believing in the potential of Swiss Environmental Domains.

We also would like to thank the Swiss Ornithological Institute and in particular Dr Niklaus Zbinden and Hans Schmid for making the atlas' data available for this analysis and for their constructive evaluation of the results.

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Source

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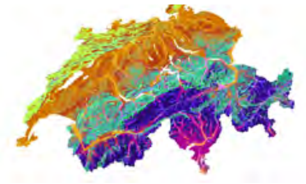

Theme: BIODIVERSITY

Animal species richness per environmental domains

- Butterflies, grasshoppers, dragonflies, mammals, reptiles, amphibians -

Purpose

In the first report presenting the Swiss Environmental Domains (Allenbach et al., 2009) the detailed procedure to create them was described following the regionalization approach developed in New Zealand by Leathwick et al. (2004). The aim of the Swiss Domains is to provide a new spatial framework for reporting on the environment. It aims at complementing existing frameworks such as biogeographical regions (Gonseth et al., 2001), and administrative boundaries. SwissED are defined quantitatively and spatially at four different levels with 10, 25, 50 and 100 groups from nine selected environmental gradients describing the geology, topography and climate of Switzerland at a 25 m resolution. SwissED are first defined in environmental space by grouping together pixels that resemble each others, and then they are projected in the geographical space to create a map. Environmental domains can represent a central piece for informed environmental management, strategy and reporting (Overton et al. 2002).

In this study we aim at testing SwissED for representing faunal biodiversity values. We also compare the results obtained with biogeographical regions and cantons. We show how domains can be used to downscale observed biodiversity data of butterflies, grasshoppers, dragonflies, mammals, reptiles and amphibians from a 1km into a 25m resolution. We explore also how the biodiversity of different faunal groups is correlated across cantons and environmental domains.

Data Description

The Swiss Centre for Mapping Fauna is the national depository for all distribution data collected in Switzerland for all faunal groups except birds. Mostly presence-only data is held in the database at various spatial accuracies ranging from a few meters to one or more kilometres. The heterogeneity of sampling characteristics and distribution makes the use and interpretation of this data particularly difficult when looking at the raw data. We propose here to explore the use of SwissED as a spatial framework to report on species richness per groups. A simple query allowed to extract from the CSCF database the number of species observed per groups within each square kilometre of Switzerland since 1960. Species richnesses are represented in figure 1 for the six faunal groups.

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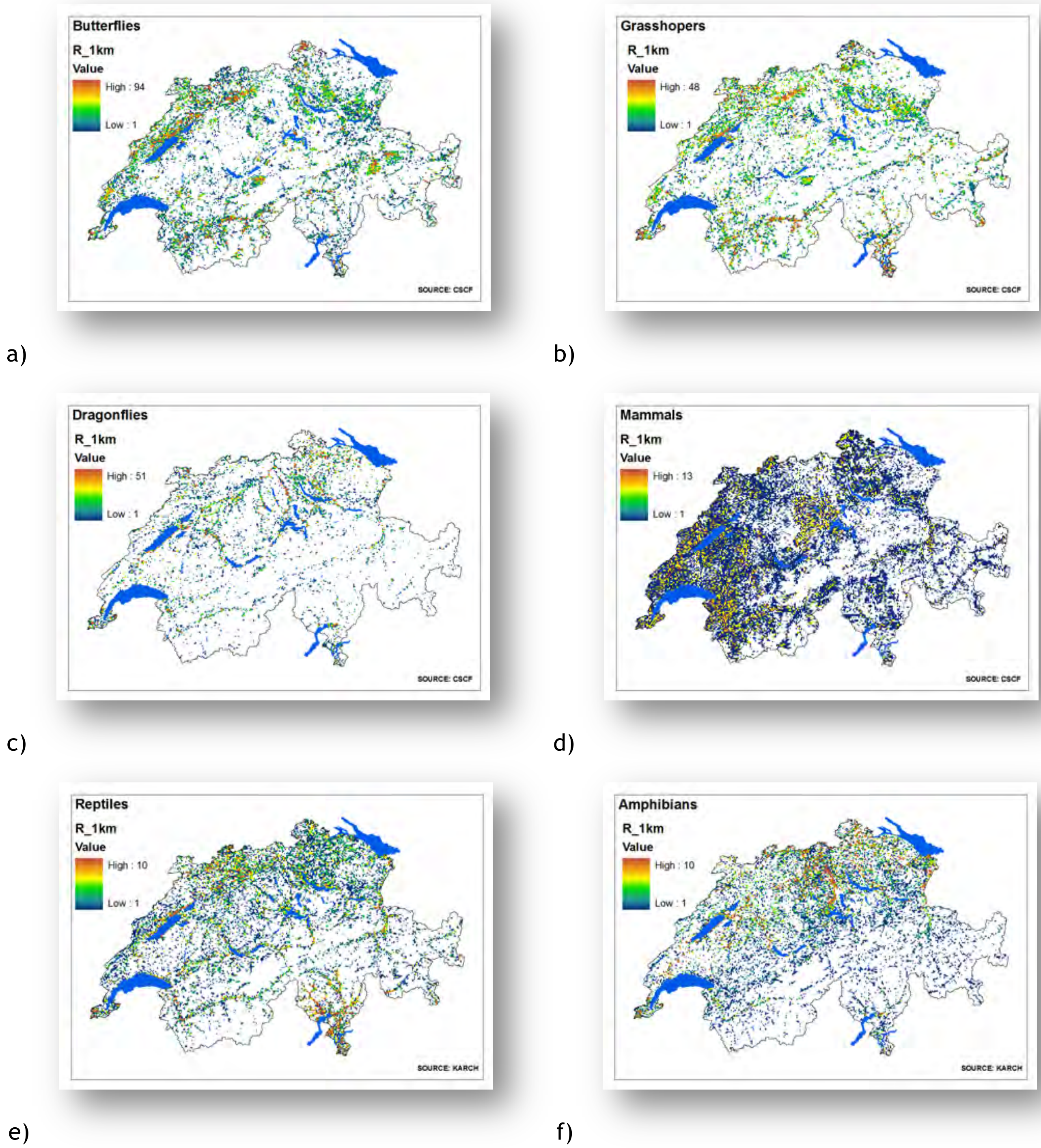
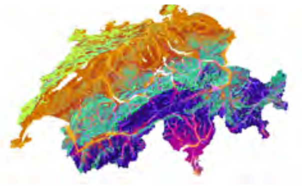


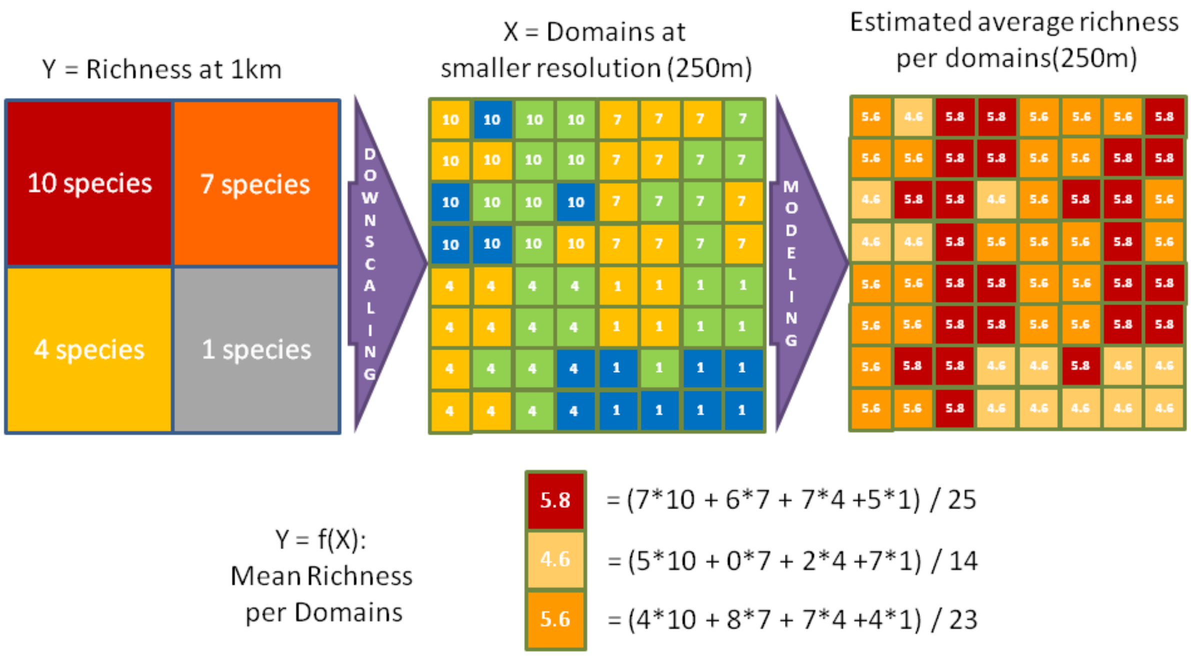
Figure 1 Observed species richness per square kilometres per a) butterflies, b) grasshoppers, c) dragonflies, d) mammals, e) reptiles, f) amphibians.



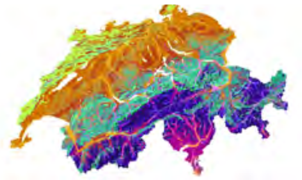
Results and interpretation

The results are obtained in two steps (Figure 2). First, species richness is downscaled at the resolution of SwisssED, which is 25 m. Then, zonal statistics per domain are calculated in order to obtain the mean species richness in each domain. This second step corresponds to modelling species richness as a function of one integrated explanatory variable, namely SwissED, which is itself a combination of the nine key environmental variables. In summary, this procedure is modelling the original response variable (species richness) in function of the proportion of its downscaled distribution belonging to the different domains.

Figure 2 Methods used to model and downscale species richness from 1km^2 to smaller resolution (in this example 250m) in function of domains



This approach was automatized in ArcGIS using the Model Builder extension (Figure 3).



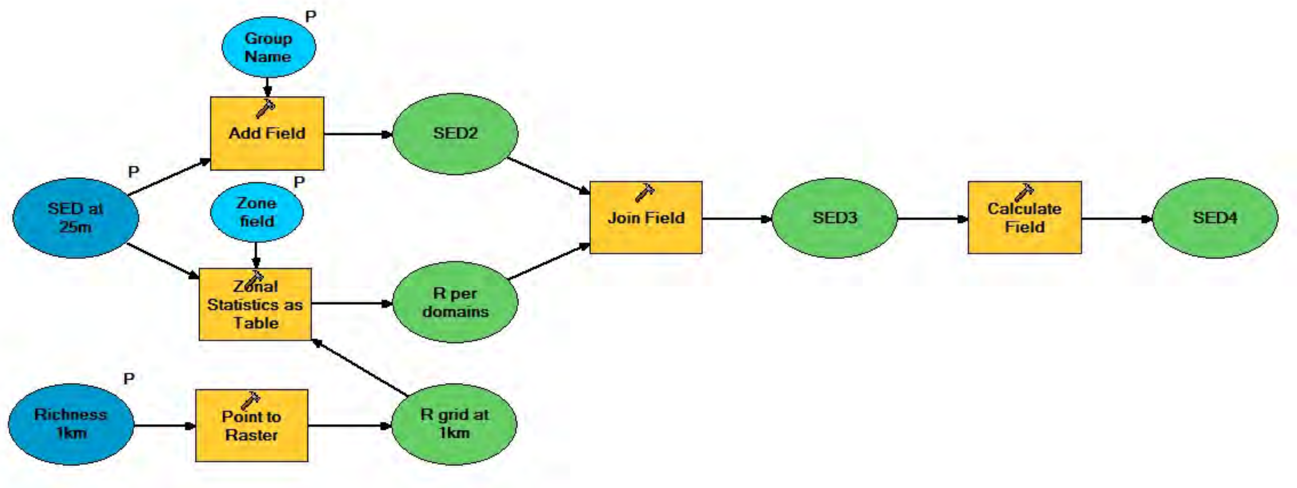


Figure 3 GIS processes used to model and downscale species richness from 1km^2 to 25 m resolution in function of domains

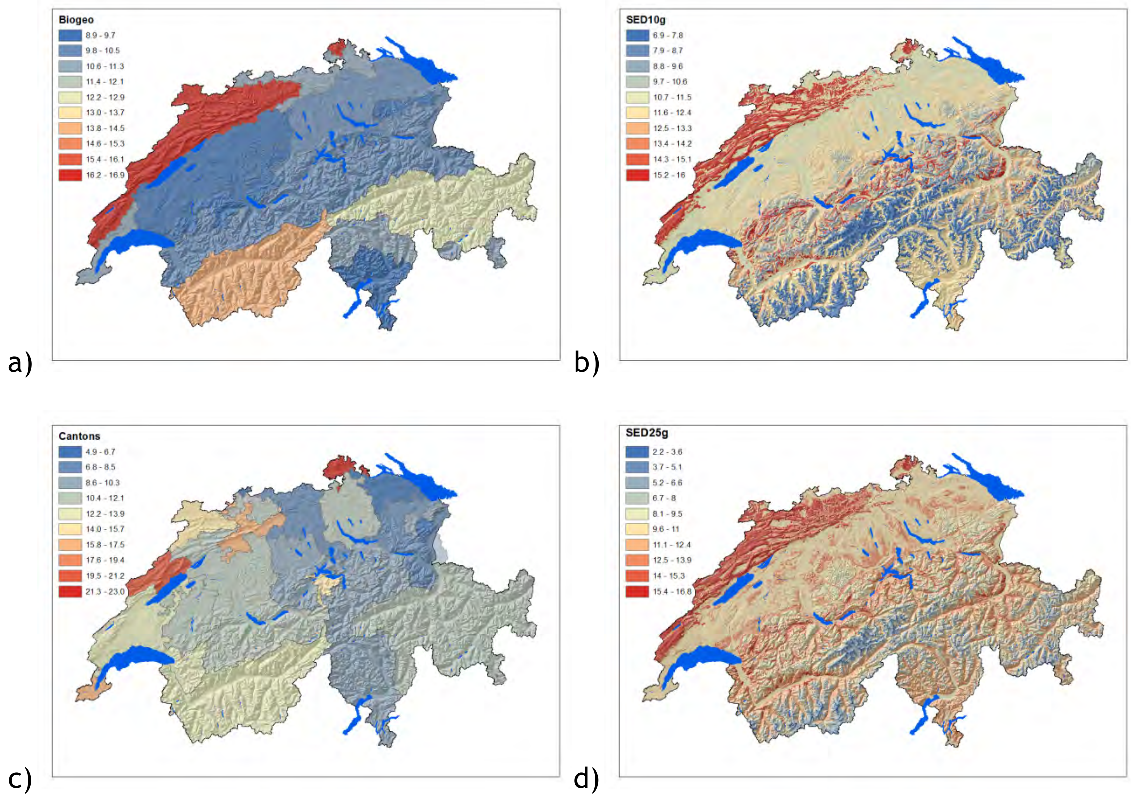
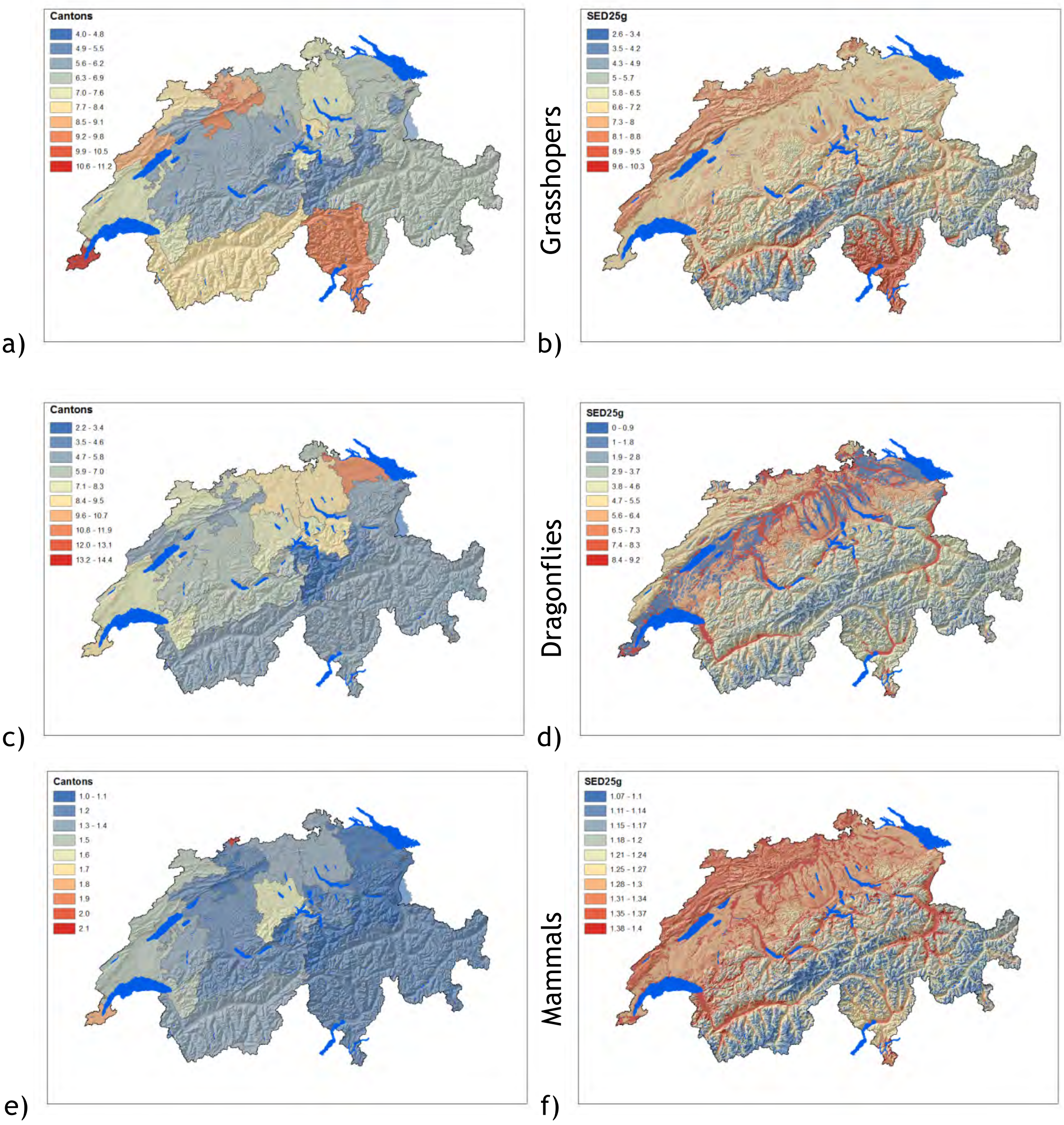


Figure 4 Representations of Butterflies species richness according to different spatial frameworks: a) biogeographic regions, b) SwissED 10 groups, c) cantons, d) SwissED 25 groups

The first results presented in Figure 4 concern the species richness of butterflies. We can see how the SwissED framework at 10 or 25 groups allows representing species richness in a much more ecologically meaningful manner than with the biogeographic regions or the cantons.

In the next figure (Figure 5), the species richnesses of other groups (Grasshopers, Odonates, Mammals, Reptiles and Amphibians) are compared between cantons and SwissED at 25 groups. We can see how the SwissED framework at 25 groups allows representing species richness in a much more ecologically meaningful manner than with the cantonal one.



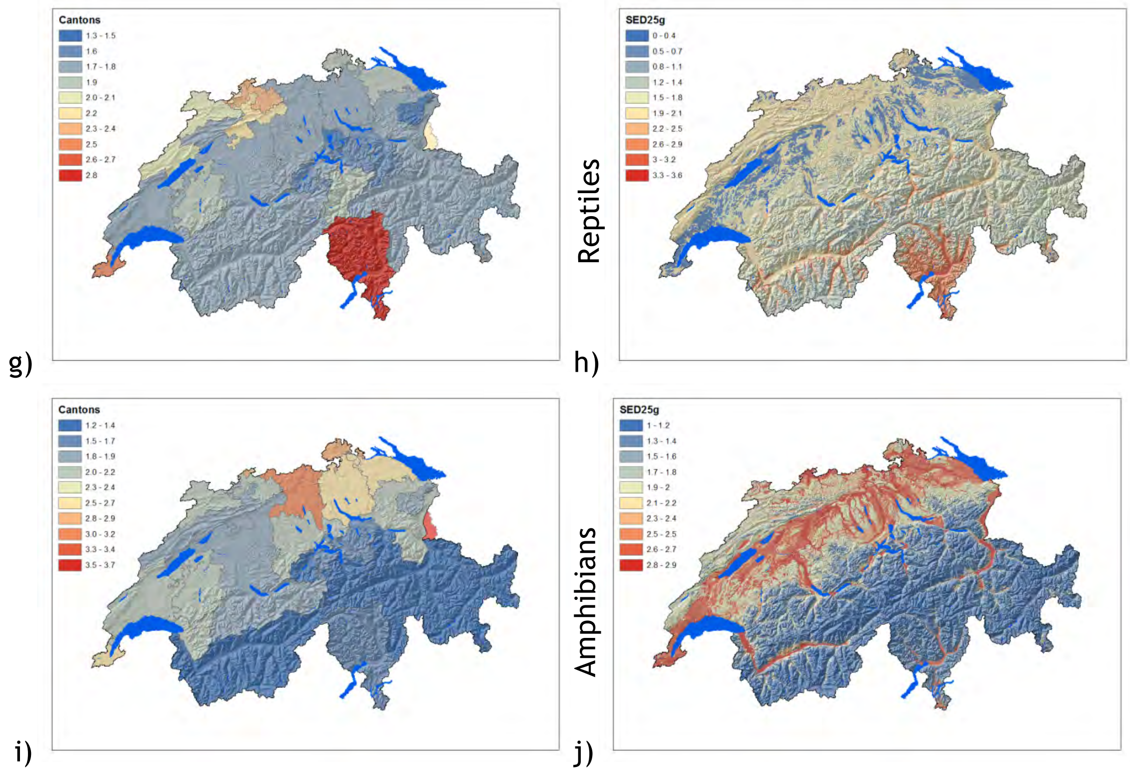
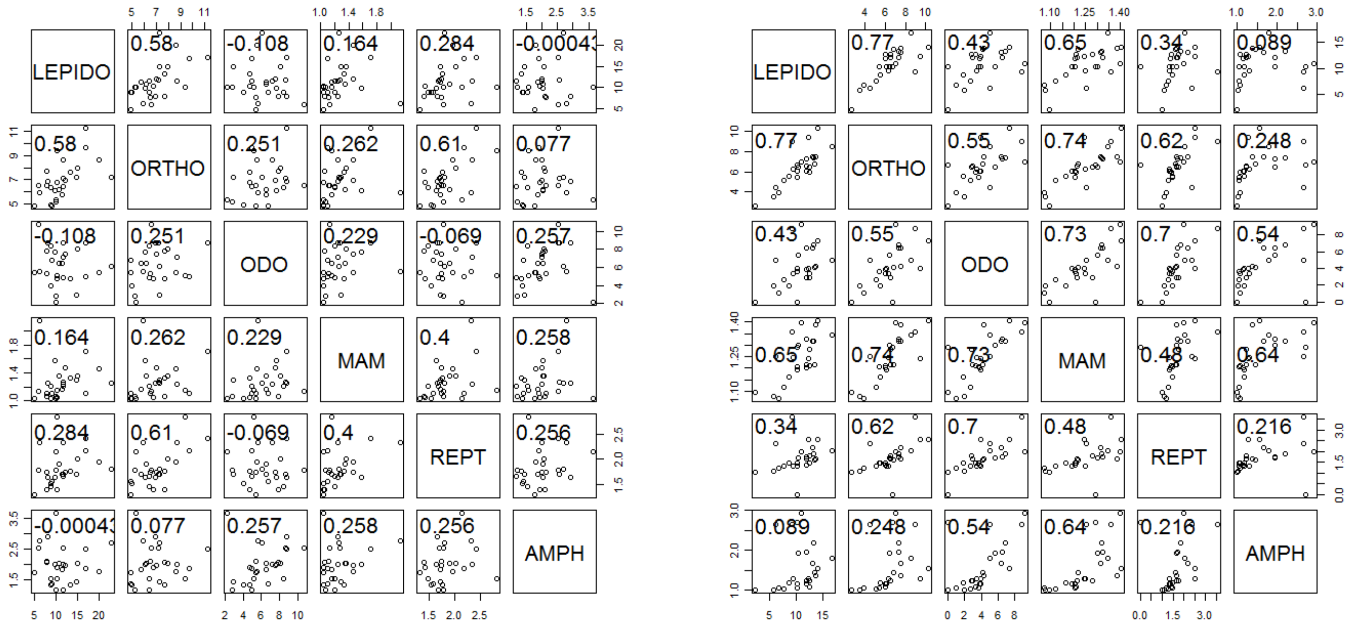


Figure 5 Representations of species richness per cantons and SwissED 25 groups: grasshoppers (a,b) dragonflies (c,d), mammals (e,f), reptiles (g,h) and amphibians (i,j).

For all groups, the maps resulting from the SwissED framework present interesting spatial patterns that can be justified by the ecological preferences of each faunal group.

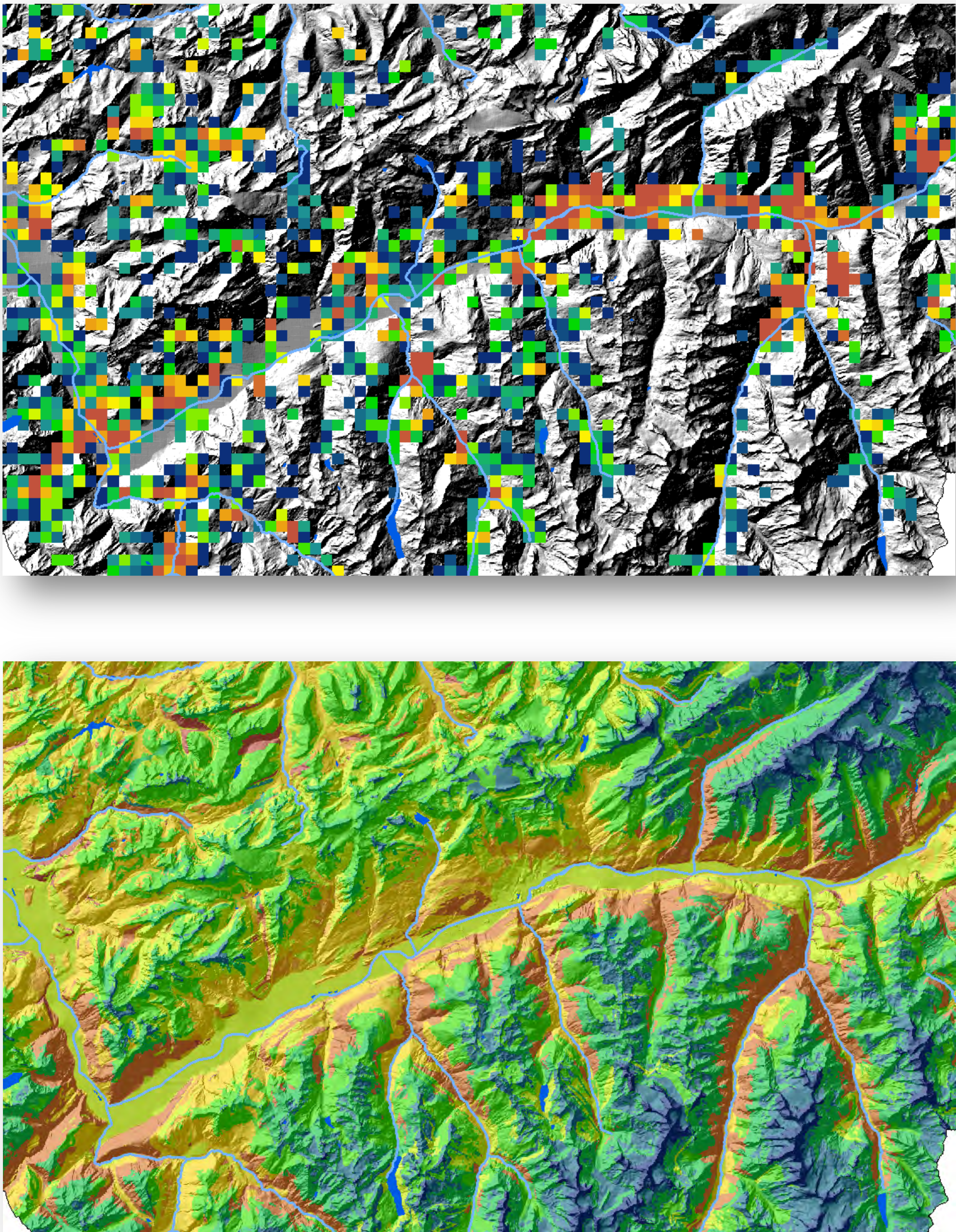
In Figure 6, we can observe the correlation between species richnesses of the six groups when compared among cantons or among SwissED at 25 groups. It appears clearly that species richness is much more correlated within Environmental Domains (mean cor = 0.51) than among cantons (mean cor = 0.23). These can be interesting patterns to keep in mind when looking for surrogate groups as indicator of species diversity of other groups. When explored with the wrong spatial framework (cantons), the correlations remain very small.



a) b)

Figure 6 Correlation of species richnesses per groups among a) cantons and b) SwissED at 25 groups.

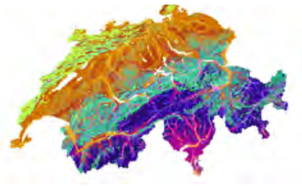
Finally, Figure 7 highlights an interesting benefit of the proposed approach. which is the combination of a simple method to model the mean species richness per domains with a downscaling of the original input data. The resulting map zooming in the Rhone valley shows the double benefit of the approach, transforming barely interpretable discontinuous 1km resolution maps into a continuous representation of species richness along main environmental gradients that are summarized into the Swiss Environmental Domains at a 25m resolution.



a)

b)

Figure 7 Zoom of observed versus predicted species richness for grasshoppers in the Rhone valley. a) Observed species richness at 1km resolution and b) predicted by SwissED25g at 25m resolution.



Perspectives

Swiss Environmental Domains can both model and downscale data of a response variable of interest. This simple technique allows making a spatial estimation at fine scale of the predicted distribution of a response variable such as species richness. Of course, better predictions can be obtained by using adapted methods for spatial predictions such as Generalized Regression Analyses and Spatial Predictions (GRASP: Lehmann et al. 2002). However, the advantage of using SwissED is to provide a single framework for all sorts of response variables that can then be more easily integrated. Recent methods such as Generalized Dissimilarity Modeling (Ferrier et al. 2007) are susceptible of producing both individual spatial predictions of variables of interest as well as a regionalisation optimising its boundary to take into account these variables.

Domains can also be defined for aquatic environments as was shown in New Zealand for marine and river environments (Snelder et al. 2006 and 2007). There should be strong interest to develop a spatial framework like this for Swiss rivers based on the output of hydrological models such as SWAT (Abbaspour et al. 2007).

Target Audience

Zoologists, conservation managers, the Federal Office for the Environment (FOEN)

Links

http://www.cscf.ch & http://www.karch.ch

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Source

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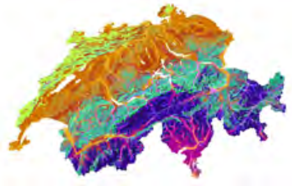
Lehmann et al., 2010. Swiss Environmental Domains: Applications. FOEN report, Bern.



Theme: LAND COVER

Four principal land use/cover types distributions 1992/97

(Forest, arable land, unproductive areas, housing and infrastructure)

Purpose

The aim of this example is to test different spatial frameworks to depict general land cover/land use distribution using Swiss Areal Statistics (GEOSTAT) dating from 1992/97.

The most simplified land cover/land use mapping of Switzerland shows a general distribution of four principal categories: forest, arable land, unproductive areas and housing and infrastructure.

Switzerland is a mountainous country consisting of a Central Plateau of hills, plains and lakes surrounded by the Alps and Jura mountains. More than one third of the territory is predominantly covered by agricultural land, a little less than a third by forests, and a quarter by unproductive areas (rocks, scree, glaciers and unproductive vegetation) mostly localized in the Alps. The remainder consists of housing and infrastructures, concentrated around the lakes on the Plateau, or along the Alps and major rivers (Fig.1).

For evident reasons, land use is strongly correlated to topography and climate. Swiss Environmental Domains (SwissED), which is a regionalization according to environmental conditions (climatic, geologic and topographic) at different levels (10, 25, 50 and 100 groups), should thus show this correlation with increased evidence than the most commonly used spatial frameworks, such as administrative boundaries and biogeographical regions.

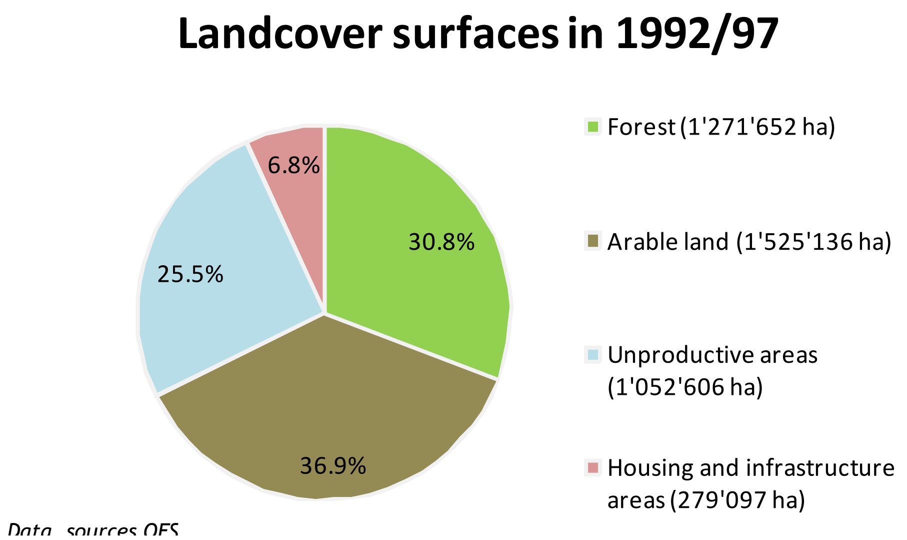


Figure 1 Landcover surfaces in 1992/97 for 4 principal categories (forest, arable land, unproductive areas, housing and infrastructure) in Switzerland

Data description

Areal Statistics related to land use/cover are provided by the Swiss Federal Statistical Office (FSO/Geostat).

The land use/cover categories are determined on aerial photographs from Swisstopo by inspecting all the intersection points of a 1-hectare grid overlapped to the image. There are 74 possible classes of land use/cover and more than 4.1 millions of points to assess for the whole of the Swiss territory. This survey represents the state of land use/cover in Switzerland in the mid-nineties (1992-97).

The initial 74 classes can be hierarchically aggregated into 25, 15 and finally 4 super-classes (housing and infrastructure, agricultural areas, wooded areas and unproductive areas).

Distribution of the four principal land cover/use classes (Areal Statistics 1992/97)

Arable land (Fig.2)

Surfaces used for production of food and fodder, i.e. arable land, meadows, pastures, usable areas for alpine economy, horticultural crops, orchards and vineyards, without other trees and shrubs situated on arable land.

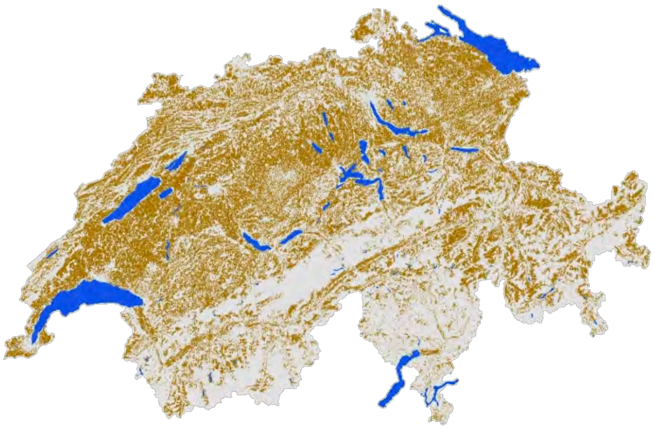


Figure 2 Agricultural land in beige, other classes in grey

Figure 3 Wooded areas in green, other classes in grey

Forest (Fig.3)

Areas populated by trees or shrubs, forest and other wooded land, excluding fruit trees and woodlands located on housing and infrastructure areas.

Unproductive areas (Fig4)

Non-forested areas located outside the region of housing and infrastructure, which are unsuitable for agriculture due to climatic condition or topography. These are in particular lakes and rivers, surfaces without vegetation, and areas covered with unproductive vegetation.

Figure 4 Unproductive areas in blue, other classes in grey

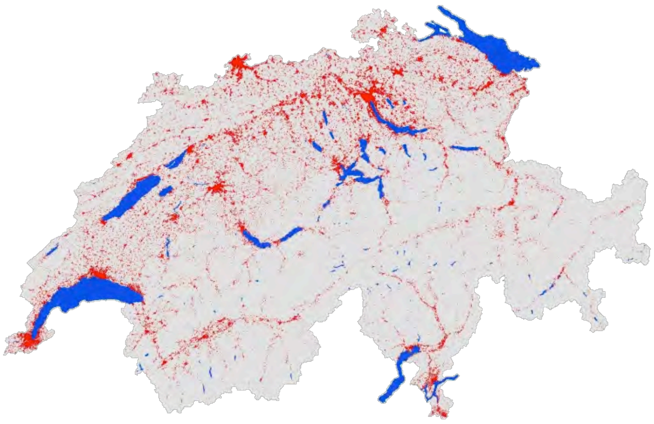


Figure 5 Housing and infrastructure areas in red, other classes in grey

Housing and infrastructure areas (Fig.5)

Areas and facilities devoted to housing, recreation, transportation, industrial production, trade and services, energy supply and disposal of wastewater and waste.

Spatial frameworks

A spatial framework serves, for instance, to illustrate statistical data or collect observation within specified units.

One of the principal advantages of using common and recognized spatial frameworks is the possibility to more easily compare results of different researches.

Bellow is the presentation of the considered frameworks within this example.

Cantonal borders (Table 1, Fig.6)

In Switzerland, each canton has its own constitution, government, parliament, its courts and its laws.

Cantons benefit from a high degree of autonomy in decision-making and administration. Therefore, the widespread use of cantonal border in statistics and mapping is more than justified.

Figure 6 Cantons of Switzerland

Table 1 Cantons (size % and km^2)

CANTONS	%	km^2
Zürich	4.2%	1729
Bern	14.4%	5959
Luzern	3.6%	1494
Uri	2.6%	1077
Schwyz	2.2%	908
Obwalden	1.2%	491
Nidwalden	0.7%	276
Glarus	1.7%	685
Zug	0.6%	239
Fribourg	4.0%	1671
Solothurn	1.9%	791
Basel-Stadt	0.1%	37
Basel-Landschaft	1.3%	518
Schaffhausen	0.7%	298
Appenzell A.Rh.	0.6%	243
Appenzell I.Rh.	0.4%	173
St. Gallen	4.9%	2026
Graubünden	17.2%	7105
Aargau	3.4%	1404
Thurgau	2.4%	991
Ticino	6.8%	2812
Vaud	7.8%	3212
Valais	12.7%	5224
Neuchâtel	1.9%	803
Geneva	0.7%	282
Jura	2.0%	838

Biogeographical regions (Table 2, Fig.7)

This is an expert classification based on patterns of distribution of flora and fauna, limited by communal boundaries when possible (Gonseth et al., 2001). This framework has been specifically defined for nature protection and conservation projects.

This spatial framework integrates an environmental approach by generalizing large geographical units within administrative boundaries. Nevertheless, in some cases, it remains too general, mostly due to the lack of accurate altitudinal subdivisions. As an example, valley bottoms cannot be differentiated from high crests.

Table 2 Biogeographical regions (size % and km^2)

Biogeographical zones (10 regions)	%	Km^2
Rhine basin and Geneva Lake area	5.1%	2116
Jura and Randen	10.4%	4307
Northern Alps	21.3%	8804
Southern Alps	5.0%	2053
Southern Ticino	3.9%	1617
Pre-Alps	6.5%	2681
Central Western Alps	11.7%	4837
Western Plateau	11.6%	4802
Central Eastern Alps	14.1%	5828
Eastern Plateau	10.3%	4251

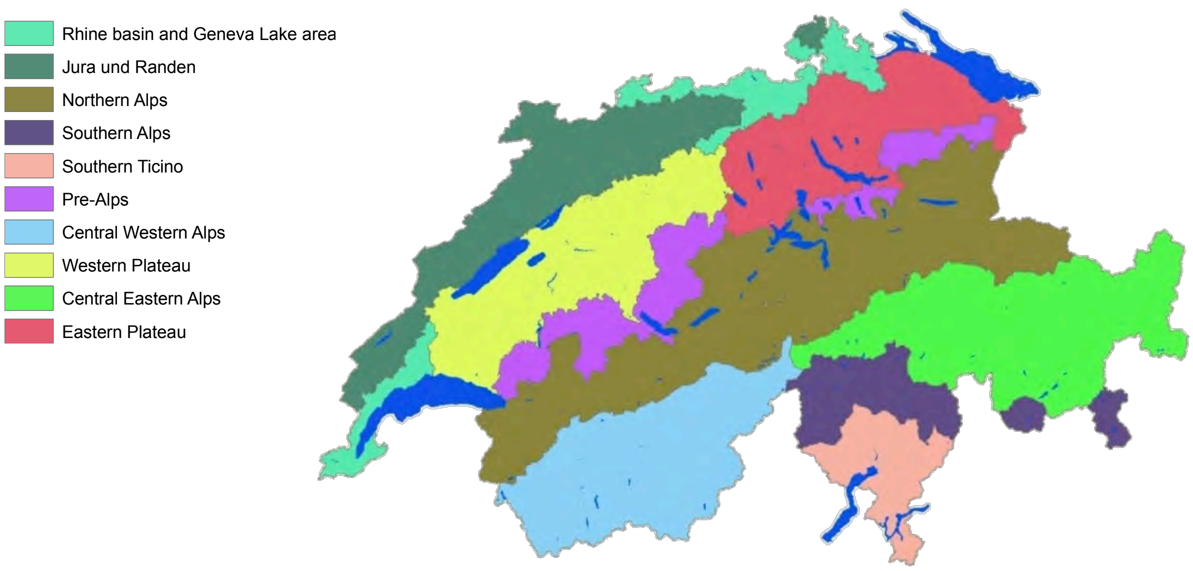
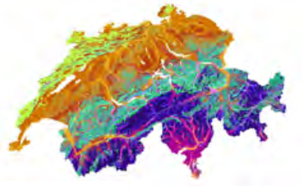


Figure 7 Biogeographical regions



Swiss Environmental Domains Levels I & II (Fig. 9, 10)

This new spatial framework consists of a multivariate classification approach of the Swiss territory using nine climatic, geologic and topographic variables.

In short, this quantitative and reproducible method is composed of two phases: first a non-hierarchical classification of large sample of pixels composing Switzerland into 120 domains, then a hierarchical classification into 100, 50, 25, 10 groups.

Table 3 SwissED level I

SwissED Level I (10 groups)	CODE	%	Km2
Calcareous reliefs	A	10.5%	4177
Molassic flats and hills	B	15.0%	5995
Quaternary hills and valleys	C	8.7%	3463
Crystalline slopes	D	10.7%	4290
Dry quaternary flats	E	16.7%	6654
Calcareous midslopes	F	7.7%	3068
Calcareous upperslopes	G	11.4%	4558
Crystalline crests	H	12.6%	5013
Crystalline quaternary slopes	I	3.6%	1424
Calcareous crests	J	3.2%	1282

Most of the existing spatial frameworks group together elements which are close within the geographical space, resulting in geographically contiguous entities. In contrast, SwissED pools together landscape elements that are close together in the environmental space defined by the climatic, geologic and topographic variables, thus resulting in geographically disjoint entities.

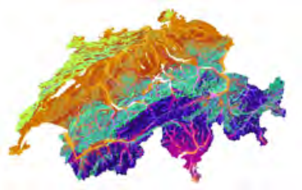
Table 4 SwissED level II

NAME	CODE	%	Km^2
Calcareous reliefs	A1	7.5%	2988
	A2	3.0%	1189
Molassic flats and hills	B1	8.7%	3470
	B2	6.3%	2525
Quaternary hills and valleys	C1	4.4%	1772
	C2	1.8%	734
	C3	1.2%	498
	C4	0.6%	248
	C5	0.0%	9
	C6	0.5%	202
Crystalline slopes	D1	4.2%	1689
	D2	6.5%	2601
Dry quaternary flats	E1	6.9%	2749
	E2	9.8%	3905
Calcareous midslopes	F1	4.2%	1688
	F2	0.3%	136
	F3	3.1%	1244
Calcareous upperslopes	G1	6.2%	2460
	G2	5.3%	2098
Crystalline crests	H1	6.4%	2556
	H2	4.9%	1963
	H3	1.2%	494
Crystalline quaternary slopes	I1	3.6%	1424
Calcareous crests	J1	1.4%	549
	J2	1.8%	733

This spatial framework should better target any phenomenon driven by environmental conditions, but its weakness could be an increased difficulty in apprehending geographically disjoint entities.

For a meaningful geographic representation, the domains have been colored following the result of a principal component analysis where red corresponds to a gradient of temperature, blue a topography gradient and green a gradient of calcareous content (Fig.8).

By representing any data with the spatial framework defined by SwissED, results will map a “potential” rather than a “reality” i.e. spreading one observed category along entities regrouping similar environmental conditions.



Only the ten domains of level I were named according to their environmental characteristics; at higher levels, groups have only been codified (Tables 3, 4).

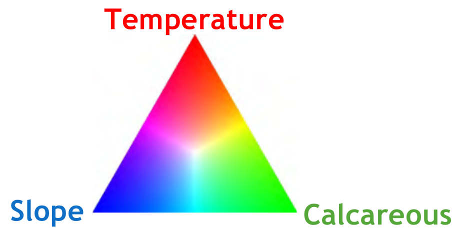
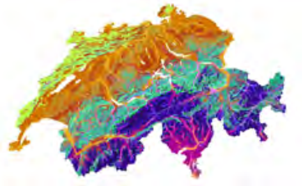


Figure 8 RGB coloring following the result of a PCA

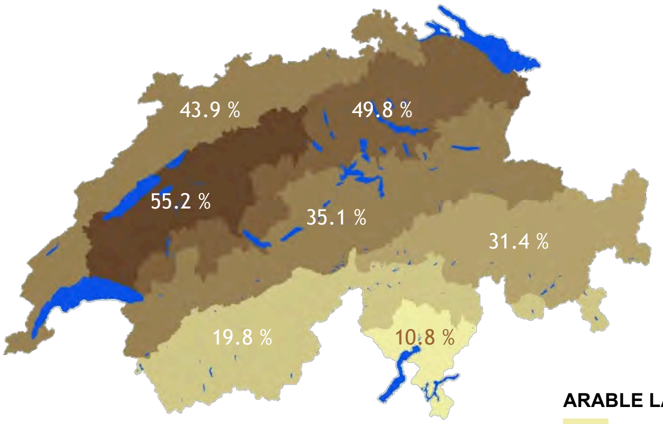
Figure 9 SwissED **Level I (10 groups)**

Figure 10 SwissED **Level II (25 groups)**

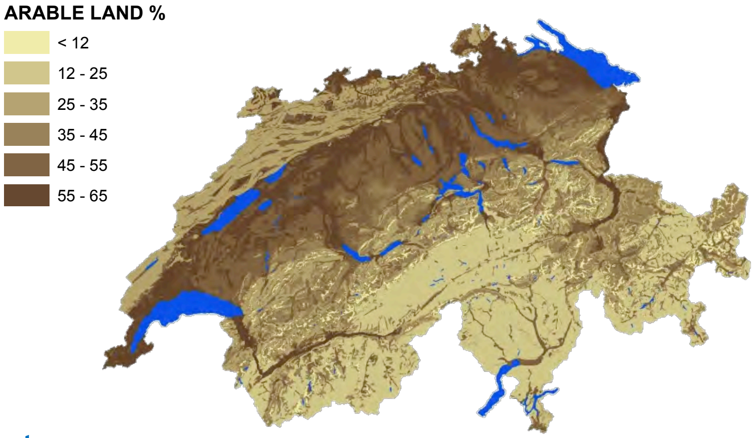
In the following figures, the four principal land covers categories are represented and compared at 10 groups level according to, respectively, biogeographical regions & SwissED level I.



Territory percentage used for agriculture:

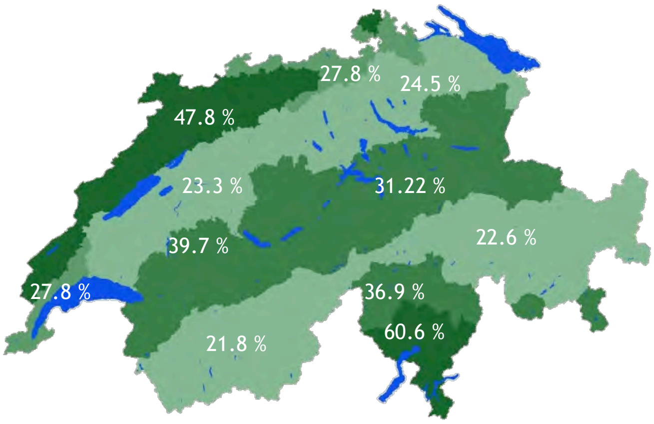


Rhine basin and Geneva Lake area	43.6%
Jura and Randen	43.9%
Northern Alps	35.1%
Southern Alps	16.3%
Southern Ticino	10.8%
Pre-Alps	48.1%
Central Western Alps	19.8%
Western Plateau	**55.2%**
Central Eastern Alps	31.4%
Eastern Plateau	**49.8%**

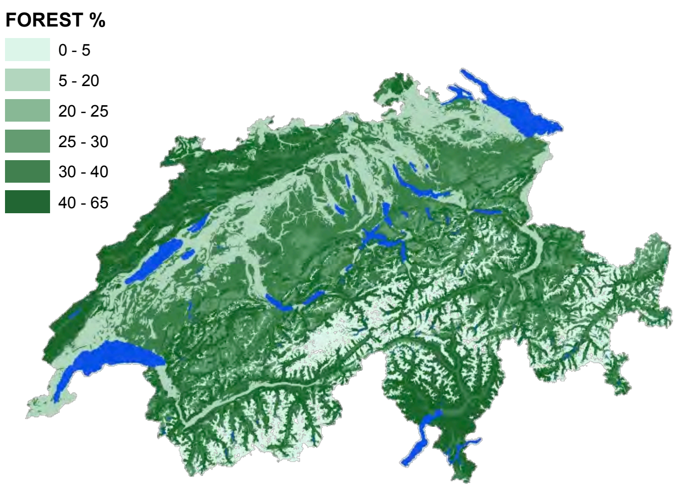


Calcareous reliefs	A	34.2%
Molassic flats and hills	**B**	**53.7%**
Quaternary hills and valleys	C	47.5%
Crystalline slopes	D	17.2%
Dry quaternary flats	**E**	**58.1%**
Calcareous midslopes	F	31.5%
Calcareous upperslopes	G	40.2%
Crystalline crests	H	15.0%
Crystalline quaternary slopes	I	44.6%
Calcareous crests	J	12.7%

Territory percentage occupied by forest:
According to biogeographic region (10 regions)

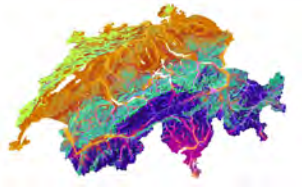


Rhine basin and Geneva Lake area	27.8 %
Jura and Randen	**47.8 %**
Northern Alps	31.2 %
Southern Alps	36.9 %
Southern Ticino	**60.6 %**
Pre-Alps	39.7 %
Central Western Alps	21.8 %
Western Plateau	23.3 %
Central Eastern Alps	22.6 %
Eastern Plateau	24.5 %

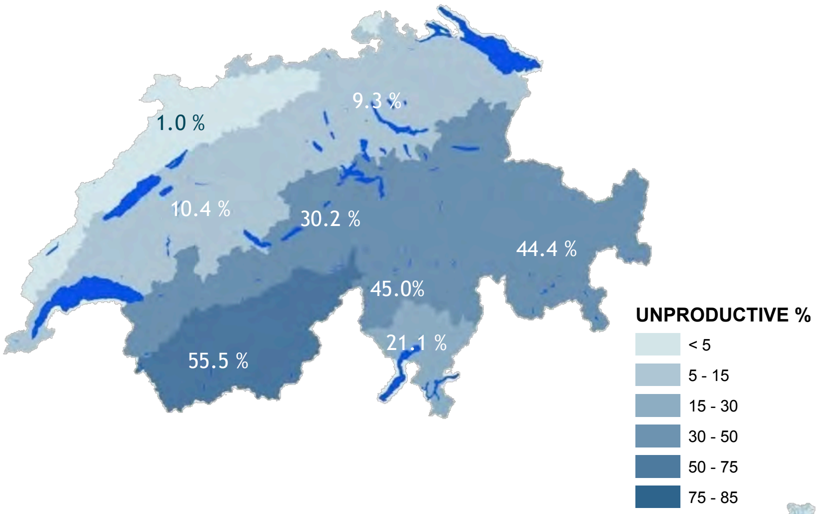


According to SwissED Level1 (10 groups)

Calcareous reliefs	**A**	**53.0%**
Molassic flats and hills	B	34.4%
Quaternary hills and valleys	C	35.4%
Crystalline slopes	**D**	**53.0%**
Dry quaternary flats	E	18.3%
Calcareous midslopes	**F**	**52.2%**
Calcareous upperslopes	G	29.5%
Crystalline crests	H	4.5%
Crystalline quaternary slopes	I	34.0%
Calcareous crests	J	4.8%



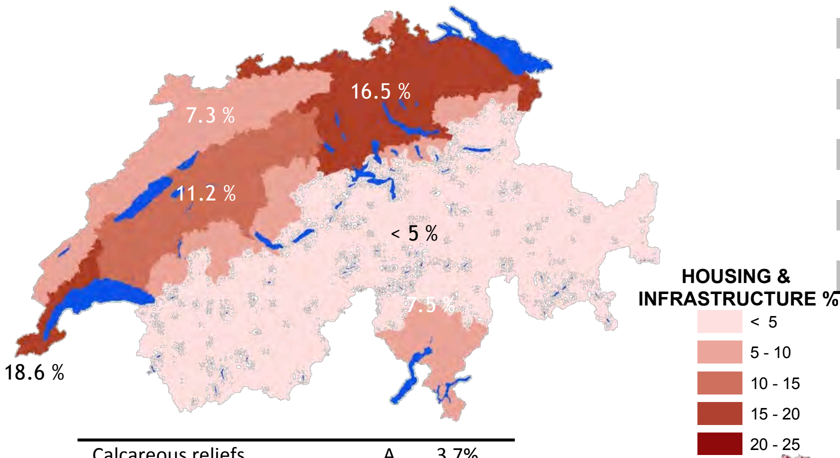
Territory percentage occupied by unproductive areas:



Rhine basin and Geneva Lake area	10.0%
Jura and Randen	1.0%
Northern Alps	30.2%
Southern Alps	45.0%
Southern Ticino	21.1%
Pre-Alps	6.4%
Central Western Alps	**55.5%**
Western Plateau	10.4%
Central Eastern Alps	44.4%
Eastern Plateau	9.3%

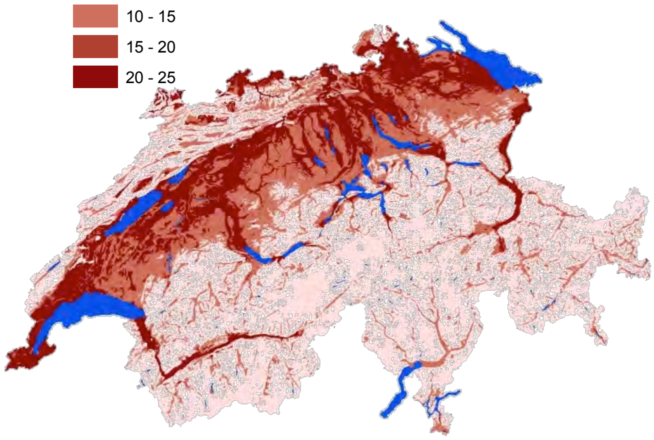
Calcareous reliefs	**A**	**9.0%**
Molassic flats and hills	B	1.5%
Quaternary hills and valleys	C	6.3%
Crystalline slopes	D	27.4%
Dry quaternary flats	E	2.5%
Calcareous midslopes	F	14.1%
Calcareous upperslopes	G	29.6%
Crystalline crests	**H**	**80.4%**
Crystalline quaternary slopes	I	19.7%
Calcareous crests	**J**	**82.4%**

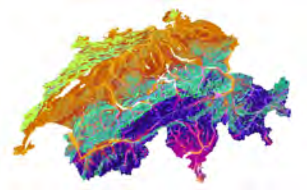
Territory percentage devoted to housing and infrastructure areas:



Rhine basin and Geneva Lake area	**18.6%**
Jura and Randen	7.3%
Northern Alps	3.4%
Southern Alps	1.8%
Southern Ticino	7.5%
Pre-Alps	5.9%
Central Western Alps	2.9%
Western Plateau	11.2%
Central Eastern Alps	1.6%
Eastern Plateau	**16.5%**

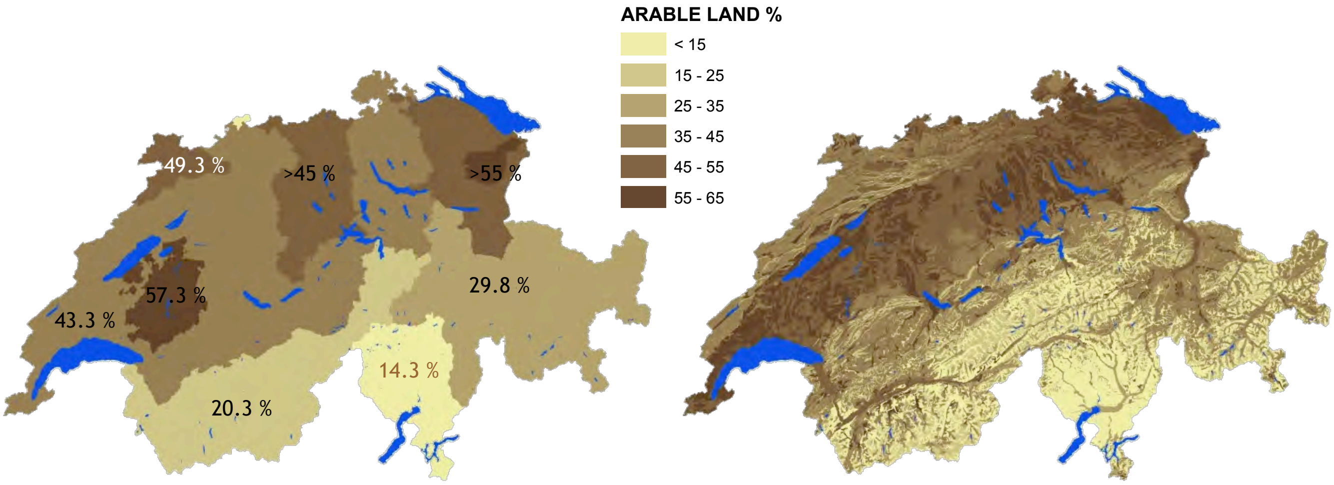
Calcareous reliefs	A	3.7%
Molassic flats and hills	**B**	**10.3%**
Quaternary hills and valleys	**C**	**10.7%**
Crystalline slopes	D	2.5%
Dry quaternary flats	**E**	**21.2%**
Calcareous midslopes	F	2.2%
Calcareous upperslopes	G	0.6%
Crystalline crests	H	0.1%
Crystalline quaternary slopes	I	1.6%
Calcareous crests	J	0.0%





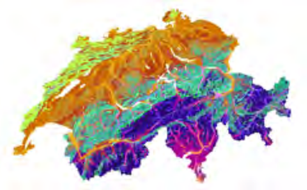
Then in the next figures, the same land cover categories are represented and compared at 25 groups level according to, respectively, cantonal borders & SwissED level II.

Territory percentage used for agriculture:

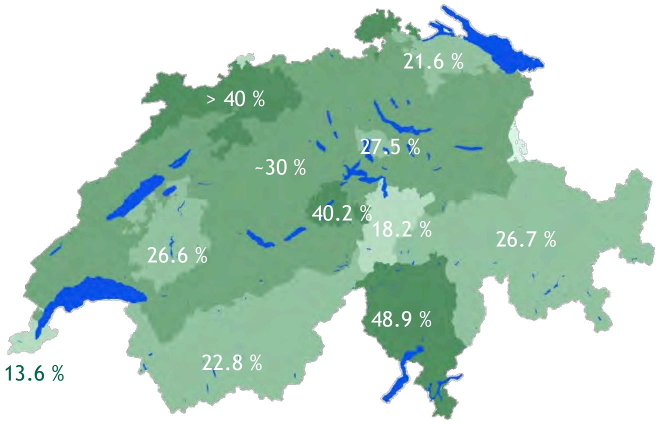


Zurich	43.4%
Bern	43.3%
Luzern	**54.7%**
Uri	24.4%
Schwyz	40.9%
Obwalden	37.9%
Nidwalden	38.0%
Glarus	30.5%
Zug	44.9%
Fribourg	**57.3%**
Solothurn	43.3%
Basel-Stadt	12.1%
Basel-Landschaft	41.4%
Schaffhausen	44.9%
Appenzell A.Rh.	**56.0%**
Appenzell I.Rh.	**55.7%**
St. Gallen	47.9%
Graubünden	29.8%
Aargau	45.4%
Thurgau	**53.4%**
Ticino	14.3%
Vaud	43.4%
Valais	20.3%
Neuchatel	42.0%
Geneva	41.6%
Jura	49.3%

Calcareous reliefs	A1	38.7%
	A2	22.7%
Molassic flats and hills	**B1**	**53.1%**
	B2	**54.6%**
Quaternary hills and valleys	**C1**	**56.5%**
	C2	41.2%
	C3	36.6%
	C4	39.8%
	C5	33.3%
	C6	30.3%
Crystalline slopes	D1	28.5%
	D2	10.0%
Dry quaternary flats	E1	50.5%
	E2	**63.4%**
Calcareous midslopes	F1	36.4%
	F2	19.6%
	F3	26.2%
Calcareous upperslopes	G1	41.4%
	G2	38.8%
Crystalline crests	H1	13.5%
	H2	20.6%
	H3	0.0%
Crystalline quaternary slopes	I1	44.6%
Calcareous crests	J1	15.7%
	J2	10.6%



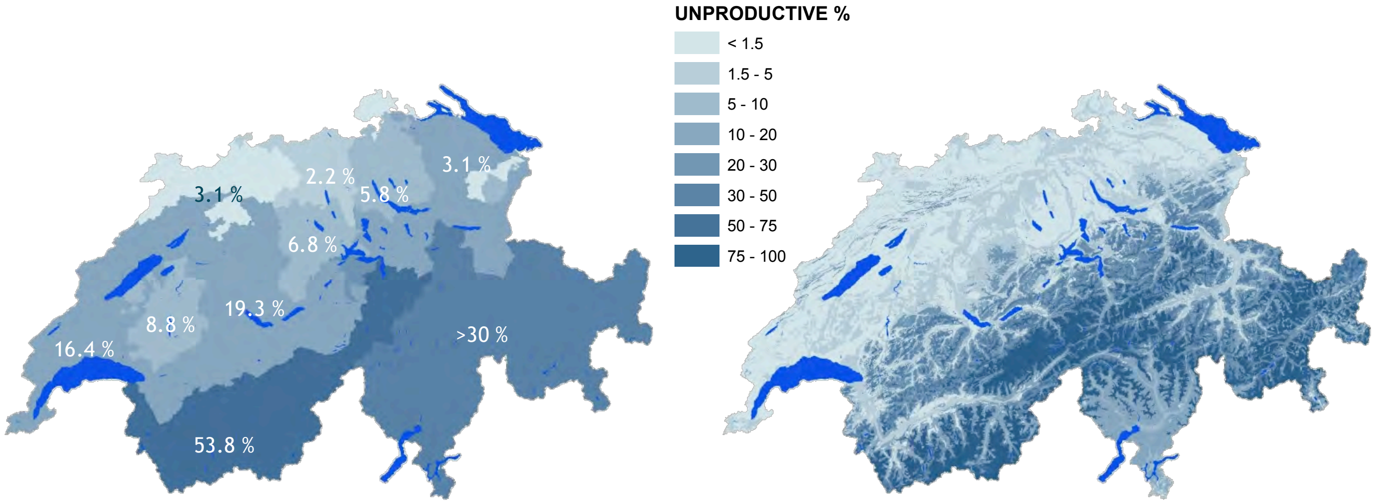
Territory percentage occupied by forest:



Zurich	30.7%
Bern	31.0%
Luzern	30.0%
Uri	18.2%
Schwyz	33.7%
Obwalden	40.2%
Nidwalden	32.8%
Glarus	30.2%
Zug	27.5%
Fribourg	26.6%
Solothurn	43.3%
Basel-Stadt	12.0%
Basel-Landschaft	41.9%
Schaffhausen	43.0%
Appenzell A.Rh.	34.2%
Appenzell I.Rh.	31.6%
St. Gallen	30.6%
Graubünden	26.7%
Aargau	37.0%
Thurgau	21.6%
Ticino	**48.9%**
Vaud	31.8%
Valais	22.8%
Neuchatel	38.8%
Geneva	13.6%
Jura	**44.1%**

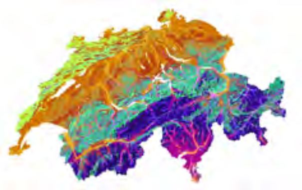
Calcareous reliefs	A1	54.9%
	A2	48.2%
Molassic flats and hills	B1	35.5%
	B2	32.8%
Quaternary hills and valleys	C1	32.4%
	C2	38.5%
	C3	35.8%
	C4	54.0%
	C5	48.6%
	C6	26.1%
Crystalline slopes	D1	23.8%
	D2	**71.5%**
Dry quaternary flats	E1	17.6%
	E2	18.8%
Calcareous midslopes	F1	57.0%
	F2	**67.5%**
	F3	43.9%
Calcareous upperslopes	G1	25.5%
	G2	34.6%
Crystalline crests	H1	8.4%
	H2	0.4%
	H3	0.0%
Crystalline quaternary slopes	I1	34.0%
Calcareous crests	J1	10.4%
	J2	0.7%

Territory percentage occupied by unproductive areas:

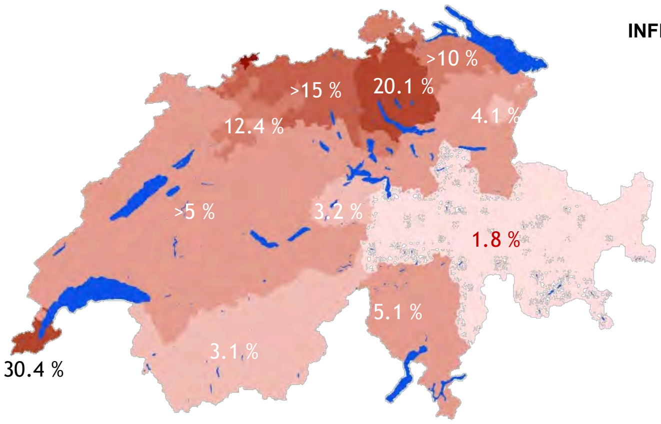


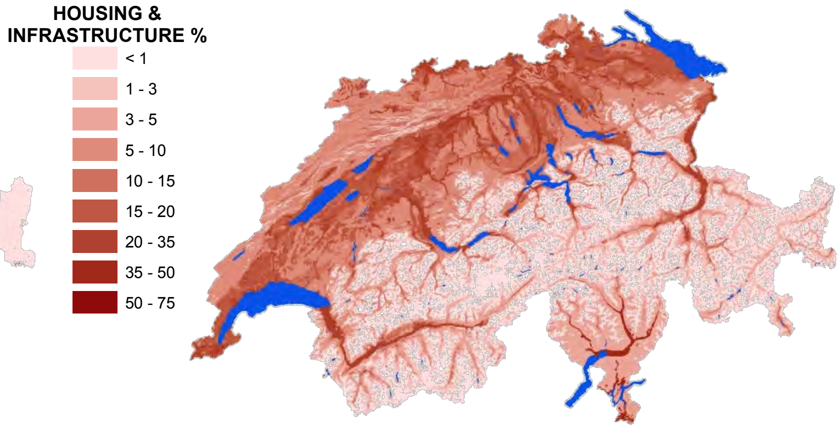
Zurich	5.8%
Bern	19.3%
Luzern	6.8%
Uri	**55.7%**
Schwyz	19.9%
Obwalden	18.6%
Nidwalden	24.3%
Glarus	36.7%
Zug	15.4%
Fribourg	8.8%
Solothurn	1.0%
Basel-Stadt	4.6%
Basel-Landschaft	0.5%
Schaffhausen	1.3%
Appenzell A.Rh.	1.4%
Appenzell I.Rh.	8.5%
St. Gallen	12.8%
Graubünden	41.6%
Aargau	2.2%
Thurgau	13.8%
Ticino	31.7%
Vaud	16.4%
Valais	**53.8%**
Neuchatel	11.5%
Geneva	14.4%
Jura	0.8%

Calcareous reliefs	A1	1.3%
	A2	28.7%
Molassic flats and hills	B1	1.9%
	B2	1.1%
Quaternary hills and valleys	C1	1.5%
	C2	6.4%
	C3	24.3%
	C4	2.3%
	C5	11.9%
	C6	7.9%
Crystalline slopes	D1	46.3%
	D2	15.3%
Dry quaternary flats	E1	3.8%
	E2	1.6%
Calcareous midslopes	F1	3.7%
	F2	7.6%
	F3	29.3%
Calcareous upperslopes	G1	32.8%
	G2	25.8%
Crystalline crests	H1	78.0%
	H2	78.9%
	H3	**100.0%**
Crystalline quaternary slopes	I1	19.8%
Calcareous crests	J1	73.8%
	J2	**88.7%**



Territory percentage devoted to housing and infrastructure areas:





Zurich	20.1%
Bern	6.4%
Luzern	8.4%
Uri	1.7%
Schwyz	5.4%
Obwalden	3.2%
Nidwalden	4.9%
Glarus	2.6%
Zug	12.2%
Fribourg	7.3%
Solothurn	12.4%
Basel-Stadt	**71.4%**
Basel-Landschaft	16.2%
Schaffhausen	10.7%
Appenzell A.Rh.	8.4%
Appenzell I.Rh.	4.1%
St. Gallen	8.7%
Graubünden	1.8%
Aargau	15.5%
Thurgau	11.2%
Ticino	5.1%
Vaud	8.4%
Valais	3.1%
Neuchatel	7.6%
Geneva	**30.4%**
Jura	5.7%

Calcareous reliefs	A1	5.1%
	A2	0.5%
Molassic flats and hills	B1	9.5%
	B2	11.6%
Quaternary hills and valleys	C1	9.7%
	C2	14.0%
	C3	3.2%
	C4	4.0%
	C5	6.2%
	C6	**35.7%**
Crystalline slopes	D1	1.4%
	D2	3.2%
Dry quaternary flats	**E1**	**28.1%**
	E2	16.3%
Calcareous midslopes	F1	3.0%
	F2	5.3%
	F3	0.7%
Calcareous upperslopes	G1	0.4%
	G2	0.9%
Crystalline crests	H1	0.1%
	H2	0.1%
	H3	0.0%
Crystalline quaternary slopes	I1	1.6%
Calcareous crests	J1	0.0%
	J2	0.0%

At SwissED level II, the group "Quaternary hills and valleys" is subdivided into 6 subgroups each characterized by specific values of environmental variables.

Figure 11 shows distribution of subgroups within the group C, highlighting minimum percentage in blue (C3, 3.2%) and maximum percentage in dark red (C6, 35.7%).

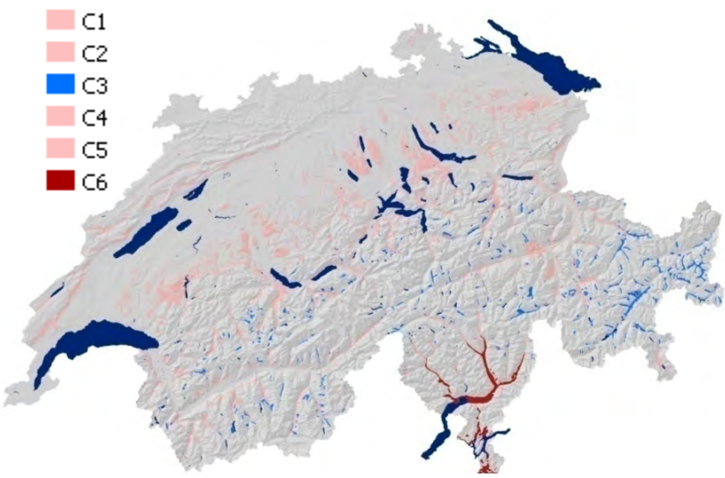


Figure 11 Quaternary hills and valleys distribution at level **II**

For instance, C3 and C6 are totally opposite regarding temperatures and slope. C6 is characterized by maximum temperatures and lowest slopes of the group, in contrast to C3, which presents the lowest temperatures and the highest slopes. Moreover, both groups have heterogeneous distribution, with C3 formed of scattered little entities (987), while C6 is composed of larger entities (59) almost all located in valleys of southern Ticino.

Interpretation

The results presented above summarize the observations (Areal Statistics) within different spatial frameworks, i.e. the occupancy percentage of each class per chosen unit (Table 5).

It turns out that **forests** are mainly localized in Southern Ticino and Jura-Randen regions (covering almost half of Ticino and Jura’s cantons), preferring mountainous zones on calcareous or crystalline substrates up to a certain altitude.

More than 50% of the Plateau is covered by **arable land**, mainly localized on quaternary and molassic flat terrains. The most agricultural cantons, those with more than half of their territory devoted to this activity, are Fribourg, Appenzell, Luzern and Thurgau.

Unproductive areas are mainly localized in central western Alps on crystalline and/or calcareous crests. In the cantons of Uri and Valais, they cover over a half of the territory.

Infrastructure and urbanization areas are principally concentrated in Rhine basin and Geneva Lake Area, as well as in the eastern Plateau. These areas are preferentially localized on rather flat Quaternary substrates. Basel-Stadt breaks all records with occupancy over 70%. Canton Geneva is in second position, with occupancy over 30%, still well above the national average of 11.3%.

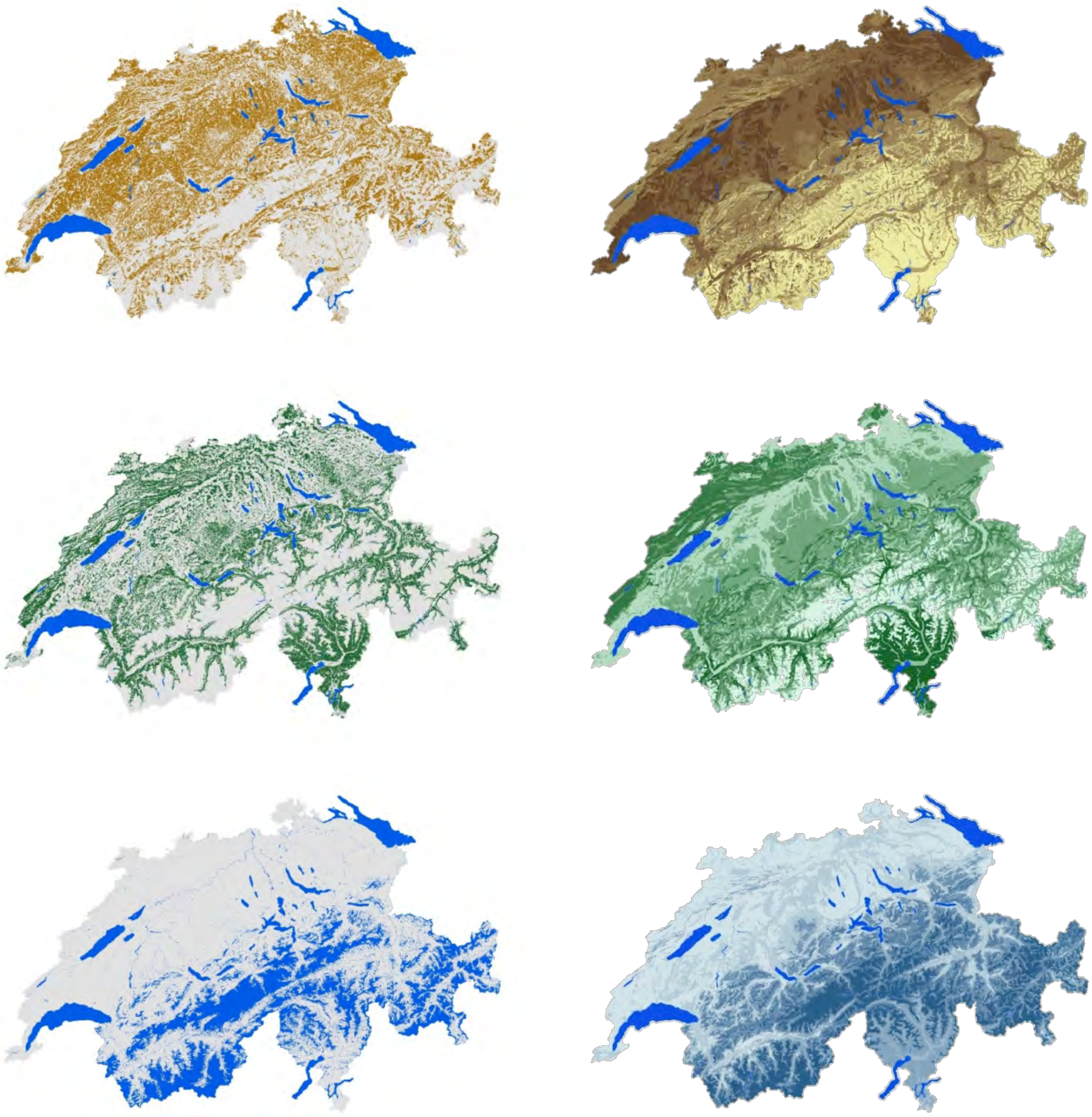
Table 5 Summary of four principal land cover/use classes distribution within different spatial frameworks

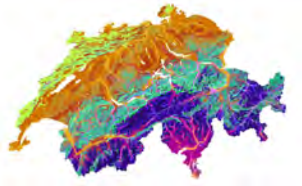
Forest	Arable Land
• Southern Ticino, Jura and Randen • Calcareous reliefs and calcareous midslopes • Crystalline slope • Ticino and Jura cantons	• Western and Eastern Plateau • Dry quaternary flats • Molassic flats and hills • Fribourg, Appenzell, Luzern and Thurgau cantons
Unproductive Areas	**Housing and Infrastructure Areas**
• Central Western Alps • Crystalline and calcareous crests • Uri and Valais cantons	• Rhine basin and Geneva Lake Area • Eastern Plateau • Dry Quaternary flats • Basel-Stadt and Geneva cantons

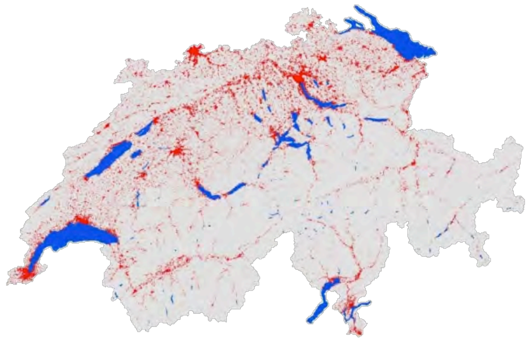
Mapping within SwissED framework illustrates a potential (Fig.12). However, when compared to traditional spatial frameworks, the maps look more realistic, distinguishing for instance cold and high calcareous or crystalline crests from warm valley bottoms. Nevertheless disjoint entities and heterogeneous sizes groups could induce spurious accuracy effects (Table 6).

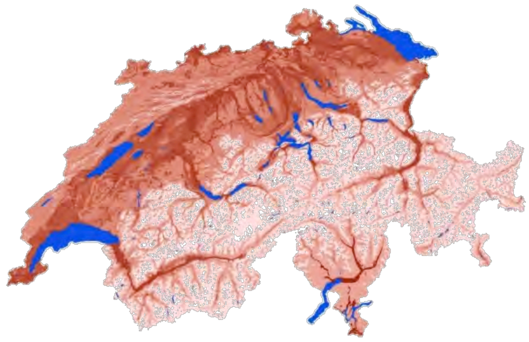
Figure 12 Observed versus potential distribution of main land use categories

OBSERVED (Aerial statistic 1997) | POTENTIAL DISTRIBUTION WITHIN SwissED level II (%)









Evaluation by Dr. Jean-Michel JAQUET (Senior Scientific Adviser)

This new and very interesting spatial framework raises new dimensions and issues. Nevertheless the lack of description of groups at higher level, weakens the relevance of the use of SwissED level II in this document. For better understanding differences between subgroups should be described, even very briefly.

Perspective

SwissED framework could enrich the way to report on environment by bringing a new environmental dimension, especially relevant to illustrate enviro-dependent data.

Therefore this new spatial framework should complete the list of recognized and commonly used frameworks.

Moreover SwissED was developed for general purpose analyses, without trying to weight the input variables. It could therefore be improved by targeting a specific need (e.g. biodiversity, land cover, agriculture). This was tested by Snelder et al. (2009, 2010) who compared different methods to select, weight and transform input variables in order to better represent land cover categories. Such model-based approaches retain the advantages of quantitative definition procedures (i.e., repeatability, hierarchical organisation, statistical stratification of variability and geographical independence) but with increased performance. Model-based procedures require that the target pattern is adequately represented by training data. For example, compositional information sampled at ecologically undisturbed sites would generally be most appropriate for regionalisations developed for conservation assessments.

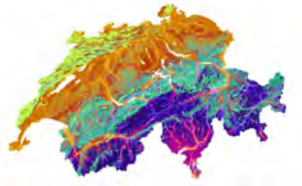
Target Audience

Cantonal and Federal land planning authorities, Academia, Research and Development Department

Links

http://www.bfs.admin.ch/bfs/portal/fr/index/themen/02/03/blank/key/01/zustand_und_entwicklung__grafiken.html

http://www.bfs.admin.ch/bfs/portal/fr/index/news/publikationen.html?publicationID=797



Authors of the factsheet

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Federal Office of Environment (FOEN), Federal Statistical Office (FSO)

We would like to kindly acknowledge the Swiss Federal Office for the Environment (FOEN) for their support and for believing in the potential of Swiss Environmental Domains.

We also would like to thank the Federal Statistical Office (FSO) for making the data available.

And finally a particular thank to Dr. Jean-Michel Jaquet for all improvements made to this fact sheet, for his great interest in this study and for their constructive evaluation of the results.

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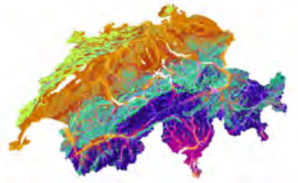
Sources

This factsheet is part of the main report:
Lehmann et al., 2010. Swiss Environmental Domains: Applications. FOEN report, Bern.



Theme: LAND COVER

Land cover evolution from 1979/85 to 1992/97

Purpose

The aim of this document is to test the capacities of SwissED to depict general trends of land use/cover in Switzerland from 1979/85 to 1992/97 and combining them with the use of different spatial frameworks.

GENERAL TREND

Growth of housing and infrastructure areas and loss of arable land

Although Switzerland is still rich in natural and rural landscapes its territory is also characterized by:

- Economic and demographic growth.
- Increased mobility of population.
- Rationalization of agriculture.

Supposing that human activities and environmental conditions are closely linked, the representation of land cover evolution according to Swiss Environmental Domains (SwissED: Allenbach et al., 2008) should improve identifying areas under similar anthropogenic pressure or with a good potential for further development, and help point out potential conflicts in land use.

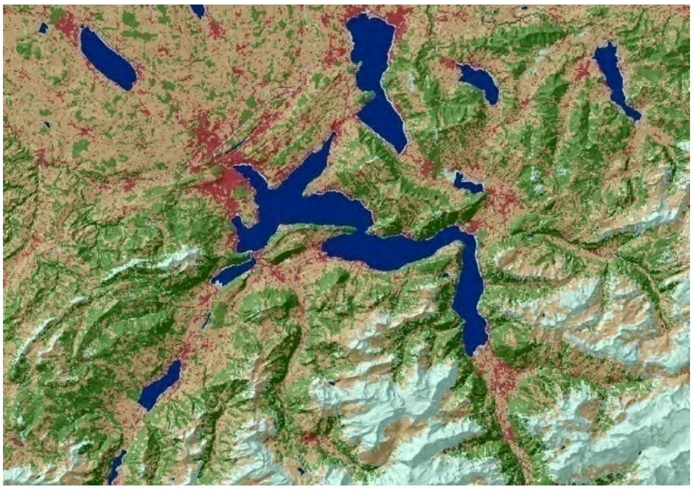


Figure 1 Extract of GEOSTAT 1992/97 showing the 4 principal land cover/use types (green: forest, light blue: unproductive areas, red: housing and infrastructure, beige: arable land).

The comparison of Areal Swiss Statistics (GEOSTAT) from 1979/85 and 1992/97 will depict general trend of land cover changes in Switzerland. In order to highlight these changes, three different spatial frameworks will be used: administrative boundaries, bio-geographical regions and SwissED. SwissED is a regionalization based on environmental conditions (climatic, geologic and topographic) at different levels (10, 25, 50 and 100 groups). Its concept is inherited from LENZ (Land Environment of New Zealand; Leathwick et al. 2003).

Land cover datasets will be displayed in four spatial frameworks at different levels of classification (Table 1).

Table 1 Table of illustrations

GEOSTAT	No spatial Framework	Cantonal Borders	Biogeographical regions	SwissED I (10 classes)	SwissED II (25 classes)
4 classes	Fig.1, 2, 3,	Table 6, 7 Fig. 16, 18, 21, 24	Table 2, 8 Fig. 8, 11, 19, 22, 25	Table 3 Fig. 9, 10, 11	Table 5, 9 Fig. 17, 20, 23, 26
15 classes	-	-	-	Table 4	-
25 classes	Fig. 4, 5, 6, 7,	-	-	-	-
74 classes	Fig. 12, 13, 14, 15	-	-	-	-

Data description

Areal Statistics related to land use/cover are provided by the Swiss Federal Statistcal Office (FSO/Geostat).

The land use/cover categories are determined on two sets of aerial photographs, taken in 1979/85 and 1992/97 from Swisstopo, by inspecting all the intersection points of a 1-hectare grid overlapped to the image. There are 74 possible classes of land use/cover and more than 4.1 millions of points to assess for the whole of the Swiss territory.

The two surveys represent the state of land use/cover in Switzerland in the early eighties and mid-nineties. They provide reliable statistical information to quantify environmental changes as a result of human activity and/or natural phenomena.

The initial 74 classes can be hierarchically aggregated into 25, 15 categories and, finally, 4 super-classes (Fig.1): housing and infrastructure areas, agricultural areas, wooded areas and unproductive areas.

Results and interpretation

Evolution of four principal land use/cover classes between 1979/85 and 1992/97

In twelve years, arable land and pastures, still covering just over one third of the Swiss territory, are those that have most regressed (Fig.2).

Compared to the early eighties situation, arable land surfaces decreased by 482 km^2 (-1.2% of the Swiss territory) at the expense of housing and infrastructure areas (327 km^2, + 0.8%) and forest (170 km^2, +0.4%), the latter having mostly grown on sloping pastures in mountainous areas (Fig. 3).

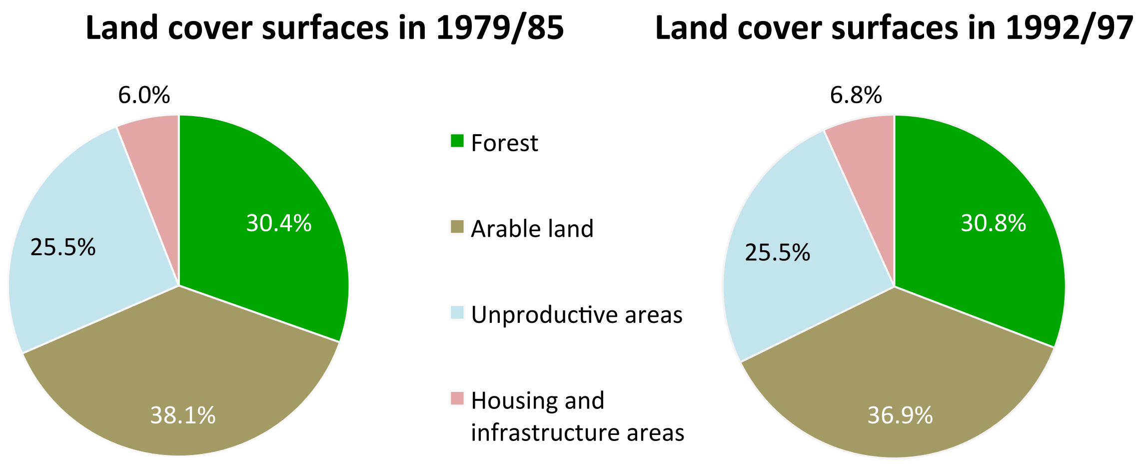


Figure 2 Four principal land cover surfaces in 1979/85 and in 1992/97

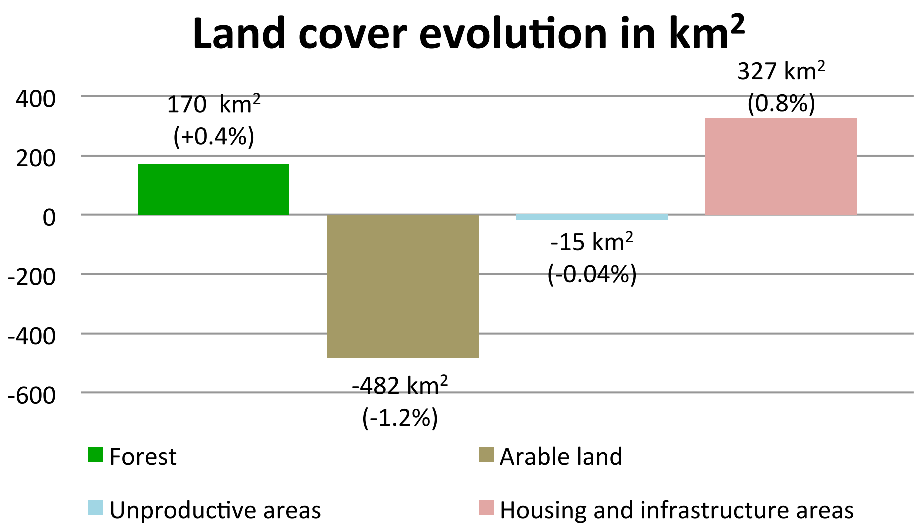


Figure 3 Four principal land cover surfaces changes in square kilometers and % from 79/85 to 92/97

Relevant changes in principal land cover classes

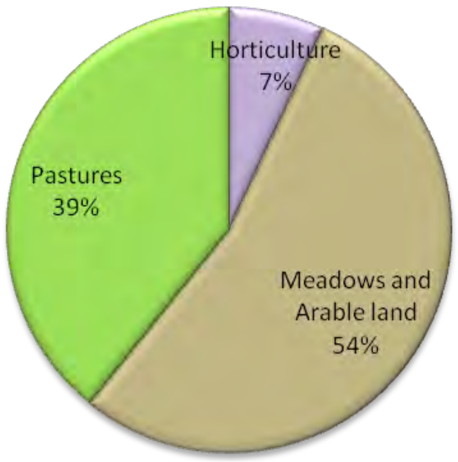


Figure 4 Categories of lost arable land

Figure 4 describes the sectors affected by the loss of 482 km^2 of agricultural surfaces between 79/85 and 92/97. More than a half comes from meadows and arable land, and more than a third from pastures. The remainder consists of fruit trees, horticulture and viticulture all regrouped into one category (horticulture).

Figure 5 illustrates various land uses into which agricultural surfaces were transformed.

More than a half has served for settlement and urban areas, with 28% only for housing, 15% for industry and special infrastructure, 9% for transportation areas and 4% for parks and recreation areas.

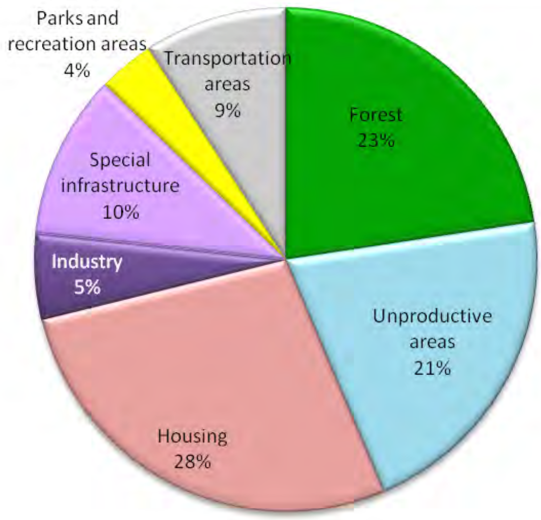


Figure 5 New distribution of lost arable land

The remaining half is divided between forested or unproductive areas probably due to the abandon of pastures in mountainous regions, difficult to access and arduous to exploit.

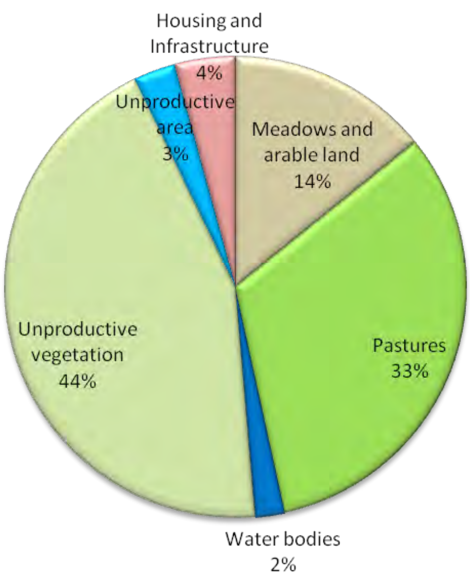
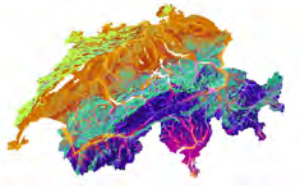


Figure 6 Origin of new forested areas

Figure 6 represents the origin of new forested areas. Almost half is coming from unproductive vegetation (probably from shrubs and bushes category) and a third effectively originated from pastures.



Finally, figure 7 shows the land categories used for developing settlement and urban areas.

Almost three quarters were provided by meadows and arable land, 10% from horticulture and 7% from pasture, totalizing 90% of arable land origin.

The remainder has mainly a forest origin (10%), with only 2% coming from unproductive areas.

The following pages describe the evolution of the four principal types of land cover between 1979/85 and 1992/97 according to different spatial frameworks: cantonal borders (26 entities), biogeographical regions (10 regions), SwissED level I (10 groups) and SwissED level II (25 groups).

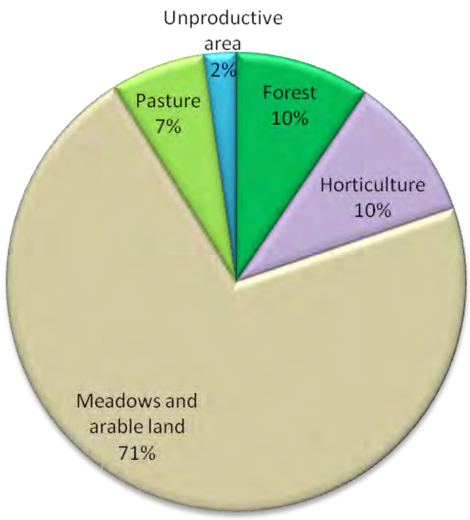


Figure 7 Origin of new areas of settlement and urban areas

Changes of four principal land cover types within biogeographical regions and SwissED level I

Tables 2 and 3 summarize the evolution of the principal landcover classes according to different spatial frameworks, biogeographical regions and SwissED level I.

The relative evolution has been computed by subtracting areas of a specific category within a specific spatial entity of 1992/97 by the corresponding one of 1979/85, and then percentages of their differences has been calculated according to the surface area of 1985.

Table 2 Land cover evolution according biogeographical regions

NAME	HOUSING	ARABLE	FOREST	UNPROD
Rhine basin and Geneva Lake	9.5%	-3.7%	0.2%	0.0%
Jura and Randen	14.4%	-1.9%	-0.1%	**-1.6%**
Northern Alps	15.1%	-2.3%	1.6%	-0.4%
Southern Alps	7.7%	-7.3%	3.9%	-0.5%
Southern Ticino	15.8%	**-14.7%**	1.6%	-0.6%
Pre-Alps	14.6%	-1.9%	0.5%	-0.4%
Central Western Alps	**21.8%**	-6.0%	2.2%	0.5%
Western Plateau	13.7%	-2.4%	0.3%	-0.3%
Central Eastern Alps	12.8%	-2.8%	**4.1%**	-0.4%
Eastern Plateau	11.9%	-3.4%	0.0%	0.3%

Table 3 Land cover evolution according SwissED level I

NAME	CODE	HOUSING	ARABLE	FOREST	UNPROD
Calcareous reliefs	A	15.1%	-1.6%	0.3%	-0.9%
Molassic flats and hills	B	14.2%	-2.4%	0.2%	-2.1%
Quaternary hills and valleys	C	13.9%	-3.2%	1.2%	**-2.9%**
Crystalline slopes	D	13.0%	**-8.6%**	2.8%	-0.3%
Dry quaternary flats	E	12.2%	-3.8%	0.2%	-0.7%
Calcareous midslopes	F	15.8%	-2.9%	1.8%	-2.0%
Calcareous upperslopes	G	**19.7%**	-1.7%	2.2%	-0.1%
Crystalline crests	H	14.8%	-2.6%	**4.2%**	0.2%
Crystalline quaternary slopes	I	**17.7%**	-3.1%	3.1%	0.8%
Calcareous crests	J	9.2%	-0.9%	2.2%	0.0%

Housing and infrastructure increase is more important in central western Alps (Table 2) and in calcareous upperslopes (Table 3). This surprising result could come from the use of too generalized data and frameworks: generalizing the 74 original classes of GEOSTAT into 4 principal types results in an oversimplified classification, regrouping together very heterogeneous data. For instance, housing and infrastructure includes housing and recreation areas, industries, special infrastructures, as well as parks and areas devoted to transport.

Moreover, regionalization of Switzerland into 10 groups is probably too coarse for a correct representation of land use/cover data. At this first level (10 groups), crystalline and calcareous crests lump together very high mountainous and moderate altitude areas, whereas crystalline crest is split into three subgroups in SwissED level II.

Cross-tabulating land cover evolution within SwissEDs indicates, as in Table 3, 15% increase in housing and infrastructure areas in crystalline crests at level I. But regarding at higher level II, as indicated in Table 5, the increase is null in the highest unvegetated and unpopulated crystalline crest (subclass H3).

This kind of results is less troublesome when considering biogeographical regions, as divisions are continuous in space without distinction of detailed environmental conditions. For instance, central western Alps zone comprises together bottom valleys as well as crystalline crests. Therefore, an increase of 22% of housing and infrastructure in this area is more acceptable.

Whereas tables provide a good synoptic view of the results, maps will be used to illustrate the evolution of a specific class.

Mapping housing and infrastructure areas evolution within biogeographical regions and SwissED level I

At first glance (Fig.8), mapping housing and infrastructure areas according biogeographical region and SwissED level I (Fig.9), indicates that the biggest evolution happens in central western Alps, Jura, Pre-Alps and Southern Ticino, at medium altitude on rather rugged landscape.

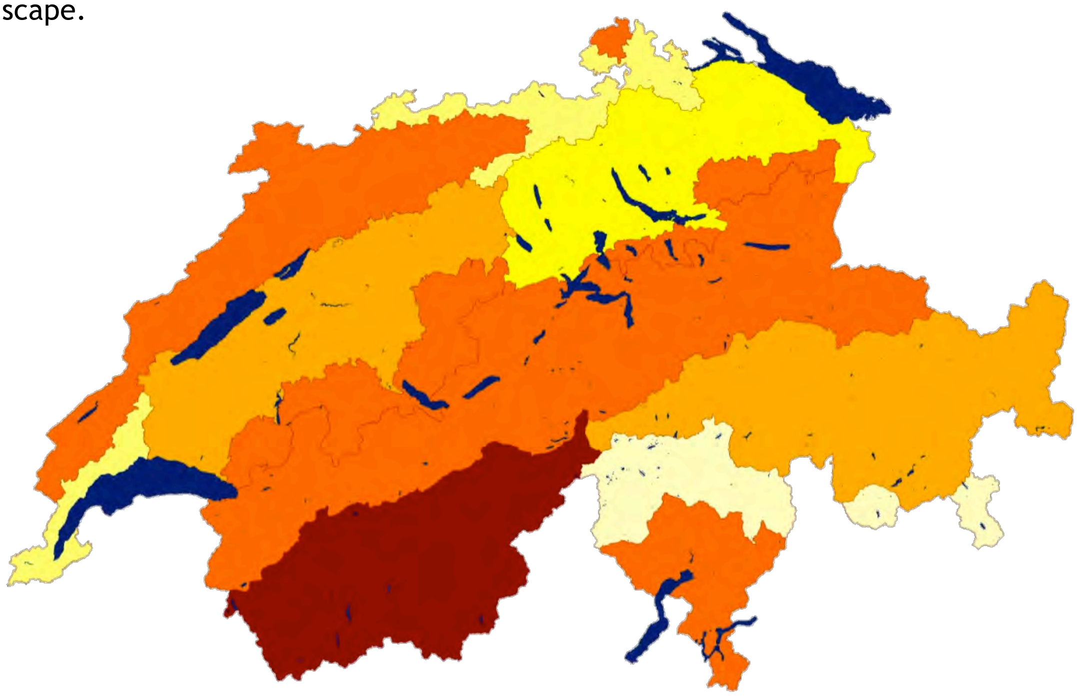


Figure 8 Map of housing and infrastructure areas within biogeographical regions

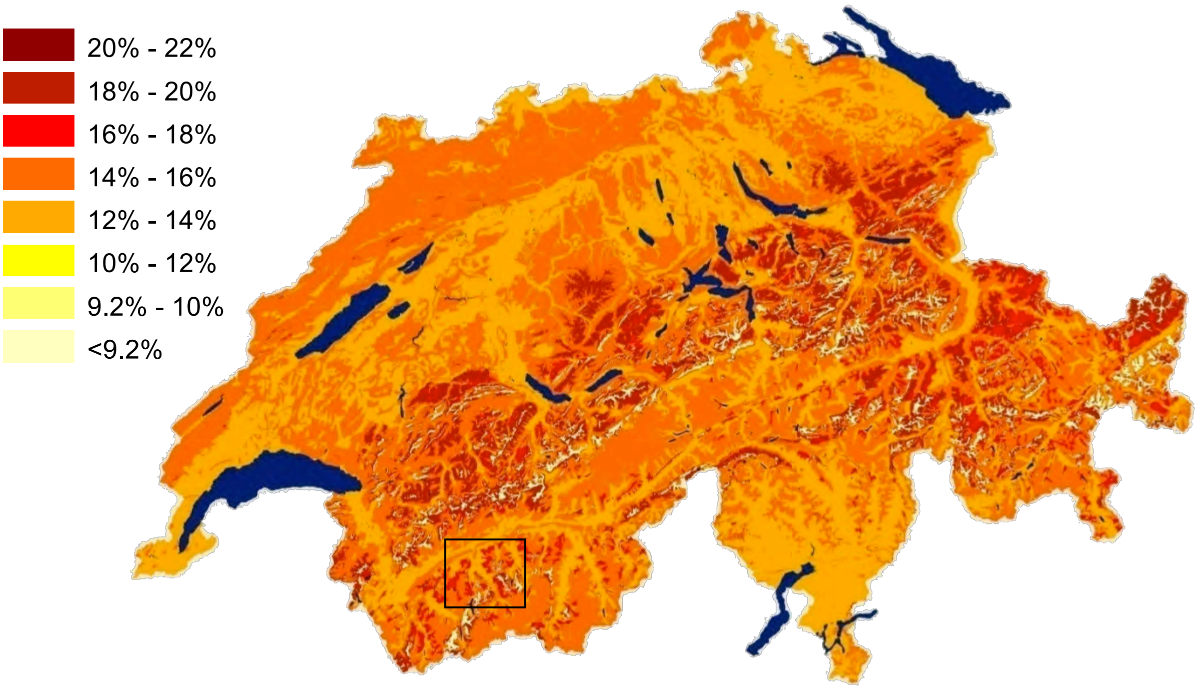


Figure 9 Map of housing and infrastructure areas within SwissED level I

A larger increase of housing and infrastructure areas would have been expected in typical areas used for construction, such as rather flat terrain located at lower altitude on the Plateau.

Figure 10 Zoom on Rhone Valley. Housing and infrastructure evolution according to SwissED level I with overlay of new pixels affected to this category between 1979/85 and 1992/97 (in light blue)

These mapped percentages represent a *relative* evolution within each group according to the situation recorded in 1979/85 and not a quantitative measure of surfaces changes per group.

By overlaying pixels that changed affectation from 1979/85 to 1992/97 in becoming housing and infrastructure (Fig. 10), most of these changes indeed focuses on areas of low altitude, rather flat areas (i.e. the Plateau and valley bottoms).

Quantitatively, housing and infrastructure areas evolution is still predominant in western-eastern Plateau on dry quaternary flats and molassic flats and hills (fig. 11):

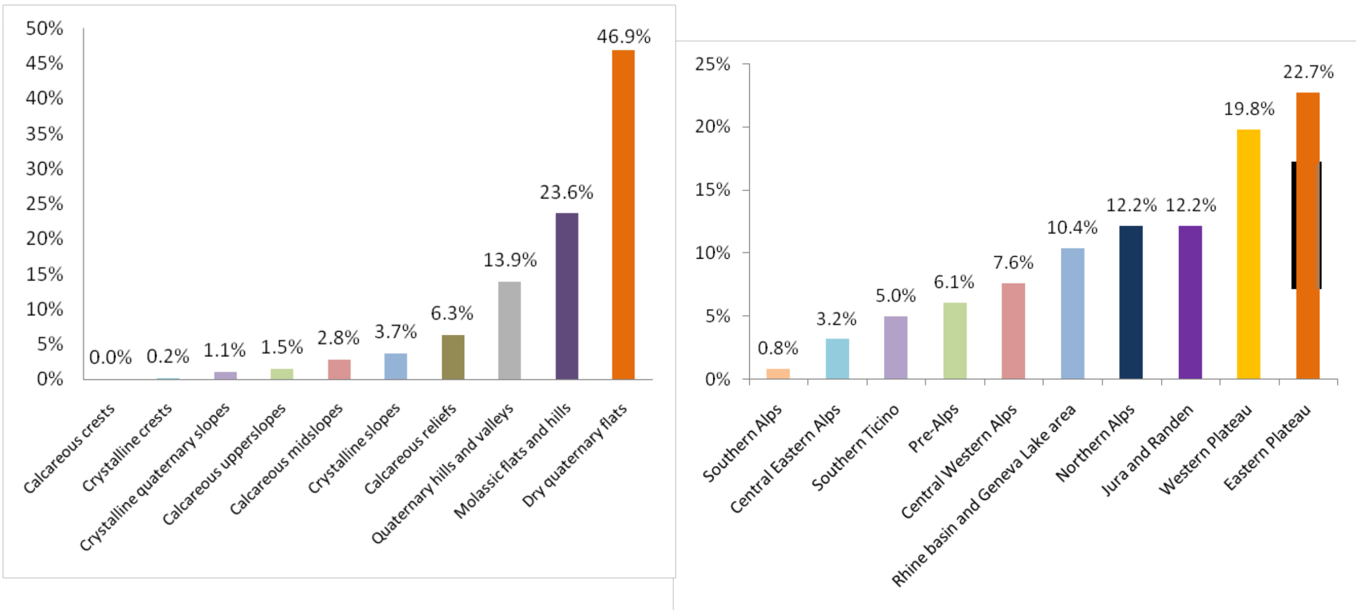


Figure 11 Quantitative evolution of housing and infrastructure areas within biogeographical regions and SwissED level I. Percentages have been calculated on total increase area of housing and infrastructure.

At a higher level of GEOSTAT categories (15 classes), housing and infrastructure areas are subdivided into housing, industry, special infrastructure, park and recreation, and transport.

Evolution in these subgroups, according to SwissED level I, indicates a relatively greater development in industry, parks and recreation areas on rough terrain at medium-high altitude (Table 4).

At the initial 74 categories level of GEOSTAT, industry category comprises industrial buildings with their adjacent land. Parks and recreations areas category includes buildings in recreation areas, outdoors sport facilities, allotments, familial gardens, camping & caravanning, golfs, cemeteries and public parks.

In table 4, the important expansion of parks and recreation areas in crystalline crests (66%) and crystalline quaternary slopes (77%) could indicate substantial touristic development in mountainous regions since 1985 (i.e. development of ski facilities).

Table 4 Housing and infrastructure areas evolution at 15 classes according SwissED level I

HOUSING AND INFRASTRUCTURE AREAS					
SwissED Level 1	Housing	Industry	Special Infrastructure	Parks and Recreation	Transport
Calcareous reliefs	16%	24%	**26%**	19%	11%
Molassic flats and hills	18%	28%	-2%	17%	9%
Quaternary hills and	19%	27%	-12%	19%	11%
Crystalline slopes	16%	28%	2%	32%	10%
Dry quaternary flats	15%	23%	-9%	15%	8%
Calcareous midslopes	18%	**46%**	-1%	24%	16%
Calcareous upperslopes	16%	**68%**	-6%	18%	**25%**
Crystalline crests	**26%**	(+1 ha)[1]	-12%	**66%**	14%
Crystalline quaternary slopes	22%	27%	-10%	**77%**	16%
Calcareous crests	4%	0%	-18%	0%	19%

[1] This category was absent in the group « Crystalline Crest » in 1985

Relevant changes in housing and infrastructure (within 5 sub-categories)

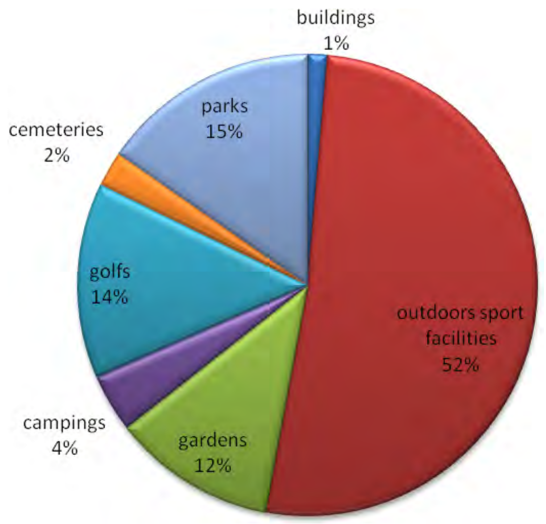


Figure 12 Evolution within Parks and Recreation areas

Parks and recreation areas (Fig.12)

Regarding change distribution within parks and recreation categories, a major increase appears in outdoors sport facilities (52%).

Housing areas (Fig. 13)

Housing areas are subdivided into five categories; individual houses, terraced houses, residential high buildings, farm buildings and undefined buildings. Major increase occurs in individual houses.

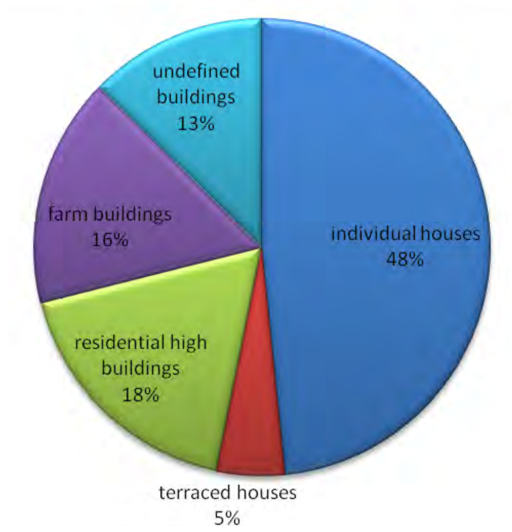


Figure 13 Evolution within housing areas

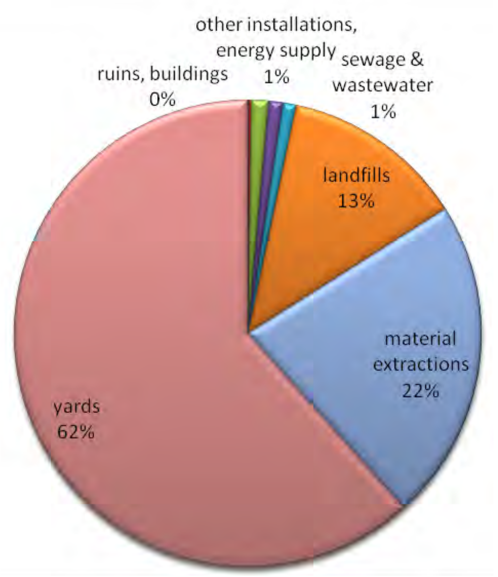
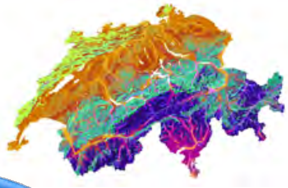


Figure 14 Evolution within special infrastructure areas

Special infrastructure areas (Fig. 14)

Special infrastructure areas are divided into buildings situated on special infrastructure areas, energy supply system, sewage and wastewater, other installation for supply and disposal, landfills, material extractions, yards and ruins. Major increase appears in yards, followed by material extractions and landfills.



Transport areas (Fig. 15)

Transport areas comprise roads, railways and airports areas. Ninety-seven percent of changes occur in roads areas, mainly for the extension of the roads and paths network.

Figure15 Evolution within roads areas

Changes of four principal land cover types within administrative boundaries and SwissED level II (25 groups)

As shown in Table 5, increase in housing and infrastructure is still predominant in calcareous upperslopes in both subgroups G1, G2. But at this scale, a similar augmentation is also visible in other subgroups from calcareous relief (A2) and quaternary hills and valleys (C4). Table 6 indicates that increase in housing and infrastructure occurs mostly in Jura, Valais and Fribourg.

Decrease in arable land remains more important in crystalline slopes (subgroup D2) but is also considerable in quaternary hills and valleys (subgroup C6). The most affected cantons are Ticino, Valais and Geneva (Table 6).

The spread of forested areas is more noticeable in crystalline slopes (subgroup D1) and crystalline crests (subgroup H2), and occurs predominantly in cantons Graubünden and Uri.

Finally, a major decrease in unproductive areas is visible in quaternary hills and valleys subgroups C4, C6 mostly in Jura and Schaffhausen.

Table 5 Land cover evolution according SwissED level II

NAME	CODE	HOUSING	ARABLE	FOREST	UNPROD
Calcareous reliefs	A1	14.9%	-1.6%	0.0%	-2.0%
	A2	**20.3%**	-1.9%	1.2%	-0.8%
Molassic flats and hills	B1	14.0%	-2.2%	0.3%	-2.2%
	B2	14.4%	-2.6%	0.1%	-1.8%
Quaternary hills and valleys	C1	14.7%	-2.4%	0.6%	-4.6%
	C2	12.7%	-4.0%	0.9%	-3.3%
	C3	8.8%	-3.7%	4.0%	-0.9%
	C4	**18.1%**	-3.2%	1.9%	**-12.9%**
	C5	1.6%	-3.0%	2.3%	-1.7%
	C6	14.7%	**-10.0%**	**-1.5%**	**-9.4%**
Crystalline slopes	D1	12.1%	-5.6%	**5.5%**	0.6%
	D2	13.3%	**-13.7%**	2.2%	-2.1%
Dry quaternary flats	E1	11.4%	-5.5%	0.4%	-0.4%
	E2	13.2%	-2.9%	0.0%	-1.1%
Calcareous midslopes	F1	16.4%	-2.7%	1.5%	-6.5%
	F2	12.2%	-6.3%	1.2%	-0.1%
	F3	15.5%	-2.9%	2.4%	-1.2%
Calcareous upperslopes	G1	**20.7%**	-1.9%	3.2%	-0.1%
	G2	**19.2%**	-1.4%	1.3%	-0.1%
Crystalline crests	H1	11.6%	-4.8%	4.2%	0.4%
	H2	**18.0%**	-0.5%	**5.7%**	0.1%
	H3	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Crystalline quaternary slopes	I1	17.7%	-3.1%	3.1%	0.8%
Calcareous crests	J1	15.8%	-1.4%	2.1%	0.0%
	J2	-4.0%	-0.3%	3.3%	0.0%

Table 6 Land cover evolution according cantonal borders

NAME	HOUSING	ARABLE	FOREST	UNPROD
Zurich	8.5%	-3.6%	0.0%	0.6%
Bern	11.0%	-1.8%	0.7%	-0.3%
Luzern	17.9%	-2.3%	0.3%	-0.7%
Uri	10.8%	-3.2%	**3.4%**	0.1%
Schwyz	18.0%	-2.4%	0.4%	0.1%
Obwalden	17.8%	-2.0%	0.7%	0.2%
Nidwalden	13.2%	-1.6%	0.8%	-0.8%
Glarus	12.6%	-2.3%	1.9%	-0.4%
Zug	14.5%	-3.3%	0.1%	-0.3%
Fribourg	19.6%	-2.4%	1.2%	-0.8%
Solothurn	13.9%	-3.4%	0.0%	-2.4%
Basel-Stadt	0.7%	-2.9%	-0.5%	-1.2%
Basel-	10.3%	-3.6%	0.0%	0.0%
Schaffhausen	8.3%	-2.3%	0.7%	**-4.0%**
Appenzell A.Rh.	12.6%	-1.7%	0.0%	2.5%
Appenzell I.Rh.	18.9%	-1.6%	0.3%	1.4%
St. Gallen	12.7%	-2.5%	1.0%	-0.3%
Graubünden	12.9%	-3.1%	**3.9%**	-0.7%
Aargau	12.6%	-3.9%	0.2%	1.9%
Thurgau	14.5%	-2.6%	0.0%	0.1%
Ticino	14.1%	**-10.4%**	2.1%	0.1%
Vaud	14.1%	-2.7%	0.7%	-0.4%
Valais	**22.2%**	**-6.0%**	2.2%	0.4%
Neuchatel	13.7%	-1.9%	-0.1%	-0.7%
Geneva	9.5%	**-5.9%**	0.5%	-0.6%
Jura	**25.2%**	-1.4%	**-1.0%**	**-5.1%**

Mapping housing and infrastructure areas evolution within administrative boundaries and SwissED level II

Major *relative* increase in housing and infrastructure occurs in Jura and Valais cantons with more than 20% of increase, closely followed by Fribourg with an augmentation of more than 19% (Fig.16).

Comparison of SwissED maps at level I (Fig. 9) and II (Fig. 17) shows similar trend of housing and infrastructure evolution. However at level II, this category is mapped with higher "accuracy" by avoiding results spreading due to improving delineation of areas under similar environmental conditions.

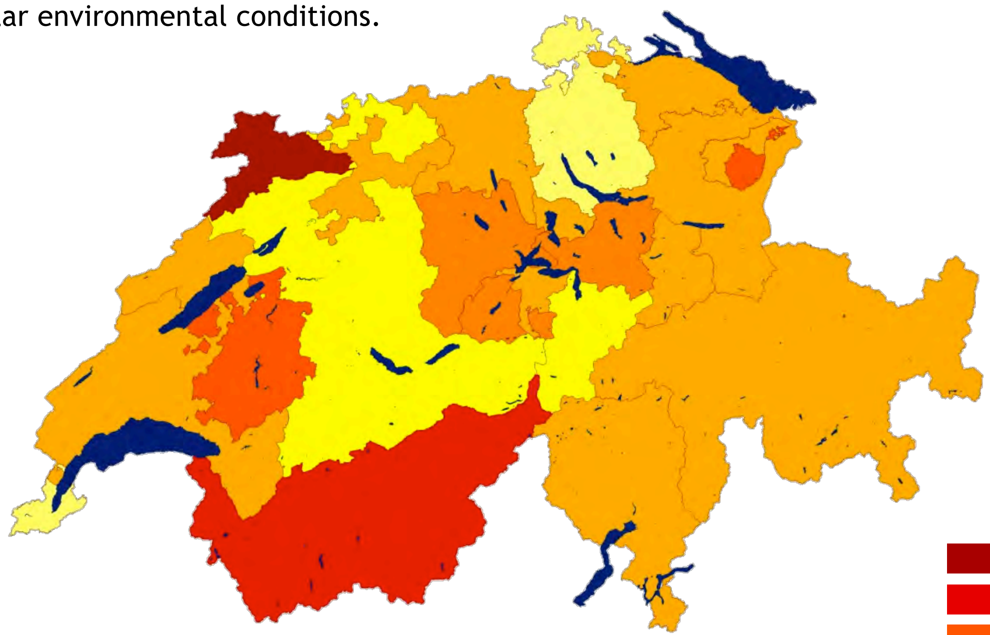
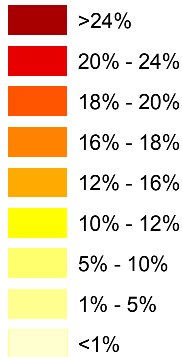


Figure 16 Map of Housing and infrastructure areas within cantonal borders



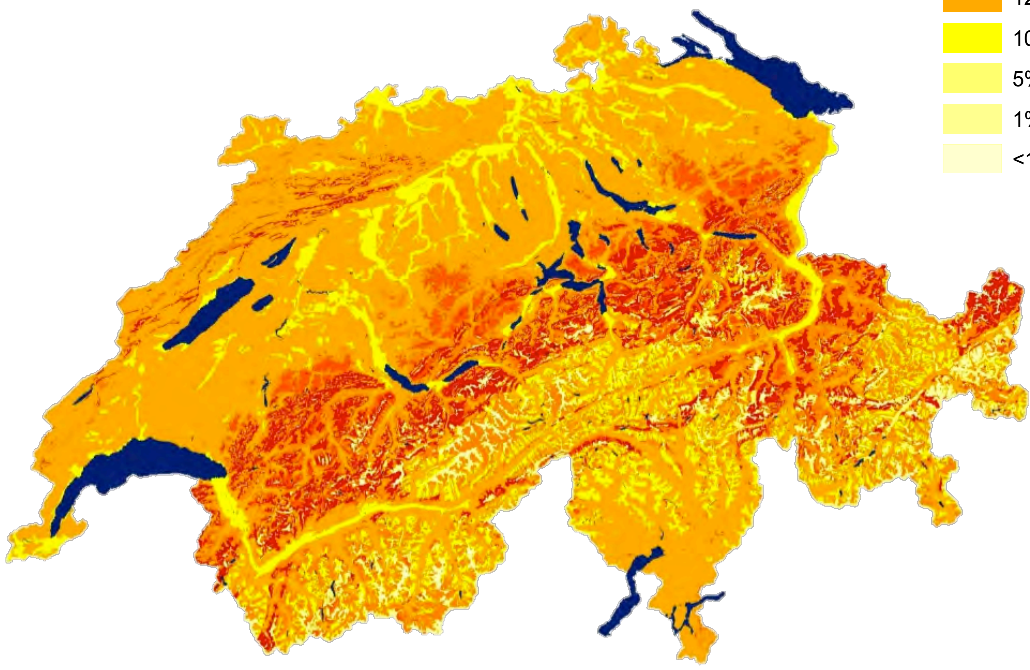


Figure 17 Map of Housing and infrastructure areas within SwissED level II

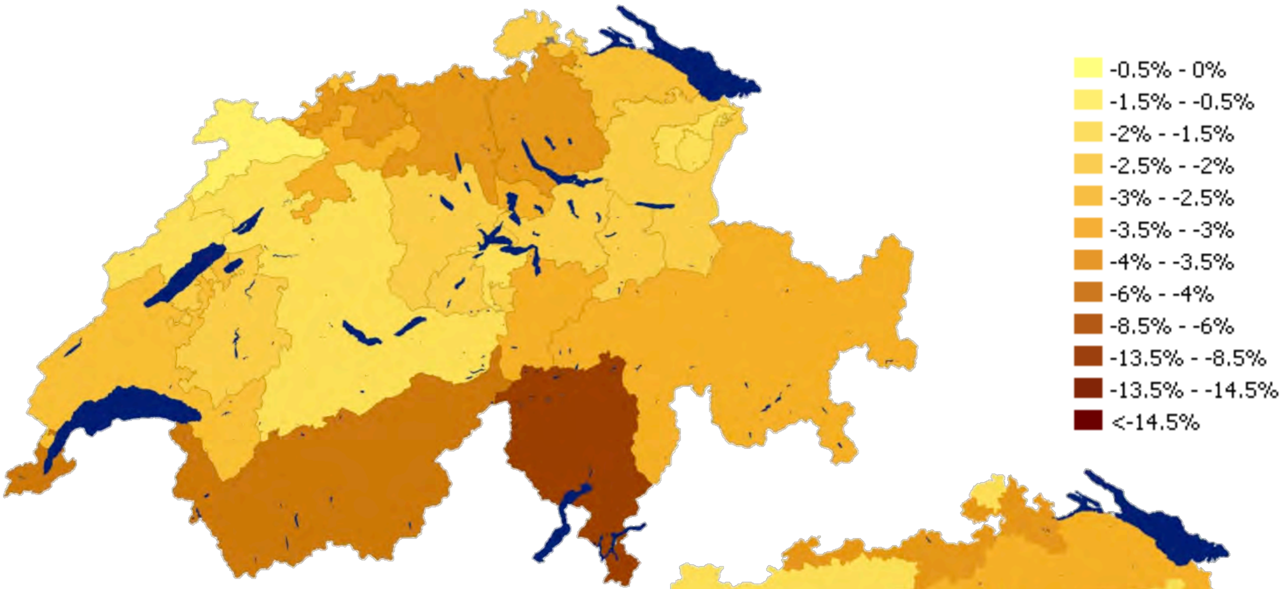
Figure 18 Map of arable land within cantonal ... SwissED

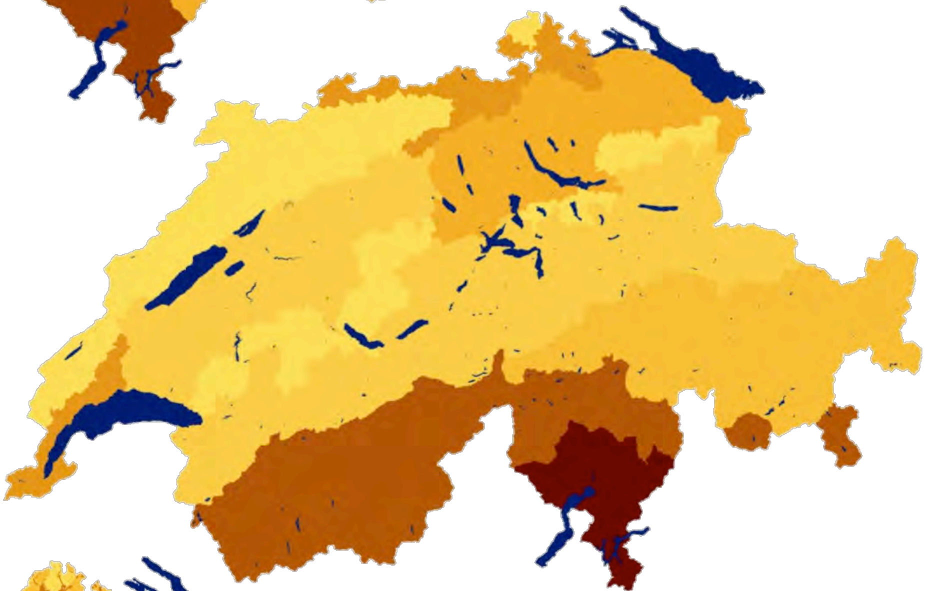
Figure 19 Map of arable land within biogeographical regions

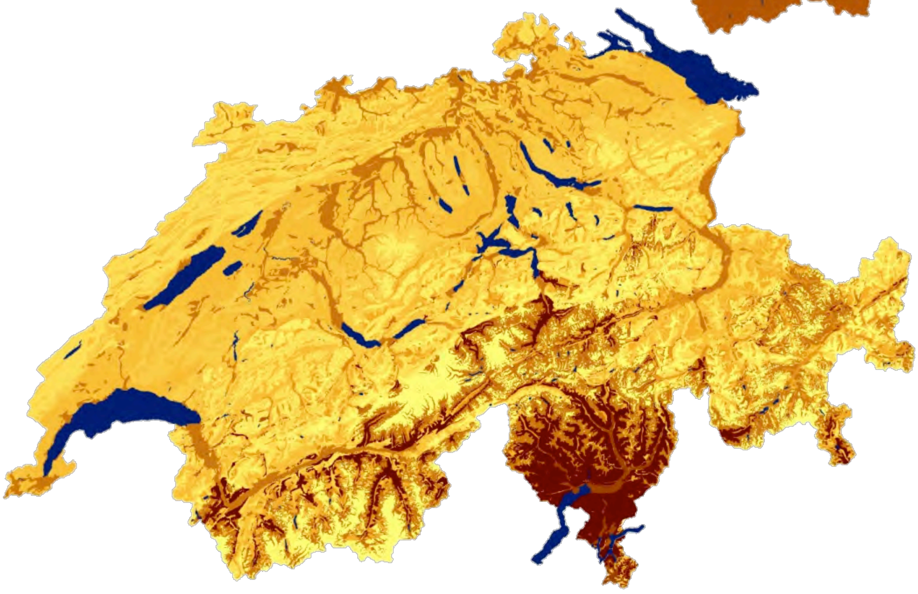
Figure 20 Map of arable land within SwissED level II

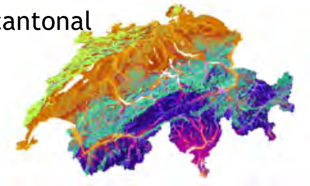
Mapping arable land areas evolution within administrative boundaries, biogeographical regions and SwissED level II

Losses in arable land are more significant in South Ticino on rather steep terrain with higher temperatures, as well as in Valais valleys (Fig. 18- 20).



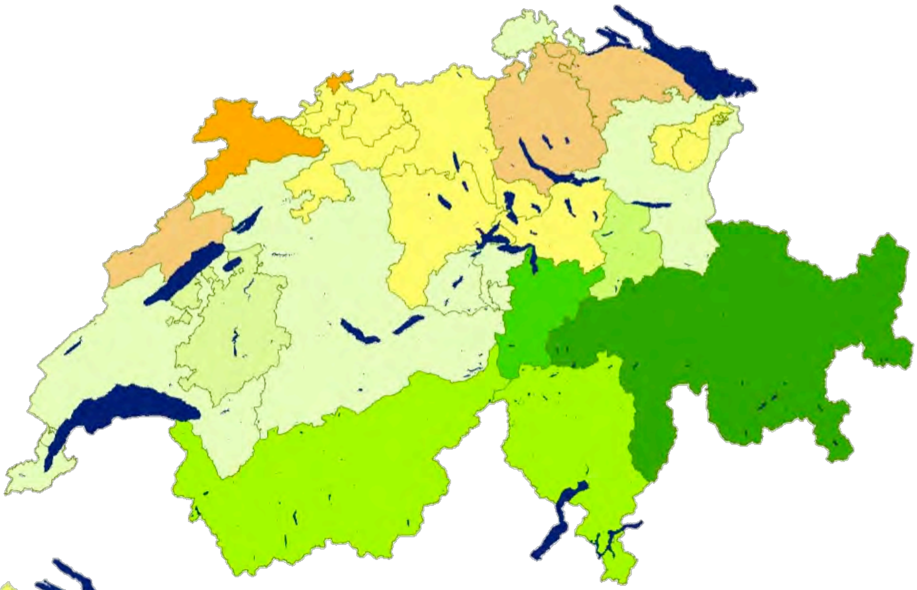


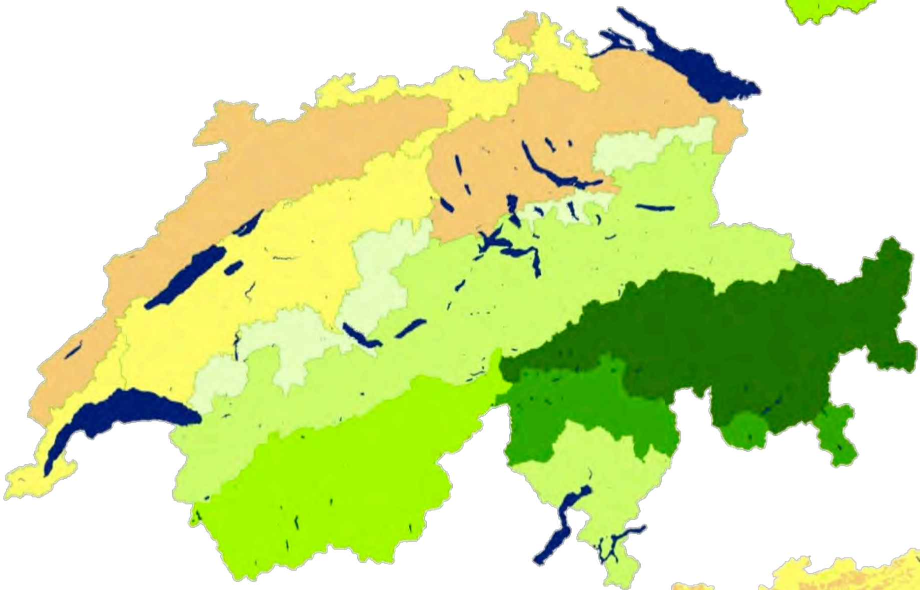


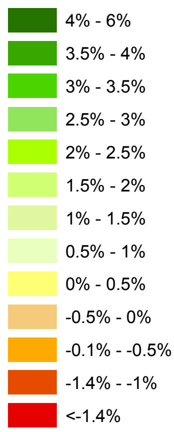


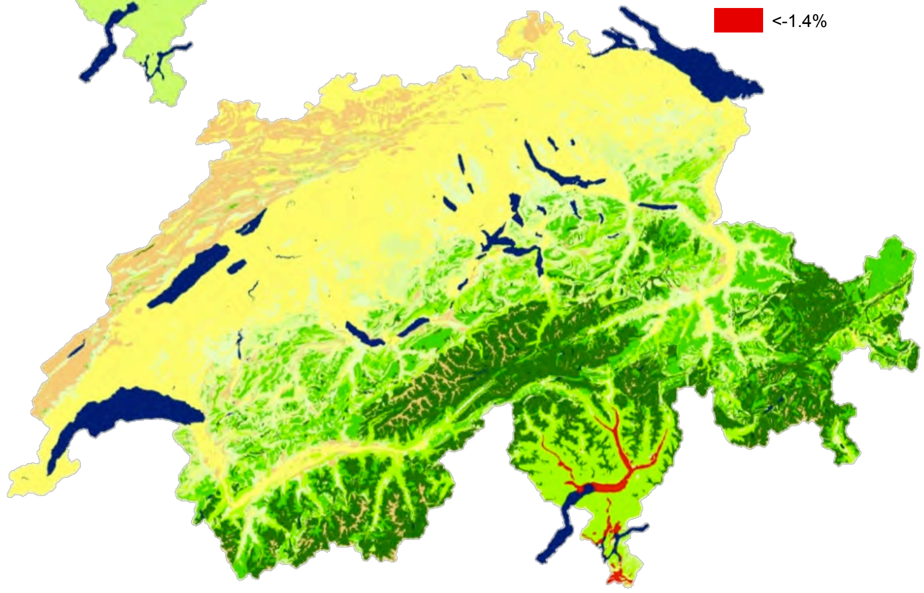
Mapping forested areas evolution within administrative boundaries, biogeographical regions and SwissED level II

Favorable reforested areas are mainly localized in cantons Graubünden and Uri at medium-high altitude on slightly sloped terrain. On the other hand, few losses of forested terrains are mostly situated in Jura and Randen and at the bottom of warm valley of south Ticino (Fig. 21-23).









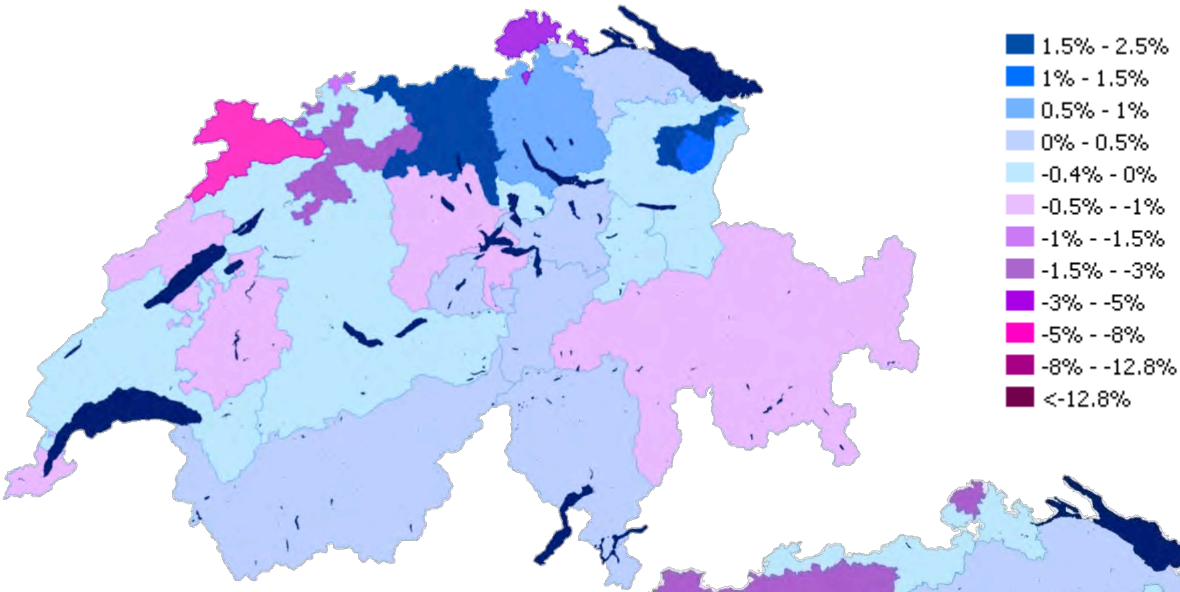
gure 24 Map of unproductive areas ithin biogeographical borders

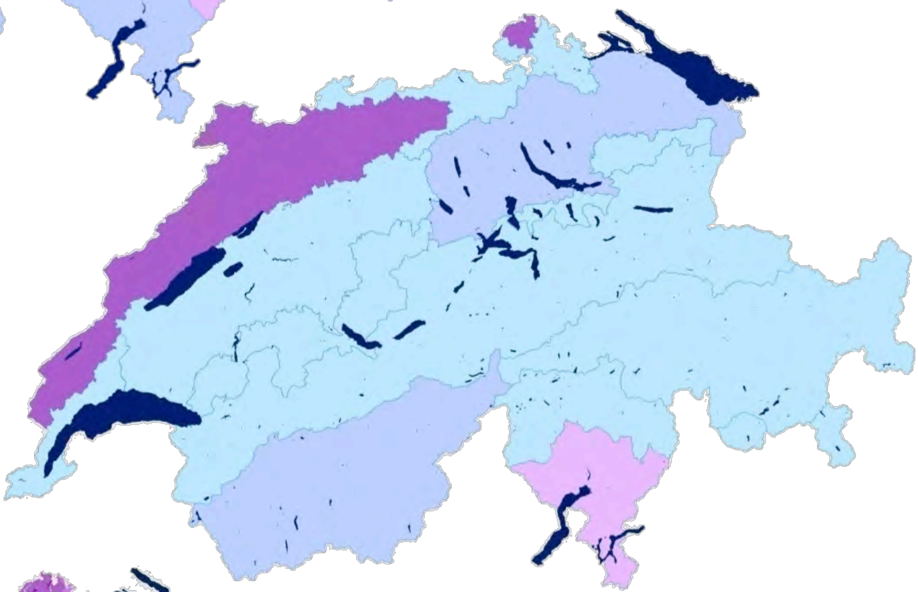
Figure 25 Map of unproductive areas within cantonal borders

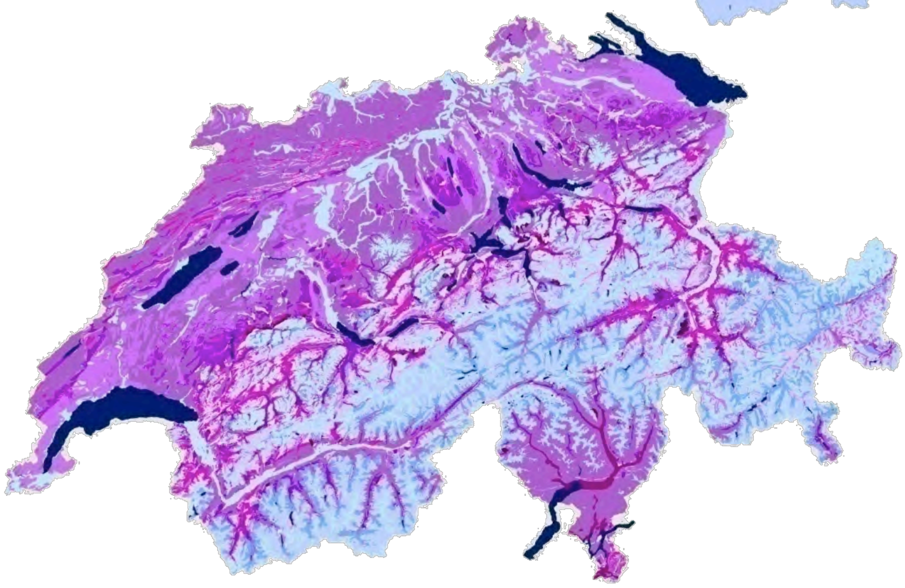
Figure 26 Map of unproductive areas within SwissED II

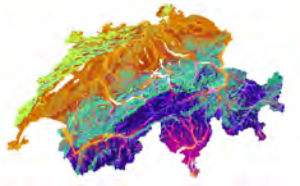
Mapping unproductive areas evolution within administrative boundaries, biogeographical regions and SwissED level II

The most important losses of unproductive areas occur in cantons Jura and Shaffhausen on Quaternary hills and valleys (Fig. 24-26).









Quantitative changes

The relative evolutions presented above in percent of changes show very different trends when compared to a quantitative assessment. Tables 7-9 below indicate the evolution in hectare within cantonal borders, biogeographical regions and SwissED level II.

Table 7 Changed surfaces in hectare according to cantonal borders

	CHANGED SURFACES (ha)			
NAME	HOUSING	ARABLE	FOREST	UNPROD
Zurich	2726	-2769	-15	58
Bern	**3779**	-4758	1326	-348
Luzern	1901	-1964	132	-69
Uri	178	-867	637	53
Schwyz	746	-896	124	26
Obwalden	238	-389	134	17
Nidwalden	157	-173	72	-56
Glarus	200	-492	395	-103
Zug	369	-361	4	-13
Fribourg	1997	-2388	513	-122
Solothurn	1196	-1192	15	-19
Basel-Stadt	17	-13	-2	-2
Basel-	782	-788	6	0
Schaffhausen	243	-315	88	-17
Appenzell A.Rh.	229	-240	4	8
Appenzell I.Rh.	113	-152	19	20
St. Gallen	1990	-2488	586	-89
Graubünden	1472	**-6672**	**7198**	**-1998**
Aargau	2434	-2581	91	56
Thurgau	1408	-1417	-9	19
Ticino	1772	-4649	2757	119
Vaud	**3346**	-3908	753	-191
Valais	2947	**-6744**	2554	**1243**
Neuchatel	736	-647	-21	-68
Geneva	735	-730	21	-25
Jura	966	-569	-360	-37

In twelve years, around 3500 hectares have been transformed into housing and infrastructure only in Bern and Vaud cantons. More than 6500 hectares of agricultural land have been lost in Valais and Graubünden cantons. Over 7000 hectares of reforested areas are situated only in Graubünden canton, mainly coming from agricultural land and the growth of shrubs and bushes (Table 7).

Table 8 Changed surfaces in hectare according to biogeographical regions

	CHANGED SURFACES (ha)			
NAME	**HOUSING**	**ARABLE**	**FOREST**	**UNPROD**
Rhine basin and Geneva Lake	3400	-3517	122	-5
Jura and Randen	3974	-3706	**-201**	-67
Northern Alps	3974	**-7378**	4450	**-1046**
Southern Alps	266	-2629	2805	-442
Southern Ticino	1639	-3017	1576	-198
Pre-Alps	1995	-2487	553	-60
Central Western Alps	2489	-6115	2295	**1331**
Western Plateau	**6468**	-6638	311	-141
Central Eastern Alps	1042	-5192	**5159**	-1010
Eastern Plateau	**7430**	**-7484**	-47	102

On the Plateau (Table 8), almost 14’000 hectares have been modified into housing and infrastructures areas. More than 7’000 hectares of agricultural land have been lost in northern Alps as well as in eastern Plateau. More than 5’000 hectares have been reforested in central eastern Alps and almost 4’500 hectares in northern Alps. Only 200 hectares of forested areas have been lost in Jura and Randen and less than 50 hectares in eastern Plateau. More than 1’000 hectares of unproductive areas have been gained in central western Alps, while similar surfaces have been lost in northern and central western Alps (Table 8).

Table 9 Changed surfaces in hectare according to SwissED level II

NAME	CODE	HOUSING	ARABLE	FOREST	UNPROD
		CHANGED SURFACES (ha)			
Calcareous reliefs	A1	1970	-1851	-38	-81
	A2	94	-513	685	-267
Molassic flats and hills	B1	4028	-4195	316	-150
	B2	3683	-3681	48	-49
Quaternary hills and valleys	C1	2186	-2412	354	-128
	C2	1149	-1244	254	-159
	C3	128	-705	687	-110
	C4	157	-325	255	-87
	C5	1	-9	10	-2
	C6	920	-675	-80	-165
Crystalline slopes	D1	242	-2812	2101	468
	D2	969	-4150	**4045**	**-863**
Dry quaternary flats	E1	**7881**	**-8033**	197	-46
	E2	**7410**	**-7364**	21	-67
Calcareous midslopes	F1	726	-1680	1393	-438
	F2	78	-182	105	-1
	F3	113	-967	1293	-439
Calcareous upperslopes	G1	181	-2028	1954	-108
	G2	303	-1130	894	-68
Crystalline crests	H1	22	-1788	887	**879**
	H2	32	-190	45	113
	H3	0	0	0	0
Crystalline quaternary slopes	I1	352	-2019	1448	220
Calcareous crests	J1	4	-128	119	5
	J2	-1	-28	16	13

More than 15'000 hectares of new housing and infrastructure areas are concentrated on dry quaternary flats, and almost 8'000 hectares in molassic flats and hills. Losses in agricultural land shows an opposite trend with losses over 15'000 ha in dry quaternary flats and over 7'000 ha in molassic flats and hills. Major reforested areas (4000 ha) are localized on crystalline slopes (Table 9).

Interpretation

The results presented above describe land use/cover evolution from 1979/85 to 1992/97 within different spatial frameworks, revealing different dimensions of the same process.

Graphs and tables give a good synoptic view of evolution, while maps are used to illustrate the geographical distribution of a given category of change.

Percentage of changes compared to previous situation serve to illustrate a *relative* progress, while the calculation of surfaces yields a quantitative approach. The two analyses may give very different results (Table 10).

For instance, major relative losses of arable land occur in Ticino, Valais and Geneva, mainly localized on crystalline slopes or quaternary hills and valleys. In contrast, quantitatively, greater arable land decreases are observed mainly in Valais and Graubünden, in Northern Alps and Eastern Plateau and on dry quaternary flats.

Table 10 Quantitative versus relative evolution of four principal land use/cover types

FOREST (gains)		ARABLE LAND (losses)	
Quantitative	*Relative*	*Quantitative*	*Relative*
• Graubünden	• Graubünden, Uri	• Valais, Graubünden	• Ticino, Valais, Geneva
• Central Eastern Alps	• Central Eastern Alps	• Northern Alps, Eastern Plateau	• Southern Ticino
• Crystalline slope D2	• Crystalline crests H3, Crystalline slope D1	• Dry quaternary flats E1-E2	• Crystalline slope D2, Quaternary hills and valleys C6

UNPRODUCTIVE (losses)		HOUSING & INFRASTRUCTURE (gains)	
Quantitative	*Relative*	*Quantitative*	*Relative*
• Graubünden	• Jura, Schaffhausen	• Bern, Vaud	• Jura, Valais
• Northern Alps	• Jura & Randen	• Western and Eastern Plateau	• Central Western Alps
• Crystalline slope D2	• Quaternary hills and valleys C4-C6	• Dry quaternary flats E1, E2	• Calcareous upperslopes G1, calcareous reliefs A2

Evaluation by Dr. Jean-Michel Jaquet (Senior Scientific Adviser)

Although I fully agree with the concept and aims of SwissED (subdividing the territory into meaningful zones based on multiple environmental criteria), I wish to raise the following issues.

- On the methodological level, the chosen geomorphological criteria do not include the terrain orientation, which is important from an environmental or climatic point of view.

- The names of the SwissED level-1 categories only reflect the geological and morphological criteria, excluding the climatic aspects. This is unfortunate, even though I understand the difficulty in keeping the names both short and informative enough.

- The subdivisions at level 2 (A1, A2, etc) are not named, although they are mentioned and given percentage values in Tables 5 and 6.

Perspective

Using the SwissED spatial framework raises new interrogations by bringing a strong environmental dimension to illustrate data. Therefore the use of this new framework could enrich the way to report on the environment.

Moreover SwissED was developed for general purpose analyses, without trying to weight the input variables. It could therefore be improved by targeting a specific need (e.g. biodiversity, land cover, agriculture). This was tested by Snelder et al. (2009, 2010) who compared different methods to select, weight and transform input variables in order to better represent land cover categories. Such model-based approaches retain the advantages of quantitative definition procedures (i.e., repeatability, hierarchical organisation, statistical stratification of variability and geographical independence) but with increased performance. Model-based procedures require that the target pattern is adequately represented by training data. For example, compositional information sampled at ecologically undisturbed sites would generally be most appropriate for regionalization developed for conservation assessments.

Target Audience

Cantonal and Federal land planning authorities, Academia, Research and Development Department

Links

http://www.bfs.admin.ch/bfs/portal/fr/index/themen/02/03/blank/key/01/zustand_und_entwicklung__grafiken.html

http://www.bfs.admin.ch/bfs/portal/fr/index/news/publikationen.html?publicationID=797

http://www.bafu.admin.ch/publikationen/publikation/00207/index.html?lang=fr

Author of the factsheet

Allenbach Karin, GIS and RS analyst at UNEP/DEWA/GRID-Europe and University of Geneva

Acknowledgments

Federal Office of Environment (FOEN), Federal Statistical Office (FSO)

We would like to kindly acknowledge the Swiss Federal Office for the Environment (FOEN) for their support and for believing in the potential of Swiss Environmental Domains.

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And finally a particular thank to Dr. Jean-Michel Jaquet for all improvements made to this fact sheet, for his great interest in this study and for their constructive evaluation of the results.

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Snelder T., Lehmann A., Lamouroux N., Leathwick J.R., Allenbach K. 2009: Strong Influence of Variable Treatment on the Performance of Numerically Defined Ecological Regions. Environmental Management, 44: 658-670.

Snelder T., Lehmann A., Lamouroux N., Leathwick J.R., Allenbach K. 2010: Effect of Classification Procedure on the Performance of Numerically Defined Ecological Regions. Environmental Management, 45: 939-952.

Sources

This factsheet is part of the main report:
Lehmann et al., 2010. Swiss Environmental Domains: Applications. FOEN report, Bern.

Theme: Socio-economic

Human population densities per Environmental Domains

Purpose

The results presented in this factsheet are based on the calculation of human population densities per environmental domains in order to estimate the demographical pressure applied on each Swiss environmental domain. These results allow also comparing and visualizing this common demographic indicator through a different spatial framework than the usual administrative frame (communes and cantons).

Data Description

Population density is the ratio between the size of the population in a geographic area and the surface of this area. The result is usually expressed in number of inhabitants per square kilometer (hab./km^2). We used the data from the Federal Population Census 2000 (FPC2000), which geocodes population through its place of residence. A complete set of variables on the population and households have been aggregated per hectare and are available as standard data in the GEOSTAT dataset (OFS-GEOSTAT 2009). Our calculation of density uses the total resident population in 2000 per hectare (P00BTOT).

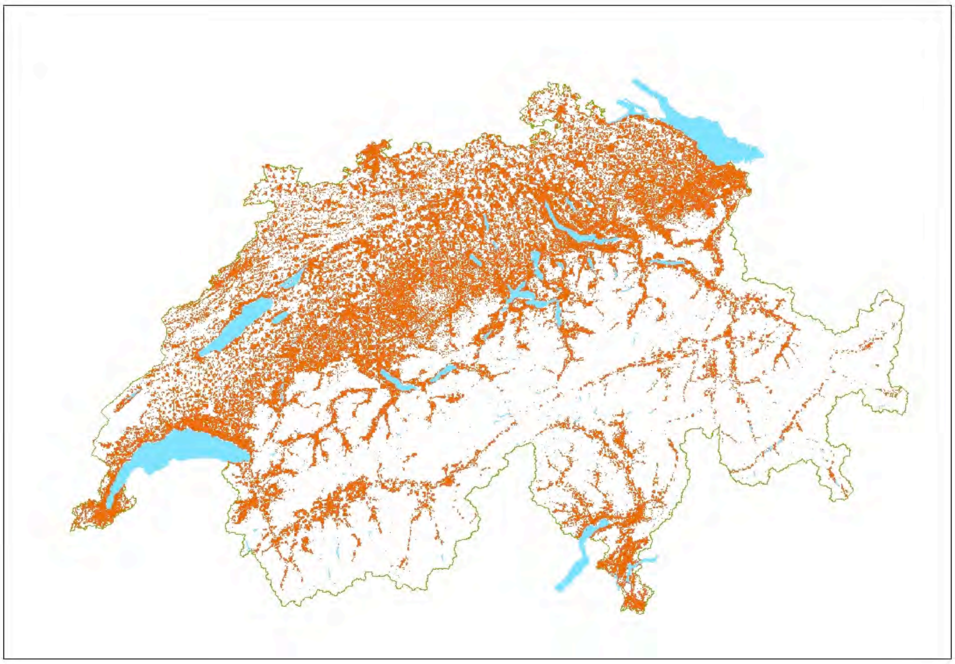

Figure 1: Total resident population in 2000 per hectare (P00BTOT), red pixels represent the available information. Source GEOSTAT (OFS-GEOSTAT 2009).

Results and interpretation

Before exploring population densities, let us consider the population distribution. How are the 7,350,674 people given by the census 2000 distributed throughout Switzerland? We can have a rough feeling using the simple visualization of the population dataset (Fig.1), but of course this does not reflect the real distribution of the population as each of the 360'809 points represents one hectare populated by 0 to 8'440 persons. The distribution by administrative subdivision is more interesting because it gives the real number of people in each entity. The usual representation of the population per canton (Fig.2) shows the weight of the most populated cantons: Zürich, Bern and Vaud. With the use of the environmental domains (level II), we see that only four identified environmental domains host 81% of the population: 59% in Dry quaternary flats (E1 and E2), 36% in Molassic flats and hills (B1 and B2) (see Fig.3).

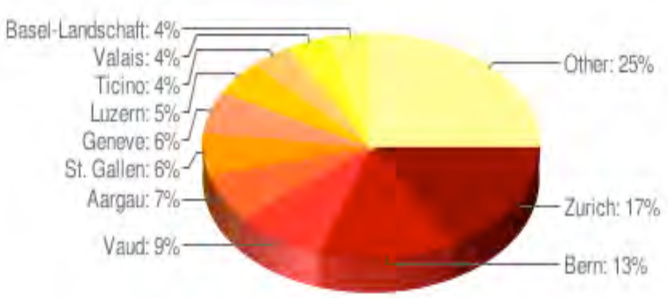

Figure 2: Population per canton in 2000.

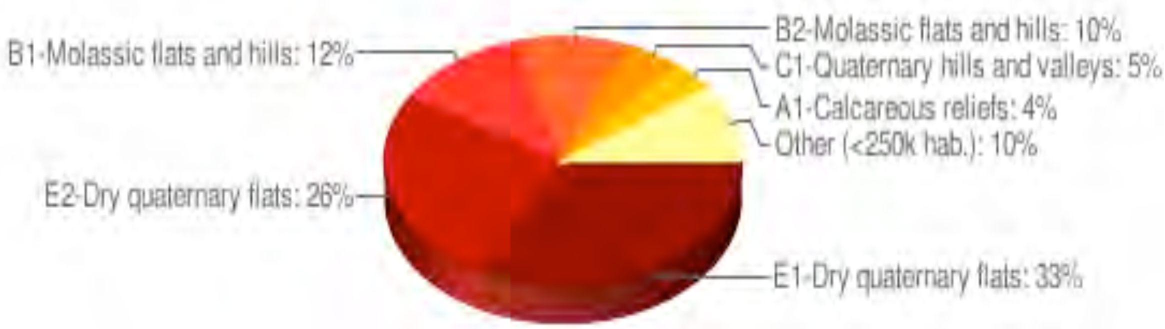

Figure 3: Population per Environmental domains level II in 2000.

If we use the environmental domains level I, it is even more obvious that in fact three domains host 93% of the population (E-Dry quaternary flats: 60%, B-Molassic flats: 22% and C-Quaternary hills and valleys: 11%). That means that around 6.3 millions of inhabitants live in 36% of the Swiss territory.

If we look at the density through the usual cantonal frame, the weight of main agglomerations like Zürich and in particular small "city-canton" like Basel (5,072 inhab./km^2) or Geneva (1,467 inhab./km^2) are underlined, opposite to the big less-urbanised cantons like Grisons (26 inhab./km^2). In general, the represented densities are relatively homogenised through the division by the canton area, with no clear patterns appearing (see Fig.4). The visualization through environmental domains gives a better view of the real population density distribution throughout the Swiss territory. One can immediately see the contrast between the Swiss Plateau, valleys and mountainous areas (see Fig.5).

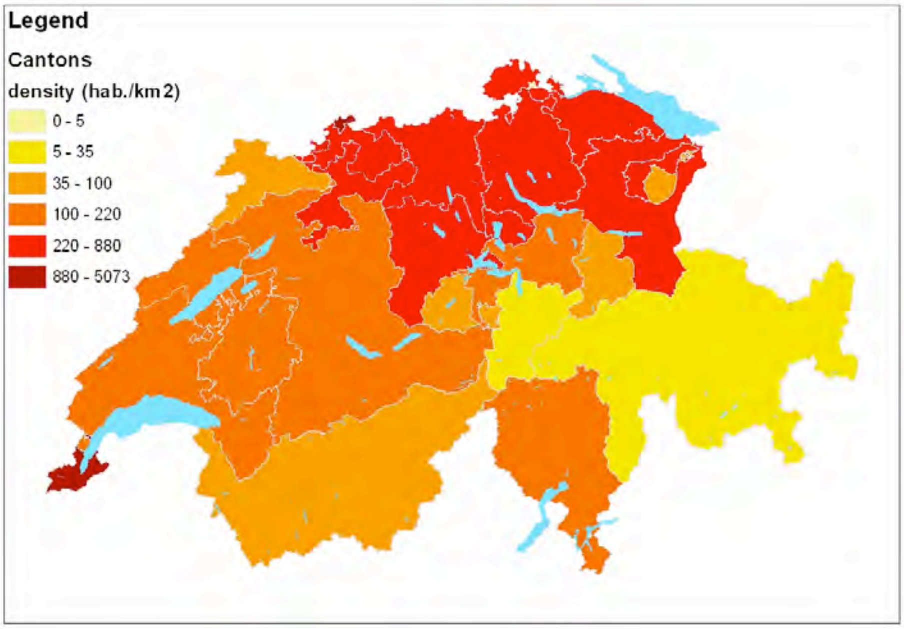

Figure 4: Population density by cantons

In terms of density, two domains (C6: Quaternary hills and valleys, and E1: Dry Quaternary Flats) are exposed to a very high population density comparatively to other Swiss domains (more that 800 inhab./km^2). These domains correspond to the main river basins where quaternary deposits are present. In the case of C6, it is localized in Tessin in the Ticino river valley with few very small areas near the Rhone outlet to Lake Leman.

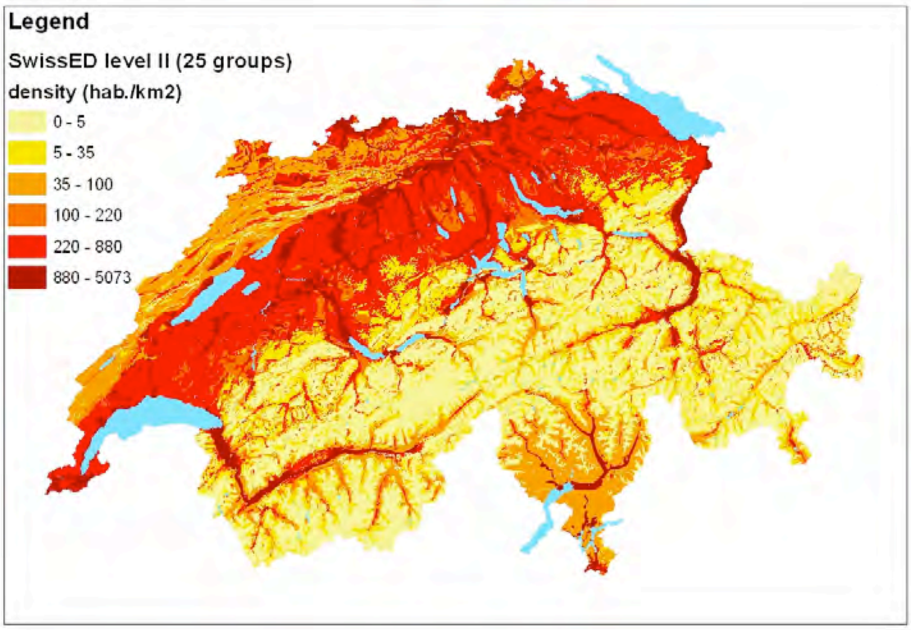

Figure 5: Population density per 25 Environmental Domains level II

E1 is more spread out the Swiss territory around the main river beds like Rhone, Rhine and Aar. Four environmental domains level II have a middle density (200-500 inhab./km^2) close to the Swiss average density (180 inhab./km^2), and 7 domains out of the 25 existing representing around a quarter of the Swiss territory have less than 2 inhabitants per square kilometers (Fig.6).

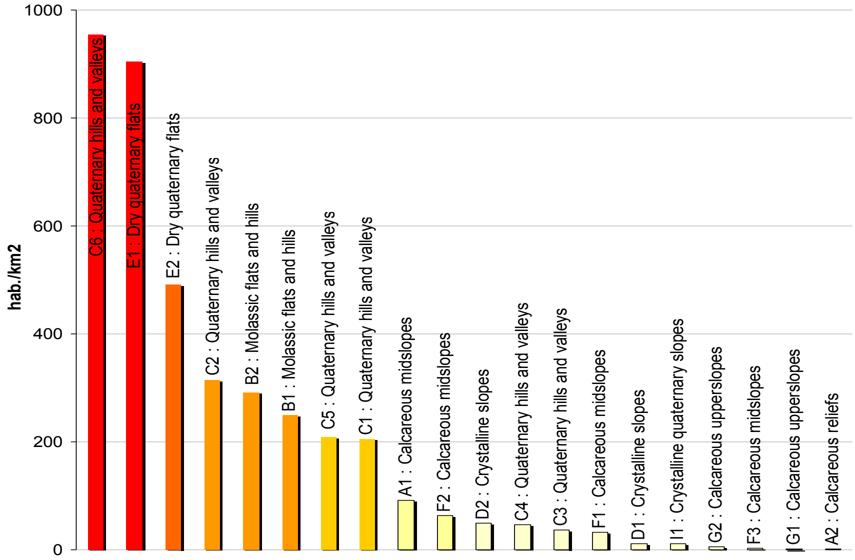

Figure 6: *Population densities by 25 Environmental Domains (level II).*

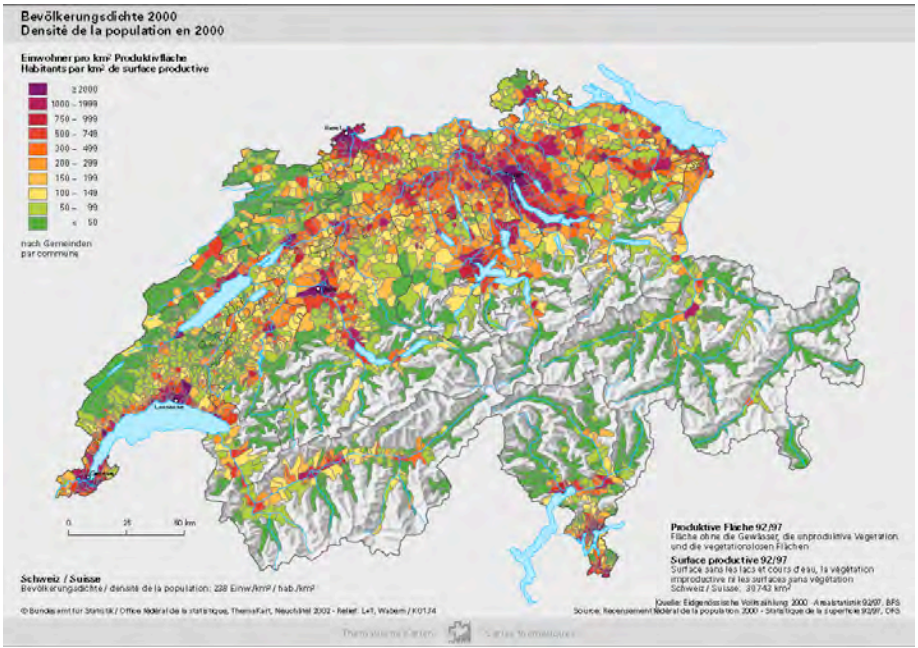

Figure 7 : Population density in 2000, sources: BFS.

It is interesting to compare the map of figure 5 with the usual administrative view at a bigger scale like communes (Fig.7). As the information represented is homogenised at the commune level, in comparison to cantonal level, the distribution of population density is more accurate and better represents where the density is high (communes with biggest agglomerations) or low. The population density per Environmental domains (Fig.5) underlines the environmental domains that sustain the highest or the lowest density. Obviously, main cities are located in the domains having the most important density. It is important not to misunderstand the information represented that is different between continuous administrative representation and the non-continuous environmental domains.
Indeed, if we compare the administrative views (cantonal or even communes) with the environmental domains for population densities, one can say that environmental domains give a better representation of the *potential* population densities distribution throughout the Swiss territory (in particular, contrast between the Swiss Plateau and valleys with mountainous areas). The main demographical development factors are also more visible than in the administrative views. The geomorphological factors used to determine environmental domains expressed their weight through the domain map (Fig.5), which of course can't be represented by the usual administrative divisions (Fig.4) even at a bigger scale like communes (Fig.7). For example high elevations and important slopes are not compatible with high density of population. The historical factors of water access (for potable water, energy source, industry resources and transportation) that enhanced settlement development are also very well illustrated by environmental domains map (Fig.5).

Expert evaluation

Consulted experts: Prof. Bernard Debarbieux, University of Geneva, Switzerland.

What is the potential interest of the Swiss Environmental Domains for the cartography of human population?

Cartography of human population usually targets two kinds of objectives: (1) to give an rough idea of the level of concentration/aggregation of population in space (which indeed can be better measured in purely quantitative terms with concentration index for example); (2) to display a potential interaction between population and some other phenomenon, or a correlation between human population distribution and some other "layer" of information and to suggest that such an interaction or correlation can be analyzed either as an explanation of the spatial distribution or a pressure index.

Objective (1) is reached with maps showing the number of inhabitants or the density per hectare, or any other similar method. Maps showing the number of inhabitants or the density per municipality are not intrinsically different; they just refer to administrative units which are those according to which the census is organized, and those at the level fo which some public policies are implemented. Objective (2) is reached when any other spatial frame and categorization (altitude, vegetation zones, etc.) is used for calculating number of inhabitants and human densities. Mapping Swiss population according to Swiss Environmental Domains can be of some interest when logically leading to statements related to contrasted degree of pressure from one domain to another, or any kind of hypothesis related to the causal links between population and domains.

How do you evaluate the spatial representation of population density of by Environmental Domains?

It is easy to see that demographic maps using a municipal frame and a environmental domain (ED) frame are fundamentally contrasted. Their epistemic value is quite different. They even cannot be really compared because of that. The municipal frame deserves attention because it relates the results with the method of counting and public action; the ED frame deserves attention for its analytic potential in terms of interaction between environmental matter and population.

However one question remains open: if ED frame for representing population aims at showing contrasted densities throughout Switzerland, it is not the best tool available; if ED frame aims at displaying that population densities can be compared according to physical and environmental categories, it doesn't differ so much from cartography using altitudinal categories or vegetation types; altitude can even be more precise; if ED frame aims at suggesting that there is some correlation between some kind of domain and density, or that there are contrasted level of pressure on various EDs, the map can deliver such message; however it is hard (much harder than for altitude or vegetation) to foresee the scientific added-value of such a suggestion.

Perspective

It could be very interesting to follow the evolution of the density by environmental domain through temporal series. It could be done with older census data. The population decrease rate is also something interesting for economic and planning policy (currently observed at European level using NUTS divisions) that could be analysed with the environmental domain approach.

Target Audience

Sociologists, Geographers, Statisticians, Swiss Federal Office for Statistics

Links

OFS environment indicators: Population density:
http://www.bfs.admin.ch/bfs/portal/fr/index/themen/02/06/ind13.informations.130104.html

OFS maps on population state :
http://www.bfs.admin.ch/bfs/portal/fr/index/regionen/thematische_karten/maps/bevoelkerung/bevoelkerungsstand/0/bevoelkerungsstand.html

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Acknowledgments

Federal Office of Environment (FOEN), Swiss Federal Statistical Office (OFS)

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OFS-GEOSTAT, 2009. Recensement fédéral de la population 2000.

Sources

This factsheet is part of the main report:
Lehmann et al., 2010. Swiss Environmental Domains: Applications. FOEN report, Bern.

Theme: Socio-economic

Evolution of farms number per Environmental Domains

Purpose

What can we say about the evolution in time of agriculture activities in Switzerland in the light of environmental domains approach? Does the calculation by environmental domains gives us a better idea of the farm distribution and of their number decrease than administrative divisions? Can a pressure indicator of agriculture be developed with the number of farms by environmental domains?

Data Description

We used the federal census on enterprises in the primary sector (REF RE S1), which is a comprehensive structural survey. That covers all establishments and primary sector jobs. This census delivers results similar for the secondary and tertiary sectors. This census has been held since 1905. It geocodes agricultural and horticultural enterprises (called "farms" here to simplify) that meet at least one of the following standards: 1 hectare of agricultural land; 30 ares of specialty crops; 10 ares of protected crops; 8 sows; 80 pigs; 80 places for pigs; 300 poultry units. A complete set of various characters on these "farms" have been aggregated per hectare and are available as standard data in GEOSTAT (OFS-GEOSTAT 2009). The number of farms used in this analysis is coming from variables L96S1 and L05S1 for years 1996 and 2005.We have compared these two years to see the evolution of farm numbers during this period.

Results and interpretation

First, the distribution of farms by canton shows the importance of Bern, which hosts 21% of the Swiss farms in 2005 (see Fig.1). The distribution by level II environmental domains is very interesting: 69% of the farms are in the Dry quaternary flats (E2, E1) and Molassic flats and hills (B1, B2) domains (see Fig.2).

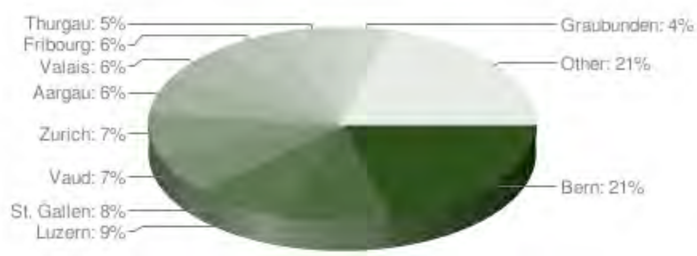

Figure 1: Farm distribution per canton in 2005.

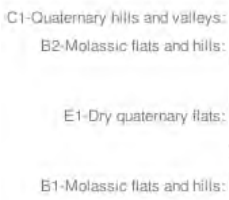

Figure 2: Farm distribution

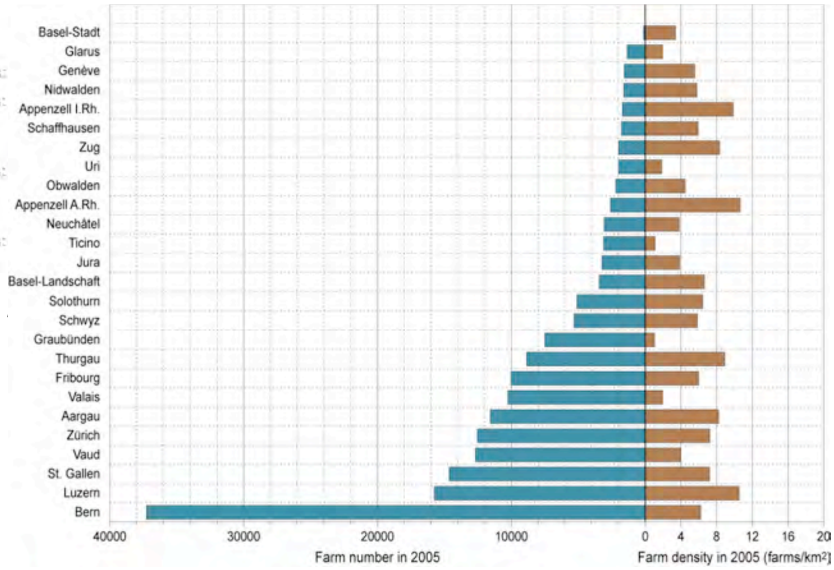

Figure 3: Farm number and Farm density per cantons in 2005.

At level I Swiss environmental domain, 85% of farms are located in only 3 environmental domains level I: B-Molassic flats and hills for 34%, E-Dry quaternary flats for 34% and C-Quaternary hills and valley for 17%. Of course this is relatively obvious as geomorphologically, farms need to occupy relatively flat areas for their implementation and activities. If we compare farm number with density (Fig.3 and Fig.4), we see that at cantonal level, Bern which is hosting most of the farms (37'250 in 2005), has not the highest density on its territory (6.3 farms/km^2); at the opposite, a small canton like Appenzell A Rh. has a more important density (10.7 farms/ km^2). The average density of farms by square kilometer in Switzerland is about 4.5. The equivalent pyramid chart for environmental domains (Fig.4), gives an interesting information in a quick look. For example, we can see the empty bar representing no farms in some domains (in mountainous crest H and J). Big flat environmental domains like the E-Dry quaternary flats and the B-Molassic flats and hills host the majority of the farms (around 124'000 en 2005). In term of density, 6 environmental domains show a greater density of farms by square kilometer than the others: C1 and C2-Quaternary hills and valleys, E-Dry quaternary flats and B-Molassic flats and hills with a density of 8 to 11 farms by square kilometer.

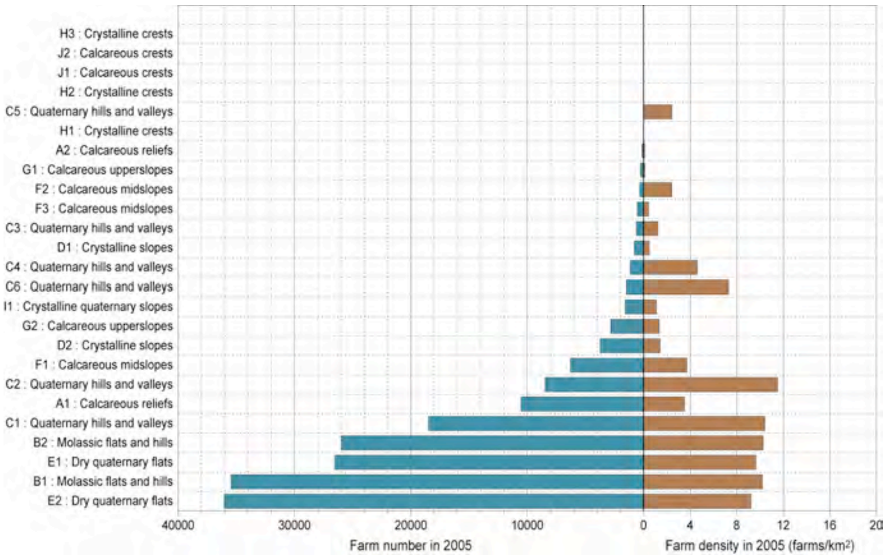

Figure 4: Farm number and Farm density by level II environmental domains in 2005.

In order to illustrate the evolution of farms in Switzerland we compared the data from two years: 1996 and 2005. We calculated the difference between the number of farms both in cantons and in environmental domains. To map the results, we chose to calculate a percentage relative to the 1996 data. In the case of the cantonal framework, we witness a clear and important decrease of the farm number in Switzerland. The Federal Office of Statistics explains in his web pages that this trend continues between 2007 and 2008. Although we assist to a real decrease in the number of farms, this should not be interpreted only as a demise of agriculture, because there also is an aggregation of small farms into bigger units. At the Switzerland scale, from 213’191 farms in 1996, only 181’283 remain in 2005 representing around 15% decrease in the number of farms. How is this decrease spatially localised throughout the territory? Ticino is facing the most important decrease with -29%, whereas the majority of other cantons show a decrease between -5 and -20%, Bale city canton totalizing -2.8%, and only Geneva having on average a positive percentage with 11.6% increase (Fig.5).

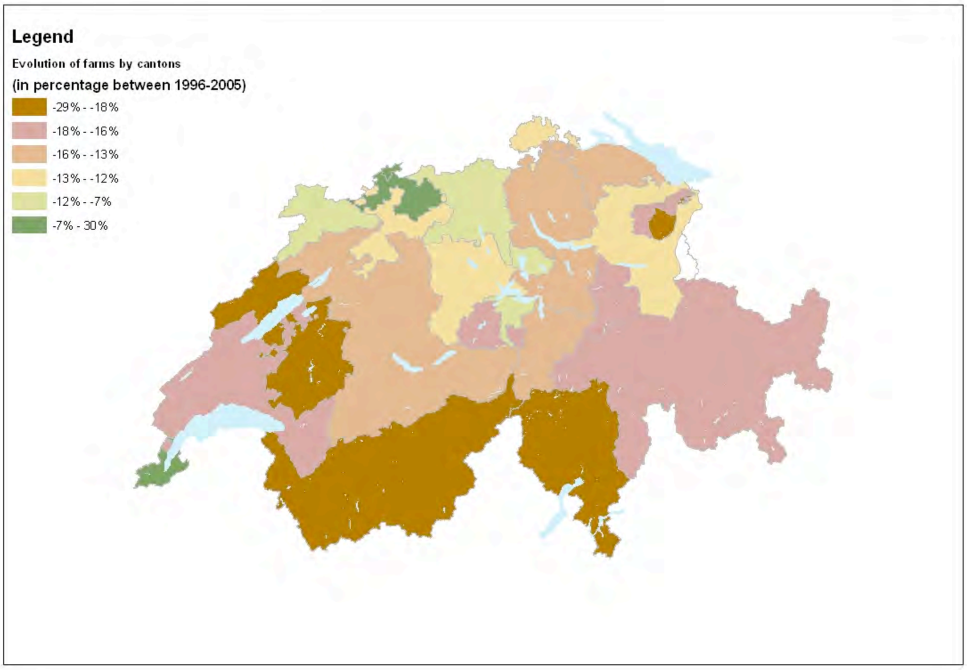

Figure 5: Farm number by canton in 2005.

We distributed the number of farms per hectare on environmental domains level II and we followed the same procedure as with cantons. The obtained map (Fig.6) illustrates a slightly different reality. The only domain with a positive increase of farms between 1996 and 2005 is in the Alps (H1: crystalline crests). How is it possible? This is an interesting example of an extreme marginal case that can lead to peculiar conclusions. Domains are not spatially contiguous and, some of them are very spread out the Swiss territory, as in the case of Crystalline crests H1 which is made of a lot of small units scattered in the Alps. In this case, there are in fact very few farms in this domain (21 in 1996 and 26 in 2005), so it represents an increase of 24.6% of the farm number! But it is of course very marginal. One has to be very careful in interpreting such results. This is why we chose a quantile classification to represent cartographically the evolution of farm number in order not to put too much weight on these marginal cases, but to show better the trend that is a decreasing one throughout every environmental domain. On figure 6, the brown colors illustrate the more important decrease and green colors the less important decrease. It is obvious that, in average, the South part of Swiss Alps are facing the most important decrease and, conversely, the Plateau and Jura areas a lesser.

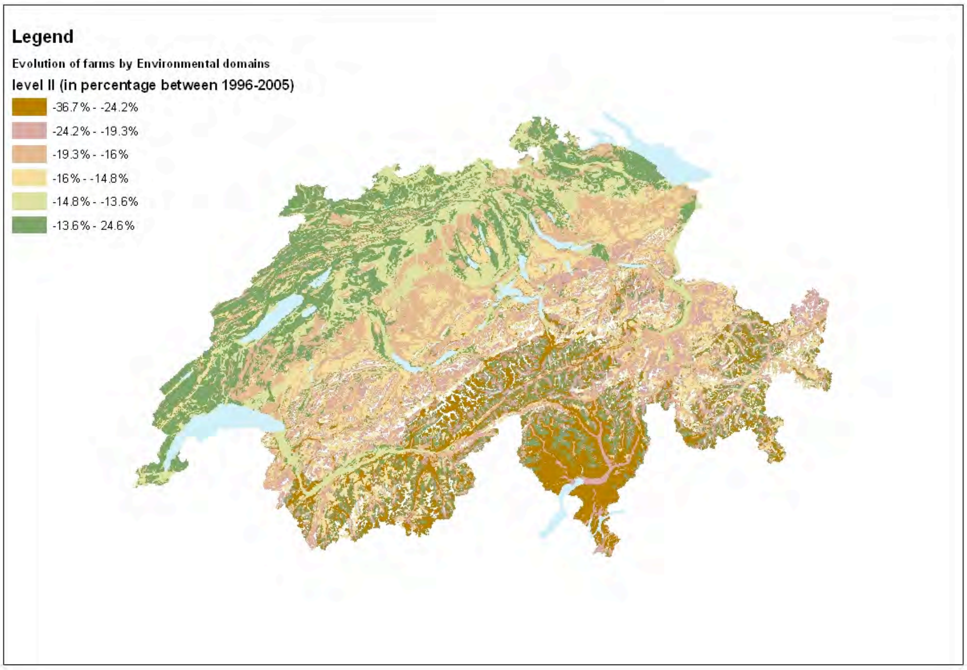

Figure 6: Farms evolution by level II environmental domains.

Perspective

It could be very interesting to monitor the evolution of the farm density by environmental domain regularly with new census data. A regionalization by disaggregation of environmental domains in small units could open the gate to think with this new geospatial framework at a bigger scale, as cantonal level for example. This approach could allow to use the SwissED to deal with more localised issues and to map them.

Indeed, a zoom in the maps produced by the SwissED approach does not make any sense since the values displayed concerns the entire domain, which is generally composed of hundred of polygons distributed throughout the Swiss territory. The concerned entity is less obvious in the non-contiguous spatial units such as the Swiss environmental domains, whereas single polygons should never be interpreted individually. With a usual cantonal administrative representation it is obvious for everybody that the value in a canton polygon concerns the complete entity; nobody thinks that every pixel of the polygon have this value. This is really less obvious in non-contiguous groups like environmental domains especially if it is zoomed in.

A regionalized approach of the Swiss environmental domains could allow focusing on subregions while taking into account this aspect. Once clipped on the subregions (for example with the administrative border of a canton), the statistical calculation could be done at this scale only with the selected polygons of the given domain. With this approach a zoom at cantonal scale makes sense as the mean value represented by a color really describes the environmental domains of the zoom and not the value of an environmental domain for the whole Switzerland. With this approach, a subregional map could answer to questions like what is the farm density in Dry quaternay flats of Geneva.

Target Audience

Agricultural and economic planning departments, federal offices, cantonal governments.

Links

OFS agricultural indicators: Number of farms :
http://www.bfs.admin.ch/bfs/portal/fr/index/themen/07/03/blank/ind24.indicator.240201.2402.html

OFS census on the primary sector :
http://www.bfs.admin.ch/bfs/portal/fr/index/infothek/erhebungen__quellen/blank/blank/bzs1/01.html

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Acknowledgments

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Bibliography

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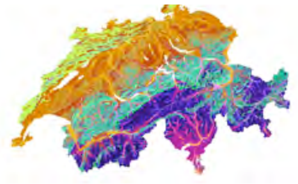


Theme: Socio-economic

Employment by sectors per Environmental Domains

Purpose

Employment through out Switzerland is usually calculated and displayed by canton or possibly by commune. But how is employment by sectors distributed in the framework of environmental domains? Are some environmental domains more dedicated to a particular sector development? Are the environmental domain subdivision and representation more accurate or relevant to analyse the employment location? This factsheet tries to answer these questions.

Data Description

To treat employment by sectors within environmental domains, we used the federal census on enterprises in the primary, second and tertiary sectors. This census geocodes enterprise locations and associates a complete set of variables on the enterprises aggregated per hectare and available as standard data in the GEOSTAT dataset (OFS-GEOSTAT 2009). The dataset on primary sector is a comprehensive structural census, which covers all establishments and jobs in this sector. Census on agricultural enterprises has been held since 1905. The dataset for secondary and tertiary sectors is coming from the demographical statistics on enterprises (UDEMO) from the Federal office of statistics. UDEMO is covering private companies with commercial economic activities in secondary and tertiary sectors. Are considered only juridical forms of private right, excluding associations and foundations. According to UDEMO, are considered active only enterprises that have economic activities during at least 20 hours per week. The enterprise census tallies occupied jobs, at the opposite of population census that concerns active people. For agriculture (including horticulture), it counts workers aged of 15 years and more. Are considered full time those occupied at least at 75% percent.

To undertake this analysis, we applied the notion of FTJEN: “full time job equivalent number”. The FTJEN comes from the conversion of the workload (in term of work or number of hours) in full time employment. It can be described as the total number of hours worked divided by the annual mean of working hours in a full time job. The FTJEN used in this analysis for primary sector comes from variable called L05VZAS1, for secondary sector from variable B05VZAS2, and for tertiary sector from variable B05VZAS3 for 2005. The “employment density” used is the ratio between the FTJEN in a geographic area and the surface of this area. The result is expressed in number of full time jobs equivalent per square kilometer (jobs/km2).

Results and interpretation

The Swiss economy is caracterised by an important and increasing activity in services, and globally at the expense of industry and primary sector. With the chosen statistical figures, we can have a first look at the distribution of employment both from sectorial and geospatial points of view. Figure 1 illustrates the weight of the tertiary sector in Switzerland (2/3 of the 3.4 millions of “Full time job equivalent number”).

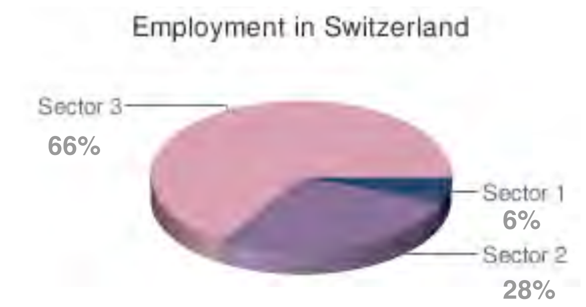


Figure 1: FTJEN *in Switzerland in 2005.*

The basic distribution by sector and canton (Fig.2) gives an idea of the typology of employment. In terms of employment, Zürich and Bern are the biggest providers in Switzerland in the three sectors (Fig.2). For primary sector, Bern is the canton hosting the largest number of full time job equivalents, followed by Luzern, Zürich and Vaud (each one more than 16’000 jobs each). For the secondary sector, Zürich is the first canton with Bern (more than 100’000 jobs each). For the third sector, Zürich is also the first one followed by Bern, Vaud and Geneva (more than 150’000 FTJEN each).

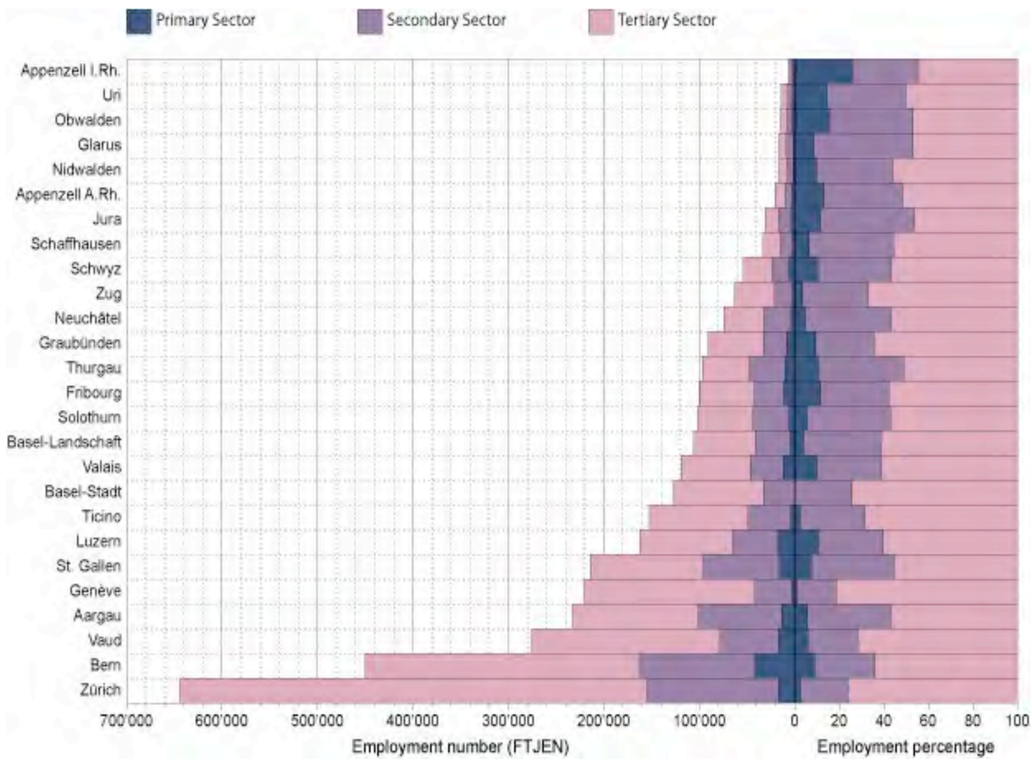


Figure 2: FTJEN *per canton in 2005.*

If we do the same type of analysis with the environmental domains, we can try to answer questions such as: What are the most agricultural-, industrial- or service-oriented environmental domains in term of activity distribution? It is interesting to see that environmental domains show a much more contrasted view of the "sectorialisation" (Fig.3). Dry quaternary flats environmental domains (E1 and E2) host 69% of the employments in Switzerland for 6'600 km2 (17% of the territory). Molassic flats and hills domains (B1 and B2) host more than 200'000 jobs each. For the primary sector only six domains (E2,B1,E1,B2,C1,A1) gather each more than 10'000 jobs, whereas Crystalline and Calcareous crests domains (J1, J2, H1, H2, H3) host less than 27 jobs each. For the secondary sector, only Dry quaternary flats (E1 and E2) and Molassic flats and hills domains (B1 and B2) domains have more than 50'000 jobs each, whereas Crystalline and Calcareous crests domains (J1, J2, H1, H2, H3) have less than 35 jobs each. The tertiary sector FTJEN distribution is very similar to the secondary sector, only Dry quaternary flats (E1 and E2) and Molassic flats and hills domains (B1 and B2) domains have more than 100'000 jobs each, whereas Crystalline and Calcareous crests domains (J1, J2, H1, H2, H3) have less than 350 jobs each.

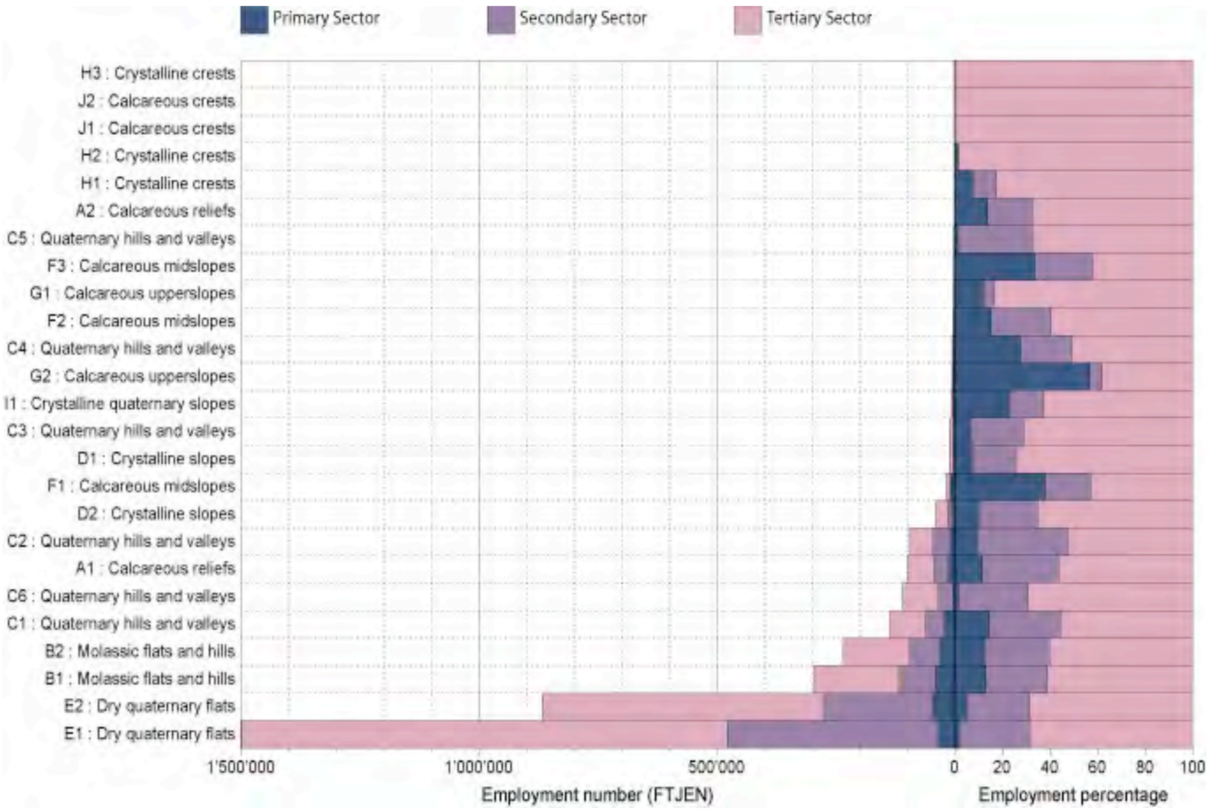


Figure 3: FTJEN *per Swiss domains level 2 in 2005.*

In terms of percentage (Fig.3, right), Calcareous upperslopes and midslopes are the most agricole domains in term of employment with 57% in this sector for G2, followed by Calcareous midslopes F1 and F3 with respectively 38 and 34%. Concerning the secondary sector, Quaternary hills and valleys (C2, C5, C1, C6) , Calcareous reliefs (A1), Dry quaternary flats (E1, E2), Molassic flats and hills (B2, B1) and Calcareous midslopes (F2) have each between 25 and 40% of employment in the secondary sector. For the tertiary sector, Calcareous and Crystalline crests (J1, J2, H3, H2, H1) and Calcareous upperslopes (G1) and Crystalline slopes (D1) have more than 70% of employment. Sometimes we reach even 100%, which can be explained by the limited number of jobs in this harsh environment, allowing neither the development of a significant employment rate nor a heavy settlement (J1, J2 and H3 gather around 400 jobs over the whole Switzerland). Slope and altitude in those domains allow essentially some leisure activities. At the opposite, it is interesting to see that Calcareous midslopes (F1 and F3) and Calcareous upperslopes (G2), being mostly agricultural have less than 43% of tertiary jobs.

Another approach is to evaluate the percentage of employment in the various sectors in each areas through a multivariate analysis. To facilitate the analysis and cartographic representation, the Pelto triangle approach was used. This ternary diagram displays 7 classes representing the degree of “sectorialisation”. In our case, the three basis variable are the percentage of primary, secondary and tertiary sector employments.

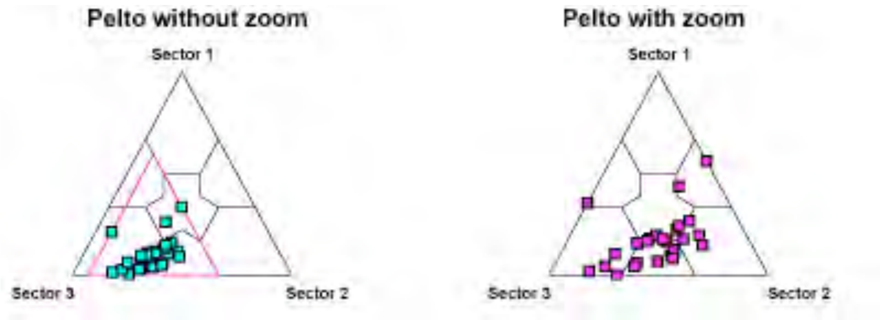


Figure 4: Distribution of the “sectorialisation” by canton using a ternary diagram (Pelto triangle).

At the cantonal level (Fig.4), the distribution is centralized in sector 3 and in the middle of sector 3 and 2, with very few jobs in the middle zone of the diagram. Of course, this is just a confirmation of the tertiarisation of Switzerland. Even if we do a zoom on the smallest triangle including all elements, we see a concentration at the basis of the triangle. In order to have more or less every class represented, we use the zoom results for the cartographic representation. It gives us an idea of the trends (Fig.5).

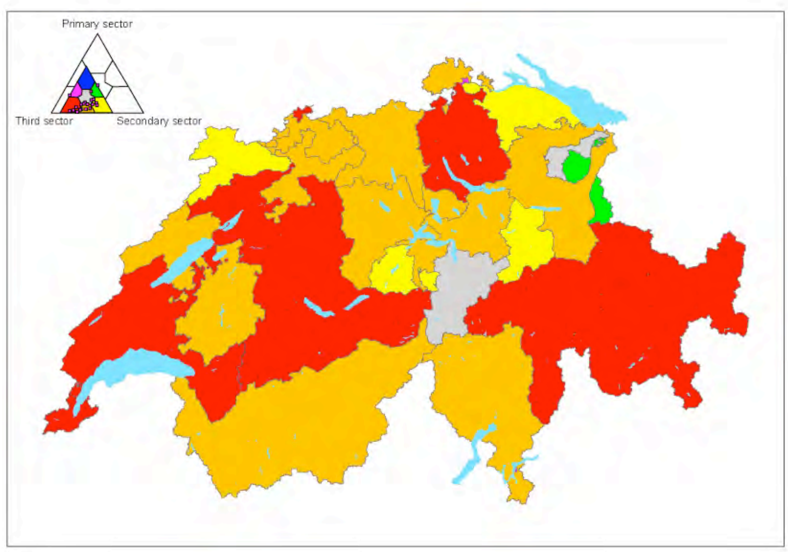


Figure 5: Distribution in canton of the “sectorialisation” using a zoomed Pelto triangle for coloring.

Only Appenzel I Rh., Obwald, Uri and Appenzel O. Rh. have more that 12% of their employments in the primary sector. The cantons with the most important level of employments in industry are Glarus and Jura with more than 40%. And finally, for the tertiary sector, Geneva, Zürich, Basel City and Vaud cantons have the largest proportion of employments with more than 75%.

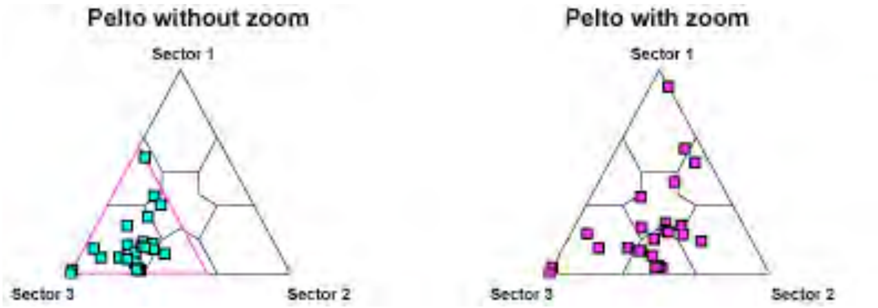


Figure 6: Distribution of the "sectorialisation" by level II Environmental domains using a ternary diagram.

The distribution accross the swiss domains at level II with 25 groups, shows a more homogeneised distribution even if as the cantonal case we can see the concentration of jobs in the lower-left part (sector 3) of the triangle (Fig. 6). The

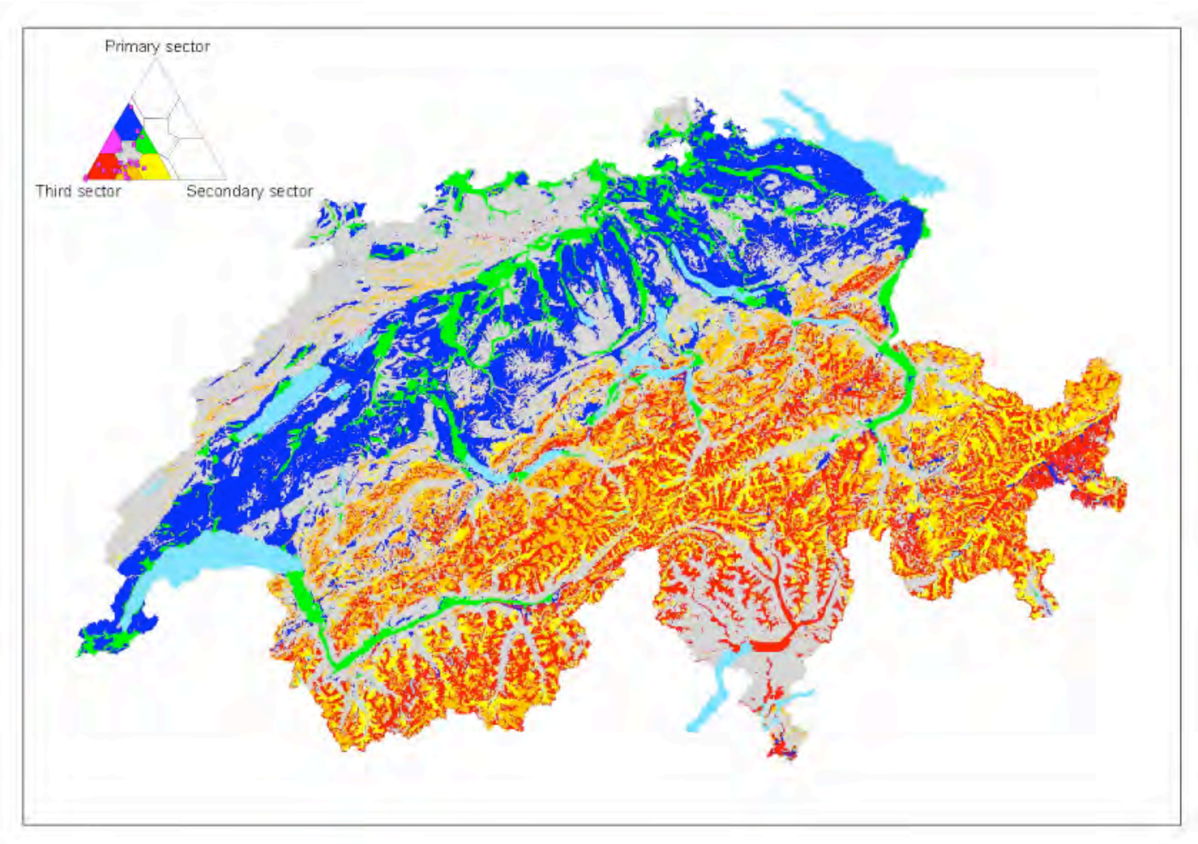


Figure 7: Distribution of the "sectorialisation" by level II Environmental domains using a ternary diagram: the Pelto triangle.

cartographic representation (Fig.7) gives a good illustration of the "sectorialisation" trends by environmental domains.

However, the purely quantitative figures of employment do not take into account the surface area. It makes therefore sense to use the density of employment. The density in the primary sector is low. The highest density of FTJEN (full time job equivalent number) per kilometer for the primary sector are in Luzern, Appenzel O Rh., Thurgau, Appenzel I Rh. and Geneva (with more than 10 jobs/km^2). Grison, Ticino, Uri, Glarus and Wallis (with less than 2.5 jobs/km^2) have the lowest density in this sector. Bale city, small urban canton, well known for its industry, is a real hot spot of employments for the industrial sector with more than 880 jobs/km^2. It is followed by Geneva (137 jobs/km^2) and Zürich (80 jobs/km2). The Grisons, Uri and Wallis cantons are the less densely industrialized (less than 7 jobs/km^2). The tertiary sector employment follows partially the secondary sector with a predominance of Bale city (2'500 jobs/km2), Geneva (633 jobs/km^2) and Zürich (283 jobs/km^2). At the other end, Uri, Grison, Glarus, Wallis and Obwald offer less than 15 services jobs per square kilometers. Small city-cantons like Bale City and Geneva have the most important density of employments in secondary and tertiary sectors. At the opposite, central small cantons in the Alps like Appenzell, Nidwald, Obwald, Glarus, Uri propose less employments. The case of Grison is interesting: although it is the biggest canton (7,100 km^2) it offers a light density of jobs in every sector, because of its mountainous and little urbanized character.

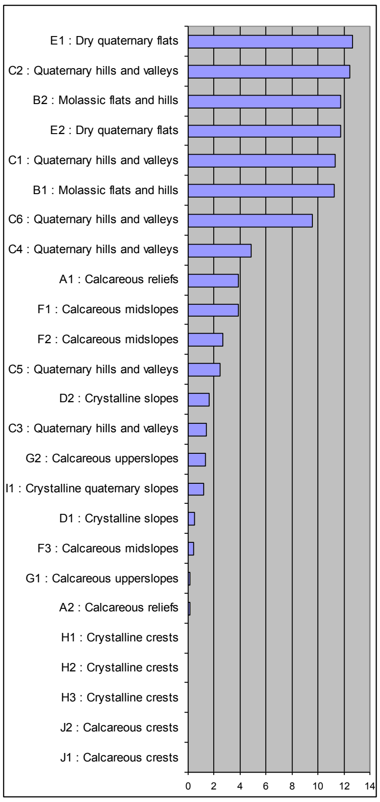


Fig.8: Density of FTJEN in primary sector *per environmental domain*

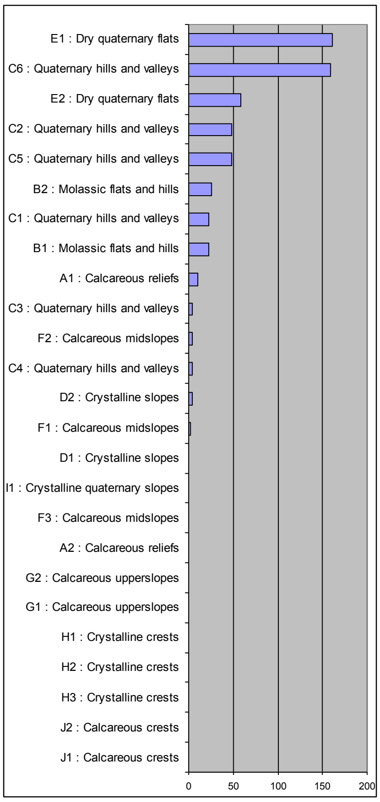


Fig.9: Density of FTJEN in secondary sector *per environmental domain*

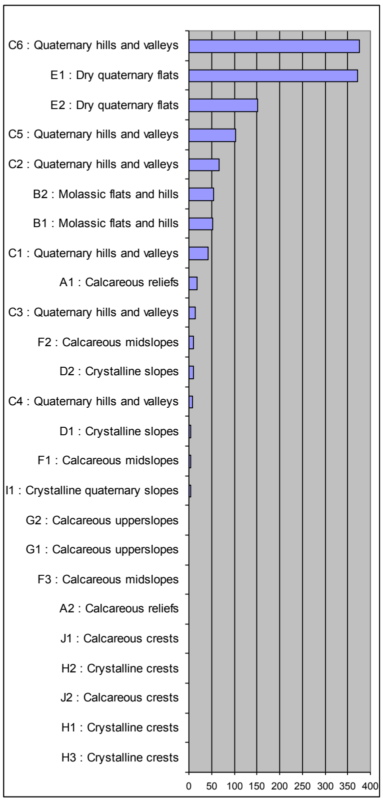
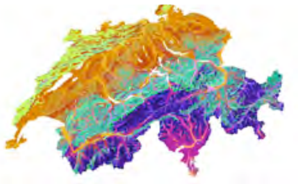


Fig.10: Density of FTJEN in third sector *per environmental domain*



How is the density of employment spread out in environmental domains? Concerning the primary sector (Fig.8), employment density is low. Nevertheless, 7 domains have more than 10 jobs/km^2: Dry quaternary flats (E1, E2), Quaternary hills and valleys (C2, C1) and Molassic flats and hills (B2, B1). Thirteen domains have less than 2 jobs/km^2. For the secondary sector (Fig.9), the Dry quaternary flats (E1), and Quaternary hills and valleys (C6) have a more important density of employment (around 160 jobs/km^2). Twelve domains have a density of employment totalizing less than 2 jobs/km^2. The trend is similar for the tertiary sector (Fig.10): Quaternary hills and valleys (C6) and Dry quaternary flats (E1) have more than 370 jobs/km2, whereas 9 domains have a density lower than 1 jobs/km^2.

On maps, the comparison between cantonal and environmental representations is revealing. For the primary sector, in the cantonal view (Fig.11) one can immediately see a rough division between South-east and North-west. The level II swiss domain view (Fig.12) is much more contrasted between the Swiss Plateau and valleys, and the mountainous areas. The quaternary flats, hills and valleys clearly show the highest density of jobs in the primary sector.

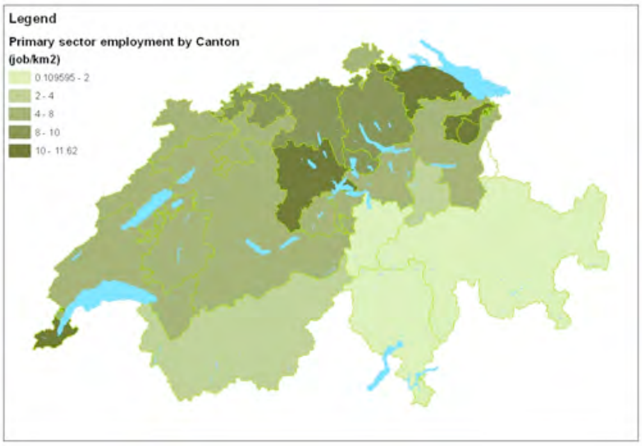


Fig.11: Primary sector employment density by cantons.

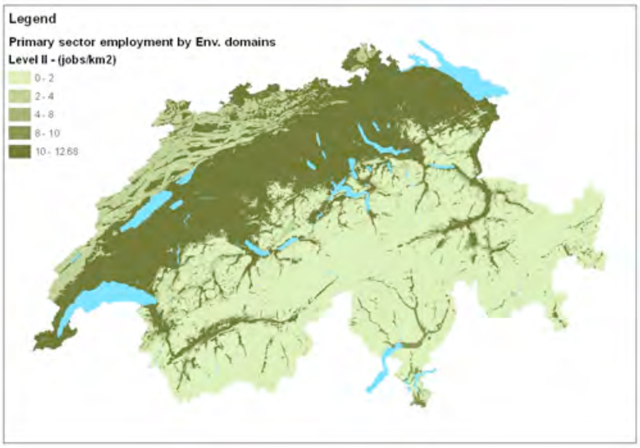


Fig.12: Primary sector employment density per level II Environmental domain.

Fig.13: Secondary sector employment density by cantons.

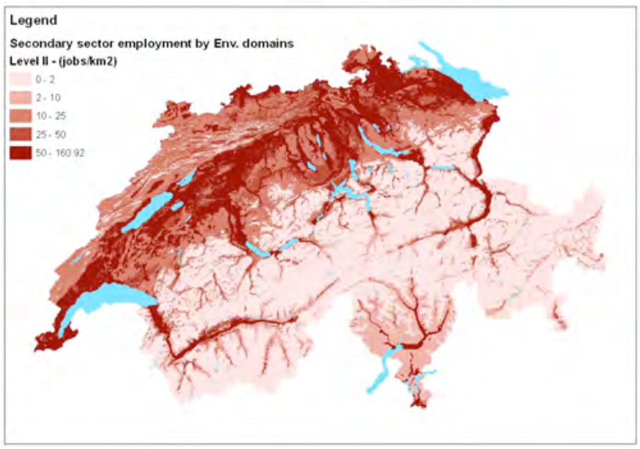


Fig.14: Secondary sector employment density per level II Environmental domain.

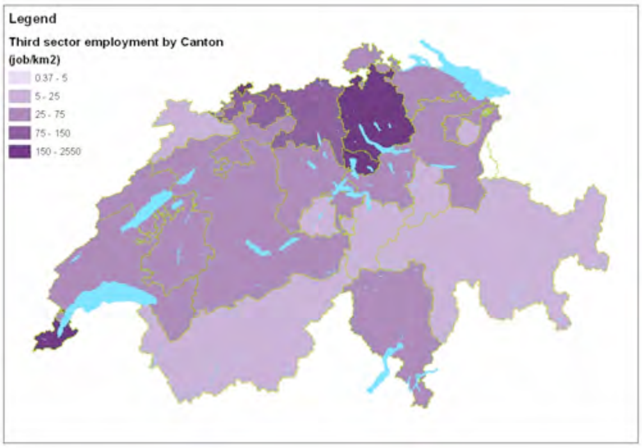


Fig.15: Tertiary sector employment density by cantons.

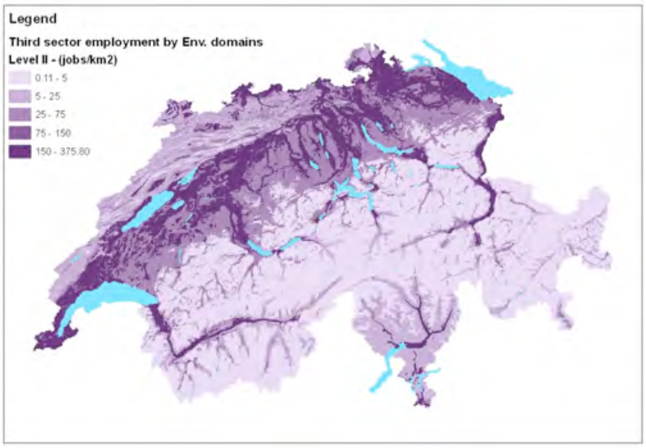


Fig.16: Tertiary sector employment density per level II Environmental domain.

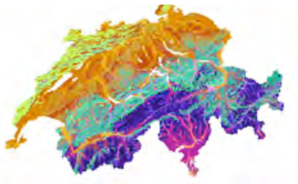
For the secondary (Fig.13-14) and tertiary sectors (Fig.15-16), we have a similar representation with environmental domains, but ever more contrasted than for the primary sector. This can be explained by the small range of values found in the primary sector (between 0 and 13 jobs/km^2 versus 0-160 jobs/km^2 for secondary sector and 0-375 jobs/km^2 for tertiary sector). The cantonal representation shows several poles of high job densities (North of Switzerland between Bale and Zürich, Geneva and Ticino). The environmental representation is more explicit and underlines probably the importance of river basins and flats areas versus mountaineous areas.

In general, quaternary flats, hills and valleys are more prone to highest density of jobs in every sectors. This is relatively obvious, because the settlements follow topographic and natural conditions. Activities have been naturally concentrated in flat areas (avoiding highest elevations and steepest slopes) and along river valleys. These environmental characteristics are taken into account in the environmental domains cartographic representation and not at all in the cantonal administrative spatial framework. In term of environmental pressure from human activities, river valleys are the most exposed, whereas mountaineous areas like crests and steep slopes are of course the less directly impacted.

Perspective

It could be very interesting to follow up the evolution of the job density by environmental domain regularly with new census data. A regionalization by disaggregation of environmental domains in small units could open the gate to think with this new geospatial framework at a bigger scale, at cantonal level for example. This approach could allow to use the SwissED to deal with more localised issues and to map them.

Indeed, as for farm density presented in factsheet S2, a zoom in the maps produced by the SwissED approach does not make any sense since the values displayed concerns the entire domain, which is generally composed of hundred of polygons distributed throughout the Swiss territory. The concerned entity is less obvious in the non-contiguous spatial units



such as the Swiss environmental domains, whereas single polygons should never be interpreted individually. With a usual cantonal administrative representation it is obvious for everybody that the value in a canton polygon concerns the complete entity; nobody thinks that every pixel of the polygon have this value. This is really less obvious in non-contiguous groups like environmental domains especially if it is zoomed in.

A regionalized approach of the Swiss environmental domains could allow focusing on subregions while taking into account this aspect. Once clipped on the subregions (for example with the administrative border of a canton), the statistical calculation could be done at this scale only with the selected polygons of the given domain. With this approach a zoom at cantonal scale makes sense as the mean value represented by a color really describes the environmental domains of the zoom and not the value of an environmental domain for the whole Switzerland. With this approach, a subregional map could answer to questions like what is the density of jobs in Dry quaternay flats of Geneva.

Target Audience

Federal Office of Statistics (OFS) in collaboration with the Federal Office fédéral of agriculture (OFAG) and the cantonal offices of agriculture.

Links

OFS census on the primary sector (RE S1) :
http://www.bfs.admin.ch/bfs/portal/fr/index/infothek/erhebungen__quellen/blank/blank/bzs1/01.html

OFS census on the secondary and tertiary sectors (UDEMO) :
http://www.bfs.admin.ch/bfs/portal/fr/index/infothek/erhebungen__quellen/blank/blank/ud/01.html

OFS census on the primary sector (agriculture indicator - employment number):
http://www.bfs.admin.ch/bfs/portal/fr/index/themen/07/03/blank/ind24.informations.240203.html#navService

OFS census on the secondary sector (environment indicator - employment number):
http://www.bfs.admin.ch/bfs/portal/fr/index/themen/02/06/ind13.informations.138402.html

OFS census on the secondary sector (environment indicator – GDP evolution):
http://www.bfs.admin.ch/bfs/portal/fr/index/themen/02/06/ind13.indicator.138401.1324.html

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Federal Office of Environment (FOEN), **Swiss Federal Statistical Office (OFS)**

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Cr. Pelto, 1954, Mapping of Multicomponent Systems, Journal of Geology, Univ Chicago Press, Chicago, IL 60637-1603, p.501-511.

Sources

This factsheet is part of the main report:
Lehmann et al., 2010. Swiss Environmental Domains: Applications. FOEN report, Bern.

Discussion

SwissED was derived from state-of-the-art techniques developed in the Land Environment of New Zealand (LENZ) to classify environment variables on large datasets (Leathwick et al. 2003). This approach aims at producing a general classification that is representing the absolute potential of purely environmental variables, independently of human activities. This general classification should perform well in many types of applications, however more advanced techniques have been developed recently to produce classifications that best summarize specific target responses (Snelder et al. 2007). Future developments of SwissED should target specific needs (e.g. biodiversity, land cover, demography), and be calibrated accordingly, by selecting, transforming and weighting variables.

Environmental classifications can be exploited in other type of ecosystems (e.g. river, marine) as demonstrated by Snelder et al. (2006; 2007) in New Zealand. If practitioners in Switzerland adopted the terrestrial approach, the next logical step would be to develop a similar approach for rivers. In order to accomplish this, a spatial framework of environmental descriptors of river segments still needs to be developed. A first attempt was made in Switzerland (Lehmann et al. 2010), but much work is still needed to create a comprehensive and useful environmental description of Swiss rivers.

The RGB coloration brings an attractive view of the territory corresponding to the main environmental gradients at stake. This colouring was used in many similar projects (e.g. Ferrier et al. 2002; Leathwick et al.2004; Hargrove and Hoffman, 2005; Mücher et al. 2006). However, the RGB coloration is somehow masking the true purpose of SwissED, which is to build groups of similar environmental conditions that can be used as a spatial framework to represent the spatial distribution of other environmental statistics (e.g. land cover, reserves, species richness). We recommend presenting the comparison of calculating such statistics on environmental domains instead of other existing spatial framework (e.g. administrative boundaries) when explaining the environmental domains to new potential users.

The purpose of this report is to present the main potential applications showing how this framework can be used to produce interesting maps of land cover, demographic and biodiversity statistics representing their potential distribution across the country. In the literature, we can find other existing or potential applications such as the assessment of existing reserve network in New Zealand (Walker et al. 2005), the distribution of environmental conditions according to past or future climate conditions in the USA (Hargrove & Hoffman, 2005) or statistics of sustainable development in Switzerland (Jaeger et al. 2008).

As demonstrated here and elsewhere, environmental domains can become useful frameworks for different applications. However, one should not overestimate its potential use and it should be clearly stated that SwissED could be useful only at some adapted scales to simplify complex approach and represent environmental statistics in an adapted framework. SwissED does not represent a simple solution for all problems; specific methods exist for species or habitat distribution modelling (Lehmann et al. 2002; Maggini et al. 2006), reserve selections (Margules and Pressey, 2000), invasive and rare species assessment (Guisan and Thuiller, 2007), or climate change predictions (Thuiller 2005).

Lessons learned from the biodiversity applications

In the first factsheet B1 on Birds richness and diversity, SwissED proved to be an effective support in order to report biological data and breeding bird richness in this specific case. Indeed, they are mainly defined according to abiotic variables belonging to three main categories, namely topography, geology and climate. These abiotic variables contribute to define unique environmental conditions that support different types of flora, fauna and ultimately different degrees of biodiversity. A particular advantage of a classification based on abiotic data is that the resulting zonation is fixed trough time and can therefore be used as a support in order to identify temporal changes in the distribution of biotic data.

In the factsheet B2 on Animal species richness we have shown that SwissED could be used as a complementary spatial framework to represent species richness as any other biodiversity indicators. SwissED performed better at explaining the observed patterns of species richness than their equivalent geographic spatial framework (10 biogeographic regions, 26 cantons). Swiss Environmental Domains can both model and downscale data of a response variable of interest. This simple technique allows making a spatial estimation at fine scale of the predicted distribution of a response variable such as species richness.

Lessons learned from the land cover applications

In the L1 factscheet on Land cover distribution we compared the observed and potential distribution of four main land cover classes (Forest, Arable land, Urban and Unproductive areas). SwissED framework could enrich the way to report on environment by bringing a new environmental dimension, especially relevant to illustrate enviro-dependent data. Therefore this new spatial framework should complete the list of recognized and commonly used frameworks. However, mapping with SwissED framework illustrates essentially a potential. When compared to traditional spatial frameworks, the maps look more realistic, distinguishing for instance cold and high calcareous or crystalline crests from warm valley bottoms. Nevertheless disjoint entities and heterogeneous sizes groups could induce spurious accuracy effects.

In the next factsheet on Land cover evolution (L2), the aim was to test the capacities of SwissED to depict general trends of land use/cover in Switzerland from 1979/85 to 1992/97, and combining them with the use of different spatial frameworks. Supposing that human activities and environmental conditions are closely linked, the representation of land cover evolution according to SwissED should improve identifying areas under similar anthropogenic pressure or with a good potential for further development, and help point out potential conflicts in land use.

One possible use of SwissED is its combination with existing land cover information in order to produce environmental classifications within each type of main land covers. A simple overlay of polygons derived from SwissED at a given level with the polygons from Vector 25 “Primary Surfaces” should produce the expected result. This small development can allow the SwissED framework to move from its general purpose into a tool useful for the management different type of land cover (forests, agriculture, grasslands).

Lessons learned from the socio-economical applications

In the first Socio-economic factsheet (S1), human population densities per environmental domains were calculated in order to estimate the demographical pressure applied on each Swiss environmental domain. These results allow also comparing and visualizing this common demographic indicator through a different spatial framework than the usual administrative frame (communes and cantons). However one question remains open: if ED frame for representing population aims at showing contrasted densities throughout Switzerland, it is not the best tool available; if ED frame aims at displaying that population densities can be compared according to physical and environmental categories, it does not differ so much from cartography using altitudinal categories or vegetation types; altitude can even be more precise; if ED frame aims at suggesting that there is some correlation between some kind of domain and density, or that there are contrasted level of pressure on various EDs, the map can deliver such message; however it is hard (much harder than for altitude or vegetation) to foresee the scientific added-value of such a suggestion. It could be very interesting to follow the evolution of the density by environmental domain through temporal series. It could be done with older census data. The population decrease rate is also something interesting for economic and planning policy (currently observed at European level using NUTS divisions) that could be analysed with the environmental domain approach.

In the factsheet on the Evolution of farms number (S2), we explored the calculation of the number of farms distribution per SwissED compared to administrative divisions. It would be very interesting to keep monitoring the evolution of the farm density by environmental domain regularly with new census data. A regionalization by disaggregation of environmental domains in small units could open the gate to think with this new geospatial framework at a bigger scale, as cantonal level for example. This approach could allow to use the SwissED to deal with more localised issues and to map them. Indeed, a zoom in the maps produced by the SwissED approach does not make any sense since the values displayed concerns the entire domain, which is generally composed of hundred of polygons distributed throughout the Swiss territory. The concerned entity is less obvious in the non-contiguous spatial units such as the SwissED, whereas single polygons should never be interpreted individually. With a usual cantonal administrative representation it is obvious for everybody that the value in a canton polygon concerns the complete entity; nobody thinks that every pixel of the polygon have this value. This is really less obvious in non-contiguous groups like environmental domains especially if it is zoomed in.

Finally, in the factsheet S3 on the Employment by sectors, we tested how SwissED behave when used as a spatial framework to express employment per primary, secondary and tertiary sectors. Here again, it could be very interesting to follow up the evolution of the job density by environmental domain regularly with new census data. A regionalization by disaggregation of environmental domains in small units could allow using SwissED to deal with more localised issues and to map them. With this approach a zoom at cantonal scale makes sense as the mean value represented by a color really describes the environmental domains of the zoom and not the value of an environmental domain for the whole Switzerland. With this approach, a subregional map could answer to questions like what is the density of jobs in Dry quaternay flats of Geneva.

Conclusions

The main conclusions that we can derive from this work are:

- The strong climatic, geologic and topographic gradients found in Switzerland represent the ideal pre-conditions for building environmental domains;
- The methodology imported from the Land Environment of New Zealand could be reused appropriately in the Swiss context with only few new developments;
- SwissED bring a new spatial framework for analyzing and reporting on all sorts of data in Switzerland;
- When compared to more traditional spatial frameworks, the maps produced when representing statistics (e.g. land cover) on SwissED return more realistic spatial patterns and surface areas;
- SwissED does not replace previous spatial framework but can bring a valuable complementary tool to represent environmental data;
- SwissED are in line with similar developments made across the world at continental, regional or national levels;
- SwissED were developed for general purposes analyses without trying to weight the input variables, they could therefore be improved by targeting a specific need (e.g. biodiversity, land cover, agriculture).

Finally, SwissED can be used to represent different statistics of natural phenomenon as well as human activities. It seems normal to represent biodiversity in function of key environmental variables. However, we tend to forget that the impact of humankind on the landscape is also very much influenced by the same basic environmental conditions. Of course, human activities are not as dependent as natural phenomenon on environmental conditions. Through the use of cheap energy, our society has learned to push the boundaries imposed by the environment, often too far. Maybe, it is good to remind decision makers and spatial planners that if we want to reach a sustainable development, we should not forget that a society is built on its environment, and that economy is built on society. So at the beginning, the environmental conditions are the base on which our society and economy is built.

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Antoine Besson is also gratefully thanked for discussing with us the possible use of pedological maps derived from the map of soil aptitudes from Agroscope.

We also appreciated very much sharing this project with two great interns who work with us for a few months, namely Mark Wilson from Australia and Alessandro Gozzoli from Geneva.

Finally, we wish to thank the participants of the SwissED workshops for their appreciated feedbacks:

SwissED workshops

Workshop 1 was organized on May 26. 2008 at FOEN with:

- FOEN: Sarah Pearson, Gilbert Thélin, Juerg Schenker, Markus Wuest, Jean-Michel Gardaz
- BFS: Laurent Zecha
- ARE: Marco Kellenberger
- Agroscope: Felix Herzog
- Vogelwarte: Peter Knaus, Ramona Maggini Lehmann
- CSCF: Fabien Fivaz
- WLS: Niklaus Zimmermann

Workshop 2 was organized on May 5. 2009 at FOEN with:

- FOEN: Jean-Michel Gardaz, Karin Fink, Tom Klingl, Chantal Donze, Marika Schaffner, Hugo Aschwanden, Christian Schlatter
- BFS: Laurent Zecha
- ARE: Reto Camenzind
- Agroscope: Gabriela Hofer
- Vogelwarte: Ramona Maggini Lehmann
- WLS: Charlotte Steinmeier

Workshop 3 was organized on February 16. 2010 at FOEN with:

- FOEN: Karin Fink, Tom Klingl, Nicolas Perritaz, Raphael Zuercher, Markus Wuest
- GRID: Hy Dao, Jean-Philippe Richard, Anthony Lehmann

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Annex 1: DVD content

1. Factsheet

Fiche_swissed.pdf

2. Variables

ArcGis 9.2 map

EVariables.mxd

Illustrations

Maps in jpeg and pdf formats of variables

3. Results

ArcGis 9.2 map

SwissED.mxd

Illustrations

Maps in jpeg and pdf formats of SwissED

4. Presentation

Power Point presentation

SwissED08.ppt

SwissED08.pdf

6. Report

Technical report (pdf) (this report)

7. References

Some interesting references

8. Geodatabase

SwissED08lyr — ArcGis 9.2 Geodatatbase

SwissED08.gdb — Raster and vector data, Legends (LYR)