4.4 Mapping relevant factors for ecological connectivity – The JECAMI mapping service

*// **Rudolf HALLER** //*
Swiss National Park, Zernez, Switzerland

4.4.1 Introduction

Ecological connectivity is a core global issue in biodiversity conservation (Crooks and Sanjayanm 2006). In Europe, it is especially important in the Alps due to the region's rich biodiversity and variety of habitats, but it is extremely limited nowadays by human activities, particularly in valley bottoms. Ecological connectivity concerns all Alpine territories at all governance levels (regions, communities and more) and can only be ensured in the future by a common cross-sectoral and cross-scaling approach (Van Dyke 2008).

The question within the Interreg IV project ECONNECT – Restoring the web of life (Füreder Leopold *et al.* 2011) formulated in the application proposal was as simple as it was demanding: "Mapping the relevant factors of ecological connectivity". But what are the relevant factors and for whom? How can the potential for ecological connectivity be described for a landscape?

During the INTERREG IV project ECONNECT we investigated this complex requirement throughout the Alps and in seven Pilot Regions. We separated structural and functional connectivity (Baguette *et al.* 2013; Crooks and Sanjayanm 2006; Hilty, Lidicker, and Merenlender 2006; Van Dyke 2008) based on particular species. In order to increase public awareness, we added to the pure ecological question a set of additional basic requirements:

1. Generally applicable criteria to evaluate connectivity across the landscape had to be worked out.

2. Access to the results for all stakeholders.

3. Add spatial analysis tools available to all stakeholders both across the Alps and locally.

4. Allow for quality assessment comprehensible to experts.

5. Analysis of the landscape in terms of ecological connectivity should be comparable with specific requirements of individual species.

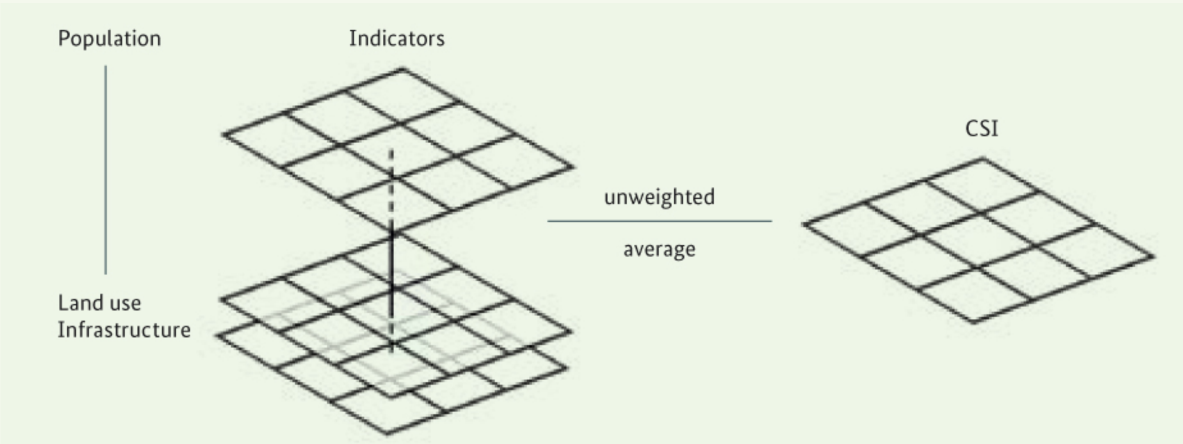
Green bridge on French highway.

// **Table 4:** List of indicators representing the Continuum Suitability Index (CSI)

1. Population (POP)	Represents the impact of human pressure. The indicator refers to the density of inhabitants and tourist overnight stays. A high indicator value describes a low density of human impact and expresses positive connectivity conditions.
2. Land Use (LAN)	Can have a large impact on connectivity, and depending on this impact, different values were defined by a group of experts. These values range from 1 – negative influence to 100 – positive influence on connectivity.
3. Patch Cohesion (COH)	Describes the continuity between areas of the same land cover type. The more connected the patches of one type (with few interruptions or barriers), the higher the index. The only aspects considered are the size and shape of the area.
4. Edge Density (ED)	The length of edges between different land cover types within an area. The impact of high edge density on connectivity depends on the species.
5. Fragmentation (FRA)	Describes the degree of fragmentation by roads, dams, railroads and more. The degree of fragmentation is expressed by the size of the area between barriers. The higher the index, the less fragmented the area, which indicates good conditions for connectivity.
6. Altitude and Topography (TOP)	Includes elevation above sea level: the assumption is that conditions get worse with increasing elevation due to decreasing temperature and vegetation cover, for example. This only refers to natural aspects rather than human impacts and pressure. Indicator values thus decrease with increasing elevation. The measure also accounts for elevation relative to surrounding areas: relative elevations indicate whether the area is a valley, a flat surface, a medium slope or a hilltop. The more the landform changes, the lower the connectivity.
7. Infrastructure (INF)	Evaluates the impact of diverse infrastructure on ecological integrity. Data on infrastructure objects are implemented such as power lines, ski slopes, ski lifts, cable cars, and more.
8. Environmental Protection (ENV)	Refers to protected areas in the region and to their level of protection under international law. A high degree of protection corresponds to a high indicator value.
9. Land Use Planning (LAP)	Refers to protected areas at the regional level and evaluates future developments which could have consequences on ecological connectivity.
10. Ecol	Quantifies small-scale existing environmental protection measures and local protected areas such as, for example, the construction of wildlife overpasses. Again, a high degree of protection translates into a high indicator value.

Source: adapted from Affolter, 2010

// **Figure 16:** Calculation of the CSI index



Source: adapted from Affolter, 2010

4.4.2 The JECAMI Framework

In order to reach the above-mentioned requirements, we built a framework called JECAMI – Joint Ecological Connectivity Analysis and Mapping Initiative. JECAMI is a web application based on Google Maps API, built by the Swiss National Park to help users analyse the connectivity and barriers of the landscape and to assess an area based on very specific criteria. The application was initially built using version two of Google Maps API in 2010, and rebuilt using Google Maps API v3 in 2014.

JECAMI incorporates a set of methodological ecological connectivity approaches. The tool is enriched with exhaustive documentation on data and methodology, as well as geoprocessing tools, which allow the user to analyse certain areas in detail or calculate a path of an animal through its habitat.

In order to stimulate discussion on structural and functional connectivity, JECAMI allows for a comparison of the two approaches, the so-called "Continuum Suitability Index" (CSI) and Species Map application (SMA), respectively. In certain regions, we also tested the potential of the application for aquatic and semi-aquatic species (Connectivity Analysis of Riverine Landscape – CARL). The CSI was built for two spatial scales: a general approach with consistent but coarse data over the entire Alps and a more spatially and thematically detailed approach within several sub-regions.

4.4.3 The continuum suitability index – A structural connectivity approach

The CSI has been developed to evaluate the current potential of an area with respect to its structural connectivity. Taking the general approach of green infrastructure (Mazza *et al.* 2011) further, the CSI evaluates every patch within a landscape based on positive (green) structural elements, but also negative barrier effects. Moreover, the CSI assigns an effect on ecological connectivity to each patch and therefore offers an enhanced perspective to the current discussion. The landscape is considered as a matrix where each pixel or patch promotes ecological connectivity. The aim of the index is to illustrate where conditions for an ecological continuum already exist and which areas require improvement.

An expert group (Plassmann 2009) evaluated factors for structural connectivity and defined the data required for corresponding indicators. While it was not possible to derive spatially and thematically detailed datasets from original data such as remote sensing imagery within the project, we concentrated on existing data for the Alps and for the Pilot Regions, keeping the advantages and disadvantages of this heterogeneous approach in mind. Moreover, not all desired data were available for all regions. However, as we wanted to work at the local level with local stakeholders within Pilot Regions, we accepted the lack of data homogeneity throughout the Alps in favour of gaining detailed insights into certain regions, which would not have been possible with a data homogenisation process.

Today, the CSI for the sub-regions consists of ten different indicators that reflect different thematic criteria that influence ecological connectivity, involving biological, landscape-ecological, as well as geographical and socio-economic issues (Table 4).

An assessment of each indicator within each patch – normally at a resolution of three to five metres at the regional level – has been developed individually and based on existing scientific publications (Affolter 2010). Each indicator has been implemented as a raster surface to represent a continuous characteristic with values between one (most unsuitable) and 100 (most suitable) in order to set up a common value scale (Figure 16).
The index was originally developed with regional data for seven Pilot Regions in the Alps, but has also been calculated for the whole Alpine arch at a lower resolution, with data available across Europe. As this was a limiting factor, the Alpine-wide calculation only consists of six out of the ten original indicators due to missing data.

Calculation of the CSI for a predefined area

The calculation is based on an unweighted mean of all raster cells inside the defined area of analysis. Thus, JECAMI outputs ten mean values – one for each indicator. The quality values of the various administrative divisions then have to be weighted by the percentage of area for the calculation of quality parameters (quality indicator). No weighting is required for the Alpine-wide CSI approach because the data quality is the same all over the Alps. The results of the CSI calculations are displayed in JECAMI as a vertical bar chart and a table (Figure 17). Both can be exported as PDF's.

Data quality

An indicator value of "80" or higher for a certain location suggests high suitability for the Ecological Continuum. However, in order to obtain a complete picture

1
2
3
4
5

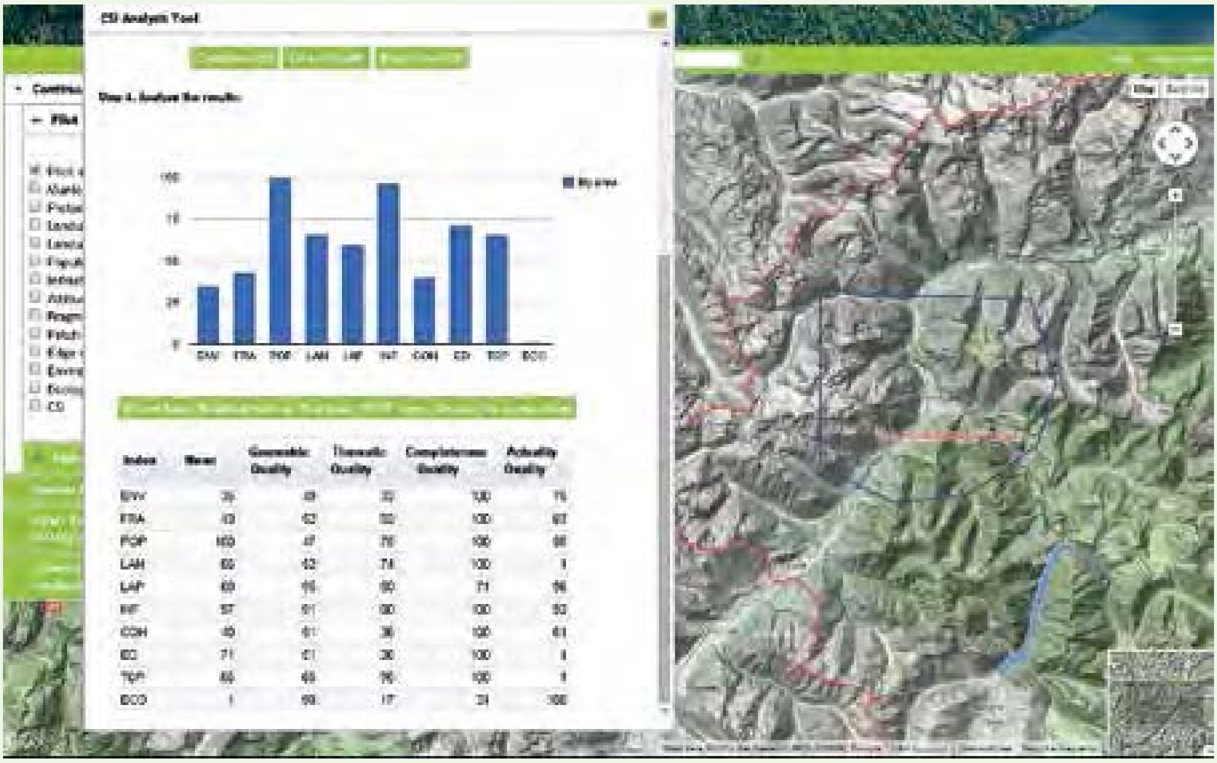
of the suitability, the quality of the database also needs to be considered. Therefore, a quality indicator was created that indicates the geometric and thematic resolution, the completeness and actuality of the data for all ten indicators inside an administrative division (dataset Data_Q). The resulting CSI values from different regions based on different databases are thus comparable.

4.4.4 Mapping species migration areas and corridors

Habitat and migration studies of several animal species were conducted by several partners during the ECONNECT project (Signer and Sedy 2010; Walzer *et al.* 2013; Füreder Leopold *et al.* 2011). Within JECAMI, we integrated the final results, a potential habitat map and a potential migration map based on an approach called GUIDOS (Vogt 2013). This integration – named Species Map Application (SMA) – helps detect and visualise possible barriers or corridors for various animal species. The SMA consists of habitat distribution and connectivity models (GUIDOS) for particular species (key species). These models were developed at a spatial resolution of 1,500 metres by the Austrian Federal Environment Office (Signer and Sedy 2010). An exception is the model for the brown bear, which has a resolution of 375 metres. We included additional geoprocessing functionality to the application, allowing

The Species Mapping Application Tool (SMA) included in JECAMI shows which areas are suitable for different species. The SMA tool calculates an optimal path for a selected species, such as the brown bear, and shows the barriers and corridors along the path.

// **Figure 17:** CSI result for a predefined area within an ecological connectivity Pilot Region in the Alps



Source: adapted from Affolter, 2010

the user to predict a possible path from one point in the Alps to another. Using a cost path function, the tool returns modelled virtual tracks of wolf, bear, lynx, red deer and black grouse between two given points. Figure 18 shows an example of a calculated path for a bear from Zernez to Bormio.

4.4.5 Technical solution

The technical solution encompasses a set of segments, including the creation of a comprehensive geodatabase, incorporation of adjusted geoprocessing tools, suitable cartography, a map publishing service and a superposed web application. Figure 19 shows the general functionality. Based on ArcGIS technology, we are currently preparing the data and geoprocessing tools in ArcGIS Desktop 10.2.2. The spatial data are published on ArcGIS Server (10.2.2), the web application based on Apache Web Server. For the online service, we use a set of external libraries including the Google maps API, the Google visualization API, different java libraries and geoxml.

4.4.6 A case study with JECAMI: Defining ecological connectivity hotspots in the Alps

In this study, realised under the Life Belt Alps Project, a European follow-up project of ECONNECT, a reclassification method of the CSI was developed to define the most important action areas and hotspots in the Alps. Action areas generally have low ecological connectivity and are located on important intersections between areas with good ecological connectivity (hotspots such

// Figure 18: An example of a virtual path for a brown bear in the central Alps, overlaid over a habitat map developed during the project ECONNECT

Source: www.jecami.eu

as a protected areas), fragmenting them into two parts. They are mostly located in a valley bottom, where land use and infrastructure dominate. Action areas are situated in locations where measures to improve ecological connectivity are important and feasible. The aim of this study was a definition of these action areas and hotspots over the Alpine arch.

Materials and methods

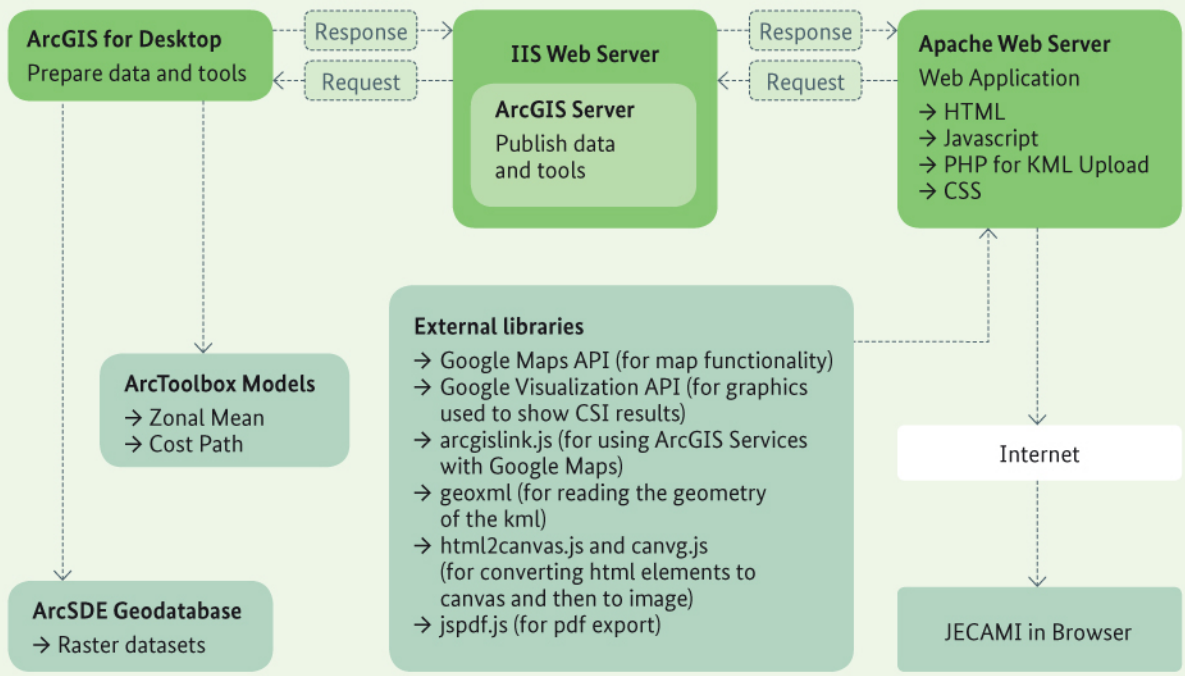
During a Life Belt Alps meeting in 2015, an expert group determined 36 spatially explicit action areas and 16 hotspots in the Alps as reference points for an Alpine-wide analysis. The structural connectivity within these locations was analysed with the JECAMI tool for a rectangle of ten square kilometres (two kilometre × five kilometre) shaped over the central point and aligned along the valley bottom. For these plots, we computed the CSI statistics based on the Alpine-wide dataset. We only considered the land use (LAN), population (POP) and environmental protection (ENV) indicators for this analysis, as they contribute most significantly to the overall CSI. The indicators land use (LAN) and population (POP) were given double weight (double) to avoid existing protected areas contributing too much to the recalculated CSI:

CSI-Alps_adopted = (2xLAN + 2xPOP + 1xENV) / 5

Predefined action areas and hotspots were re-evaluated based on this new CSI raster. A normal distribution of extracted CSI values was then computed in order to obtain CSI thresholds for predicting action areas and hotspots more generally.

The new CSI was reclassified based on these thresholds to model 4 different zones over the entire Alps: poor area, action area, transition zone and hotspot. Areas at altitudes higher than 1,800 metres above sea level were not taken into consideration. It was assumed that ecological connectivity was less of a problem at higher altitudes due to lower degrees of land use and lower human population densities. Focusing the analysis on lower altitudes (<1,800 metres above the sea level) also highlighted hotspots. This new map was integrated into the existing web map application *www.jecami.eu*. Furthermore, some priority action areas were sketched along the major axis across the Alps. They were selected visually at a scale of 1:3,000,000, based on large linear barriers within locations that

// **Figure 19:** System structure of JECAMI



Source: adapted from Affolter, 2010

The valley of the river En (Inn) in the Pilot Region Raethian Triangle was one of the territories analysed in detail using the GIS tool JECAMI.

represented the best passage to cross with respect to the reclassified CSI.

Results and discussion

Figure 20 shows the 36 action areas and 16 hotspots plotted by the expert group as points over the Alpine arch, together with their resulting CSI statistics (Tables 5 and 6). Mean CSI's for action areas are between 40 and 60. Areas with high environmental protection (ENV) have high values. Land use (LAN) values are generally low and have the greatest influence on the overall CSI. Areas at lower altitudes score better for topography (TOP) than areas at overall higher elevations or with more variable terrain. The pattern for the population (POP) indicator shows maximum values for sparsely populated areas compared to densely populated areas such as St. Margrethen or Grenoble. Cohesion (COH) shows higher values compared to edge density (ED). This means that landscape patterns are more clumped or aggregated in their distribution. Mean CSI's of hotspots range from 60 to 70, which is higher compared to the action

// Figure 20: Overview of hotspots and action points (defined by an expert group) shown with the perimeter of the CSI for the Alpine arch

Source: ALPARC, Life Belt Alps Project, 2016 areas. Only Embrun /Les Orres and Vandoies show a low CSI value of 50. This is due to the fact that they are located in areas without protection (lowest ENV) and have relatively low LAN compared with other hotspots. ED is even lower, and COH overall higher than for the action areas, as the hotspots are located in more remote areas with larger coherent landscape patches by comparison to action areas. TOP shows lower values caused by the generally higher elevations of hotspots. On the other hand, POP shows maximum values as they are typically located in sparsely populated areas.

// Table 5: Recalculated CSI for the Alpine area with only significant indicators LAN, POP and ENV included

Action area	CSI_{new}	Hotspot	CSI_{new}
Mezzocorona	56	Embrun / Les Orres	71
Kufstein	59	Saint-Paul-sur-Ubaye	95
Flintsbach	66	La Motte Chalancon	64
Telfs	53	Monts de Vaucluse	81
Farchant	74	Bergeller Kette	94
Tenneck	79	Ortler Alpen	98
Locarno	50	Kaunertal	94
Grenoble	46	Grossglockner, Hochalpenstrasse	83
Dorénaz	58	Hintertal	97
Bonneville	50	Obersulzbach	92
La Biolle	60	Badia	93
Salgesch	64	Vandoies	60
Saag	51	Lepena	89
Völkermarkt	46	Forni di Sopra	82
St. Margrethen	44	Mis	82
Altstätten – Götzis	39	Gams bei Hieflau	76
Sargans – Balzers	59	–	–
Kindberg	61	–	–
Belluno	55	–	–
Palleusieux	64	–	–
Saint-Jean-de-Maurienne	74	–	–
Aigueblanche	60	–	–

Source: ALPARC, Life Belt Alps Project, 2016

Table 5 shows the new CSI for action areas and hotspots. Values are within a similar range as with the regular CSI. Based on the computed normal distribution, CSI thresholds were selected to define hotspots, transition zones, action areas and poor areas (Table 6 and Figure 21). Light green lines show the selected range of 54 to 61 for modelling action areas (all values above normal F of 0.4.).

The dark green line shows the CSI threshold for hotspots. The four categories defining the quality of ecological connectivity were mapped using this reclassification (map 10). Some priority action areas located along the major axis across the Alps were sketched on the map with black crosses. The priority action areas are all important Alpine valleys with high land use and major traffic routes, which are located between CSI hotspots (see map 10).

Conclusions

The aim of this analysis was the definition of action areas and hotspots in the Alps regarding ecological connectivity. This was achieved with a recalculation of the CSI Alps including the most important indicators, a result of ECONNECT.

The CSI was first investigated for predefined action areas and hotspots that had previously been selected by an expert group. The CSI Alps was recalculated with only the most important indicators included. General action areas and hotspots were then modelled with a reclassification of the new CSI Alps. The output of the model has been mapped and integrated into the existing web map application *www.jecami.eu*. This map can be studied for the definition of priority action areas where measures to improve ecological connectivity are useful and feasible.

// **Figure 21:** Normal distribution of recalculated CSI values for action areas (light green) and hotspots (dark green), and indicated CSI thresholds for modelling

Source: ALPARC, Life Belt Alps Project, 2016

// **Table 6:** Reclassification values of the CSI

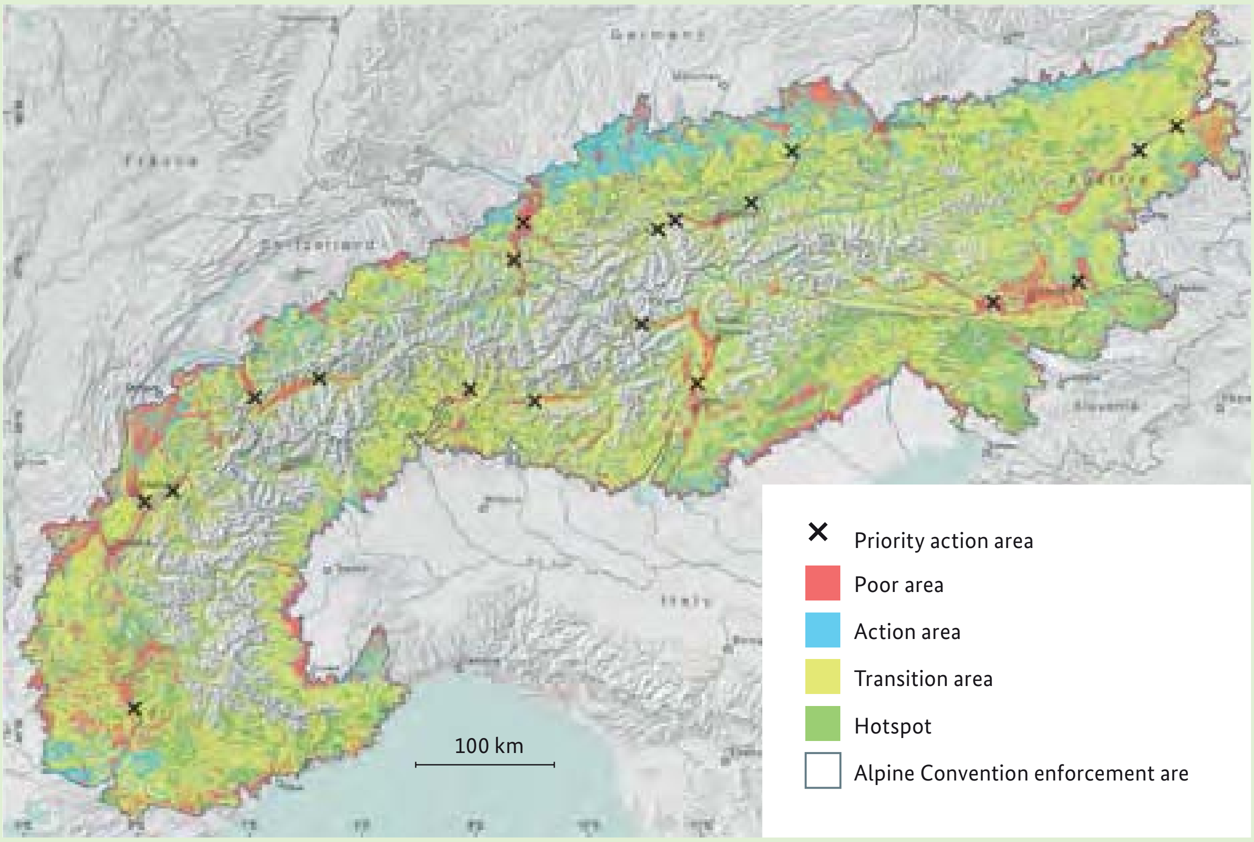
CSI reclassified	
poor area	1 – 53
action area	54 – 61
transition zone	62 – 79
H	80 – 100

Source: ALPARC, Life Belt Alps Project, 2016

Specific information like data from inventories of wetlands or other areas can be considered in the JECAMI analysis when available.

Traditional land use in the area of National Park Vanoise. Land use is one of the indicators used in JECAMI for the calculation of the Continuum Suitability Index.

// **Map 10:** Reclassified CSI Alps for areas below 1,800 metres above sea level with priority action areas



Source: SNP, ALPARC, ESRI Data, Swisstopo