Observatorio
Cambio Global
Sierra Nevada

Sierra Nevada Global Change Observatory

Structure and basic data

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SIERRA NEVADA GLOBAL CHANGE OBSERVATORY
STRUCTURE AND BASIC DATA

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PHOTOS

Photos have been taken by Ernesto Sofos Navero, except on p. 9 taken by R. Moreno, pp. 21 and 23, taken by F. J. Bonet, and pp. 27 and 29, taken by A. J. Pérez-Luque.

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The information contained in this report has been prepared by many professionals.
These works are cited appropriately in the references section.

Observatorio Cambio Global Sierra Nevada

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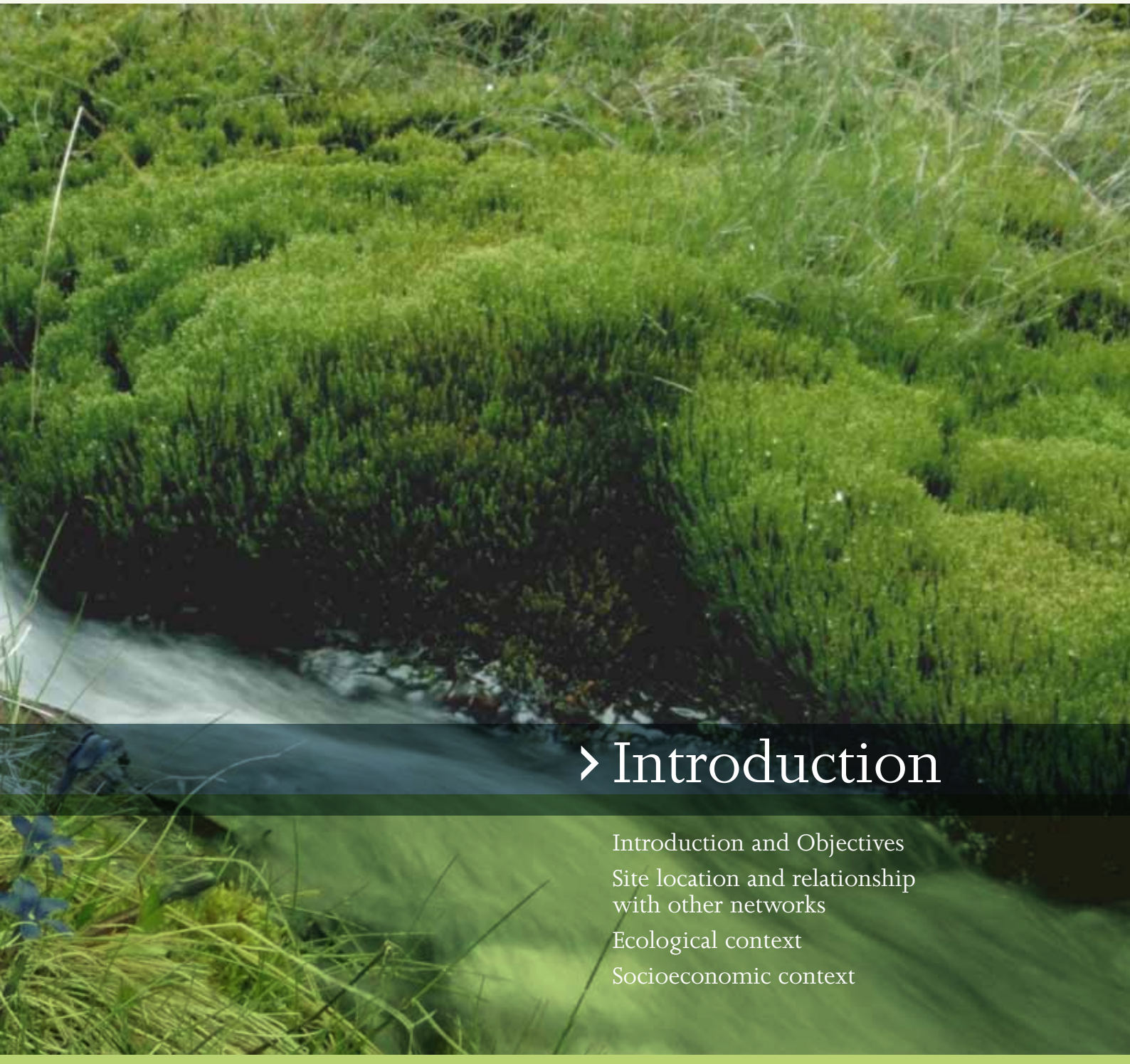


Introduction

Introduction and Objectives

Site location and relationship with other networks

Ecological context

Socioeconomic context

› Introduction and Objectives

The ultimate objective of the Sierra Nevada Global Change Observatory is to gather the necessary information to identify the impacts of global change, in order to design mechanisms that minimize those impacts and help adapt ecosystems to the new scenarios. This overall aim requires the design and implementation of a **monitoring program** on the effects of global change in Sierra Nevada.

MONITORING PROGRAM

The design of mechanisms of adaptation to tackle global change requires the existence of **relevant information** on the structure and dynamics of both the elements and processes involved in our study area's ecosystems. The first task, therefore, would be the design of a solid monitoring program.

We have been working on 20 **monitoring methodologies**, to assess both the status of the main ecological functions and structure of the main ecosystems in Sierra Nevada. These methodologies have been validated by scientific experts and have already been implemented in Sierra Nevada.

OUTREACH

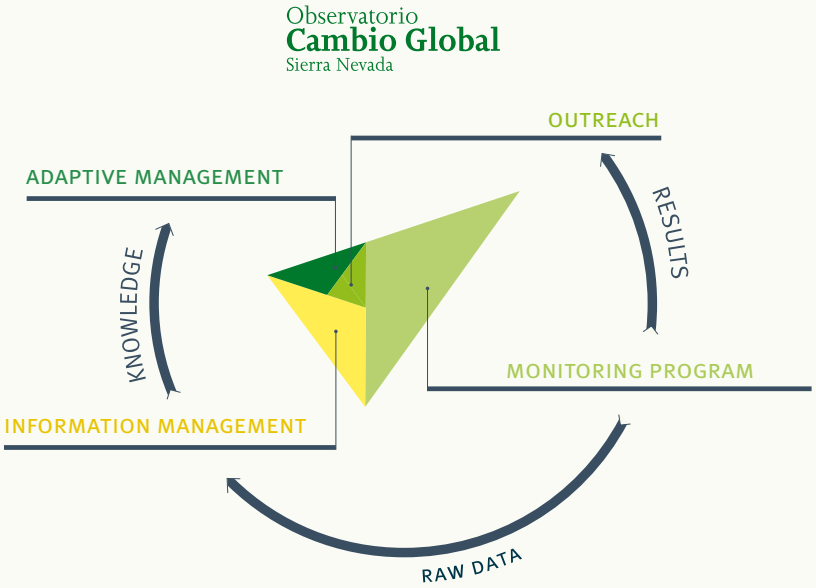
One of the main aspects regarding the success of a project like this has to do with the way in which both targets and results are reported. Therefore we consider very important all tasks related to **disseminating and reporting results**. We would like to emphasize the processes followed to make them available to the general public. The main tools we use are the project's **wiki** and **publications** in the mainstream press.

We have also made several documentaries about the Observatory's work, which will be broadcast on Andalusian regional television. Furthermore, we have initiated a process of periodic training, through regular work group meetings, workshops, seminars, pilot tests, etc, in order to:

1) Update the scientist-technical knowledge of people involved in the monitoring program.

2) Exchange knowledge and share experiences and problems on project development between scientists, managers and technicians involved in the project.

The information generated by this set of monitoring methodologies must be transformed into useful knowledge for the managers to carry out an **active and adaptive management** of natural resources. To do this, it is essential that all data is integrated and analyzed in an **information system** for the project. Finally, the general public must be informed of both the results obtained and methodologies used, through effective **feedback**.



INFORMATION MANAGEMENT

Developing an information system is in conjunction with collecting information on the status and structure of the natural systems of Sierra Nevada. The ultimate goal of this tool is to offer **useful information -knowledge-** to managers, to improve the way natural resources are managed in Sierra Nevada. This knowledge is obtained after **processing** and **analyzing** raw data obtained by the above-mentioned monitoring program.

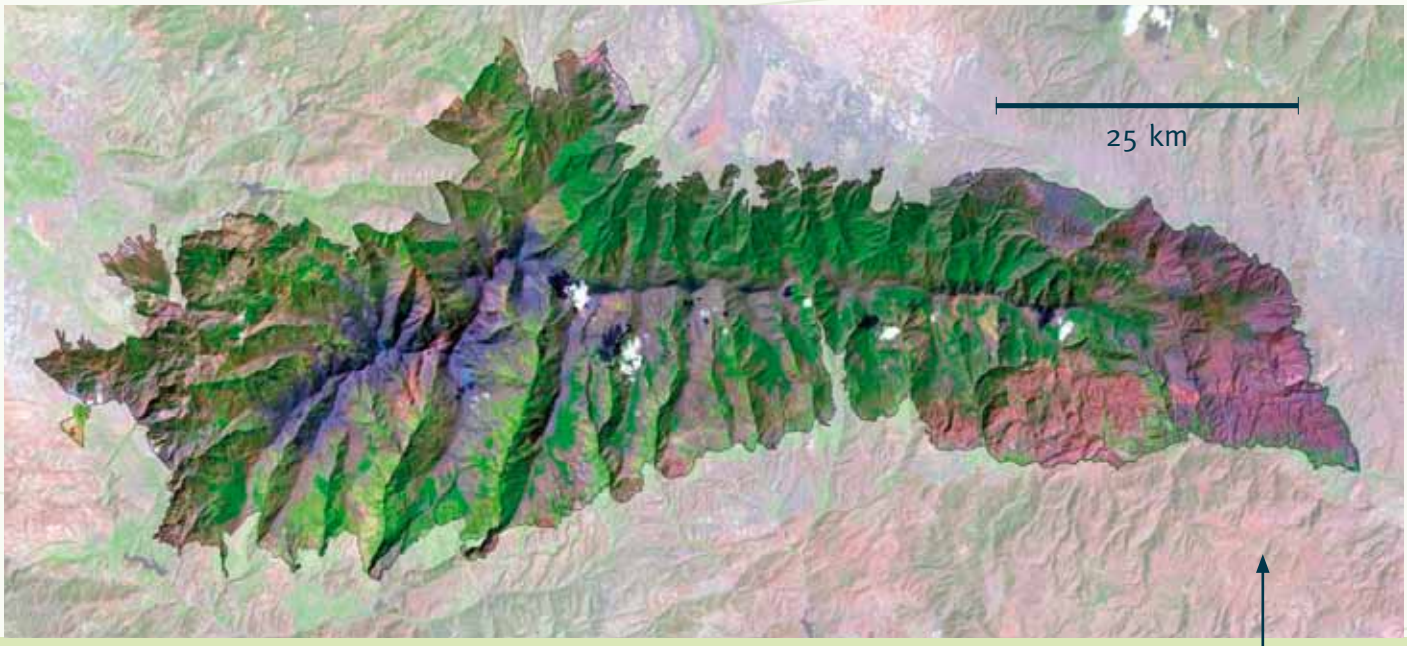
The raw data is stored in a relational database compatible with **REDIAM** (Environmental Information Network of Andalusia). The algorithms that analyze and process the data are documented and implemented in an automated way through the use of applications for scientific workflow management. In addition to this data, it generates large amounts of information difficult to standardize in a database: text documents, slides, books, videos, pictures, etc. To store this information we are using Web 2.0 technology tools. The project has a wiki (http://observatoriosierranevada.iecolab.es), where both the methodologies used and results obtained are shown. There is also a bibliography manager with over a thousand references of interest (http://refbase.iecolab.es).

ADAPTIVE MANAGEMENT

Adaptive management seeks to learn from the results of management actions on natural resources, improving management by **adapting to change**. Actions and objectives are further adjusted based on new knowledge gained. Moreover decisions and management results should be carefully documented to enable the dissemination of knowledge obtained through experience.

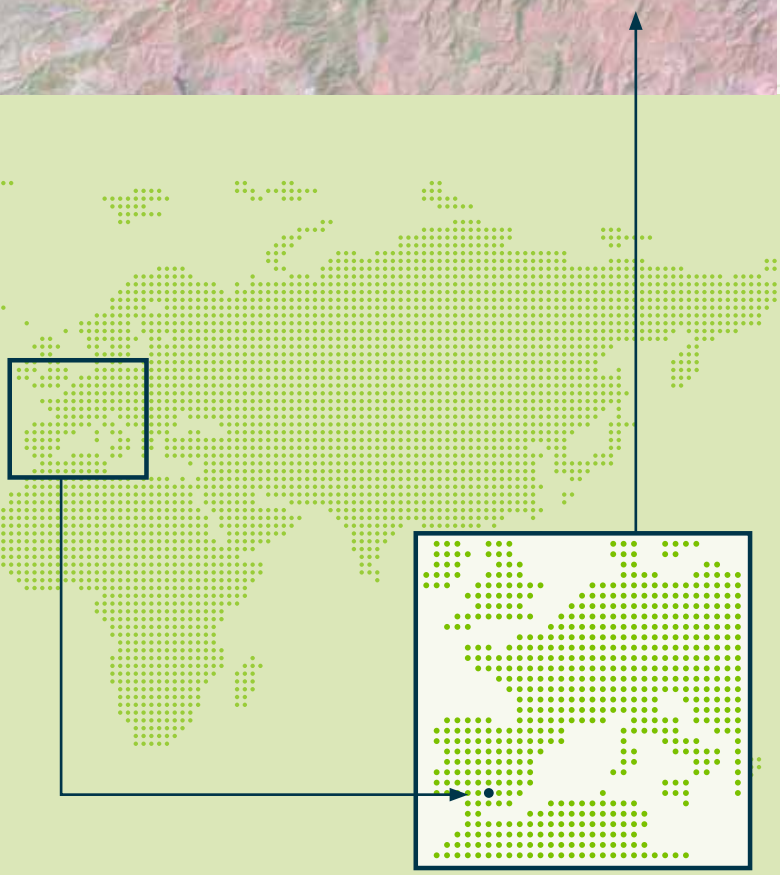
The Sierra Nevada Global Change Observatory has incorporated adaptive management approaches to their theoretical and practical management activities. The many examples of adaptive management include the Sierra Nevada experimental treatments to assess the suitability of different plant regeneration procedures after the **Lanjarón fire** in 2005. The **conservation projects and improvement** of stands of **oak, juniper, and maple** to increase the resilience of these ecosystems and promote regeneration in changing conditions are also very interesting.

Location of Sierra Nevada LTER-site



Sierra Nevada is a high mountain range (reaching 3,482 m.a.s.l.) located in Southern Spain (37ºN, 3º W) covering 2,000 km².
It has several legal protections:

- Natural Biosphere Reserve (MaB. Unesco)
- Special Protection Area and Site of Community Importance (Natura 2000 network)
- National Park and Nature Reserve



RELATIONSHIP OF SIERRA NEVADA GLOBAL CHANGE OBSERVATORY WITH OTHER MONITORING NETWORKS

REGIONAL LEVEL

ICTS- DOÑANA

http://icts.ebd.csic.es

NETWORK OF OBSERVATORIES FOR MONITORING GLOBAL CHANGE IN ANDALUSIA

GLOCHARID

http://www.caescg.org/glocharid

NATIONAL LEVEL

AUTONOMOUS ORGANISATION OF NATIONAL PARKS

http://www.mma.es/portal/secciones/el_ministerio/organismos/oapn/

BIODIVERSITY FOUNDATION

http://www.fundacion-biodiversidad.es

LTER-SPAIN

http://www.lter-spain.net

INTERNATIONAL LEVEL

GLOCHAMORE

http://www.edinburgh.ceh.ac.uk/biota/glochamore_page.htm

GLOCHAMOST

http://www.sl.ugr.es/glochamost

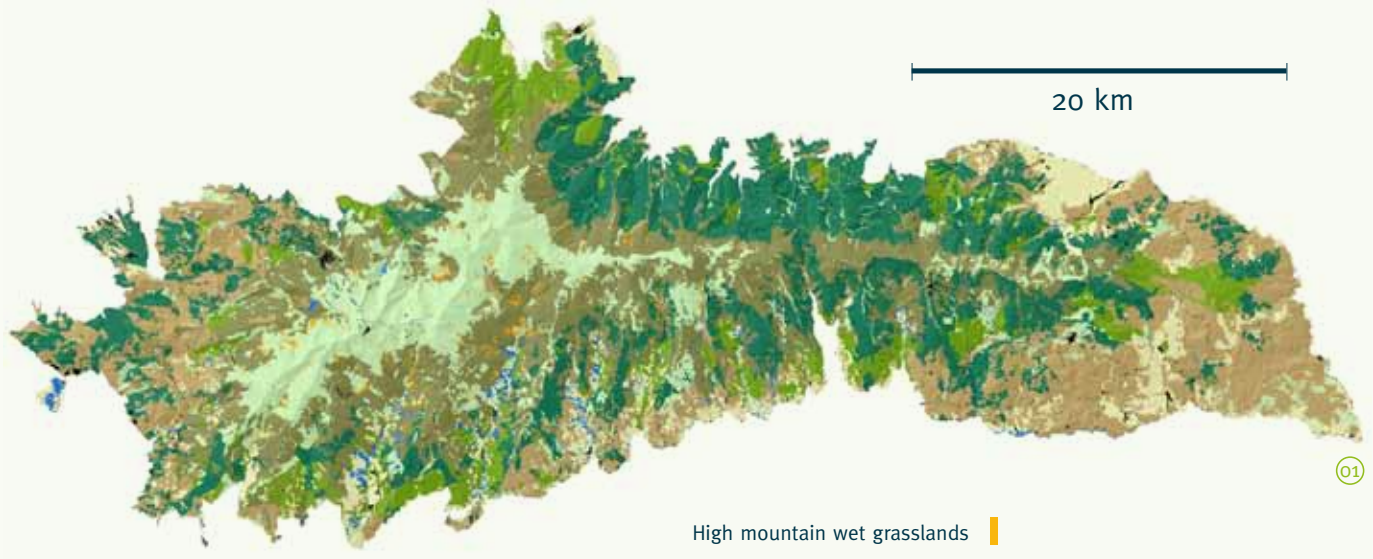
ILTER

http://www.lternet.edu

Sierra Nevada is also a key member of the LTER-Spain network. The Long Term Ecological Research (LTER) network is a global network of research sites located in a wide array of ecosystems worldwide that can help understand environmental change across the globe. LTER's focus is on long-term, site-based research, involving scientists, managers and institutions, helping to investigate ecological processes over long temporal and broad spatial scales.

Sierra Nevada has been a member of this network since 2008. Other locations such as the Doñana, Aigües Tortes and Ordesa National Parks are also members of LTER-Spain and the International LTER Network.

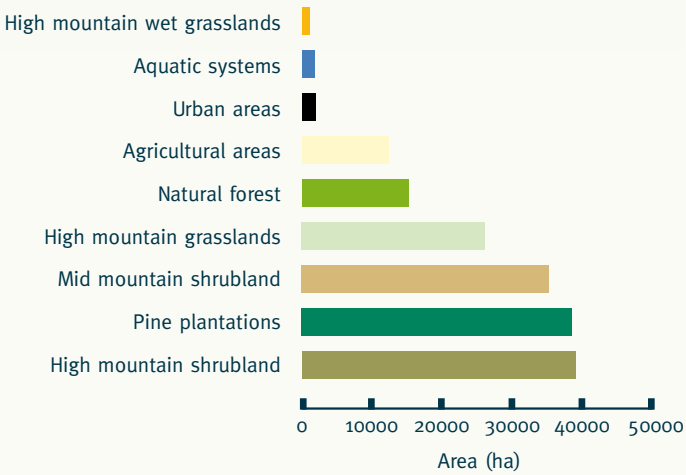
Ecological context



01

Types of Ecosystems

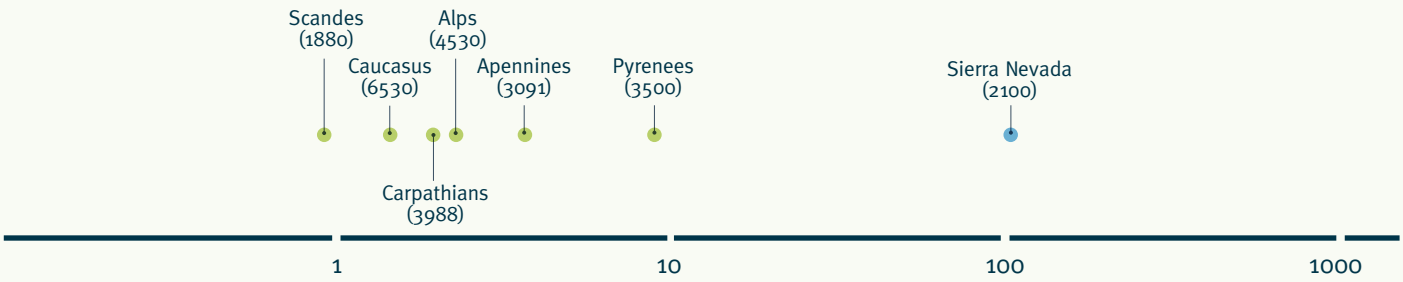
Map showing the spatial distribution of ecosystems that have been identified in Sierra Nevada. Vegetation is predominantly high mountain shrublands and pine plantations. We also have natural forests (oaks, Pyrenean oaks, maples, etc.) that are regenerating after decades of overexploitation.



SPECIES RICHNESS OF VASCULAR PLANTS

03

The figure shows the species/mountain range area ratio on a logarithmic scale. The total number of species for each mountain range is shown in parentheses.



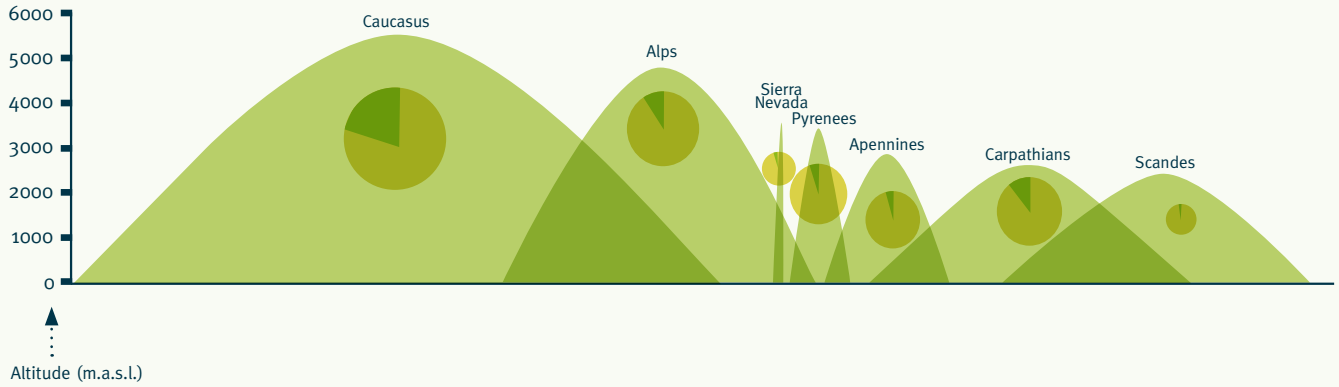
Species/mountain area (Log scale)

PLANT DIVERSITY IN EUROPEAN MOUNTAINS

02

Figure showing mountain ranges of Europe and the altitude, size and plant diversity of each mountain. The width of each mountain in the figure is proportional to its real size (in Km²). The size of each pie chart is proportional to the plant species number and the green sector indicates the proportion of endemic species per mountain range.

Due to its strategic location as a refuge for many plant species during the glaciations, Sierra Nevada is one of the most important hotspots of plant diversity in the Western Mediterranean Region. It has 80 endemic species in a total of 2,100 species of vascular plants.

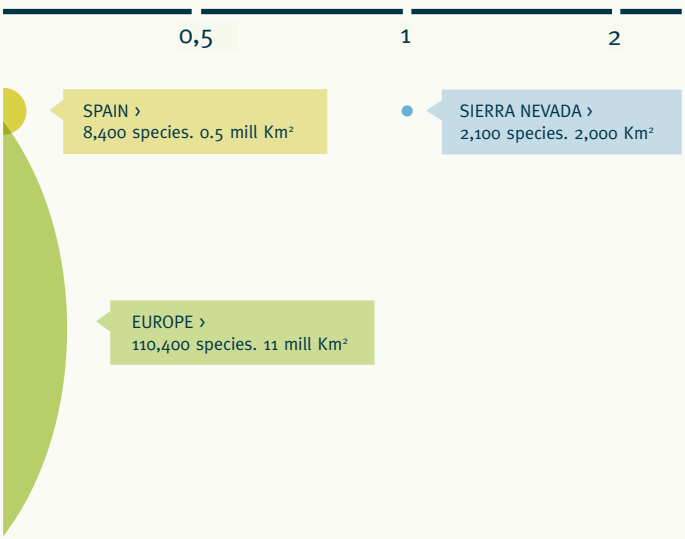


PLANT DIVERSITY OF SIERRA NEVADA

03

This mountain hosts 2100 vascular plant species, representing 25% of Spanish flora and 20% of European flora.

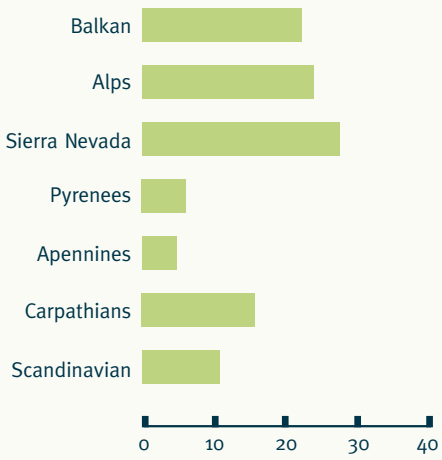
Plant Species number / area rate



SPECIES OF COMMUNITY INTEREST (HABITATS DIRECTIVE)

04

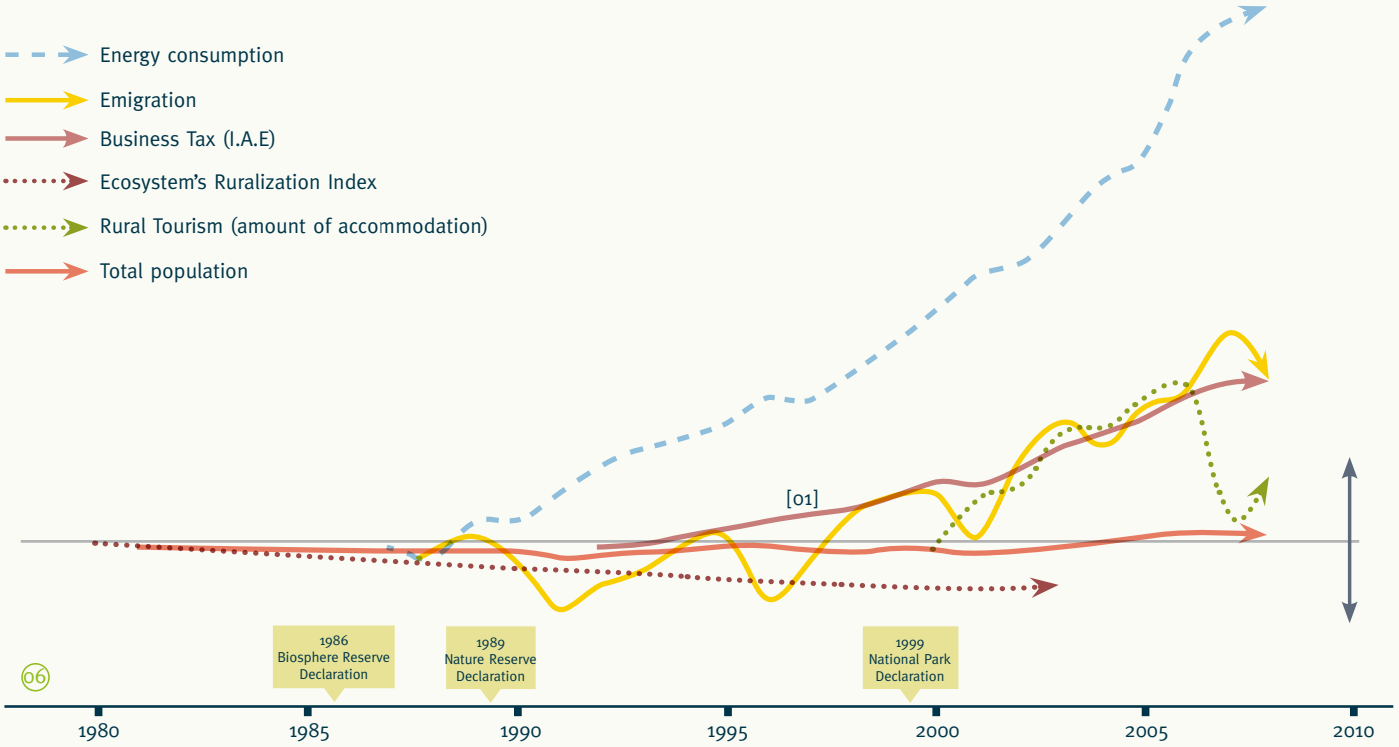
Sierra Nevada shows a particularly high number of endemic Species of Community Interest listed in Annexes II and IV of the EU Habitats Directive.



Number of endemic Species of Community Interest

Socioeconomic context

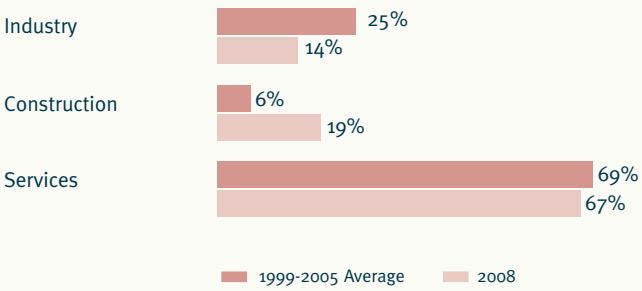
Evolution of several socioeconomic variables



This graph shows the evolution of several socioeconomic variables from 1980 to 2008. Ever since the creation of both the Nature Reserve and National Park, the number of companies and professionals removed from the IAE has been increasing. The accommodation index in rural tourism has increased noticeably, although it has fallen in relation to demand. Growing migration in the area, while the population remains stable or even increases, suggests the influence of immigration together with the natural movement of the population (births - deaths). On the other hand, the ruralization of ecosystems has been declining so they are increasingly less disturbed. This may be because of a progressive abandonment of rural areas in recent decades.

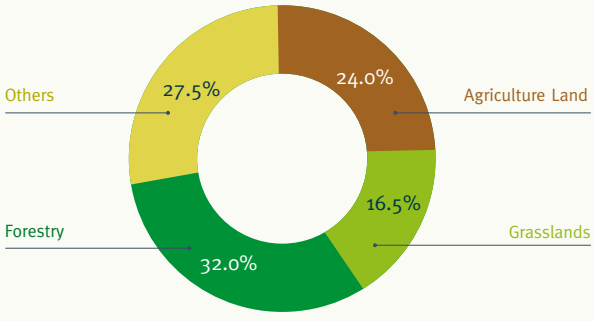
TEMPORAL VARIATION OF SECTORS OF ECONOMIC ACTIVITIES [01]

07



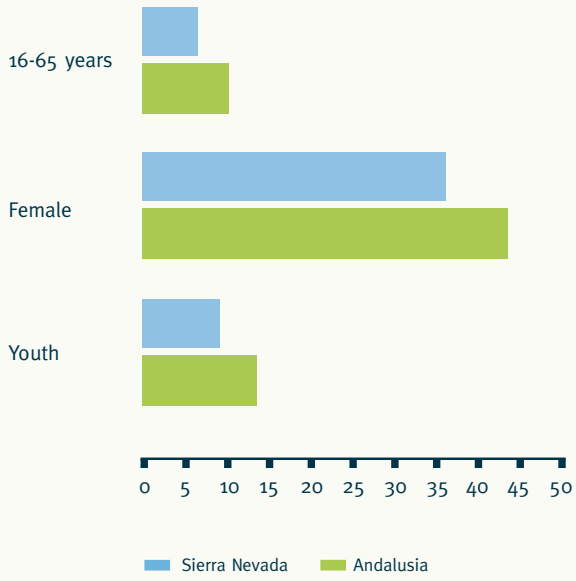
LAND USE IN SIERRA NEVADA

08



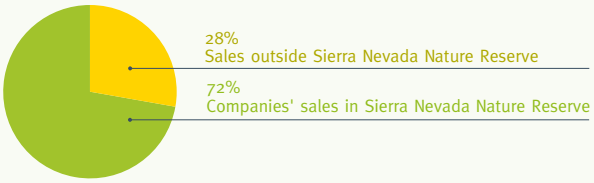
UNEMPLOYMENT PERCENTAGE PER SECTOR [01]

09



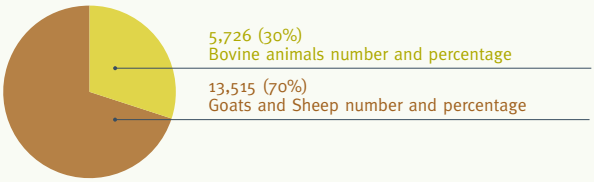
SALES OF COMPANIES IN SIERRA NEVADA

10



LIVESTOCK IN SIERRA NEVADA

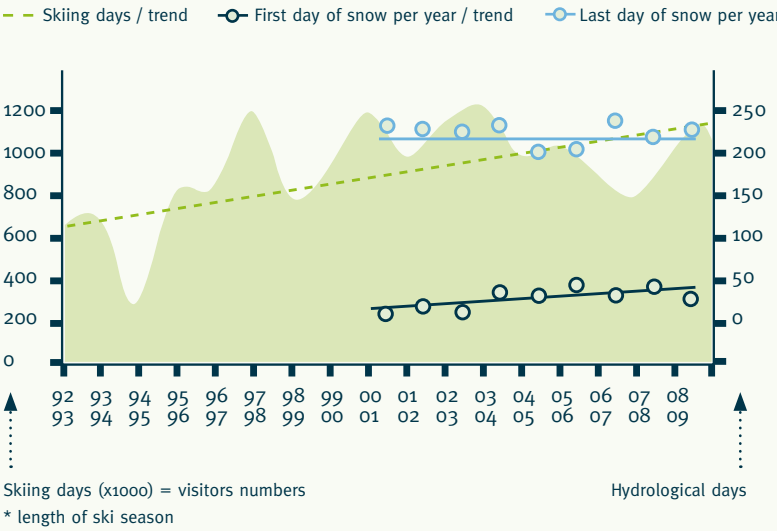
11

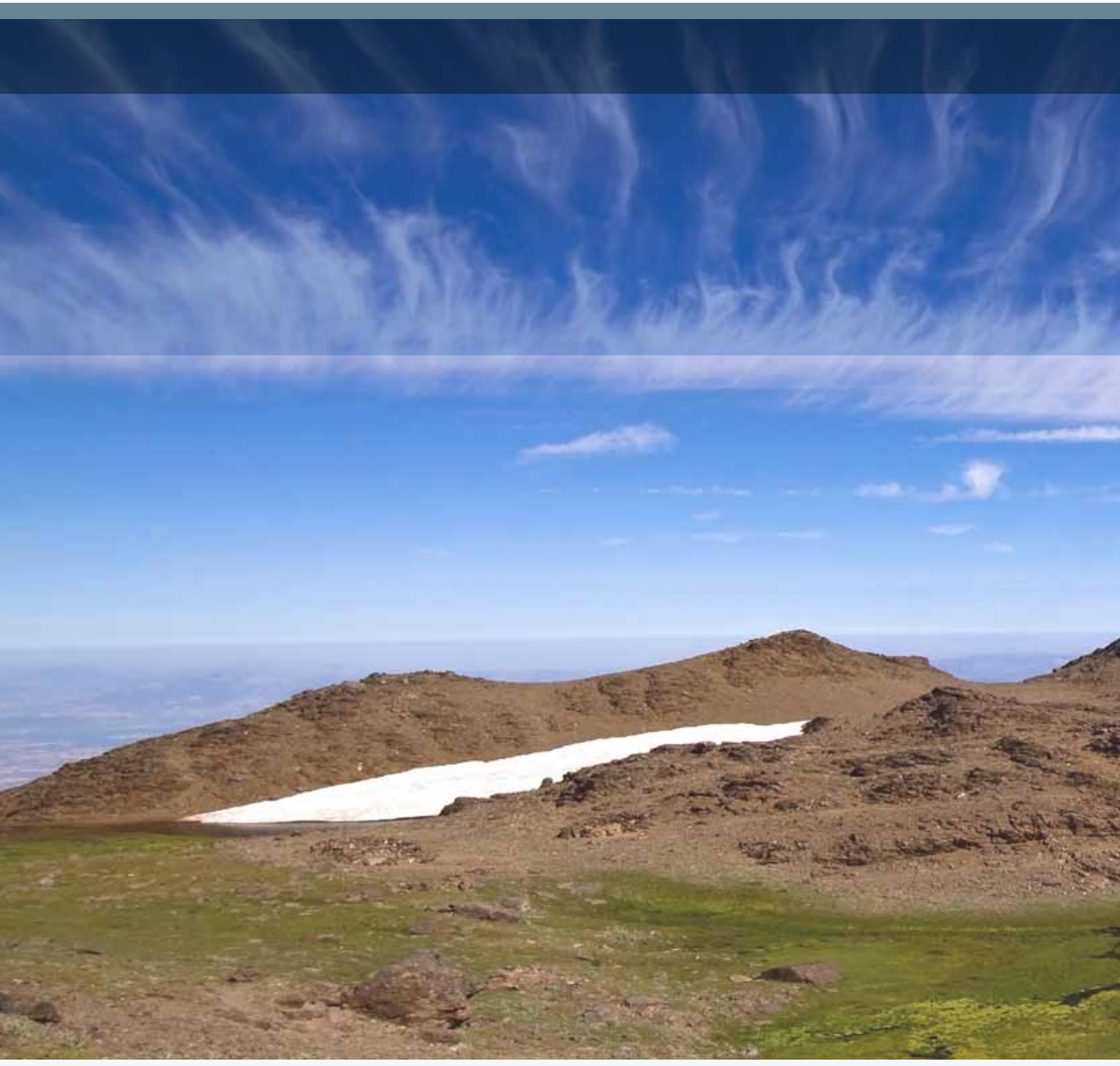


CLIMATE CHANGE AND LENGTH OF SKI SEASON

12

The figure shows the number of days skiing compared to duration of snow in the ski resort (obtained through remote sensing. MODIS images). Although skiing days have increased, the duration of snow cover appears to have declined in the last 10 years. This means that artificial snow will play a greater role in future





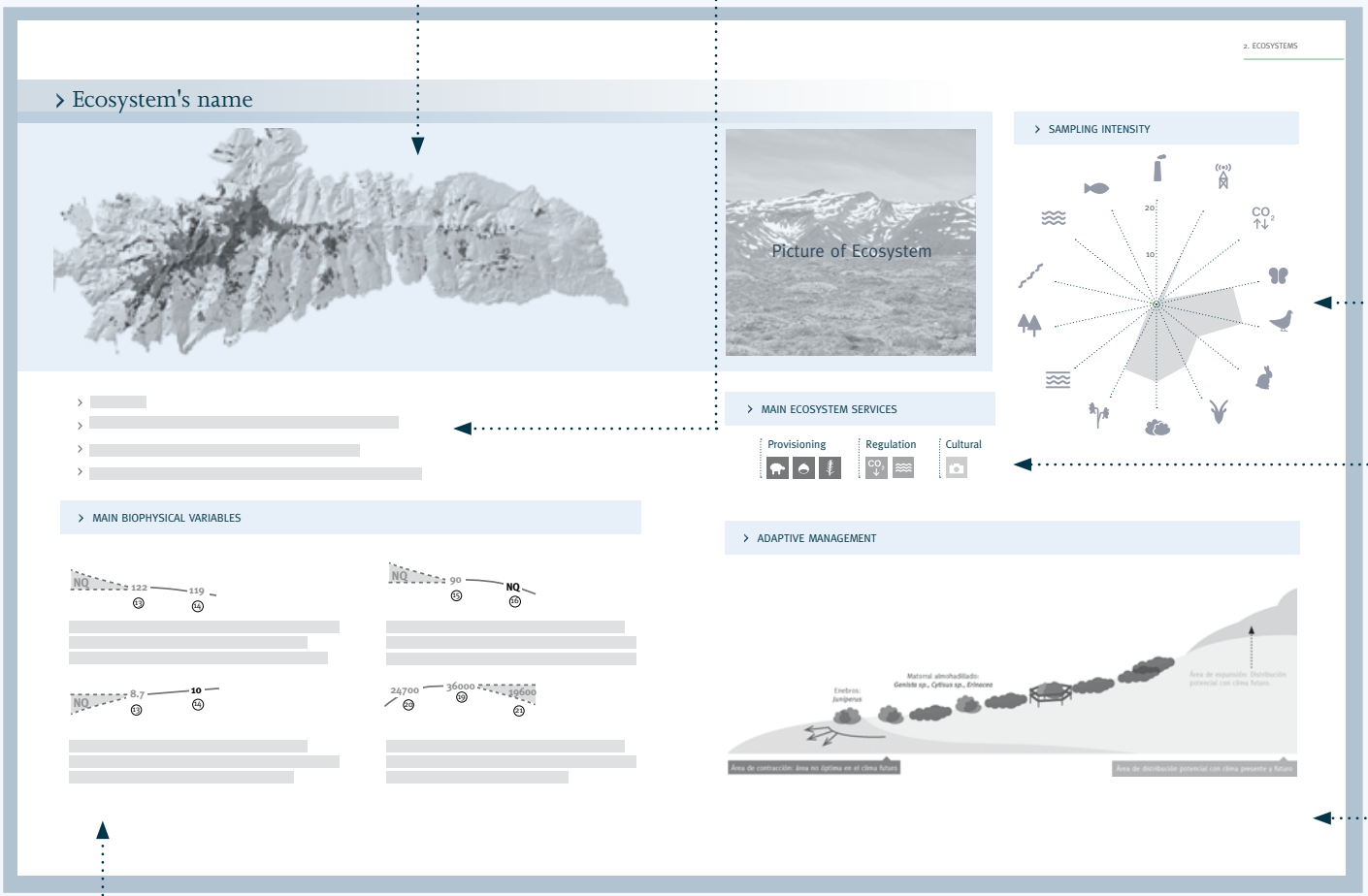
Ecosystems

High mountain wet grasslands
High mountain grasslands
Natural forest
High mountain shrubland
Mid mountain shrubland
Pine plantations
Aquatic systems

Keys to understanding ecosystem sheets

Ecosystem distribution map

General features of each ecosystem



We are showing different biophysical variables considered important for defining the conservation status of each ecosystem. The information is displayed according to three temporal scenarios: recent past (1950), present and future (2050)

Relevant ecosystem services provided

Provisioning

- Livestock
- Rocks for traditional building
- Fruit collection
- Honey
- Energy
- Aromatic and medicinal plants
- Biomass, wood and firewood
- Mushroom production
- Drinking and irrigation water

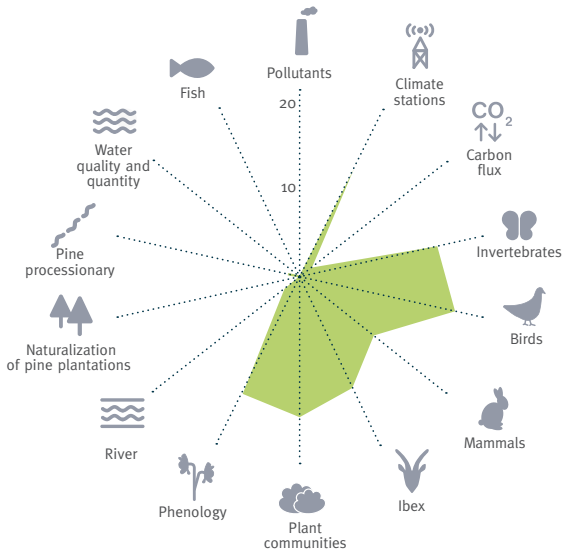
Regulation

- Water regulation
- Conservation soil
- Carbon sink

Cultural

- Recreational uses
- Angling
- Hunting

Ecosystem sampling intensity



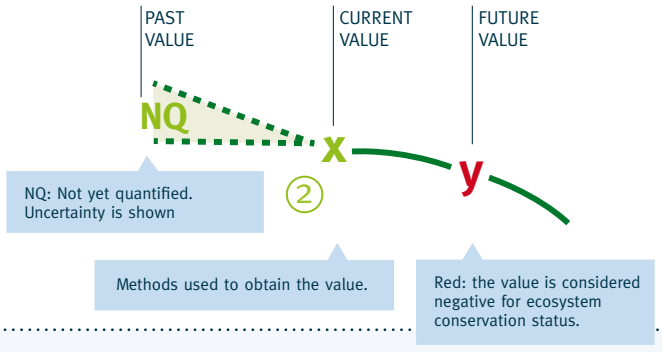
Ecosystem sampling intensity. This diagram shows the number of sampling points in each ecosystem type which correspond to the monitoring program's different methodologies. It shows the effort dedicated to characterising both the structure and functioning of different ecosystems in Sierra Nevada.

Adaptive management case studies

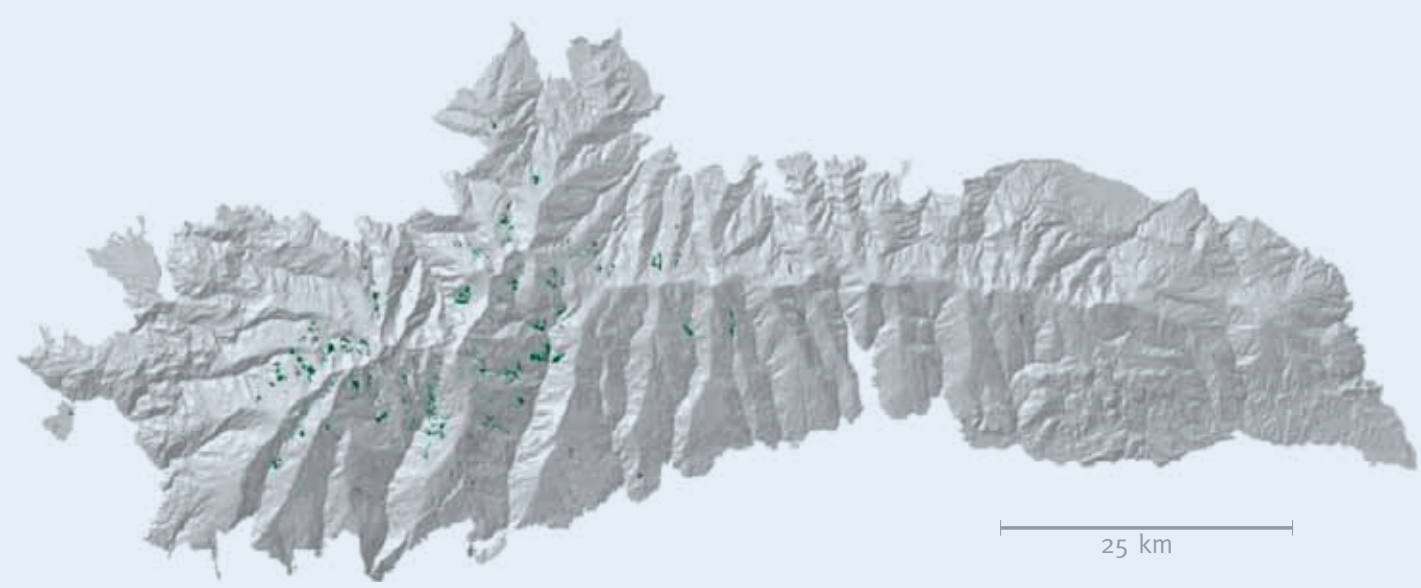
Past value: The value of the variable in the early 20th century.

Current value: The value of the variable in the late 20th century.

Future value: The expected values of the variable in the first half of this century.



High mountain wet grasslands



- 1,125 ha
- Edapho-hygrophilous vegetation, wet grassland, peatlands, water spring, etc.
- Its distribution is determined by the accumulation of meltwater. High rate of plant endemicity.

MAIN BIOPHYSICAL VARIABLES

It is expected that **annual rainfall** (l/m²) will fall in the coming decades from 1322 l/m² year recorded from 1960-1990, to 1298 l/m2 for 2011-2040.

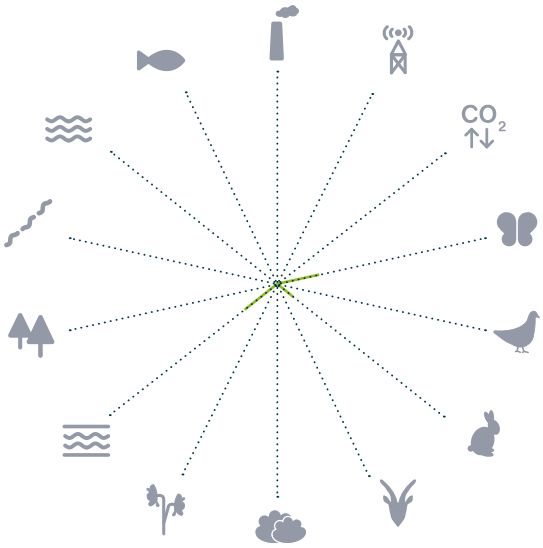
It is expected that the **average annual temperature** will increase in the coming decades from 7.8ºC recorded during 1960-1990, to 9.2ºC for 2011-2020.

Occupation area (Ha).
The abandonment of transhumance activities linked to the ecosystem may explain its reduction. It is expected to decline due to overgrazing.

Fodder production (kg dry matter/ha · year)
The observed reduction is due to overgrazing.

Average snow cover duration (days).
Although the trend is negative over the last decade, we do not have a time series long enough to quantify the long term trend.

SAMPLING INTENSITY



MAIN ECOSYSTEM SERVICES

Provisioning

Regulation

Cultural

ADAPTIVE MANAGEMENT

Past

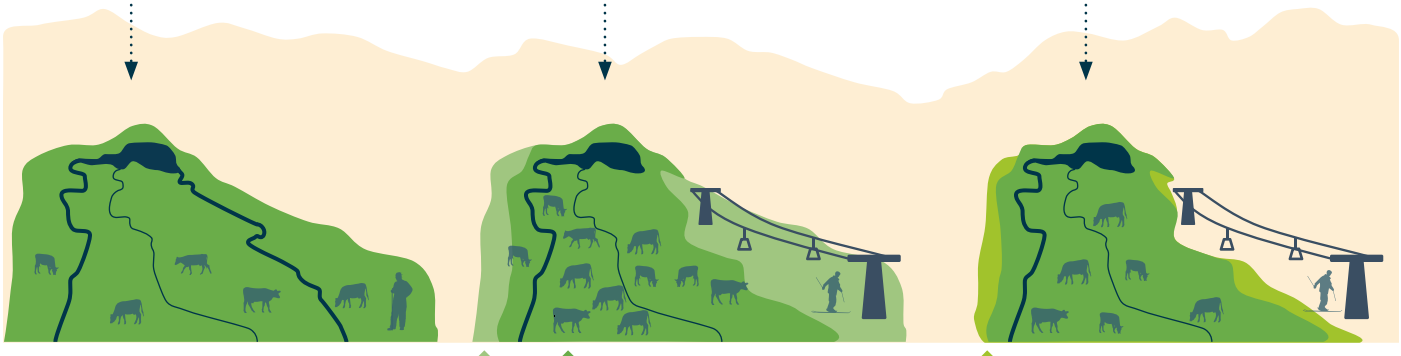
This ecosystem supported a livestock load in consonance with traditional rural activities (transhumance).

Present

Increased livestock pressure, land use change and climate change are factors causing a reduction in this type of ecosystem's area, as well as a significant decrease in grass production and degradation.

Futures

Management actions are intended to both reduce livestock and improve the water balance of this ecosystem.



Reduction in surface of ecosystem

Ecological degradation of ecosystem

Restoration of vegetation

High mountain grasslands

- 15,200 Ha
- High mountain grasses (Poaceae, Resedacea, etc.)
- Snow cover, wind and other abiotic factors are the main drivers of its ecological dynamics.

MAIN BIOPHYSICAL VARIABLES

It is expected that **annual rainfall** (l/m²) will fall in the coming decades from 1,312 l/m² year recorded from 1960-1990, to 1,282 l/m2 for 2011-2040.

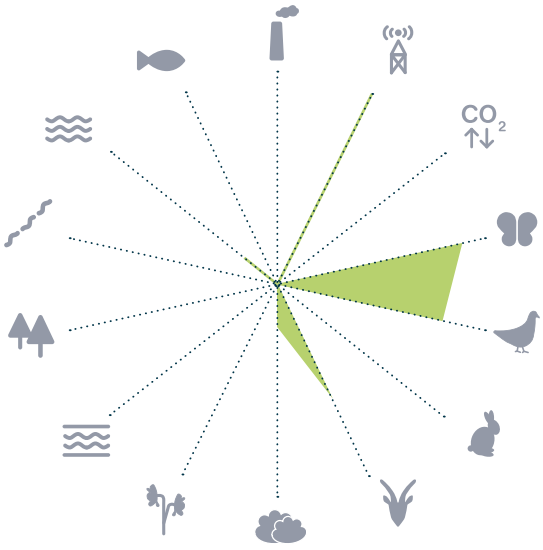
It is expected that the **average annual temperature** will increase in the coming decades from 7.8ºC recorded during 1960-1990, to 9.4ºC for 2011-2020.

Average snow cover duration (days). When analyzing last decade, the trend is negative. The reduction in snow cover duration has not been quantified yet.

Demographic trend of *Capra pyrenaica* in Sierra Nevada (ibex number / Km²). Due to scarcity of predators, a management plan has been implemented for the species, with health controls and population regulations.

Occupation area (Ha). Climate change is expected to cause a reduction in the occupation area. Future simulations predict a total loss of the potential area of this formation.

SAMPLING INTENSITY



MAIN ECOSYSTEM SERVICES

Provisioning

Regulation

Cultural

ADAPTIVE MANAGEMENT

Current situation. Veleta's summit before the restoration activities.

Simulation of appearance after restoration activities.

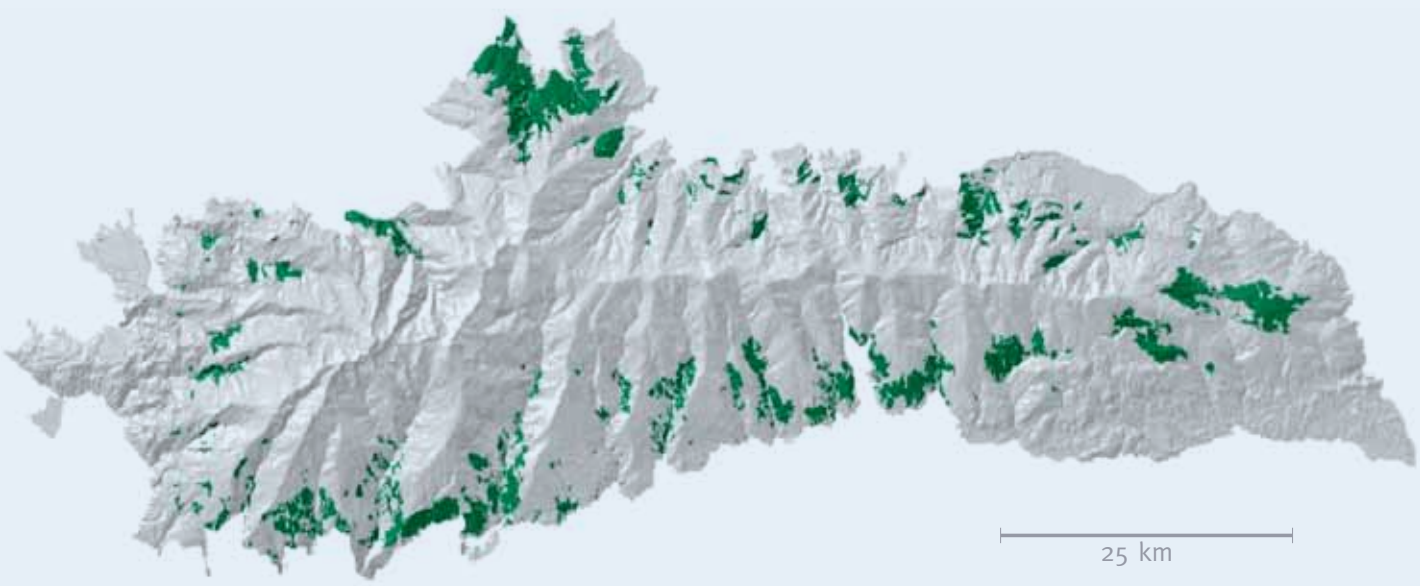
One of the most important management tasks to improve the conservation status of high mountain grasslands is **restoration at landscape level**. These actions try to **minimize the impact of past human activities**, such as building of infrastructures, waste accumulations and plant cover destruction.

The aim is to remove some elements (asphalt, antennas, buildings,) that reduce the quality and naturalness of the landscape.

Some restoration activities:

- Topographic restoration of roads
- The removal of solid waste in high mountain grasslands
- Asphalt removal over more than 3,500 m
- Plant cover restoration
- To restrict monitored vehicle access to mountain peaks

Natural Forest

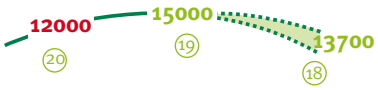


- 15,000 Ha
- Mainly holm oaks *(Quercus ilex)*, Pyrenean oak *(Q. pyrenaica)* and autochthonous Scot pine *(Pinus sylvestris* subsp. *nevadensis)* forest.
- Overexploitation and land use changes in the past are the most important drivers nowadays.

MAIN BIOPHYSICAL VARIABLES

It is expected that **annual rainfall** (l/m²) will fall in the coming decades from 935 l/m² a year recorded from 1960-1990, to 925 l/m2 for 2011-2040.

It is expected that the **average annual temperature** will increase in the coming decades from 11.6ºC recorded during 1960-1990, to 13ºC for 2011-2020.

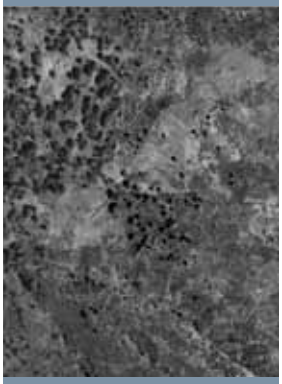


Occupation area (Ha). The observed increase is explained by the abandonment of rural areas in the last decades. Future simulations predict a 5% and 25% reduction in potential area for holm oak and Pyrenean forest respectively.

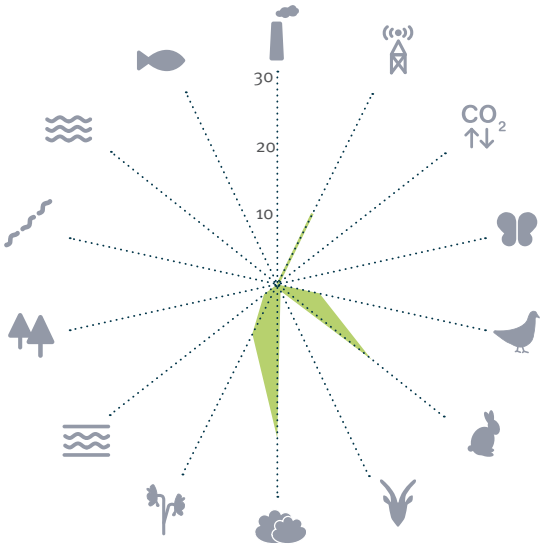
Average density of tree cover (number of trees per Ha). It is expected to increase due to the regeneration processes after abandonment of rural areas.

Marginal crops in 1956 (Dílar river valley)

Regeneration of Q. pyrenaica forest *in 2009*



SAMPLING INTENSITY



MAIN ECOSYSTEM SERVICES

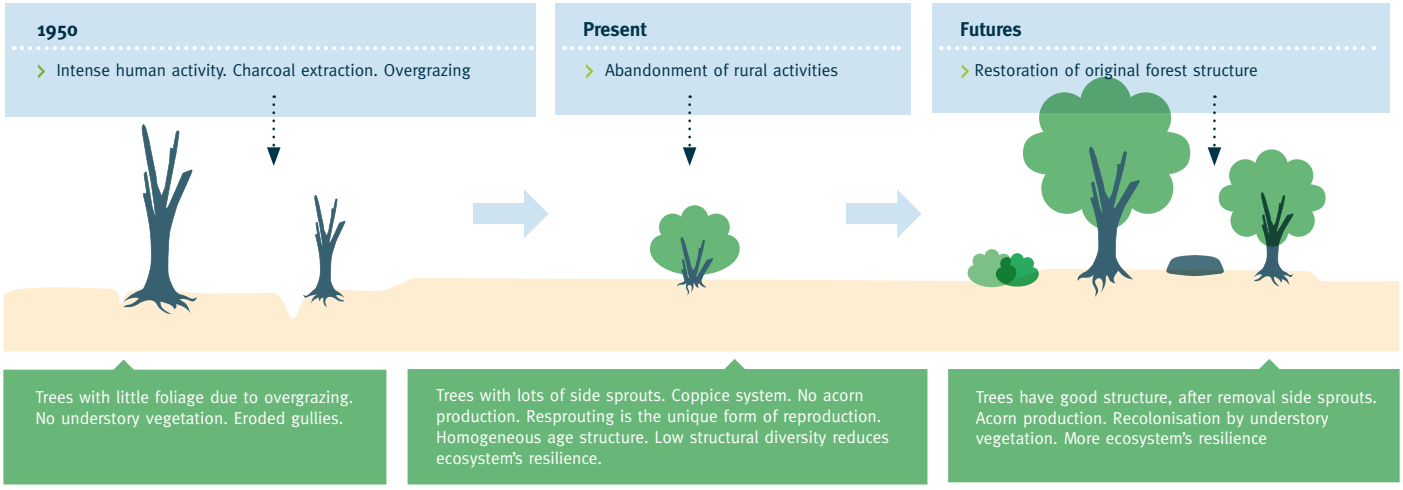
Provisioning

Regulation

Cultural

ADAPTIVE MANAGEMENT

Land use changes in the last decades are still affecting ecological dynamics and the structure of natural forests in Sierra Nevada. In the 1950s, overgrazing and charcoal extraction resulted in degradation of soil and vegetation cover. After abandonment of these rural activities, oak forests began a resprouting process up to the current situation (no understory vegetation, bush-like trees, etc.). Pruning forest actions will improve forest structure by removing side shoots and promoting well-structured tree formation.



High mountain shrubland

- 36,000 Ha
- Thorny shrubs, juniper-genista thickets.
- Highest woody ecosystem of Sierra Nevada. Its distribution seems to be determined by snow cover.

MAIN BIOPHYSICAL VARIABLES

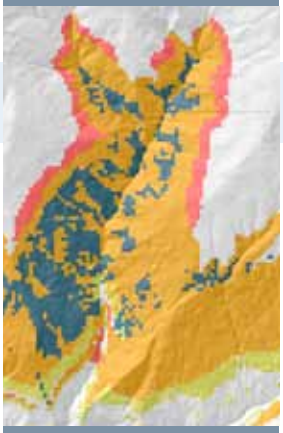
It is expected that **annual rainfall** (l/m²) will fall in the coming decades from 1,221 l/m² a year recorded from 1960-1990, to 1,195 l/m2 for 2011-2040.

It is expected that the **average annual temperature** will increase in the coming decades from 10.4ºC recorded during 1960-1990, to 11.7ºC for 2011-2020.

Average snow cover duration (days). The trend is negative if the past decade is analyzed. The reduction in snow cover duration has not been quantified yet.

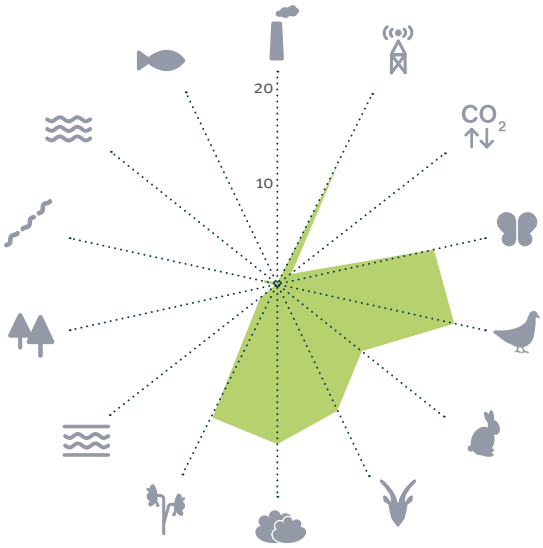
Occupation area (Ha). Decrease of wildfires and overgrazing explains how the area increased from 1956 to present day. For juniper-thickets, climate change scenarios predict a 30% reduction in potential habitat. However, genista-thickets seem to suffer a surface expansion.

POQUEIRA RIVER VALLEY



- Present distribution
- Potential distribution regarding future climate (expansion area)
- Potential distribution regarding present and future climate
- Potential distribution only with current climate (contraction area)

SAMPLING INTENSITY



MAIN ECOSYSTEM SERVICES

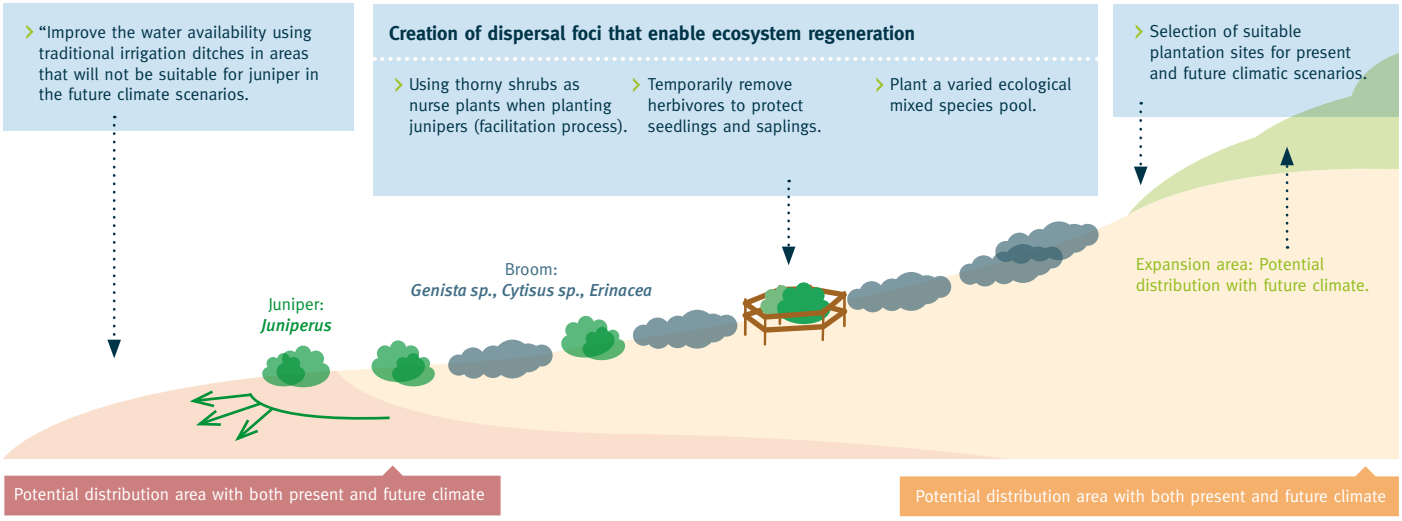
Provisioning

Regulation

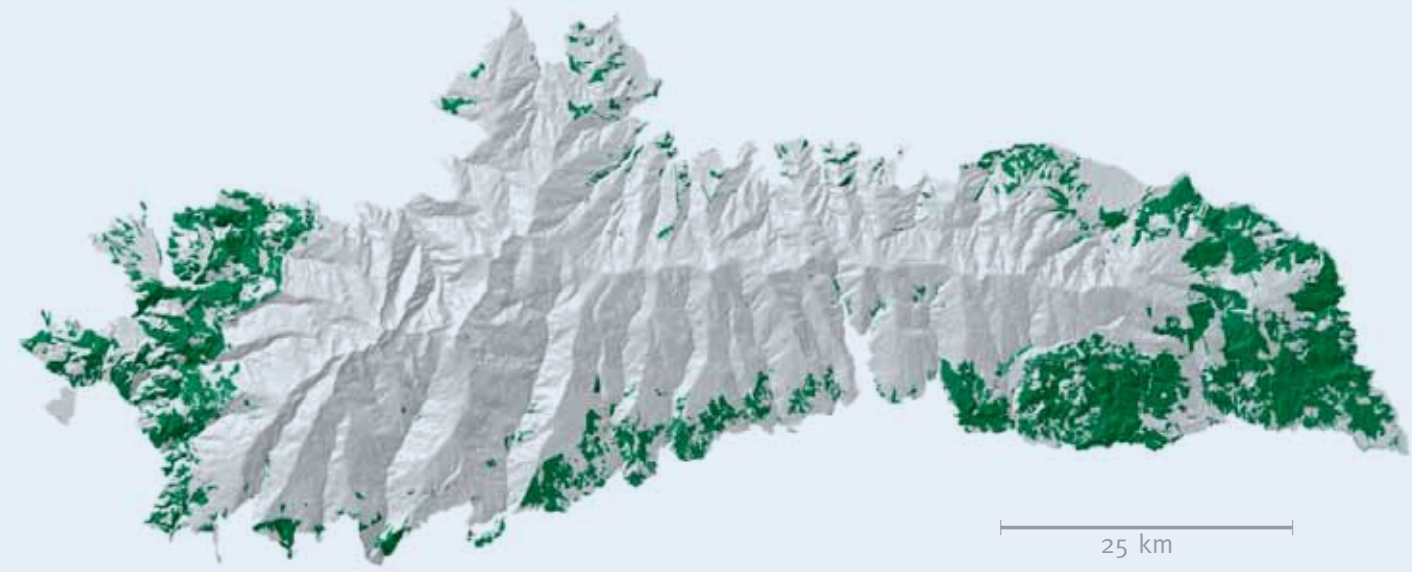
Cultural

ADAPTIVE MANAGEMENT

Threatened ecosystem due to climate change and land use changes in the last decades. In order to both avoid loss in its distribution area and to improve its conservation status, we are implementing active and adaptive management actions which are introducing new concepts (uncertainty, future dynamic vision) in the traditional environmental management of Sierra Nevada. We are also trying to transfer the best scientific available knowledge from ecological science to forestry management. Some examples are outlined below.



Mid mountain shrubland



- 30,000 Ha.
- Mainly aromatic *(Rosmarius, Thymus)* and some pyrophytes *(Ulex, Cistus, etc)* species.
- Its ecological dynamics are conditioned by factors such as grazing and recurrent wildfires

MAIN BIOPHYSICAL VARIABLES

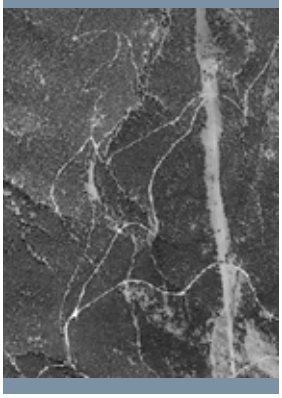
It is expected that **annual rainfall** (l/m²) will fall in the coming decades from 790 l/m² a year recorded from 1960-1990, to 788 l/m2 for 2011-2040.

Average annual temperature (ºC). The increase of temperature in the coming decades may be one of the most important stress factors for this ecosystem.

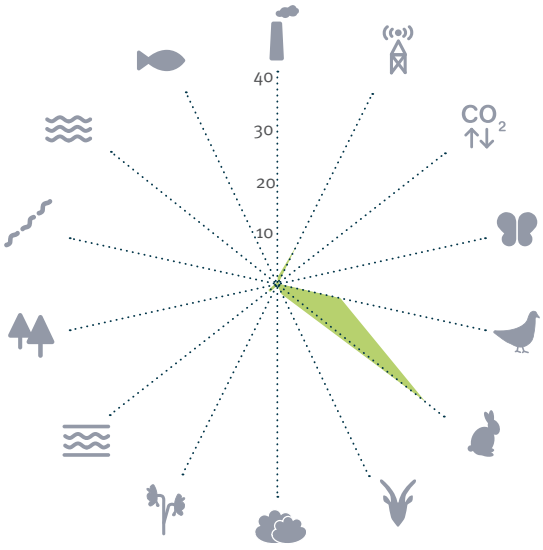
Occupation area (Ha). Pine forests were planted over highly degraded shrublands. This explains the decline in occupation area. It is expected to increase due to the naturalization process of pine plantation and occupation of marginal areas.

Degraded shrublands in 1956

Pine plantations in 2009



SAMPLING INTENSITY



MAIN ECOSYSTEM SERVICES

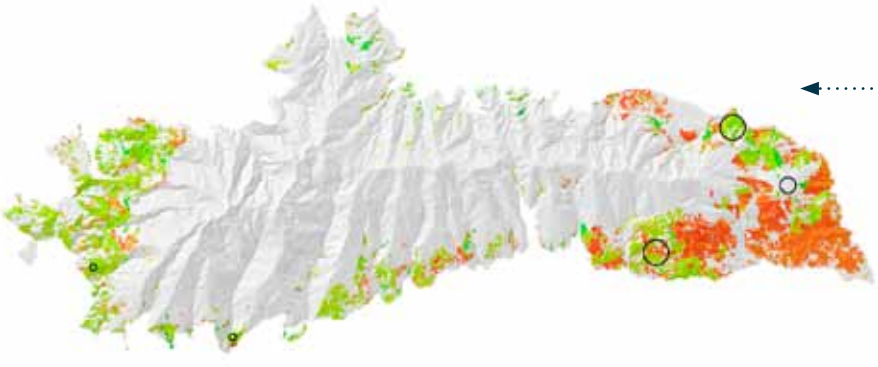
Provisioning

Regulation

Cultural

ADAPTIVE MANAGEMENT

Beekeeping is a good example of adaptive management. Environmental managers offer beekeepers some places to establish their apiaries. Land assignment is free for beekeepers, since it is considered that this activity contributes to plant pollination. The map shows land suitability to host apiaries. It is based on a model that takes into account some determining factors, such as: rainfall, temperature, accessibility, water availability and the honey's flora presence.



Green colours show high suitability areas. Red colours show unsuitable areas. The black circles indicate distribution of apiaries, with size proportional to number of hives per apiary.

The most interesting result of this model is that there are several places in Sierra Nevada that could be occupied by apiaries under an adaptive management scenario.

Pine plantations

- 40,000 Ha
- Planted between 1930-1980 to minimize soil loss in deforested areas.
- Several pine species *(Pinus sylvestris, P. pinaster, P. halepensis, P. nigra)*.
- Currently being replaced by natural vegetation due to adaptive management actions (partial clear-cuts).

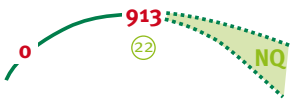
MAIN BIOPHYSICAL VARIABLES

It is expected that **annual rainfall** (l/m²) will fall in the coming decades from 1,005 l/m² a year recorded from 1960-1990, to 992 l/m2 for 2011-2040.

It is expected that the **average annual temperature** will increase in the coming decades from 10.4ºC recorded during 1960-1990, to 11.7ºC for 2011-2020.

Average snow cover duration (days). When analyzing the past decade, the trend is negative. The reduction in snow cover duration has not been quantified yet, although it seems less important here compared to other ecosystems.

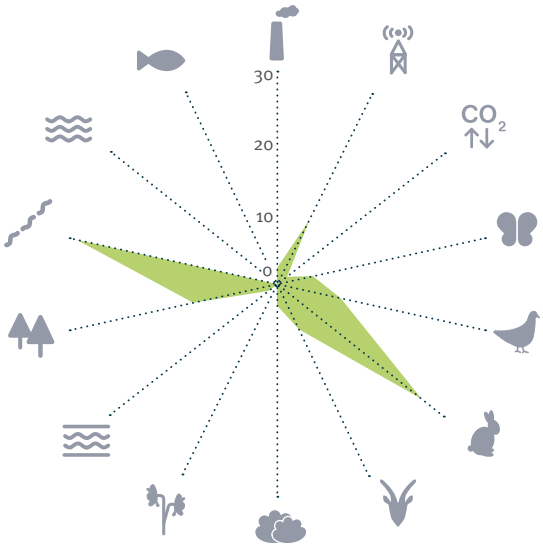
Average number of plant species. Diversity was lower in the past due to both the high rate of erosion and misuse of natural resources. It will be increased by adaptive management.



Average density of tree cover (number of trees per Ha). It is expected to decrease due to management actions (partial clear-cuts).

Occupation area (Ha). Increase due to plantations during the 1960s and 70s. Thanks to management actions the area will decrease in coming decades, becoming a mixed pine-oak forest.

SAMPLING INTENSITY



ADAPTIVE MANAGEMENT

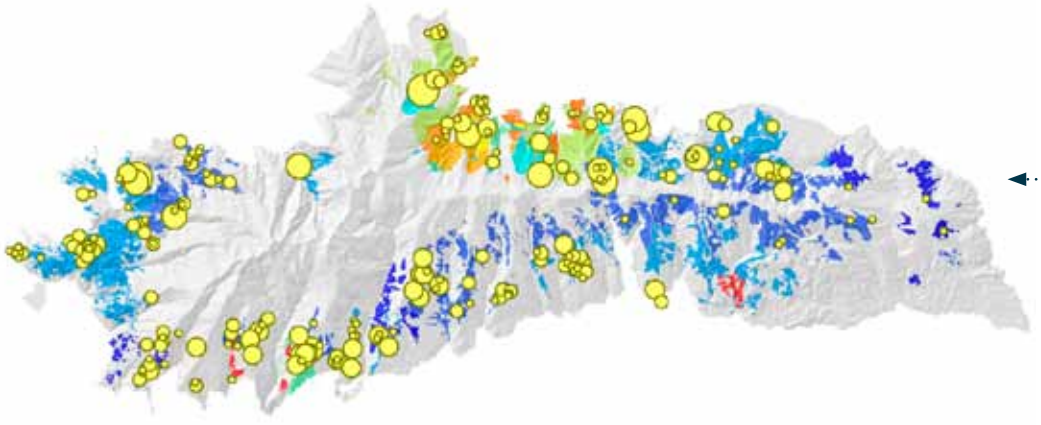
Pine plantations are being replaced by natural vegetation, which is much more resilient and better adapted to the landscape's natural features. Clear-cuts are the main management actions that are driving these “artificial forests” to a more natural mixed forest.

MAIN ECOSYSTEM SERVICES

Provisioning

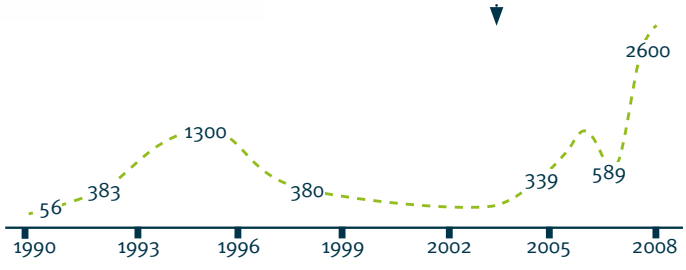
Regulation

Cultural



The map shows the approximate date (year) of each plantation. We also show the location of the clear-cuts.

The graph shows the number of hectares treated by clear-cuts per year.



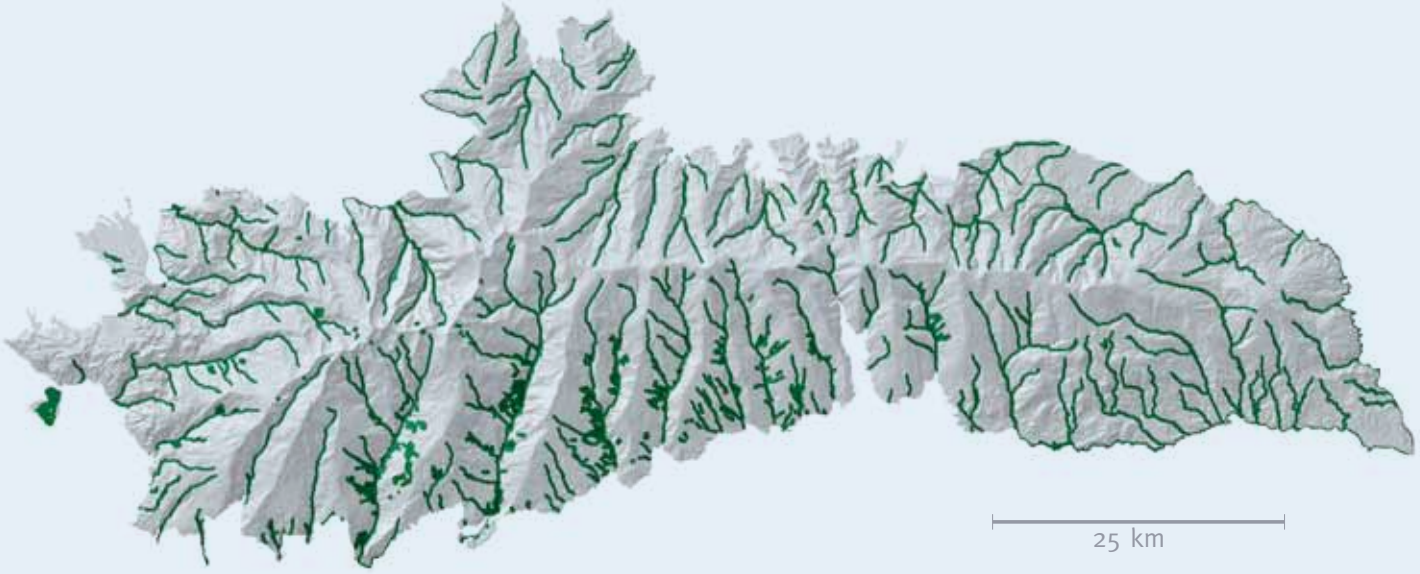
Plantation year

- 1935
- 1936-1948
- 1949-1957
- 1958-1959
- 1960-1963
- 1964-1965
- 1966-1969
- 1970-1973
- 1974-1976
- 1977-1980

Clear-cut area (Ha)

- 1.6-20
- 20-41
- 41-87
- 87-205
- 205-397

Aquatic systems



- 1,700 Ha
- Mountain rivers, glacial lakes, irrigation ditches, Riparian forest, etc.
- The spring and summer snowmelt contributes greatly to water flow.

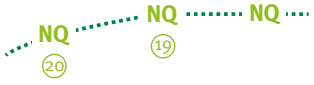
MAIN BIOPHYSICAL VARIABLES

Riparian Quality Index average (RQI. From 0 to 100). The abandonment of rural areas and management actions have helped enhance the conservation status of the Riparian forest.

Biological Quality of Riparian environment (Iberian Biological Monitoring Working Party. From 0 to 200). This index measuring water quality using species of macro invertebrates as biological indicators. It is expected to increase due to the adaptive management of this ecosystem.

River Habitat Index average (IHF. From 0 to 100). This index characterises the physical habitat of Mediterranean streams and shows the heterogeneity and structural diversity of rivers. It is expected to increase due to improvements in river water flow.

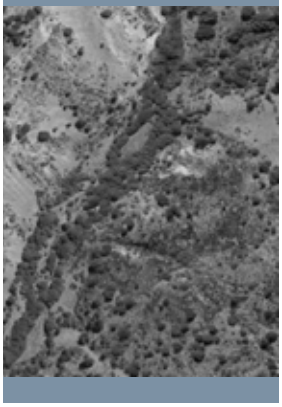
Increase in total length (%) of trout populations ***(Salmo trutta)***. Management actions will improve the conservation status of this species in the coming decades.



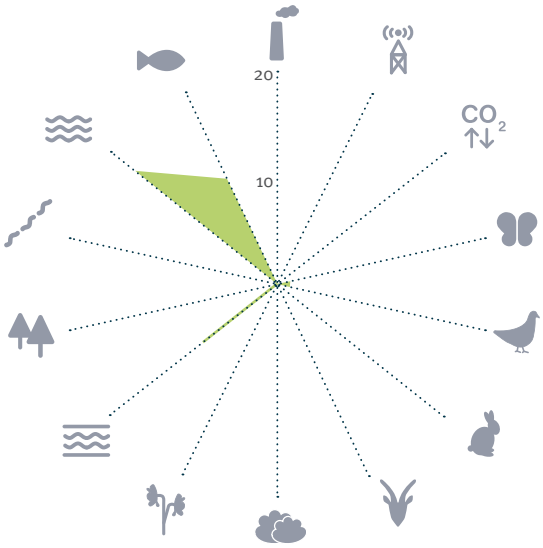
Increase in **density of Riparian forest** probably due to the abandonment of rural areas close to the rivers. Restoration activities are helping to increase the occupation areas of aquatic systems in Sierra Nevada.

Degraded Riparian forest in 1956 (Dílar river)

Regenerated Riparian forest in 2009 (Dílar river)



SAMPLING INTENSITY



MAIN ECOSYSTEM SERVICES

Provisioning

Regulation

Cultural

ADAPTIVE MANAGEMENT

Sierra Nevada rivers have a large population of brown trout *(Salmo trutta)*. These populations represent the southern limit of this species in Europe, which means that there are specific genetic patterns in Sierra Nevada. Several decades ago anglers introduced adult rainbow trout *(Oncorhynchus mykiss)* specimens. This species (native in Northwest America) behave as an invasive species in Mediterranean rivers. Nowadays, it is the main threat to native trout conservation. Management actions try to improve the conservation status of brown trout and the gradual eradication of rainbow trout populations.

Alien species: Rainbow trout
(Oncorhynchus mykiss)

Autocthonous species: Brown trout
(Salmo trutta)

- Disease transmission
- Predation of grilse
- Habitat and food competition
- Reproductive interference

Management actions to improve the conservation status of brown trout

- Delimiting the extent of rainbow trout populations
- Reducing the presence of refuges for rainbow trout in rivers
- Raking spawning grounds to avoid the rainbow trout's reproduction success
- Extraction by electrofishing of rainbow trout
- Population reinforcement of brown trout

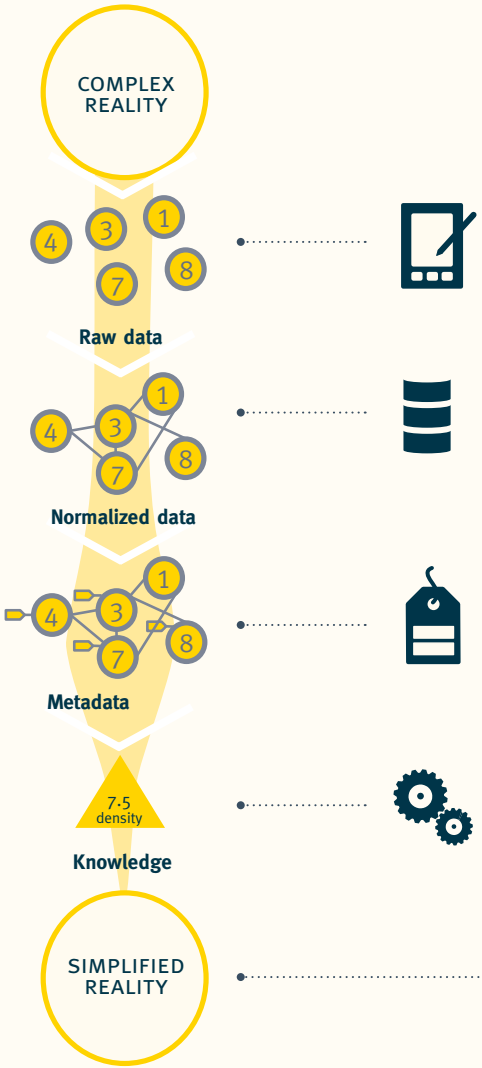
Data Processing and Dissemination of Results

Information Management System

The information system associated with the Sierra Nevada Global Change Observatory is designed as a repository for storing both raw data gathered by the monitoring program and knowledge generated through the processing of such data.

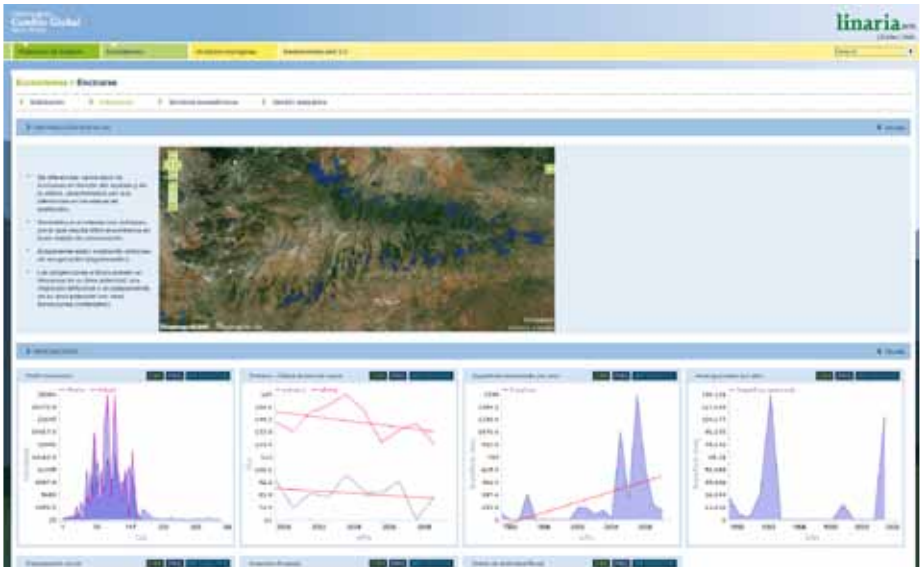
The aim is to provide all this information to managers, scientists and society in general. The main idea is to store the data in a standardised and documented way to facilitate its integration and further analysis. This process generates useful knowledge for decision making.

The diagram below shows the evolution from raw data to that knowledge. The thickness of the central line represents the volume of information in each of the phases. The standardised and documented raw data occupies more "volume" that the knowledge obtained on synthetic analysis. Further information: http://sl.ugr.es/repositorio.



- Through mobile devices such as PDAs, data capture on environmental variables is performed. ***CyberTracker*** software is used for its easy handling.
- The data is stored in normalized databases according to the relational database model, which enables compatibility with other sites and sharing this information with them.
- Metadata enables data documentation through its labelling. That way we can establish who generated the data, how it is ordered, when it was taken, etc. We use several metadata international standards (http://sl.ugr.es/metadatos).
- Through various analytical techniques (data mining, multi-criteria evaluation, statistical analysis, etc.) raw data is transformed into useful knowledge to make decisions in the territory.

[A]



[C]

[B]

[D]

› The knowledge generated therefore is available to users through the use of different techniques. The maps are distributed through web services. On the other hand, dynamic graphics (figure A) that show the temporal variation of the status indicators of Sierra Nevada are generated. The web 2.0 tools allow collaborative editing of texts through a wiki (http://observatoriosierranevada.iecolab.es, figure B), cooperative management of the bibliography (http://refbase.iecolab.es, figure C) and spreading of multimedia content (http://sl.ugr.es/canal_sshare; http://sl.ugr.es/canal_scivee, figure D).

Outreach and Dissemination of results

The Sierra Nevada Global Change Observatory is principally committed to the dissemination of updated results. We consider essential the existence of a central communication forum involving different players: scientists, managers and the general public. To carry out this task, a ***collaborative working environment*** has been created which combines traditional methods of communication with the use of new technologies (Web 2.0 tools). They help speed up the transfer of updated scientific knowledge to both managers and society and improve collaboration between different teams working on the project. We therefore use different communication-dissemination channels that allow us:

- **To improve the acquisition and creation of useful knowledge for management**
- **To improve collaboration amongst work teams**
- **To increase the availability of updated project results**

WIKI: http://observatoriosierranevada.iecolab.es

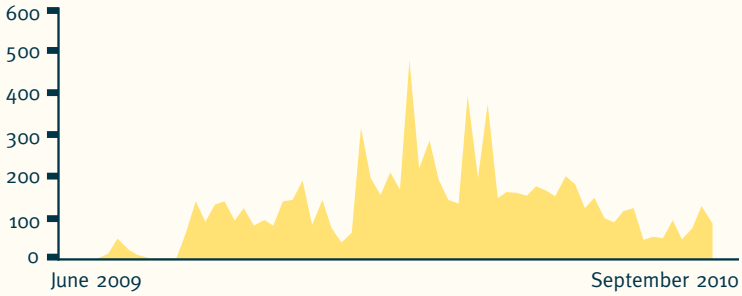
Website that enables both collaborative creation and the editing of content easily by many users. Our wiki supports both coordination activities within the project and sharing files and documents, acting as an information repository. It allows the dissemination of updated results to the managers of natural resources and to the general public.

Origin of visitors:
49 countries
469 cities

Highlights:
46,000 visitors
72 users
157 pages
609 shared files

Percentage of Visitors:
New (green)
Returning (brown)

Temporal variation of visits (numbers)



PUBLISHING DOCUMENTS THROUGH WEB 2.0 TOOLS

Youtube channel of the Sierra Nevada Global Change Observatory.

Use of dissemination of content channels in different web 2.0 platforms, in which documents, presentations, videos, etc. are published on various training activities and conferences organised by the Sierra Nevada Global Change Observatory. This enterprise has got communication channels on the following platforms:

- **SlideShare**
  http://sl.ugr.es/canal_sshare
- **Slideboom**
  http://sl.ugr.es/canal_sboom
- **Scivee Science Videos**
  http://sl.ugr.es/canal_scivee
- **Youtube**
  http://sl.ugr.es/canal_youtube

SOCIAL NETWORK

- **Twitter**
  http://sl.ugr.es/red_twitter
- **Facebook**
  http://sl.ugr.es/red_facebook

TRAINING ACTIVITIES, CONFERENCES, WORKSHOPS

29

We provide a **training activities process** through courses, workshops, conferences, with twin goals:

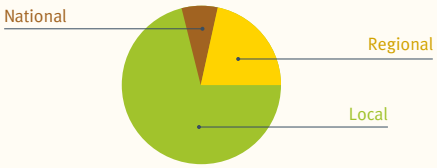
- **Updating the scientific-technical knowledge of the work team**
- **Sharing and exchange of technical knowledge and project development problems between the scientist and manager of natural resources to generate synergies between them and to improve the adaptive management of natural resources under an interdisciplinary view.**

Sierra Nevada Global Change Observatory Coordination Workshop.
June 2010

The value of mountain protected areas in the global change scenario.
Granada, May 2009

PUBLICATION OF SCIENTIFIC RESULTS IN DIFFERENT INTERNATIONAL FORUMS AND SPECIFIC JOURNALS

28



Articles in newspapers

Dissemination of updated results to general public through audiovisuals and news via several media channels (local, regional and national).

Methodologies and references

› Bibliography: methodologies and references

Interpretation of the colour code for reading this section:

Green› › Bibliography
Blue › Data Sources

01 Spatial distribution of ecosystems

- Mesa, J.; Pérez Raya, F.; López Nieto, J.M.; El Aallali, A. & Hita Fernández, J.A. (2001). Mapping and assessment of the vegetation of the Sierra Nevada Nature Reserve. Department of the Environment. Regional Government of Andalusia.
  http://sl.ugr.es/refbase_166
- Spain's Land Cover and Use Information System (SIOSE). Departments for the Environment, Agriculture and Fisheries and Public Works and Transport. Andalusian Regional Government.
  http://sl.ugr.es/siose

02 European mountain ranges: size, altitude, and total vascular plants, number and endemics.

- Blanca López, G.; López Onieva, M.R.; Lorite, J.; Martínez Lirola, M.J.; Molero Mesa, J.; Quintas, S.; Ruíz Girela, M.; Varo, M.A. & Vidal, S. (2001). Threatened and endemic flora of Sierra Nevada. University of Granada. Department of the Environment. Regional Government of Andalusia.
  http://sl.ugr.es/refbase_934
- Blanca, G.; Cueto, M.; Martínez-Lirola, M.J. & Molero-Mesa, J. (1998). Threatened vascular flora of Sierra Nevada (Southern Spain). *Biological Conservation*, 85 (3): 269–285.
  http://sl.ugr.es/refbase_302
- CERI (Carpathian EcoRegion Initiative) (2001). The Status of the Carpathians. Vienna, Austria WWF Carpathian & Danube Programme.
  http://sl.ugr.es/refbase_1446
- *Gambino, R. & Romano, B. (2003). Territorial strategies and environmental continuity in mountain systems: The case of the Apennines (Italy). In World Heritage Mountain Protected Area Field Workshop. Linking Protected Areas along the mountain range. Durban, South Africa, 5-8 September 2003.*
  http://sl.ugr.es/refbase_1450
- *Nagy, L.; Grabherr, G.; Körner, C. & Thompson, D.B.A (eds). (2003). Alpine biodiversity in Europe. Ecological Studies, 167. Springer. 477 pp.*

03 Plant Diversity in Sierra Nevada

- Blanca, G. (1991). Botanical Jewels of Sierra Nevada. La Madraza. Granada. 171 pp.
- Blanca López, G.; López Onieva, M.R.; Lorite, J.; Martínez Lirola, M.J.; Molero Mesa, J.; Quintas, S.; Ruíz Girela, M.; Varo, M.A. & Vidal, S. (2001). Threatened and endemic flora of Sierra Nevada. University of Granada. Department of the Environment. Regional Government of Andalusia.
  http://sl.ugr.es/refbase_934
- Blanca, G.; Cueto, M.; Martínez-Lirola, M.J. & Molero-Mesa, J. (1998). Threatened vascular flora of Sierra Nevada (Southern Spain). *Biological Conservation*, 85 (3): 269–285.
  http://sl.ugr.es/refbase_302
- Moreno-Saiz, J.C.; Domínguez Lozano, F. & Sainz Ollero, H. (2003). Recent progress in conservation of threatened Spanish vascular flora: a critical review. *Biodiversity and Conservation*, 113: 419–431.
  http://sl.ugr.es/refbase_469

04 Number of mountain species of community interest (annex II and IV of the EU habitats directive) endemic to mountain ranges

- *EEA (2010). Mountain ecosystems. In Biodiversity – 10 messages for 2010. European Environment Agency.*
  http://sl.ugr.es/bio_messages
- Department of the Environment (2010). The Natura 2000 network in the province of Granada. Unpublished. Provincial Delegation of the Environment, Department of the Environment. Regional Government of Andalusia. 166 pp.
  http://sl.ugr.es/refbase_934

- Natura 2000 data - the European network of protected sites. European Environment Agency.
  http://sl.ugr.es/natura2000

05 Comparison of species richness in European mountain ranges

- Blanca López, G.; López Onieva, M.R.; Lorite, J.; Martínez Lirola, M.J.; Molero Mesa, J.; Quintas, S.; Ruíz Girela, M.; Varo, M.A. & Vidal, S. (2001). Threatened and endemic flora of Sierra Nevada. University of Granada. Department of the Environment. Regional Government of Andalusia.
  http://sl.ugr.es/refbase_934
- Blanca, G.; Cueto, M.; Martínez-Lirola, M.J. & Molero-Mesa, J. (1998). Threatened vascular flora of Sierra Nevada (Southern Spain). Biological Conservation, 85 (3): 269–285.
  http://sl.ugr.es/refbase_302
- *Nagy, L.; Grabherr, G.; Körner, C. & Thompson, D.B.A (eds). (2003). Alpine biodiversity in Europe. Ecological Studies, 167. Springer. 477 pp.*

06 Temporal evolution of energy consumption, immigration, business tax (I.A.E.), ecosystem ruralization index. Capacity of rural tourism and population in Sierra Nevada. Time series from 1980 to 2008. 100 index (100 = first value of each variable in the time series)

- Fernández, M.; Cuenca, E.; Salinas, J.A.; Campos, J.; Aragón, J.A.; García, V.J.; Martín, J.M.; Aranda, J. & Vallberg, V. (2007). Socioeconomic impact on Sierra Nevada Nature Reserve: 1989-2005. Department of the Environment. Regional Government of Andalusia. Seville.
  http://sl.ugr.es/refbase_1061
- System of Multi-territorial Information of Andalusia (SIMA). Institute of Statistics of Andalusia.
  http://sl.ugr.es/SIMA_IEA

07 Percentage of companies from the services, construction and industry sectors. Time series: comparison between 1995-2005 period and 2008.

- Fernández, M.; Cuenca, E.; Salinas, J.A.; Campos, J.; Aragón, J.A.; García, V.J.; Martín, J.M.; Aranda, J. & Vallberg, V. (2007). Socioeconomic impact on Sierra Nevada Nature Reserve: 1989-2005. Department of the Environment. Regional Government of Andalusia. Seville.
  http://sl.ugr.es/refbase_1061
- Andalusian Economy. Economic Analysts of Andalusia.
  http://sl.ugr.es/datos_economia

08 Land use in Sierra Nevada municipalities, 2007.

- Andalusian Economy. Economic Analysts of Andalusia.
  http://sl.ugr.es/datos_economia

09 Unemployment rate of social sector, 2008.

- Andalusian Economy. Economic Analysts of Andalusia.
  http://sl.ugr.es/SIMA_IEA

10 Influence of National Park and Nature Reserve on turnover of companies in its area influence. Time series from 1999 to 2005.

- ***Fernández, M.; Cuenca, E.; Salinas, J.A.; Campos, J.; Aragón, J.A.; García, V.J.; Martín, J.M.; Aranda, J. & Vallberg, V. (2007). Socioeconomic impact on Sierra Nevada Nature Reserve: 1989-2005. Department of the Environment. Regional Government of Andalusia. Seville.***
  http://http://sl.ugr.es/refbase_1061

11 Number of livestock units (UGM) and percentage of each type for the 2007 census. Livestock population in Sierra Nevada.

- *Data from Regional Agricultural Offices provided by Sierra Nevada National Park*

12 Days of snow vs. natural snow duration

- Bonet García, F.J. & Cayuela Delgado, L. (2009). Monitoring snow cover in Sierra Nevada: trends over the last decade and their possible ecological implications. At 11th National Congress of the Spanish Association of Terrestrial Ecology: The ecological dimension of sustainable development: Ecology, from knowledge to application. Úbeda, 18-22 October 2009.
  http://sl.ugr.es/refbase_892
- Bonet García, F.J. (2009). Characterisation of snow cover in Sierra Nevada and temporal trends through the use of MODIS images (2000-2008).
  http://sl.ugr.es/refbase_1032

- Hall, D.K.; Riggs, G.A.; Salomonson, V.V.; DiGirolamo, N.E. & Bayr, K.J. (2002). MODIS snow-cover products. *Remote Sensing of Environment*, 83 (1-2): 181–194.
  http://sl.ugr.es/refbase_947
- Days of snow. Source: Cetursa. Sierra Nevada
  http://sl.ugr.es/cetursa

⑬ Climate variables from the analysis of data from weather stations. Time series 1960-1990.

- Information Subsystem of Environmental Climatology (CLIMA). Environmental Information Network of Andalusia (REDIAM). Department of the Environment. Andalusian Regional Government.
  http://sl.ugr.es/clima

⑭ Predictions of climatic variables obtained from the regional climate scenarios (reduction techniques scale). Time series from 2011 to 2040.

- Moreira, J.M. (2008). Climate change in Andalusia. Current and future climate scenarios. *Environment Magazine*, 59: 35–41.
  http://sl.ugr.es/refbase_1132
- Regionalized climate change scenarios. Department of the Environment. Andalusian Regional Government.
  http://sl.ugr.es/escenarios_clima

⑮ Snow data obtained by remote sensing. Analysis of snow cover products (MODA10A2) from the MODIS (NASA). Time series from 2000 to 2010.

- Bonet García, F.J. & Cayuela Delgado, L. (2009). Monitoring snow cover in Sierra Nevada: trends over the last decade and their possible ecological implications. At 11th National Congress of the Spanish Association of Terrestrial Ecology: The ecological dimension of sustainable development: Ecology, from knowledge to application. Úbeda, 18-22 October 2009.
  http://sl.ugr.es/refbase_892
- Bonet García, F.J. (2009). Characterisation of snow cover in Sierra Nevada and temporal trends through the use of MODIS images (2000-2008).
  http://sl.ugr.es/refbase_1032
- Hall, D.K.; Riggs, G.A.; Salomonson, V.V.; DiGirolamo, N.E. & Bayr, K.J. (2002). MODIS snow-cover products. *Remote Sensing of Environment*, 83 (1-2): 181–194.
  http://sl.ugr.es/refbase_947

⑯ Time series analysis of MODIS data using Mann-Kendall test.

- Bonet García, F.J. & Cayuela Delgado, L. (2009). Monitoring snow cover in Sierra Nevada: trends over the last decade and their possible ecological implications. At 11th National Congress of the Spanish Association of Terrestrial Ecology: The ecological dimension of sustainable development: Ecology, from knowledge to application. Úbeda, 18-22 October 2009.
  http://sl.ugr.es/refbase_892
- Bonet García, F.J. (2009). Characterisation of snow cover in Sierra Nevada and temporal trends through the use of MODIS images (2000-2008).
  http://sl.ugr.es/refbase_1032
- Hall, D.K.; Riggs, G.A.; Salomonson, V.V.; DiGirolamo, N.E. & Bayr, K.J. (2002). MODIS snow-cover products. *Remote Sensing of Environment*, 83 (1-2): 181–194.
  http://sl.ugr.es/refbase_947

⑰ Sampling ibex (*Capra pyrenaica*) by transect. Time series 1960-2009.

- Pérez, J.M.; Granados, J.E. & Soriguer, R.C. (1994). Population dynamics of the Spanish ibex Capra pyrenaica in Sierra Nevada Nature Reserve (southern Spain). *Acta Theriologica*, 39 (3): 289–294.
  http://sl.ugr.es/refbase_994
- Granados, J.E.; Castillo, A.; Cano Manuel-León, F.J.; Serrano, E.; Pérez, J.M.: S., R.C. & Fandos, P. (2009). Ibex management. In M. Sáenz de Buruaga & J. Carranza, (Eds.) Hunting management in Mediterranean ecosystems. Department of the Environment. Regional Government of Andalusia, 452–485.
  http://sl.ugr.es/refbase_1042

⑱ Predicting the potential distribution of vegetation in future climate scenarios.

- Benito de Pando, B. (2008). Global warming in Sierra Nevada. Models of potential distribution of vegetation on climate change scenarios. Advanced Studies Diploma Report.
  http://sl.ugr.es/refbase_149

- Benito de Pando, B. (2009). Ecoinformatics applied to conservation: Simulation of effects of global change on the distribution of flora in Andalusia. Doctoral thesis, University of Granada. 308 pp.
  http://sl.ugr.es/refbase_915

(19) Vegetation map of Sierra Nevada (1:10,000). Interpretation of aerial photography in 2005.

- Mesa, J.; Pérez Raya, F.; López Nieto, J.M.; El Aallali, A. & Hita Fernández, J.A. (2001). Mapping and assessment of the vegetation of the Sierra Nevada Nature Reserve. Department of the Environment. Regional Government of Andalusia.
  http://sl.ugr.es/refbase_166
- Spain's Land Cover and Use Information System (SIOSE). Departments for the Environment, Agriculture and Fisheries and Public Works and Transport. Andalusian Regional Government.
  http://sl.ugr.es/siose

(20) Vegetation map of Sierra Nevada (1:10,000). Interpretation of aerial photography in 1956.

- Navarro González, I. & Bonet García, F.J. (2009). Characterization of the historical evolution of ground cover and land use in Sierra Nevada in a global change scenario. At 11th National Congress of the Spanish Association of Terrestrial Ecology: The ecological dimension of sustainable development: Ecology, from knowledge to application. Úbeda, 18-22 October 2009.
  http://sl.ugr.es/refbase_893

(21) Ecological niche modelling of high mountain shrublands using the MaxEnt algorithm

- Benito de Pando, B. (2009). Ecoinformatics applied to conservation: Simulation of effects of global change on the distribution of flora in Andalusia. Doctoral thesis. University of Granada. 308 pp.
  http://sl.ugr.es/refbase_915

(22) Values of biodiversity, and understory tree density obtained from the forest inventory carried out in the Sierra Nevada National Park in 2005.

- Department of the Environment (2005). Technical assistance for the assessment, planning and dissemination of actions aimed at the diversification and naturalization of forests in the Sierra Nevada National Park. Ministry of the Environment. Tragsa.

(23) Riparian forest quality measured by the QBR index. Time series from 2001 to 2010.

- Munné, A.; Prat, N.; Solà, C.; Bonada, N. & Rieradevall, M. (2003). A simple field method for assessing the ecological quality of the Riparian habitat in rivers and streams: QBR index. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 13 (2): 147–163.
  http://sl.ugr.es/refbase_1065
- Suárez, M.L.; Vidal-Abarca, M.R.; Sánchez-Montoya, M.M.; Alba-Tercedor, J.; Álvarez, M.; Avilés, J.; Bonada, N.; Casas, J.; Jáimez-Cuéllar, P.; Munné, A.; Pardo, I.; Prat, N.; Rieradevall, M.; Salinas, M.J.; Toro, M. & Vivas, S. (2002). The banks of Mediterranean rivers and their quality: use of the QBR index. *Limnetica,* 21 (3-41): 135–148.
  http://sl.ugr.es/refbase_1064
- Data source: SAUCE: Management of Information on River Ecosystems. Environment Department. Andalusian Regional Government.
  http://sl.ugr.es/sauce

(24) Biological quality of rivers measured with the IBMWP (Iberian Biological Monitoring Working Party). Time series from 2005-2010.

- Alba-Tercedor, J.; Jáimez-Cuéllar, P.; Álvarez, M.; Avilés, J.; Bonada, N.; Casas, J.; Mellado, A.; Ortega, M.; Pardo, I.; Prat, N.; Rieradevall, M.; Robles, S.; Sáinz-Cantero, C.E.; Sánchez-Ortega, A.; Suárez, M.L.; Toro, M.; Vidal-Abarca, M.R.; Vivas, S. & Zamora-Muñoz, C. (2002). Characterization of the ecological status of Iberian Mediterranean rivers measured with the IBMWP index (previously BMWP). *Limnetica,* 21 (3-4): 175–185.
  http://sl.ugr.es/refbase_1067
- Data source: SAUCE: Management of Information on River Ecosystems. Environment Department. Andalusian Regional Government.
  http://sl.ugr.es/sauce

(25) Fluvial Habitat Index (IHF). Time series from 2006 to 2010.

- Pardo, I.; Álvarez, M.; Casas, J.; Moreno, J.L.; Vivas, S.; Bonada, N.; Alba-Tercedor, J.; Jáimez-Cuéllar, P.; Moyá, G.; Prat, N.; Robles, S.; Suárez, M.L.; Toro, M. & Vidal-Abarca, M.R. (2002). The habitat of Mediterranean rivers. Design of a habitat diversity index. *Limnetica,* 21 (3-4): 115–133.
  http://sl.ugr.es/refbase_1066
- Data source: SAUCE: Management of Information on River Ecosystems. Environment Department. Andalusian Regional Government.
  http://sl.ugr.es/sauce

(26) Monitoring populations of brown trout (*Salmo trutta*) using electrofishing methodology. Sequential sampling without replacement. Time series from 2000-2010.

- Data source: SAUCE: Management of Information on River Ecosystems. Environment Department. Andalusian Regional Government.
  http://sl.ugr.es/sauce

(27) Estimated wet meadows forage production.

- Robles, A.B. (2008). In all Andalusian sierras: pasture, production, diversity and global change. In P. Fernández-Rebollo & cols., (Eds.) Pasture, key in managing territories: combining disciplines. Spanish Society for the Study of Pastures. Department of Agriculture and Fisheries. Regional Government of Andalusia, 31-51.
  http://sl.ugr.es/refbase_1132
- González-Rebollar, J. L. (2006). Characterization, analysis and dynamics of silvopastoral systems of the Sierra Nevada National Park. O.A.P.N. Project Report 015/2002. 2004-2006.
  http://sl.ugr.es/refbase_1134

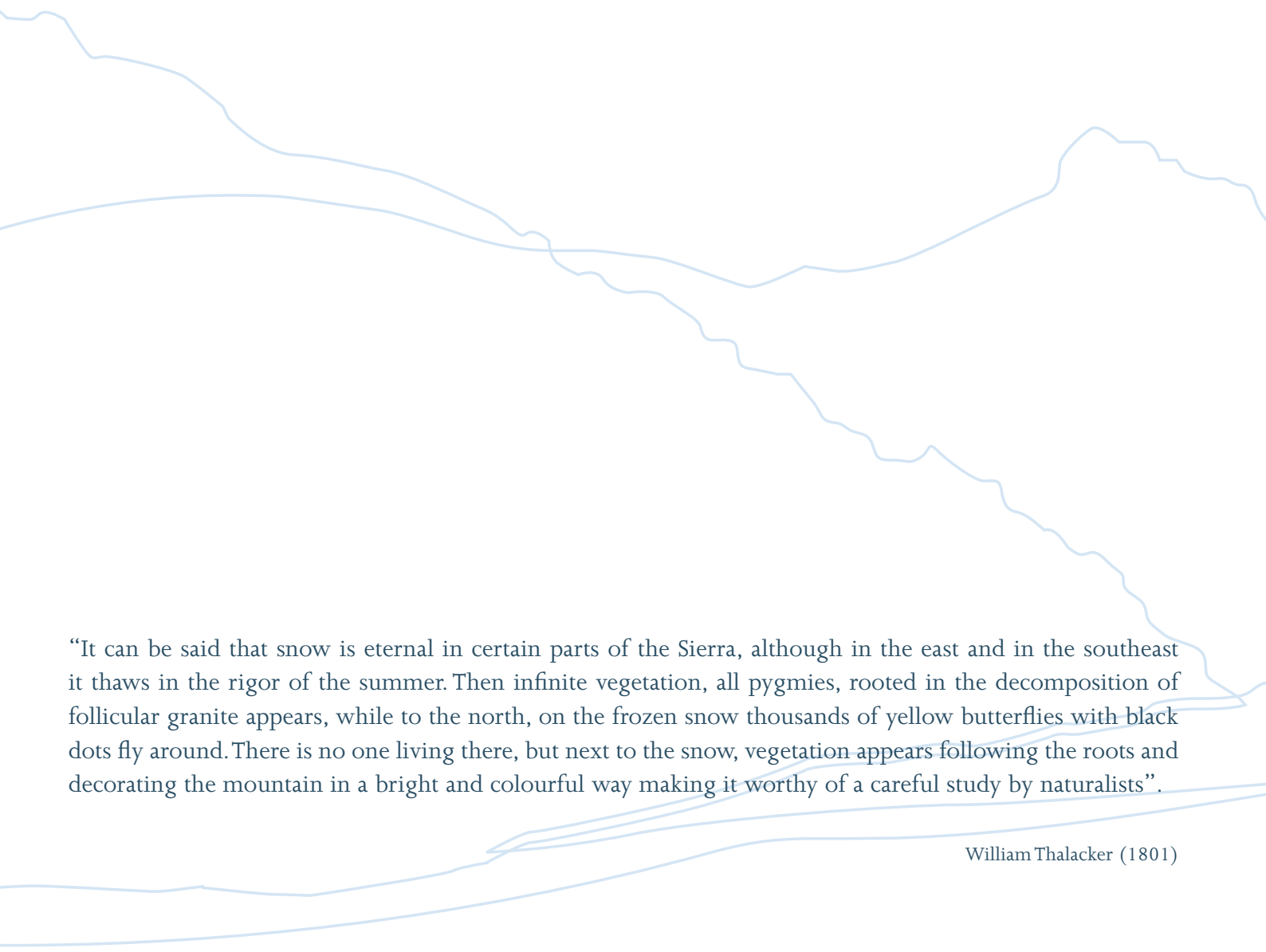
(28) Publications resulting from the Sierra Nevada Global Change Observatory.

- Aspizua Cantón, R.; Cano, F.J.; Bonet García, F.J.; Zamora, R. & Sánchez Gutiérrez, J. (2007). Sierra Nevada: International observatory monitoring global change. *Environment Magazine*, 57: 21–25
  http://sl.ugr.es/refbase_921
- Bonet García, F.J.; Aspizua Cantón, R.; Cano, F.J.; Zamora, R. & Sánchez Gutiérrez, J. (2007). Sierra Nevada Global Change Observatory (Spain). At the 1st National Conference on Environmental Global Change. April 2007. Madrid.
  http://sl.ugr.es/refbase_920
- Zamora, R. (2008). Protected areas as Global Change Observatories. In National Parks Autonomous Body, (Ed.) Adaptive Management in Protected Areas of Latin America to tackle Global Change. 187–190.
  http://sl.ugr.es/refbase_1442
- Bonet García, F.J. & Cayuela Delgado, L. (2009). Monitoring snow cover in Sierra Nevada: trends over the last decade and their possible ecological implications. At 11th National Congress of the Spanish Association of Terrestrial Ecology: The ecological dimension of sustainable development: Ecology, from knowledge to application. Úbeda, 18-22 October 2009.
  http://sl.ugr.es/refbase_892
- Gómez-Aparicio, L.; Zavala, M.A.; Bonet, F.J. & Zamora, R. (2009). Are pine plantations valid tools for restoring Mediterranean forests? An assessment of abiotic and biotic gradients. *Ecological Applications*, 19 (8): 2124–2141.
  http://sl.ugr.es/refbase_923
- Navarro González, I. & Bonet García, F.J. (2009). Characterization of the historical evolution of ground cover and land use in Sierra Nevada in a global change scenario. At 11th National Congress of the Spanish Association of Terrestrial Ecology: The ecological dimension of sustainable development: Ecology, from knowledge to application. Úbeda, 18-22 October 2009.
  http://sl.ugr.es/refbase_893
- Pérez-Luque, A.J.; Bonet García, F.J. & Zamora Rodríguez, R. (2009). Collaborative tools for the creation of useful knowledge for managing the Sierra Nevada Global Change Monitoring project. At 11th National Congress of the Spanish Association of Terrestrial Ecology: The ecological dimension of sustainable development: Ecology, from knowledge to application. Úbeda, 18-22 October 2009.
  http://sl.ugr.es/refbase_922
- Sánchez-Gutiérrez, F.J.; Henares-Civantos, I.; Cano-Manuel León, F.J.; Zamora Rodríguez, R.; Bonet García, F.J. & Aspizua Canton, R. (2009). Sierra Nevada Global Change Observatory. *Environment Magazine*, 63: 16–19.
  http://sl.ugr.es/refbase_914
- Aspizua, R.; Bonet, F. J.; Zamora, R.; Sánchez, F.J.; Cano-Manuel, F.J. & Henares, I. (2010). Sierra Nevada Global Change Observatory: towards the adaptive management of nature reserves. *Ecosystems*, 19(2): 56-68.
  http://sl.ugr.es/refbase_1402
- Bonet-García, F.J. & San Gil, I. (2010). Management of environmental information in protected areas and in global change monitoring networks. *Ecosystems*, 19(2): 84-96.
  http://sl.ugr.es/refbase_1403
- Bonet García, F.J. (2010). Coupling of snow cover and vegetation structure in Sierra Nevada (Spain). At the GMBA-DIVERSITAS international conference "Functional significance of mountain biodiversity" – Global Mountain Biodiversity Assessment. Chandolin (Switzerland), 27-30 July.
  http://sl.ugr.es/refbase_1399
- Bonet García, F.J. (2010). Converting field data into knowledge: towards adaptive management in Sierra Nevada LTER site. At the GMBA-DIVERSITAS international conference "Functional significance of mountain biodiversity" – Global Mountain Biodiversity Assessment. Chandolin (Switzerland), 27-30 July.
  http://sl.ugr.es/refbase_1400

- Navarro, I. & Bonet García, F.J. (2010). Plant cover changes in Sierra Nevada mountains (Spain) during the past 50 years and relation to land use and climate change. At the GMBA-DIVERSITAS international conference "Functional significance of mountain biodiversity" – Global Mountain Biodiversity Assessment. Chandolin (Switzerland), 27-30 July.
  http://sl.ugr.es/refbase_1398
- Pérez-Luque, A.J. & Bonet García, F.J. (2010). Assessment of the state of conservation of Mountain Ecosystem in Sierra Nevada-LTER site in a global change context. At the GMBA-DIVERSITAS international conference "Functional significance of mountain biodiversity" – Global Mountain Biodiversity Assessment. Chandolin (Switzerland), 27-30 July.
  http://sl.ugr.es/refbase_1397
- Pérez-Luque, A.J.; Bonet-García, F.J. & Pérez-Pérez, R. (2010). Use of web 2.0 technologies in monitoring global change: Sierra Nevada Global Change Observatory. 10th National Environment Conference. Madrid, 22-26 Noviembre.
- Zamora, R. (2010). Protected areas as Global Change Observatories. Ecosystems, 19(2): 1-4
  http://sl.ugr.es/refbase_1401

(29) Outreach and Training Conference of the Sierra Nevada Global Change Observatory.

- "Forest Management in the context of Global Change" Granada, April 2008.
  http://sl.ugr.es/abril2008
- "The value of mountain protected areas in the global change scenario", Granada, May 2009.
  http://sl.ugr.es/mayo2009
- "I Latin American CYTED Workshop: Ecological Interactions and Global Change: Mechanisms and Patterns", Granada, October 2009.
  http://sl.ugr.es/cyted
- "Climate Change and Protected Areas" Summit, Granada, November 2009.
  http://sl.ugr.es/uicn2009
- Training Seminar: "Introduction to Bibliographic Management System of project. First Edition", August 2009.
  http://sl.ugr.es/refbase_08
- Coordination Workshop of Monitoring Program of the Sierra Nevada Global Change Observatory. September 2009.
  http://sl.ugr.es/coordinacion
- Course: "Systems Support Environmental Decision Making", September 2009.
  http://sl.ugr.es/curso_sad
- Course: "Ecological data analysis in R. First Edition", November 2009.
  http://sl.ugr.es/curso_r
- Training Seminar: "Introduction to Bibliographic Management System of project. Second Edition", November 2009.
  http://sl.ugr.es/refbase_12
- Training Seminar: "Collaborative Edition of wiki contents", December 2009.
  http://sl.ugr.es/wiki_formacion
- Course: "Communication and Environment", February 2010.
  http://sl.ugr.es/curso_com
- Course: "Web 2.0 application in research and teaching", April 2010.
  http://sl.ugr.es/curso_web20
- Coordination Workshop of Monitoring Program of the Sierra Nevada Global Change Observatory. May 2010.
  http://sl.ugr.es/coordinacion_2010
- Course: "Ecological data analysis in R. Second Edition", November 2009.
  http://sl.ugr.es/curso_r_2010
- Course: "Design and management of geographic databases", October 2010.
  http://sl.ugr.es/curso_bd
- Course: "Introduction to writing scientific articles", January 2011.
  http://sl.ugr.es/curso_redaccion



"It can be said that snow is eternal in certain parts of the Sierra, although in the east and in the southeast it thaws in the rigor of the summer. Then infinite vegetation, all pygmies, rooted in the decomposition of follicular granite appears, while to the north, on the frozen snow thousands of yellow butterflies with black dots fly around. There is no one living there, but next to the snow, vegetation appears following the roots and decorating the mountain in a bright and colourful way making it worthy of a careful study by naturalists".

William Thalacker (1801)

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