The ecosystem functioning dimension in Natura 2000 habitats: a monitoring approach based on remote sensing

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LAREB
LABORATORIO DE ANÁLISIS REGIONAL DE ECOSISTEMAS Y BIODIVERSIDAD

CAESCG
CENTRO ANDALUZ PARA LA EVALUACIÓN Y SEGUIMIENTO DEL CAMBIO GLOBAL

UNIVERSIDAD DE ALMERÍA

Challenges for the EU policy of conservation at ecosystem level

Challenges for the EU 2020 Biodiversity Strategy

- Halting the loss of biodiversity and the degradation of ecosystem services.
- Reduce the EU´s ecological footprint.
- Ecosystem based approaches to climate change mitigation and adaptation.
- Maintain the ecosystem and the services they provide.

Challenges for the Natura 2000 Policy

- Evaluate and minimise the effects of global change drivers (land-use changes, climate change, biological invasiones, pollution, ..) on habitats.
- Strengthen common understanding of what it means to achive favourable conservation status for habitats types and species.

How to face these challenges in the Natura 2000 Network?

Convention on Biological Diversity

5th COP to the Convention on Biological Diversity (CBD)-Nairobi, Kenya- **2000**

The "ecosystem approach" is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way…

It is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment…

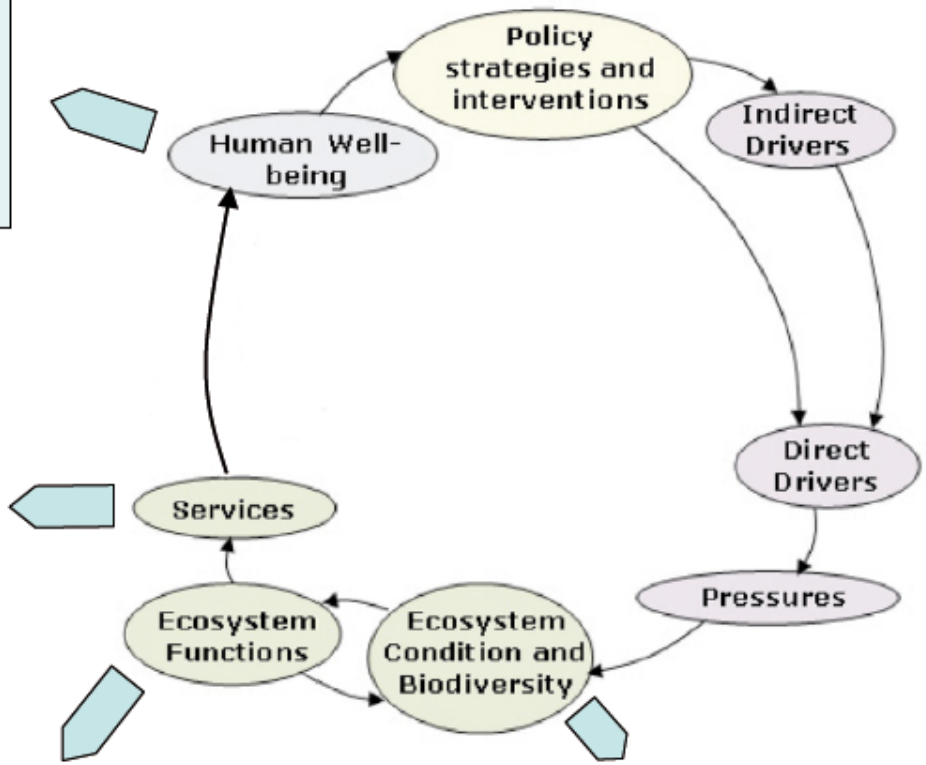
It recognizes that humans, with their cultural diversity, are an integral component of ecosystems.

Basic "guiding principles" of Ecosystem Approach (IUCN-CBD)

- Ecosystems are not isolated.
- It is never enough to consider only protected areas when planning conservation.
- Human beings are ecosystem components.
- Adaptive management is essential.

A practical way to implement the ecosystem approach

Human well-being:
The state of people's physical, economic, social, and spiritual well-being.



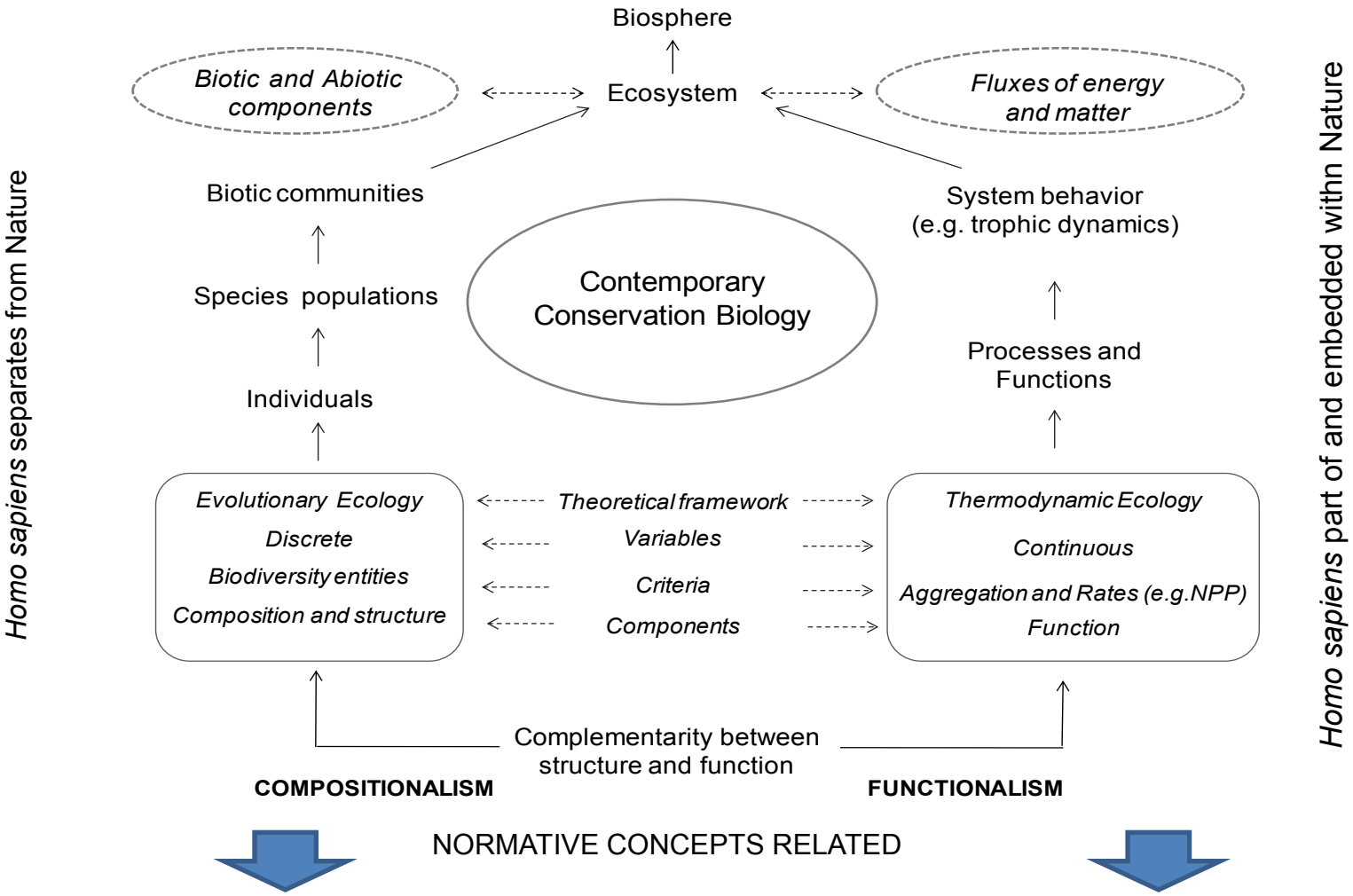
Ecosystem services:
The benefits people obtain from ecosystems.

Ecosystem functions:
The processes by which ecosystems deliver services and benefits.

Ecosystem condition and biodiversity:
The ability of ecosystems to support ecosystem processes and deliver ecosystem services.

World Resources Institute 2010

Associations between conservation philosophies, human-nature relationships, "ecologies," and conservation concepts



Preservation of biological diversity & Biological integrity, Restoration ecology

Ecosystem health, Ecosystem services, Adaptive management, Ecosystem management, Sustainable development, Ecological sustainability

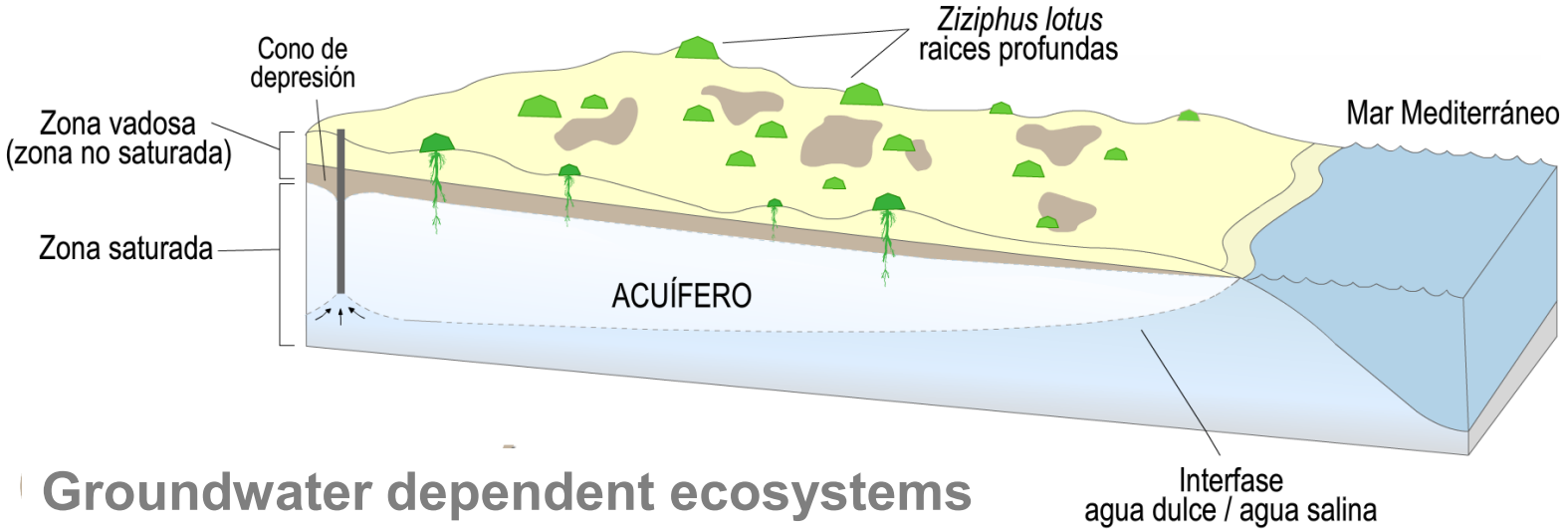
Basado en Callicot 1999 & Rodríguez 2011

- *Ecosystem services, ecological footprint, carbon economy, global change impact, baseline conditions, human benefits, and even biodiversity conservation, are issues closely related to ecological processes.*

- *To achieve such objectives, we need to incorporate the ecosystem functioning dimension into the characterization and monitoring of EU habitats.*

How to incorporate the ecosystem approach into Natura 2000 process?

From the biodiversity inventory to monitoring ecological processes



Groundwater dependent ecosystems

Important features for a monitoring program indicators

Requirements	Advantages
Inform at ecosystem level	It offers a holistic view of the ecosystem condition and connect with the concepts of ecosystem health and integrity
Short time response	It allows adaptive management and early impacts detection
Facilitate the estimation of baseline conditions	The definition of reference conditions are the most realistic way to assess habitat conservation status
Enable monitoring at regional scale	Appropriate to distinguish between local and regional anomalies and to identify trends and thresholds of change

Attributes related to the exchange of matter and energy vegetation-atmosphere meet these requirements

1. They offer a more quickly response than structural variables (vegetation physiognomy and diversity) to disturbance.

2. Enable to quantify ecosystem services (e.g. carbon gains).

3. Can be monitored through remote sensing.

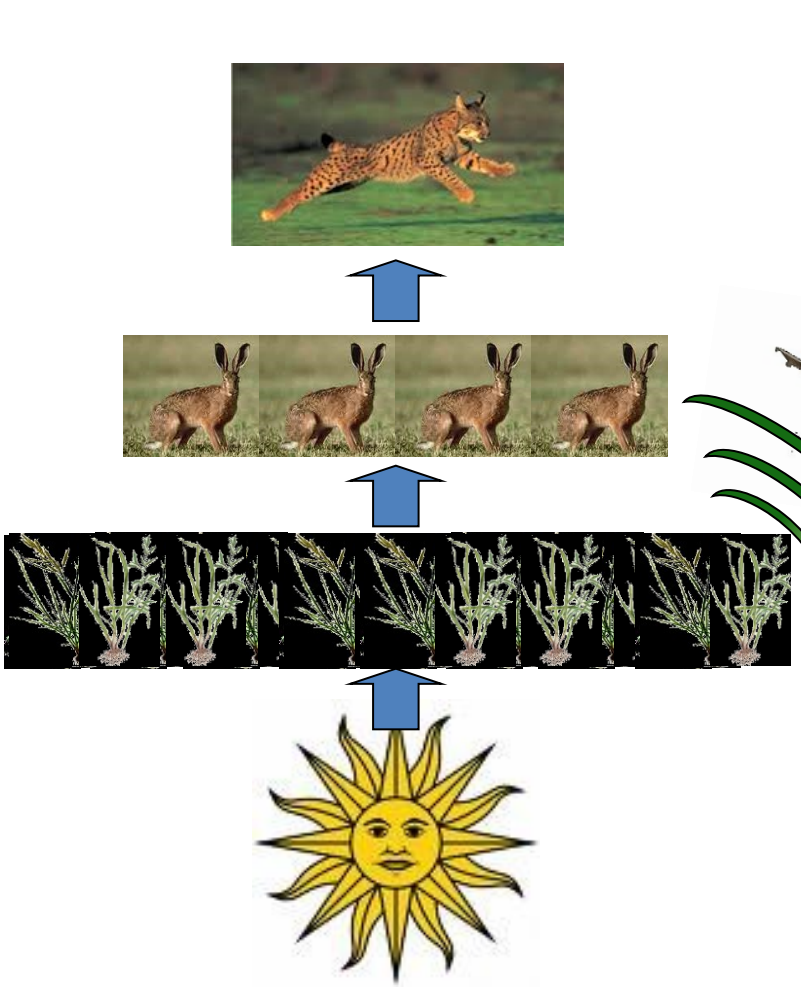
4. Provide a dynamic characterization of ecosystem processes.

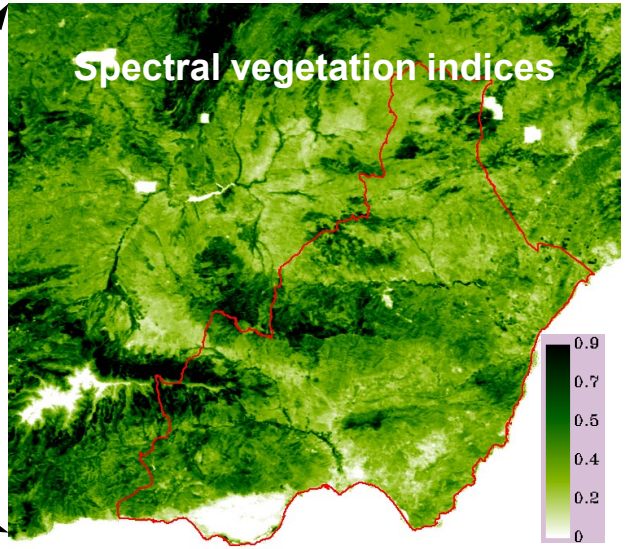
5. The spectral indices are connected with functional variables (primary production, evapotranspiration, surface temperature, albedo).

6. Spectral vegetation indices (NDVI, EVI) have been successfully used to describe regional patterns of net primary productivity.

Why these attributes characterize ecological processes at ecosystem level?

✓ Spectral vegetation indices (NDVI o EVI) are proxies of NPP.



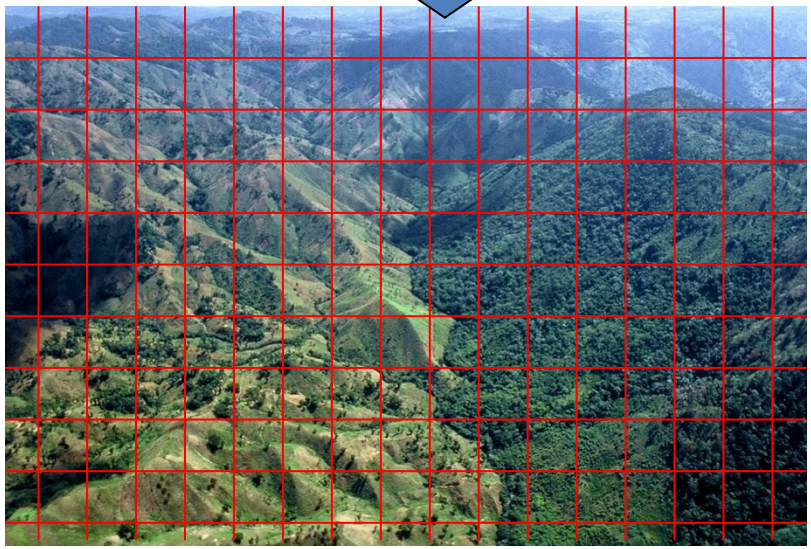


NPP:

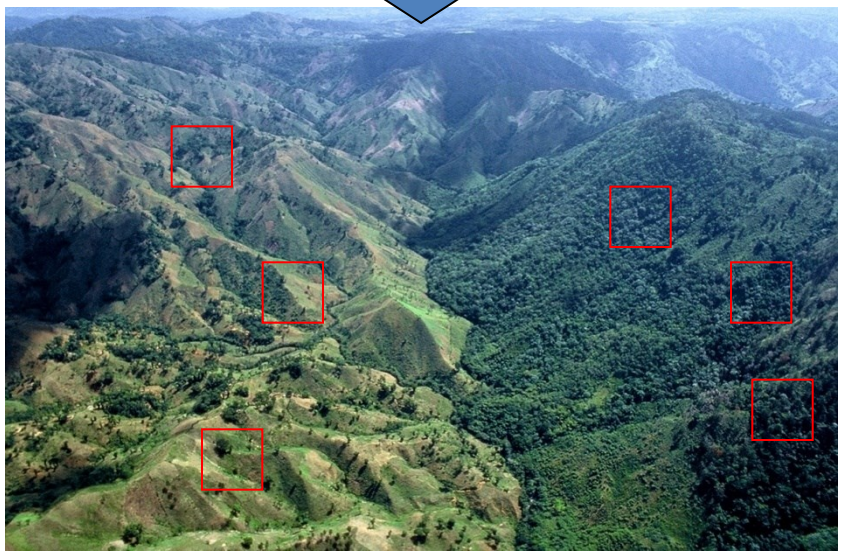
- Quantity of energy that enter into the life
- Integrative descriptor of ecosystem health
- Integrative response to environmental changes

But .... What actually is a pixel?

Regional Ecology	Applied ecology and Management
The whole are of a biome, landscape or ecosystem to obtain regional patterns.	**A plot of:** – *Ecosystems.* – *Management actions.* – *Land uses.* – *...*



THEMATIC MAPS



ECOSYSTEMs AND LAND-USES EVALUATIONS

Basis for the application of spectral vegetation indices

MONTEITH's MODEL (1972):

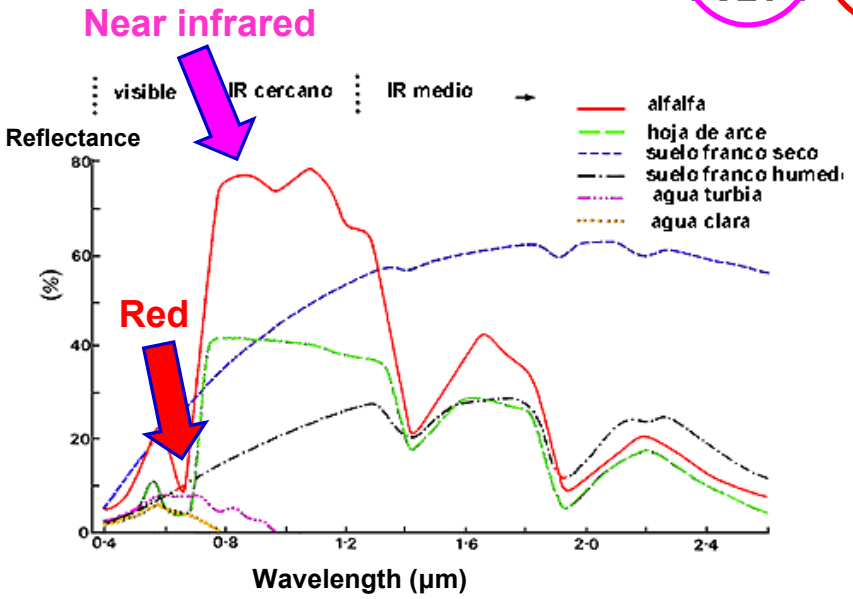
$$\underset{[gC\ m^{-2}\ year^{-1}]}{NPP} = \underset{[MJ\ m^{-2}\ year^{-1}]}{PAR} \times \underset{[proportion]}{fPAR} \times \underset{[gC\ MJ^{-1}]}{RUE}$$

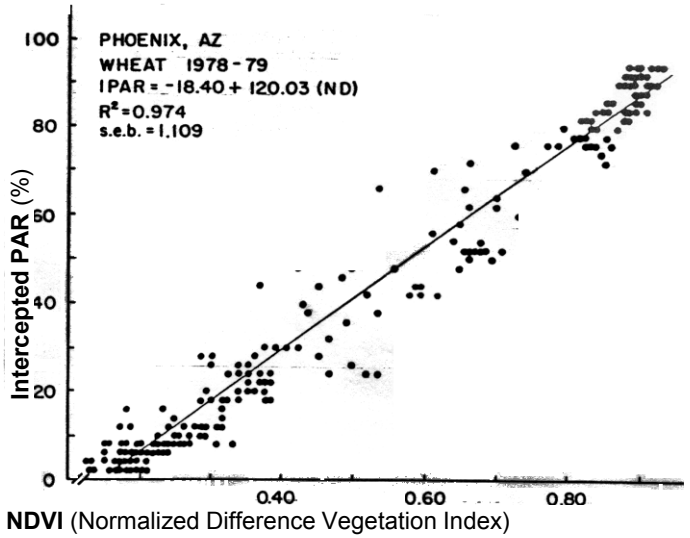
Normalized Difference Vegetation Index

$$NDVI = \frac{NIR - R}{NIR + R}$$

NPP: Net primary productivity
PAR: Photosynthetic active radiation
FPAR: Fraction of the photosynthetic active radiation intercepted
RUE: Radiation use efficiency

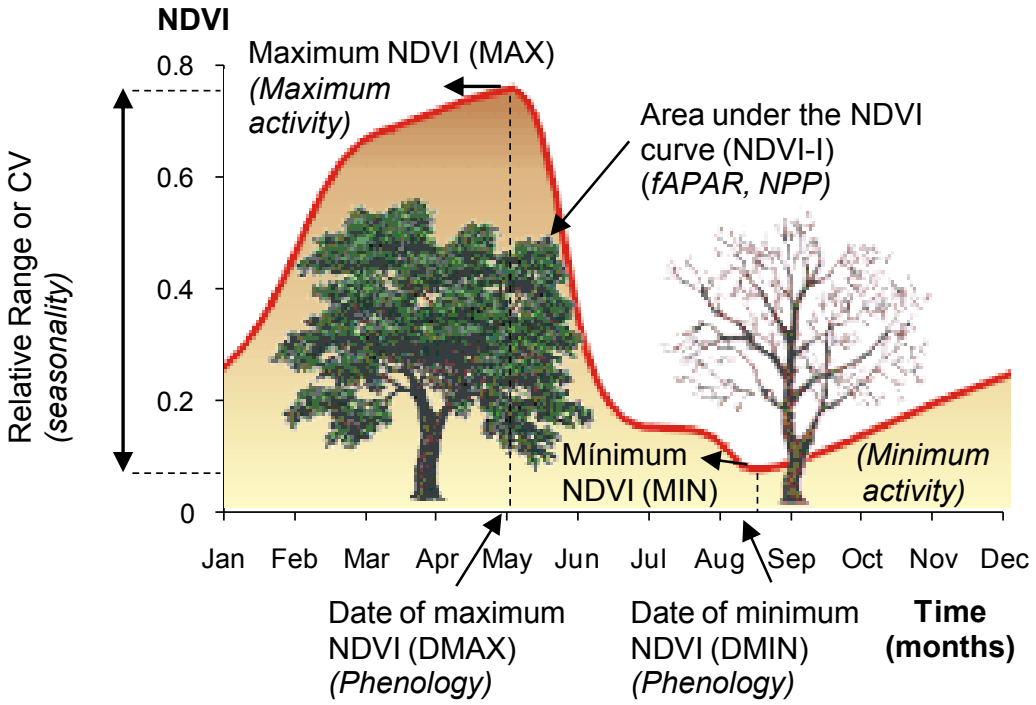
fPAR ~ f (NDVI)
fPAR = a + b NDVI





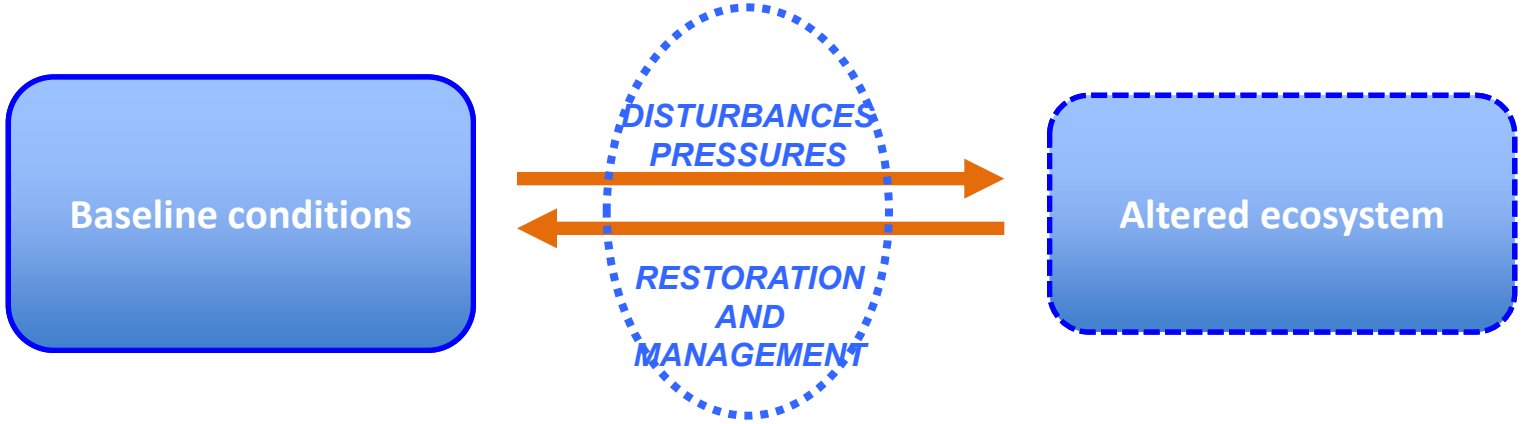
Descriptors of ecosystem functioning derived from spectral vegetation indices

(Alcaraz et al. 2009, Cabello et al. 2012, Pettorelli et al., 2005, ….)

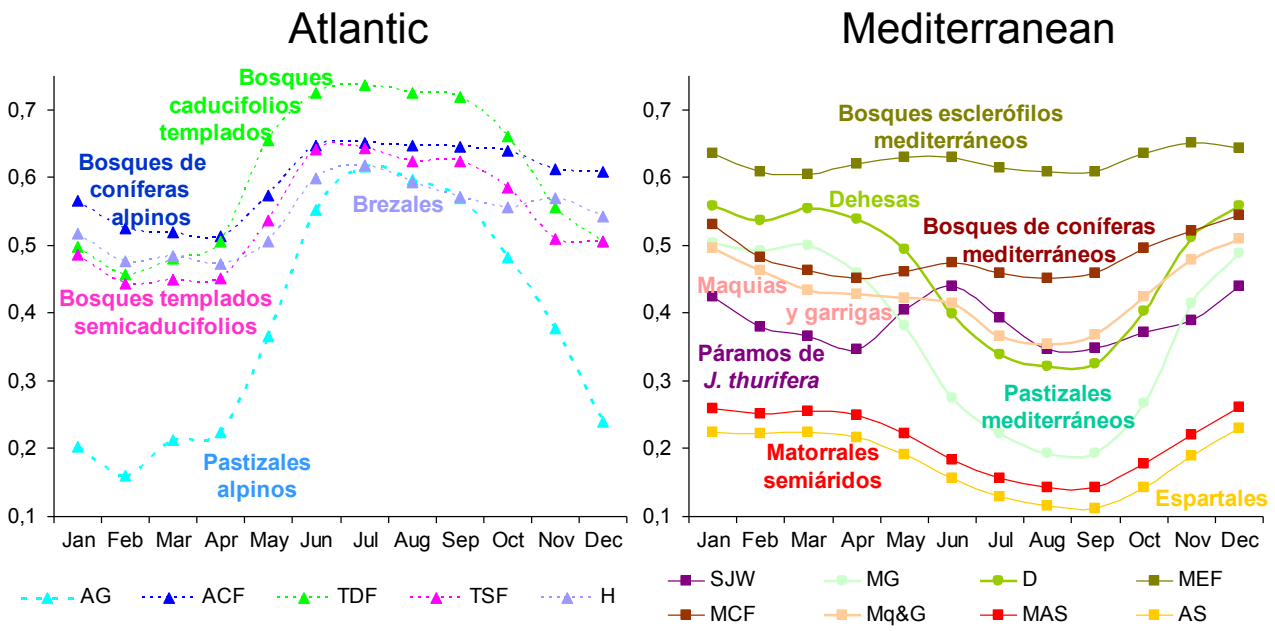


Applications for monitoring habitats

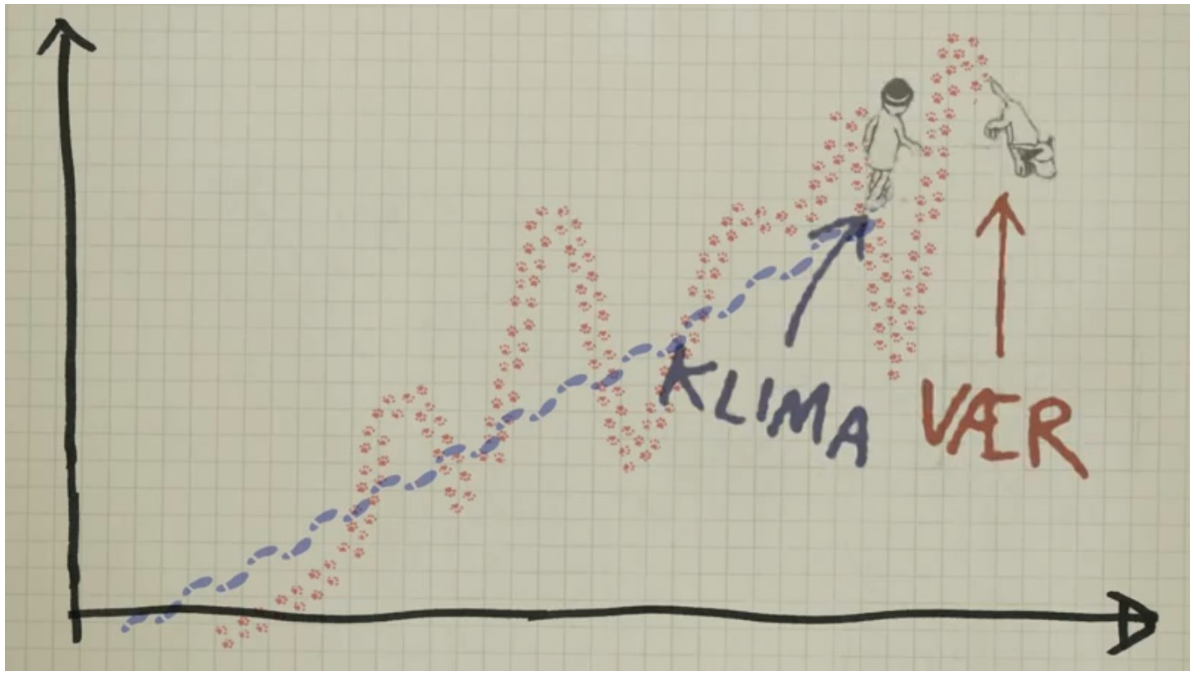
Through the use of these attributes we can characterize the ecosystem baseline conditions to assess changes in ecosystem



Annual NDVI curves and their variability: a way to characterize reference conditions

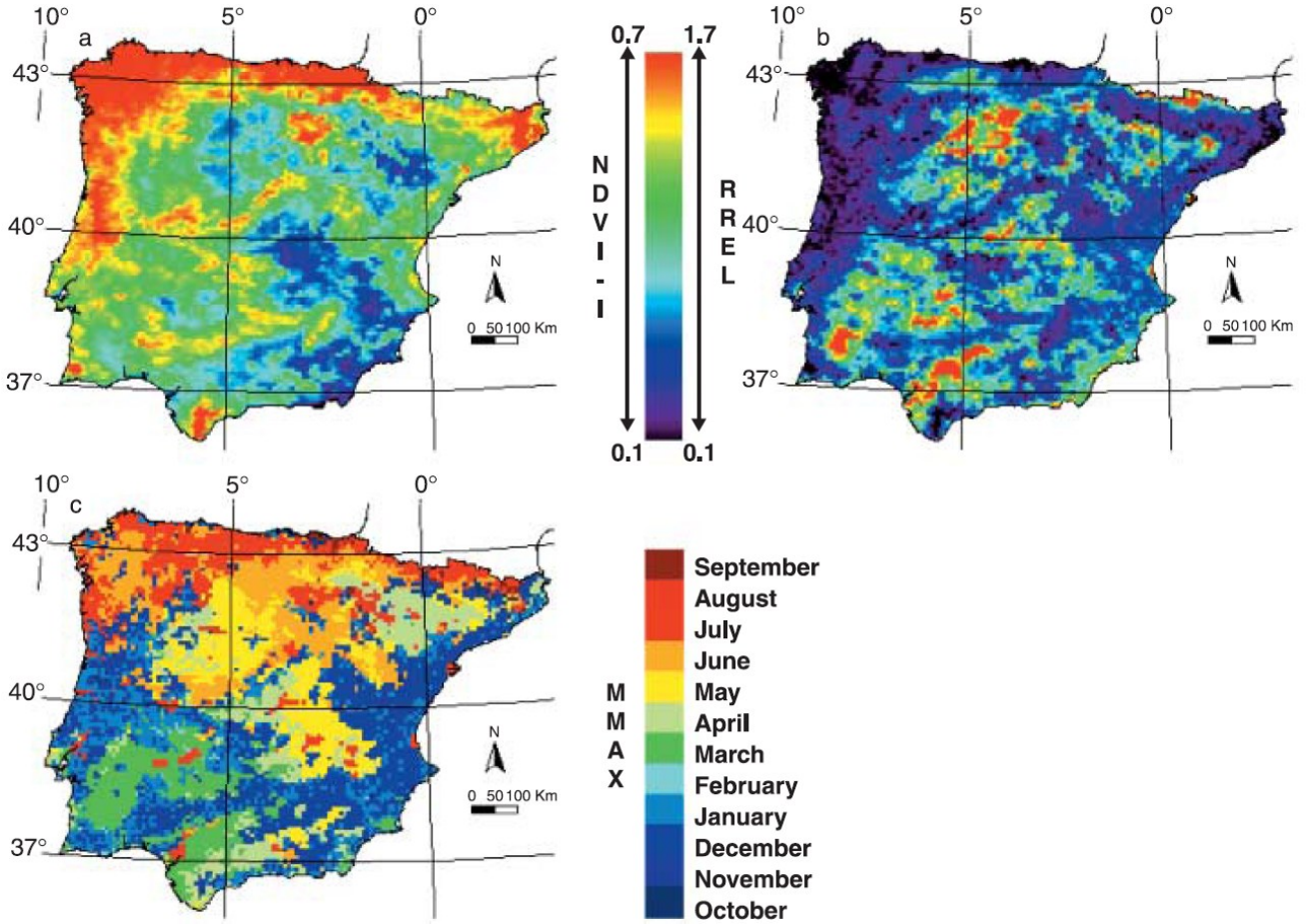


We can estimate trends (underlying changes)



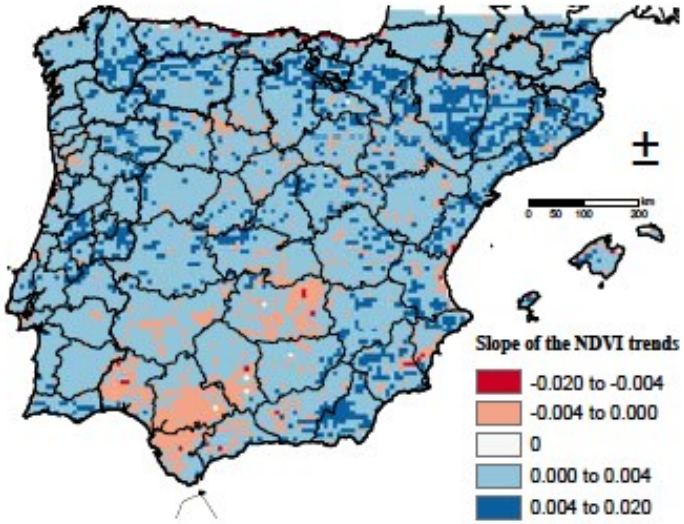
http://www.youtube.com/watch?feature=player_embedded&v=e0vj-0imOLw

Spatial patterns of ecosystem functioning at national level

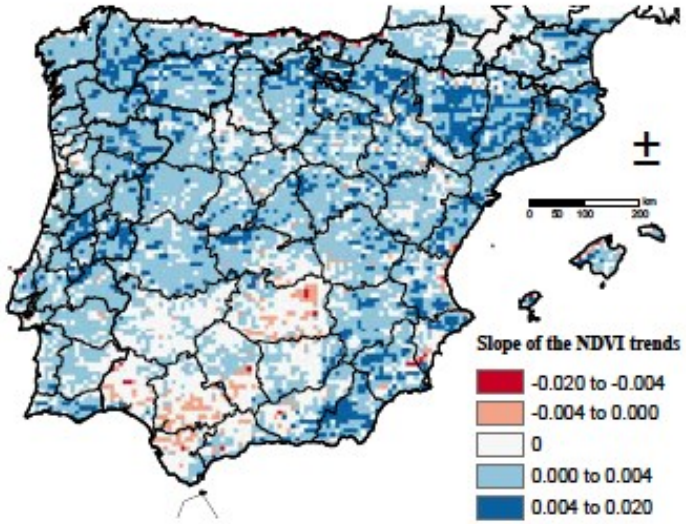


Alcaraz-Segura et al. (2006). Global Ecology and Biogeography.

Changes in the ecosystem functioning at national level



a) p-value <1 (todas las pendientes)

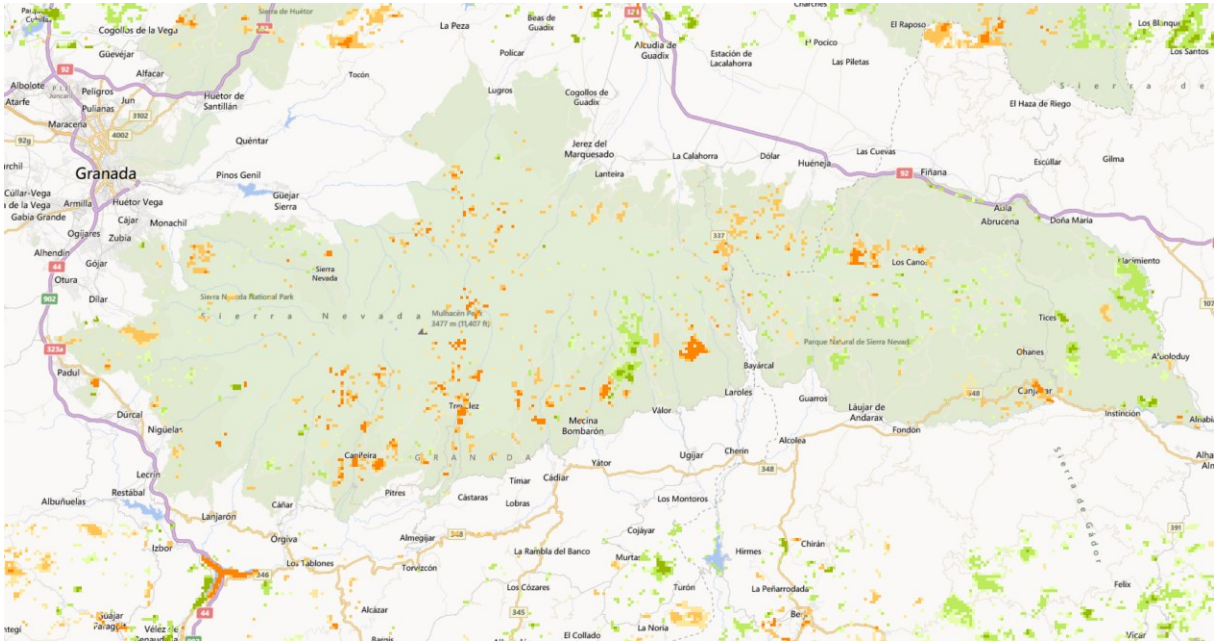


b) p-value < 0.05 (pendientes significativas)

Alcaraz-Segura et al. (2010). Sensors

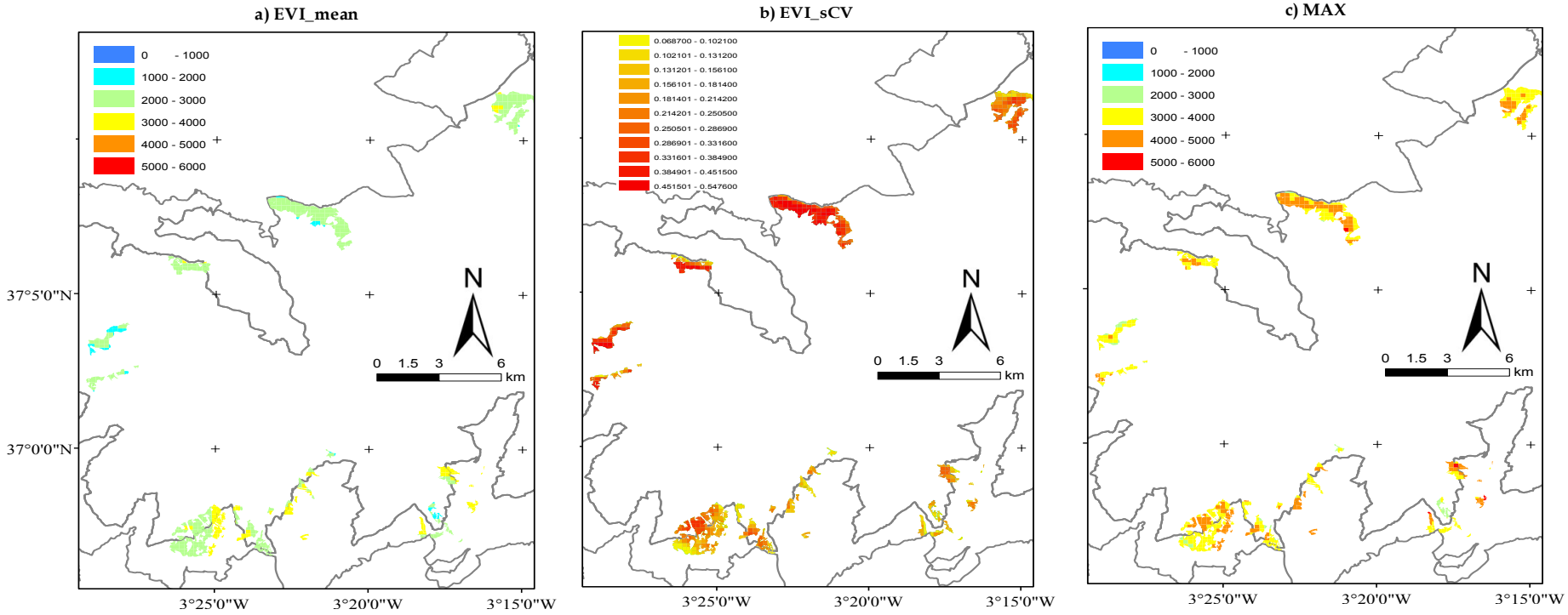
Spatial patterns of ecosystem functioning at protected areal level

Changes in the ecosystem functioning at protected area level



Sierra Nevada National Park

Spatial patterns and changes of ecosystem functioning at habitat level



Sierra Nevada National Parks oak forests

Dionisio et al. (2012), In Tech.

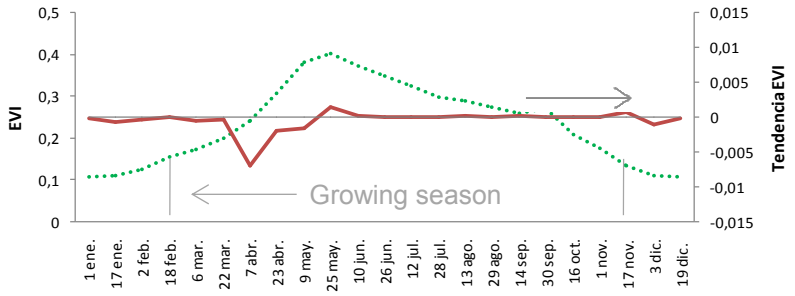
Management units of oak forests in Sierra Nevada National Park (SE Iberian Peninsula) derived from the spatial patterns of ecosystem functioning

EVI seasonal dynamics (green line)

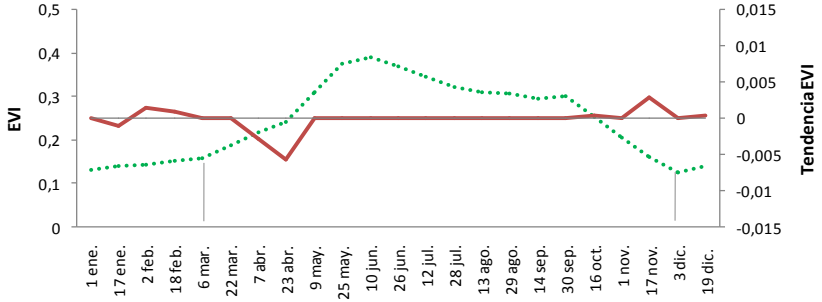
EVI seasonal trends (red line)

NW slope

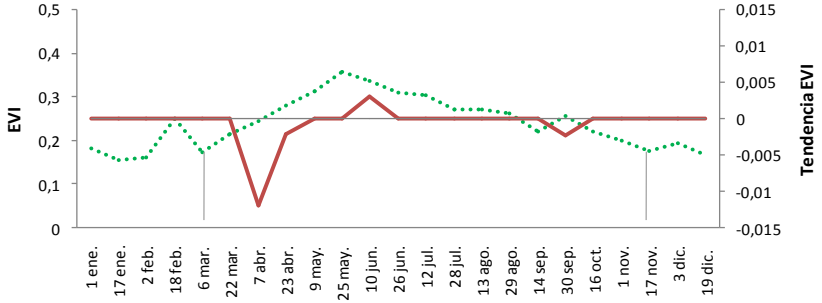
Genil river valley



Monachil river valley

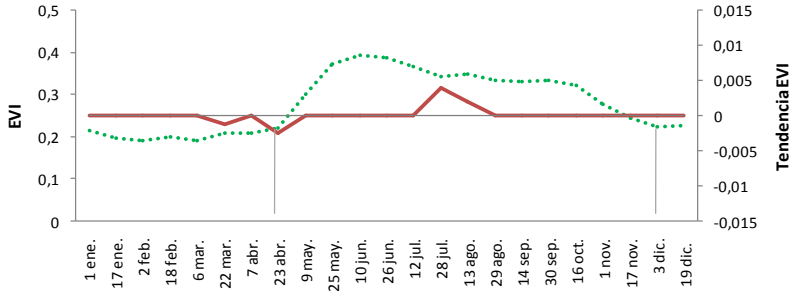


Dúrcal river valley

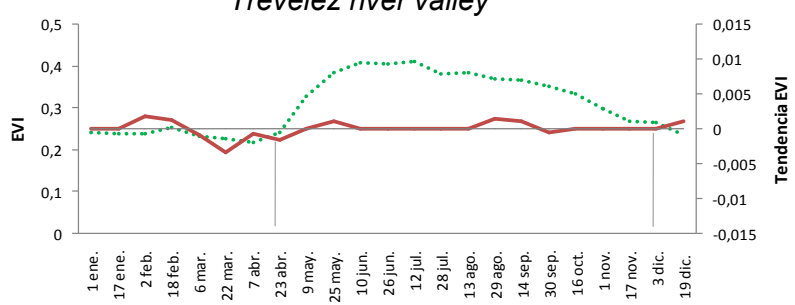


S slope

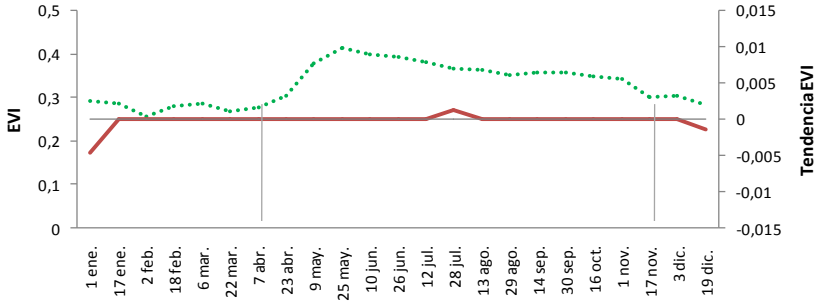
Chico river valley



Trevelez river valley



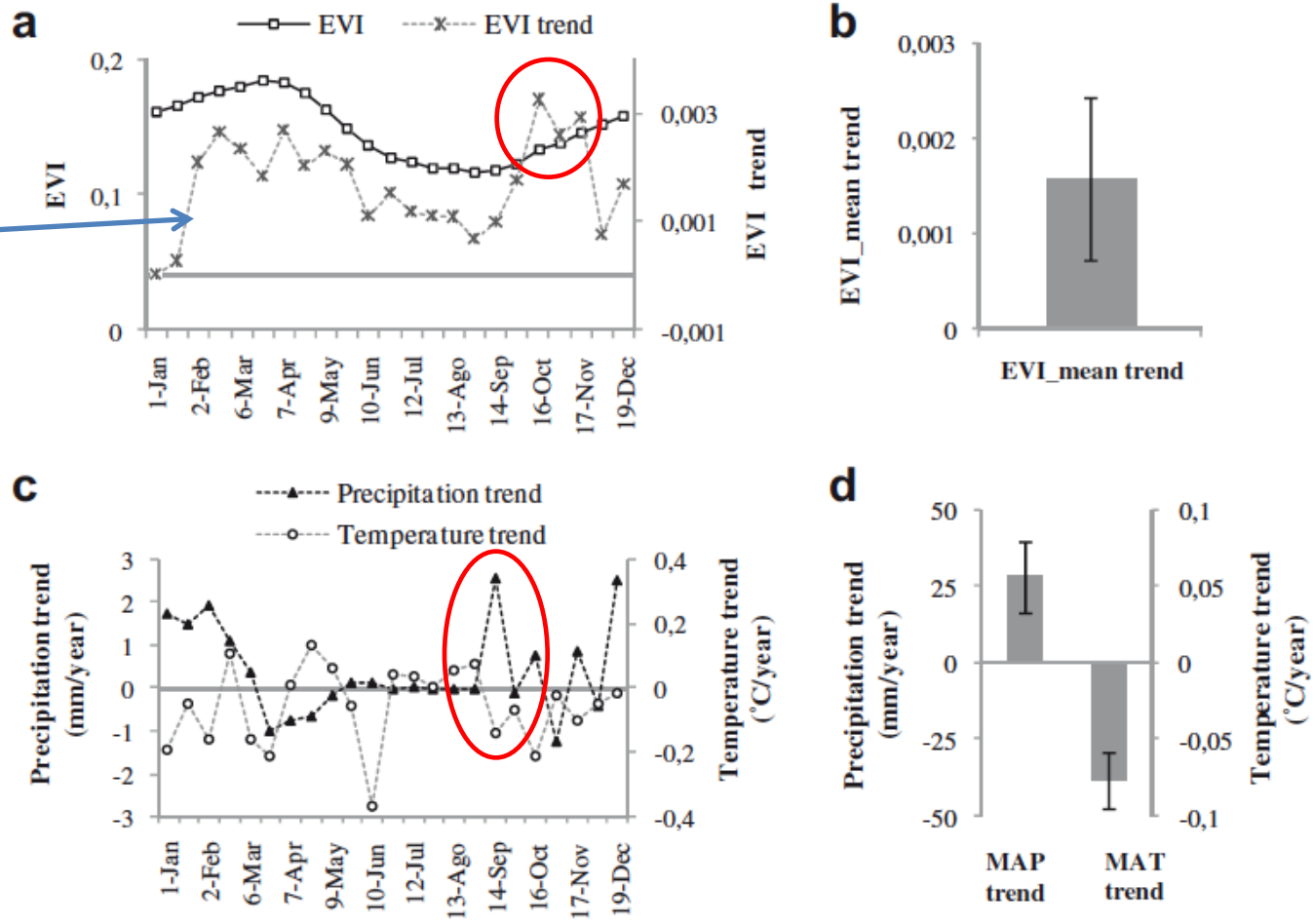
Poqueira river valley



Effects of seasonal climate changes on SE Iberian grasslands (5330 + 6220)

Seasonal EVI trends values

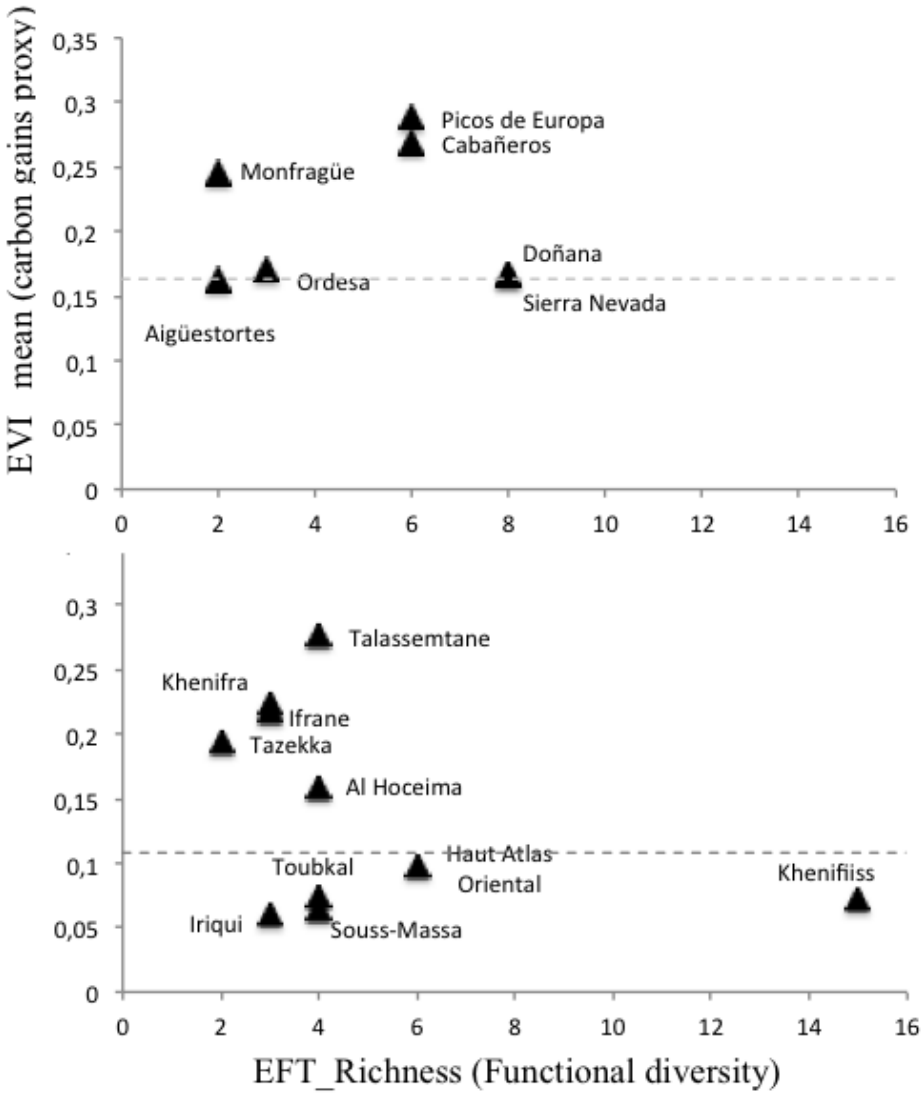
Seasonal temperature & precipitacion trends values



Inter-annual trends (2001-2010) by MODIS composites and by year

Cabello et al. 2012

Trade-offs between diversity and carbon gains



Spanish National Parks

Moroccan National Parks

Cabello et al. 2013

Niche modeling of species (e.g. of conservation concern)

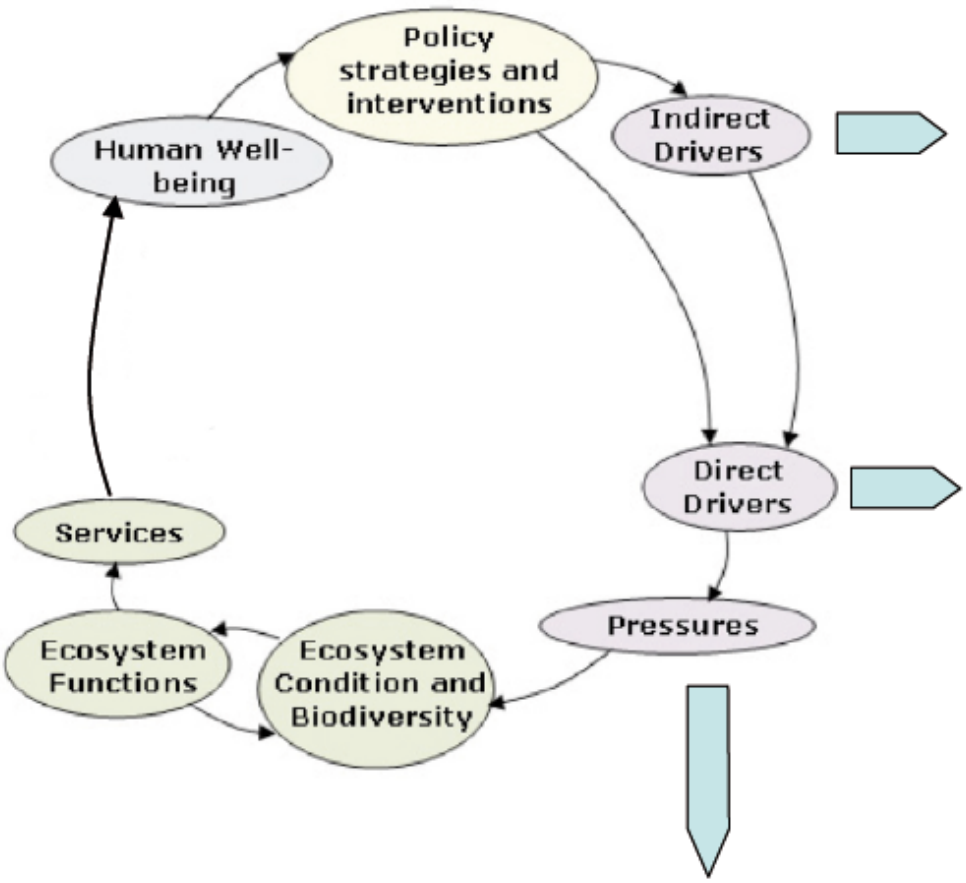
Landscape Ecol
DOI 10.1007/s10980-014-0020-4

RESEARCH ARTICLE

Modeling spatial distribution of European badger in arid landscapes: an ecosystem functioning approach

Juan M. Requena-Mullor · Enrique López · Antonio J. Castro · Javier Cabello · Emilio Virgós · Emilio González-Miras · Hermelindo Castro


ευχαριστίες!



Indirect drivers

Factors that influence human actions, globalization, type of governance, consumption choices,…

Direct drivers

Human activities that directly impact on ecosystems: changes in local land use and cover, species introduction or removal, external inputs, resource exploitation, climate change, etc

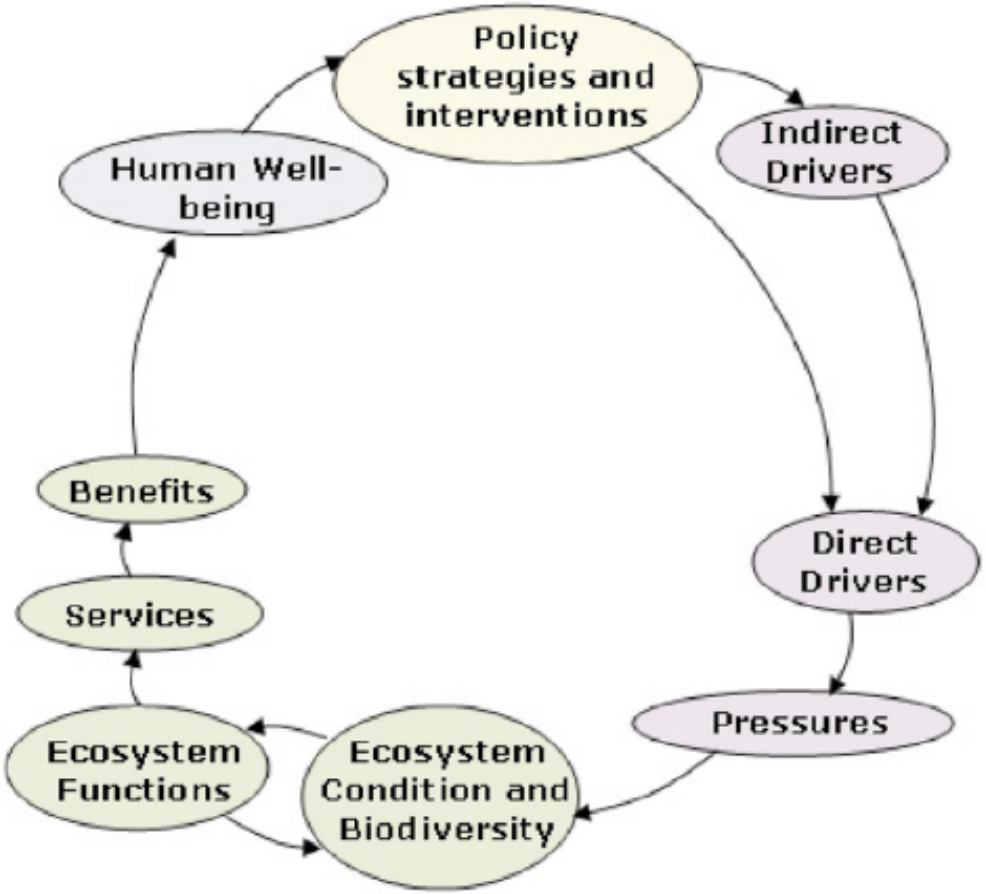
Pressures

The ***biophysical representation of human actions*** that directly impact ecosystems.

Un modelo práctico

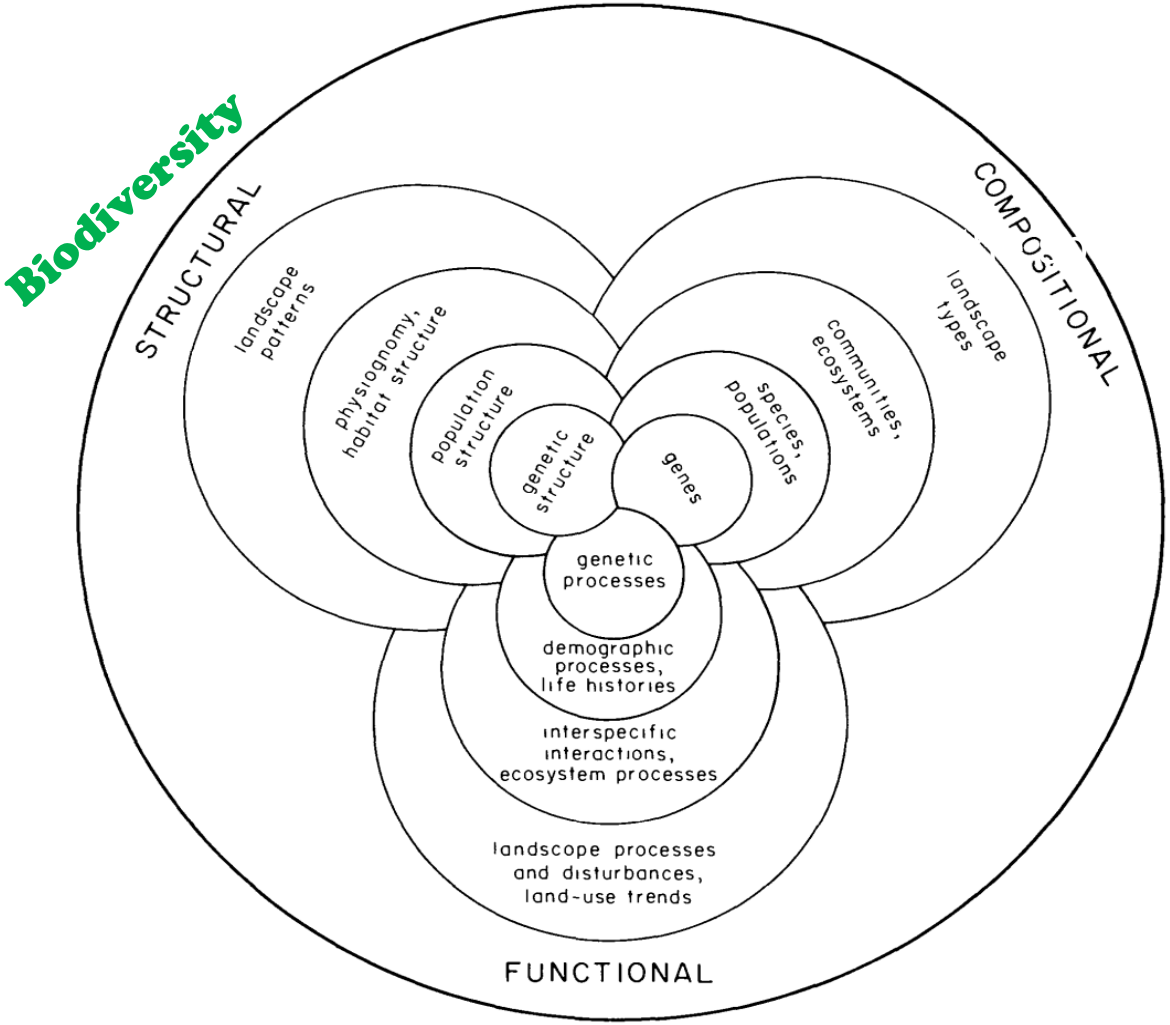
World Resources Institute (2010):

síntesis de los modelos de European Environment Agency (1999) y Millenium Ecosystem Assesment (2005)



Three components of Biodiversity: Composition, Structure and Function

Noss (1990): “This conceptual framework facilitates selection of indicators that represent the many aspects of biodiversity that warrant attention in environmental monitoring and assessment programs”.



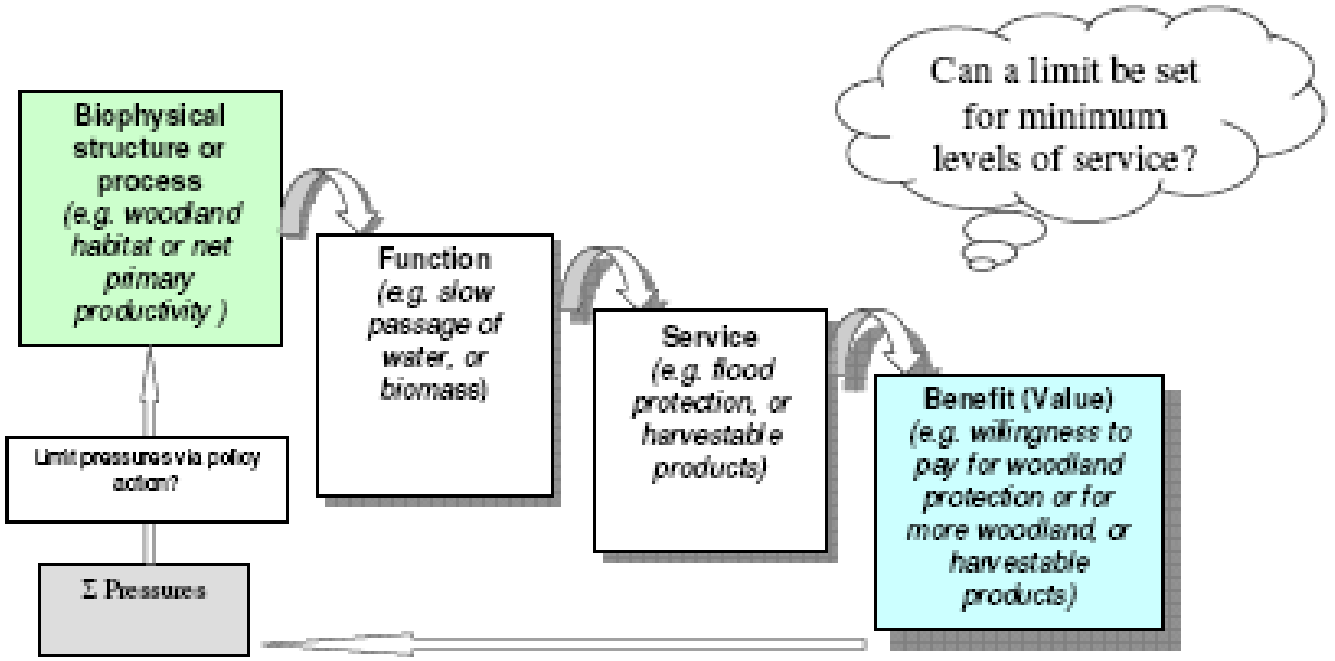
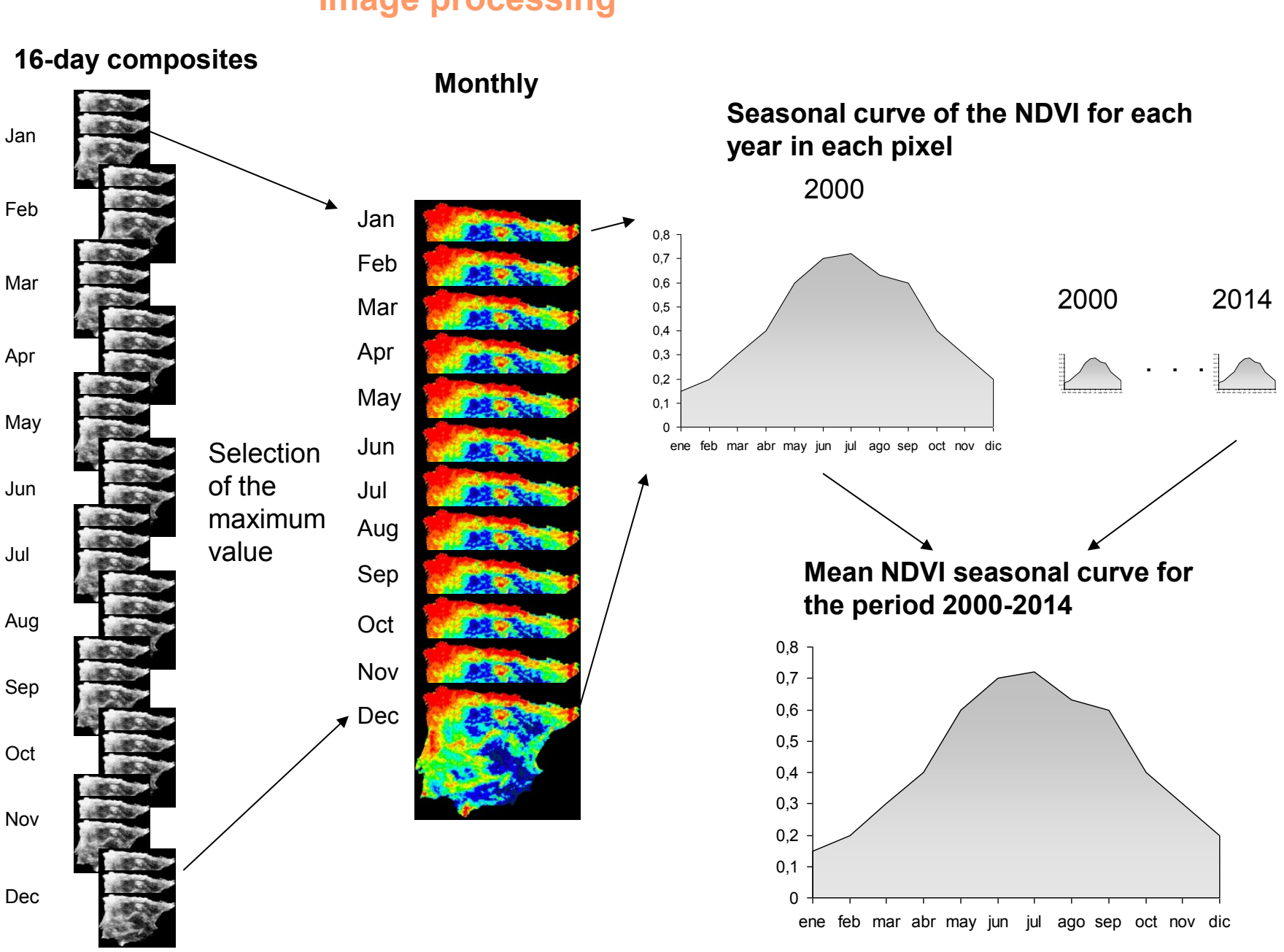


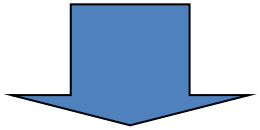
Figure 4.1: An ecosystem service cascade. Source: Haines-Young and Potschin (2007).

Image processing



Main challenges in Conservation Biology (Balmford & Cowling, 2006)

- Trying to conserve ecological and evolutionary processes
- Improving our understanding of how ecosystems change in response to anthropogenic pressures.
- Documenting and understanding the benefits of natural systems for human well-being (ecosystem services)
- Monitoring and communicating the changing state of nature
- Building overarching, spatially explicit models of nature



Functional approaches to the understanding of biodiversity may be particularly valuable, since they address the sustainability of the ecosystem via interactions between the components and provide a basis for predicting changes when drivers are modified (Lamont, 1992).

It is necessary to identify fields in conservation where ecosystem functioning is useful

Los atributos funcionales derivados de índices espectrales tienen significado biológico

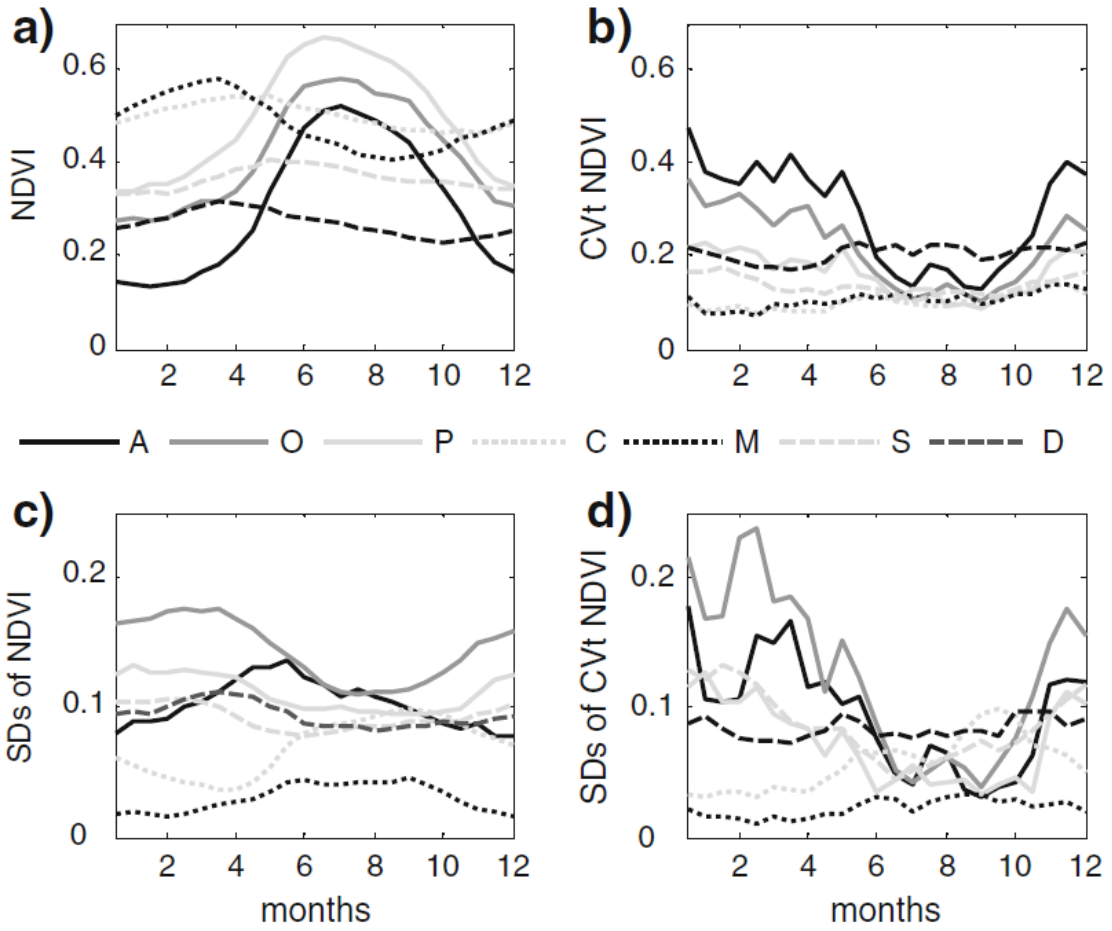
Tabla 1. Atributos derivados de la curva estacional de los índices espectrales de vegetación (NDVI y EV) y sus características. Adaptado de Pettorelli y col. (2005).

Atributo	Tipo de medida	Definición	Significado biológico	Comentarios
NDVI-I	Productividad total y biomasa	Suma de valores positivos de NDVI en un periodo de tiempo	Productividad anual de la vegetación	No es relevante cuando la calidad es tan importante como la cantidad (e.g. herbívoros muy selectivos)
Máximo NDVI	Productividad total y biomasa	Máximo NDVI en el año	Productividad anual de la vegetación	Sensible a falsos picos y 'ruido'
Rango relativo de NDVI	Variabilidad intra-anual en productividad	(Máximo NDVI - Mínimo NDVI) / NDVI-I	Permite comparaciones de estacionalidad	Sensible a falsos rangos debidos a "outliers"
Tasa de incremento o detrimento de NDVI	Fenología	Pendiente entre valores de NDVI en diferentes fechas. Pendiente de la curva logística de una serie temporal de valores de NDVI	Tasa de brotado y senescencia	Sensible a falsos picos y 'ruido'
Fecha de comienzo o final de estación de crecimiento	Fenología	Fechas estimadas a partir de valores umbral o con el método de medias móviles	Comienzo de brotado	La precisión esta ligada a la escala temporal de los datos (mayor frecuencia supone peor calidad de datos)
Duración de la estación de crecimiento	Fenología	Tiempo con valores de NDVI > 0 o periodo entre inicio y final de estación de crecimiento	En sistemas con marcada estacionalidad, número de días con producción de biomasa	Sensible a falsos picos y 'ruido'
Momento de máximo NDVI	Fenología	Fecha en la que se registra el valor máximo de NDVI	Momento de máxima producción de materia seca	Sensible a falsos picos y 'ruido'

Why ecosystem functioning has been seldom considered in conservation?

- Most concern has been focused at the species level, because the loss of species is well documented, frequent and irrevocable (Solbrig, 1991).
- Functional approaches are based on energy and matter exchanges which are not easily perceived
- Techniques to study ecosystem functioning are relatively new and not frequently used within the conservation community.

¿Cuál es la dinámica anual de la productividad en cada parque?



¿Qué parque presenta mayor variabilidad a lo largo de los años en la productividad? ¿En qué momento del año la presenta?

¿Qué parque presenta el parque un comportamiento más homogéneo a lo largo del año?

¿Qué parque presenta el parque un comportamiento más homogéneo en su variabilidad a lo largo de los años?

Gráfico tipo 1. Condiciones de referencia y su rango de variabilidad de la dinámica estacional del EVI para cada parque nacional (Evaluación a escala de Red).

Ejemplo: (a) Mean seasonal dynamics of the NDVI for the 1982–2006 period for each national park. (b) Interannual variability of the NDVI annual curve for each park calculated as the interannual coefficient of variation (CVt) of the mean seasonal dynamics. (c), (d) The spatial standard deviation of each park for the NDVI mean seasonal dynamics (in a) and the interannual variability (in b), respectively. A: Aigüestortes i E. S. Maurici; O: Ordesa y Monte Perdido; P: Picos de Europa; C: Cabañeros; M: Monfragüe; S: Sierra Nevada; D: Doñana. Tomado de Alcaraz-Segura et al. (2009). Environmental Management.