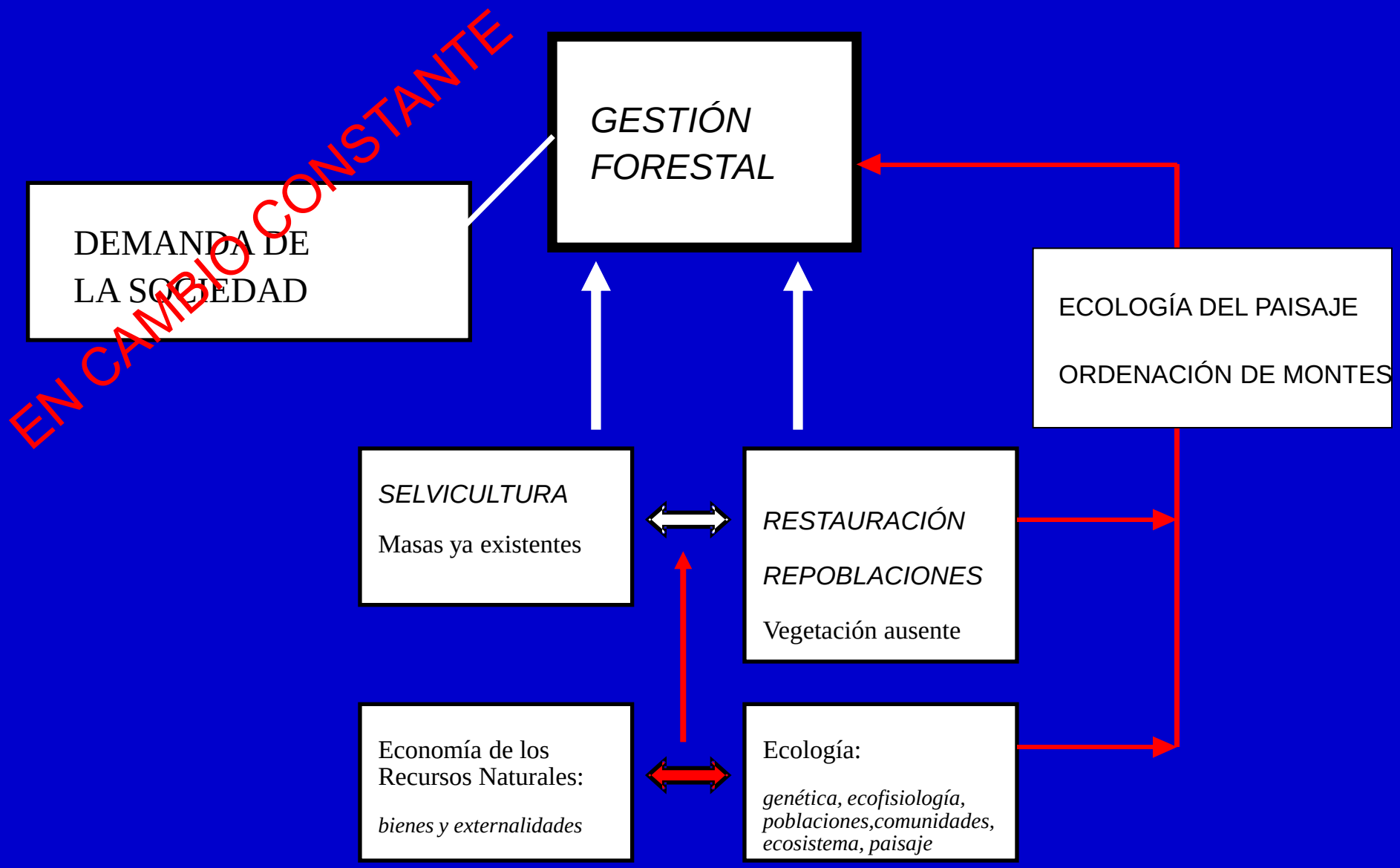
Impactos del cambio climático sobre los ecosistemas forestales en España.

Miguel A. Zavala
CIFOR-INIA
Universidad de Alcala

Adaptación al cambio climático en bosques
CENEAM, Valsaín (Segovia), 14-16 de noviembre de 2011

Universidad de Alcalá
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
INIA Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria


EN CAMBIO CONSTANTE
GESTIÓN FORESTAL
DEMANDA DE LA SOCIEDAD
ECOLOGÍA DEL PAISAJE
ORDENACIÓN DE MONTES
SELVICULTURA
Masas ya existentes
RESTAURACIÓN
REPOBLACIONES
Vegetación ausente
Economía de los Recursos Naturales:
bienes y externalidades
Ecología:
genética, ecofisiología, poblaciones,comunidades, ecosistema, paisaje

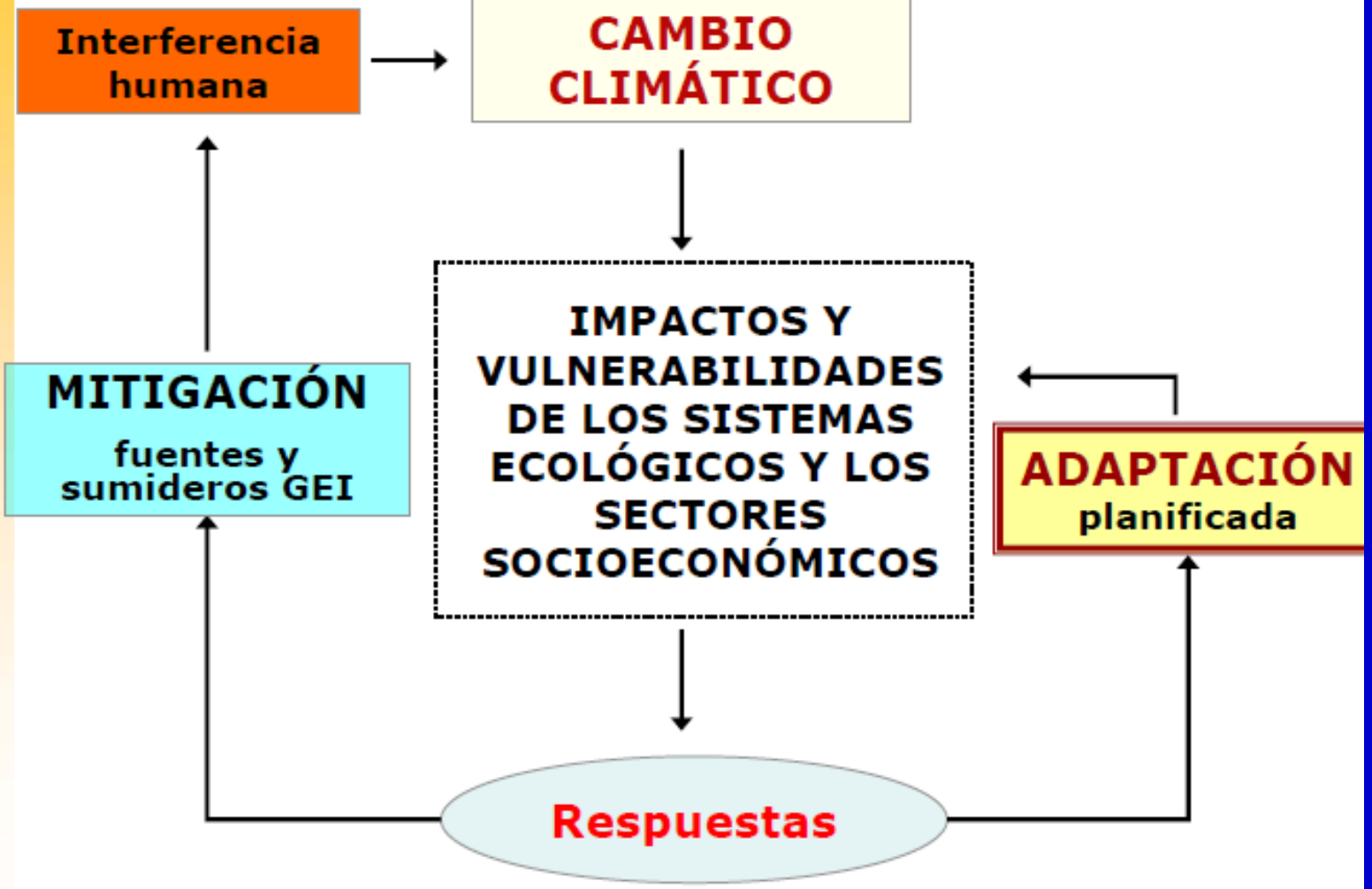
MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

Ciclo de Seminarios de Análisis y Prospectiva

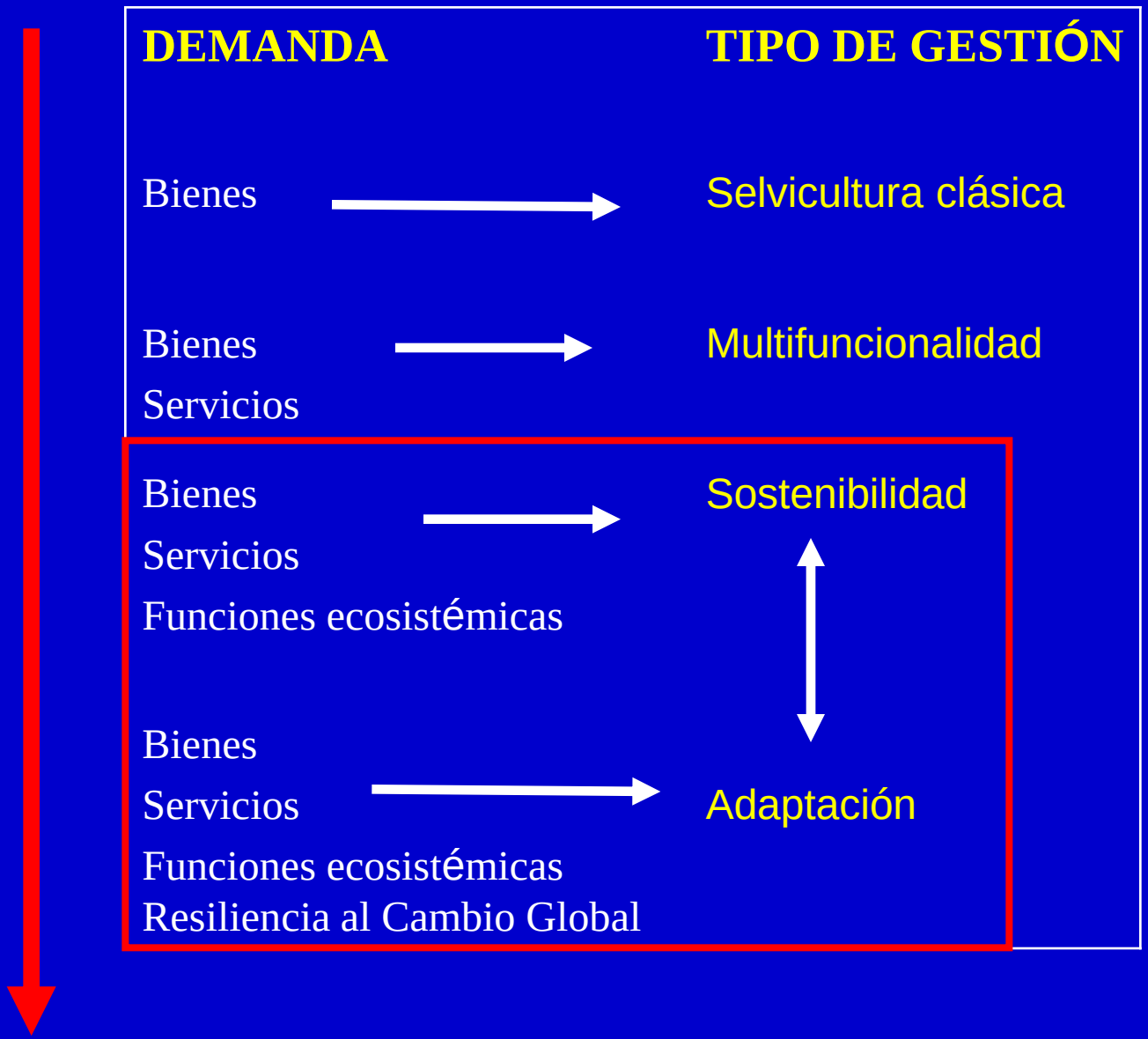
I Seminario 2009 / 26 de Febrero

Implicaciones del Cambio Climático sobre el medio ambiente, el medio rural y el medio marino

EL CAMBIO CLIMÁTICO COMO PRINCIPAL RETO AMBIENTAL



oecc


DEMANDA
TIPO DE GESTIÓN
Bienes
Selvicultura clásica
Bienes
Servicios
Multifuncionalidad
Bienes
Servicios
Funciones ecosistémicas
Sostenibilidad
Bienes
Servicios
Funciones ecosistémicas
Resiliencia al Cambio Global
Adaptación

“Cuando creíamos que teníamos todas las respuestas, de pronto, cambiaron todas las preguntas.”

Mario Benedetti

Vulnerabilidad y adaptación

(CAS; complex adaptive systems)

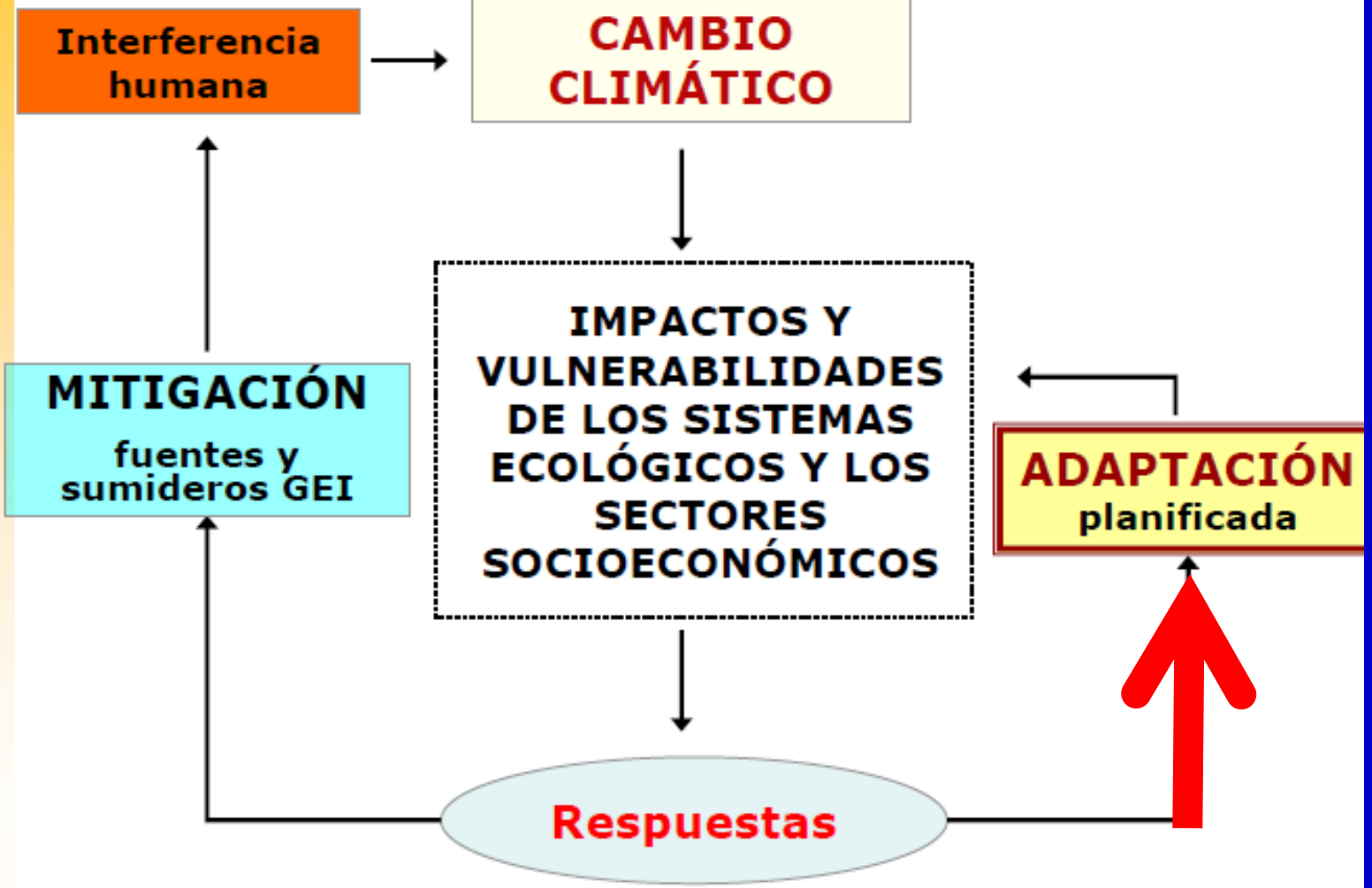
MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

Ciclo de Seminarios de Análisis y Prospectiva

I Seminario 2009 / 26 de Febrero

Implicaciones del Cambio Climático sobre el medio ambiente, el medio rural y el medio marino

EL CAMBIO CLIMÁTICO COMO PRINCIPAL RETO AMBIENTAL



oecc

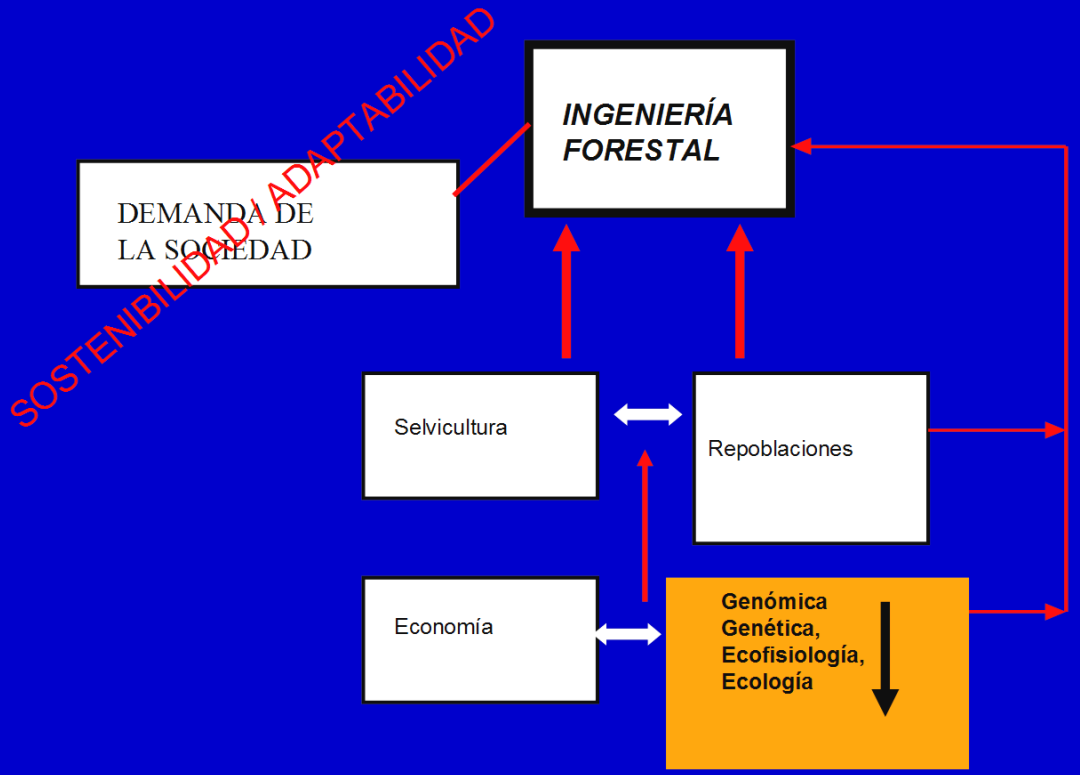
1) Información, conocimiento…

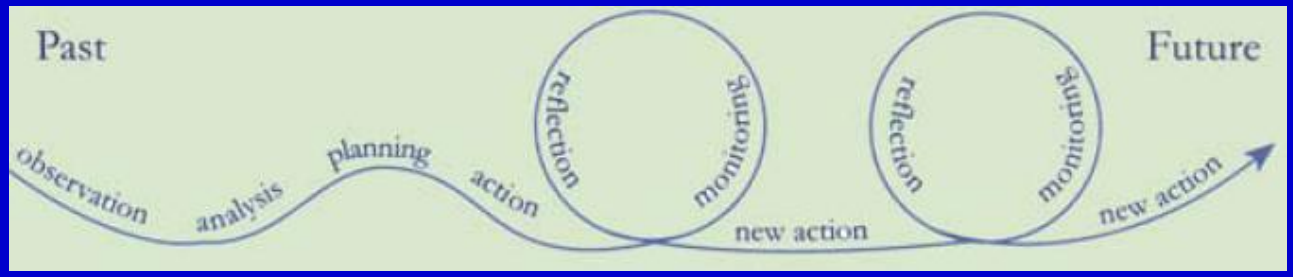
2) Transferencia (p.ej. Prospectiva crisis)

3) Trabajo en Red (p. ej. Individualismo/grupos vs. Plataformas interdisciplinares)

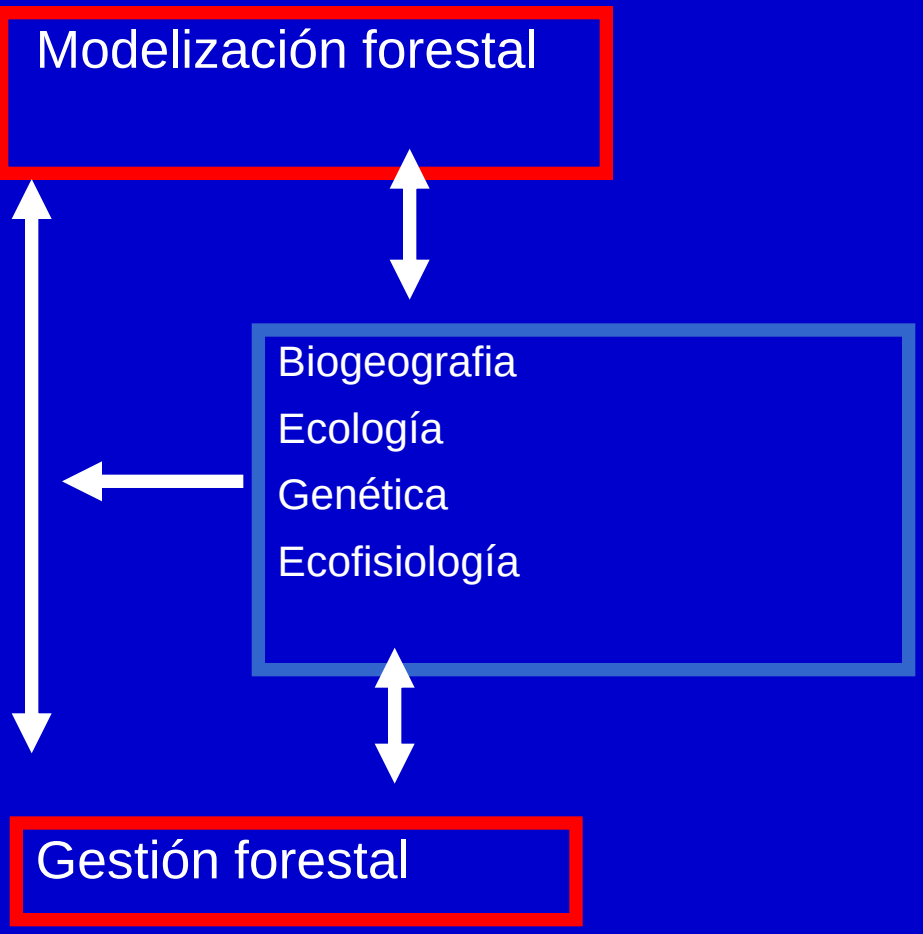
MODELOS

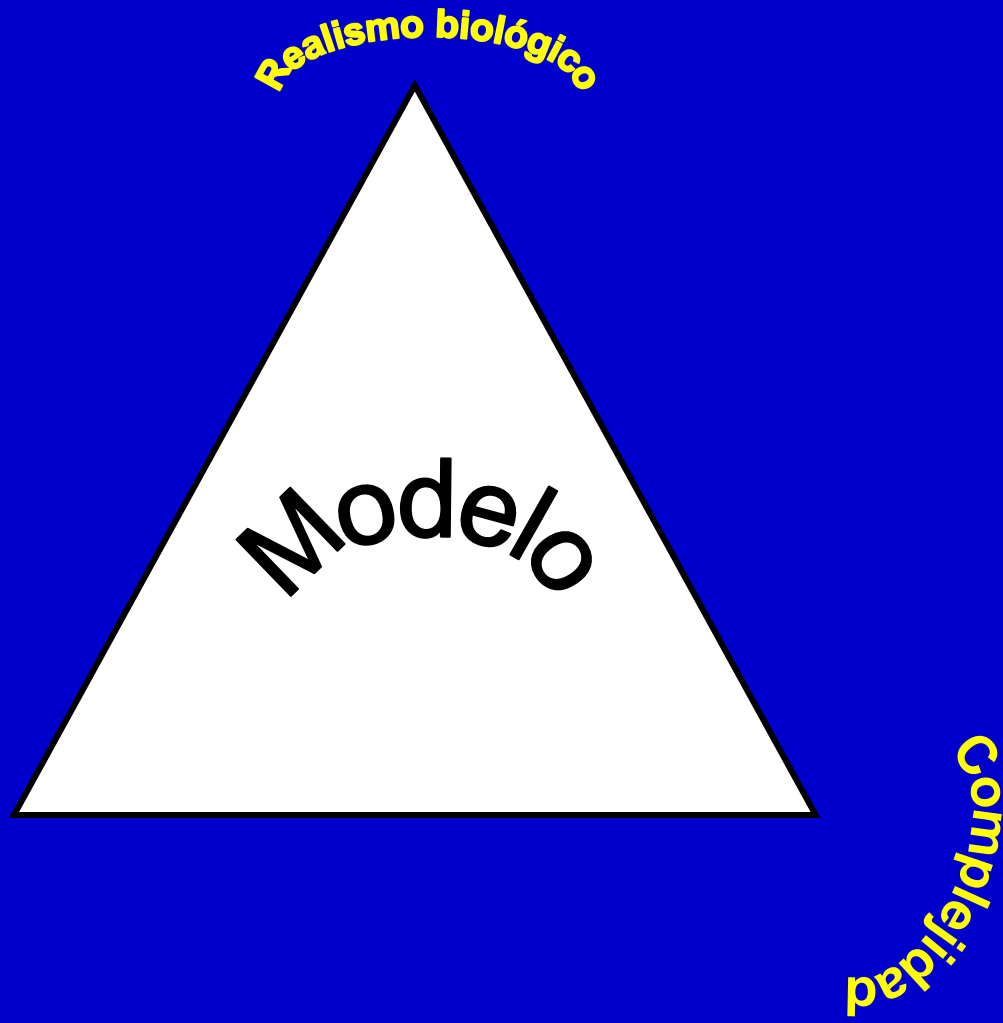
DATOS

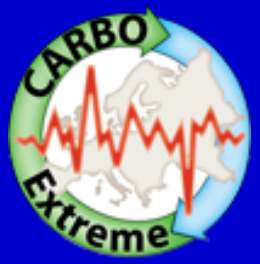




IUFRO world series vol. 22


Modelización forestal
Biogeografia
Ecología
Genética
Ecofisiología
Gestión forestal


Realismo biológico
Modelo
Tratabilidad
Complejidad



The terrestrial Carbon cycle under Climate Variability and Extremes a Pan-European synthesis

EU's 7th Framework Programme for Research and Technological Development
(Pressures on Environment and Climate), (2009 - 2013.)

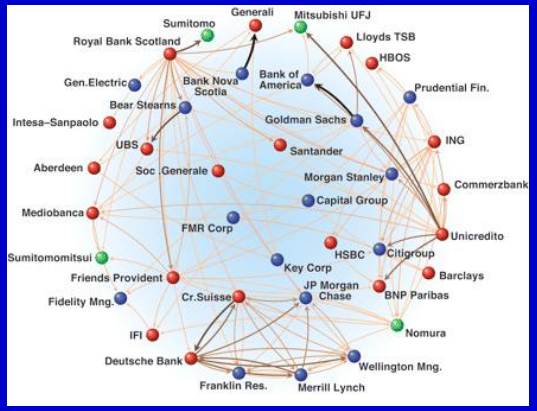
The Terrestrial Biosphere in the Earth System

COST Action ES0805.

"a cross-disciplinary assessment of our current understanding of the terrestrial biosphere from an Earth system perspective to improve the reliability of future Earth system projections in coupled climate-biosphere simulations."

FUNDIV: Functional significance of forest biodiversity

RESINEE: RESilience and Interaction of Networks in Ecology and Economics



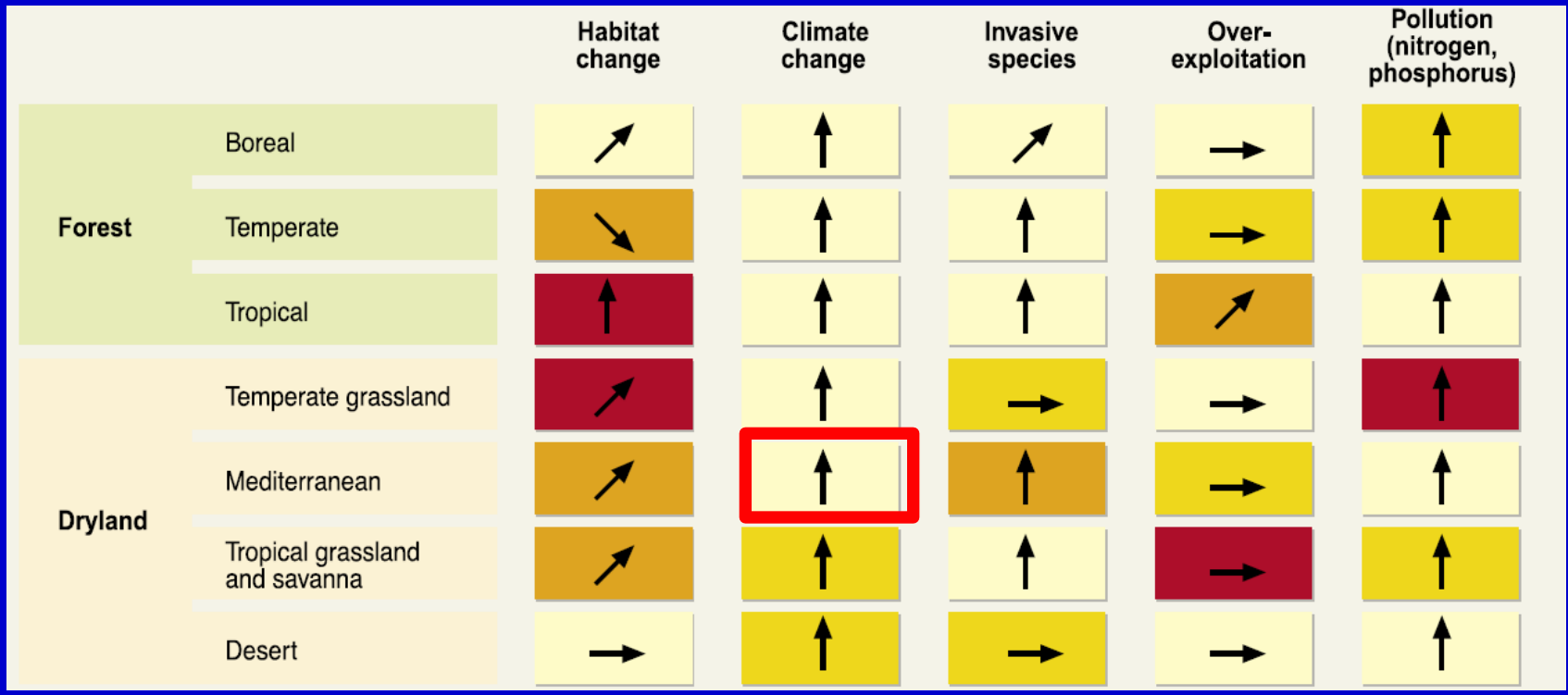
Análisis multi-escala, modelización y prospectiva del efecto sumidero de los ecosistemas forestales arbolados en España ante un escenario de Cambio Global

(SUM2008-00004-C03-01/BOS).

Interacciones ecológicas y Cambio Global en el bosque mediterráneo.

Proyecto coordinado del Plan Nacional de I+D+i
Ministerio de Ciencia e Innovación (CGL2008-04503-C03-01)

¿Por qué los bosques Mediterráneos?



Driver's impact on biodiversity over the last century

- Low
- Moderate
- High
- Very high

Driver's current trends

- Decreasing impact
- Continuing impact
- Increasing impact
- Very rapid increase of the impact

Source: Millennium Ecosystem Assessment

ECOSYSTEM SERVICES

Provisioning
- FOOD
- FRESH WATER
- WOOD AND FIBER
- FUEL
- ...

Supporting
- NUTRIENT CYCLING
- SOIL FORMATION
- PRIMARY PRODUCTION
- ...

Regulating
- CLIMATE REGULATION
- FLOOD REGULATION
- DISEASE REGULATION
- WATER PURIFICATION
- ...

Cultural
- AESTHETIC
- SPIRITUAL
- EDUCATIONAL
- RECREATIONAL
- ...

LIFE ON EARTH - BIODIVERSITY

CONSTITUENTS OF WELL-BEING

Security
- PERSONAL SAFETY
- SECURE RESOURCE ACCESS
- SECURITY FROM DISASTERS

Basic material for good life
- ADEQUATE LIVELIHOODS
- SUFFICIENT NUTRITIOUS FOOD
- SHELTER
- ACCESS TO GOODS

Health
- STRENGTH
- FEELING WELL
- ACCESS TO CLEAN AIR AND WATER

Good social relations
- SOCIAL COHESION
- MUTUAL RESPECT
- ABILITY TO HELP OTHERS

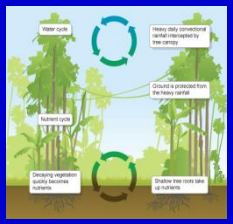
Freedom of choice and action

OPPORTUNITY TO BE ABLE TO ACHIEVE WHAT AN INDIVIDUAL VALUES DOING AND BEING

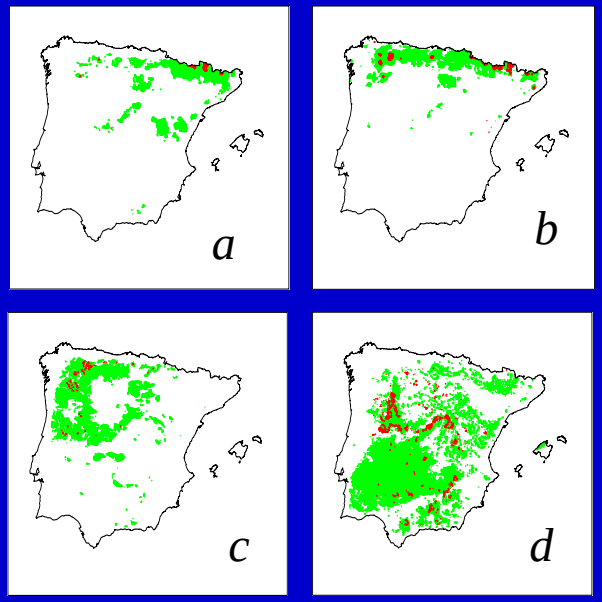
Source: Millennium Ecosystem Assessment

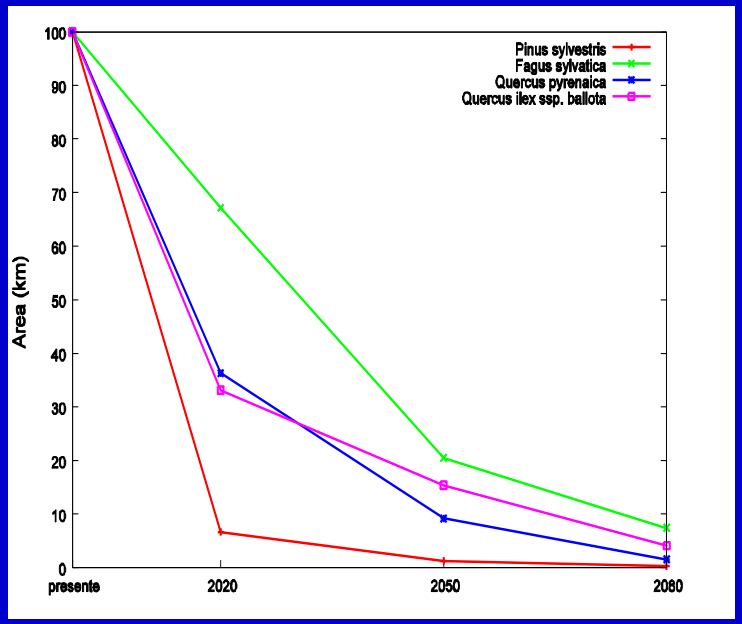
ARROW'S COLOR
Potential for mediation by socioeconomic factors
- Low
- Medium
- High

ARROW'S WIDTH
Intensity of linkages between ecosystem services and human well-being
- Weak
- Medium
- Strong



Species distribution models (SDM´S): climate change and predicted potential forest distribution

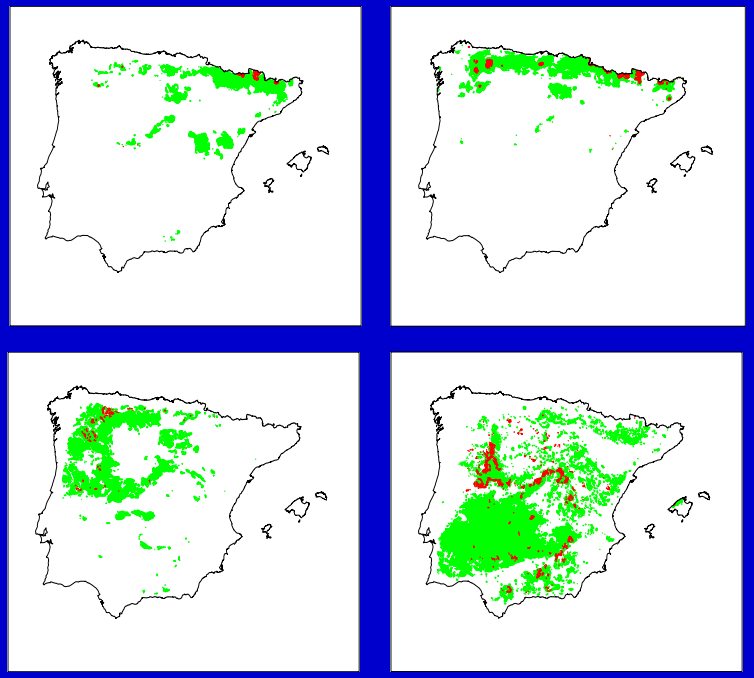




Changes in potential distribution area for for selected Iberian forest tree species. Current area = 100%. Area decreases according to climatic predictions from scenario A2 CSIRO-Mk2 for 2020, 2050 and 2080.

Informe sostenibilidad 2007. OSE. Mundi-prensa. Ministerio de Medio Ambiente.

Including ecological and adaptive mechanisms in vulnerability models.



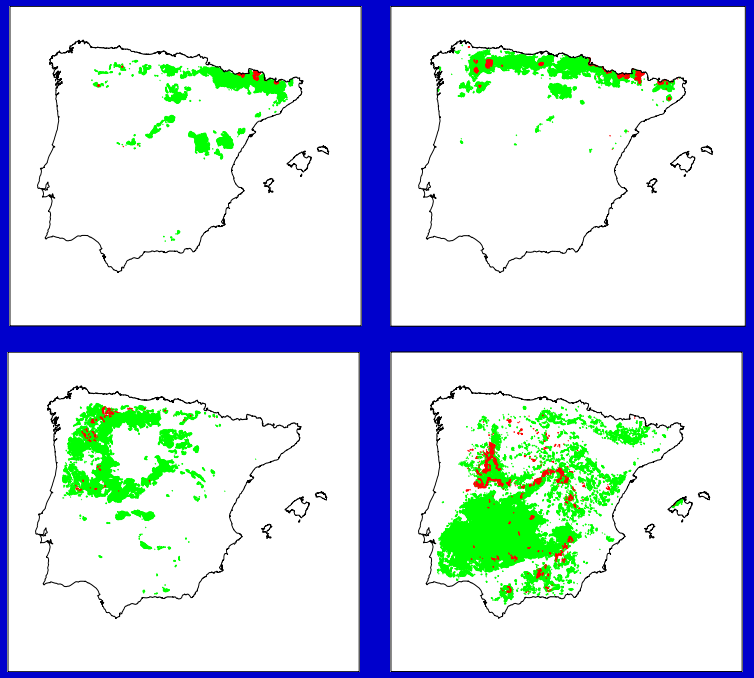
Fuente: *Elaborado a partir de Benito Garzón et al.* 2009

Genes & organismic
Epigenesis.
Evolution
Local adaptation
Plasticity

Population and communities
Migration (dispersal)
Diversity/Stabiilty

Ecosystem & landscape.
Demographic adjustments
Land use governance

Including ecological and adaptive mechanisms in vulnerability models.



Fuente: *Elaborado a partir de Benito Garzón et al.* 2009

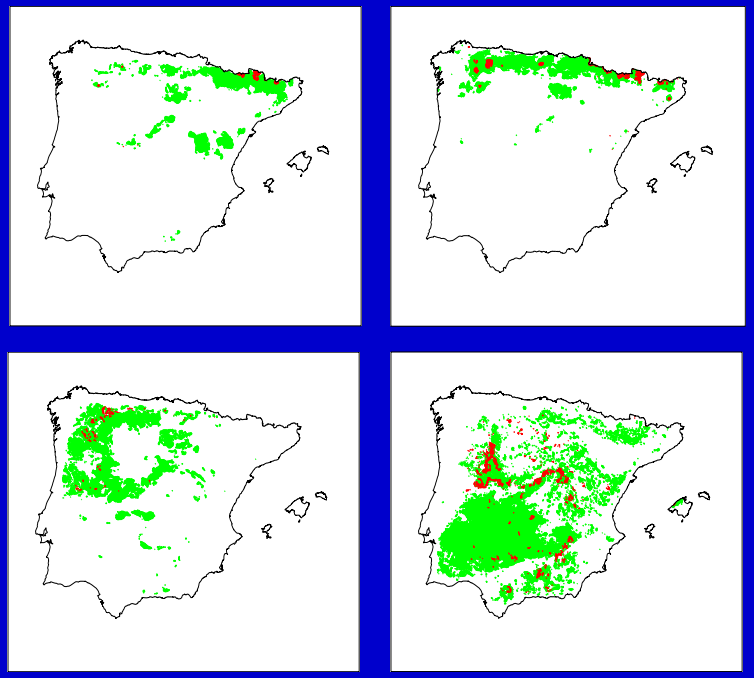
Genes & organismic
Epigenesis.
Evolution
Local adaptation
Plasticity

Population and communities
Migration (dispersal)
Diversity/Stabiilty

Ecosystem & landscape.
Demographic adjustments
Land use governance

CASE-1:

Introduction of genetic variability into SDM models.



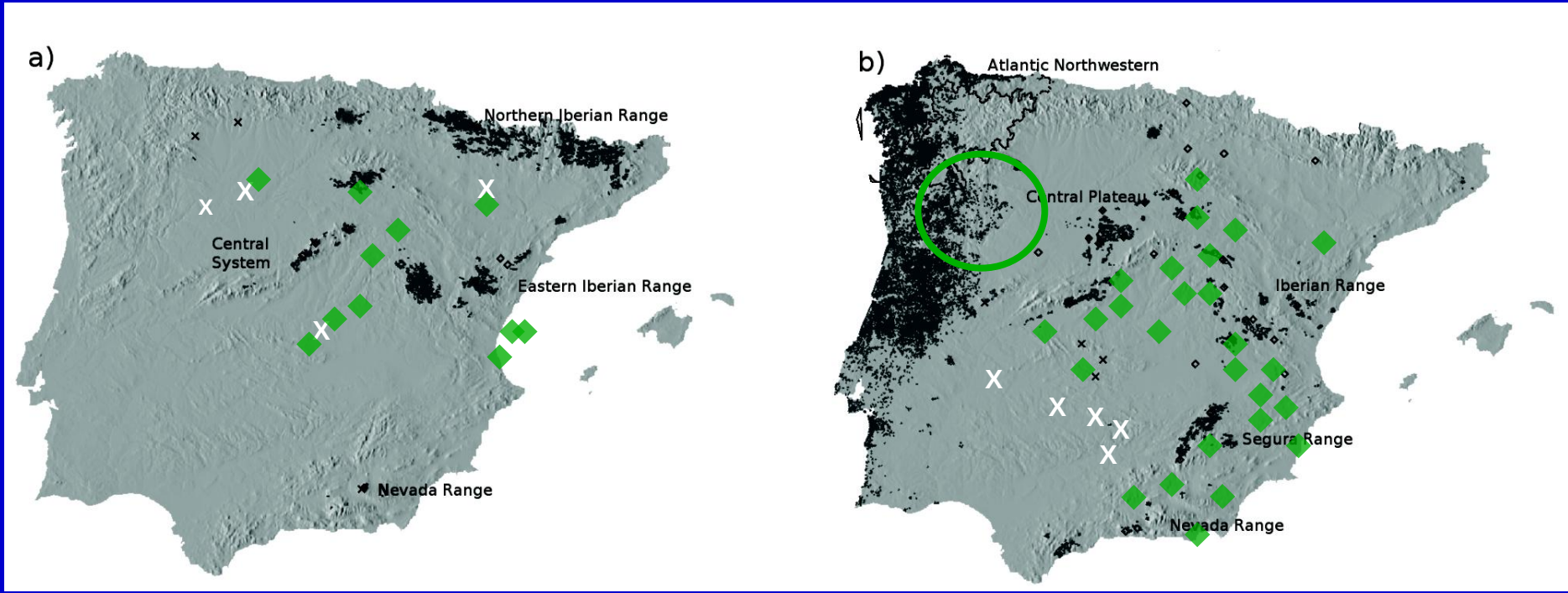
- Using experimental data.
- Including local adaptation.
- Including phenotypic plasticity.

Fuente: *Elaborado a partir de Benito Garzón et al.* 2009

Benito-Garzón *et al*. 2011. *Global Ecology & Biogeography* 20: 766–778.

CASE-1:

Introduction of genetic variability into SDM models.



Pinus sylvestris

Provenances

Plantation sites X

Pinus pinaster

Alía *et al.*, 1996; 1999; 2001; 2005

CASE-1:

Introduction of genetic variability into SDM models.

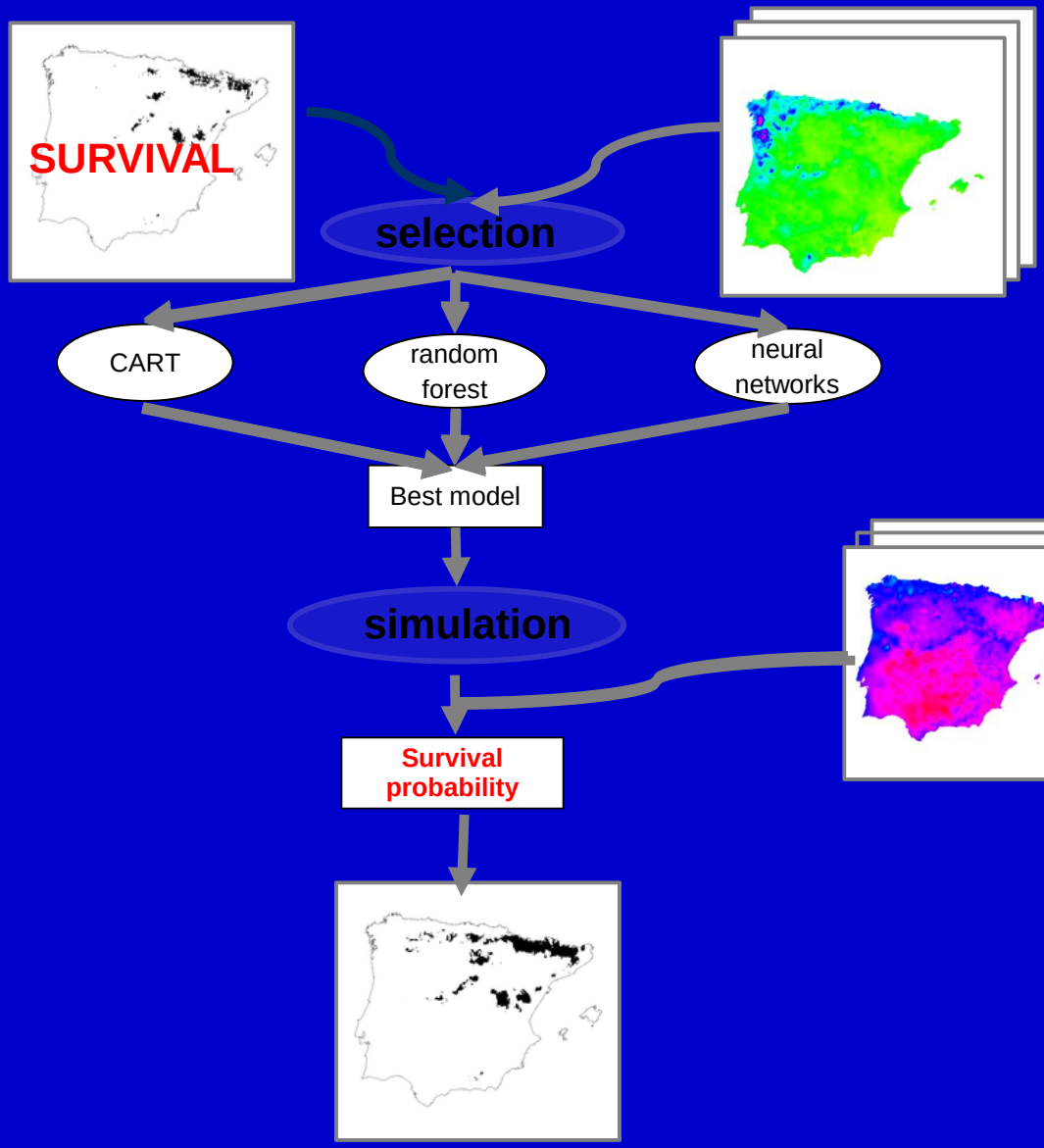
between provenances → Intra-specific genetic diversity

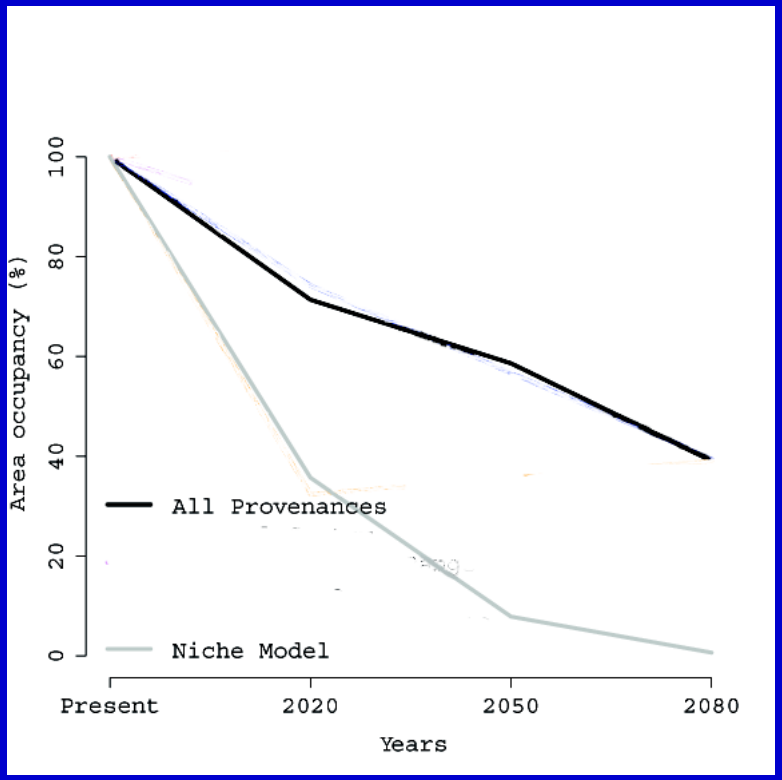
between plantation sites → Existence of phenotypic plasticity

interaction genotype - environment → Differences in plasticity among populations

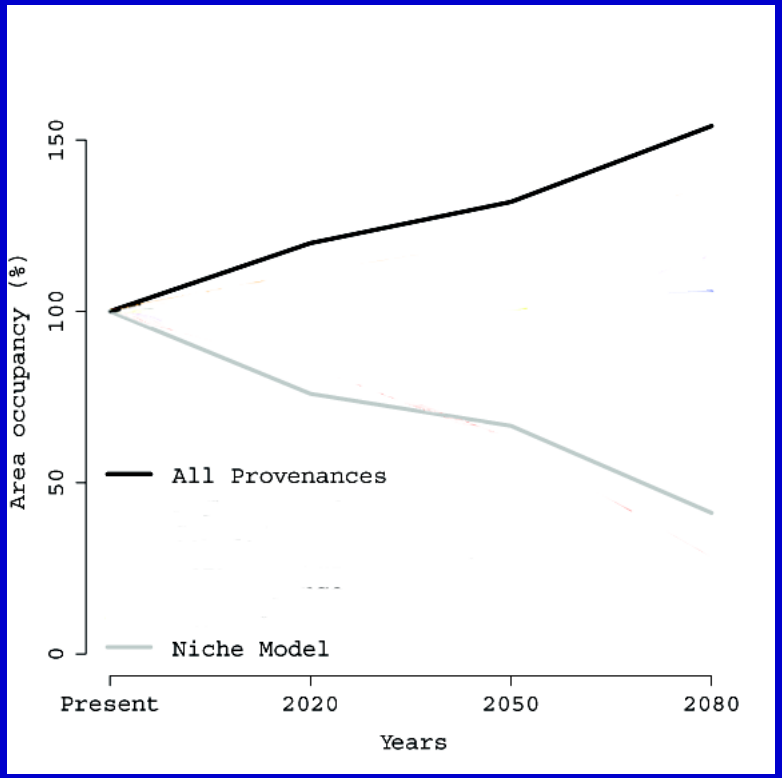
Differences in survival between provenances and plantation sites and their interaction

Benito-Garzón *et al.* 2011. *Global Ecology & Biogeography* 20: 766–778.


SURVIVAL
selection
CART
random forest
neural networks
Best model
simulation
Survival probability

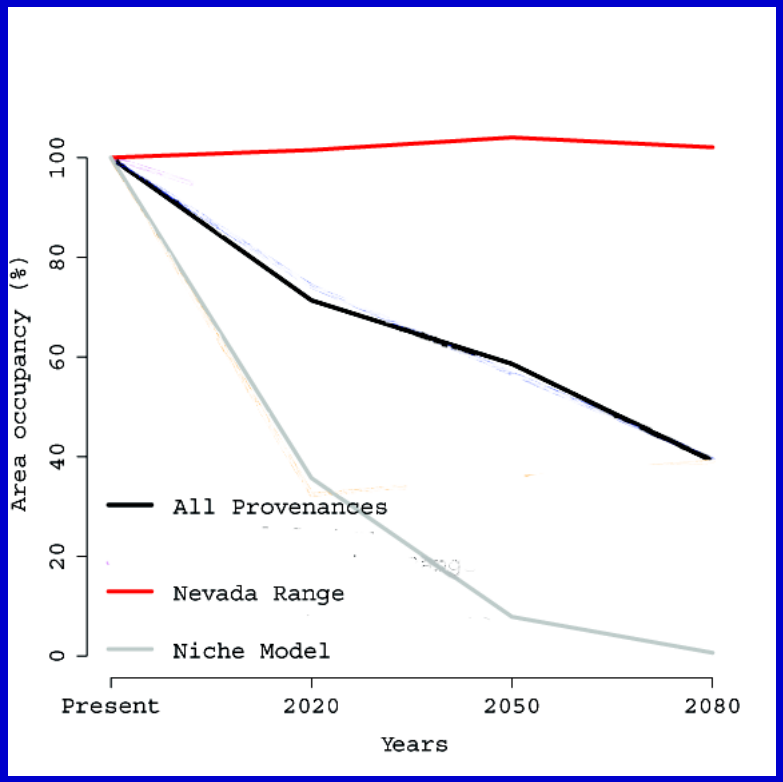


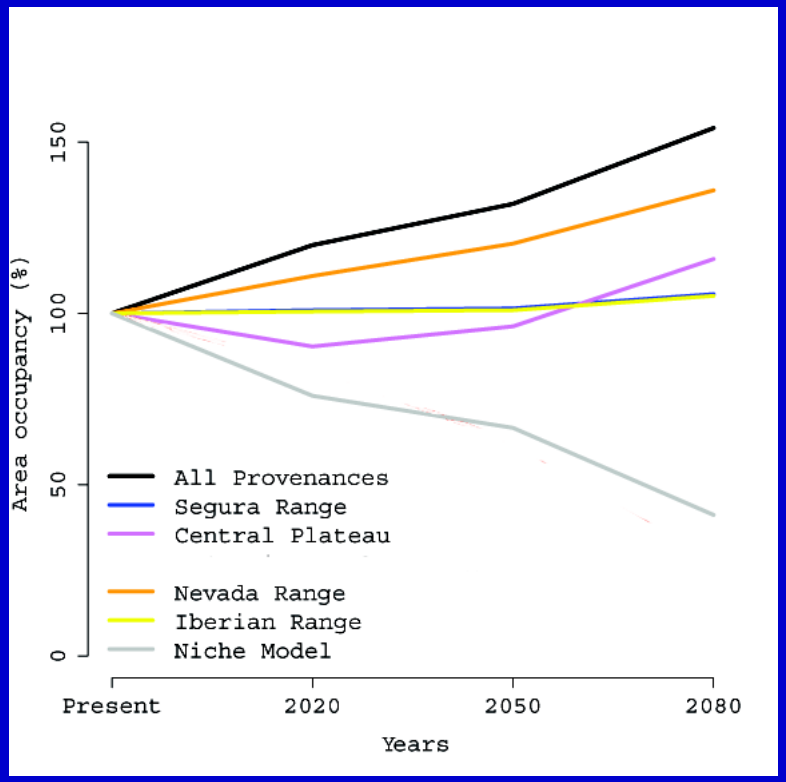
Pinus sylvestris



Pinus pinaster

Benito-Garzón *et al.* 2011. *Global Ecology & Biogeography* 20: 766–778.

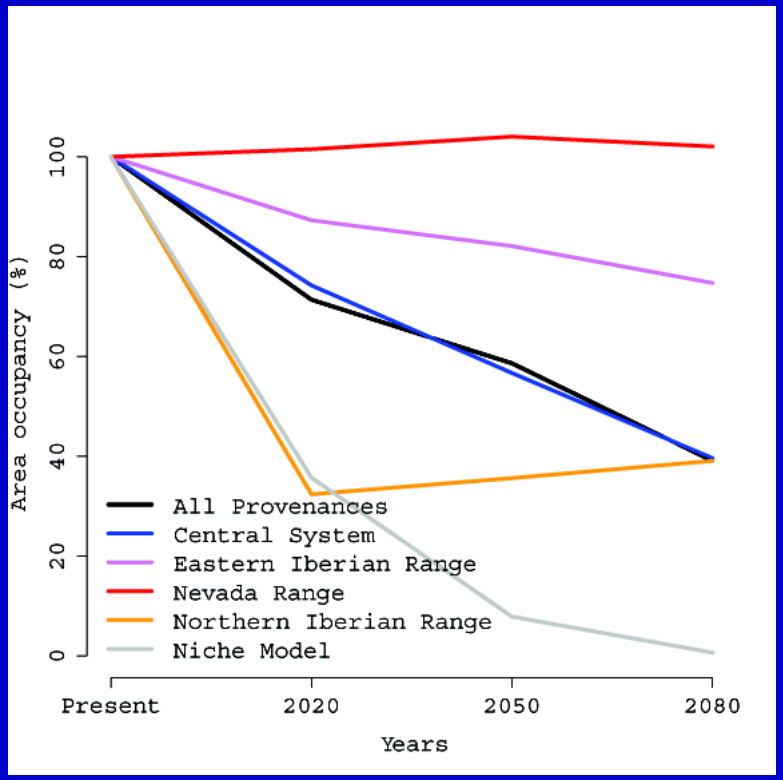


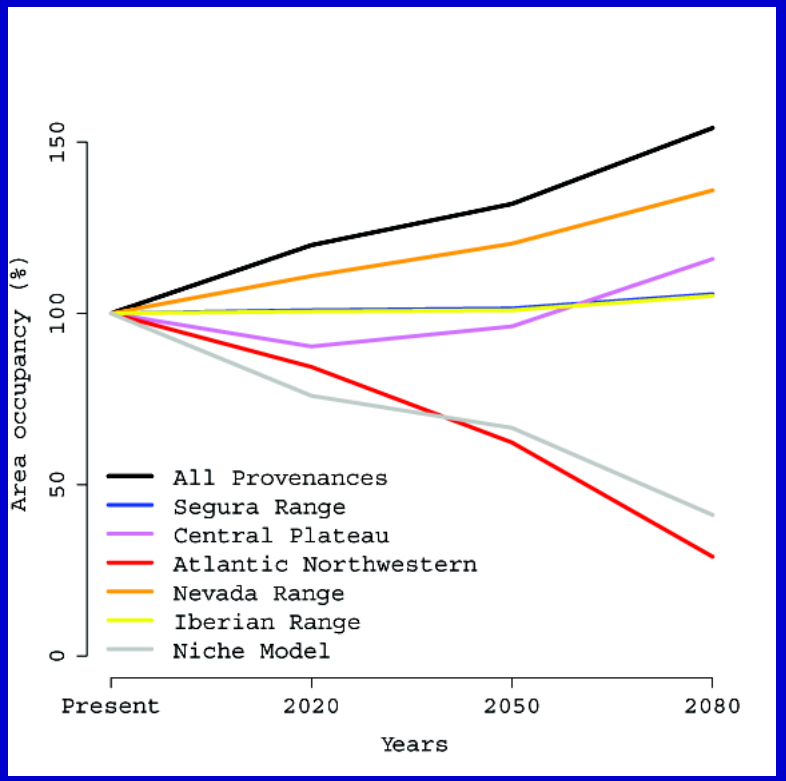


Pinus sylvestris

Pinus pinaster

Benito-Garzón *et al.* 2011. *Global Ecology & Biogeography* 20: 766–778.



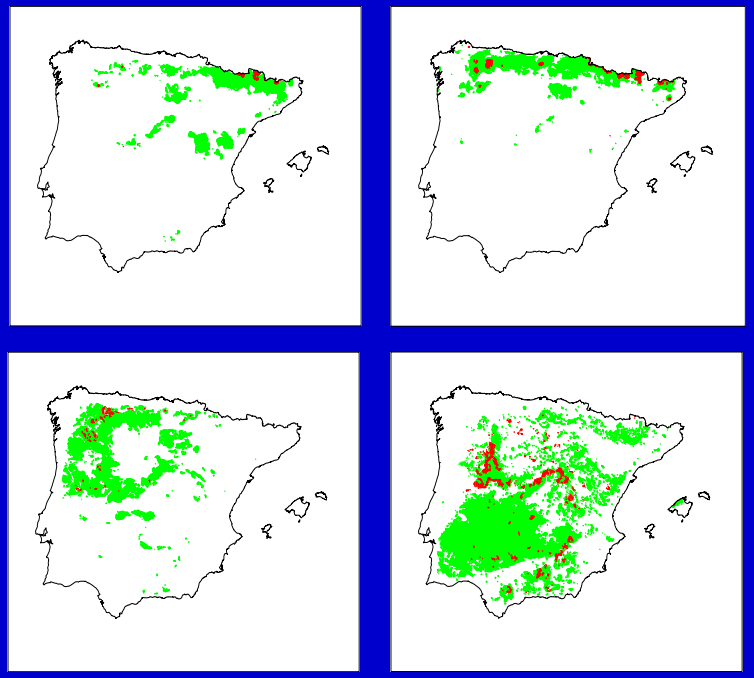


Pinus sylvestris

Pinus pinaster

Benito-Garzón *et al.* 2011. *Global Ecology & Biogeography* 20: 766–778.

Including ecological and adaptive mechanisms in vulnerability models.



Fuente: *Elaborado a partir de Benito Garzón et al.* 2009

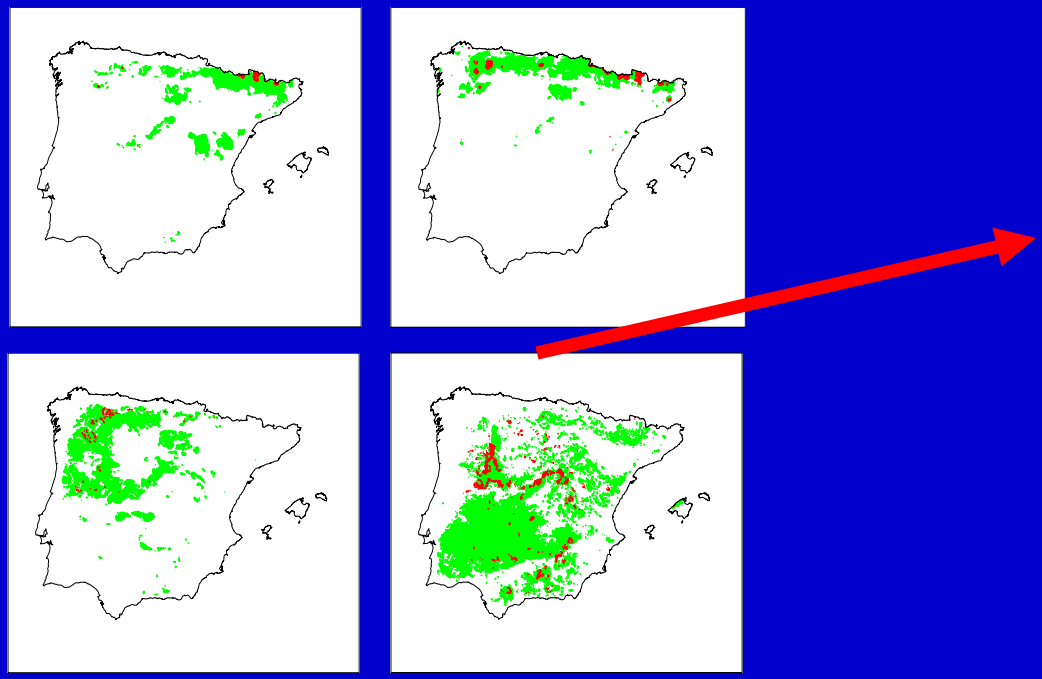
Genes & organismic
Epigenesis.
Evolution
Local adaptation
Plasticity

Population/ communities
Migration (dispersal)
Diversity/Stabiilty

Ecosystem & landscape.
Demographic adjustments
Land use governancet

CASE-2:

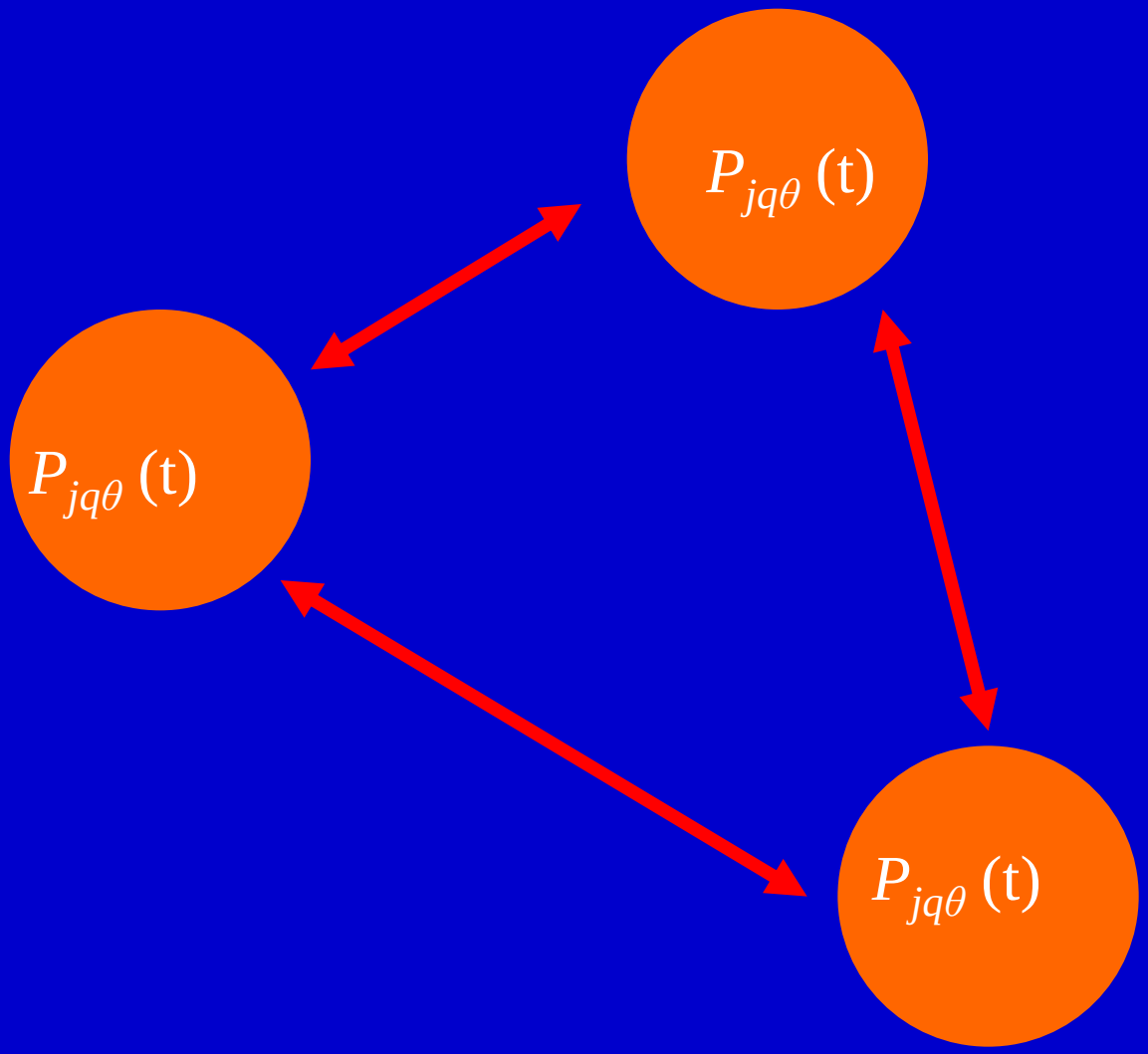
Introduction of demographic processes and non-equilibrium dynamics into SDM models.



- Using experimental data.
- Colonization/extinction rates.
- Stochastic non-equilibrium dynamics
- Dispersal

Fuente: *Elaborado a partir de Benito Garzón et al.* 2009

SPOM ("Stochastic Patch Occupancy Model")



Purves, et al. 2007. *Ecological Monographs* 77:77–97.

SPOM ("Stochastic Patch Occupancy Model")

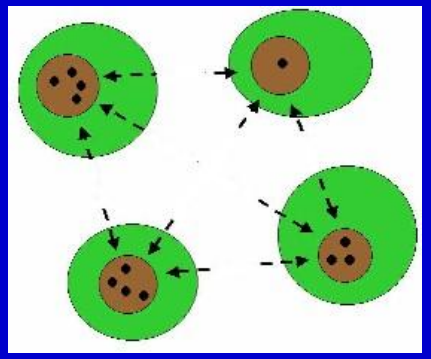
$$P\left[z_{j,i}(t+1) \mid z_{j,i}(t)\right] = \begin{cases} \phi_i & \text{if } z_{j,i}(t)=1 \text{ and } z_{j,i}(t+1)=0 \\ 1-\phi_i & \text{if } z_{j,i}(t)=1 \text{ and } z_{j,i}(t+1)=1 \\ 1-(1-\alpha_{j,i})^{S_{j,i}(t)} & \text{if } z_{j,i}(t)=0 \text{ and } z_{j,i}(t+1)=1 \\ (1-\alpha_{j,i})^{S_{j,i}(t)} & \text{if } z_{j,i}(t)=0 \text{ and } z_{j,i}(t+1)=0 \end{cases}$$

1) Distance to seed source.

2) Post-fire genet mortality.

Purves, et al. 2007. *Ecological Monographs* 77:77–97.

Model fitting



1990 2000 inside the forest

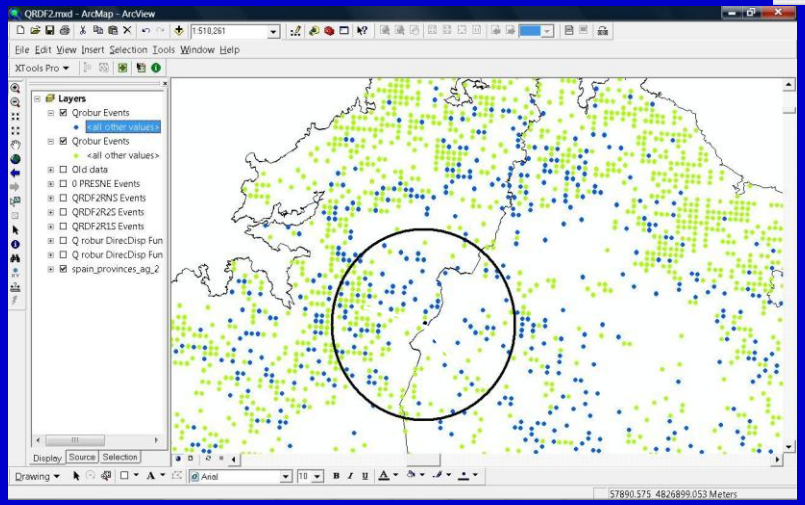
Quercus robur

0 → 1

1 → 0

$P_{j,q,\theta}$ (1→0) = f (P, T)

$P_{j,q,\theta}$ (0→1) = f (P, T, DistF, DistSp)

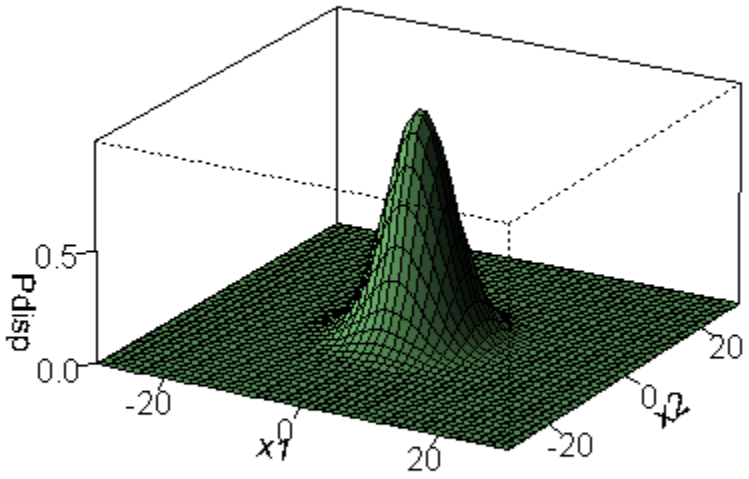


Neighborhood

Random dispersal - Mediated dispersal

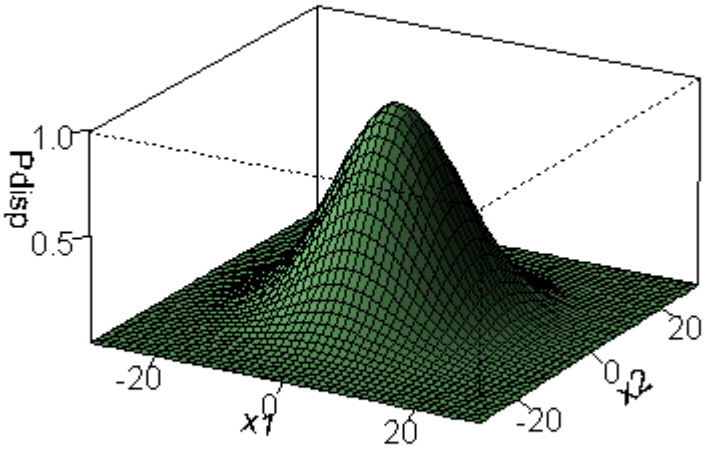
García-Valdés *et al. Under process*

Pinus sylvestris dispersal kernel



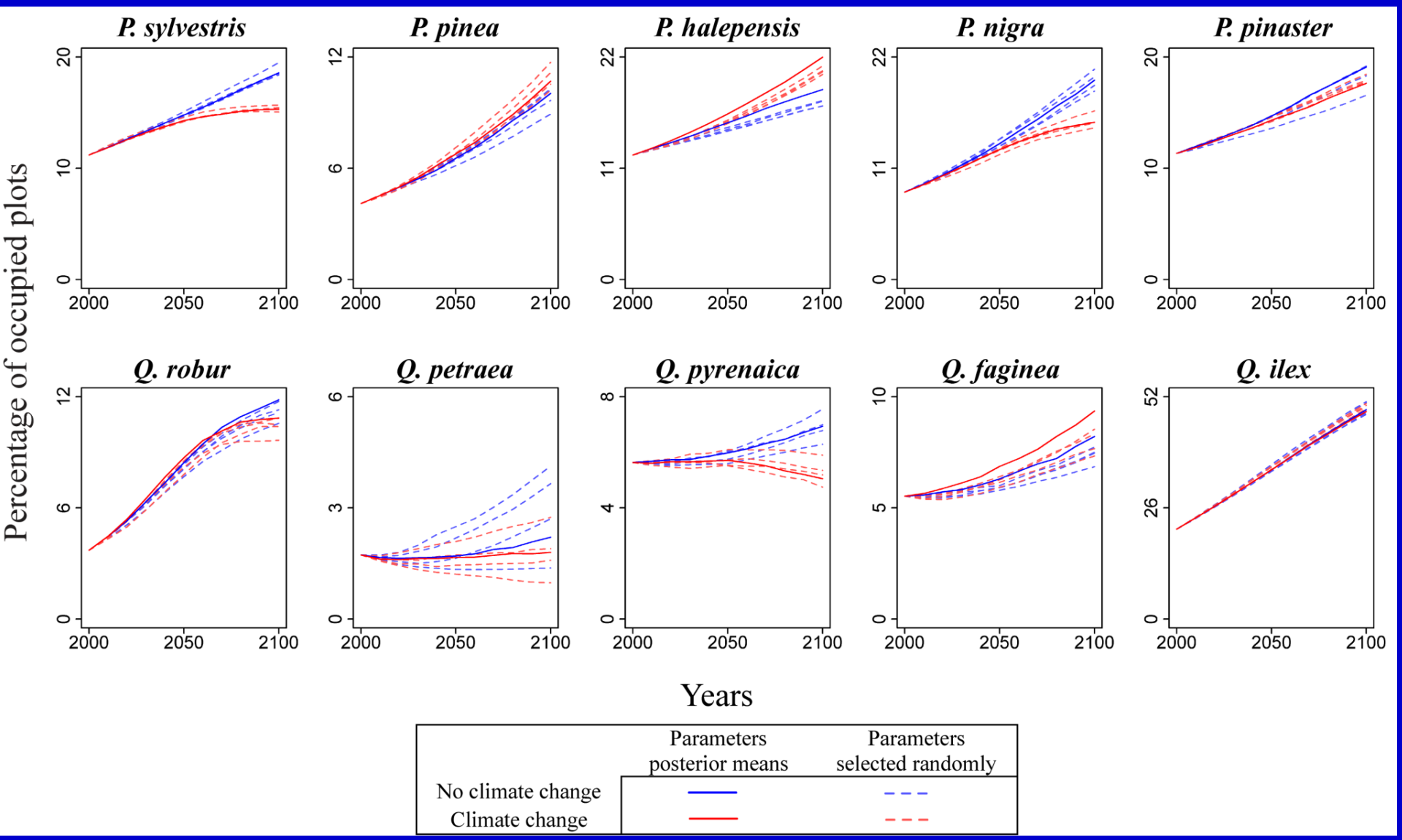
$$f(\mathbf{x}) = \exp\left(-\left[\frac{\sqrt{x1^2 + x2^2}}{\sigma}\right]^2\right) \qquad \sigma = 6.19$$

Quercus faginea dispersal kernel



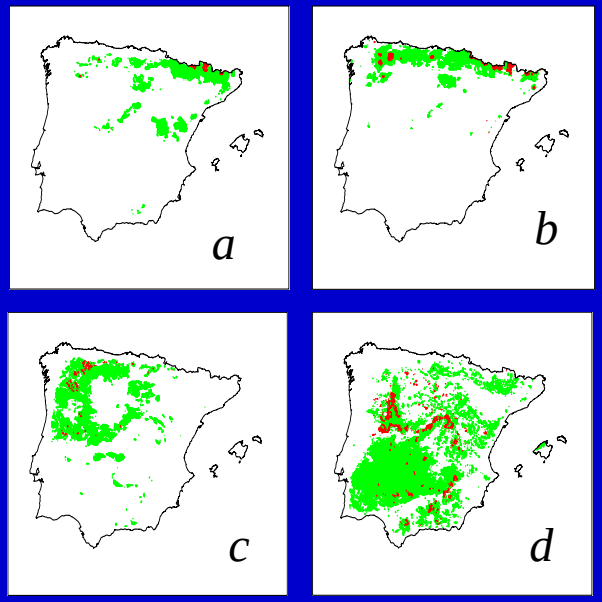
$$f(\mathbf{x}) = \exp\left(-\left[\frac{\sqrt{x1^2 + x2^2}}{\sigma}\right]^2\right) \qquad \sigma = 12.54$$

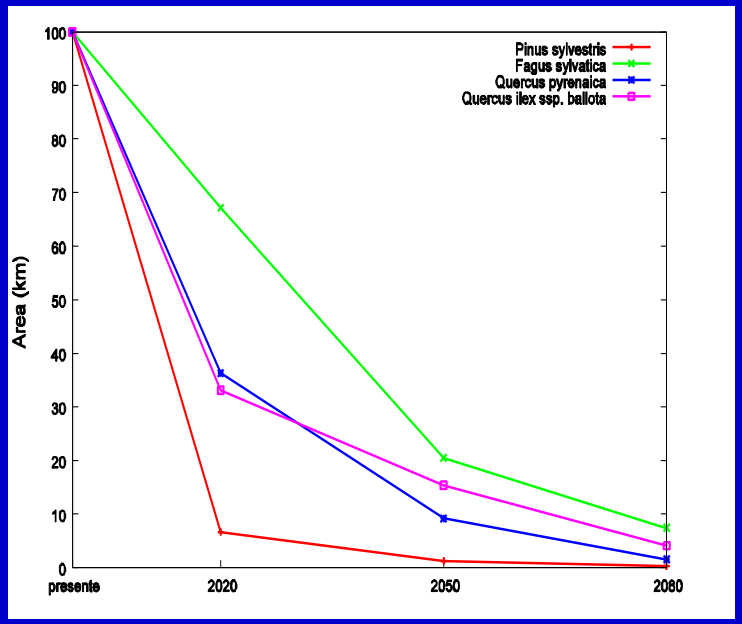
García-Valdés *et al. Under process*



Species fraction of occupied plots from year 2000 to year 2100. One simulation using the posterior means for the parameter values, and four simulations using parameter sets drawn randomly from the samples generated by the MCMC algorithm.

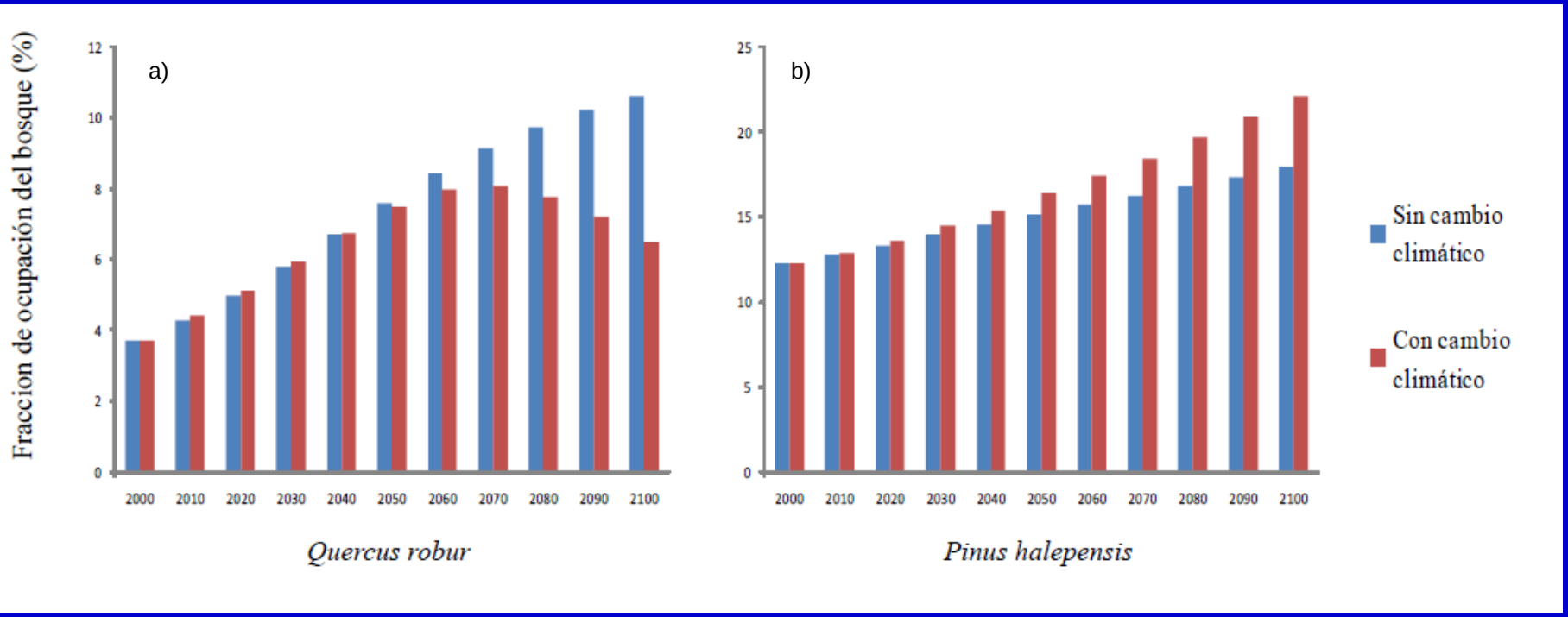
Species distribution models (SDM´S): climate change and predicted potential forest distribution





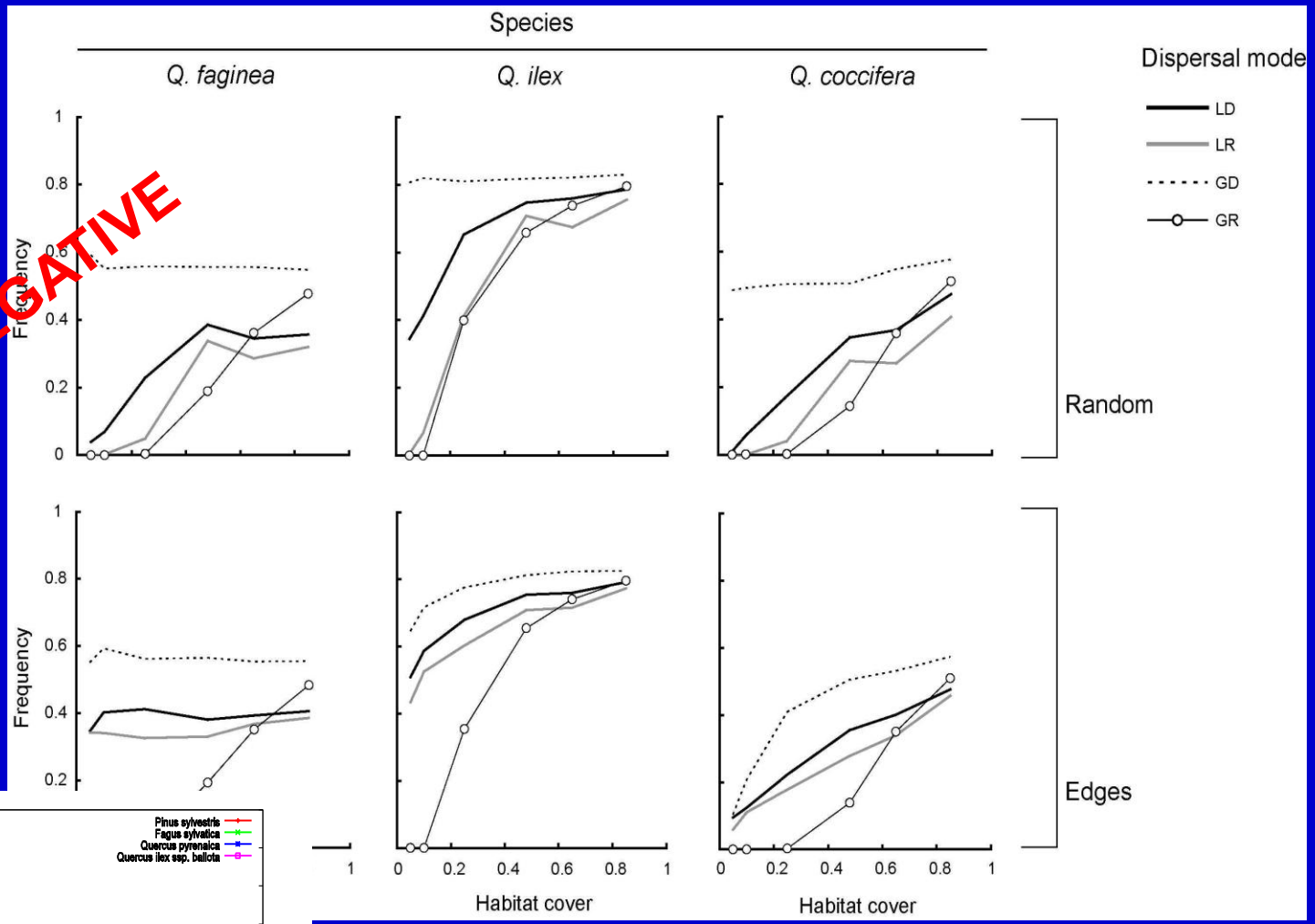
Changes in potential distribution aarea for for selected Iberian forest tree species. Current area = 100%. Area decreases according to climatic predictions from scenario A2 CSIRO-Mk2 for 2020, 2050 and 2080.

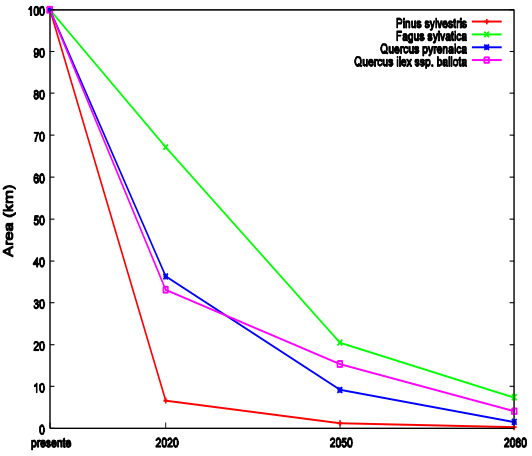
Informe sostenibilidad 2007. OSE. Mundi-prensa. Ministerio de Medio Ambiente.



Proyecciones de la fracción de ocupación del bosque, número de parcelas en las que está presente la especie respecto al total de parcelas de bosque, en 2100 con y sin cambio climático para (a) el roble común (*Q. robur*) y (b) el pino carrasco (*P. halepensis*)

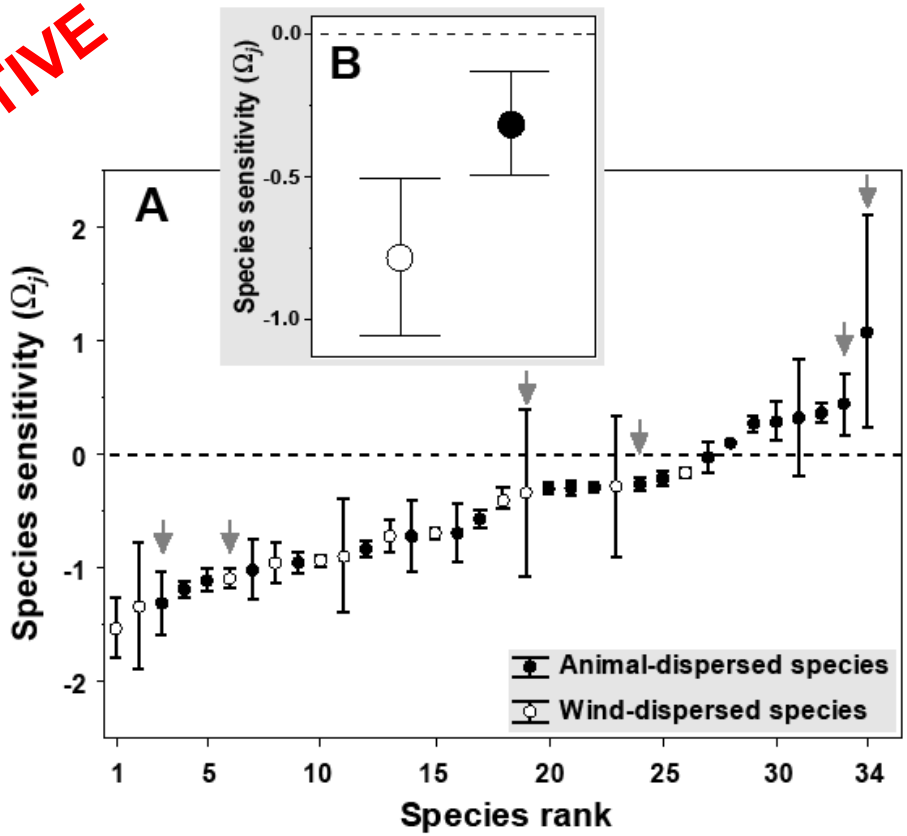
Fuente: Elaboración OSE a partir de García-Valdés *et al.* (2010).

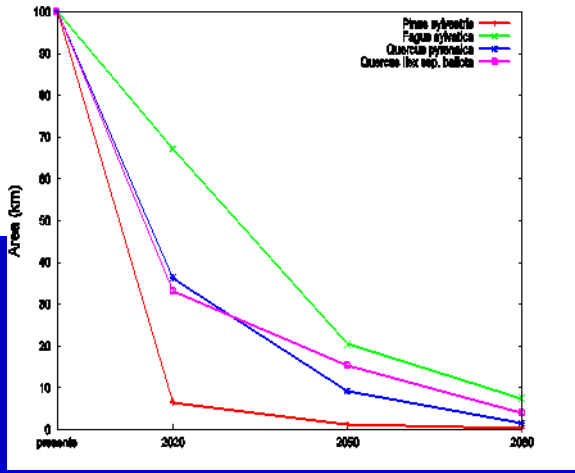




Purves, et al. 2007. *Ecological Monographs* 77:77–97.

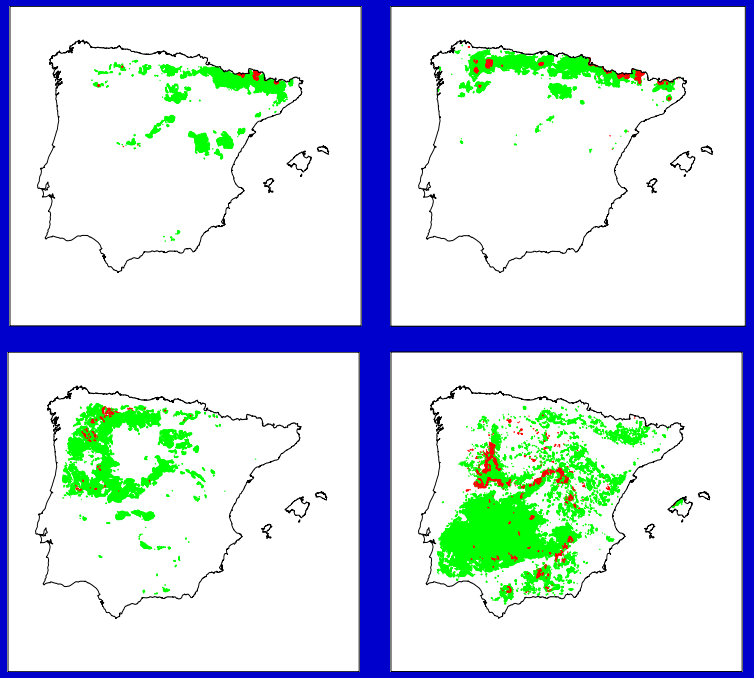
POSITIVE





Montoya *et al*. 2008. *Science* 320: 1502-1504.

Including ecological and adaptive mechanisms in vulnerability models.



Fuente: *Elaborado a partir de Benito Garzón et al.* 2009

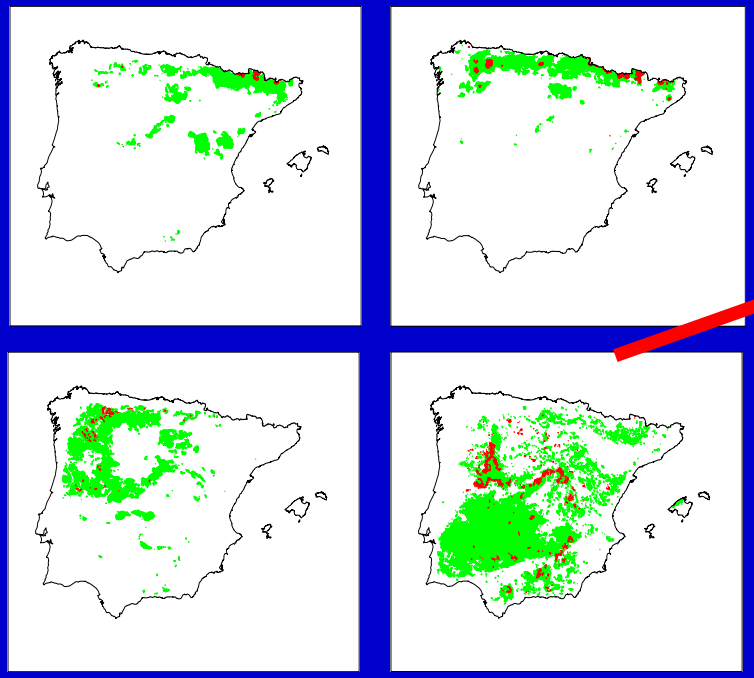
Genes & organismic
Epigenesis.
Evolution
Local adaptation
Plasticity

Population and communities
Migration (dispersal)
Diversity/Stabiilty

Ecosystem & landscape.
Demographic adjustments
Land use governance

CASE-3:

Introduction of demographic processes in NPP models.



Fuente: *Elaborado a partir de Benito Garzón et al.* 2009

- Using forest inventory data.
- Including demographic process (growth, recruitment, mortality.

Work under progress…

NET PRIMARY PRODUCTIVITY (NPP) ESTIMATION

Inventario Forestal Nacional:
IFN2, IFN3

Growth, recruitment

Individual growth biomass

$B = (B_{NFI3} - B_{NFI2}) / t$

Annual net primary productivity (NPP):

NPP $= B + B_{R3}/t$

B_{NFI3} and B_{NFI2} = individual tree biomass in the third NFI3 and the second NFI respectively

$(B_{NFI3} - B_{NFI2})$ = biomass increase of surviving trees in both inventories

t = number of years that had elapsed between surveys at province level.

B_{R3} = biomass of established new trees relative per area unit.

NNP

(tn/ha·year) estimated from

National Forest Inventories:
IFN2, IFN3

NPP ESTIMATION: NPP vs PNPP

Abiotic variables:

Climatic variables

Topography

Litology

Forest Management

Abiotic variables + (biotic, and human drivers)

(tn/ha·year) estimated from IFN2, IFN3

PNPP

- Paterson Index
- Rosenzweig

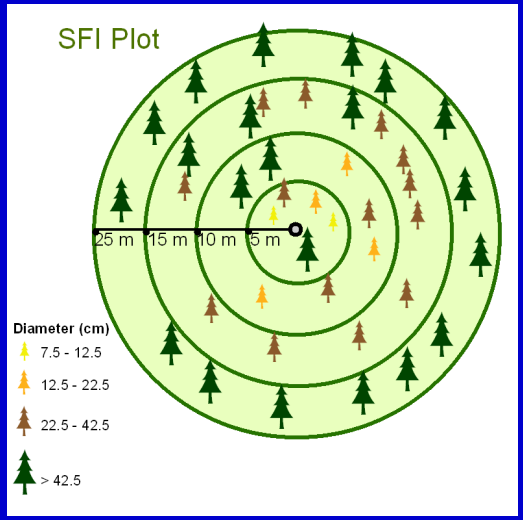
versus

NPP

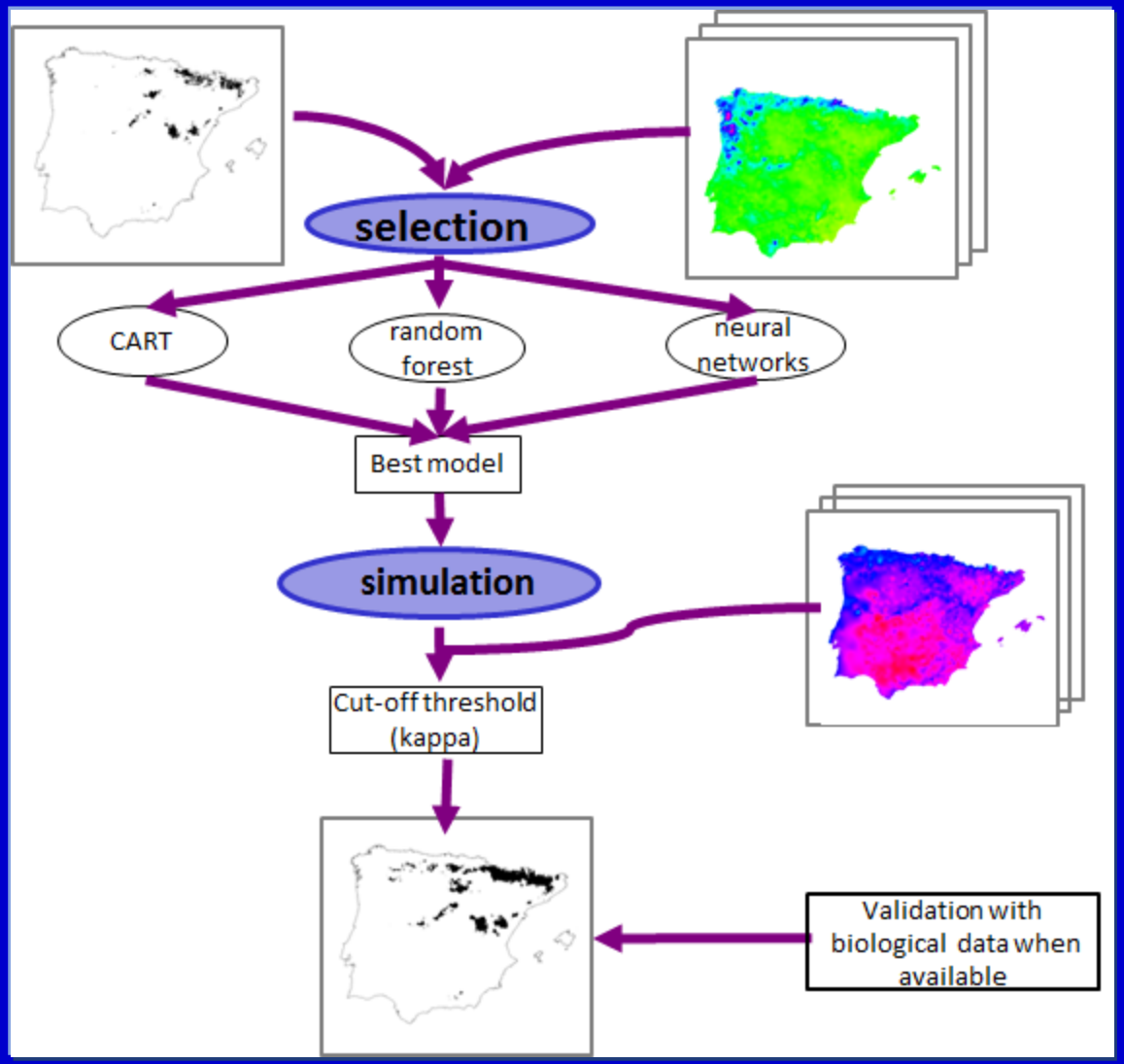
-Machine learning model

POTENTIAL PRODUCTIVITY ESTIMATION

REAL PRODUCTIVITY PREDICTION



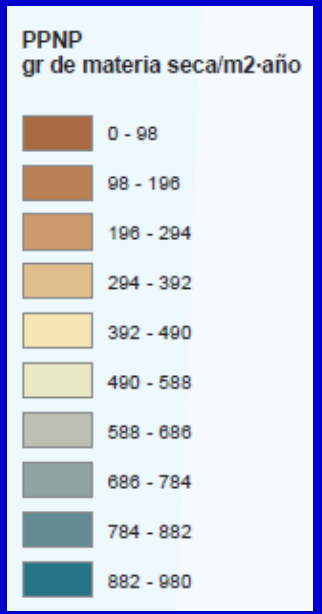
(PNPP – NPP) → DRIVERS SHAPING REAL PRODUCTIVITY


selection
CART
random forest
neural networks
Best model
simulation
Cut-off threshold (kappa)
Validation with biological data when available

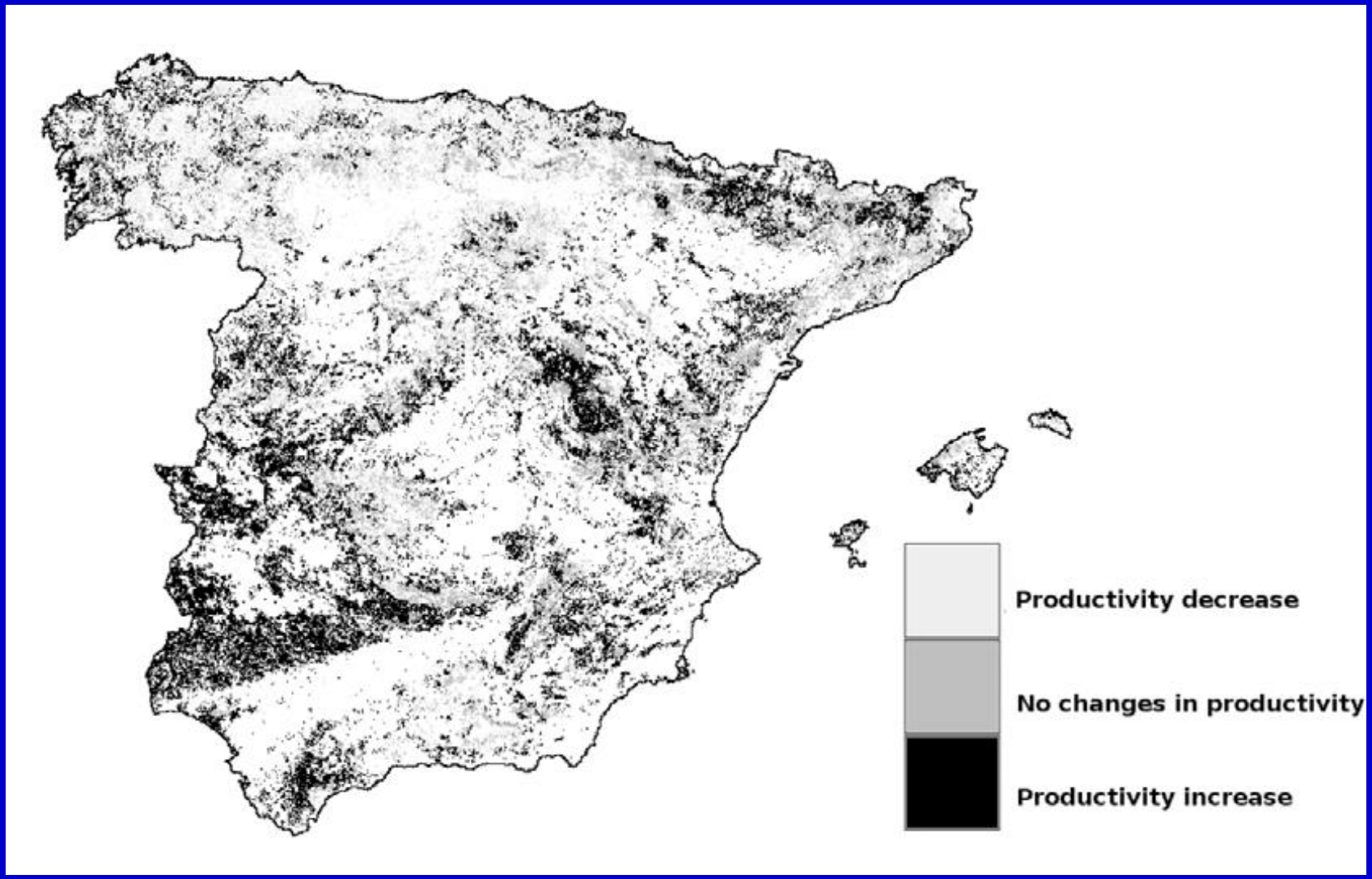
Climate change and forest potential productivity (*Indice Rosenzweig*):

Current
(climate 1971-2000)

Future ECHAM4
(climate 2011-2040)

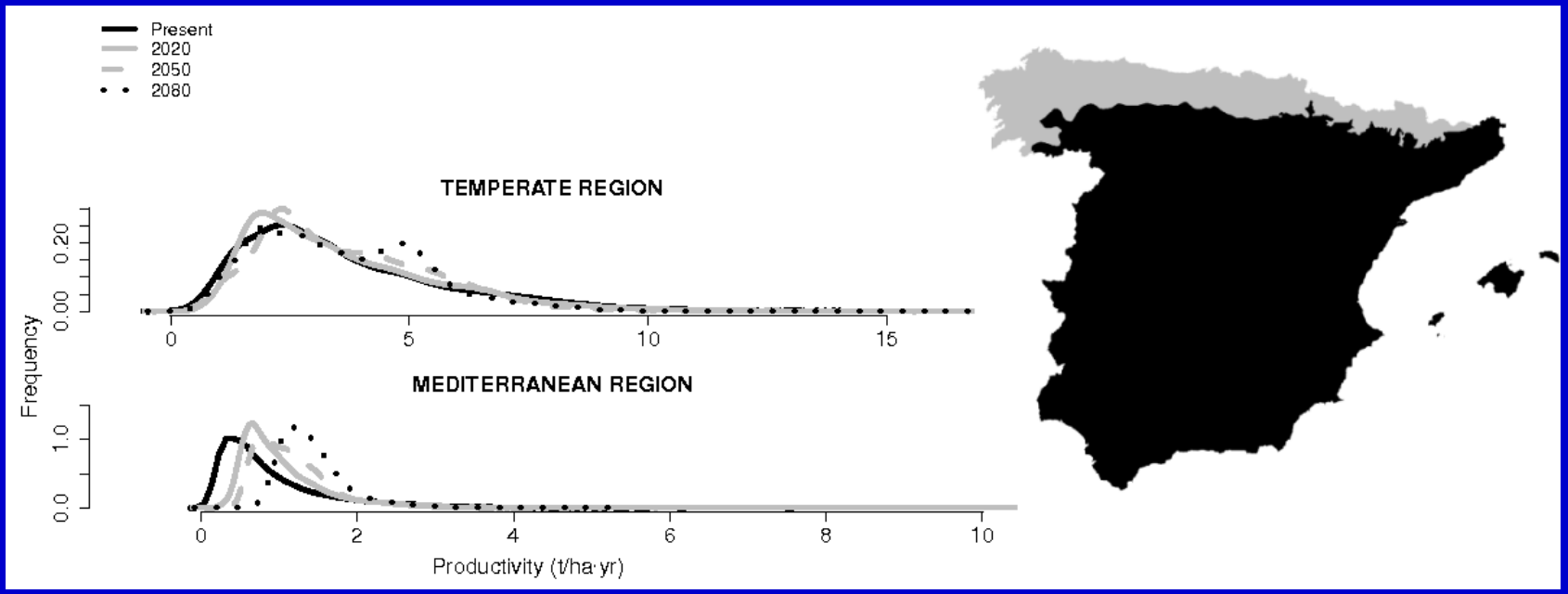


2007. OSE. Mundi-prensa. Ministerio de Medio Ambiente.

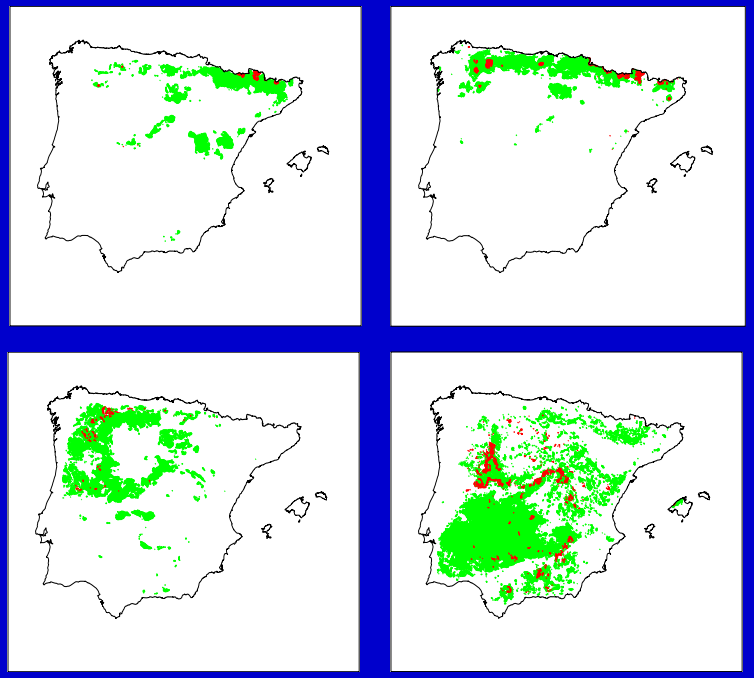


Changes in forest productivity between the present and A2 HadCM3 2080 conditions. Light grey indicates a decrease in productivity under global warming conditions and black indicates an increase in productivity for 2100, whereas grey represents areas where our model predicts no changes in productivity.

NPP ESTIMATION UNDER CLIMATE CHANGE SCENARIOS



Including ecological and adaptive mechanisms in vulnerability models.

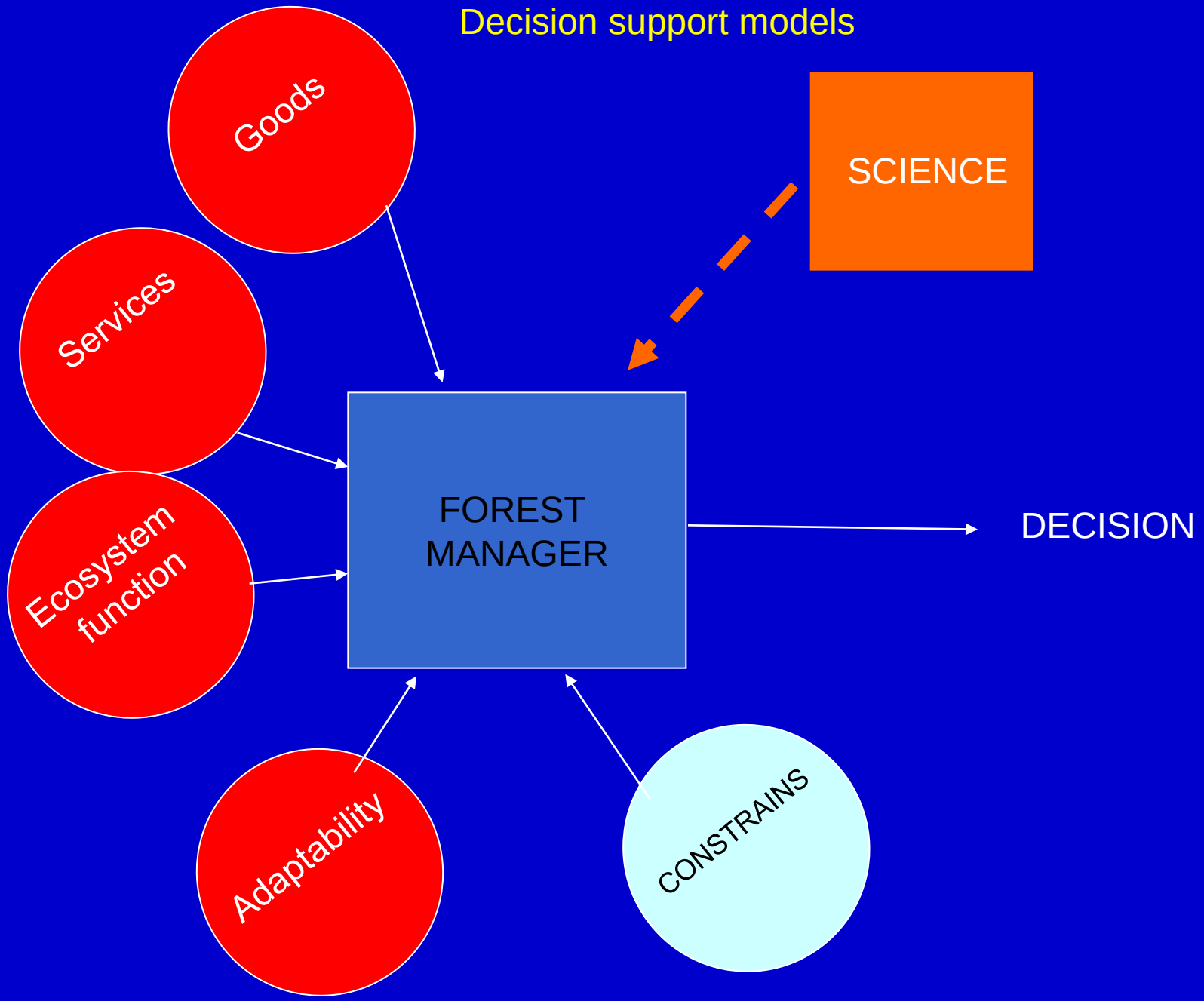


Fuente: *Elaborado a partir de Benito Garzón et al.* 2009

Genes & organismic
Epigenesis.
Evolution
Local adaptation
Plasticity

Population and communities
Migration (dispersal)
Diversity/Stabiilty

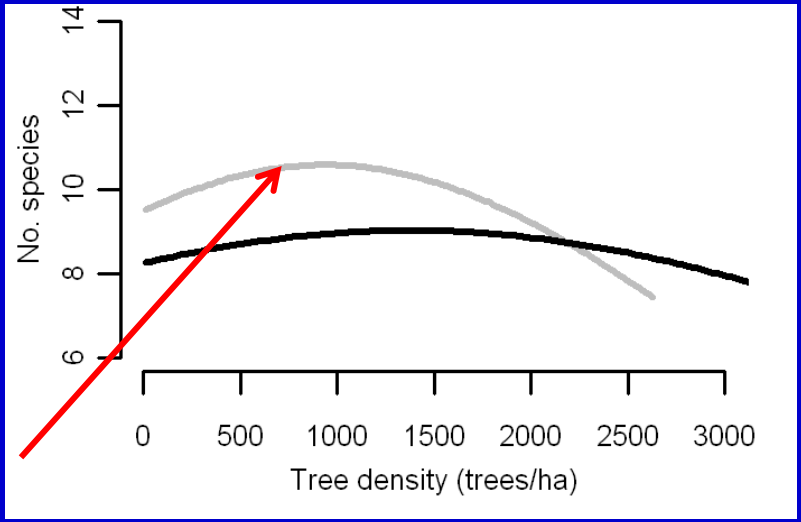
Ecosystem & landscape.
Demographic adjustments
Land use governance


Decision support models
Goods
SCIENCE
Services
FOREST
MANAGER
DECISION
Ecosystem
function
Adaptability
CONSTRAINS

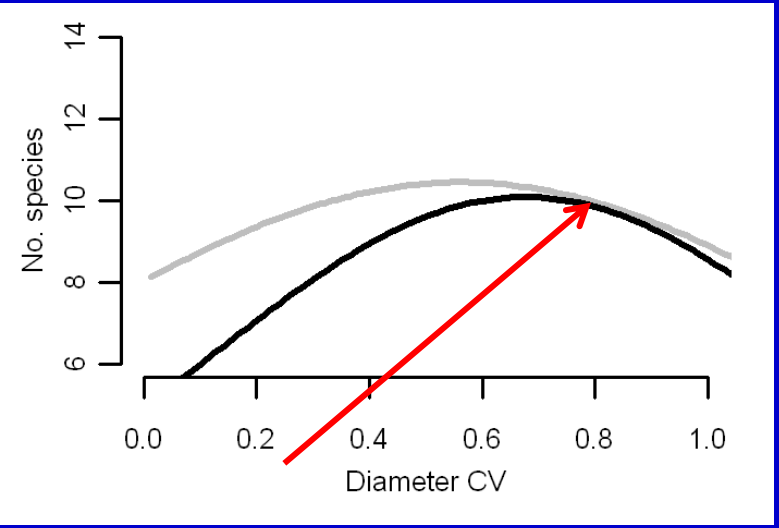
Las repoblaciones forestales.

Gómez-Aparicio et al., 2009 *Ecological Applications*

Stand tree density



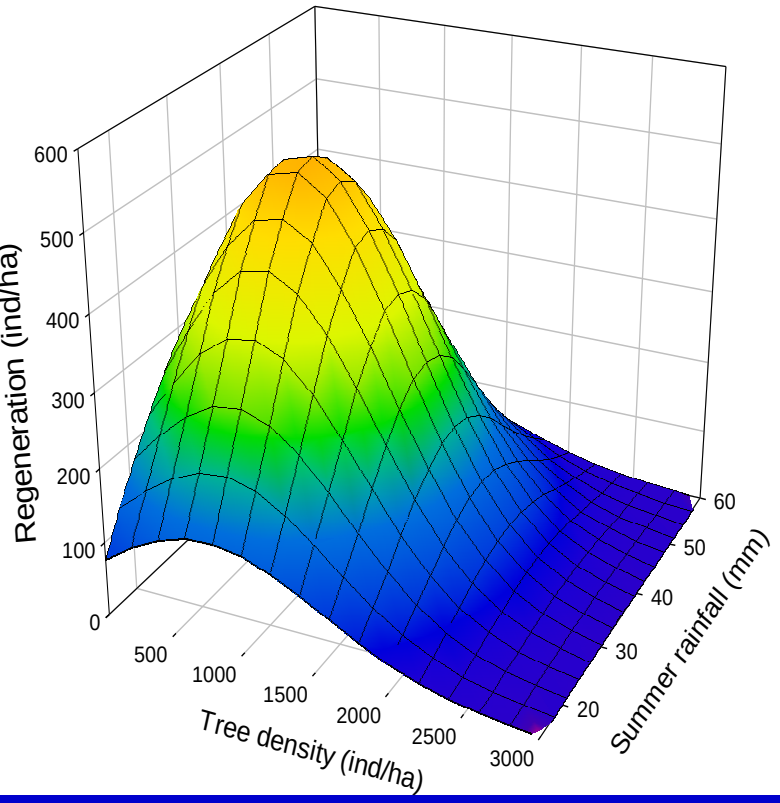
Diameter coefficient of variation

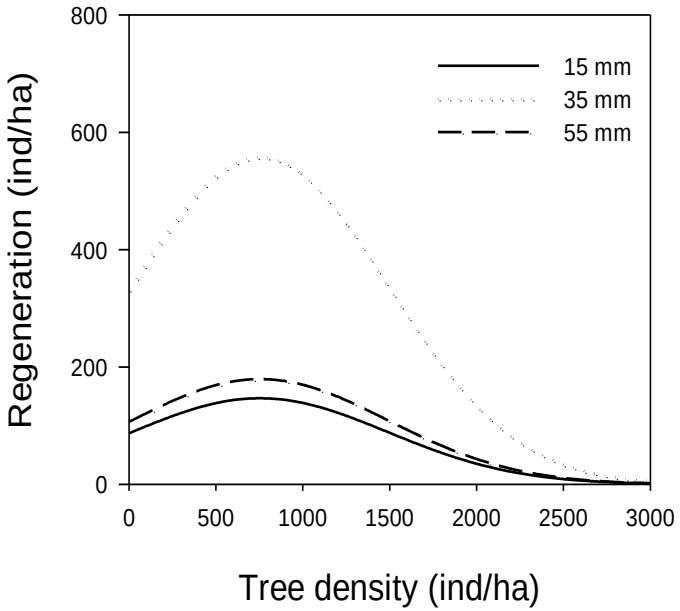


Ruiz-Benito et al. **Diversity and Distributions** (2ª revisión).

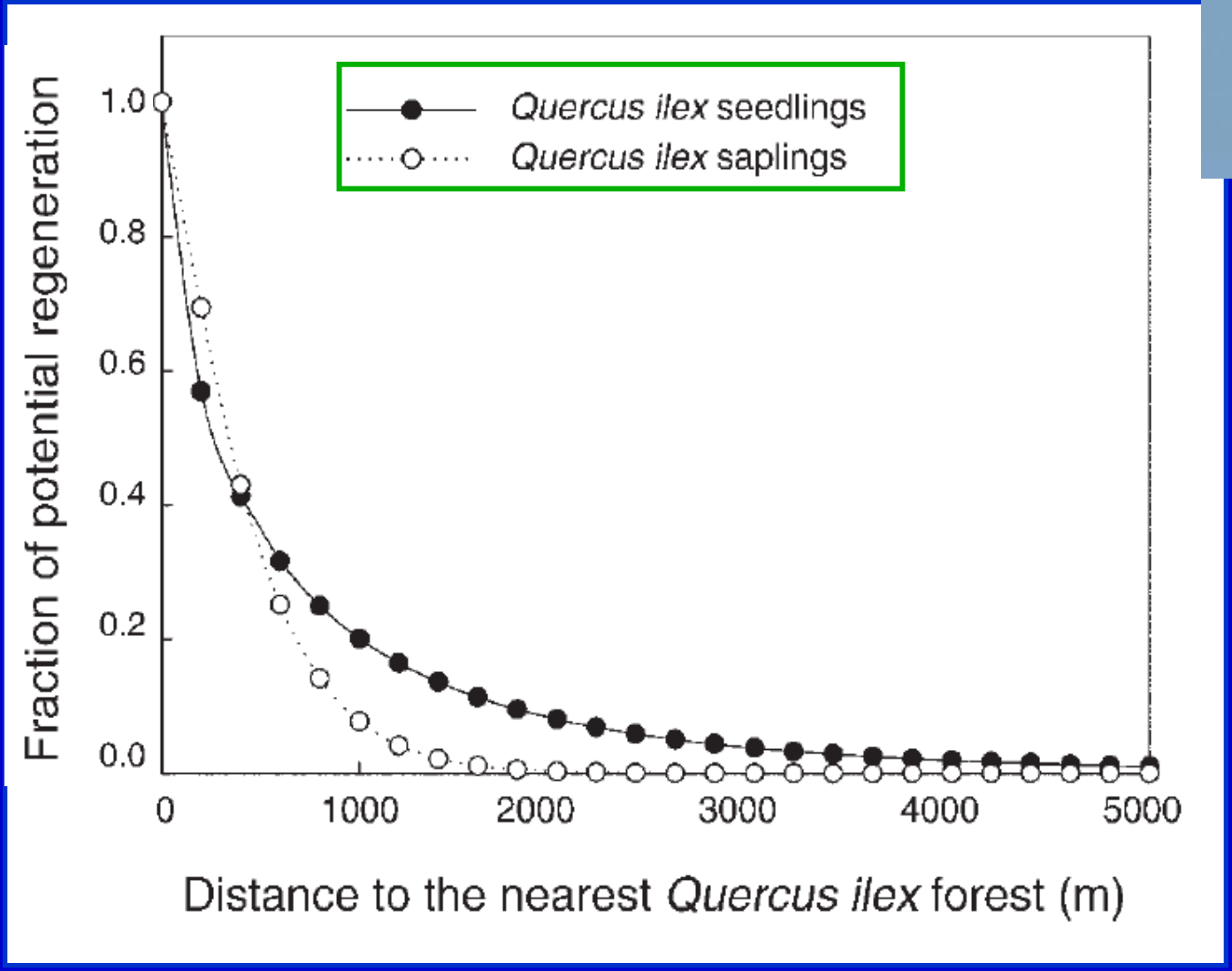
Planted stands

Natural stands





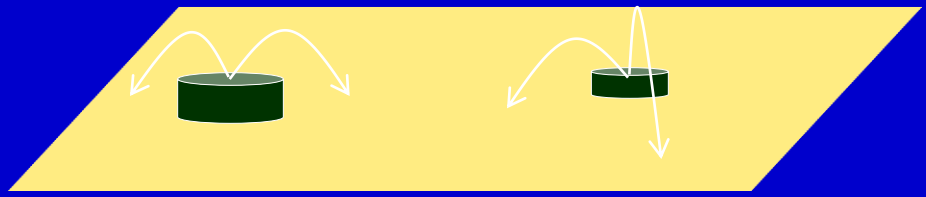
Gómez-Aparicio L., **Zavala, M.A.**, Bonet , F.J. and R. Zamora. 2009. Are pine plantations useful restoration tools of Mediterranean forests? An assessment along gradients of climatic conditions, stand density and distance to seed sources. **Ecological Applications** 19: 2124–2141.



Gómez-Aparicio L., **Zavala, M.A.**, Bonet , F.J. and R. Zamora. 2009. Are pine plantations useful restoration tools of Mediterranean forests? An assessment along gradients of climatic conditions, stand density and distance to seed sources. **Ecological Applications** 19: 2124–2141.

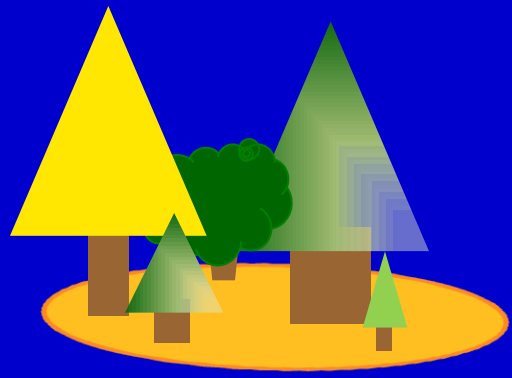
Enrichment planting

(planted forests on mesic areas)



Increment of the structural heterogeneity

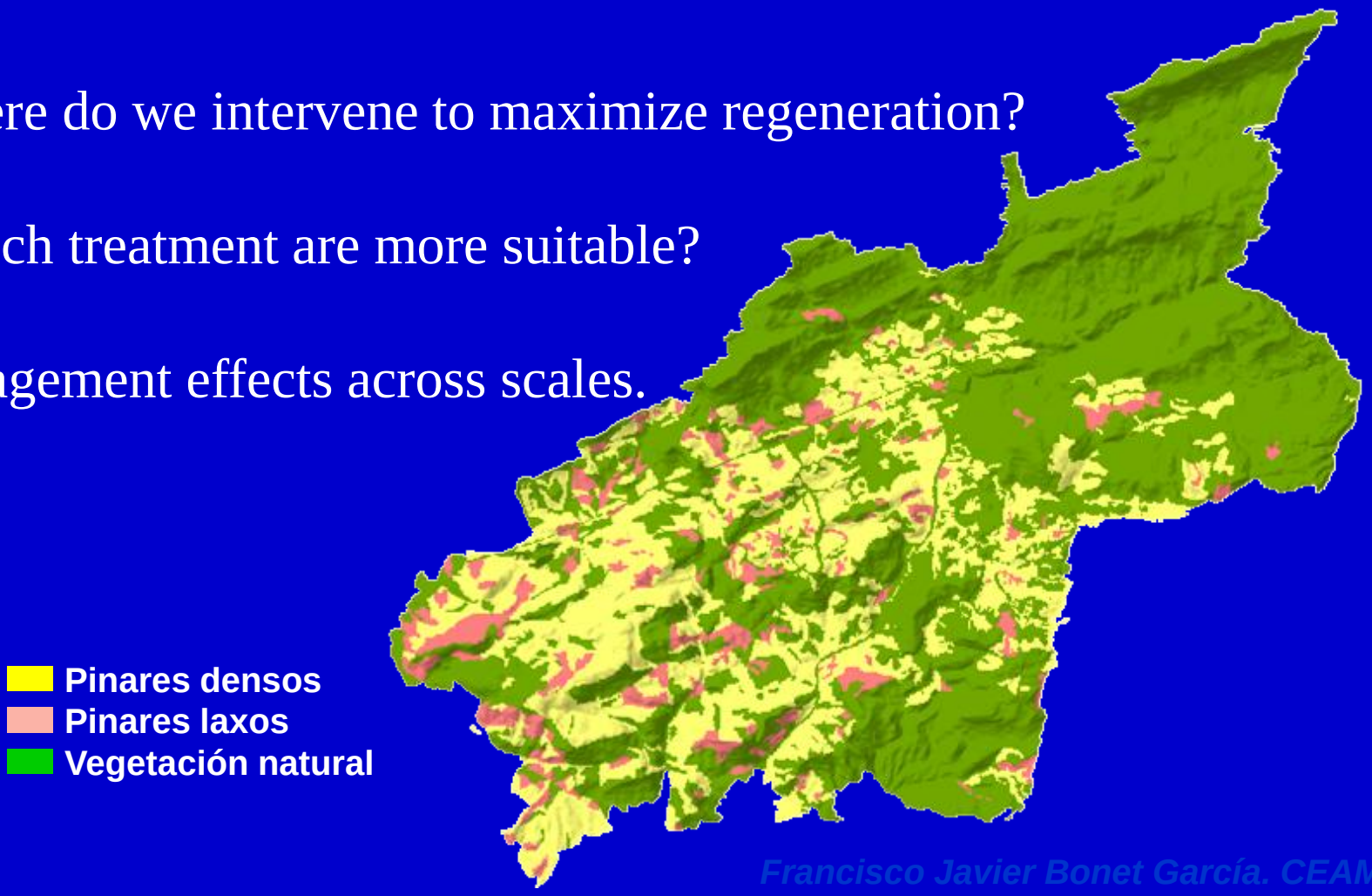
(high tree density and even-aged forests)



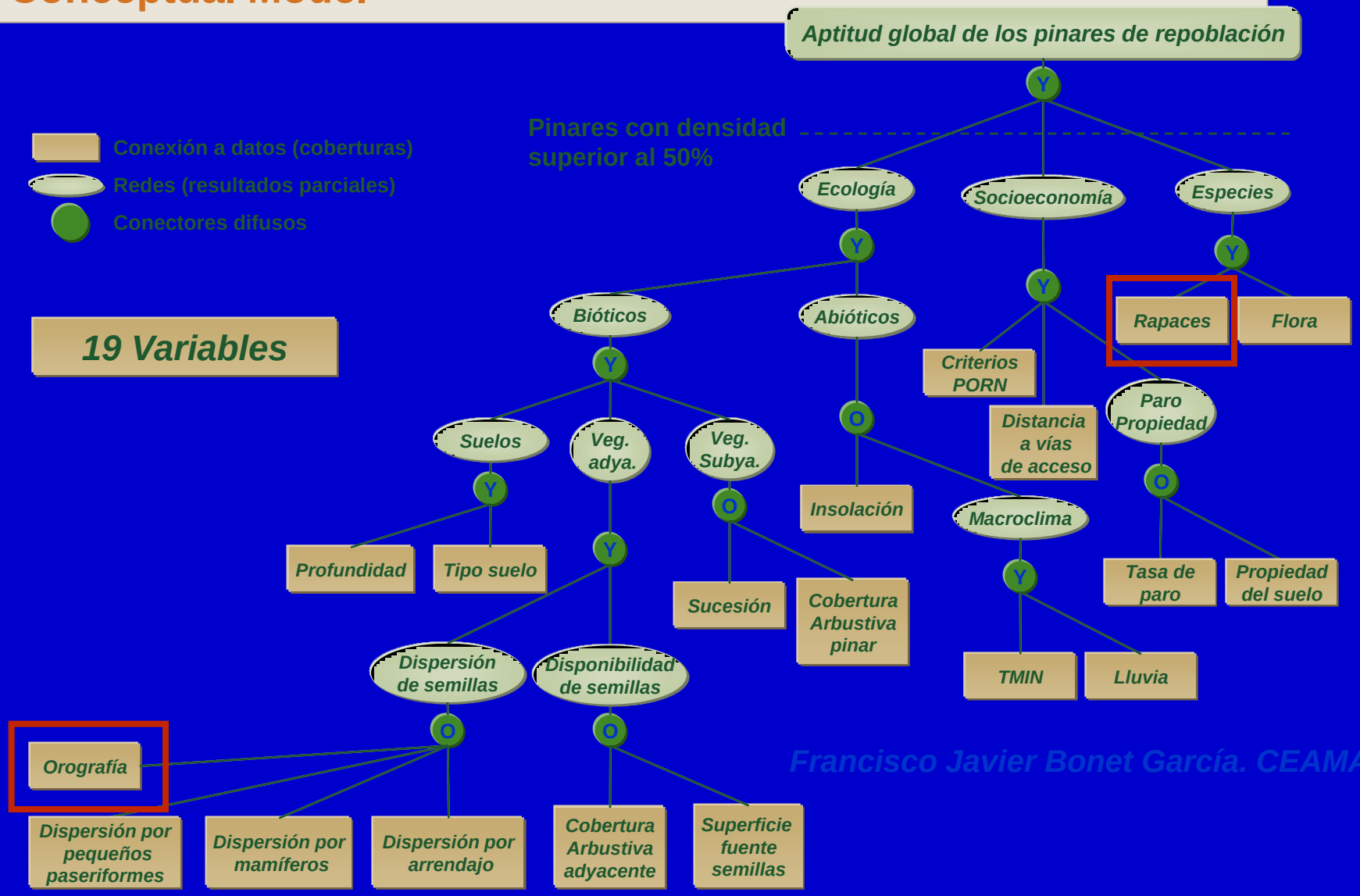
Thinning

Specific questions:

- ¿Where do we intervene to maximize regeneration?
- ¿Which treatment are more suitable?
- Management effects across scales.



Conceptual Model



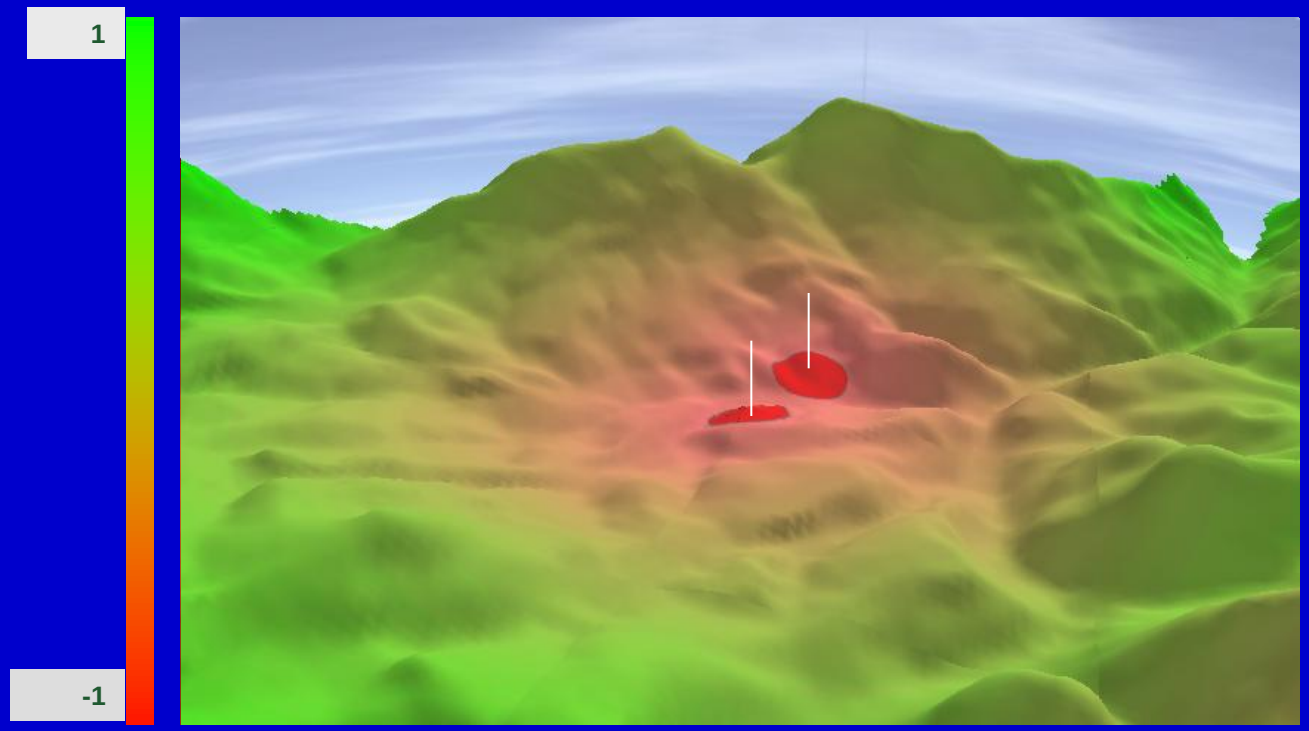
Francisco Javier Bonet García. CEAMA

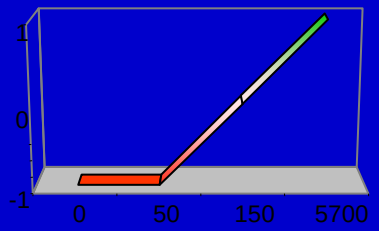
Estudio de casos: Pinares de repoblación

Presence raptor nests

Justificación: *Los tratamientos selvícolas no pueden afectar a especies amenazadas*

Procesamiento: *Mapa de distancias desde los nidos a los pinares*

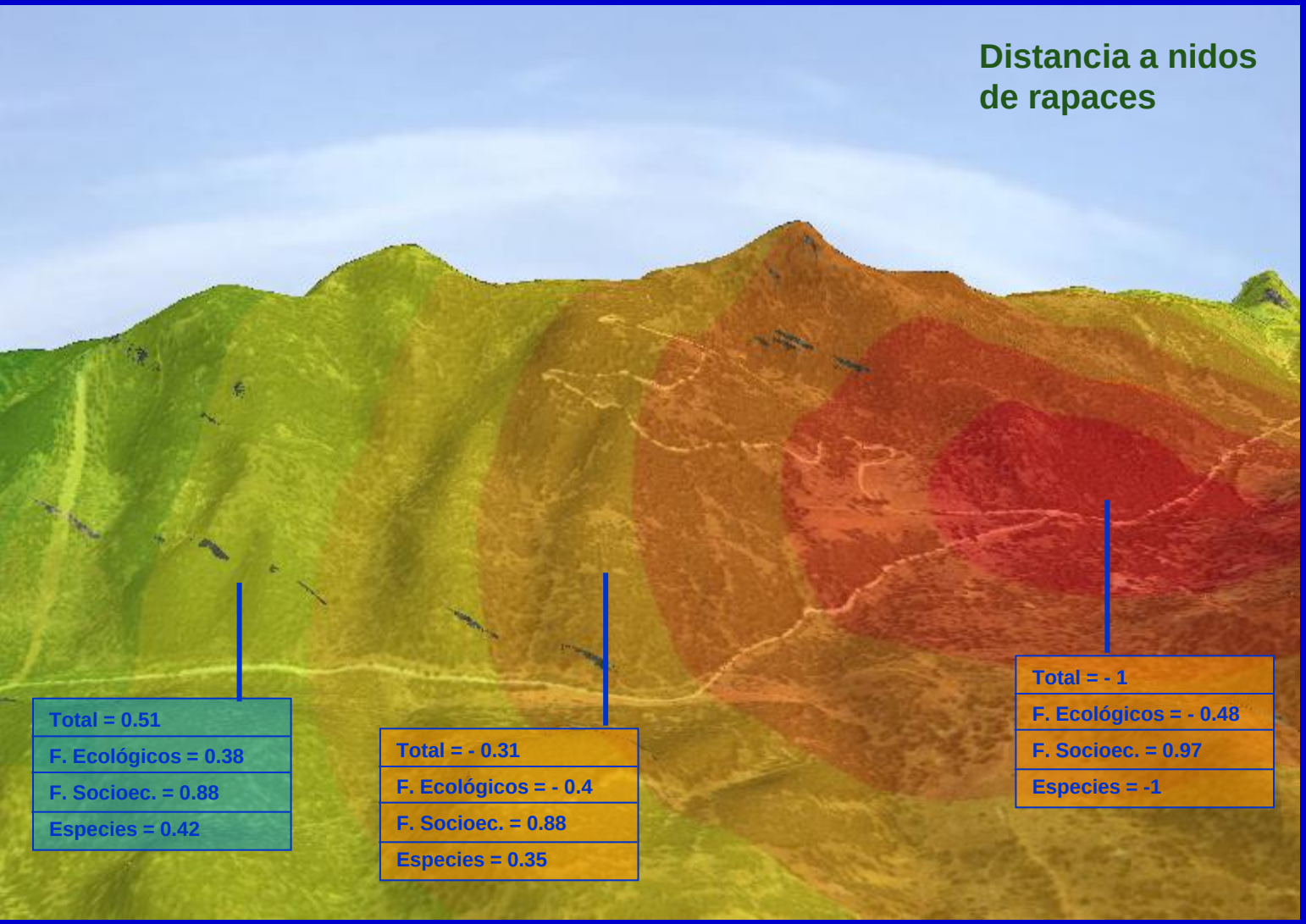




Función de pertenencia

Francisco Javier Bonet García. CEAMA

Distancia a nidos de rapaces

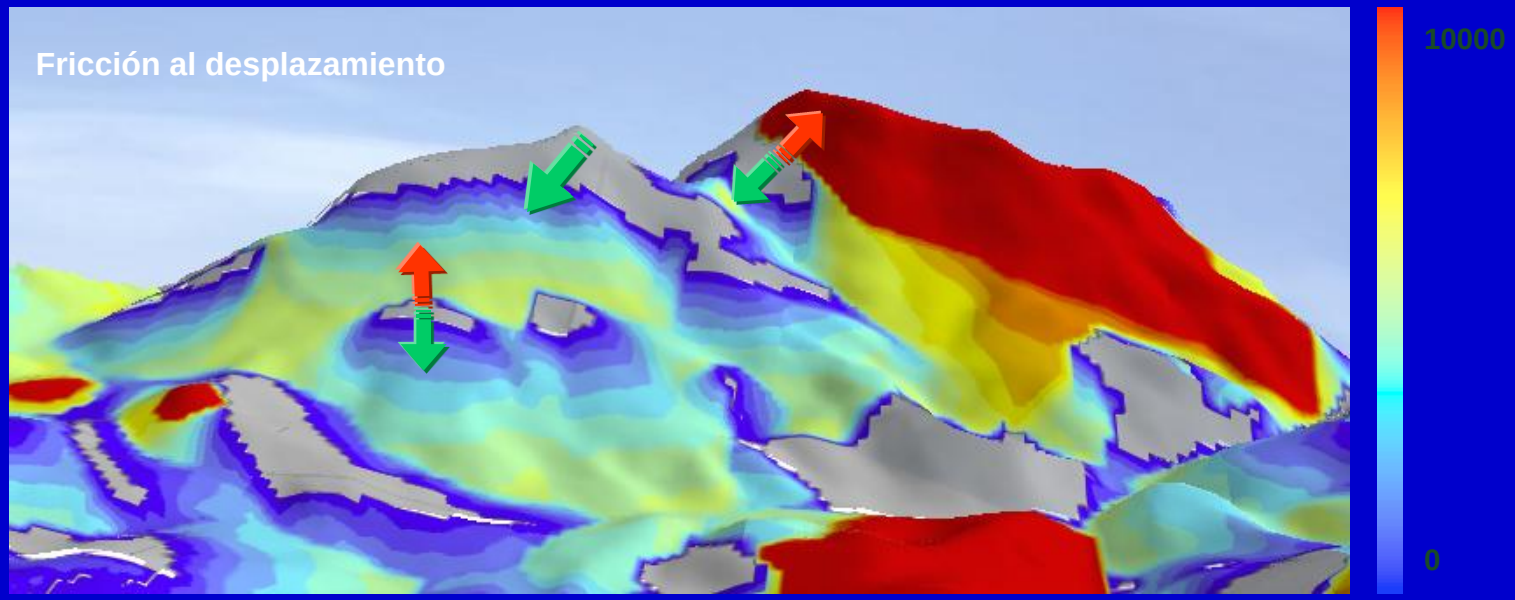


Francisco Javier Bonet García. CEAMA

Estudio de casos: Pinares de repoblación

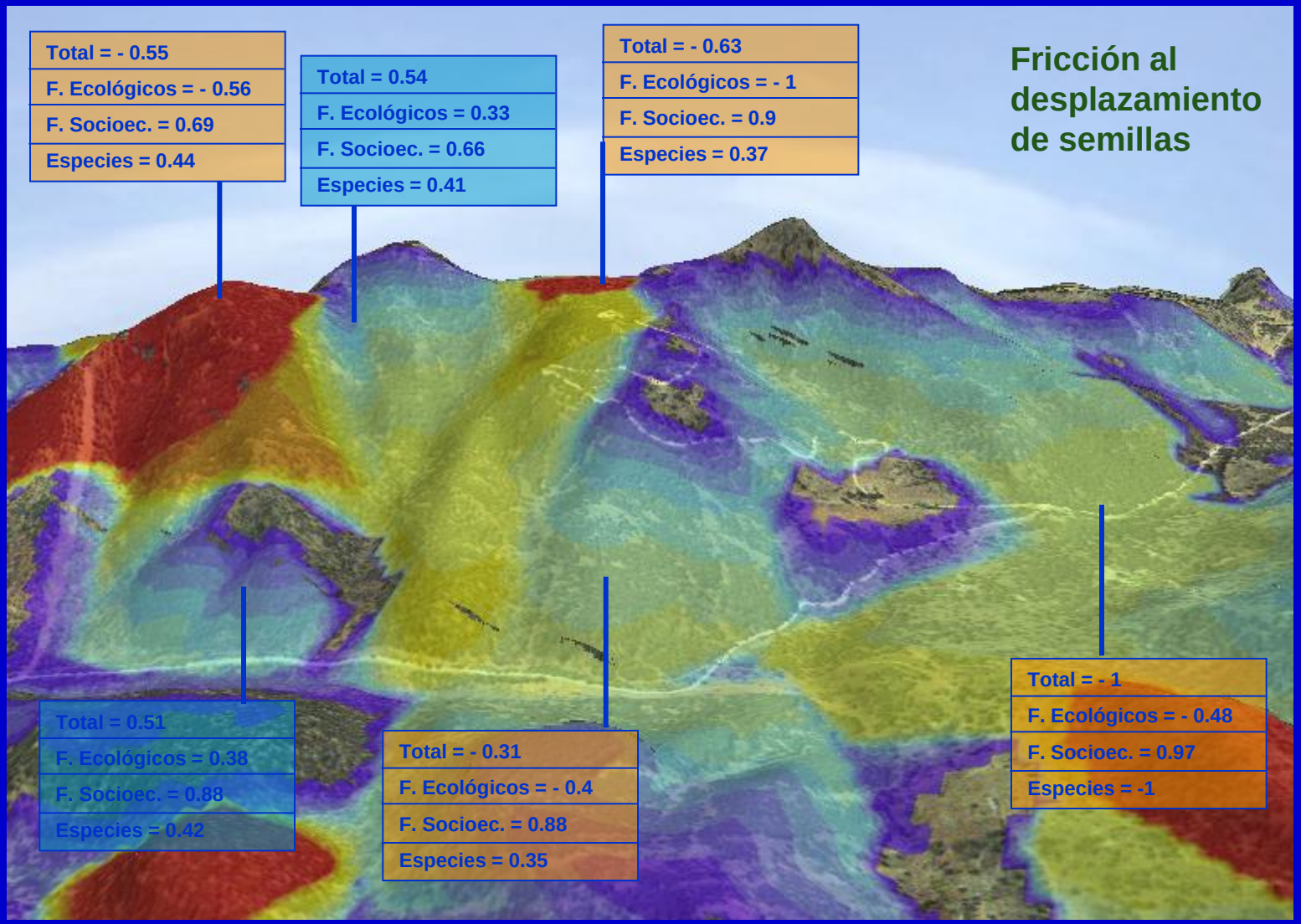
Seed dispersal

- ***Justificación:*** *La gravedad condiciona la dispersión de semillas. Es más fácil bajar una pendiente que subirla*
- ***Procesamiento:*** *Generación de una superficie de fricción anisotrópica que asemeja la dispersión de semillas a un fluido por el relieve*



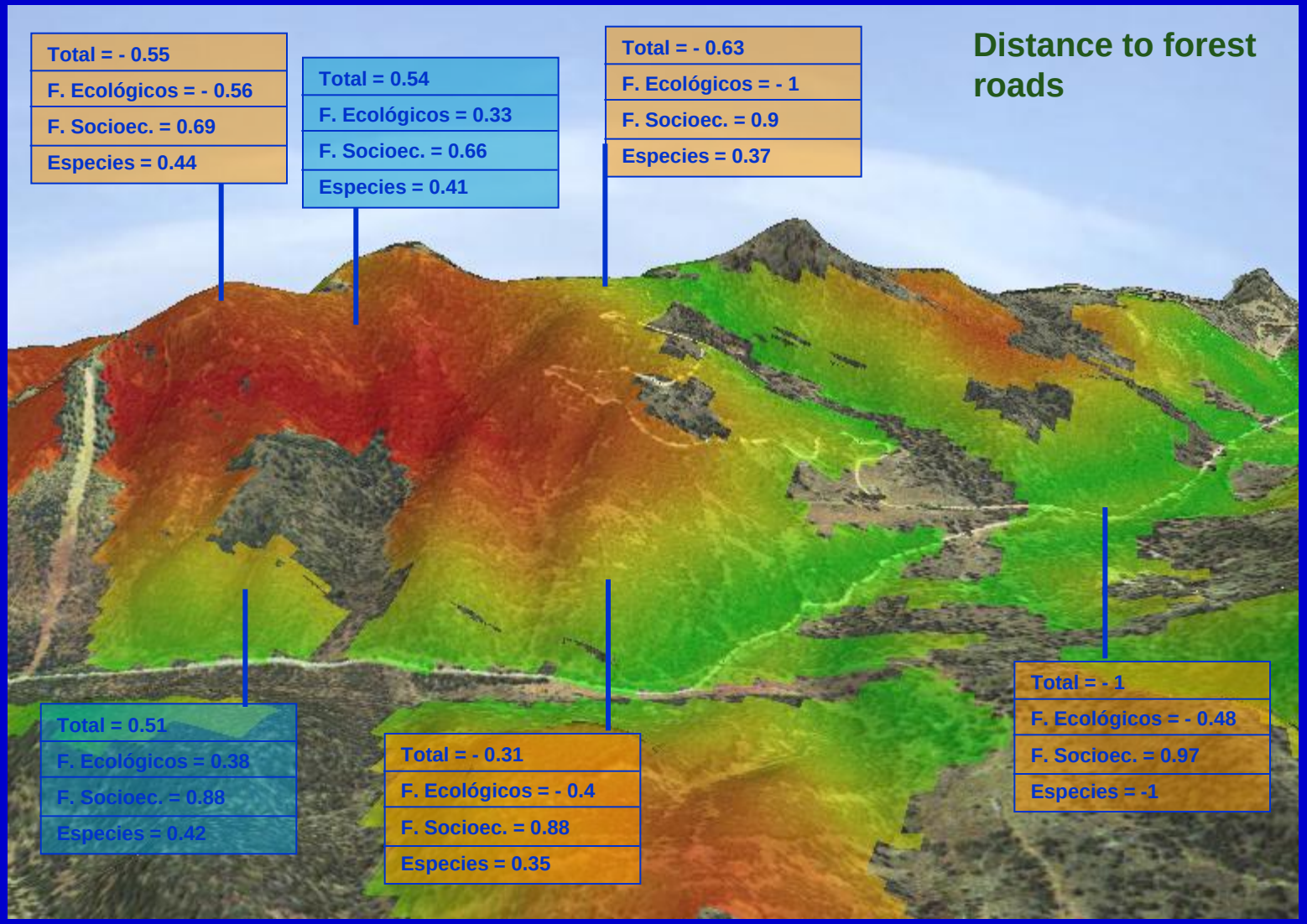
Francisco Javier Bonet García. CEAMA

Fricción al desplazamiento de semillas



Francisco Javier Bonet García. CEAMA

Distance to forest roads



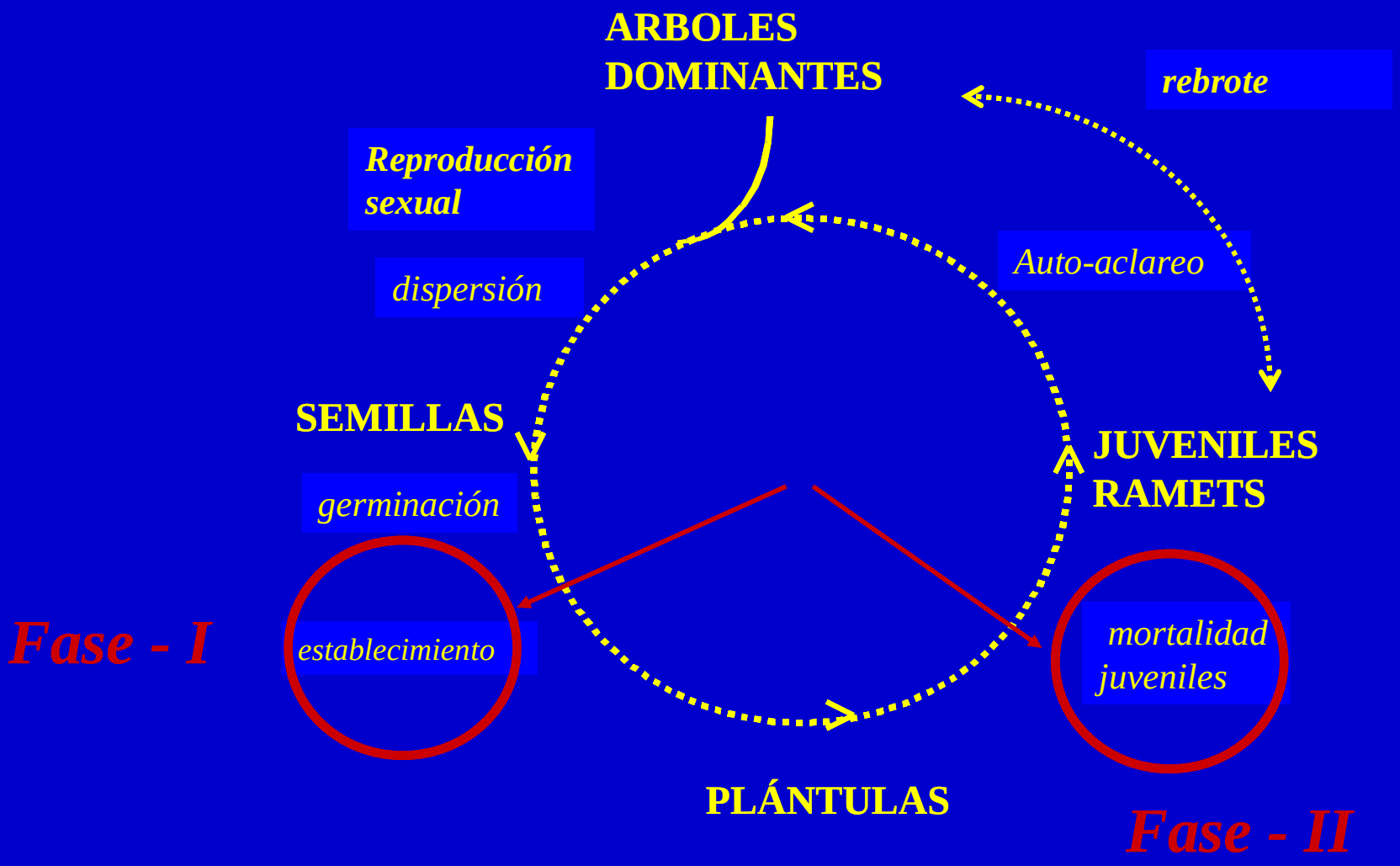
Francisco Javier Bonet García. CEAMA

Acknowledgements:

Estudiantes de doctorado: Paloma Ruiz Benito, Raúl García Valdés, Raúl Sánchez Salguero

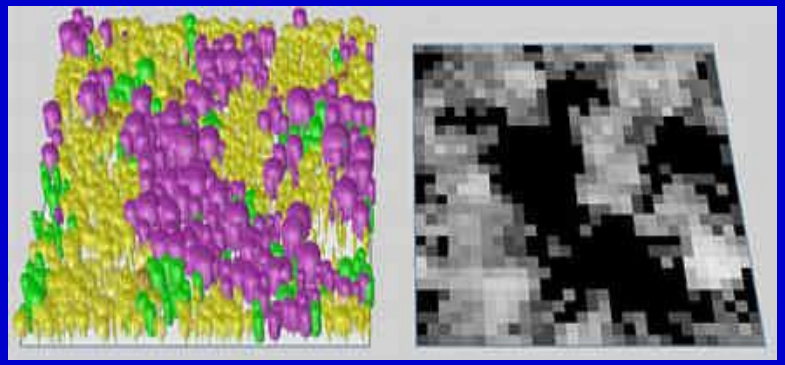
Post docs: Marta Benito Garzón

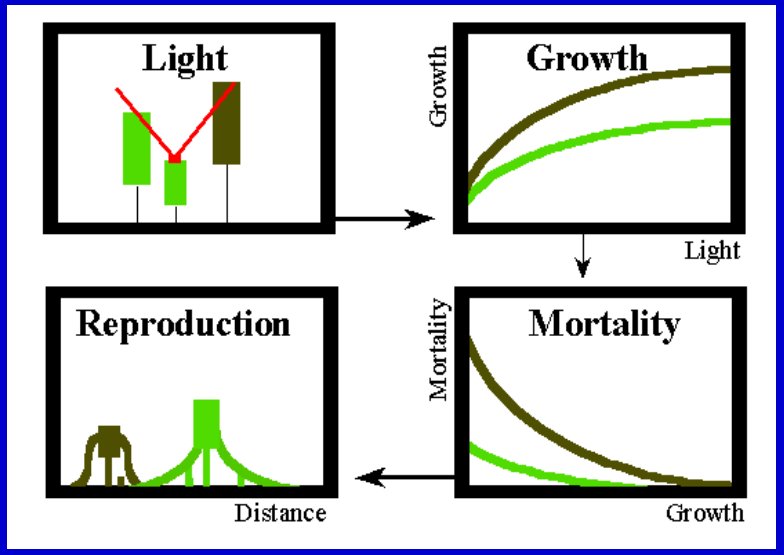
madezavala@gmail.com



Zavala, M.A. y E. Zea. 2004. Mechanisms maintaining biodiversity in Mediterranean pine-oak forests: insights from a spatial simulation model. **Plant Ecology** 171: 197-207.

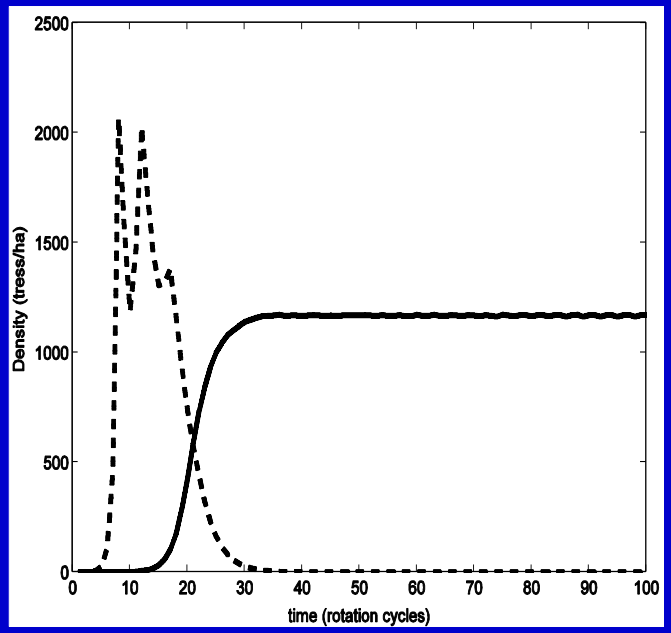
Modelo general dinámica forestal:

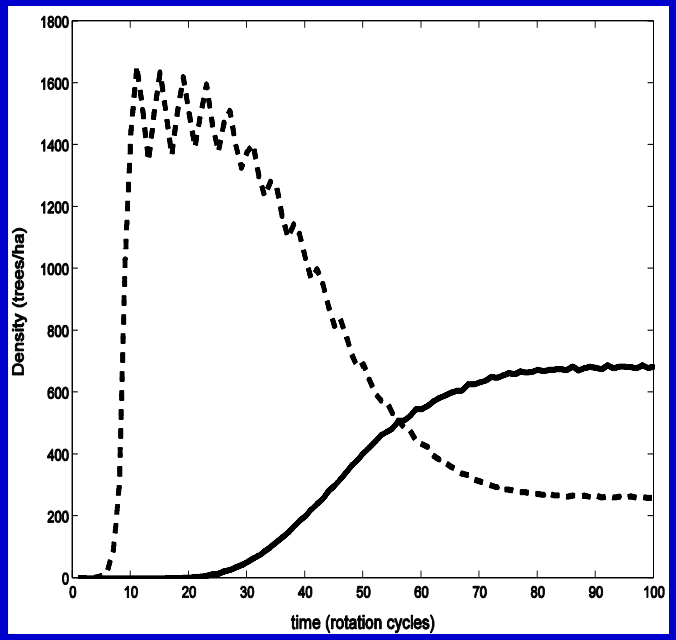


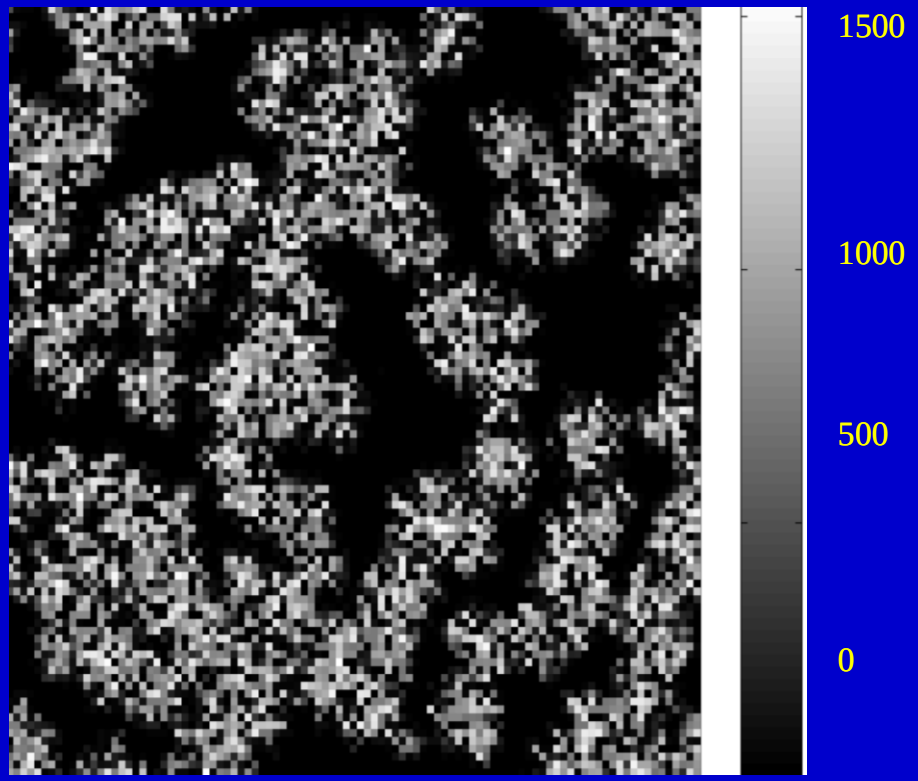


Modelo espacial estocástico

Teselas N x N
Sup. Proceso binomial
Dispersión Poisson
Heterogeneidad suelo
Perturbaciones

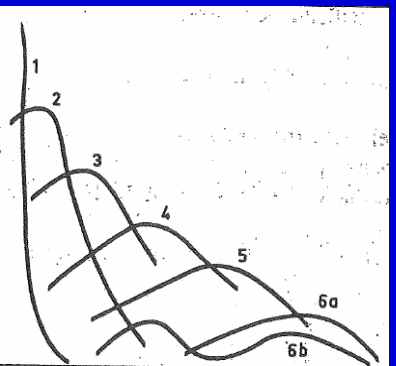


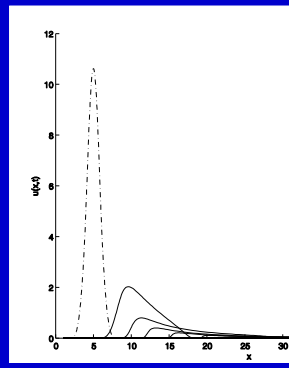




GENERAL SCALING CORRESPONDENCE

IBM		EDP
Stochastic mortality	→	Mortality term
Stochastic recuitment	→	Boundary condition
Growth dependent on light	→	Transport term
+ uncertainty (Brownian)	→	Diffusion term





Zavala, M.A. et al.2007. J.Theor. Biol. 244: 440–450

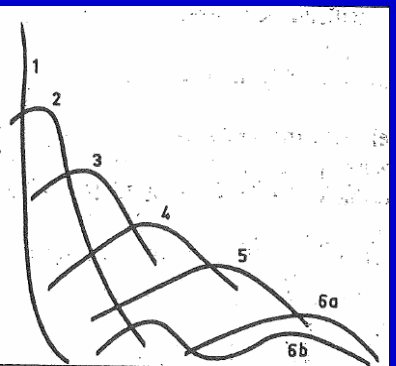
Balance law

$$u_t(x,t)+\left(g\left(x,B(x,t)\right)u(x,t)\right)_x=-\mu\left(x,\left(x,B(x,t)\right)\right)u(x,t),\quad (x_0<x<x_M\ ,\ t>0)$$

Recruitment law ***Inicial d.b.h. distribution***

$$g\left(x_0,B(x_0,t)\right)u(x_0,t)=B(x_0,t)r\left(B(x_0,t)\right),\quad (t>0)$$

$$u(x,0)=u_0(x),\quad (x_0\le x\le x_M)$$



Zavala, M.A. et al.2007. J.Theor. Biol. 244: 440–450.