Evolution of ecosystem services in intensive and extensive Agricultural Systems.

Moreno Llorca, R.A.*; Pérez-Luque, A.J. *; Castro Rodriguez, A.**; Reyes Muñoz, P. *; Benito de Pando, B. * & Suzart de Albuquerque, F. *

*Laboratorio de Ecología. Centro Andaluz de Medio Ambiente. Universidad de Granada. Granada (SPAIN). ricuni@ugr.es

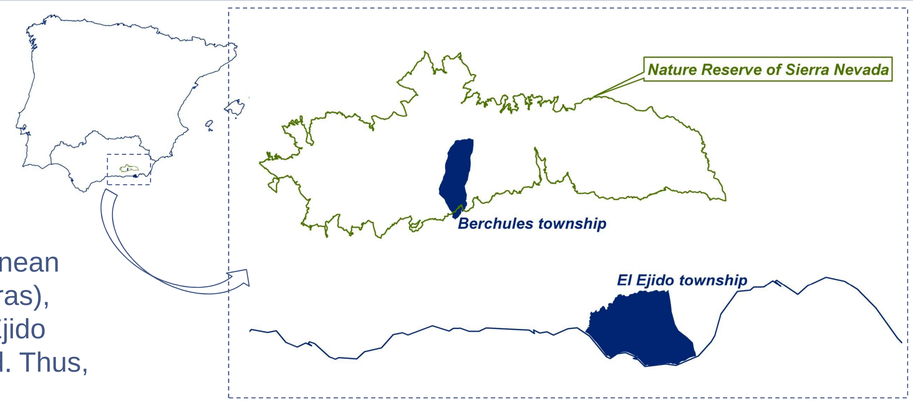
** Civil engineer self-employed

Laboratorio de Ecología del CEAMA. Universidad de Granada

1. Introduction and Objectives

This study assesses the status and trends of ecosystem services provided by biodiversity in two types of agricultural systems: extensive and intensive agriculture, which co-exist locally in Andalusia, Spain. Extensive agriculture is developed on a steep relief, organized by small terraced plots in a region known as Las Alpujarras. Intensive agriculture, instead, is practiced on low-slope land and usually in greenhouses on the coast of Almeria. In this sense, the status and trends of selected ecosystem services were evaluated, in different periods of time: from 1950 to today.

The aim of this study was to compare the status and trends of ecosystem services between two close areas of the Mediterranean basin. Results show that the relief has been less vulnerable to the intensification process in Berchules township (Las Alpujarras), without changes on its structure or function. By the other hand, results show opposite responses at the Andalusia coast (El Ejido township, Almeria), since changes on the ecosystem's structure and function, induced by agricultural policies, were observed. Thus, results provide an ideal “scene” to compare the evolution of services provided by both agricultural systems.

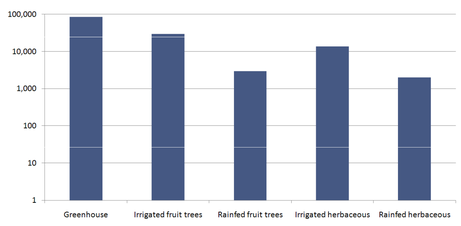


2. Methods

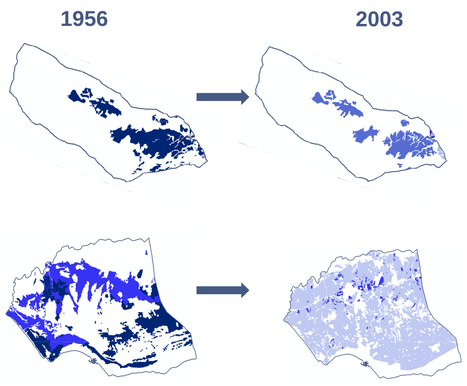
Provisioning

The ecosystem service supply has been measured in both cities in 1956 and 2003, by calculating the amount of agricultural production on different crop areas.

We calculated the mean reduction of each crop type in tons / hectare / year



We have measured the change of surface for each type of crop from 1956 to 2003 in both township



On the basis of crop types and surface changes, we calculated the variation of the supply service.

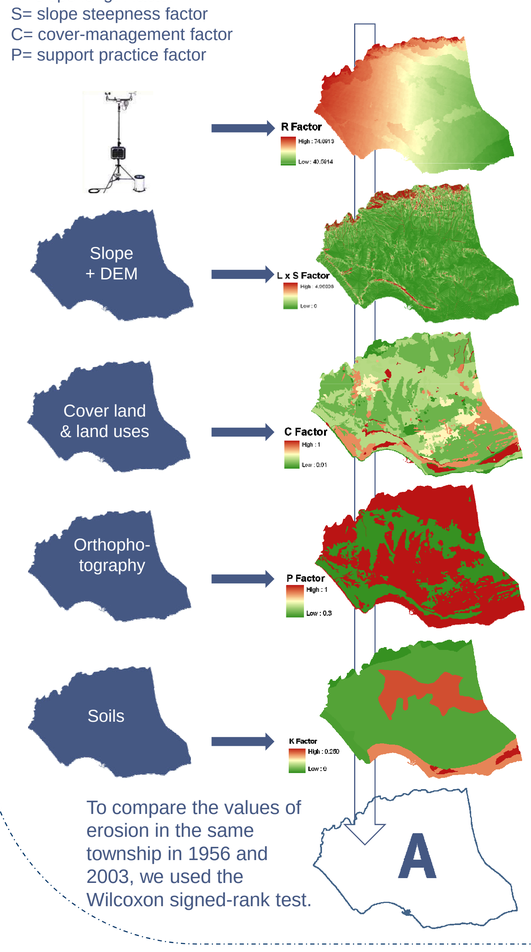
Regulatory

Prevention of soil erosion

We used the Revised Universal Soil Loss Equation (RUSLE), to measure the regulatory ecosystem service in both cities in 1956 and 2003. RUSLE was calculated as follows:

A = R * K * LS * C * P

where
A= estimated average soil loss in tons per acre per year
R= rainfall-runoff erosivity factor
K= soil erodibility factor
L= slope length factor
S= slope steepness factor
C= cover-management factor
P= support practice factor



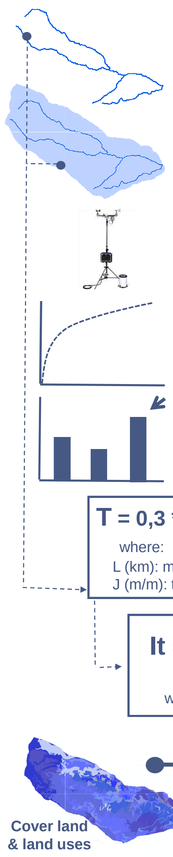
To compare the values of erosion in the same township in 1956 and 2003, we used the Wilcoxon signed-rank test.

Water regulation capacity

We also used the rational method to measure the regulatory ecosystem service in both cities (1956 and 2003). Rational method was calculated as follows:

Q = C * A * It/k

where:
C: the average coefficient of runoff.
A: area of the basin.
It: average rainfall intensity.
k: coefficient depending on the units in which express Q and A



Define primary and secondary channels and its length

Define their hydrologic basins and their areas (**A**)

Get the maximum daily rainfall of each month (AEMET) and “Maximum daily rainfall in peninsular Spain” publication.

Approach to a Gumbel and SQRT distribution function. Obtaining the expected values of precipitation for a return period of 500 years.

Choosing the greatest daily precipitation in mm.

$$T = 0{,}3 * [(L/J^{1/4})^{0{,}76}]$$

where:
L (km): main channel length.
J (m/m): the average slope.

Determine the time of concentration of the watershed

$$It = \frac{28^{0,1} - T^{0,1}}{28^{0,1} - 1}$$

Determine the average time of precipitation

where: T: time of concentration of the watershed.

Cover land & land uses

Determine the runoff coefficient

$$C = \frac{[(Pd/Po) - 1] * [(Pd/Po) + 23]}{[(Pd/Po) + 11]^2}$$

where:
Pd: daily rainfall.
Po: threshold runoff.

Q

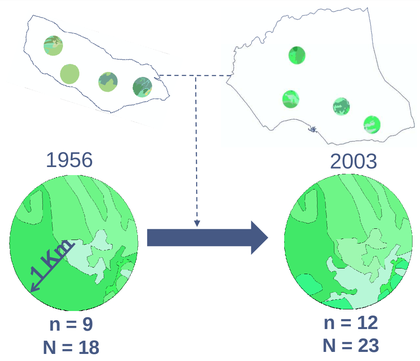
Cultural

We evaluated the cultural ecosystem services at a landscape level, measuring changes in spatial heterogeneity and complexity from 1956 to 2003 in both study sites

We used a series of indicators of landscape heterogeneity and spatial complexity based on the analysis of the boundaries between different land uses

Landscape Indices	Definition
N	Total number of boundaries between land uses.
n	Richness. Total number of types of boundaries between land uses.
E(b)	Evenness. Relative abundance of the different boundaries between land uses.
H(b)	Diversity of boundaries. It takes into account n and E(b).
H(l)	Landscape heterogeneity. It takes into account, N, and H(b).
C (s)	Spatial complexity. Measurement of the combination of spatial neighbours found in a space with a given N, H(b) and H(l).

This has been randomly selected four circular areas of 1km radius in both township. We have measured “n” and “N” in 1956 and 2003.



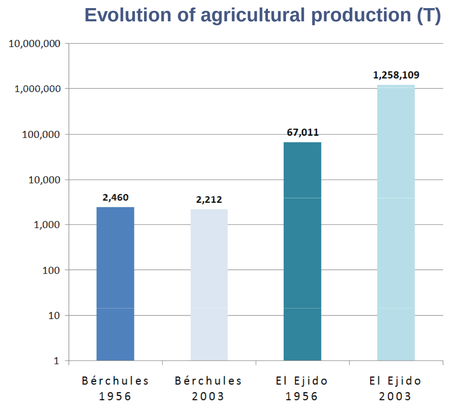
On the basis of “n” and “N”, E(b), H(b), H(l) and C (s) have been calculated.

3. Results

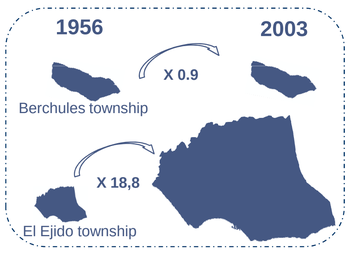
Provisioning: production of goods from cultivation

The amount of agricultural goods has greatly increased (x 18.8) in El Ejido.
Furthermore, the production of goods has remained in Bérchules .

Evolution of agricultural production (T)

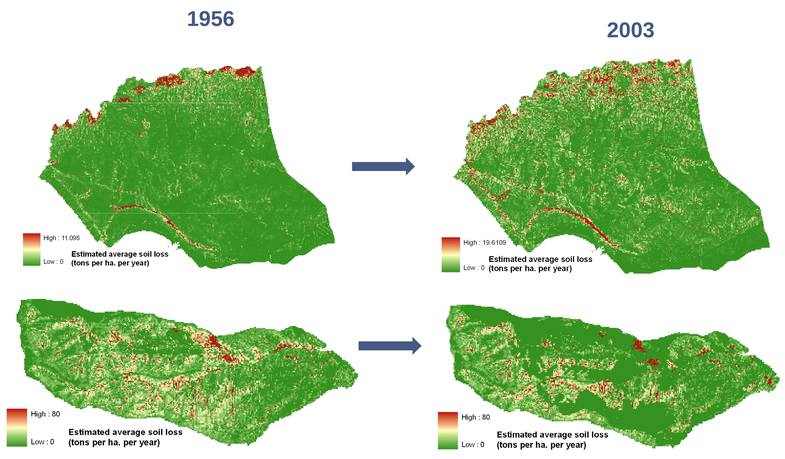


Change factor of agricultural production



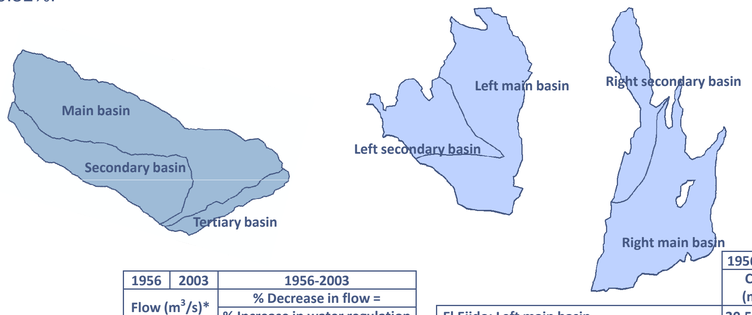
Regulatory: prevention of soil erosion

We found significant differences in the values of erosion both in El Ejido (p-value<0.0001, Z=-183.154 Er2003=0.14 ± 0.35 Er1956=0.03± 0.134) and Bérchules (p-value<0.0001, Z=-183.154 Er2003=1.07 ± 3.09 Er1956=1.61 ± 3.29).
These maps show the level of erosion in each municipality in 1956 and 2003. In El Ejido erosion potential increases in 2003 compared to 1956. However, in Bérchules potential erosion has declined over the same period.



Regulatory: water regulation capacity

Bérchules has increased its capacity to retain flood. The increase occurs in all watersheds with a mean of 50.60%. El Ejido has however reduced its capacity to regulate water in all basins with a mean of 320.51%.



	1956	2003	1956-2003
	Flow (m^3/s)*		% Decrease in flow =
			% Increase in water regulation
Bérchules: Main basin	83.47	43.91	52.60
Bérchules: Secondary basin	74.94	25.22	33.66
Bérchules: Tertiary basin	11.23	7.38	65.71

	1956	2003	Periodo 1965-2003
	Caudal (m3/s)*		% Increased flow =
			% Decrease in water regulation
El Ejido: Left main basin	30.52	72.03	236.01
El Ejido: Left secondary basin	15.82	42.46	268.31
El Ejido: Right main basin	31.63	153.41	485.06
El Ejido: Right secondary basin	10.14	29.66	292.65

* For a return period of 500 years (return period = number of years that is expected to repeat a certain average flow)

Cultural: evolution of landscape heterogeneity and spatial complexity

Bérchules has increased the relative abundance of the different boundaries between land uses indice, and has mainteined the landscape heterogeneity indice. However slightly reduced its diversity of boundaries and spatial complexity indices. El Ejido has however strongly reduced all its landscape indices

	1956	2003	Variacion %
H(b)	3,779	2,931	-22,43
E(b)	0,945	0,882	-6,60
H(l)	0,701	0,648	-7,54
C(s)	2,648	1,899	-28,28

	1956	2003	Variacion %
H(b)	4,859	4,349	-10,50
E(b)	0,926	0,948	2,44
H(l)	0,764	0,752	-1,58
C(s)	3,714	3,271	-11,92

4. Conclusions

The results show a trade-off in the intensive agricultural system (in El Ejido), with a drastic reduction in regulatory and cultural services to increasing of the provisioning services.
This conclusion contrasts with the one obtained about the extensive agricultural area (Bérchules), where the provisioning services have maintained, while regulatory and cultural ones are maintained and even improved.

5. References

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