Assessing cultural system evolution in the Mediterranean basin - The Caia Irrigation Perimeter case study

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Abstract: - Mediterranean basin ecosystem services are at risk with the loss of wildlife-rich habitats, where 300 animal and plant species are threatened with extinction, and the disappearing of small scale farmers, that are being forced to abandon their land due to their lack of competition with the great corporations with modern farming practices that dominate the marketplace, and put an inordinate amount of pressure on the surrounding environment through their high demand in pesticides, fertilizers and water irrigation leading to a severe over-exploitation of both ground and surface waters. In this study, a total of 13,400 ha located in a western Mediterranean basin were selected as the study site and the main results of this study were that the case study area is becoming monocultural with olive groves, rice and orchards having increased 968, 210% and 210% since 2002.

Key-words: - Mediterranean basin, ecosystem services, monoculture, desertification

1 Introduction

The diversity of ecosystem services provided by the Mediterranean basin landscape are invaluable and at risk with the massive change in agricultural practices across it with the last 50 years changing its biosphere with the intensification of agriculture and, as pointed by Sundseth & Wegefelt (Sundseth & Wegefelt, 2009) by the increase in the "industrial scale fruit or olive plantations and mixed rotational farming [that] has been replaced by intensive monocultures" replacing the formerly present vineyards, orchards and olive groves which is also in accordance with Siebert (Siebert, 2004) that noted the same pattern in his study where traditional farming was found to be declining for monoculture exploitation. Sánchez-Martínez & Cabrera (Sánchez-Martínez & Cabrera, 2015) in a study in southern Spain, Jaén, one of the regions with the biggest production of olive oil and table olives in the world, also point the 300% increase of the monoculture expansion of olive groves from 1986 to 2008 and to its serious consequences to the environment due to unsustainable models of production. According to Berbel and Giannocaro (Berbel Vecino & Giannocaro, 2013) olive grove monoculture is the best economic alternative to intensive agriculture either in irrigated or non-irrigated soils which is line with the productivity oriented Common Agricultural Policy (CAP) that early started subsidizing this cultural intensification.

The Mediterranean basin is a region with increasing biodiversity loss, soil erosion, water scarcity, soil salinity and soil organic matter (SOM) decrease (Lacirignola, Capone, Bari, Padilla, & Tafuri, 2010; Telo da Gama, Nunes, Loures, Lopez-

Piñeiro, & Vivas, 2019). Water resources are limited due the natural precipitation regime in the area with the most economically grown crops (e.g.: *Zea Mays* L., *Lycopersicon esculentum* L. or *Allium sativum* L.) in need of water in the months were precipitation is sparse or even inexistent leading the way to agricultural intensification through irrigation that consumes 70% of the world's available freshwater ("Meat Atlas," 2014)

Along with the increased demand for irrigation water, other anthropogenical paradigms of cultural intensification arise such as greater fertilization inputs, the increase in phytopharmaceuticals and soil erosion due to the increase in soil mobilizations, (Herzig, Dymond, & Ausseil, 2016; Khatteli et al., 2016). The need for intensification is even greater as the gap between the population increase, and arable land decrease, is widened increasing the pressure on agricultural soils demanding that they be able to feed the ever-growing members of our global community (Ray, Mueller, West, & Foley, 2013), but, if at the same time crops derived from irrigation practices produce 40% of the total food the practice it is also responsible for the permanent deterioration of the soils due to salinization, that increases at a rate of 10% per year, leading productive land towards complete unproductivity (Sojka, Bjorneberg, & Entry, 2002; Vengosh, 2003; Aldakheel, 2011; Wolschick, Barbosa, Bertol, Bagio, & Kaufmann, 2018).

In order to assess the sustainability of the ecosystem services in the Mediterranean basin the evolution in crop systems and its water usage must be evaluated. In this study we intended to assess the extent to which monoculture has gained expression in this typical area of the Mediterranean basin and that represents an identified case of what is happening in the generality of the Mediterranean basin.

2 Material and Methods

The study area was located in the western Mediterranean basin within the administrative townships of Elvas and Campo Maior, at the confluence of the Rivers Caia and Guadiana, near the Portuguese-Spanish border. The total area of the research accounted for 13,400 ha. The study area is served by the Caia dam with a total full storage level of the dam accounting for 1,970 ha with an elevation of 233.5m and a total, useful and non-useful, capacity of 203.0, 192.3 and 10.7 hm3 of water respectively. Stored water is mainly used for irrigation (90%), industrial and domestic purposes but domestic use is preferred during dry seasons. The geology is heterogeneous but mainly consisting of hyper-alkaline and basic rocks. The most important crops are olive (*Olea europaea* L.), maize (*Zea mays* L.), tomato (*Lycopersicon esculentum* L.) and cereals (Figure 1). The average annual rainfall is approximately 483 mm, most of which coincides with the coolest temperatures from October to March. The maximum average monthly temperature corresponds to July with 24.7 °C and the minimum to January with 8.8 °C. The Mediterranean region is characterized by its hot dry summers and cool wet winters and it's a Csa in the Koppen classification (Loures, Gama, Nunes, & Lopez-Piñeiro, 2017). The water is classified by FAO as C1S2 (Nunes, 2003) - very good quality with low salinity and sodicity. Classification that has remained over the years but with a marked increase in bicarbonates (HCO_3^-) since 2001 where the mean content in the study area was 68.6 mg L^{-1} while in 2012 was 101.0 mg L^{-1} marking a transition from low to moderate HCO_3^- in its levels (Telo da Gama et al., 2019).

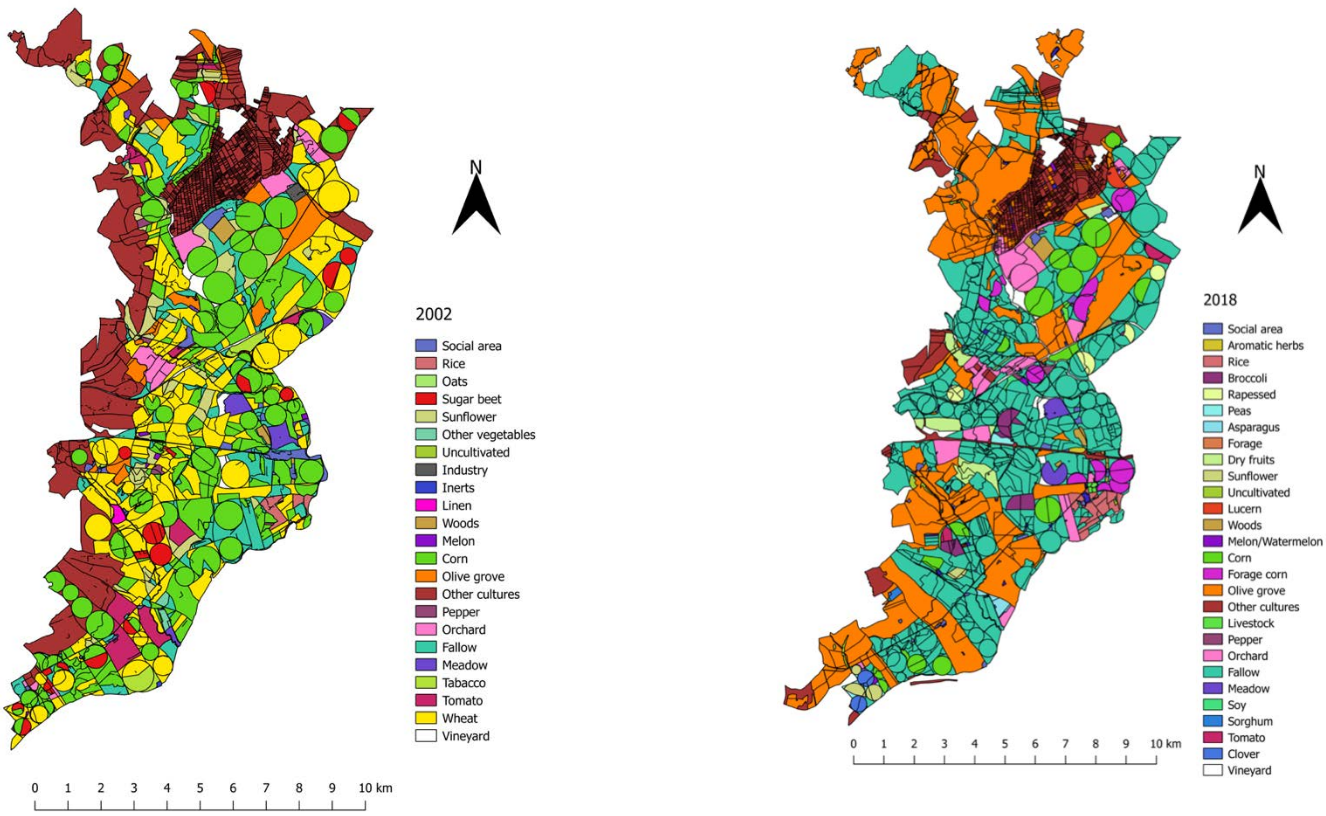


Fig. 1: Cultural system in a) 2002 and b) 2018

2.1 Cultural Data

Data from 2002 (figure 1a) was collected in field by Nunes (Nunes, 2003) in his assessment of the study area by regularly surveying the study site and performing regular analyses of its edaphic and cultural aspects through a Global Positioning System (GPS). Data from the subsequent years (Figure 1b) was provided by the 'Caia Beneficiaries Association', a non-profit organization under the supervision of the Portuguese Ministry of Agriculture and which is in charge of the management, exploitation, and conservation the Caia Hydro-agriculture Project and Irrigation Perimeter (CIP) that annually surveys the area *in situ* with a GPS identifying the crops practiced and where the new areas identified in the surveys are added to the Geographic Information System (GIS).

2.2 Statistical Analysis

Our results have a Confidence Interval (CI) >= 95%. All null hypothesis (H0) were rejected for a p < 0,05. Geographic Information System analysis were performed using Esri ArcGIS v.10.5 software package (headquarters in 380 New York Street, Redlands, California, U.S.A.) and QGIS v.2.18.28 "Las Palmas" (QGIS, 2019) under Creative Commons Attribution-ShareAlike 3.0 license (CC BY-SA).

3 Results and Discussion

Preliminary results show that there have been some major changes in grown crops in the study area (Table 1, Figure 2). Olive groves, that in 2002 occupied 424.19 ha had a 968% increase since and occupied 4,106.93 ha in 2018, representing the greatest change over time in the CIP. Spatially this is also the culture with the greatest representation in the study area, largely surpassing its predecessor, corn. Rice, broccoli, druid fruits, rapeseed and orchards also increased in the CIP. Rice and orchards had increases of 210% and occupy, as of 2018, 121.69 and 511.71 ha, respectively. Broccoli, dried fruits and rapeseed are new crops practiced in the region and, in 2002, they were not being grown by local farmers but in 2018 gained some expression occupying areas of

122.70, 201.94 and 90.29 ha, respectively. Except from cereals all other crops in the study area have decreased over time. Sunflower and tomato had the most, relative, accentuated decreases over time both with -85% area from 2002 to 2018. Sunflower went from 461.10 to 67.59 ha and tomato from 279.82 to 43.00 ha, but it was corn that had the greatest decrease in area. Corn was, at 2002, the crop with the greatest representation in the study area occupying 3086.82 ha but it has declined -72% since (2,214.28 ha) to a total area of corn and forage corn of 872.54 ha. Sugar beet and tobacco, that occupied 286.94 and 94.92 ha, respectively, in 2002 have been abandoned in detriment of other crops. Cereal production (mainly *Triticum aestivum* L., but also *Hordeum vulgare* L. and *Triticosecale cereale* L.) have also increased in the CIP by 120%.

Table 1: Area (ha) by crop in 2002 and 2018

Crops	Area (ha)	
	2002	**2018**
Cereals	4,553.27	5,478.87
Corn	3,086.82	872.54
Dry fruits	0.00	201.94
Cucurbitaceae	11.61	15.24
Other vegetables	432.56	196.29
Olive grove	424.19	4,106.93
Tomato	279.82	43.00
Vineyard	69.09	67.21
Forage	0.00	81.23
Woods	61.33	79.45
Livestock	0.00	26.09
Buildings	160.05	91.59
Orchard	242.32	511.71
Other cultures	4.50	65.48

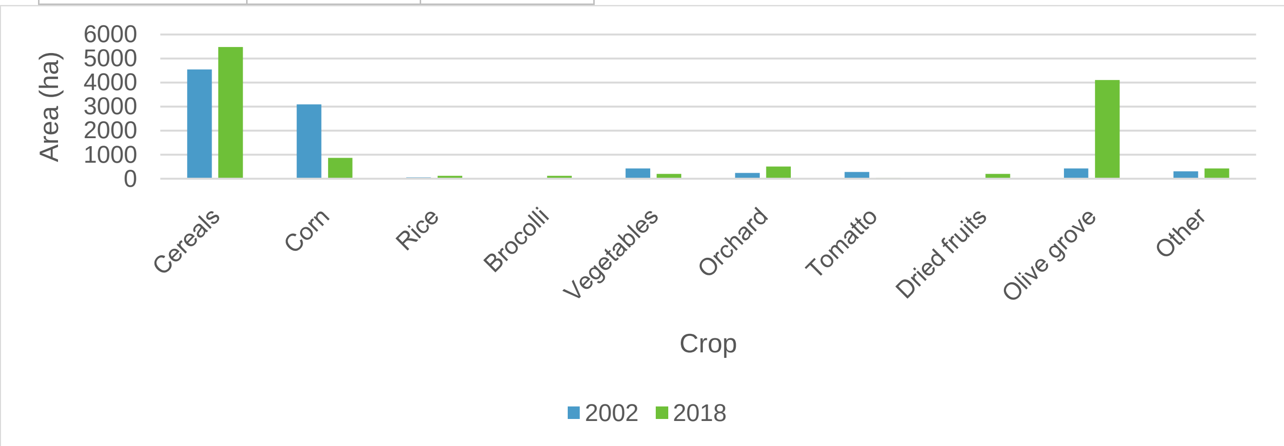


Figure 2: Area (ha) by crop in 2002 and 2018

With the cultural change, there was an equivalent change in water consumption and the crops in 2017 now consume 155% more water than the crops in 2002 in the study area (Table 2). Worth noting is that there has been a registered efficiency in water usage since 2002 where 42.75% of all water served to the farmers was wasted compared to the 20.64% registered in 2017 (Table 3, Figure 3). Comparing the water consumption by crop in the CIP with what would be the expected for the region (REP-USO_AGUA) the study area olive groves are consuming 2.18x more water than the average which is correlated with the intensification of olive groves by hedge formation where a greater number of trees per hectare lead to greater water consumption per hectare. The olive grove increase in water consumption is interesting from an ecological perspective as the newly implanted hedge formation have large productions, once fully developed, and provide better soil protection against erosion while increasing biodiversity between olive lines. These benefits are only counteracted by the 36 and 34% increase in soil salinity where cereals and olive groves are present, respectively. When we compare the vineyard water consumption in the CIP to what would be expected no statistical difference emerges.

Table 2: expected and effective water consumption by crop in the region

Culture	expected water consumption ($m3.ha^{-1}$)	effective water consumption ($m3.ha^{-1}$)
Rice	15,152	20,072
Cereals		740
Forage	5,873	4,820
Vegetables	4,281	4,871
Corn	4,155	8,452
Olive grove	1,888	4,120
Orchards	5,000	17,004
Meadow	5,873	7,759
Broccoli		5,677
Tomato	4,247	7,235
Vineyard	1,859	1,830
Dried fruits	1,899	4,835
other	2,060	4,860

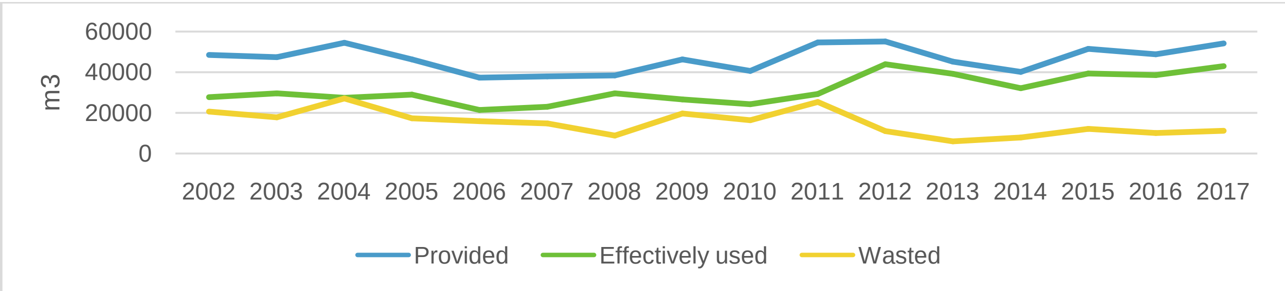
Adapted from the CIP report (Caia, 2018) and (Leão & Morais, 2011)

Table 3: Water provided, effectively used and wasted in the CIP by year

	Provided (m^3)	Effectively used (m^3)	%	Wasted (m^3)	%
2002	48,397.000	27,707.578	57,25	20,689.422	42,75
2003	47,405.000	29,643.380	62,53	17,761:620	37,47
2004	54,435.000	27,355:968	50,25	27,079.032	49,75
2005	46,290.000	29,005.049	62,66	17,284.951	37,34
2006	37,277.000	21,361.069	57,30	15,915:931	42,70
2007	37,850.000	23,011.348	60,80	14,838.652	39,20
2008	38,422.000	29,589.292	77,01	88,32.708	22,90
2009	46,193.000	26,591.705	57,57	19,601.295	42,43
2010	40,569.000	24,204.583	59,66	16,364.417	40,34
2011	54,562.000	29,286.228	53,68	25,275.772	46,32
2012	55,006.000	43,965.573	79,93	11,040.427	20,07
2013	45,201.000	39,192.535	86,71	6,008.465	13,29
2014	40,067.000	32,132.204	80,20	7,934.796	19,80

2015	51,503.000	39,297.782	76,30	12,205.218	23,70
2016	48,718.000	38,607.604	79,25	10,110.396	20,75
2017	54,204.000	43,015.000	79,36	11,189.000	20,64

Figure 3: Water provided, effectively used and wasted in the CIP by year (Caia, 2018)



4 Conclusions

These results are preliminary and data ranging from 2002 to 2018 will also be studied and further analysed in order to better access the results. In order to assess the sustainability of the ecosystem services in the Mediterranean basin the evolution in crop systems and its water usage was evaluated. Corn has been losing area to olive groves that gained expression in this typical area of the Mediterranean basin and that represents an identified case of what is happening in the generality of the Mediterranean basin. This study is aligned with the studies of other authors that assess the Mediterranean Basin cultural system evolution and the diversity of ecosystem services provided by its landscape.

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