Agropastoral over-exploitation and its socioeconomic implications in Messara Valley, Crete, Greece.

Ioannis N. Daliakopoulos[1], Ioannis K. Tsanis[2]

[1]*Postdoctoral Research Engineer at the Department of Environmental Engineering, Technical University of Crete, Chania, Greece*

[2]*Professor at the Department of Environmental Engineering, Technical University of Crete, Chania, Greece*

Introduction

Aridity reduces the degree of soil development properties such as soil and infiltration depth, organic content and nutrients, thus hindering the interlinked services of primary production and nutrient cycling (Safriel et al., 2005). Therefore, in semi-arid and arid areas where ecosystem resilience is low, pressures can force land to become irreversibly non-productive. The Mediterranean Basin has a pronounced overall gradient of aridity from the northwest to the southeast. Within the European coastal zone of the Mediterranean, about 300,000 km^2 of land is undergoing desertification, affecting the livelihoods of 16.5 million people. The majority of the affected drylands are within the territory of six southern European countries: Spain, Portugal, Greece, Italy, France and Cyprus.

In most Mediterranean basin drylands, the downward spiral of land productivity that results in ecological thresholds breaches and ends up in desertification is driven by population pressure coupled with the degree of aridity (Safriel et al., 2005). Rise of living standards, development of irrigated agriculture, and new activities such as tourism have drastically changed the water uses. Enhanced by intervals of intense land over-exploitation, the high natural climate variability of the Mediterranean basin and the Middle East has contributed to land degradation. These adverse conditions are often augmented by shortage of financial resources and institutions that are critical for arresting or avoiding this spiral.

Messara Valley is one of the 6 Study Sites of the CASCADE European Project that addresses catastrophic shifts relevant to soil and vegetation in the Mediterranean dryland ecosystems. The CASCADE Project works towards understanding the causes and characteristics of these shifts and to provide new recommendations for sustainable land management in Mediterranean drylands, under which the chances of catastrophic shifts are reduced. Here we briefly present essential information about ecological and socioeconomic status of Messara and overview the drivers of change that expose this dryland to soil degradation and eventually the desertification threat.

The Messara basin

The Messara basin encompasses an area of 611 km^2 located in the central-south Crete (Figure 1). Messara's hills and surrounding mountains as well as its antiquities are strong landmarks, among the many that make Crete famous for its landscape and nature. The geomorphological relief of the watershed is typical of a graben formation with elevation dropping from 2,454 m asl in Psiloritis Mountain to 45 m asl at Phaistos within 15 km. The valley covers an area of 398 km^2 within the watershed, with a mean altitude of 435 m. The Geropotamos River to the west and the Anapodaris River to the east drain the homonymous catchments that host the largest alluvium aquifer system of the island.

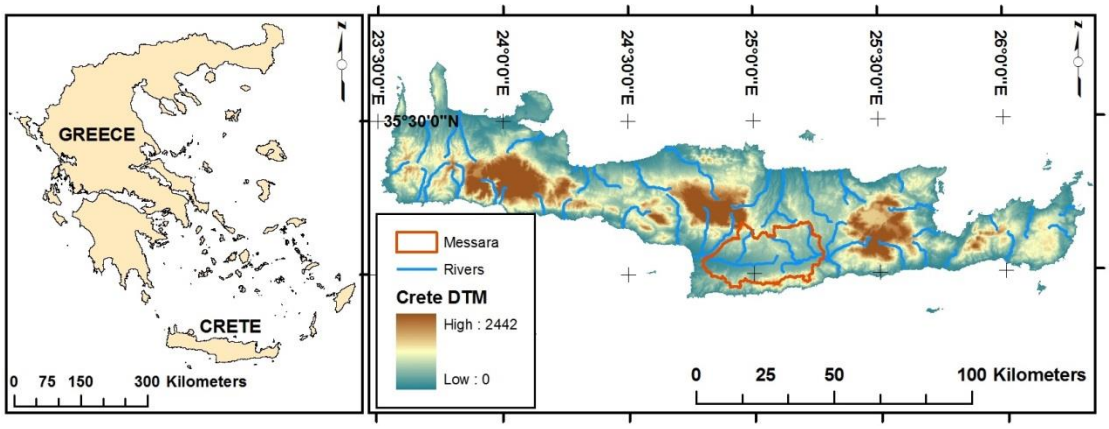

Figure 1: Messara basin in Crete, Greece.

Crete's climate is classified as dry sub-humid, with a hydrological year of two seasons (Tsanis and Apostolaki, 2008) and about 53% of the annual precipitation occurring in the winter, 23% during autumn, 20% during spring while there is negligible rainfall during summer (Koutroulis and Tsanis, 2010). Messara Valley receives on average about 650 mm of rainfall per year (Figure 2), unevenly distributed mainly due to the topography (Tsanis et al., 2006), and it is estimated that about 65% is lost to evapotranspiration, less than 10% as runoff and about 25% recharges the groundwater store (Daliakopoulos et al., 2005). The Neogene sediments and flysch are both characterized by a relatively high runoff while a small part of the mountain area is occupied by karstic formations of negligible runoff and high infiltration (CASCADE, 2013). For the available record, Messara's temperature has an annual mean of 19.3 ^{o}C, oscillating between 12 ^{o}C (winter) and 28 ^{o}C (summer). Winter relative humidity is

about 70% whereas in the summer it reaches 60% with potential evaporation estimated at 1,300 mm/year (Daliakopoulos et al., 2005).

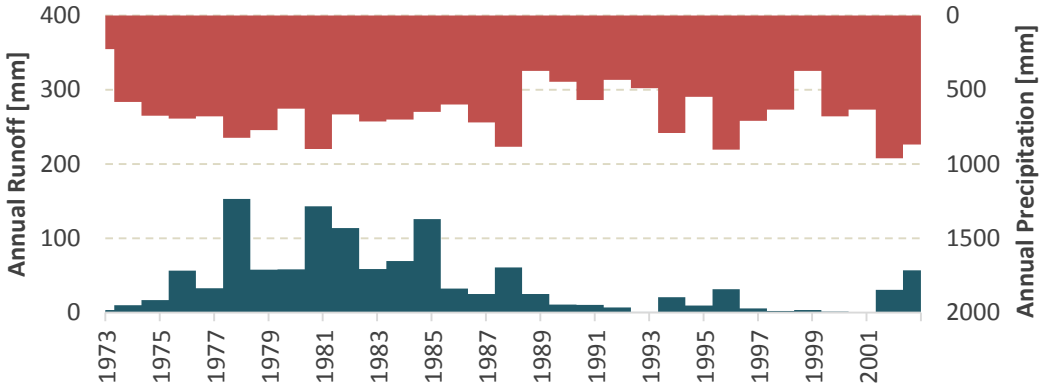

Figure 2: Annual precipitation (red) and runoff (blue) of the Messara Valley

The Cretan landscape has been cultivated since thousands of years, leading to 30% of its flora being linked to agriculture (CASCADE, 2013). Nowadays, Cretan agricultural practices mainly include monocultures, with about 250 km^2 of the Valley cultivated for olives (175 km^2, half of which drip irrigated) and grapes (40 km^2, mostly drip irrigated) with vegetable, fruit and cereal growing being part of a secondary production (Daliakopoulos et al., 2005). Natural vegetation is dominated by evergreen maquis and includes two interacting agro-ecological zones depending on elevation (CASCADE, 2013). The fauna, consisting of 2500 members 180 of which are endemic, is the result of a severe human-induced selection in favor of domestic livestock species. The dominant pastoralism model involves free grazing of sheep and goats. Livestock population in Crete reached 2.200mil. in 2000 and is now estimated to be around 1.700mil. On average, each producer has about 200-250 animals about 20% of which are goats. Livestock population in the lowland urban tourist destinations is gradually stabilizing while highland population increases (Figure 3).

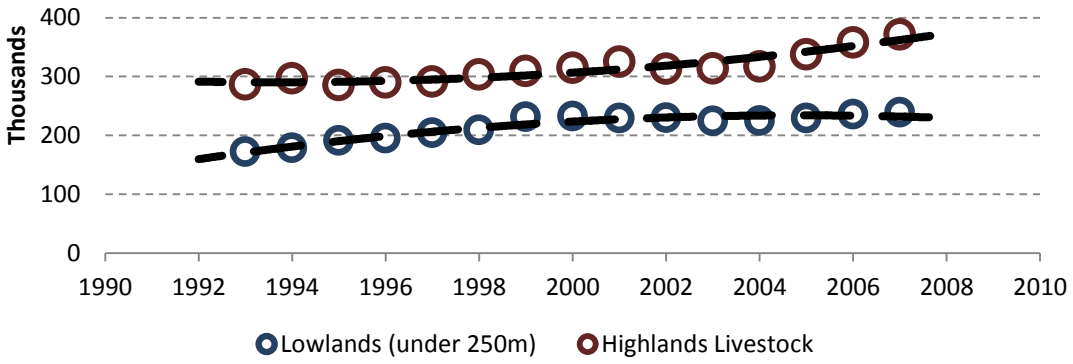

Figure 3: Livestock (sheep and goats) population in the Messara Valley. Source: Hellenic Statistical Authority

The Messara Valley has remained rural with a small population of almost 45,000 inhabitants. Although human induced changes have affected the landscape, agriculture predominates in the area, thus being a staple to the local economy and making Messara the most important agricultural region of Crete. Nevertheless, socio-economic and political factors such as outmigration and off-farm employment, especially in the highlands, have promoted environmental degradation (CASCADE, 2013). In Messara, fields are traditionally fragmented in small ownerships scattered around villages as island customs discourage land consolidation that would make farming more profitable. At the same time the excellent local products have entered a highly competitive international market that marginalizes profits and presents farmers with the risks of the single-commodity approach.

Key Drivers of Land Degradation

While climate variability can be a main driver of land degradation, the Standardized Precipitation Index (SPI) shows no prolonged drought events taking place during recent years in the Messara Valley (CASCADE, 2013). Throughout the available record, the area is mostly under normal conditions; nevertheless, extreme drought conditions took place in the years 1992–93 (Figure 4).

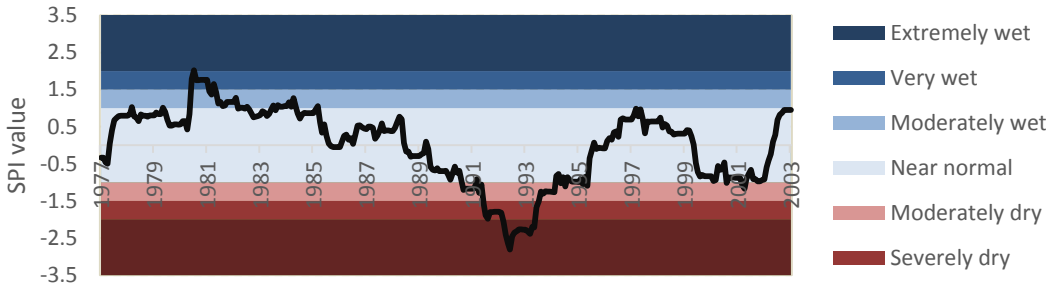

Figure 4: SPI 48 estimated for the period 1963-2002 for Messara Valley.

A synoptic view on vegetation health and the associated function of ecosystems at the basin (Figure 5), derived from analysis of archival Normalized Vegetation Index (NDVI), depicts a pronounced susceptibility of vegetation of the plain to drought precisely during the early 90s (CASCADE, 2013). While in this case vegetation displayed resilience and gradually recovered to its previous state (Figure 5), the complications of this behavior on soil health are still unknown.

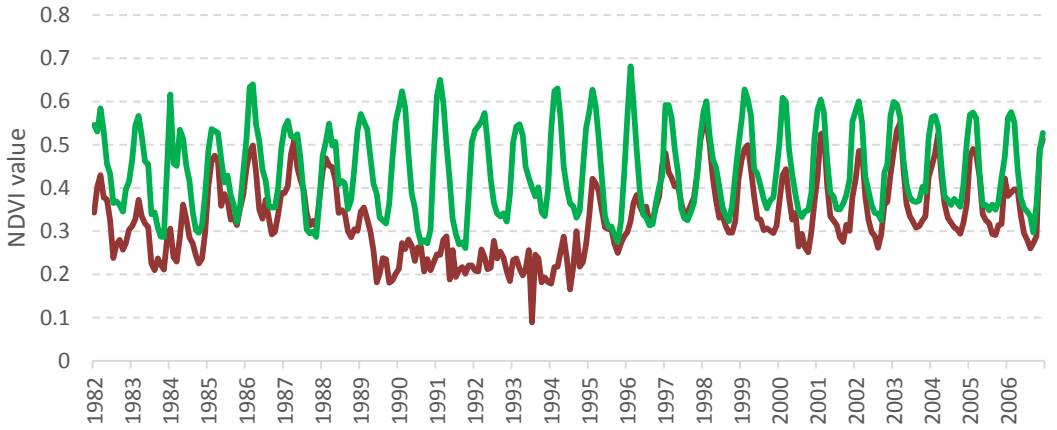

Figure 5: NDVI evolution at the plain (brown) and higher grounds (green) of Messara (Pinzon et al., 2005; Tucker et al., 2005).

The relationship between the density of livestock population and restoration rate of the natural flora is a tipping point indicator for land degradation (CASCADE, 2013). The traditional rational grazing model was harmonized with the local biodiversity and contributed to its protection by preventing abandonment but nowadays Messara Valley is exposed to an increasing grazing pressure that often induces signs of irreversible degradation, especially in the highlands. An apparent lack of grazing-capacity studies, of a clear tenure regime of

grazing grounds and distribution of resources on behalf of the state, provides legal tolerance to unsustainable pastoralism practices. Climate variability can also take its toll to such a marginally managed system (Daliakopoulos and Tsanis, 2013). Nevertheless, the financial crisis appears to have brought balance to the system, as imported fodder that substituted the cheap pasture vegetation became unprofitable, eventually leading to an estimated 30% reduction of the animal population from 2007 to present.

In Messara, high profitability of irrigated farming has led to over-exploitation of water resources, beginning with the installation of an extensive pumping system in the 80s (Daliakopoulos et al., 2005). As a consequence of the temporal and spatial variations of precipitation and water demand, water imbalance is often experienced. With meager surface water flow outside the winter months, groundwater, the main source of irrigation water in Messara (Daliakopoulos et al., 2005), controls the economic development of the region. Before the establishment of the irrigation network in the 80s, groundwater level used to be 5 m below surface, but the now over 1,400 legal pumping wells (CASCADE, 2013), and numerous non-accounted illegal wells, have depressed the water table to as much as 45 m. As a result, there has been growing concern over the possible depletion or deterioration of the groundwater quality in the basin due to intensive pumping beyond the safe yield of the basin (Tsanis and Apostolaki, 2008).

The large population shift towards the urban centers (Figure 6) has led to rural land abandonment or leasing, thus facilitating poor land management. Mass tourism (> 2 million/year) has also put a pressure on the Cretan landscape in the last few decades. As a result and as a means to improve their financial profile, farmers in some dry areas, particularly along the cost, have sold their land to developers for the construction of tourist infrastructure.

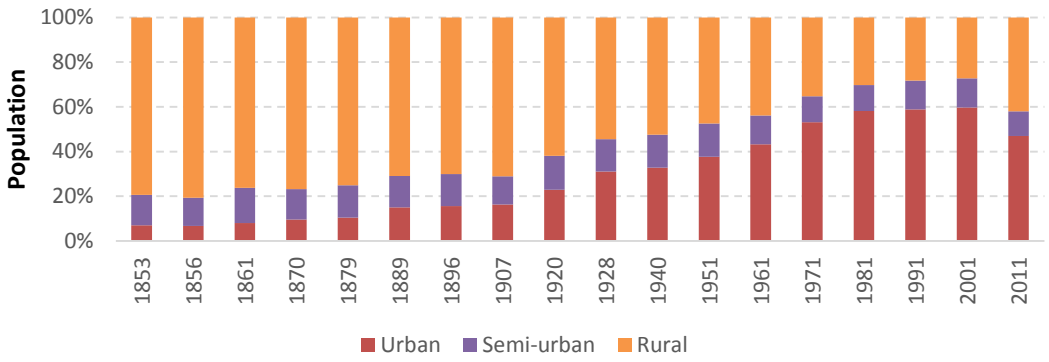

Figure 6: Changes in urban and rural population between 1985 and 2010 in Greece. Based on data from Greek National Statistical Service.

By joining the European Economic Community in 1981, Greek agriculture became subject to the Common Agricultural Policy (CAP). Up until 1992, the aim of the CAP was to increase production, and to provide cheap rural products accompanied by reasonable rural incomes. Accordingly, agricultural production was intensified and mechanized, unique endogenous varieties were replaced by hybrids aimed for the needs of globalized markets, and the adoption of monocultures led to some extent to the loss of self-sufficiency. In addition, regional development, infrastructure, spatial planning policies and the implementation of Integrated Mediterranean Programmes constitute the factors that have considerably affected the exploitation of natural resources (LEDDRA, 2013).

Concluding Remarks

The state of the art on climate change research for the Mediterranean region indicates a strong susceptibility to change in hydrological regimes, an increasing general shortage of water resources and consequent threats to water availability (Koutroulis et al., 2012) and land degradation. While future regional precipitation patterns are uncertain, IPCC projects a mean temperature increase of 3.4^{o}C over the next century in the northern Mediterranean. This warming trend and the resulting drought episodes will potentially force Messara Valley to exceed ecological thresholds such as vegetation health and grazing pressure, thus approaching a state or irreversible degradation of soil and relevant ecosystem services.

On a socioeconomic level, the CAP, through its structural policies, has supported an adequate income to farmers, contributing to the development of regional economies and reform of landscapes, particularly in less favored areas. Nevertheless, the lack of coordination between state services as well as knowledge gaps and poor implementation of measures and incentives, have been liable for the lack of Cretan landscape policy application. Organized efforts from the EU seek to bridge these shortcomings in management, infrastructure and knowhow. Although not specifically mentioning Mediterranean states, the new EU CAP addresses strategic objectives particularly relevant to the region. The resent reform and features a more flexible and fairer distribution of financial support while respecting local priorities.

Many solutions are bound to come through a combination of innovative technologies and traditional practices. For example, flora biodiversity can be fully restored with the application of rational grazing, fertilization or exclusion of degraded areas, and water conservation can be promoted by sustainable irrigation and land management practices. The CASCADE Project strives to investigate such approaches and to fill knowledge gaps through a series of multi-scale experiments, such as rainfall exclusion for drought simulation, post-fire soil treatment and landscape restoration among others. Integrated soil-water-plant models are being applies to the wealth of collected data in order to discover and confirm the nature of ecological mechanisms relevant to catastrophic shifts. Socio-economic factors are also being linked to ecological model, in order to facilitate policy scenarios. The results of the Project will provide insight to the causes and characteristics of tipping points in the Mediterranean drylands, thus leading to meaningful and scalable natural resource management recommendations for preventive and restorative best practices.

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