



Much More than Simply “Desertification”: Understanding Agricultural Sustainability and Change in the Mediterranean

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Keywords (separated by '-') Desertification - Land degradation - Europe - Mediterranean - Heterogeneity - Policy



Chapter 15

Much More Than Simply “Desertification”: Understanding Agricultural Sustainability and Change in the Mediterranean

Mark Mulligan, Sophia Burke and Andrew Ogilvie

Abstract In the socio-economic and climatic complexity of a Mediterranean environment, desertification involves many processes and is much more spatio-temporally sophisticated than is often suggested by both the policy and academic communities. Here we examine the spatial variability of the Mediterranean environment and its agriculture—a supposed key driver of desertification in the region. We examine trends in agricultural production and climate in the region and the differences between north and south. We review the recent history of Mediterranean desertification research and its changing policy context. In particular, we examine the evidence for Mediterranean desertification, and what we now understand of it, with the hindsight of three decades of research and having ‘come out of the other side’ of decadal drought events that prompted large-scale concern over the desertification of Mediterranean Europe in the 1990 s. We focus particularly on the spatial heterogeneity of the Mediterranean and the implications of this heterogeneity for understanding perceived desertification in the region, and explore implications for land use and management policy-making, indicating the need for a much more locally nuanced approach.

Keywords Desertification · Land degradation · Europe · Mediterranean · Heterogeneity · Policy

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15.1 Introduction

Desertification is an umbrella term that is used to represent a range of biophysical and socio-economic processes that may combine to reduce the biological potential of the land in arid and semi-arid agricultural areas. In contrast, at the edges of true deserts, desertization can be a simple process of desert encroachment by migrating dunes. In the socio-economic and climatic complexity of a Mediterranean environment, desertification involves many more processes than desertization and is much more spatio-temporally sophisticated than is often suggested by both the policy and academic communities. Here we examine the Mediterranean environment and its agriculture—a supposed key driver desertification in the region—and look into the recent history of Mediterranean desertification research. In particular, we examine the evidence for Mediterranean desertification, and what we now understand of it, with the hindsight of three decades of research and, moreover having ‘come out of the other side’ of decadal drought events that prompted large-scale concern over the desertification of Mediterranean Europe in the 1990s. We focus particularly on the spatial heterogeneity of the Mediterranean and the implications of this heterogeneity for understanding perceived desertification in the region in the 1990s and now, having access to much more detailed spatial data.

15.2 The European Mediterranean: Environments and Agriculture

The Mediterranean is characterised by a semi-arid to sub-humid climate that is highly seasonal for both solar radiation (and thus temperature) and for cloud generation (and thus rainfall). The long, hot and dry summer ‘drought’ followed by heavy October rainfall provides both a constraint to vegetation production and conditions of low cover and intense rainfall which favour soil erosion and degradation. Degradation is variously attributed to overgrazing, poor soil management, poor drainage on irrigated land, and the over-abstraction of woodland for fuel wood.

Over the long-term the Mediterranean climate has combined with the region’s geology to create rugged, highly dissected landscapes with sparse vegetation and poor, stony soils. Traditional agriculture is well adapted to this environment through sparse cropping of hardy species (Almond, *Prunus dulcis*; Olive, *Olea europea*; Fig, *Ficus carica*) combined with careful management of water through: runoff capture; mulching of soils; terracing and occasional irrigation. However, recent trends include larger fields, mechanized ploughing, significant soil movements (Ramos and Mulligan 2005; van Wesemael et al. 2005), and intensively irrigated crops including greenhouse vegetables, rice, wheat and citrus. These may not be so well adjusted to both the seasonal water shortages and inter-annual and longer-term climate variability that characterise the region. Agricultural change in the Mediterranean is driven by: complex changes in population distribution

(especially urbanization); demography and socio-economic change (including the development of the service sector and of tourism); changes to transportation costs; subsidies and markets in Europe and beyond; and technological change.

We examine the countries of the northern (largely European) Mediterranean with a coastline on the Mediterranean sea. The Mediterranean countries have strong latitudinal precipitation (P) and temperature (T) gradients. Precipitation decreases from north to south and from west to east and temperature increases along the same gradients. There are, however, significant montane and coastal effects with mountain and coastal areas generally being cooler and wetter.

Rainfed agriculture dominates the northern and western Mediterranean countries (Fig. 15.1) and is intensive in northern France and Spain. If >50 % cover signifies ‘intensive’ then some 16.6 % of the study area can be considered intensive rainfed cropping. Irrigated cropland (Fig. 15.2), on the other hand, is concentrated in a few areas (NE Italy, and parts of Spain, France and Greece) at high intensity but is common over small areas throughout the region. Irrigation is a significant drain on groundwater resources in some of the drier regions and is estimated to use some 16 % of groundwater production in the Mediterranean (Siebert et al. 2010). If >50 % cover signifies intensive then some 2.1 % of the study area can be considered intensive irrigated cropping.

Figure 15.3 shows grazing is much more extensive than intensive in the Mediterranean and occurs throughout the Northern and Eastern Mediterranean,

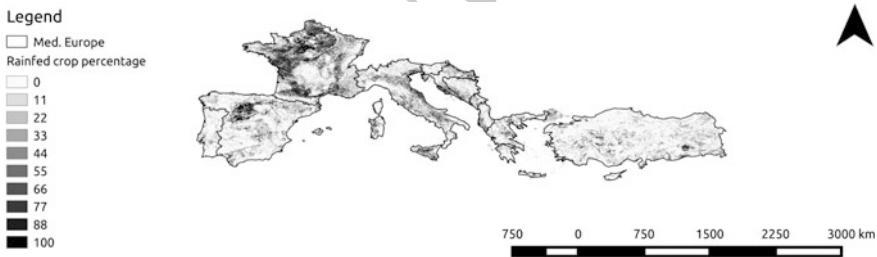


Fig. 15.1 Rainfed crops in Mediterranean countries according to GlobCover continuous fields (Mulligan 2009a)

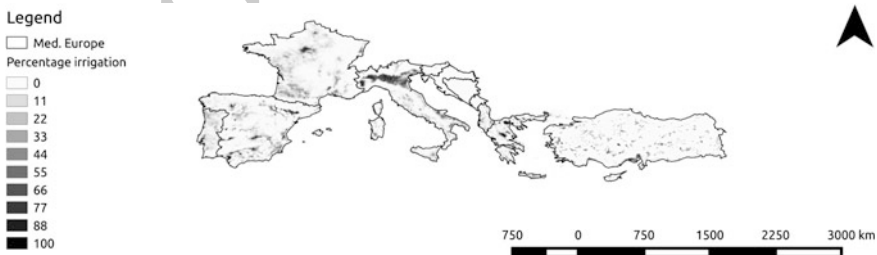


Fig. 15.2 Percentage of land irrigated. *Source* Siebert et al. (2007)

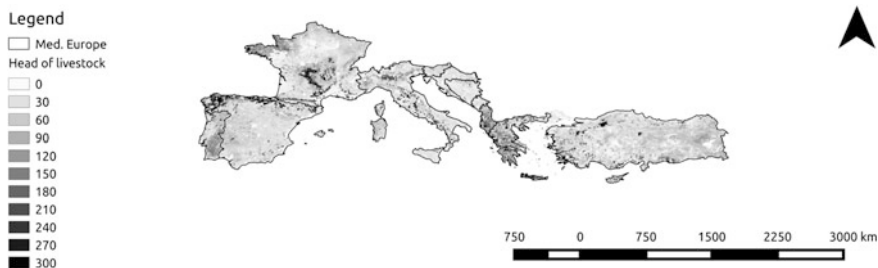


Fig. 15.3 Total grazers (headcount/km²). *Source* Wint and Robinson (2007)

especially in mountains, coastal areas and river margins. If >200 head per square km signifies intensive then some 4.9 % of the study area can be considered intensive grazing land.

The greatest cereals producers in the EU and southern Mediterranean countries in 2007 (an average year for the decade) according to EUROSTAT were France (59.4 million tonnes), Germany (40.6 million tonnes) and Poland (27.1 million tonnes). These are followed by Spain (23.8 million tonnes), UK (19.4 million tonnes) and Italy (18.8 million tonnes). Non-EU southern Mediterranean countries, on the other hand, have lower cereal production, most countries producing 5 million tonnes of cereal annually or less, with the exception of Egypt which produced as much as 15.3 million tonnes of cereal in 2007 (Petit 2007). Though statistics for the southern Mediterranean countries are not as comprehensive, productivity remains lower than for the EU. Fruit and vegetable production is also very variable across the Mediterranean, with Spain, Italy and Egypt having the highest production in the last decade according to EUROSTAT. The European Union is by far the largest producer of olives, producing about 75–80 % of the world's supply (Muller 2004). Greece, Spain and Italy are the top olive producers; followed by Portugal, Algeria, Egypt, Argentina, Lebanon, Libya, Morocco, Palestine, Tunisia and the USA. Production of olives has greatly benefited from EU subsidies. Italy, Spain, and France are the top grape and wine producers in the world, followed by the USA and China. Of the top twelve global producers, the EU producers (Italy, Spain, France and Germany) account for about 67 % of wine production (Patterson and Josling 2005, using FAOSTAT data).

Population is distributed throughout the north and east Mediterranean land-masses with some significant urbanisations also present in those areas (Fig. 15.4). In the southern Mediterranean there are large areas with very low or no populations, people being highly concentrated in the coastal fringe and the major river valleys. This reflects the distribution of climatic and agricultural suitability and also determines the demand for water and the human pressure (directly and through agriculture) on the environment.

The northern Mediterranean is highly urbanised (Fig. 15.5) with these urbanisations being dense (in population terms), extensive and highly concentrated around coasts (e.g. Spain, Italy) and major rivers (e.g. Egypt).



Fig. 15.4 Population (persons/km²). *Source* Landsan (2007)



Fig. 15.5 Urban areas. *Source* CIESIN (2004)

Figures 15.1, 15.2 and 15.3 indicate that the Mediterranean landscape is both extensively and intensively agriculturalised, whilst Fig. 15.6 shows dry matter productivity for the Mediterranean. This measure is for all plant systems, not only for crops and shows strong gradients with the highest observed values in the northern areas (of Italy, Sardinia, northern Spain, Greece) and a strong decline towards the southern areas (especially of Spain, Turkey). Towards the South and East, water becomes limiting because of the gradient of decreasing precipitation in this direction.

Overall, the north and west Mediterranean is productive and extensively used for dryland or irrigated agriculture or grazing. Despite this intensive, extensive and productive agricultural situation, the Mediterranean has long been considered an

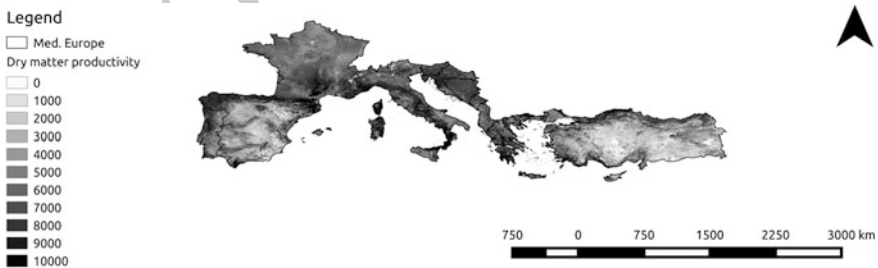


Fig. 15.6 Dry matter productivity (Dg/ha/day) for the Mediterranean. *Source* Mulligan (2009b)

area under threat of desertification and land degradation driven by unsustainable exploitation of water resources, abandonment and subsequent degradation of managed farmland and significant changes to farming practices over the last decades (Brandt and Thornes 1996; Puigdefábregas and Mendizabal 1998; Geeson et al. 2003; Briassoulis 2004; Rubio and Recatalá 2006; Safriel 2009a, b).

15.3 Recent Drivers for “Mediterranean Desertification”

Here we review some of the reasons that Mediterranean desertification has received a great deal of scientific, political and media attention over the last three decades. Some of the reasons are biophysical whilst others are socio-economic in origin. These drivers include agricultural land use change, change to grazing lands, changes in agricultural policy, climate variability and change and, finally, changes to human exposure to land degradation.

15.3.1 *Agricultural Land Use Change in the Mediterranean*

Agricultural production in the Mediterranean has significantly increased over the past fifty years. Since 1961, production increased 3-fold for cereals, 2.5-fold for vegetables and 5-fold for citrus fruits and these crops account for over 85 % of the total agricultural production in the Mediterranean (Plan Bleu 2009). The growth rate in agricultural production has started to fall in recent years in all Mediterranean countries with the exception of Egypt, which showed remarkable increases in the period 1961–1983 and still grew (but at a much slower growth rate) in the period 1984–2007 (Plan Bleu 2009). This has affected trade balances and Mediterranean countries are becoming increasingly dependent on foreign food imports. Nevertheless, southern Europe exports much of its produce.

Although rain-fed agriculture predominates in the Mediterranean, it is on irrigated land that the greatest productivity and productivity gains have been achieved in recent decades (Montgomery 2009), as is also the case outside the Mediterranean (Siebert and Döll 2010). The total irrigated area in the Mediterranean countries doubled in the previous 40 years to exceed 26 million hectares in 2005, possibly representing over 20 % of the land under cultivation (Plan Bleu 2009). The area under arable and permanent cropping has not increased alongside annual agricultural production, indicating a trend for intensification rather than extensification, again replicating the global trend. In fact, since 1961, arable land per capita in both the north and south of the Mediterranean has halved (Plan Bleu 2009a) as land that is suitable for cultivation is lost to urbanisation and abandonment every year, largely because of migration to coastal urban areas but also in response to EU set-aside policy.



15.3.2 *Recent Changes to Grazing Lands*

In the European Mediterranean—there has been a major shift in land use from livestock that grazed on extensive rangelands to intensively farmed cereals and intensive grazing systems. This is partly driven by markets and regional agricultural policies, in particular subsidies designed to increase biodiversity but also as a more sustainable method of management (Roeder et al. 2008). Taking animals to graze is a hard and time-demanding job (Ruiz et al. 2001) with low economic rewards compared with many others. Intensification necessitates the utilization of supplementary feedstuffs, either on-farm (cultivated pastures and crops) or most frequently off-farm through concentrates and forages (Riedel 2007).

In the Southern Mediterranean, cultivation has encroached onto rangelands, driven by population growth and national policies, often resulting in land degradation (Safriel 2009a, b). In the south and the east (from Morocco to Turkey), despite rural to urban migration, the agricultural population increased by 10 million (16 %) within 40 years, reaching 71 million in 2000 (Thivet 2007). This can be contrasted with the Northern Mediterranean where, from Spain to Greece, the agricultural population decreased from 46 million to 12 million over the same period (Thivet 2007).

15.3.3 *Recent Changes in Agricultural Policy*

Much of the rise in productivity in the EU has been encouraged by the Common Agricultural Policy (CAP), which was set up initially with the treaty of Rome (1957) to control food production across Europe and latterly focuses on environmental concerns. Through the provision of incentives and a number of accompanying policies, the CAP is a key driver of agricultural change in the EU. The impact of the CAP on Mediterranean land use has been well-documented (Shucksmith et al. 2005; van Meijl et al. 2006; Verburg et al. 2008; Serra et al. 2008). The effect of the CAP also needs to be seen alongside other drivers, such as the substantial level of national funding for agriculture, the fluctuations on world markets for food products and the negotiations taking place within the World Trade Organisation (Gay et al. 2005). In particular the CAP has provided support (via intervention buying and storage) for a few Mediterranean products such as olive oil, tobacco and cotton, although this no longer takes place. Increased interest in energy efficiency and climate change is increasingly raising questions about the relevance of current CAP objectives (Cooper and Arblaster 2007). The likely continued future enlargement of the Union will also necessitate significant change to future CAP policy. The Mediterranean will also be affected by the establishment of a Mediterranean Free Trade Zone (MFTZ), which will encompass 12 non-EU nations of the Mediterranean region as well as the entire European Union. This was expected to be completed by now but has been delayed by: foreseen negative social

and environmental consequences; the Sarkozy initiative to set up a Union for the countries that border the Mediterranean sea; and questions as to the relationship between this and the EU-GCC (Gulf Cooperation Council) free trade initiative.

15.3.4 Recent Climate Variability, the Prolonged 1990s Drought and Climate Change Scenarios

The climate of the Mediterranean region is characterised by hot, dry summers and cool, wet winters (Conacher and Conacher 1998) with December, January and February precipitation (DJF) a major contributor to the annual total. It is a region of significant climate variability, both spatially and temporally. This climate variability is due to the Mediterranean's location in a transitional zone between the competing "marine west coast climate" and the "subtropical desert climate" (Lionello et al. 2006). The Mediterranean climate is exposed to the South Asian Monsoon in summer and the Siberian high pressure system in winter. Variability is expressed as changes in annual total rainfall (both inter-annually and on decadal time scales) and changes in rainfall seasonality and the frequency and magnitude of extreme rainfall events and seasonal drought episodes. Rainfall records since 1900 indicate strong multi-decadal variations in regional precipitation (meteorological drought) coupled with a long term trend in the Palmer Drought Severity Index (PDSI) suggestive of increased land surface aridity associated with observed long term temperature increase since the 1960s (Mariotti 2010). DJF precipitation in the Mediterranean showed a striking decrease during the 1960–1990s which may result from circulation changes in the North Atlantic climate Oscillation (NAO). This meteorological drought has been realised as hydrological drought with river discharge for major Mediterranean rivers such as the Ebro, Jucar and Arno showing a considerable decline over the 20th Century. Current rainfall trends in the region continue the clear downward trend during the second half of the 20th Century (de Luis et al. 2009; García-Ruiz et al. 2011) but much less dramatically than during the 1990s. This drying is experienced in the form of more frequent and intense drought, especially in the winter with 10 of the 12 driest winters since 1902 occurring from 1992–2012 (Hoerling et al. 2012).

Future climate change scenarios for the Mediterranean are also complex. Generally, a change in circulation patterns is expected for the Mediterranean region as a result of increases in sea level pressure, a northward shift of the Atlantic storm track and a deflection of storms north of the Mediterranean into higher latitude areas (Giorgi and Lionello 2008). These changes in circulation are expected to lead to a general reduction in precipitation for the Mediterranean regions and an increase for the northern European regions. Changes in variability of precipitation and temperature are also expected. Schar et al. (2004) concluded that as a result of an increase in inter-annual variability of temperature along with mean long-term warming, the Mediterranean region might experience a much more frequent

occurrence of extremely high temperature events and heat waves. As a region with already marginal climate for some types of agriculture, the Mediterranean is expected to be affected significantly by climate change.

Giorgi (2006) analyzed IPCC SRES AR4 simulations to calculate a climate change index based on precipitation and temperature means and variation. The Mediterranean was amongst a small number of climate change “hot-spots” globally. Weib et al. (2007) considered socio-economic and climate changes as indicated by the IPCC SRES A2 and B2 scenario forcing the ECHAM4 GCM. Under this scenario a current 100-year drought would likely occur 10 times more frequently in the Northern Mediterranean while in North Africa, a current 100-year drought will occur less frequently. There is thus the expectation of significant negative effects of climate change in the Mediterranean. According to Giorgi and Lionello (2008), climate change scenarios from general circulation models (GCMs) indicate a “*pronounced decrease in precipitation, especially in the warm season, except for the northern Mediterranean areas (e.g. the Alps) in winter*”. These effects are projected to lead to a progressive decline in streamflow (García-Ruiz et al. 2011).

Using the more recent Coupled Model Intercomparison Project Phase 5 (CMIP5) data, Peleg et al. (2014) compared current climate with projected mid-21st century climate based on Representative Concentration Pathway (RCP) RCP4.5 and RCP8.5 scenarios using four of the available CMIP5 models. The models projected a decreasing frequency of rainfall in the region with a 10–22 % reduction in wet events. Also using CMIP data, Diffenbaugh and Giorgi (2012) indicate the Mediterranean as one of a few hotspot areas for prominent climate change using a multi-variable metric including rainfall and temperature.

However, a large source of uncertainty in projections for the Mediterranean region derives from unrealistic modelling of the climate influence of the Mediterranean Sea (Somot et al. 2008; Lionello et al. 2008). Furthermore, particularly for regional models, uncertainties in future land use and land cover change adds considerably to uncertainty in climate projections. Uncertainties in climate simulations with RCMs for Europe were addressed in the PRUDENCE project (<http://prudence.dmi.dk/>) which found that, particularly for temperature, uncertainty in boundary forcing plays a greater role than the RCM used (Déqué et al. 2007). In addition to these climate changes, the future of the Mediterranean environment will also be determined by changes in population, technology, agriculture and thus land use and cover.

15.3.5 Changing Exposure: Population Growth and Economic Development

Spatial projections for population and GDP are publicly available in map form only for the Special Report on Emissions Scenarios (SRES) B2 scenario (Fig. 15.7).

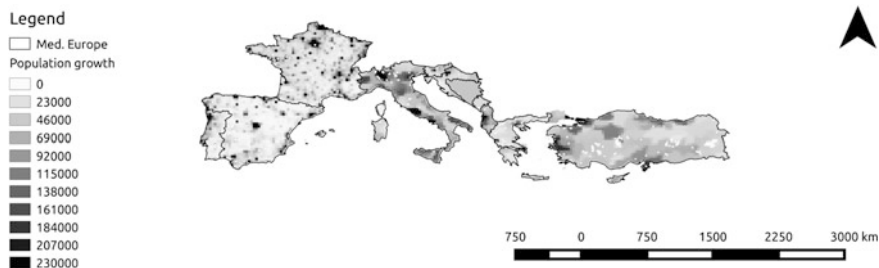


Fig. 15.7 Population projection for 2025 (persons/km², SRES B2). *Source* CIESIN (2002)

Under SRES B2, population increases by 2025 are expected to be greatest in the south and east of basin, concentrated in coastal areas. De-population is expected to occur in parts of the north Mediterranean (especially Spain, Italy and Greece).

15.3.6 The Water Resources Situation

In addition to the observed low productivity in some areas of the Mediterranean (and expectation that this will reduce further with land degradation and climate change), water resources are also a key constraint on productivity and sustainable land management in this environment. We have calculated water balance as rainfall (Hijmans et al. 2005) minus actual evapotranspiration (Mu et al. 2011) on a 1 km resolution basis with negative local water balances (representing areas where evapotranspiration is supported by lateral surface or subsurface inflows) set to zero. The results of this analysis are shown in Fig. 15.8a. Dark areas have plenty of water, whereas those in lighter shades show progressively lower water balance. The most water stressed areas are in the southern Mediterranean, in the eastern Mediterranean and in coastal northern Mediterranean. Water stress can lead to over-cultivation and to the negative effects of irrigation in drylands. Note that this water balance does not include inflows of water from rivers nor unsustainable use of fossil water but focuses on the locally produced renewable water resources (the water balance) since this will be critical for sustainable agricultural production. Some 8 % of the area has a local water balance of zero, indicating all local rainfall consumed by local evapotranspiration. Figure 15.8b shows the same data averaged over watersheds, indicating clearly the more water stressed catchments. Only 0.3 % of basin area experiences basin closure (all rainfall evaporated within the basin) on an annual basis under current conditions. Though a positive water balance will lead to the generation of runoff and thus river flow, this analysis does not explicitly account for available water in rivers and groundwater that is used to supplement the local water balance at the pixel scale in some regions, though these are determined entirely by water balance at the basin scale.

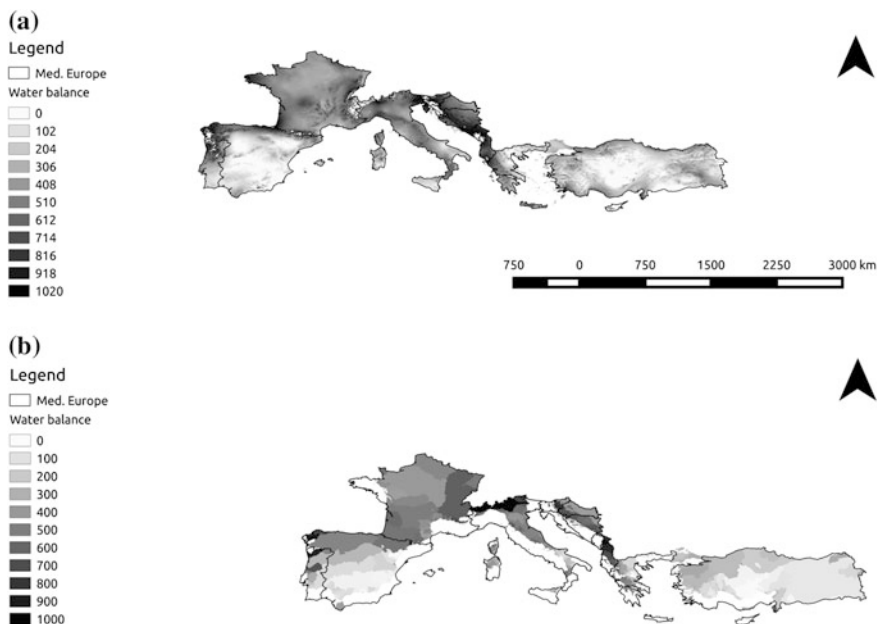


Fig. 15.8 **a** Water balance (rainfall-ET) (mm/yr). **b** Water balance (rainfall-ET) (mm/yr) by catchment

Table 15.1 Evapotranspiration by different land covers and as a percentage of rainfall as calculated by WaterWorld

All vegetation	Irrigated croplands	Croplands	Pastures	Natural vegetation
Actual evapotranspiration (percent of total)	0.41	26.8	16.1	56.1
Actual evapotranspiration (percentage of rainfall)	0.2	15.3	9.2	31.9

We carry out an analysis of evapotranspiration through the different types of vegetation cover in the region (Table 15.1), calculated using WaterWorld¹ and based on the actual evapotranspiration (AET) dataset of Mu et al. (2011), the irrigated cropland dataset of Siebert et al. (2007) and the cropland and pasture dataset of Ramankutty (2008). Results indicate that, some 0.41 % of actual evapotranspiration in the region occurs through irrigated croplands, 26.8 % through all

¹WaterWorld is a modelling platform containing a range of global databases and the capacity to run detailed algorithms at scales from local through to continental. It is available free for non-commercial use from www.policysupport.org.



Fig. 15.9 Watersheds of dams

croplands, 16.1 % through pastures and 56.1 % through natural vegetation, with the remainder over bare soil and water bodies. The majority of AET thus occurs through natural vegetation, though croplands also evaporate a significant volume. In total AET consumes 56 % of rainfall in the region, some 32 % of which is evaporated through natural vegetation though only 15 % is evaporated through croplands and 0.2 % through irrigated croplands. The remaining 44 % is available to fill surface stores and generate runoff. On this basis irrigation consumes relatively little of the available rainfall, most of which evaporates through natural vegetation. The pressure points on water are thus highly localised to low rainfall and high AET areas, including those under intensive irrigation and pressure is not extensive throughout the region. The French and Italian Alps in particular will experience very different conditions that lower elevation areas with warmer, drier climates.

The demand for water storage (in reservoirs) during the dry season in the Mediterranean is evidenced by the distribution of dammed watersheds in the Mediterranean (Fig. 15.9), with the exception of certain dams in central France whose primary output is hydropower. The black areas indicate those watersheds that outflow at a dam according to the global census of Mulligan et al. (2011). Some 45 % of the European Mediterranean area, 41 % of its rainfall according to WorldClim (Hijmans et al. 2005) and 33 % of its water balance (according to WorldClim rainfall minus μ et al. (2011) AET) drains into a dam. This represents a very significant human appropriation of the hydrological fluxes of this region, supporting irrigation, industrial and domestic use.

As well as the annual total, the seasonality of rainfall and evaporation is a key component of water stress in the Mediterranean. Figure 15.10 shows the Walsh and Lawler (1981) seasonality index calculated using WorldClim monthly rainfall (mean 1950–2000) and indicates that seasonality is greatest in the SW of the Iberian peninsula, in southern Italy, Greece and Turkey. Some 8.2 % of the area is considered seasonal and some 0.7 % is markedly seasonal using this metric. In these areas a high winter rainfall elevates the annual total but the summer rainfall is a key limit to crop growth.

Legend

Med. Europe

Rainfall seasonality



Precipitation spread throughout the year

Precipitation spread throughout the year, but with a definite wetter season

Rather seasonal with a short drier season

Seasonal

Markedly seasonal with a long dry season

Most precipitation in < 3 months

Extreme seasonality with almost all precipitation in 1-2 months



Fig. 15.10 The Walsh and Lawler (1981) seasonality index for the Mediterranean

15.4 The Scientific Response to Perceived Mediterranean Desertification

Concern over desertification in the European Mediterranean has led to the funding of a range of field and modelling based assessments in the region. The field programmes aimed to understand the processes operating and assess desertification at various sites whereas the modelling projects aimed to provide a detailed analysis of causes and consequences in a spatially explicit manner, at the landscape scale. We will focus here on the modelling projects since they operate at more policy relevant scales than the field programmes, though they are—of course—informed by data and knowledge from the field. A series of models have been developed at scales from the hillslope to the continent. The MEDALUS I project developed and applied models for soil erosion at the hillslope scale (Thornes et al. 1996), MEDALUS II combined these soil erosion models with models for vegetation growth and development as well as soil hydrology and MEDALUS III culminated in the development of the MEDRUSH model for forecasting hydrology, soil erosion and sediment yield in catchments of up to 2000 km² in a spatially explicit fashion using the GRASS GIS (Kirkby et al. 2002). The MODMED project (1995–1999, Mazzoleni and Legg 1998) built predictive models for understanding natural vegetation dynamics and their response to changes in grazing and burning pressure resulting from developments in agricultural policy. The MODULUS project (1998–1999) led by the Research Institute for Knowledge Systems (RIKS) took models

and datasets developed in a range of previous EC projects (in particular EFEDA 1988–1991 (Bolle 1995), MEDALUS and MODMED 1995–1999) and combined them in an integrated model for climate, hydrology, plant growth and vegetation development, soil erosion and socio-economic processes as an operational decision support system (DSS) aimed at regional policy-makers and applied in the Marina Baixa, SE Spain and the Argolid of Greece (Oxley et al. 2004). The hydrology, crop growth, climate and erosion models were based on the PATTERN model (Mulligan 1996, 1998) which was developed alongside the EFEDA project.

MODULUS was a technical experiment in that it took existing models that had been developed in previous projects, left them in their native code and wrapped them with a software ‘layer’ to permit their integration as a single model capable of running simulations for scenarios of land use and climate change and provided results as graphics and maps. The project showed that models developed for scientific purposes could be integrated together to tackle policy-relevant questions and then supported by a sophisticated but user-friendly interface and thus approach the requirements for policy application. MedAction (2001–2004) further developed the MODULUS DSS into a Policy Support System (PSS) capable of advising policy. This required the engagement of end users at the start of the project, the definition of clear policy goals with them and the re-engineering of models from the bottom up for careful integration into an integrated model. The PSS was applied to land use and water management issues in the Guadalentin basin (SE, Spain) (van Delden et al. 2007). In the DESURVEY project (2005–2010), the MedAction PSS was further developed for application across Europe and North Africa as the DESURVEY surveillance system. It was enhanced through the incorporation of multi-scale modelling with a simpler model, based on PESERA (Kirkby et al. 2003) being applied for application at the pan-European scale (1 km resolution) and a more complex and data demanding model based on PATTERN (Mulligan 1998)—as implemented in MedAction—used for application for local scale analyses (at 1 hectare resolution). New process descriptions, policy options and datasets necessary for application to North Africa were also developed alongside much more extensive training and application throughout Europe.

Throughout this period of model building, the models have become more and more sophisticated both in terms of the processes represented, the degree of feedback between processes, the degree of integration and inclusion of biophysical and socio-economic processes, and the degree of spatial detail and spatial heterogeneity incorporated. This evolution reflects our improved understanding of the complexities of processes that are grouped together under the umbrella of desertification. Later projects built upon these efforts to interface and adapt models for use in advising policy—driven by increasing pressure from the EC to connect its science with its policy agendas, though there is little evidence that such tools are used in supporting policy at the EC.



15.5 Revisiting Mediterranean “Desertification”

With 20 years of hindsight we now revisit the science on Mediterranean desertification with a view to understanding better the current thinking around this issue.

15.5.1 *Where Actually Desertified?*

According to the literature, land degradation is said to affect 80 % of the arid and dry areas of the Mediterranean, especially pasturelands and rain-fed croplands, but even irrigated land is considered under threat (Thivet 2007). Degradation is variously attributed to overgrazing, poor soil management, poor drainage on irrigated land, and the over-abstraction of woodland for fuel wood. This has been linked to population migration in the past, for example the Thessaly Plain was grazed for centuries by transhumance flocks and herds but after significant immigration in the early 1920s these areas were converted for wheat cultivation (Kosmas et al. 1999). For sure groundwater resources in the region have declined significantly, largely reflecting increasing agricultural abstraction (Iglesias et al. 2007).

Yet, agricultural production has continued to increase in the European Mediterranean (Leetmaa et al. 2004; Montgomery 2009) at the same time that much land has been returned to nature. Moreover, the rainfall-use-efficiency corrected negative NDVI (normalised difference vegetation index) analysis of Bai et al. (2008) indicate negative trends in vegetation cover (possibly reflecting degradation) over only 1 % of the study region, largely in the intensive agricultural areas of SW Spain, NE Italy and Montenegro—which are likely the result of major land use changes rather than actual land degradation. Coastal parts of North Africa and of the eastern Mediterranean are also considered to be degrading (García-Ruiz et al. 2011). Therefore developments so far in agricultural practices and technology seem to be keeping pace with any degradation so that ‘desertification’ appears not to be having large-scale societal impacts in the region. Increasingly fewer families depend on agricultural livelihoods, especially in the EU; agriculture is generally larger scale and more ‘commercialised’; and much of the population lives and works in an urban setting. The land degradation picture is thus more heterogeneous and complex than the large scale ‘desertification’ of the region that was anticipated in the 1990s.

15.5.2 *What Did We Really Mean by Mediterranean “Desertification”?*

Desertification is a term used to cover a ‘multitude of evils’ and can fairly well incorporate any socio-economic or biophysically-driven problem in a dryland



context from the multiple impacts of climate change, through land degradation, through application of over-intensive methods to overgrazing, water resource stress and other issues associated with poor management of common pool resources. So what did (do) we really mean by Mediterranean desertification? We can identify three different lenses that have been used.

15.5.2.1 The Land Degradation Lens (Pressure-Response)

In the land degradation phase, desertification is considered to be the response of the landscape to the application of pressure (drought, overcropping, overgrazing, over-extraction of groundwater). As the pressure increases, the environment reacts to create a problem (agricultural drought, soil exhaustion and erosion, grazing-land degradation, salinisation of groundwater), see for example Catalinas and Cantón (2012). The system is seen as a pressure response system and the kinds of pressure-response tools (models) used suggested continued progressive degradation into the future (see Mulligan 2009a, b, c). Each element of the system is considered independently as an independent pressure response system and research is usually focused on one set of processes e.g. soil erosion, ignoring the links between different pressure-response systems. The focus is on land degradation as the outcome (to be avoided) rather than as we might see it today: as a driver itself that will act to reduce economic and agricultural pressure in a negative feedback cycle (where alternatives to agricultural livelihoods exist).

15.5.2.2 The Sustainability Lens (Pressure-Response-Feedback)

With this approach the focus is on understanding the limits of environmental systems and the likely impacts once these limits are reached. This approach examines desertification in a more integrated manner looking into a range of processes and systems and focusing on the changes to socio-economic systems that would be required to achieve sustainability. The focus is thus on sustainability as the outcome (to be achieved), see Laras (2004), Perry (2006) and Turner et al. (2007).

15.5.2.3 The Ecosystem Services (ES) Phase (Tipping Points and Complexity)

With this approach the focus is on maintaining the ES that are critical to local populations. This involves understanding how and where ES are delivered, the role of natural environments and of agriculture in delivery, and who benefits from them. The science concentrates on highlighting the pressures on ecosystems that are likely to result in degradation of the ecosystem functions that provide these ES and seeks to maintain these pressures at levels below those tipping points that would lead to

significant impact on humanity. Maintenance of ecosystem service provision whilst maintaining and increasing agricultural production is the outcome sought (see for example Schröter et al. 2005; Benayas et al. 2007; Bugalho et al. 2011; Willaarts et al. 2012).

15.6 The Importance of Policy, Place, Space and Variability in Assessing and Managing Desertification

As Figs. 15.1, 15.2, 15.3, 15.4, 15.5, 15.6, 15.7, 15.8, 15.9 and 15.10 highlight, the European Mediterranean shows significant spatial variability in the biophysical and socio-economic factors that might influence land degradation. This variability combines with the policy context to determine the impact of policies on desertification. Farming policy in Mediterranean Europe is dominated by the CAP. Current trends in the CAP could lead to further abandonment of production in zones of high nature conservation value (Caraveli 2000) and this may lead to reduced land degradation (Ruecker et al. 1998) or increased land degradation especially on steep slopes (e.g. Koulouri and Giourga 2007) in the areas abandoned. Mediterranean water policy is largely focused on drought management. According to Iglesias et al. (2007) water management in the region works best when carried out at the basin scale and when institutional responsibilities are clear but they argue that all countries in the region show weak inter-institutional cooperation and gaps the roles of the state, the region and the river basin authorities. This situation impairs the implementation of legislation. The European Water Framework Directive (2000/60/EC) does attempt to develop legislation and institutions for water management and planning at the basin level. However, key issues in implementation of the WFD include the difficulties of transboundary cooperation (across regions as well as countries) and lack of provision for water quality management during drought conditions (Iglesias et al. 2007). Indeed monitoring, early warning and management of drought, including the provision of contingency sources needs much further development throughout the Mediterranean region. Legislation around the management of groundwater pumping for irrigation also requires a much more adaptive and locally nuanced approach that takes better account of varying climatic and hydro-geological conditions over time and space.

According to WDPA (2013) some 18 % of the area studied here is at least nominally protected with 0.06 % of this with RAMSAR designation as wetlands of international importance. Protected areas cover 13.75 % of the rainfall of the region calculated with WorldClim data (Hijmans et al. 2005) and 17.25 % of the water bodies calculated with SRTM SWBD (lakes, rivers, USGS 2006) data. To the extent that protected area designation is effective at reducing pressure on the ground, these represent an important mechanism to manage land degradation.



South of the Mediterranean Sea, a large divide exists between national desertification policy objectives and their local implementation, notably as a result of institutional complexity and inadequacies. Institutions suffer from weak resources and capacities, as well as the legal pluralism generated by the overlap of traditional, state and project-led institutions which can undermine the effective regulation of practices (Briassoulis 2004). Though the success of these policies hinge largely on changing end user practices, consultation of these stakeholders in the design and implementation of policies remains low, leading to weak participation and concern for desertification issues. Degradation of resources (overgrazing, over-abstraction etc.) often ensues with officials and traditional authorities turning a blind eye to support smallholder's agricultural practices in the absence of alternative livelihoods (Le Goulven et al. 2009).

Past policies also suffered from ministries addressing complex socio-environmental problems from an isolated, single perspective, leading to unexpected results such as reducing aquifer recharge as a result of local irrigation efficiency improvements (Molle 2009). Concepts such as green, blue and virtual water accounting (Allan 1998) or payment for ecosystem services have started to filter into policies (Besbes et al. 2010) and further holistic methods are required for researchers and stakeholders to understand the mutual interactions between hydrological and agricultural processes as well as wider socio-economic influences (subsidies, land tenure, water pricing, etc.) on land degradation. Data scarcity (both absolute and as a result of deficient data sharing) on the spatial and temporal gravity of desertification also currently impedes the targeting of resources towards local, site specific strategies.

15.7 Conclusions: If the Problem Is Complex, the Solution Is Complex

Change in agricultural policy is often not tested for long-term sustainability in the face of soil degradation and long-term climate variability and this has the potential to lead to severe degradation that may render short term economic gains as long term losses. To be of real benefit, land use strategies and incentives for the Mediterranean must be sustainable and profitable in the long term and land management options must also be effective for the long-term. The impacts of both land use and land management strategies must also be understood for the range of socio-economic and biophysical conditions that exist in the region of influence of the proposed policy, since response will not be uniform across variable landscapes and those applying policy should not assume it will. The legislative and institutional framework must recognise this need for spatio-temporal sophistication to build robust and sustainable agriculture.

Policies that need to be tested in this way include:

- (a) investment or incentivisation of particular crop choices or land management techniques including irrigation, terracing, contour ploughing, ploughing and slope reforming,
- (b) infrastructural investments such as dams, water transfers, desalinisation facilities,
- (c) conservation and protection schemes such as designation of protected areas, deforestation, buffer strips, check dams.

All of these have complex interactions with biophysical processes and thus stores and fluxes of water, sediment, soil and plant productivity and on human behaviour such as crop choice and land management.

It is clear that the desertification narrative of the 1990s was not representative of the spatial complexity and subtlety of land degradation processes in the Mediterranean (see Geeson et al. 2003; Mulligan et al. 2004) and the spatial heterogeneity that is clear in Figs. 15.1, 15.2, 15.3, 15.4, 15.5, 15.6, 15.7, 15.8, 15.9 and 15.10 here. The significant declines in rainfall throughout the region in this decade provoked concerns about large-scale desertification that then never materialised. Even under current intensive agriculture, much of the rainfall in the region still evaporates through natural vegetation rather than agriculture and there is little evidence (for example in agricultural or economic output) of large scale degradation in the region. In fact the abandonment of agricultural land is generally reducing soil and water degradation (Ruecker et al. 1998), except in areas of very steep slopes where terraces are now breaking down (Koulouri and Giourga 2007) but will revegetate and recover in time. Over spatially and temporally explicit landscapes the kinds of large scale desertification mapping efforts of the 1990s (e.g. UNEP 1997) do not capture this spatial heterogeneity at all. An effective way to manage such complexities and test policies in silico before they are applied in vivo is through the application of data and process-based, spatially detailed modelling of the type used here but also to ensure that such modelling is accessible in a policy-support context (cf. Mulligan 2009a, b, c) and is well supported by extensive field and remote sensing datasets.

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