5 Mediterranean society and economy

5.1 Introduction

Having established links between hemispheric-scale circulation and indices of extreme climate in the previous three chapters, the remainder of this study aims to assess potential impacts of extreme climate behaviour upon the economy and society of the Mediterranean. This chapter introduces the northern Mediterranean basin in human (as opposed to geographic or circulatory) terms, discusses sectors of activity that may be vulnerable to extreme climate behaviour at the temporal (i.e. seasonal) and spatial (i.e. regional) scales discussed previously in this study, and proposes impact hypotheses that can be investigated in the following chapters.

Section 5.2 details the socio-economic context of this study, framing the northern Mediterranean basin as part of southern Europe, and considering the relevant countries (Portugal, Spain, Greece, France, and Italy) with reference to the European Union (Section 5.2.1). Section 5.2.2 briefly considers non-EU related events in the histories of each country, as they may affect the sectors under consideration in this study, and 5.2.3 their possible future development given climate change. Section 5.3 introduces (Section 5.3.1) and then describes in more detail, a selection of socio-economic sectors that may directly experience impacts of extreme climate, including finance (Section 5.3.2), agriculture production (Section 5.3.3), energy supply and consumption (Section 5.3.4), and human mortality (Section 5.3.5). Each sector is discussed in terms of the effects of mean climate, key vulnerabilities to extreme conditions, and potential responses to climate extremes. Section 5.4 summarises important points from the previous discussion and identifies null hypotheses that are then explored in Chapters 6 and 7.

5.2 Economic and social context

5.2.1 The Mediterranean, Europe, and the EU

The majority of Mediterranean countries considered in this study are distinctively southern European in terms of socio-economic development, just as they possess a well-defined climate type. Of the countries included in the Köppen Cs climate classification (see Section 2.1), Portugal, Spain, Greece, France, and Italy are member states of the European Union (EU), the development of which is outlined in Table 5.1. Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Macedonia, and Albania, although part of the geographic definition of southern Europe (and in the case of Montenegro a de facto member of the Eurozone), are not members of the EU and are not (as of 2006) due to become so. The climate station data used in this study (Table 3.1) is drawn from:

- Countries that have been subject to common European policy since 1951 (France, Italy), 1981 (Greece), and 1986 (Spain, Portugal),
- Countries that are near EU accession (2007), having recently attempted to bring their development into agreement with the Copenhagen criteria for EU membership (Romania),
- Countries that are geographically European, but are not negotiating for EU membership (Croatia and Serbia),
- And non European countries (Algeria).

The EU has grown out of a number of successive economic unions to provide a spectrum of intergovernmental functions for members, covering legislation for agriculture, health, economic policy, security, and trade. Partially as a result, partially due to stringent entry requirements (i.e. the Copenhagen criteria) EU countries possess high levels of productivity and strong economies (Kundzewicz *et al.*, 2001). European populations also tend toward highly managed health, agriculture, and economic systems that result in a relatively low vulnerability to external factors (Kundzewicz *et al.*, 2001). States within the EU are subject to a number of common policy agreements that those outside are not governed by. Agreements including the Common Agricultural Policy

(CAP), the Schengen Agreement, and the Euro have implications for economy, sustainability, and vulnerability (and therefore this study). Non-EU states have a greater degree of freedom to govern their own economic development, as can be seen in the self-sufficiency of Romania (World Bank, 2006), but cannot draw on stability oriented policies such as the CAP or the EU Cohesion Fund.

Shared European Union technology and trade also have implications for vulnerability. Advanced health care in Europe has lead to a high population density, high life expectancy at birth, and low infant mortality. Birth rates are low, population growth is largely negative, and the European population as a whole is aging faster than that for any other continent (McMichael *et al.*, 2001). Of the European countries, Italy and Spain are amongst those with the highest aging index, calculated as a ratio of those over 65 to those under 14 (Koppe *et al.*, 2004). Although there are internal societal inequalities, due to a highly structured approach to governance and development, the majority of the European population has access to the health care detailed above, both food and social security, and as of 2001 was not adversely pressured by mean climate change (Kundzewicz *et al.*, 2001).

However, all European countries are vulnerable to changes in extreme climate behaviour as described in Chapter 2, including changes in the frequency and magnitude of extreme seasons and short-duration events (Watson *et al.*, 1997; Kundzewicz *et al.*, 2001; McMichael, 2001). The combination of patterns and trends evident in Mediterranean extreme climate (Chapter 3.4), and the relatively high levels of wealth emplaced in infrastructure common to all EU states, creates a region more vulnerable than the more northern European countries (Schröeter et al, 2004).

Although strictly environmental pressures are generally less intense for the south eastern non-EU states (e.g. Croatia and Serbia) than for those in the Mediterranean, recent internal conflict has weakened infrastructure and led to instability and insecurity (Section 5.2.2), which also enhance climate vulnerability and sensitivity (Adger, 2004). The conditions discussed above reveal a Mediterranean region that is characterised both by environmental (Chapter 2) and developmental (Section 5.2.2) pressures that are common to most southern European countries, and political issues that vary between national issues (e.g. differences in demographics), the successive implementation of the policies of the EU, and the troubled status of individual Balkan states.

5.2.2 Relevant socio-economic history

Although several of the countries of the Mediterranean (i.e. France, Italy) display economies regularly ranked among the top 10 globally in terms of Gross Domestic Product (GDP) (World Bank, 2006), various historical events have directly affected southern Europe's political and financial progress over the second half of the 20th century, and most display troubled periods that have affected local production and population. An understanding of historical factors may help to explain long-term trends and non-climatic variations in data series considered in Chapter 6. Each of the EU countries listed in Section 5.2.1 are briefly outlined in terms of major historical events in Table 5.2 so that sudden socio-economically driven steps and trends in productivity, population growth, mortality, or energy use, can be more easily identified.

As the non EU Mediterranean countries (e.g. Algeria, Croatia, Serbia) listed in Section 5.1 have undergone boundary reforms (e.g. changes to the structure of Yugoslavia), suffered from prolonged periods of civil unrest and revolution (e.g. Algerian war of Independence 1954-1962; Croatian war of Independence, 1991-1995; Algerian civil war, 1991-2002; Serbian civil war, 1998-1999), and otherwise experienced major infrastructural change (e.g. the collectivisation of Algerian agriculture) during the socio-economic target period (1960-2000), reliable demographic and economic information has proven difficult to acquire for those regions. As climate change entered international policy debate (during the 1990s), parts of the Former Republic of Yugoslavia experienced international sanctions, political upheaval, economic depression, and military action (Pesic, 2003). Even were reliable records available, the detection of a socio-economic signal induced by extreme climate, amongst the trends and jumps produced by the political events outlined above, could prove highly challenging. For these reasons the remainder of this study is concerned only with the nations listed in Table 5.2.

5.2.3 EU policy and climate extremes

In 1996 the Electricity liberalization directive was passed in order to breakdown monopolies, encourage competition, and create a common but diverse European energy market (Vrojlik, 2002). A mandatory market for the trading of rights to carbon emission (the EU-ETS) was opened on the 1st of January, 2005 (Bell and Drexhage, 2005), and at the end of that year sustainable development entered discussion of the Common Agricultural Policy, as part of a series of serious reforms begun in 2000 (DEFRA, 2005). Sensitivity to climate in Europe may decline as these policies are developed, but whether they are an appropriate level of response is a matter of international debate. The economic stabilisation of certain countries in the Balkans (e.g. Romania) as part of accession to the EU may have lessened sensitivity within the eastern Mediterranean (although only in recent years). With continued assimilation Balkan countries are likely to strengthen their market economies, attract foreign investment, lower external economic vulnerabilities (Sorsa, 2006), and gain aid from the EU Cohesion Fund (which Portugal, Spain, and Greece are currently eligible for). This may also lower environmental vulnerability and sensitivity to extreme climate, as there is a body of evidence suggesting that the ability to mitigate climate risk has a strong negative relationship with national wealth (UNDP, 2001).

However, although the EU acts as a strong influence on European policy (and therefore, as seen above, on most of the northern Mediterranean), and as a stabilising economic factor (Kundzewicz *et al.*, 2001), changes to policy concerning mitigation of the impacts of extreme climate change have only recently been implemented or considered. The EU can be assumed to have influenced relatively stable economic progress (as discussed above) but although some measures have been implemented to combat water shortages (e.g. Spanish National Water Plan, 1993, the Water Framework Directive, 2000), and poor air quality (e.g. the 1972 Air Protection Law), there has been no attempt through EU policy (over the 1958-2000 period) to specifically react directly and quickly to the extremes of climate change (Ebi *et al.*, 2006).

5.3 Mediterranean vulnerability and climate impacts

5.3.1 Introduction

Climate change is known to affect human societies, but there is little detail available concerning the effects of extreme climate behaviour upon socio-economic activity over time (Schneider and Sarukhan, 2001), possibly as the majority of extreme climate behaviour (excluding drought) has only recently been considered in time series (Chapter 2). Until recently, discussions regarding exposure may therefore have been poorly constrained. Although the discussion in previous chapters concerns Mediterranean climate variability, much of the socio-economic literature discusses the impacts of individual extreme events (Kundzewicz *et al.*, 2001), or considers the future implications of projected conditions (i.e. climate change, see below). Taken together these studies suggest that extreme events and climate variability are likely to have important ramifications for climate impacts (Schneider and Sarukhan, 2001). For the rest of Section 5.3 a representative selection of the relevant discussion is considered, and although such an approach inevitably leads to a slight change in the emphasis of this chapter, the importance of climate variability can be inferred from available literature (Schneider and Sarukhan, 2001). The following sections summarise the known effects of climate upon sectors that have received recent attention as sensitive to climate- finance, agricultural production, energy supply, and health (Smith *et al.*, 2001). In each case, these sectors reflect a major part of human activity, are therefore of international importance, and (apart from finance) have been substantially affected by extreme events occurring within the last decade (e.g. Beniston, 2005; Garcia-Herrera *et al.*, 2006).

5.3.2 Finance

Changes to temperature, rainfall amount, and sea level can cause dramatic impacts upon almost every sector of human activity (Baric and Gasparovic, 1992). Financial costs can arise from direct damages (i.e. degradation of goods or services), from the costs of climate change mitigation (e.g. flood barriers, etc.), from changes in the global market (e.g. changing flows of trade goods or customers), or from damages due to feedback effects, such as the increased potential for damages due to water shortage, where both water requirements are elevated, and water supply is diminished (Geeson *et al.*, 2002). Benefits may also arise that in some instances act to partially offset such damages. However, estimates generally place the costs of a 2-4°C increase in temperature at 1.0-2.5% of gross national product (GNP) for industrialised countries such as Canada and the U.S. (Fankhauser, 1995). In the short term (i.e. seasonally) the economies of countries are potentially susceptible to climate extremes through either an an effect upon trade and industry (Agnew and Palutikof, 1997), or through the financial outcomes of degradation or destruction of infrastructure (Llasat *et al.*, 2003). The Mediterranean countries considered here are economically structured such that they are highly dependent on infrastructure and trade (i.e. they are largely service or industry based) and as such may be sensitive to extremes of climate (Section 2.4.2; Agnew and Palutikof, 1997; Thornes, 1997; Kundzewicz *et al.*, 2001).

However, the complexity of costing climate change is multi-dimensional, and market forces do not act in isolation. It has been shown (for the U.K.) that although small residual effects can be seen due to the persistence of fair weather during winter, the annual total gross domestic product (GDP) of developed nations (e.g. the U.K.) is surprisingly inflexible to short-term, non-persistent, changes in weather conditions (Palutikof *et al.*, 1997). Indices associated with retail prices show marginally stronger relationships with weather than those related to domestic product, but attendant losses in one sector may be offset by expenditure in another (Palutikof *et al.*, 1997). Increases in domestic tourism may, for example, decrease domestic expenditure on shopping (Agnew, 1997). This inflexibility may occur between, or within, sectors of national economy. The U.K. heatwave of 1995 may have resulted in small gains for the sale of fruit and vegetables but a heatwave associated decrease in August rainfall has been linked to a decline in footwear and clothing revenue (Agnew and Palutikof, 1997). Suggested effects of climate change upon the manufacturing sector are currently highly speculative (Jáuregui *et al.*, 2001), but a link to retail is suggested as one of the few mechanisms for short term climate driven impact upon a sector that is largely unaffected by weather (Jáuregui *et al.*, 2001).

The effects of hot or (particularly) cold weather upon transportation (as detailed in Chapter 2.4.2) and economies partially dependent on haulage have received little attention to date. Existing studies are, however, largely concerned with the effects of extremely high or low temperatures (Cornford and Thornes, 1996; Thornes, 1997), and show that both extremes can affect transportation (e.g. through snowfall, or the warping of train tracks, during the U.K. summer of 1995).

Banks and insurers regularly engage in the regulation of pricing and the transferral of risk between companies and thus limit both their sensitivity (Berz *et al.*, 2001), and the sensitivity of insured goods. Climate change may, however, alter the degree of certainty that can be attached to fiscal outcomes regarding high magnitude climate extremes with large associated costs based around losses in infrastructure (Berz *et al.*, 2001), The difference between conditions that cause losses or gains in expenditure, and losses of infrastructure which effect both national economy (directly) and the financial sector, are a case of coverage, position, and magnitude of event, and when events reach a level sufficient to cause infrastructural damage or deterioration in vulnerable areas, overall costs increase dramatically (Agnew and Palutikof, 1997; Em-dat, 2006).

Events such as these are termed ‘catastrophes’ where currently, an event is defined as catastrophic by the insurance industry if associated claims are expected to exceed 25 million USD (Munich Re, 2004). Weather extremes such as the hot summer of 2003 account for a larger proportion (64% since 1980) of ‘catastrophic’ European events than non-weather events (Munich Re, 2003). If the magnitudes of catastrophes rise to levels where the ability of insurance companies to predict and cover losses is compromised (i.e. costs exceed reserves), financial institutions can be stressed to the point of bankruptcy, resulting in serious economic impacts that may only balance (e.g. through pricing changes and policy withdrawal) over long time scales (Fankhauser, 1995; Berz *et al.*, 2001). It is worth noting, however, that over the period of study, due to the developed nature of the European economy, damages that result in very large economic losses (and the bankruptcy of insurance firms) are more likely to have occurred from hurricanes or earthquakes than heatwaves or floods (often not covered by insurers) and are therefore generally not likely to have arisen from within Europe (Parry and Duncan, 1995; Munich Re, 2000; Kundzewicz *et al.*, 2001).

It is worth noting that annual economic losses from weather and climate related catastrophes far outweigh insured losses (Munich Re, 2004), and that damages from catastrophic events are thus not entirely absorbed by the financial sector. Either high frequencies of small events, or singular extremely dramatic episodes can cause substantial losses, and climate extremes account for the majority (79% since 1980) of catastrophe relevant economic losses. These losses (adjusted to 2002 values) have increased significantly since 1984 (Munich Re, 2003; EEA, 2004), from global average annual figures of less than 5 billion USD between 1980 and 1985 to over 11 billion USD in the 1990s. This increase is due to both a rise in the frequency of extreme climate events and an increase in exposed wealth (Munich Re, 2004). Human infrastructure (related to transportation, agriculture, manufacturing, tourism, etc.) is less mobile than populations, and losses are likely to continue to increase while populations expand and require further development in potentially vulnerable areas, and concentrate wealth in cities (Karl and Easterling, 1999). The Mediterranean states in general display an increasing tendency towards urbanization of populations (World Bank, 2006). Even were the frequency and magnitude of extreme events to remain static, losses would still increase as the sensitivity of infrastructure rises due to economic and demographic expansion, including factors such as (Munich Re, 2000):

- Population growth.
- An increased mean living area per capita.
- A greater concentration of wealth in expensive buildings.
- More valuable building contents (electronics, furnishings etc.)
- More value placed in trade and industry stocks.
- More value placed in private and industrial vehicles.

There is, however, sufficient parity between the (increasing) mean sum insured by homeowners and GDP (over a 1989-1998 period), taking inflation into account, that GDP can be used to approximate the net increase in values of insured goods with time (Munich Re, 2000). Adjusting loss values against both inflation and GDP shows that the increase in catastrophe losses over the last fifty years are increasing even after taking financial and related demographic factors into account (Munich Re, 2000).

Although long term climate change is likely to have dramatic impacts upon economy (Fankhauser, 1995), some sectors of economic activity (e.g. international tourism) may only balance internationally (Hamilton *et al.*, 2005), and large scale catastrophic events induce losses that are not entirely absorbed by insurers (Munich Re, 2004), the above discussion suggests that when aggregated across sectors, over annual periods (as opposed to monthly or decadal periods), some measures of European economic activity may be insensitive to short-lived extremes of climate. Additionally, there is a tendency of the financial sector to either manage risk or balance benefits and losses, and European economies are not likely to suffer breakdowns in insurance due to large reserves. Both economic growth and the emplacement of wealth in infrastructure and possessions can therefore be represented by Gross Domestic Product (GDP), which (for the Mediterranean countries under consideration) can be considered inflexible to extreme climate behaviour, and has been used as a financial indicator to remove economic activity from time series when considering extremes of climate.

5.3.3 Agricultural production

Although agriculture in Europe represents a small proportion of total employment and GDP (between 2 and 4.5% for France, Spain, Italy and Portugal, 7.6% for Greece 2000) (World Bank, 2006), and the European economy therefore displays a low vulnerability to changes in agricultural productivity (Maracchi *et al.*, 2005), food security is a highly important consideration for impact studies (Gitay, 2001). Due to the fact that much of European agriculture is strictly managed, agricultural yields have increased continuously throughout Europe since the early to mid 1960s (and consistently up until the first significant reform of the CAP in 1992) as a result of technological progress and changes in policy, with little impact upon CAP dominated long-term trends by climate change (Mata Porras, 1995; EEA, 2004; DEFRA, 2005). Wheat production in Europe, as of 1999, had reached around 100 million tonnes

(Cantelaube and Terres, 2005) ranking the EU as the second largest producer in the world after Asia (FAO, 2004).

The degree of response of agriculture to climate (i.e. agricultural climate sensitivity) may be preconditioned by policy decisions made at the supranational level (Maracchi *et al.*, 2005). Non-climate factors affecting crop yield include changes in national capital, land tenure, irrigation and good seed stock availability, agricultural practice, crop variety, fertiliser use, and the availability of markets, most of which can be altered by European policy (Xoplaki *et al.* 2001). Through subsidies the CAP can promote the yield of a particular set of crops (such as certain breeds of cereal), different approaches to land management (e.g. the use or abandonment of particular fertilisers) and the general level of intensification or extensification of farming, all of which may (positively or negatively) affect land quality over time (Mata Porras, 1995), and therefore the vulnerability of crops. The CAP is progressive, and can be used to introduce crop and irrigation options better suited to the higher temperature environments expected in southern Europe over time (Gitay *et al.*, 2001). However, the CAP may also introduce changes that are not optimal in terms of the agronomic sustainability of a region with regards to local climate and soil (Tudela *et al.*, 2005). Socio-economically, and locally, the influence of nationally applied policies such as the CAP upon regional land and soil quality (and therefore vulnerability) is highly complex (Mata Porras, 1995).

Mediterranean crops are diverse and range from traditional arable farming to the large-scale, market-focussed, cultivation of cereals, vegetables, citrus fruit, olives, and grapes (Kostrowicki, 1991). However, Mediterranean crop production often falls short of export targets or internal demand, and displays a high level of sensitivity to intra-annual changes in weather (Iglesias *et al.*, 2003). Local climatology produces direct effects upon agriculture via water availability, heat stress, and the length of the growing season for a particular crop, with growing season directly linked to temperature. Although the socio-economic factors described above have a major effect on annual totals and averages of crop yield, the main source of irregular and seasonal uncertainty for European crop yield remains weather (Xoplaki *et al.*, 2001; Cantelaube and Terres, 2005). Temperature and rainfall effects vary with crop type and region (EEA, 2004).

The majority of work that has been done concerning agricultural responses to weather has been conducted with numerical crop simulations, rather than observations (Chen *et al.*, 2004).

Projected variations in crop yield with temperature change are generally dependent on whether crops respond positively or negatively to CO_2, and if such a response is sufficient to offset the potentially negative effect of higher temperatures upon growing season (Maracchi *et al.*, 2005). CO_2 concentrations affect both photosynthesis and water use efficiency (Kimball *et al.*, 1993), particularly for tuber crops (e.g. potatoes) that possess large subsurface carbon ground sinks (Bindi and Howden, 2004). Potato yields in Italy have also been found to show a statistically significant link to summer precipitation (Galeotti *et al.*, 2004). Crops can be usefully divided by CO_2 response into 'C4' and 'C3' type, with C4 crops benefiting more from CO_2 increases than C3 crops (Giannakopoulos *et al.*, 2005a; Maracchi *et al.*, 2005). Even with CO_2 effects, scenarios (both 'A2' and 'B2') that project increased temperature and precipitation largely show decreased yields for all crops in most regions due to a combination of shortened growing period and a lack of water availability, more severe in the south of Europe than the north, where some yields, as seen above, may increase (Gitay *et al.*, 2001).

Temperature increases are particularly likely to decrease the growing period (dependent on season) of determinate crops (those whose stems end in flowers or buds, e.g. cereals, oilseed, protein crops, some species of tuber, onion), but not of indeterminate crops (those whose stems do not end in flowers or buds, e.g. sugar beet, carrot, silage maize). The effects of climate upon permanent crops (grape, oranges), those that take several years to reach maturity, are varied (Gitay *et al.*, 2001). Grapevines flourish in relatively high temperatures, and increases in temperature may expand the areas suitable for cultivation (Harrison *et al.*, 2000). In areas of current growth, uncertainty over temperature dependent crop variability poses significant economic risk for growers. Although grape yields may also be strongly simulated by CO_2 production (Bindi and Howden, 2004), temperatures may rise to the point where high quality wine cannot be produced (Butterfield *et al.*, 2000). Nemani *et al.* (2000) found that the quality of wine crops is most influenced by frost occurrence, spring temperatures, and growing season length. Future climate scenarios with an increase in temperature generally show:

- a reduction in yields for maize across southern Europe (Wolf and van Diepen, 1995),
- an increase in wheat yields (Hulme *et al.*, 1999),
- a reduction in onion (a determinate crop) yields for south eastern Europe (Harrison *et al.*, 1995),
- an increase in yield for indeterminate crops (including carrot),
- a generally lower yield for seed crops (Peiris *et al.*, 1996),
- and little influence on yields of vegetables such as lettuce (Maracchi *et al.*, 2005).

Although, projections have been conducted and, using an ensemble multi-model approach, crop yield predictions have been obtained using forecasts of seasonal climatology (Cantelaube and Terres, 2005), there is relatively little qualitative work considering crop yields and seasonal extreme conditions (Gitay *et al.*, 2001). However, it has been shown that the permanent crops of the Mediterranean are susceptible to climate extremes, such as storms and extreme fluctuations in temperature (Maracchi *et al.*, 2005), and that bad harvests may be linked to droughts, floods, storms, and hail (Gitay, 2001; EEA, 2004). Heavy precipitation may cause root development retardation of any crop type, water logging of soil, drowning of seeds, and direct damage to plant structure (Xoplaki *et al.*, 2001), but only seriously affects crop yield if it occurs during grain filling or harvest periods (Harrison *et al.*, 1995). Extremely cold weather can cause direct damage through hail, can cause frost damages at the heading and flowering stages of some crops, and can negatively affect the quality of soil (Bourke, 1984; Sioutas and Flocas, 2003). Many crops possess critical temperatures above or below which crop damage occurs (Rosenzweig and Liverman, 1992). For the Thessaly region of Greece (the most cultivated and productive area), winters are cold, summers are hot, and significant losses of crop (largely wheat and maize) yield may occur in either season due to frosts or drought (Loukas and Vasilades, 2004). Long dry spells during the early 1990s produced pronounced negative impacts on Valencian agriculture (Estrela *et al.*, 2000), and during the 2003 European heatwave Portugal, France, Italy, and Greece suffered drops in wheat yield of between 10% and 30% while northern countries (e.g. Denmark) benefited from elevated temperatures (EEA, 2004). Europe as a whole experienced a drop in crop yields that represented a negative deviation from the long-term trend greater than any seen in the previous 43 years as crops started growing 3-4 weeks earlier than expected, wilting prior to harvest (Beniston, 2004; EEA, 2004; FAO, 2004).

Increases in the frequency of prolonged dry spells and periods of high temperature are projected to increase to a point such that lower wheat yields (by 3 tonnes per hectare by 2050) may occur in southern Portugal and southern Spain (Harrison and Butterfield, 2000) while greater yields are experienced further north (see above). Extremely hot conditions may negatively affect even crops that benefit from mean global warming. Although winter and spring cereals (such as winter wheat) may benefit from dry and hot weather, very hot weather can scorch immature grain, and induce exceptionally light harvests early (Xoplaki *et al.*, 2001).

Although growers possess many different coping mechanisms (e.g. changes in planting and growing times, density, crop type, general farming system) sometimes enforced or limited by policy, and may adapt to climate change, the yields of particular crops within the Mediterranean are likely to change with mean climate (Bindi and Harrison, 2004). For the Mediterranean as a whole increases in the variability of yield are expected in the near future due to the more frequent occurrence of extreme events (Harrison *et al.*, 2000).

5.3.4 Energy supply and consumption

Climate change is likely to have a substantial impact upon energy use, as applied to space heating fuels and electricity, used for air conditioning and refrigeration to maintain comfortable conditions in a changing climate (Climate Change Impacts Review Group, 1991, 1996; Amato *et al.*, 2005). Variations in energy use between different climates can be seen between the U.S. and Greece. In Greece, high temperatures bring increased cooling needs and 50% of all commercial energy use is for cooling (Cartalis *et al.*, 2001). In the U.S., roughly 22% of all energy is applied to space heating and cooling, split roughly 60%/40% between residential and commercial needs (Amato *et al.*, 2005). The majority of energy use literature regarding climate focuses upon the U.S. However, a small number of studies that concern Mediterranean regions exist (generally conducted by Mediterranean authors), and are explored below.

As with agricultural production (Section 5.3.3) upward annual trends in energy consumption are largely due to changes in socio-economic factors such as the size of population, household sizes, economic growth, and the proliferation of heating and cooling technologies (Amato *et al.*, 2005; Giannakopoulos and Psiloglou, 2005). Annual commercial energy use per capita possesses a highly significant relationship with annual GDP per capita (Fig 5.1). Annual energy consumption variation is thus influenced socio-economically, but (for Greece) seasonal and irregular variation is largely determined by prevailing weather, particularly air temperature, with the highest annual consumption values for summer and winter, and lower values for the transition seasons of spring and autumn (Giannakopoulos and Psiloglou, 2005). Major deviations from these seasonal patterns occur only in August, when large proportions of urban populations in both Greece and Spain leave cities for rural vacations and energy demand declines, and at the end of December, when energy consumption increase may be linked to winter holidays (Valor *et al.*, 2001; Giannakopoulos and Psiloglou, 2005).

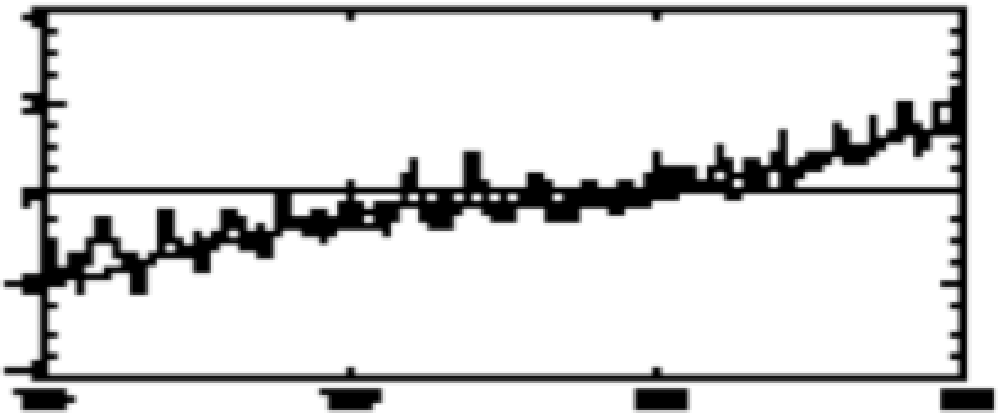

Figure 5.1: Variation of Spanish commercial electricity consumption and GDP (normalised values, y-axis) with time (years, x-axis). Data sourced from the World Development Indicators data set (2006).

Variation in electricity production and consumption is more likely to be sensitive to weather than other forms of power generation, as electrical power cannot be stored, which implies that it must be instantly consumed and that any relationship will experience zero lag (Valor *et al.*, 2001; Giannakopoulos and Psiloglou, 2005). Generally, studies that link climate and energy consider temperatures above specific thresholds and electricity consumption (Al-Zayer and Al Ibrahim, 1996; Valor *et al.*, 2001; Sailor, 2001; Pardo *et al.*, 2002, Amato *et al.*, 2005). Climate variables such as cloud cover and precipitation have been shown to have some effect upon energy consumption, but more so for north-western temperate countries (i.e. England) than for Mediterranean conditions (Giannakopoulos *et al.*, 2005b). For Italy, correlations between electricity consumption and temperature are highly significant (Galeotti *et al.*, 2004). For Spain, air temperature has been found to be the most significant weather variable for electricity load (Valor *et al.*, 2001).

In theory, a 'balance point' temperature exists where environmental air temperature provides a desired (comfortable) temperature for people within buildings. At this point energy requirements for heating and cooling are zero. Any deviation from the balance point, however, may necessitate some form of energy consumption (Amato *et al.*, 2005). Balance point, or 'comfort level', is dependent upon acclimatisation (Section 5.3.5), non-temperature weather conditions (such as cloud cover, rainfall, or wind speed), and building qualities such as level of insulation, thermal mass, or other climate sensitive construction (Amato *et al.*, 2005). In practice (in Spain, Greece, and the U.S.), the balance point is often taken to be a single value of 18°C (Valor *et al.*, 2001; Amato *et al.*, 2005; Giannakopoulos and Psiloglou, 2005). Studies have shown, however, that balance points vary regionally, with values for Massachusetts of 15.5°C (Giannakopoulos and Psiloglou, 2005), Florida of 21°C (Sailor, 2001), and Athens of 22°C (Giannakopoulos and Psiloglou, 2005). Generally, warmer regions possess higher balance points due to adaptation.

Both residential and commercial energy use tend to display a seasonal variation with temperature, but they may possess different levels of sensitivity (Sailor, 2001). Differences of 3°C may exist between residential and commercial comfort levels (Fig 5.2) due to internal heating from lighting, machinery, and a relatively dense concentration of employees (Sailor, 2001; Amato *et al.*, 2005). Industrial (e.g. manufacturing) energy consumption has been shown as largely inflexible with changing weather (Sailor and Muñoz, 1997; Amato, 2005).

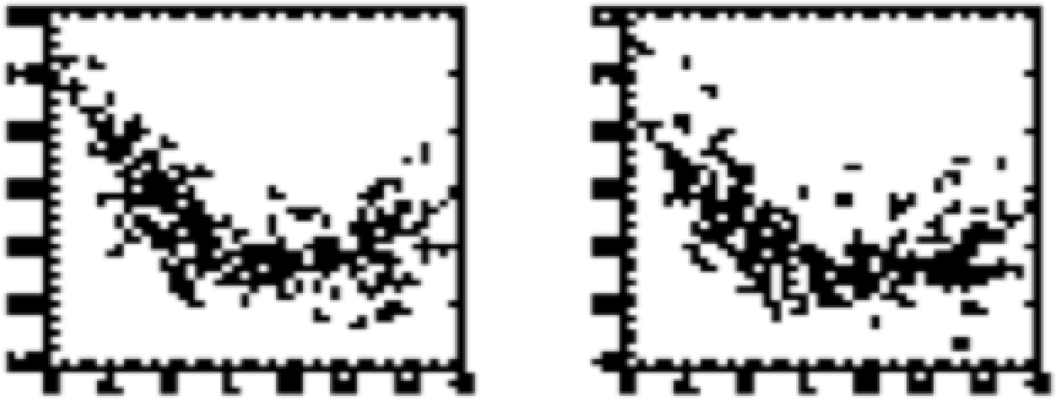

Figure 5.2: Differences in monthly electricity consumption per capita (gigawatt hours per person) against temperature (°C) for Spain. Commercial consumption is shown on the left, residential consumption is shown on the right. Data sourced from the World Development Indicators data set (2006).

Even the use of a balance point derived from local experimentation (i.e. plots such as Fig. 5.2), rather than the standard 18°C value, may not prove sufficient for accurate study, as an insensitive temperature range around the balance point (a 'comfort zone') exists, which can also vary regionally. Upper and lower bounds for the comfort zone have been defined for various regions as follows:

- 15°C and 21°C for Spain (Valor *et al.*, 2001)
- 15.5°C and 18°C for south east Greece (Cartalis *et al.*, 2001).
- 15°C and 24°C for Turkey (Kadioglu *et al.*, 2001),

Little consensus has been drawn as to whether to use one value or both (Giannakopoulos and Psiloglou, 2005).

Studies that link energy consumption and temperature often use heating degree days and cooling degree days (Al-Zayer and Al Ibrahim, 1996; Valor *et al.*, 2001; Sailor, 2001; Pardo *et al.*, 2002, Amato *et al.*, 2005). These are defined as the cumulative number of days below or above a particular threshold, generally given by the comfort level or bounds of the comfort zone. Heating degree days (HDD) are the excess heat outside the comfort zone, such that an excess of 5 degrees for one day or one degree for five days both create 5 heating degree days (Giannakopoulos and Psiloglou, 2005). There is an implicit assumption in the heating and cooling degree day method that over a given period, intensity and duration effects are analogous. In extreme conditions, however, it is unclear as to whether intensity and duration may provoke differing levels of response in heating or cooling.

Greek summer maximum energy consumption has been linked to extreme values of temperature, and January maximum consumption linked to minimum temperature (Giannakopoulos and Psiloglou, 2005) with maximum and minimum daily temperatures better able to explain peaks and troughs in Spanish consumption than the mean (Valor *et al.*, 2001). In Greece, consumption is expected to increase with both rising mean temperature, and more frequent extreme conditions in an attempt to maintain comfort (Giannakopoulos and Psiloglou, 2005). Large deviations in temperature from the balance point may result in large increases in energy consumption, but the response is not entirely linear (Valor *et al.*, 2001; Amato *et al.*, 2005; Giannakopoulos *et al.*, 2005b), and temperature/electricity consumption scatter plots generally show a u-shaped distribution (Fig. 5.2).

Projections of temperature have been used to estimate potential future energy demand (Millbank, 1989; Cartalis *et al.*, 2001; Giannakopoulos and Psiloglou, 2005). HDD are projected (for 2031-2060) to decrease across all of the northern Mediterranean, with the largest decrease in northern (Atlantic) Spain and France, and the smallest decreases in Italy and Greece. This pattern is reversed for increases in CDD (Giannakopoulos and Psiloglou, 2005). Mild winters are likely to result in a decrease in energy demand (Galeotti *et al.*, 2004), while hot summers may result in an increased demand for cooling (Climate Change Impacts Review Group, 1991, 1996). For northern Europe as a whole a 4.5°C rise is projected to more than double summer electricity consumption by cooling systems (Millbank, 1989). In Greece, otherwise assuming business as usual, a 1°C increase in temperature is projected to decrease winter energy consumption for heating by 10%, and increase summer energy consumption for cooling by 28.4% (Cartalis *et al.*, 2001).

Under conditions of increasingly extreme heat the means of electricity production may require a greater degree of cooling. Very high temperatures and low water availability can limit the ability of both hydro-electric plants and conventional power plants to meet demand (Valor *et al.*, 2001). During 1993 and 2005 droughts have caused power failures in Athens (Karavatis, 1998) and throughout Spain (Gonzales-Hidalgo *et al.*, 2005). These infrastructural limits (which may vary from plant to plant) constrain total energy production, but not necessarily consumption, as power may be imported to meet requirements (Karavitis, 1998; Valor *et al.*, 2001; Gonzales-Hidalgo *et al.*, 2005). Over the last 50 years the European energy market has developed into a single body where many regions are supplied on the same network, as overseen by regional transmission organisations (e.g. UCTE for Portugal, France, Spain, etc., SUDEL for Italy, Macedonia, Greece, etc.) (CENTREL, 2001). Due to local reliability issues and international supply lines, energy supply may be difficult to predict on a national level under extreme conditions. This study therefore focuses on energy consumption, a factor of local populations and environmental conditions (Valor *et al.*, 2001; Amato *et al.*, 2005; Giannakopoulos *et al.*, 2005b), rather than production, which may possess links to infrastructural issues and international demand.

5.3.5 Health

Climate change may have a number of adverse effects upon human health, either indirectly via changes in occurrence of water-born pathogens, water quality or availability, food quality or availability, and the prevalence of disease, or directly through death and injury caused by hazardous events (e.g. floods) and thermal stress (McMichael *et al.*, 2001; WHO, 2003). In Europe the risk of communicable disease following flooding is considered small due to a well-developed public health infrastructure (Ebi, 2006). In future years, diseases such as malaria may become a serious problem (Viner and Agnew, 1999), but risk levels are currently very low (Balderi *et al.*, 1998). Food availability, although not its affect upon health, is considered in part in Section 5.3.3. The main concern for this study is therefore limited to direct effects upon human health in the form of heat stress and flood related mortality. Of annual deaths resulting from catastrophic European events 82% are due to weather and climate related events, mainly due to these causes (EEA, 2004).

At rest the human body possesses a core body temperature of 37°C, which can fluctuate by up to 2°C if the thermoregulatory system is functioning efficiently and means of heat loss (convection, conduction, sweating) balance internal and external gains (Koppe *et al.*, 2004). When the thermoregulatory response fails to cope heat related illnesses arise. Heat exhaustion may lead to the rapid onset of potentially fatal heat stroke (at a body temperature of 40.5°C and above) associated with heart irregularities, cellular, and regulatory damage (Koppe *et al.*, 2004). Cases of heat stroke often lead to death (a high case to fatality ratio) in the fit and young who continue strenuous activity when temperatures are very high. Low levels of fitness can lead to a lower heat tolerance and a greater susceptibility to heat related illness as both the resulting dilation of blood vessels and dehydration can increase cardiovascular stress and exascerbate heart disease (Koppe *et al.*, 2004). Due to the systematic (biological) failures that result from heat related mortality, lag times between extreme temperatures and death are short, generally less than a week and closer to 1-3 days (Kalkstein and Davis, 1989; Conti *et al.*, 2005). However, there is some evidence that those who survive heat stroke may still die, up to a year later, due to severe neurological damage. After the 1995 heatwave in Chicago, a third of surviving heat stroke victims developed neurological problems that proved lethal within a year for 29% of affected survivors (Bouchama, 2004).

The growing elderly proportion of the Mediterranean population (Section 5.2.1) is likely to be particularly susceptible to extreme warm events (Faunt *et al.*, 1995; Huynen *et al.*, 2001; Koppe *et al.*, 2004; Conti *et al.*, 2005), as a large proportion of 'excess' mortality (deaths over an expected value, Chapter 6.3.1) is due to cerebrovascular, cardiovascular, and respiratory disease (Rooney at al., 1998; Huynen *et al.*, 2001), all more prevalent with age (WHO, 2003). The elderly possess a reduced sweating capacity, weaker cardiovascular systems (Koppe *et al.*, 2004), reduced muscle strength, and a generally weakened ability to avoid cold or heat, resulting in increased risks associated with extreme conditions (Havenith, 2001). Certain pharmaceuticals are also known to impair the thermoregulatory ability of (often old) patients (Faunt *et al.*, 1995; Conti *et al.*, 2005). Of the total number of Italian heat related deaths during the heatwave event of 2003, 92% occurred among those older than 75 (Conti *et al.*, 2005). For very warm weather deaths from a surprisingly large number of causes escalate, and attempts to consider only mortality directly linked to heat stress may underestimate true values (Kalkstein and Davis, 1989). For the 1987 Athens heatwave, 926 deaths were officially classified as heat related, but other estimates give an attributable excess mortality of more than 2000 (Katsouyanni *et al.*, 1988).

In addition to demographic factors, urban populations display an increased vulnerability to high temperatures due, in part, to differing rates of cardiovascular disease, the heat island effect (Katsouyanni *et al.*, 1988; Rooney 1998; Conti *et al.*, 2005), and the construction and ventilation of urban buildings (Menne and Ebi, 2006). Many of the deaths associated with the 2003 European heatwave occurred in urban buildings (including hospitals) with poor air conditioning (Bouchama, 2004). A further factor that may influence the response of mortality is whether occupants live alone. Taken together, these factors suggest that economic status might be an influencing factor in mortality arising from heat stress (Kovats and Jendritzky, 2006).

Although the reliance of urban populations upon air-conditioning may reduce mortality, it also likely to reduce the level of acclimatisation to high temperatures that may be important in surviving extremes of heat over the long term (decades) (Menne and Ebi, 2006). A greater proportion of deaths in Italy occurred during 2003 for northern cities and those at altitude (than those in the south or close to the coast), suggesting that geographical acclimatization is an important process in limiting mortality (Conti *et al.*, 2005). In stable subtropical environments that produce little in the way of thermal stress (e.g. Brisbane, Australia) the highest rates of myocardial infarction (i.e. ‘heart attack’, often associated with cardiovascular disease) coincide with periods of extreme warmth and cold (Auliciems and Frost, 1989). Short-term acclimatization occurs over several days and disappears several weeks after a decline in heat stress (Koppe *et al.*, 2004). Longer-term adaptation occurs over years (Koppe *et al.*, 2004). Adaptation shifts both the comfort zone of populations and the magnitude of their response (Koppe *et al.*, 2004; Kovats *et al.*, 2003).

Acclimatization is important for both warm and cold events. Where the latter events are less common, the coping mechanism of cold avoidance may not be effectively employed (Auliciems and Frost, 1989), particularly among those over 65 (Kalkstein and Davis, 1989). However, winter acclimatization is complex and may overall have the opposite effect (increasing sensitivity). Persistently cold and damp regions are therefore more susceptible to mortality effects (Kalkstein and Davis, 1989). Climate-related excess mortality is often 10-25% greater in winter than summer, with Portugal and Spain showing the highest rates of excess winter mortality in Europe (Healy, 2003; Kovats *et al.*, 2003). As for summer, housing quality may also be an important factor, as countries with poor housing in terms of thermal efficiency (Portugal, Greece) show high rates of excess winter mortality (Healy, 2003). Extreme events such as blizzards and cold waves have been linked to a significant increase in deaths from heart disease occurring during the following week (Glass and Zack, 1979). Respiratory failure is greater in winter than summer due to both temperature effects and a seasonal increase in infectious conditions such as influenza (Kovats and Jendritzky, 2006), outbreaks of which correlate poorly with mean winter temperature (Kalkstein and Greene, 1997). Seasonally enforced human proximity may exacerbate the risk of infection (Kalkstein and Davis, 1989). However, little in the way of Mediterranean specific literature discusses mortality through winter-time infectious disease.

It has been shown that total mortality rises as summer temperatures increase (Katsouyanni *et al.*, 1993; Kunst *et al.*, 1993; Bentham 1997), and that heat related mortality is likely to increase in warming temperate regions, such as the Mediterranean (McMichael *et al.*, 2001). The reverse is true for cold conditions, and the relation of physical fitness to mortality implies that the number of cold-related elderly deaths may decline over time in regions that show a warming winter trend (Langford and Bentham, 1995). There exists a U-shaped mortality curve (Figure 5.3) when the number of deaths are plotted against mean temperature (Kunst *et al.*, 1993; Bentham, 1997), although above a given cut-off point a linear relationship between mortality and temperature is often assumed with a steeper slope (greater sensitivity) for warm temperatures than cold (Koppe *et al.*, 2004). The distribution is asymmetrical, and excess and extreme heat affects mortality more acutely than cold (Alberdi *et al.*, 1998).

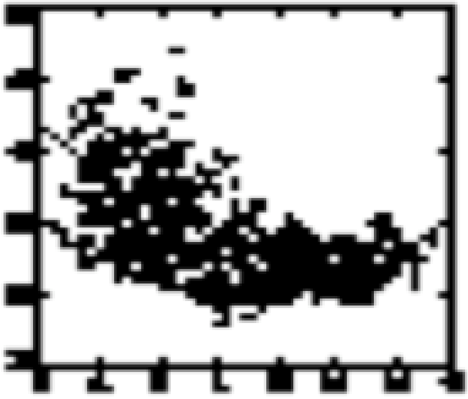

Figure 5.3: Spanish mortality (1000s of deaths) against temperature (°C). Data sourced from Eurostat (2006).

Alberdi *et al.* (1998) found a 1% increase in mortality per degree assuming a 20.3°C cut-off and a 1-day lag over the 1986-1991 period for Madrid. With a 24°C cut-off Ballester *et al.* (1997) found a 3.6% increase in mortality per degree for Valencia. As with energy usage the assumption of linearity may not be appropriate. Milan hospital admissions with temperature were distinctly nonlinear for the summer of 2003 (Pauli and Rizzi, 2006). For very high temperatures, such as those occurring in France during the 2003 heatwave, population groups that were not considered generally vulnerable to heat stress still displayed a significant increase in mortality. French populations in the 45-54 and 55-74 age groups showed a 20% and 40% increase in mortality during August 2003 (Bouchama, 2004). It has been shown that extremely hot days trigger large volumes of excess mortality, as much as a 31.1% increase per degree over 33°C in Lisbon, and 21.5% per degree for Madrid (Koppe *et al.*, 2004). With a cut-off of 36.5°C, and considering only those over 65, Madrid mortality rises by 28.4% per degree (Diaz *et al.*, 2002). Kalkstein and Davis (1989) show that this threshold may be regionally specific. A cut-off value of 33°C is appropriate for New York City, but not for Las Vegas, where it is closer to 43°C. There is a distinction between a high temperature range that produces relatively small increases in mortality (1% per degree), and a very high temperature range that is linked to much larger increases in mortality (over 25% per degree). The second set of values is generally equivalent to the warmest 10-20% of days for any given region (Kalkstein and Davis, 1989).

For the European 2003 event, the magnitude and sustained nature of heating did not simply result in a percentage increase in mortality, but in an almost exponential increase from day to day (Table 5.3). Even with short-term acclimatization, the cumulative day-to-day effect of heatwaves upon mortality is more intense than the sum of a series of isolated events (Kalkstein and Davis, 1989; Pauli and Rizzi, 2006). The large number of casualties due to the 2003 heatwave event have also been linked to the high level of minimum night time temperatures (Rooney 1998; Bouchama, 2004; EEA, 2004) which when low provide an opportunity to recover from daytime extremes (Matzarakis and Mayer, 1991). High night-time temperatures characterise both the 2003 European heatwave and the 1987 Athens heatwave (Matzarakis and Mayer, 1991; Beniston, 2004). In the latter case, thermal stresses were higher in central Athens than in suburban regions as the heat island effect further increased night-time temperatures (Matzarakis and Mayer, 1991).

In summers when two heat or cold wave events occur, even if the second event is substantially more extreme than the first, total associated mortality for the second event is likely to be lower than the first (e.g. Madrid heatwaves inc. 1995) (Kalkstein and Davis, 1989; Diaz *et al.*, 2002). June heatwaves also tend to be associated with greater mortality impacts (for the same population) than comparable or hotter conditions later in the summer (Kovats and Jendritzky, 2006). This phenomenon may be due to both short-term acclimatization and short term ‘mortality displacement’, where the death of susceptible members of the population is brought forward by days or weeks (Kovats and Jendritzky, 2006), i.e. the pool of susceptibles has been depleted (Kalkstein and Davis, 1989). As deaths increase, rather than decrease, with heatwave duration (see above), it seems likely that short-term mortality displacement is more important over weeks and months than days, although the important question remains as to the proportion of mortalities brought forward by more than days (Kovats *et al.*, 2003). Kalkstein (1995) suggests that 20-40% of heatwave induced mortality represents displacement, although in 1966 New York experienced a heatwave displacement of 43% (Kalkstein, 1993), and after the 2003 event no apparent dip in mortality in Paris occurred (Kovats and Jendritzky, 2006). Thus the degree of displacement for acute episodes of heat stress remains uncertain (Kovats and Jendritzky, 2006). Further complication of the displacement effect occurs when considering inter-annual effects, as an extremely acute event in one year may reduce the pool of susceptibles available for an acute event in the next (Kalkstein, 1995), particularly as a large proportion of mortality occurs among the elderly (see above).

Although high levels of precipitation rarely lead to mortality, flooding may produce a wide range of outcomes including drowning. Mortality due to flooding is, however, on the decline despite an increased frequency of events (since 1974), likely due to improvements in emergency response (that may vary by region) (EEA, 2004). In many cases the number of people adversely affected outweighs (by several orders of magnitude) those killed (Em-dat, 2006). Non-mortality effects of flooding are complex and difficult to measure, but include (McMichael *et al.*, 2001; Kovats *et al.*, 2003):

- psychological effects,
- displacement of populations and effects on health through disruption of local infrastructure,
- illness due to increased risk of water related and other infectious diseases (skin, gastrointestinal, repiratory),
- increases in respiratory and diarrhoeal diseases because of crowding of survivors
- poisoning due to exposure to dangerous chemicals or pathogens,
- and direct injury.

The flash floods particularly prevalent in Mediterranean rivers, however, induce drowning as the leading cause of death (Malilay, 1997), with a resulting near zero lag between event and effect. Such floods (see Chapter 2.4.2) are most common across Mediterranean coastlines, some parts of the coasts of Portugal, Alpine valleys, and the Po valley in Italy, due to geographic and climatological factors (Chapter 2, Chapter 3). Vulnerability to flooding is modified by changes in land use and economic structure, and in the case of (non-flash) floods with lower velocities, social pre-preparedness (Estrela *et al.*, 2000). For non-flash floods, however, mortality lags are likely to be more complex and causes more varied. Vulnerable groups again include the elderly, very young, and generally less physically fit, due to lower resilience and mobility (Menne and Ebi, 2006). Large areas of concentrated population are particularly susceptible to flooding, and qualities of urban regions, including large areas of sealed (concreted) ground, may exascerbate problems associated with already heavy surface flow, including an effective increase in local runoff (Karl and Easterling, 1999; Guerrierri, 2002).

5.4 Summary and implications for this study

The above detail has several repercussions for the remainder of this study. Firstly, it can be seen that non-climatic events dominate the long term trends in many given sectors of activity (e.g. the Common Agricultural Policy in agriculture, economic growth in electricity consumption) and that specific events can cause substantial impacts in economy or sectoral behaviour (e.g. the 1973 oil crisis). In particular, certain factors directly influence the vulnerability of Mediterranean populations, including the increasing urbanization of the Mediterranean, and the increase in exposed wealth within large communities. In any given impacts study, care must be taken to recognise these non-climatic influences. Both the volume in wealth placed in material goods, and commercial energy use, are highly related to national GDP (Munich Re, 2003; World Bank, 2006). GDP is also sensitive to large-scale European economic events. Further, it has been shown (for the U.K.) that GDP possesses a high degree of inflexibility to extreme climate events (Agnew and Palutikof, 1997). GDP may, therefore (with care), be used to represent non-climatic year-to-year changes in economic expansion (Munich Re, 2003).

On seasonal scales, however, mortality, energy consumption (although not necessarily production), and agricultural yield all show substantial sensitivity to weather variability, and particularly extreme climate behaviour. Mortality is particularly sensitive to the magnitude and duration of summer extreme heat, to winter extreme cold (although possibly to a lesser extent), and (for the Mediterranean, much less importantly) to flash flood (i.e. intense) levels of rainfall in vulnerable regions, generally during spring and autumn (Chapter 2.5.2, Section 5.3.5, EM-DAT, 2005). Particularly vulnerable to extreme events are those over 65 and those living in urban areas (Section 5.3.5). Energy use is also sensitive to (magnitude and duration of) summer heat and winter cold and again, conditions in urban areas are likely to be highly important (Section 5.4.4). The sensitivity of agricultural yield to extremes of climate is highly dependent on crop type, of which the most sensitive to mean climate change are considered likely to be:

- C4 cereals (e.g. wheat)
- C3 cereals (e.g. maize)
- Permanent crops (e.g. olive, grape, orange)
- Indeterminate crops (e.g. some varieties of tomato)

Permanent crops are likely to display the greatest sensitivity to extreme climate due to their long maturation period. Particular sensitivities in terms of seasonality and climate change are dependent on crop type but are likely to include intense and prolonged rainfall, prolonged dry periods, the occurrence of frost, and both the magnitude and intensity of very high temperatures.

Responses to climate of mortality, agriculture and energy consumption may be non-linear, although in agriculture effects may vary between negligible non-linearities and an increase in yield up to a threshold temperature, followed by a dramatic decline in yield thereafter. Relationships between socio-economic factors and mean and extreme climate variables may, therefore, differ. Temporal lags between climatic cause and agricultural effect may also vary by crop type but are likely to include the winter and autumn of the previous year for non-permanent crops (due to annual growing periods) and all seasons of the previous year for permanent crops (due to longer than annual growing periods). Electricity consumption is likely to show a near-zero lag, as electrical power cannot be stored. Mortality may show small lags, but complex serial effects, as short-term mortality displacement may affect both inter- and intra- annual responses to extreme climate events, as may acclimatization.

Having discussed three potentially vulnerable sectors, the potential for taking into account non-climatic effect, and the potential for drawing relationships between socio-economic factors and the climate variables detailed in Chapter 3, the available data and an initial analysis are detailed in Chapter 6 concerning the following null hypotheses:

1.) The large-scale economy of nations and the placement of wealth into product (as described by the GDP) varies to some degree with climate, but individual sectors of activity show no such variation.

2.) Agricultural yield also varies only with demand per capita. Changing methods of farming have shown no uniform improvement in yield over time and the long-term trend evident in agricultural yield cannot be approximated by linear growth. Individual crops show consistently negligible relationships to regional temperature or precipitation.

3.) Mediterranean electricity consumption is proportional to national population size alone as a direct function of invariable individual demand. Short-term variations (anomalies) show negligible relationships with regional temperatures. Winter and summer relationships with climate are equally negligible.

4.) Mortality varies only as a proportion of total population size. Any substantial deviation from expected mortality can be attributed to intermittent periods of unrest, and not consistently with summer or winter temperatures.

5.) Any relationship that is evident between socio-economic activity and climate variability is strictly linear and constant between measures of mean (e.g. TAVG), high (TMAX), and extreme (TX90) behaviour. The duration (HWDI, TNFD, PX5D) of extreme events has no discernable additional effect on mortality, agricultural yield or electricity consumption. In addition, relationships are constant between regions.

Table 5.1: Chronology of the European Union.

Year	Event
1951	France and Italy among the founding members of the European Coal and Steel Community (ECSC, also including Belgium, the Netherlands, Luxembourg and West Germany), formed to pool industrial resources.
1957	Founding members of the ECSC propose the Treaty of Rome.
1958	Treaty of Rome implemented to create the European Economic Community (EEC). The EEC went beyond steel and coal to establish the “four freedoms” of goods, services, capital, and people, between member states.
1972	Britain, Ireland and Denmark join the EEC.
1981	Greece joins the EEC.
1986	Spain and Portugal join the EEC.
1992	Maastricht treaty reforms the EEC as the European Community (EC), one of the three “pillars” of the European Union, although the main concerns of the EC remain economic. The other two pillars are concerned with Justice and Home Affairs, and Common Foreign and Security Policy.
1999	France, Italy, Portugal, and Spain, along with seven other countries, adopted a common European currency in the form of the Euro.
2001	Greece joins the Euro placing all of the Mediterranean EU member states in the European currency union, or “Eurozone”.
2007	Romania and Bulgaria due to join the Union.

Table 5.2: Historical factors in the growth of the EU nations considered in this study. Compiled from de Guovell (2002), Pavan (2002), EUROSTAT (2006), World Bank (2006), and the Encyclopaedia Britannica (2006).

Year	France	Portugal	Spain	Italy	Greece
1946	Electricité du Francaise (EDF), a publically owned power company, founded.	Engaged in colonial warfare until 1974		Italian republic created, monarchy abolished, very strong economic growth until 1964	
1953			Pact of Madrid and the start of the 'Spanish Miracle' of economic growth.		
1958	The Fifth French Republic established under Charles de Gaulle, forms part of the new EEC.				
1959			Economic Stabilization Plan, economic growth almost unparalleled until 1974 at 6.8%. economy shifts away from agriculture		
1962	Algerian war of Independence settled with an independent Algeria		Urban boom during the 60s, more and more move to cities	Electricity industry nationalised (ENEL), almost full employment	
1965					King Constantine II dismisses the government of George Papandreou

Table 5.2: Continued

Year	France	Portugal	Spain	Italy	Greece
1967					Coup d'etat and military junta
1968	Protests over poor working conditions and education affect elections				
1973	International Oil Crisis				
1973			Francisco Franco surrenders role of prime minister		Abolishment of monarchy, student action and a countercoup
1974	Population growth has stalled, but power consumption starts to rise rapidly, 30 years of high unemployment begin.	The Carnation revolution, a bloodless coup, results in a democratic regime and a rapid decolonization effort. High levels of economic growth stall.	Period of strong economic growth ends		Democracy established
1975		First free elections in 50 years held, generally a troubled year of social instability	Franco dies		Constitution ratified and democratic abolishment of monarchy
1978			Democratic constitution ratified		
1980		Revisions to constitution and general modernisation	Strong economic growth returns, energy consumption starts to grow rapidly		
1981			Attempted military coup		Enters EEC, period of high economic growth begins (5.9%)

Table 5.2: Continued

Year	France	Portugal	Spain	Italy	Greece
1982			The socialist PSOE party are elected, marking the transition to a liberal democratic state		
1985			Unemployment high at 21.5%, remains a problem along with inflation and trade union action until mid 90s		
1986		Gains membership of the EEC, strong economic growth re-established	Gains membership of EEC	Strong economic growth returns in late 80s	
1990	Annual population growth only 0.39%			Period of unrest between north and south, southern unemployment reaches 20%	
1992				Power market opened to renewables and cogeneration 83% of power produced by ENEL. Political difficulties until 1994	
1999	EDF contributes 94% of national power, largely from nuclear (75%) and hydroelectric (14%) sources			Power largely generated by oil (42%) and gas (28%)	
2004	Annual population growth back to 0.68%				
2005			Energy consumption has doubled compared to 1985 levels		

Table 5.3: Mortality and temperature for Paris, August 2003 (Bouchama, 2004).

Month	Day	Excess deaths	Temperature
August	4th	300	Temperature reaches 37°C
	8th	3,900	High temperature maintained
	12th	10,600	High temperature maintained, Temperature starts to decrease on the 13th
	20th	14,800	Back to ambient level of 25°C