Economics Bulletin

Volume 38, Issue 4

Climate and output variability in the Euro-Mediterranean region, 1950-2000

Jean-pascal Bassino
Normal Superior School of Lyon, France.

Celine Gimet
Institute of Political Studies Aix-en-Provence, France.

Stephane Quefelec
ENERGIES 2050, France

Abstract

Despite the large literature on the link between climate evolution and country economic performance, the specific question of the effects of climatic changes via the agricultural sector broken down by annual seasons in the Euro-Mediterranean region, which is considered as a hotspot of climate change, remains largely understudied. This paper investigates both the incidences of seasonal rainfall and temperature variations on GDP from an historical perspective and the impact of climate anomalies on cereal output. Our results point to the fact that climate shocks affect significantly the GDP of Euro-Mediterranean countries specialized in the agricultural production, in particular during winter and spring. In these seasons, the impacts of climate anomalies are strong on cereal output in southern and eastern Mediterranean countries. These results underline the fact that agriculture is one of the main channels of the influence of climate change on GDP in this region. Crop diversification could be part of the response for enhancing resilience of the entire economy while preserving food security objectives.

Citation: Jean-pascal Bassino and Celine Gimet and Stephane Quefelec, (2018) "Climate and output variability in the Euro-Mediterranean region, 1950-2000", *Economics Bulletin*, Volume 38, Issue 4, pages 1811-1822
Contact: Jean-pascal Bassino - jean-pascal.bassino@ens-lyon.fr, Celine Gimet - celine.gimet@sciencespo-aix.fr, Stephane Quefelec - quefelecstephane@yahoo.fr.
Submitted: September 07, 2017. **Published:** October 10, 2018.

1. Introduction

In recent years, a growing literature has provided evidence of a link between climatic variables and GDP (Master and McMillan 2001, Barrios *et al.* 2003, 2010, Dell *et al.* 2009, 2012, 2014, Eboli *et al.* 2010). However, these analyses are mainly based on annual climate data whereas economic performances in emerging countries are likely to be more affected by seasonal climate variability. Moreover, they don't take into account the specific role of the agricultural sector as a transmission channel or they fail to demonstrate the increased vulnerability of countries whose economies are heavily dependent on agricultural production, to climate change (Dell *et al.* 2012). This is why this paper presents an empirical assessment of the economic impacts of seasonal rainfall and temperature variations on Mediterranean countries highlighting the role played by the agricultural sector which represents a large percentage of this region's GDP (see appendix). The impact of climate change on agriculture is clearly demonstrated by the literature that follows the seminal paper of Adam *et al*. (1990). However, there is no consensus concerning the link between a country's dependence on the agricultural sector and its level of GDP per capita (Gollin 2010, Dell *et al.* 2014). The paper attempts to extend the existing empirical literature in three directions. First, using monthly series and considering changes in GDP and cereal output during a large sample period (1950-2000), the analysis points out the fact that historical and seasonal data are the two main dimensions that need to be considered to study this phenomenon. Second, using country-level observations covering 18 countries of the Euro-Mediterranean region,[1] compared with a control group of 14 non-Mediterranean European countries[2], the paper focuses on the Mediterranean area, a major hotspot for global warming, that has not yet been analyzed in a systematic way. Finally, it points out the central role of the agricultural sector which is particularly impacted by climate change and which can generate a reduction in economic activity. Thus, attention is drawn to the particular impact of climate anomalies[3] on different agricultural products. Indeed, climate change is expected to generate not only a rise in long-term average temperature levels and a decrease in long-term average rainfall with a change in the seasonal pattern of temperatures and rainfall (IPCC 2013) in this area, but also higher amplitude and frequency of climate anomalies (Giannakopoulos *et al.* 2005, Parry *et al.* 2007, IPCC 2013). This phenomenon is likely to cause sizable losses in output in the Mediterranean region over the coming decades. In particular, significant vulnerability to rainfall and temperature anomalies during the cultivation period of the main crops can result in a high variability of Mediterranean agricultural output with spillover effects to the rest of the economy. This detailed three-step approach should enable us to fill the gap in the literature on this topic. It underlines the fact that, in the Euro-Mediterranean region, climate change impacts crop yields, which can be

---

[1] We consider a country as Mediterranean if it borders the Mediterranean Sea and/or if the climate is partly or entirely of a Mediterranean type. Only a few of the Mediterranean countries have a purely Mediterranean climate across the entire territory. Some areas have a desert climate (e.g. Algeria, Egypt, Libya, Morocco, and Syria), or a semi-continental one (central Turkey), or even an oceanic one (northwest Spain). Although Portugal does not border the Mediterranean, its climate is mainly of a Mediterranean type. The list of countries is Albania, Algeria, Bulgaria, Egypt, Spain, France, Greece, Israel, Italy, Jordan, Lebanon, Libya, Morocco, Portugal, Syria, Tunisia, Turkey, and Former Yugoslavia (from 1990 onward, figures for Yugoslavia are aggregated from data available for Bosnia and Herzegovina, Croatia, Macedonia, Montenegro, Serbia, and Slovenia).

[2] European non-Mediterranean countries: Austria, Belgium, Finland, Denmark, Hungary, Germany, Ireland, the Netherlands, Norway, Poland, Romania, Sweden, Switzerland, and the United Kingdom.

[3] We define "anomaly" according to the general definition provided by the NOAA: "The term 'temperature anomaly' means a departure from a reference value or long-term average. A positive anomaly indicates that the observed temperature was warmer than the reference value, while a negative anomaly indicates that the observed temperature was cooler than the reference value".
Source: https://www.ncdc.noaa.gov/monitoring-references/faq/anomalies.php

considered as one of the most important sources of GDP per capita in countries where the industrial revolution is still in progress. Calling attention to this phenomenon helps the countries to envisage policy implications concerning the fundamental reforms that would allow them to improve their resilience to extreme climate variations.

In the remainder of the paper, we first focus on the economic impact of the seasonal climate variations in the region, particularly on agricultural countries. Secondly, to draw more precise conclusions, we consider the influence of monthly climate anomalies on yearly yields of two cereal crops, wheat and barley which account for a large share of agricultural output[4] in all of these countries. The policy implications of our findings are considered in the conclusion.

2. Assessing the impact of climate change on production in the Euro-Mediterranean region via the agricultural sector

The purpose is to test whether a significant statistical relationship exists between GDP per capita and climate trends (increase in average temperatures and decrease in average precipitation) broken down by agricultural sector and by season in the Euro-Mediterranean area. To consider long-term trends in the region, we use 10-year averages of temperatures and rainfall during the 1950-2000 period (Maddison 2001). The sample is composed of 32 Euro-Mediterranean countries. Yearly changes in per capita GDP (*lgdpk*) are determined by a large array of factors, including stochastic shocks other than climate (*rainfall* and *temperature*), in particular to investment share of real GDP (*Investment*), rate of openness, that is to say the ratio of exports plus imports to GDP (*Openness*), and the public spending share of real GDP (*Public spending*) (available in the Penn World Table)[5]. Finally, country dummy variables are introduced in the estimation to control for country location and specialization (*Agri*)[6]. Considering the lagged value of the dependent variable in our regression ($lgdpk_{t-1}$), along with explanatory variables for the *t*-1 period, the difference Generalized Method of Moments (GMM) method is appropriated to our estimation with a small number of countries, as it uses fewer instruments than the system GMM estimator, Blondel and Bond (1998). When the ordinary least squares (OLS) estimator is used for this purpose, a correlation between the explanatory variables and the error term due to individual effects can result in an upward bias. This problem is eliminated by the use of a *within* estimator that integrates fixed effects accounting for national characteristics. In our analysis, the number of periods is limited, which could produce a significant correlation between the lagged dependent variable and the error term. The use of this estimator is also biased but in the opposite direction. It is therefore suitable to use a dynamic model that introduces instrumental variables. These variables are correlated with the lagged value of the endogenous variable and not with the error term of the model, which solves our problem (Bond 2002). Our model is as follows:

$$y_{i,t} = \alpha y_{i,t-1} + \beta X_{i,t-1} + u_i + v_{i,t} \qquad (1)$$

With $i = 1, \ldots, 32$ (the number of countries), and $t = 1950, \ldots, 2000$ (10-year averages). In this regression, $y_{i,t-1}$ represents the lagged dependent variable for each country in the period *t*-1, $X_{i,t}$ the set of explanatory variables[7] with $\beta X_{i,t}$ defined as:

[4] The value of cereal production in the total value of crop production ranges between 20% and 30% in several Mediterranean countries (FAO data for the period 2005-2011). Crop production represents the largest percentage of agricultural production (up to 70%).

[5] http://cid.econ.ucdavis.edu/pwt.html.

[6] This variable represents Mediterranean countries with a value added higher than 15% of the GDP, and an employment in agriculture higher than 20% of the total employment on average during the period.

[7] *Gdpk*, *Investment*, *Public spending* and *Openness* are taken in log. There is no correlation between the variables.

$\beta_1 Climate\ variable_{i,t} + \beta_2 (Climate\ variable_{,,t} * A$[illegible]$ri_i$[illegible]$) + \beta$[illegible]$ve$[illegible]$me$[illegible]$_{i,t} +$
β[illegible]$ubli$[illegible]$_{i,t} + \beta$[illegible]$_{i,t}$

u_i the specific individual effects for each country, and $v_{i,t}$ the specific shock during each period and on each country and where [illegible]$_{i,t}(u_i + v_{i,t}$[illegible]$=$ [illegible] (2)

Using quarterly data (*Q1*, *Q2*, *Q3*, *Q4*), we assess the impact of seasonal patterns of climate change on agriculture.

Table I. Estimation results (GMM-Difference) for equation 1 using quarterly climate data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.gdpk	0.530***	0.560***	0.559***	0.595***	0.561***	0.541***	0.552***	0.546***
	(0.0291)	(0.0406)	(0.0258)	(0.0271)	(0.0287)	(0.0252)	(0.0253)	(0.0314)
Q1temperature	0.0360**							
	(0.0150)							
Q1 temperature x Agri	-0.164***							
	(0.0372)							
temperatureQ2		0.0479**						
		(0.0186)						
Q2 temperature x Agri		0.0164						
		(0.0207)						
Q3 temperature			0.00401					
			(0.0124)					
Q3 temperature x Agri			0.000146					
			(0.0318)					
Q4 temperature				0.0127*				
				(0.00694)				
Q4 temperature x Agri				0.0215				
				(0.0206)				
Q1rainfall					0.000926			
					(0.000689)			
Q1 rainfall x Agri					-0.00122			
					(0.00141)			
Q2 rainfall						0.000998		
						(0.000738)		
Q2 rainfall x Agri						-0.00342		
						(0.00239)		
Q3 rainfall							-0.000193	
							(0.000647)	
Q3 rainfall x Agri							-0.00292	
							(0.00198)	
Q4 rainfall								-0.00165***
								(0.000534)
Q4 rainfall x Agri								0.00281**
								(0.00137)
Investment	0.0764*	0.106**	0.122***	0.144***	0.118***	0.0531	0.119***	0.133***
	(0.0399)	(0.0479)	(0.0439)	(0.0475)	(0.0379)	(0.0349)	(0.0421)	(0.0405)
Public spending	0.0771***	0.0188	0.0367**	0.0372	0.0529***	0.0350**	0.0520***	0.0357**
	(0.0153)	(0.0202)	(0.0175)	(0.0249)	(0.0147)	(0.0134)	(0.0153)	(0.0158)
Openness	-0.0603***	-0.0262	-0.0325	-0.0568**	-0.0409**	-0.0192	-0.0433**	-0.0705***
	(0.0168)	(0.0438)	(0.0321)	(0.0262)	(0.0160)	(0.0341)	(0.0179)	(0.0212)
Observations	106	106	106	106	106	106	106	106
Number of *i*	31	31	31	31	31	31	31	31
Hansen statistic	22.28	25.41	21.85	26.79	23.60	20.49	22.94	19.38
p-value of Hansen statistic	0.844	0.705	0.859	0.634	0.790	0.903	0.818	0.932
Arellano-Bond test for AR(2)	1.075	0.958	0.890	0.968	0.898	0.998	0.887	0.882
p-value AR2	0.282	0.338	0.373	0.333	0.369	0.318	0.375	0.378

Notes: * significant at the 10% level; ** significant at 5%; *** significant at 1% (standard errors in parentheses).
Note: Q1: Quarter 1 of the year (January to Mars). Q2: April to June. Q3: July to September. Q4: October to December.

Our results are presented in Table I. The hypothesis that climate change influences GDP is not rejected if we consider seasonal temperatures and rainfall. In all cases, the Hansen tests of over-identifying restrictions validate the instruments used in the model. Furthermore, the Arellano and Bond (1991) tests do not reject the assumption of the absence of second-order autocorrelation of residuals, which indicates that the estimation results are robust. Time dummies are included to support the assumption that there is no correlation across countries in idiosyncratic disturbances[8].

Significant results are obtained for rainfall and temperatures in winter (*Q1temperature, Q2temperature, and Q4rainfall*). For the whole sample, an increase in temperature has a positive effect on GDP during the period of analysis, whereas, when we focus on Mediterranean agricultural countries, we can see significant negative effects of an increase in temperatures on growth (*Q1temperature*Agri*). Moreover, the GDP of Mediterranean agricultural countries is positively influenced by precipitation (*Q4rainfall*Agri*), whereas, when we focus on the whole sample, we can see that an increase in precipitation has a negative impact on GDP. The dependent variable is in log and the climate variables in level (due to negative data). Thus we can conclude that during the first quarter, in agricultural Mediterranean countries, an increase of 1°C would be at the origin of a decrease in GDP per capita of about 12.8% whereas during the third quarter, an increase of 1 ml in precipitation generates an increase in GDP per capita of about 0.01%. This phenomenon can be explained by the fact that a frost can have a positive influence on agriculture by killing some organisms and by reducing pathogens and parasites. This can increase the productivity and thus have a positive influence on average growth rates in some countries in which the growth mechanism are dependent on climate change and on the ecological context (Masters and Mcmillan 2001). This result suggests that in countries, which are largely specialized in agricultural production, crops, whose physiology is consistent with these patterns, play a disproportionate role in the connection between climate and output. Agriculture seems to be a major transmission channel of adverse climate shocks because a reduction in production has spillover effects to the rest of the economy.

Among the macroeconomic variables included in the estimation, *Investment* and *Public spending* have a significant coefficient. As expected these results are positive and correspond to those of the theoretical literature on growth and development (Aghion and Howitt 2009). This suggests that capital-intensive technologies, and investment in infrastructure, education and health can contribute to mitigating, to some extent, the effects of climate anomalies. The variable *Openness* has a negative and significant impact on the dependent variable. These findings can be explained by the fact that firstly, during the period of analysis many countries in the sample, in particular southern Mediterranean economies, had a low level of trade openness and secondly, some of them suffered from market imperfections that reduced the benefits of trade openness on GDP per capita (Rodriguez and Rodrik, 2001).

To study more precisely the impact of climate change on agricultural countries, it is necessary to focus on the vulnerability of different types of crops, considering the gap between current temperatures and precipitation levels and those at the beginning of the century (taken as a reference period), and focusing on shorter time periods within the same century.

3. The impact of climate anomalies on agricultural production in the Mediterranean area

The existing literature in agronomy and agricultural economics points toward a significant correlation between agriculture and climatic change at specific period in time during

[8] For the dependent endogenous variables lag 2 and deeper are used. The other variables are considered as endogenous and instrumented with lag 2 and deeper except for the time dummies and the climatic variables that are taken as exogenous.

the year (Porter and Semenov 2005, Reidsma *et al.* 2010, Schlenker and Lobell 2010, Jacobsen *et al.* 2012, Souissi *et al.* 2013, Jarlan *et al.* 2014), particularly in emerging and/or arid countries (Mendelson *et al.* 1994; Mendelson and Neuman 1999, Nordhaus and Boyer 2000, Roson 2003, Tol, 2002a, 2002b, 2009, Mendelson *et al.* 2006, Roson and Sartori 2010). Climate anomalies could have a negative influence on land productivity in the following cultivation cycle. Moreover, the combination of drought and high temperatures affects microbial life and destroys the humus content of soil. Depending on soil characteristics, some moisture retention could persist over several months and mitigate the impact of adverse climate anomalies on land productivity. However, most areas under wheat and barley cultivation in the Mediterranean countries during the 20th century have comparatively light soils with limited moisture retention. We can therefore expect a relatively strong impact of adverse climate conditions on yields.

In order to test the influence of climate anomalies on agricultural production in the Mediterranean area during the last century (from 1900 to 2008), we implement panel-data regressions based on the same sample of countries as the previous tests. As a dependent variable, we selected wheat and barley yields (output volume relative to harvested acreage) which are the most vulnerable varieties of rain-fed cereals (data published by the FAO[9] and, for the period 1900 to 1960, from Mitchell (1992, 2003)[10]). We introduce average monthly temperatures and rainfall as explanatory variables (Bassino and Dormois 2010, Hsiang 2010). Considering the magnitude of seasonal patterns in Mediterranean agriculture, annual data did not seem appropriate as shown by the first test. Climate anomalies are therefore constructed for each month as the deviation from normal average at a monthly frequency, measured as the average value of the previous 20-year period. Rainfall anomalies are measured as the absolute value of the difference in normal value to observed rainfall if rainfall anomalies have a negative value[11]; temperature anomalies are measured as the absolute value of the ratio of the observed value to normal temperature levels if temperature anomalies are above average. A threshold value of 0.01 is assigned otherwise (Hsiang 2010), i.e., with rainfall above normal and temperature below normal; these conditions are supposed to be equivalent to normal values in terms of impact on yields[12]. Anomalies are also measured using interaction terms between rainfall and temperatures to assess the combined effect of low rainfall and high temperatures resulting from evapotranspiration (the cumulative effect of temperature and rainfall anomalies) and loss of soil moisture (Barrios *et al.* 2010)[13].

We test the panel relationship between yields and climate anomalies and other potential explanatory variables in the following log-log form:

$$y_i = \alpha + \sum_{m=1}^{m} \beta_m . Ev_{mi} + \sum_{k=1}^{k} \gamma_k . x_{ki} + \beta Trend + \varepsilon_i \qquad (3)$$

Where y_i is the dependent variable, i.e., cereal yield[14] (*Wheat yield* and *Barley yield*); Ev_{mi} is the interaction term of temperature and rainfall anomalies described above for each of the 12 months[15]; x_{ki} represents a set of k other explanatory variables (*wheat acreage* and *barley*

[9] FAO Stat online database: http://faostat.fao.org/default.aspx?lang=en).

[10] Some series of agricultural output volume and meteorological records are available for the second half of the 19th-century data set. However, the coverage is mostly restricted to European countries and some limited coastal regions on southern and eastern Mediterranean shores (e.g., Algeria, Egypt, Lebanon, and present-day Turkey).

[11] In order to avoid negative values, we use a log-log specification.

[12] Another possibility could be to use the ratio of the difference between the observed value and average one standard deviation (see Barrios *et al.* 2010).

[13] Instead of the calendar year, from January to December, it appears preferable to use the cultivation cycle, from August to July; wheat and barley harvests are either completed or well under way in most Mediterranean areas in late June, but we also have to take into account the comparison with non-Mediterranean countries.

[14] Yield per hectare (production/area).

[15] *Ev. January* to *Ev. December*.

acreage) and country dummies[16]; ε_i a residual β is the coefficient of a time trend introduced to consider technological change that may have an impact on agricultural yields. Finally, the large size of our sample allows us to test for northern Mediterranean countries, southern and eastern Mediterranean countries, and non-Mediterranean countries to consider non-linear effects across country groups.

Table II. Estimation results for equation 3 (panel regressions) (1920-2000)

	Northern Mediterranean Countries		Southern and eastern Mediterranean Countries		European Non-Mediterranean countries	
	(1) *Wheat yield*	(2) *Barley yield*	(3) *Wheat yield*	(4) *Barley yield*	(5) *Wheat yield*	(6) *Barley yield*
Year	0.0187***	0.0158***	0.0153***	0.00781***	0.0186***	0.0166***
	(0.000445)	(0.000551)	(0.000739)	(0.000944)	(0.000268)	(0.000309)
Wheat acreage	-0.0409		-0.197***		-0.0861***	
	(0.0291)		(0.0357)		(0.0120)	
Barley acreage		0.190***		-0.236***		-0.0450***
		(0.0281)		(0.0416)		(0.0120)
Ev. January	0.00182	-0.00328	-0.00652*	-0.0135***	0.00141	0.000636
	(0.00232)	(0.00274)	(0.00360)	(0.00448)	(0.00135)	(0.00137)
Ev February	0.000356	-0.000204	-0.0108***	-0.0170***	0.00409***	0.00166
	(0.00229)	(0.00273)	(0.00332)	(0.00413)	(0.00138)	(0.00140)
Ev. March	-0.00153	-8.71e-05	-0.0104***	-0.0215***	0.00356***	0.00191
	(0.00210)	(0.00246)	(0.00346)	(0.00433)	(0.00127)	(0.00128)
Ev. April	-0.00609***	-0.00724***	-0.0111***	-0.0161***	-0.00162	-0.00247*
	(0.00209)	(0.00245)	(0.00344)	(0.00428)	(0.00125)	(0.00126)
Ev. May	-0.00499**	-0.00463*	-0.00734**	-0.0134***	-0.00408***	-0.00440***
	(0.00205)	(0.00237)	(0.00362)	(0.00450)	(0.00121)	(0.00122)
Ev. June	-0.00149	-0.00380	0.00964**	0.0161***	-0.000870	-0.00193
	(0.00223)	(0.00258)	(0.00421)	(0.00522)	(0.00119)	(0.00119)
Ev. July	0.00137	0.00309	-0.00251	-0.0107	0.00419***	0.00246**
	(0.00235)	(0.00272)	(0.00570)	(0.00703)	(0.00116)	(0.00117)
Ev. August	0.000286	-0.00162	0.00748	0.0136**	0.000787	0.00268**
	(0.00220)	(0.00256)	(0.00504)	(0.00627)	(0.00114)	(0.00115)
Ev. September	0.00321	0.00620**	0.0127***	0.00731	0.00156	-0.00111
	(0.00221)	(0.00257)	(0.00433)	(0.00531)	(0.00123)	(0.00123)
Ev. October	0.00110	0.00296	0.00203	-0.00442	-0.00274**	-0.00316**
	(0.00219)	(0.00259)	(0.00355)	(0.00439)	(0.00125)	(0.00126)
Ev. November	-0.00485**	-0.00110	-0.00212	-0.00562	0.00500***	0.000884
	(0.00217)	(0.00256)	(0.00346)	(0.00433)	(0.00135)	(0.00136)
Ev. December	-0.000169	0.00560*	-0.00913***	-0.0193***	0.00330**	0.00290**
	(0.00244)	(0.00292)	(0.00350)	(0.00439)	(0.00133)	(0.00135)
Constant	-36.16***	-31.26***	-29.27***	-14.08***	-35.40***	-31.14***
	(0.887)	(1.083)	(1.454)	(1.891)	(0.499)	(0.560)
Countries	8	8	7	7	14	14
Observations	699	663	519	471	1,046	1,046
R-squared	0.816	0.777	0.774	0.708	0.900	0.873

Notes: * significant at the 10% level; ** significant at 5%; *** significant at 1% (standard errors in parentheses).

[16] We also repeated the tests including year dummies in addition to country dummies. This was justified by the fact that non-climatic variables may impact cereal yields (e.g. war). Results are quite similar for our variables of interest although the value of coefficients is generally slightly lower.

Table II presents the estimation results for equation 3. As expected, negative and significant coefficients are obtained for winter and early spring (from December to May) anomalies, for both *Wheat yield* and *Barley yield*, in Mediterranean countries. For non-Mediterranean countries, significant results with positive signs and lower coefficients are observed for winter anomalies (from December to March). This implies that higher winter temperatures and/or lower rainfall could have a positive influence on cereal yields in countries with comparatively cold winters. These results support those of our first test and are consistent with some studies (e.g. Mendelson and Neuman 1999) suggesting that global warming could have a positive impact on agricultural output in high latitude regions. However, it should be noted that evapotranspiration in May, a critical period in the development of wheat and barley crop, has a negative impact on yields in non-Mediterranean countries, just as in Mediterranean ones. This negative effect could be amplified in non-Mediterranean countries in the case of a permanent rise in average temperatures.

A rise in *Wheat acreage* or *Barley acreage*, which implies the cultivation of marginal land, has a negative influence on yields in southern Mediterranean countries. On the contrary, our results show a positive influence of *Barley acreage* on *Barley yields* in northern Mediterranean countries which supposes a positive effect of technical developments such as irrigation and fertilizers. Additional effects are observed but without a consistent pattern. The sole exception is the negative and significant coefficient for evapotranspiration in December in southern and eastern Mediterranean countries that can be interpreted in terms of reduced moisture content of the soil having a negative influence on the quality of winter cultivations.

4. Conclusion

Using agricultural output series covering most of the 20th century, this analysis shows that the Euro-Mediterranean region is largely vulnerable to climate change. In particular, crops in southern and eastern Mediterranean countries are principally exposed to the combined effect of high temperatures and low rainfall in late winter and early spring. The resilience of the farming system can be improved by a large range of adaptation measures including water conservation, water-efficiency initiatives, energy efficiency, structural improvements to water-supply infrastructures, regional- or basin-water management and drought-management plans (World Bank 2007). The positive effect is enhanced when these measures are jointly implemented. From an agronomic point of view, a shift in sowing dates can contribute to reducing cereal-output volatility. In areas of high yield, variable crop diversification i.e., a shift away from cereals towards lentils, peas and other dry vegetables less vulnerable to spring climate anomalies, has been identified as a water-efficient option[17]. They can also contribute to the maintenance and improvement of soil fertility. The sustainable productivity of agro-ecosystems has been identified as an option (Kölling *et al.* 2012). From a food-security perspective, reducing the share of cereals in agricultural value-added seems to be an unattractive proposition, even if it may result in lower exposure to climate shocks and enhanced resilience of the economy. However, in terms of total caloric availability in normal years, and even more in terms of reduced volatility of output in calories, crop diversification could be part of the solution for enhancing resilience in the entire economy while preserving food-security objectives.

[17] Estimates of shadow prices of water for Morocco indicate that water efficiency is higher for legumes and pulses than for barley (Bouhia 2001, tables 4-29).

References

Aghion P. and Howitt P. (2009). *The Economics of Growth*. MIT Press.

Arellano M. and Bond S.R. (1991). “Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations” *Review of Economic Studies* **58**, 277–297.

Barrios S., L. Bertinelli and Strobl E. (2003) “Dry times in Africa: rainfall and Africa's growth performance” CORE discussion paper 2003/61.

Barrios S., L. Bertinelli and Strobl E. (2010) “Trends in rainfall and economic growth in Africa: a neglected cause of the growth tragedy” *Review of Economics and Statistics* **92**(2), 350-366.

Bassino J.P. and Dormois J.P. (2010) “Rainfall, the Méline tariff, and wheat production in Mediterranean France, 1885-1914” *Australian Economic History Review* **50**(1), 23-38.

Bond S.R. (2002) “Dynamic panel data models: a guide to micro data methods and practice” *Portuguese Economic Journal* **1**, 141-162.

Bouhia, H. (2001) *Water in the Macro Economy: Integrating economics and engineering into an analytical model*. Ashgate.

Blundell R. and Bond S.R. (1998) “Initial conditions and moment restrictions in dynamic panel data models” *Journal of Econometrics* **87**(1), 115-143.

Dell M., Jones, B. F. and Olken, B.A. (2009) “Temperature and income: reconciling new cross-sectional and panel estimates” *American Economic Review 99*, 198-204.

Dell M., Jones, B. F. and Olken, B.A. (2012) “Temperature shocks and economic growth: evidence from the last half century” *American Economic Journal: Macroeconomics* **4**(3), 66-95.

Dell M., Jones, B. F. and Olken, B.A. (2014) “What do we learn from the weather? The new climate-economy literature” *Journal of Economic Literature* **52**(3), 740-798.

Eboli F., Parrado R. and Roson R. (2010) “Climate-change feedback on economic growth: explorations with a dynamic general equilibrium model” *Environment and Development Economics* **15**, 515-533.

Giannakopoulos C., Bindi M., Moriondo M., LeSager P., and Tin T. (2005) *Climate Change Impacts in the Mediterranean Resulting from a 2°C Global Temperature Rise*. A report for the WWF for a Living Planet. The global conservation organization, Gand, Switzerland.

Hsiang S. M. (2010) “Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America” *Proceeding of the National Academy of Sciences* **107**(35), 15367-15372.

IPCC (2013) *Climate Change 2013: The Physical Science Basis*. Working Group I Contribution to the IPCC 5th Assessment Report. http://www.climatechange2013.org/.

Jacobsen S-E., Jensen C.R. and Liu F. (2012) “Improving crop production in the arid Mediterranean climate” *Field Crops Research* **128**, 34-47.

Jarlan, L., Abaoui J., Duchemin B., Ouldbba A., Tourre Y.M., Khabba S., Le Page M., Balaghi R., Mokssit A. and Chehbouni G. (2014) “Linkages between common wheat yields and climate in Morocco (1982–2008)” *International Journal of Biometeorology* **58**, 1489-1502.

Kölling, A., Fertl, T., Schlüter, M. (2012) *Organic Food and Farming*. Imprimerie Eschedé-Van Muysewinkel, Belgium

Maddison A. (2001) *The World Economy: a Millennial Perspective*. Paris: OECD.

Masters W.A. and McMillan M.S. (2001) “Climate and scale in economic growth” *Journal of Economic Growth* **6**, 167-187.

Mendelson R., Nordhaus W. and Shaw D. (1994) “The impact of global warming on agriculture: a ricardian analysis” *American Economic Review* **84**(4), 753–71.

Mendelson R., Neuman J.E. (1999) *The Impact of Climate Change on the United States Economy*, Cambridge University Press, Cambridge.
Mendelson R., Dinar A., Williams L. (2006) “The distributional impact of climate change on rich and poor countries” *Environment and Development Economics* **11**, 159-178.
Mitchell B. R (1992) *International Historical Statistics - Europe 1750-2000*, Third Edition. Basingstoke, Hants, England: Macmillan; New York, N.Y., USA: Stockton Press.
Mitchell B. R. (2003) *International Historical Statistics - Africa, Asia and Oceania 1750-2000*, Third Edition. Basingstoke, England: Palgrave Macmillan.
Nordhaus W.D., Boyer J.G. (2000) *Warming the World: the Economics of the Greenhouse Effect*, Cambridge, MA: MIT Press.
Parry O.F., Canziani J.P., Palutikof P.J., Van Der Linden and C.E. Hanson (2007) *Climate Change Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Eds., Cambridge University Press, Cambridge, UK, 976 pp.
Porter, J.R. and Semenov, M.A. (2005) “Crop responses to climatic variation” *Philosophical Transaction B* **360**, 2021-2035.
Reidsma, P., Ewert, F., Lansink, A.O. and Leemans, R. (2010) “Adaptation to climate change and climate variability in European agriculture: The importance of farm level responses” *European Journal of Agronomy* **32**, 91–102.
Rodriguez, F. and D. Rodrik (2001) “Trade policy and economic growth: a skeptics guide to the cross-national evidence”, in B. Bernanke and K. Rogoff (eds), *NBER Macroeconomics Annual 2000*, Vol. 15, Cambridge, MA: MIT Press, 261–325.
Roson R. (2003) “Modeling the economic impact of climate change” EEE working paper series n°9.
Roson, R. and Sartori M. (2010) “The Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) Model. Introducing Climate Changes Impacts and Adaptation. Changes in the Model Structure and Parameters’ Estimation” Mimeo, the World Bank.
Schlenker, W. and Lobell D. B. (2010) “Robust negative impacts of climate change in African agriculture” *Environmental Research Letters* **5**(1), 014010.
Souissi I., Temani N., and Belhouchette H. (2013) “Vulnerability of Mediterranean agricultural Systems to climate: from regional to field scale analysis”. In: R. Pielke (ed.) *Climate Vulnerability*, Academic Press, Oxford, 89-103.
Tanzi, V. and Schuknecht, L. (2000) *Public Spending in the 20th Century: A Global Perspective*, Cambridge: Cambridge University Press.
Tol R.S.J. (2002a) “Estimates of the Damage Costs of Climate Change, Part I: Benchmark Estimates” *Environmental and Resource Economics* **21** (1), 47-73.
Tol R.S.J. (2002b) “Estimates of the damage costs of climate change – part II: dynamic estimates” *Environmental and Resource Economics* **21**, 135-160.
Tol R S.J. (2009) “The economic effects of climate change” *Journal of Economic Perspectives* Spring **23**, 29–51.
World Bank (2007) *Making the most of Scarcity - Accountability for Better Water Management in the Middle East and North Africa*. The World Bank, Washington.

Appendix

Table A.I. The weight of the agricultural sector in the economies of the region

		Agriculture, value added (% of GDP)				Employment in agriculture (% of total employment) (modeled ILO estimate)	
Region	**Countries**	**1968**	**1981**	**1991**	**2000**	**1991**	**2000**
Southern and Eastern Mediterranean countries	Algeria	11	9	10	9	22.2	21.9
	Egypt. Arab Rep.	29	20	18	17	31.5	29.7
	Libya	..	..	..	..	11.8	13.8
	Morocco	..	12	20	13	38.8	40.2
	Syrian Arab Republic	..	..	33	24	29.8	31.0
	Turkey	43	25	16	11	46.4	36.0
	Tunisia	..	32	19	11	18.6	17.7
	Israel	..	17	..	1	3.5	2.2
	Jordan	..	..	8	2	6.6	4.9
	Lebanon	8	4	..	7	11.5	8.6
Northern Mediterranean countries	Albania	..	..	39	26	61.6	53.7
	Bulgaria	..	..	17	13	14.7	13.2
	Spain	..	..	..	4	10.8	6.7
	France	11	6	3	2	5.8	4.1
	Greece	..	..	..	6	22.4	17.4
	Italy	..	..	4	3	8.5	5.2
	Portugal	20	16	..	4	13.0	12.5
	Bosnia and Herzegovina	..	..	..	11	33.6	27.4
	Croatia	..	..	..	6	17.7	14.5
	Macedonia. FYR	..	..	14	12	14.9	17.6
	Montenegro	..	..	..	12	7.6	11.0
	Serbia	..	..	..	20	25.6	25.5
	Slovenia	..	..	..	3	9.6	9.6

Source: World Bank. World Development Indicators

Table A.II. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	Variable	Obs	Mean	Std. Dev.	Min	Max
gdpk	168	9.21	.84	7.153	10.69	Q1temp*Med	352	2.110	4.520	0	15.62
Investment	168	3.170	.426	1.5987	3.92	Q2temp*Med	352	4.904	8.810	0	27.733
Public spending	168	2.71	.440	1.7479	4.11	Q3temp*Med	352	6.23	11.021	0	31.83
Openness	168	3.839	.6886	.862	5.100	Q4temp*Med	352	3.201	6.0340	0	20.26
Q1temperature	352	4.563	6.15	-10.18	15.62	Q1 rainfall*Med	352	10.43	22.14	0	99.14
Q2temperature	352	14.97	5.566	4.07	27.73	Q2 rainfall*Med	352	7.670	17.896	0	77.76
Q3temperature	352	19.76	5.61	9.325	31.83	Q3 rainfall*Med	352	4.205	11.5	0	65.09
Q4temperature	352	8.59	5.97	-3.644	20.26	Q4 rainfall*Med	352	11.34	26.51	0	139.2
Q1rainfall	352	56.40	30.26	2.633	136.9	Wheat acreage	2971	1352.24	1702.4	0	9800
Q2rainfall	352	49.362	31.3479	.66	154.9	Wheat Yield	2894	2.365	1.856	0	9.924
Q3rainfall	352	48.87	40.08	.0633	198.0	Barley acreage	2910	653.89	795.72	0.8	4412.8
Q4rainfall	352	65.981	36.179	4.55	191.0	Barley Yield	2768	2.1265	1.505	0	7.869

Table A.III. Coefficient of variation for wheat and barley yields (25-year periods)

	1900-1924		1925-1949		1950-1974		1975-2000	
	Wheat	Barley	Wheat	Barley	Wheat	Barley	Wheat	Barley
Albania	:	:	:	0.15	0.12	0.39	0.31	0.67
Algeria	0.26	0.26	0.32	0.23	0.25	0.18	0.31	0.27
Bulgaria	0.23	0.37	0.22	0.82	0.19	0.88	0.19	0.21
Egypt	0.79	0.79	0.52	0.12	0.91	0.10	0.14	0.39
France	0.22	0.13	0.24	0.16	0.24	0.28	0.19	0.16
Greece	0.12	0.18	0.15	0.24	0.28	0.20	0.12	0.12
Israel	:	:	:	0.23	0.38	0.44	0.62	0.33
Italy	0.16	0.13	0.16	0.14	0.23	0.16	0.14	0.12
Jordan	:	:	:	0.23	0.56	0.47	0.48	0.51
Lebanon	:	:	:	:	0.10	0.93	0.33	0.30
Libya	:	:	:	:	0.52	0.28	0.22	0.33
Morocco	0.16	0.23	0.33	0.31	0.35	0.30	0.40	0.35
Portugal	0.27	0.19	0.24	0.32	0.24	0.29	0.38	0.27
Spain	0.15	0.14	0.19	0.16	0.20	0.51	0.23	0.23
Syria	:	0.05	0.22	0.26	0.52	0.36	0.55	0.35
Tunisia	0.44	0.29	0.47	0.26	0.45	0.30	0.38	0.31
Turkey	:	:	0.21	0.21	0.12	0.14	0.10	0.07
F. Yugoslavia	0.14	0.11	0.10	0.19	0.62	0.34	0.11	0.11

Source: Mitchell (1992. 2003) and FAO.

Table A.IV. Average annual temperature and total annual rainfall patterns in Mediterranean countries

	Average annual temperat. °C	Average annual rainfall (mm)	Coefficient of variation for rainfall	Average annual temperat. °C	Average annual rainfall (mm)	Average annual temperat. °C	Average annual rainfall (mm)	Variation in average temperat. °C	Variation in average rainfall (mm)
PERIOD:	**1900-2000**	**1900-2000**	**1900-2001**	**1900-1930**	**1900-1930**	**1970-2000**	**1970-2000**	**1930-1970 /1970-2000**	**1930-1970 /1970-2001**
Albania	11.33	992	0.15	11.08	993	11.53	964	0.45	-28.49
Algeria	22.36	91	0.16	21.93	92	22.61	89	0.69	-2.92
Bulgaria	10.49	605	0.14	10.36	605	10.57	601	0.20	-4.38
Egypt	22.25	52	0.17	22.12	53	22.23	52	0.11	-0.81
France	10.71	858	0.12	10.47	858	10.95	875	0.48	17.18
Greece	15.35	656	0.13	15.13	656	15.33	628	0.20	-28.14
Israel	19.13	446	0.23	18.71	446	19.25	426	0.54	-20.39
Italy	13.44	835	0.10	13.25	836	13.63	830	0.38	-5.78
Jordan	18.23	112	0.25	17.86	113	18.35	112	0.49	-0.79
Lebanon	16.30	660	0.21	16.00	661	16.35	628	0.35	-32.87
Libya	21.85	55	0.20	21.70	56	21.96	56	0.25	0.30
Morocco	17.12	343	0.20	16.81	344	17.22	323	0.40	-20.56
Portugal	14.90	808	0.19	14.48	809	15.33	838	0.86	29.18
Spain	13.13	613	0.13	12.64	614	13.55	617	0.91	3.54
Syria	17.65	313	0.19	17.35	313	17.80	307	0.45	-6.41
Tunisia	19.00	298	0.19	18.47	298	19.44	309	0.97	10.57
Turkey	10.94	583	0.10	10.68	583	11.02	580	0.34	-3.45
F. Yugoslavia	9.84	793	0.15	9.61	794	10.02	782	0.41	-11.62

Source: see text.
Note: *F. Yugoslavia* stands for *Former Yugoslavia*.