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Economic Impacts of Climate Change in the Southern Mediterranean

Francesco Bosello and Fabio Eboli

MEDPRO Technical Report No. 25/February 2013

Abstract

This report analyses the potential economic impacts of climate change on 11 southern and eastern Mediterranean countries through the effects of changes on the coastal ecosystem and on agriculture. The impacts are quantified through bottom-up studies assessing the consequences of the deterioration of the coastal ecosystem and protected areas for tourism arrivals, and the effects on yields of major crop families by mid-century. These data are then used as inputs into a world CGE model that quantifies the impact on GDP, sectoral production and prices. The results point to a generalised, albeit moderate loss in the region's GDP, ranging from -0.1% to -0.25% in 2050. The countries that are more adversely affected are Tunisia (-0.26%/-0.41% of GDP in 2050) and Morocco (-0.04%/-0.14% of GDP in 2050). High losses (-0.13%/-0.36% of GDP in 2050) are also highlighted for the 'Middle East' aggregate (including among others Jordan, Syria, Palestine, Lebanon and Israel), which together make up 26.5% of the region's GDP. Negative impacts are more perceptible at the sectoral level. In the Reference Scenario, the average production loss for the agricultural sector is -0.5% in 2050, with a peak of -1.4% in Tunisia, while that of the service sector is -0.45% in 2050 with a peak of -0.9% in the Middle East. In general, GDP losses linked to tourism activity are greater than those related to agriculture, although this is not the case for Tunisia or Morocco.

Keywords: Climate change impacts, integrated assessment, CGE modelling

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Economic Impacts of Climate Change in the Southern Mediterranean

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1. Introduction and background

As part of the MEDPRO project, Work Package 4a focuses on the management of environmental and natural resources. Emphasis is placed on climate change pressures on water, agriculture and biodiversity in coastal areas in 11 southern and eastern Mediterranean countries (SEMCs).[1] Task 4a4 of the Work Package calls for an economic assessment of potential climatic impact on agriculture and coastal biodiversity in the area under different possible scenarios of economic development.

Specific to this exercise is the attempt to describe and estimate not only the direct economic costs (or gains) associated, but also the final implications in terms of growth and wealth for the economic systems affected. In other words, the methodology proposed gives a description of the social and economic ramifications triggered within economic systems by the changes.

Table 1 offers a simple and very broad classification of the approaches followed by the economic discipline when changes in key economic variables or ultimately welfare have to be assessed.

Table 1. Methodological approaches in the economic assessment of climate change

	Market value-based assessments	**Non-market value-based assessments**
Partial equilibrium	Direct costing and partial equilibrium	Direct costing + non-market evaluation
General equilibrium	Computable general equilibrium (CGE) modelling	CGE approach + non-market evaluation

A partial and a general equilibrium perspective can first be identified.

The former offers an assessment of costs that does not take into account the feedback that an economic perturbation in a sector or activity exerts on the rest of the system. While there are many differences in direct costing techniques, cost estimation is generally confined to the direct effects and the final results can be described in the following process:

> (Economic cost of the change) = (‘Quantity with the change’ – ‘Quantity without the change’) x (‘Price’).

This approach is widely used in economic assessments of climate change.[2] It is also the typical perspective of revealed or stated preference methods of evaluation (Remoundou et al., 2009).

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[1] The 11 countries are Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia and Turkey.

[2] See e.g. Fankhauser (1994), Yohe et al. (1996), Yohe and Schlesinger (1998), Volonte and Nicholls (1995), and Gambarelli and Goria (2004). Concerning sea-level rise, see Hamilton et al. (2005a) and (2005b), Amelung et al. (2007), Elsasser and Burki (2002), and Scott et al. (2004) and (2007). For tourism, see Agrawala (2007) and for health see the survey by Viscusi and Aldy (2003).

The strength of direct costing is its relatively smaller number of assumptions about the economic dynamics compared with a general equilibrium approach. Moreover, it is often the only viable approach when non-market values are involved (see below).

Its shortcoming is that it cannot measure possible rebounds on overall economic activity that a changing economic context can trigger.

The systemic perspective necessary to capture these feedbacks can be provided by CGE models.

A notable feature of CGE models is market interdependence. All markets are linked, as in response to price signals utility-maximising consumers and cost-minimising producers readjust their demand and supply schedules across all markets. Eventually, CGE models can capture and describe the propagation mechanism induced by a localised shock in the global context and vice versa. The final impact on national GDPs summarises these 'higher order' effects, which are usually very different from the initial impacts.

The second differentiation pertains to assessments based/oriented on market values and on non-market values.

Broadly speaking, as long as a 'use value' can be associated with a good or service it is also possible to derive an indication of its value provided by some market transaction. A lot of goods and services have a direct use, are traded and have a well-defined market price. Sometimes, as is often the case with environmental goods and services, a market does not exist explicitly, but the transaction and the associated 'use price' can be revealed by an observable behaviour. This happens for instance when time and money are spent on visiting a natural environment even though no entrance fee is charged, or when it is possible to quantify the money a society can save because an ecosystem provides 'for free' a buffer against some specific risks (e.g. hydro-geological risks or desertification), or finally when a change in the price of goods or services that are similar, e.g. housing, but which are introduced into different environmental contexts, can be observed. In all these cases observable behaviours can partially reveal the value. The techniques using these supports for evaluation, such as travel costs, averting behaviour and hedonic pricing methods, are called 'revealed preference' methods.

A particularly challenging situation arises when the assessment regards a good or service for which no use – and accordingly no market transaction or value – can be identified. This is again typical for environmental goods and services. Often their value, or the great part of it, is related to their mere existence or to a possible but unknown use in the future. In these circumstances, when no markets are at hand, the only route viable for the assessment is to 'restore fictitious markets'. This basically means asking selected respondents to state their willingness to pay to avoid or to accept compensation for the loss of the good or service. The 'stated preference' methodologies are represented by contingent valuation and stated choice experiments.

The exercise hereby conducted is based on the application of a recursive-dynamic CGE model: the intertemporal computable equilibrium system (ICES). This places the research in the general equilibrium stream and it does consider the economic feedback that the changes in agriculture and the marine ecosystem exert on the economies of the 11 SEMCs.

It is worth stressing that the assessment related to the ecosystem is confined to market impacts on the associated recreational services, as a CGE model only describes market transactions. The existence or option values not directly influencing agents' demand and supply schedules are outside the descriptive range of the model, as they are not part of 'national accounting', the usual database of CGE models.

Section 2 introduces the economic model and the scenarios adopted. Section 3 presents the economic assessment of the impact of climate change on agriculture. Section 4 concerns the ecosystem and tourism. Section 5 provides an economic assessment of the combined effects on the two sectors and section 6 concludes.

2. The ICES model and scenario building

The ICES model (Eboli et al., 2010) used for the investigation is a recursive-dynamic CGE model running for the period 2004–50 in one year time steps. The model is calibrated in 2004 and is based on the GTAP 7 database (Narayanan and Walmsley, 2008). As is standard in the CGE literature, its dynamics consist of a sequence of static equilibria (one for each simulation period) linked by the process of capital accumulation (more details are given in appendix 2). The sectoral and regional details of the ICES model used for this exercise are provided in Table 2.

The current ICES database allows four SEMCs to be represented in isolation: Turkey, Tunisia, Algeria and Morocco. Libya and Algeria appear as a single aggregate, whereas Jordan, Syria, Israel, Lebanon and Palestine are part of a larger 'Middle East' aggregate that also includes Bahrain, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates and Yemen.

Albeit the focus is on the 11 SEMCs, the modelling exercise cannot disregard the 'rest of the world', which is linked through the trade of goods and services to the 11 SEMCs. This is represented in its major geopolitical blocks.[3]

Table 2. Sectoral and regional details of the ICES model (this exercise)

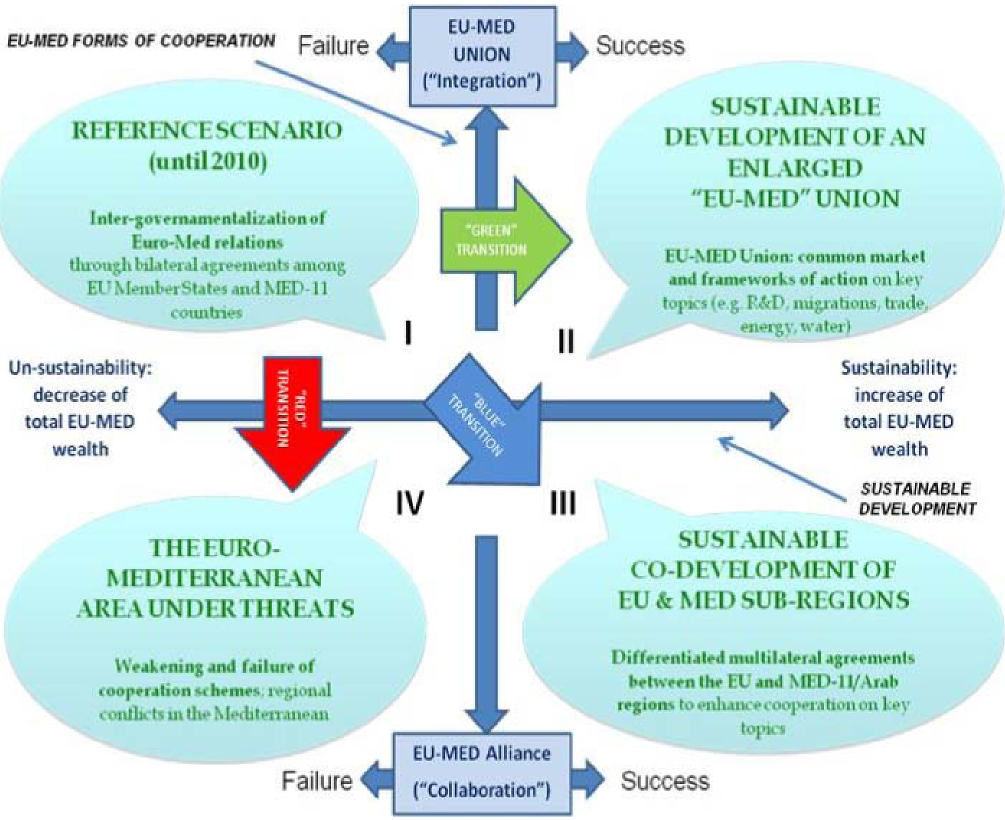
Industries/sectors	**Countries/regions**
Wheat	Turkey (TUR)
Cereal crops	Israel + Jordan + Syria + Lebanon + Palestine + Bahrain + Iraq + Kuwait + Oman + Qatar + Saudi Arabia + United Arab Emirates + Yemen (MDE)
Sugar crops	Egypt (EGY)
Vegetables and fruit	Tunisia (TUN)
Livestock	Morocco (MOR)
Coal	Libya + Algeria (RNA)
Oil	Northern EU (NEUR)
Gas	Eastern EU (EEUR)
Oil_pcts	Mediterranean EU (MEUR)
Electricity	USA
Industry	Korea + South Africa + Australia (KOSAU)
Market services	Canada + Japan + New Zealand (CAJANZ)
Public services	Sub-Saharan Africa (SSA)
	South Asia (SASIA)
	CHINA
	East Asia (EASIA)
	Latin and Central America (LACA)

The next step of the exercise consists of building a baseline or 'without climate change' reference scenario, i.e. the benchmark against which to contrast climate change effects, for the period 2004 to 2050. This is represented by the MEDPRO 'Reference Scenario', one of the four qualitative scenarios of socio-economic development for the 11 SEMCs adopted by the project (see Figure 1 and Sessa, 2011). Assumptions about the total population, the active population and GDP growth rates up to 2030

[3] In principle having just one large, residual aggregate, 'Rest of the World' would have worked. Technically, however, it is better to have a sufficient number of regions in order to prevent the situation whereby one very large region interacts with a few small regions. This usually provokes strange terms-of-trade effects that are then difficult to explain.

for the 11 SEMCs coincide with those characterising the MEDPRO Reference Scenario. After 2030, the population evolves according to UN population projections, while GDP trends are extrapolated from the path for 2004–30. For countries not included in the 11 SEMCs, we use UN population projections for the total and active population. In addition, the GDP trends are consistent with scenario A1b by the Intergovernmental Panel on Climate Change. All the data are reported in Table 3.

Figure 1. MEDPRO socio-economic development scenarios



Source: Ayadi and Sessa (2011).

Table 3. MEDPRO Reference Scenario: Quantitative implementation in the ICES model (% annual growth rate)

	2010	2020	2030	2040	2050
			Turkey		
Total population	1.1	1.0	0.7	0.4	0.2
Active population	1.2	1.2	1.1	0.7	0.3
GDP	7.9	4.2	4.0	3.2	2.7
			Middle East		
Total population	2.9	1.9	1.6	1.1	0.8
Active population	3.0	2.3	2.1	1.4	1.1
GDP	4.6	4.1	3.9	3.4	3.2
			Egypt		
Total population	1.7	1.6	1.3	0.9	0.6
Active population	2.2	1.7	1.8	1.2	0.8
GDP	5.1	4.2	4.2	3.5	2.8

Table 3. cont'd

Tunisia					
Total population	1.0	1.0	0.6	0.3	0.1
Active population	1.7	0.9	1.1	0.5	0.2
GDP	3.7	4.1	4.4	5.0	4.8
Morocco					
Total population	1.2	1.1	0.8	0.5	0.3
Active population	1.7	1.1	1.3	0.7	0.4
GDP	3.9	3.3	3.9	3.6	3.2
Algeria and Libya					
Total population	1.7	1.4	0.9	0.6	0.4
Active population	2.3	1.6	1.6	1.0	0.7
GDP	3.4	3.5	2.6	2.9	2.7

Before moving to the modelling exercise proper and its results, some important qualifications are necessary.

The general ones refer first to the scope of the assessment. It is undertaken for the 11 SEMCs, and it also assumes that climate change affects only the 11 SEMCs. This has obvious and important consequences. Thinking for instance of impacts on agriculture, these could also be negative elsewhere, with the effect that the crops of the 11 SEMCs could be penalised less in relative terms in international markets. By the same token, a worsening of ecosystem attractiveness outside the 11 SEMCs could slow a decline in tourism demand in the 11 SEMCs. In addition, indirect effects could exacerbate initial impacts. If economic losses from climate change are expected at the world level, this means that lower demand could be experienced for the agricultural commodities of and tourism in the 11 SEMCs. These effects related to a worldwide economic assessment of the impact of climate change, however, are beyond the scope of the present research.

Second, this study considers just two potential impacts related to changes in climatic conditions. Therefore the costs highlighted are only a fraction of the losses that climate change could generate in the area.

Third, an entire Work Package of the MEDPRO project is devoted to a full-blown CGE assessment of the MEDPRO scenarios, considering all the drivers of change for the region in the mid-term. The present assessment is much more limited in scope, but still not a duplication. By focusing on the specific effects of climate change on two aspects – agriculture and the ecosystem – this study considers the issues in finer detail and pushes the analysis further into the future.

Specific caveats relate to the nature of the investigation tool used, i.e. the CGE model. Stating the more typical caveat, CGE models are based on a 'Walrasian' view of the economic system, where all markets are in equilibrium and respond to the decision of optimising agents. Accordingly, they cannot examine the behaviour of imperfect markets. In CGE models, the adjustment to equilibrium is instantaneous, and thus they cannot represent frictions or transitions. CGE models are calibrated to some specific years, so they can offer reliable information only if the economic context remains reasonably similar to the initial one. CGE models are usually static and, when dynamic, they usually allow for myopic expectations and systematic errors.

All this calls for a great caution in interpreting the results. At the same time, the indications provided are still useful qualitatively, as they can highlight the economic mechanisms at play, and also quantitatively in terms of the orders of magnitude involved.

3. Modelling and assessing the impact of climate change on ecosystem recreational services: Changes in coastal tourism demand in the 11 SEMCs

3.1 Inputs and modelling strategy

Although climate is by no means the only determinant of a holiday destination,[4] the "amenity of climate" is recognised as one of the major determinants of tourism flows (Maddison, 2001; Lise and Tol, 2002). The biodiversity component of the natural and environmental amenities available in different countries has not been addressed in the relevant literature. Indeed, research has mostly focused on ecotourism, a specific segment of the tourism market (Wunder, 2000; Naidoo and Adamovicz, 2005).

The estimation of the role of biodiversity in determining the choice of coastal tourist destinations and then the potential impact of climate change on this is based upon the MEDPRO Technical Report by Onofri et al. (2013). Their study aims at understanding determinants affecting the choice of worldwide coastal tourist destinations, highlighting in particular the effects of environmental and biodiversity indicators. Tourist arrivals in coastal countries worldwide have been analysed and disaggregated into their international and domestic components. By applying three-stage least squares (3SLS) estimations of three equation models for each selected category of tourists, the main economic result is the identification of a category of tourists – 'the greens' – who effectively regard biodiversity and environmental amenities as factors directly affecting the destination choice. It is also shown that this effect is greater among international tourists, while the strong appreciation of biodiversity and ecosystem goods and services by domestic tourists appears to be related to other motivations, such as the desire to preserve national environmental patrimony.

More importantly for the present research, Onofri et al. (2013) estimate the coefficients relating to tourism demand according to different biodiversity proxies: a biodiversity index of mammals, a biodiversity index of birds, wetland areas and the percentage of protected areas. Compounded, all these effects produce a coefficient ranging between 0.6 and 1.65, respectively for the domestic and international tourists. This means that the loss of 1% of a biodiversity rich area would impose losses of 0.6% of domestic and 1.65% of international tourism demand.

Starting with this information, in a second phase of the study the potential differences in tourism demand induced by variations in these determinants under changing climate conditions has been estimated, linking biodiversity losses to changes in biodiversity rich areas.

To quantify the impact of climate change on tourism activity through the effects on biodiversity attractiveness, Onofri et al. (2013) make the following assumptions:

- The climate change-induced temperature increase (+1.9°C in 2050) is the same in the four MEDPRO scenarios. This is reasonable, as it is well known that because of the long-term inertias in the climate system, current trends in the temperature increase are basically predetermined until the mid-century.
- Therefore, different impacts on the tourism sector are driven by different assumptions about adaptation, rather than by mitigating policy actions. At the same time, the final impact on GDP triggered by the dynamics in the tourism sector also depends on the alternative economic contexts in which these dynamics materialise – more specifically, on the varying importance of the tourism industry in 2050 in the 11 SEMCs. Both sets of assumptions are described in detail in Onofri et al. (2013), to which the interested reader is referred. Here it is sufficient to recall that in pessimistic scenarios (i.e. 'Business as Usual' or quadrant I and 'Decline and Conflict' or quadrant IV), the negative impacts on tourism activity are larger, as it is assumed that fewer

[4] See Crouch (1995), Witt and Witt (1995), Gossling and Hall (2006), Bigano et al. (2007) and Rossello et al. (2005).

resources are available to protect biodiversity or contrast its loss. Meanwhile, in these scenarios tourism activity is less developed than in the more optimistic ones (i.e. ‘Fragmented Cooperation’ or quadrant III and ‘Enhanced Cooperation’ or quadrant IV). This partially counterbalances the negative impacts as these hit the sector, as tourism is slightly less important than it would otherwise be.

Table 4 reports the final impacts on the services sector (which includes recreational services) of the ICES model used as an input in the exercise.

Table 4. Climate change impacts on tourism demand in 2050: Change (in %) with respect to the no climate change baseline (temperature increase of +1.9°C compared with 2000)

	Reference Scenario	**Enhanced Cooperation Scenario**	**Fragmented Cooperation Scenario**	**Decline and Conflict (Failed Cooperation) Scenario**
Turkey	-0.420	0	-0.219	-0.628
Middle East	-1.404	0	-0.732	-2.118
Egypt	-0.401	0	-0.216	-0.631
Tunisia	-1.766	0	-0.912	-2.799
Morocco	-3.728	0	-2.052	-6.068
Algeria and Libya	-0.213	0	-0.116	-0.338

With the exception of the Enhanced Cooperation scenario – where, by assumption, adaptation policies are able to completely offset the threats to the coastal ecosystem (or to keep them at their current status) – the effects of climate change on tourism demand, through fewer arrivals, are negative everywhere. In 2050 they are particularly strong in Morocco, which in the Failed Cooperation scenario could experience a decline of -6%, while the effects are moderate in Libya and Algeria (-0.34%). Note also that the Reference case, which by assumption represents a possible business-as-usual outlook, entails non-negligible losses for Morocco (-3.7%), Tunisia and the 5 Middle Eastern countries of the 11 SEMCs. While in general, the impact on tourism activity may appear moderate, in fact this is not so considering that these negative effects relate just to losses determined by the reduced recreational attractiveness of the coastal ecosystem.

Decreases in tourism demand are then implemented in the ICES model through a reduction of household demand, addressing recreational services in the respective 11 SEMCs.

Demand schedules are typically endogenous variables, i.e. outputs, of CGE models. Working on these then imposes a particular procedure. The computed percentage variations in demand have been imposed as exogenous shifts in the respective demand equations. The implicit assumption is that the starting information refers to a partial equilibrium assessment that assumes all prices and income levels are constant. The model is then left free to determine the final demand adjustments. Modification of the demand structure, however, requires compliance with the budget constraint, so the changed consumption of recreational services is compensated by opposite changes in demand addressing all other sectors.

3.2 Results

The final potential impact on GDP in the 11 SEMCs of decreased attractiveness of the ecosystem is shown in Figure 2 and Table 5.

Figure 2. Climate change impacts on tourism in the 11 SEMCs: Changes in GDP (in %) with respect to the no climate change baseline (temperature increase of +1.9°C compared with 2000)

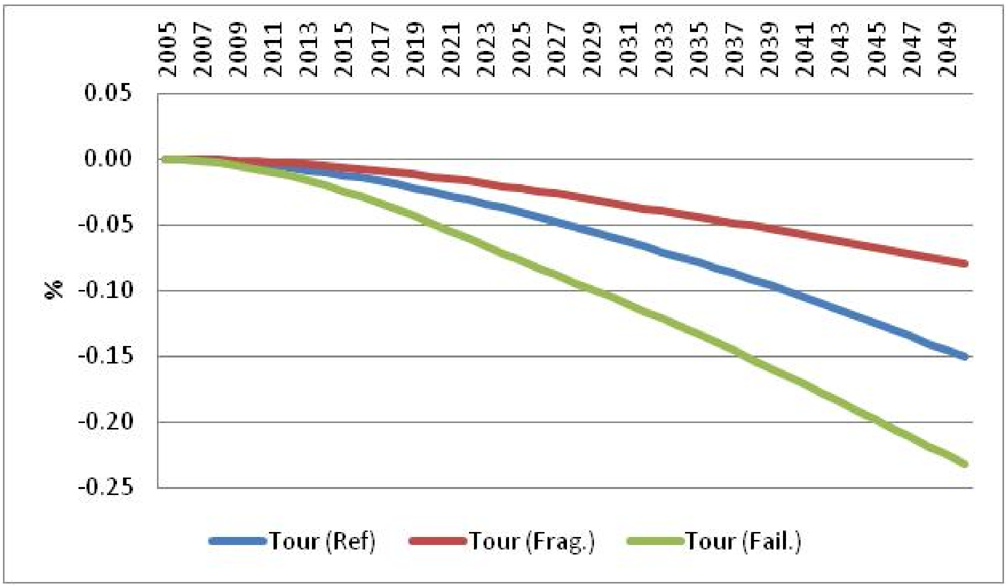


Table 5. Climate change impacts on tourism in the 11 SEMCs: Changes in GDP (in %) with respect to the no climate change baseline (temperature increase of +1.9°C compared with 2000)

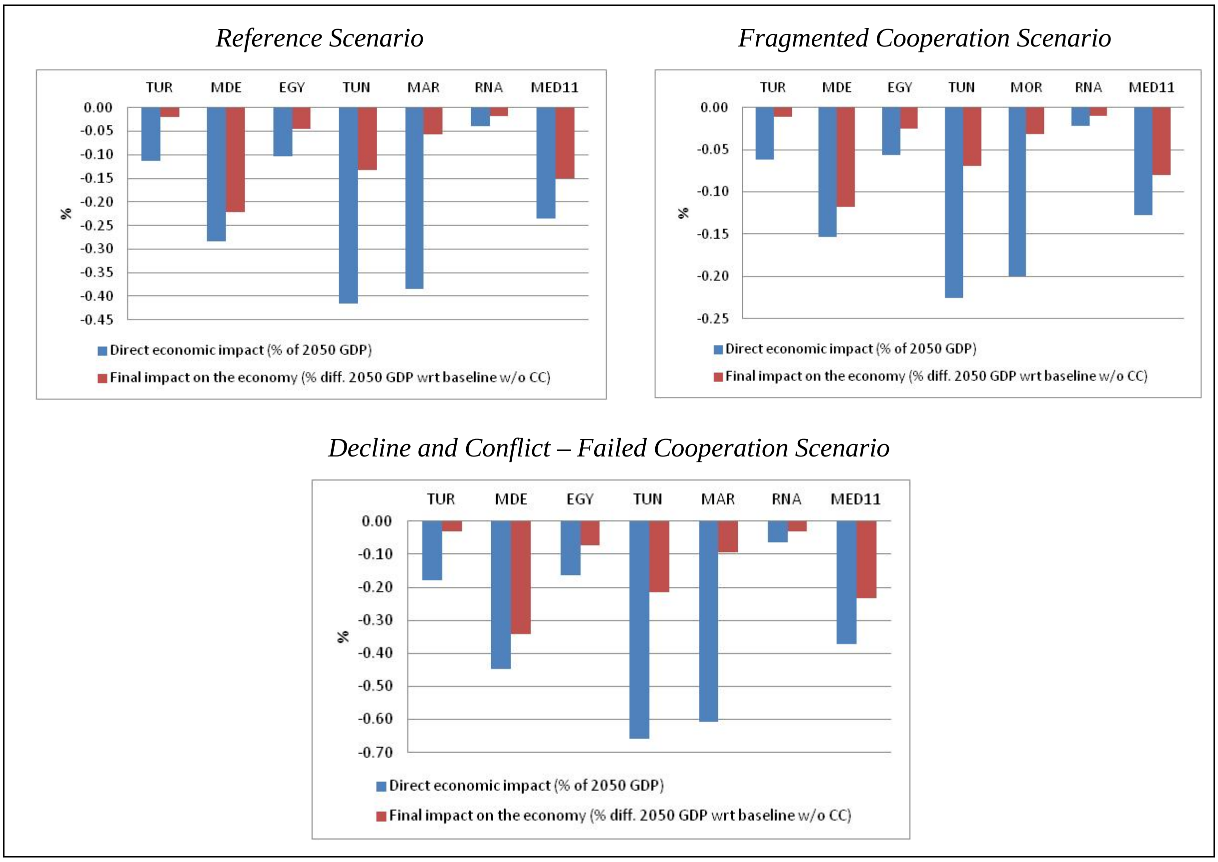
	2010	2020	2030	2040	2050
Turkey					
Tourism (Ref. Scen.)	0.00	0.00	0.00	-0.01	-0.02
Tourism (Frag. Coop.)	0.00	0.00	0.00	-0.01	-0.01
Tourism (Failed Coop.)	0.00	0.00	-0.01	-0.02	-0.03
Middle East					
Tourism (Ref. Scen.)	-0.01	-0.04	-0.09	-0.15	-0.22
Tourism (Frag. Coop.)	0.00	-0.02	-0.05	-0.08	-0.12
Tourism (Failed Coop.)	-0.01	-0.08	-0.16	-0.25	-0.34
Egypt					
Tourism (Ref. Scen.)	0.00	0.00	-0.01	-0.03	-0.05
Tourism (Frag. Coop.)	0.00	0.00	-0.01	-0.01	-0.02
Tourism (Failed Coop.)	0.00	-0.01	-0.02	-0.04	-0.07
Tunisia					
Tourism (Ref. Scen.)	0.00	-0.01	-0.03	-0.07	-0.13
Tourism (Frag. Coop.)	0.00	0.00	-0.02	-0.04	-0.07
Tourism (Failed Coop.)	0.00	-0.02	-0.05	-0.11	-0.22
Morocco					
Tourism (Ref. Scen.)	0.00	0.00	-0.01	-0.03	-0.06
Tourism (Frag. Coop.)	0.00	0.00	-0.01	-0.02	-0.03
Tourism (Failed Coop.)	0.00	-0.01	-0.02	-0.05	-0.10
Algeria and Libya					
Tourism (Ref. Scen.)	0.00	0.00	0.00	-0.01	-0.02
Tourism (Frag. Coop.)	0.00	0.00	0.00	-0.01	-0.01
Tourism (Failed Coop.)	0.00	0.00	-0.01	-0.02	-0.03

The overall effect of decreased tourism demand on GDP is quite modest. As a whole, the 11 SEMCs experience a decline in GDP ranging from -0.09% to -0.24% depending on the scenario in 2050. At the country level, the higher losses are experienced by Morocco, Tunisia and the Middle East aggregate, which largely determine the regional performance. Tiny losses are experienced by Egypt, Turkey, Algeria and Libya.

Two aspects are interesting. The first is that the final impact on GDP tends to be smaller than the initial decline in tourism demand and also the direct costs.

The comparison between the direct and final GDP costs for the year 2050 is shown in Figure 3, where the direct costs as a percentage of GDP are computed, reducing the value added of the tourism sector proportionally to the decline in demand.

Figure 3. Climate change impacts on tourism in the 11 SEMCs: Difference between the direct and final economic costs in 2050 as a % of GDP



It can be noted that the indirect effects – such as changes in the composition of demand in response to price changes and resource reallocation across economic sectors – are nicely captured by the GE framework, and partially smooth initial shocks. Second, a moderate re-ranking of country losses is also shown. For instance, Morocco experiences the sharpest decrease in tourism demand, but the final impact on its GDP, albeit still among the highest, is lower than that of Tunisia and the Middle East aggregate. This is not due to a lower degree of importance of tourism activity in the country. In fact, with the exception of Lebanon, Morocco exhibits the highest contribution of tourism to GDP in all the scenarios. It is rather due to a different reallocation of demand and production across its entire economy, which in turn is dependent on a different preference structure and factor substitution possibilities.

4. Modelling and assessing the impact of climate change on agriculture in the 11 SEMCs

4.1 Inputs and modelling strategy

Climatic impacts on agriculture in the 11 SEMCs are directly derived from MEDPRO D4a2 (Scardigno and Lamaddalena, 2011). The goal of that study was to calculate water requirements for crops, net irrigation requirements and relative yield under various conditions in the southern and eastern Mediterranean environment, from Morocco in the west to Turkey in the north-east. Each of the 11 SEMCs is represented by three or four locations, entailing their soil and climatic conditions.

Crop response to water has been tested for 16 crops and 4 to 5 different management strategies. The investigation tool used is the CROPWAT 8.0 decision support system developed by the Land and Water Development Division of the UN Food and Agriculture Organization.

Starting with this information, a representation of the potential consequences of a changing climate in the 11 SEMCs is then provided, exploiting intra-country variability in climatic conditions across the different locations examined. The approach is that of climate analogues. Put differently, the yield differential between a cooler and a warmer location in a country provides an estimate of the potential evolution in crop yield when the climate is warming.

The 16 crops examined by Scardigno and Lamaddalena (2011) have been aggregated consistently with the details of the ICES CGE model for the agricultural sector, which offers a coarser description of the crops produced.

Changes in crop yields and agricultural industries in the ICES model are reported in Table 6.

Table 6. Changes in potential crop yields under changing climatic conditions in the 11 SEMCs (in %)

	Wheat	Cereal crops	Sugar crops	Vegetables and fruit
Turkey	-8.7	-4.8	-0.6	-3.6
MDE	-2.5	-0.8	-0.008	-2.4
Egypt	2.2	-1.1	0.01	0.7
Tunisia	-5.7	-2.5	0.000	-11.7
Morocco	-7.3	-3.6	-0.05	-0.8
Libya + Algeria	-0.3	-1.2	0.0	-0.7

It can be noted that when moving from cooler to warmer climatic conditions the crop yields are expected to decrease, especially in the case of vegetables and fruit in Tunisia, and wheat in Turkey and Morocco. Egypt, by contrast, could experience small productivity gains.

These alterations refer to the crop responses to changing environmental and climatic conditions, and therefore are uniform across the four different MEDPRO scenarios. Unlike the case of tourism, we do not have differentiated assumptions about the possible effectiveness of adaptation strategies in agriculture, nor about the evolution of the agricultural sector in the four MEDPRO scenarios. Accordingly, in the case of agriculture, just one set of climate change impacts is imposed on the Reference Scenario. Finally, it is assumed that the negative impacts computed are experienced in 2050.

The practical implementation in the CGE model is quite straightforward. In ICES, land is an explicit factor of production used by various agricultural industries representative of each crop production. The effects on potential yields are thus captured by appropriate changes in the exogenous productivity parameter of the land production factor allocated to each crop.

4.2 Results

Figure 4 depicts the consequences for GDP deriving from the adverse impacts of climate change on yields in the region. The country more adversely affected is Tunisia (-0.2% of GDP in 2050), which also shows the strongest negative shocks on yields on average. It is then followed by Morocco and the other 11 SEMCs. The effects on GDP, however, are tiny and for the 11 SEMCs as a whole they amount to a total of -0.02% in 2050.

As shown in Figure 5, the direct economic losses that are calculated simply considering the value of lost production, which in its turn is proportional to the reduction in productivity, are larger than the final effects on GDP. Once again, the possibility of factor substitution, in this case compensating the loss in land productivity with an increase in labour and capital use, smoothes the initial impact.

Figure 4. Climate change impacts on agriculture in the 11 SEMCs: Changes in GDP (in %) with respect to the no climate change baseline

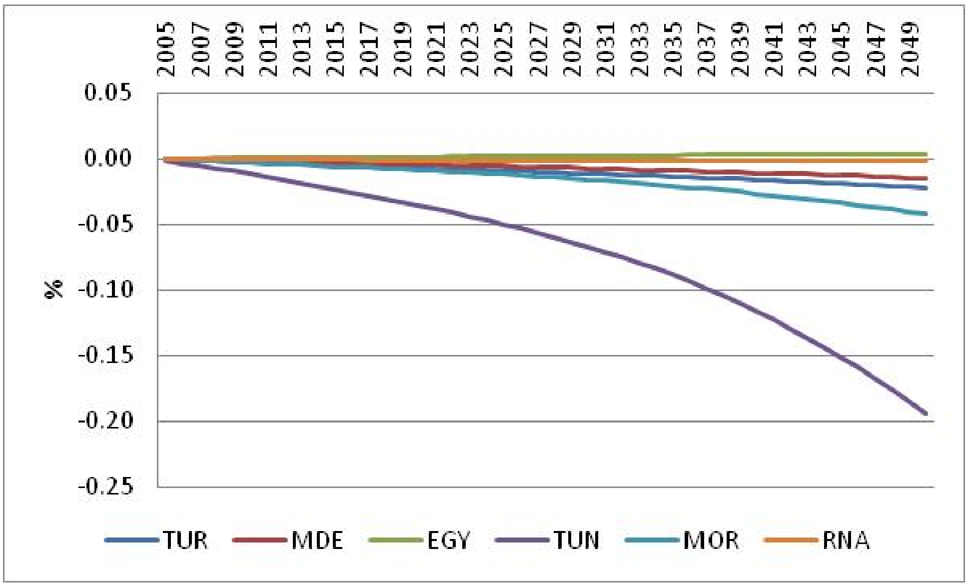
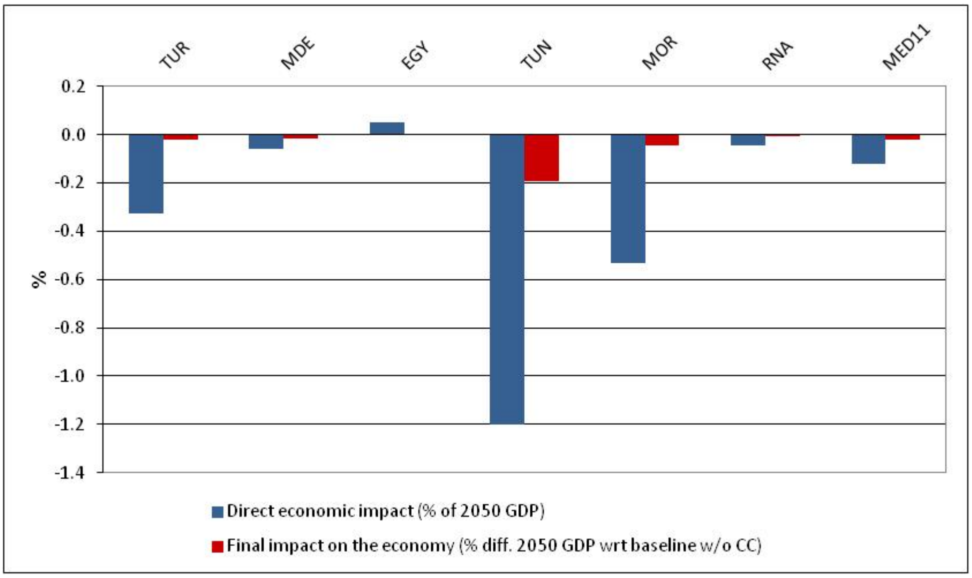


Figure 5. Climate change impacts on agriculture in the 11 SEMCs: Difference between the direct and final economic costs in 2050 as a % of GDP



More evident, but still small, are the impacts at the sectoral level. The production of crops, as expected, declines, particularly in Tunisia and Morocco in the wheat and cereal industries (Table 7). As an effect of the decreased production, the prices of agricultural commodities increase (Table 8) to a peak of +1.5% with respect to the baseline in 2050 for the vegetable and fruit industry of Tunisia. This also worsens the trade balance of agricultural goods (Table 9), as their net imports increase in almost in all of the 11 SEMCs, with peaks in Morocco (wheat) and Tunisia (vegetables and fruit).

Table 7. Climate change impacts on agriculture in the 11 SEMCs: Changes in agricultural production (in %) with respect to the no climate change baseline

	2010	**2020**	**2030**	**2040**	**2050**
			Turkey		
Wheat	-0.03	-0.06	-0.08	-0.11	-0.15
Cer. Crops	-0.08	-0.12	-0.19	-0.28	-0.42
Sugar	0.00	0.00	-0.01	-0.01	-0.01
Veg. Fruit	-0.03	-0.04	-0.07	-0.09	-0.12
			Middle East		
Wheat	-0.06	-0.13	-0.21	-0.30	-0.41
Cer. Crops	-0.02	-0.05	-0.09	-0.12	-0.16
Sugar	0.00	-0.01	-0.01	-0.02	-0.03
Veg. Fruit	-0.03	-0.07	-0.12	-0.18	-0.25
			Egypt		
Wheat	0.05	0.14	0.24	0.37	0.49
Cer. Crops	-0.01	-0.02	-0.05	-0.10	-0.15
Sugar	0.00	0.00	0.00	0.00	0.00
Veg. Fruit	0.01	0.03	0.05	0.08	0.11
			Tunisia		
Wheat	-0.20	-0.36	-0.58	-0.93	-1.37
Cer. Crops	-0.25	-0.46	-0.73	-1.08	-1.43
Sugar	-0.01	-0.03	-0.06	-0.11	-0.19
Veg. Fruit	-0.10	-0.20	-0.33	-0.52	-0.77
			Morocco		
Wheat	-0.12	-0.24	-0.37	-0.59	-0.86
Cer. Crops	-0.06	-0.12	-0.19	-0.30	-0.44
Sugar	0.00	0.00	0.00	0.00	0.00
Veg. Fruit	-0.03	-0.06	-0.09	-0.13	-0.17
			Algeria and Libya		
Wheat	-0.01	-0.02	-0.01	0.00	0.02
Cer. Crops	-0.02	-0.02	-0.01	0.00	0.02
Sugar	0.00	0.00	0.00	0.00	0.00
Veg. Fruit	0.00	-0.01	-0.01	0.00	0.00

Table 8. Climate change impacts on agriculture in the 11 SEMCs: Changes in agricultural prices (in %) with respect to the no climate change baseline

	2010	2020	2030	2040	2050
Turkey					
Wheat	0.09	0.14	0.21	0.29	0.39
Cer. Crops	0.07	0.10	0.15	0.21	0.29
Sugar	0.03	0.05	0.08	0.12	0.16
Veg. Fruit	0.05	0.07	0.10	0.13	0.17
Middle East					
Wheat	0.03	0.08	0.13	0.19	0.27
Cer. Crops	0.02	0.04	0.07	0.10	0.13
Sugar	0.01	0.03	0.04	0.06	0.08
Veg. Fruit	0.04	0.10	0.16	0.22	0.29
Egypt					
Wheat	-0.02	-0.06	-0.12	-0.17	-0.22
Cer. Crops	0.01	0.03	0.07	0.12	0.18
Sugar	0.00	-0.01	0.00	0.00	0.01
Veg. Fruit	-0.01	-0.03	-0.04	-0.06	-0.07
Tunisia					
Wheat	0.13	0.24	0.39	0.59	0.87
Cer. Crops	0.12	0.23	0.37	0.55	0.75
Sugar	0.11	0.21	0.35	0.53	0.75
Veg. Fruit	0.21	0.38	0.62	0.97	1.49
Morocco					
Wheat	0.11	0.22	0.34	0.53	0.76
Cer. Crops	0.07	0.13	0.21	0.32	0.44
Sugar	0.03	0.06	0.10	0.15	0.19
Veg. Fruit	0.04	0.07	0.11	0.15	0.19
Algeria and Libya					
Wheat	0.01	0.01	0.02	0.02	0.02
Cer. Crops	0.01	0.02	0.02	0.03	0.03
Sugar	0.01	0.01	0.01	0.01	0.02
Veg. Fruit	0.01	0.02	0.02	0.03	0.03

Table 9. Climate change impacts on agriculture in the 11 SEMCs: Changes in net imports of agricultural commodities (in %) with respect to the no climate change baseline in 2050

	Turkey	MDE	Egypt	Tunisia	Morocco	Algeria and Libya
Wheat	2.02	3.55	-0.53	9.52	11.55	-0.02
Cer. Crops	-3.98	0.50	2.86	1.35	5.09	0.03
Sugar	0.38	0.29	0.02	1.67	0.56	0.02
Veg. Fruit	-0.44	-4.51	1.17	10.20	-0.37	0.02

5. An assessment of the combined effects on the 11 SEMCs

This section of the report assesses the combined effects of climate change on the ecosystem and agriculture.

At the aggregate level, the implications for GDP are basically additive (the combined impacts coincide almost perfectly with the sum of the two sectors considered individually) as shown in Figure 6, and are largely dominated by tourism effects. This is not surprising given the large share of value added built up by the tourism industry in the area. The economic effects start to be detectable after 2025 and are higher in the Fragmented Cooperation scenario, which assumes a lower level of intervention in defence of the ecosystem.

Some important country specificities are also worth noting, however (Table 10). For instance in Turkey, Tunisia and Morocco, the impact on GDP deriving from yield losses is comparable in magnitude with that from the lower degree of tourism attractiveness. Accordingly, in 2050 the impact on GDP in these countries, when the effects on the agricultural sector are considered, are on average 127%, 170% and 83% higher than when they are not taken into account.

Figure 6. Climate change impacts in the 11 SEMCs, combined effects on tourism and agriculture: Changes in GDP (in %) with respect to the no climate change baseline (temperature increase of +1.9°C compared with 2000)

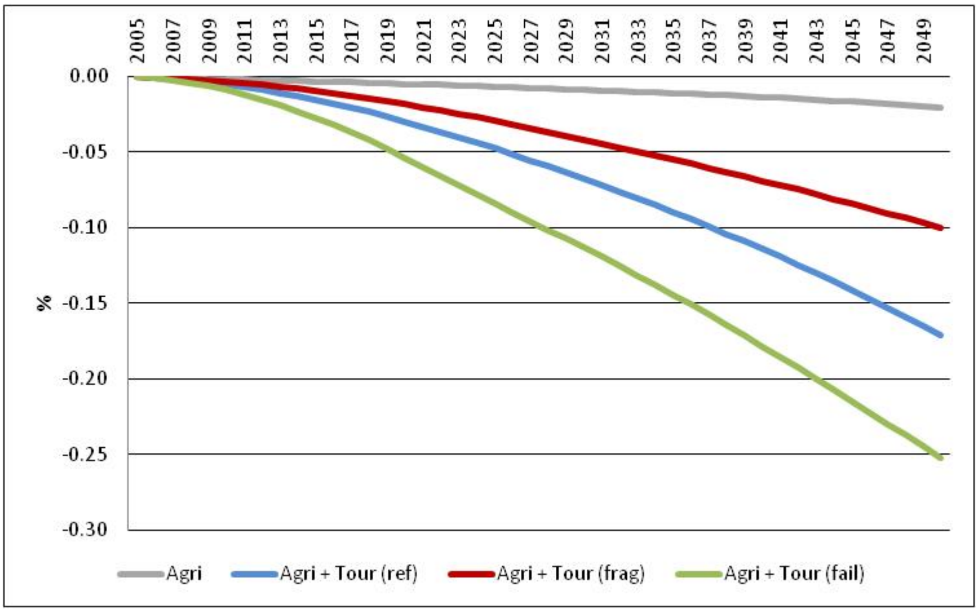


Table 10. Climate change impacts in the 11 SEMCs, combined effects on tourism and agriculture: Changes in GDP (in %) with respect to the no climate change baseline (temperature increase of +1.9°C compared with 2000)

	2010	2020	2030	2040	2050
		Turkey			
Agriculture only	0.00	-0.01	-0.01	-0.02	-0.02
Agri. + Tourism (Ref. Scen.)	0.00	-0.01	-0.02	-0.03	-0.04
Agri. + Tourism (Frag. Coop.)	0.00	-0.01	-0.01	-0.02	-0.03
Agri. + Tourism (Failed Coop.)	0.00	-0.01	-0.02	-0.03	-0.05

Table 10. cont'd

Middle East					
Agriculture only	0.00	0.00	-0.01	-0.01	-0.01
Agri. + Tourism (Ref. Scen.)	-0.01	-0.04	-0.10	-0.16	-0.24
Agri. + Tourism (Frag. Coop.)	0.00	-0.03	-0.06	-0.10	-0.13
Agri. + Tourism (Failed Coop.)	-0.01	-0.08	-0.17	-0.26	-0.36
Egypt					
Agriculture only	0.000	0.001	0.002	0.003	0.003
Agri. + Tourism (Ref. Scen.)	0.00	0.00	-0.01	-0.02	-0.04
Agri. + Tourism (Frag. Coop.)	0.00	0.00	0.00	-0.01	-0.02
Agri. + Tourism (Failed Coop.)	0.00	-0.01	-0.02	-0.04	-0.07
Tunisia					
Agriculture only	-0.01	-0.04	-0.07	-0.12	-0.19
Agri. + Tourism (Ref. Scen.)	-0.01	-0.04	-0.09	-0.18	-0.33
Agri. + Tourism (Frag. Coop.)	-0.01	-0.04	-0.08	-0.15	-0.26
Agri. + Tourism (Failed Coop.)	-0.01	-0.05	-0.12	-0.23	-0.41
Morocco					
Agriculture only	0.00	-0.01	-0.02	-0.03	-0.04
Agri. + Tourism (Ref. Scen.)	0.00	-0.01	-0.03	-0.06	-0.10
Agri. + Tourism (Frag. Coop.)	0.00	-0.01	-0.02	-0.04	-0.07
Agri. + Tourism (Failed Coop.)	0.00	-0.02	-0.04	-0.08	-0.14
Algeria and Libya					
Agriculture only	0.000	-0.001	-0.002	-0.002	-0.002
Agri. + Tourism (Ref. Scen.)	0.00	0.00	-0.01	-0.01	-0.02
Agri. + Tourism (Frag. Coop.)	0.00	0.00	0.00	-0.01	-0.01
Agri. + Tourism (Failed Coop.)	0.00	0.00	-0.01	-0.02	-0.03

Table 11 reports the impact on sectoral production in the 11 SEMCs in 2050 for the Reference Scenario, which is somewhat the intermediate one (the results for the Fragmented and Failed Cooperation scenarios are provided in appendix 1). As expected, the sectors most adversely affected remain the agricultural and the service ones, with the latter including recreational activities linked to tourism. Higher losses in crop production continue to be experienced by Turkey, Tunisia and Morocco. Yet the presence of the negative shock on tourism activity changes the sign for some of the crops produced, which, albeit remaining small, turns from being negative to positive. This is a typical second-order effect driven by the interaction of impacts. A decrease in tourism demand indeed implies a change in the composition of demand that can favour, among others, crop production. It is also worth noting that the generalised (slight) decline in investment brings about the contraction in GDP. Usually a lower GDP implies a lower remuneration of factors of production, including capital. In the ICES model, this is free to move internationally and therefore it shifts towards those regions where returns are higher.

Table 11. Climate change impacts in the Reference Scenario for the 11 SEMCs, combined effects on tourism and agriculture: Changes in sectoral production (in %) with respect to the no climate change baseline (temperature increase of +1.9°C compared with 2000) in 2050

	Turkey	Middle East	Egypt	Tunisia	Morocco	Algeria and Libya
Wheat	0.02	-0.49	0.52	-0.85	-0.61	0.16
Cer. Crops	-0.32	0.07	-0.12	-1.61	-0.17	0.07
Sugar	0.11	0.33	0.11	0.13	0.25	0.05
Veg. Fruit	0.08	0.19	0.22	-0.34	0.03	0.09
Livestock	0.18	0.52	0.06	-0.01	0.32	0.05
Coal	0.01	0.03	0.01	0.04	0.03	0.00
Oil	0.00	0.00	0.00	0.01	0.01	0.00
Gas	0.34	0.21	0.03	0.39	0.19	0.02
Oil_Pcts	-0.01	0.18	0.01	-0.10	0.09	0.01
Electricity	0.04	0.36	0.05	0.09	0.26	0.09
Industry	0.11	0.31	0.07	0.15	0.25	0.05
Services	-0.19	-0.87	-0.18	-0.74	-0.60	-0.09
Public Serv.	0.12	0.16	0.07	0.30	0.20	0.03
Investment	-0.07	-0.40	-0.08	-0.62	-0.19	-0.02

6. Conclusions

This report analyses the potential economic impacts of climate change on 11 SEMCs through the effects of changes on the coastal ecosystem and on agriculture. The impact is quantified through bottom-up studies assessing the consequences of the deterioration of the coastal ecosystem and protected areas for tourism arrivals, and the effects on yields of major crop families by mid-century. These data are then used as inputs into a world CGE model that quantifies the impact on GDP, sectoral production and prices up to the mid-century. The results point to a generalised, albeit moderate loss in the region's GDP, ranging from -0.1% to -0.25% in 2050. The countries that are more adversely affected are Tunisia (-0.26%/-0.41% of GDP in 2050) and Morocco (-0.04%/-0.14% of GDP in 2050). High losses (-0.13%/-0.36% of GDP in 2050) are also highlighted for the Middle East aggregate (including among others Jordan, Syria, Palestine, Lebanon and Israel). Negative impacts are more perceptible, but still moderate, at the sectoral level. In the Reference Scenario, the average production loss for the agricultural sector is -0.5% in 2050, with a peak of -1.4% in Tunisia. The average losses of the services sector in the 11 SEMCs affected by the decline in demand for tourism services range, depending on the scenario, between -0.25% and -0.7% in 2050 with a peak of -1.32% in the Middle East. In general, GDP losses linked to tourism activity are greater than those related to agriculture, but this is not the case for Tunisia or Morocco, where the two are comparable in magnitude.

The CGE approach captures interesting second-order effects. First, it is shown that factor substitution and changes in the composition of demand tend to reduce the direct impacts. Indeed, when compared with direct costs, final GDP losses are 57% and 88% smaller in the case of tourism and agriculture respectively. Second, the negative effects typically expand outside the sectors initially concerned. For instance, it is shown that lower crop yields and demand for tourism, through the induced decline in GDP, generate a generalised contraction in investment. In the presence of capital mobility, this switches to countries where capital returns are higher, that is, outside the 11 SEMCs. Third, all this boils down to a moderate re-ranking of losses across countries: those with the highest direct costs are not necessarily those with the highest GDP losses.

In all, it may appear that the costs of climate change for the 11 SEMCs could be limited. Yet this study considers the potential impacts related to changes in climatic conditions on just two sectors. Therefore, the costs highlighted are only a fraction of the losses that climate change could generate in the area.

Moreover, many other caveats suggest a certain degree of caution in the interpretation of results. The more important one relates to the fact that the analysis is conducted on the 11 SEMCs assuming that climate change affects only this region. The implications of this assumption for costs are ambiguous. On the one hand, it could lead to an overestimation of costs, as some regions could be hit harder and this could somehow favour the 11 SEMCs; on the other hand, economic losses outside the 11 SEMCs could imply lower demand for their goods and services, which could exacerbate an initial loss.

Furthermore, specific caveats relate also to the nature of the investigation tool used, i.e. a CGE model. Stating the more typical one, CGE models are based on a Walrasian view of the economic system, where all markets are in equilibrium and respond to the decision of optimising agents. Accordingly, they cannot examine the behaviour of imperfect markets. In CGE models, the adjustment to equilibrium is instantaneous, and thus they cannot represent frictions or transitions. CGE models are calibrated to some specific years, so they can offer reliable information only if the economic context remains reasonably similar to the initial one. CGE models are usually static and, when dynamic, they usually allow for myopic expectations and systematic errors.

Nonetheless, the indications provided are still useful qualitatively in terms of highlighting the mechanisms at play and also quantitatively in terms of the order of magnitude involved.

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Appendix 1. Impact on sectoral production in the Fragmented and Failed Cooperation scenarios

Table A1. Climate change impacts in the Fragmented Cooperation scenario for the 11 SEMCs, combined effects on tourism and agriculture: Changes in sectoral production (in %) with respect to the no climate change baseline (temperature increase of +1.9°C compare with 2000) in 2050

	Turkey	Middle East	Egypt	Tunisia	Morocco	Algeria and Libya
Wheat	-0.06	-0.45	0.50	-1.10	-0.72	0.10
Cer. Crops	-0.37	-0.04	-0.13	-1.52	-0.29	0.05
Sugar	0.05	0.16	0.06	-0.02	0.13	0.03
Veg. Fruit	-0.02	-0.02	0.17	-0.55	-0.06	0.05
Livestock	0.06	0.25	0.02	-0.15	0.15	0.03
Coal	0.00	0.02	0.00	0.02	0.02	0.00
Oil	0.00	0.00	0.00	0.01	0.00	0.00
Gas	0.18	0.11	0.02	0.22	0.09	0.01
Oil_Pcts	-0.02	0.09	0.01	-0.16	0.02	0.01
Electricity	0.02	0.18	0.03	-0.08	0.13	0.05
Industry	0.05	0.15	0.03	-0.01	0.14	0.03
Services	-0.10	-0.46	-0.10	-0.45	-0.33	-0.05
Public Serv.	0.07	0.08	0.04	0.16	0.10	0.02
Investment	-0.05	-0.22	-0.04	-0.48	-0.14	-0.02

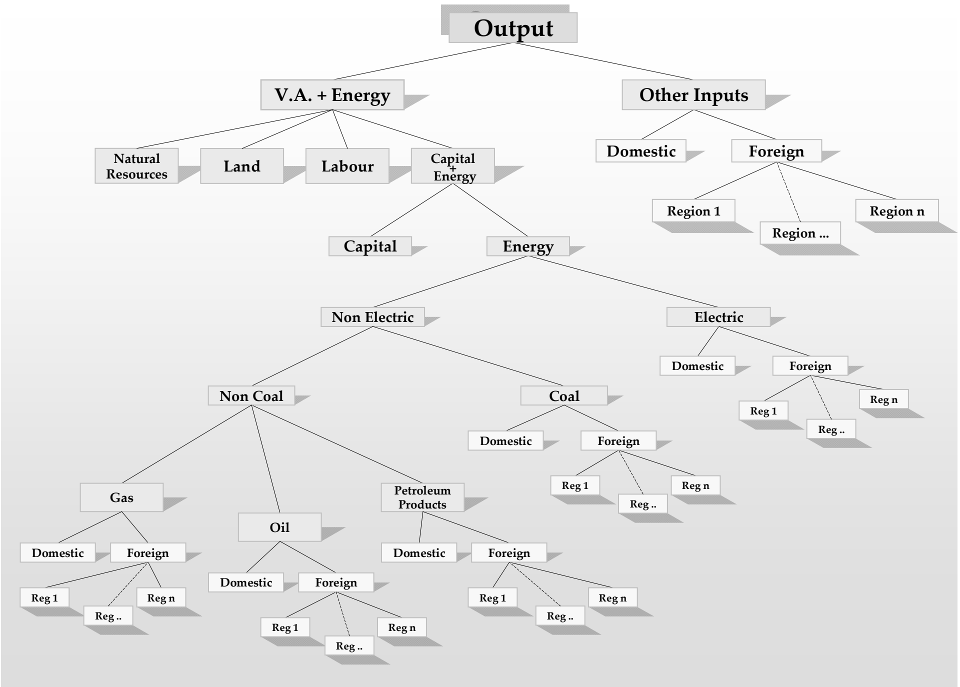
Table A2. Climate change impacts in the Failed Cooperation scenario for the 11 SEMCs, combined effects on tourism and agriculture: Changes in sectoral production (in %) with respect to the no climate change baseline (temperature increase of +1.9°C compared with 2000) in 2050

	Turkey	Middle East	Egypt	Tunisia	Morocco	Algeria and Libya
Wheat	0.11	-0.55	0.53	-0.54	-0.45	0.24
Cer. Crops	-0.27	0.19	-0.09	-1.72	0.00	0.10
Sugar	0.17	0.50	0.18	0.31	0.40	0.07
Veg. Fruit	0.18	0.42	0.27	-0.10	0.16	0.15
Livestock	0.30	0.80	0.11	0.14	0.54	0.07
Coal	0.01	0.05	0.01	0.05	0.04	0.00
Oil	0.00	0.01	0.01	0.01	0.01	0.00
Gas	0.50	0.32	0.05	0.57	0.32	0.04
Oil_Pcts	0.01	0.27	0.02	-0.03	0.19	0.02
Electricity	0.07	0.55	0.07	0.28	0.45	0.14
Industry	0.17	0.47	0.11	0.34	0.40	0.08
Services	-0.28	-1.32	-0.29	-1.09	-0.99	-0.15
Public Serv.	0.17	0.23	0.11	0.46	0.33	0.06
Investment	-0.10	-0.58	-0.13	-0.79	-0.27	-0.04

Appendix 2. Short description of the ICES model

As in all computable general equilibrium (CGE) models, the intertemporal computable equilibrium system (ICES) makes use of the Walrasian perfect competition paradigm to simulate market adjustment processes, although the inclusion of some elements of imperfect competition is also possible. Industries are modelled through a representative firm, minimising costs while taking prices as given. In turn, output prices are given by average production costs. The production functions are specified through a series of nested CES functions. Domestic and foreign inputs are not perfect substitutes, according to the so-called 'Armington' assumption (Figure A1).

Figure A1. Nested tree structure for industrial production processes in the ICES model

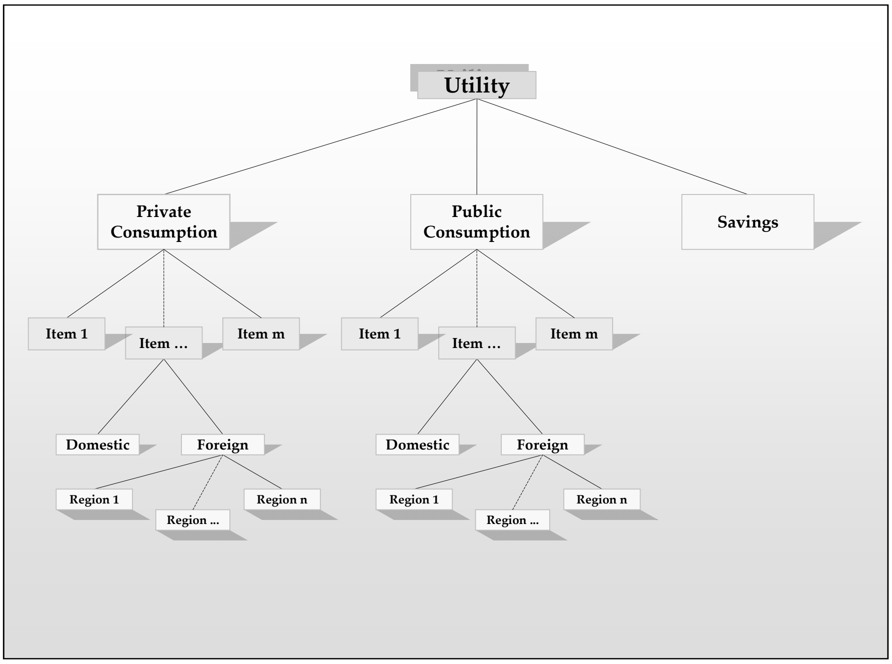


A representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labour and capital). Capital and labour are perfectly mobile domestically but immobile internationally. Land and natural resources, on the other hand, are industry-specific. This income is used to finance three classes of expenditure: aggregate household consumption, public consumption and savings. The expenditure shares are generally fixed, which amounts to saying that the top-level utility function has a Cobb-Douglas specification.

Public consumption is split into a series of alternative consumption items, again according to a Cobb-Douglas specification. Almost all expenditure, however, is actually concentrated in one specific industry: non-market services.

Private consumption is analogously split into a series of alternative, composite Armington aggregates. Yet the functional specification used at this level is the constant difference in elasticities form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods (Figure A2).

Figure A2. Nested tree structure for final demand in the ICES model



Investment is internationally mobile: savings from all regions are pooled and then investment is allocated so as to achieve equality of expected rates of return to capital.

In this way, savings and investments are equalised at the world, but not at the regional level. Because of accounting identities, any financial imbalance mirrors a trade deficit or surplus in each region.

The recursive-dynamic engine for the model can replicate dynamic economic growths based on endogenous investment decisions. As is standard in the CGE literature, the dynamic is recursive. It consists of a sequence of static equilibria (one for each simulation period, which in the present exercise is the year) linked by the process of capital accumulation. As investment decisions that build regional capital stocks are taken from one year to the other, i.e. not taking into account the whole simulation period, the planning procedure is 'myopic'. Two factors drive endogenous investment and its international allocation: the equalisation of the expected rate of return to capital and the international GDP differentials. In other words, a country can attract more investment and increase the rate of growth of its capital stock when its GDP and its rate of return to capital are relatively higher than those of its competitors.

About MEDPRO

MEDPRO – Mediterranean Prospects – is a consortium of 17 highly reputed institutions from throughout the Mediterranean funded under the EU's 7th Framework Programme and coordinated by the Centre for European Policy Studies based in Brussels. At its core, MEDPRO explores the key challenges facing the countries in the Southern Mediterranean region in the coming decades. Towards this end, MEDPRO will undertake a prospective analysis, building on scenarios for regional integration and cooperation with the EU up to 2030 and on various impact assessments. A multi-disciplinary approach is taken to the research, which is organised into seven fields of study: geopolitics and governance; demography, health and ageing; management of environment and natural resources; energy and climate change mitigation; economic integration, trade, investment and sectoral analyses; financial services and capital markets; human capital, social protection, inequality and migration. By carrying out this work, MEDPRO aims to deliver a sound scientific underpinning for future policy decisions at both domestic and EU levels.

Title	MEDPRO – Prospective Analysis for the Mediterranean Region
Description	MEDPRO explores the challenges facing the countries in the South Mediterranean region in the coming decades. The project will undertake a comprehensive foresight analysis to provide a sound scientific underpinning for future policy decisions at both domestic and EU levels.
Mediterranean countries covered	Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia and Turkey
Coordinator	Dr. Rym Ayadi, Centre for European Policy Studies (CEPS), rym.ayadi@ceps.eu
Consortium	Centre for European Policy Studies, **CEPS**, Belgium; Center for Social and Economic Research, **CASE**, Poland; Cyprus Center for European and International Affairs, **CCEIA**, Cyprus; Fondazione Eni Enrico Mattei, **FEEM**, Italy; Forum Euro-Méditerranéen des Instituts de Sciences Economiques, **FEMISE**, France; Faculty of Economics and Political Sciences, **FEPS**, Egypt; Istituto Affari Internazionali, **IAI**, Italy; Institute of Communication and Computer Systems, **ICCS/NTUA**, Greece; Institut Europeu de la Mediterrania, **IEMed**, Spain; Institut Marocain des Relations Internationales, **IMRI**, Morocco; Istituto di Studi per l'Integrazione dei Sistemi, **ISIS**, Italy; Institut Tunisien de la Compétitivité et des Etudes Quantitatives, **ITCEQ**, Tunisia; Mediterranean Agronomic Institute of Bari, **MAIB**, Italy; Palestine Economic Policy Research Institute, **MAS**, Palestine; Netherlands Interdisciplinary Demographic Institute, **NIDI**, Netherlands; Universidad Politecnica de Madrid, **UPM**, Spain; Centre for European Economic Research, **ZEW**, Germany
Budget and Funding	Total budget: €3,088,573 EC-DG RESEARCH contribution: €2,647,330
Duration	1 April 2010 – 31March 2013 (36 months)
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