Mediterranean countries’ food consumption and sourcing patterns:
An Ecological Footprint viewpoint

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HIGHLIGHTS
• Ecological Footprint accounting is applied to Mediterranean countries’ food sector.
• Food consumption and sourcing profiles for Mediterranean countries are investigated.
• Dietary patterns are among the key drivers of the region’s ecological deficit.
• France is the sole biocapacity self-sufficient country in terms of food provision.
• Calorie-adequate diets and changes in dietary patterns could reduce the Footprint.

GRAPHICAL ABSTRACT

ABSTRACT
Securing food for growing populations while minimizing environmental externalities is becoming a key topic in the current sustainability debate. This is particularly true in the Mediterranean region, which is characterized by scarce natural resources and increasing climate-related impacts.

This paper focuses on the pressure Mediterranean people place on the Earth ecosystems because of their food consumption and sourcing patterns and then explores ways in which such pressure can be reduced. To do so, it uses an Ecological-Footprint-Extended Multi-Regional Input-Output (EF-MRIO) approach applied to 15 Mediterranean countries. Results indicate that food consumption is a substantial driver of the region’s ecological deficit, whereby demand for renewable resources and ecosystems services outpaces the capacity of its ecosystems to provide them. Portugal, Malta and Greece are found to have the highest per capita food Footprints (1.50, 1.25 and 1.22 global hectares (gha), respectively), while Slovenia, Egypt and Israel have the lowest (0.63, 0.64 and 0.79 gha, respectively). With the exception of France, all Mediterranean countries rely on the biocapacity of foreign countries to satisfy their residents’ demand for food.

By analyzing the effect of shifting to a calorie-adequate diet or changing dietary patterns, we finally point out that the region’s Ecological Footprint – and therefore its ecological deficit – could be reduced by 8% to 10%.

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1. Introduction

Humanity is facing deeply interlinked economic, social and environmental crises that stem, in large part, from current unsustainable patterns of consumption and production (Clay, 2011). Humanity is now consuming more resources than ever, both per person and in absolute terms (e.g., Galli et al., 2014; Steffen et al., 2015). Therefore, for achieving global sustainable development, fundamental changes in the way societies consume and produce are indispensable (UNEP, 2012a, 2012b).

By 2050 the world’s population will reach 9.7 billion, 32% higher than today (UN-DESA, 2015). Urbanization will continue at an accelerated pace, and about 66% of the world's population will be urban (compared to 54% today) (UN-DESA, 2014). To feed this larger, urbanized and richer population, Alexandratos and Bruinsma (2012) projected that a 60% increase in agricultural production is needed to provide an adequate food supply from 2006 to 2050. According to Davis et al. (2016), the environmental burden from the food sector will likely grow in this same period, despite societal improvements in agricultural production efficiencies.

The provision of food is one of the vital services that nature provides to humanity (Fischler, 1988; Nordström et al., 2013). Nonetheless, the exploitation of nature to meet humanity’s demand for food is among the major causes of environmental degradation (Foley et al., 2011; Ge hath et al., 2016; Pintstrup-Andersen and Pandya-Lorch, 1998). The food we choose, its production and distribution chains, and the way in which we eat have multifaceted effects on our environment, society and economy (DeFries et al., 2004; Foley et al., 2005; Vitousek et al., 1997). This places food at the heart of the sustainability debate (Ehrlich et al., 1993). Moreover, the way in which humans acquire food, through agriculture and food systems, is one of the largest contributors to biodiversity loss, greenhouse gas emissions, and agrochemical pollution of ecosystems (MEA, 2005; IPCC, 2013; IAASTD, 2009).

Environmental degradation in the Mediterranean has reached a level that requires immediate action (UNEP, 2010). With urbanization and rising incomes, typical dietary patterns are shifting towards consumption patterns based on animal products, requiring more water, land and energy (Pimentel and Pimentel, 2003; Gerbens-Leenes and Nonhebel, 2005; Lundqvist et al., 2008) and increasing greenhouse gas emissions (Carlsson-Kanyama and Gonzalez, 2009). A growing body of research is showing that changes in our food production and distribution systems and in our dietary choices can however achieve substantial reductions in food-related GHG emissions (Marlow et al., 2009; Garnett, 2011; Macdiarmid et al., 2012; Vieux et al., 2012).

The aims of this paper are thus to: i) provide a benchmark assessment of the pressure Mediterranean residents place on ecosystems within and outside their region due to their current food production, trade and final consumption patterns; and ii) identify changes in dietary choices that could lower such pressure and ease access to food resources – through both domestic production and trade – in the long run.

2. Methodology and data sources

Three main datasets and their associated methodologies are used in this analysis:

- Food supply data from FAO Food Balance Sheets (FAO, 2015a);
- Ecological Footprint data drawn from Global Footprint Network’s National Footprint Accounts (NFAs) 2014 Edition, covering nearly 160 countries, for the year 2010 (GFN, 2014);
- Version 8 of the Global Trade Analysis Project (GTAP) Multi-Regional Input-Output (MRIO) model, which consists of 57 sectors – 12 of which are agricultural – and refers to 129 countries and regions for the year 2007 (GTAP, 2014; Narayanan et al., 2012).

2.1. Food supply

Countries’ food supply data is used here to assess the quantity of each food commodity available for utilization within a given country during the course of a year. This data is drawn from the FAOSTAT database (FAO, 2015a) and refers to the supply concept defined by FAO and used in compiling national food balance sheets (FAO, 2001):

\[ S_{d,u} = P_i + I_i - E_i + CS_i \]

where \( S_{d,u} \) is the total food supply for domestic utilization, \( P_i \) is the amount of each food product \( i \) domestically produced, \( I_i \) and \( E_i \) are the amount of each food product \( i \) imported and exported, respectively, and \( CS_i \) is the annual change in stocks (decrease or increase) of each food product \( i \) considered in the FAO food balance sheet.

On the utilization side, a distinction should be made between the quantities exported, fed to livestock, used for seed, processed for food and non-food uses, lost during storage and transportation, and the quantities provided as food supplies available for human consumption at the retail level. Distinction between food supply available for human consumption and real food consumption is not easily computed by the FAO food balance sheets and food consumption surveys would likely provide a more complete picture (FAO, 2001). We assume, however, that food supply data from the FAO food balance sheets provide a good first approximation of countries’ apparent food consumption.

Food supply data is expressed in terms of quantity (kg yr\(^{-1}\) or g day\(^{-1}\)) and, through the use of appropriate food composition factors for all primary and processed products, in terms of caloric value/energy (kcal cap\(^{-1}\) day\(^{-1}\)). By dividing food supply data by population data, per capita figures expressed in kcal cap\(^{-1}\) day\(^{-1}\) are obtained (FAO, 2001).

2.2. Ecological Footprint analysis

The Ecological Footprint (Wackernagel et al., 1999) is a biomass-based resource accounting tool tracking key resource provisioning and one critical regulating ecosystem service (i.e., climate stabilization through carbon sequestration) that humans consume (aggregated into a metric called Ecological Footprint) and comparing it with the biosphere’s supply of such provisioning and regulating services (aggregated into a metric called biocapacity) (Galli et al., 2014). Both metrics are expressed in hectare-equivalent units, or global hectares (gha), which represent productivity-weighted hectares (Galli, 2015). Full details on the calculation of the two metrics as well as their limitations can be found in Borucke et al. (2013).

Adopting a consumer-based approach, a country’s Ecological Footprint is calculated by tracking the ecological assets (i.e. crop-, grazing-, forest-, fish-, built-up and carbon-uptake land) appropriated by national production activities and then adding the ecological assets embedded in imported goods and subtracting those embedded in exported goods (Galli et al., 2014). While country-level Ecological Footprint analyses are usually performed via a process-based approach relying on physical trade flows data (Borucke et al., 2013), the detailed tracking of countries’ food consumption and sourcing profiles performed in this paper requires that the traditional Footprint method (Borucke et al., 2013; Wackernagel and Rees, 1996) be extended by means of the GTAP & Multi-Regional Input-Output (MRIO) model.

While a global model is used to run the analysis, results are provided for just 15 Mediterranean countries (Albania, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Malta, Morocco, Portugal, Slovenia, Spain, Tunisia, and Turkey). The decision to focus on the Mediterranean region

1 For primary commodities, production relates to the total domestic production whether inside or outside the agricultural sector (i.e. including non-commercial production and production in kitchen gardens). Production is reported at the farm level for primary crops (i.e. excluding pre-harvest and harvesting losses for crops) and livestock items and in terms of live weight for primary fish items. Production of processed commodities relates to the total output of the commodity at the manufacture level.
is motivated by the scope of the grant supporting this research; the
country selection was determined by the following criteria: A) countries with populations greater than 1 million inhabitants direct-
ly bordering the Mediterranean Sea and/or characterized by biomes
typical of the Mediterranean region, and B) availability of country’s
MRIO and Ecological Footprint data.

The traditional Footprint methodology (as described in Borucke
et al., 2013) is first used to calculate the Ecological Footprint of all na-
tional production activities \( (EF_P) \). Secondly, to estimate the overall na-
tional Ecological Footprint of consumption by means of the EF-MRIO
model, six environmental extension tables are required, which initially
allocate the Ecological Footprint of production \( (EF_P) \) for crop-, grazing-
, forest-, built-up and carbon-uptake land as well fishing grounds to
each of the 57 producing economic sectors identified by GTAP 8. The
\( EF_P \) for cropland is allocated to GTAP sectors 1 to 8; the \( EF_P \) for grazing
land is allocated to GTAP sectors 9 to 12; the \( EF_P \) for forest land is allocat-
d to sector 13 and that of fishing grounds to sector 14; the \( EF_P \) for
carbon-uptake land is allocated to each one of the 57 sectors depending
on the basis of each sector’s share of the total emissions as provided by
the energy-environmental extension already present in GTAP; the \( EF_P \) of
built-up land is assigned to each one of the 57 sector depending on
the sector’s value added to the country’s GDP. See Appendix A for
the full list of GTAP 8 sectors.

Following Weinzettel et al. (2011) and Ewing et al. (2012), the na-
tional Ecological Footprint of consumption \( (EF_C) \) is thus derived accord-
ing to Eq. (1):

\[
EF_C = F(1 - A)^{-1} y_N
\]

where \( F \) is the environmental extension matrix (direct \( EF_P \) of sectors
normalized per unit of sector output, which is expressed in gha \( $^{-1} \))
derived from the above \( EF_P \)-to-sector allocation; \( y_N \) is the country total nal
demand for goods, expressed in $; \( I \) is the identity matrix (a matrix of
zeros for 57 columns and rows with diagonal consisting of one’s) and
\( A \) is the technical coefficients matrix (representing the Leontief inverse),
which reflects the monetary exchange between each sector to produce
one currency unit worth of output from a specific sector of the economy.
Eq. (1) thus accounts for all indirect/upstream resource requirements
from final consumption and also allows determining the Footprint em-
bedded in multilateral trade exchanges (i.e., the natural resources and
ecological services required to produce commodities and services, and
exchange them on the international market).

As the EF-MRIO model calculates the resource requirements of each
sector in the economy - including both food-related and food-unrelated
sectors (see Appendix A) – household resource requirements are then
calculated by analyzing the composition of household final demand for
goods and services by COICOP\(^2\) consumption categories such as
food, transport and the like. Different goods and services are produced
with varying inputs from the different economic sectors in the econo-
my. The household demand matrix ( Concordance table) assigns to each
consumption category the respective amount of resource require-
ments by sector ( Wiedmann et al., 2006 ). We refer to the household re-
source requirements by consumption category as Consumption Land-
Use Matrix (CLUM), which displays the biomass requirements by land
 type for each consumption category. We then refer to the Ecological
Footprint of household’s food consumption (i.e., the resource provision-
ing and the regulatory services demanded to provide households with
the food they consume) as food Footprint or \( EF_F \).

The \( EF_F \) of any country thus include a) direct demands such as the
cropland Footprint needed to produce wheat, the grazing land needed
to produce meat, the fishing ground needed to produce fish; and b) indirect demands such as the carbon Footprint from CO\(_2\) released
during food production/cultivation (e.g., emissions from fertilizer and
pesticide production, farm vehicle CO\(_2\) emissions, emissions from electricity-operated machineries used in harvesting, processing, etc.)
and trade, as well as the built-up land Footprint occupied by food
industries.

Given the impossibility to distinguish between resources available
for food production vs. resources available for other uses (e.g., fibers, etc.)
in calculating a country’s biocapacity, \( EF_F \) is compared in this study
with the Ecological Footprint of food producing sectors \( (EF_P) \) to get
a macro-level insight on each country’s food sourcing profile
(i.e., the percentage of \( EF_F \) provided by local ecosystems within each
nation vs. the amount imported from ecosystems in foreign countries).
\( EF_F \) is calculated as the sum of the \( EF_F \) of each land type allocated to
GTAP sectors 1 to 12 and 14.

2.3. Calculating Footprint intensities and Footprint reduction potentials

The Footprint intensity of each country’s dietary consumption pattern
(i.e., its food Footprint intensity) is also used for cross-country comparisons
and for assessing Footprint reduction potentials: it is calculated by
dividing the country’s household \( EF_F \) by its food supply (see Section 2.1)
and expressed in gha kcal\(^{-1}\). Moreover, an approach similar to Davis et al. (2014)
is used to account for diets’ moderation. However, while Davis et al. (2014) considered a calories–adequate diet of 3000 kcal cap\(^{-1}\) day\(^{-1}\)
with 20% calories from animal origin, we opted for using the FAO–
recommended benchmark of 2500 kcal cap\(^{-1}\) day\(^{-1}\), and assumed unvar-
ied compositions of countries’ diets. This assumption was implemented to
keep the effect of an overall reduction in calories separate from that of
a change in food Footprint intensity resulting from a change in diet com-
position (see Section 3). This reduction could also be achieved in part through
reductions in food losses and waste. Resource efficiency was then consid-
ered in terms of national food Footprint intensities (expressed in gha
demanded per kcal produced), taking the highest actual efficiency ob-
served in the region (that of Egypt) as a benchmark.

3. Results

Food accounts for a large part of the Mediterranean region’s overall
Ecological Footprint. In the 15 countries analyzed, food and non-
alcoholic beverages account for an average 0.9 gha per person, which rep-
resents 28% of the regional Ecological Footprint (approximately 3.2 gha
per person). Food, therefore, constitutes the largest sector of demand
ahead of transportation, whose share accounts for 22% (see Fig. 1).

Behind this regional average, there are important differences in the
\( EF_F \) of individual Mediterranean countries (see Fig. 1): Portugal has by
far the largest per capita \( EF_F \) in the region at 1.5 gha, followed by Malta
(1.2 gha) and Greece (1.2 gha). Egypt and Slovenia, in contrast, have
per capita \( EF_F \) levels that are just over half that of Portugal with
0.64 gha and 0.63 gha, respectively. Countries in the region also exhibit
considerable variability in the share of \( EF_F \) in their total Ecological Foot-
prints. While in Slovenia \( EF_F \) represents only 14% of total Ecological Foot-
print, it represents about 45% of the total in Albania and Tunisia and up to
50% in Morocco. Accordingly, food represents the largest share of the Eco-
logical Footprint for 9 out of the 15 countries considered in the region.

Mediterranean countries also vary considerably in terms of their
food supply (see Fig. 2A). Most countries in the region have a daily
food supply that is 20% to 40% higher than the average 1 FAO–

\(^2\) COICOP stands for Classification Of Individual Consumption According to Purpose and
is the internationally agreed classification system for reporting household consumption
expenditures. It is published by the United Nations Statistics Division for use in Expendi-
tures Classification, National Accounts, Household Budget Survey and the Consumer Price
Index.

\(^3\) Per capita minimum daily energy requirements depend on many factors such as age,
gender, weight, height and physical activity. For adult persons (over 18), values vary from
2000 (sedentary) to 3200 (active) kcal cap \(^{-1}\) day \(^{-1}\) for males, and from 1600 (sedentary)
to 2400 (active) kcal cap \(^{-1}\) day \(^{-1}\) for females (FAO, 2008). Due to the lack of data to derive
country-specific values, the FAO-determined value of 2,500 kcal cap \(^{-1}\) day \(^{-1}\) is used in
this study as a regional average benchmark.
determined minimum daily dietary energy requirement benchmark of 2500 kcal cap$^{-1}$ day$^{-1}$ (FAO et al., 1985; see also Pimentel and Pimentel, 2003). Cyprus is the only exception, with a food supply only 6% above the benchmark. Moreover, comparison of countries’ food Footprint intensities reveals a considerable spread, with the lowest value found in Egypt (4.98E-07 gha kcal$^{-1}$) and the highest in Portugal (1.17E-06 gha kcal$^{-1}$) (see Fig. 2B).

Protein-intensive diets are found in countries such as Portugal and Malta, which have the highest food Footprint intensity (see Fig. 2B). The reasons for Portugal’s high value are fourfold: 1) overall high food consumption (people in Portugal consume up to 3518 kcal cap$^{-1}$ day$^{-1}$, approximately 41% more than the FAO-recommended daily dietary energy requirement), 2) high proportion of products from the fish sector within the daily diet (contributing to 44% of the Portuguese food Footprint in 2010), 3) decreasing national fish landings (Baeta et al., 2009) balanced by increased imports (see FAO, Fisheries and Aquaculture Department, 2016) of fish commodities (contributing to an increase in the trade-embedded carbon Footprint) and 4) consumers’ preference to eating high trophic level fishes such as the Atlantic cod and tuna (especially skipjack tuna), which place a high demand on the planet’s marine primary production (Grunewald et al., 2015; Pauly and Christensen, 2002). Egypt’s low intensity is due to its low-protein, cereals- and vegetables-rich diet as well as the high productivity of its crops, which reduce its dependence on imported food and thus also on the carbon associated with trade (see Fig. 3).

At the regional level, $\varepsilon_{FP}$ and $\varepsilon_{FC}$ are nearly in balance (see Fig. 4), meaning that food production in the region requires as many renewable natural resources and ecosystem services as those associated with Mediterranean residents’ food consumption. However, a considerable variation among countries exists. France and Spain are the only two countries with a $\varepsilon_{FC}$ lower than their $\varepsilon_{FP}$ by 46% and 22%, respectively. Turkey’s $\varepsilon_{FP}$ and $\varepsilon_{FC}$ are nearly in balance. All other countries in the region have a $\varepsilon_{FC}$ higher than their $\varepsilon_{FP}$. In some cases the imbalance is particularly acute indicating a noticeable reliance on food resources from the outside: the $\varepsilon_{FP}$ is only 13% and 24% of the $\varepsilon_{FC}$ in Malta and Israel, respectively.

The simple comparison of the Ecological Footprints of food production and consumption can be further disaggregated to better understand the food production and sourcing profiles of individual countries, making a distinction between production for domestic food consumption, production for domestic non-food consumption, and...
production for exports. Similarly, total food consumption can be broken down between domestic sources and imports.

Looking at the $\text{EF}$ embedded in traded products, we observe that although some countries are net exporters of certain food categories, all the countries in the analysis – except France – rely on net imports of food biocapacity to satisfy the food consumption needs of their residents (Fig. 5). This highlights the role of ecosystems located in other countries in meeting the food needs of populations in Mediterranean countries.

Cereals represent the largest share of net $\text{EF}$ trade in all 15 countries of the region (see Fig. 5). On a per capita basis, external food-related biocapacity dependency is particularly high in small countries such as Cyprus, Israel and Malta as well as in Portugal (Fig. 5A). High per capita import dependency in small countries is consistent with findings from previous studies (e.g., Weinzettel et al., 2013) while Portugal’s high value is due to a high calories supply coupled with a low per capita biocapacity (Galli et al., 2015).

At the country level, Italy is the largest net importer of $\text{EF}$ for the consumption of all food types (Fig. 5B), primarily importing from France (wheat and bovine cattle, sheep and goats, horses), China (bovine cattle, sheep and goats, horses and vegetables, fruit, nuts) and Brazil (bovine cattle, sheep and goats, horses and cereal grains). Conversely, France exports mainly cereal-related $\text{EF}$ (i.e., wheat, cereal grains and oil seeds) to Italy, Germany and Spain and imports $\text{EF}$ embodied in

![Fig. 3. Per capita Ecological Footprint of food consumption ($\text{EF}_{FC}$) broken down by product type based on data for 2010.](image1)

![Fig 4. Per capita $\text{EF}_{F}$ and $\text{EF}_{C}$ for 15 selected Mediterranean countries and the region (Med15) average. Results are expressed in global hectares (gha).](image2)
Dairy, Vegetables, fruit, nuts, Cereals, Other Food

Fig. 5. EF embedded in net trade, by type of food, for 15 selected Mediterranean countries and the region average (Med15), in 2010. Results are expressed in global hectares (gha) in both per capita (A) and total (B) terms. Positive values in the y-axis indicate net import while negative values indicate net export flows.

fishing (from Norway, USA and China), bovine cattle, sheep and goats (from China, Brazil and New Zealand) and vegetables, fruit, nuts (from Spain, China and Madagascar). Spain exports EF embedded in vegetables, fruits, nuts (to France, Germany and UK), while it imports embedded EF mostly in cereal grains (from Brazil, France and Argentina) and in fishing (from South Africa, Norway and Morocco) (see the Supplementary Online Material for detailed results on the Footprint embedded in trade flows by product and trade partner).

Finally, Fig. 6A shows the reduction in EF, that countries could experience should they shift to a calories-adequate diet of 2500 kcal cap⁻¹ day⁻¹ (assuming no change in the dietary composition); Fig. 6B shows reductions in EF, that countries could experience if they were to keep the same current amount of food energy supply but shift the composition of diets to the least Footprint intensive one (see also Fig. 2B).

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Countries such as Italy, France, Turkey, Tunisia and Morocco, would achieve the same level of EF, reduction irrespective of the action taken (calories adequate shift or shift to less Footprint intensive diets). Slovenia, Egypt and Israel would obtain the higher saving by shifting to a calories adequate diet as they possess the three lowest dietary Footprint intensities. All other countries would benefit more (in terms of EF reduction) by keeping their current kcal level but shifting the composition of their diets towards increasing the consumption of cereals as well as unprocessed fruits and vegetables, while limiting the intake of protein, fat, sugar and salt (thereby lowering their food Footprint intensity).

4. Discussions & conclusions

The Mediterranean region is in a situation of severe ecological deficit, consuming around 40% more renewable natural resources and ecosystem services than it provides (Galli et al., 2015). The analysis presented in this paper reveals that household food consumption accounts for 28% of the Mediterranean region’s Ecological Footprint. In the majority of the analyzed countries, food consumption is the largest of the COICOP categories considered (see Fig. 1), while in France, Slovenia, Italy, Greece, Israel and Cyprus it represents the second highest share of the Ecological Footprint after transportation.

Food consumption is therefore a key area to consider when searching for means to reduce the environmental impacts of consumption in the region. Addressing these impacts entails dealing with increasing resource use efficiency and productivity (through sustainable intensification of food production), reducing food losses and waste (FLW), and moderating diets (especially the demand for meat and animal products) (Davis et al., 2016; Lacirignola et al., 2014), as several studies have demonstrated that solely increasing agricultural productivity might not be sufficient to reduce the environmental pressure of humanity’s growing food demand (e.g., Davis and D’Odorico, 2015; Davis et al., 2016; Jalava et al., 2014; Tilman and Clark, 2014) and that commodities’ consumption rate tends to increase when production efficiency increases (e.g., Jevons, 1866). As such, we explored the potential of three of the above strategies for Ecological Footprint reductions, which can be seen as elements of a sustainable consumption and production (SCP) program: reducing calorie intake through moderating diets, reducing FLW, and increasing resource use efficiency via changes in diets’ composition. Reductions in both caloric intake and food waste decrease the food Ecological Footprint. It is important in this regard to recognize that a substantial portion of the food footprint represents waste or discarded food in the supply chain or by households. The FAO estimates that approximately one-third of food supply is lost or wasted (FAO, 2012, 2013a, 2013b; Kummu et al., 2012). Thus a reduction in calorie consumption can entail both a moderation of diets and a decrease in waste by efficiency improvements in supply change as well as behavior change by households.

Overall, our analysis of the food-related Footprint saving options found that by shifting to a calories adequate diet of 2500 kcal cap⁻¹ day⁻¹, the EF of the Mediterranean region (considered here as the weighted-average of 15 countries analyzed) could potentially be reduced by 28%. This would lead to an overall reduction of 7.7% in the Ecological Footprint of the region. Conversely, should all countries adopt the least Footprint intensive diet, the food Footprint of the Mediterranean region could be reduced by 30% and the region’s overall Footprint by 8.3%. Should each country implement the best strategy to reduce its respective food Footprint, the region’s overall Ecological Footprint would be reduced by 10%.

Such a reduction could improve the region’s food security in aggregate by lowering the environmental externalities associated with the consumption of food: other things being equal, diets that require less biocapacity imply less demand for agricultural land whose scarcity and degradation (Zdruli et al., 2007; Zdruli, 2012) is a key issue for the region’s future food security, alongside water scarcity and biodiversity loss (CIHEAM and FAO, 2015; Lacirignola et al., 2014; Rastoin and Cheriet, 2010; UNEP, 2012c).

Implementing the three strategies investigated in this study would only address some of the multiple threats to future food security in the region. A fuller treatment would, in addition to the issue of moderating or otherwise changing diets, consider agricultural intensification and increasing resource use and sustainability. Additionally, the current issue of food and nutrition security in the Mediterranean region goes far beyond the issue of how many calories are consumed, as many in the region still lack vitamins and other micronutrients and many countries in the eastern and southern Mediterranean still have precarious food situations or are just overcoming food insecurity (Padilla et al., 2005; FAO, 2015b). National food security may not be sufficient to ensure food security at the individual level but arguably can improve food availability at the household and individual levels.
Moreover, we acknowledge that pressure on the region’s land resources also depends on food trade policies. For instance, food self-sufficiency might expose countries to domestic food supply disruption: countries with extreme self-sufficiency policies (e.g., import barriers, exports bans, and a complete reliance on domestic production), could be hit by supply disruption harder than countries with diversified food sourcing profiles. Conversely, dependence on imports can expose countries to external shocks such as those arising from production shocks affecting key commodity exporters and the policy responses that may follow (e.g., the grain export bans announced by several countries during the 2007–2008 food price crisis).

Leaving a more comprehensive analysis of these trade-related issues to future work, the comparative analysis of Mediterranean countries’ food consumption and food sourcing profiles provided in this paper identifies specific behavioral policy interventions and estimates their potential to support more sustainable consumption and production patterns. According to Leach et al. (2016), product-specific food Footprint values could also be used in the development of environmental impact food labels; these labels could support producers who provide sustainable products as well as trigger sustainable behavioral choices in consumers.

Although applied here to just 15 Mediterranean countries, our approach could be easily extended to approximately 130 world countries for which Ecological Footprint and MRIO data exist.

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Appendix A. GTAP 8 Data Base sectors

| GTAP sector number | GTAP sector CODE | Sector description | GTAP sector number | GTAP sector CODE | Sector description |
|--------------------|-----------------|--------------------|--------------------|-----------------|--------------------|
| 1                  | PDR             | Paddy rice         | 30                 | LUM             | Wood products      |
| 2                  | WHT             | Wheat              | 31                 | PPP             | Paper products, publishing |
| 3                  | GRO             | Cereal grains nec  | 32                 | _P_C_           | Petroleum, coal products |
| 4                  | V_F             | Vegetables, fruit, nuts | 33     | CRP             | Chemical, rubber, plastic products |
| 5                  | OSD             | Oil seeds          | 34                 | NMM             | Mineral products nec |
| 6                  | C_B             | Sugar cane, sugar beet | 35     | L_S             | Ferrous metals     |
| 7                  | PPB             | Plant-based fibers | 36                 | NIM             | Metals nec         |
| 8                  | OCR             | Crops nec          | 37                 | FMP             | Metal products     |
| 9                  | CTL             | Bovine cattle, sheep and goats, horses | 38 | MVH             | Motor vehicles and parts |
| 10                 | OAP             | Animal products nec | 39    | OTN             | Transport equipment nec |
| 11                 | RMRK            | Raw milk           | 40                 | ELE             | Electronic equipment |
| 12                 | WOL             | Wool, silk-worm cocoons | 41    | OME             | Machinery and equipment nec |
| 13                 | FRS             | Forestry           | 42                 | OMF             | Manufactures nec   |
| 14                 | FSH             | Fishing            | 43                 | ELY             | Electricity        |
| 15                 | COA             | Coal               | 44                 | GDT             | Gas manufacture, distribution |
| 16                 | OIL             | Oil                | 45                 | WTR             | Water              |
| 17                 | GAS             | Gas                | 46                 | CNS             | Construction       |
| 18                 | OMN             | Minerals nec       | 47                 | TRD             | Trade              |
| 19                 | CMT             | Bovine meat products | 48    | OTP             | Transport nec      |
| 20                 | OMT             | Meat products nec  | 49                 | WTP             | Water transport    |
| 21                 | VOL             | Vegetable oils and fats | 50   | ATP             | Air transport      |
| 22                 | MIL             | Dairy products     | 51                 | CMN             | Communication      |
| 23                 | PCR             | Processed rice     | 52                 | O_FI            | Financial services nec |
| 24                 | SGR             | Sugar              | 53                 | ISR             | Insurance          |
| 25                 | OFD             | Food products nec  | 54                 | OBS             | Business services nec |
| 26                 | _B_T_           | Beverages and tobacco products | 55 | ROS             | Recreational and other services |
| 27                 | TEX             | Textiles           | 56                 | OSG             | Public Administration, Defense, Education, Health |
| 28                 | WAP             | Wearing apparel    | 57                 | DWE             | Dwellings          |
| 29                 | LEA             | Leather products   |                    |                 |                    |

Fig. 6. Per capita EFc of 15 Mediterranean countries and Footprint saving due to shifting to a calories-adequate diet (A) or adopting the region’s lowest Footprint intensive diet (B), in 2010. In each figure, the height of the bar indicates the current per capita value, light colors indicate the Footprint saving associated with dietary or efficiency changes and the darker colors indicate the resulting (after-saving) Footprint value.
Appendix B. GTAP 8 Data Base countries and regions

| GTAP Country CODE | Country NAME | GTAP Country CODE | Country NAME | GTAP Country CODE | Country NAME |
|------------------|-------------|------------------|-------------|------------------|-------------|
| ALB              | Albania     | IDN              | Indonesia   | ROU              | Romania     |
| ARE              | United Arab Emirates | IND          | India       | RUS              | Russian Federation |
| ARG              | Argentina   | IRL              | Ireland     | SAU              | Saudi Arabia |
| ARM              | Armenia     | IRN              | Iran, Islamic Republic | SEN         | Senegal     |
| AUS              | Australia   | ISR              | Israel      | SGP              | Singapore   |
| AUT              | Austria     | ITA              | Italy       | SLV              | El Salvador |
| AZE              | Azerbaijan  | JPN              | Japan       | SVK              | Slovakia    |
| BEL              | Belgium     | KAZ              | Kazakhstan  | SVN              | Slovenia    |
| BGD              | Bangladesh  | KEN              | Kenya       | SWE              | Sweden      |
| BGR              | Bulgaria    | KGZ              | Kyrgyzstan  | THA              | Thailand    |
| BHR              | Bahrain     | KHM              | Cambodia    | TUN              | Tunisia     |
| BLR              | Belarus     | KOR              | Korea, Republic of | TUR         | Turkey      |
| BOL              | Bolivia, Plurinational Republic of | KWT          | Kuwait      | TGN              | Taiwan      |
| BRA              | Brazil      | LAO              | Lao People's Democratic Republic | TZA          | Tanzania, United Republic of |
| BWA              | Botswana    | LKA              | Sri Lanka   | UGA              | Uganda      |
| CAN              | Canada      | LIT              | Lithuania   | UKR              | Ukraine     |
| CHE              | Switzerland | LUX              | Luxembourg  | URV              | Uruguay     |
| CHL              | Chile       | LVA              | Latvia      | USA              | United States of America |
| CHN              | China       | MAR              | Morocco     | VEN              | Venezuela   |
| CIV              | Cote d’Ivoire | MDG            | Madagascar  | VNM              | Viet Nam    |
| CMR              | Cameroon    | MEX              | Mexico      | XAC              | South Central Africa |
| COL              | Colombia    | MLT              | Malta       | XCA              | Rest of Central America |
| CRI              | Costa Rica  | MNG              | Mongolia    | XCB              | Caribbean   |
| CYP              | Cyprus      | MOZ              | Mozambique  | XCF              | Central Africa |
| CZE              | Czech Republic | MUS           | Mauritius   | XEA              | Rest of East Asia |
| DEU              | Germany     | MVH              | Malawi      | XEC              | Rest of Eastern Africa |
| DNK              | Denmark     | MYS              | Malaysia    | XEE              | Rest of Eastern Europe |
| ECU              | Ecuador     | NAM              | Namibia     | XEF              | Rest of EFTA |
| EGY              | Egypt       | NGA              | Nigeria     | XER              | Rest of Europe |
| ESP              | Spain       | NIC              | Nicaragua   | XNA              | Rest of North America |
| EST              | Estonia     | NLD              | Netherlands | XNF              | Rest of North Africa |
| ETH              | Ethiopia    | NOR              | Norway      | XOG              | Rest of Oceania |
| FIN              | Finland     | NPL              | Nepal       | XSA              | Rest of South Asia |
| FRA              | France      | NZL              | New Zealand | XSC              | Rest of South African Customs Union |
| GBR              | United Kingdom | OMN            | Oman        | XSE              | Rest of Southeast Asia |
| GEO              | Georgia     | PAK              | Pakistan    | XSM              | Rest of South America |
| GHA              | Ghana       | PAN              | Panama      | XSU              | Former Soviet Union |
| GRC              | Greece      | PER              | Peru        | XTW              | Rest of the World |
| GTM              | Guatemala   | PHL              | Philippines | XWF              | Rest of Western Africa |
| HKG              | Hong Kong   | POL              | Poland      | XWS              | Rest of Western Asia |
| HND              | Honduras    | PRT              | Portugal    | ZAF              | South Africa |
| HRV              | Croatia     | PRY              | Paraguay    | ZMB              | Zambia      |
| HUN              | Hungary     | QAT              | Qatar       | ZWE              | Zimbabwe    |

Appendix C. Supplementary data

Supplementary data to this article can be found online at http://dx.doi:10.1016/j.scitotenv.2016.10.191.

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