ENVIRONMENTAL SCIENCE & POLICY 51 (2015) 125–136

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Physical limits to resource access and utilisation and their economic implications in Mediterranean economies

Alessandro Galli *, *Martin Halle, Nicole Grunewald*

Global Footprint Network, Geneva, Switzerland

ARTICLE INFO

Article history:
Available online 25 April 2015

Keywords:
Ecological deficit
Production vs. consumption
Trade
Resource access and availability
Resource related risks
Economic competitiveness

ABSTRACT

This paper applies Ecological Footprint accounting to Mediterranean countries to track ecological asset balances and investigate the long-term feasibility of fulfilling natural resource and service needs. Our findings are that the Mediterranean region currently uses approximately 2.5 times more natural resources and ecological services than their ecosystems can provide. We argue that when consumption exceeds local availability, countries either resort to depletion of ecological assets or turn to international trade in order to satisfy their demands. Access to outside resources is however limited by (a) the availability of resources on international markets and (b) their affordability. Countries highly dependent on natural resource imports therefore expose their economies to the macroeconomic consequences of price volatility. We find that trade-related effects of natural resource price volatility are significant for Mediterranean economies as a 10% increase in the price of natural resources corresponds with a change in the trade balance between +7% and −2.4% of the GDP. We conclude that, in a world characterised by the existence of physical limits to the availability of global ecological assets, a systemic risk may exist for Mediterranean economies due to the concurrence of (1) ecological asset scarcity, (2) increasing prices and (3) challenging financial situations.

1. Introduction

Transitioning towards sustainable human development requires better understanding and management of the relationships between ecosystems' life-supporting capacity, humanity's effective use of the services that they provide, and the economic consequences of overburdening them (Costanza and Daly, 1992; Daly and Farley, 2004; Pulselli et al., 2008). While the Earth provides many ecosystem services (MEA, 2005), no single indicator can comprehensively monitor humanity's use of these services and inform on the implications of this use in a way that captures the full complexity of these relationships (Bossel, 1999; Ewing et al., 2012; Galli et al., 2012a; Singh et al., 2012).

Decision-makers face the challenge of interpreting complex information from a broad range of sources to inform their policy choices and investment decisions (Moldan et al., 2012; Ness et al., 2007; Warhurst, 2002). In trying to simplify complex systems and issues to facilitate decision-making, key factors may end up being omitted (Ewing et al., 2012). In such a way, considerations of social well-being or environmental integrity may have become sidelined by decision makers focusing primarily on short-term economic or political considerations,

* Corresponding author. Tel.: +39 3466760884..
E-mail address: alessandro.galli@footprintnetwork.org (A. Galli).
http://dx.doi.org/10.1016/j.envsci.2015.04.002

leading to resource and ecosystem services limitations being ignored as irrelevant to economic planning and national prosperity (Costanza et al., 2014; Wackernagel and Galli, 2012).

However, natural capital's significance in determining a country's success is increasing (Kubiszewski et al., 2013; Niccolucci et al., 2007, 2012) and managing the planet's ecological assets is becoming a central issue for decision makers around the world (Best et al., 2008). A proper understanding of the way human activities interact with the Earth's ecosystems is thus needed (Vörösmarty et al., 2000; Weisz and Lucht, 2009).

Given the unique characteristics of the region – a socio-economic laboratory where the North and the South, the East and the West merge – Global Footprint Network started a Mediterranean Programme in 2012 to support leaders and decision makers in developing a cross-cutting approach to environmental public policy for tracking and managing human demands on nature and their economic implications. Over the past five decades, the Mediterranean region has been shaped by the combined effects of environmental and economic trends: economic growth led to an increase in consumption levels that was compounded by a doubling of the region's population (UNEP/MAP-Plan Bleu, 2009). Similar trends worldwide have led to increasing global resource overuse that is affecting the availability and price of essential natural resources (see EEA, 2011; UNEP, 2012).

An increasing competition for access to resources is occurring at a time in which the economic performance of many Mediterranean countries is weakening. Together, the combination of excessive resource demand, global scarcity, and economic crisis may put the region's resource security at risk (Ahmed, 2013a; Brown, 2012; Grantham, 2011). As many other regions of the world are experiencing similar population and consumption trends, the situation in the Mediterranean holds important lessons for decision-makers across the globe.

By using Ecological Footprint accounting, this paper analyzes the situation of ecological assets in the Mediterranean region and its constituent countries.[1] Potential risks due to higher and more volatile prices that threaten the region's future access to resources and the effects on its economic performance and societal well-being are then discussed.

2. Ecological Footprint Accounting (EFA) methodology

2.1. *Ecological Footprint and biocapacity: two sides of an ecological balance sheet*

All economic activities ultimately depend on ecological assets, such as productive land and marine areas, and the services and resources they produce (Costanza et al., 2014; Daly, 1977, 1990; Georgescu-Roegen, 1971; Perrings, 1987). In the globalised world we live in, access to these key life-supporting resources is often mediated through international trade (Lambin and Meyfroidt, 2011; Mayer et al., 2005; Peters et al., 2011; Weinzettel et al., 2013; Wiedmann, 2009). Up to date, however, few indicators or accounting tools exist – namely Footprint-type of indicators (EC et al., 2014; Galli et al., 2013a) – that are able to track the flow of natural resources from their point of origin to their point of consumption. Ecological Footprint Accounting (EFA) is one of such tools; it provides an "ecological bank statement" for countries and can be used to highlight resource demand and supply trends (therefore identifying eventual overconsumption) as well as potential economic, environmental and social consequences.

Introduced in the early 1990s by Mathis Wackernagel and William Rees (Wackernagel and Rees, 1996), EFA tracks demand for biologically productive land and marine areas to produce the natural resources and ecological services that humans consume (Borucke et al., 2013; Wackernagel et al., 2002). This demand for productive areas is expressed in global hectares (gha), which represent hectares with world average biological productivity (Galli et al., 2007; Monfreda et al., 2004; Galli, 2015).

Although EFA is applicable at scales ranging from single products to the world as a whole, country-level assessments are often regarded as the most complete (Kitzes et al., 2009). The aggregate demand of a country's population is thus called the country's *Ecological Footprint of consumption* (EF_C) and is derived by tracking production, import and export economic activities as reported in Eq. (1):

$$EF_C = EF_P + EF_I - EF_E = \sum_{i=1}^{n} \frac{P_i}{Y_{W,i}} \times EQF_i + \sum_{i=1}^{n} \frac{I_i}{Y_{W,i}} \times EQF_i - \sum_{i=1}^{n} \frac{E_i}{Y_{W,i}} \times EQF_i \quad (1)$$

where:

- EF_P, EF_I and EF_E, are the Ecological Footprint of production, import and export activities, respectively;
- P_i, I_i and E_i are the produced, imported, and exported amount of each product *i* (in tonnes), respectively;
- $Y_{W,i}$ is the world-average (W) annual yield (in t wha^{-1} yr^{-1}) for the production of each product *i*, given by the tonnes of product, *i*, produced annually across the world divided by all areas in the world on which this product is grown.
- EQF_i is the equivalence factor[2] for the land type producing each product *i*.

Since Ecological Footprint is a consumption-based measure tracking both production and trade data, it can provide valuable information on the resources and services embedded in international trade flows and how they affect countries' patterns of production and consumption.

[1] The Mediterranean is here defined as the countries that directly border the Mediterranean Sea plus three countries – Jordan, Macedonia, and Portugal – that are ecologically characterised by biomes typical of the Mediterranean region. For reasons of data availability, countries with populations of under 500,000 are excluded from the analysis. As 1961 is the earliest year for which Ecological Footprint data is available, the analysis is here performed for the period 1961–2010 (this is the last year for which all data are available).

[2] Equivalence Factors (EQFs) captures the difference between the productivity of a given land type and the world-average productivity of all biologically productive land types (see also Galli et al., 2007).

The Footprint of a country can be compared to the capacity of that country's ecosystems to supply natural resources and services. Each country's *biocapacity* (*BC*) is also measured in global hectares and calculated as in Eq. (2):

$$BC = \sum_i A_{N,i} \times YF_{N,i} \times EQF_i \quad (2)$$

where:

- $A_{N,i}$ is the bioproductive area that is available for the production of each product *i* at the country level,
- $YF_{N,i}$ is the country-specific yield factor[3] for the land producing products *i*,
- EQF_i is the equivalence factor for the land use type producing each product *i*.

Although not a comprehensive measure, EFA adopts a systemic approach in monitoring diverse anthropogenic demands that are typically evaluated independently. It can thus be used to track human demand for and nature supply of those resource provisioning and regulatory ecosystem services that directly compete for Earth's biologically productive surfaces (Galli et al., 2014; Galli, 2015). Full details on the calculation methodology and the products included in the calculation can be found in Borucke et al. (2013).

2.2. *Value-added and limitations of EFA*

The rationale behind EFA is to provide as comprehensive a picture as possible of national economies' demand for, and the Biosphere's supply of, finite ecosystem services. According to Galli (2015), the main value-added of EFA is its capacity to highlight trade-offs between competing human activities by assessing the relationships between many of the anthropogenic drivers of ecological overshoot (Catton, 1980; Odum, 1997). In doing this, EFA uses a conservative approach and provides a minimum reference value for the magnitude of human demand on the Biosphere (Galli, 2015; Goldfinger et al., 2014). These conservative figures nonetheless show that human societies are living beyond the nature's budget (Galli et al., 2014).

While the theoretical approach of EFA leans towards comprehensiveness, its actual implementation is more limited in scope (Galli, 2015; Lin et al., 2015; Wiedmann and Barrett, 2010). EFA tracks resource provisioning services and only one regulatory service: climate stabilisation via CO_2 sequestration (Galli et al., 2014; Galli, 2015). As EFA does not measure all aspects of sustainability, it should be complemented with other indicators to arrive at comprehensive assessments (Galli et al., 2012a; Borucke et al., 2013).

During the last decade, EFA has become widely used and has helped to re-open the sustainability debate (e.g., Wiedmann and Barrett, 2010; WWF international et al., 2014) by communicating the scale of humanity's overuse of Earth's natural resources and ecosystem services in simple and powerful terms. Although a few researchers have conducted critical reviews of EFA (e.g., Blomqvist et al., 2013; Giampietro and Saltelli, 2014; van den Bergh and Grazi, 2013), the Ecological Footprint is currently prominent in the scientific literature as a measure of sustainability and it has unparalleled visibility in the public sphere. Its policy relevance is, however, yet to be fully understood and further discussion on this topic is needed (Galli, 2015; Gondran, 2012; Lawrence and Robinson, 2014; van den Bergh and Grazi, 2013).

3. Measuring physical dependencies and their economic implications

A country's Ecological Footprint of consumption (EF_C) is determined by three main factors: the average consumption level, how intensive this consumption is in terms of natural resources and services (the Footprint intensity), and the population level. Conversely, a country's biocapacity (*BC*) is affected by two factors: the area of biologically productive land and water, and its biological productivity level (Galli et al., 2012b; Niccolucci et al., 2011).

EF_C and *BC* of a country represent two sides of an ecological balance sheet. Biologically productive areas can be thought of as ecological assets that can generate a given flow of natural resources and services. Examples of the flows tracked and the ecosystem-types providing them include: cropland for the provision of plant-based food and fibre products; grazing land and cropland for animal products; fishing grounds for fish products; forests for timber and other forest products as well as for sequestration of waste (CO_2, primarily from fossil fuel burning) thus regulating the climate. Built-up surface for shelter and other urban infrastructure is also tracked.

If a country's consumption of natural resources and services is greater than the capacity of its natural assets to supply them, it creates a situation of *Ecological Deficit* (*ED*) in the same way that a situation of financial budget deficit occurs when spending is greater than revenue (Monfreda et al., 2004). The *ED* of countries can occur through three different modes (Niccolucci et al., 2011). Firstly, a country can import the natural renewable resources that it consumes but does not produce. This net import increases the exposure of the country's economy to commodity price volatility and to possible supply disruptions which have been exacerbated by a global context of resource scarcity. Secondly, a country can overharvest its own resources for a time through unsustainable agricultural practices, overgrazing, overfishing, or deforestation. Eventually however, this degrades the productive capacity of the land or sea and leads to an even greater mismatch between demand for and the capacity to produce natural resources. Thirdly, a country can be in *ED* due to its carbon Footprint if it emits more CO_2 in the atmosphere than it has the capacity to sequester.[4] Conversely, if a country's Ecological Footprint of consumption is smaller than its biocapacity, it is living within the capacity of its ecosystems to regenerate the natural resources and ecosystem services that its population consumes and is running an *Ecological Reserve* (*ER*). Such ER is not sufficient to determine whether the

[3] Yield Factors (YFs) capture the difference between the productivity of a given land type in a specific nation and that same land type productivity at world-average level.

[4] See Borucke et al. (2013) and Galli et al. (2012a) for further details on the carbon Footprint component and its calculation.

country is sustainable (Galli et al., 2012a), notably because a full use of biocapacity for human consumption would leave no biocapacity for use by other species (Galli et al., 2014; Kitzes et al., 2008, 2009; Kitzes and Wackernagel, 2009), but it is an essential minimum condition for sustainability (Bastianoni et al., 2013).

In addition to the comparison between EF_C and BC, further distinctions can be made to evaluate a country's impact on ecosystems' resources and services not contained within its borders, and understand its reliance on them.

The share of a country's EF_C not met by production on its own ecosystems – its Ecological Footprint of production (EF_P) – reveals, in net terms, the burden that a country's consumption of renewable natural resources and ecosystem services displaces on foreign ecosystems. We call this the country's *External Biocapacity Dependence* (*EBD*) and it is calculated as in Eq. (3):

$$EBD = \frac{(EF_C - EF_P)}{EF_C} \times 100 \tag{3}$$

The smaller the *EBD*, the higher is the share of the country's demand for renewable natural resources and services met through production within its borders. Conversely, the higher the *EBD*, the more the country depends on ecosystems outside its boundaries to meet its consumption of natural resources or to sequester the CO_2 it releases in the atmosphere. A negative *EBD* value indicates that production activities within a country's borders are providing more resources and services than those demanded by that country's residents. *EBD* is useful to understand the overall demand for biocapacity of a country's consumption and how that demand may affect other countries.

It is also useful to distinguish between renewable biomass-based resources that need to be purchased (such as food, fibres, etc.) and ecosystem services such as carbon sequestration that are largely unpriced. To evaluate a country's dependence on the outside world in terms of biomass-based resources, we then calculate the *External Resource Dependence* (*ERD*) of the country as the share of a country's resource needs that is met by imported resources. The carbon component of the Ecological Footprint ($_CEF$) is thus removed from the Ecological Footprint of both imports (EF_I) and production (EF_P), and ERD calculated as in Eq. (4):

$$ERD = \left(\frac{EF_I - cEF_I}{(EF_P - cEF_P) + (EF_I - cEF_I)}\right) \times 100 \tag{4}$$

ERD is then used in considering resource scarcity and possible economic risks that countries may face as a result.

To compare countries in terms of how sensitive their economies may be to commodity price changes, we calculate the change to their trade balance caused by a 10% increase in the price of natural resources, all else remaining equal. To do so, the country's Current Trade Balance (*CTB*) is calculated as in Eq. (5):

$$CTB = \frac{(E - I)}{Y} \tag{5}$$

where *E* is the country's total merchandise exports, *I* its total merchandise imports, and Y is the country's Gross Domestic Product.

To evaluate the sensitivity of this trade balance to natural resource price changes, isolating natural resources in the country's trade is first needed. Using UNCTAD statistics (UNCTAD, 2014), primary commodities[5] in both the imports and exports of the country are identified as per Eq. (6):

$$E = E_{pc} + E_n \text{ and } I = I_{pc} + I_n \tag{6}$$

where E_{pc} and I_{pc} are the exports and imports of primary commodities and E_n and I_n are the exports and imports of non-primary commodities respectively.

The primary commodity component of both imports and exports is then multiplied by 1.1 to simulate a 10% across-the-board rise in the price of natural resources. This gives us new totals for exports and imports (E^* and I^*) as reported in Eq. (7):

$$E^* = (1.1 \times E_{pc}) + E_n \text{ and } I^* = (1.1 \times I_{pc}) + I_n \tag{7}$$

Using these figures, the new trade balance (*NTB*) is derived as per Eq. (8):

$$NTB = \frac{(E^* - I^*)}{Y} \tag{8}$$

The sensitivity to natural resource price changes (*SPC*) is then calculated in Eq. (9) as the difference between the current trade balance and the new trade balance:

$$SPC = NTB - CTB \tag{9}$$

4. Results

4.1. *Regional analysis*

Per capita demand for resources and services due to production activities within the Mediterranean borders (its EF_P) has increased by 24% from 1961 (1.7 gha per capita) to 2010 (2.1 gha per capita). This was due mainly to a doubling in the per capita carbon Footprint of production. During the same period per capita EF_C has increased by 54% (from 2.0 to 3.0 gha per capita) indicating an increased dependence on external biocapacity (Galli and Halle, 2014). This was again mainly due to an increase in the carbon Footprint. During this same time period, regional population has increased by 102% causing an overall increase in the total regional Footprint by approximately 211% (Fig. 1).

Total *BC* in the region has also increased between 1961 and 2010 (+59%) due to improvements in agricultural practices (e.g., fertilizers use and mechanisation of agricultural practices) (Galli et al., 2013b). However, such increase in the overall productivity has been outpaced by the regional population increase, leading to a 21% decrease in per capita *BC* from 1961 (1.6 gha per capita) to 2010 (1.2 gha per capita). It should also be noted that these increases in biocapacity may be unsustainable if they are due to cultivation of unsuitable land or an increase in the use of artificial inputs that ultimately push biocapacity beyond a natural threshold in the short-term, and likely lead to a long-term decline in productivity (Kitzes et al., 2008; Moore et al., 2012).

[5] Primary commodities are defined as all products being reported – following the SITC coding system – under *sections* 0, 1, 2, 3, 4 and *division* 68.

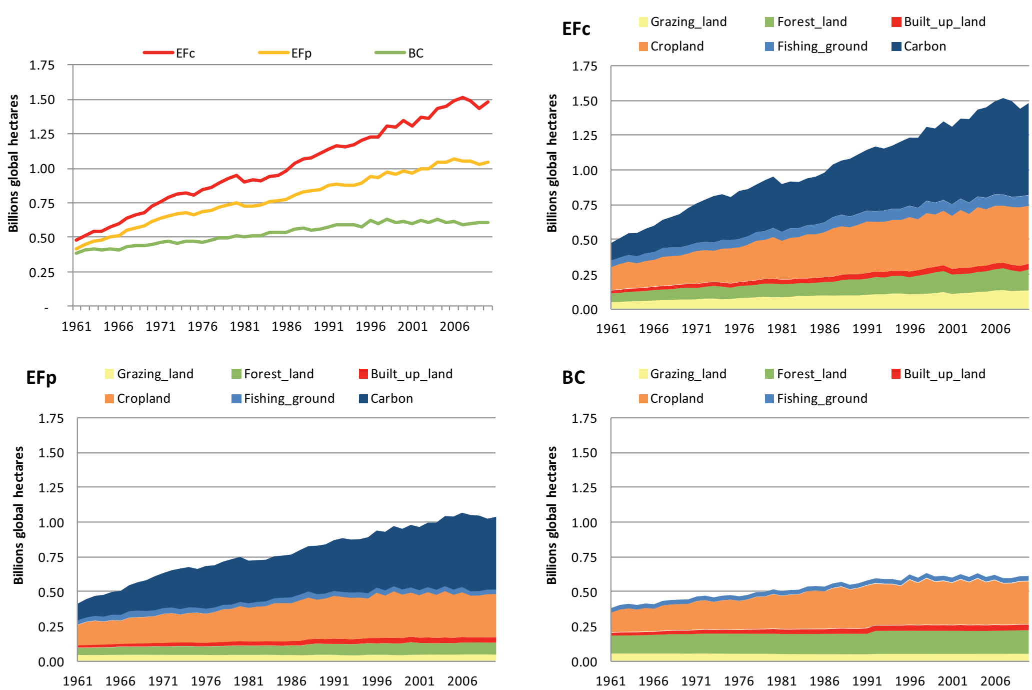

Fig. 1 – Total EF_P, EF_C and *BC* for the Mediterranean region (top left graph) as well as detailed breakdown of EF_P (bottom left graph), EF_C (top right graph) and *BC* (bottom right graph) by land type, over the period 1961–2010.

The Mediterranean region was already in a situation of ecological deficit (*ED*) in 1961 with an EF_C larger than its *BC*. As a result of the trends since then, this *ED* has strongly increased. The region's available *BC* is now only capable of supplying half of the natural resources and services that the region consumes (Fig. 1). As a result, dependence on imported *BC*, mainly from USA, China and non-Mediterranean European countries (such as Germany, Belgium, and the Netherlands), as reported in Galli and Halle (2014), has increased by 139% during 1961–2010 and now contributes to approximately 30% of the total demand.

Of the 24 countries included in this analysis, the 5 countries contributing the most to the regional EF_C are France, Italy, Spain, Turkey and Egypt (Galli et al., 2013b), together accounting for 73% of the overall demand in 2010.

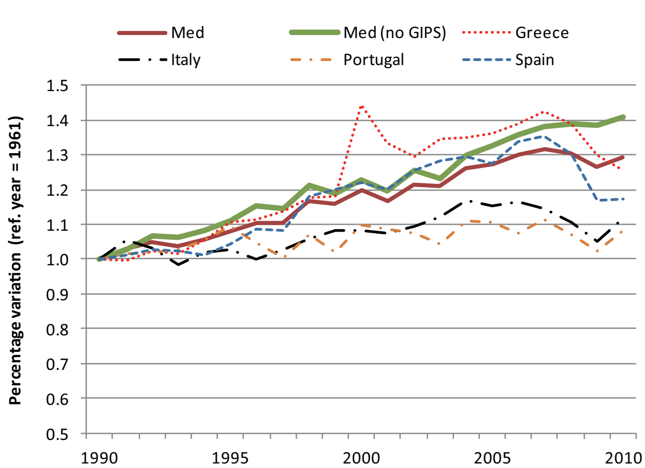

Fig. 2 – Percentage variation in per capita Ecological Footprint of Mediterranean region and GIPS countries, 1990–2010.

In recent years, the fairly steady growth trend in the Mediterranean region's EF_C has been disrupted. Indeed, from 1961 to 2006 the region's EF_C grew at an average annual rate of 2.6% with temporary sharp reductions associated with economic crises in 1975, 1980 and 2001 (Fig. 1). Between 2007 and 2009, the regional EF_C fell by more than 5%; this was the first time that the region's EF_C fell for two consecutive years. This is, we argue, a marked effect of the economic crisis in the region. Indeed it appears that Greece, Italy, Portugal and Spain (hereafter referred to as GIPS), the countries that are among the worst affected by the economic crisis, are largely responsible for the fall in the Mediterranean region's EF_C between 2007 and 2009. All four countries experienced larger reductions in their respective Footprints than the region as a whole. If these countries are excluded, the Mediterranean region's EF_C increases slightly (+0.2%) between 2007 and 2009 (Fig. 2).

As in previous economic crises, it is the carbon component of the Footprint that has been the most responsive to the economic downturn with a fall of 9% (see Fig. 1). These findings are in line with those from Peters et al. (2012) indicating a correlation between short-run changes in economic conditions and reductions in CO_2 emissions. Such correlation is likely due to the fact that economies in the region are still primarily fossil fuel dependent.

It is clear however that economic crises do not constitute any kind of solution to the problem of natural resource and ecosystem overconsumption in the region. Not only are such crises accompanied by a high human cost through the loss of jobs and livelihoods, their effects in terms of reduced consumption tend to be short-lived. Indeed, carbon emissions worldwide have already far surpassed their pre-crisis levels (Peters et al., 2012).

4.2. Country analysis

In 2010, all 24 countries of the Mediterranean region were in a situation of ecological deficit (Table 1). However, there are important distinctions in countries' natural endowments as well as in their consumption patterns.

The countries with the largest per capita EF_C in 2010 were France, Slovenia, Italy, Portugal and Malta (Fig. 3). The carbon component represents the largest share of the Ecological Footprint for all five of these countries. At the lower end of the scale, the countries with the smallest per capita EF_C were Palestine, Morocco, Syria, Algeria and Albania. The carbon component forms the largest share of the Ecological Footprint for three out of five of these countries. In Morocco and Albania, the cropland Footprint is the largest component.

France, Croatia, Montenegro, Slovenia, and Bosnia and Herzegovina had the highest per capita *BC* in 2010. The countries of the region with the lowest biocapacity per capita were Palestine, Israel, Jordan, Cyprus, and Lebanon (Table 1).

Some countries in the region were still in an ecological reserve (ER) situation in the 1960s (see Fig. 4): of those, Syria entered in an ecological deficit (*ED*) during the 1960s; Algeria, Libya, Morocco and Tunisia entered *ED* situations in the 1970s, while Turkey did in the 1980s. The remaining countries either did not exist or were already overusing their *BC* in the 1960s.

Between 1961 and 2010, the capacity of local ecosystems (*BC*) to satisfy national demand has decreased on a per capita basis in all countries and, as of 2010, *BC* contributes to less than half of the region's resource and service demand, ranging from over 80% in countries like Croatia and Montenegro to under 10% in Cyprus, Israel and Lebanon. In general, those countries whose *BC* only covers a small share of their EF_C are also among those most dependent on imports of external biocapacity and resources (see Fig. 4 and Table 1).

This dependence may have important economic implications for Mediterranean countries as their economies appear to be highly sensitive to volatility in the international price levels of natural resources such as agricultural commodities, minerals or fossil fuels. Indeed, the sensitivity to natural resource price change (*SPC*) analysis shows that the *SPC* is positive in all but two countries in the region, meaning that

Table 1 – per capita EF_C, *BC*, *BC* as a percentage of EF_C, *EBD* (External Biocapacity Dependence), *ERD* (External Resource Dependence) and *SPC* (Sensitivity to natural resource price changes) of the 24 Mediterranean countries in 2010.

Country	Ecological Footprint (EFC) per capita	Biocapacity (BC) per capita	Biocapacity as a % of Ecological Footprint	External Biocapacity Dependence (EBD)	External Resource Dependence (ERD)	Sensitivity to natural resource price changes (SPC)
Albania	1.8	1.2	67%	38%	33%	-0.9%
Algeria	1.8	0.6	33%	33%	55%	2.8%
Bosnia and Herzegovina	2.5	1.7	68%	3%	43%	-1.4%
Croatia	3.2	2.7	84%	20%	35%	-0.6%
Cyprus	4.2	0.3	7%	55%	89%	-1.2%
Egypt	1.8	0.5	28%	35%	47%	-0.6%
France	4.7	3.0	64%	17%	39%	-0.3%
Greece	4.4	1.4	32%	32%	60%	-0.4%
Israel	4.3	0.3	7%	41%	88%	-0.4%
Italy	4.5	1.0	22%	46%	72%	-0.5%
Jordan	1.9	0.3	16%	47%	82%	-2.4%
Lebanon	3.3	0.3	9%	58%	85%	-1.6%
Libya	3.3	0.6	18%	21%	65%	7.0%
Macedonia	3.0	1.6	53%	28%	49%	-2.0%
Malta	4.4	0.5	11%	60%	90%	-1.4%
Montenegro	3.2	2.6	81%	41%	49%	-1.6%
Morocco	1.5	0.8	53%	21%	32%	-1.1%
Palestine	0.5	0.1	20%	52%	66%	
Portugal	4.5	1.3	29%	48%	68%	-0.6%
Slovenia	4.6	2.3	50%	31%	70%	-1.1%
Spain	4.0	1.4	35%	23%	53%	-0.4%
Syria	1.6	0.6	38%	21%	45%	-0.1%
Tunisia	1.8	0.8	44%	37%	53%	-0.5%
Turkey	2.6	1.5	58%	22%	29%	-0.3%

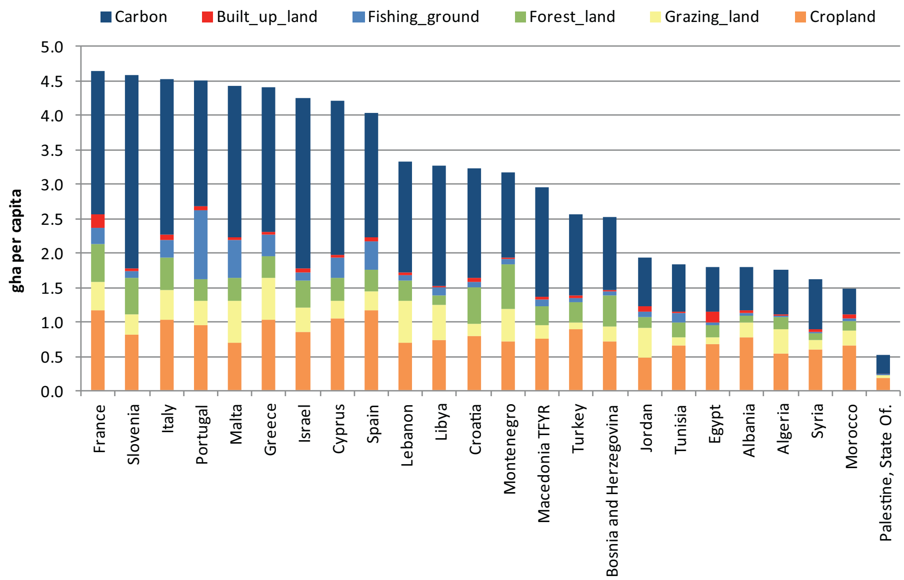

Fig. 3 – EF_C by land type of the 24 Mediterranean countries, in 2010.

commodity price increases are associated with an increase in the import bill. For these countries, the *SPC* is between 0.1% and 2.4% (Fig. 5). Conversely, for Algeria and Lybia the *SPC* is strongly negative at −2.8% and −7%, meaning that an increase in commodity prices would contribute to an improvement of their trade balance due to increased revenues from oil exports.

The exposure to commodity price volatility appears to be higher in Mediterranean countries than in other world countries: China and the United States have *SPCs* of just 0.8% and 0.2% of their respective GDPs (Fig. 5).

5. Discussion

The ecological deficit (*ED*) of Mediterranean countries is likely to put at risk the region's habitats and biodiversity due to anthropogenic-driven threats such as habitat loss, fragmentation or change; overexploitation of species; pollution; spread of invasive species or genes outcompeting endogenous species; and climate change shifting the conditions of regional habitats (Cardinale et al., 2012; Díaz et al., 2006; Galli et al., 2014; Médail and Quézel, 1999; Myers et al., 2000; Sparks et al., 2011). A detailed examination of these ecological consequences is, however, beyond the scope of this paper.

ED also creates significant risks to countries' socio-economic stability. All economic activities ultimately depend on ecological assets such as productive land and marine areas, and the resources and services they produce (Daly, 1977; Ahmed, 2013b). The mismatch between the region's consumption of these resources and services and the capacity of its ecosystems to regenerate them makes the region dependent on imported resources at a time of growing global resource scarcity, thereby putting the region's future access to essential resources at risk.

As indicated in Section 3, there are three different mechanisms through which countries can sustain an *ED* situation, all of which carry some risks for future economic performance (UNEP FI and Global Footprint Network, 2012; Hill Clarvis et al., 2013).

Over the long term, it is likely that production losses due to climate change or over-intensive use of croplands, grazing lands, fishing grounds, and forests will cause severe economic impacts in a number of Mediterranean countries. The nature and timing of such biophysical tipping points is however still uncertain. For this reason, and due to the high ERD values of many Mediterranean countries, we argue that trade-related risks are perhaps the most immediate short-term economic risk that the countries of the Mediterranean region are facing as a result of their overconsumption of natural resources and services. Today, the region is dependent on imports to meet about 50% of its demand for biomass-based resources, up from 21% in 1961. Some countries, such as Malta, Cyprus and Israel seem to be particularly exposed to trade related risks as their ERD is approximately 90% of the total demand for biomass-based resources (see Table 1).

The future ability of countries in the region to rely on imports to meet their resource demands depends on both the availability of such resources on international markets and on their affordability. Both of these aspects may worsen in the near future due to a global situation of overconsumption. Humanity now consumes one and a half times more natural resources and services than what the planet's ecosystems can regenerate (Borucke et al., 2013; WWF International et al., 2014). The resulting scarcity is making international commodity prices both higher and more volatile. In the past ten years, commodity prices have gone from a long-term trend of declining prices to a trend of rapidly increasing prices with heightened volatility (Grantham, 2011; Lee et al., 2012). Between 2000 and 2008, the World Bank commodity price index (World Bank, 2014) for food and agricultural products as well as metals and minerals nearly tripled in real terms. Since then, it has fluctuated considerably, with yearly changes of 8–19% (Fig. 6). High prices and volatility have adverse macroeconomic implications for countries in the Mediterranean who have high SPCs. They may also, in some countries of the region, affect the security of access to essential resources

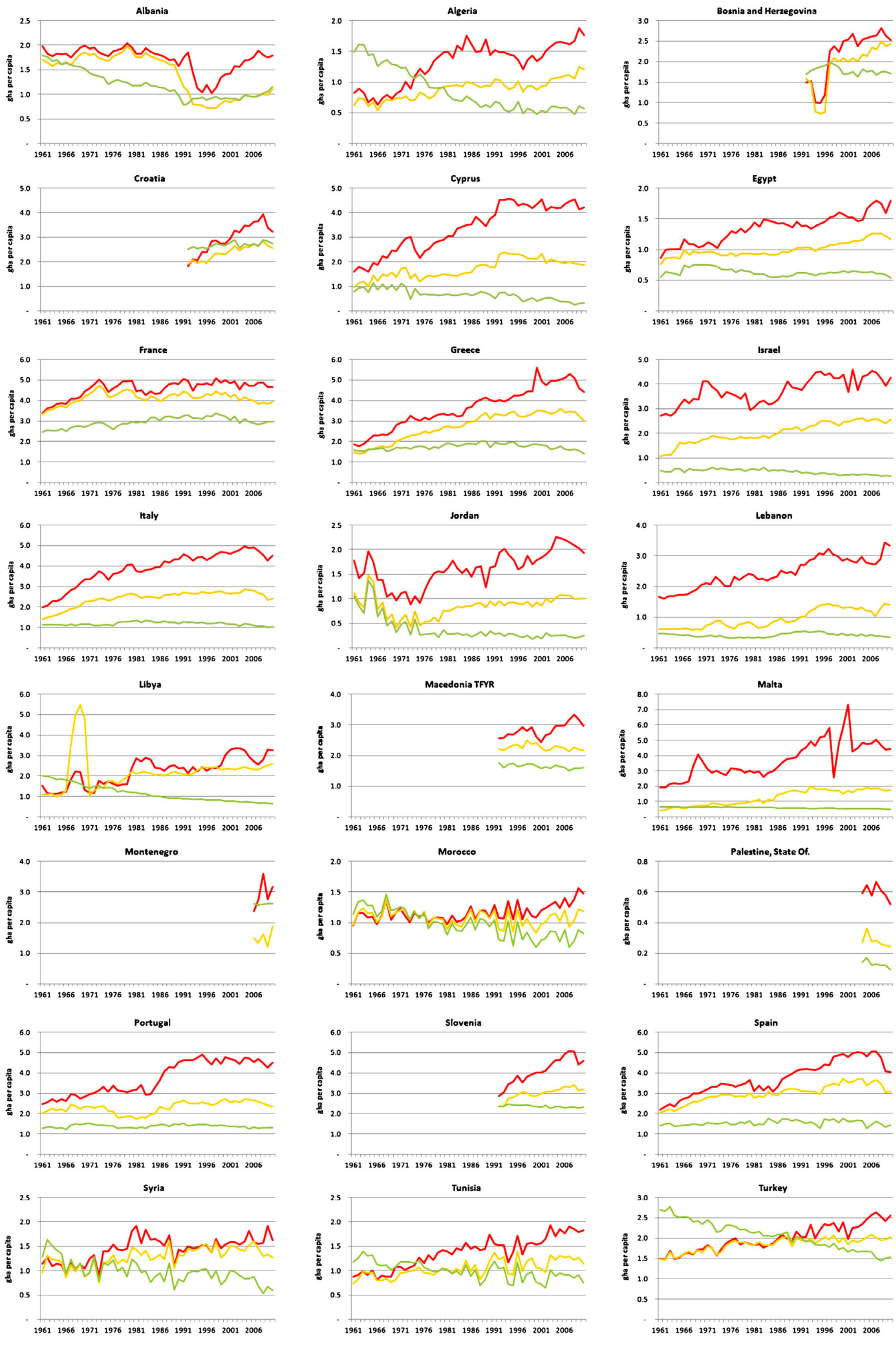

Fig. 4 – Per capita EF_P, EF_C and BC of the 24 Mediterranean countries, during 1961–2010.

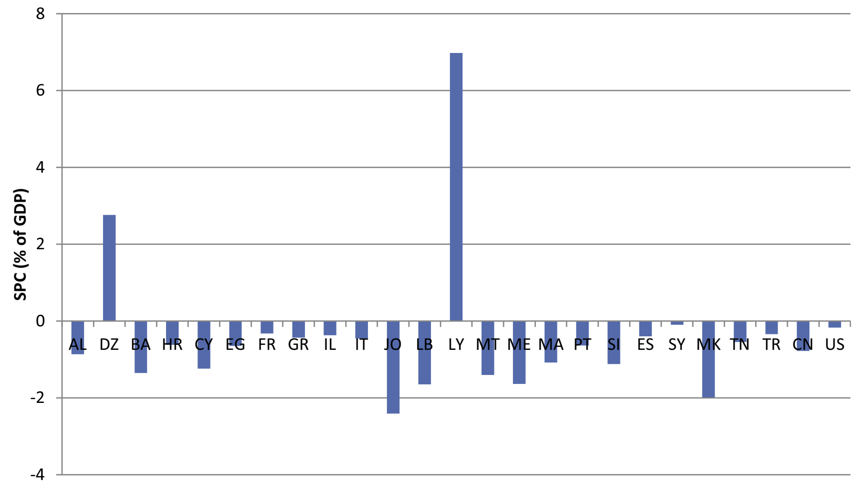

Fig. 5 – Sensitivity to natural resource price changes (SPC) for Mediterranean countries. Two-letter ISO codes are here used to indicate countries.

for the poorest households who already spend a high proportion of their income on such resources (Subramanian and Deaton, 1996).

In some extreme cases such as the food crisis of 2008, scarcity has led to severe social and political unrest (e.g., in Egypt, Haiti, Mozambique, Senegal, and Yemen) triggered by rapidly rising prices as many of the world's largest food crop exporters put in place export restrictions to protect their own population's access to food (Demeke et al., 2009). This global situation marked by resource scarcity has important implications for Mediterranean countries, which came to rely on imports of biomass-based resources during a time of relative abundance. They now have to face rapidly rising yet unpredictable commodity import bills at a time when many of them are facing an economic crisis.

Moreover, 45% of the overall Mediterranean region's EF_C is accounted for by the carbon component (see Fig. 1 – top right graph). This large carbon Footprint may also represent a risk to the future economic performance of these countries. Most obviously, their carbon Footprint represents a contribution to the accumulation of carbon dioxide in the atmosphere and to the resulting climate change: the Mediterranean region has been identified as one where the impacts in terms of warming temperatures and changing precipitation patterns are likely to be high (IPCC, 2013).

In addition, countries in the East and South of the region are particularly exposed to the impacts of climate change due to the importance of sectors such as agriculture and tourism as well as a marked vulnerability to water stress and desertification (Lelieveld et al., 2012; Milano, 2010).

The large carbon Footprint of Mediterranean countries (see Fig. 3) is also an indication of continued reliance on fossil fuels, which may pose a more immediate threat to the many Mediterranean countries that are net fossil fuel importers. According to statistics of the United States Energy Information Administration (US EIA, 2014), this was the case of all Mediterranean countries with the exception of Algeria, Libya and Syria in 2010.

As can be seen in Fig. 6, energy prices increased rapidly between 2002 and 2008. This sharp increase in fuel prices had a noticeable effect on the trade balance of fuel-importing countries in the region in the years preceding the economic crisis. Since then, fossil fuel prices have remained above their long-term averages while simultaneously undergoing considerable volatility.

While some countries have made significant efforts to improve their fuel efficiency, notably in Europe as a result of EU 20-20-20 regulations (EU, 2003, 2009), the gains were not pronounced enough to offset the increase in demand and so largely failed to lead to important falls in fuel consumption and carbon emissions.

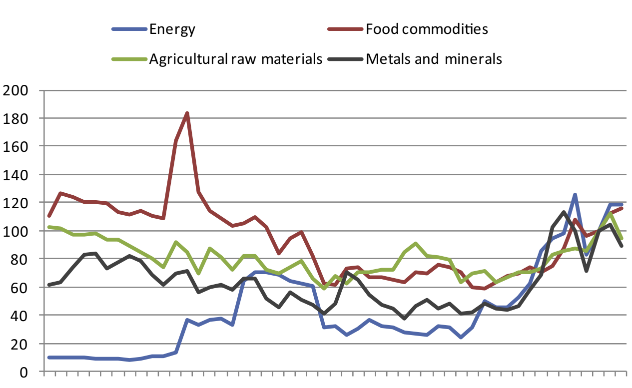

Fig. 6 – Price data in real terms for different natural resource categories from 1962 to 2012, indexed to 2001, derived from World Bank commodity price data (World Bank, 2014).

6. Conclusions

Overall, it appears that the changing global context of resource availability is making the long-held pattern of resource consumption in the Mediterranean untenable. The region currently relies on imports to meet around 50% of its biomass-based natural resource needs. In an era of heightened competition for natural resources, better resource management will be a key factor in maintaining security of access to natural resources for the region's population. We found commodity price fluctuations and supply disruptions on resource markets to be the main economic risks. The demand for resources and the ability to pay for them is closely correlated to economic cycles as the recent recession has shown.

Decision makers in the region need to recognise the interconnection between ecological assets and economic performance, seek to measure and understand it, identify the main drivers of resource dependence and opportunities to reduce it. Currently, increased attention is being paid to Sustainable Consumption and Production (SCP) practices in the region; however, it remains to be seen if decoupling alone can address the issue of overconsumption. Eventually, for a region like the Mediterranean that has below world-average biocapacity and higher Footprint, the issue of sustainable consumption levels may need to be addressed.

Acknowledgments

We would like to acknowledge MAVA Foundation pour la Nature (Grant No. 13/09) for its support to Global Footprint Network's Mediterranean-Mena Program. We also wish to thank Scott Mattoon and Mathis Wackernagel for their work on a preliminary draft of the manuscript, as well as Michael Borucke, Katsunori Iha, Elias Lazarus, David Lin and David Zimmerman for their work on the National Footprint Accounts. Finally, thanks are due to Nicoletta Patrizi for her helpful comments on an early version of the paper.

REFERENCES

Ahmed, N., 2013, August. How resource shortages sparked Egypt's months-long crisis. The Atlantic Available at: http://www.theatlantic.com/international/archive/2013/08/how-resource-shortages-sparked-egypts-months-long-crisis/278802/ (accessed 19.02.14).

Ahmed, N., 2013, July. Economists forecast the end of growth. The Guardian Available at: http://www.theguardian.com/environment/earth-insight/2013/jul/19/economy-end-growth-resource-scarcity-costs (accessed 19.02.14).

Bastianoni, S., Niccolucci, V., Neri, E., Cranston, G., Galli, A., Wackernagel, M., 2013. Sustainable Development: Ecological Footprint in Accounting. Encyclopedia of Environmental Management, 2467–2481Copyright© 2013 by Taylor & Francis. Available at: http://www.tandfonline.com/doi/abs/10.1081/E-EEM-120047347.

Best, A., Giljum, S., Simmons, C., Blobel, D., Lewis, K., Hammer, M., Cavalieri, S., Lutter, S., Maguire, C., 2008. Potential of the Ecological Footprint for monitoring environmental impacts from natural resource use: analysis of the potential of the Ecological Footprint and related assessment tools for use in the EU's Thematic Strategy on the Sustainable Use of Natural Resources. Report to the European Commission, DG Environment. .

Blomqvist, L., Brook, B.W., Ellis, E.C., Kareiva, P.M., Nordhaus, T., Shellenberger, M., 2013. Does the shoe fit? Real versus imagined Ecological Footprints. PLoS Biol. 11, e1001700.

Borucke, M., Moore, D., Cranston, G., Gracey, K., Iha, K., et al., 2013. Accounting for demand and supply of the Biosphere's regenerative capacity: the National Footprint Accounts' underlying methodology and framework. Ecol. Indic. 24, 518–533.

Bossel, H., 1999. Indicators for Sustainable Development: Theory, Method, Applications. A Report to the Balaton Group. IISD, Canada.

Brown, L.R., 2012, July. The world is closer to a food crisis than most people realise. The Guardian Available at: http://www.theguardian.com/environment/2012/jul/24/world-food-crisis-closer (accessed 29.08.14).

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., et al., 2012. Biodiversity loss and its impact on humanity. Nature 486, 59–67.

Catton Jr., W., 1980. Overshoot: The Ecological Basis of Revolutionary Change. The University of Illinois Press, Urbana, IL, USA.

Costanza, R., Kubiszewski, I., Giovannini, E., Lovins, H., McGlade, J., Pickett, K.E., Ragnarsdóttir, K.V., Roberts, D., De Vogli, R., Wilkinson, R., 2014. Time to leave GDP behind. Nature 505, 283–285.

Costanza, R., Daly, H.E., 1992. Natural capital and sustainable development. Conserv. Biol. 6 (1) 37–46.

Daly, H., 1977. Steady-State Economics. WH Freeman and Company. .

Daly, H., 1990. Towards some operational principles of sustainable development. Ecol. Econ. 2, 1–6.

Daly, H.E., Farley, J., 2004. Ecological Economics: Principles and Application. Island Press, Washington, USA.

Demeke, M., Pangrazio, G., Maetz, M., 2009. Country Responses to the Food Security Crisis: Nature and Preliminary Implications of the Policies Pursued. FAO, Initiative on Soaring Prices, Rome.

Díaz, S., Fargione, J., Stuart Chapin III, F., Tilman, D., 2006. Biodiversity loss threatens human well-being. PLoS Biol. 4 (8) e277, http://dx.doi.org/10.1371/journal.pbio.0040277.

European Commission (EC), Food and Agriculture Organization of the United Nations (UN FAO), Organisation for Economic Co-operation and Development (OECD), United Nations (UN), World Bank (WB), 2014. System of Environmental-Economic Accounting 2012: Applications and Extensions. Available at: http://unstats.un.org/unsd/envaccounting/seearev/ (accessed 29.08.14).

EEA (European Environmental Agency), 2011. The European Environment – State and Outlook 2010: Assessment of Global Megatrends. European Environmental Agency, Copenhagen, http://dx.doi.org/10.2800/76887ISBN: 978-92-9213-208-8.

European Commission, 2003. DIRECTIVE 2003/30/EC. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri¼OJ:L:2003:123:0042:0046:EN:PDF (accessed 19.09.14).

European Commission, 2009. DIRECTIVE 2009/28/EC. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri¼OJ:L:2009:140:0016:0062:en:PDF (accessed 19.08.14).

Ewing, B.R., Hawkins, T.R., Wiedmann, T.O., Galli, A., Ercin, A.E., Weinzettel, J., Steen-Olsen, K., 2012. Integrating Ecological and Water Footprint accounting in a multi-regional input–output framework. Ecol. Indic. 23, 1–8.

Galli, A., 2015. On the rationale and policy usefulness of Ecological Footprint Accounting: the case of Morocco. Environ. Sci. Policy 48, 210–224.

Galli, A., Halle, M., 2014. Mounting debt in a world in overshoot: an analysis of the link between the Mediterranean Region's economic and ecological crises. Resources 3, 383–394, http://dx.doi.org/10.3390/resources3020383.

Galli, A., Wackernagel, M., Iha, K., Lazarus, E., 2014. Ecological Footprint: implications for biodiversity. Biol. Conserv. 173, 121–132.

Galli, A., Weinzettel, J., Cranston, G., Ercin, E., 2013a. A Footprint Family extended MRIO model to support Europe's transition to a one planet economy. Sci. Total Environ. 461–462, 813–818.

Galli, A., Moore, D., Brooks, N., Iha, K., Cranston, G., 2013b. Mediterranean Ecological Footprint Trends. Available at: http://www.footprintnetwork.org/images/article_uploads/Mediterranean_report_FINAL.pdf (accessed 19.02.14).

Galli, A., Wiedmann, T.O., Ercin, E., Knoblauch, D., Ewing, B.R., Giljum, S., 2012a. Integrating ecological, carbon and water footprint into a ''Footprint Family'' of indicators: definition and role in tracking human pressure on the planet. Ecol. Indic. 16, 100–112.

Galli, A., Kitzes, J., Niccolucci, V., Wackernagel, M., Wada, Y., Marchettini, N., 2012b. Assessing the global environmental consequences of economic growth through the Ecological Footprint: a focus on China and India. Ecol. Indic. 17, 99–107.

Galli, A., Kitzes, J., Wermer, P., Wackernagel, M., Niccolucci, V., Tiezzi, E., 2007. An exploration of the mathematics behind the Ecological Footprint. Int. J. Ecodyn. 2 (4) 250–257.

Georgescu-Roegen, N., 1971. The Entropy Law and the Economic Process. Harvard University Press, Cambridge.

Giampietro, M., Saltelli, A., 2014. Footprints to nowhere. Ecol. Indic. 46, 610–621.

Goldfinger, S., Wackernagel, M., Galli, A., Lazarus, E., Lin, D., 2014. Footprint facts and fallacies: a response to Giampietro and Saltelli (2014) Footprints to Nowhere. Ecol. Indic. 46, 622–632.

Gondran, N., 2012. The Ecological Footprint as a follow-up tool for an administration: application for the Vanoise National Park. Ecol. Indic. 16, 157–166.

Grantham, J., 2011. Time to Wake Up – Days of Abundant Resources and Falling Prices are Over Forever. The Oil Drum. Available at: http://www.theoildrum.com/node/7853 (accessed 19.02.14).

Hill Clarvis, M., Halle, M., Mulder, I., Yarime, M., 2013. Towards a new framework to account for environmental risk in sovereign credit risk analysis. J. Sustain. Financ. Invest. 4 (2) 147–160.

IPCC, 2013. Climate Change 2013: The Physical Science Basis, Working Group 1 contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Kitzes, J., Wackernagel, M., 2009. Answers to common questions in Ecological Footprint accounting. Ecol. Indic. 9, 812–817.

Kitzes, J., Galli, A., Bagliani, M., Barrett, J., Dige, G., et al., 2009. A research agenda for improving national Ecological Footprint accounts. Ecol. Econ. 68, 1991–2007.

Kitzes, J., Wackernagel, M., Loh, J., Peller, A., Goldfinger, S., Cheng, D., Tea, K., 2008. Shrink and share: humanity's present and future Ecological Footprint. Philos. Trans. R. Soc. 363, 467–475.

Kubiszewski, I., Costanza, R., Franco, C., Lawn, P., Talberth, J., Jackson, T., Aylmer, C., 2013. Beyond GDP: Measuring and achieving global genuine progress. Ecol. Econ. 93, 57–68.

Lambin, E.F., Meyfroidt, P., 2011. Global land use change, economic globalization, and the looming land scarcity. Proc. Natl. Acad. Sci. U. S. A. 108, 3465–3472.

Lawrence, T.J., Robinson, G.R., 2014. Reckoning perverse outcomes of resource conservation policies using the Ecological Footprint. Ecol. Indic. 41, 87–95.

Lee, B., Preston, F., Kooroshy, J., Bailey, R., Lahn, G., 2012. Resources Future: A Chatham House Report. Available online: http://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/1212r_resourcesfutures.pdf (accessed 04.03.15).

Lelieveld, J., Hadjinicolaou, P., Kostopoulou, E., Chenoweth, J., El Maayar, M., Giannakopoulos, C., Hannides, C., Lange, M.A., Tanarhte, M., Tyrlis, E., Xoplaki, E., 2012. Climate change and impacts in the Eastern Mediterranean and the Middle East. Clim. Change 114 (3–4) 667–687.

Lin, D., Wackernagel, M., Galli, A., Kelly, R., 2015. Ecological Footprint: Informative and Evolving – A Response to van den Bergh and Grazi (2014). (forthcoming).

Mayer, A.L., Kauppi, P.E., Angelstam, P.K., Zhang, Y., Tikka, P.M., 2005. Importing timber, exporting ecological impact. Science 308, 359–360.

MEA (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington, DCAvailable at: http://www.millenniumassessment.org/documents/document.356.aspx.pdf (accessed 29.08.14).

Médail, F., Quézel, P., 1999. Biodiversity hotspots in the Mediterranean Basin: setting global conservation priorities. Conserv. Biol. 13 (6) 1510–1513.

Milano, M., 2010. The Foreseeable Impacts of Climate Change on the Water Resources of Four Major Mediterranean Catchment Basins. Plan Bleu, Sofia-Antipolis.

Moldan, B., Janousková, S., Hák, T., 2012. How to understand and measure environmental sustainability: indicators and targets. Ecol. Indic. 17, 4–13.

Monfreda, C., Wackernagel, M., Deumling, D., 2004. Establishing national natural capital accounts based on detailed ecological footprint and biological capacity assessments. Land Use Policy 21, 231–246.

Moore, D., Cranston, G., Reed, A., Galli, A., 2012. Projecting future demand on the Earth's regenerative capacity. Ecol. Indic. 16, 3–10.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858.

Ness, B., Urbel Piirsalu, E., Anderberg, S., Olsson, L., 2007. Categorising tools FOS sustainability assessment. Ecol. Econ. 60, 498–508.

Niccolucci, N., Tiezzi, E., Pulselli, F.M., Capineri, C., 2012. Biocapacity vs Ecological Footprint of world regions: a geopolitical interpretation. Ecol. Indic. 16, 23–30.

Niccolucci, V., Galli, A., Reed, A., Neri, E., Wackernagel, M., Bastianoni, S., 2011. Towards a 3D National Ecological Footprint Geography. Ecol. Model. 222, 2939–2944.

Niccolucci, V., Pulselli, F.M., Tiezzi, E., 2007. Strengthening the threshold hypothesis: economic and biophysical limits to growth. Ecol. Econ. 60, 667–672.

Odum, E.P., 1997. Ecology: A Bridge Between Science and Society. Sinauer, Sunderland, MA, USA.

Perrings, C., 1987. Economy and Environment. Cambridge University Press, Cambridge.

Peters, G.P., Marland, G., Le Quéré, C., Boden, T., Canadell, J.G., Raupach, M.R., 2012. Rapid growth in CO_2 emissions after the 2008–2009 global financial crisis. Nat. Clim. Change 2, 2–4.

Peters, G.P., Minx, J.C., Weber, C.L., Edenhofer, O., 2011. Growth in emission transfers via international trade from 1990 to 2008. Proc. Natl. Acad. Sci. U. S. A. 108, 8903–8908.

Pulselli, F.M., Bastianoni, S., Marchettini, N., Tiezzi, E., 2008. The Road to Sustainability. WIT Press, Southampton, UK.

Singh, R.K., Murty, H.R., Gupta, S.K., Dikshit, A.K., 2012. An overview of sustainability assessment methodologies. Ecol. Indic. 15, 281–299.

Sparks, T.H., Butchart, S.H.M., Balmford, A., Bennun, L., Stanwell-Smith, D., et al., 2011. Linked indicator sets for addressing biodiversity loss. Oryx 45, 411–419.

Subramanian, S., Deaton, A.S., 1996. The demand for food and calories. J. Polit. Econ. 104, 133–162.

UNCTAD, 2014. Trade Structure by Partner, Product or Service-Category Data. Available at: http://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx?sCS_ChosenLang=en (accessed 26.08.14).

UNEP/MAP-Plan Bleu, 2009. State of the Environment and Development in the Mediterranean. UNEP/MAP, Athens.

UNEP, 2012. Global Environmental Outlook (GEO) 5. Progress Press LTD., Valletta, MaltaISBN: 978-92-807-3177-4.

UNEP Finance Initiative and Global Footprint Network, 2012. A New Angle on Sovereign Credit Risk – E-RISC: Environmental Risk Integration in Sovereign Credit Analysis. UNEP and Global Footprint Network, Geneva.

US EIA, 2014. International Energy Statistics. Available at: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm (accessed 22.09.14).

van den Bergh, J.C.J.M., Grazi, F., 2013. Ecological footprint policy? Land use as an environmental indicator. J. Ind. Ecol., http://dx.doi.org/10.1111/jiec.12045.

Vörösmarty, C.J., Green, P., Salisbury, J., Lammers, R.B., 2000. Global water resources: vulnerability from climate change and population growth. Science 289, 284–288.

Wackernagel, M., Schulz, B., Deumling, D., Linares, A.C., Jenkins, M., Kapos, V., Monfreda, C., Loh, J., Myers, N., Norgaard, R., Randers, J., 2002. Tracking the ecological overshoot of the human economy. Proc. Natl. Acad. Sci. U. S. A. 99 (14) 9266–9271.

Wackernagel, M., Rees, W.E., 1996. Our Ecological Footprint: Reducing Human Impact on the Earth. New Society Publishers, Gabriola Island, BC.

Wackernagel, M., Galli, A., 2012. Ecological footprint: economic performance and resource constraints. Glob. Dialog. 14, 12–26 Available online: http://www.worlddialogue.org/content.php?%20id=512 (accessed 29.05.14).

Warhurst, A., 2002. Sustainability Indicators and Sustainability Performance Management. Report to the Project: Mining, Minerals and Sustainable Development (MMSD) International Institute for Environment and Development (IIED), Warwick, EnglandAvailable at: http://www.commdev.org/files/681_file_sustainability_indicators.pdf (accessed 29.08.14).

Weinzettel, J., Hertwich, E.G., Peters, G.P., Steen-Olsen, K., Galli, A., 2013. Affluence drives the global displacement of land use. Glob. Environ. Change 23, 433–438.

Weisz, H., Lucht, W., 2009. Climate change and sustainable use of resources. In: Oral Presentations at the World Resources Forum 2009, Davos, Switzerland.

Wiedmann, T., Barrett, J., 2010. A review of the Ecological Footprint indicator—perceptions and methods. Sustainability 2, 1645–1693.

Wiedmann, T., 2009. A review of recent multi-region input–output models used for consumption-based emission and resource accounting. Ecol. Econ. 69, 211–222.

World Bank, 2014. Global Economic Monitor (GEM) Commodities. Available at: http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=global-economic-monitor-%28gem%29-commodities (accessed 15.08.14).

WWF (WWF International), ZSL. (Zoological Society of London), Global Footprint Network, Water Footprint Network, 2014. Living Planet Report 2014. WWF, Gland, SwitzerlandISBN: 978-2-940443-87-1. Available at: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/ (accessed 25.08.14).