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On the rationale and policy usefulness of Ecological Footprint Accounting: The case of Morocco

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ABSTRACT

Ecological Footprint and biocapacity metrics have been widely used in natural capital and ecosystem accounting, and are frequently cited in the sustainability debate. Given their potential role as metrics for environmental science and policy, a critical scrutiny is needed. Moreover, these metrics remain unclear to many, are subject to criticisms, and discussion continues regarding their policy relevance. This paper aims to explain the rationale behind Ecological Footprint Accounting (EFA) and help ensure that Ecological Footprint and biocapacity results are properly interpreted and effectively used in evaluating risks and developing policy recommendations. The conclusion of this paper is that the main value-added of Ecological Footprint Accounting is highlighting trade-offs between human activities by providing both a final aggregate indicator and an accounting framework that shed light on the relationships between many of the anthropogenic drivers that contribute to ecological overshoot.

1. Introduction

Numerous studies have been dedicated in the last few years to Ecological Footprint Accounting (e.g., Bastianoni et al., 2012, 2013; Best et al., 2008; Fiala, 2008; Kitzes et al., 2009a; Kratena, 2008; Senbel et al., 2003; van den Bergh and Grazi, 2013a; Wiedmann and Barrett, 2010), including in this journal (e.g., Jury et al., 2013; Kissinger et al., 2011), examining its ability to quantify a key aspect of planetary limits and the extent to which human activities exceed them. However, Ecological Footprint Accounting (EFA) remains subject to methodological criticisms and discussion is ongoing regarding its relevance in policy making.

Over the years, both Footprint practitioners and critics have identified research priorities for improving national Ecological Footprint Accounting (Kitzes et al., 2009b) and, in few instances, proposed alternative methodological approaches. These include tracking greenhouse gases other than carbon dioxide (e.g., Dias de Oliveira et al., 2005; Walsh et al., 2009); the removal of the carbon component from Ecological Footprint Accounting (e.g., van den Bergh and Verbruggen, 1999); and the incorporation of input–output models (e.g., Bicknell et al., 1998; Lenzen and Murray, 2001; Wiedmann et al., 2006), Net Primary Productivity (NPP) data (e.g., Venetoulis and Talberth, 2008), and emergy (Zhao et al., 2005) or exergy (Chen and Chen, 2007) analyses in calculating Ecological Footprint results. Arguing for the need to focus on the various ecosystem compartments separately (e.g., Giljum et al., 2011), researchers have proposed alternative domain-specific indicators such as the Carbon Footprint (Hertwich and Peters, 2009), Water Footprint (Hoekstra and Chapagain, 2007), Land Footprint (Weinzettel et al., 2013), Nitrogen Footprint (Leach et al., 2012), Material Footprint (Wiedmann et al., 2013) and Chemical

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Footprint (Sala and Goralczyky, 2013). The combined use of Footprint indicators as a *Footprint Family* has also been explored (Galli et al., 2012a, 2013; Steen-Olsen et al., 2012).

According to the 2014 Edition of the National Footprint Accounts (NFA), productive capacity 1.54 times that of Earth was needed in 2008 to meet humanity's demands on nature, this causing humanity to be in ecological overshoot (WWF et al., 2014).[1]

This result has been subject to criticism (e.g., Blomqvist et al., 2013; van den Bergh and Grazi, 2013a), in part based on a misunderstanding of what the accounts are intended to measure, and what the results imply (Rees and Wackernagel, 2013; Wackernagel, 2013). EFA conforms to neither traditional economic nor traditional environmental indicators. Fiala (2008), for instance, argued that the Ecological Footprint represents "*bad economic and bad environmental science*." A competing perspective, however, might be that the accepted fragmented paradigm of separating economy and environment is deficient. As such, could the Ecological Footprint bring value as an accounting tool at the interface between economy and the environment? Moreover, van den Bergh and Grazi (2013a) have highlighted "*the lack of specific connections with policies in the EF approach*," a view shared by Wiedmann and Barrett (2010). But, could it be that many of the assessment tools and indicators upon which our policies are built are not relevant to measure and monitor sustainability, as argued by Costanza et al. (2014), Pulselli et al. (2008), Tiezzi and Bastianoni (2008) and Wackernagel (2013)?

A clear assessment of Ecological Footprint Accounting can help reduce confusion about the specific research questions that it addresses and the methodology used to calculate Ecological Footprint and biocapacity results. This in turn can help ensure that these results are properly interpreted and used effectively in evaluating risk and in developing sustainable solutions and policies. This paper aims to explain the rationale behind Ecological Footprint Accounting, address some misconceptions about the methodology, and, through a case study, initiate a discussion on the potential policy implications that can be derived from the Footprint application. While this is not a direct response to recent critical reviews of the Ecological Footprint (e.g., Blomqvist et al., 2013; Giampietro and Saltelli, 2014; van den Bergh and Grazi, 2013a), the paper touches on some of the key concerns these reviews have raised.

2. Methodology

2.1. *On the rationale behind Ecological Footprint Accounting*

Created in the 1990s by Mathis Wackernagel and William Rees (Wackernagel and Rees, 1996), Ecological Footprint Accounting (EFA) is comprised of two metrics, the *Ecological Footprint* and *biocapacity*.

As with all accounting systems, EFA is historical rather than predictive, tracking past human pressure on the biosphere's capacity to supply *resource provisioning* and *regulatory* ecosystem services (MEA, 2005). While nature provides many ecosystem services, the rationale for including these particular services is that they directly compete for Earth's biologically productive surfaces and can thus be measured in terms of the biologically productive area necessary to provide them.[2] They compete for space if the provision of one renewable resource excludes growing a different resource, or is in contradiction with leaving biomass un-harvested to support carbon sequestration. Each biologically productive surface is thus considered to be serving a single mutually exclusive function. This does not imply that bio-productive surfaces are unable to provide a number of services simultaneously but that only the primary function of such surfaces is captured by EFA to avoid double counting (Monfreda et al., 2004; Wackernagel et al., 1999). Moreover, although conceived to track resource provisioning and regulatory services in their entirety (Wackernagel et al., 2002), data availability limits current EFA tracking at the national level to only the provision of animal (including fish) and plant-based food, fiber and wood products as well as climate regulation through sequestration of anthropogenic CO_2 emissions (Borucke et al., 2013).

Biocapacity, the "availability" side of EFA, refers to the capacity of Earth's biologically productive surfaces to provide renewable resource-provisioning and climate-regulation ecosystem services. For each nation, biocapacity (BC) is calculated as in the equation below:

$$BC = \sum_i A_{N,i} \cdot YF_{N,i} \cdot EQF_i$$

where $A_{N,i}$ is the bioproductive area that is available for the production of each product *i* in the nation, $YF_{N,i}$ is the nation-specific yield factor[3] for the land producing products *i*, EQF_i is the equivalence factor[4] for the land use type producing each product *i*.

Biocapacity is meant to reflect prevailing technologies and resource management practices and it thus tracks the current, actual productivity of ecosystems rather than the theoretical productivity these ecosystems would have without human intervention (Goldfinger et al., 2014).

At its core, biocapacity reflects the actual ability of autotrophic organisms to capture energy from the sun via photosynthesis, and then use this energy to concentrate and structure matter into resources, the latter defined as any form of biomass that humans find useful. The exclusive consideration of products (and services) that are directly useful to humans reflects the anthropocentric underpinnings of EFA

[1] The term *overshoot*, is commonly used in ecology to indicate the state in which a population's demands exceed its environment's ability to support those demands (its *carrying capacity*). In Footprint terms, ecological overshoot occurs when a population's demand on an ecosystem exceeds the capacity of that ecosystem to regenerate the resources it consumes and to absorb its wastes leading to liquidation of natural capital stock (Monfreda et al., 2004). See also Catton (1980) and Odum (1997) for further details on the *overshoot* concept.

[2] As indicated by Wackernagel et al. (2002), those services that cannot be measured in terms of biologically productive surfaces are excluded from EFA.

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

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

(Monfreda et al., 2004). In other words, the planet is our largest solar collector, and the ecosystem services upon which humans depend are generated by the negentropic capacity of plants to convert, via photosynthesis, low-quality forms of energy (e.g., solar energy) into high-quality forms of energy and products that can be used by humans and other species, and for which we compete (Rees, 2013).

Conversely, Ecological Footprint, the "demand" side of the accounting, refers to the demand humans place (because of their production, import, export and consumption economic activities) on Earth's capacity to produce the above described sub-set of ecosystem services via photosynthesis (Borucke et al., 2013; Galli et al., 2014). For each nation, the Ecological Footprint of consumption activities (EF_C) is calculated as in the equation below:

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

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 t yr^{-1}), 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 tons of product, i, produced annually across the world divided by all areas in the world on which this product is grown.[5] For any given land type Y refers to the amount of products being produced by that land type (its natural regeneration rate); however, in the case of cropland, the amount of products being produced equals the amount of products being harvested as this is a human-created and actively-managed land use type (Kitzes et al., 2009b).[6] EQF_i is the equivalence factor for the land type producing each product i.

Full details on the Footprint and biocapacity calculation methodology as well as the products and area types included in the calculation and the original data sources can be found in Borucke et al. (2013).

Comparison of humanity's Ecological Footprint against Earth's biocapacity provides a quantitative assessment of how successful humans have been in meeting a key sustainability challenge: that of living within Earth's actual means for providing the resources we consume and maintaining the stable climatic conditions that have made civilization possible. At a national level, when a country's Ecological Footprint is greater than its biocapacity, a biocapacity deficit occurs. When a country's Ecological Footprint is smaller than its biocapacity, it is said to have a biocapacity reserve. This does not determine whether the country is sustainable (Galli et al., 2012a), but it describes an essential minimum condition for sustainability (Bastianoni et al., 2013; Kitzes et al., 2009a).

Comparing Ecological Footprint with biocapacity provides an assessment of humanity's compliance with the first two sustainability principles identified by Daly (1990): that harvest rates should not exceed regeneration rates, and that waste emission rates should not exceed the natural assimilative capacities of the ecosystems into which the wastes are emitted. Although researchers have argued that current demand should be compared with the theoretical "natural" biocapacity that areas would have without human intervention, thus arriving at a larger overshoot (e.g., Giampietro and Saltelli, 2014), EFA uses a conservative approach tending to underestimate human demand and overestimate Earth's biocapacity (Goldfinger et al., 2014). This is intended to avoid easy dismissal of results as hyperbole and to provide a minimum reference value for the magnitude of human demand on nature. Despite such conservative approach, current EFA points to significant global overshoot (Borucke et al., 2013; WWF et al., 2014) and significant biocapacity deficits for many economies (Galli et al., 2014), a reality often ignored in mainstream economic assessments and development models.

2.2. *On the meaning of global hectares*

EFA expresses results in terms of equivalent land units or hectare-equivalents — namely *global* hectares, where each *global* hectare (*g*ha) represents the capacity of a hectare of land of world-average productivity (across all croplands, grazing lands, forests and fishing grounds on the planet) to provide ecosystem services useful to people through photosynthesis in a given year (Galli et al., 2007). This is conceptually similar, for instance, to the emergy analysis approach (Odum, 1988, 1996), which measures the solar energy embedded over time in the natural and artificial resources that support human activities on a given area. Its unit is the solar emjoule (semj). Building on this parallel, the Ecological Footprint can be said to represent the embedded photosynthetic area needed to support the activities of a given population. However, EFA differs from emergy analysis in that it uses a consumer (rather than geographic) approach and provides a benchmark (namely biocapacity) against which human demand can be compared. Additional information on the similarities and differences between emergy and EFA can be found in the scientific literature (e.g., Agostinho and Pereira, 2013; Marchettini et al., 2007).

The fact that Ecological Footprint uses an area-equivalent unit (i.e., global hectares) as a unit of measure does not imply that it is an indicator of land use, contrary to the claims of van den Bergh and Grazi (2013a). More precisely, the Ecological Footprint is an indicator of human appropriation of Earth's photosynthetic capacity, although expressed in hectare-equivalents. A parallel with the unit CO_2 equivalent (CO_2eq) can be used here to further clarify the nature of a global hectare: the release of 1 t of CO_2eq does not mean that this amount has actually been released, as there is no molecule called CO_2eq. Rather, it means that various GHGs with the equivalent global warming potential of 1 t of CO_2 have been released. Similarly, when an average resident in Morocco (see Section 3.2) is said to have an annual per capita Ecological Footprint of 1.48 gha, this does not mean that 1.48 ha of

[5] In the case of cropland, an adjustment factor is used in the calculation of each product's yield to account for the amount of cropland left unharvested (see Lazarus et al., 2014 for further details).

[6] A land type enters overshoot when the harvest yield exceeds the production yield. However, in the case of cropland, these two yields are identical; this causes cropland Footprint of production to be equal to cropland biocapacity within the current accounts. This is a known area for improvement within EFA (Kitzes et al., 2009b), which is currently being discussed among Footprint practitioners (e.g., Bastianoni et al., 2012; Passeri et al., 2013).

physical land in Morocco are used.[7] It means, rather, that the equivalent capacity of 1.48 gha of productive land is needed to produce via photosynthesis the renewable resource provisioning services this average resident demands and to sequester the carbon dioxide emissions produced by Morocco on a per capita basis.

Because the surface area of the planet that is suitable for the growth of autotrophic organisms is limited, as are other factors that influence their growth (e.g., sunlight, soil nutrients, water), Earth's total biocapacity is constrained. While technology and management practices can shift both available growing area and productivity, using global hectare-equivalents as a reference measurement unit becomes a reasonable first approximation to quantitatively assess the limits of Earth's photosynthetic process. This measurement unit can be used for tracking biocapacity supply and a population's demands on it. Through their metabolism, human societies and economies demand various ecosystems services, thus causing a competition for the photosynthetic capacity of bioproductive surfaces (Galli et al., 2014). The Ecological Footprint tracks these competing demands, adding together the area required to produce the biomass that is harvested for renewable resources (i.e., provisioning services), the area of biomass needed to be left un-harvested for long-term storage of anthropogenic carbon emissions (i.e., regulating service), and the biomass-producing area (continually and fully) covered over with buildings, roads and other human infrastructure.

It has been argued that, as biological productivity varies over time, EFA results expressed in year-specific (non-constant) gha could be difficult to interpret, as changes in productivity cannot be distinguished from changes in human demand for resources and services (Kitzes et al., 2007; van den Bergh and Grazi, 2013a). This issue has been debated among Ecological Footprint practitioners (e.g., Haberl et al., 2001; Kitzes et al., 2009b; Reed et al., 2010) and a constant gha approach has been implemented in National Footprint Accounts (NFA) since 2011 (Borucke et al., 2013). This approach adjusts for changing yields over time by specifying the most recent year for which data is available as the reference year (e.g., the reference year is 2010 for the NFA 2014 Edition, which covers data from 1961 to 2010). Using "constant 2010 gha" to compare the Ecological Footprint of nations over time is conceptually analogous to, for example, using "constant 2010 US$" to compare the GDP of nations over time.

3. On the policy usefulness of Ecological Footprint Accounting

3.1. *Adding value through a macro-level crosscutting approach*

Multiple stakeholders have embraced EFA due to its ability to communicate in simple language human overuse of Earth's ecosystem services (e.g., Costanza, 2000; Deutsch et al., 2000; Herendeen, 2000; Rapport, 2000; Rees, 2000; Wiedmann and Barrett, 2010). At the same time, EFA has been criticized as having limited policy relevance (e.g., Fiala, 2008; van den Bergh and Grazi, 2010, 2013a,b; Wiedmann and Barrett, 2010). In a few instances, researchers have called for using multiple indicators to measure the use of specific resources in specific places and times, arguing that such alternatives could provide more direct guidance for specific land-use policies (e.g., Giljum et al., 2007, 2013).

A few studies have explored EFA policy potential (Abdullatif and Alam, 2011; Bagliani et al., 2008; Bassi et al., 2011; Gondran, 2012; Hopton and White, 2012; Kuzyk, 2012; Lawrence and Robinson, 2014; Niccolucci et al., 2009; Rugani et al., 2014), but a full picture of its policy usefulness has to date not been presented. Concerns about the Ecological Footprint's application in policy setting are likely due to acknowledged methodological shortcomings (Kitzes et al., 2009b), potential results misinterpretation and Ecological Footprint users' habit of reporting only aggregate results. In most cases, only Ecological Footprint of consumption and biocapacity data, total or disaggregated by land categories, are provided, but these land use categories often do not link to the specific activities or policies most relevant to decision-makers.

In order to assess the policy usefulness of the Ecological Footprint, one must therefore define what "policy useful" means, what steps are involved in developing and implementing policies, and what information decision-makers need (compared with what a measure can provide) in each step of the policy formulation process. According to Bassi et al. (2011), breaking down this process into clear, distinguishable steps can make the decision-making process more understandable and help identify weaknesses and opportunities in each step of the policy-making process. As a first approximation, this iterative process — described by a *policy cycle* –is here summarized in five steps (adapted from Knill and Tosun, 2008), as illustrated in Fig. 1.

Each stage of the cycle is of key importance and indicators are needed that can inform decision-makers at every stage. Yet, this does not imply that any particular indicator should be solely used at the exclusion of all others, as different indicators may be required at different stages in the process.

Moving toward sustainable development pathways, different measures and indicators are needed to help provide initial guidance for policy actions and show the consequences, from an environmental perspective, of socio-economic strategies and planning. Issue-specific environmental indicators (e.g., those following the DPSIR framework) however might not be enough to provide information on the overall direction a complex system is going. Macro-level, compound indicators reflecting complex interactions are often essential in decision-making processes (Pulselli et al., 2008). Without a broad systemic perspective, solving one issue can ignore other related issues or create new problems elsewhere. Climate change, for example, is seen as the key environmental issue impeding sustainability. But looking at carbon in isolation — rather than as a symptom of humanity's overall metabolism of resources — downplays other dangers (e.g., growing overconsumption and scarcity of water, food, timber, and many other resources) as well as displacement effects (e.g., the potential increase in biomass demand due to fossil fuel use reduction) (Galli et al., 2012a; Robinson et al., 2006).

In approaching policy formulation, differences between the systemic and crosscutting nature of the EFA and the

[7] It should be noted that a complete interchangeability exists between actual and global hectares (see Galli et al., 2007).

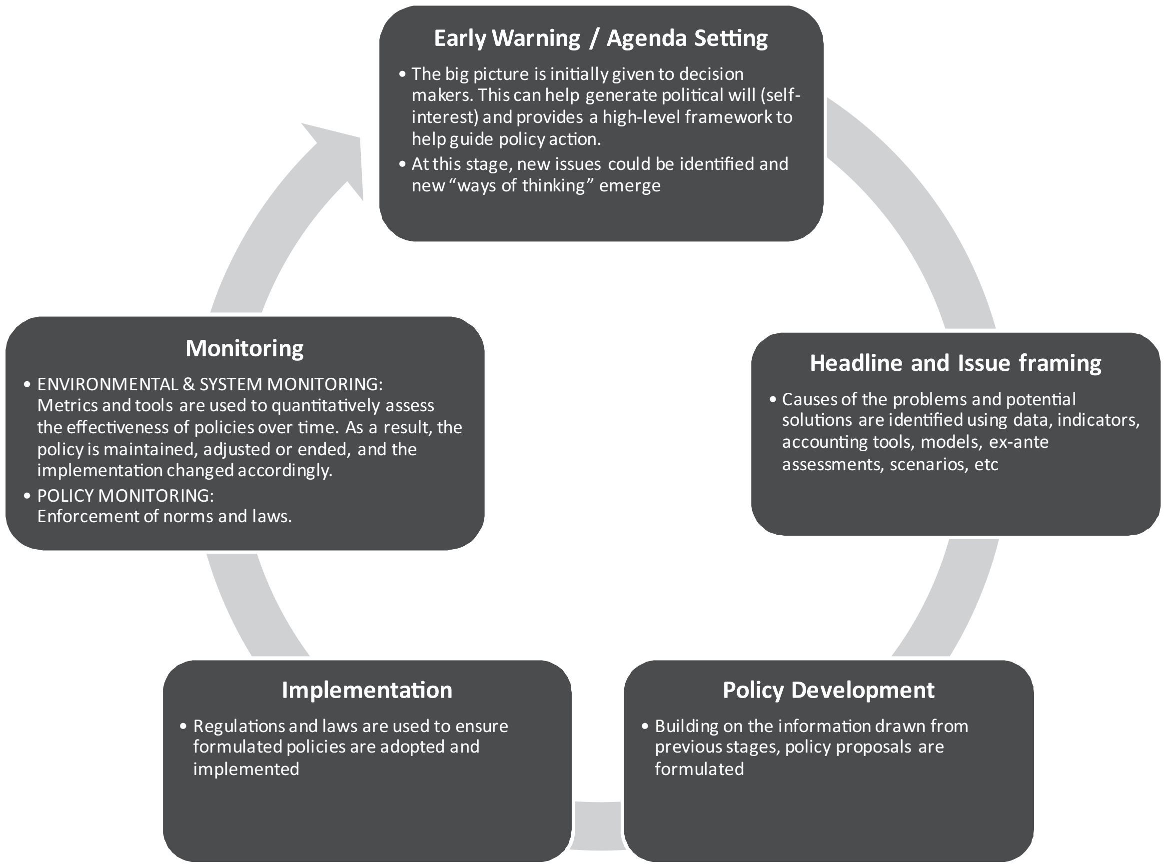

Fig. 1 – Five-step policy cycle in this study. A single straightforward definition of a standardized process for developing policy does not exist, thus there are different versions of the policy cycle. The version used here is adapted from Knill and Tosun (2008).

resolution and granularity needed to derive issue-specific policies must be considered. A macro-level indicator like EFA can offer guidance to the planning and management of societies given the reality of resource limitations. However, while it can help in identifying areas of potential intervention (Footprint hotspots) and in setting goals, EFA must be complemented with issue-specific indicators in policy development and implementation (see Fig. 2) as no single indicator is able to comprehensively monitor all aspect of sustainability. This holds true for EFA, as it does not track key economic, social and political dimensions of sustainability and, even within the "environmental pillar" of sustainability, it is unable to track all competing human demands (Bastianoni et al., 2013; Galli et al., 2012a).

Once policies are implemented, specific measures and indicators can be used to monitor progress in the specific issues; however these might not provide a broad enough picture of the full range of consequences of the implemented policies or the overall direction in which such policies are driving the whole system. A broader systemic view is thus needed to integrate the various issues-specific policies and provide an overall view of sustainability. Although not a comprehensive measure of sustainability, EFA represents a step in this direction and might serve as a minimum reference framework. Over time, it can help track policies' effectiveness in reducing humanity's appropriation of Earth's biocapacity.

EFA is therefore useful for providing policy-makers with a crosscutting viewpoint and for encouraging new "limits aware" thinking in the policy process. Such a macro-level integrated view — informative for the "early warning" and "monitoring" stages of the policy cycle — is just as important as the capacity to inform the drafting and implementation of issue-specific policies.

3.2. *Morocco as a case study*

According to World Bank (2003), human pressure in Morocco has reached a level beyond what local ecosystems can bear, with direct costs to the economy: environmental degradation in Morocco was estimated at about 13 billion dirham, or approximately 3.7% of Morocco's GDP for the year 2000. Recognizing the socio-economic threats this poses, the Moroccan government has planned to integrate environmental and social dimensions into development plans of economic sectors. Nonetheless, a common macro-level reference framework to ensure that the different sectoral strategies are coherent in their goals and quantitative targets — so that all contribute ultimately to the sustainable development of the nation — is still lacking. This is the role envisaged for the National Strategy for Sustainable Development (NSSD), whose aim is to provide a framework to help achieve coherence between existing strategies and assess their contribution to

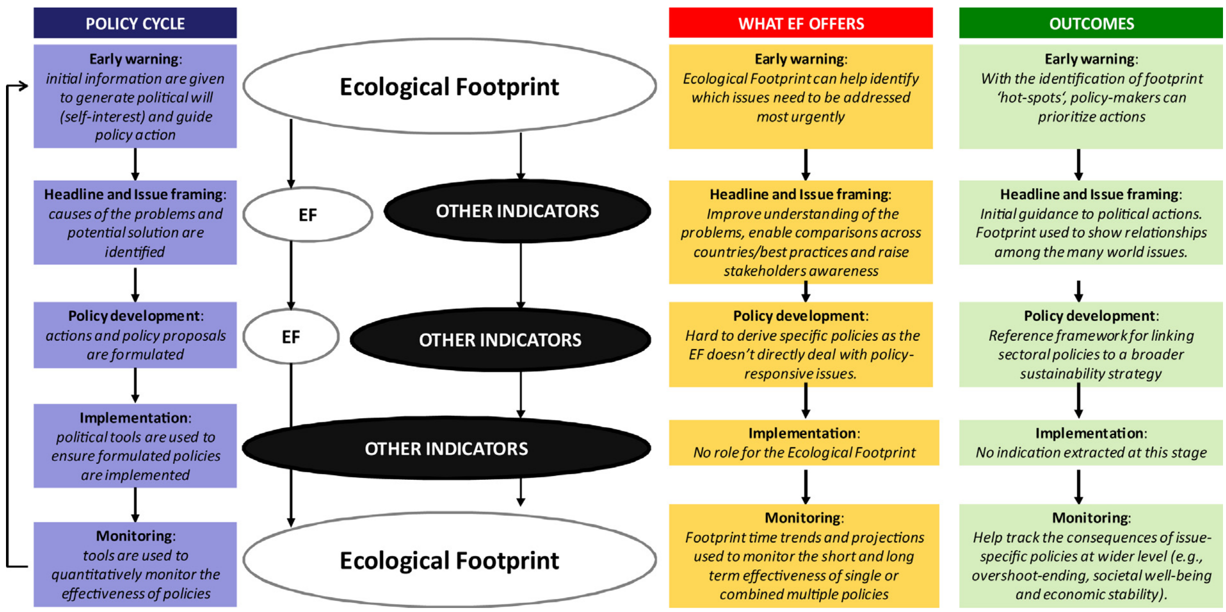

Fig. 2 – Policy usefulness of the Ecological Footprint for each policy cycle's step. For ease in visualization, the policy cycle has been represented here in linear fashion.

sustainable economic prosperity and the well-being of the Moroccan people.

In light of the approach described in Section 3.1, Morocco is here used as a case study to discuss EFA role in informing the policy formulation process alongside the five steps of the policy cycle. Keeping in mind the contribution of each sectoral strategy to the overall NSSD, it was decided to focus the analysis on the agricultural sector.

3.2.1. *Ecological Footprint and biocapacity usefulness: early warning*

During the period 1961–2010, per capita demand for resources and services due to consumption activities (EF_C) of an average Moroccan resident increased by approximately 54% from 0.96 gha to 1.48 gha (Fig. 1C). During this same time period, national population increased from 12.6 to 31.6 million residents (+160%) causing the national consumption Footprint to triple (Fig. 1A). This was mainly due to an increase in the cropland and carbon Footprint components.

Total biocapacity (BC) increased by 50% between 1961–1965 and 2005–2010 (Fig. 3B) mainly due to an increase in the land dedicated to agriculture.[8] The area covered by *arable land and permanent crops* increased by nearly 30% from 6.9 (in 1961) to 9.0 (in 2010) million hectares (FAOSTAT, 2014a). The productivity of wheat, barley and olives, the three most produced agricultural products in Morocco (≈40% of the total harvested tonnage in 2010) (FAOSTAT, 2014b), was characterized by extreme variations during the period 1961–2010 — due to the changes in the availability of internal surface water reflecting variable quantities of rainfall (FAOSTAT, 2014c) — and peaked in 2009 (Fig. 3B and C). However, the increase in productivity and in area dedicated to agriculture has been outpaced by population increase, leading to a 27% decrease in per capita BC from 1961 (1.14 gha per capita) to 2010 (0.83 gha per capita) (Fig. 3C).

Per capita EF_P followed a trend similar to that of EF_C until it started to diverge in the late 1980s, reaching a +23% increase (compared to 1961) in 2010 (Fig. 3C). While characterized by a biocapacity reserve during the 1960s and 1970s, Morocco had a biocapacity deficit by 1977; this deficit has been growing ever since (Fig. 3C).

Morocco presents a very unique profile as the sole Mediterranean country in which a strong correlation exists among EF_C, EF_P and BC trends (Galli et al., 2012b). Oscillations in Morocco's biocapacity over time are due to seasonal variability in surface water, which highly affects the productivity of crops. The high correlation of BC with EF_P is primarily due to (A) the high contribution that cropland areas have on the overall Moroccan biocapacity (see Fig. 3B) and (B) the fact that, by definition, crops' growth and harvest yields are equal within the current accounts (Borucke et al., 2013). EF_C and EF_P present parallel variations as net imports account for a small proportion of the overall Footprint (≈20% in 2010).

A country can operate with a biocapacity deficit in one or more of the following ways: (a) by running a biocapacity deficit in trade (i.e., the Footprint of its imports is greater than that of its exports); (b) by harvesting resources from its own ecosystems faster than these resources can regenerate; and (c) by emitting carbon dioxide in the global atmosphere at a rate faster than it can be sequestered by Earth's ecosystems (i.e., by using the global commons) (Niccolucci et al., 2011).

In the case of Morocco, results show that until the late 1970s, trade was balanced (in terms of embedded biocapacity)

[8] Five-year averages have been used here as the annual variability of biocapacity is very high in Morocco, reflecting the prevalence of rain-fed agriculture in the country. Use of annual data to assess biocapacity variation over the period 1961–2010 would have led to apparently unrealistic results (+95% in total biocapacity) with 1961 and 2010 corresponding to years of extreme low and high productivity, respectively.

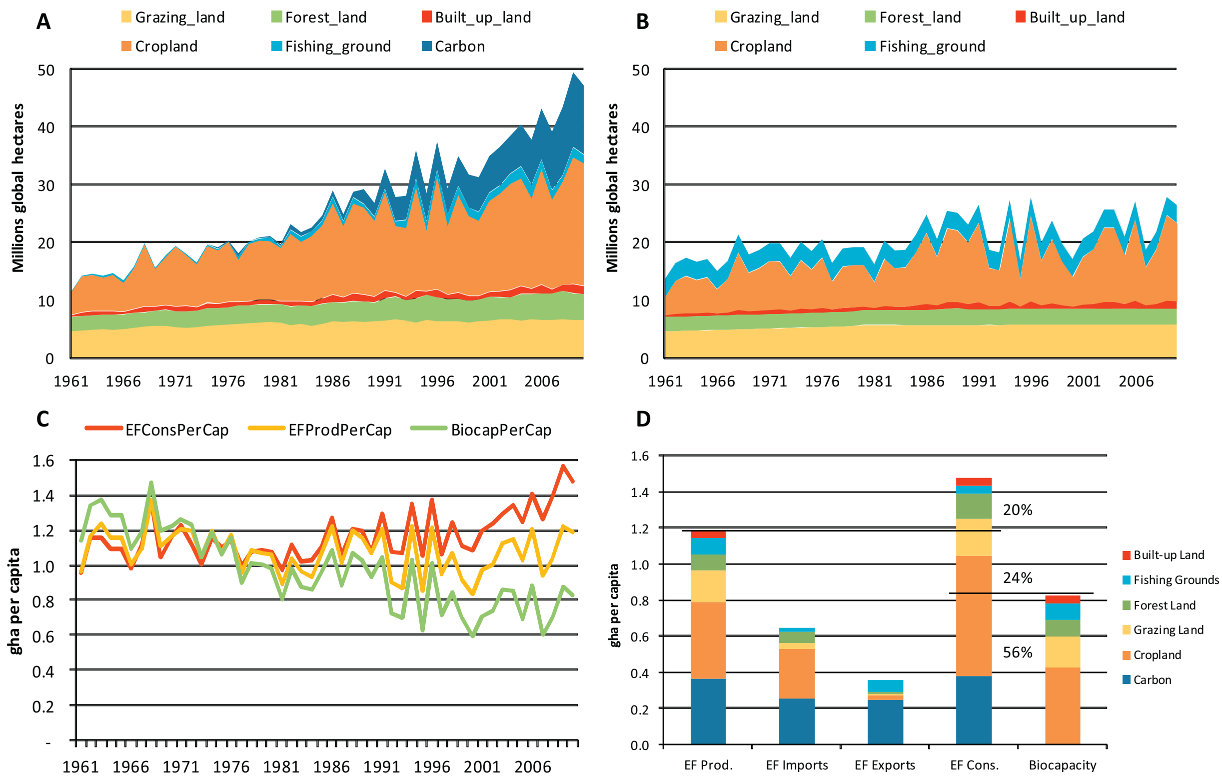

Fig. 3 – Morocco's total Ecological Footprint of consumption (A) and biocapacity (B) by land type, 1961–2010 as well as per capita Ecological Footprint of production (EF_P) and consumption (EF_C) activities compared to available biocapacity (BC), 1961–2010 (C) and their detailed disaggregation (D) for the year 2010, the most recent year for which results are currently available.

and human demand did not exceed local biocapacity. As consumption exceeded local availability, Morocco started to have a negative biocapacity trade balance in the early 1990s. This is an insight for policymakers, which would have been harder to discern using a ''warehouse of metrics'' approach, in which each metric could provide specific trade information but which would not interpret the different information collectively. Some could argue that an economic indicator such as US Dollar amounts could serve this integrative function; however, using currency units would not allow us to understand the upper biophysical limit to human demand and, in turn, set benchmarks and thresholds.

As of 2010, local biocapacity was able to meet only 56% of Morocco's total EF_C (see Fig. 3D). Morocco met its deficit by net biocapacity imports (20%) and a combination of local resource overuse and overload of global carbon sinks (24%). Except for fish resources, Fig. 3D indicates that Morocco is a net importer for all types of ecosystem services the Ecological Footprint tracks.

As access to outside biocapacity is limited by (a) the global ecological assets budget, and (b) the financial ability of countries to pay for the resources and services these assets yield, dependency on biocapacity imports exposes the Moroccan economy to price volatility and possible supply disruption with potential social and economic consequences (Galli and Halle, 2014).

Solely comparing EF_C and BC typically provides only vague policy prescriptions — e.g., we should limit consumption. However, information on the Ecological Footprint embedded in production and consumption activities (compared to local availability), the trade balance and the land breakdown can be informative at the ''early warning'' stage of the policy cycle as it helps policymakers identify the hot spots of human pressure and prioritize policy interventions.

3.2.2. *Footprint and biocapacity usefulness: headline and issue framing*

Assessing the usefulness of Ecological Footprint methodology for national/sectoral strategies requires the use of detailed information extracted from the National Footprint Accounts as indicated in Section 3.2.1. Moreover, as the NFAs only provide results by land categories, EFA can be enhanced with input–output analysis — in what can be defined as Ecological Footprint-extended multi-regional input–output analysis[9] (EF-MRIO) — to derive information on the consumption

[9] The methodology used here is described in details in Moore et al. (2013); data from the GTAP8 multi-regional input–output (MRIO) model (Narayanan et al., 2012) have been used to assess the consumption activities that contribute the most to the Moroccan Ecological Footprint. Explaining the methodology behind environmentally extended input–output analysis and its use in Ecological Footprinting is beyond the scope of this article. Readers interested in this topic are thus suggested to review Lenzen and Murray (2001) and Wiedmann et al. (2006). The issue of comparability between process-based (e.g., the one used in the traditional NFAs) and input–output analyses and their respective strengths and weaknesses is becoming a key research topic (e.g., Kastner et al., 2013; Weinzettel et al., 2014). In this area, research still needs to fill significant gaps.

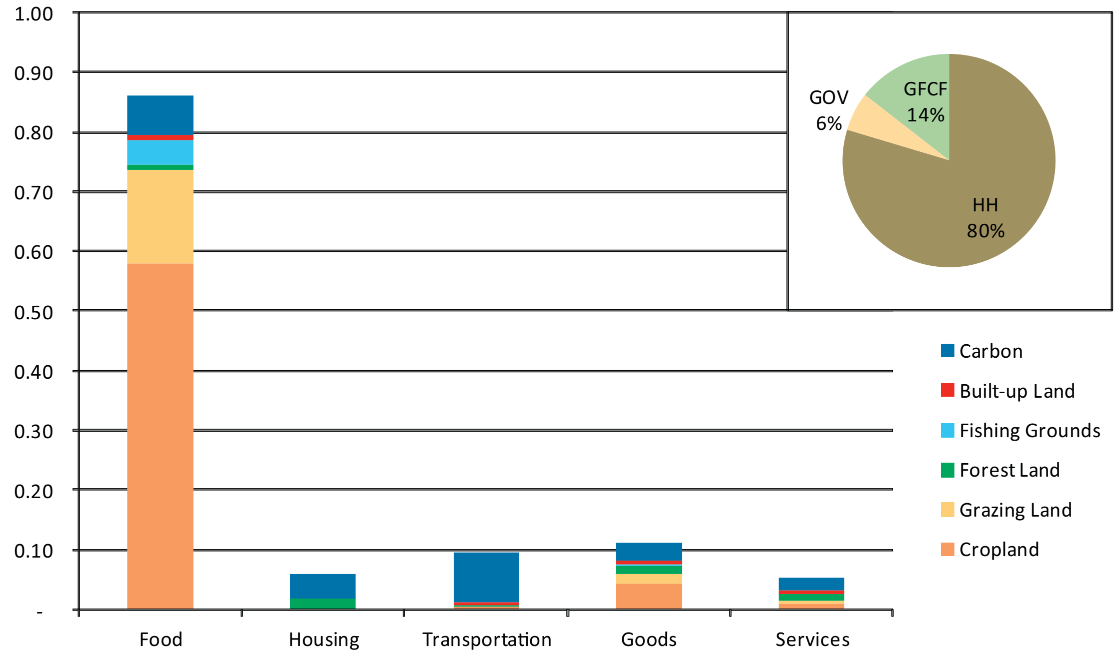

Fig. 4 – Breakdown of the per capita Ecological Footprint of an average Moroccan household, by land type and main consumption category, in 2010. The top-right chart indicates what percentage of the EF_C is paid for directly by household (HH), the government (GOV), and how much is for expenditure of long-lasting goods (Gross Fixed Capital Formation — GFCF).

activities driving a country's Footprint and thus identify areas of intervention.

As reported in Fig. 4, approximately 80% of Morocco's EF_C is due to consumption of for short-lived goods directly paid for by households (HH), followed by expenditures for long-lasting goods (GFCF) and government expenses (GOV). Food is the largest component (≈73%) of the Ecological Footprint of consumption of an average Moroccan household, followed by the demand for goods (≈9%) and transportation (≈8%). This is indicative of the key role of the agricultural sector for the Moroccan economy (43% of employment and nearly 15% of GDP)[10] and differs quite substantially from the average Mediterranean breakdown, where food (35% of the total), housing (≈20%) and transportation (≈20%) are more equal in their contribution to the region's Ecological Footprint of consumption (Galli and Halle, 2014). As the development of Morocco is highly dependent on the agricultural sector, increasing efficiency and implementing sustainable resource management practices in this sector is key for the long-term prosperity of the country.

Morocco places its greatest demands on its cropland ecosystem, whose provisioning services (agricultural products, crop-based feeds and fibers) are mostly used (45% of the total EF_C) to produce food, goods and services. This is followed by the carbon Footprint component (25% of the total), which indicates the un-harvested photosynthetic area needed for long-term storage of anthropogenic carbon emissions (i.e., regulating service).

Moreover, the EF-MRIO approach allows complementing the analysis of the biocapacity embedded in import and export flows, provided in Fig. 3, with details on trade partners. This represents useful information for a country like Morocco aiming to maximize exports, increase the range of exports markets and reduce import dependency. Fig. 5 shows Morocco's three top trading partners in terms of imports (map A) and exports (map B) of embedded biocapacity. It can be seen that Morocco is highly dependent on the United States, France and Canada for crop products and dependent on China, Russia and Spain for energy (electricity and fossil fuels) and energy-intensive commodities. Although Morocco imports fish commodities from the Netherlands, China and Norway, it is still a net exporter, with most fish commodities exported to Spain, Japan and Italy. Fig. 5B also indicates a very limited market range with Moroccan resources being exported mainly to France and Spain.

Results in Figs. 4 and 5 suggest that policy interventions — in terms of trade dependency and security of supply — need to be prioritized in the agricultural/food sector to reduce human pressure and limit socio-economic threats.

Fig. 6 illustrates the flow of embedded cropland resources through the Moroccan economy, where inputs into the economy take the form of imports and domestic production, while outputs are either exported or consumed domestically. Three macro-categories are here considered with data derived from the UN Food and Agricultural Organization (FAO), as described in Borucke et al. (2013): crop products, feeds for animal and aquaculture, and food aids.

Results indicate a net dependency on external cropland biocapacity for the Moroccan economy: only about 63% of the total demand for crop products (for direct human use or for feeding animals) is met by local production activities and the

[10] See http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS.

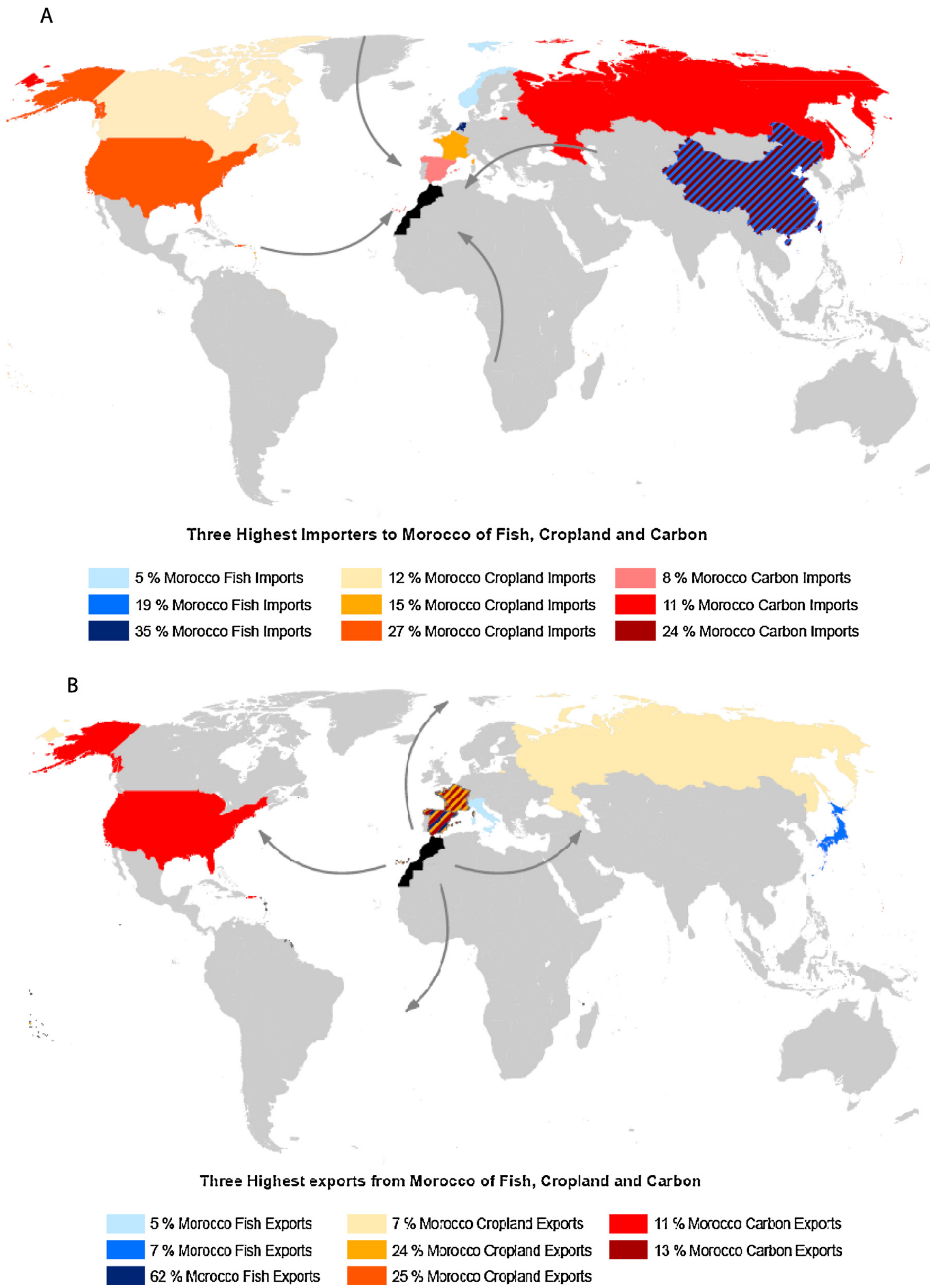

Fig. 5 – Top three exporters to (A) and importers from (B) Morocco of cropland (shade of orange), fish (shade of blue) and carbon (shade of red) Footprint, 2010. Multiple colors are used for countries with which Morocco is trading more than one type of embedded biocapacity. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

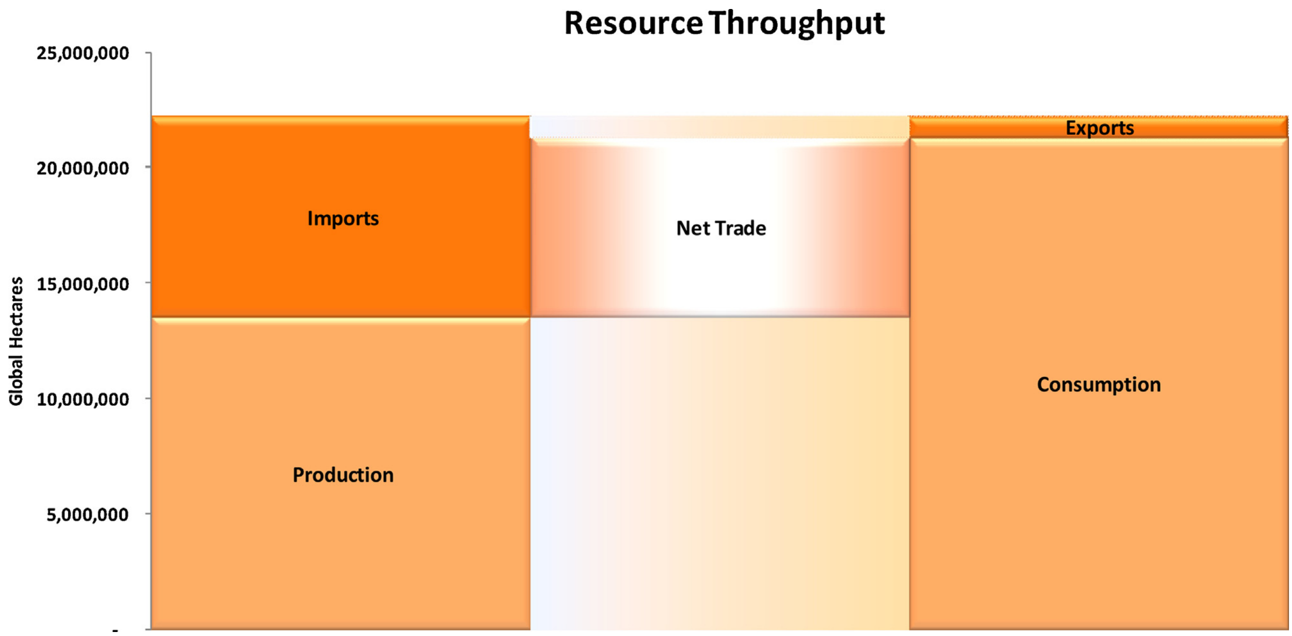

Fig. 6 – Cropland Footprint flows through the Morocco's economy, in global hectares, 2010. Inputs to the economy are local production and imports. Outputs from the economy are exports and internal consumption. The sum of the inputs is equal to the sum of outputs; from the Ecological Footprint point of view this relationship can be expressed as $EF_P + EF_I = EF_C + EF_E$.

remaining 37% is met through net biocapacity imports primarily from the United States, France, Canada, Argentina and China (nearly 70% of the total imports). Such dependency on external resources is coupled with the fact that three of the top five trading partners (United States, France and China) on which Morocco depends to sustain its agricultural needs are characterized by biocapacity deficits (Galli et al., 2014) as the Footprint of local production activities in these countries exceed local biocapacity. There have been several instances in the past decade of large food grain exporting countries implementing temporary export bans or price increases when the security of their own citizens' food supply was threatened (Rocha et al., 2012).

Objectives of the Plan Maroc Vert[11] (Green Morocco Plan), such as the increase of local productions (i.e., high value added products) and the maximization of agricultural exports, might be key to reduce the risks associated with high dependency on outside resources. Looking at each of the 164 crop products produced in Morocco tracked by the Ecological Footprint, it was found that three products alone contribute to approximately 73% of the total production Footprint in 2010: wheat (≈35% of the total), barley (≈21%) and olives (≈16%). These products are characterized by a low productivity (tons per hectare) compared to world average: in 2010 wheat in Morocco had a yield of about 1.7 t ha^{-1} (world average yield was 3.0 t ha^{-1}), barley had a yield of 1.3 t ha^{-1} (world average was 2.6 t ha^{-1}) and olives had a yield of 1.8 t ha^{-1} (world average was 2.0 t ha^{-1}) (FAOSTAT, 2014b). Moreover, looking at the cropland yield factor[12] for Morocco and other countries in the region, one average hectare of cropland in Morocco was found to be 60% as productive as a world-average hectare of cropland and less productive than cropland in other countries in the region (Fig. 7A). This is likely because agriculture in Morocco depends largely on rainfall while other Mediterranean countries characterized by higher agricultural productivities (such as Egypt and Israel) make more use of irrigation (Fig. 7B).

Debating the full implications of results in Fig. 7 goes beyond the scope of this article. However, they suggest that local agricultural productivity (e.g., increase in efficiency) could be among the priority areas of intervention to meet Plan Maroc Vert's objectives and reduce the country's biocapacity deficit. Policies could be envisioned to (a) favor a shift toward producing agricultural products with higher productivity level in Morocco and lower water demand, (b) favor alternative production techniques, and (c) improve rainwater collection techniques. This analysis, however, must be complemented with other indicators as well as socio-economic considerations missing in Ecological Footprint Accounting. Ex-ante assessments — via Ecological Footprint scenario analysis (e.g., Moore et al., 2012) — could also be performed to forecast the impact of proposed policies and assess their effectiveness

[11] See http://www.agriculture.gov.ma/pages/la-strategie for details on Morocco's national strategy for the agriculture sector.

[12] A nation's cropland Yield Factor (YF) indicates how much more (or less) productive an average hectare of cropland in the given nation is, compared to a world average hectare of land, to produce agricultural products. Average productivity is calculated considering a basket of 164 primary crop products. See Borucke et al. (2013) for details.

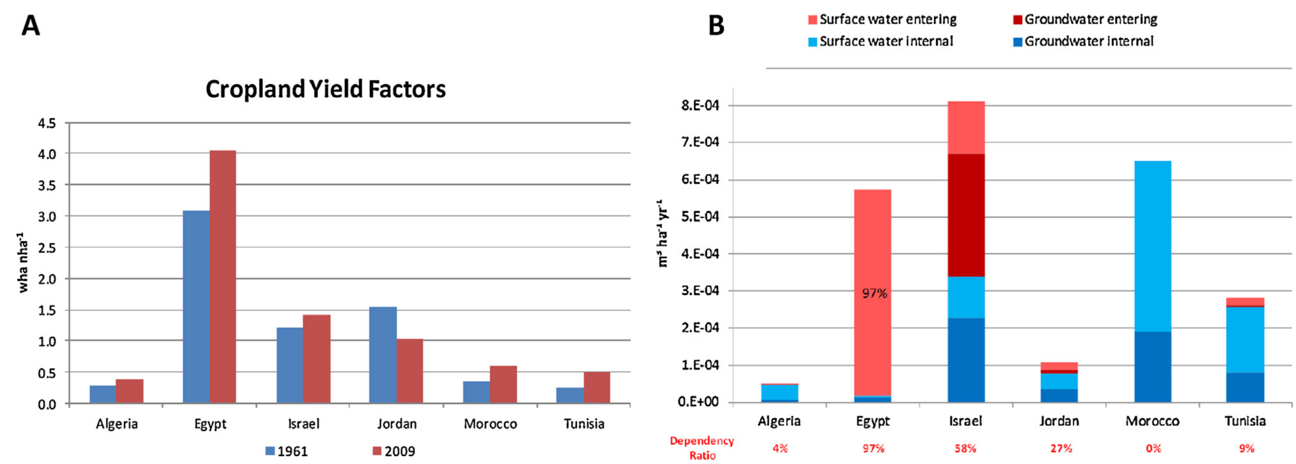

Fig. 7 – Cropland yield factors (A) and annual water availability per hectare of country area as well as water dependency ratios (B) for Morocco and selected countries in the region. Dependency ratios indicate the level of dependency from external (e.g., via bordering river and lakes) water resources.
***Source*: calculation based on FAO data for yield factors, and raw AQUASTAT data for water availability figures.**

before implementation (see Abdullatif and Alam, 2011, for information on the case of the United Arab Emirates).

3.2.3. *Footprint and biocapacity usefulness: monitoring*

The value added of the Ecological Footprint lies in its capacity to function as a reference framework for linking sectoral issues to the broader concept of sustainability. Such reference framework is essential for ensuring that the different sectoral issues and the strategies to address them are coherent in their goals and to verify that they all contribute to sustainable development.

Moran et al. (2008) have proposed the combined use of Ecological Footprint and UN Human Development Index (HDI)[13] (Anand and Sen, 1992) to monitor nations' overall progress toward advancing human well-being while respecting the biocapacity limits of the biosphere.

Results in Fig. 8 indicate that countries with the highest HDI values tend to have high per capita Ecological Footprints. The development path followed by high-income countries has been resource-intensive: as countries improved the well-being of their citizens, their resource use grew in parallel (Moran et al., 2008). In addition, as development increases beyond a certain level, small gains in HDI are associated with very large Ecological Footprint increases.

This is potentially a limiting factor to future well-being of countries highly dependent on outside ecosystems services. Over the period 1980–2010, Morocco experienced a significant increase in the average well-being (as measured by HDI) of its residents (+60%) (UNDP, 2011) coupled with a less significant increase in per capita Ecological Footprint (+37%). However, while the annual growth rate for the HDI parameter slowed down in the period 2000–2011 (+0.04% per year) compared to the 1980–1990 period (+1.96% per year), per capita Ecological Footprint of consumption increased by +4% per year during the period 2000–2010 (it was +0.05% per year during the period 1980–1990).

This might indicate that Morocco is turning toward the resource-inefficient development path followed by high-income countries. In a world in which several key planetary boundaries have already been passed (Rockström et al., 2009), banking on continuous physical expansion to stabilize an economy is unlikely to be a viable solution. More likely, increasing costs and possible supply disruptions for essential resources such as food (or fuel) can undermine long-term welfare.

The Ecological Footprint-HDI framework can thus provide macro-level guidance to the government, helping ensure that different sectoral strategies are coherent in their goals and quantitative targets, and monitor the combined effect of such policies toward pressure reduction and increase in societal well-being.

4. Discussions and conclusions

According to DeFries et al. (2004), appropriating land to grow crops, raise animals, harvest timber and build cities is one of the foundations of human civilization, although doing so alters a range of other ecosystem functions. The EFA intent is to systemically track a wide range of the human demands (resource consumption as well as waste disposal) that compete for available productive area, and compare this with Earth's capacity to meet these demands (Rees and Wackernagel, 2013).

Ecosystem functions, in turn, influence our socio-economic activities; economic and environmental systems are thus highly interconnected and actually part of a single interlinked system, although economists are likely to consider them as different realms of reality. For instance, according to van den Bergh and Grazi (2013a,b) aggregating distinct environmental

[13] Despite concerns on the use of HDI as a measure of well-being, according to Raudsepp-Hearne et al. (2010) it constitutes an adequate measure of human well-being as it strongly correlates with health-adjusted life expectancy, adult and youth literacy, gender equality and other measures.

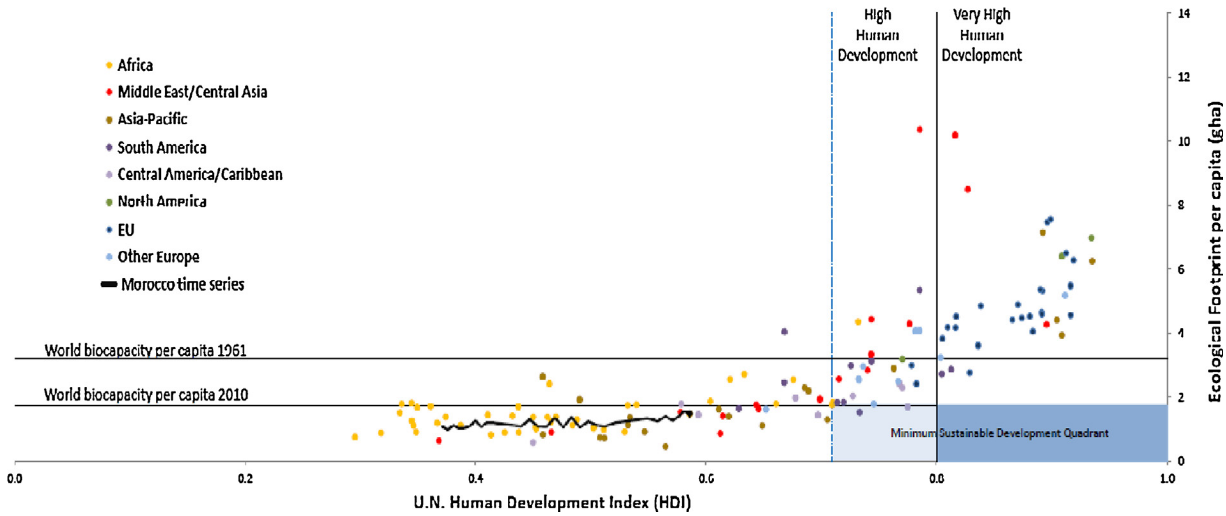

Fig. 8 – Ecological Footprint (*y*-axis) and Human Development Index (*x*-axis) framework for world countries (color-coded dots) in 2010 as well as Morocco's progresses during the period 1980–2010 (black line). A low average Ecological Footprint and a high HDI score are the necessary (although not sufficient) minimum conditions for globally replicable sustainable human development (indicated by the bottom-right quadrant). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

issues into a single indicator would cause, among other deficiencies, the impossibility to analyze trade-offs. Yet, in line with Wackernagel (2013), one could argue that it is the capacity to bring competing demands on biocapacity into one overall equation — rather than looking at each issue in isolation — that is the real value of EFA. These are clearly two conflicting, and most likely irreconcilable, worldviews on global environmental changes and their relationships to the global political economy. It is thus up to policymakers and indicator users to decide whether a systemic view can help them plan toward sustainable development.

EFA provides a crosscutting approach to assessing human pressure on the biosphere, and its results provide the greatest utility when interpreted with a systemic perspective, rather than with a reductionist approach. For instance, food production may be expanded by converting forest into cropland. But viewed through the EFA lens, this comes at a cost: reduced production of forest resources, which means either fewer trees available to harvest for wood and wood products, and/or fewer trees left standing to absorb anthropogenic carbon emissions. Moreover, converting a hectare of forest into cropland in a tropical zone could potentially result in an overall decrease in the biocapacity associated with that hectare, as most of the nutrients in tropical forests accumulate in the trees rather than in the soil, resulting in low crop productivity (Goldfinger et al., 2014). Or, one could envision replacing fossil fuels with first generation biofuels: although such a sectoral policy could reduce GHG emissions, viewed through the EFA lens, it would likely shift pressure from one domain to another — for example, using more croplands to provide biomass — rather than result in a net pressure decrease. Assessments of risks and opportunities associated with the use of biofuels thus require comprehensive and crosscutting approaches (see Koh and Ghazoul, 2008; Patrizi et al., 2013). Perhaps the main value-added of EFA is that it makes trade-offs clear by providing both a final aggregate indicator and an accounting framework that shed light on the relationships between many of the anthropogenic drivers that contribute to ecological overshoot.

The transition from several specific environmental issues to the global interconnected dimension of sustainability is crucial, and EFA could offer a reference framework for this. With human demand equivalent to 1.54 Earths' worth of provisioning and regulatory ecosystem services in 2010 (WWF et al., 2014), we have reached the point where the planet's bioproductive area is no longer sufficient to support our various competing demands. Continuing on this path is not a viable long-term strategy.

A systemic approach can help us visualize the *big picture* of global environmental changes; it represents a key feature of EFA since pressures leading to, for example, climate change, fisheries collapse and land degradation are more commonly evaluated independently. According to Clapp and Dauvergne (2005), first understanding the *big picture* is essential before identifying and tackling the many socio-ecological issues we face. Unfortunately, too often such *macro-level* guidance is missing, leading to the formulation of inadequate recommendations and policies. The real challenge — and the real opportunity — is to look at things holistically, to shift from ''*silo thinking*'' to ''*systemic thinking*,'' thus favoring integrated environmental and economic policies. There is no ''world economy'' with a problem, or ''global ecosystem'' with a problem, but a single world with interconnected problems.

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REFERENCES

Abdullatif, L., Alam, T., 2011. The UAE Ecological Footprint Initiative. http://awsassets.panda.org/downloads/en_final_report_ecological_footprint.pdf.

Anand, S., Sen, A., 1992. Human Development Index: Methodology and Measurement. United Nations Development Programme. Human Development Report Office Occasional Paper 12. .

Agostinho, F., Pereira, L., 2013. Support area as an indicator of environmental load: comparison between Embodied Energy, Ecological Footprint, and Emergy Accounting methods. Ecol. Indic. 24, 494–503.

Bagliani, M., Galli, A., Niccolucci, V., Marchettini, N., 2008. The Ecological Footprint analysis applied to a sub-national area: the case of the Province of Siena (Italy). J. Environ. Manage. 86 (2) 354–364.

Bassi, S., Cranston, G., Galli, A., Mazza, L., Newman, J., Owen, A., Roelich, K., Stoessel, S., Turcotte, I., Wentrup, K., Withana, S., 2011. Summary Evaluation: EUREAPA as a Tool for Informing Policy Decisions on the Basis of the Footprint Family of Indicators. http://www.oneplaneteconomynetwork.org/.

Bastianoni, S., Niccolucci, V., Neri, E., Cranston, G., Galli, A., Wackernagel, M., 2013. Ecological Footprint as accounting tool for sustainable development. In: Encyclopedia of Environmental Management. Taylor and Francis, NY, USA, 2467–2481, http://dx.doi.org/10.1081/E-EEM-120047347.

Bastianoni, S., Niccolucci, V., Pulselli, R.M., Marchettini, N., 2012. Indicator and Indicandum: sustainable way vs. prevailing conditions in Ecological Footprint definition. Ecol. Indic. 16, 47–50.

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. .

Bicknell, K.B., Ball, R.J., Cullen, R., Bigsby, H.R., 1998. New methodology for the Ecological Footprint with an application to the New Zealand economy. Ecol. Econ. 27, 149–160.

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., Katsunori, I., Larson, J., Lazarus, E., Morales, J.C.M., Wackernagel, M., Galli, A., 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.

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

Chen, B., Chen, G.Q., 2007. Modified Ecological Footprint Accounting and analysis based on embodied exergy—a case study of the Chinese society 1981–2001. Ecol. Econ. 61, 355–376.

Clapp, J., Dauvergne, P., 2005. Paths to a Green World: The Political Economy of the Global Environment. The MIT Press, Cambridge, MA, 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., 2000. The dynamics of the Ecological Footprint concept. Ecol. Econ. 32, 341–345.

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

DeFries, R.S., Foley, J.A., Asner, G.P., 2004. Land-use choices: balancing human needs and ecosystem function. Front. Ecol. Environ. 2 (5) 249–257.

Deutsch, L., Jansson, Å., Troell, M., Rönnbäck, P., Folke, C., Kautsky, N., 2000. The 'Ecological Footprint': communicating human dependence on nature's work. Ecol. Econ. 32, 351–355.

Dias de Oliveira, M.E., Vaughan, B.E., Rykiel, E.J., 2005. Ethanol as fuel: energy, carbon dioxide balances, and Ecological Footprint. Bioscience 55, 593–602.

FAOSTAT (The Statistics Division of the Food and Agriculture Organization of the United Nations), 2014a. Inputs Statistics Database. Available at: http://faostat.fao.org/site/377/Desktop Default.aspx?PageID=377#ancor (accessed 09.10.14).

FAOSTAT (The Statistics Division of the Food and Agriculture Organization of the United Nations), 2014b. Production Statistics Database. Available at: http://faostat.fao.org/site/567/Desktop Default.aspx?PageID=567#ancor (accessed 09.10.14).

FAOSTAT (The Statistics Division of the Food and Agriculture Organization of the United Nations), 2014c. AQUASTAT Database. Available at: http://www.fao.org/nr/water/aquastat/main/index.stm (accessed 27.10.14).

Fiala, N., 2008. Measuring sustainability: why the Ecological Footprint is bad economics and bad environmental science. Ecol. Econ. 67 (4) 519–525.

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.

Galli, A., Wiedmann, T., Ercin, E., Knoblauch, D., Ewing, B., 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., Moore, D., Brooks, N., Iha, K., Cranston, G., 2012b. Mediterranean Ecological Footprint Trends. Global Footprint Network (GFN), Oakland, CA, USA. Available online: http://www.footprintnetwork.org/images/article_uploads/Mediterranean_report_FINAL.pdf (accessed on 20 December 2013).

Galli, A., Weinzettel, J., Cranston, G., Ercin, E., 2013. 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., 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 (2) 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.

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

Giljum, S., Lutter, S., Bruckner, M., Aparcana, S., 2013. State-of-play of National Consumption-based Indicators: A Review and Evaluation of Available Methods and Data to Calculate Footprint-type (Consumption-based) Indicators for Materials, Water, Land and Carbon. ENV Fl/2013/env.fl(2013) 296596. Available at: http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/FootRev_Report.pdf.

Giljum, S., Burger, E., Hinterberger, F., Lutter, S., Bruckner, M., 2011. A comprehensive set of resource use indicators from the micro to the macro level. Resour. Conserv. Recycl. 55, 300–308.

Giljum, S., Hammer, M., Stocker, A., Lackner, M., Best, A., Blobel, D., Ingwersen, W., Naumann, S., Neubauer, A., Simmons, C., Lewis, K., Shmelev, S., 2007. Scientific assessment and evaluation of the indicator ‘‘Ecological Footprint’’. Project Z 6 – FKZ: 363 01 135, Final Report. German Federal Environment Agency, Dessau.

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.

Haberl, H., Erb, K., Krausmann, F., 2001. How to calculate and interpret Ecological Footprints for long periods of time: the case of Austria 1926–1995. Ecol. Econ. 38, 25–45.

Herendeen, R.A., 2000. Ecological footprint is a vivid indicator of indirect effects. Ecol. Econ. 32, 357–358.

Hertwich, E.G., Peters, G.P., 2009. Carbon Footprint of nations: a global, trade-linked analysis. Environ. Sci. Technol. 43 (16) 6414–6420.

Hoekstra, A.Y., Chapagain, A.K., 2007. Water Footprints of nations: water use by people as a function of their consumption pattern. Water Resour. Manage. 21 (1) 35–48.

Hopton, M.E., White, D., 2012. A simplified Ecological Footprint at a regional scale. J. Environ. Manage. 111, 279–286.

Jury, C., Rugani, B., Hild, P., May, M., Benetto, E., 2013. Analysis of complementary methodologies to assess the environmental impact of Luxembourg's net consumption. Environ. Sci. Policy 27, 68–80.

Kastner, T., Schaffartzik, A., Eisenmenger, N., Erb, K.H., Haberl, H., Krausmann, F., 2013. Cropland area embodied in international trade: contradictory results from different approaches. Ecol. Econ., http://dx.doi.org/10.1016/j.ecolecon.2013.12.003.

Kissinger, M., Rees, W.E., Timmer, V., 2011. Interregional sustainability: governance and policy in an ecologically interdependent world. Environ. Sci. Policy 14, 965–976.

Kitzes, J., Galli, A., Wackernagel, M., Goldfinger, S., Bastianoni, S., 2007. A ‘‘constant global hectare’’ method for representing Ecological Footprint time trends. In: International Ecological Footprint Conference – Stepping up the Pace: New Developments in Ecological Footprint Methodology, Policy & Practice, 8–10 May, Cardiff.

Kitzes, J., Moran, D., Galli, A., Wada, Y., Wackernagel, M., 2009a. Interpretation and application of the Ecological Footprint: a reply to Fiala (2008). Ecol. Econ. 68 (4) 929–930.

Kitzes, J., Galli, A., Bagliani, M., Barrett, J., Dige, G., Ede, S., Erb, K., Giljum, S., Haberl, H., Hails, C., Jolia-Ferrier, L., Jungwirth, S., Lenzen, M., Lewis, K., Loh, J., Marchettini, N., Messinger, H., Milne, K., Wada, Y., Walsh, C., Wiedmann, T., 2009b. A research agenda for improving national Ecological Footprint accounts. Ecol. Econ. 68, 1991–2007.

Knill, C., Tosun, J., 2008. Policy making. In: Caramani, D. (Ed.), Comparative Politics. Oxford University Press, Oxford, UK, pp. 495–519.

Koh, L.P., Ghazoul, J., 2008. Biofuels, biodiversity, and people: understanding the conflicts and finding opportunities. Biol. Conserv. 141, 2450–2460.

Kratena, K., 2008. From Ecological Footprint to ecological rent: an economic indicator for resource constraints. Ecol. Econ. 64, 507–516.

Kuzyk, L.W., 2012. The Ecological Footprint housing component: a geographic information system analysis. Ecol. Indic. 16, 31–39.

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

Lazarus, E., Zokai, G., Borucke, M., Panda, D., Iha, K., Morales, J.C., Wackernagel, M., Galli, A., Gupta, N., 2014. Working Guidebook to the National Footprint Accounts: 2014 Edition. Global Footprint Network, Oakland.

Leach, A., Galloway, J., Bleeker, A., Erisman, J.W., Kohn, R., Kitzes, J., 2012. A nitrogen footprint model to help consumers understand their role in nitrogen losses to the environment. Environ. Dev. 1, 40–66.

Lenzen, M., Murray, S.A., 2001. A modified Ecological Footprint method and its application to Australia. Ecol. Econ. 37, 229–255.

Marchettini, N., Niccolucci, V., Pulselli, F.M., Tiezzi, E., 2007. Environmental sustainability and the integration of different methods for its assessment. Environ. Sci. Pollut. Res. 14 (4) 227–228.

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

Monfreda, C., Wackernagel, M., Deumling, D., 2004. Establishing national natural capital accounts based on detailed Ecological Footprint and biocapacity assessments. Land Use Policy 21, 231–246.

Moran, D., Wackernagel, M., Kitzes, J., Goldfinger, S., Boutaud, A., 2008. Measuring sustainable development — nation by nation. Ecol. Econ. 64, 470–474.

Moore, D., Larson, J., Iha, K., Gracey, K., Wackernagel, M., 2013. Methodology for Calculating the Ecological Footprint of California. Available at: http://www.footprintnetwork.org/images/article_uploads/EcologicalFootprintCalifornia_Method_2013.pdf.

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

Narayanan, G., Angel Aguiar, B., McDougall, R. (Eds.), 2012. Global Trade, Assistance, and Production: The GTAP 8 Data Base. Center for Global Trade Analysis, Purdue University.

Niccolucci, V., Galli, A., Bastianoni, S., 2009. Deriving environmental management practices with the Ecological Footprint Analysis: a case study for the Abruzzo Region. WIT Trans. Ecol. Environ. 122 , http://dx.doi.org/10.2495/ECO090191.

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.

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

Odum, H.T., 1988. Self-organization, transformity, and information. Science 242, 1132–1139.

Odum, H.T., 1996. Environmental Accounting. Emergy and Environmental Decision Making. Wiley & Sons, NY, USA.

Passeri, N., Borucke, M., Blasi, E., Franco, S., Lazarus, E., 2013. The influence of farming technique on cropland: a new approach for the Ecological Footprint. Ecol. Indic. 29, 1–5.

Patrizi, N., Caro, D., Pulselli, F.M., Bjerre, A.B., Bastianoni, S., 2013. Environmental feasibility of partial substitution of

gasoline with ethanol in the Province of Siena (Italy). J. Clean. Prod. 47, 388–395.
Pulselli, F.M., Bastianoni, S., Marchettini, N., Tiezzi, E., 2008. The Road to Sustainability: GDP and Future Generations. WIT Press, Southampton, UK.
Rapport, D.J., 2000. Ecological footprints and ecosystem health: complementary approaches to a sustainable future. Ecol. Econ. 32, 367–370.
Reed, A., Galli, A., Wackernagel, M., 2010. Inclusion of intertemporal yield factors in time series Ecological Footprint assessments. In: Bastianoni, S. (Ed.), Footprint Forum 2010: The State of the Art in Ecological Footprint Theory and Applications. pp. 131–132, Available at: http://www.footprintnetwork.org/images/uploads/Academic_Conference_Book_of_Abastracts.pdf.
Rees, W.E., Wackernagel, M., 2013. The shoe fits, but the footprint is larger than earth. PLoS Biol. 11 (11) e1001701, http://dx.doi.org/10.1371/journal.pbio.1001701.
Rees, W.E., 2013. Ecological Footprint, Concept of. Encyclopedia of Biodiversity, vol. 2. pp. 701–713.
Rees, W.E., 2000. Eco-footprint analysis: merits and brickbats. Ecol. Econ. 32, 371–374.
Robinson, J., Bradley, M., Busby, P., Connor, D., Murray, A., Sampson, B., Soper, W., 2006. Climate change and sustainable development: realizing the opportunity. Ambio 35 (1) 2–8.
Rocha, N., Giordani, P., Ruta, M., 2012. Export Policy and Food Price Escalation. Available at http://www.voxeu.org/article/world-food-prices-and-protectionism (accessed 19.02.13).
Rockström, R., Steffen, W., Noone, K., Persson, A., Chapin, F.S., et al., 2009. A safe operating space for humanity. Nature 461, 472–475.
Raudsepp-Hearne, C., Peterson, G.D., Tengo, M., Bennett, E.M., Holland, T., Benessaiah, K., MacDonald, G.K., Pfeifer, L., 2010. Untangling the Environmentalist's Paradox: why is human well-being increasing as ecosystem services degrade? Bioscience 60 (8) 576–589.
Rugani, B., Roviani, D., Hild, P., Schmitt, B., Benetto, E., 2014. Ecological deficit and use of natural capital in Luxembourg from 1995 to 2009. Sci. Total Environ. 468–469, 292–301.
Sala, S., Goralczyky, M., 2013. Chemical footprint: a methodological framework for bridging life cycle assessment and planetary boundaries for chemical pollution. Integr. Environ. Assess. Manage. 9 (4) 623–632.
Senbel, M., McDaniels, T., Dowlatabadi, H., 2003. The Ecological Footprint: a nonmonetary metric of human consumption applied to North America. Global Environ. Change 13, 83–100.
Steen-Olsen, K., Weinzettel, J., Cranston, G., Ercin, A.E., Hertwich, E.G., 2012. Carbon, land, and water footprint accounts for the European union: consumption, production, and displacements through international trade. Environ. Sci. Technol. 46, 10883–10891.
Tiezzi, E., Bastianoni, S., 2008. Sustainability of the Siena Province through ecodynamic indicators. J. Environ. Manage. 86, 329–331.
United Nation Development Programme (UNDP), 2011. Human Development Report 2011. Available at: http://www.undp.org/content/undp/en/home/librarypage/hdr/human_developmentreport2011.html.
van den Bergh, J.C.J.M., Verbruggen, H., 1999. Spatial sustainability, trade and indicators: an evaluation of the Ecological Footprint. Ecol. Econ. 29, 61–72.
van den Bergh, J.C.J.M., Grazi, F., 2010. On the policy relevance of Ecological Footprints. Environ. Sci. Technol. 44 (13) 4843–4844.
van den Bergh, J.C.J.M., Grazi, F., 2013a. Ecological footprint policy? Land use as an environmental indicator. J. Ind. Ecol., http://dx.doi.org/10.1111/jiec.12045.
van den Bergh, J.C.J.M., Grazi, F., 2013b. Letter to the Editor: response to Wackernagel. J. Ind. Ecol., http://dx.doi.org/10.1111/jiec.12096.
Venetoulis, J., Talberth, J., 2008. Refining the Ecological Footprint. Environ. Dev. Sustain. 10, 441–469.
Wackernagel, M., Rees, W.E., 1996. Our Ecological Footprint: Reducing Human Impact on the Earth. New Society Publishers, Gabriola Island, Canada.
Wackernagel, M., Onisto, L., Bello, P., Callejas Linares, A., Lopez Falfan, I.S., Mendez Garcıa, J., Suarez Guerrero, A.I., Suarez Guerrero, M.G., 1999. Natural capital accounting with the Ecological Footprint concept. Ecol. Econ. 29 (3) 375–390.
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. PNAS 99 (14) 9266–9271.
Wackernagel, M., 2013. Letter to the Editor: comment on Ecological Footprint policy? Land use as an environmental indicator. J. Ind. Ecol., http://dx.doi.org/10.1111/jiec.12094.
Walsh, C., O'Regan, B., Moles, R., 2009. Incorporating methane into Ecological Footprint analysis: a case study of Ireland. Ecol. Econ. 68, 1952–1962.
Weinzettel, J., Hertwich, E.G., Peters, G.P., Steen-Olsen, S., Galli, A., 2013. Affluence drives the global displacement of land use. Global Environ. Change 23, 433–438.
Weinzettel, J., Steen-Olsen, K., Hertwich, E., Borucke, M., Galli, A., 2014. Ecological footprint of nations: comparison of process analysis, and standard and hybrid multiregional input–output analysis. Ecol. Econ. 101, 115–126.
Wiedmann, T., Minx, J., Barrett, J., Wackernagel, M., 2006. Allocating Ecological Footprints to final consumption categories with input–output analysis. Ecol. Econ. 56, 28–48.
Wiedmann, T., Barrett, J., 2010. A review of the Ecological Footprint indicator—perceptions and methods. Sustainability 2, 1645–1693.
Wiedmann, T., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., Kanemoto, K., 2013. The material footprint of nations. PNAS. http://www.pnas.org/cgi/doi/10.1073/pnas.1220362110.
World Bank, 2003. Kingdom of Morocco Cost Assessment of Environmental Degradation. Report No 25992-MOR. Available at: http://siteresources.worldbank.org/INTMOROCCO/Resources/MoroccoEnvPolicyNote30June2003ENG23May05.pdf.
WWF (WWF International), ZSL (Zoological Society of London), Global Footprint Network, Water Footprint Network, 2014. Living Planet Report 2014. WWF, Gland, Switzerland, ISBN: 978-2-940443-87-1. Available at: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/
Zhao, S., Li, Z., Li, W., 2005. A modified method of Ecological Footprint calculation and its application. Ecol. Model. 185, 65–75.