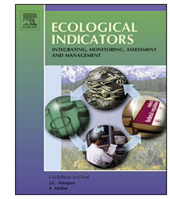
Ecological Indicators 91 (2018) 689–697

Contents lists available at ScienceDirect

Ecological Indicators

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



Short Note

Linking the water-energy-food nexus and sustainable development indicators for the Mediterranean region

F. Saladini[a], G. Betti[b], E. Ferragina[c], F. Bouraoui[d], S. Cupertino[b], G. Canitano[c], M. Gigliotti[a], A. Autino[e], F.M. Pulselli[a], A. Riccaboni[f], G. Bidoglio[d], S. Bastianoni[a,*]

[a] *Ecodynamics Group, Department of Earth, Environmental and Physical Sciences, University of Siena, Pian dei Mantellini 44, 53100 Siena, Italy*
[b] *Department of Economics and Statistics, University of Siena, Piazza San Francesco 7, 53100 Siena, Italy*
[c] *Institute of Studies of Mediterranean Society (ISSM), National Research Council (CNR), Via Guglielmo Sanfelice 8, 80134 Naples, Italy*
[d] *European Commission, Joint Research Centre (JRC), Directorate for Sustainable Resources, Via E. Fermi 2749, 21027 Ispra, VA, Italy*
[e] *Santa Chiara Lab, University of Siena, Via Valdimontone, 1, 53100 Siena, Italy*
[f] *Department of Business and Law, University of Siena, Piazza San Francesco 7/8, 53100 Siena, Italy*

ARTICLE INFO

Keywords:
PRIMA programme
Water-food-energy nexus
Sustainable water use
Sustainable food production
Monitoring system
Sustainability
Sustainability indicators

ABSTRACT

Water use and agricultural practices in the Mediterranean area are unsustainable. The situation is worsened by the increased frequency of droughts and floods, as well as desertification and soil depletion, associated with climate change. The aim of Partnership for Research and Innovation in the Mediterranean Area (PRIMA) is to foster an integrated programme of sustainable food production and water provision in the framework of the water-energy-food nexus. A monitoring tool developed under PRIMA is based on the Sustainable Development Goals, two of which are specifically dedicated to food security (SDG 2) and sustainable management of water (SDG 6).

The 12 indicators that have been chosen to be monitored in the Mediterranean area are: Multidimensional Poverty Index (MPI); population overweight (%); land use (%); GHG emissions (total and AFOLU)(tCO_{2e}); cereal yield (kg/ha); agriculture value added (US$/worker); fertilizer consumption ($kg/ha_{arable\ land}$); crop water productivity (kg/m^3); annual freshwater withdrawal for agriculture (%); population served using with safely managed water service (rural, %); population served using with safely managed sanitation (rural, %); amount of agricultural residues used for energy purposes (t). Datasets for these indicators are collected by international bodies such as the World Bank, WHO, FAO and UNFCCC; recent series are available for almost all Mediterranean countries and are constantly updated. The aim of the proposed monitoring tool is to keep track of the impact generated in by PRIMA research and innovation projects Mediterranean countries.

1. Introduction

Food production and water provision are two urgent socio-economic and environmental issues in the Mediterranean region. Because these two aspects are closely linked, they need to be tackled by an integrated approach known as *Water-Energy-Food (WEF) Nexus* (e.g. Bazilian et al., 2011; Rasul, 2014; Riccardini and De Rosa, 2016; Ringler et al., 2013). The recent global food crises of 2008 (Headey and Fan, 2010) and 2011[1] (Hochmana et al., 2014) drew attention to the crucial role of food security in the Mediterranean area, especially considering the consequences for socio-political equilibrium in certain countries of the Middle East and North Africa (MENA) (Ferragina, 2015). By 2050, the food imbalance in this region, which depends more on cereal imports than any other region in the world, is forecast to

* Corresponding author.
E-mail address: bastianoni@unisi.it (S. Bastianoni).

[1] "After reviewing the evidence, the study suggests the 2007/2008 food crisis was primarily driven by a combination of rising oil prices, a greater demand for biofuels and trade shocks in the food market. Rising oil prices led to increased costs of cereal production, as agriculture is generally an energy intensive enterprise. At the same time, there was increasing demand for cereal foods from wealthy oil-exporting countries. More importantly, higher energy prices increased the demand for biofuels, which became more competitively priced when compared with oil. In particular, this drove up the demand for biofuels derived from maize in the United States" (European Commission, 2011). "A sharp escalation in the price of basic foods is of special concern to the world's poor. All poor people spend large portions of their household budgets on food, and most impoverished people depend on food production for their livelihoods but have very limited capacity to adjust quickly to sharp changes in relative prices. Consequently, surging food prices have caused panic and protest in developing countries and have presented the policymaking community with a challenge at least as severe as the 1972–74 global food crisis." (Headey and Fan, 2010). See also: Hochmana et al. (2014), Pages 106–114.

https://doi.org/10.1016/j.ecolind.2018.04.035
Received 15 December 2017; Received in revised form 13 April 2018; Accepted 15 April 2018
Available online 27 April 2018
1470-160X/

reach nearly 60%, making MENA extremely vulnerable in terms of food security (IPEMED, 2010). The sustainable management of water resources is closely related to food security, since 70% of total global freshwater withdrawals are driven by agriculture (FAO, 2014). Energy plays a key role in producing and distributing food, as well as in extracting, treating and supplying water (FAO, 2014).

Problem solving in the frame of the WEF Nexus is expected to become more challenging due to the impacts of climate change and other factors, such as population growth, urbanization and change of diet. Water resources are expected to decrease further, while municipal and agricultural water demand is increasing in the region, also driven by population growth on the southern shore. On the basis of climate projections to 2050 elaborated by the Intergovernmental Panel on Climate Change (IPCC, 2013), the Euro-Mediterranean Center on Climate Change (CMCC) confirms that an average temperature increase of 2 °C would generate a 6–12 cm rise in Mediterranean sea level, a 5–10% fall in precipitation and more frequent extreme climatic events (Ferragina, 2015). According to this scenario, the agricultural production of countries on the southern and eastern shores will decrease by 50% by the end of the century (Porter et al., 2014). Hence, adaptation of Mediterranean society to climate change requires a new cross-sectoral approach to the management of energy and water resources aimed at "doing more and better with less". Such management solutions should be inspired by a philosophy of mutual benefit for each sector and should prevent adoption of policies that might privilege one sector to the detriment of another. PRIMA[2] was recently launched with the specific aim of fostering an integrated programme on sustainable food systems and water resources for the development of inclusive, sustainable and healthy Mediterranean societies.

Recent adoption of the Sustainable Development Goals (SDGs) by all UN member states, promoted by the United Nations Sustainable Development Solution Network (UN-SDSN, 2015), offers an appropriate framework to track impacts of WEF-related measures in the Mediterranean region. Indeed, among the 17 SDGs, three specific goals are dedicated to nexus problems. These are: 1) *food security* (SDG 2 – End hunger, achieve food security and improved nutrition and promote sustainable agriculture); 2) *sustainable management of water* (SDG 6 – Ensure availability and sustainable management of water and sanitation for all); 3) *affordable and clean energy* (SDG 7 – Ensure access to affordable, reliable, sustainable and modern energy for all). Many other aspects related to food production systems, water resources and clean energy also cut across different goals (*cross-cutting issues*). This means that improving efficiency and sustainability in the WEF Nexus can have a positive domino effect, promoting progress in other goals.

The aim of this study is to introduce a monitoring tool based on selected indicators shaped on the SDG framework. The purpose of the tool is to obtain information on the effects of PRIMA research and innovation, addressing WEF interdependency in the Mediterranean region, although the E (Energy) component of WEF is clearly underestimated because the primary objective of PRIMA is more "water and food" oriented.

The Inter-Agency and Expert Group (IAEG) of the United Nations has suggested around 230 indicators for monitoring progress towards the 17 SDGs (UN, 2016) and an approach that relies on the relationship between indicators and targets, which are sublevels of the SDGs. However, targets can be misleading because they tend to be reductionist and at odds with the complexity of interactions across goals. The monitoring tool proposed in this paper pays more attention to goals than to targets. This will help overcome what Costanza et al. (2014) defined a missing element of the SDG definition process, namely the "articulation and measurement of the overarching goal or 'ultimate end' of the SDGs and how the list of sub-goals and targets contribute to achieving that larger goal".

[2] http://prima-med.org.

Section 2 of this paper explains the criteria used to identify the indicators to be monitored. Each indicator is then described in detail and the geographical area is outlined. Section 3 is dedicated to a description of the monitoring tool. The baseline is presented and the results shown graphically. Insights into the monitoring process at local scale are also given. The last section of the paper provides some recommendations on how the monitoring tool can be used to help the decision-making on WEF Nexus-related issues in the Mediterranean region.

2. Selection of sustainable development indicators

To implement this systems approach for the Mediterranean region, we developed a monitoring tool based on a set of indicators satisfying the following criteria:

- *Cover most SDGs:* the indicators should be able to monitor the progress of Mediterranean decision-making bodies in achieving as many goals as possible, in addition to SDGs concerned with *food security*, *water provision* and *access to energy* (i.e. cross-cutting issues).
- *Consider biophysical limits:* it is fundamental to have indicators that give information about the biophysical limits of the system, both from the resource consumption and environmental loading viewpoints.
- *Consider the nexus:* water, energy and food have a strong relationship with each other and play a crucial role in the achievement of SDGs; the use of indicators that can highlight the linkages among all three is needed.
- *Consider both national and sectoral systems:* some indicators have to monitor national systems (e.g. poverty, health, land use, GHG emissions), while others shall monitor sectoral systems (e.g. agriculture, water services).
- *Be limited in number:* the indicators should be limited in number in order to be an effective tool that can easily support the monitoring process of evaluated systems.
- *Data availability should be guaranteed* frequently enough to be meaningful in the desired time horizon.

To this end we have shortlisted a set of indicators (see Table 1) among those provided by UN-SDSN (2015), rather than using the indicators released by UN-IAEG (2016). We believe that, in this way, the monitoring tool is more consistent with the needed systems approach, avoiding the reductionism of a target based approach. Moreover, the indicators we selected have the capacity of describing not only the specific goals the PRIMA programme refers to (namely #2 and #6), but also the influence on the remainder of the goals (see Table 2).

Among the selected indicators providing a picture of the Mediterranean region, four of them deliver information at local scale with a spatial resolution of 5 km × 5 km. The relevance of such indicators is related to the above criterion on the biophysical limits of the evaluated system by providing a frame for spatially explicit assessments.

2.1. Indicator description

For each indicator a brief description is given in the following, to explain their meaning, the reason for their selection and the source of data upon which they are based.

2.1.1. Multidimensional Poverty Index (MPI)

This is an international poverty indicator developed by the Oxford Poverty and Human Development Initiative (OPHI) of the United Nations Development Program. The index reflects the multiple deprivations that a poor person faces with respect to education, health and living standards. According to Alkire and Foster (2011), the MPI is an index of acute multidimensional poverty. It assesses the nature and

Table 1
Shortlist of indicators for the monitoring tool. The spatial resolution the indicators refer to is the country level. It is possible for some of these indicators (or for others strictly connected) to have information at a lower scale. See Section 3.2 for such examples.

#	Indicator	Unit
1	Multidimensional Poverty Index (MPI)	–
2	Population overweight	%
3	Land use	%
4	GHG emissions (total and AFOLU)	t CO_{2e}
5	Cereal yield	kg/ha
6	Agriculture value added	US$/worker
7	Fertilizer consumption	$kg/ha_{arable\ land}$
8	Crop water productivity	kg/m^3
9	Annual freshwater withdrawal for agriculture	%
10	Population using safely managed water services (rural)	%
11	Population using safely managed sanitation services (rural)	%
12	Amount of agricultural residues used for energy purpose	t

intensity of poverty at the individual level, creating a vivid picture of people living in poverty within and across countries. The three dimensions of MPI (i.e. health, education, and living standards) are measured using 10 indicators. It represents the first international measure of its kind and offers an essential complement to income poverty because it measures deprivations directly.

Source: the MPI indices for the Mediterranean countries are based on the works of Alkire et al. (2014) and Alkire and Robles (2017).

2.1.2. Population overweight (%)

This indicator was selected to investigate the nutrition aspects in Mediterranean countries. According to the Millennium Development Goals Report 2015 (United Nations, 2015), they all have reached values that are lower than 5% for what concerns the share of population undernourished.

The percentage of population overweight is estimated according to the data related to the Body Mass Index (BMI), that is an index of weight-for-height that is commonly used to classify underweight, overweight and obesity in adults (WHO, 2000).

Source: World Health Organization (WHO), Global Database on Body Mass Index (http://apps.who.int/bmi/index.jsp).

2.1.3. Land use (%)

A proxy indicator of land use was identified to monitor how land area changes in time with particular regard to agriculture and forest. The extension of the different types of land area is expressed as percentage of the total land area. The *Agricultural land* includes the land area that is arable, under permanent crops, and under permanent pastures. The *Forest area* is the land under natural or planted stands of trees of at least 5 m in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens.

It is important to follow the variation in time of these portions of total land use to monitor possible conflicts between urban, forest and agricultural land due, for example, to population increase and/or other pressures.

Source: World Bank database (http://data.worldbank.org/indicator/AG.LND.AGRI.ZS).

2.1.4. GHG emissions (total and AFOLU (t CO_{2e}))

This indicator aims at defining the total net greenhouse gas (GHG) emissions, expressed in tons of CO_2 equivalent (tCO_{2e}), with a specific focus on the Agriculture, Forest and other Land Use (AFOLU) sector, according to the Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines (with updates to the 2013 ones) for the national GHG inventory (IPCC, 2006).

Investigating the GHG emissions of the AFOLU sector allows monitoring the emissions related to different land types and land use change. Livestock is an increasingly important factor for GHGs increase.

Table 2
Representation of which SDG (rows) can be positively affected by an improvement of the proposed indicators (columns).

SDGs \ INDICATORS	1	2	3	4	5	6	7	8	9	10	11	12
1. No poverty	■					■			■			
2. Food security and sustainable agriculture		■		■	■	■	■	■	■			
3. Good health and well-being	■	■		■		■			■	■	■	■
6. Clean water and sanitation								■	■	■	■	■
7. Affordable and clean energy			■									■
8. Decent work and economic growth	■					■						
10. Reduce inequalities	■					■				■	■	■
11. Sustainable cities and communities	■	■	■		■	■		■	■	■	■	■
12. Sustainable consumption and production		■	■		■	■		■	■			
13. Climate action		■	■				■					
14. Sustainable management of oceans		■					■					
15. Sustainable land use, forests, etc.		■	■		■			■				

By means of this indicator and the indicator No. 3 it is possible to evaluate the behavior of Mediterranean countries with respect to climate change.

Source: UNFCCC database (http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php).

2.1.5. Cereal yield (kg/ha)

The efficiency in producing cereals is a major agricultural indicator for the evaluation of countries. It is worth noting that this indicator has to be coupled with indicators No. 8 and 9 on water efficiency and availability, indicator No. 7 on fertilizer efficiency and should be combined with one about the integrity of soil to better analyze the performance of systems under study. Indeed, an improvement of the agriculture yield is desired, unless the soil is stressed with an excessive uptake of nutrients, or too much water is used, thus compromising its availability for other purposes.

Source: World Bank database (http://data.worldbank.org/indicator/AG.YLD.CREL.KG).

2.1.6. Agriculture value added (US$/worker)

This indicator aims at measuring the agricultural productivity in money terms. It measures the difference between the output of the agricultural sector (International Standard Industrial Classification – ISIC divisions 1–5[3]) and the value of intermediate inputs. Agriculture comprises value added from forestry, hunting and fishing, as well as cultivation of crops and livestock production. Data are in constant 2010 U.S. dollars.

Source: World Bank database, (http://data.worldbank.org/indicator/EA.PRD.AGRI.KD).

2.1.7. Fertilizers consumption (kg/$ha_{arable\ land}$)

This indicator, together with *Cereal yield* and *Agriculture value added*, provides a focus on the agriculture sector. With regard to fertilizers, it is worth highlighting its relevance for monitoring processes at the local scale. *Fertilizer consumption* is expressed as kilogram of fertilizer per hectare of arable land and it measures the quantity of plant nutrients used per unit of arable land. Fertilizer products include nitrogen, potassium and phosphorous fertilizers (including ground rock phosphates). Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow.

Source: World Bank database, (http://data.worldbank.org/indicator/AG.CON.FERT.ZS).

2.1.8. Crop water productivity (kg/m^3)

This indicator is directly related to freshwater use for irrigation. Under the System of Environmental-Economic Accounting (SEEA), water productivity is defined as the value added of agriculture divided by water use by agriculture.[4] For this indicator, data are needed in order to monitor the evolution of countries with time. Currently, the available data refer to 2007 and were included in the baseline with all the other indicators.

The role of this indicator is pivotal since it represents the nexus between two fundamental sectors such as agri-food and water.

Source: Zwart (2010).

2.1.9. Annual freshwater withdrawal for agriculture (%)

This indicator measuring the level of total freshwater withdrawals is defined as the annual percentage used in agriculture for irrigation and also in livestock production. The withdrawal can include water from desalination plants but not counting evapotranspiration losses from storage basins. This indicator can exceed 100% of the total renewable resources when there is a significant component of non-renewable water or desalination.

Source: World Bank database, (http://data.worldbank.org/indicator/ER.H20.FWAG.ZS).

2.1.10. Population using safely managed water services (rural, %)

This indicator measures the percentage of the rural population using safely managed drinking water services, as defined by the WHO/UNICEF Joint Monitoring Program.[5] A basic drinking water source is a source or delivery point that by nature of its construction or through active intervention is protected from outside contamination with fecal matter. Basic drinking water sources can include: piped drinking water supply on premises; public taps/stand posts; tube well/borehole; protected dug well; protected spring; rainwater; and bottled water (when another basic source is used for hand washing, cooking, or other basic personal hygiene purposes).

Source: UNSTAT, MDG (http://unstats.un.org/UNSD/MDG/Data.aspx).

2.1.11. Population using safely managed sanitation services (rural, %)

This indicator measures the percentage of the population in rural areas using safely managed sanitation services, as defined by the WHO/UNICEF Joint Monitoring Programme.

Safely managed sanitation services are those that effectively separate excreta from human contact, and ensure that excreta do not re-enter the immediate environment. This means that household excreta are contained, extracted, and transported to designated disposal or treatment site, or, as locally appropriate, are safely re-used at the household or community level.

The present and the No. 10 indicators investigate countries behavior at sectoral level (i.e. water services).

Source: UNSTAT, MDG (http://unstats.un.org/UNSD/MDG/Data.aspx).

2.1.12. Amount of agricultural residues used for energy purpose (t)

This indicator aims at identifying and quantifying the agricultural and food industry waste as well as those fractions of municipal and animal solid waste that are available and can be converted, by means of biotechnological processes, into food, feed, value-added products for nutraceuticals and healthcare, biogas and organic based fertilizer.

It is worth stressing that this indicator is fundamental for the nexus food-energy and is especially relevant in the development of the south-shore Mediterranean countries. For the relevance of this issue in North Africa, see also Saladini et al. (2016).

Source: data are needed.

By monitoring the identified indicators, it is possible to evaluate the actual progress in achieving not only the SDGs to which indicators belong (i.e. SDG 2, SDG 6 and SDG 7), but also the other goals that are positively affected by improvements in such indicators (cross-cutting issues), as shown in Table 2.

For what concerns the monitoring process at local scale, a brief description of the four selected indicators is provided below. For all of them data are available for the whole Europe and the non-EU river basins draining into the Mediterranean Sea. The same data are also available at country level for all northern African and Middle East countries.

- <u>Cereal yield</u>

  This indicator (kg/ha), also used for country level evaluation, is calculated on an annual basis for a grid with a resolution of

[3] UNSTAT, International Standard Industrial Classification of all Economic Activities, Rev.3 (http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=2).

[4] UNSTAT, System of Environmental-Economic Accounting (SEEA) (http://unstats.un.org/unsd/envaccounting/seea.asp).

[5] WHO/UNICEF Joint Monitoring Programme (http://www.wssinfo.org).

Fig. 1. Study area. Mediterranean countries evaluated by means of the proposed monitoring tool.

5 km × 5 km and depends on the type of cereal, management practices, water and fertilizer availability. It specifically refers to non-irrigated cereals.

- Fertilizers consumption
  The present indicator, proposed here for evaluations both at the national level and at the local scale (5 km × 5 km) is based on the estimation of fertilizer application, both for mineral and manure nitrogen and phosphorus. The measuring unit is $kg/ha_{arable\ land}$.
- Crop water requirements
  Strictly related to the indicators on *crop water productivity* and *proportion of total water used* (i.e. No. 8 and 9 of the proposed monitoring tool, respectively), an estimation of crop water requirement in irrigated areas both as depth and volume on a grid of 5 km × 5 km is provided. In addition, the proportion of water used in agriculture as a fraction of total water requirement at grid level is evaluated.
- Wastewater treatment plants
  With this indicator, strongly linked to the *population using safely managed sanitation services* (i.e. indicator 11 of the shortlist), it is possible to geo-localize the major wastewater treatment plants for all North Africa, and for the coastal Middle East including Lebanon, Israel, Palestine and Syria. Data on the treatment level, and the volume of water treated and associated nutrient discharge are available.

2.2. Study area

The study area includes then those countries that directly border the Mediterranean Sea, i.e. Albania, Algeria, Bosnia-Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Montenegro, Morocco, Palestine, Slovenia, Spain, Syrian Arab Republic, Tunisia and Turkey, plus Jordan, Macedonia and Portugal that are ecologically characterized by biomes typical of the Mediterranean region (Fig. 1). Only countries with populations > 500,000 were included (UNEP/MAP-Plan Bleu, 2009).

3. Baseline

Available updated datasets for each indicator have been collected to develop a baseline. This is intended to provide an insight of the current situation of the Mediterranean region and serve as a reference for monitoring the future performance of countries in the region. Results at country scale are reported in Table 3. The indicators *Land use* and *GHG emissions (total and AFOLU)* are represented separately by means of pie charts and histograms, respectively (Figs. 2 and 3). As an example, the baseline of three countries from different areas of Mediterranean region is reported (Italy, Morocco and Jordan).

3.1. Synthetic representation of national performances

The monitoring tool is meant to track progress towards the achievement of SDGs, rather than for a comparison among countries and the establishment of rankings. A useful representation of the results (and of the evolution with time) is provided by the *radar diagram* (or "amoeba"; see Fig. 4), highlighting its strong points and where efforts are needed. For each country, the data collected for the different indicators have been normalized to a range of values between 1 and 10. The normalization of data has produced an amoeba in which, for each indicator, the higher the distance from the center the higher the level of sustainability for that indicator. As an example, Fig. 4 reports the case of Italy.

3.2. Monitoring processes at local scale

As shown in Fig. 5a-d, referred to 2010 data, the four supplementary indicators at a spatial resolution of 5 km × 5 km provide a different level of information. Rainfed wheat production is lower in Northern African countries and higher in Southern Europe. Wheat yield is not only limited by low rainfall, but also by management practices, in particular fertilizer applications, which are lower in the Maghreb leading to lower crop production (Pastori et al., 2015).

Irrigation is developed mostly in Southern Europe, while the Maghreb countries exhibit a much lower application rate, due to the low water availability. Water reuse, still quite limited in these countries, could provide an alternative water source, with economic and environmental benefits. Egypt is an exception, with a very high water use for irrigation. In conjunction with high fertilizer application rates, crop yields are as high as those obtained in many European countries.

4. Future perspectives

The proposed monitoring tool is meant to help keep track of the impacts generated by research and innovation projects promoted by the PRIMA Programme. Indicators accounting for national and local peculiarities of the food-water interdependencies are necessary to help socio-economic decision-making in the Mediterranean region. The

Table 3
Baseline for the selected sustainable development indicators.

	Multidimensional Poverty Index (MPI)	Population overweight, %	Cereal Yield, kg/ha	Agriculture value added per worker, 2010US$	Fertilizer consumption, kg/ha	Crop water productivity, kg/m^3	Annual freshwater withdrawal for agriculture, %	Safe water service (rural), %	Safe sanitation service (rural), %
Albania	0.005	57.7	4893	4254	87.7	1.09	39.5	95	90
Algeria	n.a.	62.0	1369	6222	51.3	0.72	59.2	82	82
Bosnia and Herzegovina	0.002	53.3	3977	45,582	109.2	1.04	n.a.	100	92
Croatia	n.a.	59.6	6037	35,659	251.0	0.98	1.3	100	96
Cyprus	0.108	59.1	291	20,088	175.9	n.a	65.7	100	100
Egypt, Arab Rep.	0.014	63.5	7231	5454	662.5	1.22	85.9	99	93
France	0.084	59.5	7634	88,578	151.5	1.42	10.4	100	99
Greece	0.121	62.3	4134	16,848	157.2	1.05	87.8	100	98
Israel	n.a.	64.3	4356	n.a.	239.3	1.01	57.8	100	100
Italy	0.096	58.5	5709	59,978	130.9	1.21	44.1	100	100
Lebanon	n.a.	67.9	2620	74,761	473.9	0.62	59.5	99	81
Libya	0.006	66.8	673	n.a.	4.9	0.74	83.2	68	96
Malta	0.089	66.4	4763	n.a.	468.0	n.a.	64.0	100	100
Montenegro	0.001	59.4	3451	12,656	271.9	1.06	1.1	99	92
Morocco	0.067	60.4	1454	5018	66.7	0.82	87.8	65	66
Palestine	0.006	n.a.	1851	3468	n.a.	n.a.	45.2	82	90
Slovenia	0.054	56.1	6481	248,525	260.0	n.a.	0.3	99	99
Spain	0.100	61.6	3246	45,621	151.4	0.91	68.2	100	100
Syrian Arab Republic	0.016	61.4	1063	n.a.	5.4	0.67	87.5	87	95
Tunisia	0.004	61.6	1756	n.a.	31.8	0.95	80.0	93	80
Turkey	n.a.	66.8	2831	10,724	105.3	0.64	80.9	100	86
Portugal	0.166	57.5	4416	10,070	184.8	1.07	78.7	100	100
Jordan	0.006	69.6	1455	8414	388.0	0.51	65.0	92	99
Macedonia, FYR	0.002	58.1	3900	19,127	71.7	0.94	22.8	99	83

monitoring tool proposed here consists of a dozen of indicators, for which (except for one) a reliable baseline has been developed. It is a flexible set that can be integrated with other indicators, e.g. on land degradation/soil erosion, which would support the assessment of *cereal yields*. Indeed, addressing the interdependencies of food security and water provision in the Mediterranean area requires an inclusive nexus system of indicators, rather than indicators focusing on individual SDGs or, worse, their targets. An effective monitoring tool should follow countries' development both in time and space. In order to check progress in the implementation of SDGs, changes from baselines has to be assessed at regular intervals. The temporal dimension enters the game also when it comes to predict impacts of the programmes of measures necessary to achieve the 2030 objectives. Indicators should be extrapolated to the future for an ex-ante assessment of which types of measures are likely to produce most of the desired benefits towards the SDGs. This introduces also the need of spatially identifying where these measures are most effective. The second set of indicators, as defined in Fig. 5a–d would then help target places for action in a spatially explicit approach. Modeling is an essential component of the monitoring tool, which is an avenue that we are exploring.

Based on existing stakeholders' analyses, field studies and research, the PRIMA programme offers an opportunity for the development of

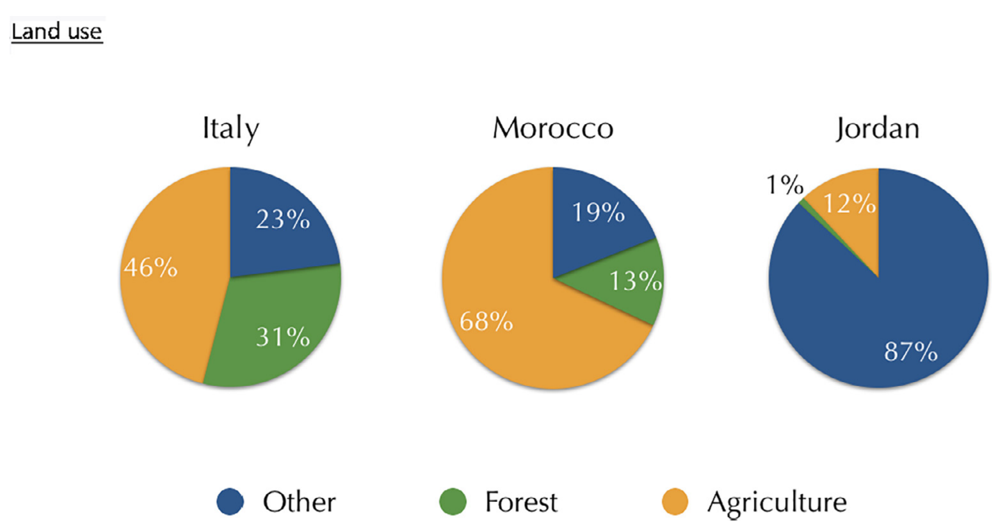


Fig. 2. Baseline for the indicator *Land use* (Italy, Morocco and Jordan are reported as an example).

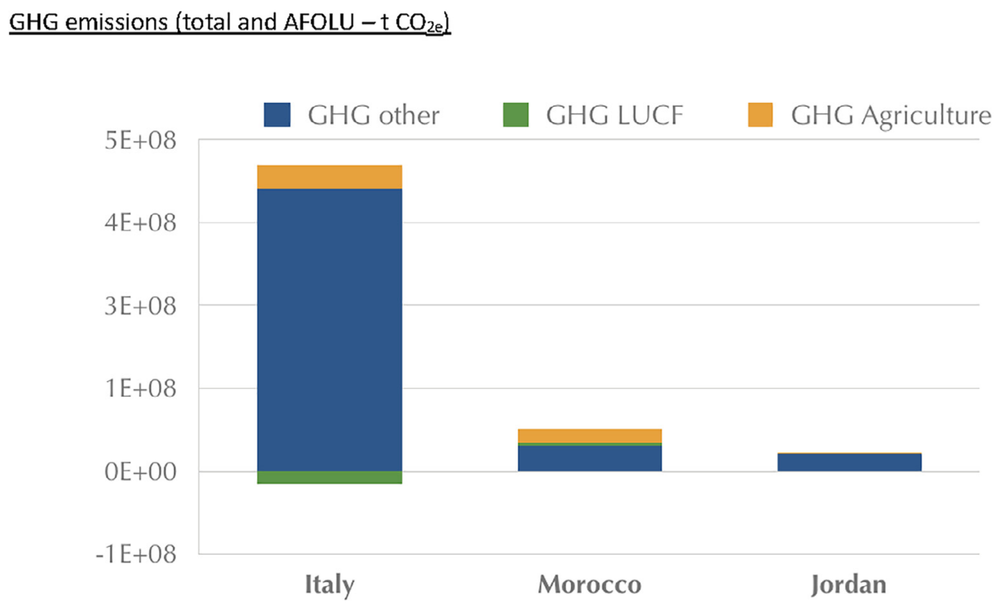


Fig. 3. Baseline for the indicator *GHG emissions* (Italy, Morocco and Jordan are reported as an example). LUCF = *Land Use Change and Forestry*.

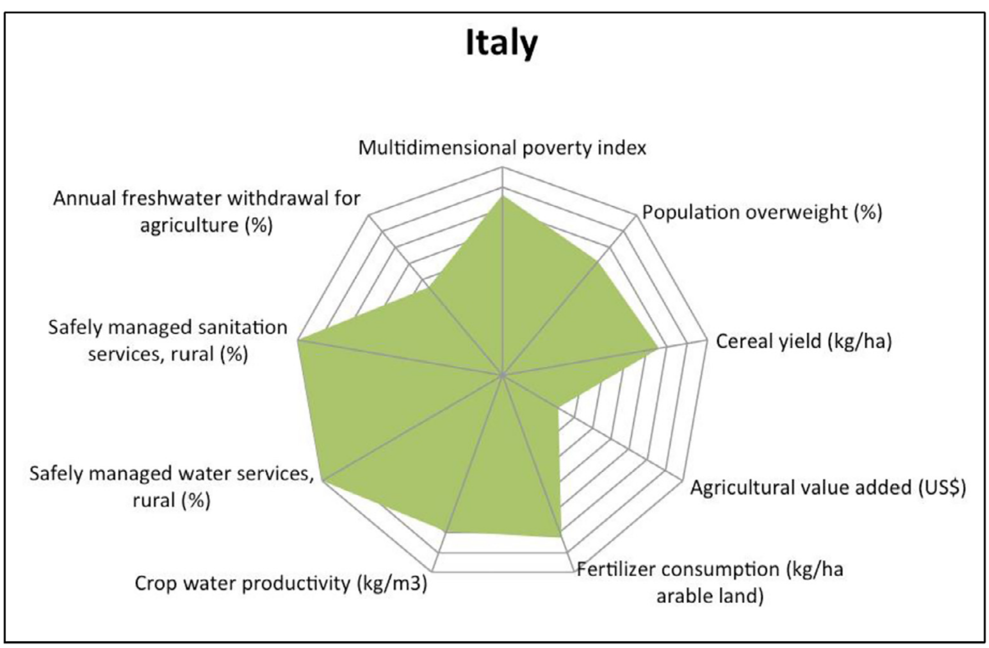


Fig. 4. Radar diagram for Italy. For each indicator, the higher the distance from the origin of the axis, the higher the level of sustainability.

innovative technical solutions promoting sustainable food production and water provision in the Mediterranean area, within the framework of a reinforced Euro-Mediterranean co-operation. The current economic-financial crises and socio-political uprising in the region need to encourage the creation of synergies based on common rules and objectives and the adoption of long-term strategies. The proposed combination of indicators represents a valuable diagnostic tool capable to support Mediterranean policy makers. Countries and other decision-making bodies can rely on the feedbacks provided by the monitoring process to outline their performance regarding the dimensions of the WEF nexus. According to such profiles, Mediterranean policy-makers would be able to define which sectors they have to pay attention to, implementing targeted policies for improving current situations. It is worth noting that the improvement of expected results about the selected indicators can positively reflect on other sectors that are not necessarily investigated by this monitoring tool, as there are many other aspects related to food production systems, water resources and clean energy that cut across different goals. This would help achieve most of the SDGs in the Mediterranean area.

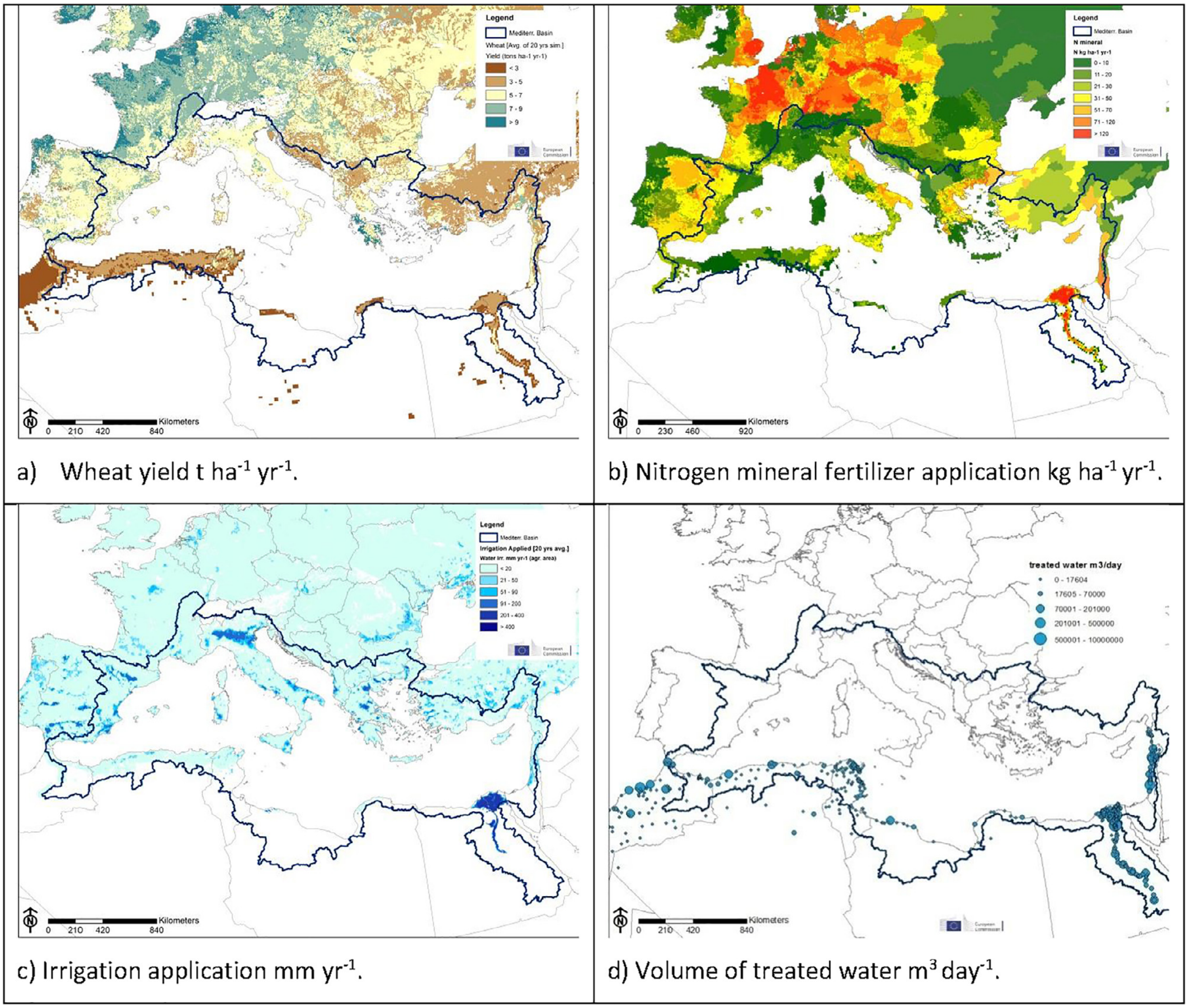


Fig. 5. a–d. Grid mapping of the Mediterranean region for local scale indicators.

Acknowledgments

This work was supported by the Ministero dell'Istruzione dell'Università e della Ricerca under the project IT4PRIMA – Segretariato Italiano & Unità di Ricerca di PRIMA (Partnership for research and innovation in the Mediterranean Area).

The activity was included in the Others Activities in the Annual Work Plan 2018 for the PRIMA "Partnership for Research and Innovation in the Mediterranean Area". The PRIMA programme is an Art.185 initiative supported and funded under Horizon 2020, the European Union's Framework Programme for Research and Innovation. Right before the acceptance of this paper Dr. Eugenia Ferragina passed away. Dr. Ferragina had greatly promoted the studies of the socio-economic development of the Mediterranean area. Her early disappearence is a loss for the other authors and for the whole scientific community.

References

Alkire, S., Apablaza, M., Jung, E., 2014. Multidimensional poverty measurement for EU-SILC countries. OPHI Research in Progress 36b.

Alkire, S., Foster, J., 2011. Understandings and misunderstandings of multidimensional poverty measurement. J. Econ. Inequal. 9, 289–314.

Alkire, S., Robles, G., 2017. Multidimensional Poverty Index Summer 2017: Brief methodological note and results. OPHI Methodological Note 44. University of Oxford.

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., Steduto, P., Mueller, A., Komor, P., Tol, R.S.J., Yumkella, K.K., 2011. Considering the energy, water and food nexus: Towards an integrated modelling approach. Energy Policy 39, 7896–7906.

Costanza, R., Mcglade, J., Lovins, H., Kubiszewski, I., 2014. An overarching goal for the UN sustainable development goals. Solutions 5, 13–16.

European Commission, 2011. Causes of the 2007-2008 global food crisis identified in "Science for Environment Policy": European Commission DG Environment News Alert Service, edited by SCU. The University of the West of England, Bristol.

FAO, 2014. The Water-Energy-Food Nexus. A New Approach in Support of Food Security and Sustainable Agriculture. FAO, Rome.

Ferragina, E., 2015. Rapporto sulle economie del Mediterraneo. Istituto di Studi sulle società del Mediterraneo (ISSM-CNR). Società editrice il Mulino, Bologna.

Headey, D., Fan, S., 2010. Reflections on the Global Food Crisis. How Did It Happen? How Has It Hurt? And How Can We Prevent the Next One? International Food Policy Research Institute. Research Monograph 165. The report can be accessed at: http://www.ifpri.org/sites/default/files/publications/rr165.pdf.

Hochmana, G., Rajagopalb, D., Timilsinac, G., Zilbermand, D., 2014. Quantifying the causes of the global food commodity price crisis. Biomass Bioenergy 68, 106–114.

IPCC, 2006. In: Egglestion, S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.), IPCC Guidelines for National Greenhouse Gas Inventories. IGES, Japan.

IPCC, 2013. Climate Change 2013: The Physical Science Basis. In: Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bexand, V., Midgley, P.M. (Eds.), Working Group I Contribution to the Fifth AssessmentReport of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1535.

IPEMED, 2010. Jean-Louis Rastoin, Foued Cheriet, Food Security in the Mediterranean: A

Major Geostrategic Issue. Les Notes IPEMED n°6. Institut de Prospective Economique du Monde Méditerranéen (IPEMED).
Pastori, M., Udías, A., Bouraoui, F., Aloe, A., Bidoglio, G., 2015. Multi-objective optimization for improved agricultural water and nitrogen management in selected regions of Africa. Int. Ser. Oper. Res. Manage. Sci. 224, 241–258.
Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B., Travasso, M.I., 2014. Food security and food production systems. Climate Change 2014. Impacts, Adaptation and Vulnerability.
Rasul, G., 2014. Food, water, and energy security in South Asia: a nexus perspective from the Hindu Kush Himalayan region. Environ. Sci. Policy 39, 35–48.
Riccardini, F., De Rosa, D., 2016. How the nexus of water/food/energy can be seen with the perspective of people well being and the Italian BES framework. Agric. Agric. Sci. Proc. 8, 732–740.
Ringler, C., Bhaduri, A., Lawford, R., 2013. The nexus across water, energy, land and food (WELF): potential for improved resource use efficiency? Curr. Opin. Environ. Sustain. 5, 617–624.
Saladini, F., Vuai, S.A., Langat, B.K., Gustavsson, M., Bayitse, R., Gidamis, A.B., Belmakki, M., Owis, A.S., Rashamuse, K., Sila, D.N., Bastianoni, S., 2016. Sustainability assessment of selected biowastes as feedstocks for biofuel and biomaterial production by emergy evaluation in five African countries. Biomass Bioenergy 85, 100–108.
UN, 2015. The Millennium Development Goals Report 2015. United Nations, New York.
UNEP/MAP-Plan Bleu, 2009. State of the Environment and Development in the Mediterranean. UNEP/MAP-Plan Bleu, Athens.
UN-IAEG, 2016. Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators. Economic and Social Council, Forty-seventh session, E/CN.3/2016/2.
UN-SDSN, 2015. Indicators and a monitoring framework for Sustainable Development Goals – Launching a data revolution for the SDGs.
WHO, 2000. Obesity: Preventing and Managing the Global Epidemic. Geneva.
Zwart, S.J., 2010. Benchmarking Water Productivity in Agriculture and the Scope for Improvement – Remote Sensing Modelling from Field to Global Scale. Delft University of Technology.