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

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1   **Linking the Water-Energy-Food Nexus and Sustainable Development Indicators for the Mediterranean**

2   **Region**

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19   **Abstract**

20   Water use and agricultural practices in the Mediterranean area are unsustainable. The situation is

21   worsened by the increased frequency of droughts and floods, as well as desertification and soil depletion,

22   associated with climate change. The aim of Partnership for Research and Innovation in the Mediterranean

23   Area (PRIMA) is to foster an integrated programme of sustainable food production and water provision in

24   the framework of the water-energy-food nexus. A monitoring tool developed under PRIMA is based on the

25   Sustainable Development Goals, two of which are specifically dedicated to food security (SDG 2) and

26   sustainable management of water (SDG 6).

27   The 12 indicators that have been chosen to be monitored in the Mediterranean area are: Multidimensional

28   Poverty Index (MPI); population overweight (%); land use (%); GHG emissions (total and AFOLU)(tCO$_{2e}$);

29   cereal yield (kg/ha); agriculture value added (US$/worker); fertilizer consumption (kg/ha$_{arable\ land}$); crop

30   water productivity (kg/m^3); annual freshwater withdrawal for agriculture (%); population served using with

31   safely managed water service (rural, %); population served using with safely managed sanitation (rural, %);

32   amount of agricultural residues used for energy purposes (t). Datasets for these indicators are collected by

33   international bodies such as the World Bank, WHO, FAO and UNFCCC; recent series are available for almost

34   all Mediterranean countries and are constantly updated. The aim of the proposed monitoring tool is to

35   keep track of the impact generated in by PRIMA research and innovation projects Mediterranean countries.

36

1. Introduction

38   Food production and water provision are two urgent socio-economic and environmental issues in the

39   Mediterranean region. Because these two aspects are closely linked, they need to be tackled by an

40   integrated approach known as *Water-Energy-Food (WEF) Nexus* (e.g. Bazilian et al., 2011; Rasul, 2014;

41   Riccardini and De Rosa, 2016; Ringler et al., 2013). The recent global food crises of 2008 (Headey, Fan,

42   2010) and 2011[1] (Hochmana, Rajagopalb, Timilsinac, Zilbermand , 2014) drew attention to the crucial role

43   of food security in the Mediterranean area, especially considering the consequences for socio-political

44   equilibrium in certain countries of the Middle East and North Africa (MENA)(Ferragina, 2015). By 2050, the

45   food imbalance in this region, which depends more on cereal imports than any other region in the world, is

46   forecast to reach nearly 60%, making MENA extremely vulnerable in terms of food security (IPEMED, 2010).

47   The sustainable management of water resources is closely related to food security, since 70% of total global

48   freshwater withdrawals are driven by agriculture (FAO, 2014). Energy plays a key role in producing and

49   distributing food, as well as in extracting, treating and supplying water (FAO, 2014).

50   Problem solving in the frame of the WEF Nexus is expected to become more challenging due to the impacts

51   of climate change and other factors, such as population growth, urbanization and change of diet. Water

52   resources are expected to decrease further, while municipal and agricultural water demand is increasing in

53   the region, also driven by population growth on the southern shore. On the basis of climate projections to

54   2050 elaborated by the Intergovernmental Panel on Climate Change (IPCC, 2013), the Euro-Mediterranean

55   Center on Climate Change (CMCC) confirms that an average temperature increase of 2 C° would generate a

56   6-12 cm rise in Mediterranean sea level, a 5-10% fall in precipitation and more frequent extreme climatic

57   events (Ferragina, 2015). According to this scenario, the agricultural production of countries on the

58   southern and eastern shores will decrease by 50% by the end of the century (Porter et al., 2014). Hence,

59   adaptation of Mediterranean society to climate change requires a new cross-sectoral approach to the

60   management of energy and water resources aimed at "doing more and better with less". Such

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[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, D. and Fan, S., 2010).
See also: Hochmana, G. et al., 2014, Pages 106-114

61   management solutions should be inspired by a philosophy of mutual benefit for each sector and should

62   prevent adoption of policies that might privilege one sector to the detriment of another. PRIMA[2] was

63   recently launched with the specific aim of fostering an integrated programme on sustainable food systems

64   and water resources for the development of inclusive, sustainable and healthy Mediterranean societies.

65   Recent adoption of the Sustainable Development Goals (SDGs) by all UN member states, promoted by the

66   United Nations Sustainable Development Solution Network (UN-SDSN, 2015), offers an appropriate

67   framework to track impacts of WEF-related measures in the Mediterranean region. Indeed, among the 17

68   SDGs, three specific goals are dedicated to nexus problems. These are: 1) *food security* (SDG 2 - End hunger,

69   achieve food security and improved nutrition and promote sustainable agriculture); 2) *sustainable*

70   *management of water* (SDG 6 - Ensure availability and sustainable management of water and sanitation for

71   all); 3) *affordable and clean energy* (SDG 7 - Ensure access to affordable, reliable, sustainable and modern

72   energy for all). Many other aspects related to food production systems, water resources and clean energy

73   also cut across different goals (*cross-cutting issues*). This means that improving efficiency and sustainability

74   in the WEF Nexus can have a positive domino effect, promoting progress in other goals.

75   The aim of this study is to introduce a monitoring tool based on selected indicators shaped on the SDG

76   framework. The purpose of the tool is to obtain information on the effects of PRIMA research and

77   innovation, addressing WEF interdependency in the Mediterranean region, although the E (Energy)

78   component of WEF is clearly underestimated because the primary objective of PRIMA is more "water and

79   food" oriented.

80   The Inter-Agency and Expert Group (IAEG) of the United Nations has suggested around 230 indicators for

81   monitoring progress towards the 17 SDGs (UN, 2016) and an approach that relies on the relationship

82   between indicators and targets, which are sublevels of the SDGs. However, targets can be misleading

83   because they tend to be reductionist and at odds with the complexity of interactions across goals. The

84   monitoring tool proposed in this paper pays more attention to goals than to targets. This will help

85   overcome what Costanza et al. (2014) defined a missing element of the SDG definition process, namely the

86   "articulation and measurement of the overarching goal or 'ultimate end' of the SDGs and how the list of

87   sub-goals and targets contribute to achieving that larger goal".

88   Section 2 of this paper explains the criteria used to identify the indicators to be monitored. Each indicator is

89   then described in detail and the geographical area is outlined. Section 3 is dedicated to a description of the

90   monitoring tool. The baseline is presented and the results shown graphically. Insights into the monitoring

91   process at local scale are also given. The last section of the paper provides some recommendations on how

92   the monitoring tool can be used to help the decision-making on WEF Nexus-related issues in the

93   Mediterranean region.

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

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 x 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.

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

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.

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 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. 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).

152 *Source*: World Health Organization (WHO), Global Database on Body Mass Index

153 (http://apps.who.int/bmi/index.jsp)

154

155 *3. Land use (%)*

156 A proxy indicator of land use was identified to monitor how land area changes in time with particular

157 regard to agriculture and forest. The extension of the different types of land area is expressed as

158 percentage of the total land area. The *Agricultural land* includes the land area that is arable, under

159 permanent crops, and under permanent pastures. The *Forest area* is the land under natural or planted

160 stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in

161 agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in

162 urban parks and gardens.

163 It is important to follow the variation in time of these portions of total land use to monitor possible

164 conflicts between urban, forest and agricultural land due, for example, to population increase and/or other

165 pressures.

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

167

168 *4. GHG emissions (total and AFOLU (t CO_{2e}))*

169 This indicator aims at defining the total net greenhouse gas (GHG) emissions, expressed in tons of CO_2

170 equivalent (tCO_{2e}), with a specific focus on the Agriculture, Forest and other Land Use (AFOLU) sector,

171 according to the Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines (with updates to the

172 2013 ones) for the national GHG inventory (IPCC, 2006).

173 Investigating the GHG emissions of the AFOLU sector allows monitoring the emissions related to different

174 land types and land use change. Livestock is an increasingly important factor for GHGs increase. By means

175 of this indicator and the indicator no. 3 it is possible to evaluate the behavior of Mediterranean countries

176 with respect to climate change.

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

178

179 *5. Cereal yield (kg/ha)*

180 The efficiency in producing cereals is a major agricultural indicator for the evaluation of countries. It is

181 worth noting that this indicator has to be coupled with indicators no. 8 and 9 on water efficiency and

182 availability, indicator no. 7 on fertilizer efficiency and should be combined with one about the integrity of

183 soil to better analyze the performance of systems under study. Indeed, an improvement of the agriculture

184 yield is desired, unless the soil is stressed with an excessive uptake of nutrients, or too much water is used,

185 thus compromising its availability for other purposes.

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

187

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)

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)

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.

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

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[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)

219 exceed 100 percent of the total renewable resources when there is a significant component of non-

220 renewable water or desalination

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

222

223 *10. Population using safely managed water services (rural, %)*

224 This indicator measures the percentage of the rural population using safely managed drinking water

225 services, as defined by the WHO/UNICEF Joint Monitoring Program[5]. A basic drinking water source is a

226 source or delivery point that by nature of its construction or through active intervention is protected from

227 outside contamination with fecal matter. Basic drinking water sources can include: piped drinking water

228 supply on premises; public taps/stand posts; tube well/borehole; protected dug well; protected spring;

229 rainwater; and bottled water (when another basic source is used for hand washing, cooking, or other basic

230 personal hygiene purposes).

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

232

233 *11. Population using safely managed sanitation services (rural, %)*

234 This indicator measures the percentage of the population in rural areas using safely managed sanitation

235 services, as defined by the WHO/UNICEF Joint Monitoring Programme[11].

236 Safely managed sanitation services are those that effectively separate excreta from human contact, and

237 ensure that excreta do not re-enter the immediate environment. This means that household excreta are

238 contained, extracted, and transported to designated disposal or treatment site, or, as locally appropriate,

239 are safely re-used at the household or community level.

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

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

242

243 *12. Amount of agricultural residues used for energy purpose (t)*

244 This indicator aims at identifying and quantifying the agricultural and food industry waste as well as those

245 fractions of municipal and animal solid waste that are available and can be converted, by means of

246 biotechnological processes, into food, feed, value-added products for nutraceuticals and healthcare, biogas

247 and organic based fertilizer.

248 It is worth stressing that this indicator is fundamental for the nexus food-energy and is especially relevant

249 in the development of the south-shore Mediterranean countries. For the relevance of this issue in North

250 Africa, see also Saladini et al., 2016.

251 *Source*: data are needed.

252

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

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.

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

INDICATORS / SDGs	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.		■	■		■			■				

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

- <u>Fertilizers consumption</u>

The present indicator, proposed here for evaluations both at the national level and at the local scale (5 km x 5 km) is based on the estimation of fertilizer application, both for mineral and manure nitrogen and phosphorus. The measuring unit is kg/ha$_{arable\ land}$.

272 • Crop water requirements

273 Strictly related to the indicators on *crop water productivity* and *proportion of total water used* (i.e. no. 8

274 and 9 of the proposed monitoring tool, respectively), an estimation of crop water requirement in irrigated

275 areas both as depth and volume on a grid of 5 km x 5 km is provided. In addition, the proportion of water

276 used in agriculture as a fraction of total water requirement at grid level is evaluated.

277 • Wastewater treatment plants

278 With this indicator, strongly linked to the *population using safely managed sanitation services* (i.e. indicator

279 11 of the shortlist), it is possible to geo-localize the major wastewater treatment plants for all North Africa,

280 and for the coastal Middle East including Lebanon, Israel, Palestine and Syria. Data on the treatment level,

281 and the volume of water treated and associated nutrient discharge are available.

282

283 **2.2. Study area**

284 The study area includes then those countries that directly border the Mediterranean Sea, i.e. Albania,

285 Algeria, Bosnia-Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta,

286 Montenegro, Morocco, Palestine, Slovenia, Spain, Syrian Arab Republic, Tunisia and Turkey, plus Jordan,

287 Macedonia and Portugal that are ecologically characterized by biomes typical of the Mediterranean region

288 (Figure 1). Only countries with populations greater than 500,000 were included (UNEP/MAP-Plan Bleu,

289 2009).

290

291

292 **Figure 1**. Study area. Mediterranean countries evaluated by means of the proposed monitoring tool.

293

294 **3. Baseline**

295   Available updated datasets for each indicator have been collected to develop a baseline. This is intended to

296   provide an insight of the current situation of the Mediterranean region and serve as a reference for

297   monitoring the future performance of countries in the region. Results at country scale are reported in Table

298   3. The indicators *Land use* and *GHG emissions (total and AFOLU)* are represented separately by means of

299   pie charts and histograms, respectively (Figures 2 and 3). As an example, the baseline of three countries

300   from different areas of Mediterranean region is reported (Italy, Morocco and Jordan).

301

302 **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/m³	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	45582	109.2	1.04	n.a.	100	92
Croatia	n.a.	59.6	6037	35659	251.0	0.98	1.3	100	96
Cyprus	0.108	59.1	291	20088	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	88578	151.5	1.42	10.4	100	99
Greece	0.121	62.3	4134	16848	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	59978	130.9	1.21	44.1	100	100
Lebanon	n.a.	67.9	2620	74761	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	12656	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	248525	260.0	n.a.	0.3	99	99
Spain	0.100	61.6	3246	45621	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	10724	105.3	0.64	80.9	100	86
Portugal	0.166	57.5	4416	10070	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	19127	71.7	0.94	22.8	99	83
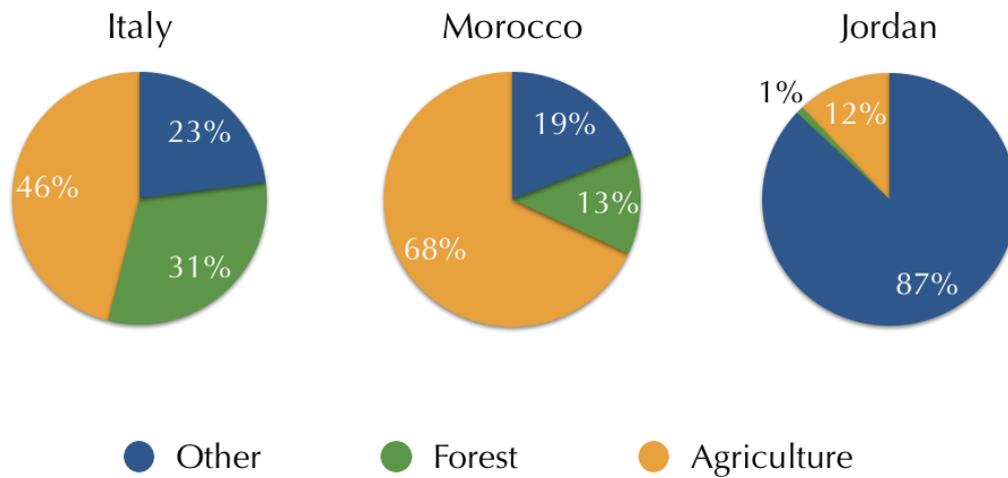
Land use

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

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

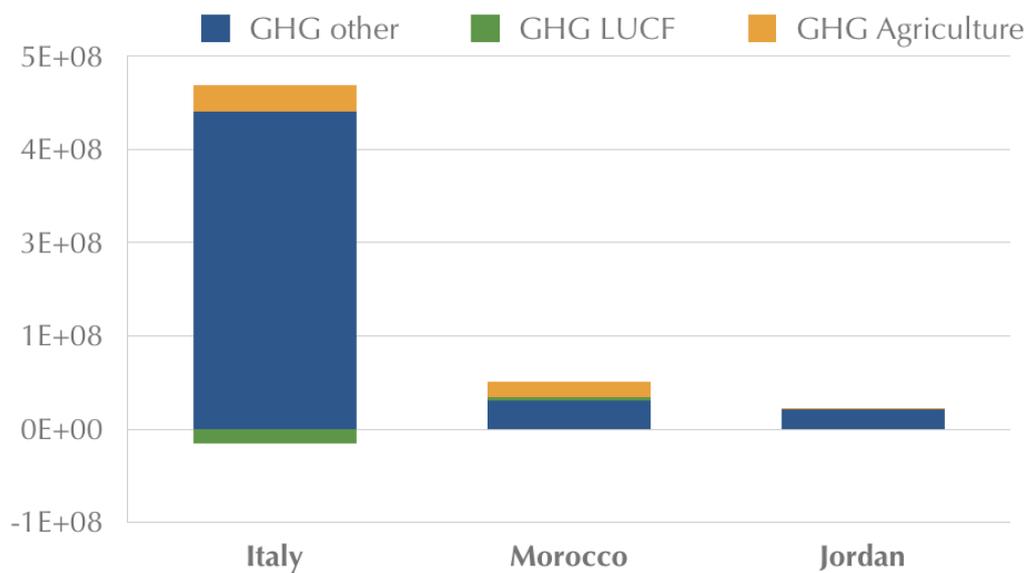**Figure 3**. Baseline for the indicator *GHG emissions* (Italy, Morocco and Jordan are reported as an example). LUCF = *Land Use Change and Forestry*.


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 Figure 4), highlighting its

329   strong points and where efforts are needed. For each country, the data collected for the different

330   indicators have been normalized to a range of values between 1 and 10. The normalization of data has

331   produced an amoeba in which, for each indicator, the higher the distance from the center the higher the

332   level of sustainability for that indicator. As an example, Figure 4 reports the case of Italy.
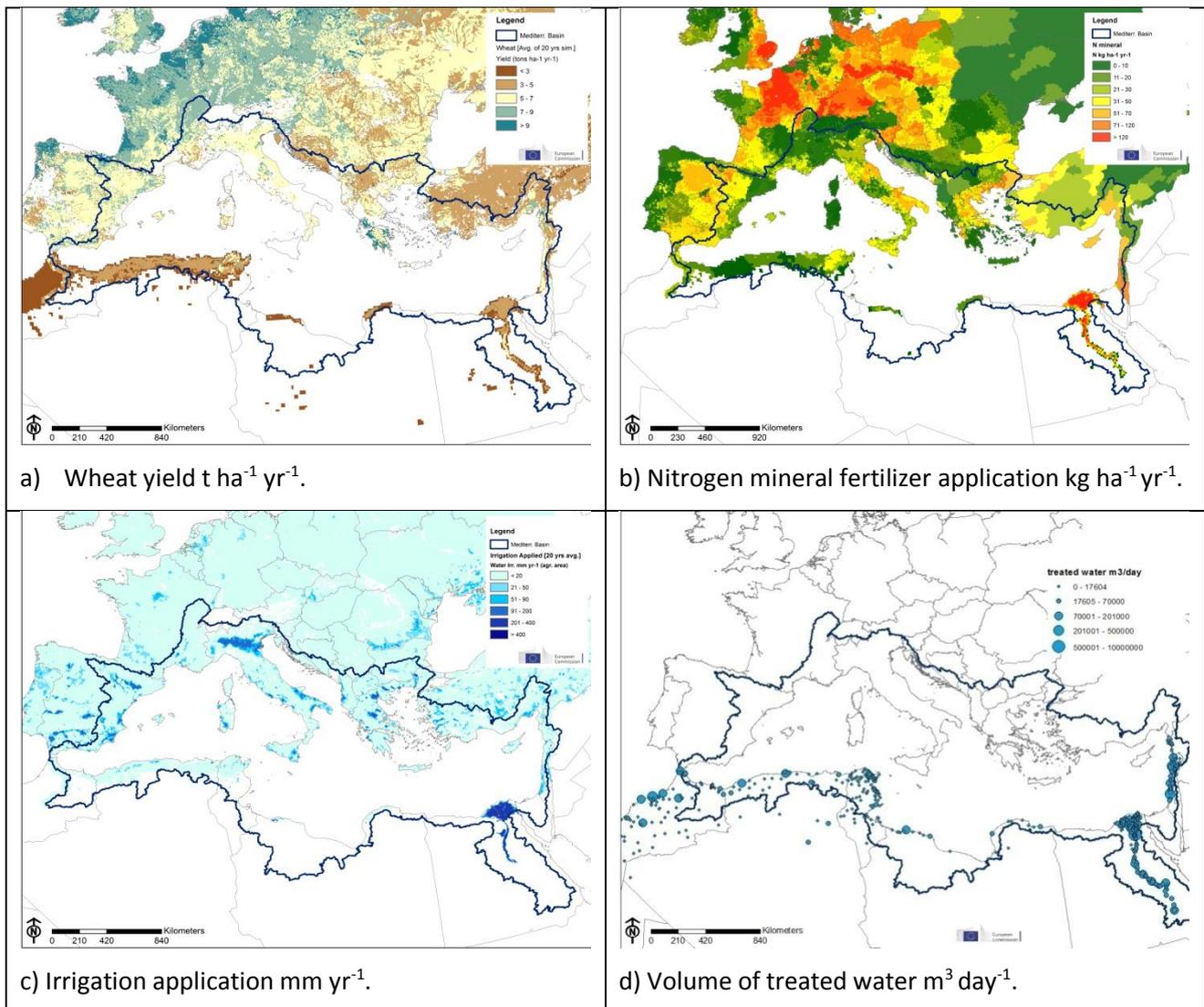
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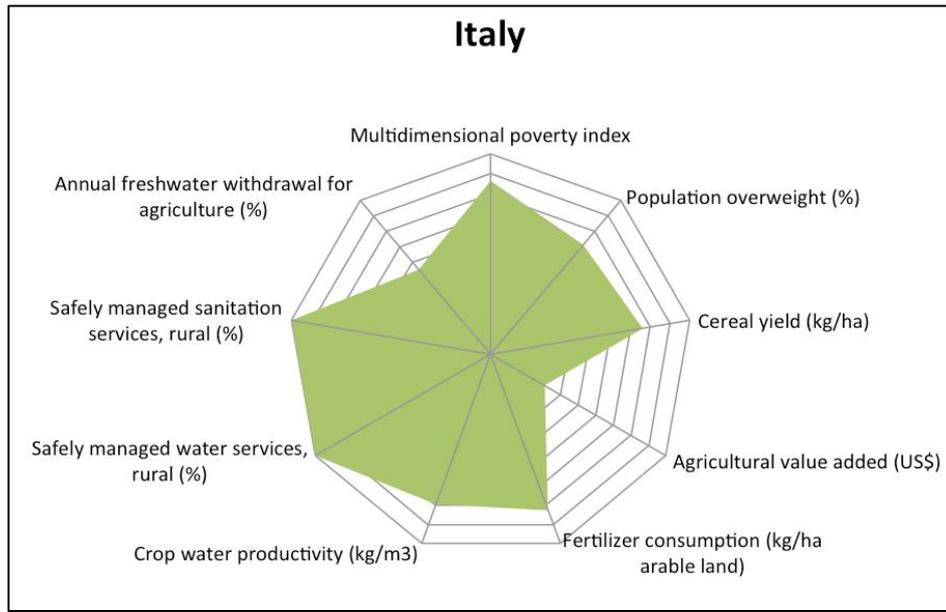
Figure 4. Radar diagram for Italy. For each indicator, the higher the distance form the origin of the axis, the
higher the level of sustainability.

337

3.2. Monitoring processes at local scale

As shown in Figure 5a-d, referred to 2010 data, the four supplementary indicators at a spatial resolution of
5 km x 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).

344

a) Wheat yield t ha^{-1} yr^{-1}.

b) Nitrogen mineral fertilizer application kg ha^{-1} yr^{-1}.

c) Irrigation application mm yr^{-1}.

d) Volume of treated water m^3 day^{-1}.

345 **Figure 5a-d**. Grid mapping of the Mediterranean region for local scale indicators.

346

347 Irrigation is developed mostly in Southern Europe, while the Maghreb countries exhibit a much lower

348 application rate, due to the low water availability. Water reuse, still quite limited in these countries, could

349 provide an alternative water source, with economic and environmental benefits. Egypt is an exception, with

350 a very high water use for irrigation. In conjunction with high fertilizer application rates, crop yields are as

351 high as those obtained in many European countries.

352

353 **4. Future perspectives**

354 The proposed monitoring tool is meant to help keep track of the impacts generated by research and

355 innovation projects promoted by the PRIMA Programme. Indicators accounting for national and local

356 peculiarities of the food-water interdependencies are necessary to help socio-economic decision-making in

357 the Mediterranean region. The monitoring tool proposed here consists of a dozen of indicators, for which

358 (except for one) a reliable baseline has been developed. It is a flexible set that can be integrated with other

359 indicators, e.g. on land degradation / soil erosion, which would support the assessment of *cereal yields*.

360 Indeed, addressing the interdependencies of food security and water provision in the Mediterranean area

361 requires an inclusive nexus system of indicators, rather than indicators focusing on individual SDGs or,

362 worse, their targets. An effective monitoring tool should follow countries' development both in time and

363 space. In order to check progress in the implementation of SDGs, changes from baselines has to be

364 assessed at regular intervals. The temporal dimension enters the game also when it comes to predict

365 impacts of the programmes of measures necessary to achieve the 2030 objectives. Indicators should be

366 extrapolated to the future for an ex-ante assessment of which types of measures are likely to produce most

367 of the desired benefits towards the SDGs. This introduces also the need of spatially identifying where these

368 measures are most effective. The second set of indicators, as defined in Figure 5 a-d would then help target

369 places for action in a spatially explicit approach. Modeling is an essential component of the monitoring tool,

370 which is an avenue that we are exploring.

371 Based on existing stakeholders' analyses, field studies and research, the PRIMA programme offers an

372 opportunity for the development of innovative technical solutions promoting sustainable food production

373 and water provision in the Mediterranean area, within the framework of a reinforced Euro-Mediterranean

374 co-operation. The current economic-financial crises and socio-political uprising in the region need to

375 encourage the creation of synergies based on common rules and objectives and the adoption of long-term

376 strategies. The proposed combination of indicators represents a valuable diagnostic tool capable to support

377 Mediterranean policy makers. Countries and other decision-making bodies can rely on the feedbacks

378 provided by the monitoring process to outline their performance regarding the dimensions of the WEF

379 nexus. According to such profiles, Mediterranean policy-makers would be able to define which sectors they

380 have to pay attention to, implementing targeted policies for improving current situations. It is worth noting

381 that the improvement of expected results about the selected indicators can positively reflect on other

382 sectors that are not necessarily investigated by this monitoring tool, as there are many other aspects

383 related to food production systems, water resources and clean energy that cut across different goals. This

384 would help achieve most of the SDGs in the Mediterranean area.

385

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