Tracking on food and agriculture-related SDG indicators in the Mediterranean region

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Abstract

The Mediterranean region is facing important socioeconomic, demographic, environmental and geopolitical dynamics, leading to a continuous rise in food requirements.
These interlinked challenges are embodied in the 2030 Agenda for Sustainable Development, adopted by all UN member states in 2015 and built around 17 Sustainable Development Goals (SDGs).
The aim of the study is to classify countries of the Mediterranean region, based on their agriculture and food related SDGs progress, in order to understand the key implementation strategies, define the gaps between countries and identify priorities for action. To classify countries, a cluster analysis based on Euclidean distance is used, followed by the ANOVA.
The analysis shows that the level of food security is a discriminating factor for the clustering of countries: a clear gap emerges between the countries of Western Europe and those of the MENA area. The transition towards more sustainable food production and consumption models has also reached different stages in the various countries of the area, representing a further element of distance.

Keywords*: Sustainable Development Goals, Agenda 2030, Agriculture, Agrifood, Mediterranean Countries.*

1. Introduction

The Mediterranean region is facing important socioeconomic, demographic, and geopolitical dynamics, leading to a continuous rise in food requirements (Valls Bedeau *et al.*, 2021; Cramer *et al.*, 2018). However, simply producing a larger volume of food and healthier food more sustainably will not ensure human wellbeing. Other crucial challenges must also be addressed, such as poverty reduction, social inclusion, and negative impact on natural resources such as water scarcity, erosion and soil degradation, which pose serious threats to a population of 500 million people, with consequences on agriculture and livestock and the risk of political instability, new conflicts and rising migratory flows (Saladini *et al.*, 2018; Herrero *et al.*, 2020). It must be noted that the Mediterranean region is using about three times more natural resources than its ecosystems can provide, and the pandemic has had a negative impact on the poverty rate, access to food and food security, social and gender inequality, and the unemployment rate (Sachs *et al.*, 2021).

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Moreover, the global food crises of 2008 (Headey and Fan, 2010) and 2011 (Hochman *et al.*, 2014) and the increased threat for grain-importing Middle Eastern and North African (MENA) countries consequent to the Russia-Ukraine conflict have drawn attention to the crucial role of food security in the Mediterranean area, especially considering the consequences for the socio-political equilibrium in certain countries of the MENA (FAO, 2022).

The shortcomings in the performance of most Mediterranean economies have also significantly contributed to deteriorating social conditions. The persistent poverty and unemployment have led to social marginalization, which is further compounded by income disparities.

These interlinked challenges are embodied in the 2030 Agenda for Sustainable Development, adopted by all UN member states in 2015 and built around the 17 Sustainable Development Goals (SDGs). The agenda emphasizes the importance of the research and application of methodologies that can better understand and reflect the negative and positive impacts of the agrifood supply chain (UN, 2013; UN-SDSN, 2015). In this context, food and agriculture will be instrumental to achieving multiple SDGs. This means that improving efficiency and sustainability in agriculture and food related to SDGs can have a positive domino effect, promoting progress in other goals. However, because of the large range of potential indicators connected to sustainability and related key actors, even though the 2030 Agenda provides an appropriate framework to track the impacts of agriculture and food-related measures in the Mediterranean region (UN-SDSN, 2015), tracking the SDGs is a big challenge. Indeed, according to Bele *et al.* (2018), the development of sustainable agricultural models is frequently marked by the use of metrics that differ significantly from traditional ones. Although biodiversity plays a critical role in maintaining long-term sustainability, ecological sustainability metrics may not always be able to capture its importance (Bele *et al.*, 2018). In addition, there is no universal agreement on the use of a specific indicator for the social dimension, which leads to uncertainty and ambiguity. Among the 17 SDGs, those related to agrifood have unique characteristics that call for adjusted approaches, even more so when they are considered in the Mediterranean context. Indeed, the Mediterranean regions have specificities (due to their climatic conditions) that distinguish them from their neighbors (Martinho, 2021). From this perspective, it seems pertinent to analyze the different dimensions of agrifood sustainability in the Mediterranean region.

The remainder of the study is as follows. In the next section, the theoretical foundations of the study and related literature are explained. Then, in Section 3, the research design, study area, data and the method of the empirical study are described. In Section 4 the results of the analysis are shown and discussed. Finally, conclusions and policy implications are presented in Section 5.

2. Background

The 2030 Agenda's member states declared that the development of policies for its implementation should be evidence-based and aligned with scientific principles (Schmalzbauer and Visbeck, 2016). In this view, research is a good way to promote sustainability by bolstering the findings of successful solutions to complex problems and pointing the way forward (Capone *et al.*, 2021; Schmalzbauer and Visbeck, 2016). Sustainability research is particularly interdisciplinary, so that it should take a transformative approach, bringing together experts from various fields to address societal issues (Annan-Diab and Molinari, 2017). In this context, the adoption of SDG targets and indicators launched a series of new research on sustainable development, enabling researchers from various fields of interest to devote their research to this topic. Guijarro and Poyatos (2018) presented a goal programming model for calculating the composite SDG index, which they applied to EU-28 Member States, thus providing insight into the relative position of the observed countries when it comes to achieving the Sustainable Development Goals. On the other hand, Szopik-Depczyńska *et al.* (2018) focused solely on SDG 9, which refers to innovation as an important factor of economic growth, and therefore employment growth. In Georgescu and Herman (2019), productive employment is linked to in-

clusive and sustainable development within EU countries during the recent economic crisis and recovery period. According to study findings, the high level of inclusive and sustainable development can be explained by high labor productivity, as well as an efficient employment structure per sector, and a low degree of precarious work. The study of Salvia *et al.* (2019) declined the global dimension of the SDGs on a local scale, identifying the main SDGs addressed by experts from different geographical regions and discussing the relation between these SDGs and the main local issues and challenges in each region. As a result, they found out that the implementation of SDGs in different regions and countries, depends on the set priorities of the observed country, as well as on the main problems the nation is struggling with.

Researchers in the field of social innovations (Eichler and Schwarz, 2019) created and executed a categorization system for various social needs using the Sustainable Development Goals as a guide.

In the study by Ramcilovic-Suominen and Pülzl (2018) the approach of European policies to the bioeconomy is strongly contested. In particular, authors believe that the EU bioeconomy policy gives primacy to the economic dimension as compared to the social and environmental dimensions, which, according to them would lead to negative effects on biomass production.

Siegel and Lima (2020) examined how the SDGs have been taken up in the domestic politics of agrifood governance in three South American countries: Brazil, Paraguay and Uruguay. The analysis shows that the ability of the SDGs to strengthen inclusiveness is largely shaped by domestic politics, pre-existing institutions and power relations, as well as the resources, capacities and prior experiences of civil society and subnational governments. The study of Secundo *et al.* (2022) analyzed the impact of digital technologies on the achievement of the SDGs through a cross-case analysis of companies active in the Italian agrifood sector. Furthermore, the study conducted by Saladini *et al.* (2018) analyzed the interdependence between water, energy and food in the Mediterranean basin, introducing a monitoring tool based on the SDG framework.

In addition, many sustainability frameworks have been developed at a national level in recent years to better manage countries' sustainability (Muff *et al.*, 2017). They have been developed by different organizations, such as the United Nations (UN, 2021), OECD (2022, 2019), (2018), UNSD (2021), SDG Index (Sachs *et al.*, 2017) and FAO (2019b, 2021) and show the increasing importance of the issues and challenges addressed.

In this context, Dlouhà *et al.* (2018) found that networks between scientific and non-scientific stakeholders facilitate the flow of information by creating circumstances for sharing technology and knowledge, as well as offering open space for innovation and catalyzing local change. Science and research provide a starting point for policymakers to determine priorities and take action in this way. After a few years of implementation, various studies have been published on the indicators used to measure the SDGs, how to track progress and evaluate performance in different regions and the role of teaching and research for long-term development. (Muff *et al.*, 2017; Friedman *et al.*, 2020; Temmer and Jungcurt, 2021; Kubiszewski *et al.*, 2022). However, there are very few publications focusing on the extent to which the SDGs are being reached across geographical regions and there is no evidence of scientific studies that have focused attention on achieving agrifood related SDGs, which justifies the development of this research and its contribution to theory (Whetten, 1989). Moreover, there are not many studies in the literature that use cluster analysis to classify countries in terms of the SDGs. However, prioritizing the SDGs and related targets based on national specific circumstances is essential for countries (Allen *et al.*, 2018; 2021). Prioritization of the SDGs can be carried out by identifying local-specific levels of progress and local-specific features and needs. From this perspective, this study aims to classify countries of the Mediterranean region, based on their agriculture and food related SDG progress, in order to understand the key implementation challenges, define the gaps between countries and identify priorities for action. To classify countries, a cluster analysis based on Euclidean distance is used, followed by ANOVA.

3. Materials and methods

The study area includes those countries that directly border the Mediterranean Sea, belonging to three continents (Europe, Asia and Africa) and forming the Mediterranean basin: Albania, Algeria, Bosnia-Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Italy, Lebanon, Libya, Malta, Montenegro, Morocco, Palestine, Slovenia, Spain, Syrian Arab Republic, Tunisia, Turkey, Jordan, Macedonia and Portugal.

3.1. *Data collection*

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 the impacts of agrifood-related measures in the Mediterranean region. Therefore, five specific targets for which agrifood is critical have been chosen in the current study from

Table 1 - Agriculture-related SDG indicators included in the study.

Target	*Target description*	*Indicators*	*Source*
SDG 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Prevalence of undernourishment (%)	FAOSTAT (2022)
		Population in severe food insecurity (%)	
		Proportion of local breeds classified as being at risk as a share of local breeds with known level of extinction risk (%)	
		Agriculture shares of Government Expenditure (%)	
		Agriculture value added share of GDP (%)	
		Agriculture orientation index for government expenditures	
SDG 6	Ensure availability and sustainable management of water and sanitation for all	Irrigated Agriculture Water Use Efficiency (US$/m^3)	World Bank (2022)
		Industrial Water Use Efficiency (US$/m^3)	
		Services Water Use Efficiency (US$/m^3)	
		Total Water Use Efficiency (US$/m^3)	
		Level of water stress: freshwater withdrawal as a proportion of available freshwater resources (%)	
SDG 12	Ensure sustainable consumption and production patterns	Household food waste (ton/year)	UNEP (2021)
		Food service food waste (ton/year)	
		Retail food waste (ton/year)	
SDG 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Terrestrial and marine protected areas (% of total territorial area)	World Bank (2022)
SDG 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Forest area (thousands of hectares)	FAOSTAT (2022)
		Forest area as a proportion of total land area (%)	
		Land area (thousands of hectares)	
		Forest area under an independently verified forest management certification scheme (thousands of hectares)	
		Mountain Green Cover Index	

among the 17 SDGs. These are: food security (SDG 2 - End hunger, achieve food security and improved nutrition and promote sustainable agriculture); sustainable management of water (SDG 6 - Ensure availability and sustainable management of water and sanitation for all); sustainable consumption and production (SDG 12 - Ensure sustainable consumption and production patterns); sustainable management of marine resources (SDG 14 - Conserve and sustainably use the oceans, seas and marine resources for sustainable development); sustainable use of terrestrial ecosystems (SDG 15 - Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss). The level of achievement of each of the four selected targets was measured using a total of 17 indicators, specified in Table 1.

We created a database containing values for all indicators referring to the year 2019, the last year for which complete information could be extracted from the following institutional sources: FAOSTAT (2022), the World Bank (2022), UNEP (2021).

3.2. *Statistical analysis*

Cluster analysis was chosen as the most appropriate method for grouping and identifying similarities of the observed countries due to the large number of heterogeneous indicators included in the analysis and the low level of dependency between them. Cluster analysis is a method designed to classify individual observation units based on their similarity which aims to form a number of very internally homogeneous groups of observation units. The grouping (clustering) of observation units is based on different characteristics (indicators), measured for each observation unit individually, and the starting point is the selection of an appropriate distance measure, since it is necessary to determine how "similar" or "different" they are to each other. There are several different distance measures and the most used include (Euclidean distance, squared Euclidean distance, Mahalanobis distance, Minkowski distance, and Manhattan distance) (Hair *et al.*, 2010). In this study, Euclidean distance is used as a distance measure, which is calculated using the following expression:

$$d_{ij}^2 = \sum_{k=1}^{p}(X_{ik} - X_{jk}) \qquad (1)$$

where p is the number of indicators, x_{ik} is the value of the observation unit x_i for the indicator X_k, and x_{jk} is the value of the observation unit x_j for the indicator X_k. Using the selected distance measure and the starting (n x p) data matrix (n objects classified based on p indicators), a distance matrix (n x n) is formed and reflects the degree of similarity or difference between all pairs of objects that are grouped. For the purposes of the present analysis, a total of six agglomerative hierarchical clustering analyses were developed, i.e., one for each of the five targets specified in Table 1 and a final analysis which simultaneously considered all targets with their respective 17 indicators. Each analysis was based on the application of Ward's method.

Moreover, in order to determine the relevant number of clusters of each analysis, *NbClust R package* was used. It provides 30 indices which determine the number of clusters in a data set and it offers the best clustering scheme from different results obtained by varying all combinations of number of clusters, distance measures, and clustering methods. Once the best number of clusters was determined, the agglomerative hierarchical clustering based on Ward's method was performed and presented in the form of the dendrogram.

In conclusion, one-way ANOVA was used to determine if there was a statistically significant difference between the separated clusters of each of the observed indicators (Ward, 1963). The ANOVA was calculated only for one of the six cluster analyses, i.e., on the one that considers all the agrifood-related goals and all the respective indicators at the same time. The analysis of the collected data and all necessary statistical calculations were carried out using R software. Table 2 presents the minimum and maximum values, as well as the average values and standard deviation of selected indicators.

Table 2 - Descriptive statistics of the agriculture-related SDG indicators included in the study.

	Variables	*Min.*	*Max.*	*Mean*	*Std. Dev.*
SDG 2	Prevalence of undernourishment (%)	2.50	38.00	5.65	7.59
	Population in severe food insecurity %	4.30	60.00	18.21	13.39
	Proportion of local breeds classified as being at risk as a share of local breeds with known level of extinction risk (%)	0	100.00	44.82	39.39
	Agriculture share of Government Expenditure (%)	0	3.97	0.96	0.99
	Agriculture value added share of GDP (%)	0.79	20.59	6.43	5.60
	Agriculture orientation index for government expenditures	0	1.31	0.27	0.32
SDG 6	Irrigated Agriculture Water Use Efficiency (US$/m3)	0	47.32	3.40	9.94
	Total Water Use Efficiency (US$/m3)	0	178.83	33.98	39.25
	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources (%)	1.50	817.14	85.07	168.94
SDG 12	Household food waste (ton/year)	0	9,136,941.00	2,083,604.34	2,616,785.54
	Food service food waste (ton/year)	0	2,775,538.00	635,328.48	804,493.04
	Retail food waste (ton/year)	0	1,667,568.00	355,836.30	513,259.65
SDG 14	Terrestrial and marine protected areas (% of total territorial area)	0.19	55.07	11.16	13.06
SDG 15	Forest area (thousands of hectares)	0.46	21,908.36	4,125.84	6,569.74
	Forest area as a proportion of total land area (%)	0.05	61.67	21.93	19.53
	Land area (thousands of hectares)	32.00	238,174.10	38,808.07	61,615.91
	Mountain Green Cover Index	0	3,312.00	210.38	693.93

4. Results and discussions

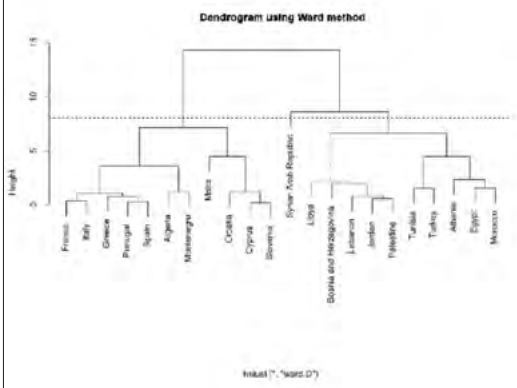
Using Ward's approach and the squared Euclidean distance as distance measurements between observation units (i.e., observed countries), cluster analysis was applied to standardized values of each of the indicators.

The first clustering of the Mediterranean countries was carried out based on SDG 2 - Zero Hunger, which aims at the eradication of hunger, achieving food security and promoting adequate nutrition. Visual interpretation of the procedure and the results of hierarchical agglomeration for the observed countries is presented in the form of the dendrogram in Figure 1.

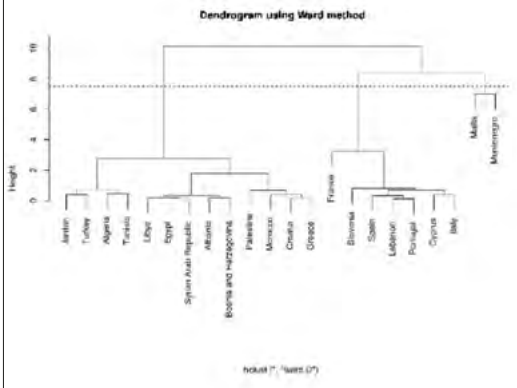
Three clusters emerge from the analysis which, except for Algeria and Cyprus, see European countries (Cluster 1) separated from those of the MENA region (Cluster 3). The latter extends from Morocco to Southeast Asia and is characterized by severe geo-political vulnerability determined by geographic, territorial and climatic elements, which negatively affect all economic sectors, including agribusiness.

Cluster 2 consists solely of the Syrian Republic, indicating that the country's food security condition is peculiar. In this sense, the Syrian republic has been facing a civil conflict since 2011, which has negatively impacted the country's poverty level, also bringing the risk of hunger to around 60% (World Food Programme, 2020). FAO (2019a) reported that wheat production is at less than 25% of pre-conflict levels, which has significantly affected food security in the country. Syrians are facing multiple shocks, including the collapse of the Syrian pound, its impact on the

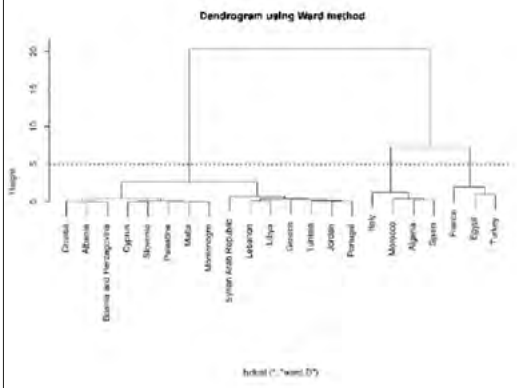
Figure 1 - Results of cluster analyses based on SDGs 2, 6 and 12.



GOAL 2		
Cluster 1	**Cluster 2**	**Cluster 3**
Algeria	Syrian Arab Republic	Albania
Croatia		Bosnia and Herzegovinia
Cyprus		Egypt
France		Jordan
Greece		Lebanon
Italy		Libya
Malta		Morocco
Montenegro		Palestine
Portugal		Tunisia
Slovenia		Turkey
Spain		

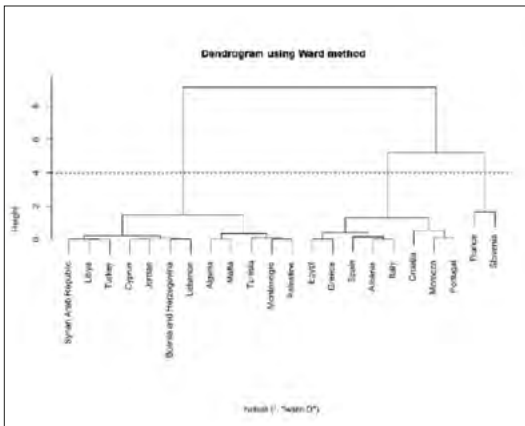


GOAL 6		
Cluster 1	**Cluster 2**	**Cluster 3**
Albania	Cyprus	Malta
Algeria	France	Montenegro
Bosnia and Herzegovina	Italy	
Croatia	Lebanon	
Egypt	Portugal	
Greece	Slovenia	
Jordan	Spain	
Libya		
Morocco		
Palestine		
Syrian Arab Republic		

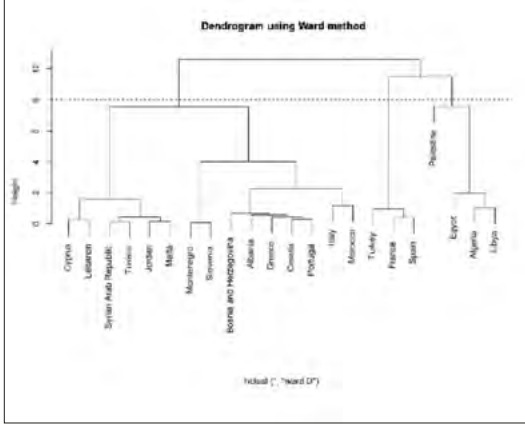


GOAL 12		
Cluster 1	**Cluster 2**	**Cluster 3**
Albania	Algeria	Egypt
Bosnia and Herzegovina	Italy	France
Croatia	Morocco	Turkey
Cyprus	Spain	
Greece		
Jordan		
Lebanon		
Libya		
Malta		
Montenegro		
Palestine		
Portugal		
Slovenia		
Syrian Arab Republic		
Tunisia		

Figure 1*bis* - Results of cluster analyses based on SDGs 14 and 15.



GOAL 14		
Cluster 1	**Cluster 2**	**Cluster 3**
Algeria	Albania	France
Bosnia and Herzegovina	Croatia	Slovenia
Cyprus	Egypt	
Jordan	Greece	
Lebanon	Italy	
Libya	Morocco	
Malta	Portugal	
Montenegro	Spain	
Palestine		
Syrian Arab Republic		
Tunisia		
Turkey		



GOAL 15		
Cluster 1	**Cluster 2**	**Cluster 3**
Albania	France	Algeria
Bosnia and Herzegovina	Spain	Egypt
Croatia	Turkey	Libya
Cyprus		Palestine
Greece		
Italy		
Jordan		
Lebanon		
Malta		
Montenegro		
Morocco		
Portugal		
Slovenia		
Syrian Arab Republic		
Tunisia		

price of commodities, the aftermath of the financial crisis in Lebanon, as well as ongoing hostilities and large-scale displacement. The COVID-19 pandemic has further exacerbated the food security situation (World Food Programme, 2020).

The results of the second cluster analysis, based on SDG 6 - Clean water and sanitation, which aim at ensuring the availability and sustainable management of water and sanitation for all, are also shown in Figure 1. Cluster 1 is the largest and includes all the countries of the African continent included in the analysis, most of the countries belonging to the Balkan area (Albania, Greece, Croatia, Bosnia Herzegovina, Turkey) and three countries of the Asian area (Jordan, Syria, Palestine). Cluster 2 includes the countries of the Western European area together with Slovenia, Cyprus and Lebanon. Finally, Cluster 3 only includes Malta and Montenegro, countries with severe water scarcity which has sensitized citizens' behavior towards water saving actions especially in the leisure and business sectors (MBB, 2014; EEA, 2023).

Also in Figure 1 is the cluster analysis of countries based on SDG 12 - Responsible production and consumption. The SDG's metrics consider the quantities of food waste produced annually by each country. The analysis led to the formation of three clusters: Cluster 1 is the most heterogeneous and numerous, including 15 countries belonging to all three continents studied. Cluster 2 is characterized by Morocco, Algeria, Italy, and Spain, while Cluster 3 includes the three most populous countries in the survey

area, where the highest level of food waste is found: France, Egypt and Turkey.

The first dendrogram in Figure 1*bis* shows the clustering of countries based on SDG 14 - Life below water, which aims at conserving and using marine resources in a sustainable way. In the present analysis the presence of marine protected areas was used as a proxy for the sustainable management of marine resources, leading to a division into three groups of countries. Cluster 1 includes almost all the countries of the MENA area, Cluster 2 mainly includes European countries, except for Egypt and Morocco. Finally, only France and Slovenia belong to Cluster 3, both characterized by the highest percentage of protected areas with respect to the total territory (about 55% in Slovenia, about 30% in France).

The fifth clustering was conducted based on SDG 15 - Life on land, whose ultimate meaning is to protect, restore and promote sustainable use of the terrestrial ecosystem, sustainably manage forests, combat desertification, halt and reverse land degradation and stop the loss of biological diversity. Three clusters were created as a result of the analysis, each of which displays some degree of morphological regularity (Figure 1*bis*). In Cluster 2 are Turkey, France and Spain, which are the regions with the most extensive mountainous territory, and therefore also with a significant forest cover. Countries with desert territories belong to Cluster 3: Palestine, Egypt, Algeria, Libya. Cluster 1 is the most heterogeneous.

The final analysis, which simultaneously considered all agrifood-related targets and their corresponding 17 indicators, is shown in Figure 3. Based on the cluster analysis results, it is observed that the Mediterranean countries do not form a homogeneous group in terms of achieving sustainability, with three distinct clusters. The list of countries identified by groups is presented in Table 3. The first cluster is the largest and is made up of almost all North Africa (Algeria, Libya, Tunisia, Morocco) and the Middle East (Palestine, Syria, Jordan and Lebanon) together with Albania, Bosnia and Herzegovina. The second cluster is the smallest and consists of France, Italy, Spain, Egypt and Turkey. Finally, Portugal, Greece, Malta, Cyprus and the three countries of the eastern side of the Adriatic form the third cluster.

Separate clusters indicate the regional distribution of Mediterranean countries according to the realized agrifood-related sustainable development indicators.

The first cluster covers only non-EU countries and, except for Albania and Bosnia and Herzegovina, all belonging to the MENA region. As shown in Table 3, Cluster 1 ranked last in most indicators. The disparity between the food security indicators and the average values of the other clusters is particularly evident. In fact, according to World Food Programme (2020), MENA regions are the most vulnerable in the world regarding the relationship between food insecurity and armed conflict. Within Cluster 1, Syria represents the country with the most serious food crisis, where the level of food security has degenerated due to armed clashes and the economic repercussions of sanctions, the Lebanese economic crisis and the pandemic (Skaf *et al.*, 2019; Zuntz *et al.*, 2021; Selimian *et al.*, 2022).

Figure 2 - Results of cluster analysis of 22 Mediterranean countries.

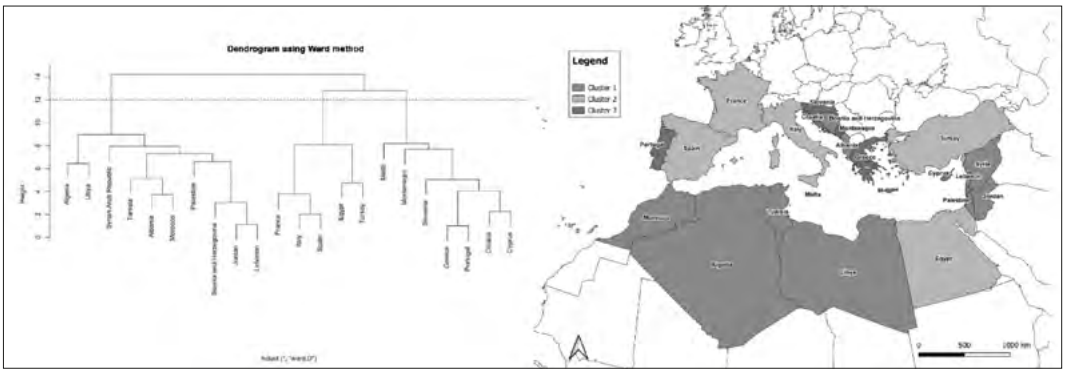


Table 3 - Average values and ranking of SDG indicators per each identified cluster.

		CLUSTER 1		*CLUSTER 2*		*CLUSTER 3*	
		Average	*Ranking*	*Average*	*Ranking*	*Average*	*Ranking*
SDG 2	Prevalence of undernourishment (%)	8.84	3	3.38	2	2.71	1
	Population in severe food insecurity (%)	28.32	3	13.82	2	9.13	1
	Proportion of local breeds classified as being at risk as a share of local breeds with known level of extinction risk (%)	22.00	1	55.00	2	70.14	3
	Agriculture share of Government Expenditure (%)	0.86	3	1.17	1	0.96	2
	Agriculture value added share of GDP (%)	9.81	1	4.72	2	2.84	3
	Agriculture orientation index for government expenditures	0.09	3	0.27	2	0.53	1
SDG 6	Agriculture Water Use Efficiency (US$/m^3)	1.19	2	0.82	3	8.39	1
	Total Water Use Efficiency (US$/m^3)	14.45	3	37.56	2	59.31	1
	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources (%)	145.62	3	51.70	2	22.40	1
SDG 12	Household food waste (ton/year)	1,275,659.60	2	6,019,127.00	3	426,723.54	1
	Retail food waste (ton/year)	216,158.13	2	1,072,166.01	3	43,712.44	1
	Food service food waste (ton/year)	382,114.36	2	1,884,031.16	3	105,132.46	1
SDG 14	Terrestrial and marine protected areas (% of total territorial area)	5.34	3	14.66	2	16.98	1
SDG 15	Forest area (thousands of hectares)	1,231.70	3	13,412.33	1	1,627.12	2
	Forest area as a proportion of total land area (%)	10.93	3	25.77	2	34.89	1
	Land area (thousands of hectares)	51,102.01	2	62,159.17	3	4,565.94	1
	Mountain Green Cover Index: Elevation All	377.04	1	74.12	3	69.61	2

A particularly critical situation can also be seen in terms of the sustainable use of natural resources and especially water, in line with the results of previous studies (Pastore *et al.*, 2015; Saladini *et al.*, 2018). The scarcity of water and the desert climate, together with climate change, mean that the countries of the MENA area are net food importers, as they cannot meet the demand for food independently (Zolfaghari and Sahabi, 2021). Dependence on imports has consequences that reflect on the economic conditions of the region. According to FAO (2014), the sustainable management of water resources is closely related to food security, since 70% of total global freshwater withdrawal are driven by agriculture. The morphological conformation of the territories also means that Cluster 1 is last in terms of forest cover, however, the presence of a high Mountain Green Cover Index balances the effect and improves the general performance to achieve SDG 15 - Life on land.

Cluster 2 is composed of the most economically developed countries in the study area, all of

Table 4 - Results of the ANOVA.

	Indicators	*F-value*	*Significance*
SDG 2	Prevalence of undernourishment (%)	1.749	0.2009
	Population in severe food insecurity %	7.690	0.0036***
	Proportion of local breeds classified as being at risk as a share of local breeds with known level of extinction risk (%)	4.336	0.0281**
	Agriculture share of Government Expenditure (%)	0.155	0.8577
	Agriculture value added share of GDP (%)	4.738	0.0214**
	Agriculture orientation index for government expenditures	5.832	0.0106**
SDG 6	Irrigated Agriculture Water Use Efficiency (US$/m^3)	1.338	0.2860
	Total Water Use Efficiency (US$/m^3)	3.315	0.0582*
	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources (%)	1.251	0.3089
SDG 12	Household food waste (ton/year)	24.137	0.0000***
	Food service food waste (ton/year)	31.025	0.0000***
	Retail food waste (ton/year)	15.653	0.0001***
SDG 14	Terrestrial and marine protected areas (% of total territorial area)	2.056	0.1554
SDG 15	Forest area (thousands of hectares)	4.213	0.0306**
	Forest area as a proportion of total land area (%)	1.757	0.1994
	Land area (thousands of hectares)	0.504	0.6120
	Mountain Green Cover Index	24.137	0.0000***

** Significant on 90% level, ** significant on 95% level, and *** significant on 99% level.*

which belong to the European Union, except for Turkey. The countries belonging to Cluster 2, as highlighted in Table 3, are the ones particularly struggling to achieve SDG 12 - Ensure sustainable consumption and production patterns. In line with the literature, high-income countries are the ones attributed the highest percentage of food waste (Ishangulyyev *et al.*, 2019). In fact, according to the FAO (2014) classification, food loss along the first links of the chain (production, harvesting, storage and processing) is attributable to the lack of technologies and tools for efficient food production and storage and mainly affects low-income countries. Food waste, on the other hand, occurs at the point of distribution, at the level of consumers and retailers. Noteworthy is the strong role of the consumer in industrialized countries, where the major problem is not due to insufficient anti-waste technologies but, for the most part, to the habits of individual consumers (Agnusdei *et al.*, 2022).

Cluster 3 includes countries that, according to our indicators, are closest to achieving the agriculture and food-related sustainable development goals. It consists primarily of Balkan countries, Cyprus, and Portugal. On average, these countries perform particularly better than other clusters in terms of both food waste and water consumption. In terms of the orientation of public expenditures, agriculture also seems to play a prominent role in the countries of Cluster 3.

On the other hand, indicator 3 demonstrates the highest level of extinction risk of local genetic resources for Cluster 3 countries. The indicator has a direct link to "biodiversity" in that animal or livestock genetic resources are an integral part of agricultural ecosystems and biodiversity as such (UN, 2019). They are critical for adapting to changing socioeconomic and environmental conditions, including climate change and, being the raw material of the livestock farmer, are essential for sustainable agricultural production.

Table 4 presents the results of the one-way ANOVA, which determined whether the clusters were statistically significantly different from each other according to the observed indicators of sus-

tainable development. The results show that the clusters differ in most indicators, therefore, given that the differences between the clusters are statistically significant for 10 indicators, it can be concluded that the clusters differ strongly in achieving agrifood-related sustainable development goals. Overall, SDG 2 and 12 make the biggest differences in how Mediterranean countries are grouped in terms of agri-food sustainability.

5. Conclusions

The Mediterranean region is widely recognized as one of the most exposed in the world to the effects of climate change, water scarcity, biodiversity loss and land degradation, together with the nutritional transition of its populations (Antonelli *et al.*, 2022). In such a context, analyzing this transition process towards agrifood sustainability by grouping the different countries of the region is of both political and theoretical interest. Moreover, the current armed conflicts, the economic-financial crises and the socio-political uprisings in the region need to encourage the creation of synergies based on common rules and objectives and the adoption of long-term strategies.

In this study, using cluster analysis, the countries of the Mediterranean region were grouped according to their progress on agriculture and food related SDGs to understand the main implementation strategies and guide priority actions for policymakers.

The analysis showed that the level of food security is a discriminating factor for the clustering of countries: a clear gap emerges between the countries of Western Europe and those of the MENA area. The transition towards more sustainable food production and consumption models has also reached different stages in the various countries of the area, representing a further element of distance (Mulazzani *et al.*, 2020). For example, the extent of food loss at various stages of the supply chain varies considerably from one region to another. In developing countries, it tends to occur earlier in the supply chain. This is often due to limitations in harvesting techniques, storage and transport infrastructure. These differences underline that the fight against food loss must take place above all at the national and regional levels and then be extended to a larger scale.

The proposed analysis represents a valuable diagnostic tool capable of supporting Mediterranean policymakers, who can base their decisions on the similarities and differences across the region's countries. Innovation is viewed as a key means by which the economic, social and environmental joint goals will be achieved. It should embrace all actors, private, public and voluntary, in the rural economy and rural communities and include the policy process, its integration and implementation.

Countries and other decision-making bodies can rely on the feedback provided by the monitoring process to outline their performance regarding the dimensions of the sustainability.

Based on such profiles, Mediterranean policymakers are able to define which sectors they should pay attention to implementing targeted policies to improve current situations, taking into account both the diversities and the affinities among the different countries. It is important to improve, for example, policies and practices in the food sector promoting sustainable agriculture and healthy behaviors concerning diets and food waste. Or incentivize public and private investments addressed to SDG-oriented research and innovation.

It is worth noting that the improvement of expected results regarding 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.

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