Cuadernos de Investigación Geográfica *Geographical Research Letters*	2024	Nº 50 (1)	pp. 85-107	EISSN 1697-9540

http://doi.org/10.18172/cig.5724

ASSESSING THE SECURITY STATUS AND FUTURE SCENARIOS OF THE MEDITERRANEAN REGION THROUGH THE WATER-ENERGY-FOOD NEXUS: A CLUSTER ANALYSIS APPROACH

PABLO GARCÍA-GARCÍA*

Departamento de Economía y Estadística. Grupo de Investigación GIEA. Universidad de León. Campus de Vegazana, 24007 León, Spain.

ABSTRACT. Over the past decades, the Mediterranean region has faced significant challenges due to the impacts of climate change and ongoing conflicts. This study proposes an assessment of the region's security status and potential future scenarios through the lens of the water-energy-food nexus, utilising indicators that align with the Sustainable Development Goals (SDGs). These indicators include agricultural yields, value-added, and land variations, water and sanitation services, income and inequality, use of renewable energy, carbon footprints, and political stability. To evaluate the situation, this analysis applies Ward's hierarchical clustering algorithm to group countries based on these indicators, examining the average terms and the years 2006 and 2015 for comparative analysis. Additionally, an exponential smoothing algorithm forecasts future trends and generates clusters for the years 2030 and 2050. By computing an index of convergence for each cluster and indicator, this contribution identifies areas of particular interest from a security perspective. The findings of this analysis reveal a growing polarisation within the Mediterranean region, with European countries and Israel forming one distinct group, and African and Eastern countries (excluding Israel) forming another. Notably, recurring disparities exist in variables such as agricultural land, political stability, violence, income per capita, and agricultural value added. Conversely, certain variables, including the Gini coefficient, prevalence of overweight population, and access to drinking water services, show signs of convergence. These results shed light on potential areas of both conflict and cooperation in the Mediterranean region, highlighting the importance of addressing the challenges posed by climate change. By understanding the geopolitical dynamics and identifying key areas of concern, policymakers can develop informed strategies to promote stability and sustainable development in the region.

Evaluación del estado de seguridad y escenarios futuros de la región mediterránea a través del nexo agua-energía-alimentos: un enfoque a partir del análisis cluster

RESUMEN. En las últimas décadas, la región del Mediterráneo se ha enfrentado a importantes desafíos debido a los efectos del cambio climático y a los conflictos en curso. Este estudio propone una evaluación del estado de seguridad de la región y posibles escenarios futuros a través de la conexión agua-energía-alimentos, utilizando indicadores que se alinean con los Objetivos de Desarrollo Sostenible (ODS). Estos indicadores incluyen los rendimientos agrícolas, el valor añadido y las variaciones de la tierra, los servicios de agua y saneamiento, los ingresos y la desigualdad, el uso de energías renovables, las huellas de carbono y la estabilidad política. Para evaluar la situación, este análisis aplica el algoritmo de agrupación jerárquica de Ward para agrupar países en base a estos indicadores, examinando los términos promedio y los años 2006 y 2015 para un análisis comparativo. Además, un algoritmo de suavizado exponencial pronostica tendencias futuras y genera clusters para los años 2030 y 2050. Al calcular un índice de convergencia para cada grupo e indicador, esta contribución identifica áreas de interés particular desde una perspectiva de seguridad. Los resultados de este análisis revelan una creciente polarización dentro de la región mediterránea, con países europeos e Israel formando un grupo específico y países africanos y orientales (excluyendo Israel) configurando otro. Cabe destacar que existen disparidades recurrentes en variables como el suelo agrícola, la estabilidad política, la violencia, el ingreso per cápita y el valor agregado agrícola. Por el contrario, ciertas variables, como el coeficiente de Gini, la prevalencia de la población con sobrepeso y el acceso a los servicios de agua potable, muestran signos de convergencia. Estos resultados arrojan luz sobre las posibles esferas de conflicto y cooperación en la región del Mediterráneo y ponen de relieve la importancia de abordar los desafíos que plantea el cambio climático. Al comprender la dinámica geopolítica y determinar las principales esferas de preocupación, los encargados de formular políticas pueden elaborar estrategias bien fundamentadas para promover la estabilidad y el desarrollo sostenible en la región.

Keywords: Regional analysis, geopolitics, sustainability, conflict, convergence.

Palabras clave: Análisis regional, geopolíticas, sostenibilidad, conflicto, convergencia.

Received:25 April 2023

Accepted: 17 August 2023

*** Corresponding author:** Pablo García-García. Departamento de Economía y Estadística. Grupo de Investigación GIEA. Universidad de León. Campus de Vegazana, 24007 León, Spain. E-mail: pagag@unileon.es

1. Introduction

The Mediterranean region plays a crucial role in socioeconomic and environmental transformations, as it faces many challenges interconnected and driven by the force of climate change. Effective management of energy resources, environmental preservation, population growth, scarcity, and existing tensions are among the pressing issues confronting the Mediterranean region (Scheffran, 2020). As a result, this region is projected to be highly vulnerable to the impacts of climate change.

The Mediterranean region is expected to experience a decline in rainfall and rising temperatures, exacerbating environmental stress, and causing water scarcity, heatwaves, and wildfires. These challenges will be further compounded by population growth and rapid urbanisation, particularly in the Southern and Eastern areas, where social conflicts and political instability are more prevalent.

Paradoxically, despite the abundance of renewable energy sources available in the Mediterranean, countries within the region continue to rely heavily on fossil fuels, leading to an ongoing energy crisis. The European Union, which has seen a decline in its influence over the Mediterranean since the 1990s (Anoushivaran *et al.,* 2017), is particularly vulnerable to this crisis.

The energy challenges faced by the European Mediterranean countries are multi-faceted and complex. These challenges include ensuring energy security, diversifying energy sources, promoting renewable energy, and mitigating the environmental impact of energy production. By working together in a bilateral framework, the EU and the Mediterranean countries can pool their resources, knowledge, and expertise to address these challenges more effectively (Tagliapietra and Zachmann, 2016), particularly considering the current energy scenario shaped by the COVID pandemic (Bianchi, 2020) and the conflict in Eastern Europe.

The COVID-19 pandemic has significantly impacted the energy sector. Lockdown measures and economic slowdowns have caused fluctuations in energy demand and prices. The pandemic has highlighted the importance of energy resilience and the need to build more sustainable and resilient energy systems. Collaborative efforts between the EU and the Mediterranean countries can help to mitigate the negative effects of the pandemic on the energy sector and promote a more resilient recovery.

Furthermore, the security scenario in Eastern Europe implies factual and potential disruptions in energy supplies and transit routes. Cooperation can help diversify energy sources and routes, reducing dependency on a single supplier or route and enhancing energy security for all parties involved.

In these circumstances, cooperative security (Wohlfeld, 2020) emphasises the importance of building trust, dialogue, and support among nations to address common security challenges. Applying this concept to the energy sector, cooperative security can provide a framework for Mediterranean countries to collaborate on energy-related initiatives, exchange best practices, and coordinate policies. By viewing energy security as a shared interest, countries can work together to enhance their collective resilience and stability.

Network diplomacy (Prontera, 2020) can guide the creation of networks and partnerships among various stakeholders to achieve common goals. In the context of energy cooperation between the EU and the Mediterranean countries, network diplomacy can facilitate the exchange of knowledge, technology, and investments. It can bring together governments, international organisations, private sector entities, and civil society to mobilise resources and support common interest projects, such as the development of renewable energy infrastructure or the establishment of interconnection projects for electricity and gas transmission.

The gas potential of countries like Israel, Egypt, and Cyprus (Giuli, 2021; Prontera and Ruszel, 2017; Tsakiris, 2018) is seen as an opportunity for the European Mediterranean countries to diversify their energy sources and reduce reliance on traditional fossil fuel suppliers. Developing gas reserves in these countries can contribute to regional energy security and provide economic opportunities for both producers and consumers. However, it is essential to ensure that the development and extraction of these resources are done in an environmentally sustainable manner, considering the potential impact on ecosystems and local communities.

Against this backdrop, this paper aims to analyse the current situation and potential future scenarios of the Mediterranean region through the lens of the water-energy-food nexus. By exploring the interrelationships between water, energy, and food, this approach can help identify security threats and suggest strategies to address them. Section 2 provides a context for the current situation, highlighting the relevance of the water-energy-food nexus and proposing a selection of indicators to assess it. Section 3 presents the finalised selection of indicators, describes the composition of the sample, and outlines the techniques used to process the data. Section 4 presents the results, and Section 5 summarises the key findings.

By employing a cluster analysis approach, this study seeks to shed light on the security challenges facing the Mediterranean region and provide insights into potential internal behaviours that can effectively address these challenges. Ultimately, this research aims to contribute to the development of sustainable and resilient strategies for the future of the Mediterranean region.

2. Contextualisation

The Mediterranean region is currently facing and is expected to continue experiencing a range of environmental and societal challenges (Scheffran and Brauch, 2014). One of the key factors shaping the region is the increasing temperatures. It is projected that the southern parts of the Mediterranean will experience a rise of 2-3 ºC (Schilling *et al.*, 2020), leading to shorter and milder winters, intensified droughts, and increased water shortages and evaporation rates during summers. This vulnerability is particularly significant in the Southern and Eastern zones, which have lower adaptation capacities.

Another pressing issue is the declining precipitation in the region. With a temperature increase of 2 ºC, it is estimated that precipitation will decrease by 5-10%, and sea levels will rise by 6-12 cm (IPCC, 2013). These changes can have adverse effects on ecosystems and densely populated coastal areas, thereby potentially resulting in social and economic impacts.

Furthermore, the Mediterranean region faces various forms of environmental stress due to its high biological and geographical diversity, as well as demographic changes, socio-political transitions, and conflicts (Lange, 2019). The environmental changes expected in the region are likely to compound these challenges, potentially leading to unequal social impacts across different areas.

Water scarcity, heat waves, polluting particles, and wildfires are additional factors that pose threats to human and animal health (Cramer *et al.,* 2018) and can exacerbate existing geopolitical conflicts in resource-rich areas and important trade routes (Scheffran, 2020). Water scarcity has the potential to fuel conflicts in the region (Messerschmidt, 2012).

Population growth and increasing urbanisation are noteworthy factors, especially in the most vulnerable areas such as North Africa and the Eastern zone. Environmental changes can trigger distributive conflicts and migrations, potentially leading to population traps (Geddes, 2015).

Food security is a significant concern in the Mediterranean region (Scheffran, 2020). Climate change could negatively impact soil productivity and agriculture, resulting in food shortages and higher prices, disproportionately affecting the most vulnerable populations. This vulnerability is expected to be more pronounced in the Northern and Western areas, where agriculture is more intensive.

The energy patterns in the Mediterranean region are complex, characterised by a dependence on fossil fuels, a need to increase the use of renewable resources, and the potential for the utilisation of nuclear energy for defence purposes.

In summary, the Mediterranean region is facing substantial environmental and societal challenges in the coming years. These challenges are expected to worsen existing vulnerabilities, and their impacts may be unevenly distributed across the region. As a result, there has been a growing recognition of the water-energy-food security nexus in the region in recent years (Stockholm Environment Institute, 2011). The interconnectedness of these sectors highlights the need for integrated approaches and proactive measures to address the challenges and promote sustainable development in the Mediterranean region.

The water-energy-food security nexus is a concept that recognises the interdependencies and linkages between water, energy, and food systems. It highlights the complex relationships and trade-offs among these sectors and emphasises the need for an integrated and holistic approach to ensure sustainable development and security in each area.

Water, energy, and food are essential for economic development and are interconnected in various ways:

Energy production requires water, particularly for cooling power plants and extracting and refining fuels. At the same time, water supply and treatment require energy. Changes in water availability or energy generation can have significant impacts on each other.

Agriculture accounts for a significant portion of water usage, as crops and livestock need water for irrigation, hydration, and processing. Water availability and quality directly affect agricultural productivity and food production.

Modern food production, processing, and distribution systems heavily rely on energy inputs, including fossil fuels. Energy costs and availability can influence agricultural practices, food processing, and transportation, thereby impacting food security.

These interdependencies create a nexus where actions and decisions in one sector can have ripple effects on others. For example, if water resources become scarce due to drought or overuse, it can limit agricultural production, which may lead to food shortages. Similarly, energy shortages or high energy costs can affect irrigation systems, food processing, and transportation, leading to food insecurity.

Addressing the water-energy-food security nexus requires a coordinated and integrated approach that considers the interactions and trade-offs between these sectors. It involves promoting sustainable practices that ensure efficient water use in agriculture, adopting renewable energy sources and improving energy efficiency, and implementing policies that enhance food security while minimising environmental impacts.

By recognising and managing the interdependencies among water, energy, and food systems, policymakers, researchers, and stakeholders can work towards achieving Sustainable Development Goals and enhancing the resilience of communities and ecosystems in the face of challenges such as population growth, climate change, and resource scarcity.

By analysing a set of indicators based on the Sustainable Development Goals (SDGs), we can gain insights into the current and potential security concerns related to these interconnected systems (Saladini *et al.,* 2018). Building upon the insights presented by Saladini *et al*. (2018), this analysis not only endorses their proposal but also seeks to further enhance and expand upon their findings.

One of the indicators highlighted is the Multidimensional Poverty Index (MPI). This indicator measures deprivations in living standards, health, and education, providing a broader understanding of poverty beyond income measures. In the context of the water-energy-food nexus, the MPI helps assess the impact of inadequate access to water, energy, and food on human well-being.

The prevalence of overweight in the adult population is another significant indicator in this framework. It sheds light on the health implications of the nexus, as it reflects the share of the population that is considered overweight based on the Body Mass Index. This indicator suggests that imbalances in the availability and accessibility of nutritious food can lead to health issues such as obesity.

The variation of the share of agricultural land over the total land area is a key indicator that helps understand the evolution of agricultural activities. By monitoring changes in agricultural land annually, including arable land, permanent crops, and pastures, we can assess the sustainability and efficiency of land use practices, which are vital for food production and the preservation of ecosystems.

Greenhouse gas (GHG) emissions, both total and AFOLU (agriculture, forestry, and other land uses), provide insights into a country's behaviour regarding climate change and its relationship with land use. These indicators become particularly relevant when cross-checked with the variation of land uses, indicating the environmental impact of agriculture and energy systems on the water-food-energy nexus.

Cereal yield, measured in kilograms per hectare, is an indicator that reflects the efficiency of cereal production, as well as the efficient use of water and fertilisers. This indicator is valuable for evaluating agricultural productivity and resource management, highlighting the potential for improving water and nutrient use efficiency in food production.

Agricultural value added, calculated in constant USD per worker, captures the difference between the sector's output in agriculture and the value of its intermediate inputs in monetary terms. This indicator helps assess the economic contribution of the agricultural sector and its productivity in generating income and employment opportunities.

Fertiliser consumption per hectare of arable land is an important indicator that reflects the amount of plant nutrients used in agriculture per unit of arable land. Monitoring this indicator helps evaluate the efficiency of fertiliser use, which is crucial for sustainable agricultural practices and minimising environmental impacts.

Crop water productivity, measured in kilograms per cubic meter, highlights the value added by agriculture concerning the freshwater used for irrigation. This indicator provides insights into the efficiency of water use in agriculture, emphasising the importance of optimising water resources to meet food production demands.

The annual freshwater withdrawal for agriculture, measured as a percentage, indicates the relative scale of freshwater withdrawals used in agriculture and livestock for irrigation, excluding evapotranspiration losses. Monitoring this indicator helps understand the level of water resource allocation to agriculture and its potential impacts on water availability for other sectors and ecosystems.

Indicators related to access to safe drinking water and sanitation services are crucial for assessing the water component of the nexus. The population using safely managed drinking water services and safely managed sanitation services indicators measure the share of the population that can access protected water sources and sanitation facilities. These indicators reflect the importance of ensuring access to clean water and adequate sanitation, which are essential for human health, well-being, and food safety.

Lastly, the indicator of agricultural residues used for energy purposes quantifies the waste generated by the agricultural and food industry, as well as the potential for energy production from these residues. This indicator provides insights into the food-energy nexus, particularly in less developed contexts, where innovative approaches to utilising agricultural waste can contribute to energy security and sustainable resource management (Saladini *et al.,* 2016).

In conclusion, the water-energy-food security nexus, analysed through a series of indicators, offers a comprehensive framework for understanding and addressing the interconnected challenges and opportunities related to water, energy, and food systems. These indicators provide valuable insights into the social, economic, and environmental dimensions of the nexus, supporting evidence-based decision-making and policy development to achieve the SDGs.

3. Methodology and data

Constructing a comprehensive database grounded on the proposed indicators necessitates the collection of empirical data. However, data availability poses challenges for this analytical study, as some indicators are either unobtainable or outdated:

- The Multidimensional Poverty Index (MPI) is not calculated for all Mediterranean countries, requiring an estimation based on previous works as done by Saladini *et al.* (2018).
- For most less developed countries in the region, the original sources do not provide data on GHG emissions (total and AFOLU, t CO_2). Moreover, emissions are measured solely at the national level, overlooking the global impact of a country's environmental degradation.
- Although agricultural residues' use for energy purposes is relevant in representing the food-energy nexus in less developed contexts, it has not been computed at this level.
- The data on crop water productivity is outdated, with the latest available figures dating back to 2007.

To address the challenge of unavailable data, this study proposes the inclusion of additional indicators that are more readily available and can provide a more comprehensive picture of the situation in the Mediterranean region. These indicators include:

- Gini coefficient (0-100): This measure indicates the extent of income inequality in a country and can be used to assess the level of social inequality.
- Adjusted net national income per capita (constant 2015 USD): This indicator deducts the consumption of fixed capital and the depletion of natural resources from gross national income and references the result to the total population of the country. It is especially relevant for resource-rich, low-income countries. By using 2015 as the base year, the effect of price variation is removed, allowing for a more accurate assessment of the evolution of income.
- Carbon footprint, consumption-based accounting (t CO_2 per capita): This measure provides a more complete picture of a country's environmental impact by accounting for both national

emissions and those associated with international activities such as trade (Eora MRIO, 2023; Moran *et al.,* 2020).

- Renewable energy share in total final energy consumption (%): This indicator, which corresponds with SDG indicator 7.2.1, reflects the proportion of a country's total final energy consumption that is covered by renewable energy. It can provide insights into a country's efforts to transition to more sustainable energy sources (United Nations, 2023).

In addition, to enhance the assessment of security threats, this study suggests introducing an Index of Political Stability and Absence of Violence/Terrorism. This index measures the perceived risk of political instability or violence motivated by political factors, including terrorism. By standardising the scores to a normal distribution, the index typically ranges from -2.5 to 2.5 (World Bank, 2023b).

By incorporating these indicators, this study aims to provide a more comprehensive and nuanced assessment of the situation in the Mediterranean region. The final selection, units, codes, and data sources are disclosed in Table 1.

Table 1. Data sources

Variable – Abbreviation: Description, Unit (Database code)	Source
Pop Over: Adult population overweight, % (NCD_BMI_25C)	The Global Health Observatory (World Health Organization, 2023)
Var Agri Land: Variation of the share of agricultural land over the total land area, % (AG.LND.AGRI.ZS)	World Development Indicators (World Bank, 2023a)
Cer Yield: Cereal yield, kg/ha (AG.YLD.CREL.KG)	
Agri VA: Agricultural value added, constant USD 2015/worker (NV.AGR.EMPL.KD)	
Fert Consump: Fertilisers consumption, kg/ha arable land (AG.CON.FERT.ZS)	
Freshw Withd: Annual freshwater withdrawal for agriculture, % (ER.H2O.FWAG.ZS)	
Drink Wat Serv: Population using safely managed drinking water services, % (SH.H2O.SMDW.ZS)	
Sanit Serv: Population using safely managed sanitation services, % (SH.STA.SMSS.ZS)	
Gini: Gini coefficient, 0-100 (SI.POV.GINI)	
Adj NNI: Adjusted net national income per capita, constant 2015 USD (NY.ADJ.NNTY.PC.KD)	
Ren Energ: Renewable energy share in the total final energy consumption, % (SDG indicator 7.2.1)	UNSDG (United Nations, 2023)
Pol Stab: Index of Political Stability and Absence of Violence/Terrorism, standard normal distribution	Worldwide Governance Indicators (World Bank, 2023b)
C Footprint: Carbon footprint, t CO2/person	The Eora Global Supply Chain Database: Carbon Footprints of Nations (Eora MRIO, 2023; Moran *et al.,* 2020)

To enhance the comprehensiveness and precision of the analysis, this paper recommends focusing on countries that share a direct border with the Mediterranean Sea. Consequently, the selected territories include Spain, France, Italy, Malta, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece, Türkiye, Cyprus, Syria, Lebanon, Israel, Egypt, Libya, Tunisia, Algeria, and Morocco.

An essential consideration in selecting indicators is data availability. To address this issue, this paper has developed a three-dimensional database, encompassing retrieved datasets for the chosen indicators and countries. While certain indicators have data available as early as 1960, it is important to note that data collection has not been continuous, resulting in variations in data availability across different years. Figure 1 illustrates the percentage of available data for each selected indicator and country.

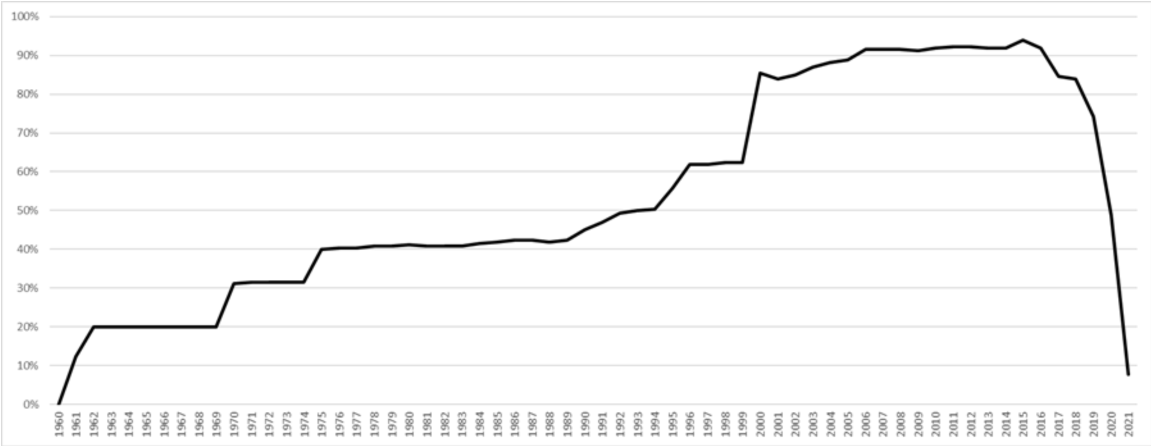

Figure 1. Share of data availability, 1960-2021. Source: Own elaboration based on the data in Table 1.

To ensure the most robust analysis, this paper strongly advises prioritising the years with the highest availability of data. This approach will allow for a more accurate representation of the trends and patterns within the Mediterranean region, enabling a deeper and more insightful examination of the chosen indicators' impact and significance.

Figure 1 illustrates the data availability over time, reaching its peak in 2015 with 94% of the database available. To ensure a suitable time gap from 2015, it is recommendable to select the year 2006, which boasts availability of 92%. Consequently, the analysis focuses on two years in the sample: 2006 and 2015. To estimate unavailable data, this proposal adopts two strategies.

The first strategy entails replacing missing indicators for a given year with the closest available value. If multiple values are equidistant from the missing year, the strategy prioritises the value from the previous year. On the other hand, the second strategy replaces completely missing indicators for a particular country with the mean value of the same indicator for the entire Mediterranean region for that specific year.

For the 2006 dataset, Strategy 1 is applied to compute the Gini coefficient for Croatia (2009), Bosnia and Herzegovina (2007), Montenegro (2012), Albania (2005), Syria (2003), Lebanon (2011), Egypt (2004), Tunisia (2005), and Algeria (2011). Additionally, the adjusted net national income per capita is estimated for Türkiye (2015), Syria (2015), and Libya (2015) using the same strategy. On the other hand, Strategy 2 is employed to determine the agricultural value added in Syria and Libya, freshwater withdrawals in Bosnia and Herzegovina, drinking water services in Türkiye, Syria, Egypt, and Libya, sanitation services in Syria, the Gini coefficient in Libya, and the adjusted net national income per capita in Malta.

Moving on to the 2015 dataset, Strategy 1 helps complete the data for drinking water services in Croatia (2007), the Gini coefficient in Bosnia and Herzegovina (2011), Syria (2003), Lebanon (2011), Algeria (2011), and Morocco (2013). As before, Strategy 2 is applied in the same instances as in the previous dataset.

Finally, an additional dataset is generated to compute the average values for each country and indicator. Here, the only missing values are those referenced in Strategy 2, specifically indicators that are fully unavailable for a country throughout the entire period.

Regarding procedures, this paper presents a comprehensive methodological sequence to analyse geopolitical actors, areas of cooperation and conflict, as well as convergences and divergences in the Mediterranean region. The proposed approach incorporates clustering techniques, forecasting, and convergence indexes to gain valuable insights into the region's future development.

The first methodological step involves using Ward's hierarchical clustering method to calculate clusters within the sample. This technique helps identify internally homogenous groups that play a crucial role in shaping the Mediterranean reality. To determine the optimal number of clusters, this proposal utilises the Thorndike criterion, which reduces distances between resultant groups (Thorndike, 1953). The clustering algorithm is performed for selected years (2006 and 2015) as well as average values across the sample.

One potential concern might be the influence of missing values on clustering results. However, the implemented analysis inherently lowers the degree of conditioning caused by these missing values. This is because clustering relies on various indicators that sufficiently reflect the national situation, making the absence of a few indicators unlikely to significantly affect the overall results since available variables serve as an anchor point.

In the second step, this method forecasts indicator values for each country up to 2030 and 2050 to repeat the clustering process with future projections. For simplicity, the forecasting technique is a non-seasonal exponential smoothing algorithm, applicable to data without seasonality and clear trends, like the dataset under study. These forecasts consider the entire time series, with more weight assigned to recent values as present events have more impact on subsequent happenings than past events. In cases where forecasting is not possible due to missing values or the unavailability of certain indicators, Strategy 2 is applied.

After implementing the clustering process with both present and future data, the resultant clusters are labelled based on the average values of each indicator within the group. This approach allows the identification and understanding of the characteristics of each cluster more effectively.

The third step involves computing convergence indexes for all past and future years considered. The index of convergence (IC) is calculated as the ratio between the value of an indicator (I) for a country and the average value of that indicator ($\bar{I}$) for the Mediterranean region (Med) in a particular year (t).

$$\mathrm{IC}_{\mathrm{c,Med,t}} = \frac{\mathrm{I}_{\mathrm{c,t}}}{\bar{\mathrm{I}}_{\mathrm{Med,t}}}$$

An IC value greater than 1 indicates that the cluster performs above the regional average, while values below 1 suggest the cluster performs below the average. The larger the deviation from 1, the greater the divergence between the cluster and the region. Analysing the convergence or divergence of each cluster helps provide valuable insights into potential future developments beyond a business-as-usual (BAU) projection.

This understanding of convergence and divergence assists in identifying areas of potential conflict and cooperation, allowing for a more realistic approach to future evolutions. Instead of solely relying on a BAU projection, our methodology considers the possible impact of various geopolitical actors and their interactions, providing a more nuanced understanding of the region's future dynamics. By incorporating clustering, forecasting, and convergence indexes, this paper offers a framework to analyse the complexities of the Mediterranean region and facilitate informed conclusions.

4. Results

In this section, the results of the previous methodology are presented in three subsections. Subsection 4.1 introduces the clusters obtained using factual data in average terms, 2006, and 2015. Subsection 4.2 presents the clusters forecasted for 2030 and 2050. Finally, Subsection 4.3 evaluates the degree of convergence or divergence for all the computed clusters.

4.1. Factual clusters

By utilising the mean values of each indicator and applying the criterion of optimality, the clustering algorithm successfully identifies two optimal clusters. This clustering approach results in a substantial coefficient reduction of 88.175 units in the agglomeration schedule, which is visually represented in Figure 2.

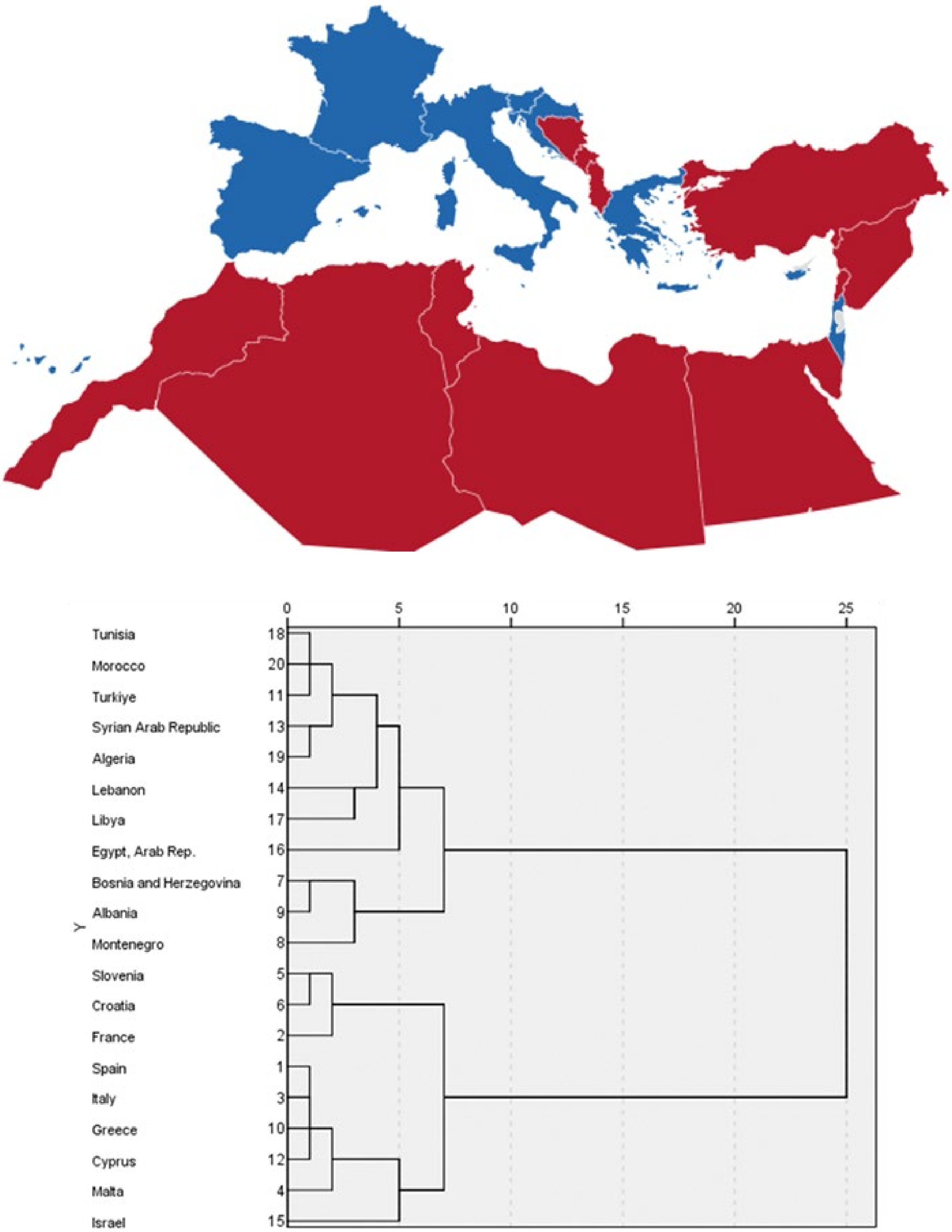

Figure 2. Dendrogram of average values. Source: Own elaboration based on the data in Table 1.

In terms of averages, the Mediterranean region can be categorised into two distinct clusters. Cluster 1 comprises Southern and Eastern countries, excluding Israel, along with European countries with relatively lower adaptation capacity. The countries included in Cluster 1 are Tunisia, Morocco, Türkiye, Syria, Algeria, Lebanon, Libya, Egypt, Bosnia and Herzegovina, Albania, and Montenegro. On the other hand, Cluster 2 consists of European countries with higher adaptation capacity, namely Slovenia, Croatia, France, Spain, Italy, Greece, Cyprus, Malta, and Israel. The values for each of the indicators considered to characterise these two clusters are presented in Table 2.

Table 2. Profiles of the clusters based on average values

	Cluster 1	Cluster 2
Countries	Tunisia, Morocco, Türkiye, Syria, Algeria, Lebanon, Libya, Egypt, Bosnia and Herzegovina, Albania, and Montenegro	Slovenia, Croatia, France, Spain, Italy, Greece, Cyprus, Malta, and Israel
Pop Over	45.94	53.21
Var Agri Land	0.0012	-0.0048
Cer Yield	2215.04	3741.62
Agri VA	9726.64	30920.21
Fert Consump	98.39	188.67
Freshw Withd	68.07	43.59
Drink Wat Serv	75.91	95.73
Sanit Serv	41.28	81.50
Gini	35.43	32.64
Adj NNI	3549.01	17541.51
Ren Energ	14.56	12.27
Pol Stab	-0.72	0.38
C Footprint	5305707.60	10394019.37

Table 2 reveals significant differences between Cluster 1 and Cluster 2 across various indicators. Cluster 2 stands out with higher values in several key metrics, including the prevalence of overweight population, cereal yield, agricultural value added, consumption of fertilisers, access to drinking water services, sanitation services, equality, adjusted national income, political stability, and carbon footprints. On the other hand, Cluster 1 experiences a positive annual variation of agricultural land, whereas Cluster 2 exhibits a negative trend in this regard. Moreover, freshwater withdrawals are higher in Cluster 1, along with a greater reliance on renewable energy sources.

However, it is essential to recognise that these average groupings are subject to annual fluctuations, as highlighted by the comparison of two selected moments: 2006 and 2015 (Fig. 3). This temporal analysis shows that the characteristics of both clusters may change over time, underlining the dynamic nature of the indicators and the need for ongoing monitoring and evaluation.

In 2006, the clustering algorithm identified 7 optimal clusters with a coefficient reduction of 76.846 units (Fig. 3 A). In contrast, in 2015, the algorithm revealed 5 clusters with a coefficient reduction of 64.768 units (Fig. 3 B). Notably, the composition of these clusters exhibited three prominent differences.

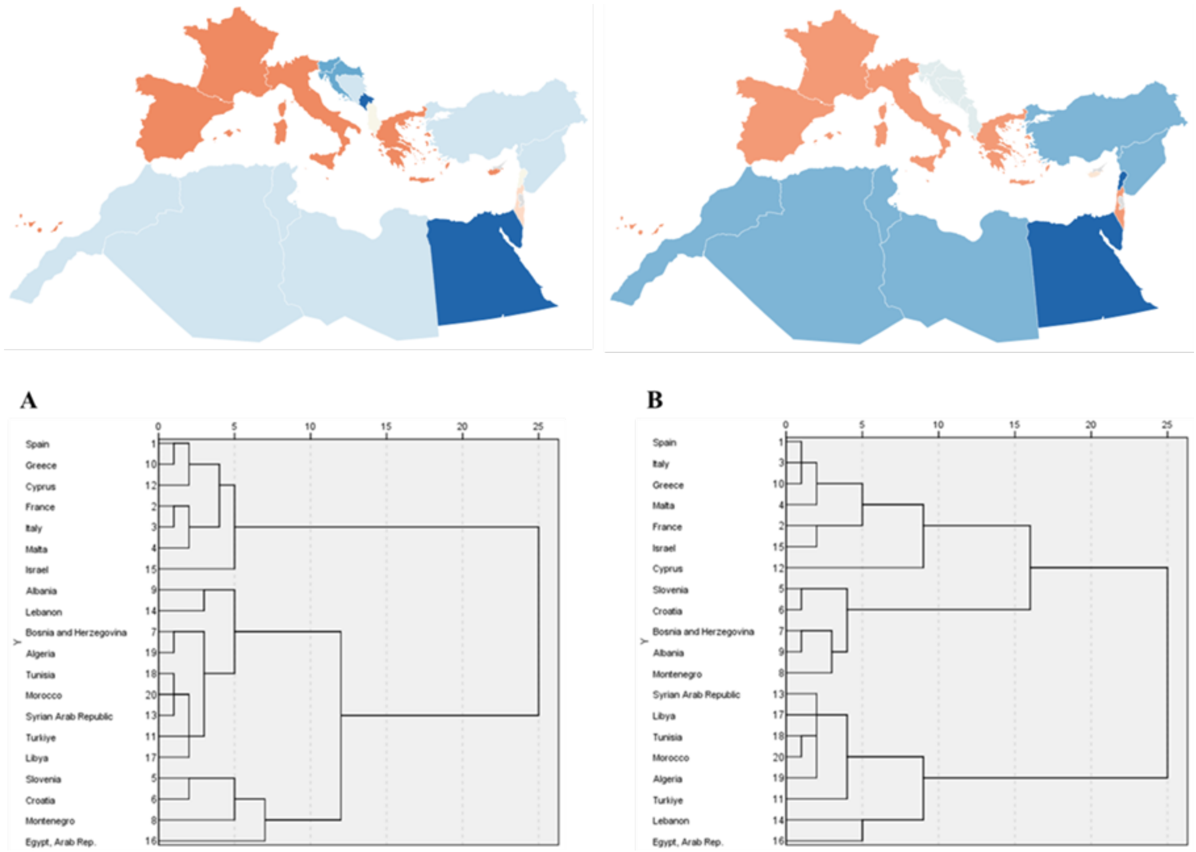

Figure 3. Dendrogram in 2006 (A) and 2015 (B). Source: Own elaboration based on the data in Table 1.

Firstly, there was a significant change in the proximity of Cyprus and Israel to European countries. In 2006, Cyprus was closer to the European cluster, while Israel stood as a unique one-case cluster, highlighting its distinctiveness. However, by 2015, the roles had reversed, and Cyprus became an individual case, while Israel joined the European cluster.

Secondly, Slovenia and Croatia remained in the same cluster in both years, but in 2015, they were joined by Bosnia and Herzegovina, Albania, and Montenegro, forming a larger cluster. Back in 2006, Bosnia and Herzegovina had been clustered with the Southern and Eastern countries, Albania had formed a cluster with Lebanon, and Montenegro had stood alone as an individual case. These shifts indicated a notable movement towards the European side of the sample and away from the African and Eastern regions.

Thirdly, in 2015, Egypt was no longer a single-case cluster, as it was joined by Lebanon.

These observations suggest significant changes in the clustering patterns over time, reflecting shifts in regional affiliations and highlighting the evolving dynamics within the dataset.

In Table 3, a detailed description of each cluster identified in 2006 is provided:

Cluster 1 is characterised by a higher prevalence of overweight population, a high share of drinking water and sanitation services, a high national income, and an elevated carbon footprint.

Cluster 2, represented by the individual case of Israel, shares some similarities with Cluster 1, but it has a lower cereal yield, higher agricultural value added and consumption of fertilisers, higher inequality, and lower political stability.

Cluster 3 is defined by a higher positive variation of agricultural land, poor agricultural value added, access to drinking water and sanitation services, as well as low carbon footprints.

Cluster 4 is determined by the low prevalence of overweight individuals, poor cereal yield, low fertiliser consumption, low sanitation services, higher inequality, lower national income, as well as low carbon footprints.

Cluster 5 is delimited by low freshwater withdrawals, higher equality, elevated national income, energy renewability, and political stability.

Cluster 6, which consists of the individual case of Montenegro, stands out for showing poor consumption of fertilisers and freshwater withdrawals, low sanitation services, and high inequalities, combined with high energy renewability and political stability.

Finally, Cluster 7, which consists of the individual case of Egypt, stands out for the low prevalence of overweight population, the lowest agricultural value added and national income, low renewability and carbon footprints, and high cereal yield, consumption of fertilisers, and freshwater withdrawals.

These clusters collectively offer valuable insights into the diverse socioeconomic and environmental characteristics observed during the 2006 study.

Table 3. Profiles of the clusters in 2006

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Countries	Spain, Greece, Cyprus, France, Italy, and Malta	Israel	Albania and Lebanon	Bosnia and Herzegovina, Algeria, Tunisia, Morocco, Syria, Türkiye, Libya	Slovenia and Croatia	Montenegro	Egypt
Pop Over	60.08	61.10	56.10	52.50	56.40	56.50	54.20
Var Agri Land	-0.0225	-0.0111	0.0399	-0.0025	-0.0098	0.0000	0.0028
Cer Yield	4052.62	2398.50	3143.70	1998.50	5268.10	2971.20	7500.20
Agri VA	30800.30	80343.90	4717.28	9677.25	8934.48	18421.84	4214.75
Fert Consump	144.44	304.95	99.66	52.63	351.40	18.70	586.56
Freshw Withd	52.25	56.84	48.66	75.55	0.76	5.42	86.08
Drink Wat Serv	98.05	99.86	49.90	78.03	83.56	83.87	83.43
Sanit Serv	86.31	84.36	26.75	40.31	57.97	28.14	56.23
Gini	31.85	41.60	31.20	35.71	28.50	41.20	31.80
Adj NNI	22387.49	24545.23	3917.64	3380.07	12901.46	4336.55	2397.43
Ren Energ	6.12	6.86	19.33	9.98	21.44	44.83	6.22
Pol Stab	0.30	-1.63	-0.80	-0.42	0.77	0.82	-0.61
C Footprint	13669131.67	13035500.00	4416144.50	4145240.29	10238664.00	9050883.00	3314026.00

Table 4 presents an analysis of the Mediterranean region in 2015, revealing distinctive characteristics and trends within five identified clusters.

Cluster 1 stands out for its high prevalence of overweight population, cereal yield, agricultural value added, access to drinking water and sanitation services, national income, and carbon footprints. This cluster represents countries with strong agricultural and economic performance, coupled with relatively healthy living conditions.

Cyprus (Cluster 2) shares similarities with Cluster 1 in various aspects. However, it differs with lower cereal yield and higher freshwater withdrawals, as well as facing challenges with political stability.

Cluster 3 is characterised by a lower prevalence of overweight population, agricultural value added, and freshwater withdrawals. Notably, it shows a positive aspect of higher equality and energy renewability.

On the other hand, Cluster 4 is defined by poor cereal yield, high consumption of fertilisers, low national income, limited energy renewability, and political instability. Additionally, this cluster experiences significant inequality issues, reflecting socio-economic challenges.

Cluster 5 exhibits a mixed profile, with a high prevalence of overweight population and cereal yield, but also poor agricultural value added, limited access to drinking water and sanitation services, low national income, and renewable energy usage. Moreover, this cluster faces difficulties in achieving a low carbon footprint.

Globally, the clustering patterns suggest an evolution towards a bipolar Mediterranean region. While less adaptable European countries were previously clustered with African and Eastern countries in 2006, by 2015, they gravitated towards a distinct European sphere, leaving African and Eastern countries in their respective geographically specific groups. Consequently, the clusters in 2015 are less geographically diverse than in 2006. The observed trends indicate that the conditions of the nexus no longer vary country by country, but rather from one geographical context to another, creating a clear bipolar trend within the region.

Table 4. Profiles of the clusters in 2015.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Countries	Spain, Italy, Greece, Malta, France, and Israel	Cyprus	Slovenia, Croatia, Bosnia and Herzegovina, Albania, and Montenegro	Syria, Libya, Tunisia, Morocco, Algeria, and Türkiye	Lebanon and Egypt
Pop Over	65.62	60.30	49.90	61.20	63.60
Var Agri Land	-0.0040	0.1624	0.0058	0.0011	0.0123
Cer Yield	5038.82	2683.00	3968.55	1649.02	5193.00
Agri VA	48227.13	18079.58	9023.20	14424.08	5997.44
Fert Consump	151.69	158.00	157.86	45.04	417.51
Freshw Withd	50.71	66.33	22.89	81.72	61.21
Drink Wat Serv	98.92	99.17	70.37	81.13	67.01
Sanit Serv	90.14	76.83	43.01	48.16	38.89
Gini	34.90	34.00	26.88	35.75	31.80
Adj NNI	22333.57	20097.61	6498.41	3890.27	4690.78
Ren Energ	12.24	10.51	26.86	6.80	4.81
Pol Stab	0.20	0.49	0.29	-1.43	-1.40
C Footprint	10133597.00	11524140.00	6279532.83	4100844.33	3998917.00

4.2. Forecasted clusters

After applying the clustering algorithm to the forecasted values, the data reveals two distinct clusters for the year 2030, showcasing a notable coefficient reduction of 72.643 units (Fig. 4 A). In 2050, the algorithm identifies six clusters, resulting in a significant coefficient reduction of 68.316 units (Fig. 4 B).

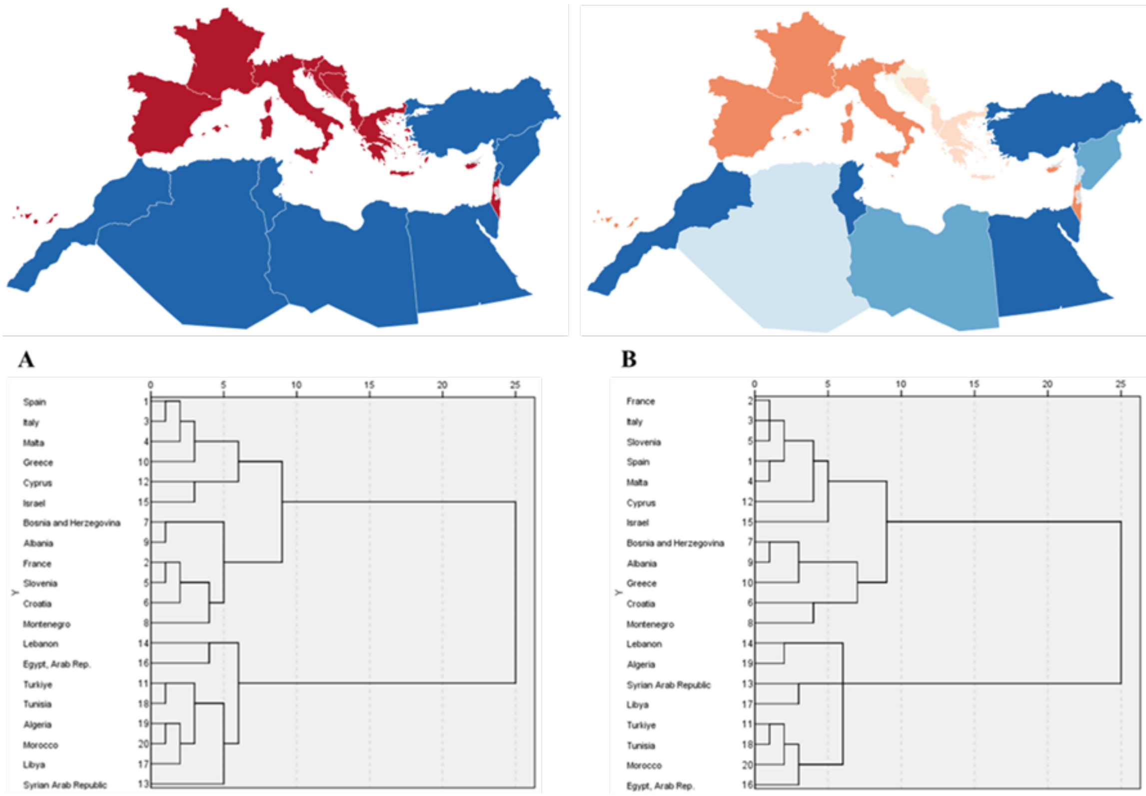

Figure 4. Dendrogram in 2030 (A) and 2050 (B). Source: Own elaboration based on the data in Table 1.

In 2030, the clustering algorithm segregates Europe and Israel from North African and Eastern countries (excluding Israel) into two distinct clusters.

By 2050, the clustering outcomes demonstrate more profound differences between the clusters. The European cluster strengthens as Slovenia joins its ranks, indicating closer ties among its member countries. Croatia and Montenegro form a separate cluster, suggesting a shift in their relations with the broader European group. Greece, Bosnia and Herzegovina, and Albania unite to form a distinct cluster, indicating a departure from the larger European majority. Fragmentation occurs among the Southern and Eastern countries, with Lebanon and Algeria forming one cluster and Syria and Libya forming another. Türkiye forms a close association with Tunisia, Morocco, and Egypt, implying increased collaboration with North Africa.

These changes reflect the evolving geopolitical landscape and the emergence of new alliances and relationships in the regions, shaping the future dynamics of Europe, Israel, North Africa, and the Eastern countries.

Table 5 presents a comprehensive overview of the year 2030, highlighting Cluster 1 as a standout performer across various indicators. This cluster demonstrates a higher prevalence of overweight population, cereal yield, agricultural value added, consumption of fertilisers, access to drinking water and sanitation services, income equality, renewable energy usage, and political stability. However, it also shows lower freshwater withdrawals and agricultural land compared to other clusters. Despite its strengths, Cluster 1 does exhibit a concerning characteristic: a high carbon footprint.

Fast forward to the year 2050, Table 6 reveals some striking forecasted values that surpass the maximum or minimum thresholds of their respective indicators. These values indicate significant variations in recent years, likely attributed to the forecasting algorithm's heavier reliance on the most recent available data within the sample. In Table 6, these instances are marked as “Min./Max. Logical value (Forecasted value)”, underlining the extreme nature of these deviations. It is essential to interpret these extreme values with caution due to their potential sensitivity to the most recent data inputs in the forecasting model.

Table 5. Profiles of the clusters in 2030

	Cluster 1	Cluster 2
Countries	Spain, Italy, Malta, Greece, Cyprus, Israel, Bosnia and Herzegovina, Albania, France, Slovenia, Croatia, and Montenegro	Lebanon, Egypt, Türkiye, Tunisia, Algeria, Morocco, Libya, and Syria
Pop Over	70.88	75.52
Var Agri Land	-0.0021	0.0016
Cer Yield	5467.85	2770.06
Agri VA	42299.96	17630.88
Fert Consump	194.30	165.59
Freshw Withd	40.11	73.63
Drink Wat Serv	96.07	83.40
Sanit Serv	80.33	52.80
Gini	31.48	33.71
Adj NNI	17593.52	7984.19
Ren Energ	25.08	4.74
Pol Stab	0.26	-2.15
C Footprint	9824054.90	3354755.24

Table 6. Profiles of the clusters in 2050

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Countries	France, Italy, Slovenia, Spain, Malta, Cyprus, and Israel	Bosnia and Herzegovina, Albania, and Greece	Croatia and Montenegro	Lebanon and Algeria	Syria and Libya	Türkiye, Tunisia, Morocco, and Egypt
Pop Over	81.25	82.73	81.54	96.61	91.68	93.53
Var Agri Land	0.0115	-0.0114	-0.0200	0.0053	-0.0068	0.0022
Cer Yield	6513.28	6872.47	6959.29	3286.33	1629.87	4246.55
Agri VA	83992.88	14954.49	29825.93	27506.65	44316.70	12555.47
Fert Consump	160.95	170.08	652.24	164.95	63.79	274.93
Freshw Withd	38.56	62.89	11.35	30.69	85.50	81.74
Drink Wat Serv	Max. 100.00 (104.78)	Max. 100.00 (102.79)	85.84	66.63	97.49	Max. 100.00 (102.03)
Sanit Serv	95.34	89.80	71.60	18.56	47.39	91.20
Gini	32.28	35.27	11.42	30.73	41.84	28.73
Adj NNI	26086.71	6630.31	14973.32	7169.57	15354.32	7398.53
Ren Energ	26.21	42.22	37.77	0.67	1.22	2.72
Pol Stab	0.56	-0.05	-0.02	-1.46	Min. -2.50 (-7.50)	-2.24
C Footprint	11437537.75	10765808.09	9565674.22	3057415.50	Min. 0 (-3836096.22)	4886482.31

Table 6 presents the clustering results for the year 2050, showcasing distinct characteristics and trends among the identified clusters:

Cluster 1 stands out for its remarkable positive variations in several indicators, including agricultural land, cereal yield, agricultural value added, drinking water and sanitation services, national income, political stability, and carbon footprint. Additionally, it exhibits the lowest prevalence of overweight population.

Similar to Cluster 1, Cluster 2 shares many characteristics, but it has lower levels of agricultural value added and national income.

Cluster 3 is characterised by a low prevalence of overweight population, a negative trend in agricultural land, high cereal yield, and fertiliser consumption. It also displays low freshwater withdrawals, along with high levels of equality and energy renewability.

In contrast to the previous clusters, Cluster 4 is defined by a very high prevalence of overweight population, along with low levels of drinking water and sanitation services, national income, and renewability.

Cluster 5 shares similarities with Cluster 4, but it features lower cereal yield and fertiliser consumption, reduced sanitation services, higher inequality, and poorer renewability.

Cluster 6 stands out with poor agricultural value added, high freshwater withdrawals, drinking and sanitation services, and lower income and renewability.

There are two cases where certain values exceed the maximum or minimum levels of their respective indicators. In European countries and Israel, as well as in Türkiye, Tunisia, Morocco, and Egypt, there has been a positive evolution in drinking water services. Particularly, the less adaptable countries in Southern and Eastern regions are gradually catching up with European countries. However, the evolution of sanitation services is more pessimistic in these regions. In Syria-Libya, the projected values adopt extreme rhythms of evolution due to recent security events observed in the cited countries, leading to a massive increase in political instability and a considerable reduction in carbon footprint.

4.3. Convergence

The index of convergence shows the following results in the average clustering (Table 7), 2006 (Table 8), 2015 (Table 9), 2030 (Table 10), and 2050 (Table 11).

The analysis uncovers noteworthy divergences between clusters, primarily revolving around agricultural land variation, political stability index, adjusted net national income per capita, and agricultural value added. Initially, the consumption of fertilisers shows convergence until 2030 but diverges again in 2050. In contrast, prominent convergences are observed in the Gini coefficient, prevalence of overweight population, and drinking water services. However, the Gini coefficient shifts towards significant divergence in 2050, primarily influenced by the behaviour of two clusters: Cluster 3 (comprising Croatia and Montenegro) and Cluster 5 (encompassing Syria and Libya). It is crucial to consider that the recent trends in these countries may drive significant future evolutions, which could potentially moderate in the forthcoming years, thus mitigating the apparent divergence.

It is evident that the Mediterranean region significantly differs in terms of agricultural evolution, productivity, income levels, and country stability. However, it shares similarities in terms of the prevalence of overweight populations, the progress of drinking water facilities, and to a noteworthy extent, the level of equality measured by the Gini coefficient.

Table 7. Index of convergence in the clustering of average values.

	Cluster 1	Cluster 2
Countries	Tunisia, Morocco, Türkiye, Syria, Algeria, Lebanon, Libya, Egypt, Bosnia and Herzegovina, Albania, and Montenegro	Slovenia, Croatia, France, Spain, Italy, Greece, Cyprus, Malta, and Israel
Pop Over	0.93	1.07
Var Agri Land	-0.66	2.66
Cer Yield	0.74	1.26
Agri VA	0.48	1.52
Fert Consump	0.69	1.31
Freshw Withd	1.22	0.78
Drink Wat Serv	0.88	1.12
Sanit Serv	0.67	1.33
Gini	1.04	0.96
Adj NNI	0.34	1.66
Ren Energ	1.09	0.91
Pol Stab	-4.27	2.27
C Footprint	0.68	1.32

Table 8. Index of convergence of the clusters in 2006.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Countries	Spain, Greece, Cyprus, France, Italy, and Malta	Israel	Albania and Lebanon	Bosnia and Herzegovina, Algeria, Tunisia, Morocco, Syria, Türkiye, Libya	Slovenia and Croatia	Montenegro	Egypt
Pop Over	1.06	1.08	0.99	0.93	0.99	1.00	0.96
Var Agri Land	48.76	23.99	-86.33	5.43	21.30	0.00	-6.15
Cer Yield	1.04	0.61	0.81	0.51	1.35	0.76	1.92
Agri VA	1.37	3.58	0.21	0.43	0.40	0.82	0.19
Fert Consump	0.65	1.37	0.45	0.24	1.58	0.08	2.63
Freshw Withd	1.12	1.22	1.05	1.62	0.02	0.12	1.85
Drink Wat Serv	1.19	1.21	0.61	0.95	1.01	1.02	1.01
Sanit Serv	1.59	1.55	0.49	0.74	1.07	0.52	1.04
Gini	0.92	1.20	0.90	1.03	0.82	1.19	0.92
Adj NNI	2.12	2.33	0.37	0.32	1.22	0.41	0.23
Ren Energ	0.37	0.42	1.18	0.61	1.31	2.73	0.38
Pol Stab	1.36	-7.31	-3.61	-1.87	3.48	3.68	-2.73
C Footprint	1.65	1.58	0.53	0.50	1.24	1.09	0.40

Table 9. Index of convergence of the clusters in 2015.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Countries	Spain, Italy, Greece, Malta, France, and Israel	Cyprus	Slovenia, Croatia, Bosnia and Herzegovina, Albania, and Montenegro	Syria, Libya, Tunisia, Morocco, Algeria, and Türkiye	Lebanon and Egypt
Pop Over	1.09	1.00	0.83	1.02	1.06
Var Agri Land	-0.11	4.57	0.16	0.03	0.35
Cer Yield	1.36	0.72	1.07	0.44	1.40
Agri VA	2.52	0.94	0.47	0.75	0.31
Fert Consump	0.82	0.85	0.85	0.24	2.24
Freshw Withd	0.90	1.17	0.40	1.44	1.08
Drink Wat Serv	1.19	1.19	0.84	0.97	0.80
Sanit Serv	1.52	1.29	0.72	0.81	0.65
Gini	1.07	1.04	0.82	1.09	0.97
Adj NNI	1.94	1.75	0.56	0.34	0.41
Ren Energ	1.00	0.86	2.19	0.56	0.39
Pol Stab	0.54	1.33	0.78	-3.85	-3.79
C Footprint	1.41	1.60	0.87	0.57	0.55

Table 10. Index of convergence of the clusters in 2030.

	Cluster 1	Cluster 2
Countries	Spain, Italy, Malta, Greece, Cypurs, Israel, Bosnia and Herzegovina, Albania, France, Slovenia, Croatia, and Montenegro	Lebanon, Egypt, Türkiye, Tunisia, Algeria, Morocco, Libya, and Syria
Pop Over	0.97	1.03
Var Agri Land	8.12	-6.12
Cer Yield	1.33	0.67
Agri VA	1.41	0.59
Fert Consump	1.08	0.92
Freshw Withd	0.71	1.29
Drink Wat Serv	1.07	0.93
Sanit Serv	1.21	0.79
Gini	0.97	1.03
Adj NNI	1.38	0.62
Ren Energ	1.68	0.32
Pol Stab	0.28	-2.28
C Footprint	1.49	0.51

Table 11. Index of convergence of the clusters in 2050

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Countries	France, Italy, Slovenia, Spain, Malta, Cyprus, and Israel	Bosnia and Herzegovin, Albania, and Greece	Croatia and Montenegro	Lebanon and Algeria	Syria and Libya	Türkiye, Tunisia, Morocco, and Egypt
Pop Over	0.92	0.94	0.93	1.10	1.04	1.06
Var Agri Land	-3.58	3.55	6.22	-1.63	2.13	-0.69
Cer Yield	1.32	1.40	1.42	0.67	0.33	0.86
Agri VA	2.36	0.42	0.84	0.77	1.25	0.35
Fert Consump	0.65	0.69	2.63	0.67	0.26	1.11
Freshw Withd	0.74	1.21	0.22	0.59	1.65	1.58
Drink Wat Serv	1.12	1.10	0.92	0.71	1.05	1.09
Sanit Serv	1.38	1.30	1.04	0.27	0.69	1.32
Gini	1.07	1.17	0.38	1.02	1.39	0.96
Adj NNI	2.02	0.51	1.16	0.55	1.19	0.57
Ren Energ	1.42	2.29	2.05	0.04	0.07	0.15
Pol Stab	0.31	-0.03	-0.01	-0.82	-4.20	-1.25
C Footprint	1.91	1.80	1.60	0.51	-0.64	0.82

5. Discussion

The study's findings present an opportunity for policymakers to address pressing challenges and foster a more secure future for the Mediterranean region. To achieve this, several politically relevant actions and areas for future research can be proposed:

Firstly, climate adaptation measures should be a top priority for policymakers, especially in vulnerable Southern and Eastern Mediterranean countries. Rising sea levels, extreme weather events, and water scarcity necessitate urgent actions to enhance resilience and preparedness. Collaboration and information exchange between clusters of countries can facilitate mutual learning and accelerate adaptation efforts. Policymakers should actively promote regional cooperation to tackle shared climate challenges effectively.

Secondly, with evolving clustering patterns and potential geopolitical shifts, policymakers must engage in proactive diplomatic efforts. Building strong relationships and promoting dialogue can be instrumental in mitigating conflicts and enhancing regional stability. Diplomacy should focus on finding common ground and fostering cooperation among nations to ensure shared interests are addressed and tensions are minimised.

Furthermore, policymakers should adopt nexus-based policies that recognise the interconnected nature of water, energy, and food resources. Integrated approaches can promote sustainability, efficiency, and resilience across the region. By acknowledging the interdependencies between these critical resources, policymakers can design more effective and holistic policies that avoid unintended consequences and enhance overall security.

Long-term planning is crucial to navigating potential fragmentation and convergence trends identified in the study. Policymakers should develop flexible plans that account for changing geopolitical dynamics. This approach enables adjustments as new information emerges and ensures that policies remain relevant and effective over time.

Future research is essential for enhancing our understanding of the region's dynamics. Updating the study with more recent data and including additional indicators can provide a more comprehensive and up-to-date perspective. Investigating the impacts of specific events or policy interventions on clustering patterns will offer valuable insights for policymakers, guiding them in making informed decisions and evaluating the effectiveness of implemented measures.

Incorporating relevant stakeholders, such as governments, international organisations, academia, and civil society, in the decision-making processes is crucial for successful policy implementation. Engaging diverse perspectives can lead to more inclusive and robust policies and strategies. Stakeholders' involvement ensures that policies are well-rounded, practical, and reflect the needs and aspirations of various groups in the region.

6. Conclusions

This paper presents an analysis of the security status of the Mediterranean region, focusing on the water-energy-food nexus and its vulnerability to climate change. The study utilises a set of indicators chosen to reflect the nexus within the framework of the Sustainable Development Goals (SDGs) and augments it with data availability and timeliness. The Thorndike's optimal geopolitical groups are identified using the Ward's hierarchical clustering algorithm for two distinct time points (2006 and 2015) with factual data and two projected values for 2030 and 2050 using the exponential smoothing algorithm.

The average security status of the area is shaped by two main clusters: the Southern and Eastern countries (excluding Israel) and the European countries with lower adaptation capacity on one side, and the European countries with higher adaptation capacity, including Israel, on the other. However, the clustering pattern varies annually due to ongoing events, resulting in 7 clusters in 2006 and 5 clusters in 2015. Several noteworthy shifts occurred during this period, such as the role reversal between Cyprus and Israel, the clustering of Slovenia, Croatia, Bosnia and Herzegovina, Albania, and Montenegro, and Egypt's transition from a single-case cluster to a joint cluster with Lebanon.

Looking into the future, the study identifies 2 optimal clusters for 2030 and 6 clusters for 2050. Significant changes are observed between these forecasted periods, including Slovenia joining the vast European cluster, Croatia forming a cluster with Montenegro, and Greece separating from the European majority to create a cluster with Bosnia and Herzegovina and Albania. Additionally, there is fragmentation within the Southern and Eastern countries, with Lebanon and Algeria, Syria and Libya forming two-case clusters, and Türkiye clearly associated with Tunisia, Morocco, and Egypt.

To further delineate these groups, the paper calculates the index of convergence for each indicator in the resulting clusters. The indicators that exhibit recurrent divergences include variation in agricultural land, the index of political stability, adjusted net national income per capita, and agricultural value added. However, the consumption of fertilisers converges until 2030 and diverges in 2050. Furthermore, there are convergences in the Gini coefficient, the prevalence of overweight population, and drinking water services, with the Gini coefficient showing an evolution towards divergence in 2050.

The findings of this study hold significant importance for policymakers, researchers, and stakeholders concerned with the security and sustainability of the Mediterranean region. By focusing on the water-energy-food nexus and its vulnerability to climate change, the study sheds light on critical aspects that require attention to ensure the region's resilience and stability.

The identification of optimal geopolitical clusters provides valuable insights into the region's dynamics and interconnections. Understanding the clustering patterns helps in recognising potential alliances, partnerships, and shared challenges among countries. Policymakers can use this knowledge to foster cooperation and build adaptive strategies to tackle climate change impacts on the nexus components.

The study's forecasted scenarios for 2030 and 2050 offer valuable foresight into the region's potential trajectories. By identifying shifts and fragmentations in the clusters, decision-makers can anticipate geopolitical changes and proactively address emerging security challenges. These projections aid in preparing long-term policies and investments that align with the evolving geopolitical landscape.

Furthermore, the index of convergence for different indicators provides a nuanced understanding of the factors that drive or hinder regional cooperation and convergence. Policymakers can use this information to target specific areas for improvement, such as promoting sustainable agricultural practices, enhancing political stability, and addressing income disparities. By identifying areas of convergence, policymakers can also foster knowledge-sharing and capacity-building among countries facing similar challenges.

The study's findings offer an opportunity in the Mediterranean region to address pressing challenges and foster a more secure future. Key actions proposed include prioritising climate adaptation measures, engaging in proactive diplomacy, adopting integrated nexus-based policies for water, energy, and food resources, and developing long-term flexible planning to address geopolitical shifts. Future research is recommended to update data and indicators and investigate the impacts of specific events or policies. Additionally, involving diverse stakeholders in decision-making processes is essential for successful policy implementation, ensuring inclusivity and practicality in the region's policies and strategies. By implementing these actions and conducting further research, our societies can work towards a more secure and sustainable future for the Mediterranean.

References

Anoushivaran, E., Huber, D., Paciello, M.C., 2017. *The Mediterranean Reset: Geopolitics in a New Age*. Global Policy.

Bianchi, M., 2020. Prospects for Energy Transition in the Mediterranean after COVID-19. *Istituto Affari Internazionali* 20|18, 12.

Cramer, W., Guiot, J., Fader, M., Garrabou, J., Gattuso, J.-P., Iglesias, A., Lange, M.A., Lionello, P., Llasat, M.C., Paz, S., Peñuelas, J., Snoussi, M., Toreti, A., Tsimplis, M.N., Xoplaki, E., 2018. Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change* 8 (11), 972-980. https://doi.org/10.1038/s41558-018-0299-2

Eora MRIO, 2023. *Carbon Footprints of Nations*. https://worldmrio.com/ footprints/carbon/

Geddes, A., 2015. Governing migration from a distance: interactions between climate, migration, and security in the South Mediterranean. *European Security*, *24*(3), 473-490. https://doi.org/10.1080/09662839.2015.1028191

Giuli, M., 2021. Europe and the Eastern Mediterranean Energy Resources. In *Transnational Security Cooperation in the Mediterranean* (pp. 115-145). Springer International Publishing. https://doi.org/10.1007/978-3-030-54444-7_6

IPCC, 2013. Climate change 2013: the physical science basis. *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, *1535*.

Lange, M.A., 2019. Impacts of Climate Change on the Eastern Mediterranean and the Middle East and North Africa Region and the Water-Energy Nexus. *Atmosphere* 10 (8), 455. https://doi.org/10.3390/atmos10080455

Messerschmidt, C., 2012. Nothing new in the Middle East – reality and discourses of climate change in the Israeli-Palestinian conflict. In *Climate change, human security and violent conflict*. Springer.

Moran, D., Kanemoto, K., Geschke, A., 2020. *Carbon Footprint of Nations*. Eora MRIO. https://worldmrio.com/footprints/carbon/

Prontera, A., 2020. Energy Security and Euro- Mediterranean Cooperation: A Historical and Conceptual Map. In *Mediterranean Academy of Diplomatic Studies* (Issue Cooperative Security and the Mediterranean) pp. 58-64.

Prontera, A., Ruszel, M., 2017. Energy Security in the Eastern Mediterranean. *Middle East Policy* 24(3), 145-162. https://doi.org/10.1111/mepo.12296

Saladini, F., Betti, G., Ferragina, E., Bouraoui, F., Cupertino, S., Canitano, G., Gigliotti, M., Autino, A., Pulselli, F.M., Riccaboni, A., Bidoglio, G., Bastianoni, S., 2018. Linking the water-energy-food nexus and sustainable development indicators for the Mediterranean region. *Ecological Indicators*, 91 (April), 689-697. https://doi.org/10.1016/j.ecolind.2018.04.035

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 and Bioenergy* 85, 100-108. https://doi.org/10.1016/J.BIOMBIOE.2015.11.016

Scheffran, J., 2020. The Geopolitical Impact of Climate Change in the Mediterranean Region: Climate Change as a Trigger of Conflict and Migration. In *Mediterranean Yearbook 2020: Climate Change in the Mediterranean*.

Scheffran, J., Brauch, H.G., 2014. Conflicts and Security Risks of Climate Change in the Mediterranean Region. In *The Mediterranean Sea*. Springer, pp. 625-640, Netherlands. https://doi.org/10.1007/978-94-007-6704-1_39

Schilling, J., Hertig, E., Tramblay, Y., Scheffran, J., 2020. Climate change vulnerability, water resources and social implications in North Africa. *Regional Environmental Change* 20 (1), 15. https://doi.org/10.1007/s10113-020-01597-7

Stockholm Environment Institute, 2011. Understanding the Nexus. Background paper for the Bonn2011 Nexus Conference. *Bonn2011 Conference the Water, Energy and Food Security Nexus Solutions for the Green Economy*.

Tagliapietra, S., Zachmann, G., 2016. *Energy across the Mediterranean: a call for realism*. Bruegel Policy Brief. https://www.jstor.org/stable/resrep28614

Thorndike, R.L., 1953. Who belongs in the family? *Psychometrika* 18(4), 267-276. https://doi.org/10.1007/BF02289263

Tsakiris, T., 2018. The importance of east Mediterranean gas for EU energy security: The role of Cyprus, Israel, and Egypt. *Cyprus Review* 30 (1), 25-50.

United Nations, 2023. *UNSDG*. https://unstats.un.org/sdgs/dataportal

Wohlfeld, M. (Ed.), 2020. *Cooperative Security and the Mediterranean.* Med Agenda-Special Issue. Mediterranean Academy of Diplomatic Studies, University of Malta, pp 1-84, Malta

World Bank, 2023a. *World Development Indicators*. https://databank.worldbank.org/source/world-development-indicators

World Bank, 2023b. *Worldwide Governance Indicators*. https://databank.worldbank.org/source/worldwide-governance-indicators

World Health Organization, 2023. *The Global Health Observatory*. https://www.who.int/data/gho/data/indicators/indicator-details/GHO/prevalence-of-overweight-among-adults-bmi-greaterequal-25-(crude-estimate)-(-)