

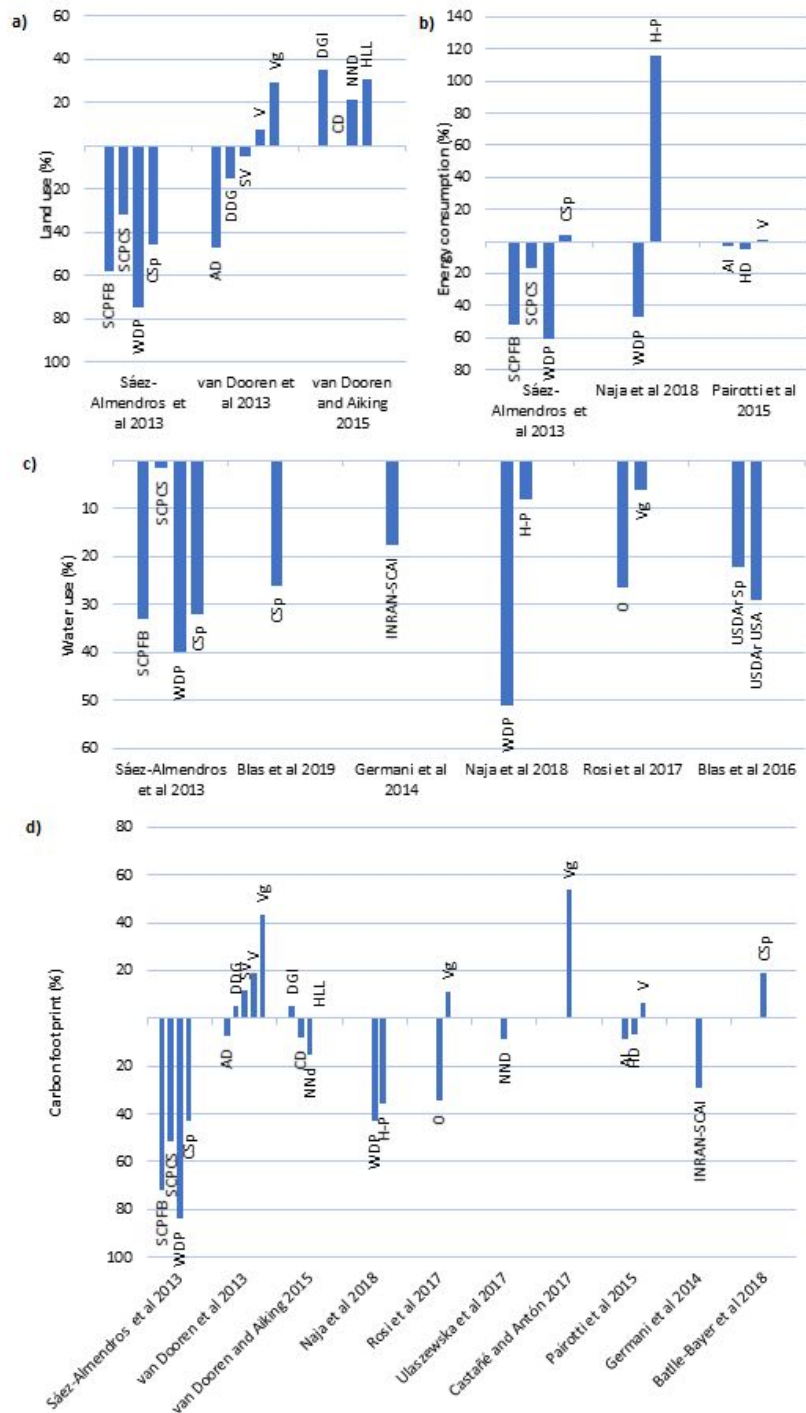
Perspectives of Environmental Health Promotion and the Mediterranean Diet: A Thematic Narrative Synthesis

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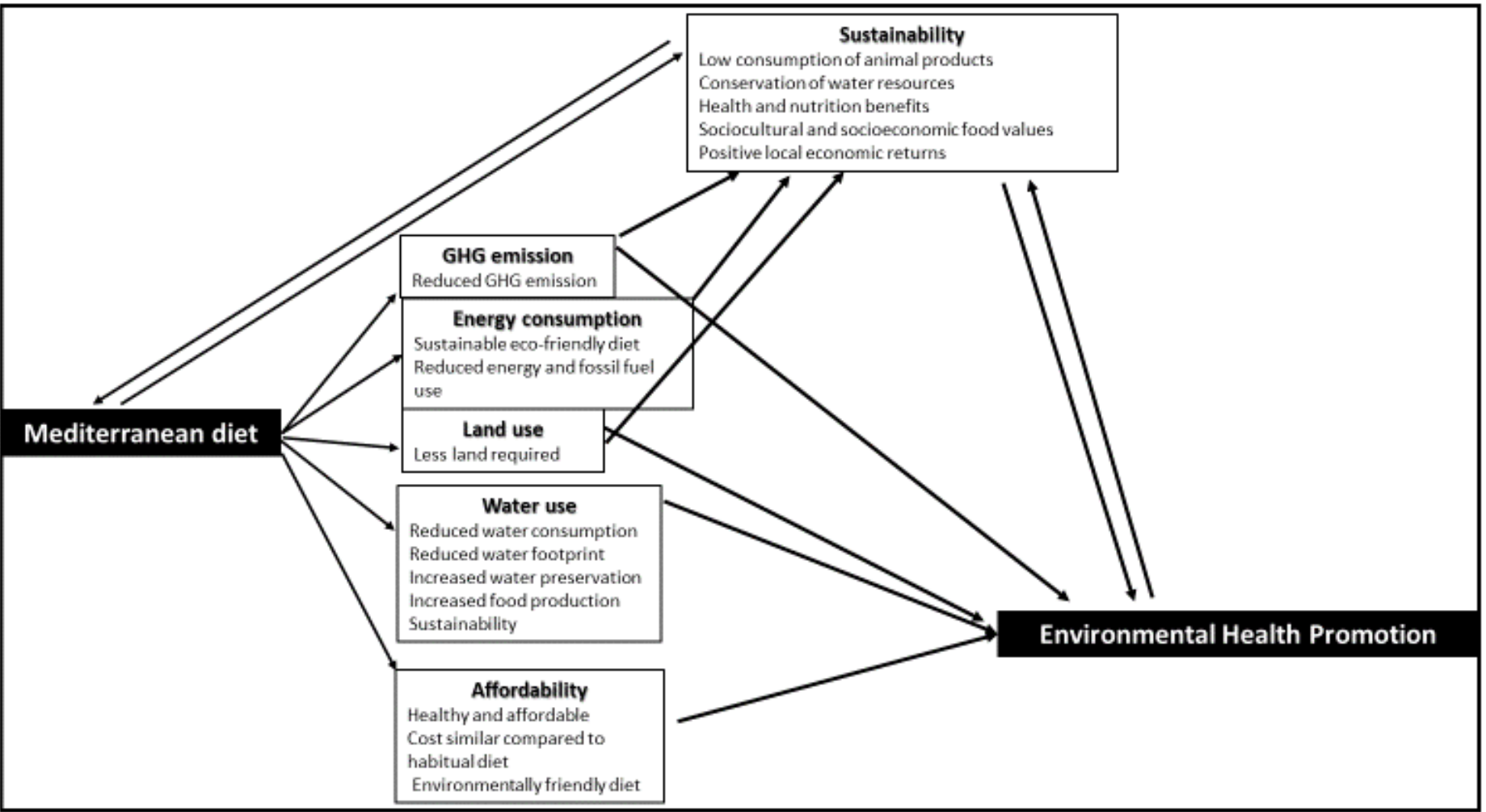
Table 1. Environmental health benefits of the MDiet Pattern

Increased consumption of: plant-based Foods whole grains legumes Olive Oil	<ul style="list-style-type: none"> • Emphasis on seasonal and locally grown/produced items • Decreased reliance on fossil fuels for processing and distribution
Decreased red meat intake	<ul style="list-style-type: none"> • Reduction of greenhouse gas emissions • Improved use of arable land • Lower water usage
Decreased processed foods	<ul style="list-style-type: none"> • Decreased reliance on fossil fuels for processing and distribution • Lower water usage
Inclusion of fish and seafood	<ul style="list-style-type: none"> • Emphasis on locally sourced items
Dairy and yogurt consumed daily in low to moderate amounts	<ul style="list-style-type: none"> • Reduction of greenhouse gas emissions • Improved use of arable land • Lower water usage

Figure 1. Environmental impact of MDiet compared to other dietary patterns

Note* a) land use, b) energy consumption, c) water use, and d) carbon footprint. AD: Average Dutch, AI: Average Italian, CD: Current Dutch, CS_p: Current Spanish, DDG: Dutch Dietary Guidelines, DGI: Dietary guidelines, H-P: High-Protein, HD: healthy diet, HLL: Historical Low Lands, INRAN-SCAI: The Italian National Food consumption survey, NND: New Nordic, O: omnivorous, SCP_{CS}: the current Spanish dietary pattern estimated from the Household Consumption Surveys of the Spanish Ministry of Agriculture, Food and Environment SCP_{FB}: the current Spanish dietary pattern estimated from the FAO food balance sheets, USDAr: The American recommended diet by the US Department of Agriculture, SV: semi vegetarian, V: vegetarian, Vg: vegan, WDP: Western Dietary pattern.

Figure 2. The Mediterranean Diet and Environmental Health Promotion – A Conceptual Framework



Abstract

A thematic narrative synthesis was conducted to identify literature exploring the Mediterranean Diet (MDiet) and its impact on the environment in terms of land and water use, Greenhouse Gas emissions, fossil fuels, affordability, and acceptability. The MDiet is a sustainable diet that can reduce some environmental impacts of food production while improving both the health of the population and world, diet acceptability, cost, cultural and socio-economic factors should be considered when determining appropriateness of a recommended dietary pattern to a regional or global population.

Key Words

Mediterranean diet; Environmental health; Sustainability

Introduction

Food production places detrimental pressures on the environment by increasing land and water usage, toxic emissions, and climate change. Food production accounts for 19–29% of Greenhouse gas emissions (GHGE) ¹, 70% of freshwater use ², increased eutrophication ³, and consumption of 35% of ice-free land ^{4,5}; it is also the greatest cause of deforestation and biodiversity loss ⁵. However, global dietary patterns govern the production of food. Thus, diet as well as dietary choices and practices affect resource consumption and environmental impact ^{6,7}.

Baroni, et al. ⁸ showed that diets with a greater consumption-content of animal products, compared to diets with a greater consumption of plant products, have a larger influence on the environment, such as increased fossil fuel use, climate change, and ecotoxicity. Whereas plant-based diets with high intake of fruits, vegetables, cereals, and legumes have lower GHGE compared to diets with high intake of meat ^{6,7,9}. A 2005 epidemiological study showed that a 50% reduction in meat intake, replaced by fruits, vegetables, and grains, related to a 19% reduction in GHGE and 42% reduction in land usage in the United Kingdom ¹⁰. Therefore, the production of animal-based products clearly has a large and deleterious role on the environment.

The environmental impact of food production will likely continue to rise as the world population continues to increase and if associated consequentially as consumption of animal based and processed foods increases. For example, from 1993–2013 population increased by 29%, which correlated to a 62% increase in demand for animal products ¹¹. In correspondence with predicted food consumption and population, the United Nations' Food and Agriculture Organization (FAO) projects a 60% increase in crop and pasture-based food production by 2050 ¹². Based on such projections, the environmental impact of food production will rise, if the world does not adopt more sustainable dietary habits.

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3 Sustainable dietary practices refer to diets with low environmental impacts and maintain
4 food and nutritional security and long-term health of a population ¹³⁻¹⁵. According to the FAO,
5 “sustainable diets are protective and respectful of biodiversity and ecosystems, culturally
6 acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy;
7 while optimizing natural and human resources” ¹⁶. One diet which reduces consumption of
8 animal products and processed foods is the Mediterranean Diet (MDiet). The MDiet consists of
9 high intake of fruits and vegetables, legumes, oils, and fish, with relatively small amounts of red
10 meat or processed food items ¹⁷. The MDiet focuses on increased intake in plant-based products
11 compared to animal protein and processed foods, reducing environmental impact. Thus,
12 compared to further diet patterns and food production methods, the MDiet has environmentally
13 friendly dietary guidelines and goals to maintain an environmentally sustainable food system.
14 Studies show that the MDiet reduces land usage, GHGE, and global warming compared to meat-
15 centric diets and meat-based food production methods ^{6,7,10,18}, while reducing risk for
16 cardiovascular and metabolic disease ¹⁹.

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Despite the **environmental** negative consequences of a more Westernized diet, the world
population has consistently adopted such dietary patterns when the choice exists; this diet is high
in meat products, saturated fats, refined grains, sugar, salt, and as a result, tends to result in
reduced consumption of fruits and vegetables ²⁰. Westernized Diet increases GHGE and use of
land, livestock, water, and agrochemicals ²¹. Additionally, when compared to MDiet,
Westernized Diet increases risks for obesity, cardiovascular disease, and metabolic diseases ²².
Prevalence of these diseases are predicted to rise over the next 30 years, if dietary and lifestyle
changes are not made ^{22,23}. Since Westernized ~~diet Diet~~ directly influences human and
environmental health, adoption of the Westernized ~~diet Diet~~ places a great burden on the world

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3 itself. On the other hand, it appears that the MDiet is a healthful alternative dietary pattern to
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5 Westernized ~~diet~~ ~~Diet~~ and could lower detrimental outcomes on the environment through
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7 encouraging consumers to consume more plant-based products ^{19,24}. However, the complete
8
9 environmental impact of the MDiet is not comprehensively understood. Therefore, this thematic
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11 narrative synthesis will identify contemporary literature exploring the MDiet and its impact on
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13 the environment in terms of land and water use, GHGE, energy consumption, affordability, and
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15 other environmental considerations (see Figure 1).
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22 **Methods**

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24 A thematic review of the literature was carried out prior to September 2019. No time
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26 frame was set during the search in order to obtain a more comprehensive search of relevant
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28 published literature data. Articles were identified by applying search strategies to eight academic
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30 electronic databases: Scopus, PubMed, SpringerLink, EBSCOhost, SAGE, Wiley Online, Taylor
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32 & Francis, and ScienceDirect. The Search phrases, terms, and key words included in the final
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34 search syntax were “environment; conservation; biodiversity; carbon footprint; water;
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36 environmental health; sustainability; climate change; human impact; consumption AND
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38 Mediterranean diet; Mediterranean-style diet; Mediterranean dietary pattern”. All retrieved
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40 articles were screened for relevance to the topic. Additionally, references from retrieved articles
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42 were examined to identify any further additional articles. Grey literature was excluded in this
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44 review.
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51 ***Inclusion and exclusion criteria***

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3 Footprint measurements and methodology studies, quantitative analyses, cohort studies,
4 communications, commentaries, editorials, brief reports, position, practice, policy, and
5 hypothesis-generating statements, literature reviews, and studies that conducted comparison of
6 the MDiet against other dietary patterns were included. Publications were excluded if publication
7 samples described dietary patterns other than the MDiet. Non-refereed publications also were
8 excluded. Only articles in English were included in the review. Study protocols, grey literature,
9 and conference abstracts were excluded.
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21 **Results and Discussion**

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23 According to the FAO, food security exists when all people at all times have physical and
24 economic access to sufficient, safe, and nutritious food to meet their dietary needs and food
25 preferences for an active, healthy life. Sustainable diets are those diets that have low
26 environmental impact and contribute to food and nutrition security and a healthy life for present
27 and future generations ^{16,25}.
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35 **The world** population is increasing and requires strategies for a food supply that ensures
36 food security with minimal impacts on our environment. The capacity to produce sufficient
37 quantities of food is potentially limited by water and land use, soil fertility, and conservation of
38 seas and oceans.
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44 The global food production system is responsible for 80% of deforestation²⁶, more than
45 70% of freshwater utilization, and up to 30% of GHGE that have significantly **increased^{1-over}**
46 **the last 50 years**. Additionally, large scale food production has been shown to negatively affect
47 biodiversity²⁷ and growing evidence indicates that the loss of biodiversity can have a significant
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3 environmental impact. Natural resources are, by definition, finite; water, land, and fossil fuels
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5 will not be available for future generations if not well managed.
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8 9 10 ***Methodologies used to quantify the environmental impact of consumption and production***

11 Concerning quantification of food consumption patterns' impact on the environment, a
12
13 significant amount of work has been anticipated, and therefore, various tools and analytical
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15 methodologies have been suggested. GHGE and utilization of natural resources for agriculture
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17 constitute the environmental impacts that were most frequently modelled. Several authors have
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19 examined the impact of habitual eating patterns on the environment among different population
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21 categories. Comparisons between dietary intakes, dietary recommendations, and theoretical diets
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23 were performed using numerous indicators such as greenhouse gas (GHG), land use (LU) and
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25 agricultural capacity, water use, throughout the Life Cycle Analysis (LCA). This effective tool
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27 uses mass as the functional unit (FU) ²⁸, standardized by the International Organization for
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29 Standardization ²⁹. GHGE is generally expressed in kgCO₂ eq per kg of food item. Nevertheless,
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31 this GHGE expression be corrected otherwise to the daily or weekly or yearly amount of food
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33 item consumed per capita.
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40 An Italian research team used the environmental hourglass approach, based on a LCA, to
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42 examine whether acquiescence with nutritional recommendations could reduce some negative
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44 environmental effects on the food production ³⁰.
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47 Because of some limitations of LCA, another Italian group of researchers ³¹ used a
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49 method they called hybrid input-output analysis (IOA)-LCA. The IOA-LCA approach consists of
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51 taking into consideration the positive aspects of the LCA and the IOA. This hybrid approach
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53 consists of taking into consideration the positive aspects of the life cycle assessment and the
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3 input-output analysis. IOA could assign emissions to various sectors, considering the overall
4 country's economy, and provides researchers the opportunity to get, on one hand, authentic
5 estimates of the environmental impact of food consumption based on per-capita consumption
6 and, on the other hand, to have complete and accessible data against the constraints of collecting
7 a huge quantity of information.
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12 In sum, the hybrid method is primarily based on products' life cycle from specific
13 categories of products. Through this method, some stages of the cycle could be accounted either
14 through standard LCA or via IOA ³¹. The same authors do not consider that GHGE and energy
15 consumption are representatives of all the environmental impacts related to food production and
16 consumption.
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28 *The Mediterranean diet impact on greenhouse gas emissions and Land use*

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31 In 2010, the United Nations Educational Scientific and Cultural Organisation (UNESCO)
32 recognized the MDiet as an intangible heritage of humanity. The MDiet is a traditional diet
33 distinguished by potential utilization of olive oil with a considerable consumption of plant and
34 plant-based foods such as vegetables, fruits, cereals, legumes, seeds and **nuts**; moderate
35 consumption of seafood, fermented dairy products, eggs and poultry; and lower intake of red and
36 processed meats (RPM) and sweets ³². This dietary pattern is healthy and nutritious, including
37 foods with various components promoting health.
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47 In addition to its environmental positive impact, the MDiet pattern is associated with
48 reduced prevalence of type 2 diabetes and some types of cancers and neurodegenerative
49 pathologies ³³. **Reduced total mortality, reduced risk of developing metabolic syndrome with its**
50 **components, and cardiovascular diseases reflect the protective effects of this diet pattern** ³⁴⁻³⁷.
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3 The low environmental impact of the MDiet is based on sustainable farming systems ³⁸,
4 primarily as it constitutes a more plant-based diet and thus is envisaged as an eco-friendly diet.
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8 During the last decades, several studies have assessed the environmental sustainability of
9
10 MDiet. When compared to current Western dietary patterns, the MDiet can be considered a
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12 plant-based diet with lower GHGE and lower water footprints ³⁹. However, other authors have
13
14 recently stated that plant-based diets from greenhouses may not have the lower environmental
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16 impact these plant-based diets are qualified with and tend to increase GHGE when consumption
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18 of such dietary patterns increases ⁴⁰⁻⁴².
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22 Van Dooren and Aiking ⁴³ calculated a score (cf. formula 01), they called health score,
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24 based on 10 nutritional characteristics of three diets in the Netherlands; MDiet, New Nordic Diet
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26 (NND) composed of local Scandinavian traditional products, and Low Lands Diets (LLD) with
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28 ~~and~~ identical health benefits as the NND. The LLD is a semi-vegetarian dietary pattern is
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30 characterized by a traditional, mostly plant-based diet, with high consumption of fresh and local
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32 vegetables, fruits and whole grains. Furthermore, the LLD provides a local vegetable oil such as
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34 **rapeseed oil** with limited quantities of fish, meat, milk, and eggs.
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38 Another score was calculated by the same authors called Combined GHGE-LU Score.
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40 This score is presented as the average of the GHG and LU score per diet based on LCA. The
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42 MDiet scored 122 with the health score formula, which exceeds the recommendations. However,
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44 males scored 90 with Combined GHGE-LU Score and remain below the formulated goals
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46 (=100). The score was defined as the average of the GHG and LU score per diet as shown by
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48 Van Dooren, et al. ⁴⁴.
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52 **In their studies, Tilman ⁶ and Clark ⁷** compiled data to make comparison between
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54 reference diets (considering all food groups) to three dietary patterns alternatives: MDiet; being
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3 abundant in vegetables and fruit, seafood and other foods); pescatarian diet (PD); which includes
4 fish and virtually no meat (both red and poultry); and a vegetarian diet (VD), composed of dairy
5 products and eggs as well as vegetables and fruits and grains with virtually no meat or fish. An
6 important reduction ($P < 0.05$) in adverse health indicators such as type 2 diabetes (16–41%) and
7 cancer (7–13%) incidence was recorded across the three alternative diets. Moreover, heart
8 disease mortality (20–26%) and overall mortality (0–18%) also decreased across the three
9 alternative diets. Concerning environmental impact, these authors assessed GHGE and LU in 120
10 published papers which contain 555 lifecycle assessment (LCA) considering 82 food types. They
11 concluded that GHGE are highest when animal products are consumed especially ruminant meat.
12 GHGE are reduced for diets containing larger amounts of most cereals, fruits, vegetables and
13 pulses (beans, lentils, and peas).
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28 For an average Italian family, when the MDiet pattern is applied, the monthly
29 expenditure is € 441.77 being **nearly** identical to the national average food consumption budget
30 (€ 440.12) with a different proportion of each product class ³¹. In the same study, authors found
31 that the MDiet requires **3817.4** MJ per month in energy consumption, lower than the actual MJ
32 for the national average and lower than the healthy diet (2.44% and 4.36% respectively).
33 However, the vegetarian diet pattern represented the lowest energy consumption (**3790.13**
34 MJ/month), 0.71% less than the MDiet and 3.24% less than the Italian average.
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44 Concerning GHGE, the Italian national average diet pattern presented the highest
45 monthly GHGE with **402.9** kg CO_{2eq}. The Health diet contributes the second largest amount of
46 GHG emissions, at 2.28% less than the Italian diet, followed by the MDiet, which is 6.81%
47 lower. The vegetarian diet showed the lowest emission rate of 14.55% below the national
48 average and 6.74% below the MDiet ³¹.
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5 The vegetarian diet pattern appears more environmentally sustainable than the MDiet.
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8 However, for social, cultural and psychological or even ecological considerations, willingness to
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10 replace/reduce meat with vegetables and/or plant-based proteins might be a difficult goal to
11 achieve⁴⁵. The MDiet could represent a practical alternative bridging the need to decrease the
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impact of food consumption on the environment and maintaining the social/cultural aspect of dietary behaviour. For maintaining the heritage of the MDiet, this balance should be considered when developing policies to reduce GHGE.

A recent systematic review⁴⁶, included 18 studies on GHG, four studies on energy use and three studies on water use. Comparisons have been made between both health and environmental outcomes with different methodologies including modelling (food components), LCA, and LU analysis. The environmental impacts modelled were GHGE and natural resources utilization, such as lands used for agriculture, energy consumption and water. Analysis of those studies revealed that reduced meat consumption improves health outcomes, and reduces GHGE as well as land, energy, and water usage.

Concerning GHGE based on a per gram of protein basis, the major difference of about 250-fold was recorded between ruminant meats mainly for beef and lamb, and legumes. Semi-vegetarian and vegetarian diets should reduce GHGE and mortality rates when compared with nonvegetarian diet⁴⁶. The lowest health score and the highest environmental impact was observed in Italian average diet, where beef meat represented the food with the most significant projected impact on natural resources and on the ecosystem⁸. **Conversely**, the vegan diet showed the lowest environmental impact and the highest health score. In the United States, land, water usage and energy were higher in the American meat-based diet -compared to lacto-ovo

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3 vegetarian diet ⁴⁶. However, using other indicators of nutritional quality, a French study showed
4 that among four dietary patterns, not every diet showing highest nutritional quality, as
5 substituting fruit and vegetables for meat, could reduce GHGE ⁴⁷. Except for ruminant meat
6 group, as shown in EPIC-Oxford cohort in the United Kingdom, among self-selected meat and
7 fish eaters, vegetarians, and vegans ⁴⁸ and in the Netherlands Dutch diet ⁴⁴, the same authors
8 draw a conclusion that the high-quality diet with high vegetable and fruit consumption had
9 elevated GHG emissions compared to the low-quality diet characterized by starches, sweets, and
10 salted snacks consumption. In a UK study, the highest GHGE amounts were observed among
11 people consuming >100 g/d of meat. The emissions diminished when meat intake decreased
12 from 50–99 g/d to <50 g/d. The emissions become the lowest in fish consumers, vegetarian
13 individuals, and vegans ⁴⁸. The GHGE, LU, water and energy usage decreased in Spanish MDiet
14 pattern ⁴⁹.

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31 In the previously cited systematic review ⁴⁶, a UK study observed that lowest RPM plus
32 vegetarian decreased GHGE by 0.47 kg CO₂eq.person⁻¹. d⁻¹ (12%) to 3.96 kg CO₂eq person⁻¹. d⁻¹
33 in men and 3.02 kg CO₂eq. person⁻¹. d⁻¹ in women vs. current diet with a yearly GHGE decrease
34 of 27.8 million tons. According to the UK government, variations in livestock production will
35 not be sufficient to achieve emission reduction targets.

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42 In Italy, Baroni, et al. ⁸ made a comparison between seven diet patterns: omnivorous,
43 organic farming; omnivorous, conventional farming; vegan, organic farming; vegan,
44 conventional farming; vegetarian, organic farming; vegetarian, conventional farming and
45 average Italian diet with conventional farming. They concluded that beef was the primary food
46 displaying the highest environmental impact. Milk, cheese, and could also contribute to a high
47 impact.

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3 In a French cross-sectional study (INCA-2), Masset, et al. ⁵⁰ compared four diet patterns
4 according to their GHGE and cost between men and women. Authors showed that the major food
5 components contributing to the increase in the daily GHG in the average French diet were meats.
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10 Another French study carried out by Drewnowski, et al. ⁵¹ reported identical observations for 661
11 different foods and beverages. Meat, meat products, and dairy products expressed the highest
12 amounts of GHGE per 100 g product compared to frozen and processed fruits, vegetables, grains
13 and sweets.
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19 Saez-Almendros, et al. ⁵², analysed through LCA, the impact of production through
20 transportation and retail on four dietary patterns, including the new MDiet pyramid in Spain. The
21 authors showed that the MDiet, when compared to the other diet patterns, would diminish GHGE
22 that reach 35,510 Gg CO₂-eq year⁻¹ (72%), land use at 58%, energy at 52%, and water at 33%.
23 The annual GHGE of CO₂ 35,510 Gg CO₂-eq year⁻¹, water consumption 13.2 Km³ year⁻¹, and
24 agricultural LU 8,365 (10³ Ha year⁻¹) were the lowest too in the MedDiet pattern. The authors
25 concluded that switching from the current Spanish pattern to the MDiet using the new MDiet
26 pyramid would be advantageous for consumers' health as well as the environment.
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38 In a global modelling and data analysis performed by Tilman and Clark ⁶ on the four
39 previously mentioned diets, the MDiet pattern displayed a reduction of 30% in GHGE (~0.8 Gt
40 CO₂-C_{eq} per year), where ruminant meats showed the highest impact (CO₂-C_{eq}: 0.023 ± 0.002
41 g/MJ / 330±18 g/serving and 62±3.4 g/g-protein). Omnivorous diets are expected to require more
42 crop land (370–740 million Ha) than MDiet, vegetarian and pescatarian diets.
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49 Comparatively, in the Netherlands modelling and data analysis performed by Van Dooren
50 and Aiking ⁴³, the MDiet pattern exhibited, compared to the other diet patterns, the highest health
51 score (118), an acceptable GHG index 96 (3.4 Kg CO₂eq/d), the lowest LU index 107 (2.75 m²
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3 year⁻¹ day⁻¹) and was second only to the vegan diet (130) in Sustainability with a score of score
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5 of 102.
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8 In an **previous** study, comparing six dietary patterns: current average Dutch, official
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10 **“recommended”** Dutch, vegetarian, semi-vegetarian, vegan diet and MDiet, Van Dooren, et al. ⁴⁴
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12 found that the MDiet (96) and semi-vegetarian diet (96) both were close to reference score (100).
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14 Furthermore, the same authors reported that the four diets had a GHGE score closer to the
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16 European Union’s target (20%) of GHG reduction. The vegan diet exceeded the reference score
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18 (123). The greatest reduction in GHGE and LU could be achieved with limited consumption of
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20 meat, dairy products, **calorie-dense foods**, and beverages such as alcoholic, juices, soft drinks,
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22 coffee, and tea, in the given order. The reduction of meat consumption is the most effective
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24 option since this group was implicated in increasing GHGE emissions to 34% (considering the
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26 use of household energy) and 54% of LU. The authors of this study stated that even consuming a
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28 considerable amount of vegetables and fruits, pulses, and some more (whole grain) cereals and
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30 shifting to olive oil, will only slightly impact the climate.
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36 Recently, an investigation was conducted by Naja, et al. ⁵³ from previous national survey
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38 data on 337 adults using a 61-item FFQ. Three dietary patterns were assessed: Lebanese-
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40 Mediterranean, Western, and High-Protein. Environmental footprints of the three food
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42 consumption patterns were compared. The Lebanese-MDiet showed lower water consumption
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44 (**602.06-1 ± 330.70** L/d) and GHG emissions (0.90 ± 0.56 Kg CO_{2eq}/d). However, the other
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46 patterns displayed high environmental footprints: Western **1231.02 ± 937.23** L/d / 1.58 ± 1.23
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48 CO_{2eq}/d, High-Protein: **653.87-9 ± 452.92** L/D / 1.40 ± 0.99 CO_{2eq}/d, respectively. Moreover, for
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50 the Lebanese-MDiet, whole dairy products significantly contributed to increased water use to
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52 43.01% when vegetables substantially increased energy use to 60.12% and GHGE to 50.75%.
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3 Concerning the High-Protein diet, the most elevated contributor to all three environmental
4 footprints were meat products which increased water consumption to 69.30%, energy use to
5 50.87% and GHGE to 73.08%.
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10 According to Rosi, et al. ⁵⁴, few studies based on real food intakes have been carried out,
11 and their three key environmental indicators were water footprint, carbon footprint, and
12 ecological footprint. The originality of this study includes assessment of environmental impact of
13 three diets among 153 Italian adult consumers, equally distributed to omnivores, ovo-lacto-
14 vegetarians, and vegans. The Italian Mediterranean index was calculated to assess the nutritional
15 quality of the three diets and both, with food group intakes, were presented as medians and
16 interquartile range. The three dietary groups displayed different levels of adherence to the
17 MDiet. The MD index was significantly ($p<0.05$) higher in the vegan category, 7.0, and
18 significantly ($p<0.05$) lower for the omnivore category, 4.0. The environmental impacts' analysis
19 of the three diet categories indicated that omnivores' diet was the most significant diet affecting
20 the three environmental indicators. This pattern produced significantly higher carbon, water, and
21 ecological footprints ($p<0.001$) when compared to the other diets. It should be noted that meat
22 and fish categories' contribution to the omnivorous diet was: 38% for the water footprint, 37%
23 for the carbon footprint, and 44% for the ecological footprint. Cereals and derivatives, then
24 further vegetable-based foods accounted for 24%, 56%, and 84% of the carbon footprint; 31%,
25 69%, and 92% of the water footprint; and 21%, 58%, and 90% of the ecological footprint for the
26 omnivores, ovo-lacto-vegetarians, and vegan groups, respectively. The authors mentioned in
27 their conclusion that Italians appear to have a moderately high adherence level to the MDiet.
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51 A recently published study called the Seguimiento Universidad de Navarra (SUN)
52 project, by Fresán, et al. ⁵⁵, assessed an overall sustainable diet considering simultaneously
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3 health, environment and monetary cost on a sample of 18,429 Spanish university graduates.
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5 Trichopoulou, et al. ⁵⁶ measured the adherence to the MDiet through a suggested index. The
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7 SUN project authors designed an index they named Overall Sustainable Diet Index that considers
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9 the impact of the daily diet on environmental footprints, health, and monetary costs. ~~A score~~ A
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11 score was assigned to each attribute. The dietary patterns of participants were clustered in the
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13 upper quartile. The MDiet was the most sustainable pattern followed closely by the
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15 Provegetarian dietary pattern. However, although considered the healthiest option and exhibiting
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17 relatively low environmental footprints, the MDiet financial cost was the highest. The
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19 Provegetarian dietary pattern represented the most eco-friendly pattern, positively affecting
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21 health and lowering cost.
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26 In the same country (Spain), an LCA approach has been recently performed by Batlle-
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28 Bayer, et al. ⁵⁷ to assess the nutritional quality of the current food consumption and GHGE.
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30 Comparisons have also been made with two alternative diets; the first was called
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32 Strategy for Nutrition, Physical Activity and the Prevention of Obesity (NAOS) Strategy. NAOS,
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34 launched by the Spanish Ministry of Health and Consumer Affairs, refers to the dietary
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36 guidelines of Spain. The second diet was based on the MDiet. A common functional unit was
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38 applied to the three types of diets for comparison purpose; that consists of a food basket with the
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40 representative food products consumed yearly inside and outside home by a Spanish citizen
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42 including around 790 kg of food and drink products (11.16 MJ/d 2665 kcal/d). This average daily
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44 calorie intake emits approximately 1.6 t CO₂ eq per year (1.4 to 2.0 t CO₂ eq). When adjusted to
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46 a food basket that covers the average recommended calorie intake, an amount of 1.4 t CO₂ eq per
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48 year is emitted. Animal-based products significantly contributed to this effect as follow: meat
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50 (33%), fish (22%), dairy products (17%), vegetables (5%), and cereals with derivates (5%) and
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3 beverages (5%). Comparatively, the MDiet and the food baskets emit 1.2 to 1.3 t CO₂ eq,
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5 respectively because of the reduced meat consumption. The leading contributors for both food
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7 baskets were the dairy products that represented 33% and 26% for NAOS and MEDiet,
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9 respectively. Fish represented 18% and 12%; vegetables 12% and 22%, while meat accounted for
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11 12% and 13% for both diets in respective orders.
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15 An Italian team ⁵⁸ explored, through a review paper, the natural resources-food nexus in
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17 the Mediterranean region and focused on the ecological footprints (EF) of existing consumption
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19 and production patterns. In addition, statistics obtained from various international databases,
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21 such as the FAOSTAT, and other sources, were utilized to examine the situation over 21
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23 countries of Mediterranean region. It has been highlighted from this ecological analysis that EF
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25 of consumption of almost all of the 21 Mediterranean countries were constantly higher compared
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27 to production's EF. The carbon footprint (CF) itself was higher than the biocapacity, with the
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29 exception of seven countries.
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34 Regarding water footprint (WF), consumption of meat products contributed one-third to
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36 the entire WF in Bosnia and Italy. Cereals' contribution to WF was the highest in Egypt,
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38 Morocco, and Turkey, where cereal accounted up to one-third of water use. For vegetable oils,
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40 such as olive oil, the contribution to the WP was solely significant in Italy. However, meat and
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42 dairy products, accounted for one- half of the total WF of Italian and Bosnian food supply.
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46 American authors discussed, in their review ⁹, how shifting to healthier diets, such as
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48 some Mediterranean, vegetarian, vegan and pescatarian diet patterns, could have a positive effect
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50 on diet-related disease incidence as well as ameliorate environmental outcomes. LCA meta-
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52 analyses shows that plant-based foods display the lowest GHGE per kilocalorie of food
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54 produced. Compared to the previous group, dairy products, eggs, pork, poultry, and low-impact
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3 fish production systems contribute approximately 100 to 2500% higher GHGE ~~which are higher~~.
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5 Beef, sheep, and goat meats have GHGE ranging between 2,000% to 10,000% higher than plant-
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7 based foods per kilocalorie of food produced. Furthermore, meat production recorded the highest
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9 levels of nutrient pollution; ~10,000% higher than plant-based foods.
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12 It should be emphasized that diets which produce minor environmental effects are not
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14 necessarily healthy. Whereas, healthier diets do not necessarily have a lower environmental
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16 impact. So, substituting foods within a diet could positively impact health, but might decrease or
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18 increase GHGE.
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21 22 23 *Land use*

24 Since 1961, land used for global agriculture has increased by 15%. Compared to other
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26 dietary patterns, plant-based diets like the MDiet require less land per kilocalorie of food
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28 produced. For instance, ruminant meats need 20 to 100 times more land than plant-based foods⁹.
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30 Nelson, et al.⁴⁶ found in their systematic review that adherence to a diet lower in animal-based
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32 foods and total energy and rich in plant-based foods, such as the MDiet, has lower environmental
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34 impacts and promotes greater health. Shifting toward MDiet appears to deal with both health and
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36 environmental concerns⁵⁹.
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42 Saez-Almendros, et al.⁵² compared the MDiet with the ~~w~~Western diet based on the
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44 American diet and the Spanish diet patterns from the FAO food balance sheets and from the
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46 Household Consumption Surveys of the Spanish Ministry of Agriculture, Food and
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48 Environment. The agricultural LU of the MDiet was 8365.10³ Ha /year, the lowest among the
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50 other diets, a reduction of 58% when compared to the Western diet. Similarly, a higher
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3 adherence to the MDiet in Spain resulted in a reduction of LU (mean for the highest versus
4 lowest adherence category to MDiet = -0.71 (95 % CI -0.76, -0.66) m²/d) ⁵⁵.

7 Furthermore, Van Dooren, et al. ⁴⁴ compared the LU of six diets for female adults in the
8 Netherlands. The MDiet had a land use of 2.8 m²*year/day, lower than the average Dutch diet,
9 the recommended Dutch dietary pattern and the semi-vegetarian diet, but higher than the
10 vegetarian and the vegan diets. LU is mostly attributed to the amount of meat in the diet (54%)
11 along with processed foods (snacks, pastries, sweets, etc. 18%) and dairy products (11%). The
12 LU estimate for the MDiet (4.15 m²*year) was similar to the present Dutch diet and higher than
13 the NND and LLD patterns for adult men and it did not meet the Dutch dietary guidelines (3.08
14 m²*year) ⁴³.

25 26 27 28 *Water use*

29 Water footprint is a measure of the water resources required for the production of goods.
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31 Water footprint takes into account blue water that contains fresh surface water and/or
32 groundwater, green water which is composed of soil and crop plants' rainwater
33 evapotranspiration, and grey water made up of polluted water resulting from the production
34 process ⁶⁰.

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42 Compared with ~~western diet~~ Western diets, the MDiet has a lower environmental impact
43 ^{61,62}, particularly its reduced water use which constitutes an additional argument in favor of the
44 MDiet, since water scarcity is a challenging and worrying issue all over the world ⁶³. In fact,
45 better adherence of a Spanish population to the MDiet resulted in a reduction of 33% of water
46 consumption ⁵². In the same context, Fresan, et al. ⁶⁴ found that the mean for the highest vs.
47 lowest adherence category to MDiet = -58.88 (95 % CI -90.12, -27.64) l/day.

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3 Studies showed that adopting the MDiet could result in reducing the water footprint up to
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5 29% in the United States, which is a decrease by 1629 l/person/day⁶⁵, 750 l/capita day in Spain
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7⁶⁵, and 3000 l/kg of food product per week in Italy¹⁸. A study in Lebanon found that MDiet had
8
9 the lowest water consumption compared to the ~~western diet~~ Western diet and the high-protein diet
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11 243.35 ± 112.0, 443.61 ± 197.15, 264.72 ± 161.67 l/kg per 4.18 MJ ~~1000 Kcal~~ respectively⁵³.

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14 Growing evidence suggests that the dietary pattern which is rich in plant-based foods and
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16 poor in animal-based foods exerts less environmental impact including water use (10,17,41).
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18 Moreover, two studies explored the environmental impact of three different diets. The
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20 omnivorous diet comprises food of animal (including animal flesh) and plant origin, the lacto-
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22 ovo-vegetarian diet which includes plant-based food and animal products (excluding animal
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24 flesh), and the vegan dietary pattern which is an exclusively plant-based menu. Both studies
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26 concluded that the lacto-ovo-vegetarian and the vegan diets which were more adherent to the
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28 MDiet had a lower impact on the water footprint compared with the omnivorous dietary pattern
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30^{54,66}. Furthermore, Lacirignola, et al.⁵⁸ showcased in a review article the importance of the
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32 promotion of the MDiet on preserving water resources and emphasis on reducing food waste in
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34 the production chain to make it even more sustainable. The food industry, and particularly the
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36 dairy, meat, and fruit and vegetable processing sectors, is one of the most water-consuming
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38 industries⁶¹.

43 44 45 46 47 ***Energy consumption***

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49 The current food system is considered ineffective, environmentally unsustainable, and
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51 highly dependent on low-price fossil fuels⁶⁷. Furthermore, a Spanish study of university
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53 graduates compared the environmental footprints of several diets concluded that the MDiet and
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3 the pro-vegetarian dietary pattern are a sustainable and eco-friendly alternatives to the ~~western~~
4 ~~diet~~ Western diet ⁵⁵. An inverse association was observed between adherence to the MDiet and
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6 energy use when comparing the highest vs. the lowest categories (mean= -0.86; 95 % CI -1.01, -
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8 0.70 MJ/d) ⁶⁴. Studies that compared the energy consumption of ~~western diet~~ Western diets and
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10 the MDiet showed that the latter uses less energy. The MDiet had the lowest energy consumption
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12 (239 042 TJ/year) compared with the American ~~w~~ Western dietary pattern (-52%) and the
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14 Spanish current dietary patterns ⁵². The Lebanese-MDiet had lower energy use compared to the
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16 ~~western diet~~ Western diet (10.82 ± 6.3 vs 20.53 ± 17.5) but higher than the High-Protein diet
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18 (5.00 ± 4.4) ⁵³. Vegetables and dairy foods showed the highest energy use in the MDiet. The
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20 energy use of the MDiet was 3817.41 MJ per month which is lower than both the national
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22 average and the healthy diets (≈ 3910.655 and 3983.985 MJ per month respectively) but higher
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24 than the vegetarian diet (3790.13 MJ per month) ³¹. Consistently with the prior discussed
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26 environmental parameters, energy consumption was reduced in plant-based dietary patterns
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28 relative to animal-based diets ⁴⁶. Reducing the energy consumption of the food production
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30 system requires increasing the efficiency of energy use and shifting toward renewable energies
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Affordability

Towards the end of the 1990s, a growing interest in financial costs of food products with regard to their consumption was perceived ⁶⁸. Since then, an upsurge in studies assessing health, environment and monetary costs, separately or focusing on these different metrics at the same time has been observed ^{69,70}. Seconda and colleagues performed a comparison between four groups of participants by evaluating the organic food part in their diet; (Organic vs.

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3 Conventional) and the MDiet adherence (Med vs. NoMed). The higher cost (euro/day) was
4 observed on the Organic–MDiet (11.43 [95% CI=11.34-11.52]) comparing to the Organic–Non
5 MDiet, Conventional–MDiet and Conventional–Non MDiet (10.90 [95% CI=10.81-10.98], 9.11
6 [95% CI=9.03-9.19] and 8.59 [95% CI=8.55-8.63], respectively) ⁷⁰.

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12 Recommendations of the Spanish SUN project (*Seguimiento Universidad de Navarra*,
13 University of Navarra Follow-up) showed that plant-based diets, especially the MDiet and a pro-
14 vegetarian diet model, might be a good option to accomplish a complete sustainable diet,
15 according to a high score bringing together the three dimensions of a healthy, affordable and
16 environmentally friendly diet ⁵⁵. These authors assessed three dietary patterns (the
17 Mediterranean, the Western and the Pro-vegetarian dietary patterns) for monetary costs.
18 Participants with higher adherence to the MDiet spent €1.42/day more in their daily diet
19 comparing to those with adherence to the two other diets ⁵⁵.

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31 In their study performed in the Northern Bank of the Mediterranean (Italy),
32 suggested that the substitution of animal-based products with vegetable proteins might lead to a
33 significant decrease in CO_{2eq} emission and resource reduction, at the same cost for consumers.
34 This indicates that food choice based on environmental and health goals is not necessarily more
35 costly. However, other Italian authors, who found that the monthly expenditure of the MDiet was
36 somewhat higher in the total budget compared to the regular expenditure on food by the Italian
37 population, reported remarkable results even with a clear difference in the budget distribution by
38 different food groups ¹⁸. By comparing the cost (in Euro) of the MDiet to the ordinary Italian
39 household food consumption, the cost of the MDiet was higher at about 0.7 euro/week per
40 person especially regarding milk, cheese and eggs (20 vs. 14.06 euros) and regarding potatoes,
41 fruit and vegetables (34 vs. 16.36 euros) ¹⁸.

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3 The idea that the reliance on the MDiet is relatively expensive was also the most
4 important conclusion from a French study showing that consumers following the MDiet pattern
5 with a higher intake of organic food fit the previous definition of sustainability published by the
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FAO, except for economic considerations ⁷².

In a very recent multidisciplinary literature review, combining evidence from several fields (nutritional sciences, health, environmental, agricultural and sustainability studies) on the diets impacts on the environment, ecosystems, and the rural landscape, a Portuguese team has drawn conclusions of the need to promote and invest in the financial viability of the MDiet as a "modern" affordable diet for consumers in general and as a mean to reduce chronic diseases ³⁸.

Sustainability

According to the definition provided by Conway ⁷³; “*Sustainability is the ability of a system to maintain productivity in spite of a major disturbance, such as caused by intensive stress or a large perturbation*” ⁷³. The main sustainable advantages of the MDiet are currently characterized by health ⁷⁴ and nutrition benefits, with positive effects on biodiversity richness and environmental impact. In addition, the MDiet is also characterized by a low consumption of animal products, conservation of water resources and a reduction of GHGE with high sociocultural food values and positive local economic returns ^{16,75,76}. At the end of 2010, the UNESCO added the MDiet in the Representative List of the Intangible Cultural Heritage of Humanity, and described it as follows: “*The MDiet -derived from the Greek word *diáita*, way of life- is the set of skills, knowledge, rituals, symbols, and traditions, ranging from the landscape to the table, which in the Mediterranean basin concerns the crops, harvesting, picking, fishing, animal husbandry, conservation, processing, cooking, and particularly sharing and consuming*

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3 *of food*"⁷⁷. In parallel with this recognition of UNESCO, Serra-Majem, et al.⁷⁶ collected key
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5 documents presented at the 8th International Conference on the MDiet, held in Barcelona in
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7 2010, which focused on issues related to food sustainability and how food production and
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9 transport contribute to the impacts of climate change. The most significant recommendations
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11 were to update trends and developments around the MDiet, helping to improve access, raise
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13 awareness among health and nutrition professionals and, ultimately, encourage compliance and
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15 the population in a sustainable and coherent manner⁷⁶.
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20 In the field of nutrition, an Italian team of researchers has developed a methodological
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22 approach and a nutritional sustainability index for agri-food products⁷⁸. Their approach is
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24 founded on two macro-indicators; the first one, named "business distinctiveness", which
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26 considers the different standards and regulations relating to quality, safety and traceability, as
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28 well as the origin of raw materials; while the second macro-indicator, known as "nutritional
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30 quality", assesses the micronutrients and bioactive phytochemicals quality composition of the
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32 product. Based on typical products and Mediterranean food groups, the proposed index could be
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34 a highly valuable guide to assess both the sustainability and the diet overall quality⁷⁸. However,
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36 concerns remain about the sustainability of family eating practices in the Mediterranean region.
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38 Policy makers and marketers need to take initiatives that focus on education and facilitate access
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40 to sustainable food products that are specific to the MDiet in the Mediterranean.^{79,80}
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46 According to a recent study on the guiding principles for sustainable development, three
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48 suggestions to increase the sustainability of the MDiet could be applied to the Mediterranean
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50 region; more plant foods, reducing food waste, and consuming less meat⁸¹. Furthermore, in
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52 2016, on behalf of the Scientific Committee of the International Foundation of MDiet, Dernini et
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54 al.⁸² proposed the "*Med Diet 4.0: the MDiet with four sustainable benefits*" based on potential
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3 indicators that can help to assess the sustainability of the MDiet. These indicators are; (A)
4 Nutrition and Health, (B) Environment, (C) Economy, and (D) Society and culture. The Med
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6 Diet 4.0 can play a vital, educational and communicative role in revitalizing the MDiet by
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8 providing a larger understanding of its sustainability features with country-specific and culturally
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10 appropriate applications. A conceptual framework (see figure 2) is proposed to illustrate the
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12 dynamic interactions and interrelations between environmental health promotion and the MDiet.
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19 Conclusion

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21 This thematic review explored the environmental health benefits of the MDiet Pattern
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23 (see Table 1). Global health efforts that combine environmental health policies with aspects of
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25 public health nutrition are warranted in light of the findings in this review. The MDiet,
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27 considered a plant-oriented dietary approach, appears to be an appropriate choice to preserve
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29 both human and environmental health and to reduce the environmental impact associated with
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31 food consumption. Regrettably, its erosion is a consequence of the loss of its adherence by the
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33 Mediterranean populations, which impacts health, social, cultural, economic and environmental
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35 trends. Preference should be attributed to diets characterised by low environmental impacts and
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37 providing sufficient quantities of macronutrients and micronutrients. The largest challenge
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39 presented based on this review is how to make the MDiet the dominant dietary lifestyle pattern
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41 for the majority of the people living in this region and whether this pattern might be globalized.
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43 Further challenges include how to effect consumer's behaviour change and make consumption
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45 more realistic. Diet cost, culture and social factors should also be considered in promoting MDiet
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47 as a sustainable and maintainable dietary pattern.
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