Current Research in Environmental Sustainability 3 (2021) 100047

Contents lists available at ScienceDirect

Current Research in Environmental Sustainability

journal homepage: www.sciencedirect.com/journal/current-research-in-environmental-sustainability

Integrating environmental and socio-economic indicators to explore the sustainability of food patterns and food security in Lebanon

L. Skaf [a], E. Buonocore [a], S. Dumontet [a], R. Capone [b], P.P. Franzese [a,*]

[a] UNESCO Chair in "Environment, Resources and Sustainable Development", Department of Science and Technology, Parthenope University of Naples, Centro Direzionale, Isola C4, 80143 Naples, Italy
[b] International Center for Advanced Mediterranean Agronomic Studies (CIHEAM), Mediterranean Agronomic Institute of Bari, Italy

ARTICLE INFO

Keywords:
Environmental indicators
Sustainability
Food diet
Food security
Refugees

ABSTRACT

Food security is a complex issue whose comprehension requires multidisciplinary research exploring environmental, socio-economic, and policy aspects. World population is expected to continue increasing in the next decades. As a consequence, the global food demand is also expected to increase, exacerbating the contribution of food consumption and production patterns to environmental problems and climate change. In addition, the problem of socio-economic inequalities is also noteworthy, with a very high number of undernourished people at global level. Considering the complex nature of food security, the integration of environmental and socio-economic indicators is much needed for assessing its multiple dimensions. In this study, environmental and socio-economic indicators were assessed to explore the sustainability of food patterns and food security in Lebanon. Environmental indicators were calculated to assess the environmental costs and impacts of the Lebanese and refugee diets. All the environmental indicators calculated for the Lebanese diet resulted higher compared to the refugee diet. The overall contribution of the refugee diet to the investigated impact categories resulted in about 25%, confirming its significance in terms of direct and indirect natural resources consumption and environmental impacts. The socio-economic indicators showed that food security is a critical issue for the Lebanese population and, particularly, for the refugees living in Lebanon. In particular, 59% and 15% of Lebanese and refugee populations resulted having an adequate individual access to food. In conclusion, the outcomes of the study provide scientific information to support policy-makers and a benchmark for future studies aimed at improving food security in Lebanon.

1. Introduction

Food security is a complex issue whose comprehension requires a multicriteria approach based on different disciplines encompassing both environmental and socio-economic aspects (Berry et al., 2015; Prosekov and Ivanova, 2018). Multidisciplinary research is required to explore different aspects related to food security, among which human pressures on natural resources, effects of climate change on agroecosystems, food access, poverty and distribution of wealth, human health, and international policies (Cole et al., 2018; Godfray et al., 2010).

The food security issue can be faced by analyzing four main dimensions: availability, access, utilization, and stability (FAO, 2006a). Ecosystems and their goods and services contribute to these dimensions. For instance, soil biodiversity supports and regulates a wide range of ecosystem processes, thus influencing agricultural productivity and, as a consequence, food availability (El Mujtar et al., 2019). Ecosystems such as wetlands and mangrove forests help in protecting coastal areas against natural hazards (e.g., storms and coastal erosion) increasing the stability of food production from fields and fish ponds (Spalding et al., 2014). Considering the important role that natural ecosystems play in ensuring food security, their degradation due to human pressures represents a serious threat to long-term human well-being (IUCN, 2013).

It is projected that the world population will reach 9.7 billion by 2050 (UN, 2017). As a consequence, the global food production is also expected to increase, worsening environmental problems due to intensive agricultural practices and unsustainable food production and consumption patterns (FAO, 2019; Gaffney et al., 2019; Govindan, 2018). In fact, the population growth will lead to higher demand for both agricultural products and processed food, exacerbating the contribution of food production chains to environmental problems and climate change

* Corresponding author.
E-mail address: pierpaolo.franzese@uniparthenope.it (P.P. Franzese).

https://doi.org/10.1016/j.crsust.2021.100047
Received 3 September 2020; Received in revised form 21 April 2021; Accepted 22 April 2021
Available online 14 May 2021

(FAO, 2018). Nonetheless, climate variability and extreme events have been one of the major drivers of recent food crises, reducing the capability of natural ecosystems to sustain the food demand (Lipper et al., 2014; Wheeler and Von Braun, 2013). In fact, food security and climate change are interlinked issues that need to be addressed simultaneously (FAO, 2019).

Besides environmental aspects, the problem of socio-economic inequalities is also noteworthy. While at global level 2.1 billion people are overweight or obese, more than 820 million people remain undernourished, in addition to 151 million stunted children, 51 million wasted children, and more than 2 billion suffering from micronutrient deficiencies (Willett et al., 2019). The prevalence of hunger is higher in countries with fast population growth making more challenging the achievement of global food security goals (FAO et al., 2020).

The adoption of sustainable food diets can play an important role in improving food availability and nutrient provision, food access and utilization, and the resiliency of food systems towards the achievement of food security targets (Bowdren and Santo, 2019).

Food diets are directly linked to environmental sustainability and human health. It is expected that by 2050 current dietary patterns, if stable, will cause an estimated 80% increase in global GHG emissions from food production (Tilman and Clark, 2014). Therefore, more sustainable diets capable of generating lower environmental impacts while contributing to food security and human health are much needed (Capone et al., 2019; FAO, 2019).

Several studies explored the environmental impacts of food production and consumption patterns (Galli et al., 2017; Ibidhi et al., 2017; Sala et al., 2017). Among different methods, Life Cycle Assessment – LCA (ISO 14040, 14,044; ILCD, 2010) has been widely used to assess the environmental performance and sustainability of different phases of food production chains, including agricultural production, food-processing, packaging, transport, and waste management at local, national, and global scale. Notarnicola et al. (2017) used LCA to assess the environmental burden of food consumption in Europe and showed that meat and dairy products have the highest environmental impacts compared to the other investigated food items. Eberle and Fels (2016) assessed the environmental burden of food consumption in Germany, showing that animal products generate high environmental burdens and that agriculture and consumption cause the highest environmental impacts.

Many LCA studies were focused on investigating local and specific food production processes (Espadas-Aldana et al., 2019; Gésan-Guiziou et al., 2019; Skunca et al., 2018; Taki et al., 2018), while others were aimed at assessing the overall impacts of alternative food diets (Nemecek et al., 2016; Muñoz et al., 2010). Among them, Pairotti et al. (2015) assessed the environmental burdens of different Mediterranean diets in terms of their energy consumption and carbon footprint by combining LCA and Input-Output Analysis highlighting the environmental sustainability of the vegetarian diet. Similarly, Naja et al. (2018) showed the high environmental burdens of high-protein dietary patterns in Lebanon. At country level, Muñoz et al. (2010) used LCA to assess the average Spanish diet showing that food production is the main hotspot in the Spanish diet. On the other hand, a large set of studies is focused on specific socio-economic aspects of food security, especially at country level. A recent study by Clement et al. (2019) discussed how the linkages between women empowerment and food security are complex and country specific. Barzegar et al. (2019) assessed the relationship between food security, dietary patterns, and the socio-economic status of Iranian women, showing the critical importance of education level and income as indicators of risk for food insecurity. Irani et al. (2018) explored the issue of food waste in relation to food security, providing suggestions and a management perspective to reduce food waste. Bhuyan and Sahoo (2017) assessed the socio-economic determinants of food security in India, highlighting the direct link between food security and education, social classes, and salary. Alonso et al. (2018) provided a review of the impact of culture on the four dimensions of food security.

Considering the complex nature of food security, the integration of environmental and socio-economic indicators is much needed for assessing its multiple dimensions (Barrett, 2010; Ogundari, 2017; Skaf et al., 2019).

The complexity of the food security issue is even more challenging in countries including groups of vulnerable people like immigrants and refugees (WFP, 2017a; FAO, 2017). This is for instance the case of Lebanon, a small Eastern Mediterranean country in which refugees constitute about 30% of the total population, contributing in reducing land availability and increasing food demand in an already food insecure context (ECPHAO, 2020; GoL and UN, 2019; MOE/EU/UNDP, 2015).

While several studies were conducted to assess the direct pressure of the demographic growth on natural resources available in Lebanon (MoE/EU/UNDP, 2014, 2015), no studies addressed the environmental impacts associated to refugee food diet at a national level.

In this study, indicators exploring the environmental costs and impacts of Lebanese and refugee food diets were calculated at an individual and a national scale. In addition, socio-economic indicators were calculated to provide a comprehensive assessment of food security in Lebanon from a multicriteria perspective, focusing on environmental, social, and economic issues.

2. Materials and methods

2.1. The area of study

Lebanon is a small Eastern Mediterranean country covering a total area of 10,452 km^2 and hosting a population of about 6 million people (The World Bank, 2018; UNICEF, 2016). Lebanon is characterized by a massive food import accounting for about 80% of the country's food needs (Halabi and Ghanem, 2016). Despite its Mediterranean climate with fertile soils and a relative abundance of water and natural resources, agricultural production in Lebanon has decreased during the last years, exacerbating the problem of inadequate access to food, especially for poorer people (FAO, 2014; Skaf et al., 2019; WFP, 2017b).

Since the Syrian crisis in 2011, the number of refugees in Lebanon has largely increased. Lebanon currently hosts approximately 1.5 million Syrian and Palestinian refugees, constituting about 30% of the total population with the highest per capita concentration of refugees in the world (EU, 2019; Nassar and Stel, 2019). The population increase has led to a heavy burden on the already fragile socio-economic and environmental context of Lebanon (GoL and UN, 2019).

2.2. Data collection

The assessment of environmental and socio-economic indicators was based on data collected in Lebanon by using a structured questionnaire available in English, Arabic, and French languages (available as online supplementary material). The questionnaire was organized into four sections. The first section covered the demographic structure of the participants. Based on the collected information, the demographic profile of the investigated participants was developed (Table 1). The second and third sections were aimed at collecting information to evaluate food access, the dietary patterns, and food waste. The fourth section was aimed at collecting information useful to assess educational level and food awareness. In particular, the respondents were asked to provide information about: the amounts of servings of each food categories they think should be eaten per day to achieve a healthy eating pattern, exclusive breastfeeding to assess their knowledge on this issue, and their knowledge on the subject of food security. All data were collected for both Lebanese and refugees.

Data were collected in the period September 2018–January 2019 through face-to-face interviews. A sample of 568 individuals was interviewed. Interviews were carried out across the five regions of Lebanon: Beirut, Mount Lebanon, Beqaa, North Region, and South Region. The survey was conducted within houses and other different places

Table 1
Demographic profile of interviewed Lebanese and refugees.

Characteristics									
Age	<18	18–25	25–35	35–45	45–55	55–65	65–75	>75	
%	2.46	29.93	23.94	19.19	14.96	7.75	1.41	0.35	
Gender	Female	Male							
%	73.77	26.23							
Nationality	Lebanese	Syrian	Palestinian	Egyptian	Other				
%	84.51	13.38	0.88	0.18	1.06				
Region	Beirut	Bekaa	Mount Lebanon	North	South				
%	14.44	36.62	20.25	13.91	14.79				
Household size	1	2	3	4	5	6	>7		
%	4.4	10.74	15.14	22.01	26.41	12.68	8.63		
Individual income LBP per month	0-500,000	500,000-1,000,000	1,000,000-1500,000	1500,000-2,000,000	2,000,000-2,500,000	2,500,000-3,000,000	3,000,000-3,500,000	3,500,000-4,500,000	>4,500,000
%	39.97	18.31	16.73	8.27	7.22	2.82	0.88	2.99	2.81
Household incomeLBP per month	0-1500,000	1500,000-3,000,000	3000,000-4,500,000	4,500,000-6,000,000	6,000,000-9,000,000	>9,000,000			
%	37.14	26.05	14.79	7.835	8.365	5.82			

Note 1. LBP = Lebanese Pounds. One USD is equal to 1500 LBP.

(e.g., markets, malls, universities, schools, streets, and hospitals) to include in the sample respondents with different backgrounds and cultural level. In addition, to obtain relevant information, respondents were selected in the range between 16 and 80 years old. Senior female respondents were chosen more often (74% of the sample, Table 1) being responsible and more aware of the household context.

2.3. Environmental indicators

The Life Cycle Assessment (LCA) methodology was used to assess the environmental costs and impacts of Lebanese and refugee food diets. LCA is a standardized tool for assessing the environmental impacts of a product throughout its lifecycle, from raw material acquisition, via production and use phases, to waste management, adopting the so-called "cradle-to-grave" perspective (ISO 14040, 2006; ILCD, 2010). All human activities and processes result in environmental costs and impacts due to resource consumption and release of emissions into the environmental matrices. LCA allows for the identification and quantification of all energy, materials and emissions flows related to all steps involved in the life cycle of a product, assessing their environmental burden and evaluating opportunities for improvement (ILCD, 2010). LCA studies are conducted through four phases: Goal and scope definition, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), and Interpretation (ISO 14040, 14046; ILCD, 2010). Environmental impacts were calculated with reference to 1-day diet for both Lebanese and refugees. Table 2 shows the inventory of the food intake for main categories evaluated in this study. In addition, in Table 3 the average daily individual food intake (kcal/person/day) of Lebanese and refugee populations is compared with the minimum dietary requirements based on Hirvonen et al. (2020).

Food production processes were derived from the Ecoinvent database. LCI data on food diets were used to calculate the contributions to environmental impact categories in the Life Cycle Impact Assessment (LCIA) phase. The RIVM and Radboud University, CML, and PRé (ReCiPe) midpoint method was selected among the LCA methods. This method allowed for the assessment of environmental costs and impacts due to the investigated food diets in terms of contribution to the following selected impact categories: climate change, fossil depletion, agricultural land occupation, freshwater eutrophication, human toxicity, natural land transformation, photochemical oxidant formation, particulate matter formation, terrestrial acidification, and water depletion. Finally, LCA indicators were calculated on annual basis and upscaled at national level considering the size of Lebanese and refugee populations.

Table 2
Average daily individual food intake for Lebanese and refugee populations.

Food category	Lebanese (g capita^{-1} day^{-1})	Refugees (g capita^{-1} day^{-1})
Vegetables	171	147
Fruits	237	140
Cereals	118	161
Dairy	231	185
Meat	62	17
Fish	20	11
Eggs	31	30
Total	869	690

Table 3
Comparison between the minimum dietary requirements (Hirvonen et al., 2020) and the average daily individual food intake of Lebanese and refugee populations.

Food category	Minimum Dietary requirements (kcal capita^{-1} day^{-1})	Lebanese (kcal capita^{-1} day^{-1})	Refugees (kcal capita^{-1} day^{-1})
Vegetables	117	85.77	64.20
Fruits	126	161.94	83.12
Grains	811	602.20	752.50
Dairy	153	136.02	94.44
Protein	726	502.58	224.22
Total	1933	1488.51	1218.48

2.4. Socio-economic indicators

Socio-economic indicators were assessed by processing the data collected through the interviews conducted in Lebanon. The dietary patterns of Lebanese and refugee populations were assessed based on the daily food intake reported in the answers. The daily consumptions were then upscaled to an annual basis. In addition, based on the dietary patterns, the economic value of the food basket was estimated by conducting a market study. Food prices were collected from a total number of 31 local markets located in all the Lebanese regions (a threshold of five markets per region was chosen). Markets were randomly selected in each region. Big supermarket chains and small local grocery shops were examined in both poor and rich areas where the Lebanese live as well as nearby refugees' settlements.

Then, the average food basket price was calculated for both Lebanese and refugees for each Lebanese region. The individual average food basket price was 373,734 LBP per month for Lebanese and 326,366 LBP per month for refugees.

Finally, to measure the ability of Lebanese and refugees to access affordable and nutritious food, the "individual access to food" and

"household access to food" indicators were calculated by comparing the market price of the food basket to the economic income. Inadequate access to food was identified as the situation in which the food basket price was more than half of the economic income (Cochrane and D'Souza, 2015; Rose et al., 2013). The individual and household access to food indicators were calculated as the percentage of people having adequate access to food compared to the total sample.

Based on the dietary pattern, the "food consumption vs dietary requirements" indicator was calculated as the average consumption for each food category compared to the USDA dietary guidelines values (USDA, 2019). The indicator was calculated by averaging the values obtained for all food categories.

In addition, the "adequately nourished adult" and "adequately nourished children" indicators were calculated as the percentage of Lebanese and refugee adults and children meeting the minimum dietary requirements compared to the total sample.

The "jobs in agricultural sector" indicator was calculated as the percentage of people working in agriculture compared to the total sample.

The "gender equality" indicator was assessed considering the number of unemployed females out of the total female respondents and then compared to the share of unemployed males.

The "awareness on nutrition and food security" indicator was assessed considering the answers of the respondents to questions dealing with their general knowledge on the food security issue, the dietary requirements, and the importance of breastfeeding, among others. The indicator was calculated as the percentage of people aware of these topics compared to the total number of respondents.

Finally, the "food waste" indicator was calculated as the individual average amount of food trashed by Lebanese and refugees on annual basis.

3. Results

3.1. Environmental indicators

Indicators in Table 4 show the contribution of the Lebanese and refugee food diet to selected environmental impact categories. All indicators calculated for the Lebanese diet resulted higher compared to those calculated for the refugee diet. In particular, the contribution of the individual Lebanese food diet to climate change resulted in 642.24 kg $CO_{2\text{-eq}}$ per year, while the contribution of the individual refugee food diet resulted in 448.55 kg of $CO_{2\text{-eq}}$ per year (Table 4). The annual contribution to terrestrial acidification of the Lebanese and refugee individual food diet was 6.91 and 4.50 kg $SO_{2\text{-eq}}$, respectively. In terms of indirect resource consumption connected to food diets, the fossil depletion resulted in 105.41 and 76.57 kg $oil_{\text{-eq}}$ per year, while water depletion was 46.72 and 39.22 m^3 per year, respectively (Table 4).

Fig. 1 shows a comparison between the individual Lebanese and refugee food diet based on selected environmental impact categories.

Table 4
LCA indicators calculated for the individual Lebanese and refugee food diet on annual basis.

Impact category	Lebanese food diet	Refugee food diet
Agricultural land occupation (m^2)	530.45	381.99
Climate change (kg $CO_{2\text{-eq}}$)	642.24	448.55
Fossil depletion (kg $oil_{\text{-eq}}$)	105.41	76.57
Freshwater Eutrophication (kg $P_{\text{-eq}}$)	0.61	0.40
Human toxicity (kg 1,4-$DCB_{\text{-eq}}$)	420.95	281.13
Natural land transformation (m^2)	0.05	0.04
Particulate matter formation (kg $PM10_{\text{-eq}}$)	1.59	1.07
Photochemical oxidant formation (kg $NMVOC_{\text{-eq}}$)	2.50	1.75
Terrestrial acidification (kg $SO_{2\text{-eq}}$)	6.91	4.50
Water depletion (m^3)	46.72	39.22

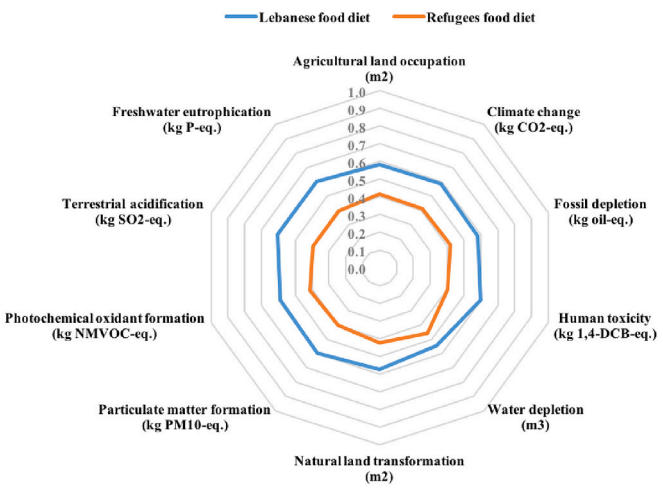

Fig. 1. Comparison of LCA indicators calculated for the individual Lebanese and refugee food diet. Values were normalized from Table 4, dividing the impacts calculated for the individual Lebanese and refugee food diet by the total generated impacts.

Table 5 shows the annual contribution to the selected impact categories of the Lebanese and refugee food diets at national scale. The contribution of the Lebanese food diet to climate change resulted in 2.62 Mt. $CO_{2\text{-eq}}$ per year, while the contribution of the refugee food diet resulted in 0.89 Mt. $CO_{2\text{-eq}}$ per year. The total annual contribution to climate change resulted in about 3.5 Mt. $CO_{2\text{-eq}}$ (Table 5).

The total annual contributions to terrestrial acidification and human toxicity were $3.72{\cdot}10^7$ kg $SO_{2\text{-eq}}$ and 2.28 10^9 kg 1,4-$DCB_{\text{-eq}}$. In terms of indirect resource consumption, the total fossil depletion resulted in about 583,000 t $oil_{\text{-eq}}$, while the total water depletion was about 269 million m^3.

3.2. Socio-economic indicators

Table 6 summarizes the socio-economic indicators calculated for the Lebanese and refugee populations. The "individual access to food" resulted 59% for the Lebanese and 15% for the refugees. Lebanese population was characterized by higher "gender equality" (81%) compared to refugees (48%). The "awareness on nutrition and food security" was 24% and 17% for the Lebanese and refugee populations. Regarding "food consumption vs food dietary requirements", Lebanese meet 77% of the USDA food dietary requirements, while this indicator was 63% for refugees. Finally, the annual food waste produced per person was 9.20 kg for the Lebanese and 2.43 kg for the refugees.

Table 5
Contribution to selected environmental impact categories of the Lebanese and refugee's food diet at national scale on annual basis.

Impact category	Lebanese food diet	Refugee food diet	Total
Agricultural land occupation (m^2)	2.17E+09	7.64E+08	2.93E+09
Climate change (kg $CO_{2\text{-eq}}$)	2.62E+09	8.97E+08	3.52E+09
Fossil depletion (kg $oil_{\text{-eq}}$)	4.30E+08	1.53E+08	5.83E+08
Freshwater Eutrophication (kg $P_{\text{-eq}}$)	2.48E+06	7.93E+05	3.27E+06
Human toxicity (kg 1,4-$DCB_{\text{-eq}}$)	1.72E+09	5.62E+08	2.28E+09
Natural land transformation (m^2)	2.12E+05	7.62E+04	2.88E+05
Particulate matter formation (kg $PM10_{\text{-eq}}$)	6.48E+06	2.13E+06	8.61E+06
Photochemical oxidant formation (kg $NMVOC_{\text{-eq}}$)	1.02E+07	3.51E+06	1.37E+07
Terrestrial acidification (kg $SO_{2\text{-eq}}$)	2.82E+07	9.00E+06	3.72E+07
Water depletion (m^3)	1.91E+08	7.84E+07	2.69E+08

Table 6
Food security socio-economic indicators calculated for Lebanese and refugee populations.

Socio-economic indicators	Lebanese	Refugees
Individual access to food	59%	15%
Household access to food	43%	35%
Jobs in agricultural sector	5%	21%
Gender equality	81%	48%
Awareness on nutrition and food security	24%	17%
Food waste (kg per person per year)	9.20	2.43
Food consumption vs. food dietary requirements	77%	63%
Adequately nourished adult	42%	35%
Adequately nourished children	91%	78%

The socio-economic indicators were plotted through a radar graph to better compare and visualize the results obtained for the Lebanese and refugee populations (Fig. 2). The size of the area in the graph represents an overall measure of food security from a socio-economic viewpoint. The larger the area, the higher the food security at national level.

4. Discussion

4.1. Environmental indicators

The LCA methodology allowed the assessment of the environmental performance of the Lebanese and refugee food diets at individual and national level. The total contribution to climate change due to food diets in Lebanon calculated at national scale resulted in 3.52 Mt. $CO_{2\text{-eq}}$ per year, representing about 13% of the total $CO_{2\text{-eq}}$ emissions in Lebanon (MoE/UNDP/GEF, 2017). Fig. 3 shows the contribution of the investigated food categories to climate change. Dairy products, one of the most consumed food items in Lebanon, account for 43% and 50% of the total contribution to climate change for the Lebanese and refugee populations. The contribution of meat to climate change of 28% and 14% is also significant.

The Lebanese food diet showed a higher contribution to all the impact categories compared to the refugee food diet (Fig. 1), both at individual and national scale (Tables 4 and 5). Although the contribution of refugee food diet was lower compared to the Lebanese diet, its impact at national scale remains significant. In terms of water and fossil depletion at national scale, the refugee food diet accounted for 29% and 26%, while its impact in terms of climate change and agricultural land occupation was 25% and 26% (Fig. 4). These figures confirm that despite the lower food intake of refugees, their population has a significant contribution in terms of direct and indirect natural resources consumption and environmental impacts. Overall, the environmental burden of the refugee food diet represents about 25% of the total environmental impact due to food consumption at country level.

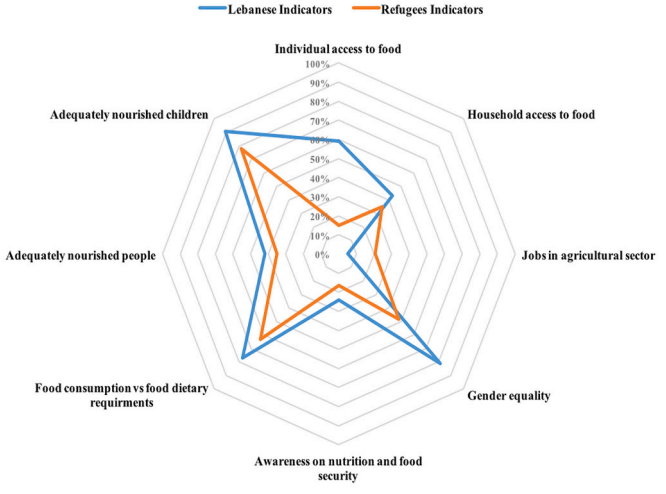

Fig. 2. Comparison of socio-economic indicators calculated for the Lebanese and refugee populations.

The environmental impacts of Lebanese and refugee food diet resulted lower than European diets such as German and Swedish diets (Martin and Brandão, 2017; Treu et al., 2017). This is mainly due to the features of the Mediterranean food diet prevailing in Lebanon, traditionally characterized by a higher consumption of food items like cereals, vegetables, and fruits whose production has lower environmental impacts compared to meat, fish, and other processed food items (Estruch et al., 2013; Pairotti et al., 2015). Our results are also in line with the systematic review conducted by Aleksandrowicz et al. (2016) showing that shifting to sustainable dietary patterns (e.g., vegan, vegetarian, and Mediterranean) highly reduces GHG emissions, land use, and water use. Considering that food preferences, choices, and eating habits are hard to change, future research should contribute to fill the substantial gap between favorable attitudes and actual purchase and consumption of more sustainable food products (Vermier et al., 2020).

4.2. Socio-economic indicators

In addition to environmental indicators, socio-economic indicators were also calculated to provide a multi-perspective assessment of food security in Lebanon. The radar diagram in Fig. 2 shows that the overall Lebanese food security level is higher compared to refugees. In fact, all socio-economic indicators calculated for the Lebanese were higher than refugees, except for the "jobs in the agricultural sector".

The indicator "jobs in the agricultural sector" was evaluated because the issue of employment in agriculture is highly recognized for its importance in reducing poverty, raising incomes and improving food security, especially for poor people living in rural areas (The World Bank, 2019). The "jobs in the agricultural sector" indicator was higher for refugees (21%) compared to Lebanese (5%). These results, in line with the results obtained by Chlouk (2016) and Bou Khater (2017), highlighted an unbalanced situation in which refugees highly support the agricultural sector and, therefore food production, while they are more food insecure. In fact, only 15% of refugees have an adequate access to food (Table 6). This is also related to the high unemployment rate that, based on the conducted survey, resulted in about 30% and 58% for the Lebanese and refugee populations. These figures were also in line with the unemployment rate estimated for Lebanon by ILO (2014) and Kadi (2017). It is worth noting that the status of refugees gives a social status for specific type of employment and refugees need a special permit if they are willing to work in other sectors than construction and agriculture. In addition, the low average income of refugees limits their capability of meeting their basic food and living needs.

The "individual access to food" for Lebanese people was four times higher than refugees, while lower differences were found at household level (Table 6). This result was due to several reasons. First, through the questionnaires it was found that refugees tend to buy and consume higher quantities of food with lower market prices (e.g., cereals and eggs) and less quantities of more expensive food (e.g., meat and dairy products), thus reducing the economic expenditure to feed the entire family. Moreover, the number of working children in refugee families was higher compared to the Lebanese, resulting in a higher total household income. Finally, more refugee families declared to receive cash assistance compared to Lebanese families (Fig. 5), enabling refugees to partially improve their access to food at household level.

Gender equality is also an important factor for achieving food security (Garcia and Wanner, 2017). In this study, the "gender equality" indicator was 81% for Lebanese and 48% for refugees (Table 6), highlighting the higher food insecurity level of refugees compared to Lebanese.

In addition, both Lebanese and refugees showed low awareness on nutrition and food security. This was mainly due to a low perception about the needed quantity of some important food categories (e.g.,

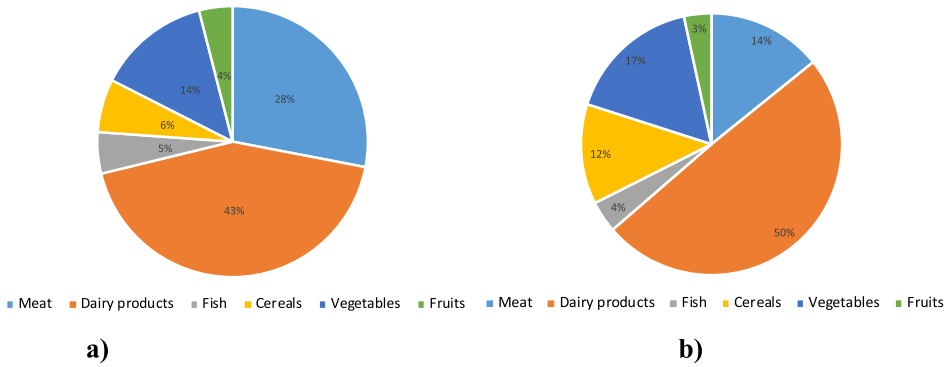

Fig. 3. Contribution of the investigated food categories to climate change for the Lebanese (a) and refugee (b) food diets.

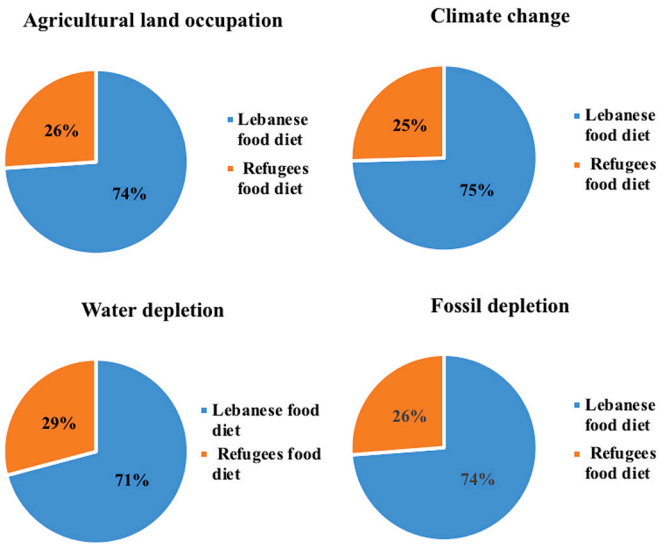

Fig. 4. Comparison of Lebanese and refugee food diet at national scale for selected environmental impact categories.

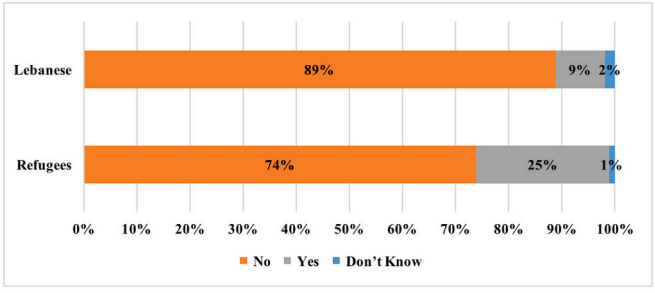

Fig. 5. Cash assistance to Lebanese and refugee families.

cereals and meat), highly recommended by international food and nutrition programs (USDA, 2019).

The lack of adequate knowledge about food security and nutrition combined with inadequate access to food affect the food consumption patterns and the level of nourishment of both Lebanese and refugees. While the share of adequately nourished people was low for adults, higher values resulted for children (Table 6), showing that Lebanese and refugees are more aware of the importance of appropriate nutrition schemes for children growth and development.

Finally, the annual production of food waste was higher for Lebanese (9.2 kg) compared to refugees (2.43 kg). However, these values are much lower than the food waste production estimated for developed European countries, ranging between 55 and 190 kg per year (Vanham et al., 2015). These outcomes confirm that food security remains a critical issue for the Lebanese population and, particularly, for the refugees living in Lebanon.

4.3. Limitations of the study

The present study was conducted by the Authors without external funds and, therefore, with a limited availability of resources. Nonetheless, the survey was conducted on 585 individuals located in all the five regions of Lebanon of which 568 were fully cooperative and responded to all the questions.

On the base of the collected information, the average daily individual food intake of Lebanese and refugee populations was calculated and related environmental costs and impacts were assessed and compared using the LCA method. Socio-economic indicators were also assessed on the base of the conducted survey.

In addition, the LCA indicators were upscaled at the national scale of Lebanon to provide a first assessment of the environmental footprints due to food diets. This last step shows some limitations. First, although the number of respondents to the questionnaire was substantial, also compared to other studies performed at the national scale of Lebanon (Charbel et al., 2016; Naja et al., 2018), a sample of a larger size could have been more representative of the Lebanese and refugee diets.

Moreover, the dietary and food habits system is affected by seasonal effects from outdoor to indoor (Stelmach-Mardas et al., 2016). Therefore, a larger survey's timeline would have been useful to capture such a variability.

Finally, the "food consumption vs. food dietary requirements" indicator was calculated with reference to the USDA dietary guidelines values. An alternative approach to evaluate food diets is based on the Nutrient Rich Foods Index (NRF9.3) exploring the nutrient quality of different food items (Green et al., 2020). The NRF9.3 index was not applied because it would have required more detailed information on food categories not available in this study. However, given the importance of the NRF9.3 index to assess healthy diets, its application could be useful for future development of the present study.

Despite the aforementioned limitations, the main goals of the upscale of the environmental indicators were to shed light on the importance of the environmental burden of food diet at national scale and calculate figures that can represent a first assessment and a reference benchmark for future studies aimed at improving food security in Lebanon.

5. Conclusions

Environmental and socio-economic indicators were calculated to explore multiple dimensions of food security in Lebanon. The LCA methodology allowed the assessment of the environmental burden of food diets for the Lebanese and refugee populations. The Lebanese food diet showed a higher contribution to all the environmental impact

categories compared to the refugee food diet. Overall, the environmental burden of the refugee food diet was about 25% of the total environmental impact at country level.

In terms of socio-economic indicators, 59% of Lebanese resulted having access to food while this value was only 15% for the refugees, showing that food security remains a critical issue in Lebanon.

The integrated approach applied in this study provides a first assessment and a benchmark for future studies aimed at exploring multiple aspects related to the food security issue. The outcomes of the study provide scientific information to support policy makers for improving food security in Lebanon. Considering the complexity of the food security issue, exacerbated by the co-existence of different populations and cultures, such information encompassing environmental and socio-economic aspects could be useful in the achievement of food security targets.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crsust.2021.100047.

References

Aleksandrowicz, L., Gree, R., Joy, E., Smith, P., Haines, A., 2016. The impacts of dietary change on greenhouse gas emissions, land use, water use and health: a systematic review. PLoS One 11 (11).

Alonso, E.B., Cockx, L., Swinnen, J., 2018. Culture and food security. Global Food Security 17, 113–127.

Barrett, C., 2010. Measuring food security. Science 327 (5967), 825–828.

Barzegar, A., Abbaszadeh, N., Sarbakhsh, P., Jafari, A., 2019. The relationship between food security, dietary patterns and socioeconomic status in Iranian pregnant women. Prog. Nutr. 21 (1), 261–269.

Berry, E., Dernini, S., Burlingame, B., Meybeck, A., Conforti, P., 2015. Food security and sustainability: can one exist without the other? Public Health Nutr. 18 (13), 2293–2302.

Bhuyan, B., Sahoo, B., 2017. Socio-economic determinants of food security in India: a quantile regression analysis. SSRN Electron. J. https://doi.org/10.2139/ssrn.2985647. Available at SSRN: https://ssrn.com/abstract=2985647.

Bou Khater, L., 2017. Labour policy and practice. In: The Peace Building in Lebanon, 16.

Bowdren, C.F., Santo, R., 2019. Chapter 15 - Sustainable Diets for a Food-Secure Future. Joan Sabaté.

Capone, R., Bottalico, F., Palmisano, G.O., El Bilali, H., Dernini, S., 2019. Food systems sustainability, Food Security and Nutrition in the Mediterranean Region: The Contribution of the Mediterranean diet. In: Reference Module in Food Science. Encyclopedia of Food Security and Sustainability, 2, pp. 176–180.

Charbel, L., Capone, R., Grizi, L., Debs, P., Khalife, D., El Bilali, H., Bottalico, F., 2016. Preliminary insights on household food wastage in Lebanon. J. Food Sec. 4, 131–137.

Chlouk, G., 2016. Economic Opportunities and Job Creation Agriculture Sector. United Nations (UN), Beirut-Lebanon, 19pp.

Clement, F., Buisson, M.C., Leder, S., Balasubramanya, S., Saikia, P., Bastakoti, R., Karki, E., van Koppen, B., 2019. From women's empowerment to food security: revisiting global discourses through a cross-country analysis. Global Food Security 23, 160–172.

Cochrane, N., D'Souza, A., 2015. Measuring Access to Food in Tanzania: A Food Basket Approach. Economic Research Service/United States Department of Agriculture (USDA), Washington D.C, 27pp.

Cole, M., Augustin, M., Robertson, M., Manners, J., 2018. The science of food security. Npj Sci. Food 2, 14.

Eberle, U., Fels, J., 2016. Environmental impacts of German food consumption and food losses. Int. J. Life Cycle Assess. 21 (5), 759–772.

ECPHAO, 2020. Lebanon. European Civil Protection and Humanitarian Aid Operations (ECPHAO). Beirut-Lebanon. https://ec.europa.eu/echo/where/middle-east/lebanon.

El Mujtar, V., Muñoz, N., Prack Mc Cormick, B., Pulleman, M., Tittonell, P., 2019. Role and management of soil biodiversity for food security and nutrition; where do we stand? Global Food Security 20, 132–144.

Espadas-Aldana, G., Vialle, C., Belaud, J.P., Vaca-Garcia, C., Sablayrolles, C., 2019. Analysis and trends for life cycle assessment of olive oil production. Sust. Product. Consumpt. 19, 216–230.

Estruch, R., Ros, E., Salas-Salvadó, J., Cora, M.I., Corella, D., Arós, F., Gómez-Gracia, E., Ruiz-Guitérrez, V., Fiol, M., Lapetra, J., Lamuela-Raventos, R.M., Serra-Majem, L., Pintó, X., Basora, J., Muñoz, M.A., Sorlí, J., Martínez, A., Martínez-González, M.A., 2013. Primary prevention of cardiovascular disease with a Mediterranean diet. N. Engl. J. Med. 378 (25), 2441–2442.

EU, 2019. Lebanon. European Union (EU): European Civil Protection and Humanitarian Aid Operations (ECHO), Beirut-Lebanon.

FAO, 2006a. Food Security. Policy Brief. Food and Agriculture Organization (FAO).

FAO, 2014. Lebanon FAO plan of action for resilient livelihoods 2014–2018. In: Addressing the Impact of the Syria Crisis & Food Security Response and Stabilization of Rural Livelihoods. Food and Agriculture Organization (FAO), Beirut-Lebanon.

FAO, 2017. Monitoring food security in countries with conflict situations: A joint FAO/WFP update for the united nations security council June 2017. Issue n°2. Food and Agriculture Organization (FAO) and World Food Programme (WFP).

FAO, 2018. The Future of Food and Agriculture- Alternative Pathways to 2050. Food and Agricultural Organization (FAO), Rome, 224pp.

FAO, 2019. Food-Based Dietary Guideline: Dietary Guidelines and Sustainability. Food and Agriculture Organization (FAO), Rome.

FAO, IFAD, UNICEF, WFP and WHO, 2020. The State of Food Security and Nutrition in the World 2020. Transforming Food Systems for Affordable Healthy Diets. FAO, Rome.

Gaffney, J., Challender, M., Califf, K., Harden, K., 2019. Building bridges between agribusiness innovation and smallholder farmers: a review. Global Food Security 20, 60–65.

Galli, A., Iha, K., Halle, M., El Bilali, H., Grunewald, N., Eaton, D., Capone, R., Debs, P., Bottalico, F., 2017. Mediterranean countries' food consumption and sourcing patterns: an ecological footprint viewpoint. Sci. Total Environ. 578, 383–391.

Garcia, A., Wanner, T., 2017. Gender inequality and food security: lessons from the gender-responsive work of the international food policy research institute and the bill and Melinda gates foundation. Food Security 9 (5), 1091–1103.

Gésan-Guiziou, G., Sobańtka, A.P., Omont, S., Froelich, D., Rabiller-Baudry, M., Thueux, F., Beudon, D., Tregret, L., Buson, C., Auffret, D., 2019. Life cycle assessment of a milk protein fractionation process: contribution of the production and the cleaning stages at unit process level. Sep. Purif. Technol. 224, 591–610.

Godfray, C., Beddington, J., Crute, I., Haddad, L., Lawrence, D., Muir, J., Pretty, J., Robinson, S., Thomas, S., Toulmin, C., 2010. Food security: the challenge of feeding 9 billion people. Science 327 (5967), 812–818.

GoL and UN, 2019. Lebanon crisis response plan 2017–2020 (2019 update). Government of Lebanon (GoL) and United Nations (UN), Beirut-Lebanon, 220pp. https://www.unhcr.org/lb/wp-content/uploads/sites/16/2019/04/LCRP-EN-2019.pdf.

Govindan, K., 2018. Sustainable consumption and production in the food supply chain: a conceptual framework. Int. J. Prod. Econ. 195, 419–431.

Green, A., Nemecek, T., Chaudhary, A., Mathys, A., 2020. Assessing nutritional, health, and environmental sustainability dimensions of Agri-food production. Global Food Security 26, 100406.

Halabi, S., Ghanem, N., 2016. Strategic review of food and nutrition security in Lebanon. In: Short Version. The United Nations Economic and Social Commission for West Asia (ESCWA), Beirut-Lebanon, 21pp.

Hirvonen, K., Bai, Y., Headey, D., Masters, W., 2020. Affordability of the EAT-lancet reference diet: a global analysis. Lancet Global Health 2020 8 (1), 59–66.

Ibidhi, R., Hoekstra, A., Winnie Gerbens-Leenes, P., Chouchane, H., 2017. Ecol. Indic. 77, 304–313.

ILCD, International Reference Life Cycle Data System, Handbook, 2010. General Guidance for Life Cycle Assessment. Detailed Guidance. Joint Research Centre, European Commission, EC-JRC.

ILO, 2014. Assessment of the Impact of Syrian Refugees in Lebanon and their Employment Profile. International Labour Organization (ILO), Beirut-Lebanon.

Irani, Z., Sharif, M., Lee, H., Aktas, E., Topaloglu, Z., Vant Wout, T., Huda, S., 2018. Managing food security through food waste and loss: small data to big data. Comput. Oper. Res. 98, 367–383.

ISO 14040, International Standard, 2006. Environmental management-life cycle assessment-principles and framework. International Organization for Standardization (ISO), Geneva, Geneva, Switzerland.

IUCN, 2013. Food Security Policies: Making the Ecosystem Connections. IUCN, Gland, Switzerland.

Kadi, 2017. Lebabon's Youth Bearing the Brunt of Unemployment, Regional Instability (The Arab Weekly).

Lipper, L., Thornton, P., Campbell, B., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Thi, Sen P., Sessa, R., Shula, R., Tibu, A., Torquebiau, E., 2014. Climate-smart agriculture for food security. Nat. Clim. Chang. 4, 1068–1072.

Martin, M., Brandão, M., 2017. Evaluating the environmental consequences of Swedish food consumption and dietary choices. Sustainability 9, 2227.

MoE/EU/UNDP, 2014. Lebanon Environmental Assessment of the Syrian Conflict & Priority Interventions. Ministry of Environment (MoE), Beirut-Lebanon.

MoE/EU/UNDP, 2015. Lebanon Environmental Assessment of the Syrian Conflict & Priority Interventions. Updated fact sheet. Ministry of Environment (MoE), Beirut-Lebanon.

MoE/UNDP/GEF, 2017. Lebanon's Second Biennial Update Report to the UNFCCC. Ministry of Environment (MoE), Beirut-Lebanon.

Muñoz, I., Milà, I., Canals, L., Fernández-Alba, A.R., 2010. Life cycle assessment of the average Spanish diet including human excretion. Int. J. Life Cycle Assess. 15 (8), 794–805.

Naja, F., Jomaa, L., Itani, L., Zidek, J., El Labban, S., Mehio Sibai, A., Hwalla, N., 2018. Environmental footprints of food consumption and dietary patterns among Lebanese adults: a cross-sectional study. Nutr. J. 17 (85), 1–11.
Nassar, J., Stel, N., 2019. Lebanon's response to the Syrian refugee crisis- institutional ambiguity as a governance strategy. Polit. Geogr. 70, 44–54.
Nemecek, T., Jungbluth, N., Milà, I., Canals, L., Schenck, R., 2016. Environmnetal impacts of food consumption and nutrition: where are we and what is next? Int. J. Life Cycle Assess. 21 (5), 607–620.
Notarnicola, B., Tassielli, G., Renzulli, P.A., Castellani, V., Sala, S., 2017. Environmental impacts of food consumption in Europe. J. Clean. Prod. 140, 753–765.
Ogundari, K., 2017. Categorizing household into different food security states in Nigeria: the socio-economic and demographic determinants. Agricult. Food Econ. 5 (8).
Pairotti, M.B., Cerutti, A.K., Martini, F., Vesce, E., Padovan, D., Beltramo, R., 2015. Energy consumption and GHG emission of the Mediterranean diet: a systemic assessment using a hybrid LCA-IO method. J. Clean. Prod. 103, 507–516.
Prosekov, A.Y., Ivanova, S.A., 2018. Food security: the challenge of the present. Geoforum 91, 73–77.
Rose, D., Wadhwa, A., Bottone, R., Miller, D., Hjelm, L., Mathiassen, A., Horjus, P., 2013. Food security assessment at WFP: report on continued development and testing of a standardized approach. In: Food Security, Markets, and Vulnerability Analysis World Food Programme (WFP), 24pp.
Sala, S., Anton, A., McLaren, S., Notranicola, B., Saouter, E., Sonesson, U., 2017. In quest of reducing the environmental impacts of food production and consumption. J. Clean. Prod. 140, 387–398.
Skaf, L., Buonocore, E., Dumontet, S., Capone, R., Franzese, P.P., 2019. Food security and sustainable agriculture in Lebanon: an environmental accounting framework. J. Clean. Prod. 209, 1025–1032.
Skunca, D., Tomasevic, I., Nastasijevic, I., Tomovic, V., Djekic, I., 2018. Life cycle assessment of the chicken meat chain. J. Clean. Prod. 184, 440–450.
Spalding, M., McIvor, A., Tonneijck, F.H., Tol, S., van Eijk, P., 2014. Mangroves for Coastal Defence. Guidelines for coastal managers & policy makers. Published by Wetlands International and The Nature Conservancy, 42 pp.
Stelmach-Mardas, M., Kleiser, C., Uzhova, I., Peñalvo, J.L., La Torre, G., Palys, W., Lojko, D., Nimptsch, K., Suwalska, A., Linseisen, J., Saulle, R., Colamesta, V., Boeing, H., 2016. Seasonality of food groups and total energy intake: a systematic review and meta-analysis. Eur J Clin Nutr, Jun 70 (6), 700–708.
Taki, M., Soheili-Fard, F., Rohani, A., Chen, G., Yildizhan, H., 2018. Life cycle assessment to compare the environmental impacts of different wheat production systems. J. Clean. Prod. 197 (1), 195–207.
The World Bank, 2018. Lebanon: Population. The World Bank, Whasington D.C.
The World Bank, 2019. Understanding poverty. In: Agriculture and Food: Overview. Washington D.C, The World Bank.
Tilman, D., Clark, M., 2014. Global diets link environmental sustainability and human health. Nature 515 (518), 522.
Treu, H., Nordborg, M., Cederberg, C., Heuer, T., Claupien, E., Hoffmann, H., Berndes, G., 2017. Carbon footprints and land use of conventional and organic diets in Germany. J. Clean. Prod. 161, 127–142.
UNICEF, 2016. UNICEF annual report 2016: Lebanon. In: United Nations international Children's emergency fund (UNICEF). Beirut-Lebanon, 51pp.
United Nations (UN), 2017. World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. In: United Nations (UN) Department of Economic and Social Affairs: New York- US.
USDA, 2019. Dietary Guidelines for Americans 2015–2020 Eighth Edition. United States Department of Agriculture (USDA), Washington D.C.
Vanham, D., Bouraoui, F., Lei, A., Grizzetti, B., Bidoglio, G., 2015. Lost water and nitrogen resources due to EU consumer food waste. Environ. Res. Lett. 10, 084008.
Vermier, I., Weijters, B., De Houwer, J., Geuens, M., Slabbinck, H., Spruyt, A., Van Kerckhove, A., Van Lipper, W., De Steur, H., Verbeke, W., 2020. Environmentally sustainable food consumption: a review and research agenda from a goal-directed perspective. Front. Psychol. 11, 1603. https://doi.org/10.3389/fpsyg.2020.01603. Erratum in: Front Psychol. 2020 Oct 21;11:585387. PMID: 32754095; PMCID: PMC7381298.
WFP, 2017a. At the Root of Exodus: Food Security, Conflict and International Migration. World Food Programme (WFP), Rome-Italy.
WFP, 2017b. Lebanon Country Strategic Plan (2018–2020). World Food Programme (WFP), Beirut-Lebanon.
Wheeler, T., Von Braun, J., 2013. Climate change impacts on global food security. Science 341 (6145), 508–513.
Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L., Fanzo, J., Hawkers, C., Zurayk, R., Rivera, J., De Vries, W., Majele Sibanda, L., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crona, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, S., Cornell, S., Reddy, Srinath, Narain, S., Nishtar, S., Murray, C., 2019. Food in the Anthropocene: the EAT-lancet commission on healthy diets from sustainable food systems. The Lancet Commissions 393, 447–492.