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Additional Information

Integrating sustainability into the multi-criteria assessment of urban dietary patterns

INTRODUCTION

The food chain is a multi-functional system that addresses related environmental, economic, social and nutritional issues (Lang et al 2009). In the past 50 years, food production and dietary patterns have changed substantially, in such a way that the global food system needs to be transformed to reduce its impact on human health and environmental stability. This change should recognise the link between human health and the environment, consequently integrating these concerns into a common global agenda to achieve sustainable food systems (Willet et al 2019). Cities are part of the food system, and with more than 60% of the world's population living there, they will play a key role in future food security (Seto and Ramankutty, 2016). In addition, cities are becoming key transition spaces where new forms of governance are being created through the participation of policymakers, academics and civil society actors (Moragues and Morgan 2015). One dimension of governance is the strategic guidance for local food policies (Guyomard *et al* 2012, Debru *et al* 2017). Multi-sector groups are needed to advise cities to reach a compromise about what a sustainable diet is and to build consensus on how to raise awareness on suitable dietary patterns. Local dietary patterns have significant links with environment, health and social concerns, which suggests the need to integrate different criteria to define sustainable diets.

The environmental impact of urban food systems has been assessed elsewhere. For instance, a review by Goldstein et al (2017) points out that food demand was typically the third largest source of carbon footprint in cities. Vanham et al (2016) estimated the blue water footprint related to different diets in Mediterranean cities, which resulted to be minimum 20 times larger than direct domestic water use. Furthermore, a growing body of research analyses the environmental impacts in high-income countries of alternative diets (e.g. Pradhan et al., 2013; Veeramani et al., 2017; Castañé and Antón, 2017). Most of those studies point out that reducing the dependence on animal-based products in diets would lead to lower environmental footprints (Sáez-

Almendros *et al* 2013; Clark and Tilman 2017). In addition, an increase in legume consumption could compensate nutritional deficiencies when transitioning to diets with lower meat, bringing additional benefits (Röös et al., 2018). Regarding health, a reduction in red meat consumption has frequently been associated with lower triglyceride and cholesterol levels in blood, preventing type 2 diabetes, cardiovascular diseases, colorectal and other cancers, and all-cause mortality (Aleksandrowicz *et al* 2016;WHO, 2015; Ekmekcioglu et al., 2018).

A sustainable dietary pattern implies not only environmental and nutritional aspects, but also a broad range of socioeconomic and cultural factors including food access, availability, cultural acceptability and religion (Dernini *et al* 2013), these concerns being crucial for the transition towards sustainable dietary patterns. Along these lines, when food policies are formulated, local stakeholders are key actors to promote a holistic approach that considers also socio-economic concerns. In the last few years, cities are becoming increasingly involved in food related initiatives, as evidenced by the emergence of EU-funded projects, which involve local authorities and focus on urban food strategies (de Cunto et al., 2017). The creation of the "Milan Urban Food Policy Pact" (MUFPP), led by the city of Milan, has been key in the recognition of cities as food policy actors. Those cities that wish to join the MUFPP agreement, must implement local policies to promote sustainable food systems. Likewise, local administrations in many countries have shown an increasing support to local food initiatives such as Food Policy Councils (FPC) in the United States (Patel, 2009), United Kingdom (Moragues-Faus, 2017) and African cities (Morgan, 2009). FPC provides governance platforms to provide guidance to support the transition towards sustainable local food systems (Prové et al. 2019).

Valencia (Spain) was one of the first cities that signed the MUFPP in October 2015 and it was selected by the FAO as the world's food capital in 2017. Later on, in October 2018, Valencia created its FPC (called *Consell Alimentari*) and approved a food strategy to support the transition towards more sustainable, healthy, affordable, safe and diversified local food systems and encourage the adoption of sustainable diets. The Valencia FPC is governed by participatory approaches, and formed by a multi-actor group from 50 organizations that attempt to reach consensus on sustainable dietary guidelines in a context of growing concerns on food related diseases in the Mediterranean region (Dernini and Berry, 2015).

The literature shows different approaches to design and assess sustainable diets. Linear and goal programming techniques have been used to determine optimum solutions (Macdiarmid, 2012; Horgan et al

54 2016; Ribal et al 2016). Those studies incorporate nutritional, environmental (mainly carbon footprint) and

55 price related criteria, although fail to take account of social aspects of eating and the reasons behind consumers'

56 food choices, such as habits, culture and social norms (Horgan et al 2016), nor involve other relevant

57 stakeholders. The multicriteria decision-making (MCDM) field can provide numeric techniques to help

58 decision makers, in a multi-person decision context with multi-criteria situations (Triantaphyllou 2013).

59   This study aims at developing a MCDM method based on the Analytical Hierarchy Process (AHP) to

60 assess the sustainability of diets by using an alternative participatory process involving policy-makers and

61 other stakeholders to obtain consensus applied to the Valencia metropolitan area. The approach integrates

62 environmental, health and socioeconomic concerns. Consequently, this study addresses the complex challenge

63 of integrating several criteria that are not always aligned. Four dietary patterns were evaluated in such a

64 context, through a participatory methodology in which different local stakeholders have been involved; in this

65 way, they can shape political interventions aiming at promoting healthier and more sustainable dietary patterns.

66 The AHP has not been directly applied to diet evaluation, although there are some precedents to measure the

67 importance of factors for obesity prevention (Bizjak et al 2016) or to calculate the weight of factors affecting

68 adolescents' choice to eat out (Lan et al , 2017). Sylvie et al (2013) turned to AHP to identify the environmental

69 settings and factors that promote healthy eating in older adults. All the primary sources in those studies were

70 expert panels.

71 **METHODS**

72 **Evaluation procedure**

73   The evaluation procedure is based on the AHP (Saaty 2005), which is capable of translating experienced

74 decision makers' qualitative and quantitative assessments into a multi-criteria classification. The AHP

75 produces weights for each evaluated criterion after decision makers perform pairwise comparisons of criteria

76 and alternatives (Scholl *et al* 2005, Alfares and Duffuaa 2008). Weights of criteria and alternatives are

77 combined for ranking alternatives. AHP is easy to use and scalable, and its hierarchy structure can be easily

78 adjusted to fit many sized problems (Velasquez and Hester 2013). Other MCDM methods (e.g. TOPSIS or

79 Promethee) need to rely on a second tool to compute criteria weights.

80   Figure 1 shows a flow diagram that represents the entire process of reaching a compromise between the

81   consistent judgements required by the AHP and the knowledge provided by those involved. In the first stage,

82   criteria and sub-criteria to assess the dietary patterns were compared through responses to individual

83   questionnaires answered by a group of stakeholders who represent institutions of the Valencia FPC. Their

84   judgements were then aggregated to find the corresponding weights. In the second stage, a workshop was held

85   in Valencia with a smaller group of experts from the same institutions. These experts were classified into three

86   sub-groups according to the main criteria. For the main goal of identifying a sustainable diet, each sub-group

87   proposed (by consensus) the weights and ranking of the alternatives (or diets) for each criterion or sub-

88   criterion.

89   The hierarchy of the process is based on three criteria (environmental, health and socioeconomic factors)

90   and two pairs of sub-criteria (carbon/water footprint and consumer/producer perspective). This hierarchy

91   divides the main goal into a set of elements (Figure 2). The three main levels of the hierarchy are the goal, the

92   criteria (factors relating to each alternative that affect the main goal) and the alternatives for which trade-offs

93   are made to reach the goal. As indicated, the main goal is to choose the best dietary pattern from the alternatives

94   that could be recommended or considered as dietary guidelines. The alternatives were:

95   • Mediterranean dietary pattern (MDP)

96   • Pescatarian pattern (PES)

97   • Vegan pattern (VEG)

98   • Flexitarian pattern (FLEX).

99   **Figure 1**: Flow diagram for the compromise solution.

100

101   **Figure 2**: The hierarchy structure for this study.

102   **1st stage: Criteria's pairwise comparisons**

103   In the first stage of the evaluation procedure, after arranging the hierarchy structure for the main goal,

104   was to identify the priorities of the experts (or decision makers) were identified together with the weights to

105   attach to the core criteria. The interviewer explained the methodology to the experts who were compelled to

106   determine the relative importance of each criterion with respect to others.

107   The criteria were compared as follows: 'What is the relative importance of each criterion compared to

108   the other one from the decision makers' point of view?' This relative importance was in relation to the main

109   goal. In the AHP, a verbal scale is used to enter different judgments for each level but the software requires

110   numbers; therefore, and according to Saaty (2005), the verbal scale is converted to an ordinal scale. For a given

111   pair of alternatives or criteria A and B, the scale measures the intensity of preference by attaching values

112   between 1/9 (B is extremely more important than A) and 9 (A is extremely more important than B), 1 meaning

113   "equal importance".

114
115   If each pair of elements in this row is compared, the number of comparisons is given by Equation 1:

116    $$N = \frac{n\,(n-1)}{2} \qquad\qquad\qquad \textbf{\textit{Eq. 1}}$$

117   where N is the number of comparisons and n is the number of elements. There were three pairs: environmental

118   impact vs. health, environmental impact vs. socioeconomic factors and health vs. socioeconomic factors. The

119   same operation was performed for the two sub-criteria within the environmental and socioeconomic criteria.

120   This process yields a matrix of priorities or relative weights of criteria, sub-criteria and alternatives. Priorities

121   in the AHP are expressed as numbers between 0 and 1. There numbers reflect relative preference. AHP ratings

122   are assumed to be consistent, in other words, they assumed that decision makers are rational. Saaty (2013)

123   proposed the use of a Consistency Ratio (CR). If CR is greater than 0.1, the judgements should be modified

124   until they reach a consistency ratio lower than 0.1. Otherwise, the set of answers must be excluded from the

125   analysis.

126   A total of 52 experts from different backgrounds were surveyed in the first stage, from which 33

127   responses could be collected. However, eight were discarded because CR > 0.1, retaining 25 questionnaires

128   (see first stage survey's questions as Supplementary Material). As for the composition of the group with

129   consistent answers, 12 of them were female and 13 were male. Specifically, 10 participants were members of

130   research institutions (food technology, nutrition, agricultural sciences and policies), 3 participants from local

131   public institutions, 5 participants from the food chain including farmers, co-ops, local catering, food

132   manufacturing and consumers, and 7 from NGOs connected to environment, nutrition and poverty. Super

133   Decision software (v.3.2) was used to create the AHP model.

134   Grouping the pairwise comparisons is an important step when a group of experts offer judgements and

135   want to reach a consensus, in this case regarding certain dietary patterns. The chosen aggregation method for

136   the first stage (Figure 1) was based on aggregating individual priorities using the geometric mean method.

137   **Description of dietary alternatives**

138   To define the dietary alternatives considered in the multi-criteria assessment (second stage), adult dietary

139   patterns in the Valencia metropolitan area were taken into consideration. The EAT–Lancet Commission on

140   healthy dietary guidelines for sustainable food systems was used as a benchmark to define a healthy diet

141   (Willett *et al* 2019). Using the ranges indicated in this benchmark, the four alternative patterns were further

142   adjusted and provided to the experts. Actual dietary patterns (Generalitat Valenciana 2013) were also provided

143   as a complementary information.

144

145   **Table 1.** Composition and macronutrient intakes (g/day) for the Mediterranean, vegan, flexitarian and

146   pescatarian dietary patterns.

147   The Mediterranean dietary pattern (MDP) is a traditional diet in Mediterranean countries. It is

148   characterised by a high consumption of vegetables, fruits, nuts, seeds, legumes, whole grains, bread, fish,

149   seafood and olive oil. The MDP covers moderate consumption of protein from poultry, eggs, cheese and

150   yogurt. However, it is rare to consume red meat, and highly processed foods. The vegan pattern excludes the

151   consumption of all animal-based foods, also fish and dairy products. Popular foods amongst vegans include

152   grains, nuts, legumes and beans. The flexitarian diet is an eating pattern that promotes crop-based foods whilst

153   permitting the consumption of meat and other animal-based products in small quantities, thus being more

154   flexible than vegan diets. Furthermore, the pescatarian pattern refers to a vegetarian one that also allows the

155   consumption of fish and other seafood. It relies heavily on crop-based foods such as whole grains, nuts, pulses

156   and healthy fats and seafood is the principal source of proteins. All dietary alternatives must ensure that

157   people's nutritional needs are met. This means eating a set of foods that comply with the daily nutritional

158   guidelines while taking advantage of all available food choices.

159   **2nd Stage: Workshop**

160   The second stage of the fieldwork was carried out with participants from the first stage who attended a

161   workshop to rank the alternative diets according to the criteria and sub-criteria (see second stage questions as

162   Supplementary Material). The reciprocal pairwise comparison matrix among dietary patterns for each criteria,

163   sub-criteria and main goal was built by consensus. The workshop brought together 14 stakeholders (6 female,

164   8 male) who confirmed participation. They previously received some information, alongside with the

165   workshop schedule, including, firstly, a small presentation about the main objectives of the study and the

166   methodology. Secondly, a presentation with the results of the first stage showed the weights of the defined

167   criteria and sub-criteria with its initial rank. The stakeholders were classified in three sub-groups in terms of

168   the three main criteria. The nutrition and health group had four members: two nutritionists from the Red Cross,

169   one food technologist and the manager of a catering company. The environmental group had five members,

170   all of whom were academics: a specialist in LCA applied to food, two specialists in animal science with an

171   environmental focus, and another two specialists (one in water management and one in agricultural

172   economics). The socioeconomic group had five members: two NGO representatives (Right to Food

173   Observatory and CARITAS), a consultant to farming organisations, a farming organisation leader and an

174   agricultural economics PhD student. In this way, the sample reflected the possible interests and backgrounds

175   of different institutions working in Valencia and its metropolitan area. Therefore, the workshop reflected the

176   complexity of the food governance process. After a 40 minute discussion in each sub-group, AHP priorities

177   were generated for each criterion and sub-criterion. This was achieved by constructing the reciprocal pairwise

178   comparison matrix, although this time by comparing pairs of alternative dietary patterns for each criterion or

179   sub-criterion. Afterwards, each sub-group had 10 minutes to express its judgements to the other sub-groups.

180   Additionally, there was a general discussion between the groups to reach consensus.

181   **FINDINGS AND DISCUSSION**

182   After the first stage, judgements were recorded to obtain the priority (or weight) for each criterion and

183   sub-criterion. The global priorities (i.e. each sub-criterion's contribution to the main goal) were then calculated.

184   Across the hierarchy, the global priorities sum to 1. The results in Table 2 present health, with 44%, as the

185   main priority, but the other priorities are also relevant: environmental concerns represent 33%, while

186   socioeconomic factors represent 23%.

187   Results showed that, although socioeconomic factors were part of this holistic analysis, the valuation of

188   the producer perspective was perhaps not too high. A reason for this outcome is that many stakeholders live in

189   the urban area and are not growers, despite Valencia's rich peri-urban agricultural area. However, some

190   participants work with food producers or in related agricultural research fields. The importance of the

191   producer's perspective would have definitively been different if the process had taken place in a rural area.

192   Therefore, this AHP analysis reflects a decision-making process in the metropolitan area.

193   The process of comparing pairs of criteria or sub-criteria requires decisions regarding which one is most

194   relevant from the experts' point of view with respect to selecting the most appropriate dietary pattern. This

195   decision can be difficult, but the role of experts is to determine the most important criterion from their point

196   of view, and they must assess the relative importance of one criterion with respect to others.

197   The final ranking of the dietary alternatives after the workshop (2nd stage of the study) is shown in

198   Table 2.

199

200   **Table 2.** Final ranking of the alternatives according to the experts' judgements on sustainability criteria and

201   sub-criteria.

202

203

204   The workshop illustrates the trade-offs that policymakers face when designing food strategies in

205   urbanised societies where both cultural aspects and the interests of local production also play prominent roles.

206   MDP appears, according to the process, as the most suitable pattern with respect to the criteria and sub-criteria.

207   The MDP was ranked first in terms of the health criterion and socioeconomic criterion. This result is consistent

208   with the studies that focus on the Mediterranean dietary pattern and its health value (Sofi *et al* 2010; Curtis

209   and O'Keefe 2002). Cultural considerations could explain the high weight of the MDP. From the water

210   consumption perspective, the MDP was ranked lowest because of the relative importance of animal production.

211   The experts highlighted other environmental advantages due to lower greenhouse gas emissions related to

212   close proximity of food production to the city and the prominence of fruit and vegetables.

In terms of environment, the vegan diet was ranked first by the workshop experts. Animal products in big cities are typically from intensive farms, which require high quantities of animal feed and drinking water throughout the life cycle of the animals. Even though animals produce manure that can contribute to soil fertility, intensive animal production is a major source of harmful emissions, as indicated by Gerber et al (2013). Although organic livestock is less harmful to the environment, experts were asked for their judgements based on the actual production systems and technologies used for mass consumption in the city. The pescatarian dietary pattern was ranked second by the environmental experts, who considered two kinds of fish sources. The first refers to wild-caught fish. In this case, although the pescatarian diet has almost no impact on the consumptive use of water, it has a negative impact on carbon footprint because of the emissions from the fishing vessels and the transport to retail outlets. The second source is fish farming, which could also be intensive in freshwater consumption (because of fish feed). However, the experts considered that wild fish is the most consumed in Valencia.

Regarding the health sub-group's judgements, experts considered MDP the most balanced alternative with respect to health recommendations. However, they stressed the similarities between the MDP and both flexitarian and pescatarian diets, which could be considered to some extent modified forms of the MDP. In experts' minds, a balanced vegan diet needs dietary complements to meet the nutritional guidelines. However, the four proposed patterns meet the EAT–Lancet nutritional guidelines and also support the transition towards the environmental thresholds established by Springmann et al (2018). Therefore, the AHP exercise suggests an 'ideal' model that could be obtained as a weighted combination of the four alternatives with the weights shown in Table 2.

The socioeconomic sub-group considered culture, affordability and local production as the main decision elements. Their choice was in favour of products that are heavily produced in the surrounding area. Although the region of Valencia produces some fish from the Mediterranean Sea, most of the fish consumed in Valencia comes from the Atlantic Ocean. The cost of breeding some species of fish consumed heavily in Valencia is still high and the pescatarian diet was the least preferred from the producer perspective. Although fish consumption is significant in Valencia, the sub-group admitted that if consumers relied solely on fish protein, there would not be an economic benefit for the family. Furthermore, a pescatarian diet is not fully consistent with the food culture in Valencia, where people habitually combine meat and fish.

CONCLUSIONS

Most Mediterranean regions, including Valencia, are turning away from the traditional Mediterranean consumption pattern. However, experts from institutions that participate in the Valencia FPC still attach high value to this diet. Accordingly, food-system decision makers and strategic planners should promote this diet. Although there is already a wide body of research enhancing the MDP, in this case, it was chosen from a systematic participatory approach. As previously mentioned, the method used to rank the dietary patterns was supported by existing knowledge, while taking into consideration different interests and dimensions of sustainability.

Experts' judgements were tested regarding three criteria (environmental, health and socioeconomic). This participatory approach gives not only a general picture of what specialists think about dietary alternatives but also illustrates a method to support future research in identifying dietary orientations in a certain context. This governance process itself could be considered an improvement in the guidelines of food and sustainability advisory committees or commissions.

This procedure allows compromise alternatives for sustainable diets to be reached, respecting local contexts where culture and socio-economic perspectives must be considered. Of course, a balanced selection of experts supported by complementary information is needed. In any case, local expert selection is facilitated in governance bodies such as food councils, advisory food committees, etc...

The participatory approach gives strengths to the decision process. The effective use of a multi-criteria decision-making method (i.e. AHP) can provide guidelines for policymakers, particularly regarding the types of diets to be promoted in urban areas to achieve sustainable food consumption habits. Trade-offs are relevant, and the proposed method has the potential of providing a holistic view that integrates conflicting criteria, as by means of the AHP questions the experts are faced with the need of stating the comparative importance of the criteria. The AHP approach can be applied when food policy advisory groups wish to integrated socio-economic consideration in their assessment of sustainable diets.

Although the method can be used to integrate several criteria, the results only express the beliefs of a confined group of experts with respect to a specific geographical context. In addition, the conditions affecting experts' judgements and, consequently, food governance vary from one period to another. Ultimately, future

10

268   studies should compare the chosen patterns with the current patterns to differentiate between both models,

269   considering an indicator for food strategic planning at the local or national level.

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