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**Environmental and nutritional analysis of the EAT-Lancet diet at the individual level:
insights from the NutriNet-Santé study**

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Running Head: planetary health diet and environmental impacts

ELD-I;

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Abbreviations:

ANCOVA: covariance analysis

BMI: body mass index

Cumulative energy demand: CED

CU: consumption units

EAT-Lancet Diet Index: ELD-I

FBDGs: food-based dietary guidelines

Food frequency questionnaire: FFQ

Greenhouse gas emissions: GHGe

HR : hazard ratio

Land occupation: LO

PNNS-GS, Programme National Nutrition Santé-Guideline Score

PNNS-GS2: Programme National Nutrition Santé-Guideline Score 2

Q: quintile

Abstract

1 The EAT-Lancet Commission has recently proposed a “universal” healthy reference diet. However, no
2 study has specifically investigated its possible environmental benefits at the individual level based on
3 observed data. Our objective was therefore to characterize the environmental pressures and impacts
4 related to the level of adherence to the EAT-Lancet diet among French adults. Dietary data from a 264-
5 item FFQ in 29,210 NutriNet-Santé participants (75% women, mean age=53.5y (SD=14.0)), were used to
6 estimate (i) the level of adherence to the EAT-Lancet diet through the EAT-Lancet diet index (ELD-I), (ii)
7 the food production-related environmental impacts using 3 individual environmental indicators
8 (greenhouse gas emissions, cumulative energy demand and land occupation) and (iii) the overall
9 environmental impact using a validated aggregated partial score (*pReCiPe*). For clarity purpose, results are
10 presented by quintile (Q) of ELD-I. High ELD-I (Q₅), compared to low (Q₁), was associated with lower
11 greenhouse gas emissions (-56%), cumulative energy demand (-31%) and land occupation, (-54%). The
12 *pReCiPe* was 62% lower in high ELD-I than in low ELD-I but the range of *pReCiPe* in Q1 was large. In
13 this large scale-study of French adults, adherence to the EAT-Lancet recommendations led to lower
14 environmental impacts. Nonetheless, some low-EAT diets (reflecting unhealthy diets), may exhibit low
15 environmental impacts.

16 **Keywords:** environmental impacts; dietary patterns; cohort study; EAT-Lancet diet

Highlights

- 17 - the EAT-Lancet diet index was developed to assess the EAT-Lancet diet adherence while
18 accounting for farming practices (organic or conventional).
- 19 - The diets highly correlated with the EAT-Lancet diet (compared to low adherence) led to lower
20 impacts: -56% greenhouse gas emissions, -31% cumulative energy demand and -54% land
21 occupation.
- 22 - A high variability in environmental impacts was observed among individuals with low adherence
23 to the EAT-Lancet diet, reflecting a discrepancy between human and planetary health.

1. Introduction

24 It is now well established that modern eating habits, rich in fat, salt and sugar, largely contribute to the
25 development of chronic diseases (GBD 2017 Diet Collaborators, 2019). In 2017, the Global Burden of
26 Diseases estimated that 11 million (95% uncertainty interval 10–12) deaths were attributable to diet-related
27 risk factors (GBD 2017 Diet Collaborators, 2019). Besides, diet production cause serious damages and long-
28 term adverse effects on the environment. Indeed, the climate crisis, the depletion of natural resources and
29 the pollution of water and soil require a radical and urgent change at multiple levels of the global food
30 system, from field to plate (Clark et al., 2018). In case of no drastic change in the food system by 2050,
31 greenhouse gas emissions (GHGe), land use, water use, as well as nitrogen and phosphorus application
32 would drive natural processes beyond planetary limits (Springmann et al., 2018).

33 A growing body of evidence documents that diets largely based on plant foods with limited amount of
34 animal products could bring benefits to the environment (Lukasz Aleksandrowicz et al., 2016; Auestad and
35 Fulgoni, 2015; Chai et al., 2019). Specifically, vegetarian and vegan diets have been consistently associated
36 with lower environmental impacts compared to meat-based diets (Chai et al., 2019). This is in line with
37 findings from modeling studies aiming at determining environmental-friendly diets (Gazan et al., 2018; van
38 Dooren, 2018). Besides, other studies have evaluated different types of diet such as the Mediterranean diet,
39 the Nordic diet or adherence to several dietary guidelines (Lukasz Aleksandrowicz et al., 2016; Auestad and
40 Fulgoni, 2015; Chai et al., 2019; Ridoutt et al., 2017). All these findings consistently documented
41 environmental impacts of cropland and livestock (Clark et al., 2019). Livestock, in particular beef, is
42 responsible for a large part of the dietary-related GHGe and also leads to deforestation and loss of
43 biodiversity (Gerber et al., 2013). With regard to health aspects, other protein sources need to be favored,
44 while meat - in particular red and processed meat - consumption should be reduced, given the positive link
45 between meat consumption and numerous chronic diseases (cancer, cardiovascular diseases, type 2 diabetes
46 as well as overall mortality) (GBD 2017 Diet Collaborators, 2019; Mariotti, 2019).

47 In that context, in 2019, the EAT-Lancet commission proposed a universal healthy diet. The evidence-based
48 EAT–Lancet diet, aligning nutrition with planet preservation, is the first global reference diet that could

49 allow a sustainable trajectory within the planetary boundaries. It provides an anchor point for future national
50 food policies across culturally diverse countries by enabling them to incorporate environmental preservation
51 into their national food-based dietary guidelines (FBDGs). It is also designed to serve as a reference for
52 “estimating health and environmental effects of adopting an alternative diet to standard current diets (Willett
53 et al., 2019). This diet is based on the available scientific literature on the relationships between food intake
54 and health. The EAT Lancet Commission concluded that “a dietary change towards increased adoption of
55 plant-based diets has high mitigation potential, which is probably needed to limit global warming to a less
56 than 2°C increase” (Willett et al., 2019). The EAT-Lancet diet is a 2500 kcal daily diet which promotes
57 plant food consumption such as whole grains, fruit and vegetables, legumes and drastically limits the intake
58 of added fat and sugars as well as animal food such as beef, lamb, pork - and to a lesser extent fish, eggs
59 and chicken. A recent study documented nutritional comparison between the EAT-Lancet diet and Dietary
60 Guidelines for American and identified some discrepancies for some plant-based food groups that were
61 more encouraged in the EAT-Lancet such as soy-based food, nuts and seeds and whole grain starch
62 (Blackstone and Conrad, 2020). Besides, the EAT-Lancet report has generated controversies with studies
63 documenting null (Zagmutt et al., 2020) or protective association as regards the risk of ischemic heart
64 diseases, diabetes and mortality (Knuppel et al., 2019), while another study put into question its affordability
65 for the world’s poor (Hirvonen et al., 2020). A recent modelling study however indicates that the EAT-
66 Lancet recommendations were more in line with the World agenda on health and sustainability than most
67 national FBDG (Springmann et al., 2020). However, no study has explored environmental impact of
68 adherence to the EAT-Lancet diet. Thus, the translation of the EAT-Lancet recommendations at the
69 individual level and in various cultural settings is necessary to thoroughly characterize the sustainability of
70 the EAT-Lancet diet and in particular environmental dimension.

71 Most studies exploring the associations between environmental pressures and dietary patterns have used a
72 small range of indicators, mainly GHGe and land use (Jones et al., 2016). Besides, few studies have
73 considered overall impact indicators whereas this would allow to include several pressure indicators, and
74 thus to address trade-offs between the different environmental footprints (Kramer et al., 2017). In addition,

75 studies have mainly considered the dominant intensive system in their assessment while agroecological
76 systems might differ on some indicators (Gomiero et al., 2011). The use of the organic farming system as
77 an alternative model is therefore of interest, especially since it has been shown that occidental individuals
78 who eat a lot of plant foods also eat more organically-grown products (Lacour et al., 2018).
79 In the present work, we therefore aimed to explore the link between adherence to the EAT-Lancet diet and
80 associated environmental impacts considering 3 indicator of pressure and 1 impact while considering
81 farming practices for food production. A first dietary index based on binary components has been developed
82 to reflect the adherence to the EAT-Lancet diet in the EPIC-Oxford study (Knuppel et al., 2019). However,
83 this index does not account for variability in consumption, we thus, chose to develop a new continuous
84 index to better apprehend variability in consumption.

2. Material and methods

85 2.1 Population

86 These analyses were based on the NutriNet-Santé study (registered at clinicaltrials.gov as NCT03335644).
87 NutriNet-Santé is a prospective cohort study implemented in 2009 to investigate the links between food, its
88 determinants and health (Hercberg et al., 2010). Participants are volunteers recruited through a media
89 campaign and who complete regular online questionnaires. At inclusion and each year thereafter, they
90 provided data on their health, their practices (diet, lifestyles) and their socio-demographic characteristics.

91 This study was conducted in accordance with the Declaration of Helsinki, and all procedures were approved
92 by the Institutional Review Board of the French Institute for Health and Medical Research (IRB Inserm
93 0000388FWA00005831) and the National Commission on Informatics and Liberty (Commission Nationale
94 de l'Informatique et des Libertés, CNIL 908450 and 909216). Electronic informed consent was obtained
95 from all participants.

96 Data used in this work have been described elsewhere (Kesse-Guyot et al., 2020).

97 2.2 Dietary data

98 In 2014, a web-based semi-quantitative food frequency questionnaire (FFQ) (Kesse-Guyot et al., 2010) was
99 proposed to the volunteers. They were asked to report their frequency of consumption of 264 food items, as

100 well as the portion consumed with photographs helping for the identification of portion size. In addition in
 101 this modified version of the FFQ (Baudry et al., 2015), for each food item, participants declared the
 102 frequency with which the item was organic through the following modalities never, rarely, half of the time,
 103 most of the time, always. Weights (0, 0.25, 0.5, 0.75, 1) were allocated to the consumption to split the total
 104 consumption of each item into organic and conventional sources. Further details and sensitivity analyses
 105 related to computation have been published elsewhere (Baudry et al., 2015). Nutrient intakes were computed
 106 using a published composition table and under/over-reporters were excluded as previously described using
 107 percentiles of the ratio between energy intake and energy requirement (Baudry et al., 2015). Bioavailable
 108 zinc and iron were computed using published equation (Armah et al., 2013; Miller et al., 2007).

109 **2.3 EAT-Lancet diet index (ELD-I)**

110 Based on the definition of the universal healthy diet (Willett et al., 2019), component and cut-off of the
 111 EAT-Lancet diet have been already proposed in a previous work (Knuppel et al., 2019), regarding the
 112 following 14 food groups: whole grains, tubers and starchy vegetables, vegetables, fruits, dairy foods,
 113 beef/lamb/pork, chicken and other poultry, eggs, fish, legumes, nuts, saturated oil, unsaturated oils and
 114 sweeteners. Cutoffs for each component are presented in **Table 1**. For sweeteners component, intake of
 115 added sugars was used. To improve the power of discrimination of the dietary index reflecting the adherence
 116 to the EAT-Lancet diet, compared to the previously developed score (Knuppel et al., 2019), we accounted
 117 for deviation from the cut-off value. The EAT-Lancet diet index (ELD-I) for an individual j with intake for
 118 each i was computed as follows, equation (1):

$$119 \quad \text{ELD-I}_j = \frac{100 \times \left\{ \sum_{\text{component } i=1}^{14} \frac{a_i \times \left(\text{cut-off}_i - \frac{\text{consumption}_{ij} \times 2500}{\text{Energy intake}_j} \right)}{\text{cut-off}_i} \right\}}{14} \quad (1)$$

120 Where i referred to on the 14 food groups and j is the individual. $a_i = 1$ for component to limit and $a_i = -1$
 121 for component to promote.

122 **2.4 Environmental data**

123 Three environmental indicators were computed, namely greenhouse gas emissions (GHGe), cumulative
124 energy demand (CED), and land occupation (LO) whose computation has been extensively described
125 elsewhere (Baudry et al., 2019). These impacts were considered at the farm level, *i.e.* without considering
126 post-harvest storage, conditioning and transport since these data were not available for organic farming. It
127 should be however noted that most of the environmental impacts take place during the agricultural
128 production phase (Clune et al., 2017). Data were derived from the DIALECTE tool (Pointereau et al., 2012)
129 developed by Solagro (Toulouse, France) aiming to measure the environmental performance of
130 conventional and organic farms. Data were completed using other data sources (Baudry et al., 2019).
131 Environmental impacts of 92 conventional and organic raw products were assessed and converted into food
132 items using economic, cooking and edibility coefficients (Baudry et al., 2019). Environmental data related
133 to raw products for both organic and conventional farming have been previously disclosed (Baudry et al.,
134 2019). Procedures for environmental estimation is summarized on **Figure 1**.

135 Intake and related environmental impacts were compiled for each food and then summed up considering
136 organic and conventional systems to compute daily environmental indicator at the diet level.

137 To provide a synthetic index of available indicators in our study, we used the partial ReCiPe index, based
138 on the ReCiPe method, a synthetic environmental impact indicator (Kramer et al., 2017).

139 The *pReCiPe* was calculated for each individual as follows, equation (2):

$$140 \quad pReCiPe = 0.0459 \times GHGe + 0.0025 \times CED + 0.0439 \times LO \quad (2)$$

141 with GHGe, in kg of CO₂eq/d, CED, in MJ/d and LO, in m²/d. The highest the *pReCiPe*, the highest the
142 environmental impact.

143 **2.5 Other data**

144 As complementary approaches to the planetary health diet, we computed two scores: the PANDiet and the
145 health gain score.

146 The PANDiet aims at estimating the probability of adequacy of nutrient intakes (Gavelle et al., 2018). This
147 score includes an adequacy sub-score (averaging the probabilities of adequacy for 27 nutrients) and a

148 moderation sub-score including 6 nutrients and 12 penalty values referring to the probabilities of exceeding
 149 upper limits of intakes as showed **on the Figure 2**.

150 The health gain score (HS) proposed by Van Dooren *et al.* (van Dooren et al., 2014) is a synthetic score
 151 designed to measure health benefits of diets. It includes 10 components, as trans fatty acids were not
 152 available in our database, we therefore adapted it as follows, equation (3):

$$153 \quad HS = \left[\left(\frac{\text{vegetables}}{200} \right) + \left(\frac{\text{fruits}}{200} \right) + \left(\frac{\text{fiber}}{40} \right) + \left(\frac{\text{fish}}{37} \right) + \left(\frac{6}{\text{salt}} \right) + \left(\frac{30}{\% \text{ EI total fat}} \right) + \left(\frac{10}{\% \text{ EI SFA}} \right) + \left(\frac{10}{\% \text{ EI free sugars}} \right) + \right. \\ 154 \quad \left. \left(\frac{2500}{\text{EI}} \right) \right] \times \frac{100}{9} \quad (3)$$

155 where consumptions are in grams, EI denotes energy intake in kcal, and SFA denotes saturated fatty acids.

156 Sociodemographics (gender, age, education, professional categories, monthly incomes, household
 157 composition), lifestyle data (smoking status, physical activity), anthropometrics (height and weight) were
 158 collected using follow-up questionnaires (Kesse-Guyot et al., 2016). Monthly household income was
 159 calculated per consumption unit using the following weighting (“Définition - Unité de consommation |
 160 Insee,” n.d.): 1 consumption unit (CU) is attributed for the first adult in the household, 0.5 CU for other
 161 persons aged ≥ 14 y, and 0.3 CU for children aged < 14 y. Physical activity was assessed using a short form
 162 of the French version of the International Physical Activity Questionnaire (Hagstromer et al., 2006) and
 163 classified as low physical activity (< 30 min of physical activity equivalent to brisk walking/d), moderate
 164 physical activity (≥ 30 and < 60 min), or high physical activity (≥ 60 min), according to the French guidelines.
 165 BMI was calculated as the ratio of weight to squared height (kg/m^2). The data closest to the FFQ were
 166 retained.

167 Place of food purchase and prices were combined with consumption to estimate the daily cost of the diet.
 168 Briefly, a database of prices by place of purchase was developed using the Kantar database (Kantar
 169 Worldpanel, n.d.), involving 20,000 French households, and further completed with collected prices for
 170 short supply chains which are not available in Kantar. This procedure has been extensively described
 171 elsewhere (Baudry et al., 2019; Seconda et al., 2018).

172 **2.6 Statistical analysis**

173 For the present study, we selected the NutriNet-Santé participants who had completed the Org-FFQ in 2014
174 (N=37,685), with no missing covariates for weight and height (N=37,305), not detected as under- or over-
175 energy reporter (N=35,196). Next, we selected participants with available data for computation of the cost
176 of the diet (N=29,210).

177 Participants were ranked and categorized into quintiles (Q) of ELD-I reflecting the level of adherence.
178 Associations between sociodemographics, cost of the diet, food group consumption, nutritional and
179 environmental indicators and quintiles of the ELD-I were assessed with ANCOVA using observed margins.
180 Differences across quintiles were estimated providing the means and the confidence intervals of the mean.
181 For environmental indicators, additional models adjusted on energy intake were performed. For statistical
182 tests, the type I error was set at 5%. Data management and statistical analyses were conducted using SAS®
183 9.4 (SAS Institute Inc.) and graphics were performed using R® (version 3.4.2).

3. Results

184 **3.1. Relationship between adherence to the EAT-Lancet diet and socio-economic characteristics of** 185 **participants**

186 The characteristics of the sample according to the quintiles of the ELD-I are presented in **Table 2**. Compared
187 to participants with lower ELD-I, participants with higher ELD-I were less frequently men (Q₅ vs. Q₁,
188 34.51% vs. 62.20%), older (mean age about +6y), less often postgraduate (Q₅ vs. Q₁, 19.14% vs. 25.26%),
189 less often employee or manual worker (Q₅ vs. Q₁, 26.36% vs. 41.03%), and more often physically active
190 (Q₅ vs. Q₁, 44.10% vs. 27.15%) or with high income and had lower BMI (mean BMI about -2kg/m²). In
191 addition, Participants with high adherence to the EAT-Lancet had the highest diet cost. However, the
192 association appeared to be J-shaped.

193 **3.2. Relationship between adherence to the EAT-Lancet diet and the nutritional characteristics of** 194 **the diet**

195 Nutritional characteristics according to ELD-I quintiles are presented in **Table 3**. High ELD-I was
196 negatively associated with energy intake (Q₅ vs. Q₁, 1935 kcal/d vs. 2099 kcal/d), and positively with the

197 health gain score as well as the PANDiet score (mean PANDiet about +11), proportion of organic food in
198 the diet (Q_5 vs. Q_1 , 0.45 vs. 0.17), of polyunsaturated fatty acids, plant proteins, and intake of fibers, vitamin
199 C, vitamin B9, vitamin E, total iron and bioavailable zinc. Participants with higher ELD-I also exhibited
200 lower % of energy intake from saturated fatty acids and total proteins and lower intakes of sodium, zinc and
201 heme-iron.

202 **3.3. Relationship between adherence to the EAT-Lancet diet and environmental impact indicators**

203 The three studied environmental indicators (CED, GHGe and LO) as well as the aggregated score (*pReCiPe*)
204 across quintiles of ELD-I are presented in **Table 4**. Negative associations were observed between the ELD-
205 I (modeled as quintiles) and each environmental indicator, which were stronger for GHGe and LO than for
206 CED but showed in each occasion a dropout in the 5th quintile. High EAT-LS (Q_5) compared to low (Q_1)
207 was associated with lower greenhouse gas emissions (-56%), cumulative energy demand (-31%) and land
208 occupation (-54%). As regards the *pReCiPe* index, a reduction of 63% was observed when comparing Q_5
209 vs Q_1 . All associations were linear ($p < 0.0001$).

210 Further adjustment for energy intake did not strongly modify the association (for *pReCiPe* index: -62%).

211 The distributions of the *pReCiPe* across ELD-I quintiles are shown in **Figure 3**. Figure 4 showed that despite
212 a statistically significant lowering values across quintiles, a great variability occurs, especially in the 1st
213 quintile. Similar findings were showed for individual environmental indicators constituting the *pReCiPe*
214 (data not shown). Pearson correlation coefficient between the ELD-I and the *pReCiPe* was -0.59.

215 Food consumption (standardized for 2500 Kcal) by quintiles are presented in **Figure 4**. As consumption
216 were almost zero, unsaturated oil consumption was not represented. Gradients across quintiles were
217 expected by construction. However, the most stringent differences between quintiles were for fruits and
218 vegetables and legumes. We can note that fish consumption appeared to be relatively similar across quintiles
219 but a little weaker in the 5th quintile.

200 **4. Discussion**

220 In the present analysis, conducted in a large cohort of French adults, we explored, using detailed
221 environmental and food data, the potential environmental benefits associated with adherence to the

222 “Universal” healthy plant-based diet as defined by the EAT-Lancet Commission (Willett et al., 2019). We
223 showed that a higher adherence to the EAT-Lancet diet, using an individual dietary score accounting for
224 distance to cut-offs value for each component, was markedly related to a better nutritional diet quality
225 (higher PANDiet score). It is noteworthy that a high ELD-I was associated with a slightly lower bioavailable
226 iron intake. However, the mean value for individuals in the 5th quintile remained higher than the estimated
227 average losses (Hunt et al., 2009). In addition, micronutrients found in meat (such as zinc and vitamin B12)
228 were not particularly low. As expected, fiber intake, which has been associated with lower risk of cancer,
229 cardiovascular diseases, type 2 diabetes and mortality (Veronese et al., 2018), was high among participants
230 with high ELD-I. Besides, plant proteins were high but ratio between plant to total protein reached 48%
231 only. This may be directly due to the developed methodology as the score was based on probability rather
232 than a threshold to be reached. The overall health gain score (related to nutrient intakes) was 55% higher in
233 participants with high ELD-I compared to those with low ELD-I, arguing for a latent alignment between
234 environmental and nutritional dimensions of the “*planetary health diet*”.

235 Dietary patterns of participants in Q₅ were close to vegetarian dietary patterns, though animal products,
236 especially meat, were not totally excluded from Q₅ participants’ diets. This was illustrated by an increase in
237 the PANDiet score across quintiles despite a reduced animal-food consumption. Dietary pattern in Q₅ of the
238 ELD-I directly compared to the Q₅ of PNNS-GS2 reflecting French food-based dietary guidelines (FBDG),
239 which conceptually considered sustainability, after standardization for a 2500 kcal diet, exhibited lower
240 consumption in all food groups specifically, drastic lower consumption of meat (-36%), eggs (-34%), dairy
241 product (-33%), fat and sweet products (-33%), as well as whole-grain (-34%) (data not shown). This
242 stemmed from the fact that participants with high adherence to French FBDG exhibited low energy intake.
243 In turn, translation for 2500 kcal led to higher levels of consumption (Kesse-Guyot et al., 2020). Another
244 study, conducted in the US compared dietary guidelines for American (DAG) to EAT-Lancet diet
245 (Blackstone and Conrad, 2020). The authors reported some consistencies between both diets but also
246 divergences in particular concerning whole-grain starch, beans and peas and nuts, seeds and soy-based food

247 leading to high increase in total proteins. This is in line with a global study reporting that most of national
248 FBDG were not compatible with environmental objectives (Springmann et al., 2020).

249 Adherence to the EAT-Lancet diet was strongly and negatively related to the three studied environmental
250 impacts, namely GHGe, CED and LO, as well as to the synthetic environmental index (*pReCiPe*), allowing
251 to consider potential trade-offs. A reduction of 62% of the *pReCiPe* index between participants with high
252 vs low adherence to this diet was observed. This is consistent with the findings of the recent modelling study
253 by Springmann et al. documenting a reduction in the demand for environmental resources associated with
254 compliance with the EAT-Lancet diet (Springmann et al., 2020). We also showed that participants with high
255 adherence to the EAT-Lancet diet had a significantly higher consumption of organic food in their diet. As
256 previously shown, organic food consumption is positively associated with plant-based diet (Baudry et al.,
257 2019; Lacour et al., 2018). Organic farming is an acknowledged agroecological production method that has
258 been shown to be a good proxy of diet-related biodiversity due to non-use of chemical pesticides (Tuomisto
259 et al., 2012) and is associated with reduced pesticides exposure from diet in our population (Baudry et al.,
260 2018) and others (Mie et al., 2016).

261 Our results cannot be directly compared to scientific literature since, to the best of our knowledge, no study
262 has reported environmental values related to the EAT-Lancet diet at the individual level. Nevertheless, our
263 findings can be interpreted in light of findings about observed diets and dietary guidelines.

264 In France, diet is rather rich in animal products as it has been showed that comparing 4 other European
265 countries, French diet, based on the representative national study INCA-2 Study (2006-2007), exhibited the
266 highest values for land occupation and GHGe (Mertens et al., 2019). Besides, our findings are consistent
267 with the scientific literature which have consistently documented that plant-based diets are associated with
268 lower pressures on resources and environment in several observational or modelling studies (Springmann
269 et al., 2018; Chai et al., 2019; L. Aleksandrowicz et al., 2016; Clark et al., 2019; Hallström et al., 2015), in
270 line with the EAT Lancet Commission objectives. For instance, Hallström reported that changes in dietary
271 patterns (with more or less exclusion of animal products) may lead to an up to 50% reduction in GHG
272 emissions and land use demand (Hallström et al., 2015). A recent study estimating the impacts of six US

273 consumer diets considered the EAT-Lancet diet among various dietary patterns (Laroche et al., 2020). In
274 this work, the EAT-Lancet diet showed an intermediate land use, between the lacto-ovo-vegetarian and the
275 low-meat diets. Apart from an expected lower demand for land occupation, this study revealed that low-
276 meat diets rely more heavily on the abundance and diversity of pollinators and may increase impacts on
277 water resources at least in some countries. In addition, the Mediterranean Diet, permitting some animal food
278 (such as dairy) consumption is often advanced as a sustainable diet (41). Indeed, one study documented a
279 higher GHGe (+15%) and water use (+9%) for a diet based on the Spanish dietary guidelines compared to
280 the Mediterranean diet (González-García et al., 2020). However, it has also been reported that
281 Mediterranean Diet had a global warming potential about twice that of the vegan diet (Castañé and Antón,
282 2017).

283 Also, a recent study was conducted to evaluate sustainability (using a synthetic score summarizing 4
284 environmental indicators) and to compare environmental performances of different dietary guidelines. The
285 authors showed that environmental values differed according to the diet, Nordic Diet being the most efficient
286 (Grosso et al., 2020). Within the same large cohort as herein, we compared various dietary patterns and their
287 relationships with various sustainable indicators. Using a validated dietary index reflecting adherence to the
288 new French food-based guidelines (Chaltiel et al., 2019), we recently showed that high adherence was
289 associated with markedly lower environmental impacts compared to low-adherence (Kesse-Guyot et al.,
290 2020), with a 50% reduction in pReCiPe and a 46% reduction in GHGE. A lower overall environmental
291 performance for the studied indicators than the EAT-Lancet diet was, though, observed (for a 2500kcal/d
292 diet, data not shown). This seems somehow in accordance with a recent work by Springmann et al, indicating
293 a greater reduction in GHGEs with the global FBGDs than the national FBGDs (Springmann et al., 2020).
294 In contrast, a recent review focusing on analysis of sustainability of dietary guidelines for Americans
295 reported that healthy US dietary patterns may be responsible for similar or higher GHGe, energy and water
296 use compared to current US diets (Reinhardt et al., 2020). The review study also underlined, as expected,
297 that plant-based dietary guidelines may only contribute to limit environmental pressures related to food
298 systems. Consistently, the modelling study of Springmann et al., evaluating environmental and health values

299 of food-based dietary guidelines, compared to WHO and Eat-Lancet diet, showed that most of the national
300 food-based dietary guidelines do not allow achieving health and environmental goals (Springmann et al.,
301 2020).

302 It is noteworthy that the pReCiPe distribution across ELD-I quintiles revealed that low environmental
303 impact was not systematically associated with healthy dietary patterns. Thus, while nutritionally healthy
304 diet and environment preservation are overall in alignment, these dimensions however may not always go
305 hand in hand. This observation seems in line with previous works showing that unhealthy foods, such as
306 sweet and fat food, may exhibit low environmental impacts (Clark et al., 2019; Perignon et al., 2017) and
307 observational studies showing that the lowest emitting diets are not systematically the most sustainable as
308 regards their nutritional values (Vieux et al., 2020). This is of great importance from a public health point
309 of view as it highlights the need of fostering both environment-friendly and healthy diets. It is also notable
310 that unsustainable diets (low ELD-I) were those the least expensive, raising the issue related to affordability
311 of sustainable and healthy diets for vulnerable population.

312 A global score such as the ELD-I score allows to consider recommendations as a whole as it integrates
313 interrelations between food groups, (Burggraf et al., 2018). Based on predefined cut-off values (Knuppel et
314 al., 2019), we developed a continuous index based on the overall consumption distributions to improve
315 power of discrimination of the score and smooth distribution. It has indeed been shown that dietary scores
316 based on binary scoring such as some Mediterranean diet scores led to little consideration of the variability
317 in food consumption (Burggraf et al., 2018).

318 Some limitations of the present work should be noted. First, our sample was not representative of the general
319 population as the NutriNet-Santé study included voluntary participants, limiting the external validation of
320 the results. Second, our life cycle assessment did not cover the stages posterior to food production. However,
321 production is one of the major drivers of environmental pressures within the food system, although food
322 loss and waste along the supply chain are substantial (Morone et al., 2019). Few accurate information
323 covering all the food chain exists especially for alternative production systems. Finally, we did not compute
324 indicators related to water use, biodiversity, excess nitrogen or soil quality as data were not available.

325 Our study also presents major strengths that include the consideration of two different farming practices
326 (organic and conventional systems) allowing a more accurate environmental analysis. In addition, the three
327 computed environmental impacts reflect major environmental issues (Kramer et al., 2017). Furthermore, the
328 large sample size permitted the access to a large variety of dietary patterns.

329 This study documented that the planetary health diet as defined by the EAT-Lancet Commission (i.e. based
330 on a comprehensive review of the scientific literature) was associated with a higher nutritional quality and
331 lower environmental impacts in accordance with the objectives of the EAT-Lancet report. This definition
332 of a universal diet is crucial for aligning the health and environmental dimensions and allows comparable
333 assessments in different contexts. It should however be noted that in some cases, unhealthy diets may also
334 be linked to low environmental impacts arguing for dissemination of guidelines integrating both dimensions.
335 However, further work is needed to better test for the validation of the EAT-Lancet diet. Future optimization
336 models works to formulate adequate nutritional intakes with reduced environmental footprints and cultural
337 adaptation of the EAT-Lancet diet, as conducted only in Denmark, is also warranted (Lassen et al., 2020).
338 Relationships between the EAT-Lancet reference diet and various health outcomes should be evaluated in
339 different settings. In addition, as regards environmental pressures, the consideration of a larger number of
340 indicators (e.g. water use) while differentiating the type of farming system may be valuable. Finally,
341 prospective scenarios to assess feasibility would be informative.

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356 **Data sharing statement**

357 Data of the study are protected under the protection of health data regulation set by the French National
358 Commission for Information Technology and Liberties (Commission Nationale de l'Informatique et des
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360 (n.pecollo@eren.smbh.univ-paris13.fr), for review by the steering committee of the NutriNet-Santé study.

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Tables

Table 1: Cut-off for each component of the EAT-Lancet Diet Index ¹

Food component	Subcomponent	Cut-off
Whole grains		≤464 g/d
Potatoes and tuber		≤100 g/d
Vegetables		≥200 g/d
Fruits		≥100 g/d
Dairy foods		≤500 g/d
Proteins sources		
	Beef, lamb, pork	≤28 g/d
	Chicken and poultry	≤58 g/d
	Eggs	≤25 g/d
	Fish	≤100 g/d
	Legumes	≤100 g/d
	Nuts	≥25 g/d
Added fats		
	Saturated oil	≤11.8 g/d
	Unsaturated oils	≤80 g/d
Added sugars	All sweet	Added sugar ≤31 g/d

¹Cut-offs for a 2500 kcal diet based on Knuppel *et. al* (Knuppel et al., 2019).

Table 2: Characteristics of the sample across ELD-I quintiles, n= 29,210, NutriNet-Santé ¹

	Q ₁	Q ₂	Q ₃	Q ₄	Q ₅	p ²
Cut-off	≤4.35]4.35-21.46]]21.46-37.67]]37.67-59.74]	>59.74	
%men	62.2	50.91	42.03	38.13	34.51	<.0001
Age, y	50.54 (14.08)	52.12 (14.15)	53.93 (13.82)	55.16 (13.63)	56.03 (13.54)	<.0001
Education (%)						<.0001
< High-school diploma	58.14	54.15	58.13	60.27	68.76	
High school diploma	16.6	18.35	13.74	15.91	12.1	
Postgraduate	25.26	27.5	28.13	23.82	19.14	
Occupation (%)						<.0001
Unemployed	6.44	2.34	3.04	4.02	3.84	
Retired	15.31	27.89	30.56	35.25	36.32	
Employee, manual worker	41.03	28.06	28.06	26.19	26.36	
Intermediate profession	16.19	15.94	12.86	12.07	13.98	
Managerial staff and intellectual profession	8.55	9.85	11.42	8.93	7.04	
Never employed	7.97	10.25	10.43	10.47	7.44	
Self-employed, farmer	4.52	5.67	3.65	3.07	5.01	
Monthly income (%)						<.0001
Unwilling to answer	6.23	4.98	7.25	8.24	9.96	
< 1,200€	28.64	23.2	19.41	26.86	24.88	
1,200-1,800€	30.99	29.13	29.46	26.22	25.24	
1,800-2,700€	23.07	23.94	26.44	22.63	26.04	
> 2,700€	11.07	18.75	17.44	16.06	13.88	
Physical activity level (%)						<.0001
Missing data	19.76	12.3	12.23	10.46	16.49	
Low	26.74	24.15	19.94	20.44	10.41	
Moderate	26.34	30.88	33.2	33.83	29	
High	27.15	32.66	34.63	35.26	44.1	
Tobacco status (%)						<.0001
Never smoker	43.39	45.42	48.94	48.06	55.1	
Former smoker	42.72	39.1	38.92	43.68	38.09	
Current smoker	13.88	15.49	12.14	8.26	6.81	
Cost of the diet (€/d)	7.72 (2.92)	7.38 (2.65)	7.43 (2.73)	7.48 (2.73)	8.53 (3.66)	<.0001
Body mass index (kg/m²)	25.12 (4.95)	24.62 (4.62)	24.32 (4.65)	23.82 (4.44)	23.13 (4.21)	<.0001

Abbreviations: Q: quintiles;

¹Values are means (SD) or %.²P referred to ANOVA or Chi² test.

Table 3: Nutritional characteristics of the sample across EAT-Lancet Diet Index quintiles,**n= 29,210, NutriNet-Santé ¹**

	Q ₁	Q ₂	Q ₃	Q ₄	Q ₅	P ²
Energy intake (kcal/d)	2099 (694)	2030 (624)	1994 (606)	1947 (589)	1935 (612)	<.0001
PANDiet (/100)	59.47 (6.20)	62.54 (6.39)	64.81 (7.01)	67.50 (7.51)	70.55 (7.15)	<.0001
Health score (/9)	0.91 (0.22)	0.98 (0.21)	1.06 (0.22)	1.14 (0.22)	1.41 (0.38)	<.0001
Alcohol (g/d)	9.06 (13.23)	9.55 (13.06)	9.47 (13.44)	8.27 (11.45)	6.23 (10.90)	<.0001
Proportion of organic food ³	0.17 (0.19)	0.23 (0.22)	0.28 (0.25)	0.35 (0.28)	0.45 (0.32)	<.0001
% Carbohydrates	35.37 (6.98)	38.39 (6.46)	39.65 (6.54)	40.80 (6.83)	43.89 (8.00)	<.0001
% Lipids ⁴	42.96 (6.19)	41.89 (6.25)	41.30 (6.63)	40.91 (7.18)	39.05 (8.50)	<.0001
% SFA ⁴	17.15 (3.13)	16.16 (3.12)	15.31 (3.15)	14.13 (3.09)	11.87 (3.22)	<.0001
% MUFA ⁴	16.48 (3.31)	16.30 (3.52)	16.29 (3.84)	16.59 (4.31)	16.32 (5.17)	<.0001
% PUFA ⁴	6.10 (1.80)	6.33 (1.99)	6.64 (2.23)	7.19 (2.61)	7.94 (3.28)	<.0001
% Proteins ⁴	21.35 (3.72)	19.37 (3.02)	18.67 (3.09)	17.88 (3.23)	16.57 (3.53)	<.0001
Proportion of plant proteins	0.22 (0.07)	0.28 (0.07)	0.32 (0.09)	0.37 (0.12)	0.48 (0.19)	<.0001
Fibers (g/d)	16.03 (5.17)	19.38 (4.47)	22.25 (4.84)	25.74 (5.36)	33.36 (9.40)	<.0001
Sodium (mg/d)	2717 (574)	2621(473)	2563 (483)	2430 (478)	2181 (558)	<.0001
Vitamin B12 (µg/d)	8.17 (9.28)	6.84 (3.36)	6.40 (3.02)	5.97 (3.04)	5.15 (3.07)	<.0001
Vitamin C (mg/d)	108.00 (58.10)	127.08 (58.28)	142.37 (62.11)	161.19 (63.51)	223.82 (105.87)	<.0001
Vitamin B9 (µg/d)	333.10 (108.71)	366.88 (86.55)	400.76 (92.15)	443.67 (99.22)	552.95 (180.94)	<.0001
Vitamin E (mg/d)	11.80 (4.58)	13.06 (4.54)	14.15 (4.62)	15.53 (4.86)	18.34 (5.67)	<.0001
Calcium (mg/d)	1069 (323)	1119 (316)	1142 (319)	1138 (327)	1107 (331)	<.0001
Iron	14.33 (3.79)	14.52 (3.15)	15.26 (3.47)	16.05 (3.68)	17.26 (4.10)	<.0001
Heme-iron	2.17 (1.70)	1.49 (0.66)	1.23 (0.59)	1.02 (0.60)	0.74 (0.60)	<.0001
Zinc	14.25 (3.25)	12.89 (2.24)	12.58 (2.21)	12.30 (2.26)	11.78 (2.32)	<.0001

Abbreviations: MUFA: monounsaturated fatty acids, PUFA; polyunsaturated fatty acids, Q: quintiles;

SFA: saturated fatty acidsx

¹Values are means (standard deviations)²P for trend across quintiles of PNNS-GS2 assessed by linear contrast³Proportion of weight excluding water⁴As percent of alcohol-free energy intake

Table 4: Environmental indicators across EAT-Lancet Diet Index quintiles, n= 29,210,**NutriNet-Santé ¹**

	Q ₁	Q ₂	Q ₃	Q ₄	Q ₅	P ²
CED (MJ/d)						
Model 1 ²	21.98 (21.79-22.16)	18.31 (18.13-18.50)	16.98 (16.80-17.16)	15.72 (15.53-15.90)	15.16 (14.97-15.34)	<.0001
Model 2 ³	21.18 (21.05-21.30)	18.13 (18.00-18.25)	17.10 (16.97-17.23)	16.16 (16.04-16.29)	15.58 (15.45-15.71)	<.0001
GHGE (CO ₂ eq/d)						
Model 1 ²	6.03 (5.98-6.09)	4.49 (4.43-4.54)	3.85 (3.80-3.91)	3.27 (3.21-3.32)	2.63 (2.57-2.68)	<.0001
Model 2 ³	5.83 (5.79-5.88)	4.44 (4.40-4.49)	3.88 (3.84-3.93)	3.38 (3.33-3.42)	2.73 (2.69-2.78)	<.0001
LO (m ² /d)						
Model 1 ²	15.53 (15.37-15.68)	11.61 (11.45-11.77)	10.06 (9.91-10.22)	8.66 (8.50-8.82)	7.17 (7.01-7.33)	<.0001
Model 2 ³	14.99 (14.86-15.12)	11.48 (11.35-11.61)	10.14 (10.01-10.27)	8.96 (8.83-9.09)	7.45 (7.32-7.58)	<.0001
pReCiPe						
Model 1 ²	0.449 (0.445-0.452)	0.326 (0.323-0.329)	0.271 (0.268-0.275)	0.227 (0.223-0.230)	0.168 (0.165-0.172)	<.0001
Model 2 ³	0.444 (0.441-0.448)	0.325 (0.322-0.328)	0.272 (0.269-0.275)	0.229 (0.226-0.232)	0.170 (0.167-0.174)	<.0001

Abbreviations: CED, Cumulative energy demand; GHGE, Greenhouse gas emissions; LO, Land occupation; Q:

quintiles

¹ Values are means and 95% confidence interval

² Model 1 is crude

³ Model 2 is adjusted for daily energy intake

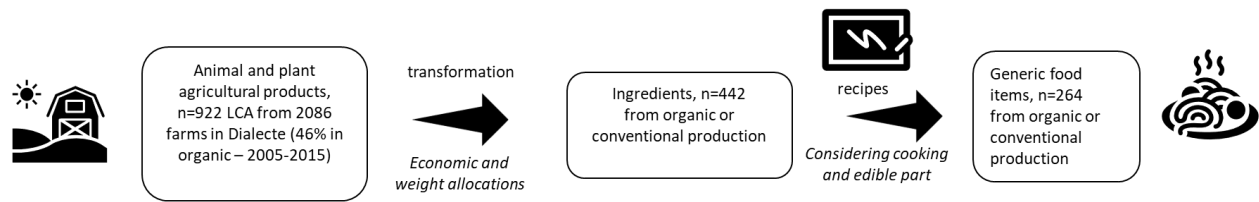


Figure 1: Steps for calculating the environmental indicators

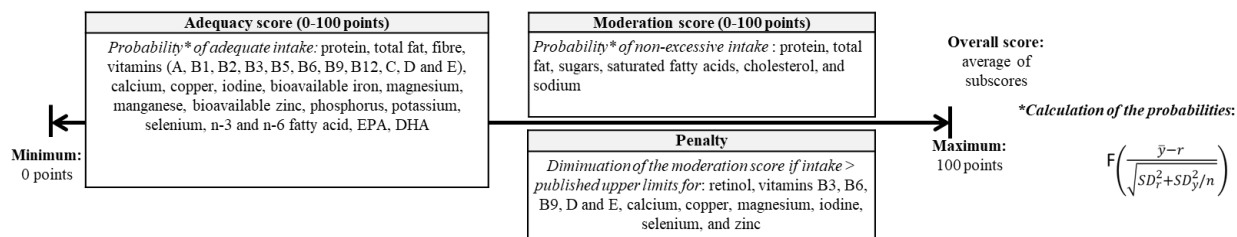


Figure 2: Computation of the PANDiet score

Abbreviations: DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid.

F (ranged from 0 to 1, where 1 represents a 100% probability that the usual intake was adequate):

‘Probnorm’ function in SAS, \bar{y} is the mean intake, SD_y the day-to-day variability of intake, n the number of dietary record days, r the nutrient reference value, SD_r the interindividual variability.

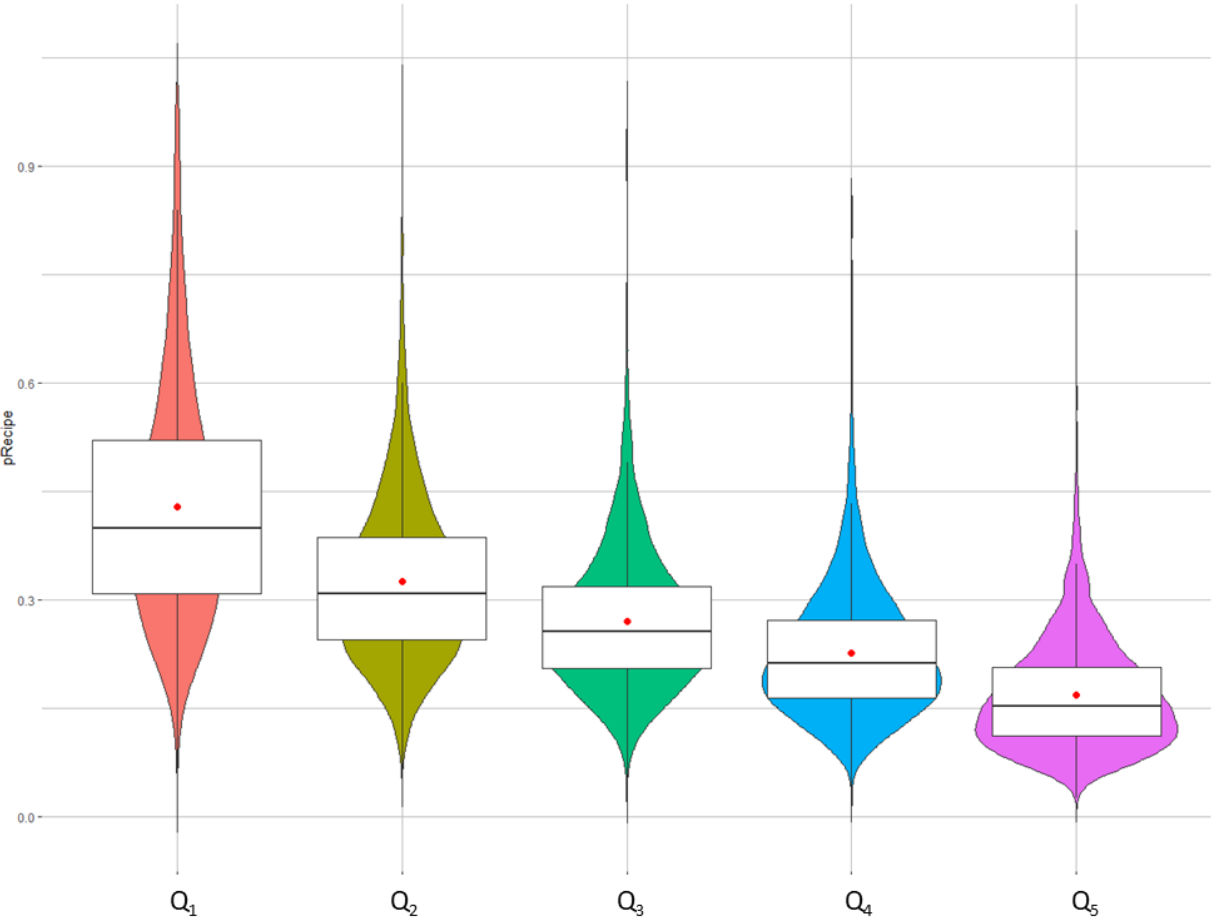


Figure 3: *p*Recipe distribution across ELD-I quintiles ¹

¹ Unadjusted distribution is presented.

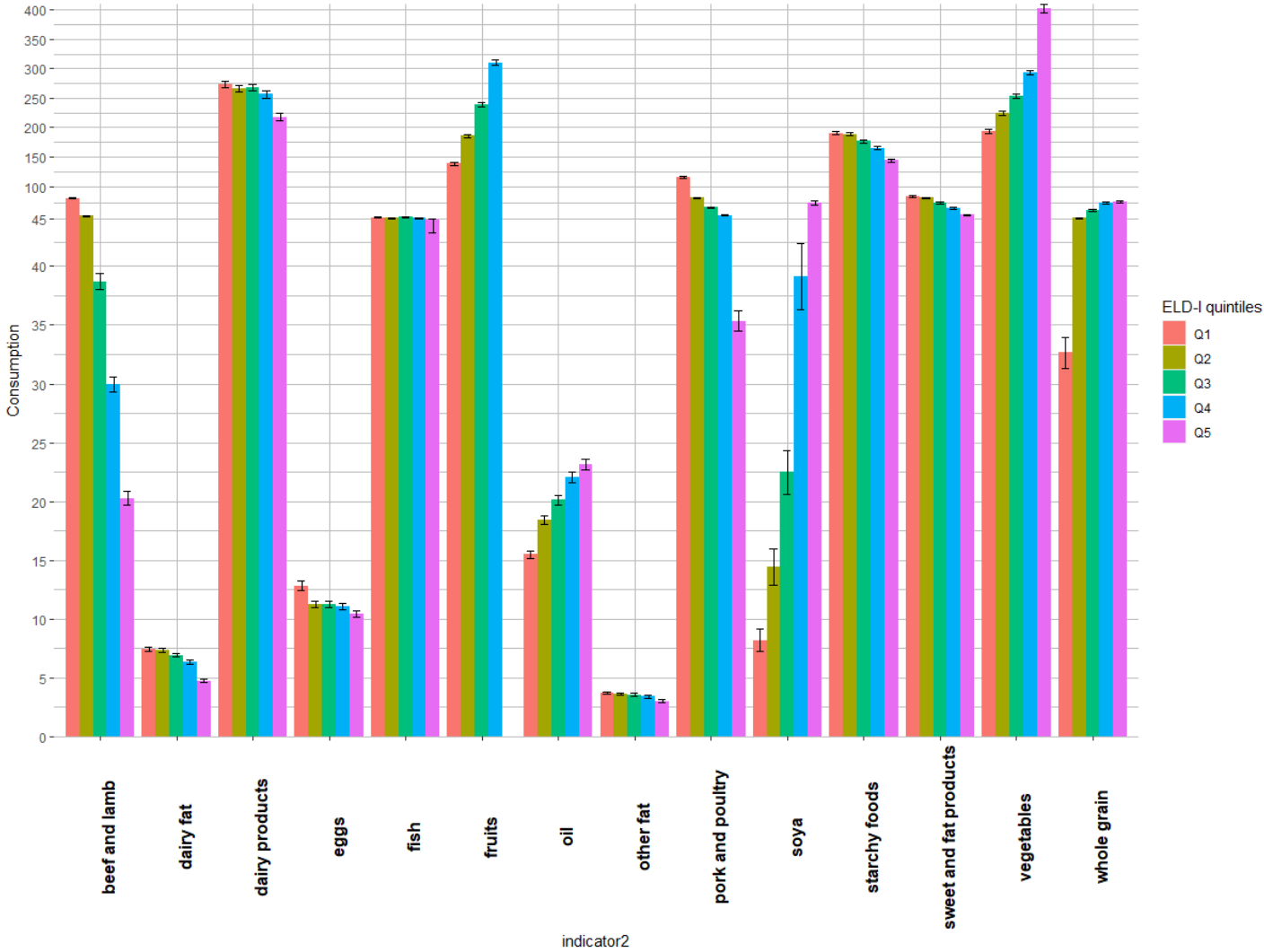


Figure 4: Food consumption (intake in g/d) across ELD-I quintiles ¹

Abbreviations: Q, quintile

¹ Values are unadjusted means and 95% confidence interval, all P-values for trend were <0.0001.