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

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**insights from the NutriNet-Santé study**

Emmanuelle Kesse-Guyot[1*], Pauline Rebouillat[1], Joséphine Brunin[1], Brigitte Langevin[2], Benjamin Allès[1], Mathilde Touvier[1], Serge Hercberg[1,3], Hélène Fouillet[5], Jean-François Huneau[5], François Mariotti[5], Denis Lairon[4], Philippe Pointereau[2], Julia Baudry[1]

**Affiliations:**

[1]Sorbonne Paris Nord University, Inserm, Inrae, Cnam, Nutritional Epidemiology Research Team (EREN), Epidemiology and Statistics Research Center – University of Paris (CRESS), 93017 Bobigny, France

[2]Solagro, Toulouse, France

[3]Public Heath Department, Avicenne Hospital, AP-HP, 93017 Bobigny, France

[4]Human nutrition, Aix Marseille Université, INSERM, INRAE, C2VN, Marseille, France

[5]Université Paris-Saclay, AgroParisTech, INRAE, UMR PNCA, 75005, Paris, France

**\*Corresponding author:**

Emmanuelle Kesse, PhD

Equipe de Recherche en Epidémiologie Nutritionnelle (EREN)-Université Sorbonne Paris Nord, SMBH - 74 rue Marcel Cachin-93017 Bobigny France

Phone number: + 33 1 48 38 89 79

e.kesse@eren.smbh.univ-paris13.fr

**Running Head**: planetary health diet and environmental impacts

ELD-I;

**Number of tables/figures:** 4/2

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 ($p$ReCiPe). For clarity purpose, results are

10  presented by quintile (Q) of ELD-I. High ELD-I ($Q_5$), compared to low ($Q_1$), was associated with lower

11  greenhouse gas emissions (-56%), cumulative energy demand (-31%) and land occupation, (-54%). The

12  $p$RECIPE 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

### 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).

### 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
$$\text{ELD-I}_j = \frac{100 \times \left\{ \Sigma_{component\ i=1}^{14} \frac{a_i \times \left( cut\text{-}off_i - \frac{consumption_{ij} \times 2500}{Energy\ intake_j} \right)}{cut\text{-}off_i} \right\}}{14} \tag{1}$$

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 *p*ReCiPe was calculated for each individual as follows, equation (2):

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

141   with GHGe, in kg of $CO_2$eq/d, CED, in MJ/d and LO, in $m^2$/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    $HS = [(\frac{vegetables}{200}) + (\frac{fruits}{200}) + (\frac{fiber}{40}) + (\frac{fish}{37}) + (\frac{6}{salt}) + (\frac{30}{\% \text{ EI total fat}}) + (\frac{10}{\% \text{ EI SFA}}) + (\frac{10}{\% \text{ EI free sugars}}) +$

154    $(\frac{2500}{EI})] \times \frac{100}{9}$                                                                            (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

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

184

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 ($Q_5$ vs. $Q_1$,

188    34.51% vs. 62.20%), older (mean age about +6y), less often postgraduate ($Q_5$ vs. $Q_1$, 19.14% vs. 25.26%),

189    less often employee or manual worker ($Q_5$ vs. $Q_1$, 26.36% vs. 41.03%), and more often physically active

190    ($Q_5$ vs. $Q_1$, 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 ($Q_5$ vs. $Q_1$, 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 (*p*ReCiPe)

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 $5^{th}$ 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 *p*ReCiPe 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 *p*ReCiPe 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 $1^{st}$

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 *p*ReCiPe 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 $5^{th}$ quintile.

## 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 5$^{th}$ 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 $Q_5$ were close to vegetarian dietary patterns, though animal products,

236    especially meat, were not totally excluded from $Q_5$ participants' diets. This was illustrated by an increase in

237    the PANDiet score across quintiles despite a reduced animal-food consumption. Dietary pattern in $Q_5$ of the

238    ELD-I directly compared to the $Q_5$ 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 ($p$ReCiPe), 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 diary) 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

359   Libertés, CNIL). The data are available upon request to the study's operational manager, Nathalie Pecollo

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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 |

[1]Cut-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;

[1]Values are means (SD) or %.

[2]P 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]**

| | Q₁ | Q₂ | Q₃ | Q₄ | Q₅ | 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

[1]Values are means (standard deviations)

[2] P for trend across quintiles of PNNS-GS2 assessed by linear contrast

[3] Proportion of weight excluding water

[4]As 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 |
| *p*ReCiPe | | | | | | |
| 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
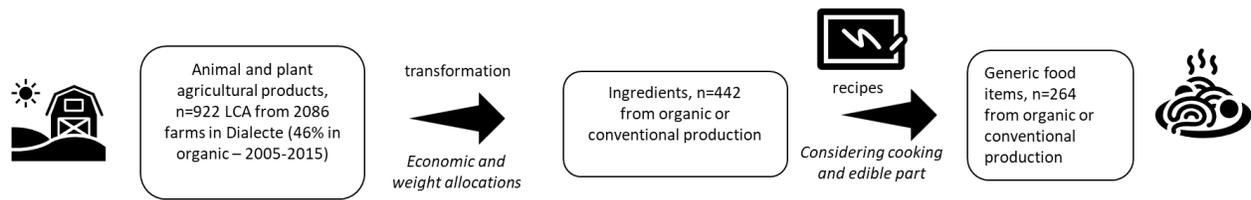
**Figure 1: Steps for calculating the environmental indicators**
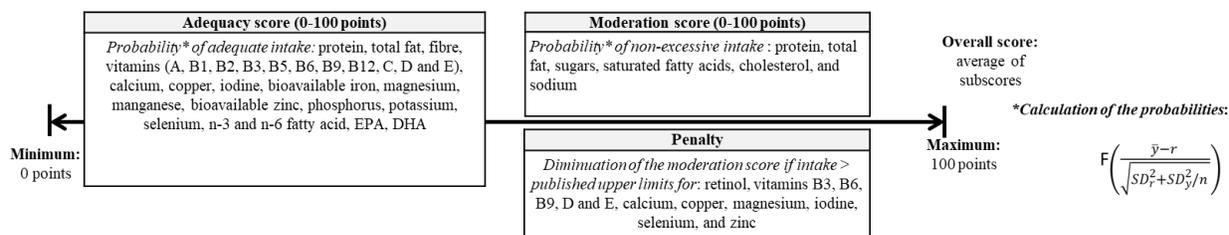
**Figure 2: Computation of the PANDiet score**

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, 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.
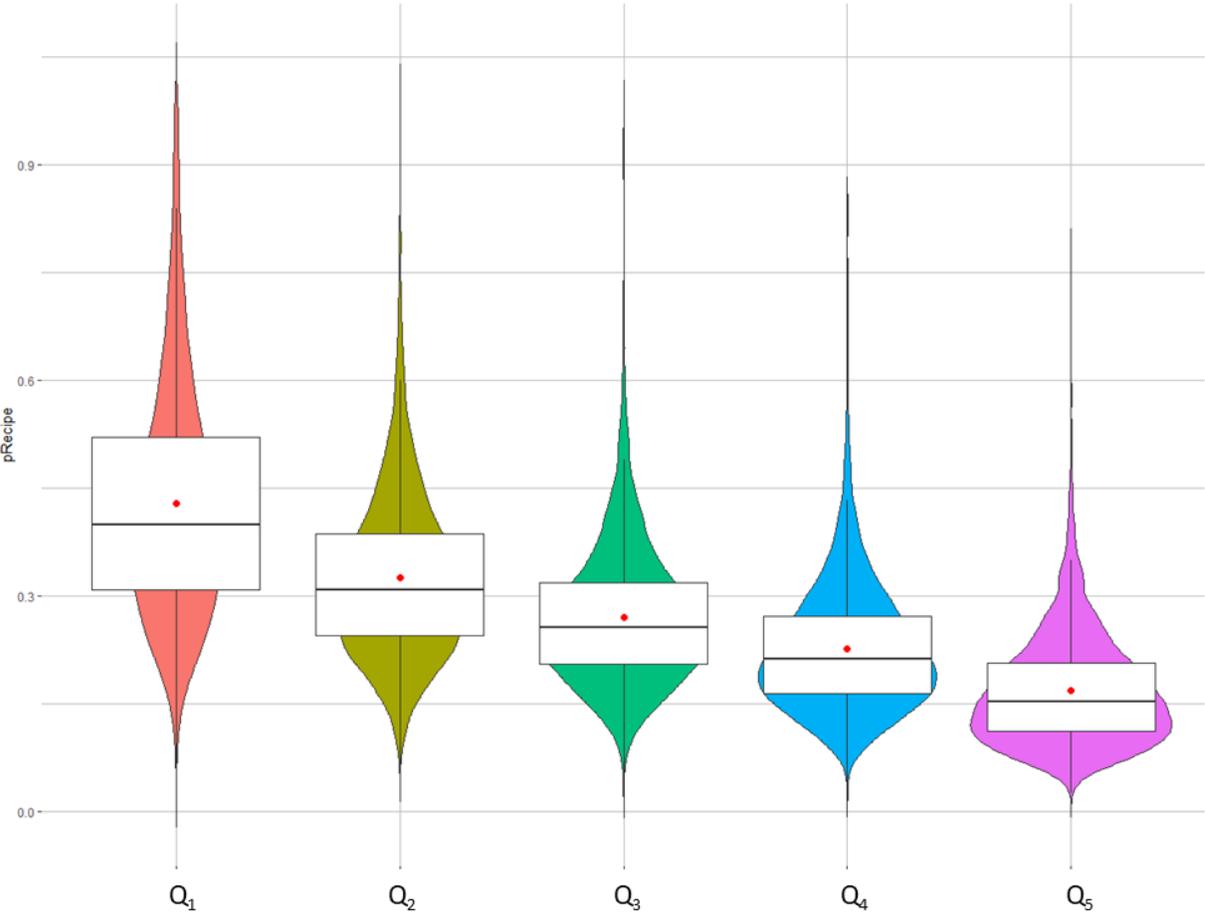
**Figure 3: *p*Recipe distribution across ELD-I quintiles [1]**

[1] Unadjusted distribution is presented.
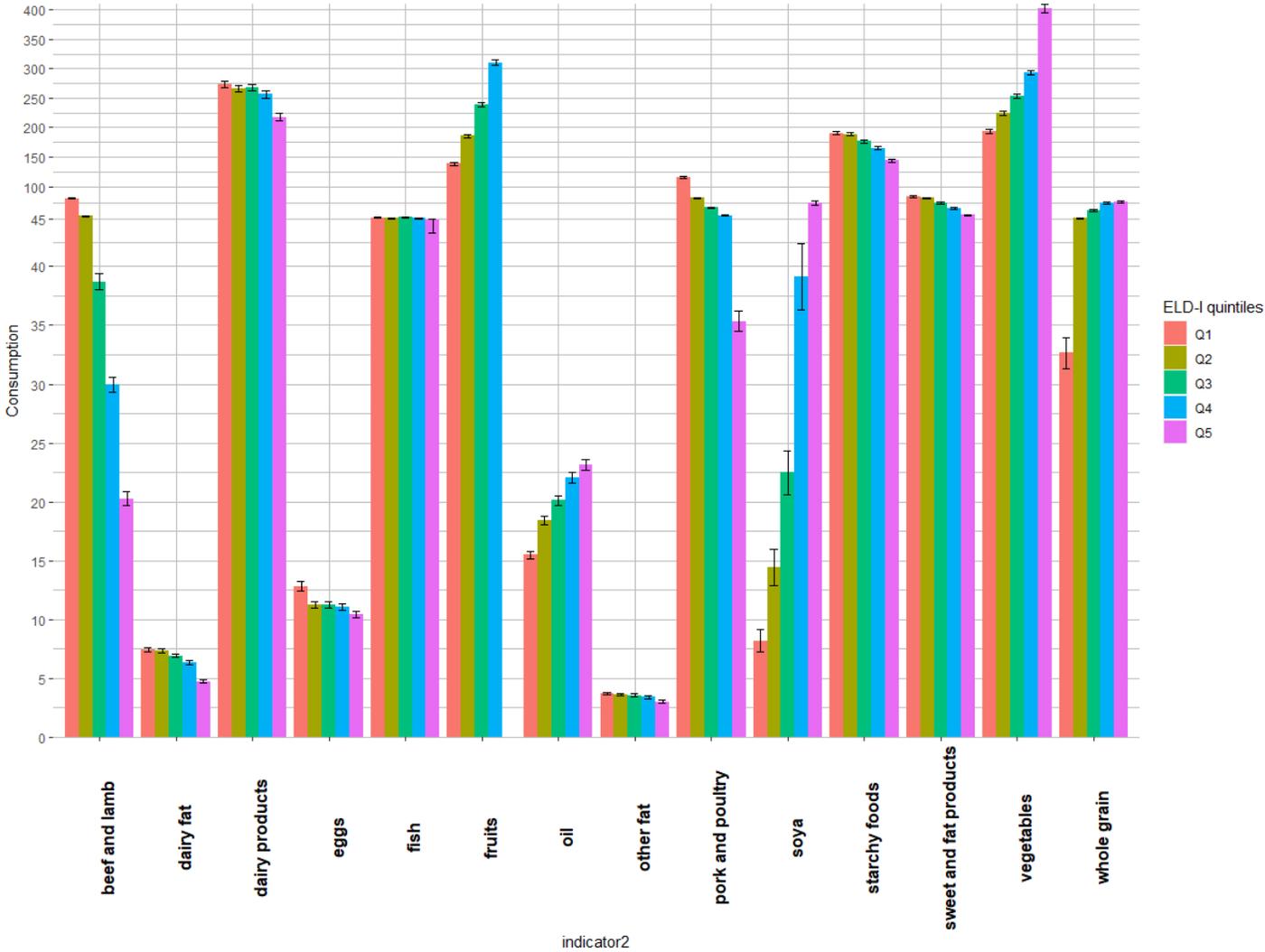
**Figure 4: Food consumption (intake in g/d) across ELD-I quintiles [1]**

Abbreviations: Q, quintile

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