Organic consumers' perceptions of environmental impacts of food overlap only partially with those considered by life cycle assessment

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1. Introduction

The Intergovernmental Panel on Climate Change has warned of rapid global warming resulting from industrial activities (The Intergovernmental Panel on Climate Change, 2018). Climate change is one of the multiple environmental impacts caused by Human activities. The agri-food sector represents 20-30% of environmental impacts in Europe (Notarnicola et al., 2017b) when all the life stages of agricultural production, processing, and transport are considered. Nevertheless, the end-of-life stage (i.e. consumption) also has significant influence (Notarnicola et al., 2017b). Trends in the number of environmentally friendly products reflect growing awareness of environmental issues (de Carvalho et al., 2015). In addition, ac European study showed that 50% of European citizens are moderate or pro-environmentalists (Golob and Kronegger, 2019). This evolution is a considerable opportunity for food companies to connect with consumers to influence purchases in ways that respect planetary boundaries (Rohm and Aschemann-Witzel, 2019; Steffen et al., 2015). In addition, consumers seek more information and guidance about environmental impacts of products when purchasing and using them (Heslouin et al., 2017).

The market for products from organic farming seems proactive about environmental issues based on the latter's restrictive specifications for agricultural and processing practices. Specific beliefs about organic products include health benefits, increased quality, and lower environmental impacts, which are the main reasons for purchasing them (Hansen et al., 2018; Massey et al., 2018). Du et al. (2017) observed a relationship between consumption of organic products and consumers with an environmental ideal. Accordingly to Research and Markets (2016), the market for organic products is expected to grow at an annual rate of 6.8% from 2016-2020. Europe is the world's second largest organic market (European Parliament, 2018), and 75% of the French population currently consumes organic products at least once per month (Agence Bio and Spirit Insight, 2019). A recent study (Agence BIO and Spirit Insight, 2020) shows that French organic consumers under the age of 35 advocate environmental and ethical issues, while older consumers pay attention to provenance and quality. For these reasons, the present study focuses on consumers of organic products as people who are sensitive to the environmental impacts (i.e. any change to the environment) caused by the production and the consumption of food.

Many environmental labels usable in food exist in France and Europe (ADEME, 2019) . Although the purchases of European consumers are not currently influenced by eco-labels, the future of these labels depends on the importance that consumers give to sustainability (Grunert et al., 2014). In less than a decade, sustainability is now more relevant than ever as environmental, social and economic impacts of activities must be controlled. Considering the environmental aspect of sustainability, some 26% of Europeans are pro-environmentalists, and 24% are moderate environmentalists (Golob and Kronegger, 2019). Despite this trend, the understanding of labels remains low, especially when the label is not self-explicit enough (Grunert et al., 2014) or poorly known (Kaczorowska et al., 2019). In general, the literature shows that “organic” and “fairtrade” labels are the best understood labels (Annunziata et al., 2019; Eldesouky et al., 2020; Grankvist and Biel, 2007; Janßen and Langen, 2017; Lea and Worsley, 2005). They allow consumers to identify more environmentally friendly practices (Annunziata et al., 2019; Lazzarini et al., 2017). The organic label generates a halo effect, i.e. the positive perception of the label and its implications will positively influence the individual's opinion of the product as a whole (Aschemann-Witzel et al., 2019; Lee et al., 2013). However, although categorized as a sustainability label, it does not communicate to the consumers on the assessment of the environmental impacts of the labelled products.

Only 57% of Europeans understand the concept of “environmental impact of a product”, and impacts such as global warming, air pollution, and water pollution seem difficult to understand (European Commission - DG Environment, 2012). Nonetheless, Swiss consumers were able to classify food products according to their impacts on climate change (Shi et al., 2018). Worldwide, expertise is growing in life cycle assessment (LCA). LCA is an assessment framework harmonized by SETAC (Society of Environmental Toxicology and Chemistry) working groups in the 90s and standardized by ISO (International Organization for Standardization) (ISO 14040 and 14044). LCA that transforms inputs and outputs (e.g. materials, energy) of a production system into impacts, represented by “midpoint” impact categories. The method can consider all or only parts of a product’s life cycle (European Commission et al., 2010). Unlike mono-criterion methods, LCA can identify potential “pollution transfers” between impact categories when stages of the life cycle are modified. Several agri-food sectors (e.g. beef cattle, pigs, cereals, dairy) have developed reliable databases of resource use and emissions for use as professional tools in multi-criteria assessment (Notarnicola et al., 2017a; Sala et al., 2017) (e.g. Agribalyse 3.0 in France). The study of the French Ministry of Ecology (Ministry of

Ecology, Sustainable Development and Energy, 2013) showed that multicriteria information was claimed by all actors, including consumers. However, the French National Consumer Council is yet concerned about the intelligibility and accessibility of environmental labeling for the public when it is based on a multi-criteria method (Conseil National de la Consommation, 2013).

Some literature exists on consumers' perceptions of the environmental impacts of food production, related to the topics of meat products, organic products, products labeling, or consumers sustainable consciousness (Apaolaza et al., 2018; Balderjahn et al., 2018; Hartmann and Siegrist, 2017). The concern is legitimate when counterproductive consumer behaviors are observed, such as inaccurate beliefs about apparently environmentally friendly practices that instead cause environmental damage (Rettie et al., 2012). Therefore, there is great interest in using consumer science to explore consumers' perceptions of sustainability (Aschemann-Witzel et al., 2019) and environmental impacts. Identifying them could provide reliable information to better guide and inform companies on consumers' choices and behaviors.

The main objective of the present study is to explore the question: What buyers of organic products perceive about the environmental impacts of food? The study used qualitative and quantitative methods to assess spontaneous perceptions of the environmental impacts of food products, and then explored what buyers perceive of the environmental impacts studied by the LCA. There were two hypotheses. With reference to the study of Grunert et al. (2014), the first hypothesis is that organic buyers have a holistic vision of the environmental impacts of food products. The second hypothesis is that there is a common space between what the LCA assesses and what consumers consider to be the environmental impacts of food. Materials and methods

This study used a triangulation between methods (Farquhar et al., 2020). Exploratory focus groups were used in a preliminary study. The insights of buyers of organic products were studied in depth in the qualitative phase, making it possible to design a national survey administered in France. It was assumed that people who buy organic food regularly also consume it regularly.

1.1. Focus groups

The focus group is a qualitative method often used to capture deep insights and nuances in consumers opinion (Krueger, 2014). It has a great flexibility of preparation.

The first selection criterion was a frequency of purchase of organic food greater than “once per month” from organic shops, organic shelves in supermarkets, and organic farmers. Participants were secondly selected according to "somewhat agree" and "strongly agree” answers to the three-question-scale of Du et al. (2017) below which assesses the perceived Organic Product Trustworthiness using a 5-level Likert scale (1, strongly disagree; 5, strongly agree).

- The likely quality of organic products is very high.
- The likelihood that organic products would be functional is high.
- Organic products are trustworthy.

Over two days, three, two-hour focus groups were held in the research unit with 8 to 10 participants in each group. Group discussions were audio- and video-recorded with the consent of all participants, who were compensated with vouchers. The moderator followed a moderation script during each focus group (Focus group moderation guidelines in supplementary material). The aim was to introduce the study and facilitate group interactions in Part 1 and then explore spontaneous perceptions of environmental impacts of food in Part 2 with the question “in your opinion, what effects do food have on the planet?”. Part 3 addressed spontaneous perceptions and understanding of 17 LCA midpoint impact categories (list in Table 1). The perceptions were measured via individual written comments followed by group discussions. The impact categories were not described to the participants to avoid influencing their perceived meanings. Part 4 confronted the descriptions of LCA impact categories (descriptions of the LCA impact categories in supplementary material) with the participants’ initial perceptions of the environmental impacts of food and this was discussed with participants.

Codes were used to anonymize participants during transcription. Verbatim transcriptions were analyzed using qualitative thematic content analysis, following guidelines of Krueger and Casey (2014). During analysis, short descriptions of LCA impact categories (in supplementary material) were compared to the participants’ verbatim. When the opinion was consensual among participants, the number of respondents is not specified in the results.

Table 1. List of LCA impact categories

Climate change
Ozone depletion
Photochemical oxidant formation
Particulate matter formation

Human toxicity
Ionizing radiation
Water depletion
Mineral depletion
Fossil fuel depletion
Freshwater eutrophication
Marine eutrophication
Freshwater ecotoxicity
Marine ecotoxicity
Agricultural land depletion
Urban land occupation
Terrestrial acidification
Terrestrial ecotoxicity

1.2. Online survey

The aim of the online survey was to quantify the qualitative results of the focus groups to obtain a general view of French perceptions of environmental impacts of food. It was pre-tested with a convenience panel. The survey polled 523 French respondents over 18 years old. They were selected based on their purchase frequency of organic food at least once per month. As the population of buyers of organic products in France is similar to the general population (based on the Barometer of consumption and perception of organic products in France by Agence BIO and Spirit Insight (2020)), Insee criteria were used to construct the sample for the quantitative study (INSEE, 2019): the quota method for gender, age, and geographic region of residence used ensured the representativeness of the sample. The sample had to represent the population with a confidence level of 95%, and margin of error inferior to 5%. The survey was open from 21 February to 7 March 2019, and was implemented by Creatests Cie.

The survey questionnaire is available in the supplementary material. The survey's introduction specified that "food" referred to food's entire life cycle: production, processing, packaging, transport, consumption, and waste treatment. The survey was then divided in two parts. The first part asked respondents about their perceptions of the environmental impacts of food. Multiple-choice questions were used to quantify the importance of the elements mentioned during the focus groups. The topics included (1) negative effects of food on the environment, (2) causes of these negative impacts, (3) positive effects of food on the environment, and (4) practices that could reduce environmental impacts. The second part asked respondents about their understanding of LCA impact categories. Some categories were combined according to their similarity perceived by participants of the preliminary focus groups. The respondents answered a 5-point Likert scale to measure their level of understanding of each LCA impact category, from "not at all understandable" to “completely understandable”. Based on comments in the focus groups, a multiple-choice question asked respondents to select practices that could reduce environmental impacts of food. At the end of the second part, an additional multiple-choice question asked from which media source(s) respondents had heard or read about the impact categories.

QuestionData® software (v. 6.8) (Gimmersoft) was used to process the survey. Descriptive statistics were done using analysis module of Question Data. Frequencies of answers to multiple-choice questions were calculated. Age was converted into categories: G1=[18,34], G2=[35,49], G3=[50,64], and G4=[65+]. χ^2 tests of independence were performed to determine the dependence of the answer to each multiple-choice question on age category, gender, and geographic region. Mixed-model analysis of variance (ANOVA) was performed on the quantitative understanding scores of LCA impact categories using the LmerTest in R software (v. 3.5.3). Effects of the individual (as random), impact category, age category, gender, region (as fixed), and all of their interactions were included in the model. The threshold for significance was set at 5%.

2. Results

2.1. Samples of organic buyers

2.1.1. Focus groups

28 regular buyers of organic products at least once per month in Angers (France) were recruited. Gender was nearly balanced (13 men, 15 women) (Table 3), and participants ranged in age from 25-65 (mean=45.2). Table 2. Characteristics of participants in focus groups (n=28). Mean and standard deviation (SD) for age were 45.2 ± 13.9.

Table 2. Characteristics of participants in focus groups (n=28). Mean and standard deviation (SD) for age were 45.2 ± 13.9.

Characteristic	Category	n
Gender	Men	13
	Women	15
Age	G1=[18,34]	10
	G2=[35,49]	6
	G3=[50,64]	11
	G4=[65+]	1
Purchase of organic food	1-3× per month	6
	1× per week	19
	>1× per week	3
"The likely quality of organic products is very high." (Du et al., 2017; trustworthiness)	Strongly agree	4
	Somewhat agree	22
	Neither agree nor disagree	1
	Somewhat disagree	1
	Strongly disagree	0
"The likelihood that organic products would be functional is high." (Du et al., 2017; trustworthiness)	Strongly agree	9
	Somewhat agree	19
	Neither agree nor disagree	0
	Somewhat disagree	0
	Strongly disagree	0
"Organic products are trustworthy." (Du et al., 2017; trustworthiness)	Strongly agree	1
	Somewhat agree	21
	Neither agree nor disagree	0
	Somewhat disagree	0
	Strongly disagree	0

2.1.2. Online survey

The representative sample of the French population consisted of 523 complete surveys (Table 4). All respondents purchased organic food at least once per month. Approximately 78% of respondents purchased organic food a few times per week, while 95% of them were the primary household buyer of organic food. The margin of error of the results was 4,3%.

Table 3. Characteristics of respondents to the online survey (n=523)

Characteristic	Category	n	%
Gender	Men	261	49.9
	Women	262	50.1
Age	18-34	130	24.9
	35-49	131	25.0

	50-65	131	25.0
	> 65	131	25.0
French region	Paris region	37	7.1
	West	174	33.3
	East	149	28.5
	Southwest	68	13.0
	Southeast	95	18.2
Purchase of organic food	<1× per month	0	0.0
	1× per month	28	5.3
	2× per month	36	6.9
	4× per month	49	9.4
	A few times per week	263	50.3
	Every day	147	28.1
Household buyer of organic food?	Yes	496	94.8
	No	27	5.2

2.2. Spontaneous perceptions of environmental impacts of food

2.2.1. Focus groups

The first result of the focus groups was that the opinions of the 28 participants spontaneously referred not only to the impacts of the food products but also to the impacts of their consumption. Participants consider "product" and "consumption" intertwined. The schematic representation of the results drawn by researchers is presented in the Fig 1. The figure reflects the spontaneous perceptions of the participants on the environmental impacts of food. Three core topics emerged from the reviewing process of the participants' verbatim: “environmental pollution”, “economic activities to produce food”, and “social aspects”. “Environmental pollution” was evoked by all participants as such. This result was expected in view of the question asked: “in your opinion, what effects do food have on the planet?”. The other two topics were interpreted terms based on what participants said. They covered more than strict environmental impacts. The dimensions in smaller boxes in Fig 1 were expressed by participant. They are linked to each core topic by a segment (e.g. core topic: social aspects, dimension: equity). Solid boxes are the perceived negative effects of food and consumption (e.g. wastage), and the dashed boxes are the perceived positive effects (e.g. feed the planet). Boxes with both solid and dashed lines are elements both perceived positive and negative (e.g. health). The arrows represent the links from some dimensions to other topics or dimensions explained by the participants. The results of the Fig 1 are detailed in the following paragraphs.

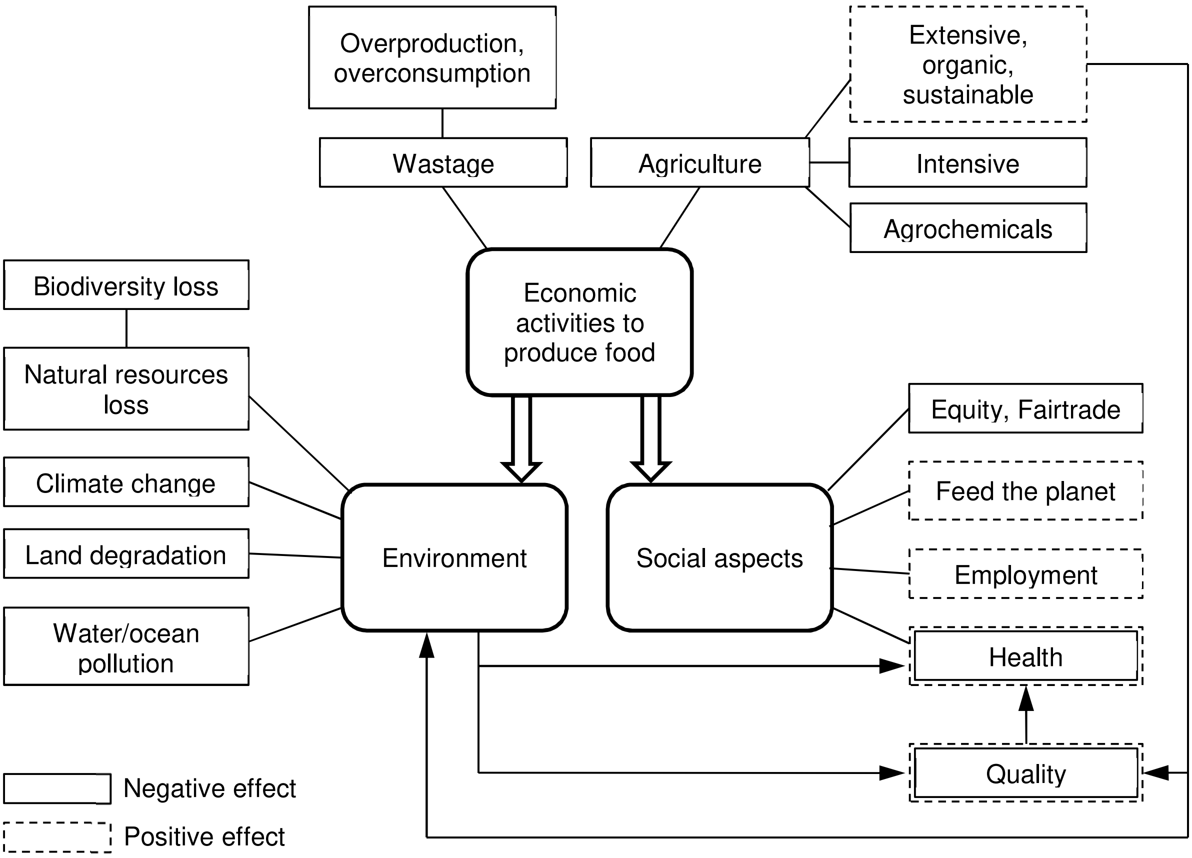

Fig 1: Map of organic buyers' spontaneous perceptions of environmental impacts of food (n=28)

Focus groups participants spontaneously refer to "pollution" to define their perception of environmental impacts of food. According to their view, pollution involves damages to oceans from the plastic waste, to groundwater from the use of agrochemicals, to lands and soils from the intensification of agriculture productions and the use of agrochemicals use as well, to the overall planet from the global warming, to natural resources such as drinking water and biodiversity from activities like deforestation and urban expansion. The participants link the above-mentioned environmental impacts to negative implications for health and product quality. For them, the environmental "pollution" affects the quality of the products. This pollution is also believed to harm the health of people either through breathing or ingestion of pollutants present in the natural environment or in food products.

Further discussions with participants revealed that they perceive food production and consumption as responsible for environmental pollution. The wastage of fresh food and disposal of large amounts of product packaging were considered by all the participants to be a major cause of pollution due to overproduction (quantity and variety) and overconsumption. The participants also believe that all actors in the food life cycle were responsible for the negative impacts: consumers themselves, restaurants, supermarkets, agri-food companies, and farmers. The agricultural production topic was discussed as well. The participants stated that agriculture often uses toxic agrochemicals that could pollute fields and rivers, and that this pollution would increase with agricultural intensification. However, participants stated that certain ways to produce and distribute food could have a positive influence on the environment, such as short supply chains, extensive animal production, "sustainable” farming, and organic farming. Nevertheless, participants called for vigilance regarding organic products produced in large quantities for supermarkets or produced abroad. These products would be less environmentally friendly than local organic or sustainable production due to the intensification of some organic productions (use of greenhouses for off-season production, long-distance transportation).

Discussion about the environmental impacts of food and consumption evoked the social aspects as a third topic, even though these were not directly related to environmental impacts. For instance, four participants stated that food negatively affects equity around the world due to inadequate geographic distribution of food. All participants consider that environmental pollution affects the quality of food and therefore human health. However, the participants believe that food products have positive consequences for society as well. The first idea was that the production chain (i.e. agriculture, industrial processing, and distribution) creates and maintains employment. The second idea was that food is necessary to “feed the planet”. Third, the production and consumption of high-quality products (e.g. resulting from extensive and organic farming methods) also have a positive influence on health.

Finally, the analysis showed links between the economic topic and the environmental and social topics. The economic activities resulted in negative environmental impacts, and negative and positive social impacts. The link from economic to environment topic was further discussed about some possibilities to reduce the impacts. The participants propose that shorter supply chains (short distances) and lower use of synthetic pesticides better limit the impacts. The reassurance of labels, such as the organic label, could also increase consumers’ perceptions of the transparency of producers about their environmental management.

2.2.2. Online survey

In the online survey, organic buyers that responded to the survey stated most often (88%) that food had negative impacts on human health. Negative impacts on the environment appeared after, with aspect such as the soil (74%), oceans and rivers (67%), biodiversity (58%), the air (50%), and climate change (45%) (Fig 2).

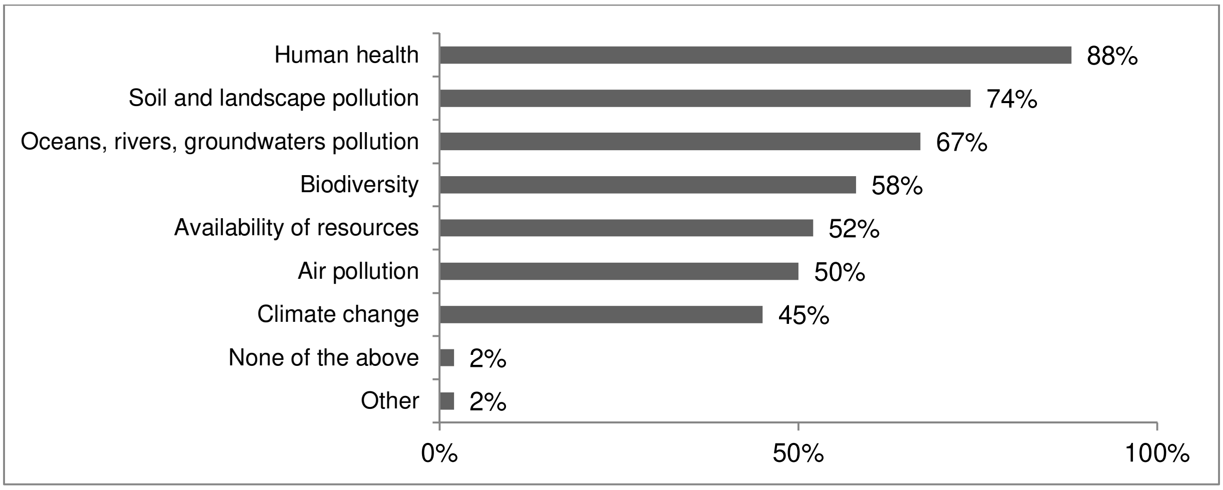

Fig 2. "In your opinion, food can have negative effects on…" (n=523; multiple answers possible)

Among the causes of negative impacts, 80% of French organic buyers considered that negative environmental impacts of food production were due to agrochemical use (Fig 3). Four other practices were considered to cause negative impacts by 61-68% of the respondents: food over-packaging, consuming food out of season, production intensification, and food waste. Overconsumption was selected less often (38%). χ^2 test results (data not shown) showed that selection of certain causes depended on age category (χ^2=38.9, $P<0.05$). Among the four age categories in this survey (18-34, 35-49, 50-64, >65), young people (18-34 years old) were more likely to select over-packaging ($P<0.01$) than other age categories, but less likely to select agricultural intensification and agrochemical use (both $P<0.05$). Conversely, senior citizens (>65 years old) were more likely to select agricultural intensification and agrochemical use (both $P<0.05$) than other categories, but less likely to select over-packaging and food waste (both $P<0.05$). The 35-49 years old respondents were more likely to select over-consumption of food ($P<0.05$) than the other age categories.

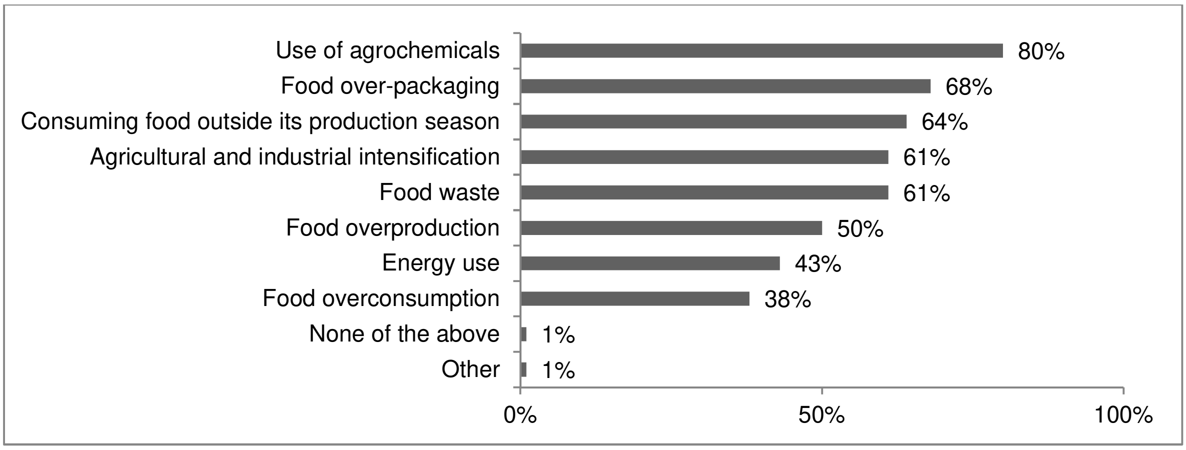

Fig 3. "In your opinion, negative effects of food on the environment are due to…" (n=523; multiple answers possible)

The most selected agriculture-related practices that reduce environmental impacts of food were organic farming (74%) and sustainable farming (72%) (Fig 4). Reducing meat consumption (63%), supporting short supply chains (62%), fair trade (60%), and reducing food waste (57%) were also selected frequently. Approximately 50% of the respondents chose "reducing the amount of packaging during production and consumption" and "improving recyclable or biodegradable packaging" as well.

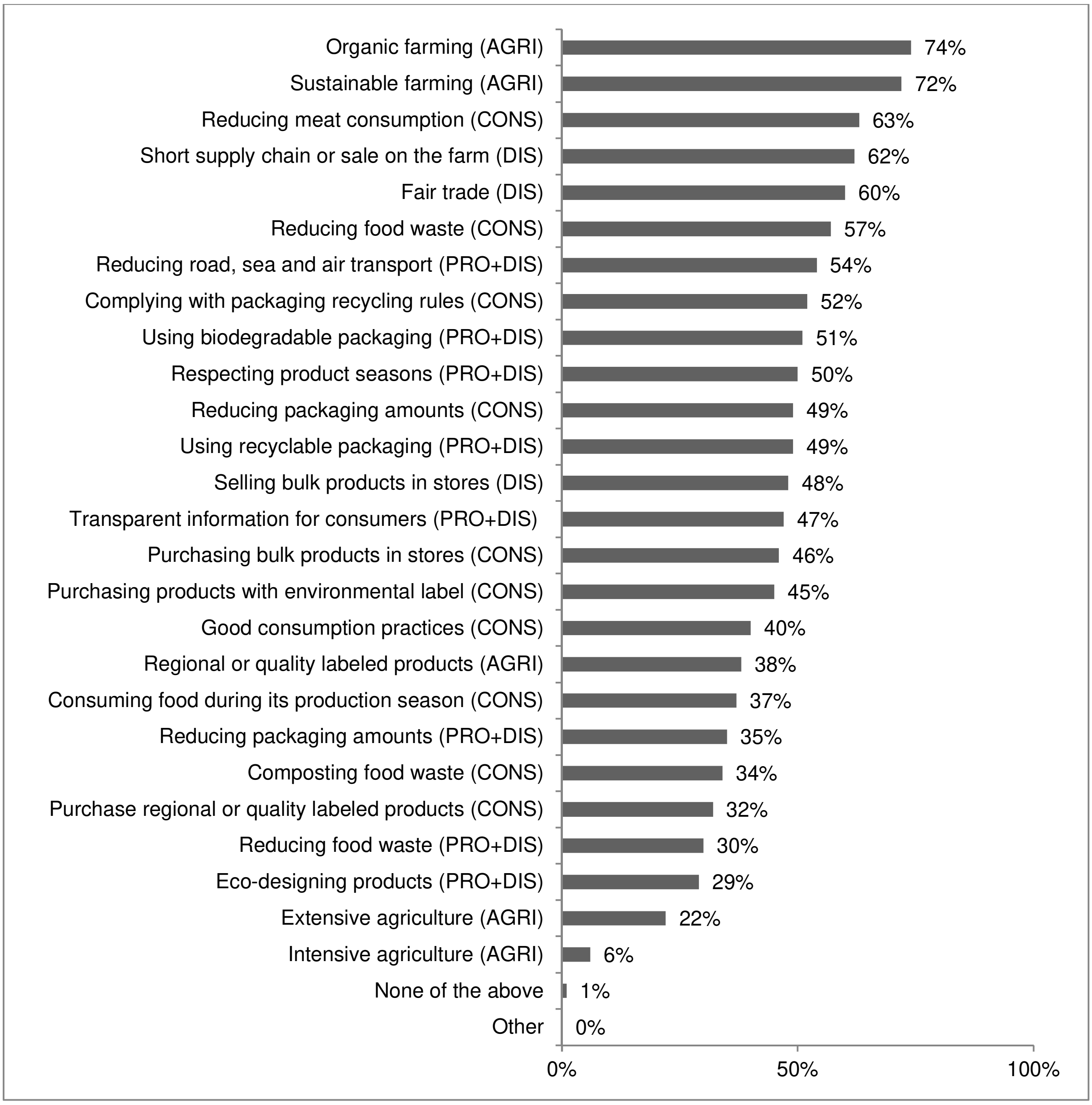

Fig 4. "Which of the following items do you think reduce environmental impacts of food?" (n=523; multiple answers possible; AGRI=agricultural stage, PRO+DIS=processing and distribution stage, CONS=consumption stage)

Among positive effects that food could have, the respondents most often chose the preservation of health (71%), potential to feed humanity (67%), preservation of the environment using sustainable production methods (60%), and preservation of employment (54%) (Fig 5).

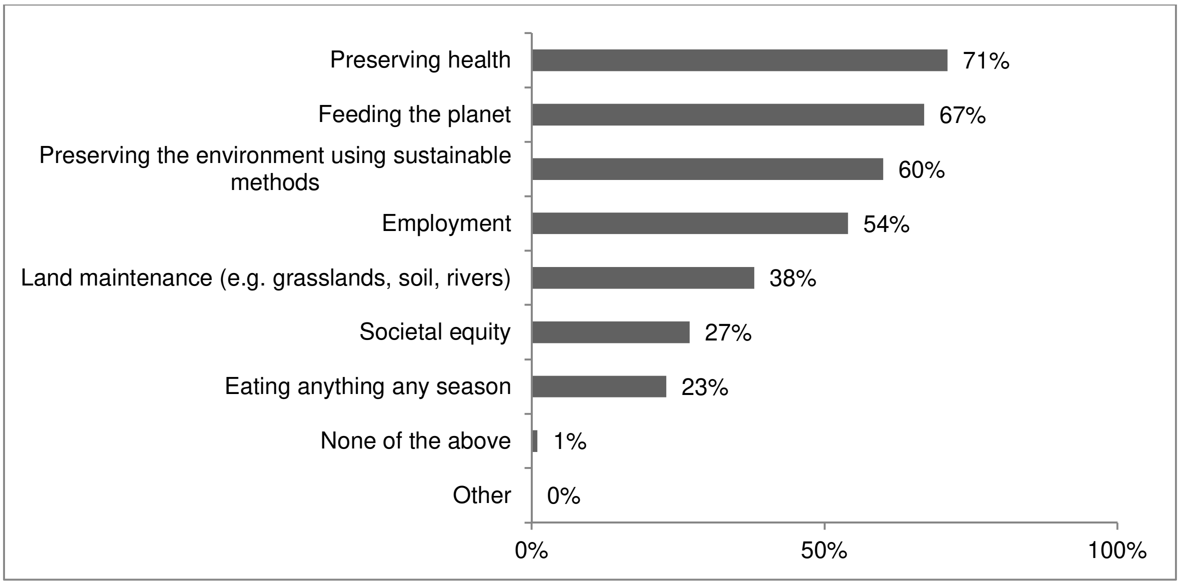

Fig 5. "In your opinion, food can have positive effects on…" (n=523; multiple answers possible)

2.3. Understanding of impact categories of life cycle assessment

2.3.1. Focus groups

In focus-group discussions, a few LCA impact categories seemed to elicit similar comments (Table 5). Some were perceived as similar because they used the same terms (e.g. "freshwater eutrophication" and "marine eutrophication", "freshwater ecotoxicity" and "marine ecotoxicity", "mineral depletion" and "fossil fuel depletion"). The "urban land occupation" and "agricultural land depletion" categories were considered complementary: when the former increases, the latter would decrease.

Focus-group discussions of overall perceptions of LCA impact categories highlighted differences in understanding (see the comments of the participants in the second column of Table 5). The participants understood most impact categories. Their spontaneous perceptions were similar to the real definitions. Two categories seemed particularly well understood. "Water depletion" was perceived as a decrease in freshwater availability because of droughts (due to climate change), overconsumption, and human conflicts over water. "Climate change" was described as global warming caused by globalization and by today's "intensive industrial way of life". This climate change would be the cause of the "natural disasters". Other categories were also understood after longer periods of reflection. For instance, "depletion of minerals and fossil fuels" was said to refer to the use of petroleum to produce energy for transportation and plastic. Participants added that these highly consumed resources were decreasing rapidly. Known reserves are indeed decreasing but the global amount of petroleum on the planet is still unknown. "Agricultural land depletion” and “urban land occupation” were described as the loss of agricultural land due to urban expansion. Standardization of agricultural production was also related to these categories. According to the participants, the current trend of urban agriculture could offset this negative effect. “Human toxicity” was related to diseases caused by waste and pollutants. Two less understood categories dealt with atmospheric pollution: “particulate matter formation” and “ozone depletion”. Two participants believe that the former was caused by vehicle emissions, while the latter was a reduction in natural protection from the sun. Both were correct but lacked information. Other causes of particulate matter exist (burning of wood, coal, oil). Hence, ozone depletion is a more complex reaction with gas pollutants released in the atmosphere.

The focus groups highlighted that some impact categories were perceived as too complex or confusing. For instance, “terrestrial acidification” was believed to be the loss of soil quality due to intensive agricultural production. Only two participants mentioned a decrease in pH, but none stated that acidity was caused by acid rain from substances released into the atmosphere. The “eco” and “toxicity” parts of the word “ecotoxicity” were perceived as contradictory, which confused participants. To them, “toxicity” referred to water and ecosystem pollution resulting from waste discharged into the environment and fertilizer use. However, “eco-” is often used as a prefix in French for “environmentally friendly”, which was perceived as a positive term. Thus, “freshwater and marine ecotoxicity” could refer either to water pollution or to good water management. Likewise, “terrestrial ecotoxicity” was also considered ambiguous, but to be similar to “terrestrial acidification”. For the “ionizing radiation” category, inaccurate subjects were discussed: participants talked about microwaves from ovens and smartphones instead of radioactive elements. However, two participants stated correctly that radiation could burn or alter DNA. For “freshwater and marine eutrophication”, participants imagined ocean pollution caused by ships dumping fuel and waste. These categories were also vaguely related to “water scarcity” or “something becoming small”. They did not perceive eutrophication referred to ecosystem damage due to nitrogen and phosphorus emissions. The least understood category was “photochemical oxidant formation” with technical words too difficult to understand. The participants initially confused it with “particulate matter formation”. However, four participants tried to determine the meaning by separating keywords, which resulted in a correct definition: a chemical reaction to light because “photo” means “light”, and “oxidant” is associated with “chemical”, which could indicate a chemical reaction. However, consequences of this impact were not clear to them.

At the end of focus groups, participants argued that the negative impact on biodiversity was missing. Participants also mentioned that LCA lacked positive impact categories to assess the environmental situation more comprehensively, such as feeding human populations, improving health from consuming organic products, and creating jobs.

2.3.2. Online survey

The understanding scores of the impact categories (range=2.7-4.1, scale from 1 to 5, Table 5) of the online survey showed that categories were understood in a similar way to that in the focus groups. The results of ANOVA calculated for the understanding scores of LCA impact categories are in supplementary material. The results showed that the understanding scores varied significantly among impact categories ($P<2.2e-16^{***}$). The two categories understood best, "water depletion" and "climate change", scored 4.1. Other relatively well understood impact categories scored from 3.6-3.9. Six impact categories scored from 2.7-3.3. "Freshwater/marine eutrophication" and "photochemical oxidant formation" were combined before the online survey according to focus groups' comments, they scored 2.8 and 2.7, respectively. They were the least understood. The age category × impact category interaction significantly influenced understanding scores ($P=1.696e\text{-}05^{***}$). For instance, young people (18-34 years old) understood "ionizing radiation" less well than other age categories ($P<0.05$) (Fig 6). Middle-aged people (35-49 years old) understood "photochemical oxidant formation" better than other age categories ($P<0.05$). Despite the significant impact category × region interaction ($P=0.0113^{*}$), the ranking of understanding scores did not vary among regions, due to the highly significant effect of impact category.

Table 4. Organic buyers' perceptions of life cycle assessment impact categories in a focus group (n=28) and mean understanding scores of the categories from an online survey (n=523; grades from 1 to 5). Gray shading groups categories by their mean understanding score.

Environmental impact category	Comments of focus group participants about the category	Online survey: Mean understanding score (from 1 to 5)	Standard deviation
Water depletion	Main comment: droughts. Causes are climate change, water waste, and overconsumption.	4.1	1.1
Climate change	Global warming, natural disasters due to overpopulation, globalization and industrial lifestyle. Endangered species.	4.1	1.0

Depletion of minerals and fossil fuels	Depletion of raw materials to make packaging, fuels and petroleum to transport products, coal, and metals. A consequence of overconsumption.	3.9	1.1
Human toxicity	Diseases due to waste and pollutants.	3.8	1.1
Agricultural land depletion and urban land occupation	Competitive relationship between agricultural land (land loss due to intensive and inadequately varied production) and urban land (increase in urban areas). Deforestation, decrease in agricultural land area, increased risk of species extinction.	3.7	1.0
Ozone depletion	Global warming, pollution, reduction in protection from the sun (ozone layer). Danger for human health.	3.7	1.0
Particulate matter formation	Particles are atmospheric pollutants from the production of energy (transport) and plastic, resulting in respiratory and cardiac problems.	3.6	1.0
Terrestrial acidification	Decrease in soil quality due to intensification. Increase in acidity due to acid rain.	3.3	1.2
Freshwater and marine ecotoxicity	“Eco”: Negative impact of plastics, fuel, and fertilizers on drinking water quality OR environmentally friendly (positive species protection)	3.2	1.2
Terrestrial ecotoxicity	Pollution (chemical products emitted into the environment) OR environmentally friendly	3.0	1.2
Ionizing radiation	Radio waves, microwaves, UV light, cosmic radiation. Genetic modifications and sickness.	3.0	1.2
Freshwater and marine eutrophication	“Eutrophication” not understood: mention of “scarcity” and that ships pollute the oceans.	2.8	1.3
Photochemical oxidant formation	Impact on air pollution. Chemical reaction to light. Photosynthesis, sun, chemicals, something that oxidizes.	2.7	1.2

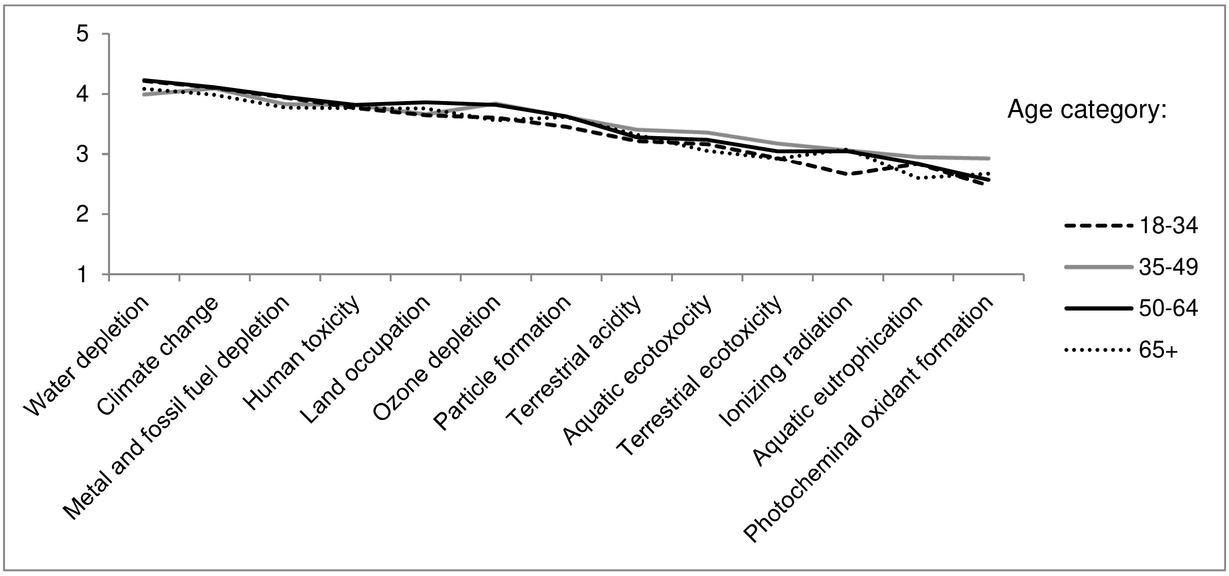

Fig 6. Mean understanding scores of LCA impact categories (from "not at all understandable" (1) to "completely understandable" (5)) of French organic buyers as a function of age categories (n=523)

According to the survey, French organic buyers obtained information about environmental impact categories most often from mass media, such as television and radio (64%), especially about climate change (73%) (Fig 7). Books, magazines, and newspapers were the next most common source of information about environmental impacts (39%). Responses depended on age category ($P<0.01$) and gender ($P=0.03$). χ^2 test results (data not shown) showed that women learned about environmental impacts from "relatives or acquaintances" more than men ($P<0.01$). Young people were more likely to select "social networks" ($P<0.01$) and less likely to select "books" ($P<0.05$) than other age categories, while 50-65 years old were more likely to select "social networks" ($P<0.05$). Senior citizens were less likely to select "relatives or acquaintances" than other age categories ($P<0.05$).

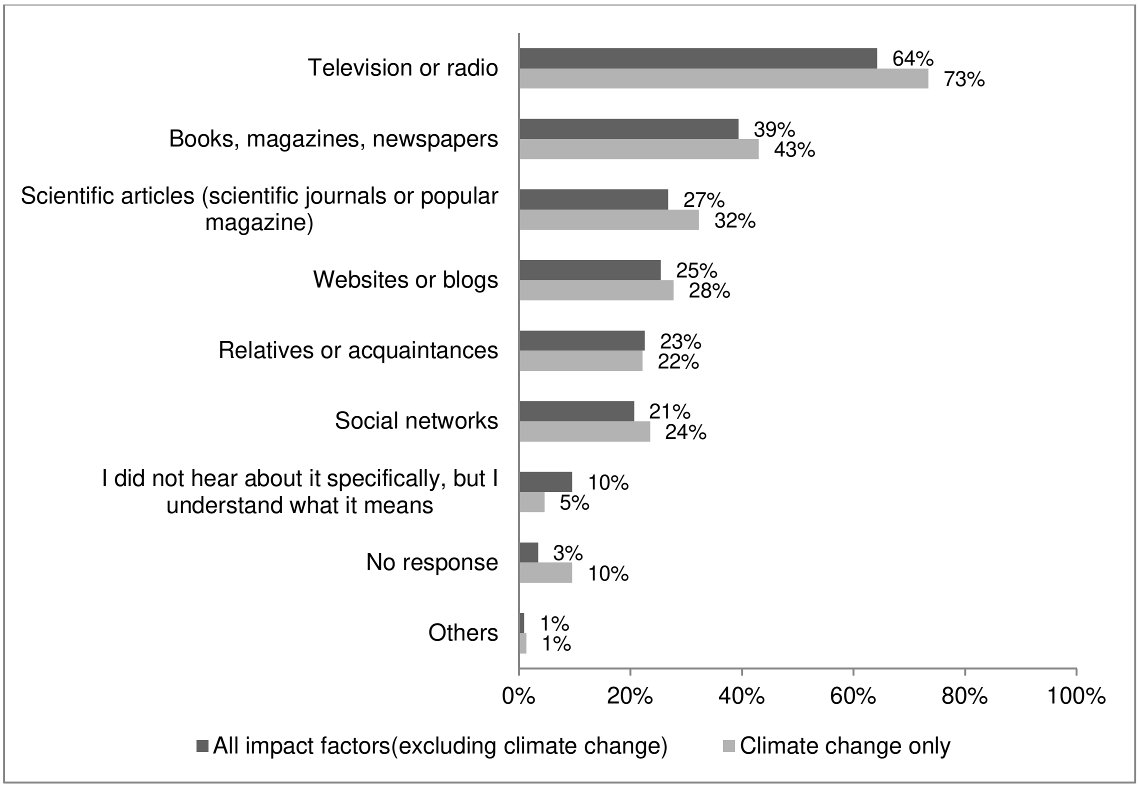

Fig 7. "From which media have you learned about LCA impact categories?" (N=523; multiple answers possible)

From a list of options (based on focus-group results), the positive impact of food "increase in sustainable and organic farming" was selected most frequently (61%), followed by the negative impacts "deforestation" (60%), "increase in dumping waste in the environment" (59%), and "overconsumption" (55%) (Fig 8). Approximately 50% of the respondents chose either the improvement or the deterioration in food quality, while 45% of them selected "biodiversity loss". The positive impacts "feed the planet", "improvement in human well-being" and "employment creation" were selected by 39%, 28%, and 20% of the respondents, respectively.

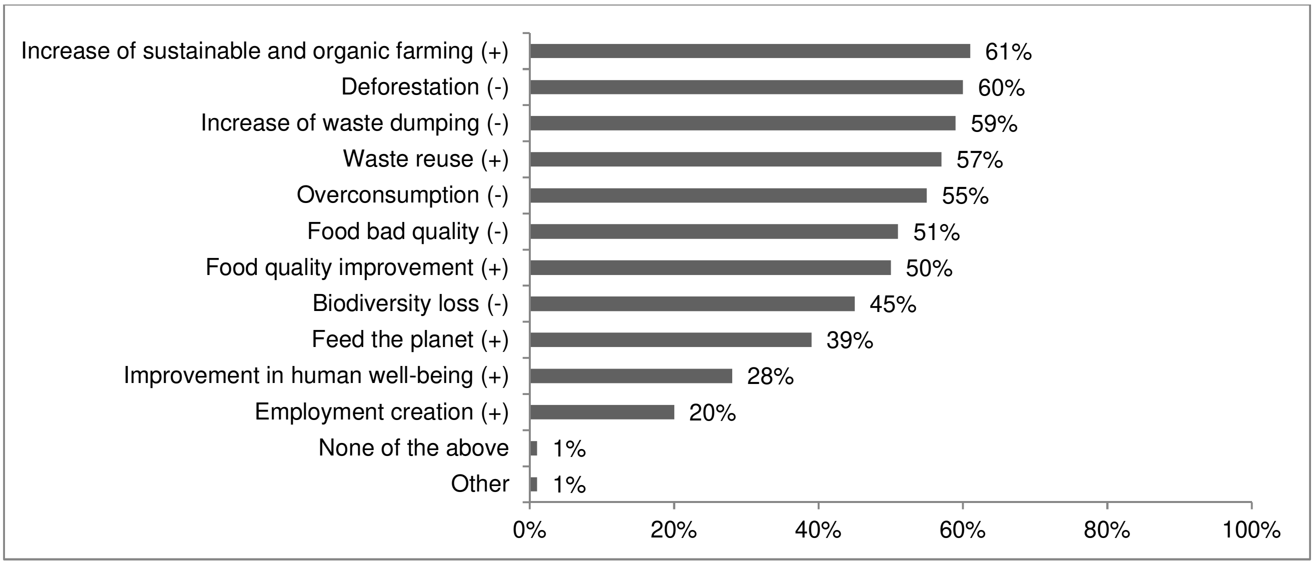

Fig 8. In your opinion, what other impact categories should be considered to assess environmental impacts of food more accurately?" (n=523; multiple answers possible)

3. Discussion

3.1. Sensitivities of organic buyers

The present study illustrates French organic food buyers' perceptions of environmental impacts of food. For these buyers, the environmental impacts mainly equaled to "pollution", but their perceptions went beyond that. They were able to identify activities that cause pollution, from agricultural activities (agrochemicals, intensification), to processing (over-packaging, intensification, producing outside of natural seasons), distribution (transport) and consumption (consuming outside of natural seasons, food waste, packaging waste). Long-distance transportation was perceived highly impacting the environment. However, the carbon footprint of product transportation per ton.km was lower for international and inland sea shipping than for domestic trucking (Wakeland et al., 2012). Organic buyers also perceived consequences of pollution on social aspects (i.e. health, employment). Thus, a major finding was that they considered not only environmental aspects but also social and economic aspects, the two other pillars of sustainability. Organic buyers perceived the overall system of relationships between the planet (environment) and human activities (economic and social activities). Even though participants in the focus groups never used the word "sustainable" to define their perceptions of the system, which confirms the results of Hauser et al. (2011), their perceptions refer to sustainability. According to Bastianoni et al. (2019), sustainability must be perceived as a holistic system that encompasses both the intensive environmental dimension and the extensive economic and social dimensions.

Interestingly, French organic buyers considered that direct impacts of foods on human health were more serious than environmental pollution. This finding was consistent with previous results showing that organic buyers are health-conscious and self-focused (Du et al., 2017; Hansen et al., 2018). Health is a key motivation for purchasing organic food (Massey et al., 2018), since organic consumers perceive that healthy products (including organic) are environmentally friendly (Lazzarini et al., 2016) and sustainable (Aschemann-Witzel, 2015). But the differences of environmental impacts of organic food are still uncertain (Meier et al., 2015). Other social aspects related to food production, such as job opportunities and fair trade, were perceived as important and positive economic dimensions.

Organic buyers' perceptions of life-cycle stages of food products were consistent with the reality of estimated environmental impacts of food. Agricultural production was correctly identified as one of the main stages responsible for environmental impacts of food products (Notarnicola et al., 2017b). Organic buyers thus believed that sustainable and organic farming were the main solutions to reduce environmental impacts of food because they use few or no synthetic pesticides. The literature on organic farming emphasizes not only the prohibition of synthetic pesticides but also the use of practices that protect soil quality, biodiversity (Tuomisto et al., 2012), human health (Mie et al., 2017), and improve animal welfare (Harper and Makatouni, 2002).

Organic buyers did not ignore other life-cycle stages. They considered that processing, distribution, and consumption generate large amounts of waste. This was in line with Notarnicola et al. (2017b) who recommend a better waste management. In the present survey, young organic buyers were more concerned about waste than other age categories. In opposition, senior organic buyers were more concerned about agricultural activities. The reason could be that seniors may have closer relationships with farmers than younger generations. It is interesting to note that reducing meat consumption was pointed out in the survey as the third most important factor in reducing the impact of food, after the demand for organic and sustainable agriculture. Some authors indeed sustain that a "sustainable diet" that includes more plants and less resource-intensive meat is a key concept of food sustainability (Bilali et al., 2019). Meat, especially red meat, has greater impacts on the environment than other foods and meat-free dishes contribute to human health and the environment (Hallström et al., 2014).

3.2. Understanding of LCA impact categories

The knowledge of the 17 LCA impact categories by French organic buyers depended on the complexity of the terms and the degree of media coverage. Technical terms such as "marine eutrophication" were complex to understand, which explained the lower understanding scores. "Climate change" was understood well. Although climate change is less visible in daily life than in the long term, it was covered by mass media. Organic buyers were able to assess how food products contributed to it (Shi et al., 2018). Other well-understood categories were more familiar in daily life. "Water resource depletion" for example was related to individual consumption. This was in line with a report of the European Commission on communication vehicles providing environmental Footprint information (Lupiáñez-Villanueva et al., 2018). Likewise, "mineral and fossil fuel depletion" was related to the manufacture of electronic and mechanical components of everyday objects. In addition, urban expansion and deforestation were identified as encroaching on agricultural land. But agricultural land also extended on natural areas. The present study showed that a criterion, if not known by the person, could have its meaning inferred from its name. This was an interesting result for the development of future eco-labels. Even though simple eco-labels are needed because consumers pay little attention to packaging labels (Orquin et al., 2019), consumers would not be completely clueless about the meaning of midpoint categories if some were used on products' packaging. Not all midpoint categories need to be displayed on food products. Some key effects can be chosen to show the global environmental effects, such as global warming and non-renewable energy categories, as used by Del Borghi et al. (2018). The choice of environmental impacts to display depends on the type of products analyzed.

Organic buyers criticized LCA that considered negative impacts only, thereby excluding potential benefits of food. To them, LCA did not indicate increases in sustainable farming, organic farming, or recycling. These practices are not environmental impacts per se but are actions for impact reduction. In LCA, an increase in recycling decreases all impacts of the waste recycled. LCA was criticized by the respondents for not indicating the capacity to "feed the planet", which in fact is already included in the calculation by the functional unit (e.g. a quantity of food). According to the organic buyers, the negative aspects such as deforestation and biodiversity loss were also lacking. But they did not know that deforestation was included in "land depletion" category. Biodiversity loss also exists as an impact category, for example in French life-cycle methodology (ADEME, 2012), but it is still difficult to assess due to high complexity and uncertainty (Pauchard et al., 2018; Winter et al., 2017).

The French organic buyers' perceptions of environmental impacts of food were similar to LCA impact categories. Their spontaneous perceptions had two levels. First the activities (e.g. production methods, waste) referred to inputs and outputs of production systems assessed in LCA. Second, damages referred to endpoint impact categories (damage to health, ecosystems and resources). Experts often use midpoint categories to assess environmental impacts of products, including food (Lemagnen, 2017; Notarnicola et al., 2017a). But they seem quite technical and may not be understood as such by buyers. Yet since 2015, midpoint categories served as a basis for environmental communication and product labeling in France (Ministry of Ecological and Solidarity Transition, 2019). Some studies began to provide a standardized method for estimating environmental impacts (Lupiáñez-Villanueva et al., 2018) using midpoint categories, endpoint categories, and scoring labels. The study of the understanding of these labels will complement our results which show an at least partial understanding of the mid-points by buyers of organic products.

3.3. Perspectives

The present qualitative and quantitative findings showed that French buyers' perceptions of the environmental impacts of food were broader than the LCA impact categories, while the impact categories were more detailed than organic buyers' perceptions. The buyers of organic food could be encouraged to sustainable attitudes and behaviors through communication by companies and politics. According to the French Ministry of Ecology, Sustainable Development and Energy (2013), there is a great interest in labels and communications that would inform and significantly improve consumers' purchasing decisions. The environmental communications by companies should give clear and understandable environmental information on products to the consumers. Another way to communicate via the media on the connection between health, social and environmental aspects, as recommended by Vega-Zamora et al. (2019). Isernia and Marcolin (2018) observed that the media increased awareness of food sustainability issues, and Molthan-Hill et al. (2019) showed that education about sustainability and climate change in schools led to sustainable attitudes. The present study did not evaluate the knowledge or impact of communication campaigns. It would be interesting to investigate how the media influence consumers' attitudes and behaviors toward the environment. Currently, LCA does not assess whether a product is truly sustainable because its standard methodology does not include thresholds of sustainability. Future work is needed in this direction.

The French organic buyers were sensitive to social aspects and biodiversity. The new "social LCA" method, tested for instance on sugar cane production (Du et al., 2019), begins to address the first issue. Likewise, biodiversity loss remains difficult to assess in LCA, but studies continue to investigate it (Crenna et al., 2019). Only the 17 well developed impact categories were presented to the participants of the focus groups and survey, but other categories could be tested in future research (e.g. soil quality, biodiversity).

French buyers of organic food products were studied as people sensitive to environmental aspects of food production. They could be pioneers in considering the environment through their food purchases and could positively influence the people that do not purchase organic food. When consumers were examined in a European study, Lupiáñez-Villanueva et al. (2018) found results similar to those of the present study: consumers can pay particular attention to midpoint categories such as climate change and water resources. In this regard, future studies could compare organic buyers' perceptions of environmental impacts of food to those of non-organic buyers' in order to show the potential for sustainable behaviors to be disseminated. In addition, the margin of error could be reduced by surveying more participants.

Finally, the present study focused on the final buyers of food. But not all the actors in the agri-food sector may understand the advantages of applying LCA to their activities. Future studies are needed to investigate how actors understand and integrate environmental considerations into their activities and communicate on them.

4. Conclusion

In the context of an increasing concern about impacts of food production on the planet, the present study elicited what French consumers of organic food (selected as regular buyers of organic food) spontaneously perceive when considering the environmental impacts of food and when considering the LCA impact categories used by companies. The originality of this study is also to explore the relationships between the organic buyers' perceptions of environmental impacts and what they understand of LCA impact categories.

Three major conclusions are drawn. Firstly, the interviewed organic buyers had an overall vision of sustainability when considering environmental impacts. The topics relating to sustainability (economic and social aspects) were also considered. Secondly, the interviewed organic buyers were not completely clueless when facing the 17 LCA midpoint categories. Although some categories remain complex to understand (ecotoxicity, eutrophication), most categories are known (e.g. climate change, water resources) or inferred from their names (e.g. mineral and fossil fuel depletion). Thirdly, the spontaneous perceptions of French buyers of organic food encompassed more aspects of sustainability than LCA impact categories did, including aspects such as biodiversity, employment and equity. However, the LCA categories were more detailed than respondents' perceptions regarding the environment pollution.

Finally, the present study is mainly addressed to companies producing organic products. It suggests that they can communicate the environmental values of their food products to French organic consumers. These communications must show a holistic view of the environmental impacts of food considering sustainability as a whole, and with the positive and negative impacts on the environment. Training professionals to evaluate and communicate environmental issues and sustainability issues into their development strategies seems necessary for the future of the food sector. On the research side, research must continue to improve LCA by taking into account factors that are complex to assess but demanded by organic consumers, such as biodiversity. To conclude, the awareness of the links and gaps between consumers' perceptions and life cycle assessments will enable future research to progress on both LCA and consumer understanding.

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