Diet and environmental impact: climate, water footprints, and biodiversity

Lukas Bertschinger
Chair of the müller-thurgau foundation
Innovation support for sustainability motivated transformation of
plant-based food-systems including horticulture, wädenswil, SWITZERLAND

Lukas Bertschinger presides the Board of the Müller-Thurgau Foundation, an institution providing applied R&D support for easing the transformation of plant-based food systems including horticulture. The foundation is named in memory of the world famous botanist, plant breeder, horticulturist, food technologist and microbiologist, Professor Hermann Müller-Thurgau, and cares for his interdisciplinary, science-based and impact-oriented transformational spirit by supporting R&D projects. Bertschinger, an agronomist, phytopathologist and horticulturist, careered in global and national applied research institutions as scientist and research manager, runs now his company klb-innovation providing expertise for agri-food value chain transformation and teaches at the Swiss Federal Institute of Technology ETH Zürich a Master course in horticultural science. As co-founder of several public private partnerships and spin-offs, he wants to foster co-creative value creation by better joining forces of the innovation ecosystem among the many actors of the value chains concerned.

If you want to do something for mitigating climate change, furthering a more efficient water use and strengthening biodiversity, eat healthier by consuming more fruits and vegetables! Whether this can be generalized beyond the specific country context of the three studies presented in this newsletter remains to be reflected. But the essence of these studies points into a promising and comprehensible direction.

A basic question remains then, however: If these studies represent reality, what prevents mankind and food systems from evolving naturally in this promising direction? Why is such scientific evidence not the leverage needed for transformation? There is no simple answer to these questions, for food systems are complex. As impact-driven plant-scientist and president of a foundation committed to sustainability-motivated innovation for food systems transformation, I increasingly miss in the transformation debate one aspect which would clearly incentivize the transformation needed: Studying and strengthening the value creation of the envisaged change of the agri-food value chain. Horticulture must keep its high value creation potential and entrepreneurial competitive spirit, which is a privilege of horticulture and provides perspective to the agri-food sector under pressure. But let's first have a look at the three mentioned, inspiring studies:

The study presented by Ellen Trolle & Anne Dahl Lassen estimates carbon footprint reduction with a transition from the current Danish diet to the new "Official Dietary Guidelines – good for health and climate", using two different databases based on life cycle assessment. This transition would reduce the carbon footprint of 31% to 43% depending on the database used.

The article of Ignazio Gallo assesses the effectiveness of a personalized food recommendation system that suggests recipes with lower water footprints ingredients to consumers, considering their food preferences. The system proposed understands user's behaviour and suggests recipes with lower water footprints and helps consumers to reduce their water footprint while having a healthier diet.

In their article, Henry Ferguson-Gow and Patricia Eustahio Colombo examine, in order to meet the increased need for vegetables, two scenarios where land used for meat production is converted to horticultural production and natural land covers. Results show that there is potential gain for biodiversity with an increasing trend in the number of species gaining in average habitable area, and also, with mitigating negative climate change impacts on biodiversity by land use changes associated with dietary shifts from less meat to more vegetables.

Enjoy reading, be aware of the impact of your dietary choices and keep considering the leveraging importance of value creation.

Reducing the carbon footprint following the Danish Climate-Friendly Dietary Guidelines

Ellen Trolle and Anne Dahl Lassen
Nutrition, Sustainability and Health Promotion Group, National Food Institute, Technical University of DENMARK

The global food system contributes to the environmental burdens and has been assessed as unsustainable. Indeed, it has a negative impact on greenhouse gas emissions as it accounts for approximately 21% to 37% of overall global anthropogenic greenhouse gas emissions (Rosenzweig, 2020). In line with the agreement of the Danish parliament upon the aim of a reduction of 70% in GHG emissions by 2030 compared to 1990 (Danish Ministry of Climate, 2020), "the Official Danish Dietary Guidelines-good for health and climate" were launched to contribute to reach this goal by transitioning to a more plant-based and still healthy diet. A plant-rich diet is low in meat and discretionary foods, high in fruit, vegetables, legumes, nuts, seeds, wholegrain products and potatoes, and moderate in fish, dairy products, eggs and vegetable oils (Lassen, 2020).

This study aims to estimate the carbon footprint reduction related to the transition from the current Danish diet to the new "Official Dietary Guidelines – good for health and climate", with two different databases, both using life cycle assessment :

- AU-DTU data set, based on an attributional life cycle assessment (with average literature-based data)
- BCD data set, divided in two sub-databases: one including the indirect land use change (BCD incl. iLUC) and one excluding the indirect land use change (BCD excl. iLUC). BCD data sets use a top-down hybrid approach and consequential LCA (with statistical data) (Schmidt, 2021).

Transitioning from the current Danish diet to the plant-rich diet leads to a great carbon footprint reduction

A transition to a plant-rich diet showed a great reduction of the carbon footprint at the retail gate: 31% with AU-DTU data (3.01 kg C02-eq per10 MJ), and 43% and 44% when using BCD excl. iLUC and incl. iLUC respectively (2.72 and 3.04 kg C02-eq per10 MJ). Similar reductions were also found when household losses were included in calculations (Table 1).

	Retail gate level		Household level	
	GHGe calculated with AU-DTU data set (kg CO2-eq/ 10 MJ)	GHGe calculated with BCD data set (kg CO2-eq/ 10 MJ)	GHGe calculated with AU-DTU data set (kg CO2-eq/ 10 MJ)	GHGe calculated with BCD data set (kg CO2-eq/ 10 MJ)
Current Danish diet	4.37	4.79 – 5.46*	4.78	5.29 – 6.04*
Climate-friendly diet	3.01	2.72 – 3.04*	3.32	3.02 – 3.38*

*values indicate the inclusion (low value) or non-inclusion (high value) of indirect land use change (iLUC) effects

Table 1 : GHGe of the current Danish diet and the Climate-Friendly diet assessed at retail gate level and household level with two data sets (mean)

Animal-based products are the greatest contributors of the carbon footprint reduction

- With AU-DTU data set:

In the current Danish diet, animal products accounted for 61% of the total carbon footprint while plant-based products accounted for 21%.

In the plant-rich diet, the carbon footprint estimated for animal products was 42% and 44% for plant-based products. The carbon footprint reduction was mainly due to the lower amount of beef and lamb in the plant-rich diet, which corresponded to a decrease of 0.63 kg CO2-eq per 10 MJ (Figure 1).

- With BCD data set:

In the current diet, animal products accounted for 69% and 71%; and plant-based products accounted for 16% and 14%, excl. and incl. iLUC respectively.

In the plant-rich diet, animal products accounted for 47% and 48% and plant-based products for 41% and 40% excl. and incl. iLUC respectively. The lower amount of beef and lamb accounted for a decrease of 1.7 kg CO2-eq per 10 MJ, which is 2.6-fold the reduction from beef and lamb with AU-DTA data (Figure 1).

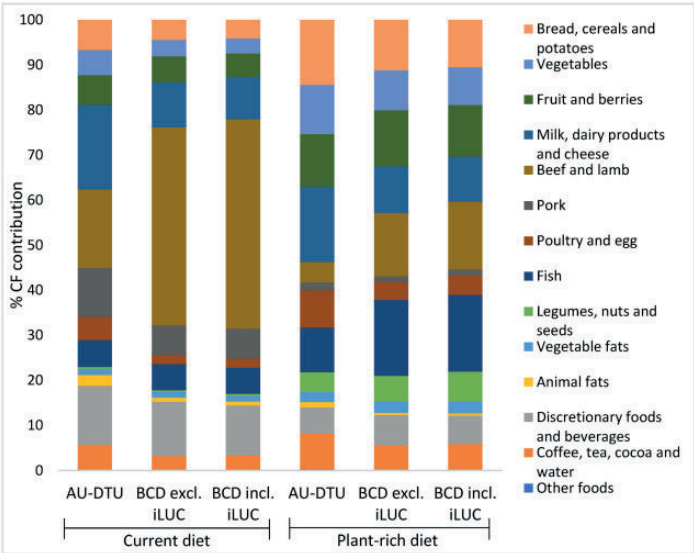

Figure 1: Proportion (%) of the total carbon footprint from selected food groups in the current and plant-rich diets (10 MJ), estimated based on three sets of data (AU-DTU, BCD excluding iLUC and BCD including iLUC); at the retail gate.

Transitioning to the climate-friendly Danish diet involves to increase the consumption of plant-based products, such as vegetables and legumes and would lead to a carbon footprint reduction due to a lower consumption of meat, especially beef and lamb. The different carbon footprint reductions show the importance of the databases and methodologies selected while developing dietary guidelines.

KEY MESSAGES

- Transitioning to the Danish Climate-Friendly Guidelines would reduce the carbon footprint of 31% according to a database, and 43% according to another one.
- Ruminant meat contributes the most to the carbon footprint reduction.
- LCA methodology and carbon footprint databases are important to be considered while developing guidelines to promote dietary change.

METHODOLOGY

The study estimated the carbon footprint of two diets:

- The current diet for Danish people: this study includes data from the Danish National Survey on Dietary Habits and physical Activity (DANSDA) 2011-2013, for adults aged 18-64 years old (n=2492). Food intake was estimated per person/day and was calculated per 10 MJ.
- The reference diet behind the Danish Foot Based Dietary Guidelines: a modelled plant-rich diet designed for 6-65 years olds people and to comply with the EAT-Lancet Commission's global reference diet, taking national health based dietary advice and national food availability and culture into account. It was achieved using Danish food composition data and food consumption data for adults aged 15-75 years (n=3189).

Carbon footprints of diets were estimated with two databases, both using life cycle assessment:

- One developed by Arhus University and the Technical University of Denmark (AU-DTU data), based on an attributional life cycle assessment (with average data) where all the processes are considered within defined system boundaries.
- And the Danish Big Climate Database (BCD data) developed by the think tank CONCITO. BCD is divided in two data sets: one including and the other excluding the indirect land use change (iLUC). BCD data sets use a top down hybrid approach and consequential LCA (with statistical data) which is an economic method that assumes a direct correlation between cost and environmental impact, where the system boundary is retail gate.

Food intake was calculated per 10 MJ as it is the approximate daily reference energy requirement for adults according to Nordic Nutrition Recommendations 2012.

The estimation of the carbon footprint of diets was done at two levels: retail (including primary production and the following processes: processing, transport, packaging, storage, losses along the chain to the point of sale (and cooking at home); home (adding to the previous assessment including the impact of food waste and cooking at home).

Based on: Trolle E, et al. Carbon Footprint Reduction by Transitioning to a Diet Consistent with the Danish Climate-Friendly Dietary Guidelines: A Comparison of Different Carbon Footprint Databases. Foods. 2022 Apr 13;11(8):1119.

Food Recommendations for Reducing Water Footprint

Ignazio Gallo
Department of Theoretical and Applied Sciences - DISTA, University of Insubria, ITALY

Water use is one of the critical aspects of planetary health, especially nowadays where we face wasteful water management and issues such as water scarcity. It is one of the most pressing environmental issues since water is a resource that both human and planet need to live (Rijsberman, 2006). The food industry is one of the most water-intensive industries, as every food product needs a particular amount of water to be produced (Hoekstra, 2003). To measure the water use, the metric Water Footprint has been introduced and defined as the total amount of freshwater used to generate consumed goods (Hoekstra, 2009). It has been shown that a diet high in vegetables and legumes and low in red meat reduces user's water footprint while improving health (Blas, 2016).

The study presents and assesses the effectiveness of a personalized food recommendation system that suggests recipes with lower water footprints ingredients to consumers, considering their food preferences. The system is based on two datasets: Planeat.eco, an Italian website selling ready ingredients and instructions for cooking recipes; and a dataset collected from Food.com, an American recipe website.

A system created to suggest tailored recipes, adapted to users' behavior, with lower water footprints

The developed system gives two score: a score to recipes from 1 to 5 (recipes with the lowest water footprint to the highest one), and a score to the user (from A to E) based on his orders history. The system combines these two scores and can thus recommend the user specific recipes that belong to a certain category with a lower water footprint than the ones consumed by the user.

Water footprint data represents the water used in production stage only. They were collected from the Water Footprint Network (WFN), an official collaborative platform, and from the HEALabel website for ingredients not provided by the WFN.

The system is therefore made up with three units: 1/ a recipe classifier that sorts recipes based on their water footprint, 2/ a user classifier according to user's history, and 3/ a recommendation algorithm that considers consumer's favourite recipes in order to recommend the best combinations.

Fruit, vegetables, and grains have a minimal water footprint whereas animal-based foods require large use of water resources to be produced

According to the WFN, beef has a water footprint of 15,415 l/kg which is 70 times higher than the water footprint of vegetables as their footprint do not exceed 250 liters per kg (Figure 1). Statistics shown in the following figure are also confirmed by scientific studies, highlighting that a healthy diet high in fruit and vegetables is more sustainable in terms of water footprint than those high in animal-based products (Tompa, 2022).

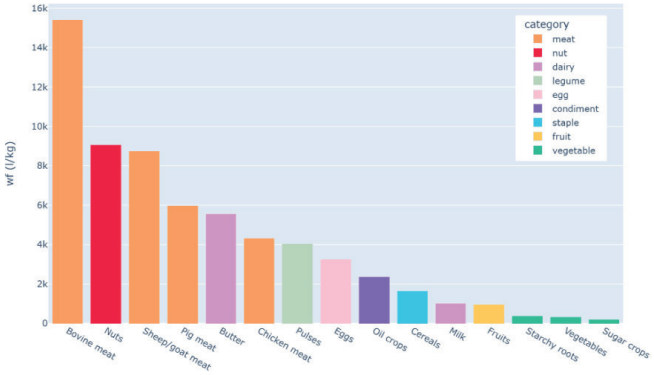

Figure 1: Water footprint used in production (in l/kg) of the different food ingredients categories

The proposed system understands the user's behaviour, suggests tailored recipes, and reduce water footprints

When evaluating the algorithm of this system to determine whether it takes users' behaviour into account, the results showed that recipes recommendations were comparable to other systems in terms of Root Mean Square Error (RMSE) ratios. This demonstrates that the suggested recipes are quite similar to the user's dietary patterns.

As regards the effect of the system on water footprint reduction, results showed that, the average water footprint of recipes was reduced by roughly 50% with the Planeat.eco dataset, and by 52% with the Food.com dataset (from around 23k L to 10,5k L).

Therefore, the system developed guarantees a significant water footprint reduction with tailored recommendations for the users.

In conclusion, the authors suggest the Mediterranean diet as a reference diet as it is high in fruit, vegetables, fish, and little meat. The system they propose understands user's behaviour and suggests recipes with lower water footprints while improving the diet.

KEY MESSAGES

- The system proposed understands user's behaviour and suggests recipes with lower water footprints
- The system helps consumers to reduce their water footprint while having a healthier diet
- Results of this system are reliable to results from the literature.

METHODOLOGY

The study explores the literature and provides an overview of similar systems of recipes recommendations and works about reducing water footprint in production. A comparison of RMSE ratios was made with two papers using the same data and methodology.

The two datasets used in the system are:

- Planeat.eco, an Italian website delivering ready ingredients with instructions for cooking recipes. It contains 813 recipes provides information on 551 users history and orders for a one year period.
- Food.com, an American dataset that provides over 180k recipes and over 700k user reviews of recipes, covering 18 years of user interactions and uploads.

Results of the system are based on two metrics: the average water footprint reduction of the ten first recipes suggested to the user, and the Hit Ratio which is the success of recipes, showing if the recipes are similar to the user's diet. The RMSE has also been used to do the comparison with literature.

Based on: Gallo et al., Food Recommendations for Reducing Water Footprint, Sustainability 2022, 14, 3833.

Potential positive effects of consuming more vegetables on biodiversity and land use

Henry Ferguson-Gow[1], Patricia Eustachio Colombo[2]
1. Centre for Biodiversity and Environment Research, University College London, UK
2. Centre on Climate Change and Planetary Health, London School of Hygiene & Tropical Medicine, London, UK; and Department of Global Public Health, Karolinska Institute, Stockholm, SWEDEN

According to several emerging studies, a shift toward a diet with more fruit and vegetables and less animal-derived protein's is not only associated with the reduction of mortality from cardiovascular diseases and some cancers (Yip, 2019) but also has benefits on the environment such as a reduction in greenhouse gas emissions and land use (Eustachio, 2021). In fact, animal-derived foods require more land per kcal dietary energy produced than plant-based foods. For instance, in UK, 85% of the farmland is used to rear animals while animal-based products provide only 32% of dietary energy consumed. Replacing meat by fruit and vegetables could then reduce land use, on a per-kcal basis (De Ruiter, 2017). Global studies have shown that food systems changes could reverse the negative trends in biodiversity, on different environmental indicators (Leclère, 2020).

This study explores how biodiversity conservation, climate change mitigation and public health can be enhanced in a politic way, at a national level in Great Britain. In order to meet the increased need for vegetables, authors examined two scenarios where land used for meat production is converted to horticultural production and natural land covers.

Two scenarios and three example cases were considered to evaluate the potential impacts of land use shifts on biodiversity

In order to examine the potential impacts of land use shifts on biodiversity, two scenarios were created:

A scenario of domestic production only (DO): which consists of expanding horticulture in Great Britain to meet all additional demand for vegetables. In this scenario, 5% of grazing land is converted to horticulture, and 18% to natural land cover.

A scenario of domestic and import productions (DI): where current domestic production/import ratios are maintained. In this scenario, 3% of grazing land is converted to horticulture, and 27% to natural land cover.

A gain for biodiversity, with an increasing trend in the number of species gaining in average habitable area

Across all Great Britain, the average habitable area of 814 species is estimated to be 28% of the land area where land use could change.

For each 10% of grazing land converted to horticulture, average habitable area decreases by 1 to 2%, while every 10% of grazing land converted to natural land cover leads to a 6% increase of average habitable area.

These results show that, on average, conversion of grazing to horticulture leads to a small loss of biodiversity but it is outweighed by the gains from converting the surplus grazing land to natural cover. All land conversion scenarios showed a potential gain of biodiversity, with more species gaining in average habitable area than losing.

Indeed, for each specie losing >10% habitable area, approximately 6.3 and 9.8 species will gain >10% habitable area, with the DO and the DI scenario respectively. Land conversion scenarios show that maintaining the domestic production/import ratio has larger benefits for biodiversity.

Climate change negative impacts on biodiversity could be mitigated by land use changes associated with dietary shifts from less meat to more vegetables

Climate change has strong negative impacts on biodiversity. Indeed, when including climate change in the scenarios, the average habitable area dropped from 28% to 21%, and the number of species losing habitable area exceeded the number gaining habitable area: for each specie gaining >10% habitable area, 4.1 and 2 species will lose >10% habitable area, respectively under the DO and DI scenario.

These results show that climate change leads to a loss of habitable area larger than all the land conversion scenarios. Although, as shown in table 1, climate change impacts would be mitigated by land use changes associated with a dietary shift from less meat to more vegetable consumption. For example, with climate change, the average habitable area increases from 21% without land changes to 23% and 25% with the DO and DI scenario respectively.

Grazing land conversion scenario	Average habitable area	Number of species with >10% habitable area increase	Number of species with >10% habitable area decrease
Baseline : no land conversion, without climate change	0,283	–	–
Scenario DO, without climate change	0,319	485	78
Scenario DI, without climate change	0,343	599	63
No land conversion, with climate change	0,205	23	649
Scenario DO, with climate change	0,233	125	485
Scenario DI, with climate change	0,253	213	406

Table 1: Projected biodiversity responses to land use and climate change scenarios (Adapted from Ferguson-Gow et al., 2022)

According to the method employed, the present study concludes that the best outcome for biodiversity in Great Britain is to maintain the domestic production/import ratio (Scenario DI). However, the potential impact of diet changes beyond national borders was not considered in the study. Also, an association between land use changes and a shift toward healthier diets could have benefits for biodiversity and potentially increase resilience to climate change. The dietary energy equivalent replacement of meat with vegetables has the potential to reduce land use for agricultural production and freeing up land for other uses.

KEY MESSAGES

- There is a potential for gains to biodiversity: more species would increase their habitable area than species that would loss some
- Maintaining the domestic production/ import ratio is more effective than relying on local production.
- Negative climate change impacts on biodiversity could be mitigated by land use changes associated with dietary shifts

METHODOLOGY

- Species were defined by the UK Joint Nature Conservation Committee and represented within the priority species indicator and the pollinating insects indicator, bolstered by additional bee and hoverfly species.
- Climate data came from bioclimatic variables obtained from CHELSA (Karger, 2017) to predict habitable suitability for the chosen species. Mean annual temperature, isothermality, mean annual precipitation and precipitation of the wettest month were used as predictors.
- A two-stage modelling process was employed, first estimating the climatic envelope of each specie and then the effects of land use on species occurrence.
- Impacts on biodiversity of land use change in scenarios were assessed with Species Distribution Models (SDMs) for 814 species in 4km2 grid cells across Great Britain. The data set used divides the UK into 2 x 2 km cells and describe the proportion of each cell that falls into 24 different land use classes.

Based on: Ferguson-Gow et al., Potential for positive biodiversity outcomes under diet-driven land use change in Great Britain. Wellcome Open Research 2022, 7, 147.

Scientific news

Long-term trends in obesity prevalence by socio-economic group in five European countries and the USA: The relevance of the diffusion of innovations theory

In order to examine whether recent obesity prevalence trends are in line with the diffusion of innovations theory, a team of researchers in the Netherlands studied long-term trends (from 1978 to 2019) by socioeconomic group (SEG) in England, France, Finland, Italy, Norway, and the USA. In all countries, except among American men, lower educated groups had higher obesity prevalence than higher educated ones over the entire examined period. Increases across educational groups were comparable until about 2000. A stagnation was then observed in obesity prevalence, first among higher educated in Finland, France, Italy, and Norway, followed then by lower and middle educated Italian women and Finnish men, and lower educated groups in USA and England. This stagnation observed in most countries is consistent with the diffusion of innovations theory and might be explained by early implementation of health prevention behaviours (increasing physical activity and reducing ultra-processed food and calorie intake). However, the fact that recent stagnation is mainly observed by higher SEG in most countries implies that lower SEG are likely to face the future burden of obesity and that, as a result, inequalities may widen further.

Kagenaar E, et al. Long-term trends in obesity prevalence by socio-economic group in five European countries and the USA: The relevance of the diffusion of innovations theory. Obes Facts. 2022 Sep 15.

Is breakfast a new opportunity to increase children total daily vegetable intake?

In many Western countries most children do not eat enough vegetables. Innovative and pragmatic ways are then needed to increase their daily intake. According to a team of English researchers, increasing children's exposure to vegetables at breakfast from an early age would allow for the development of a positive association between eating vegetables and breakfast, thus providing another opportunity in the day where vegetables might be regularly consumed by children. While the habit of serving vegetables for breakfast is unusual, yet there is no nutritional, physiological or medical reason why they should not be eaten then. This paper highlights the reasons why, conversely, vegetables should be routinely offered to young children at breakfast time in countries where this may not be the norm. However, the feasibility and acceptability of such intervention should be assessed.

McLeod CJ, et al. Would offering vegetables to children for breakfast increase their total daily vegetable intake? Public Health Nutr. 2022 Sep 12:1-5.

Are modern plant-based diets becoming unhealthy and less environmentally sustainable?

Jennie Macdiarmid from University of Aberdeen gave a plenary lecture on this topic during The Nutrition Society Summer Conference 2021. She highlighted the challenges of the trend towards a plant-based diet, a foundation for healthy sustainable diets. As consumers perceive plant-based diets as inconvenient, the emerging 'modern' plant-based diet is very different from a more traditional diet of pulses, vegetables, and whole grains. Many produced plant-based foods are in fact ultra-processed, high in energy, fats, sugar, and salt and thus, present a concern as regard to both public health and environmental impact. Indeed studies show that younger people who have been vegetarians for a short duration consume much more ultra-processed plant-based foods. While convenient, desirable and affordable plant-based foods have their place in encouraging dietary change towards a more sustainable diet, there is a need to ensure that they do not unconsciously lead to a shift that is ultimately neither healthy nor sustainable.

Macdiarmid, J. (2022). The food system and climate change: Are plant-based diets becoming unhealthy and less environmentally sustainable? Proceedings of the Nutrition Society, 81(2), 162-167.

Traditional plant-based diets are associated with lower sarcopenia prevalence

A recent narrative review including 18 studies presents the association between dietary patterns or food groups and sarcopenia. Mediterranean and Japanese dietary patterns were associated with lower sarcopenia prevalence while Western diet was significantly associated with a higher risk. Beyond the well-documented significant association between protein intake and sarcopenia, an increased intake of fruit, vegetables, and both fruit and vegetables, was significantly associated with a lower risk of sarcopenia. These findings highlight the key role of diet for the prevention and treatment of sarcopenia among older adults.

Nazri NSM, et al. Natural Food for Sarcopenia: A Narrative Review. Malays J Med Sci. 2022 Aug;29(4):28-42.

Do carbon footprint labels promote climatarian diets? Evidence from a large-scale field experiment

A recent study estimates the effect of carbon footprint labels on individual food choices and quantifies potential carbon emission reductions. This work is based on data from a large-scale field experiment at five university cafeterias with over 80,000 individual meal choices. Findings show that this type of label has statistically significant impacts on meal choices, with a consumer shift from high-carbon to mid-carbon impact meals by 2.7 percentage points. However, no effect was observed on low carbon meal choices. Carbon footprint labels has also led a transition from meat and fish-based dishes towards vegan/vegetarian dishes by 1.7 percentage points. Likewise, results showed that carbon footprint labels caused a reduction of 27 g CO2 in the average footprint consumed per 100 g servings.

Lohmann PM, et al. Do carbon footprint labels promote climatarian diets? Evidence from a large-scale field experiment. Journal of Environmental Economics and Management 114 (2022) 102693.