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Plant-based default nudges effectively increase the sustainability of catered meals on college campuses: Three randomized controlled trials

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Background: Literature suggests limiting consumption of animal products is key to reducing emissions and adverse planetary impacts. However, influencing dietary behavior to achieve planetary health targets remains a formidable problem.

Objective: We investigated the effect of changing the default meal option at catered events—from meat to plant-based—on participants' meal choices using three parallel-group, balanced, randomized controlled trials (RCT), and use these experimental results to project differences in plant-based default vs. meat default events on greenhouse gas emissions (GHGEs) (kg CO_{2-eq}), land use (m^2), nitrogen (g N), and phosphorus (g P) footprint.

Methods: Data collection was performed at three catered events ($n = 280$) across two college campuses. The selected experimental sites used convenience sampling. Events consisted of a graduate orientation, sorority dinner, and academic conference. Eligibility of individual participants included being 18 years or older and an invitation to RSVP for an enrolled event. Participants were randomly assigned to one of two groups: the control group received a RSVP form that presented a meat meal as the default catering option; whereas the intervention group received a form that presented a plant-based meal as the default. The primary outcome of interest in each group was the proportion of participants who selected plant-based meals. To explore environmental impacts, we modeled the footprints of four hypothetical meals. Using these meals and RCT results, the impact (GHGE, land use, nitrogen, phosphorus) of two hypothetical 100-person events was calculated and compared.

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Results: In all, participants assigned to the plant-based default were 3.52 (95% CI: [2.44, 5.09]) times more likely to select plant-based meals than those assigned to the meat default. Using these results, a comparison of hypothetical events serving modeled meat-based and plant-based meals showed a reduction of up to 42.3% in GHGEs as well as similar reductions in land use (41.8%), nitrogen (38.9%), and phosphorus (42.7%).

Conclusion: Results demonstrated plant-based default menu options are effective, providing a low-effort, high-impact way to decrease consumption of animal products in catered events. These interventions can reduce planetary impact while maintaining participant choice.

KEYWORDS

meat consumption, sustainable diet, default nudge, planetary boundary, carbon footprint, environmental impact, choice architecture

Introduction

Human-driven activities in food production, distribution, storage, consumption, and disposal account for roughly 23% of global greenhouse gas emissions (GHGEs). A disproportionate contribution of food-related emissions occurs in animal agriculture, which results in more than half of food-related emissions despite representing far less than half of average daily caloric intake in most societies (Gerber et al., 2013; Allen and Hoff, 2019; IPCC, 2020). A growing body of literature suggests that current food consumption patterns are unsustainable and if not modified, will prevent humanity from staying within established targets for anthropogenic climate change (Springmann et al., 2018a; Clark et al., 2020). A host of changes are needed across the food system and among consumers in order to establish a resilient food system and help combat these negative planetary health impacts.

Demand-side changes, such as adopting a flexitarian or plant-based diet, defined as "..fruits, vegetables, whole grains, legumes, nuts, seeds, herbs, and spices and excludes all animal products" (Ostfeld, 2017), represent impactful strategies for mitigating GHGEs and other environmental footprints (Hallström et al., 2015; Springmann et al., 2018b) [We define plant based as Ostfeld, 2017 does: a diet that consists of "…fruits, vegetables, whole grains, legumes, nuts, seeds hers, and spices and excludes all animal products."; though it is sometimes also used in context with diets that include animal products such as the Mediterranean diet (Scoditti et al., 2022)]. However, to date, efforts to promote the adoption of more plant-heavy diets have yielded little success (Vizcaino et al., 2020). Even among those who identify as vegan or vegetarian-roughly 10% of the global population-many are unable to maintain these diets consistently (Herzog, 2014; Nezlek and Forestell, 2019). This is despite the fact that plant-based food choices, in particular meat-replacement products, have grown considerably in the marketplace (Godfray and Oxford Martin School, 2019; Tzivia et al., 2020). Therefore, more research is needed to find low-cost and effective strategies for changing dietary behavior.

Choice architecture

While individuals' dietary choices are a reflection of important factors such as economic, social, cultural, and infrastructural influences, there are relatively simple, low cost strategies that can influence consumers to make more sustainable decisions. Choice architecture tools, or "nudges," are a promising set of interventions that can change behaviors by influencing the social, physical, or psychological environment in which people make choices (Thaler and Sunstein, 2008). Nudging aims to influence people's behaviors by changing the way an individual choice is presented, without restrictions or consumer awareness of the influence (Vandenbroele et al., 2019). More specifically, a wide range of choice architecture tools have been implemented and shown to promote environmentally friendly and healthy behaviors across a variety of settings (Garnett et al., 2019; Rare the Behavioural Insights Team, 2019).

One particularly effective choice architecture tool is the default nudge (i.e., the preselected option on a survey or form). Defaults leverage the human tendency to choose the path of least resistance (Van Gestel et al., 2020) to effect behavioral change. The default option also implies that the preselected option is the recommended choice (Carroll et al., 2009; Jachimowicz et al., 2019), which further motivates individuals to stay with the default. Research has shown that defaults have effectively achieved desired outcomes for organ donation, retirement savings, and green energy consumption in multiple countries (Thaler and Benartzi, 2004; Abadie and Gay, 2006; Pichert and Katsikopoulos, 2008).

Sustainable defaults

The default nudge is part of a specific class of choice architecture tools that are especially effective in the domain of food behaviors (Campbell-Arvai et al., 2012; Mertens et al., 2022). Defaults have been shown to shift diets toward healthier and more sustainable food options, which suggests that they might be effective for reducing meat consumption (Vecchio and Cavallo, 2019; Parkin and Atwood, 2022). Despite this promising evidence, a recent literature review by Meier's et al. (2021) emphasized that research on default nudges specifically for reducing meat consumption is still limited. Furthermore, most existing default studies targeting dietary behavior have been conducted in Europe and the majority utilized defaults in menu design or by controlling portion sizes (Campbell-Arvai et al., 2012; Meier's et al., 2021; Perez-Cueto, 2021). Additionally, only one study has attempted to quantify the potential environmental impacts based on the results of their experiment (Kurz, 2018).

Large institutional events are places where reducing individual meat consumption through the default nudge could scale to have a significant impact. For example, previous experiments among participants (n = 330) at three higher education conferences in Denmark revealed that plant-based meal selections in online pre-conference RSVP requests increased by 81-percentage points when a vegetarian buffet was presented as the default choice (Hansen et al., 2021). However, research testing the effectiveness of the default nudge to increase plant-based meal consumption is limited. To address the limitations in existing literature, the current study was designed to evaluate the effect of plant-based default nudges by: (1) testing the efficacy of plant-based meal defaults at three events on college campuses in the U.S., (2) estimating the environmental impact of the experimental results, and (3) comparing the impacts to the per-meal per-capita planetary boundaries suggested by the EAT-Lancet Commission's Global Planetary Health Diet (Willett et al., 2019; Hansen et al., 2021). The novelty of this work stems from its setting in US higher education institutions and modeling the potential environmental footprint savings possible from utilizing the default nudge.

Methods

We conducted a two part study. First, we carried out three parallel, [1:1] balanced RCTs. Then we quantified the potential environmental impact reduction of these interventions using modeled meals and lifecycle assessment (LCA) data. The RCT portion of our study was an extension of the methodology of Hansen et al. (2021). Whereas Hansen tested the impact of a plant-based default on three buffets at academic conferences, we tested the default on two individual meals and one buffet at various campus-related events.

TABLE 1 Details for three catered events included in study.

Campus	Department or Organization	Event description	n
Harvard	N/A	Workshop on Behavioral Insights in Health (BIH)	91
UCLA	Civil and Environmental Engineering (CEE)	Graduate student orientation	108
UCLA	Panhellenic Sorority	DG Monday night dinner	81

Randomized trials

Eligible participants were adults over the age of 18 who attended one of our three events. Data was collected at three independent events held at the University of California at Los Angeles (UCLA) and Harvard University, two higher education institutions in the U.S. The two events at UCLA were held in 2021: a graduate orientation for the Civil and Environmental Engineering Department and a dinner at a UCLA-affiliated sorority. The event at Harvard was a workshop on Behavioral Insights in Health (BIH) in 2017 (Table 1). The events would have been planned and held regardless of study enrollment. No demographic information was collected about participants.

At each event, event operators (EOs) decided which participants to invite, how the RSVP survey would be distributed, and which catering options to choose. The default intervention was implemented through a question on the RSVP survey. EOs sent participants a link to a Google script that randomized them into two groups: a control group and an intervention group, using a randomization function. This function then rendered one of two RSVP surveys in Google forms. Simple randomization was conducted in real-time when participants clicked on the RSVP survey link. A Google script was programmed to use the Math.floor() and Math.random() functions to select and render one of two links in an array of web links containing the survey options (control and intervention). Randomization was balanced between groups without blocking or stratification.

Each survey was identical save for the question about meal preferences for the event. No questions were asked prior to the meal preference question and the question was required. The control group received a question stating that the default meal contained meat, and participants were required to opt out if they desired a plant-based meal. Alternatively, the experimental group received the same survey with a variation of the meal preference question. The experimental group received a plant-based default meat option and participants were required to opt out if they wanted a meal containing meat.

The interventions themselves employed similar sentence structure, although wording differed slightly across events.

Specific wording of the intervention question can be found in the Supplementary material in section I. The RSVP survey purposefully conveyed endorsement and endowment by clearly stating the default meal option (plant-based or meat). The survey also required participants to click a button to select an alternative option if they desired a different meal (plant-based or meat). The buffet event RSVP survey took this process a step further by indicating that the default meal would be in the form of a buffet (where participants presumably would be given more options) and provided a space where participants could request an individual meal with no guidance on what that meal might be. The Harvard-BIH EOs interpreted plant-based as vegetarian—a superset of plant-based foods—in their RSVP survey, whereas the other events used our definition of plant-based. Hypothetical meals were analyzed with both plant-based and vegetarian meals to account for this discrepancy.

The implementation of the plant-based default and the actual menu items at each event differed. However, the primary outcome of interest in each group was the proportion of participants who selected plant-based meals. That proportion was used to calculate the environmental impact of hypothetical menu scenarios. The serving method and actual foods distributed at each event were not necessary for the goals of this research.

Caveat that Harvard event operators interpreted plant based as vegetarian. Whereas the other events used our definition of plant based. Hypothetical meals were analyzed with both fully plant based and vegetarian to account for this discrepancy.

Statistical analysis

The primary outcome was the proportion of participants who selected a plant-based meal. This was assessed by counting meal selections in each group among participants who indicated that they planned to attend the event. To compare the control and intervention groups, we used R (R Core Team, 2022) to fit two models within each site (Stapleton, 2009). First, we fit a log-binomial model to obtain risk ratios, a ratio of the probability that a participant in the intervention group selected the plant-based meal option to the probability that a participant in the control group would do so. Risk ratios >1 indicate that the intervention effect was in the desired direction. Second, we fit a linear regression model with heteroskedasticity-consistent robust standard errors to obtain differences in probabilities of plant-based meal selection within each group (White, 1980; Kleiber and Zeileis, 2008; Zeileis et al., 2020). To aggregate the results of all three RCTs and address differences in context, we fit the same two models to the data from all sites combined. This model includes fixed effects of each site to account for clustering of participants in each event (Stapleton, 2009).

Environmental footprint

To estimate environmental impact, we created four iso-caloric model sandwiches: one beef, one chicken, one cheese, and one tofu and bean sandwich. The conversion factors used to compute these environmental impacts of each food ingredient were based on lifecycle assessment values listed in section 3 in the Supplementary material. The calculations for each ingredient were then aggregated in Excel to determine the total impacts of each meal. The four sandwiches used represented meals served at a typical "boxed lunch" event. These sandwiches were based on existing catering menus from a popular sandwich shop and consisted of a plant-based sandwich (with mushrooms and a black bean-soy patty), a vegetarian sandwich (a vegetable sandwich similar to the plant-based but with mozzarella cheese instead of the patty), a chicken club (chicken and bacon sandwich) and a standard roast beef sandwich. These "standardized" model sandwiches were chosen because each experimental event provided different menus, and in some cases, what was served and consumed at the event was not known by researchers involved. The recipes used for our standard sandwiches are included in the Supplementary material. Meals were standardized to include comparable total calories (around 650) and contained a minimum of 30 g of protein to simulate an average protein rich sandwich. The meals were then used to model the potential impacts of each event (Table 2).

TABLE 2 Single-meal footprint calculations, caloric levels, and protein.

	Environmental impacts (percentages)					
	GHG g CO2-eq	Land use m2	Nitrogen g N	Phosphorus g P	Calories kcal	Protein g
Plant-based(Bean) Sandwich	410 (90%)	1.44 (121%)	4.59 (56%)	0.99 (135%)	655	30.0
Vegetarian (Cheese) Sandwich	980 (215%)	1.62 (136%)	13.7 (167%)	3.19 (437%)	647	29.4
Chicken and Bacon Sandwich	1,040 (228%)	2.77 (233%)	18.8 (228%)	3.47 (475%)	651	38.8
Beef Sandwich	3,840 (840%)	12.4 (1,040%)	27 (329%)	9.88 (1,353%)	648	37.5

Percentage of per-capita planetary boundary threshold in parentheses.

We specified 8 hypothetical catered events, each with 100 participants. These 8 events represented all possible combinations of 2 meat meals (beef or chicken), 2 non-meat meals (vegetarian or plant-based), and 2 defaults (default meat or default non-meat). For example, the first hypothetical event offered, by default, a beef sandwich, but offered the option to opt into receiving a plant-based sandwich instead.

To compare the footprints of these hypothetical events, we estimated the number of meat and non-meat selections at each event based on the effect size estimates obtained from the log-binomial model of data aggregated across sites. We used the planetary boundary framework as a standard model (Table 3). The conversion factors used to calculate the environmental footprints of each food ingredient were based on LCA values listed in section III of the Supplementary material. We then extrapolated the GHGEs, land usage, nitrogen usage, and phosphorus footprints of each event for comparison.

Results

Randomized trials

In all events, the intervention substantially increased plant-based meal selections (Table 4; Figure 1). In the two non-buffet events, Harvard-BIH ($n = 91$) and UCLA-CEE ($n = 108$), participants had 2.75 (1.59, 4.79) and 4.04 (2.04, 7.99) times the likelihood of selecting a plant-based meal in the intervention group vs. in the control group. Furthermore, the event with RSVP wording signaling that the default was a buffet was the most effective, with a risk ratio of 4.18 of participants selecting a plant-based meal in the intervention group. No recorded harms or unintended effects were reported.

TABLE 3 Per capita per meal planetary boundary (PB) thresholds as specified by the EAT-Lancet commission (Willett et al., 2019).

PB	PB for food system	PB per capita per meal
Climate change	5 Gtons year^{-1}	457 g CO_{2-eq} person^{-1} meal^{-1}
Land use	13 million km^2	1.18 m^2 land person^{-1} meal^{-1}
Blue water use	2,500 km^3 year^{-1}	0.228 m^3 person^{-1} meal^{-1}
Nitrogen	90 Tg N year^{-1}	8.23 g person^{-1} meal^{-1}
Phosphorus	8 Tg P year^{-1}	0.73 g P person^{-1} meal^{-1}

Environmental footprint

We calculated the potential environmental impacts for the 8 hypothetical events (Table 5). Under each meat and plant-based meal combination, group 1 represents a hypothetical 100-person event based on the observed meal selection of all participants in the control group (meat default) aggregated across all three RCTs. Group 2 also represents a hypothetical 100-person event but is instead based on the observed meal selection of all participants in the intervention group (plant-based default) aggregated across all three RCTs. These projected impacts were then used to calculate the potential differences between group 1, the hypothetical default meat event, and group 2, the hypothetical default veg event (Table 6). The 100-person hypothetical event was used for ease of calculation for modeled projections and does not reflect the number of participants from the RCT experiments.

None of the hypothetical events fell within the proposed limits of the planetary boundaries defined by EAT Lancet. However, the hypothetical, plant-based default event serving plant-based and chicken sandwiches aligned the most closely with these boundaries for GHGEs (150%), land use (171%), nitrogen (131%) and phosphorus (283%) (Figures 2A–D).

The meat-default and plant-based default events serving plant-based and beef sandwiches displayed the largest difference in environmental impacts. Yet the impact of the plant-based default event in this category was still relatively high for GHGEs, land use, and phosphorus due to beef's large environmental impacts in comparison to other ingredients. We found that the default-plant-based and default-vegetarian

TABLE 4 Percentages, risk ratios, and risk differences of plant-based meal selection among control and intervention groups for three events.

Primary outcome: Plant-based meal selection	Default meat		Default veg		Risk ratio (95% CI)	Risk difference (percentage points) (95% CI)
	N	Percentage (no)	N	Percentage (no)		
Harvard-BIH† ($N = 91$)	45	24.4% (11)	46	67.4% (31)	2.75 (1.59, 4.79)	42.9 (24.2, 61.7)
UCLA-CEE† ($N = 108$)	56	14.3% (8)	52	57.7% (30)	4.04 (2.04, 7.99)	43.4 (27, 59.9)
UCLA-DG† ($N = 81$)	40	17.5% (7)	41	73.2% (30)	4.18 (2.08, 8.40)	55.7 (37.4, 73.9)
All sites† ($n = 280$)	141	18.4% (26)	139	65.5% (91)	3.52 (2.44, 5.09)	46.8 (28.8, 64.8)

†$p < 0.0001$.

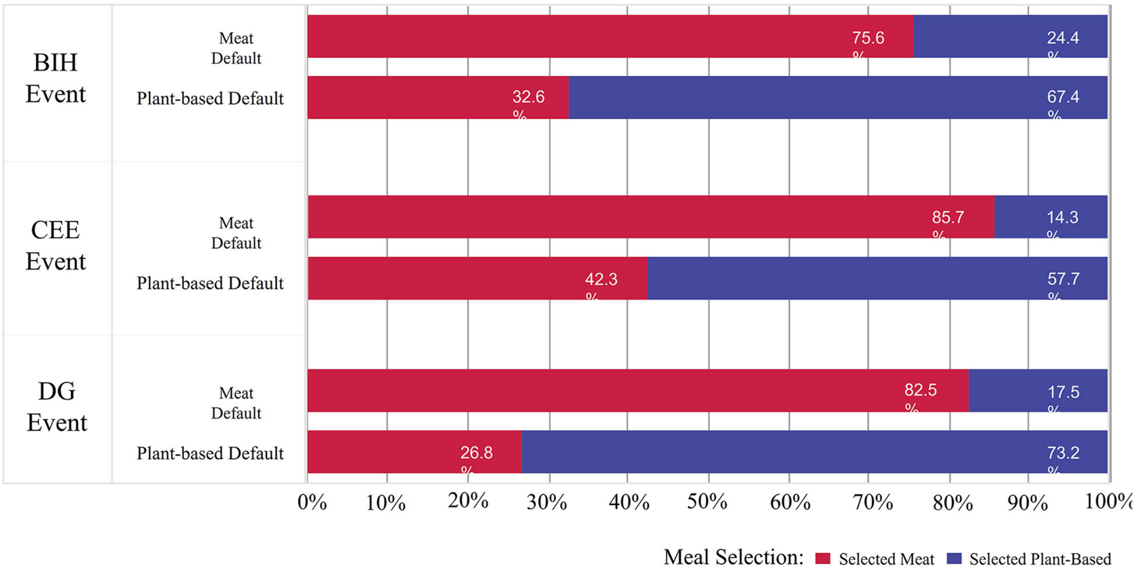

FIGURE 1
Percentages of plant-based and meat meal selection among control (meat default) and intervention groups (plant-based) for events.

TABLE 5 Estimated environmental impact in terms of GHG emissions, land use (LU), blue water (BW), nitrogen (N), and phosphorus (P) use for hypothetical 100-person events at a college campus.

	Environmental impacts (percentage of PB†)			
	GHGEs $kg\ CO_{2-eq}$	LU m^2	N g	P g
Beef and Plant-based Sandwiches				
Group 1: Default beef, Opt-in plant-based[a]	328 (719%)	1,060 (902%)	2,340 (285%)	845 (1,160%)
Group 2: Default plant-based, Opt-in beef [b]	189 (414%)	619 (525%)	1,430 (174%)	484 (663%)
Chicken and Plant-based Sandwiches				
Group 1: Default chicken, Opt-in plant-based	94 (206%)	256 (217%)	1,650 (201%)	307 (421%)
Group 2: Default plant-based, Opt-in chicken	68.3 (150%)	202 (171%)	1,070 (131%)	206 (283%)
Beef and Vegetarian Sandwiches				
Group 1: Default beef, Opt-in vegetarian	338 (739%)	1,070 (904%)	2,490 (303%)	880 (1,210%)
Group 2: Default vegetarian, Opt-in beef	222 (485%)	629 (533%)	1,950 (237%)	60 (834%)
Chicken and Vegetarian Sandwiches				
Group 1: Default chicken, Opt-in vegetarian	103 (226%)	258 (219%)	1,800 (219%)	343 (469%)
Group 2: Default vegetarian, Opt-in chicken	101 (220%)	212 (179%)	1,590 (194%)	331 (454%)

[a]The footprints of group 1 are based on the aggregated selections of participants who received a meat default (16 selected plant based, 84 selected meat).
[b]The footprints of group 2 are based on the aggregated selections of participants who received a plant-based default (57 selected plant based, 43 selected meat).
† 100% representing the planetary boundary denoted by EAT-Lancet.

events had substantially lower carbon emissions, land-use, phosphorus, and nitrogen footprints than default-meat events. For example, in the event that serves beef sandwiches and plant-based sandwiches, implementing a plant-based default is projected to reduce GHGEs by 42.3% (139 grams) of CO2-eq. We also found a projected savings of 41.8% (445 m^2) in land-use, 38.9% (912 g) for nitrogen, and 42.7% (361 g) for phosphorus. Even when the meat sandwiches are chicken rather than beef, implementing a plant-based default was still projected to substantially improve on all environmental metrics. Compared to default-meat events, default-vegetarian events also improved on all five environmental metrics, though the improvements were somewhat smaller than for default-plant-based events.

TABLE 6 Projected improvement in hypothetical planetary boundary impacts when using a vegetarian or plant-based default meal vs. a meat default meal.

	Environmental impacts			
	GHGEs Kg CO_{2-eq}	LU m^2	N g	P g
Beef and Plant-based Sandwiches				
Projected difference[a]	139	445	912	361
Projected percent change	42.3%	41.8%	38.9%	42.7%
Chicken and Plant-based Sandwiches				
Projected difference[a]	25.6	54	577	101
Projected percent change	27.3%	21.1%	34.9%	32.8%
Beef and Vegetarian Sandwiches				
Projected difference[a]	116	438	540	272
Projected percent change	34.4%	41.1%	21.7%	30.9%
Chicken and Vegetarian Sandwiches				
Group 2 and Group 1 difference[a]	2.51	46.7	205	11.4
Percent change	2.43%	18.1%	11.4%	3.32%

[a]Obtained by subtracting projected impacts for the plant-based- or vegetarian-default from impacts for the meat-default in Table 2.

Discussion

Randomized controlled trials

The goal of this study was to test the effect of a plant-based default nudge on participant meal selection at catered events and quantify potential environmental impacts of the intervention. In the RCTs, we found significant, large effect sizes across all three experiments. At the Harvard-BIH, UCLA-CEE, and UCLA-DG events, the default nudge increased plant-based meal selection by 43, 43 and 56 percentage points, respectively. Across all sites, plant-based meal selection increased by 47 percentage points.

The effect sizes we observed were substantially larger than those of existing interventions targeting eating behaviors. Mertens et al.'s meta-analysis of choice architecture interventions reported an average standardized mean difference (SMD) of 0.72 for interventions in the domain of food (2022). This is approximately equivalent to a risk ratio of 1.92 (Chinn, 2000; VanderWeele, 2020). In studies using decision structure—the class of choice architecture tools to which the default nudge belongs—to affect food behaviors, the review reported a SMD of 0.86 or approximately a risk ratio of 2.17. However, our pooled risk ratio for all three studies was 3.52. Our risk ratio is relatively high among choice architecture studies aiming to influence food behavior but this may also be attributable to differences in the variables measured.

The effectiveness of default nudges can be attributed to a variety of factors: cognitive capacity due to aspects such as time pressures and selection effort; biases such as the endowment effect and the omission bias; as well as the perception that a default is an "implicit recommendation" of one choice over another (Michalek et al., 2015; Jachimowicz et al., 2019). Interventions leveraging these factors in varying ways could elicit different results.

For example, in Meier's et al. (2021) systematic literature review on plant-based defaults, virtually all studies found that the default intervention decreased meat consumption. However, the design, implementation, and results of these interventions differ greatly. One study found that changing a plant-based menu item to the dish of the day increased plant-based meal selections by 76 percentage points (Perez-Cueto, 2021). Garvert and Kurz's 2019 study found that rearranging the meal options led to a decreased probability of meat selection from 45.7 to 21.4%. Another study reordering meals presented at a cafeteria counter increased vegetarian meals selected, but only if the vegetarian and meat meals were placed far apart (Garnett et al., 2019). Parkin and Atwood (2022) found that for menus to effectively encourage diners to choose vegetarian options over meat, menus needed to be at least 75% vegetarian options. A more recent publication by Nykänen et al. (2022) also found that two experimental nudges intended to reduce red meat consumption (a "dish of the day" nudge approach, and "sequence alteration" approach) had no effect on the choices made for the main dish, nor the proportion of meat in the overall meal weight. Of the experiments designed to reduce meat consumption, most opted to do so by altering portion sizes, reordering items listed on a menu, or altering the descriptions of foods in restaurants and cafeterias (Meier's et al., 2021; Perez-Cueto, 2021; Nykänen et al., 2022). This demonstrates the importance of further studies to explore settings in which the default is effective and those where it is not. Additionally, most existing literature is difficult to compare to our study because they measured the amount of meat consumed *by weight* as opposed to measuring selection of a meal *containing* meat.

Our study was closely modeled after a plant-based default intervention conducted over the three academic conferences in Denmark (Hansen et al., 2021). Hansen et al. (2021) plant-based default was carried out through an RSVP for three academic conferences in Denmark. Hansen's team found 85, 80, and 77 percentage point differences in plant-based meal consumption across the three events. The results of each event were larger than our overall 47 percentage point difference. A number of factors could account for this difference. Hansen's default nudge implied increased variety of food items through the buffet wording in the RSVP (with a reported total of 330 food choices between the three events). In addition, while Hansen's events were academic conferences held in Denmark, our events were highly-varied university affiliated events held in the U.S. As a result, the social contexts in which these events occurred are different, with Denmark being consistently ranked as one of the top four most sustainable countries in the world and the US ranking in 24th,

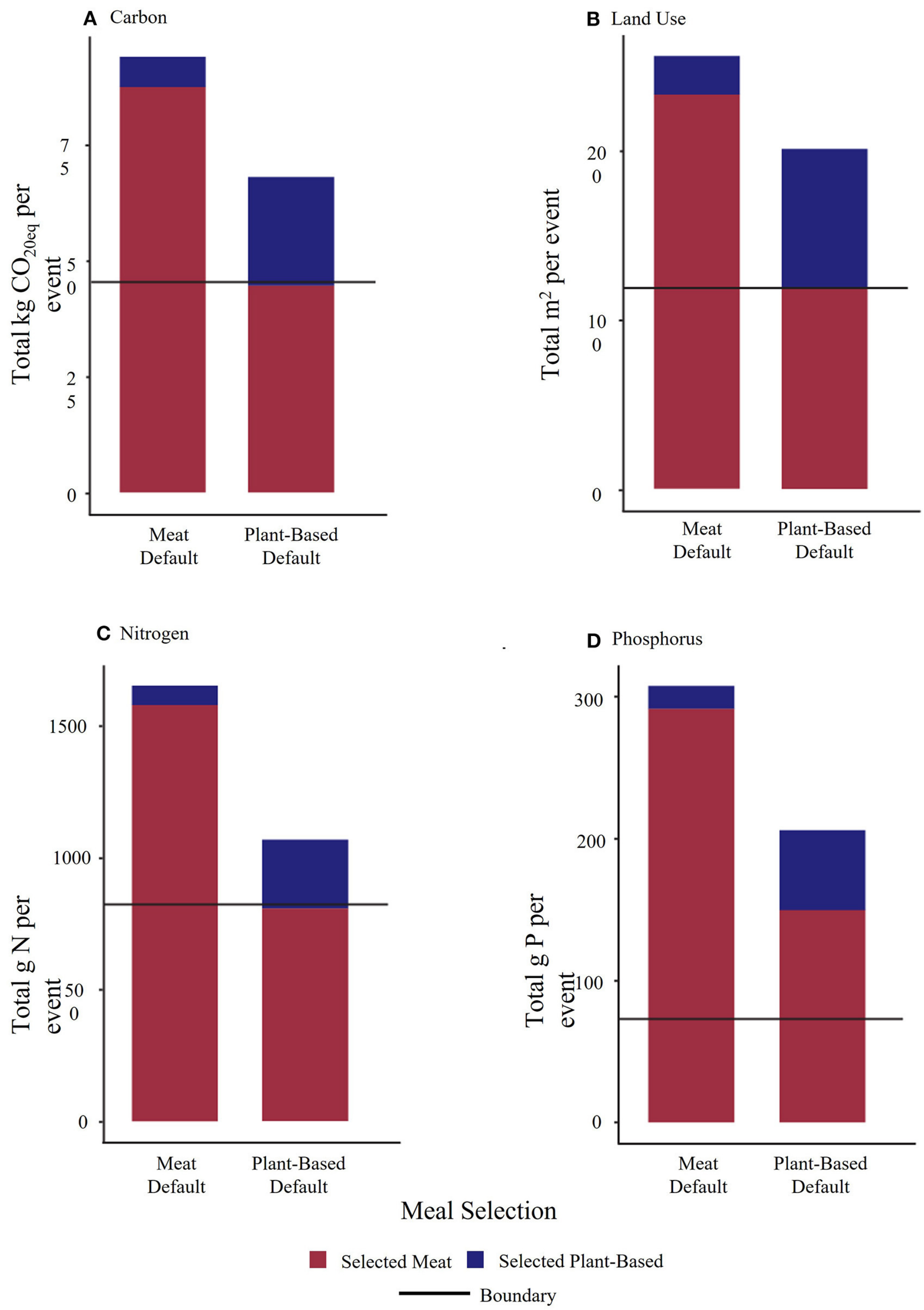

FIGURE 2
(A–D) Plant-based and chicken projected event calculations using the pooled RCTs. Colors represent breakdown of impacts from meat and veg meals. Black line represents EAT Lancet's planetary boundary for the measure (Willett et al., 2019).

27th and 26th in recent years (Hsu et al., 2016; Wendling et al., 2018, 2020).

Plant-based default interventions create positive effects for organizations, individuals, and the environment. The default intervention in our study managed to maintain participants' selections while reducing environmental impacts. Furthermore, a recent study revealed that plant-based and vegetarian dietary patterns in upper-middle-income countries were among the most affordable eating patterns (Springmann et al., 2021). As a result, organizations in the U.S using plant-based defaults could reduce environmental impact without additional cost while maintaining participant choice. Academic institutions such as UCLA, Harvard and many others have large catering services and hold regular catered events. According to the National Center for Education, 19.4 million students attended college in Fall 2020 (U. S. Department of Education, National Center for Education Statistics, 2021). If every student attended just one plant-based default catered event that year, a back of the envelope calculation estimates conservation of up to 27 million Kg (gigagram) of CO_2–carbon emissions from approximately 3 million gallons of gasoline (US Environmental Protection Agency, 2021). This calculation does not consider campus events held for faculty, staff, or industry professionals. Should a plant-based default nudge be implemented as a department-wide policy for catered events, planetary impacts could be reduced further. The concept of a default could also be applied beyond college campuses: hospitals, corporations, governments, and NGOs could also take steps to implement a plant-based default catering policy.

Environmental footprint

In the hypothetical 100-person events we modeled, we found that compared to using meat defaults, using plant-based or vegetarian defaults would reduce GHGEs, land use, phosphorus, and nitrogen by an estimated 38.9–42.7%. Implementing a plant-based or vegetarian default most improved projected impacts when the meat option was beef, but still led to substantial improvements when the meat option was chicken. Implementing a plant-based default improved projected impacts more than implementing a vegetarian default. Our results are consistent with research showing that plant-based food choices represent considerably lower environmental impacts as compared to animal-products of similar caloric content. Harwatt et al. (2017) found that substituting beans for beef could have achieved 46–74% of the reductions needed to meet the 2020 target for emissions in the US while also freeing up to 42% of cropland. A recent study modeled that rapidly phasing out animal agriculture has the potential to offset 25 gigatons of CO_2 and provide half the emissions reductions necessary for humanity to limit warming to 2°C (Eisen and Brown, 2022). Our research demonstrates that utilizing a plant-based default is a method that could help us phase out of our reliance on animal agriculture.

As seen in the single-meal calculations, the footprints of the vegetarian sandwich and the chicken sandwich were similar; so if the institution's primary objective for utilizing the default nudge is lowering the environmental footprint, a plant-based default over a vegetarian default would be the preferred choice (Table 3). The projected event with a bean and tofu sandwich as the default and a beef sandwich as the alternate option showed the greatest overall decrease in GHGE, land use, phosphorus, and nitrogen footprints compared to the situation when the default was reversed (Figures 3A–D). However, with regard to absolute footprint, serving the intervention group a plant-based meal default with a chicken meal option had the lowest environmental impact. This suggests that in the broad categories of "meat" (chicken or beef) and "plant-based" (plant-based or vegetarian), specific ingredients play a large role in determining impacts. In addition, the literature has shown that beef consumption in particular should be reduced due to its disproportionate impact on GHGEs, land use, nitrogen and phosphorus. Our results also highlight the outsized environmental effects of beef compared to other ingredients, and these findings align with other research. Beef production alone requires 28 times more land, 11 times more irrigation water, 5 times more greenhouse gas emissions, and 6 times more nitrogen than the average of dairy, poultry, pork or egg categories (Eshel et al., 2014).

Considering the environmental impacts exclusively, chicken is preferable to beef while legumes are preferable to protein from any animal source. However, because chickens are much smaller than cows, replacing beef with chicken dramatically exacerbates the negative animal welfare impact of meat consumption (Mathur, 2022). Additionally, chicken production can have other detrimental impacts, including proliferation of antibiotic resistance (Sanchez et al., 2020).

Despite significant differences in environmental impacts among the groups, each event footprint fell outside EAT-Lancet's established per-capita planetary boundaries (shown by the black lines in Figures 2A–D, 3A–D). This suggests we will need more than behavior change to fully move humanity within the planetary boundaries. Increasing food production efficiency in an equitable and sustainable manner will be necessary to limit land-use change, promote reduction as well as efficiency of nitrogen use, and encourage phosphorus recycling (Carpenter and Bennett, 2011; De Vries et al., 2013; Steffen et al., 2015; Campbell et al., 2017; Springmann et al., 2018a; Li et al., 2019). However, there are significant differences in the environmental impact of the same food items from different producers due to the diversities in agricultural practices. These differences provide opportunities to engage in both mitigation efforts at the producer level, as well as to educate consumers so they might make more environmentally friendly purchasing decisions (Poore and Nemecek, 2018).

Limitations

Our experiments were conducted at a sorority, a graduate student orientation, and an academic conference. Due to the geographical and cultural diversity of the U.S, more experiments should be conducted to determine the intervention's external validity. Regarding the limitations of the experiments themselves, one limitation is that demographic data was

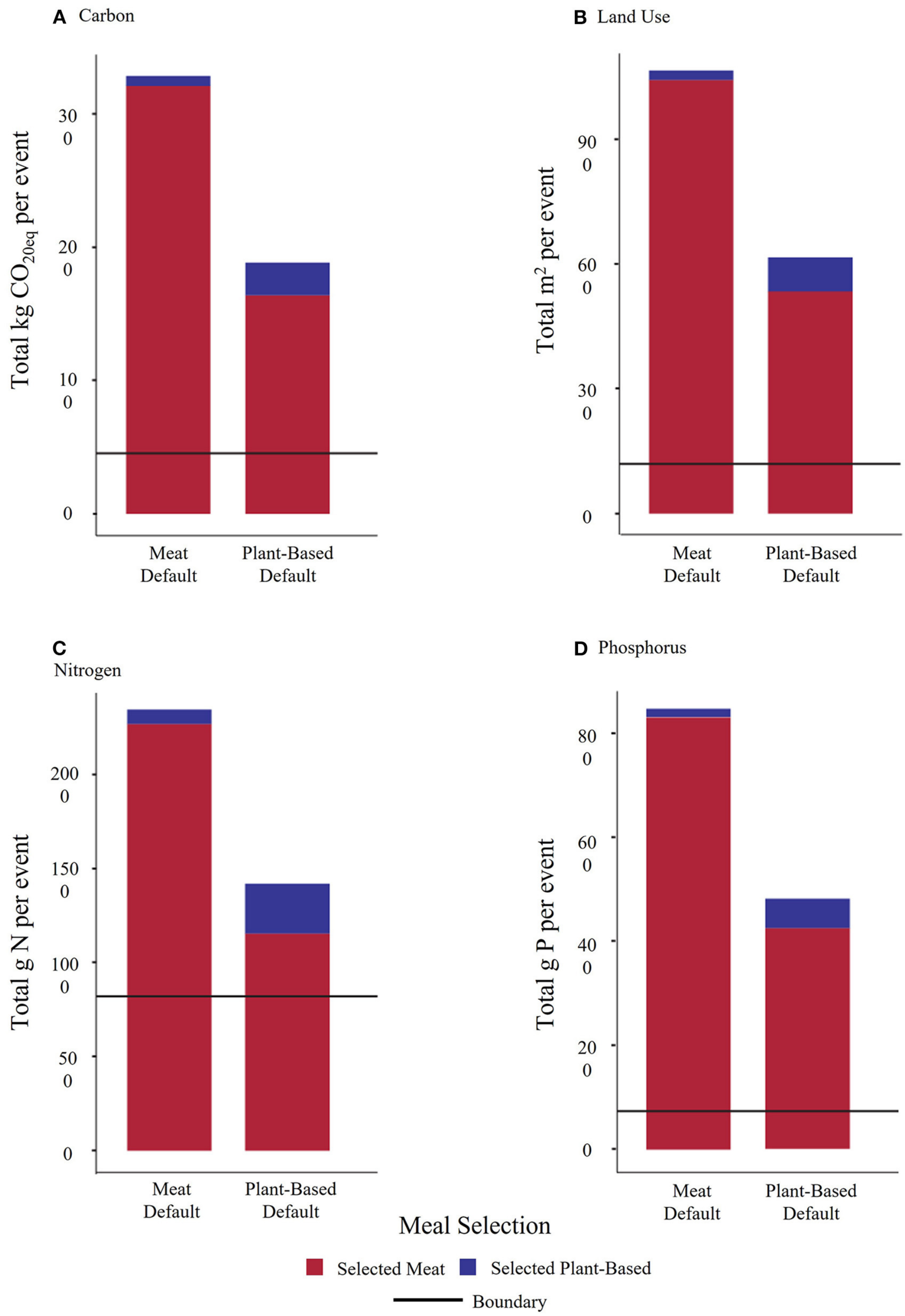

FIGURE 3
(A–D) Plant-based and beef projected event calculations using the pooled RCT results. Colors represent breakdown of impacts from meat and plant-based meals. Black line represents EAT-Lancet's planetary boundary for the measure (Willett et al., 2019).

not collected for the participants in this study. In planning this study there was concern that asking demographic questions to potential researchers (like those attending the BIH workshop or CEE graduate student orientation) would imply that they were participants in a study, thus influencing their responses. Demographic data was also considered inappropriate for the DG event given that the event was a sorority house dinner, where all attendees were well acquainted with the event operator.

Additionally, it was already known that the event would be composed of all female and female presenting participants. As a result, the lack of gender data in the CEE and BIH events, and homogeneity of genders for the DG event make it harder to disaggregate and evaluate the results of the intervention. Due to then attitudes tying meat consumption to masculinity among men (Love and Sulikowski, 2018; Nakagawa and Hart, 2019). Hansen et al. (2021) also found that women were more likely than men to remain with the default option when a plant-based meal was presented as the default.

Our study assesses the potential reductions in meat-based meals caused by using defaults to influence event participants' meal choices. The impact of food waste, food miles, and packaging were beyond the scope of our study but are required for a more accurate footprint of these events. Another limitation of our calculations is that the conversion factors used to calculate the environmental footprints are based on LCA data representing averages for food items. LCAs are created using assumptions and are ultimately simplified models for assessing an item's environmental impact (Curran, 2014). We also chose not to calculate the environmental impacts of processed foods that may typically be served due to limited available LCA data covering the complexity and variability of processed foods. The environmental impact associated with many processing methods has not yet been quantified.

We recognize the significance of the connection between health and nutrition when discussing the environmental footprints of meals. Despite this important link, our paper included no discussion on health due to prevalence of other available literature on this topic due to our focus on a single meal replacement. The EAT-Lancet report discusses health as a major priority. Therefore, if defaults are applied in other settings where they make a more significant contribution to overall caloric intake, their nutrition and health impacts should be seriously considered.

Suggestions for future research

In future work, more consideration should be made to implementation science and the barriers that event operators face in transitioning to a plant-based default. When implementing our experimental design, we found that willing event operators faced obstacles in providing delicious or varied plant-based options. Additionally, our calculations showed that specific food ingredients within broad meal categories (plant-based vs. vegetarian, beef vs. chicken) in part determined the efficacy of the intervention. Only by situating and understanding the intervention's implementation, barriers, and impacts in real contexts can we further expand institutional transitions to a plant-based default.

Future work on the default nudge for environmental purposes should test long-term efficacy and spillover effects. Previous studies investigating the default nudge have explored and shown positive effects of the intervention over time and partial persistence of behavior change after the intervention ended (Kurz, 2018). Additionally, a recent experiment on menu design for promoting sustainable food choices showed that people were more likely to choose vegetarian meals when the menu was at least 75% vegetarian (Parkin and Atwood, 2022). Future researchers could take Parkin and Atwood's findings a step further to test if the number of meal choices influence the selection of the plant-based default. This could serve to explain the discrepancy between our results and those found across the Hansen et al. events, which indicated the availability of a buffet.

Conclusion

In the U.S, few studies have explored nudging as a way to shift toward more sustainable dietary behaviors. To the authors' knowledge, this study is one of the first to do so in the context of higher education events. Furthermore, this research represents one of the few studies that quantify the potential environmental impacts of the default nudge using modeled menu choices but based on real-world food choice data. Based on our modeling, we found that the plant-based default nudge has the potential to reduce greenhouse gas, land-use, phosphorus and nitrogen footprints. We also find that specific ingredient types in broad meat and plant-based categorizations (i.e., chicken vs. beef) make a significant difference in determining event impacts.

At college campuses, adopting a campus-wide plant-based default policy can be an effective way to reduce environmental impact. A plant-based default could also be scaled and applied to other institutions beyond universities–such as corporate and government events, as well as in K-12 cafeterias. Announced September 28th, 2022, plant-based defaults have been implemented in three New York City hospitals (Mayor Adams Press Release, 2022). In January, 2022 the New York City school district also implemented a successful "Vegan Friday" program (Mayor Adams Press Release, 2022).

Our study, the established literature, and the implementation of programs like these demonstrate that people may not object to a higher proportion of plant-based meals, and that the nudge could be scaled to have a much larger impact than on catering alone. A plant-based default nudge policy could be implemented swiftly, without the use of expensive infrastructure or technology, all while maintaining participant choice. We demonstrate that this nudge has the potential to move us in the direction of a safe operating space for all.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by University of California Los Angeles Institutional Review Board and Harvard Institutional Review Board. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

RB: primary author of manuscript, made multiple revisions to draft, aided in design of study, and aided in data collection and analysis. AZ: primary author of manuscript, aided RB in making multiple revisions to draft, aided in design of study, analyzed RCT data and modeled environmental impact projections, and organized data collection. CS: wrote section in manuscript's introduction, provided expertise in design of the default intervention, and contributed edits to drafts of the manuscript. KP: aided in data collection and modeled environmental impact projections. MM: provided expertise on statistical methods and data analysis and contributed edits to drafts of the manuscript. DC: aided in design of study and contributed edits to drafts of the manuscript. DB and AM: led data collection at Harvard and reviewed manuscript. EG: aided in design of study and contributed expertise on choice architecture for sustainable behaviors. IB: aided in design of intervention and reviewed manuscript. MW: provided expertise on design of study. JJ: aided in design of study, contributed to writing of manuscript, aided in data analysis, edited multiple drafts of manuscript, and PI for project. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The Better Food Foundation (where IB was employed) provided a grant to compensate AZ, a student on our project. Author MM is a member of the Research Advisory Boards of Greener by Default and of Sentience Institute. Author CS is also a member of the Research Advisory Boards of Greener By Default. Author IB is the Co-Director of the Greener by Default Advisory board. Author MW is a member of the Technical Advisory Committee for the Los Angeles County Food Equity Roundtable.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author disclaimer

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.1001157/full#supplementary-material

SUPPLEMENTARY FILES
Supplementary Files: RSVP Surveys, Modeled meal recipes, and Environmental footprint sources.

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