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Balancing plates and planets: optimising affordable, low-emissions diets for Ghanaian adults

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Introduction: Sustainable diets have gained global recognition as food systems contribute about 25% of global greenhouse emissions (GHGEs). Meeting the dimensions of nutritional adequacy, cultural acceptability, affordability, and environmental sustainability is complex, requiring careful consideration of synergies and trade-offs. Hence, synergies and trade-offs must be established. This study aimed to simultaneously minimise the cost and GHGE of diets for Ghanaian adults aged 19–50 years, while ensuring nutritional adequacy and cultural acceptability using locally available foods.

Method: A bi-objective optimisation framework employing the ε-constraint method was applied. Cost and GHGE were first solved individually using linear programming, then jointly optimised to generate solution sets. Nutrient requirements ensured adequacy, while food group constraints maintained cultural acceptability. A Pareto frontier was generated to visualise trade-offs between cost and GHGE.

Results: A clear trade-off was observed: as cost decreased, GHGE increased, and vice versa. The correlation between cost and GHGE was strongly negative ($r = -0.93$ for males; $r = -0.95$ for females), with cost explaining most of the variability in GHGE ($R^2 = 0.87$ and 0.90, respectively). Optimal diets involved modest adjustments, emphasising nutrient-rich and environmentally friendly foods. Food baskets across solutions included staples, seafood, fats and oils, fruits and vegetables, legumes, seeds, and nuts.

Implications: This study demonstrates the feasibility of applying multi-objective optimisation to Ghanaian diets, integrating affordability, nutrition, sustainability, and cultural acceptability. The findings provide novel evidence to guide policymakers, industry stakeholders, and consumers in promoting healthier and more sustainable diets in Ghana and similar West African contexts.

KEYWORDS
diet optimisation, ε-constraint, GHGe, nutrient adequacy, sustainable diets, trade-offs

1 Introduction

Agricultural production, processing, and consumption patterns collectively account for a significant share of global emissions, linking climate change directly to the way food is produced and consumed. Global dietary patterns, characterised by high consumption of animal-sourced foods, processed products, and resource-intensive staples, have been identified as major contributors of to the environmental footprint of the global food system (Willett et al., 2019; Benton et al., 2021; Fanzo et al., 2021).

Additionally, diets play a central role in human health. Poor dietary quality is a leading risk factor for non-communicable diseases such as obesity, diabetes, and cardiovascular disease, while nutrient deficiencies remain prevalent in many low- and middle-income countries (Afshin et al., 2019). Thus, dietary choices simultaneously influence planetary health and individual well-being, showing the need for integrated approaches that address both dimensions (Fanzo, 2019). This requires a dietary shift towards nutritionally balanced diets that will reduce the pressure on the environment (Springmann et al., 2021; Gazan et al., 2022).

Transforming diets towards sustainable ones is therefore essential to mitigate environmental impacts while improving human health outcomes (Springmann et al., 2021; Gazan et al., 2022). The Food and Agriculture Organisation (FAO) define sustainable diets as those that are nutritionally adequate, affordable, culturally acceptable, and have low environmental impact (FAO, 2010). Designing such diets requires balancing multiple objectives, including cost, nutrition, and sustainability, which makes diet design inherently challenging (Fanzo et al., 2012; Fanzo, 2019). Diet optimisation should balance different objectives; nutrient requirements, cultural preferences, affordability, and environmental indicators; often leading to trade-offs that complicate the identification of feasible solutions (Perigon et al., 2016; Okekunle et al., 2024).

Diet optimisation problems inherently involve conflicting objectives (Nakayama, 2005; Cui et al., 2017). Balancing these objectives and identifying the trade-offs between them can be challenging (Augusto et al., 2012). While significant progress has been made in solving dietary problems (Dibari et al., 2012; Deptford et al., 2017; Brixi, 2018; Nykänen et al., 2018; Faksová et al., 2019; Lauk et al., 2020), little attention has been given to the environmental component (Lucas et al., 2021). Bashiri et al. (2025) indicated a gap in dietary optimisation as most research have only considered at most three sustainability indicators. They further recommended the use of multi-objective optimisation frameworks to support evidence-based decision-making in sustainable diet research. Multi-objective optimisation frameworks, including the ε-constraint method, have been widely applied to explore balancing trade-offs in different fields, but less explored within the context of sustainable diets (Mavrotas, 2009; van Dooren, 2018). Using an optimisation framework, Liu et al. (2024) demonstrated that dietary quality and nutritional adequacy can be greatly improved when diets are optimised under nutritional and resource-related constraints, highlighting the potential of optimisation-based approaches to support sustainable diet transitions. The ε-constraint method is particularly effective because it allows one objective to be optimised while treating others as constraints, thereby providing a structured way to explore feasible trade-offs. Its application in diet modelling offers a transparent approach to balancing affordability, nutrition, sustainability, and acceptability in complex food systems.

This study addresses the gap in integrated diet optimisation research by simultaneously considering nutritional adequacy, cultural acceptability, affordability and environmental sustainability (GHGE) within a local dietary context, by applying a multi-objective optimisation framework. The novelty of this work lies in its integration of environmental sustainability into diet optimisation for a West African context, where empirical data and modelling studies remain scarce. The study therefore aimed to develop optimised dietary models for Ghanaian adults that balance affordability, nutritional adequacy, cultural acceptability, and environmental sustainability, thereby contributing evidence to support sustainable food system transformation in West Africa.

2 Methodology

2.1 Study design and target population

This study adopted a model-based optimisation approach to support the formulation of sustainable diets. The target population considered in the modelling framework was healthy adult males and females aged 19–50 years. This age group was selected because it represents the economically active adult population with relatively stable nutritional requirements [Institute of Medicine (IOM), 2006].

2.2 Data acquisition

A list of locally available foods in Ghana, together with their nutrient composition and baseline cost per 100 g, was obtained from previous work by Nykänen et al. (2018). Additional nutritional information was sourced from the West African Food Composition Table (Stadlmayr et al., 2012) to complement the nutrient composition data. Also, data on food item costs were obtained from the Ministry of Food and Agriculture (MoFA). To reflect current market conditions, food prices were adjusted for inflation from February 2017 to February 2023 using the Consumer Price Index (CPI) published by Ghana Statistical Service (2023).

Carbon footprint data were not independently calculated in the scope of this study. However, secondary GHGE data were obtained from a private database developed for food product formulation and sustainability assessment due to the lack of country-specific greenhouse gas emission (GHGE) data for local food items in Ghana. GHGE values were expressed as carbon dioxide equivalents (CO_2 eq.) per kilogram (kg) of each ingredient and subsequently converted to a 100 g basis to ensure consistency with nutrient composition and cost data. Only foods that are commonly consumed within the Ghanaian context were included.

Food items were categorised into six groups: animal-sourced foods; legumes, seeds, and nuts (LSNs); fruits and vegetables; staples; fats and oils; and miscellaneous items. Yogurt, milk powder, and mushrooms were classified as miscellaneous foods, as they are not commonly consumed in Ghana.

2.3 Nutrient considerations

No human participants were recruited or studied directly; instead, the modelling framework relied entirely on secondary sources. The study adopted the Dietary Reference Intakes (DRIs) established by the

Institute of Medicine (2000, 2001, 2011) for energy, macro- and micronutrients. These reference standards were used to guide the selection of nutrients relevant to the formulation of nutritionally adequate food products for adult males and females aged 19–50 years.

The micronutrients included in the study were iron, zinc, iodine, folate, calcium, copper, vitamin A, vitamin C, vitamin E, vitamin B_6, vitamin B_{12}, thiamine, riboflavin, niacin, magnesium, phosphorus, selenium, and sodium. These nutrients were prioritised because they are implicated in commonly reported nutritional deficiencies and nutrition-related health concerns in Ghana and West Africa, including iron-deficiency anemia, vitamin A deficiency, and inadequate zinc and iodine intake (Koryo-Dabrah et al., 2021). Macronutrients, including energy, protein, fat, and carbohydrates, were also considered to ensure alignment with recommended dietary requirements for the target group. The selection of these nutrients reflects their central role in supporting overall dietary adequacy and balance. The nutrient set adopted in this study provides a comprehensive yet adaptable basis that can be modified to reflect the nutritional priorities of other population groups in future applications. All nutrients (macro and micronutrients) and energy were constrained in the optimisation problem.

2.4 Defining parameters and variables

The objective was to simultaneously minimise both cost and greenhouse gas emissions. The variables corresponded to the weights of selected ingredients. Constraints were established for the lower and upper bounds of the considered nutrients, as well as for the food groups quantities to ensure dietary diversity and acceptability purposes.

2.5 Mathematical modelling

Linear programming (LP) and the epsilon constraint methods were used to optimise the sustainable food baskets for the defined population groups in this study, as demonstrated in Figure 1.

The LP algorithm was used to obtain separate optimal diets for the target populations (males and females aged 19–50 years) for each of the distinct objectives specifically (i) diets with minimum cost and (ii) diets with minimum GHGE. Both were subject to fulfilling the nutritional criteria (the intake of each nutrient between the lower and upper limits) and acceptability (inclusion of three common ingredients and limits on food groups to prevent unrealistic portion sizes), as depicted in Equations 5–14. Equations 12–14 were included because these ingredients are commonly included in almost every Ghanaian meal prepared.

$$\text{Minimise } f_{cost} = \sum_{j=1}^{n} c_j x_j \quad (1)$$

$$\text{Minimise } f_{GHGE} = \sum_{j=1}^{n} g_j x_j \quad (2)$$

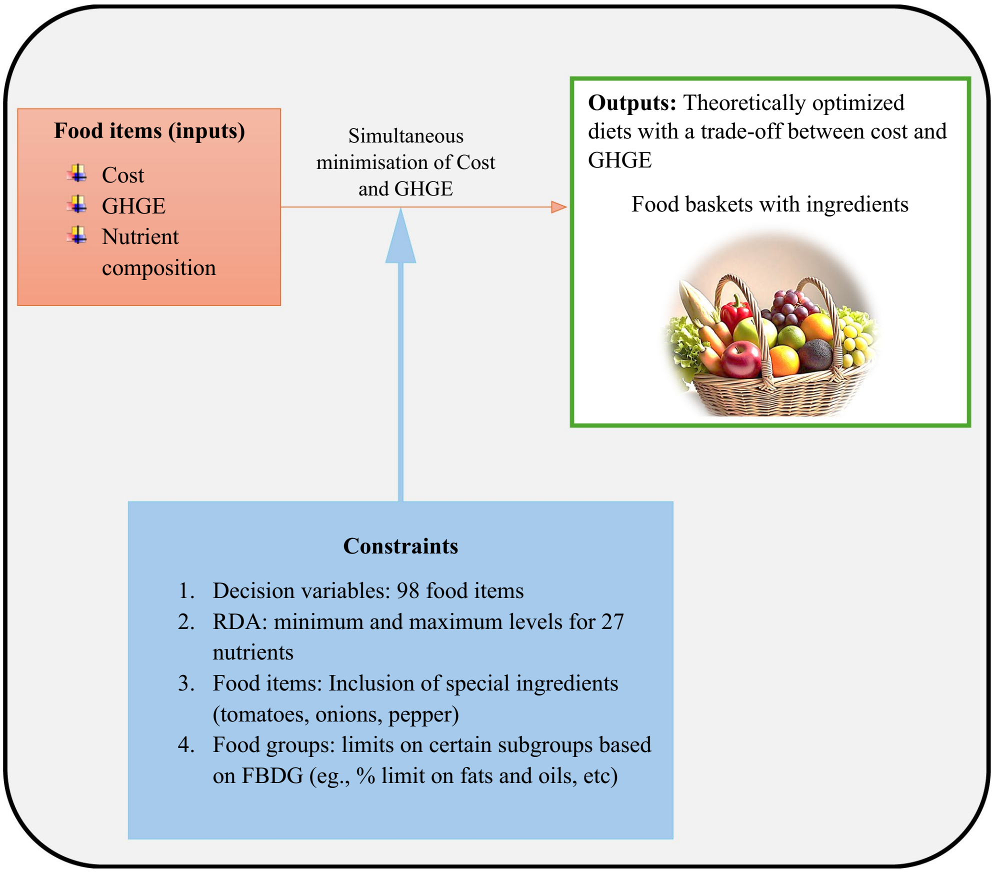

FIGURE 1
Overview of the elements of the ε-constraint optimisation process. GHGE, Greenhouse gas emission; RDA, Recommended dietary allowances (Institute of Medicine, 2000, 2001, 2011); FBDG, Food-based dietary guidelines.

Subject to the defined constraints:

$$\sum_{j=1}^{n} a_{ij} x_j \geq l_i \quad i = 1,2,3,\ldots\ldots\ldots m \tag{3}$$

$$\sum_{j=1}^{n} a_{ij} x_j \leq u_i \quad i = 1,2,3,\ldots\ldots\ldots m \tag{4}$$

$$S * p_{11} \leq FG_1 \leq p_{12} \tag{5}$$

$$S * p_{21} \leq FG_2 \leq p_{22} \tag{6}$$

$$S * p_{31} \leq FG_3 \leq p_{32} \tag{7}$$

$$S * p_{41} \leq FG_4 \leq p_{42} \tag{8}$$

$$S * p_{51} \leq FG_5 \leq p_{52} \tag{9}$$

$$S * p_{61} \leq FG_6 \leq p_{62} \tag{10}$$

$$S * p_{71} \leq FG_7 \leq p_{72} \tag{11}$$

$$S * \text{Tomatoes} \geq 164\text{g} \tag{12}$$

$$S * \text{Onions} \geq 76\text{g} \tag{13}$$

$$S * \text{Pepper} \geq 30\text{g} \tag{14}$$

$$X_j, l_i, \; u_i \geq 0 \left(x \textit{ is a continuous variable} \right) \tag{15}$$

f_{Cost} – the objective function to be minimised cost

f_{GHGE} – the objective function to be minimised, CO_2eq.

n – total number of food items in the LP analysis

x_j – portions of food j in g

c_j – the cost of food item j

g_j – the carbon footprints (CO_2 eq.) of food item j

a_{ij} – nutrient i in food item j

l_i – the lower bound for nutrient i

u_i – upper bound for nutrient i

FG_i – food groups (FG_1 – fats and oils, FG_2 –legumes, seeds, and nuts, FG_3 – animal –sourced foods, FG_4 – fruits, FG_5 –vegetables, FG_6 – miscellaneous, FG_7 – staples)

p_i – percentage of the selected food items for food groups i (p_1 : 0.4 – 0.6%, p_2 : 13.07 – 14%, p_3 : 9.5 – 10%, p_4 : 15 – 18%, p_5 : 15 – 20%, p_6 : 2.77 – 4%, and p_7 : 33.4 – 44.26)

S – the summation of x_j

Values for Equations 5–14 were defined with guidance from the Food-based Dietary Guidelines (FBDGs) for Ghana, based on the minimum daily intake for these ingredients (Ministry of Food and Agriculture (MoFA) and University of Ghana School of Public Health, 2023).

Cultural acceptability was implemented following the theme on existing diets described by House et al. (2023). Constraints were incorporated into the model based on the Ghana FBDGs. Lower and upper bounds were set for major food groups (Equations 5–11) to reflect typical consumption patterns. Additionally, only locally and commonly consumed foods were included in the food list.

$$\text{Minimise } f_{cost}(x) \tag{16}$$

Subject to constraints:

$$f_{GHGE}(x) \leq \varepsilon_1 \tag{17}$$

Subject to: Equations 3–15

$$\varepsilon = f_{GHGE}{}^{min} + \frac{\left(f_{GHGE}{}^{max} - f_{GHGE}{}^{min} \right)}{q} n, n = 1,2,\ldots\ldots..q \tag{18}$$

$$\Phi = \begin{bmatrix} f^*_{Cost}\left(x^*_1\right) & f^*_{GHGE}\left(x^*_1\right) \\ f^*_{Cost}\left(x^*_2\right) & f^*_{GHGE}\left(x^*_2\right) \end{bmatrix} \tag{19}$$

q – the number of iterations used to obtain the solution set

ε_1 – epsilon

$f_{GHGE}{}^{min}$ = the smallest value of f_{GHGE} found in the solution set

$f_{GHGE}{}^{max}$ = the largest value of f_{GHGE} found in the solution set

f^* – the optimal value of each objective function

To obtain sustainable food baskets that included cost, GHGE, nutrition, and acceptability, the two single objectives (Equations 1, 2) were considered in one simultaneous model using the ε-constraint method. When more than one objective may conflict with the other, the ε-constraint method can generate a trade-off table for each decision-making situation (Eghbali-Zarch et al., 2017). The cost was selected as the primary objective function while keeping GHGE as a constraint, and the algorithm was set to generate twenty (20) solution set (Equations 16, 17). This was to ensure a comprehensive trade-off analysis between cost and GHGE, while considering nutritional adequacies and acceptability. Nadir values (lowest or worst-case scenario values) were obtained for the objective functions (cost and GHGE, respectively) (Equation 19). These values are essential in defining the limits for each objective function (Alves and Costa, 2009).

As Eghbali-Zarch et al. (2017) demonstrated, the range between optimal solutions obtained (for both cost and GHGE) and their corresponding nadir values were computed. The range was then divided into intermediate equidistant grid points denoted as $\varepsilon_1, \varepsilon_2, \ldots\ldots\ldots \varepsilon_n$, (Mavrotas, 2009). The single bi-objective model was then solved with cost as the primary objective function while holding GHGE as a constraint, as defined in Equations 16, 17.

The value of ε was calculated using Equation 18, and the minimum and maximum values were iteratively calculated using Equation 19 to generate the trade-off table as demonstrated by Javadi et al. (2020).

2.6 Obtaining results

The optimisation procedures were implemented using the Python programming language to obtain feasible solutions to the optimisation problem. Python scripts were developed to implement linear programming and the ε-constraint method, whereby ε values were iteratively varied to generate multiple Pareto-optimal solutions that represented different trade-offs between cost and greenhouse gas emissions (GHGE). The optimal solution sets produced Pareto frontiers that visually depicted the relationship between cost and GHGE for the defined population groups, while satisfying all constraints defined.

2.7 Statistical analysis

The outputs from the optimisation runs were exported to Microsoft Excel for statistical evaluation. The coefficient of correlation (r) and coefficient of determination (R^2) were calculated to assess the strength and proportion of variance in the relationship between cost and GHGE across the Pareto optimal solutions (Equations 20, 21)

$$r = \frac{n\sum(xy) - \sum x \sum y}{\sqrt{\left[n\sum x^2 - \left(\sum x^2\right)\right]\left[n\sum y^2 - \left(\sum y^2\right)\right]}} \tag{20}$$

$$R^2 = \left(r^2\right) \tag{21}$$

$$n = \text{number of data points}$$

$$x = \text{cost of food basket}$$

$$y = \text{GHGE of food basket}$$

3 Results and discussion

3.1 Results

Figure 2 represents the Pareto frontier- a visualization of the interplay between cost and GHGE objectives for adult males and females aged 19 and 50. The graph shows the 2-dimensional (2D) representation where the x-axis denotes the cost objective function, while the y-axis signifies the GHGE objective function. Each data point within the graphical depiction corresponds to a solution that optimises the trade-off between cost and GHGE. It is important to note that improving the cost leads to an increase in GHGE and vice versa, highlighting the concept of Pareto optimality.

Every data point in Figure 2 represents nutritionally balanced and culturally acceptable diets because the nutrient and food group requirements stayed within the defined limits. Although the algorithm was set to yield twenty (20) solution sets, after the third solution set there were no changes observed in the remaining seventeen (17), hence, they are saturated in the third data point (Figure 2).

Table 1 shows a negative correlation coefficient (r) and the proportion of variance (R^2) between the cost and GHGE objectives. The cost is a dependable predictor of GHGE, as it accounts for a significant portion of the variability in GHGE values. This emphasises the relationship between cost and GHGE, indicating that variability in cost is closely linked to corresponding changes in GHGE levels.

Table 2 summarises the pay-off generated between cost and GHGE for the different population groups considered within the study scope. From the trade-off table, it was observed that as the food basket cost increased, GHGE reduced moderately, and vice versa. This represents a conflict between the two objective functions: minimum cost and minimum GHGE. Each dataset represents a distinct optimisation run, demonstrating how reductions in cost correspond to increases in GHGE, and vice versa. All solutions meet nutritional adequacy and cultural acceptability constraints.

The contribution of the food groups remained within the defined limits (Equations 5–11) within the problem statement. However, deviations from the recommended intake levels outlined in the Food-Based Dietary Guidelines (FBDG) were observed across different food categories, as illustrated in Figure 3. For example, there was approximately +4 units deviations for vegetables from the recommendations from the FBDG, although this was captured in the modified (Equations 5–11). Similarly, there was a reduction range of −4 to −6 units for staples across all the data optimal solution sets (points 1, 2, and 3) obtained (Figure 3).

Figure 4 shows the contribution of the different optimal solution set points to the energy values obtained after the optimisation process for adult males and females aged 19 to 50 years. The optimised energy values were 2,500, 2622.4, and 2,500 kcal for the three Pareto optimal points for the food baskets for adult males. Those for the female food baskets were 2355.5, 2,400, and 2040 kcal for the three points. The color spectrum in Figure 4 represents the intensity gradient, with darker red and blue colors indicating higher and lower values, respectively, and lighter colors indicating intermediate values. For example, for the optimised solution set one for the scenario defined for adult male, LSNs contributed the most to meeting the energy value obtained for that solution set. All nutrients stayed within the established lower and upper limits.

3.2 Discussion

The optimisation results revealed a strong inverse relationship between cost and GHGE in the food baskets designed for Ghanaian adults aged 19–50 years. Specifically, diets with lower costs tended to have higher GHGE values, while diets with reduced emissions were generally more expensive. While minimising cost does not directly cause higher emissions, the least-cost food combinations selected by the model often included food items with relatively greater GHGE values. This trade-off highlights the complexity of achieving affordability and environmental sustainability simultaneously, a finding consistent with other studies that have examined similar conflicts in

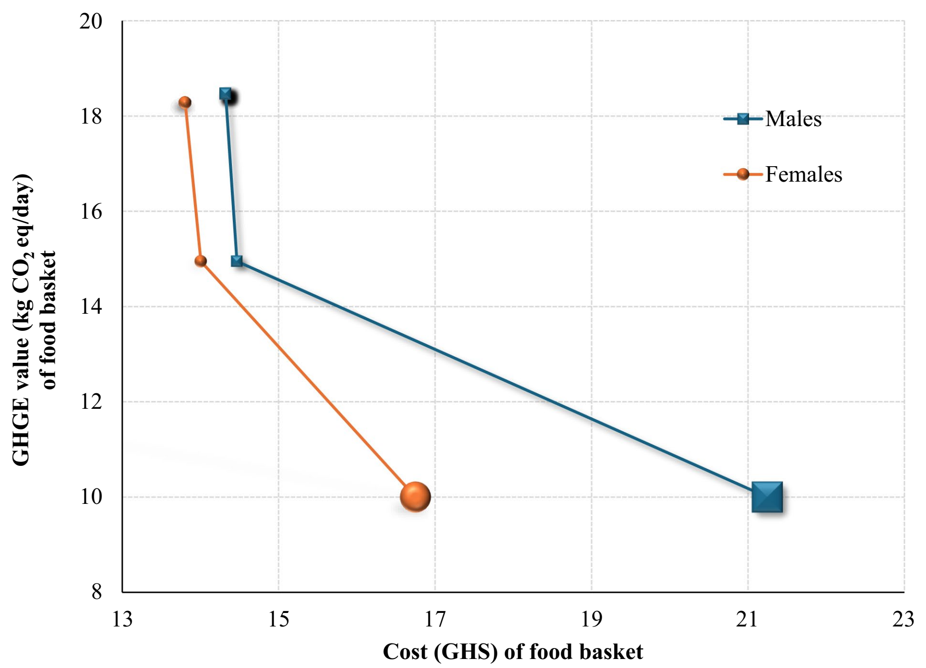

FIGURE 2
Pareto frontier illustrating the trade-offs between cost (GHS) and greenhouse gas emissions (GHGE, g CO_2 eq/day) for a nutritionally adequate and culturally acceptable diet for Ghanaian adults aged 19–50 years.

TABLE 1 Correlation coefficients (*r*) and coefficients of determination (R^2) between cost and GHGE for optimised diets for Ghanaian adults aged 19–50 years.

Target group	*r*	R^2
Males	−0.93	0.87
Females	−0.95	0.90

r, coefficient of correlation; R^2, coefficient of determination.

TABLE 2 Trade-off table summarising Pareto optimal solutions for cost (GHS) and GHGE (g CO_2 eq/day) for optimised food baskets for Ghanaian adult males and females aged 19–50 years.

Dataset	Males		Females	
	f_{Cost}	f_{GHGE}	f_{Cost}	f_{GHGE}
1	21.25	10.0	16.75	10.0
2	14.47	14.9	14.01	14.9
3	14.32	18.5	13.81	18.3

f cost, Cost (GHS) objective; f_{GHGE}, GHGE (greenhouse gas emission) kg (CO_2 eq/day) objective.

diet optimisation (Moraes et al., 2015; Reynolds et al., 2019; Lucas et al., 2021).

The results support the findings of Hendriks et al. (2023), who highlighted trade-offs existing in optimised diets, for affordability, climate, and the environment. Lucas et al. (2021) similarly established that the least expensive, nutritionally adequate diet did not necessarily result in the most environmentally sustainable diet, and vice versa. Moraes et al. (2015) observed comparable dynamics in dairy systems, where reductions in methane emissions were associated with higher diet costs, even though they did not generate a Pareto frontier. Reynolds et al. (2019) further demonstrated that in the UK, more affordable diets tended to have higher GHGE intensities, while costlier diets were slightly less emission-intensive. These findings collectively highlight that the trade-off between cost and GHGE is a fundamental consideration across diverse food systems.

The strength of the statistical associations observed in this study ($r = -0.93$ for males and −0.95 for females) underscores the robustness of the optimisation outputs. Similarly, the high coefficients of determination ($R^2 = 0.87$ for males and 0.90 for females) indicate that cost explains much of the variability in GHGE within the model, but this does not imply that changes in cost alone would directly alter emissions in real-world settings. These findings therefore provide evidence of potential trade-offs, rather than deterministic outcomes.

Balancing affordability, nutritional adequacy, and environmental sustainability is crucial for the overall well-being of individuals and societies. The inclusion of nutritional adequacy constraints in the optimisation ensured that all solutions met recommended dietary requirements, demonstrating that health considerations can be integrated into complex trade-offs. This aligns with global calls to prioritise both affordability and nutrition in food system transformations (Vermeulen et al., 2020; Neufeld et al., 2023). Importantly, the model showed that nutritionally adequate diets could be achieved across different cost-GHGE trade-offs, highlighting the potential for context-specific strategies that promote sustainable diets without compromising health.

Recent region-specific studies reinforce these findings. Okekunle et al. (2024) developed a Sustainable Diet Index for Ghanaian adults, showing that affordability and nutrition remain central challenges in dietary transitions. Darko and Martey (2025) applied optimisation approaches to Ghana's food system, highlighting the policy relevance of balancing cost, nutrition, and sustainability in national dietary strategies. Similarly, Agyapong et al. (2022) reviewed Ghana's food system and emphasised the need for culturally grounded approaches to sustainability, aligning with the food group constraints applied in this study. Drawing on the statistical associations observed in the

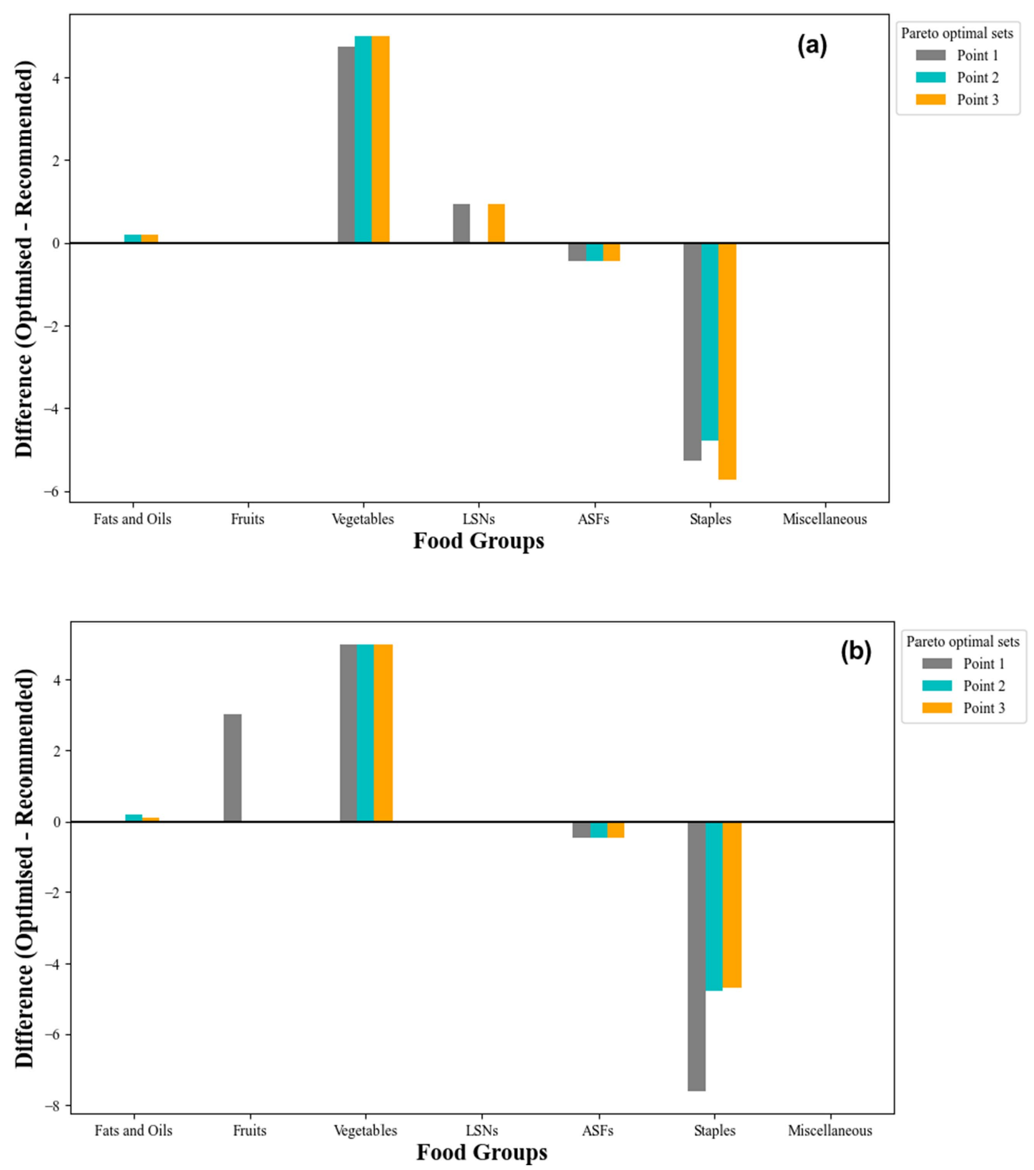

FIGURE 3
Deviations between the optimized food group contributions and recommended intake levels from the food-based dietary guidelines (FBDGs) for Ghana: adult males **(a)** and females **(b)**. ASFs, animal-sourced foods; LSNs, legumes, seeds, and nuts.

study and the conclusions of Agyapong et al. (2022), Okekunle et al. (2024) and Darko and Martey (2025), trade-offs between affordability and GHGE appear to be a consistent feature of food systems, Importantly, the inclusion of nutritional and food group constraints demonstrates that health and cultural relevance can be preserved even within these trade-offs. These regional perspectives strengthen the applicability of the current findings to Ghana and West Africa, ensuring that optimisation frameworks are not only globally relevant but also locally grounded. Furthermore, the observed adjustments in food group contributions—such as slight increases in vegetables and legumes, seeds, and nuts (LSNs), and reductions in staples—illustrate how optimisation strategies can rebalance diets to achieve multiple objectives. These adjustments, even though slightly deviated from the recommendations from the FBDGs, were necessary to ensure the dimensions of affordability, nutritional adequacy, cultural acceptability, and environmental sustainability (GHGE) were balanced. While some of the ingredient combinations generated by the algorithm may not reflect typical meal patterns, the inclusion of food group constraints ensured that the baskets remained culturally acceptable and close to the recommendations of the Food-Based Dietary Guidelines (FBDGs) for Ghana. This reinforces the importance of consumer-facing strategies that encourage dietary shifts toward sustainability without imposing unfamiliar or impractical foods (Downs et al., 2023; Tufford et al., 2023).

3.3 Limitations

The reliance on secondary, non–country-specific greenhouse gas emission (GHGE) data represents a significant limitation of this study. The GHGE values were not directly measured for the food ingredients considered, which may have led to under-, or overestimation of the actual emissions associated with the optimised food baskets.

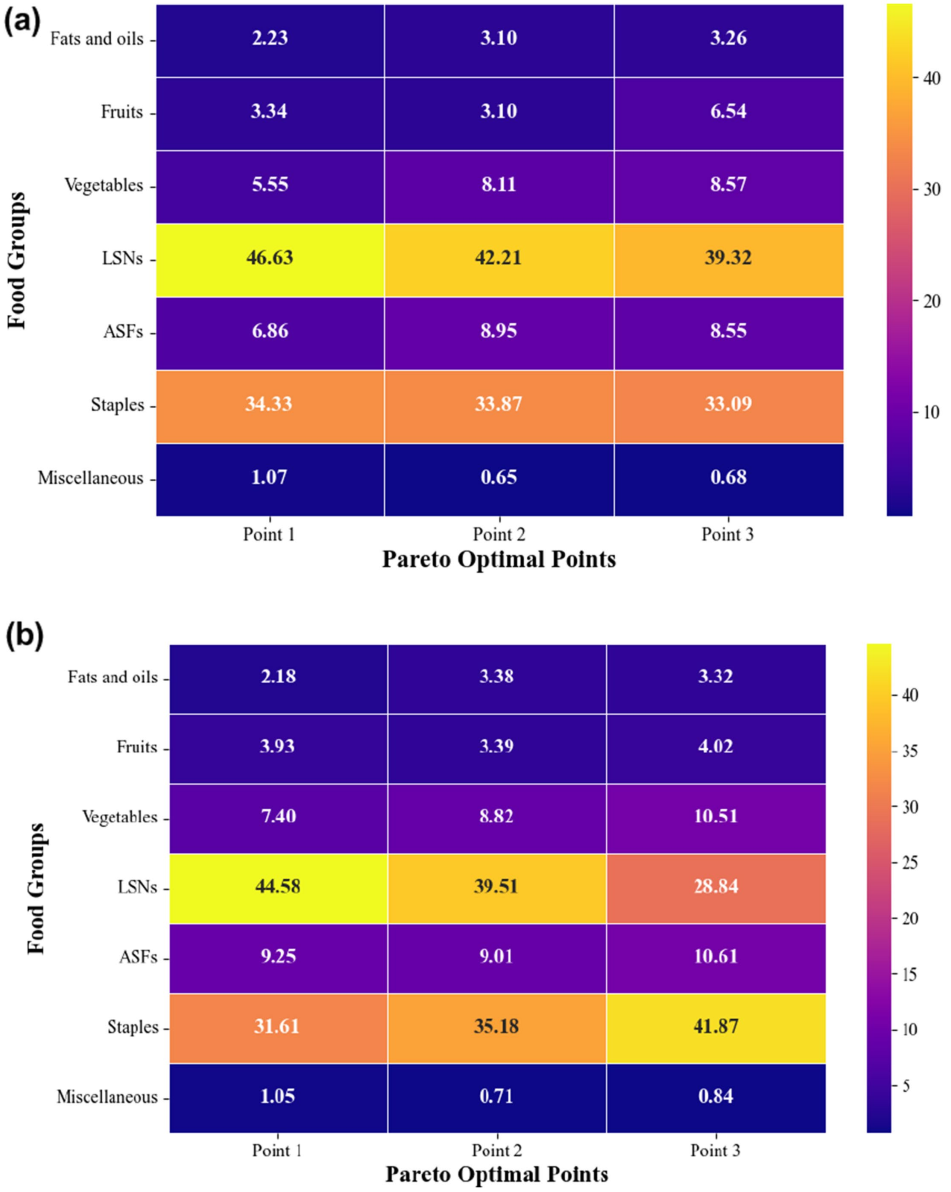

FIGURE 4
Percent contribution of the food groups to total energy (kcal) values obtained for the optimized sets (points 1, 2, and 3) for Ghanaian adult males **(a)** and females **(b)** aged 19–50 years. LSNs, legumes, seeds, and nuts; ASFs, animal-sourced foods.

4 Conclusion

Achieving sustainable diets requires a holistic approach that integrates affordability, nutritional adequacy, cultural acceptability and environmental sustainability. This study demonstrated, through a model-based optimisation framework, that strong inverse associations exist between diets cost and greenhouse gas emission (GHGE). While lower-cost diets tend to have higher emissions and vice versa, these findings reflect statistical associations within the optimisation model rather than casual mechanisms.

By applying the epsilon-constraint method, the study successfully balanced multiple objectives, showing that nutritionally adequate and culturally acceptable diets can be achieved across different cost–GHGE trade-offs. Importantly, the inclusion of nutrient and food group constraints ensured that health and acceptability dimensions were not compromised in the pursuit of affordability or environmental goals.

These insights provide valuable guidance for policymakers, industry stakeholders, and consumer-facing initiatives seeking to promote sustainable dietary practices in Ghana and similar contexts. Future work should incorporate country-specific GHGE datasets, expand food item coverage, and adapt the framework to diverse demographic groups, thereby strengthening its relevance for national nutrition strategies and global sustainability agendas.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

LD: Validation, Writing – original draft, Formal analysis, Methodology, Investigation, Data curation, Visualization, Software, Conceptualization, Writing – review & editing. EE: Conceptualization, Writing – review & editing, Data curation, Validation, Formal analysis, Software, Supervision. HV: Writing – review & editing, Software, Conceptualization, Supervision, Resources, Visualization, Validation, Methodology. JV: Software, Formal analysis, Methodology, Data curation, Writing – review & editing, Validation. E-PN: Visualization, Validation, Methodology, Data curation, Writing – review & editing. NA: Validation, Visualization, Methodology, Conceptualization, Resources, Funding acquisition, Writing – review & editing, Supervision, Investigation, Project administration. FS: Conceptualization, Writing – review & editing, Supervision, Validation, Methodology, Resources, Funding acquisition.

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Conflict of interest

Authors HV and JV were employed by company Nestlé Research.

The remaining author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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