HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

HEIDELBERG INSTITUTE OF GLOBAL HEALTH

UNIVERSITY OF KWAZULU-NATAL ™
INYUVESI YAKWAZULU-NATALI

MUHAS

MAKERERE UNIVERSITY

UNIVERSITY OF GHANA

Data Science Initiative for Africa (DSI-Africa)

Climate Change, Food Systems and Planetary Health

29 July 2024

Ina Danquah

Optimal learning atmosphere

For the online course, …

- Be seated in a quiet working environment
- Ensure stable internet access
- Keep on your cameras whenever possible
- Raise your (digital) hand when you have a question

Learning objectives

Week 1:

- Familiarizing with the course program and getting to know each other
- Statistical approaches to identifying climate change impacts on agriculture, diet and nutrition, including basic constructs of food system metrics
- Adaptive planning using data science and technology

Week 2:

- Refreshing epidemiology with a focus on food systems
- **Operationalize sustainable nutrition** using anthropometry, **dietary patterns**, and yield estimates
- **Calculate constructs of sustainable nutrition** and agriculture, incl. remote sensing

WASHA TAKWIMU
WORKING ON APPLICATIONS FOR DATA SCIENCE AND HEALTH IN AFRICA

Outline

Day	Week 1, 22 – 26 July (online)	Facilitator
Mon	Exploratory spatial analysis and model evaluation Reading: Rainfall patterns related to dietary habits	G Kallah-Dagadu Students
Tue	Hackathon: Climate Change solutions in your country Theoretical concepts: Climate change impacts on nutrition and diets Practical: Calculate rainfall pattern related to dietary habits Theoretical concepts: Nutrition and food systems	G Kallah-Dagadu I Danquah I Danquah I Madzorera
Wed	Hackathon: Climate change solutions in your country Theoretical concepts: Dietary pattern construction Calculation of food system metrics	G Kallah-Dagadu I Danquah I Madzorera
Thu	Technological innovations for sustainable agriculture Trends, scenarios and resilience planning	S Barteit S Barteit
Fri	Hackathon presentations Heat-2-Harvest project	Students S Barteit

Outline

Day	Week 2, 29 July – 02 August (in-person)	Facilitator
Mon	Opening remarks	W Fawzi
	Food Systems, Nutrition and Planetary Health - I: Descriptive Epidemiology	W Fawzi
	Theoretical concepts: Operationalize sustainable diets	I Danquah
	Practical: Calculate the Sustainable Diet Index	I Danquah
Tue	Food Systems, Nutrition and Planetary Health - II: Concepts and Associations	W Fawzi I Madzorera
	Practical: Calculate anthropometric indices	I Madzorera
	Practical: Calculate GDQS	S Barteit
	Lasso Regression for crop yield modeling Part I	
Wed	Modeling associations between climate change and nutritition	I Madzorera
	Lasso Regression for crop yield modeling Part II	S Barteit
	Practical: Optimization modelling for sustainable diets	G Kallah-Dagadu
Thu	Remote Sensing Part I+II	G Kallah-Dagadu
	Remote Sensing Part III+IV	G Kallah-Dagadu
Fri	Theoretical concepts: Vegetation indices	G Kallah-Dagadu
	Practical: Calculate vegetation indices	G Kallah-Dagadu

Operationalize sustainable diets

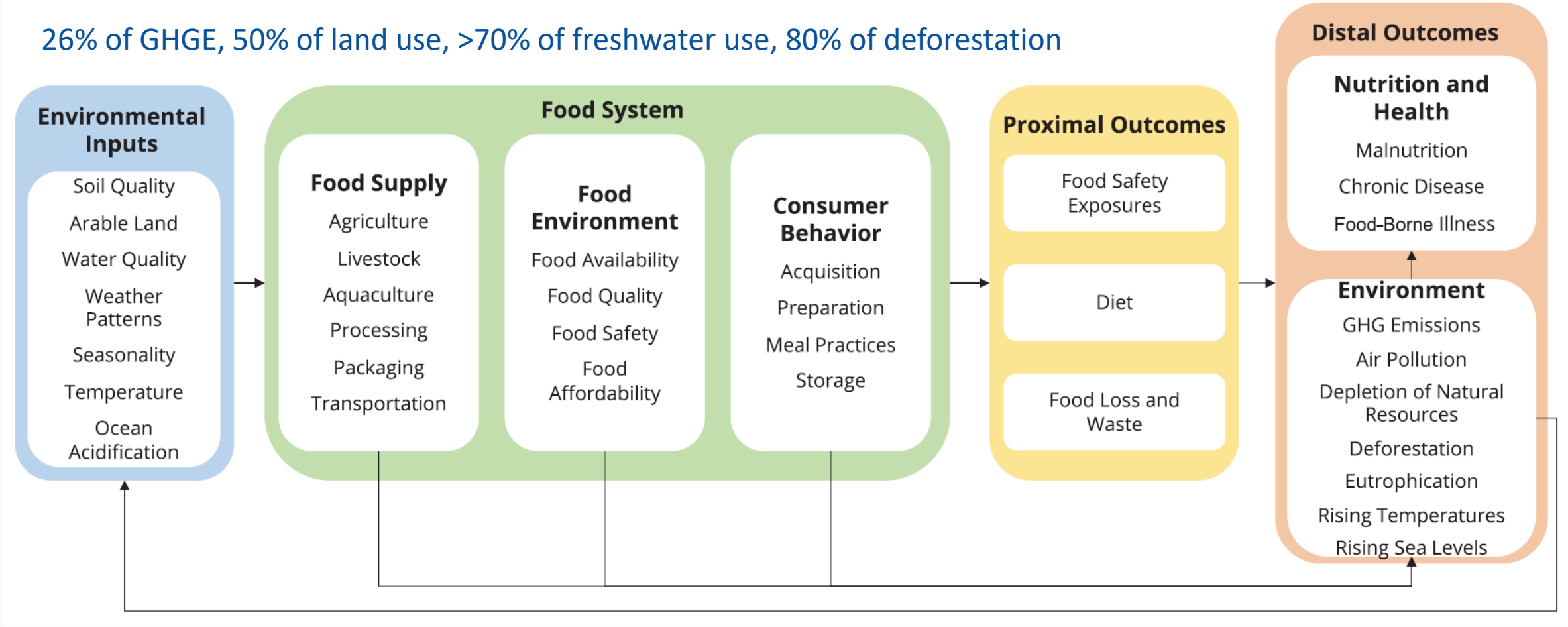
- Big picture: Food systems and sustainable diets
- Why operationalize?
- 4 Approaches
  - Approach
  - Pros and cons
  - Literature example
  - Own example
- Summary
- Practical exercise: Calculation of Sustainable Diet Index

Optional reading

- Perignon M & Darmon N. Advantages and limitations of the methodological approaches used to study dietary shifts towards improved nutrition and sustainability. Nutr Rev 2022;80(3):579-597.
- Willett W et al. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Lancet 2019;393(10170):447-492.
- Stubbendorff A et al. Development of an EAT-Lancet index and its relation to mortality in a Swedish population. Am J Clin Nutr 2022;115(3):705-716.
- Cacau LT et al. Development and Validation of an Index Based on EAT-Lancet Recommendations: The Planetary Health Diet Index. Nutrients 2021;13(5):1698.
- Seconda L et al. Development and validation of an individual sustainable diet index in the NutriNet-Sante study cohort. Br J Nutr. 2019;121(10):1166-1177.

FOOD SYSTEMS

26% of GHGE, 50% of land use, >70% of freshwater use, 80% of deforestation



Fanzo et al. 2021; Whitmee et al. Lancet 2015

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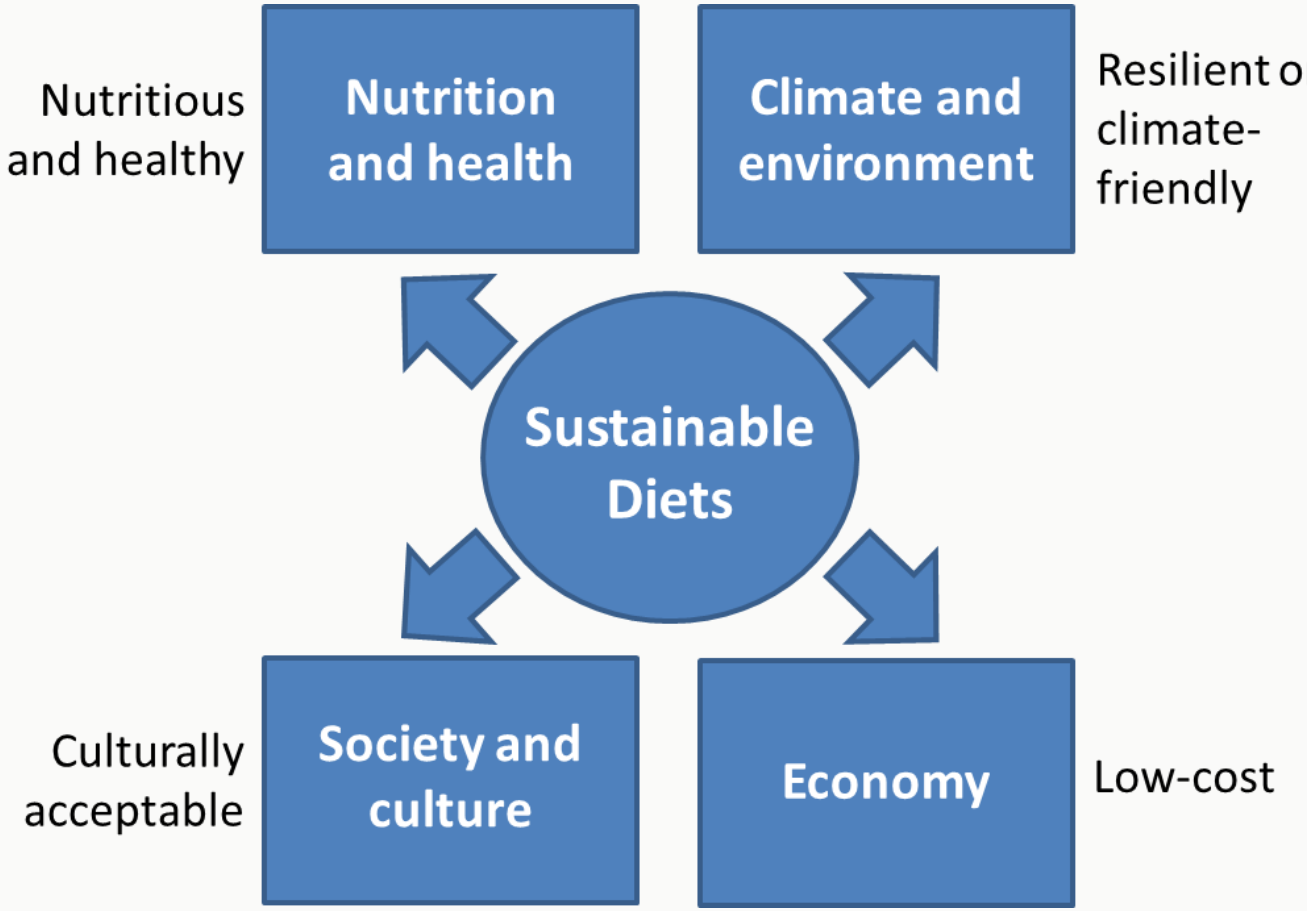
SUSTAINABLE DIETS

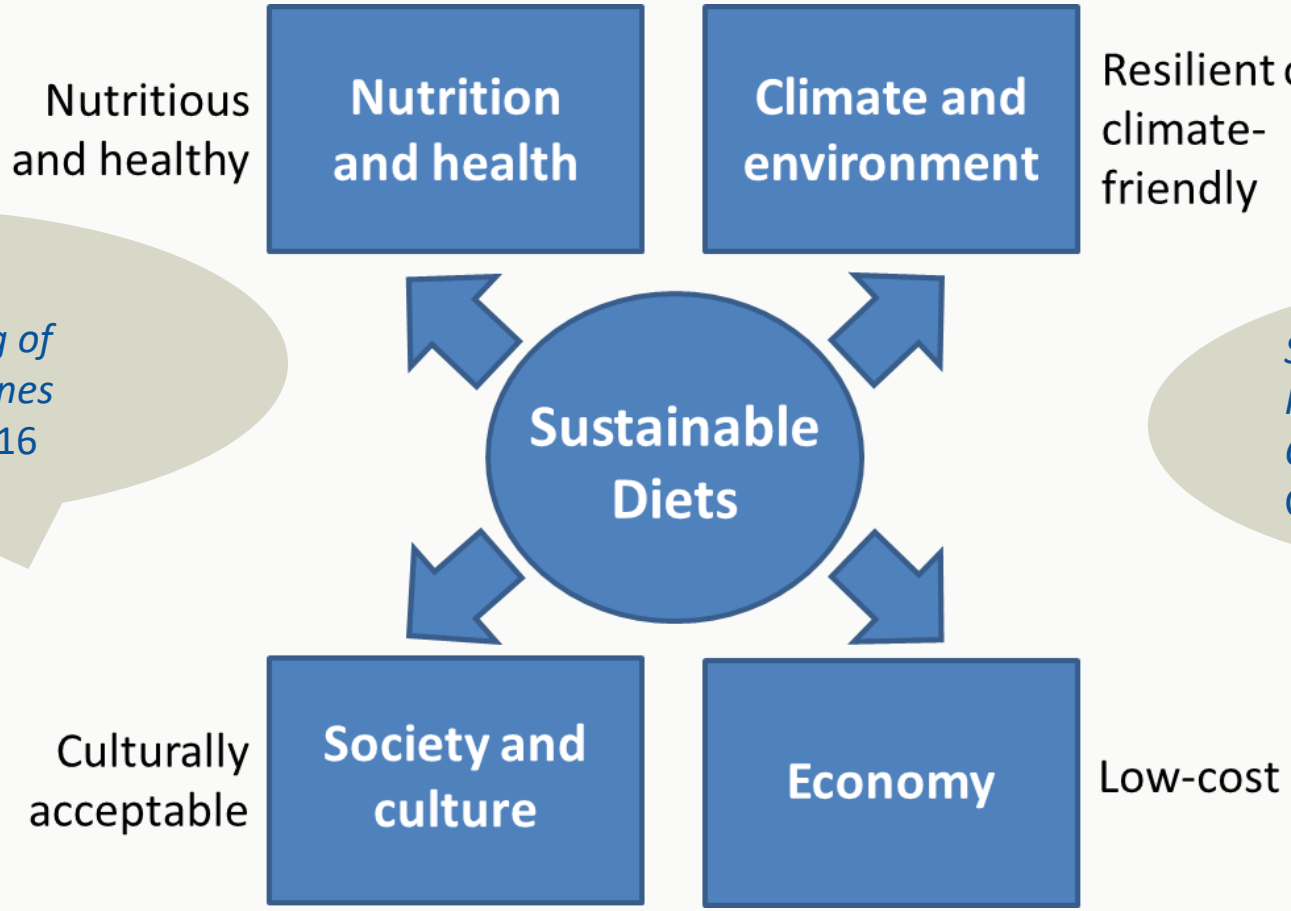
SUSTAINABLE DIETS



Burlingame & Dernini FAO, Rome 2012

SUSTAINABLE DIETS

Shifting diets is often seen as very personal…
Jeff McMahon 2022



Wicked Nutrition: The controversial greening of official dietary guidelines
Susanne Freidberg 2016

Sustainably sourced Junk Food? Big Food and the Challenge of Sustainable Diets
Caitlin Scott 2018

Burlingame & Dernini FAO, Rome 2012

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WHY OPERATIONALIZE SUSTAINABLE DIETS?

- Objectify
- Practical action points
- Transparency for decision making
- Monitor status quo
- Track progress

OPERATIONALIZE SUSTAINABLE DIETS

1. Characterize sustainability dimensions of hypothetical diets (a priori)
2. Describe sustainability characteristics of existing diets (univariate or multivariate)
3. Identify and describe positive deviants
4. Optimization of existing diets (multi-criteria approach)

Perignon & Darmon. Nutr Rev 2022

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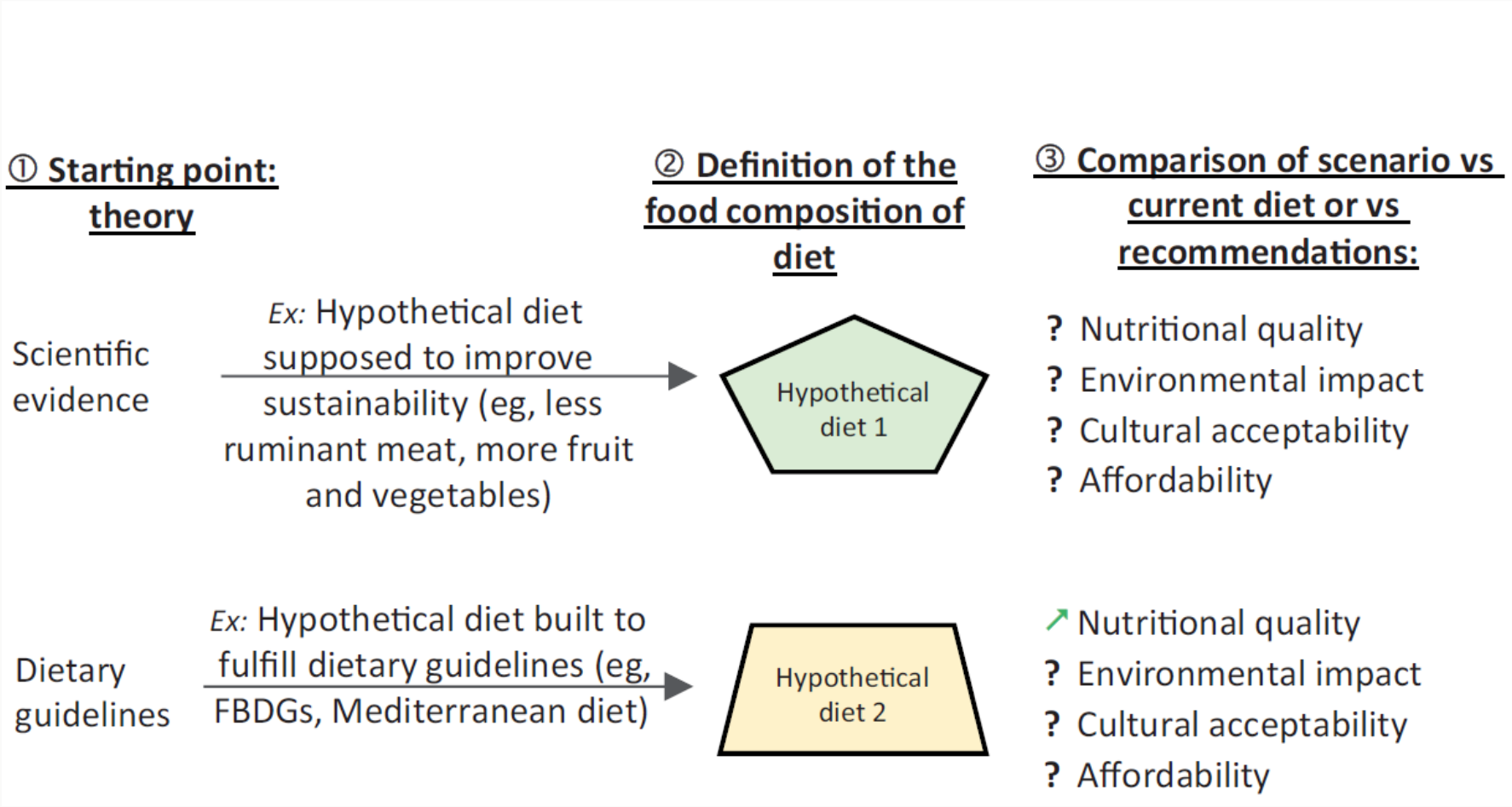
Perignon & Darmon. Nutr Rev 2022

1. SUSTAINABILITY OF HYPOTHETICAL DIETS



Perignon & Darmon. Nutr Rev 2022

1. SUSTAINABILITY OF HYPOTHETICAL DIETS

Advantages	Disadvantages
• Ease of implementation: no need of individual food consumption data	• No consideration of cultural acceptability
• Ease of communication	• Improvement in one dimension does not ensure improvement in another (e.g. health vs. cost)
	• Within one dimension, improvement of one characteristic does not ensure improvement of another (e.g. GHGE and water use)
	• No consideration of other potential sustainable diets

Perignon & Darmon. Nutr Rev 2022

1. SUSTAINABILITY OF HYPOTHETICAL DIETS

EAT-Lancet Planetary Health Diet

- Healthfulness based on systematic reviews with meta-analysis
- Environmental friendliness based on Planetary Boundaries
- No costs
- No socio-cultural appropriateness

Willett et al. Lancet 2019

1. OPERATIONALIZE THE PLANETARY HEALTH DIET

	Macronutrient intake grams per day (possible range)	Caloric intake kcal per day
Whole grains		
Rice, wheat, corn and other	**232**	**811**
Tubers or starchy vegetables		
Potatoes and cassava	**50** (0–100)	**39**
Vegetables		
All vegetables	**300** (200–600)	**78**
Fruits		
All fruits	**200** (100–300)	**126**
Dairy foods		
Whole milk or equivalents	**250** (0–500)	**153**
Protein sources		
Beef, lamb and pork	**14** (0–28)	**30**
Chicken and other poultry	**29** (0–58)	**62**
Eggs	**13** (0–25)	**19**
Fish	**28** (0–100)	**40**
Legumes	**75** (0–100)	**284**
Nuts	**50** (0–75)	**291**
Added fats		
Unsaturated oils	**40** (20–80)	**354**
Saturated oils	**11.8** (0-11.8)	**96**
Added sugars		
All sugars	**31** (0–31)	**120**

Willett et al. Lancet 2019

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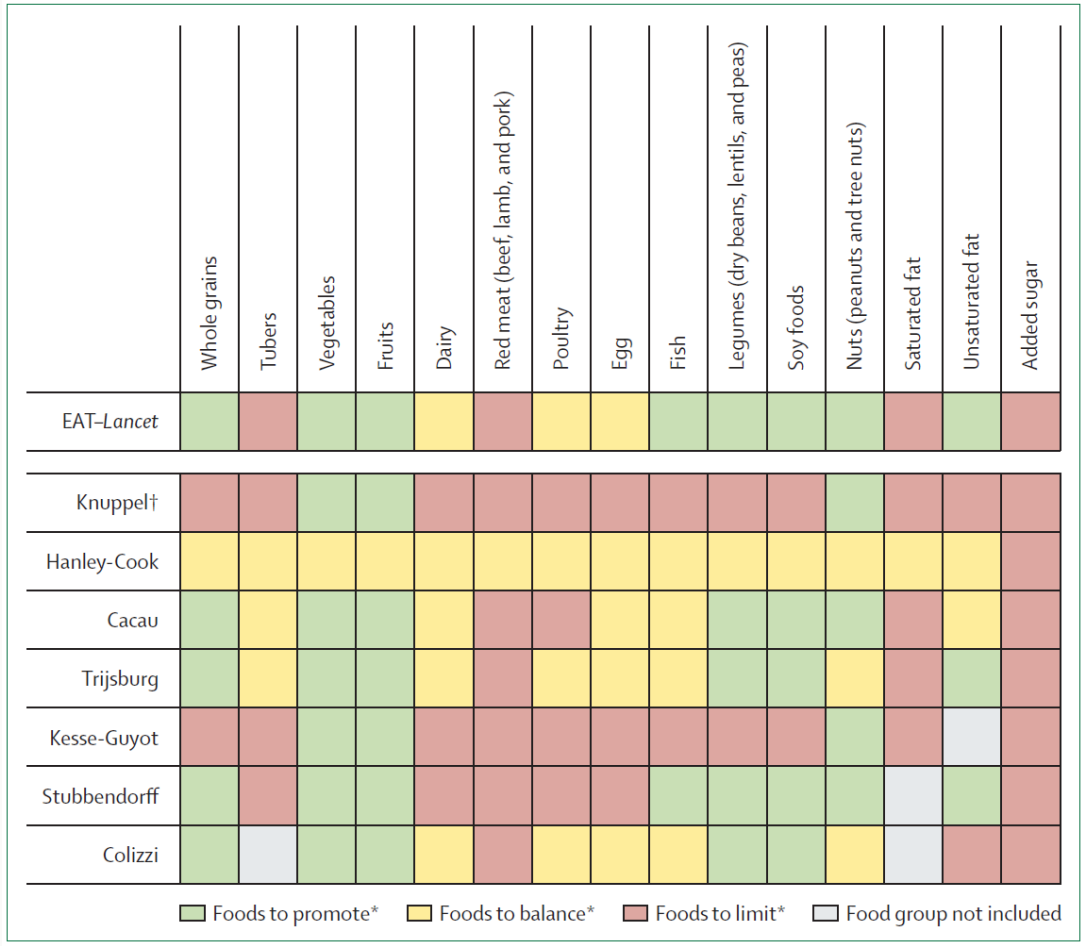
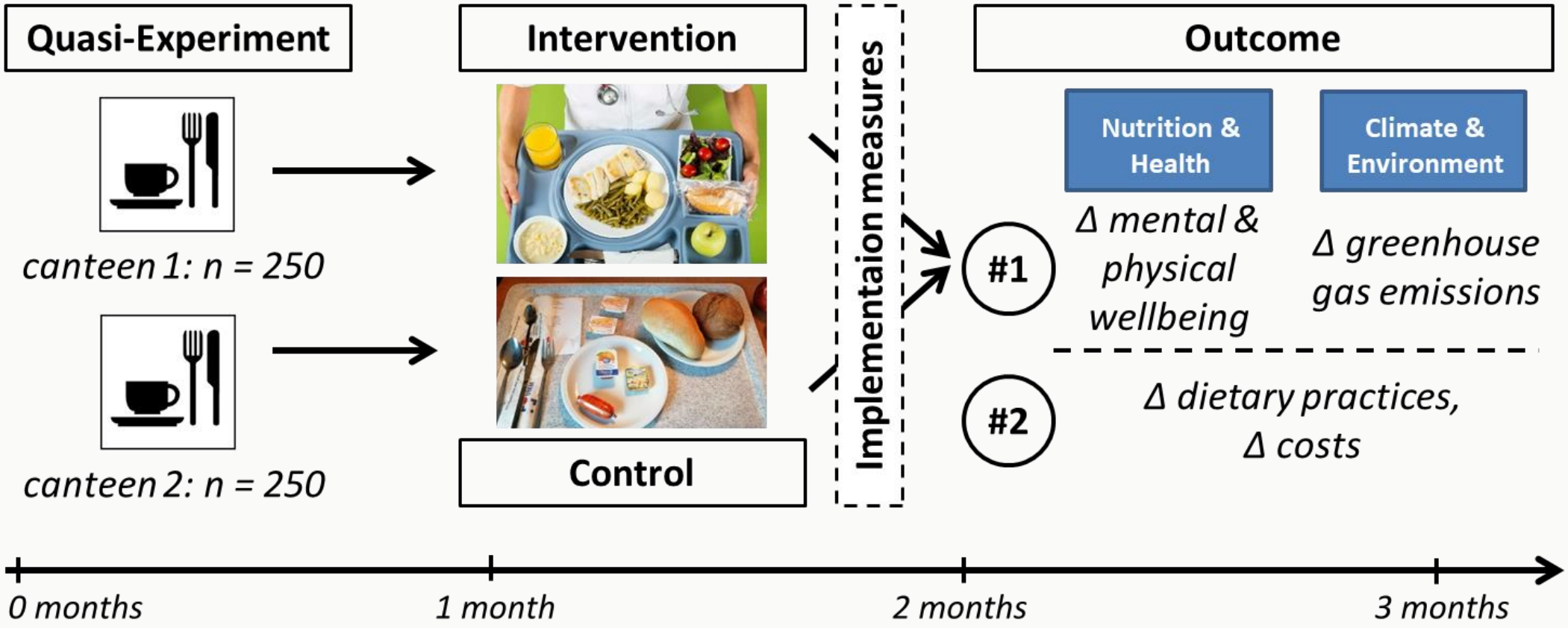
Willett et al. Lancet 2019



Stubbendorff et al. Lancet 2024

1. PHD-INDEX IN A GERMAN HOSPITAL

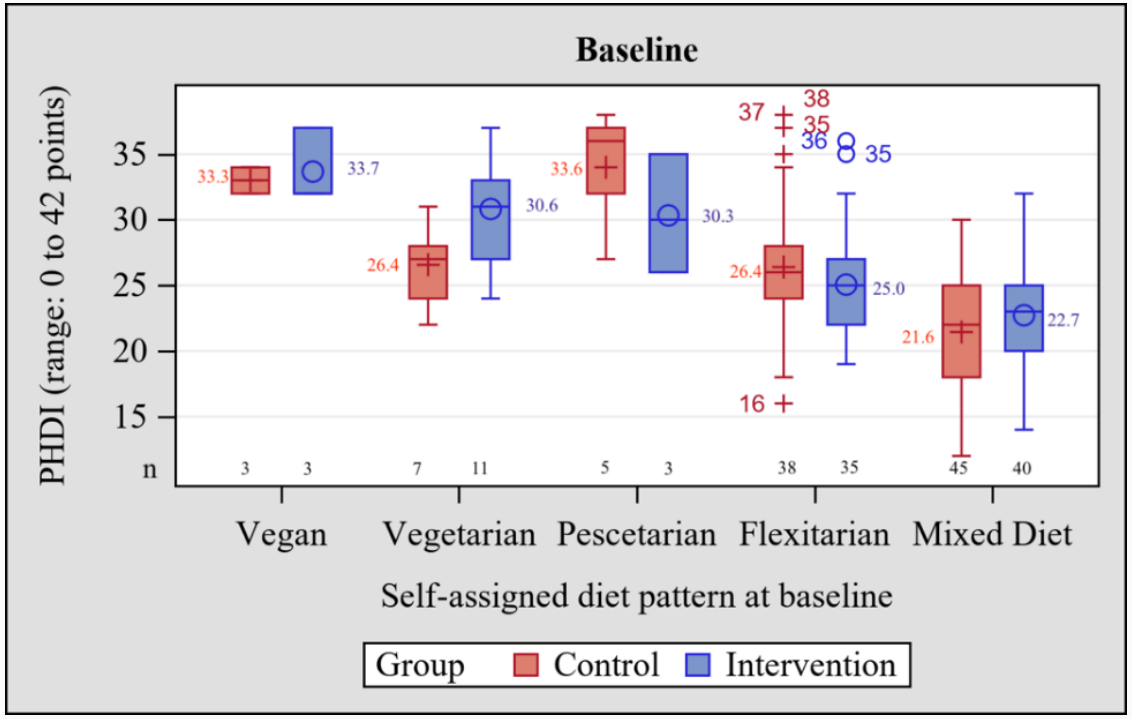
Laura Harrison
(Dr. med. candidate)

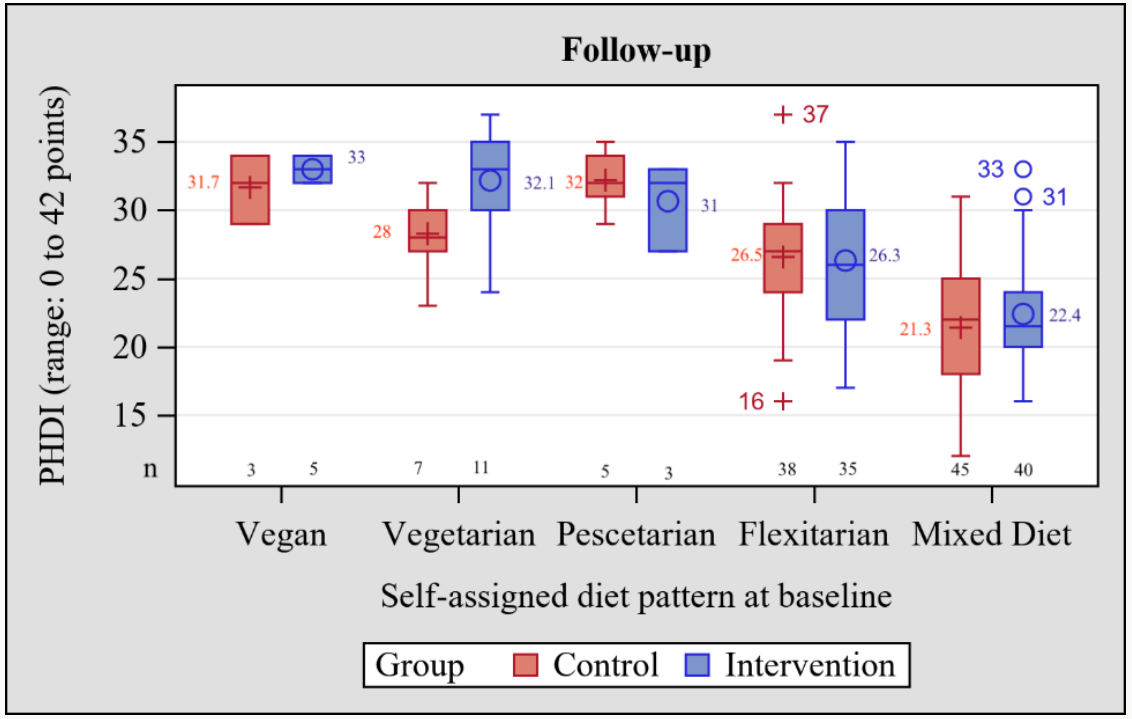


Harrison et al. Nutr J 2024 (accepted 08 July 2024)

1. PHD-INDEX IN A GERMAN HOSPITAL

Planetary Health Diet-Index





Harrison et al. Nutr J 2024 (accepted 08 July 2024)

1. PHD-INDEX IN A GERMAN HOSPITAL

Outcome	Crude Model	Model 1	Model 2
N	190	190	187
Planetary Health Diet (0-42 score points)			
Diff-in-Diff	**0.62**	**0.56**	**0.54**
95% confidence interval	-0.35, 1.58	-0.42, 1.52	-0.51, 1.59
p-value	0.210	0.260	0.310

Difference-in-differences were calculated by ANOVA.
Model 1 adjusted for education.
Model 2 adjusted for age, sex, education, occupation, marital status.

Harrison et al. Nutr J 2024 (accepted 08 July 2024)

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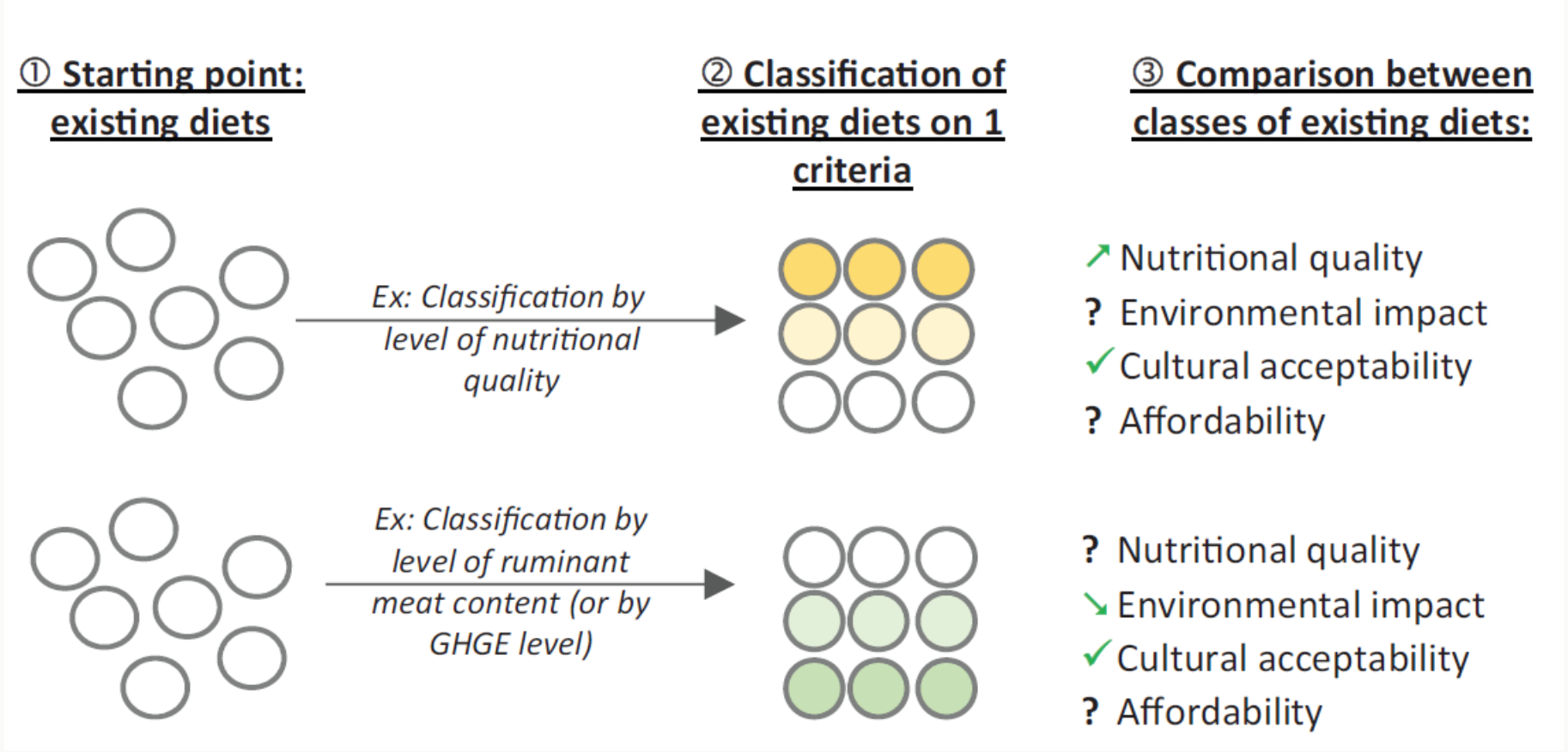
Perignon & Darmon. Nutr Rev 2022

2. SUSTAINABILITY OF EXISTING DIETS



« ↗ / ↘ » Sustainability criteria are higher/lower than the average.
« ✓ » Sustainability criteria are fulfilled.
« ? » Sustainability criteria are not ensured.

Perignon & Darmon. Nutr Rev 2022

2. SUSTAINABILITY OF EXISTING DIETS

Advantages	Disadvantages
• Better consideration of cultural acceptability	• Requires food consumption data at the individual level
• Better understanding of trade-offs between sustainability dimensions	• Improvement in one dimension does not ensure improvement in another (e.g. health vs. cost)
	• Within one dimension, improvement of one characteristic does not ensure improvement of another (e.g. GHGE and water use)

Perignon & Darmon. Nutr Rev 2022

2. SUSTAINABILITY OF EXISTING DIETS

Sustainable Diet Index by Seconda et al. 2019

	Indicators	Objectives	Points allocating	Weight in the sub-index	Assessment
Nutritional sub-index (/5)	Absolute value of difference between energy need and intake (kJ/d)	Reflects the adequacy between energy intake and energy requirements	1 point: ind >4259 2 points: 4259 ≤ ind < 2849 3 points: 2849 ≤ ind < 1812 4 points: 1812 ≤ ind <883 5 points: ind ≤883	1/2	Nutrition sub-index = the sum of points × weight
	PANDiet index (/100)	Reflects the adequacy between nutrient intake and French recommendations for twenty-four nutrients	1 point: ind ≤60·7 2 points: 60·7 < ind ≤ 64·7 3 points: 64·4 < ind ≤ 68·2 4 points: 68·2 < ind ≤ 72·8 5 points: ind >72·8	1/2	
Environmental sub-index (/5)	Land occupation (m^2/year): area required to produce raw agricultural products Greenhouse gas emissions (kg CO_2/year): quantity of carbon dioxide, methane and nitrous oxide emissions at the farm level weighted by their 100-year global warming potential Primary energy consumption (MJ/year): consumption at the farm level of renewable and non-renewable energy	The three indicators were computed together in the pReCiPe	1 point: ind >0·38 2 points: 0·38 ≤ ind < 0·29 3 points: 0·29 ≤ ind < 0·23 4 points:0·23 ≤ ind < 0·17 5 points: ind ≤0·17	3/4	Environment sub-index = the sum of points × weight
	Contribution of organic food to diet (% weight)	Mitigation of biodiversity loss in farm	1 point: ind ≤3·02 2 points: 3·02 < ind ≤ 15·5 3 points: 15·5 < ind ≤ 30·3 4 points: 30·3 < ind ≤ 54·1 5 points: ind > 54·1	1/4	
Economic sub-index (/5)	Proportion of the income devoted to diet (%)	Assesses the affordability of diet	1 point: ind >16·4 2 points: 16·4 ≤ ind < 11·4 3 points: 11·4 ≤ ind < 8·45 4 points: 8·45 ≤ ind < 5·40 5 points: 5·40 ≤ ind < 1·27	1	Economy sub-index = the sum of points × weight
Sociocultural sub-index (/5)	Place of food purchase (/2)	Index to evaluate the frequency of food purchase places other than supermarket*	1 point: ind <0·28 2 points: 0·28 ≤ ind < 0·45 3 points: 0·45 ≤ ind < 0·60 4 points: 0·60 ≤ ind < 0·79 5 points: ind ≥0·79	1/2	Sociocultural sub-index = the sum of points × weight
	Ready-made products (/3)	Index to assess the consumption of ready-made products†	1 point: ind ≥1·75 2 points: ind = 1·5 3 points: ind = 1·25 4 points: ind = 1·00 5 points: ind ≤1	1/2	
Total (/20)		SDI = nutritional + environmental + economic + sociocultural			

Seconda et al. Br J Nutr 2019

2. SUSTAINABILITY OF EXISTING DIETS AMONG 5,989 GHANAIAN ADULTS

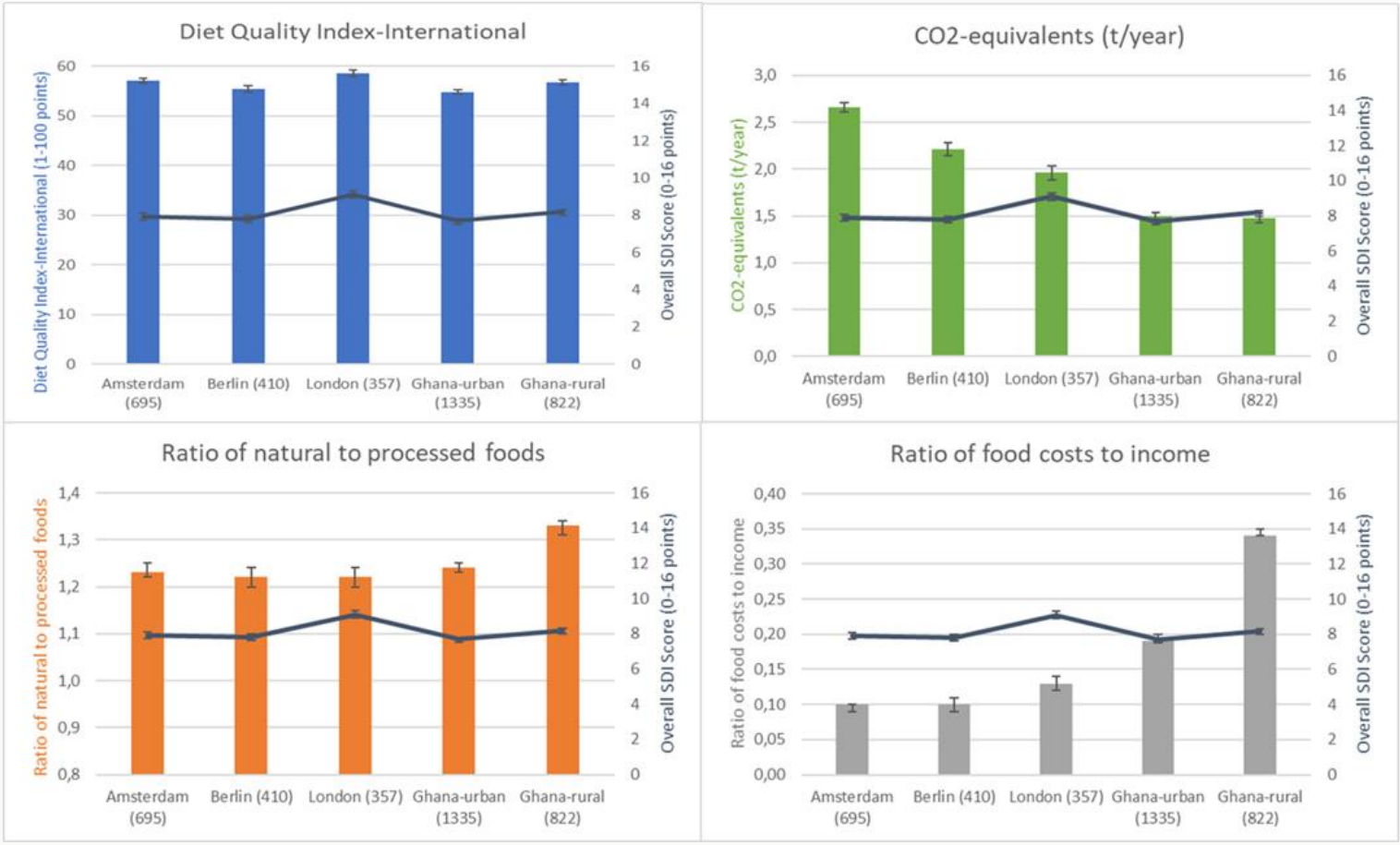
Paul A Okekunle, PhD

Nutrition and health

Climate and environment

Culture and society

Economy



Okekunle et al. Nutr J 2024 (accepted 27 June 2024)

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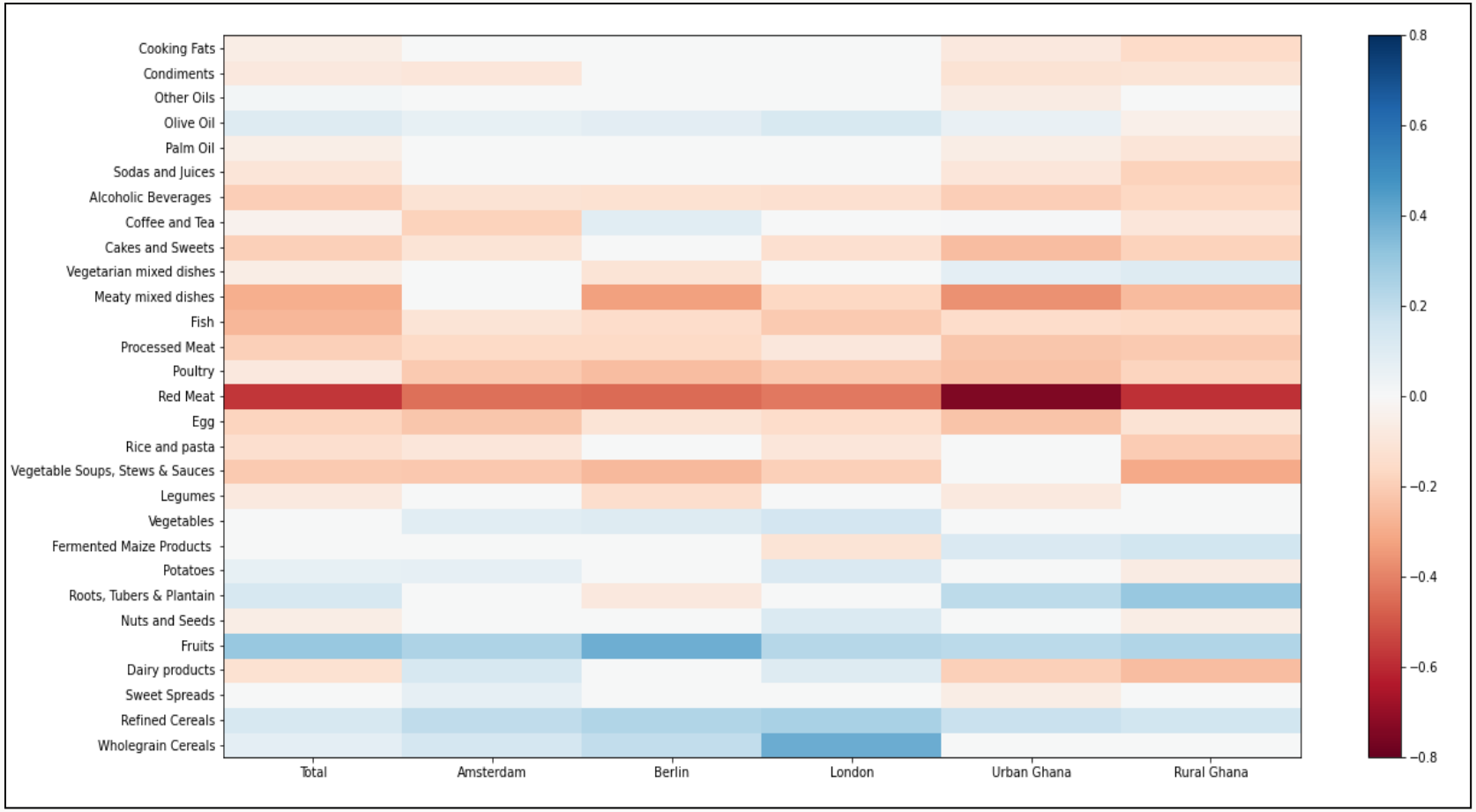

Pearson correlations Sustainable Diet Index and food intake

Okekunle et al. Nutr J 2024 (accepted 27 June 2024)

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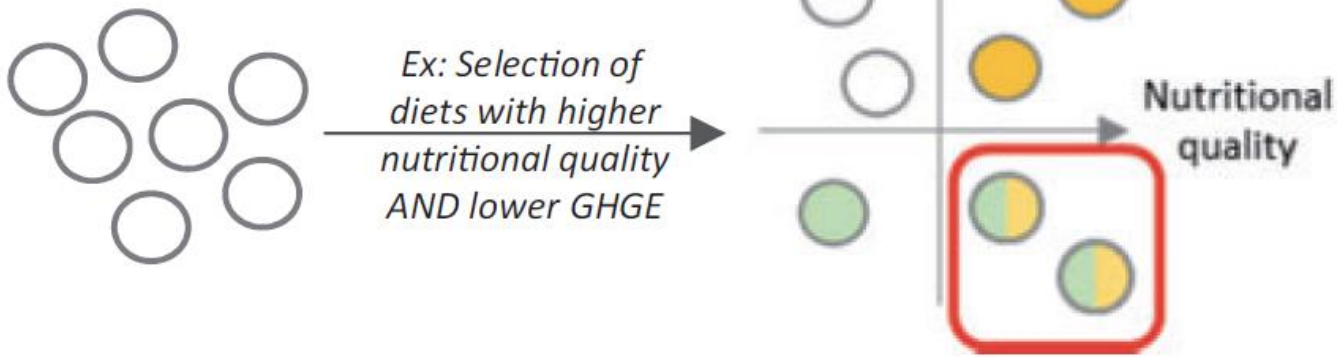
Perignon & Darmon. Nutr Rev 2022

3. IDENTIFY POSITIVE DEVIANTS

① Starting point: existing diets

② Selection of existing diets that simultaneously fulfill several sustainability criteria

③ Comparison of positive deviants vs non deviants:



↗ Nutritional quality
↘ Environmental impact
✓ Cultural acceptability
? Affordability

Perignon & Darmon. Nutr Rev 2022

« ↗ / ↘ »	Sustainability criteria is improved (higher or lower than the average)
« ✓ »	Sustainability criteria is fulfilled
« ? »	Sustainability criteria is not ensured : it needs to be assessed a posteriori, or included in the selection criteria

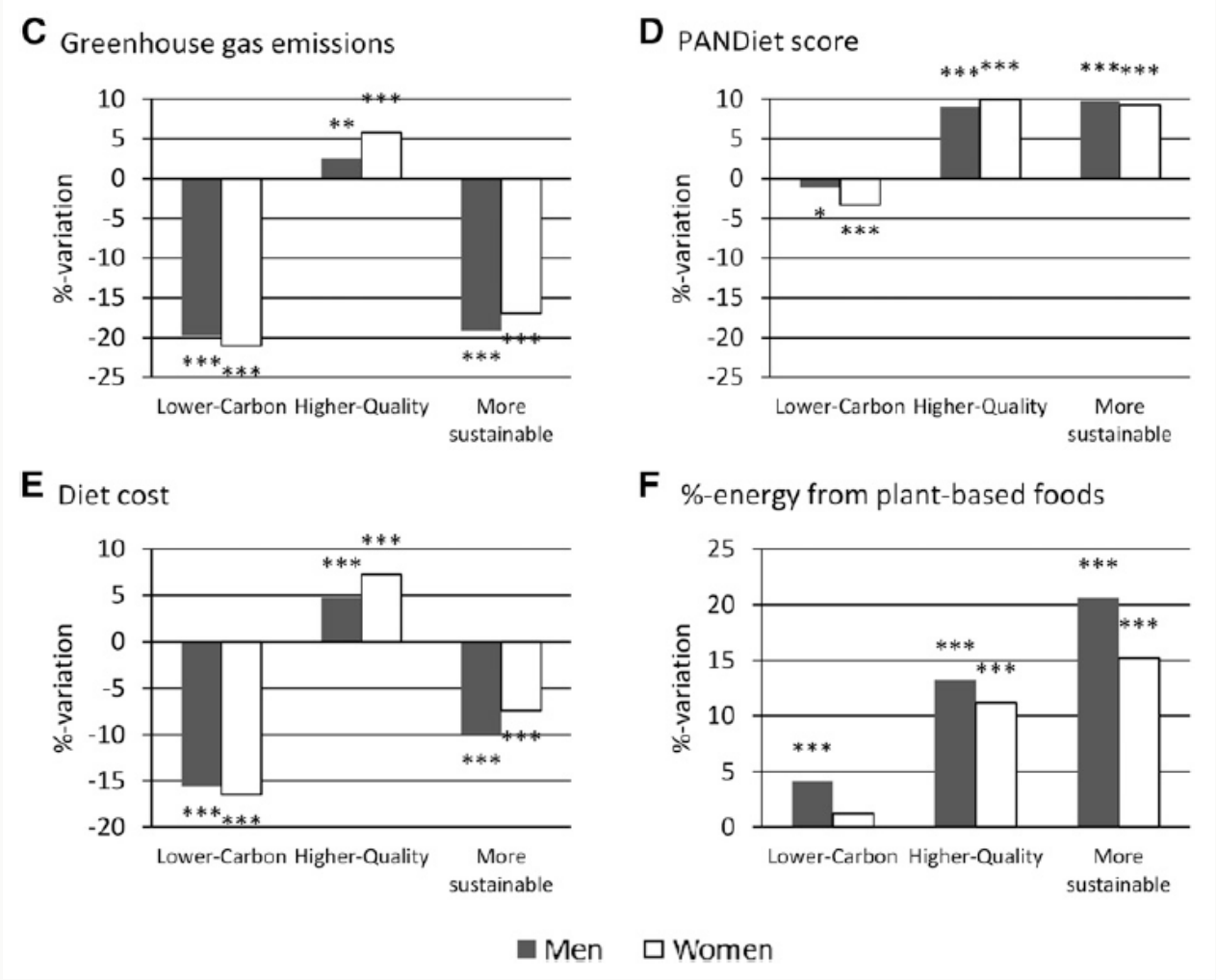
3. IDENTIFY POSITIVE DEVIANTS

Advantages	Disadvantages
• Better consideration of cultural appropriateness	• Requires food consumption data at the individual level
• Achievement of several sustainability criteria simultaneously	• Within one dimension, improvement of one characteristic does not ensure improvement of another (e.g. GHGE and water use)
	• Magnitude of improvement might be too small (e.g. nutritional quality ≠ adequacy)
	• Difficulty to identify sustainable diet when too many criteria are considered

Perignon & Darmon. Nutr Rev 2022

3. POSITIVE DEVIANTS IN FRANCE

Second Individual and National Survey on Food Consumption (INCA2) (N = 1948)



Masset et al. Am J Clin Nutr 2014

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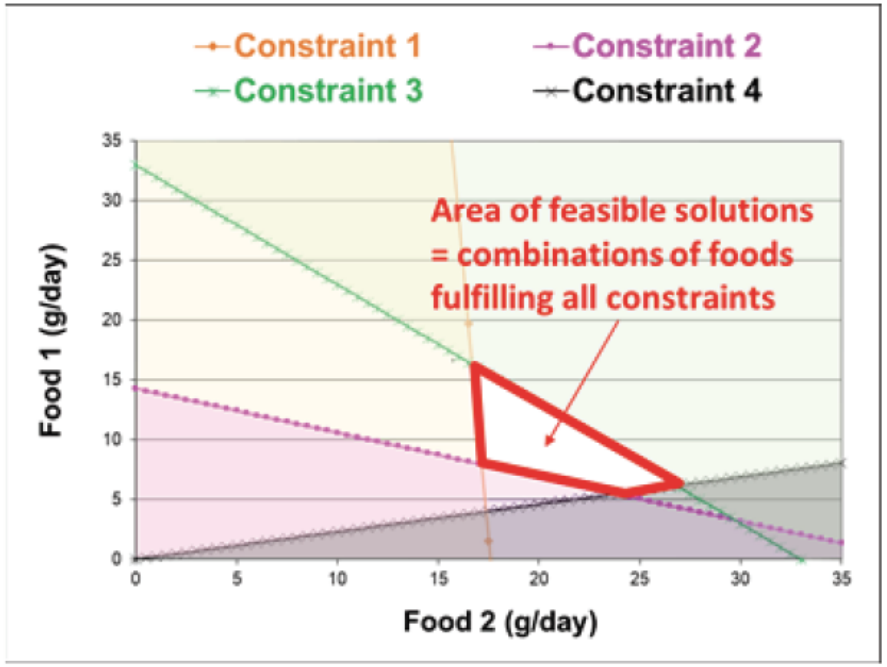
Perignon & Darmon. Nutr Rev 2022

4. OPTIMIZATION OF EXISTING DIETS

① Starting point: a combination of foods (hypothetical or existing diet)

② Optimization model imposing a set of constraints on several sustainability criteria (eg, nutrition, environment, cost)



③ Achievement of the constraints (when feasible)

- ✓ Nutritional adequacy
- ✓ Environmental targets met
- ? Cultural acceptability
- ✓ Affordability

Simplified example of constrained optimization, based on a combination of 2 foods and 4 constraints

« ↗ / ↘ »	Sustainability criteria is improved (higher or lower than the average)
« ✓ »	Sustainability criteria is fulfilled
« ? »	Sustainability criteria is not ensured

Perignon & Darmon. Nutr Rev 2022

4. OPTIMIZATION OF EXISTING DIETS

Advantages	Disadvantages
• All targets met simultaneously	• When targets are too severe or incompatible: no solution (or unrealsitic solution)
• Good understanding of trade-offs between sustainability dimensions	• Deviation from existing diets → cultural appropriateness not ensured
• The only approach able to ensure nutritional adequacy	
• Can be applied to different types of dietary data	

Perignon & Darmon. Nutr Rev 2022

4. DIETARY GUIDELINES THROUGH OPTIMIZATION MODELING

Germany

Schaefer et al. EU 03/2024

The Netherlands

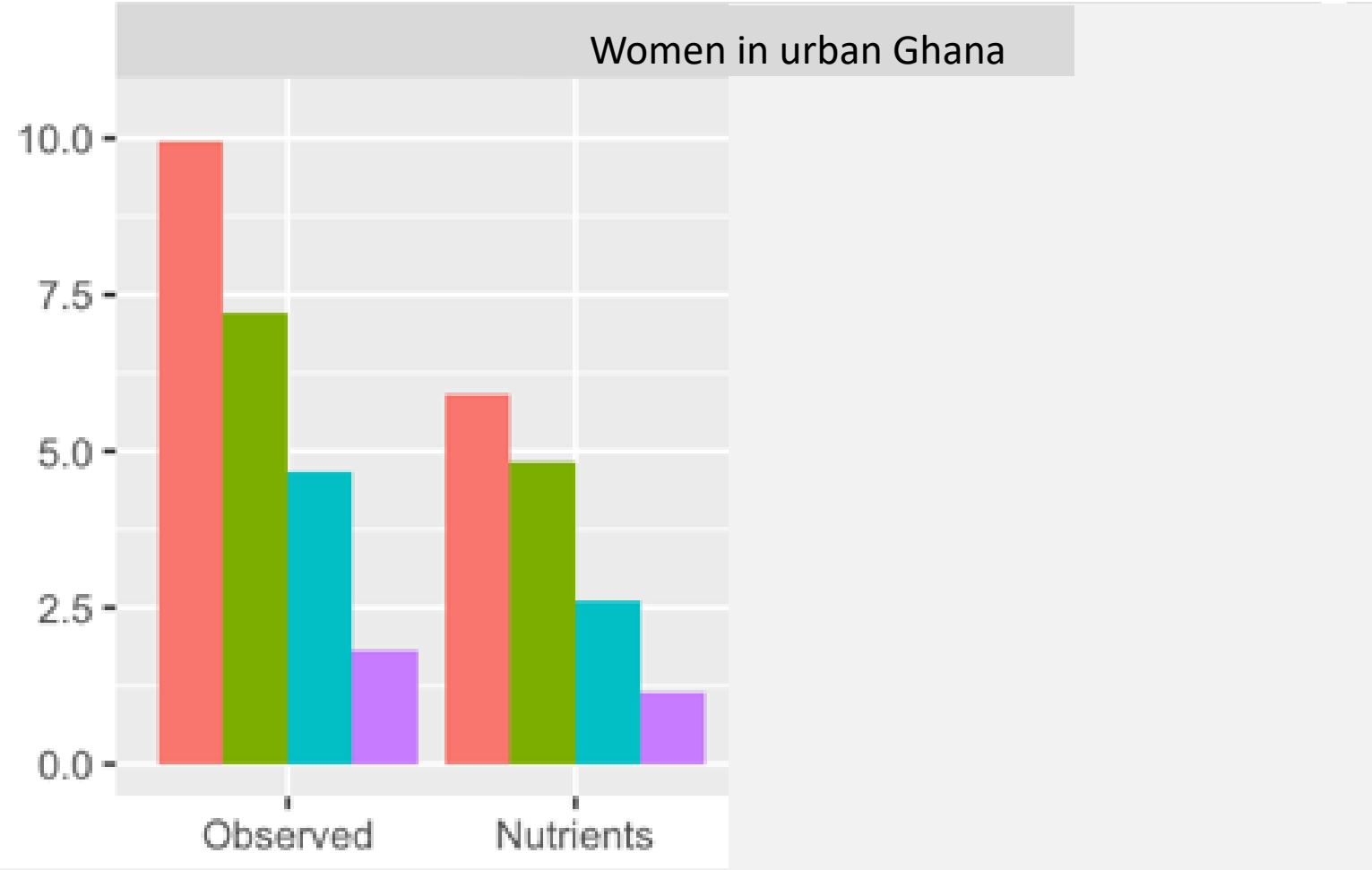
Brink et al. Pub Health Nutr 2019

Delamaire et al. Santé Publique France 2023

4. OPTIMIZATION MODELING FOR DIET PROTOYPES AMONG GHANAIANS

Gabriel Kallah-Dagadu, PhD

Red = Costs (Ghana Cedis or Euros)
Green = Energy (MJ*0.5)
Blue = GHGEs (kgCO2eq)
Purple = Total Food Weight (kg)



Kallah-Dagadu et al. 2024 (in preparation)

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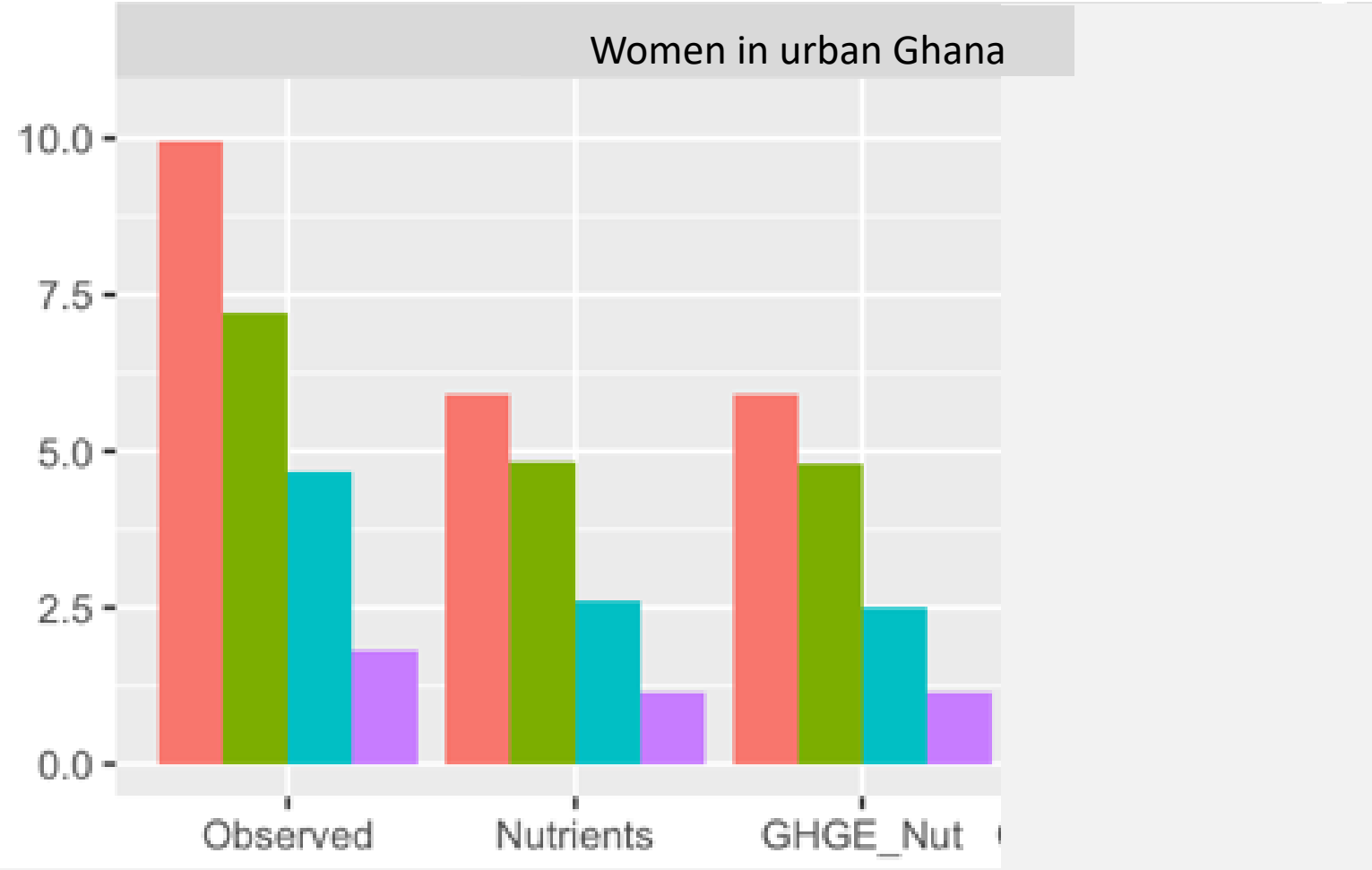

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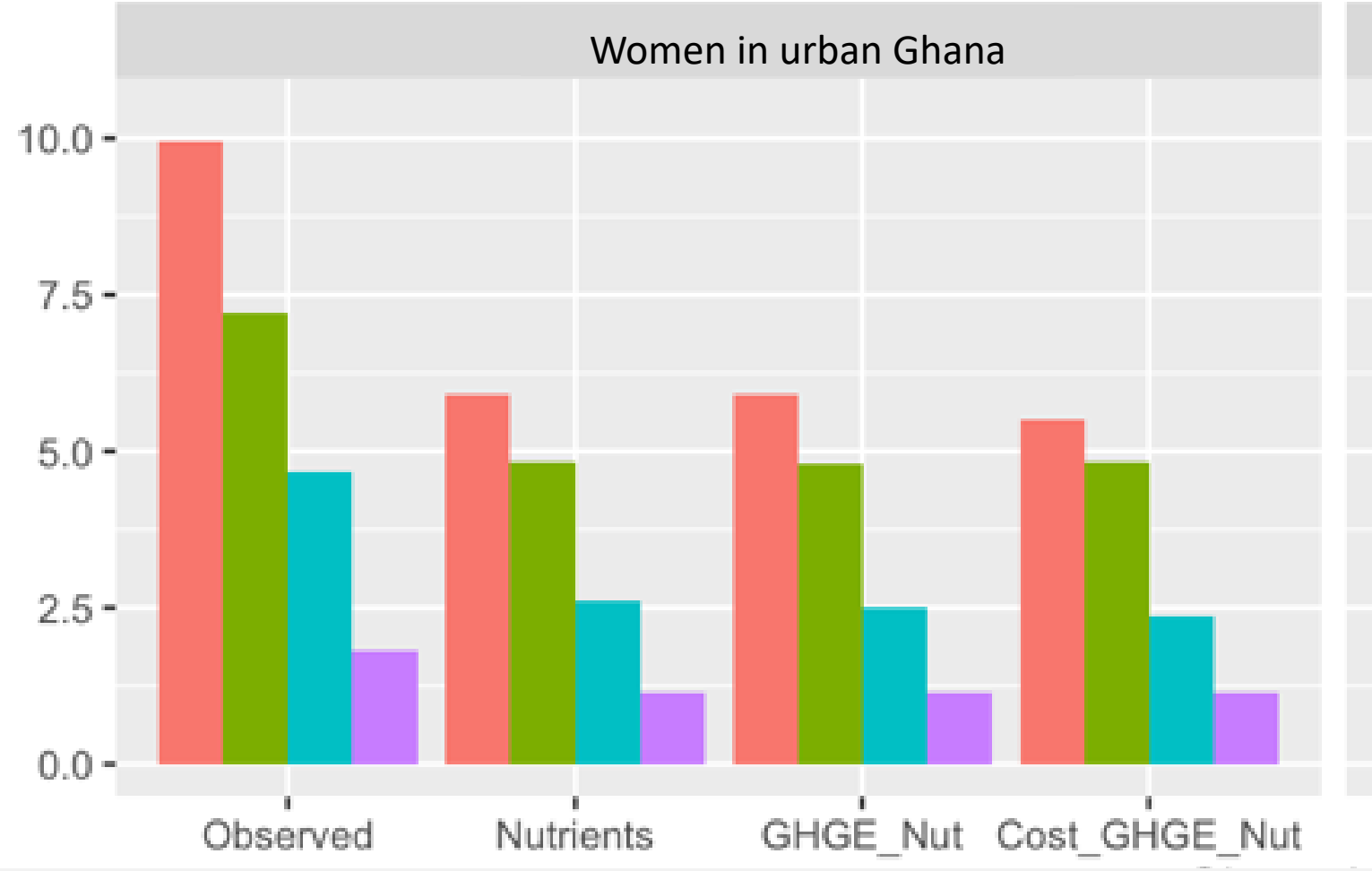

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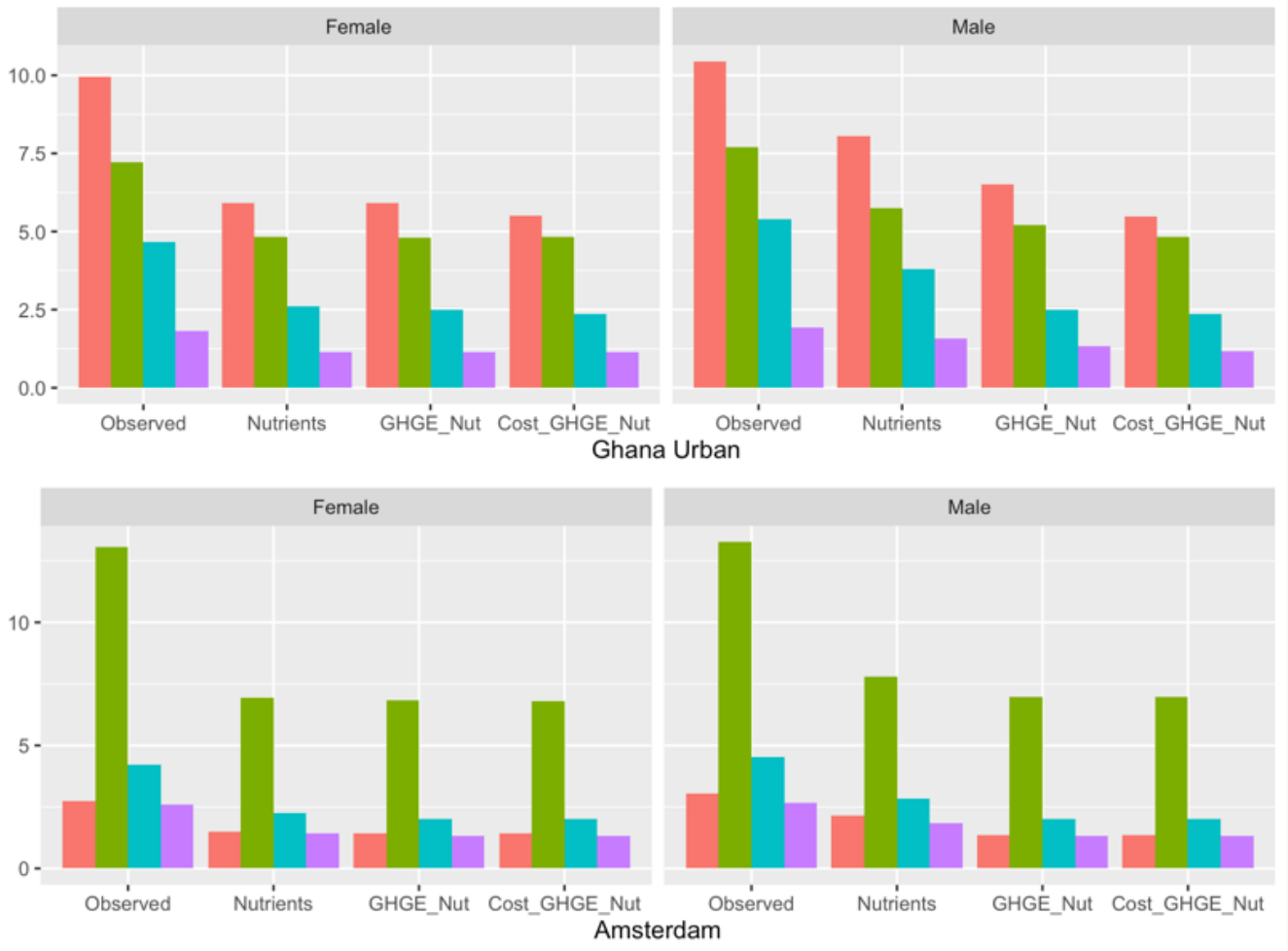


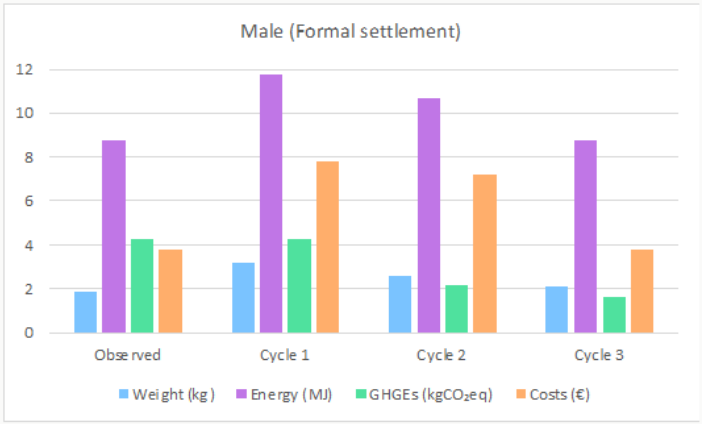
Kallah-Dagadu et al. 2024 (in preparation)

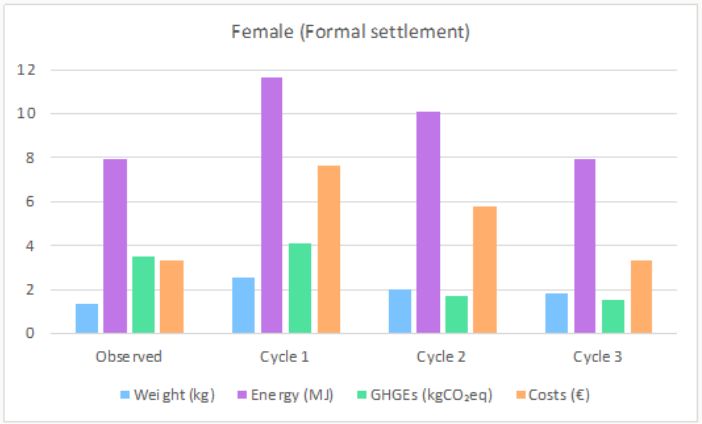
4. OPTIMIZATION MODELING FOR DIET PROTOYPES IN URBAN BURKINA FASO

Dorothee Liu
(Dr. med. candidate)

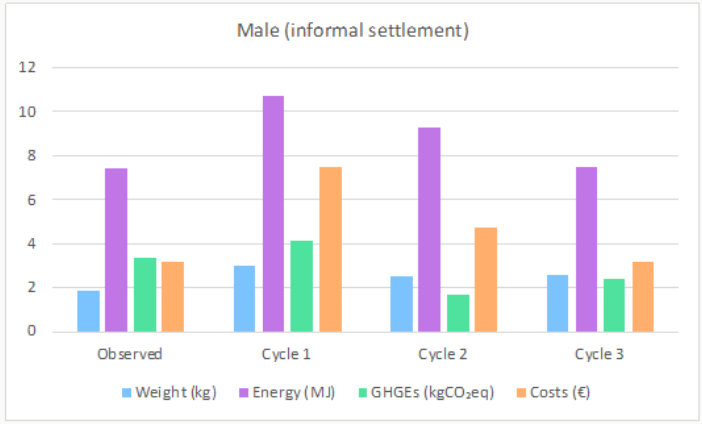
Cycle 1: nutrient adequacy
Cycle 2: + GHGE
Cycle 3: + Costs

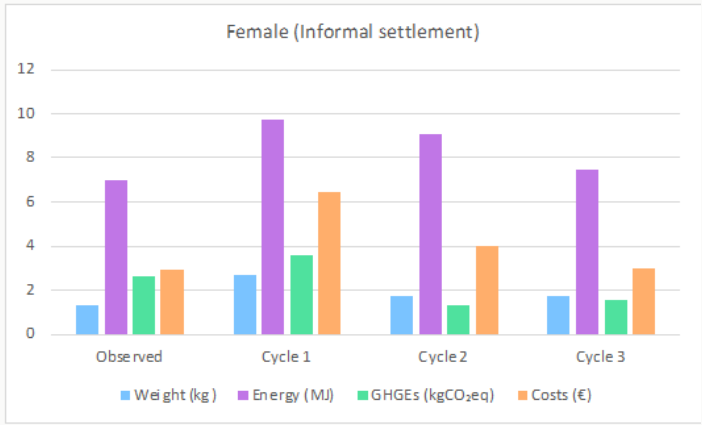
Formal settlement





Informal settlement

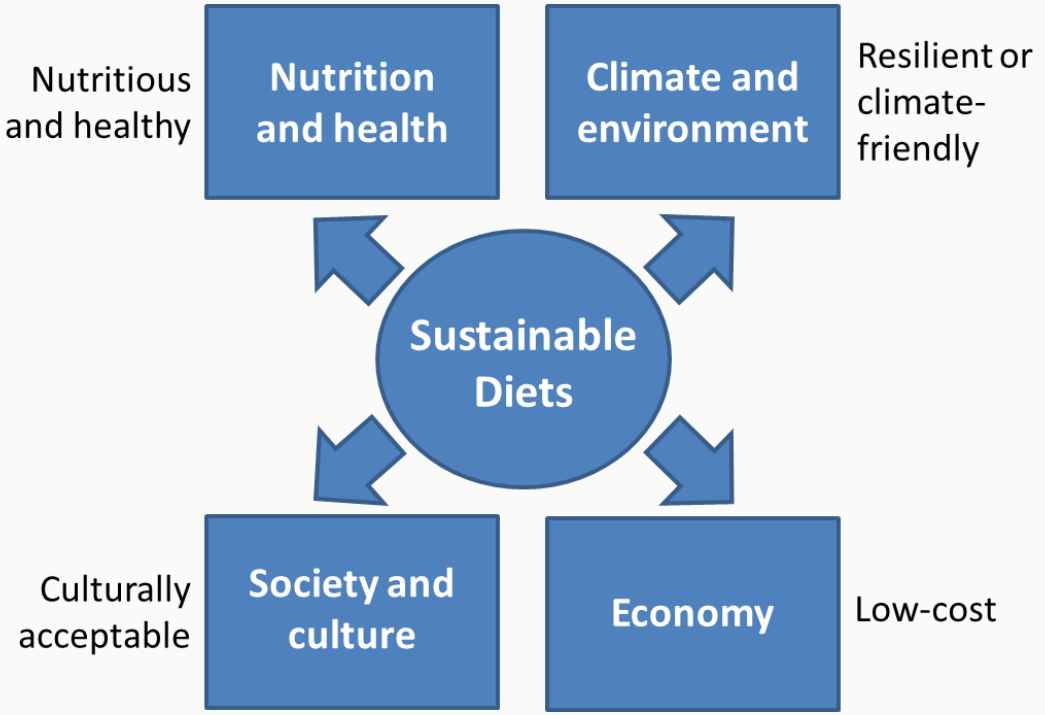




Liu et al. 2024 (in preparation)

SUMMARY: OPERATIONALIZE SUSTAINABLE DIETS

1. Characterize sustainability dimensions of hypothetical diets (a priori)
2. Describe sustainability characteristics of existing diets (univariate or multivariate)
3. Identify and describe positive deviants
4. Optimization of existing diets (multi-criteria approach)



Practical exercise

Construct the Sustainable Diet Index:

Using data from Ghanaian adults under transition – The Research on Obesity and Diabetes among African Migrants (RODAM) Study

Practical exercise – Ingredients

- Seconda et al. 2019

British Journal of Nutrition (2019), 121, 1166–1177
doi:10.1017/S0007114519000369

Development and validation of an individual sustainable diet index in the NutriNet-Santé study cohort

Louise Seconda[1,2]*, Julia Baudry[1], Philippe Pointereau[3], Camille Lacour[1], Brigitte Langevin[3], Serge Hercberg[1,4], Denis Lairon[5], Benjamin Allès[1] and Emmanuelle Kesse-Guyot[1]

[1]*EREN, INSERM (U1153), INRA (U1125), Centre d'Epidémiologie et Statistiques Paris Cité, CNAM, COMUE Sorbonne-Paris-Cité, Université Paris 13, 74 rue Marcel Cachin, 93017 Bobigny, France*
[2]*Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME), 20 avenue du Grésillé BP 90406, 49004 Angers, France*
[3]*Solagro, 75 Voie Toec, 31000 Toulouse, France*
[4]*Département de Santé Publique, Hôpital Avicenne, 125 rue de Stalingrad, 93000 Bobigny, France*
[5]*INSERM (U1062), INRA (U1260), C2VN, Faculté de Médicine de la Timone, Aix Marseille Université, 27 boulevard Jean Moulin, 13005 Marseille, France*

- Dataset RODAM_SDI
- Codebook RODAM_SDI
- R code for quintile construction

Practical exercise – Study design

- Ghanaian adults 18-70 years
- N = 3,619
- 5 study sites: rural Ghana, urban Ghana, Amsterdam, London, Berlin
- Baseline examinations: 2012-2015
- Questionnaires, physical examinations, laboratory analysis

Practical exercise – Code book

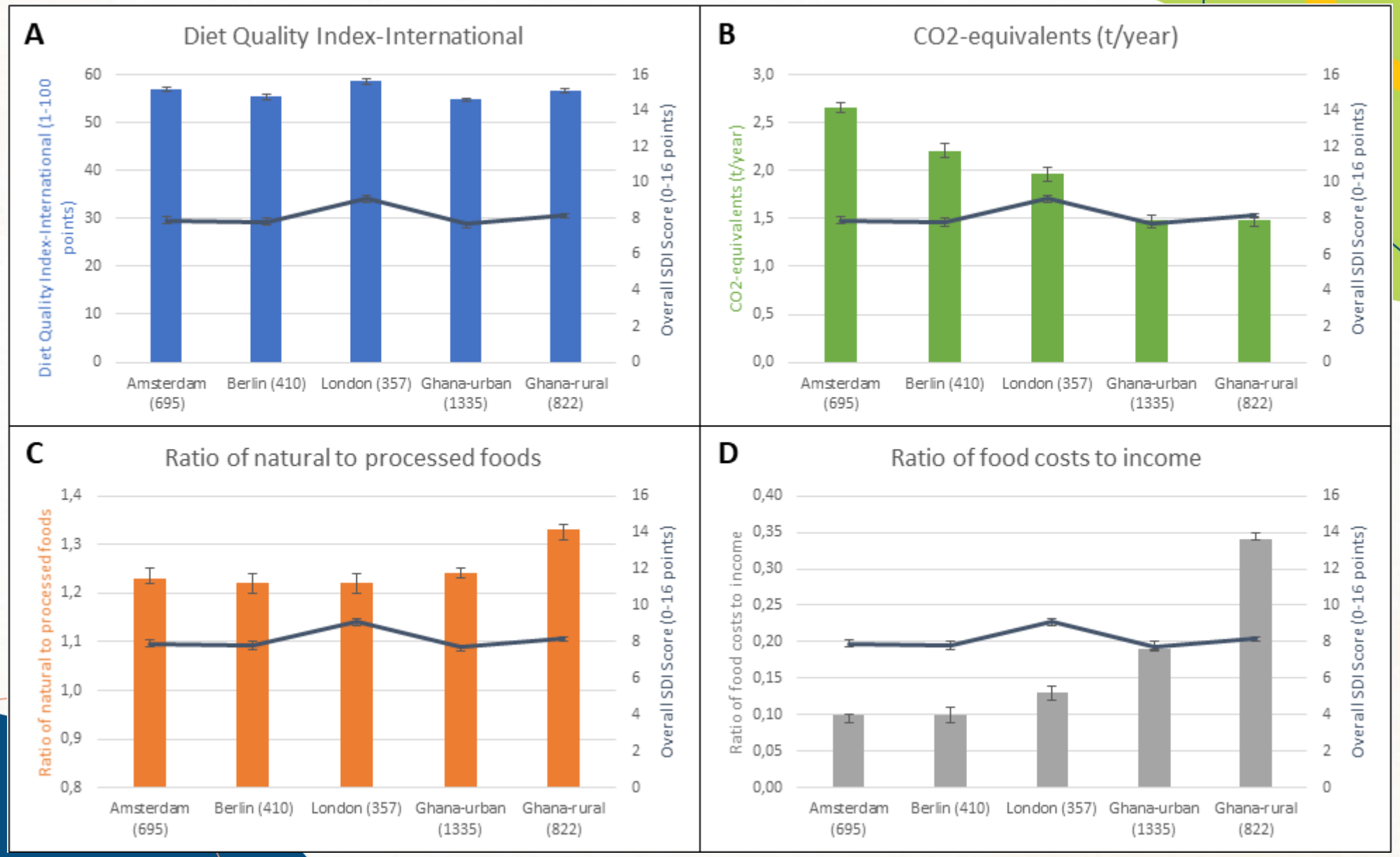
Label	Meaning	Unit
np_score	Ratio of natural to processed foods from intake frequency	-
np_score1	Ratio of natural to processed foods from intake quantity	-
tfc_30d	Total food costs per months	€
income_p	Monthly income	€
carbon_day	Greenhouse gas emission from food intake	g CO_2-equivalents
DQII	Diet Quality Index International	Score points
FVS	Food Variety Score	Score points
DDS	Dietary Diversity Score	Score points
GhanavsEurope	Study site: Ghana or Europe	2 – Europe 1 – Ghana
Site	Study site (5 categories)	
Sex	Sex	1 – male 2 – female
Age	Age	years

Practical exercise – Procedures

- Read in your dataset
- Check the variables of the 4 SDI components
- Calculate ratio of food expenses to income (economic component)
- Construct quintiles for each of the 4 components
- Assign score points to the quintiles
- Calculate the SDI sum score
- Run descriptive statistics for the SDI (means, SD)

Practical exercise – Results

Figure 1. Distributions of SDI components across study sites



Practical exercise – Results

Table 1. Characteristics across SDI quintiles

Characteristics	Q1 [2.00 – 5.00] (n=601)	Q2 [6.00 – 7.00] (n=887)	Q3 [8.00 – 8.00] (n=616)	Q4 [9.00 – 10.00] (n=965)	Q5 [11.00 – 16.00] (n=550)
Site (%)					
Amsterdam	14.8	24.6	21.8	18.3	14.0
Berlin	11.2	13.0	12.3	10.8	8.7
London	4.7	6.3	9.7	11.0	19.5
Ghana (urban)	48.9	37.3	33.3	32.3	35.1
Ghana (rural)	20.4	18.8	22.9	27.6	22.7