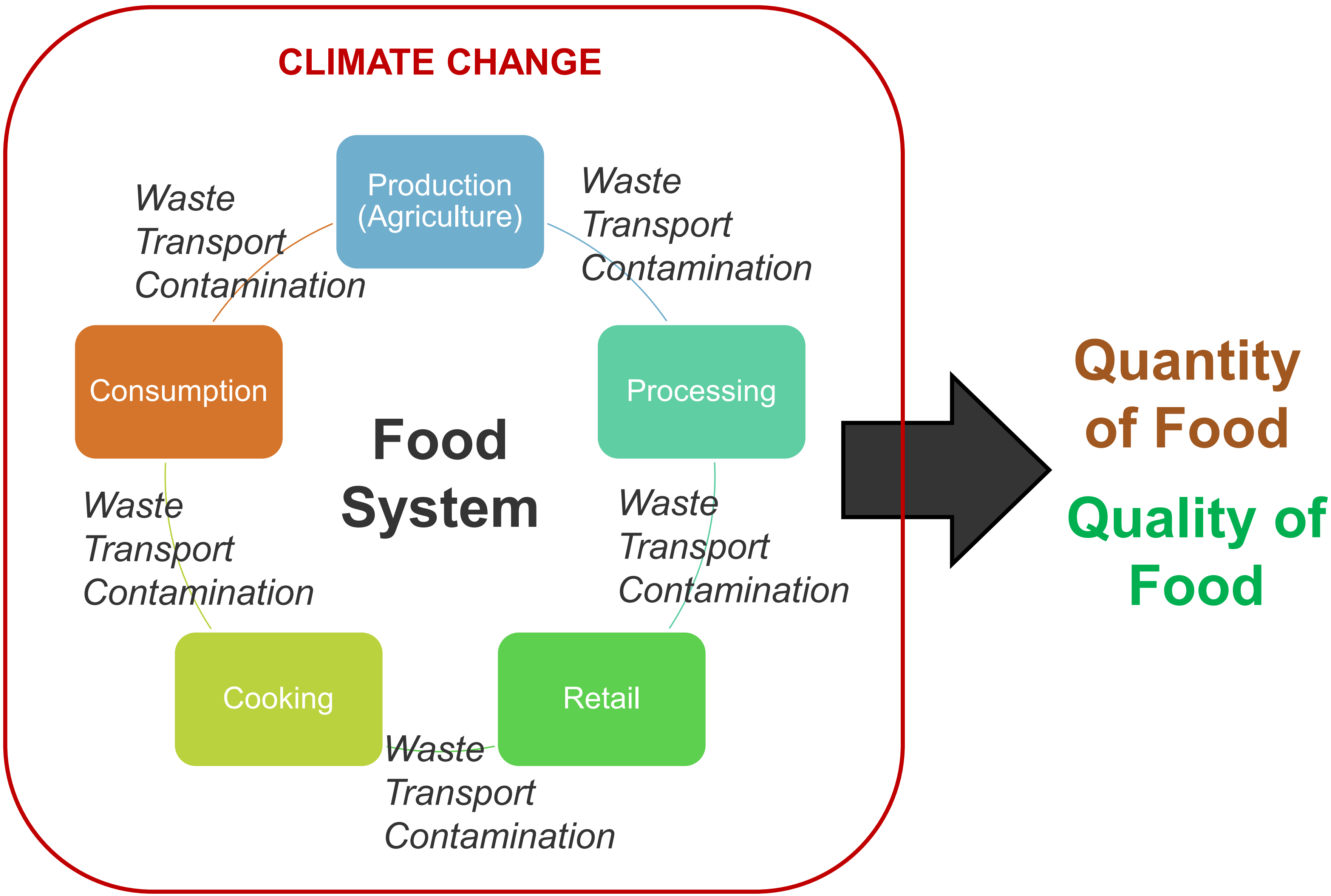
Pollutants, Food & Climate

Lindsay Jaacks, PhD, Assistant Professor of Global Health

Twitter: @LindsayJaacks   Email: jaacks@hsph.harvard.edu

Summer School on Human Rights and Development, 9 July 2019

HARVARD T.H. CHAN | SCHOOL OF PUBLIC HEALTH


CLIMATE CHANGE
Production (Agriculture)
Waste
Transport
Contamination
Processing
Waste
Transport
Contamination
Retail
Waste
Transport
Contamination
Cooking
Waste
Transport
Contamination
Consumption
Waste
Transport
Contamination
Food System
Quantity of Food
Quality of Food

Food Systems & Climate Change

- 19-29% of global greenhouse gas emissions
- 70% freshwater withdrawals
- ~33% ice-free land

Outline:
The Evolving Food System in India

1947
Independence

1950s
Drought, famine, reliance on food aid

1960s
Green Revolution Period

1990s – Present
Nutrition Transition Period

Present & Future
Climate Adaptation Period

Outline:
The Evolving Food System in India

1947
Independence

Pre-independence – 1950s
Drought, famine, reliance on food aid & imported foods

1960s
Green Revolution Period

1990s – Present
Nutrition Transition Period

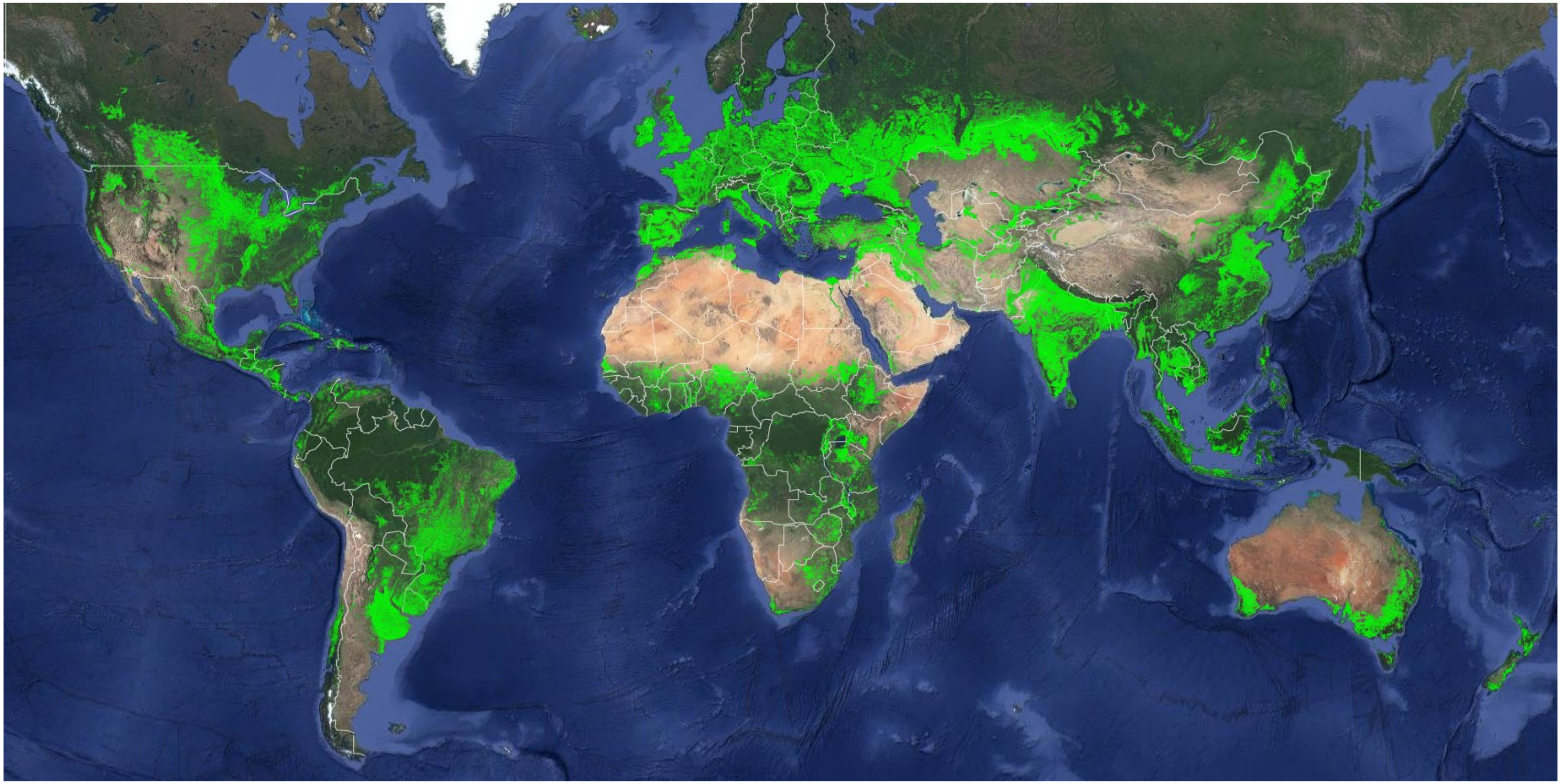
Present & Future
Climate Adaptation Period

Green Revolution in India

International Rice Research Institute (Philippines)

Green India

Map of global cropland, 2015



USGS, accessed 8 July 2019

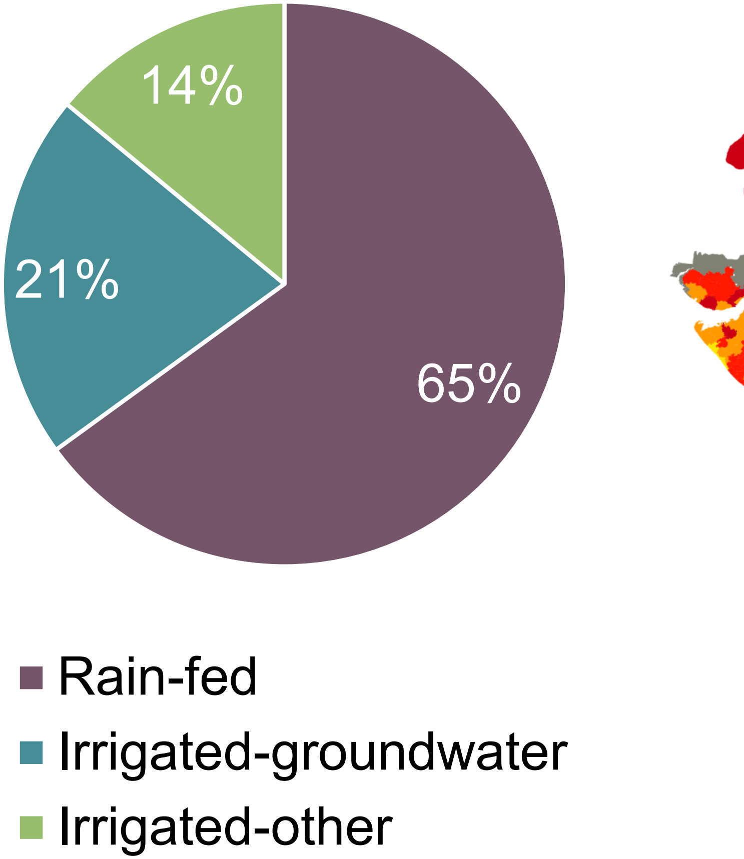
HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

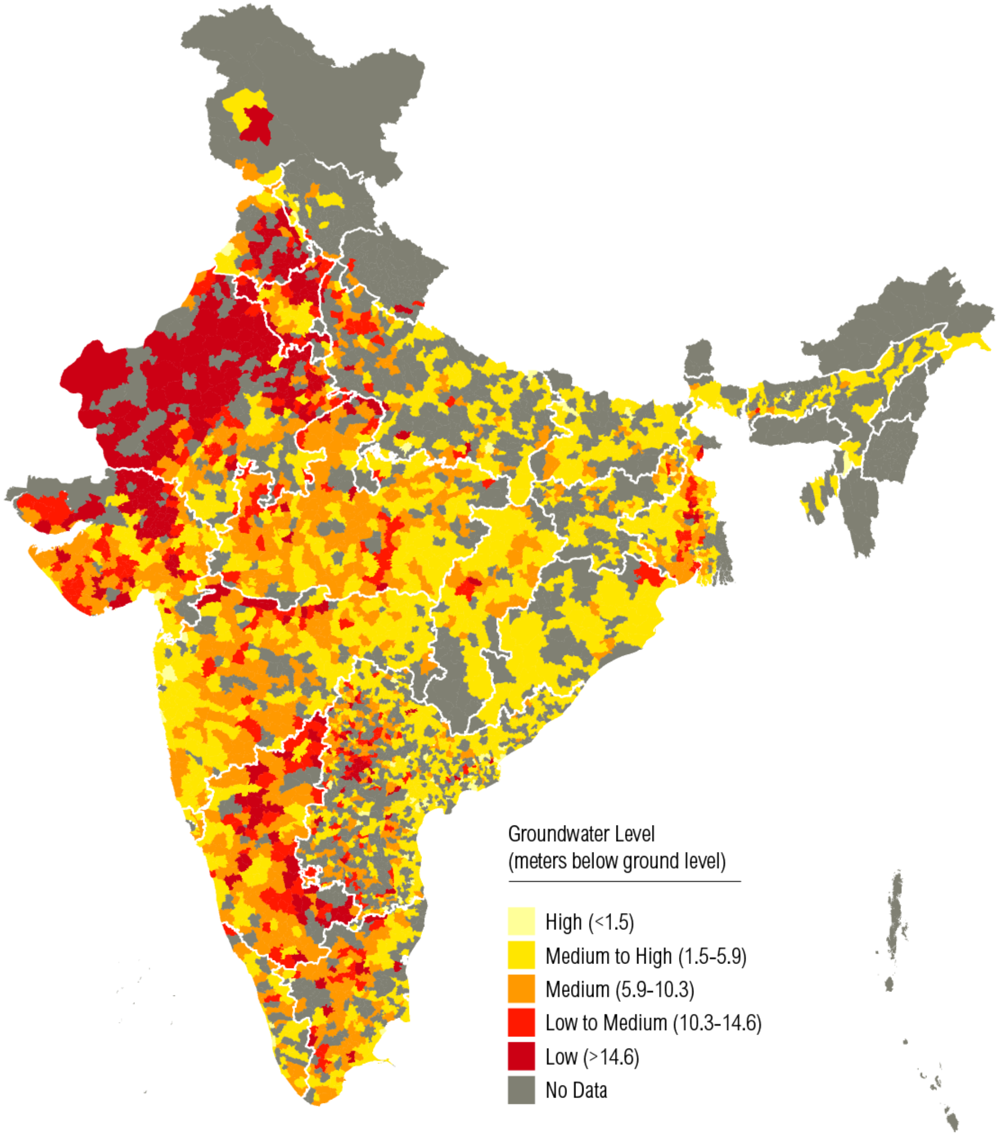
Adverse Consequences of the Green Revolution

1. Paul Ehrlich (author of *The Population Bomb*), 2009:

   *"The reduction of the hungry portion of the world population may well have been bought at a high price of **environmental devastation** to be paid by future generations"*

2. Improved yields of cereal grains, but at cost of **diet quality**





World Resources Institute, 2015

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

State / Indicator	1	2	3	4	5	6	7	8	9	10	11	12
Jammu and Kashmir	1.86	3530	H	9%	24%	100%	18%	2	238		39	MSD
Himachal Pradesh	0.37	3792	H	29%	51%	75%	50%	2	52		35	MSD
Uttarakhand	0.12	2078	L	1%	50%	89%	23%	2	314		138	Yes
Arunachal Pradesh	0.06	65	H	0%	0%	100%	0%		0		0	MSD
Sikkim		3749	H	0%	26%	100%	0%		0		0	Yes
Manipur	0.09	494	H	3%	1%	100%	0%		4		24	No
Meghalaya		375	H	4%	0%	100%	0%		1		0	MSD
Mizoram		6	L	2%	3%	100%	25%		0		17	Yes
Nagaland		5	H	0%	2%	100%	0%		0		16	No
Tripura	0.62	2169	H	64%	7%	100%	0%		61		25	No
Assam	0.07	227	H	5%	16%	100%	0%	1	9	11%	27	No
West Bengal	0.27	1559	H	24%	45%	71%	9%	1	122	47%	82	MSD
Bihar	0.11	621	M	6%	45%	97%	26%	2	42	63%	139	MSD
Uttar Pradesh	0.39	144	L	3%	74%	74%	63%	2	391	83%	104	No
Punjab	0.74	928	L	0%	149%	19%	91%	2	1301	100%	178	No
Haryana	0.62	324	L	5%	135%	25%	86%	2	1306	100%	164	No
Rajasthan	0.05	442	L	41%	140%	18%	100%	5	712		40	Yes
Gujarat	0.13	243	L	39%	68%	78%	67%	5	1153	62%	91	Yes
Jharkhand	0.35	597	L	93%	23%	94%	4%	1	59	5%	34	No
Chhattisgarh	0.26	336	L	11%	37%	86%	44%	1	435	35%	59	MSD
Odisha	0.15	1306	L	66%	30%	98%	93%	1	33	33%	35	Yes
Madya Pradesh	0.03	425	M	2%	57%	73%	96%	3	498	30%	51	Yes
Maharashtra	0.57	727	L	36%	54%	92%	83%	4	948	26%	63	Yes
Telangana	0.72	1110	L	42%	58%	70%	100%	2	2842	97%	164	MSD
Andhra Pradesh	0.24	1110	H	10%	44%	74%	100%	4	2842	97%	124	MSD
Karnataka	0.10	1379	L	38%	66%	56%	73%	6	1476	75%	88	Yes
Tamil Nadu	0.33	1497	L	0%	77%	38%	84%	3	2051	93%	87	MSD
Goa	0.14	129	H	22%	37%	100%	0%		133		22	MSD
Kerala	0.41	711	H	1%	47%	86%	79%	4	121	77%	15	Yes

Legend	
1	Pesticide consumption (kg/ha)
2	Use of Farm Yard Manure (kg/ha)
3	Organic carbon content of soils
4	% of degraded agricultural land
5	% of groundwater development
6	% wells classified as "safe"
7	% districts with nitrate concentration over permissible limits
8	No. of most sown crops to cover 50% of Total Cropped Area
9	Per hectare electricity use in agriculture (kWh/ha)
10	% area of paddy under irrigation
11	Per hectare use of nitrogen fertilizer (kg/ha)
12	Existence of sustainable/natural/ organic farming policy
MSD	Mission/Scheme/Draft Policy

Veluguri et al. *EPW* 29 June 2019

Has the West “locked farmers in [unsafe] pesticide technology”?

- 1997-2000: US pesticide companies exported >30K metric tons of pesticides banned for use in the US (Raven et al. 2008)
- Safe use of pesticides requires ability to read labels and use personal protective equipment
- Ag development agencies typically use surplus supplies, not appropriately matched supplies
- Dependence on external outputs (e.g. pesticides) → indebtedness of farmers

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Consumers Are Concerned About Safety

- "*They [fruits] are full of chemicals. It is so poisonous, that we will get other diseases….*" (older adult man in Kerala, India)

- "*When you consider the price you have to pay for the chemicals in fruits, it is better not to eat it at all*" (older adult woman in Kerala, India)

- "*Fruits, green leafy vegetables are good for health, now-a-days fresh vegetables are not available because of impurity…pulses are also adulterated but we have to eat, we don't have any choice*" (young adult woman in Delhi, India)

Daivadanam et al. *BMC Public Health* 2015;15:644
Bailey et al. *J Nutr Educ Behav* 2018 Apr 27

Heavy Metals in Vegetables from Azadpur

- 222 spinach samples tested:
  - 72% exceeded India standard for lead of 2.5 mg/kg
  - 100% exceed Codex standard for lead of 0.3 mg/kg

Data Source: Marshall et al. for DFID 2003

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Indian Grape Crisis in the Netherlands (2003)

- In midst of dispute with grape exporter in India, Dutch private company had samples tested for pesticides
- Contained residues of methomyl exceeding EU limit of 0.05 ug/kg
- Dutch government was alerted and tested 28 grape containers from India
  - 75% exceeded limit (for either methomyl or acephate)
- Price of grapes from India dropped

Policy Response

- All farmers growing grapes for export to EU must register with state Department of Agriculture
- 3 mandatory field inspections during the growing season
- Mandatory pesticide residue testing
- Phytosanitary certificate requirement

In the News…

The Indian EXPRESS
Tuesday, July 24, 2018

How maximum residue levels have become a tool to block our farm produce exports

India has no system to monitor pesticide residues in imported foods, even as its own shipments are getting detained in overseas ports.

Many Challenges

NATIONAL

All you need to know about the debate over pesticide residue tests

Vegetables and fruits that may have high levels of pesticide residue and other chemicals can make their way into the kitchens of Nepali households.

- CHANDAN KUMAR MANDAL, Kathmandu

The Role of Urbanization

- As people move to cities, distance from farm to fork increases
- Urban agriculture and community gardens unlikely to provide substantial benefits
- Growing demand for “riskier” foods (vegetables and animal products) but lack of strong food governance
- Urgent need for stronger linkages between rural production and urban consumption


WHY THERE ARE NO PESTICIDE-SNIFFING DOGS
U.S. CUSTOMS
U.S. GRAIN
POTATOES
COTTON
IMPORT TOBACCO
JNK

Pesticides & Diabetes? First Observations in India

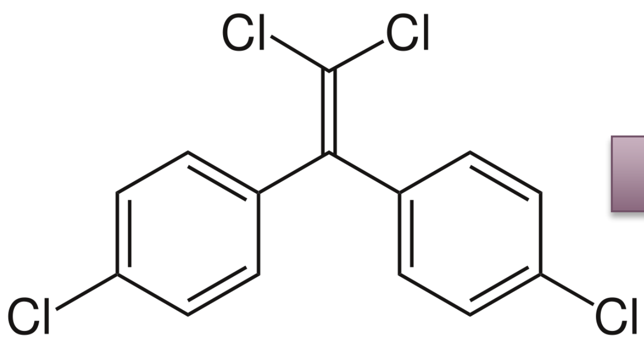
	Category 1 (n=121)	Category 2 (n=91)	Category 3 (n=48)
Body mass index (BMI)	24.2 kg/m^2	23.8 kg/m^2	23.1 kg/m^2
Prevalence of diabetes	24%	17.5%	39.5%

Category 1 = no or minimal exposure group (participants working in offices or people at home)
Category 2 = intermediate exposure group (participants involved in weeding, pruning, picking and harvesting)
Category 3 = high exposure group (participants involved in mixing and spraying pesticides)

Swaminathan and Thangavel *Practical Diabetes* 2015;32(3):111-113

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Persistent Organic Pollutants and Diabetes in India (POPDIAB)

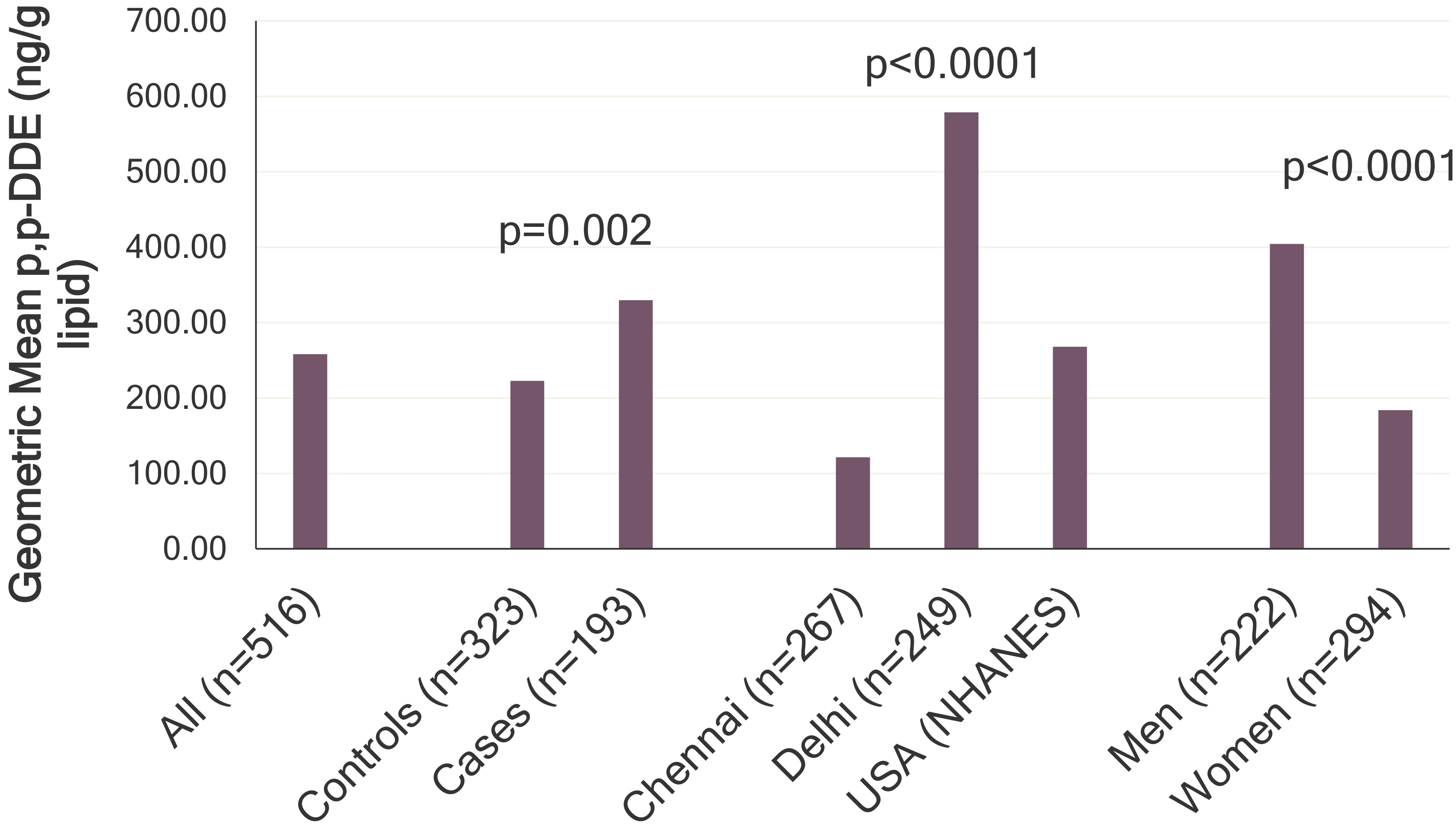


Exposure = **p,p' isomer of DDE (parent compound: DDT)**

Outcome = **incident type 2 diabetes**

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Baseline Comparisons of p,p-DDE



Jaacks et al. (under review)

Association of p,p-DDE with incident type 2 diabetes in India

	Quartile of p,p-DDE, odds ratio (95% CI)			
	1	2	3	4
Unadjusted	1.00	1.13 (0.65, 1.99)	1.08 (0.59, 1.96)	**2.30 (1.19, 4.43)**
Adjusted*	1.00	0.78 (0.20, 3.07)	1.06 (0.34, 3.34)	**0.87 (0.30, 2.55)**

* Specifically, adjusted for age, occupational status, monthly household income, ever use tobacco products, waist circumference, and fasting blood glucose.

Jaacks et al. (under review)

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Pesticides and Child Growth

Women Engaged in Agriculture

↑ Pesticide Exposure during Pregnancy

Intrauterine Growth Restriction

- Preterm Birth
- Low Birth Weight
- Stunting

Pesticide biomarkers among pregnant women in rural Bangladesh (n=289)

Pesticide biomarker	>LOD, n (%)	Geometric Mean (95% CI), µg/g creatinine	U.S. Population, Non-pregnant Females, Geometric Mean (95% CI), µg/g creatinine
2,4-D	5.6 (16)	-	0.334 (0.302 – 0.369)
TCPY	97.9 (283)	3.17 (2.82–3.56)	0.855 (0.765 – 0.954)
4-nitrophenol	100 (288)	18.66 (17.03–20.46)	0.480 (0.430 – 0.536)
MDA	2.8 (8)	-	Not calculated
IMPY	16.1 (46)	-	Not calculated
4-F-3-PBA	0 (0)	-	Not calculated
3-PBA	19.8 (57)	-	0.505 (0.453 – 0.564)
trans-DCCA	6.2 (18)	-	Not calculated

Abbreviations: 2,4-dichlorophenoxyacetic acid (2,4-D); 4-fluoro-3-phenoxybenzoic acid (4-F-3-PBA); 2-isopropyl-4-methyl-6-hydroxypyrimidine (IMPY); limit of detection (LOD); malathion dicarboxylic acid (MDA); 3-phenoxybenzoic acid (3-PBA); 3,5,6-trichloro-2-pyridinol (TCPY); trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid (trans-DCCA).

Jaacks et al. (under review)

PEAC Grow Results

Relative Risk (95% CI)		**Preterm Birth**	**Low Birth Weight**
TCPY (metabolite of chlorpyrifos and chlorpyrifos methyl)	Quartile 1 (n=73)	Ref	Ref
	Quartile 2 (n=71)	1.07 (0.60, 1.92)	1.98 (0.86, 4.58)
	Quartile 3 (n=72)	0.97 (0.52, 1.82)	0.76 (0.25, 2.27)
	Quartile 4 (n=27)	1.67 (0.92, 3.04)	2.17 (0.90, 5.24)
4-nitrophenol (metabolite of parathion and methyl parathion)	Quartile 1 (n=72)	Ref	Ref
	Quartile 2 (n=72)	1.21 (0.48, 3.06)	0.79 (0.25, 2.49)
	Quartile 3 (n=72)	2.98 (1.37, 6.48)	2.30 (0.93, 5.71)
	Quartile 4 (n=27)	2.84 (1.29, 6.24)	1.95 (0.76, 5.00)

Adjusted for household income (≤4,000 tk or >4,000 tk), gravidity (0, 1, or 2), and hemoglobin level (mg/dl).

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Jaacks et al. (under review)

Link to Climate Change

- Changes in amount and intensity of rainfall may increase leaching of pesticides into environment
- Increase in temperature may counteract leaching by increased pesticide degradation rate
- Increase in temperature and moisture → increase in weeds → increase in application of herbicides
- Greater need for insecticides and fungicides expected in absence of wide adoption of alternative management systems

Outline:
The Evolving Food System in India

1947
Independence

1950s
Drought, famine, reliance on food aid

1960s
Green Revolution Period

1990s – Present
Nutrition Transition Period

Present & Future
Climate Adaptation Period

Adverse Consequences of the Green Revolution

1. Paul Ehrlich (author of *The Population Bomb*), 2009:

   *"The reduction of the hungry portion of the world population may well have been bought at a high price of **environmental devastation** to be paid by future generations"*

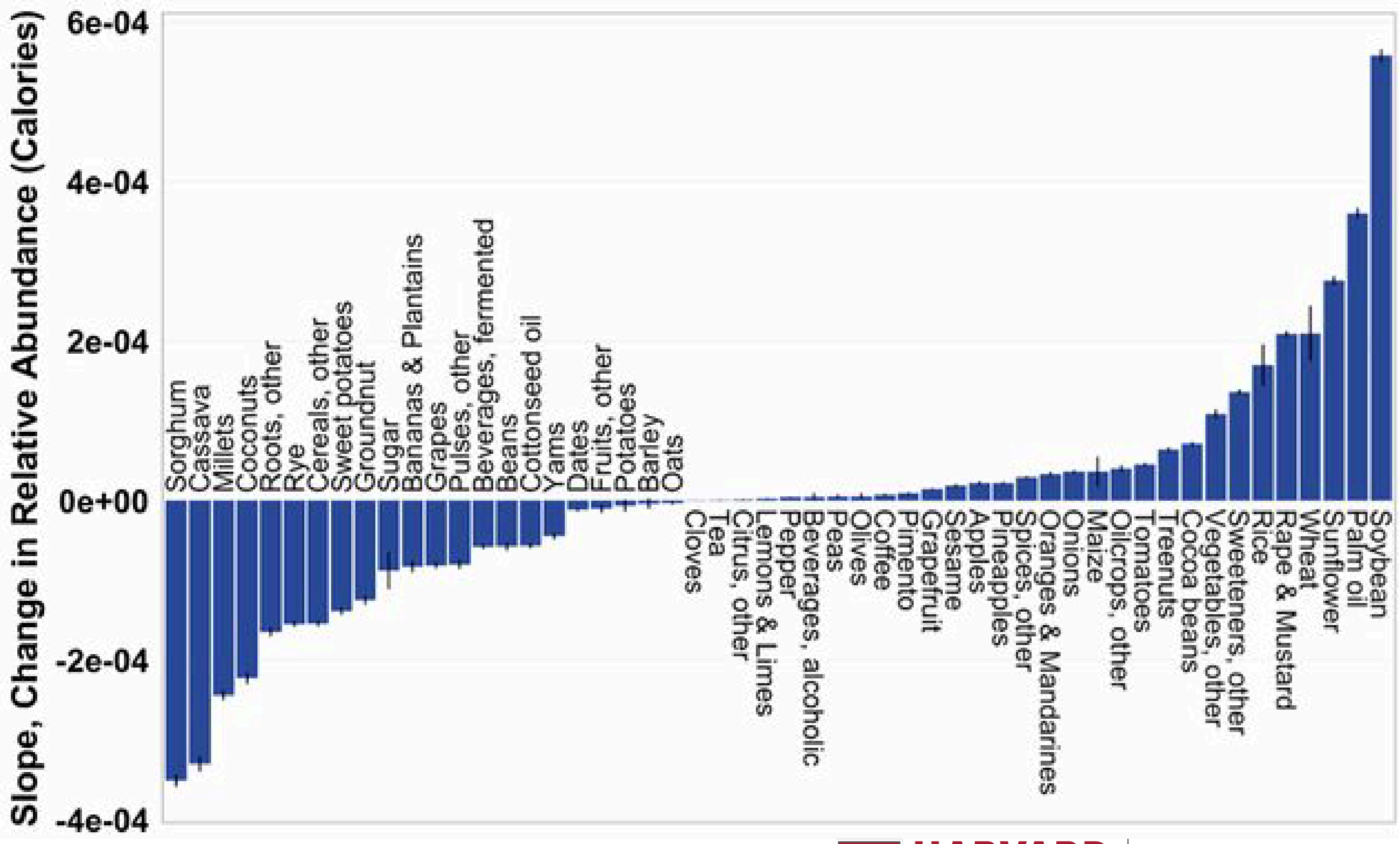
2. Improved yields of cereal grains, but at cost of **diet quality**

Shift in Crop Production Due to Green Revolution in India

		1965-1966	1995-1996
Rainy season	Pearl millet	46%	27%
	Rice	13%	34%
	Sorghum	12%	5%
	Sugarcane	8%	6%
	Maize	6%	1%
	Pulses	3%	3%
Winter	Wheat	43%	64%
	Chickpea	42%	14%
	Barley	7%	2%
	Oilseeds	6%	19%
	Pulses	2%	1%

Indian Council of Agricultural Research, 1998

Global Food Supplies Have Become Increasingly Similar



HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Khoury et al. *PNAS* 2014;111:4001-4006

What is the “nutrition transition”?

Pattern 1: Collecting Food	Pattern 2: Famine	Pattern 3: Receding famine	Pattern 4: Degenerative diseases	Pattern 5: Behavioral change
• Plants • Wild animals • Varied diet	• Cereals predominant • Diet less varied	• Fewer starchy staples • More fruits, vegetables, animal protein • Low variety continues	• More fat (especially from animal products) • More sugar and salt from processed foods • Less fiber	• Less fat and processing (“whole foods” diet) • Increased high-fiber carbohydrates, fruits, and vegetables

Popkin *Population and Development Review* 1993;19:138-15

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Characteristics of Nutrition Transition in India

- Carbs still account for a large proportion of total energy intake (~70%) but coarse grains (millet, barley, sorghum, and maize) are being replaced with refined grains (wheat and rice)
- Increased processed foods (salted snacks and prepared sweets), edible oils, and animal products (milk, egg, chicken, and fish)
- Groundnut oil is being replaced with palm and soybean oil
- Increased meal frequency (esp. snacking)
- Increased eating away from home

What the heck is this “food”?

Fortified biscuits: Britannia for a healthy business

Amrita Nair Ghaswalla | Mumbai | Updated on September 18, 2014 | Publishe

he launch of Britannia Healthy Start.

ng a sustainable business

ınia’s interest in tackling

osite of three factors — the

ıtrition in India, the compa

ıe biscuit category it opera

ed its largest power brand

Nutrition Facts

Serving Size 32 grams

Amount Per Serving	
Calories 140	Calories from Fat 35
	% Daily Value*
Total Fat 4g	**6%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 150mg	**6%**
Potassium 0mg	**0%**
Total Carbohydrate 24g	**8%**
Dietary Fiber 0g	**0%**
Sugars 8g	
Protein 2g	**4%**

Vitamin A 0%	•	Vitamin C 0%
Calcium 0%	•	Iron 2%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

It started with an order from the United Nations World Food Programme to make fortified biscuits, which sparked the idea of producing fortified biscuits for the domestic market. “Britannia’s association with the World Food Programme began in the early 2000s, and lasted until 2011. Over 32,000 tonnes of our Glucose product was supplied through this programme,” said Harris. Innovation has fuelled growth at the company. Stating that Britannia has been working with many non-government organisations (NGO) to supply specially formulated iron fortified biscuits to school-going children, Harris added: “Our desire is to reduce the prevalence of iron deficiency among children. The efficacy of our iron-fortified product in bringing down anaemia has been validated both by in-house research as well by external agencies.”

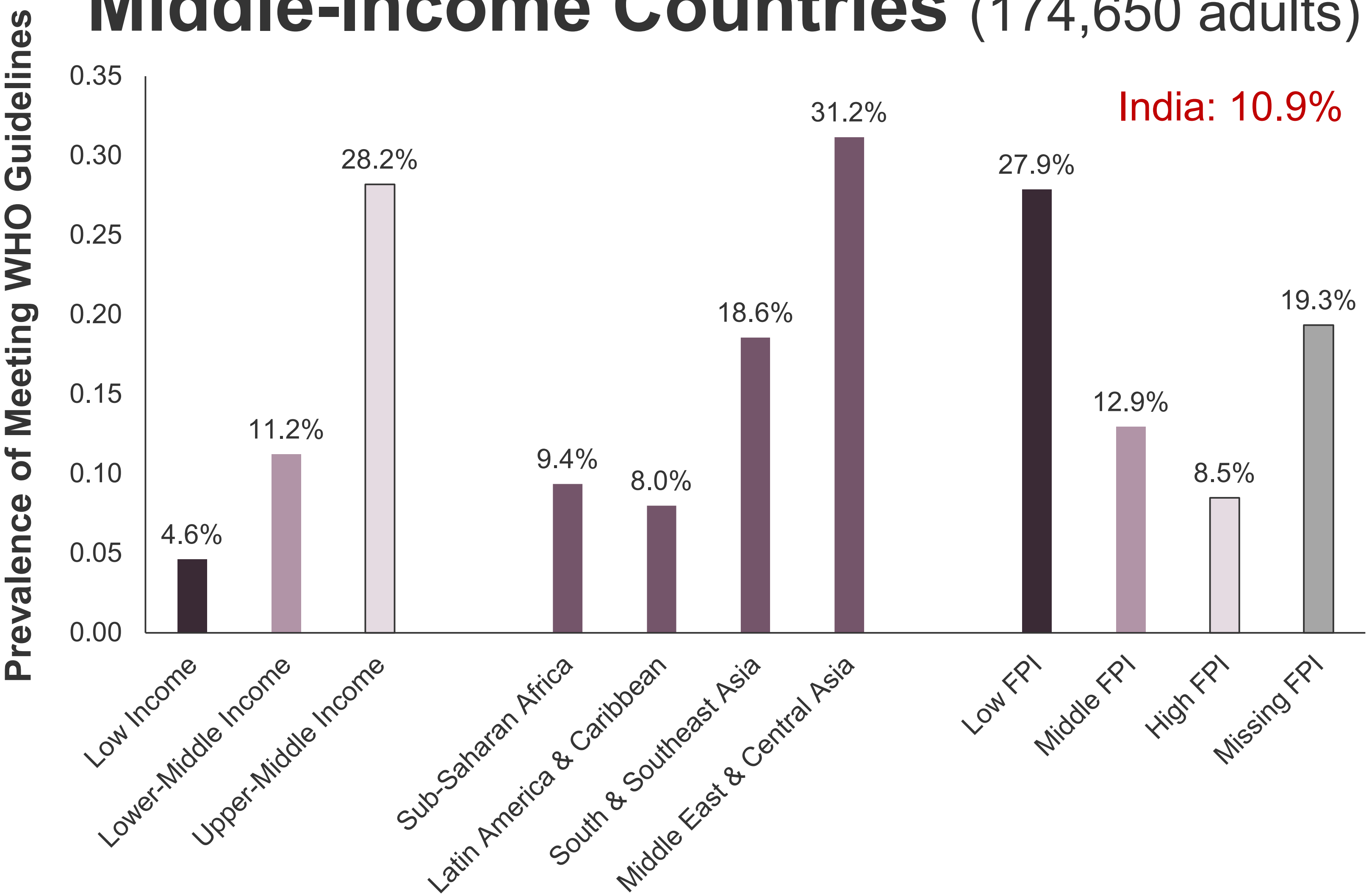
Why not just eat cashews?

	Cashew Nut Group (n=129)		Control (n=140)		P-value
Mean Values	**Baseline**	**12 weeks**	**Baseline**	**12 weeks**	
Weight, kg	67.6	67.9	67.3	67.2	0.07
SBP, mmHg	125.5	121	123.6	122	0.04
DBP, mmHg	82.3	81.2	80.9	81.4	0.09
Total cholesterol, mg/dl	161.5	165	171.7	170	0.10
LDL cholesterol, mg/dl	94.6	95.8	102.2	99.2	0.18
HDL cholesterol, mg/dl	38.4	40.1	40.1	40.2	0.01

Mohan et al. *J Nutr* 2018;148(1):63-69

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Fruit and Vegetable Intake in 28 Low- and Middle-Income Countries (174,650 adults)



HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Frank et al. *Journal of Nutrition* 2019 Jun 1 [Epub ahead of print]

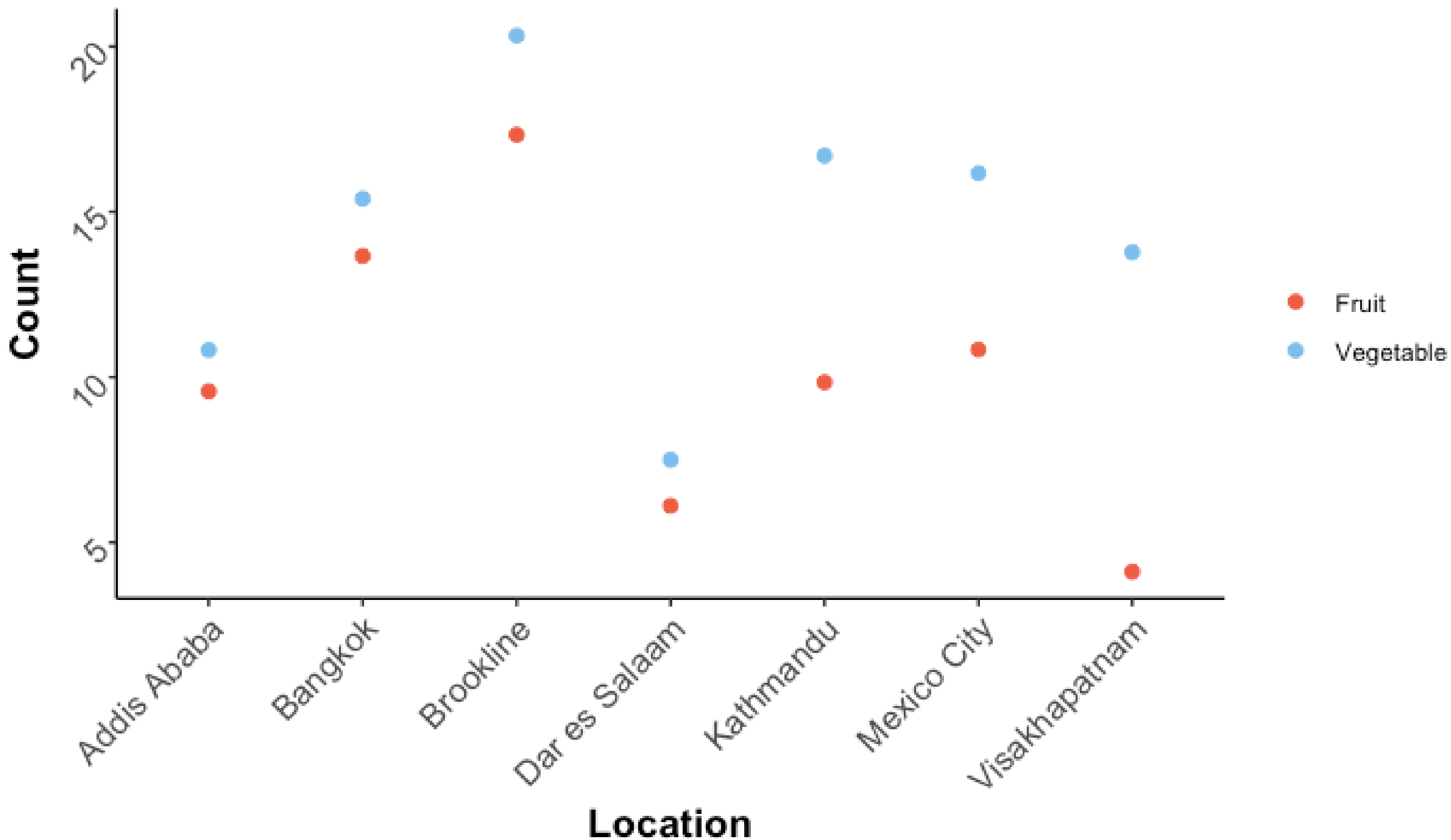
Market Basket Survey of Fresh Fruits and Vegetables in Cities in 7 Countries

Location	# vendors selling F&V in 1-km radius	Supermarket % (n)	Small stationary vendor % (n)	Mobile vendor % (n)	Other % (n)
Overall	***130***	***16.2 (21)***	***58.8 (76)***	***19.2 (25)***	***6.2 (8)***
Brookline, United States	3	100 (3)			
Mexico City, Mexico	12	33.3 (4)	16.7 (2)	0	50.0 (6)
Bangkok, Thailand	7	57.1 (4)	42.9 (3)	0	0
Visakhapatnam, India	31	12.9 (4)	35.5 (11)	48.4 (15)	3.2 (1)
Kathmandu, Nepal	40	5.0 (2)	75.0 (30)	20.0 (8)	0
Addis Ababa, Ethiopia	17	17.6 (3)	82.4 (14)	0	0
Dar es Salaam, Tanzania	20	5.0 (1)	80.0 (16)	10.0 (2)	5.0 (1)

Kirk et al. (under review)

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

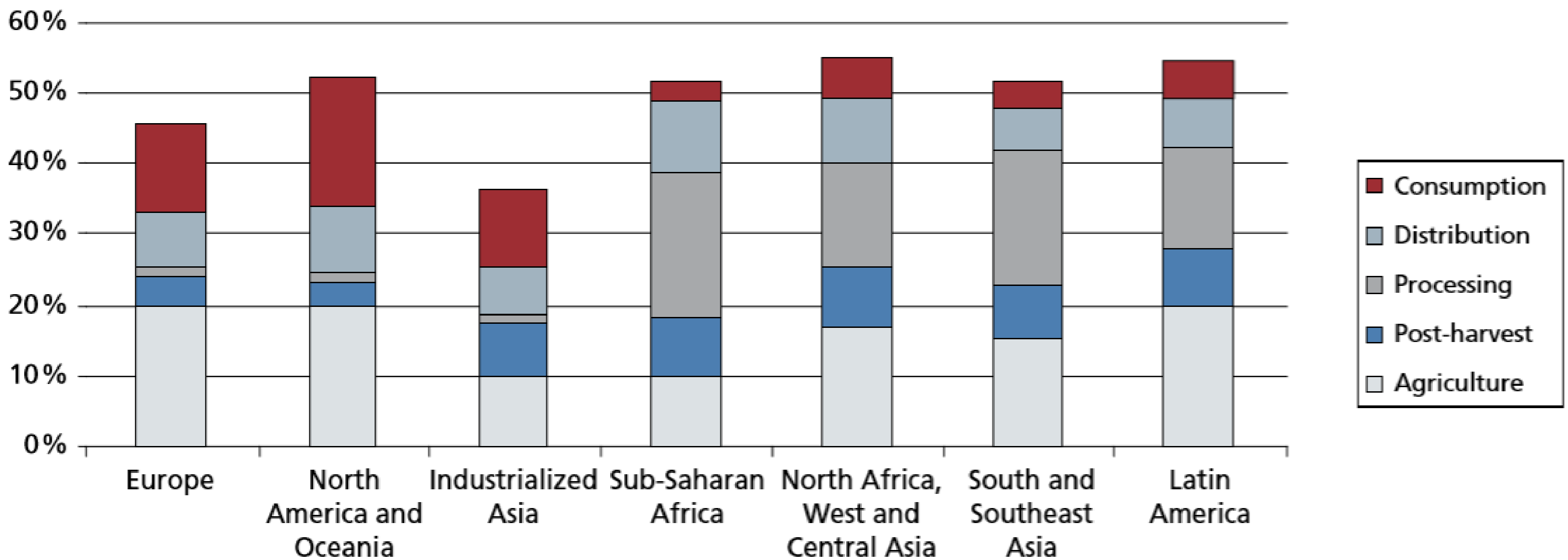
Variety of Fresh Fruits and Vegetables Available in Cities in 7 Countries



Kirk et al. (under review)

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Food Waste: Fruits and Vegetables



Over 50% of fruits and vegetables produced are not eaten!

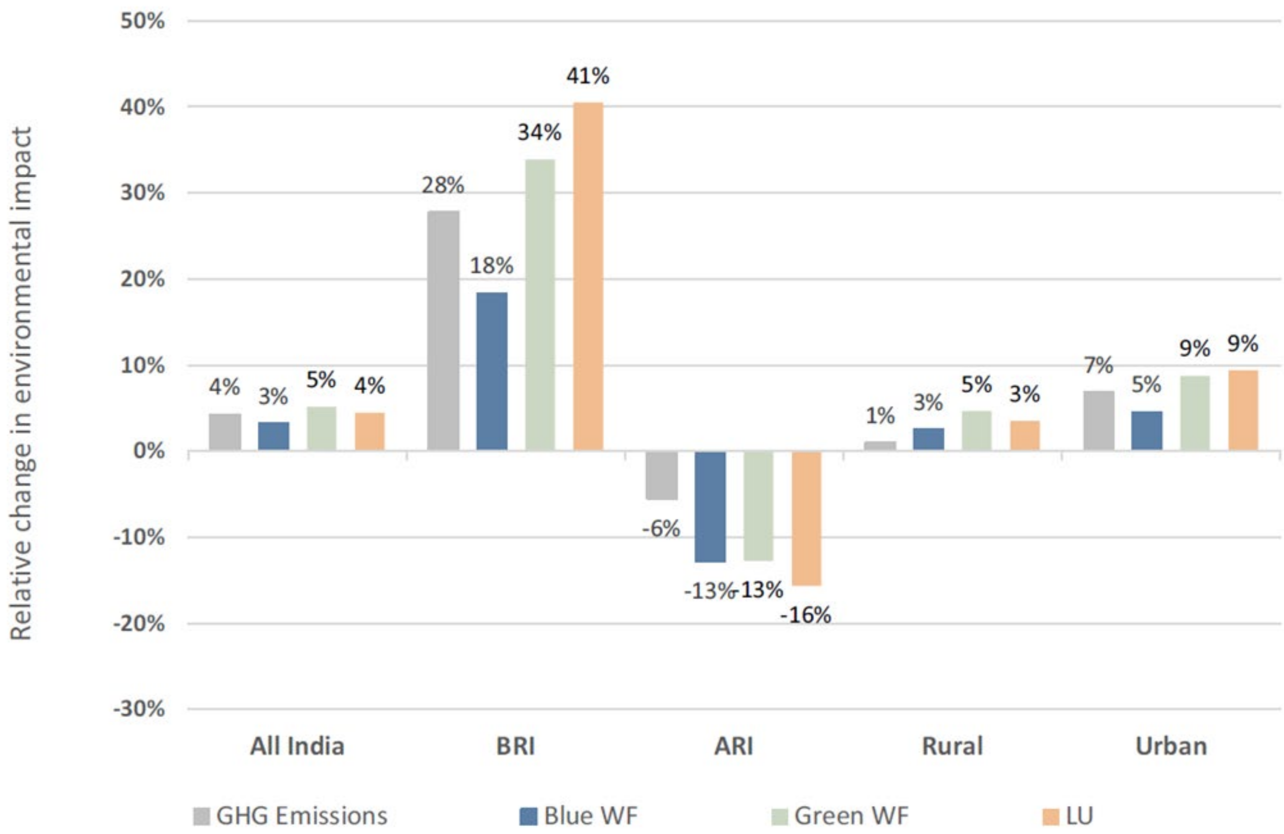
Figure Source: FAO 2011

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Low-Hanging Fruit

- **Why invest in increasing crop production only to have food rot?**

Environmental Impacts of Dietary Shifts in India



BRI = below recommended age & sex-specific intake

ARI = above recommended age & sex-specific intake

GHG = greenhouse gases

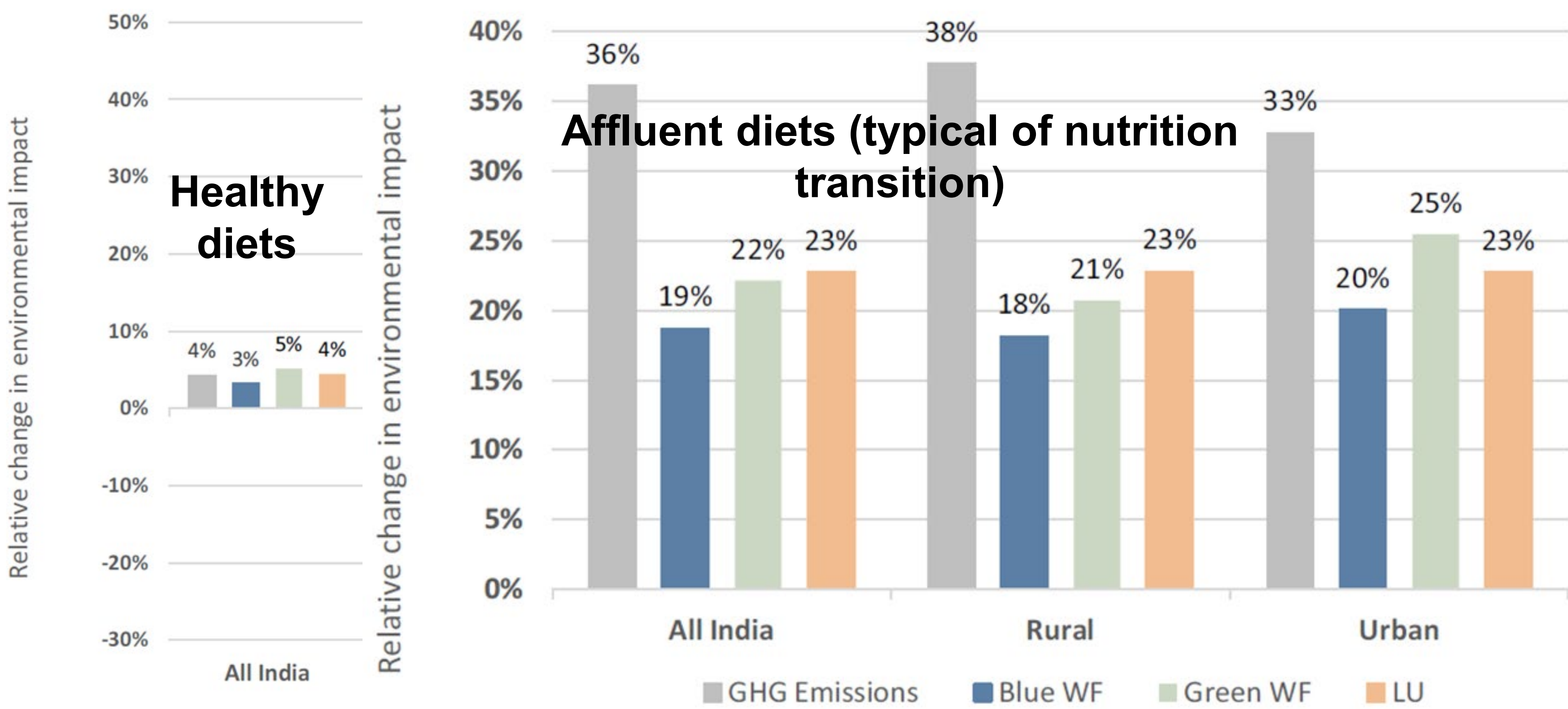
WG = water footprint

LU = land use

Aleksandrowicz et al. *Environment International* 2019;126:207-215

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Environmental Impacts of Dietary Shifts in India



Aleksandrowicz et al. *Environment International* 2019;126:207-215

Outline:
The Evolving Food System in India

1947
Independence

1950s
Drought, famine, reliance on food aid

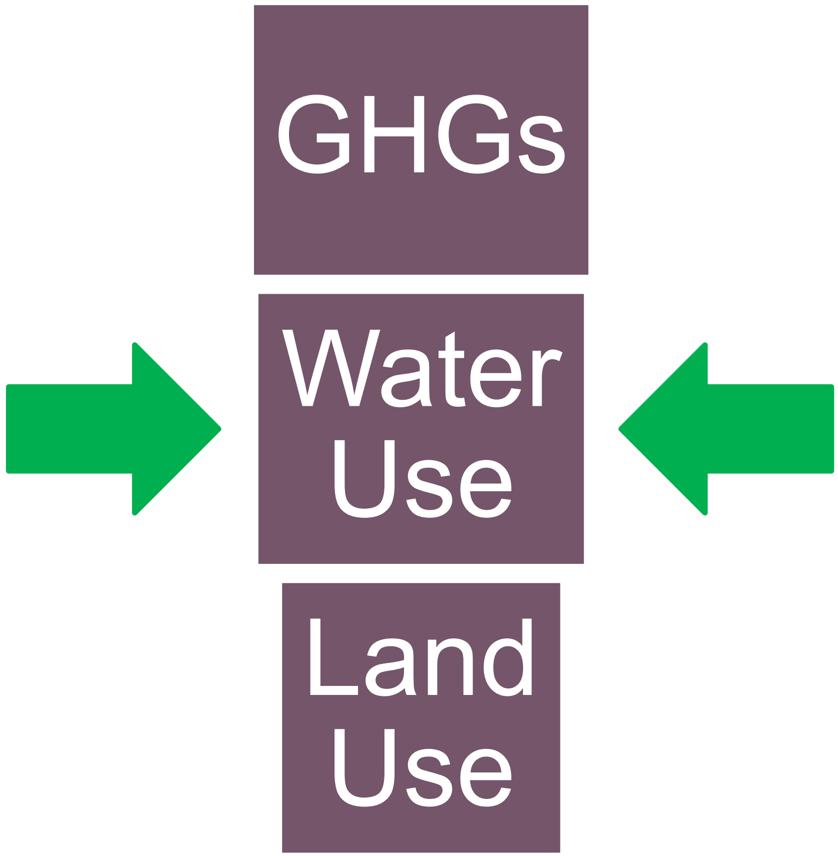
1960s
Green Revolution Period

1990s – Present
Nutrition Transition Period

Present & Future
Climate Adaptation Period

Supply Side

- Closing yield gaps
- Multiple cropping
- Improving efficiency of livestock production
- Reducing food waste



Demand Side

Dietary intake

Back to Crop Diversification

Andhra Pradesh, India 2019

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Father of Green Revolution in India: MS Swaminathan

- *"A one-degree Celsius rise in mean temperature will reduce the duration of the wheat crop by one week in the heartland of the green revolution in India"* (Swaminathan, 2010)

- "Evergreen Revolution"
  - Emphasizing importance of biodiversity preservation

Many Challenges

- Between 2001-2011 ~2358 people/day left farming in India
  - 2018 survey by Centre for Study of Developing Societies: 76% of farmers would prefer to do something else
- Average age of farmers (Jöhr *IFAMA* 2012):
  - US = 58 years
  - Japan = 67 years
  - >1/3 European farmers are older than 65

Concluding Remarks

- We cannot assume that economic growth will improve nutrition
- Goal: provide nutritious, safe and culturally appropriate food to a growing population that is also getting wealthier
  - **AND minimize the environmental impact**
- Need platforms for accountability

Concluding Remarks

- Call for a Framework Convention on Healthy Diets
  - Legally-binding global treaty similar to FCTC for tobacco
- All of the easy, important wins are gone – now the easy stuff is not very important, and the important stuff is tough

THINK BEYOND

LIVE WITHIN

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH