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Cereals and Ag Development: For the Health of It!

Speaker

Curtis L. Weller, *Jefferson Science Fellow/USAID*

Facilitator

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Cereals & Ag Development: For the Health of It!

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June 27, 2012

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Acknowledgements

Fellow Support

- US Department of State Office of the Science and Technology Adviser to the Secretary
- USAID Bureau for Food Security Office of Markets, Partnerships and Innovation
- The National Academies
- University of Nebraska

Research Support

- USDA NIFA Hatch Act funds
- USAID International Sorghum and Millet Collaborative Research Support Program (INTSORMIL)
- United Sorghum Checkoff Program
- Nebraska Sorghum Board

Where We Are Headed

- Review cereal grains grown around the world, their origin, and their typical uses;
- Compare their nutritional and agronomic similarities and differences; and
- Present evidence to help frame debate on their appropriate end uses, and roles in crop diversification and development investments.

What are they?

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Definition

- A ***cereal*** is – a member of the grass family (*Poaceae*, formerly *Gramineae*) whose one seeded, edible, starchy fruit (a caryopsis) has a seed coat fused with the ovary wall
- ***Not*** in the cereals are <u>pulses</u> (dry beans), <u>oilseeds</u> (soy, rape, flax, sunflower) and <u>pseudocereals</u> (amaranth, quinoa, buckwheat)

Basic Structure Common to Cereals

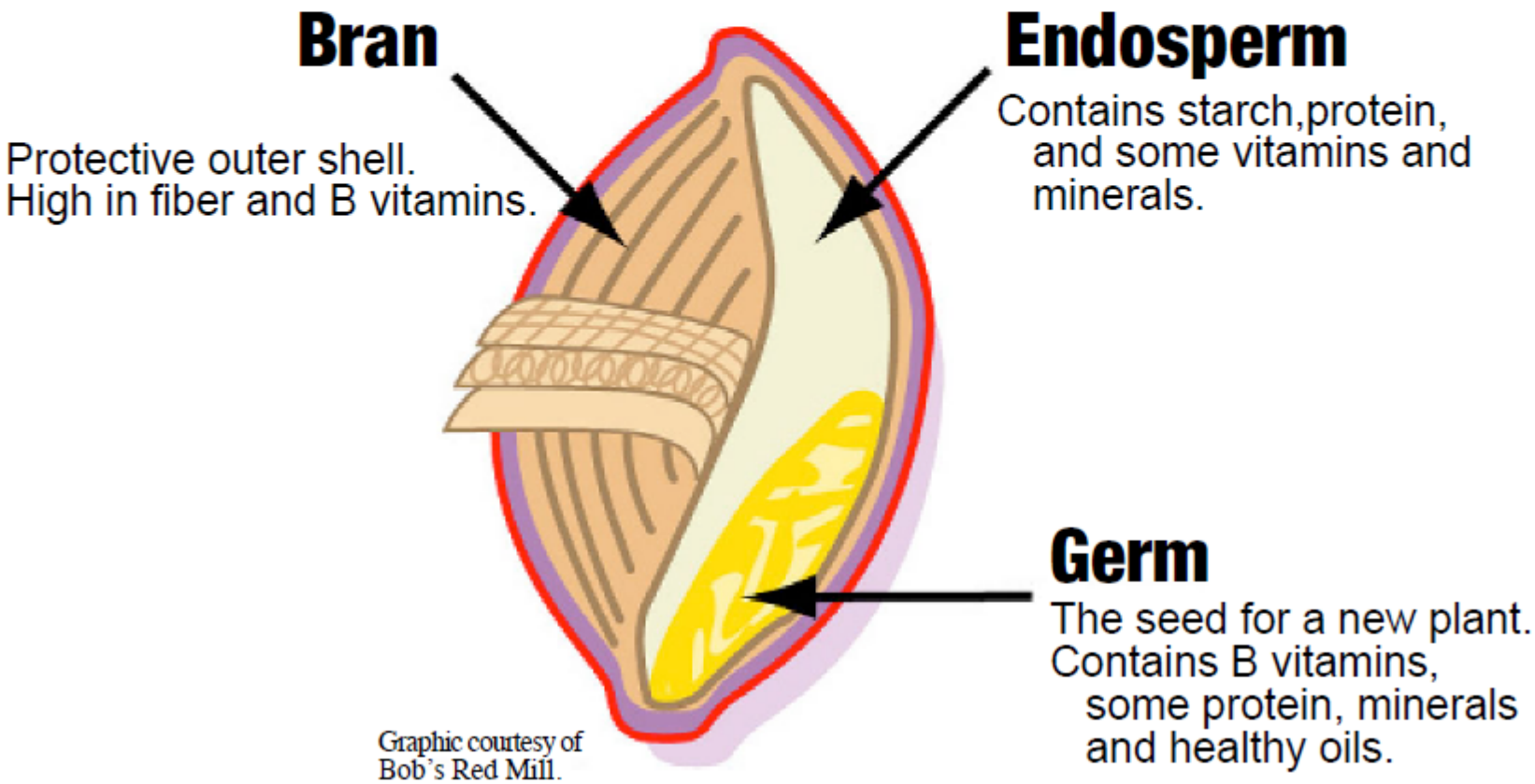


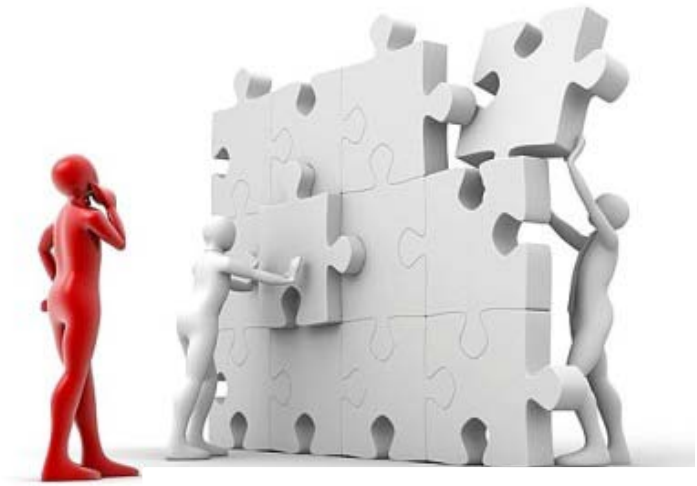
Table 1. Typical distribution of kernel parts for six major cereal grains.

Type	Part of Kernel (% mass/mass)		
	Pericarp/Bran	Germ	Endosperm
Barley*	16	3	81
Maize	5-6	10-14	80-85
Rice*	7	2-3	90-91
Rye	10-15	2-3	80-85
Sorghum	8	10	82
Wheat	14	3	83

**Hull typically found on kernels is not included*

Types Within Some Cereals

- *Barley* – 2-row and 6-row with or without hull
- *Maize* – flint, yellow dent, popcorn, variegated and sweet (green)
- *Millet* – pearl, finger, broomcorn and foxtail
- *Rice* – Asian, African, waxy, and short-, medium- and long-grain
- *Rye* – winter and spring
- *Sorghum* – bicolor, guinea, kafir, caudatum, durra, food grade and tannin-containing
- *Wheat* – einkorn, emmer, durum, red, white, winter, spring, hard, soft, spelt
- *Tef, Fonio, Triticale* and others



Where did they come from?

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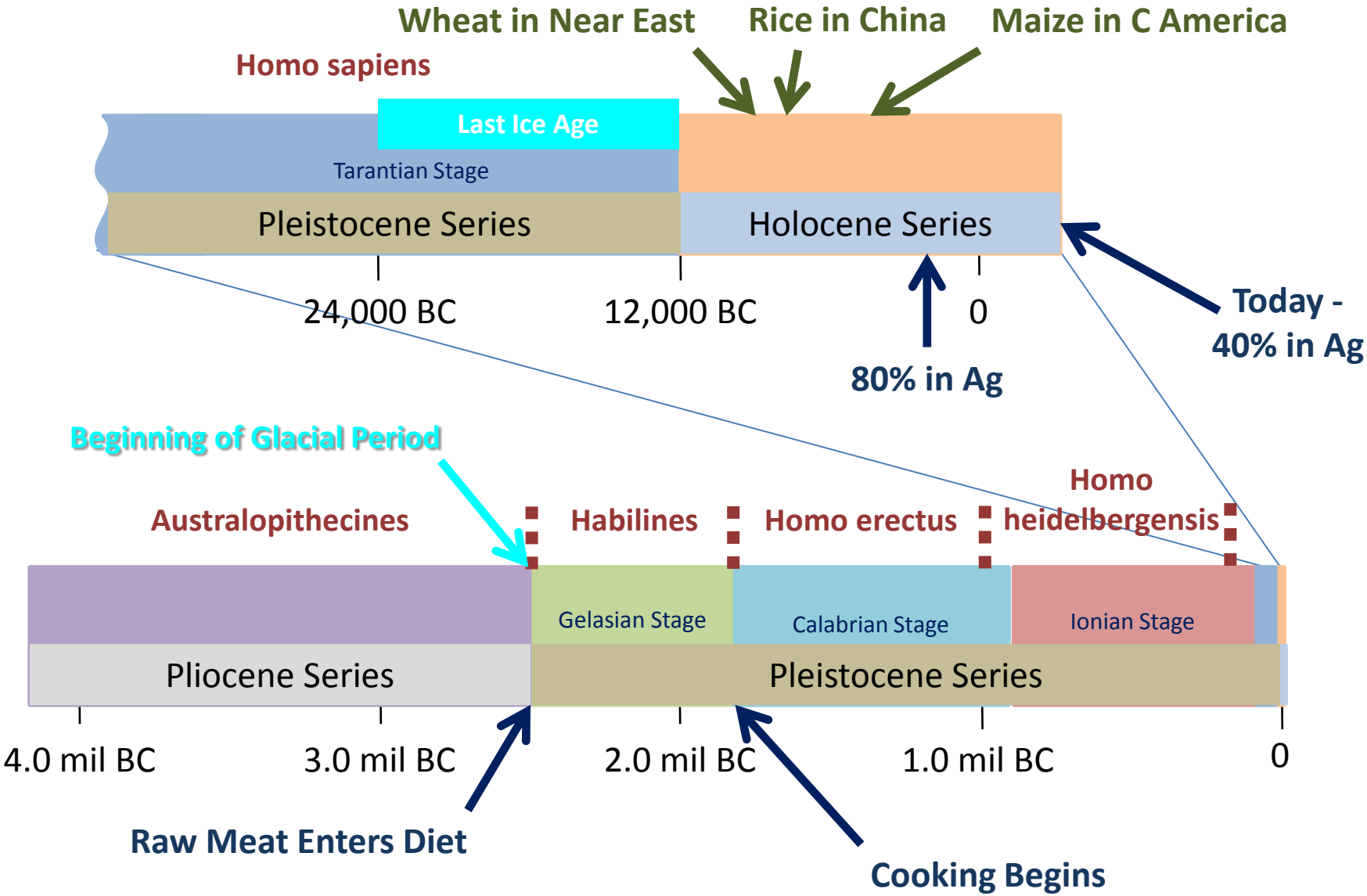
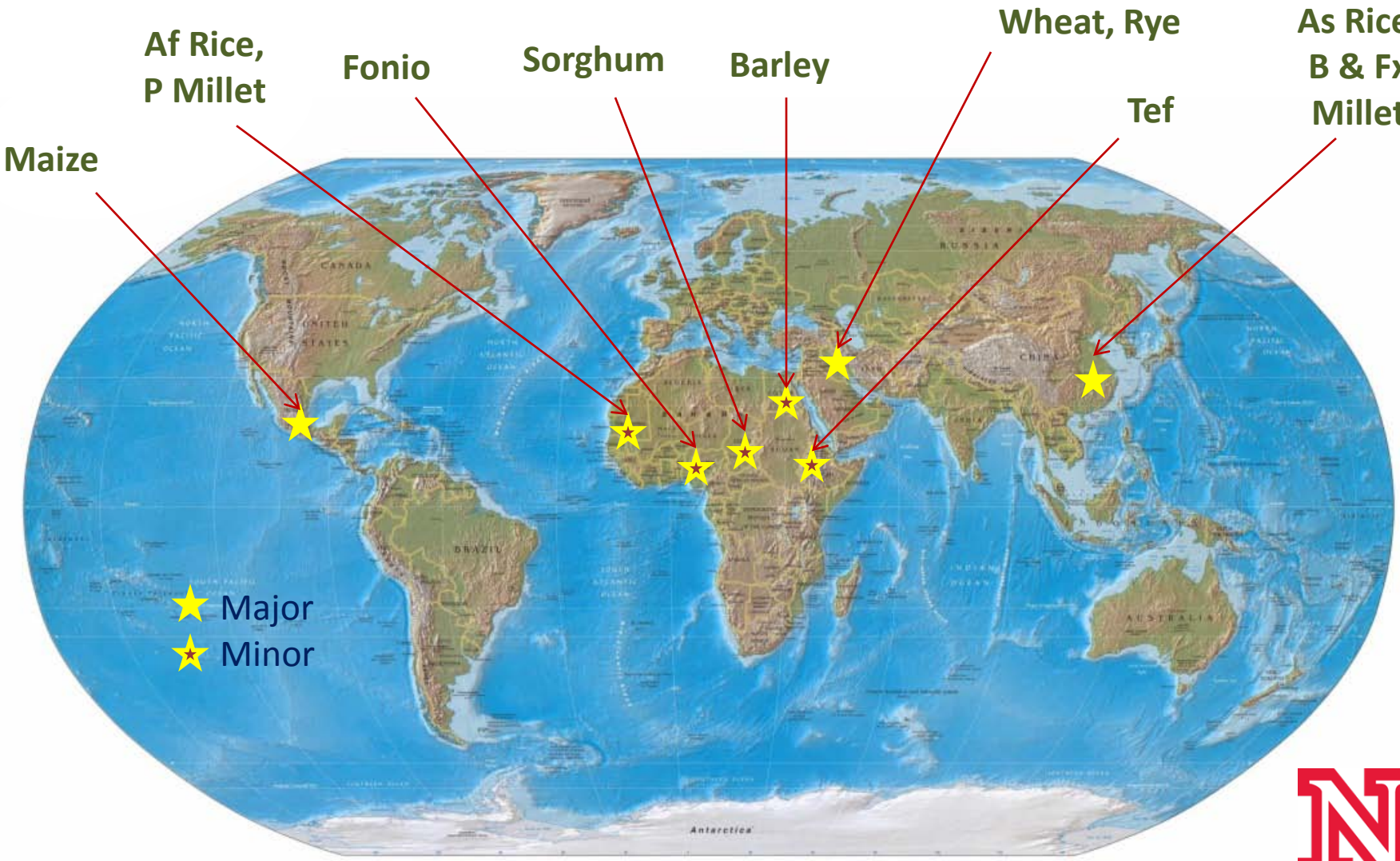
Timeline of Humans and Food



Cereal Origins



IANR

Co-Evolution of Body and Diet

- Hunter-gatherers were likely dependent on meat for about 50% of energy intake
- Cooking allowed for pre-digestion of food materials outside of body
- Development of agriculture has allowed further adaption to diets of nutritionally dense, volumetrically concentrated foods that can be largely digested in small intestine

Place of Cereal Grains

- 350,000 plant species documented
- 195,000 species are economically important
- 50 species are cultivated
- 17 species supply 90% of food supply and occupy 75% of tilled earth
- Cereals supply 50% of dietary energy and 50% of dietary protein

What do we eat?

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Forms of Cereal Products

- ***Raw*** – Really not practiced
- ***Refined*** – Separation of kernels into various fractions
  - flour, oil, protein, starch, sweetener
- ***Cooked*** – Either in whole grain or fraction form
  - function or reason to use is for product structure, energy source, protein source, fiber source, water binder, flavor carrier, filler material or other

05/04/2010 02:57

Methods of Processing

- **Malting** – allow kernels to germinate/sprout for enzymes then dry and mill (for malt beverages and porridges, and beer)
- **Pearling** – abrasively remove hull, bran and germ (for degermed, dehulled/debranned kernels)
- **Dry Milling** – degermination followed by size reduction and gravitational method to fractionate kernel components (for flour products)
- **Alkaline Cooking** – lime treatment (nixtamalization) leading to masa (for tortillas and corn chips)
- **Dry Grinding** – size reduction of whole kernels (for mash preparation for ethanol fermentation, fermented porridges, and flours)
- **Wet Milling** – use water and SO_2 to extensively fractionate kernel components (for starch, protein and oil fractions)
- **Pre-gelatinizing** – steam-cooking of large pieces of grits (vitreous endosperm) possibly followed by size reduction (for pre-cooking kernels and flours)
- **Fermenting** – solid-state substrate for Koji production (for sake)
- **Flaking** – use roller pressure with or without steam cooking to flatten kernels (for rolled or flaked kernels)

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OAT BRAN
HOT CEREAL
ROLLED OATS
SCOTTISH
OATMEAL
HIGH FIBER
HOT CEREAL
10 GRAIN
8 GRAIN
HOT CEREAL
Whole Grain
2.69
3.65
3.59
8.38
2.59
4.09
4.29
4.29
5.99
4.39
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4.79
3.18
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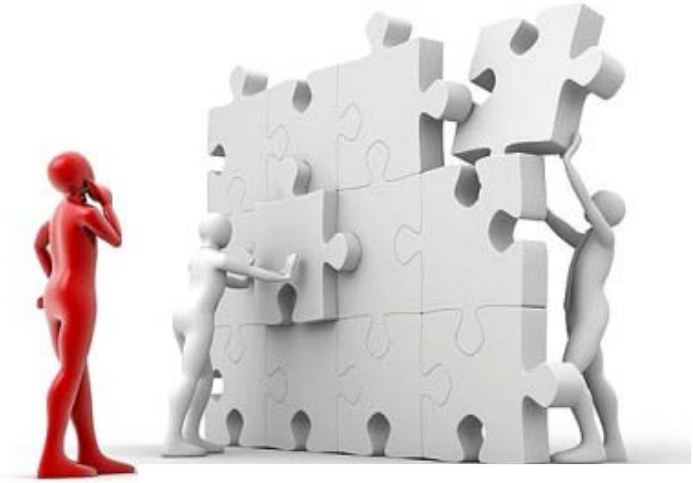
3.69
3.59
3.19
3.85



What good are they?

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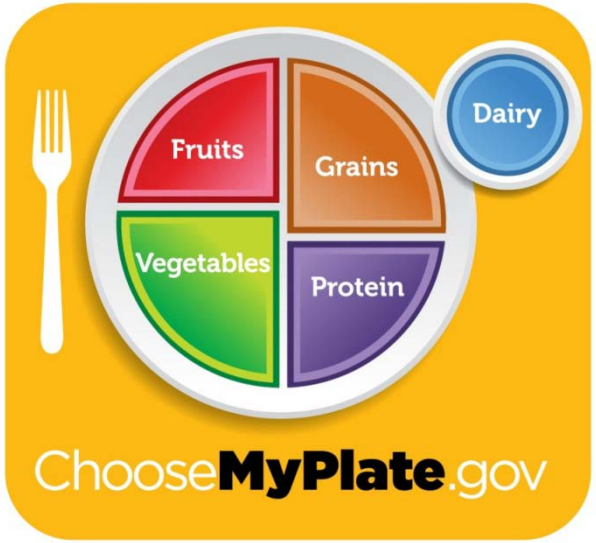


Average Age in USA
49 years

Moderately Active
walks 2.5-5 km daily
at 5-6.5 kph

2,000 kcal intake daily for female of 50 kg

Table 4. Average Daily Intake for Moderately Active Female Age 49 Following USDA Food Pattern

Food Group	Amount
Vegetables	
Dark-green	0.2 cups
Bean and peas	0.2 cups
Red and orange	0.8 cups
Other	0.6 cups
Starchy	0.7 cups
Fruits and Juices	2.0 cups
Grains	
Whole grains	≥ 85 grams
Refined grains	≤ 85 grams
Dairy	3.0 cups
Protein	
Meat	51 grams
Poultry	43 grams
Eggs	11 grams
Fish and seafood	34 grams
Beans and peas	See above in Vegetables
Nuts, seeds and soy products	17 grams
Oil	27 grams
Solid Fat	16 grams
Added Sugar	32 grams

Source: USDA-ARS & USDHHS-CDCP *What We Eat in America*

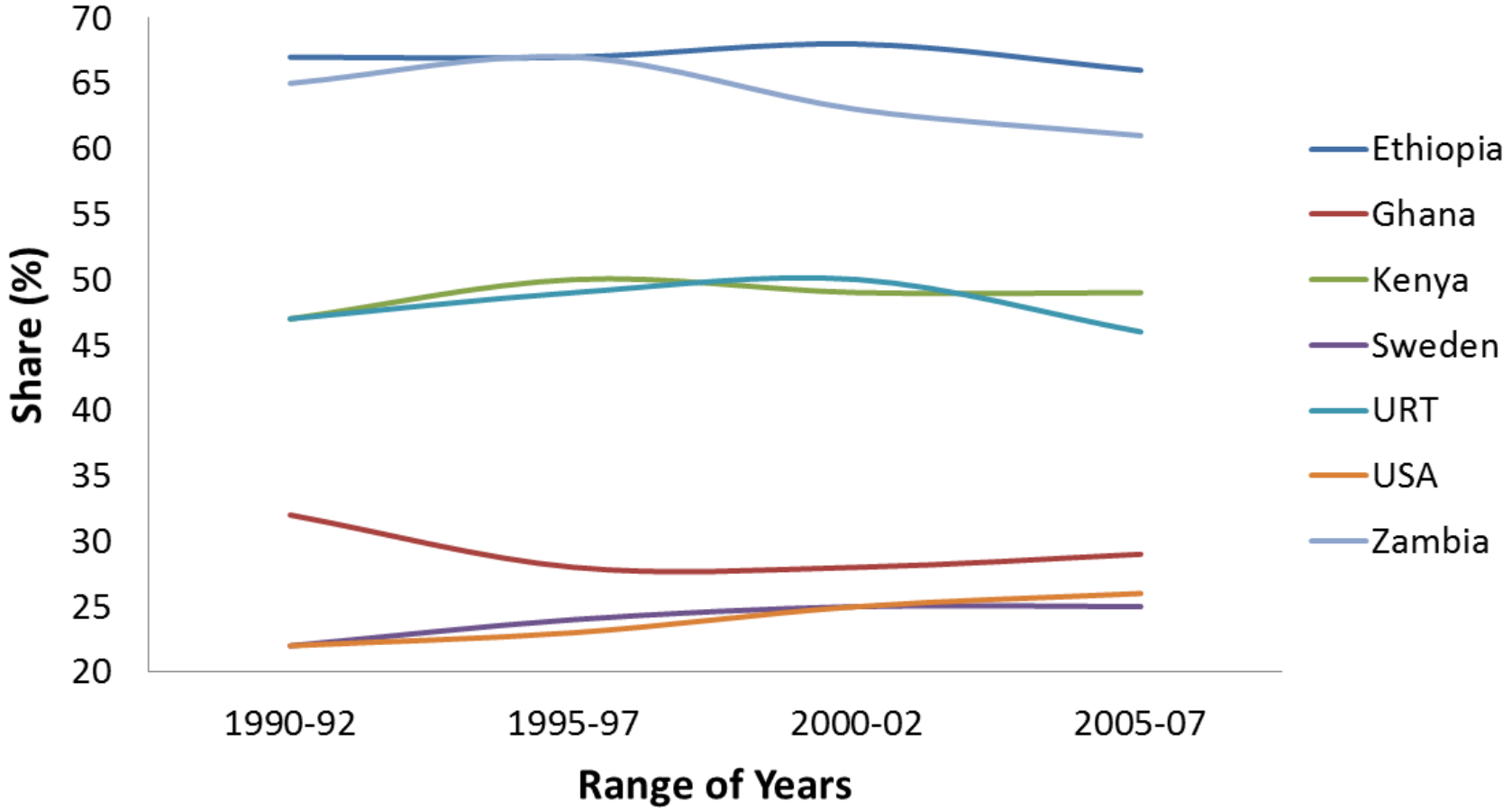


Figure 3. Share (%) of Daily Total Dietary Consumption Filled by Grains excluding alcohol

FAO, 2012

Table 1. Comparison of nutrients in various cereals relative to RDA for female (49 yr and 50 kg) given equal carbohydrate intake

Nutrient	Recommended Dietary Allowance	Maize	Rice	Wheat	Barley	Sorghum	Millet	Rye	Tef	Fonio	Oats
Carbohydrate	130 g/d	130	130	130	130	130	130	130	130	130	130
Fiber	25 g/d	12.8	5.9	23.3	30.6	11	15.2	25.8	14.2	13.5	20.8
Protein	46 g/d	16.5	11.7	29.4	22.1	22	22	17.7	17.1	15.6	33.1
Methionine & Cysteine	750 mg/d	643	513			571	790		684	1089	
Calcium	1,000 mg/d	12.6	46.1	47.8	58.4	58.4	68.8	41	283	76	105.8
Copper	900 ug/d	550	360			3294	930		1246		
Iron	18 mg/d	4.7	1.3	6.9	6.4	10.4	18.2	4.5	10.3	14.7	9.3
Magnesium	320 mg/d	223	187		235	256	212	188	303	347	
Phosphorus	700 mg/d	367	187	634	467	673	630	568	673	306	1025
Zinc	8 mg/d	3.9	1.7	5.3	4.9		3.7	4.5	3.6	7.8	
Potassium	4.7 g/d	0.5	0.2	0.6	0.8	0.4	0.8	0.9	0.7		0.8
Sodium	1.5 g/d	0.06	0.01	0.01	0.02	0.03	0.03	0.01	0.08		0.01
Thiamin	1.1 mg/d	0.68	0.12	0.96	1.14	0.64	0.58	0.54	0.53	0.81	1.5
Riboflavin	1.1 mg/d	0.35	0.09	0.21	0.5	0.26	0.35	0.43	0.32	0.17	0.27
Niacin	14 mg/d	6.44	2.59	10.91	8.15	5.12	4.84	7.3	4.45	3.29	1.88
Vitamin B6	1.3 mg/d	0.91	0.03	0.64	0.56	0.92		0.5			0.23

greater than 100% of daily value

greater than 50% of daily value

greater than 20% of daily value

greater than 10% of daily value

less than 10% of daily value

Food and Nutrion Board, Institute of Medicine, National Academy of Science, 2012

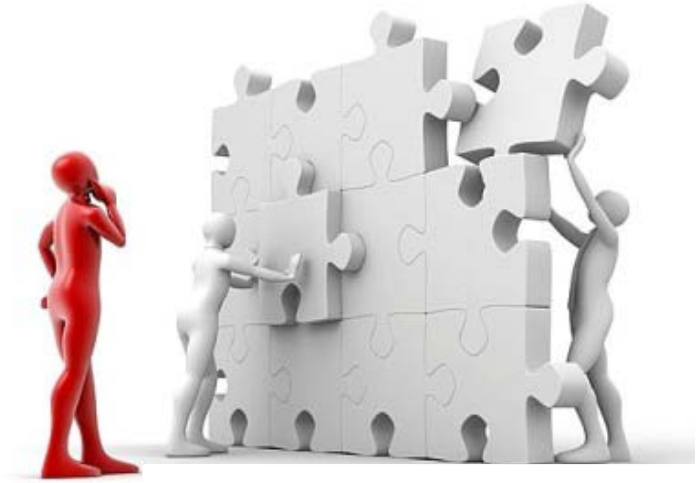
WHO, 2012

Uniqueness Among Cereals

- Barley is a short-season, early maturing crop grown on both irrigated and dry land production tolerant of cool and high altitude conditions
- Rye has the best overwintering ability and the highest tolerance to drought, salt, or aluminum stress from all small-grain cereals
- Sorghum, millets and tef are relatively more drought tolerant and heat resistant than maize and rice especially pearl millet
- Fonio can produce a crop in 6-8 weeks

Uniqueness Among Cereals

- Cereals other than wheat, barley, rye, triticale and oats (?) are non-gluten and favorable for celiacs and gluten-intolerant
- Barley and finger millet are first and second in diastatic power (ability to produce starch degrading enzymes during germination)
- Fonio is reported to be the best tasting of all cereals



What are the issues?

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Fighting Hunger Worldwide

The cost of hunger to developing nations is an estimated US$450 billion per year.

It takes only 25 US cents for WFP to give a hungry schoolchild a cup of food with all the nutrition needed for the day.

The number of undernourished people worldwide is just under 1 billion – equivalent to the population of North America and Europe combined.

Hunger Map 2011

Category	1	2	3	4	5	
Undernourished	<5%	5-9%	10-19%	20-34%	≥35%	Incomplete data
Description	Extremely low	Very low	Moderately low	Moderately high	Very high	

Source: *The State of Food Insecurity in the World 2010*, Food and Agriculture Organization of the United Nations. Please note that the SOFI 2010 data in some cases dates back to 2005 so may not always reflect the present-day situation in individual countries.

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* The Line of Control in Jammu and Kashmir agreed on by India and Pakistan is represented approximately by a dotted line. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

** A dispute exists between the governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Malvinas).

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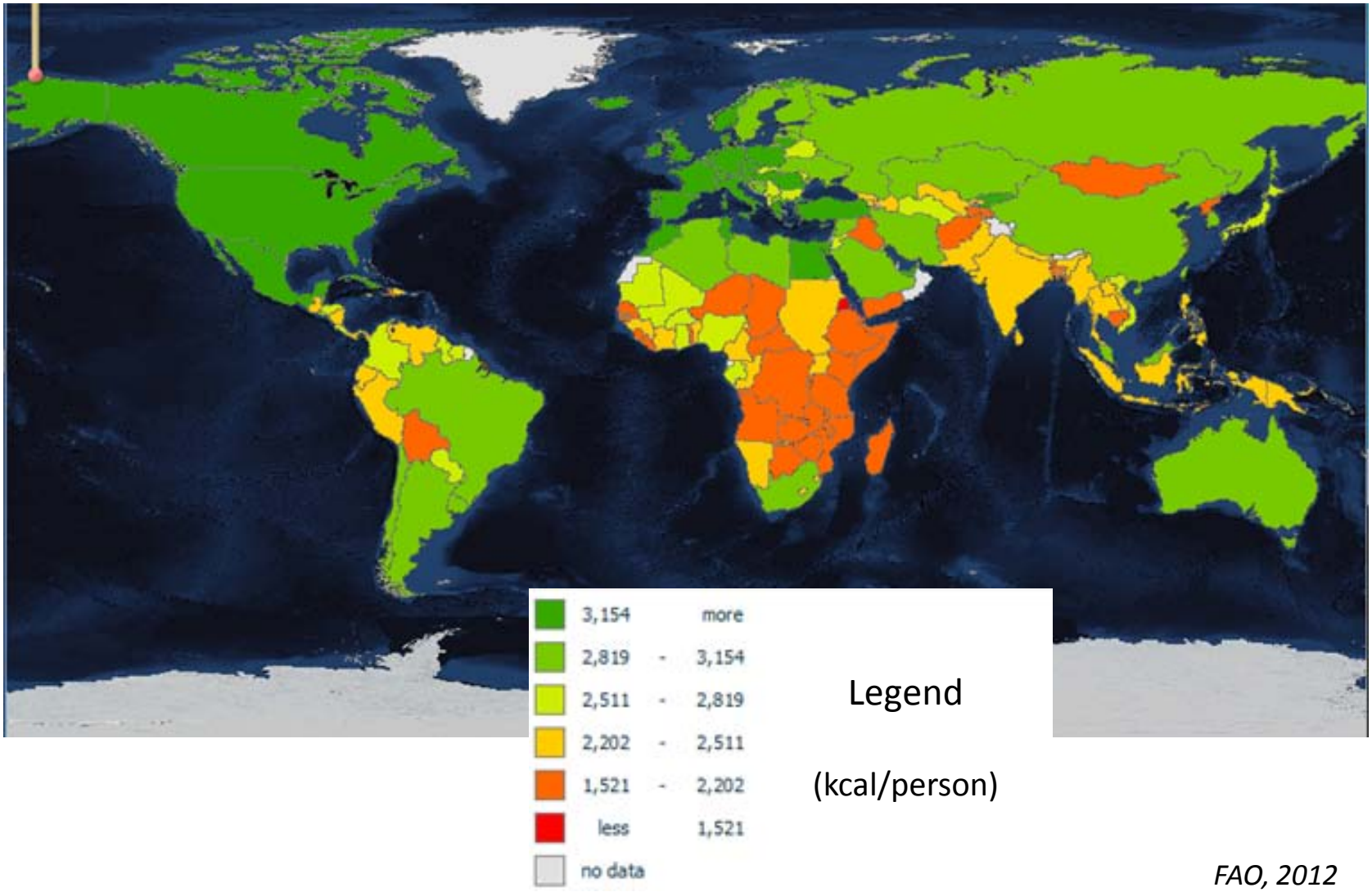
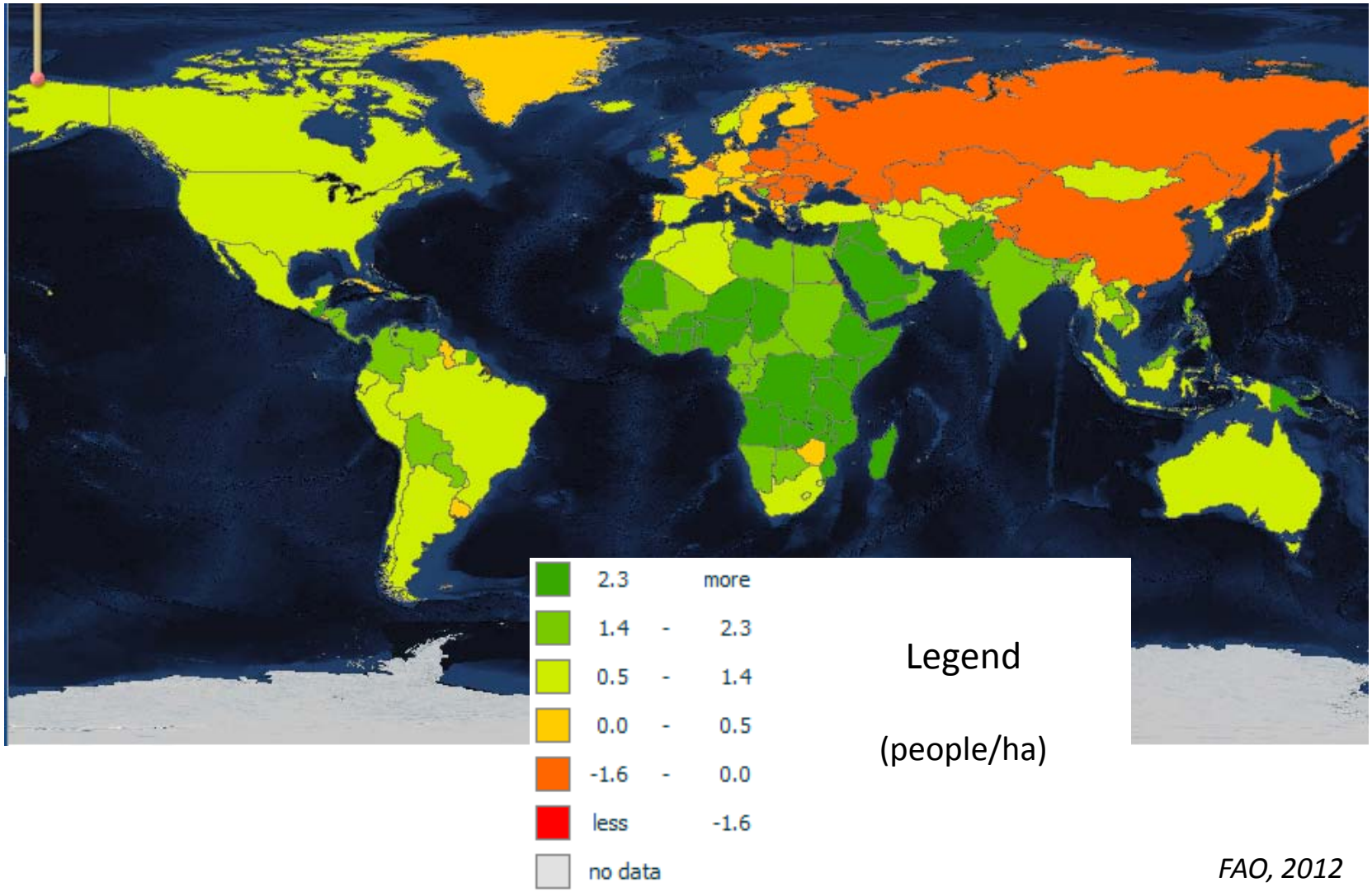
Daily Intake Energy Density



FAO, 2012

Population Density



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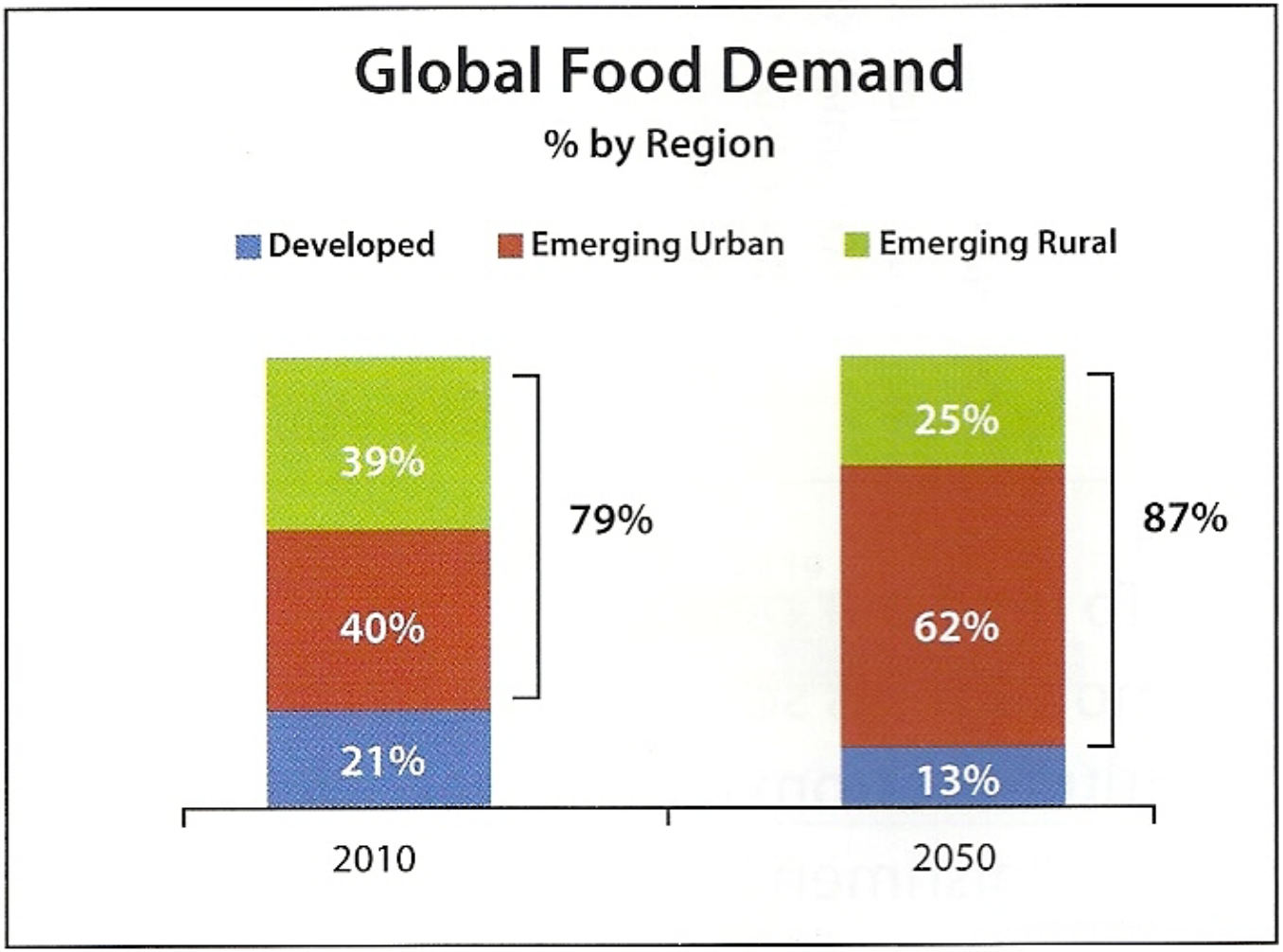
Urban vs. Rural Needs



International Fertilizer Development Center, 2012

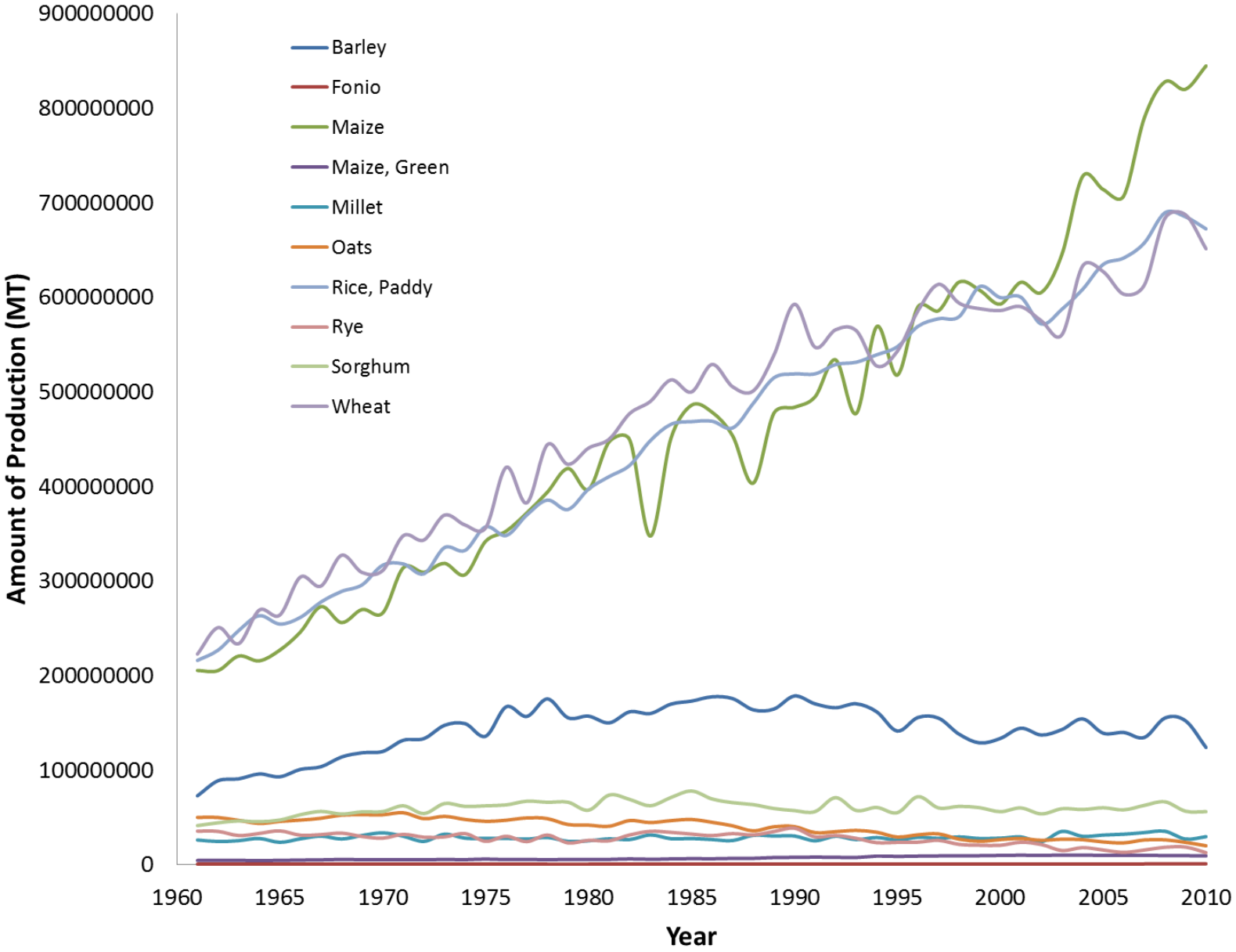


Figure 2. Total Global Cereal Production (MT) from 1961 to 2010

FAO, 2012

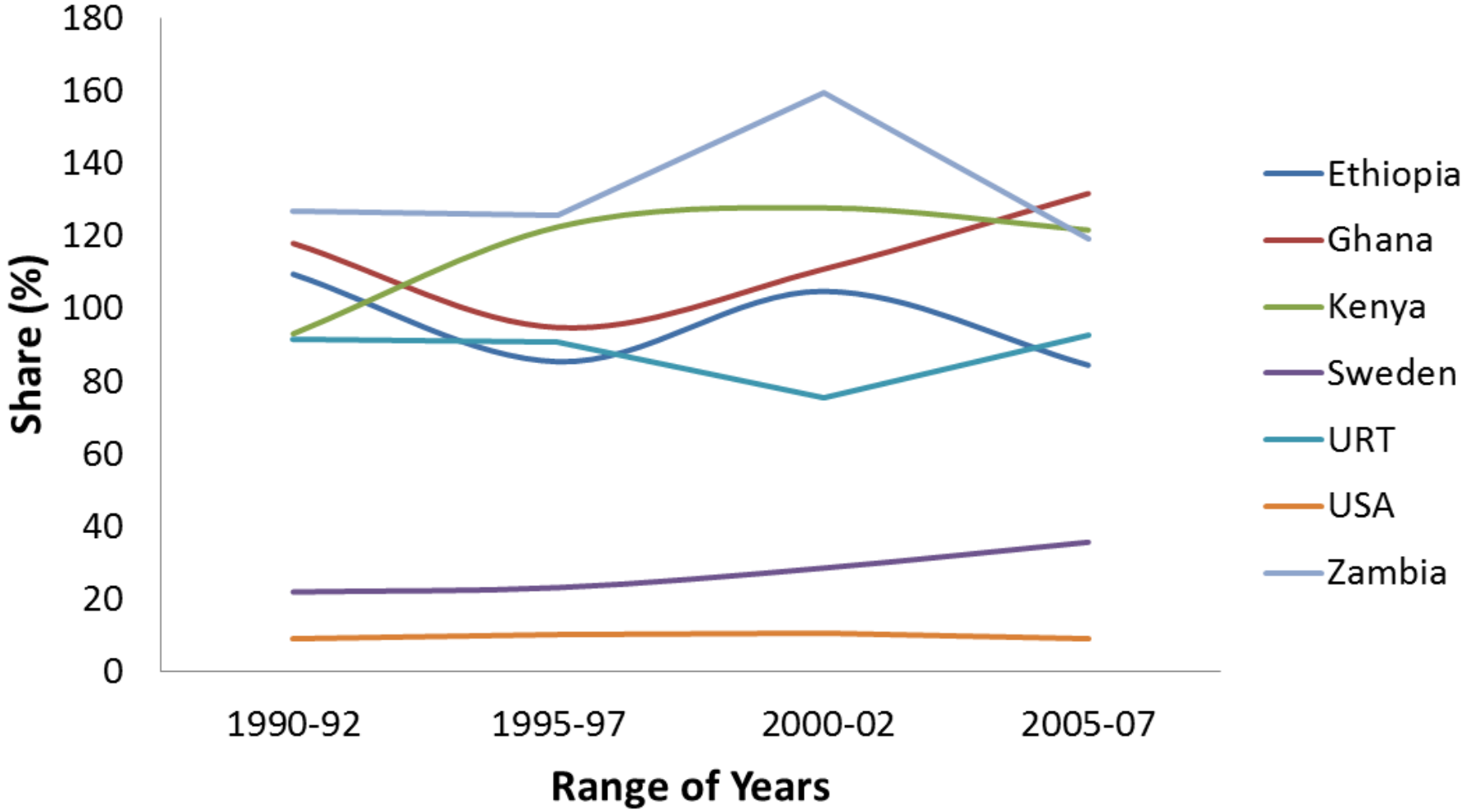
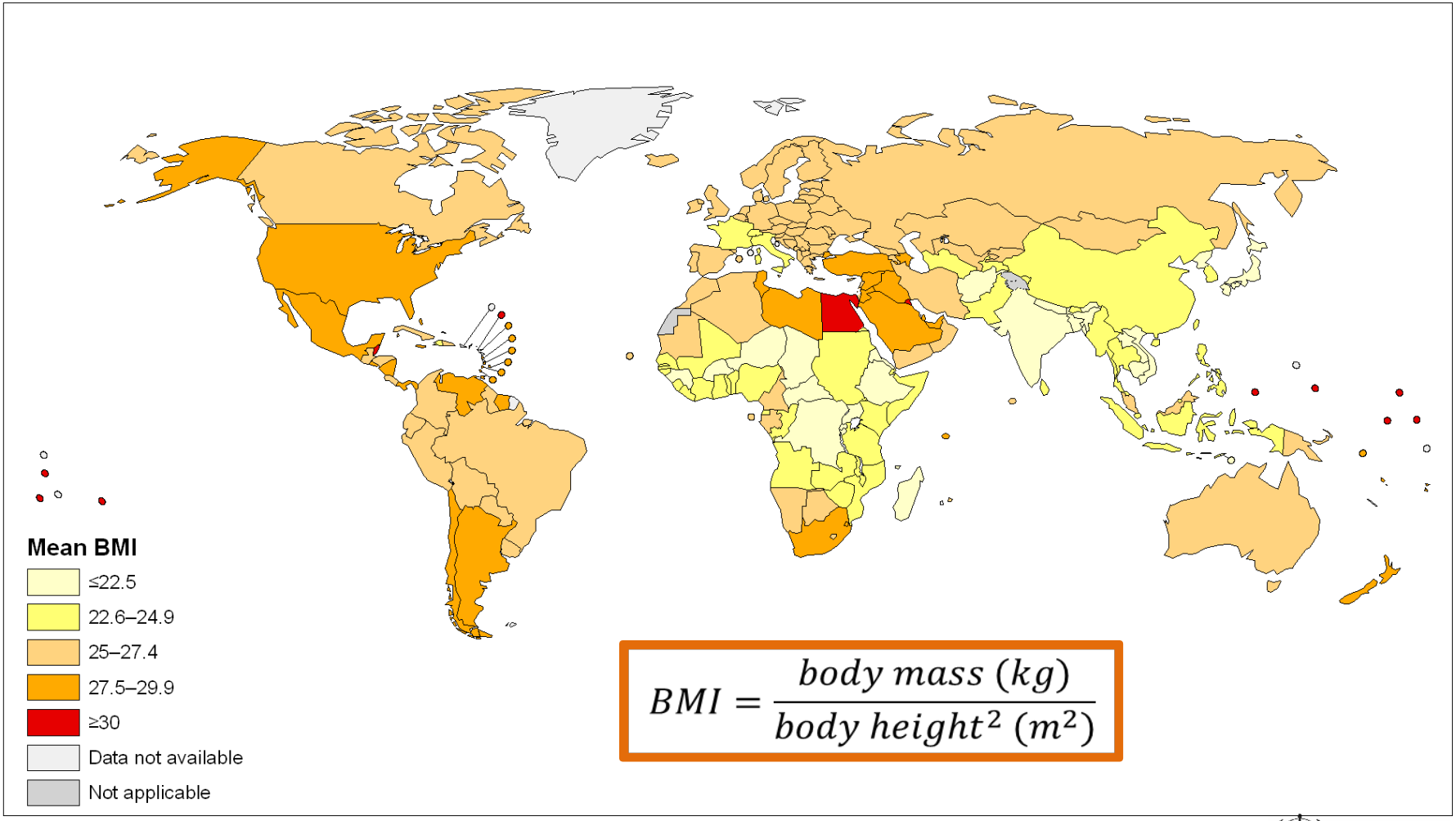


Figure 6. Share (%) of Yearly Grain Produced in-country For Food Use

FAO, 2012

Mean Body Mass Index (BMI), ages 20+, age standardized
Females, 2008



$$BMI = \frac{body\ mass\ (kg)}{body\ height^2\ (m^2)}$$

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Map Production: Public Health Information and Geographic Information Systems (GIS)
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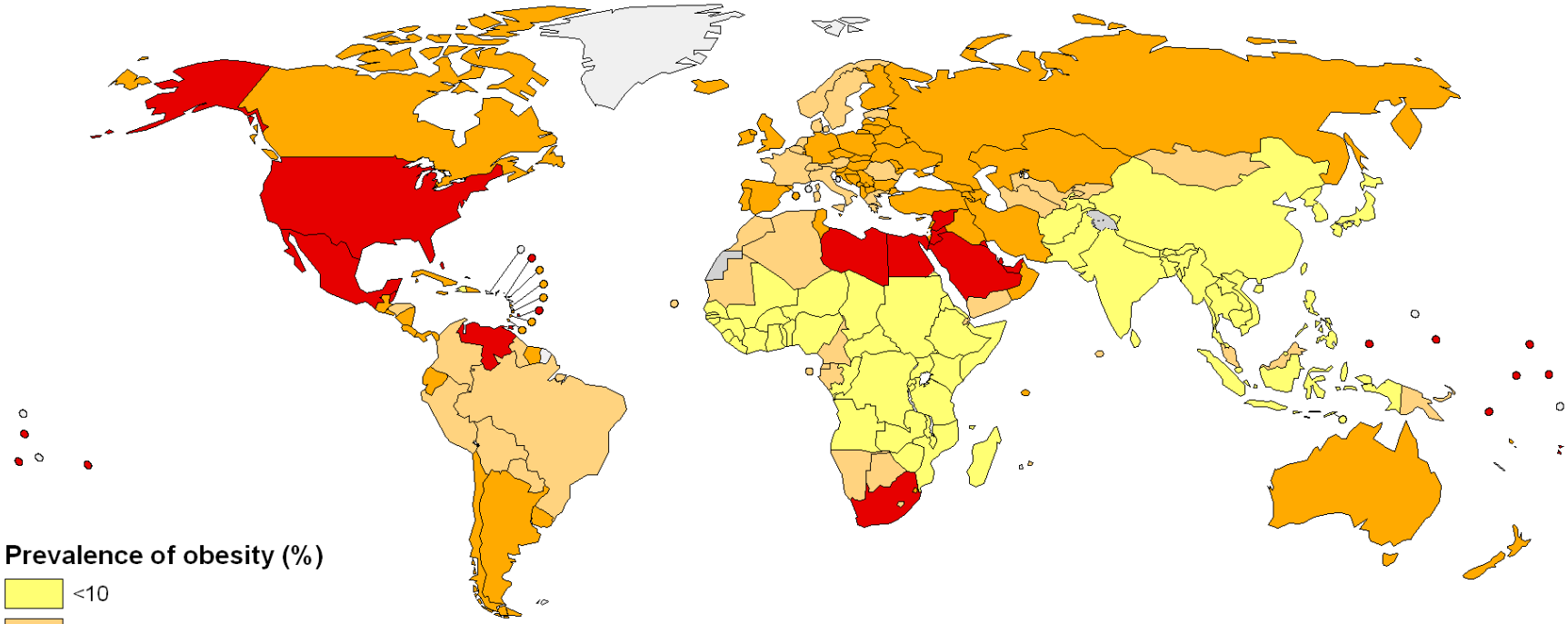
Prevalence of obesity*, ages 20+, age standardized
Both sexes, 2008



Prevalence of obesity (%)

- <10
- 10–19.9
- 20–29.9
- ≥30
- Data not available
- Not applicable

* BMI ≥30kg/m2

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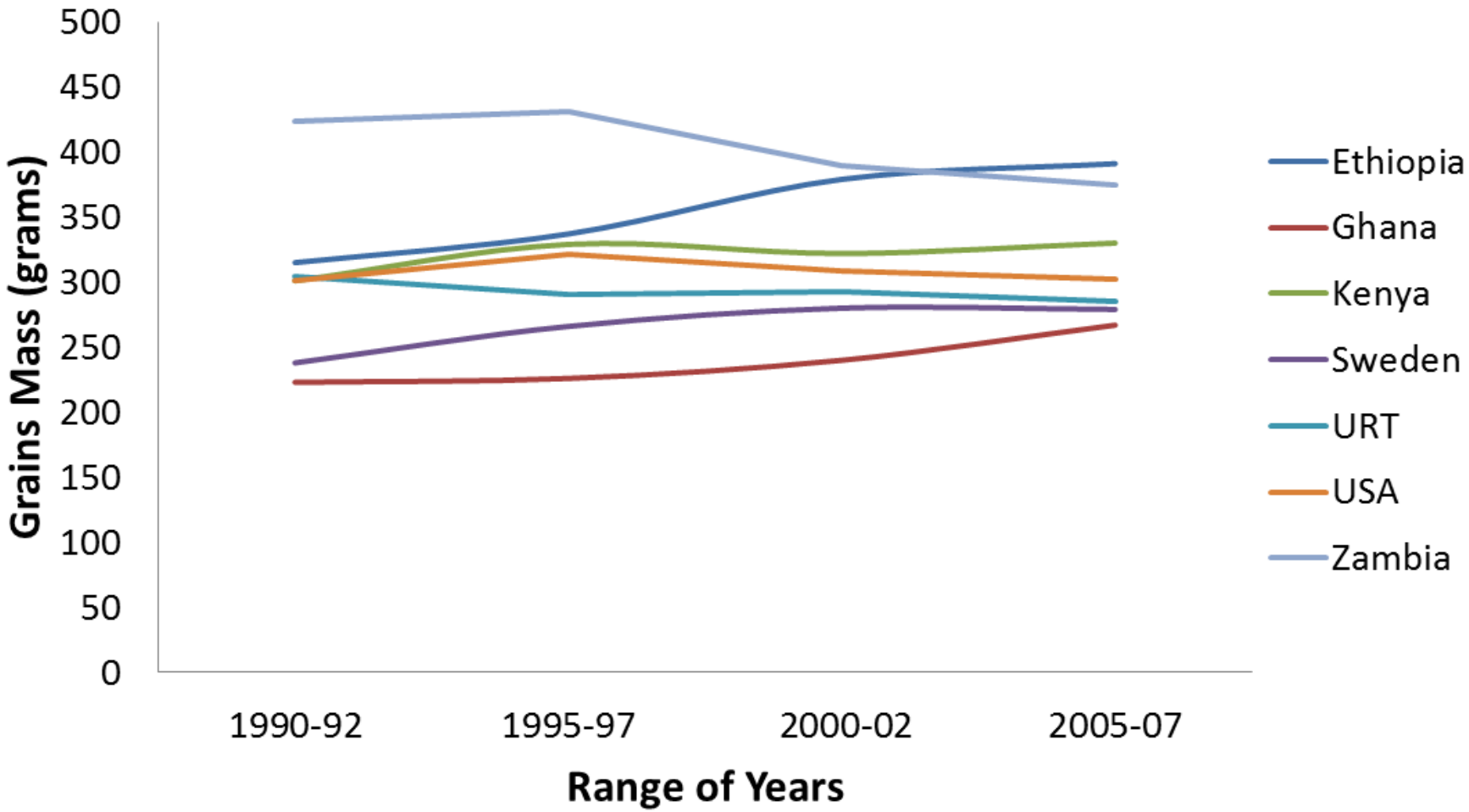


Figure 5. Mean Daily per Capita Grains (grams) Consumption

FAO, 2012

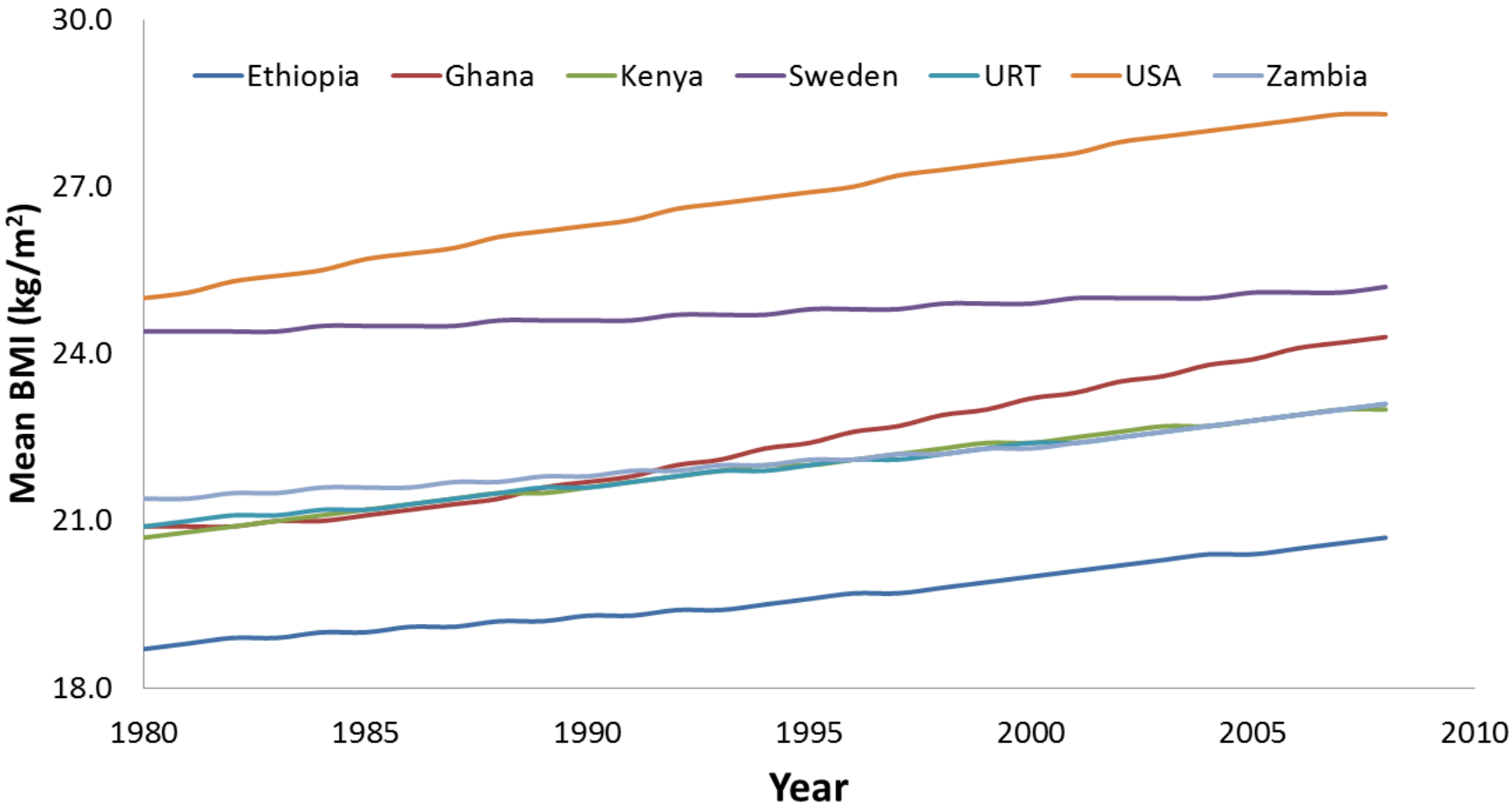


Figure 1. Mean BMI for Females Age 20+ in Select Countries between 1980 and 2008

Compiled from WHO data, 2012

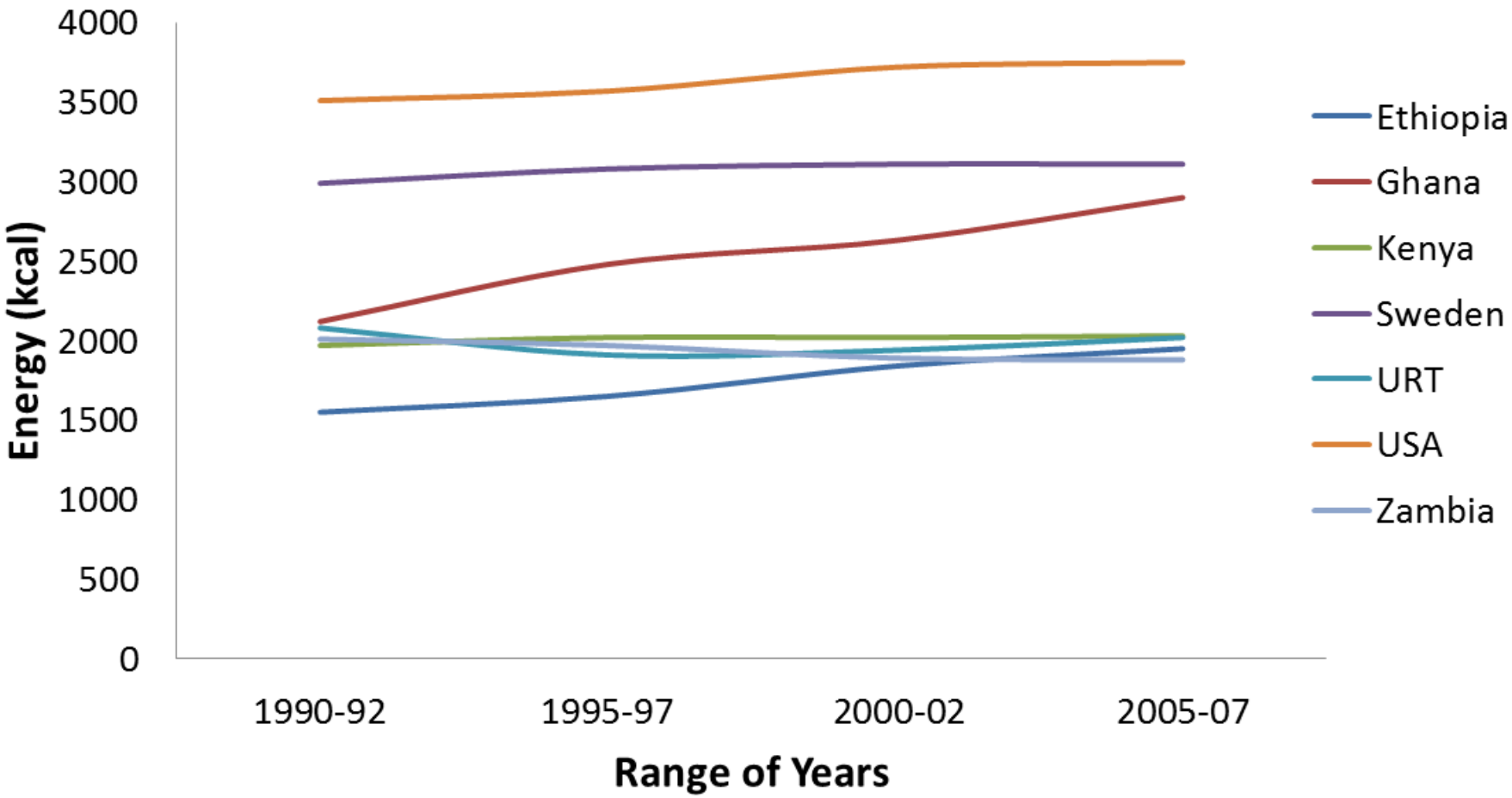
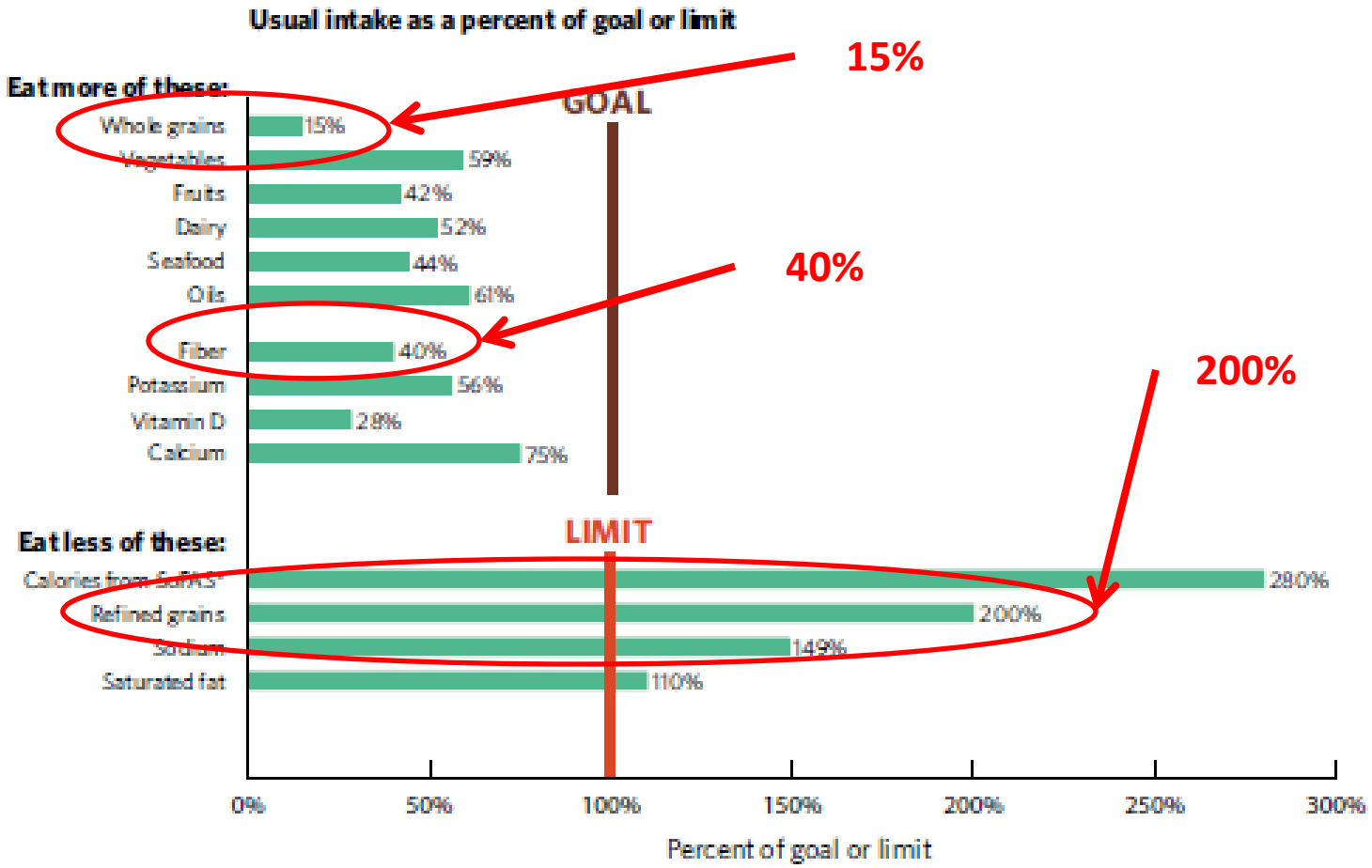


Figure 4. Mean Daily per Capita Dietary Energy (kcal) Consumption

FAO, 2012

FIGURE 5-1. How Do Typical American Diets Compare to Recommended Intake Levels or Limits?

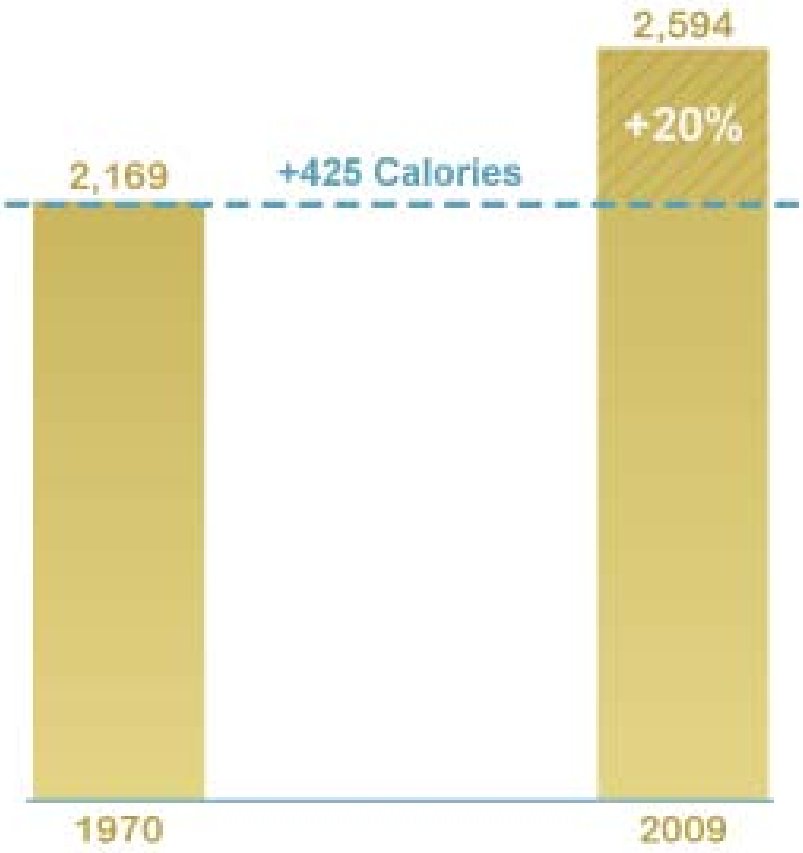


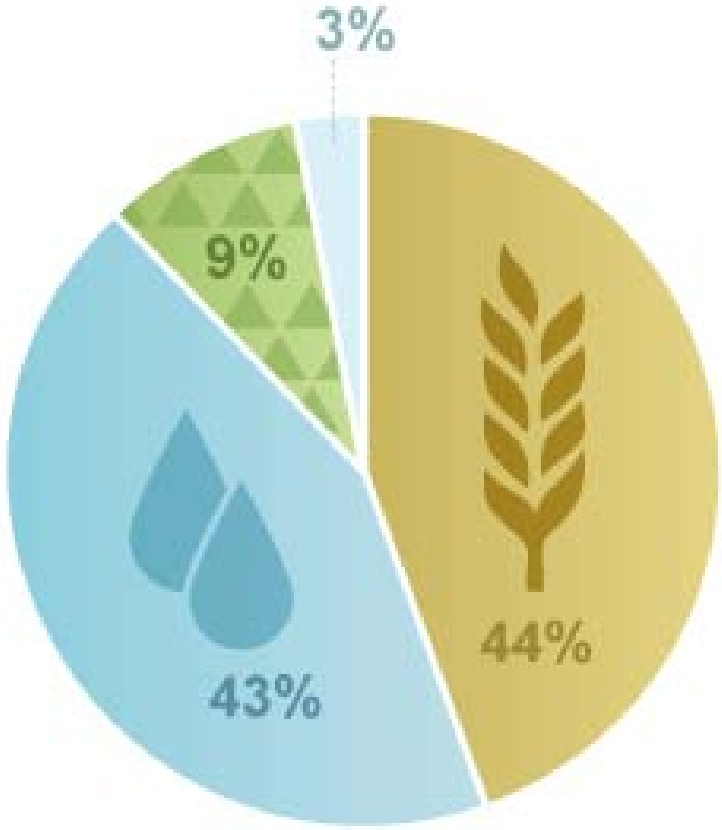
*SoFAS = solid fats and added sugars.

Note: Bars show average intakes for all individuals (ages 1 or 2 years or older, depending on the data source) as a percent of the recommended intake level or limit. Recommended intakes for food groups and limits for refined grains and solid fats and added sugars are based on amounts in the USDA 2000-calorie food pattern. Recommended intakes for fiber, potassium, vitamin D, and calcium are based on the highest AI or RDA for ages 14 to 70 years. Limits for sodium are based on the UL and for saturated fat on 10% of calories. The protein foods group is not shown here because, on average, intake is close to recommended levels.

Based on data from: U.S. Department of Agriculture, Agricultural Research Service and U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. What We Eat in America, NHANES 2001-2004 or 2005-2006.

Sources of Added Calories





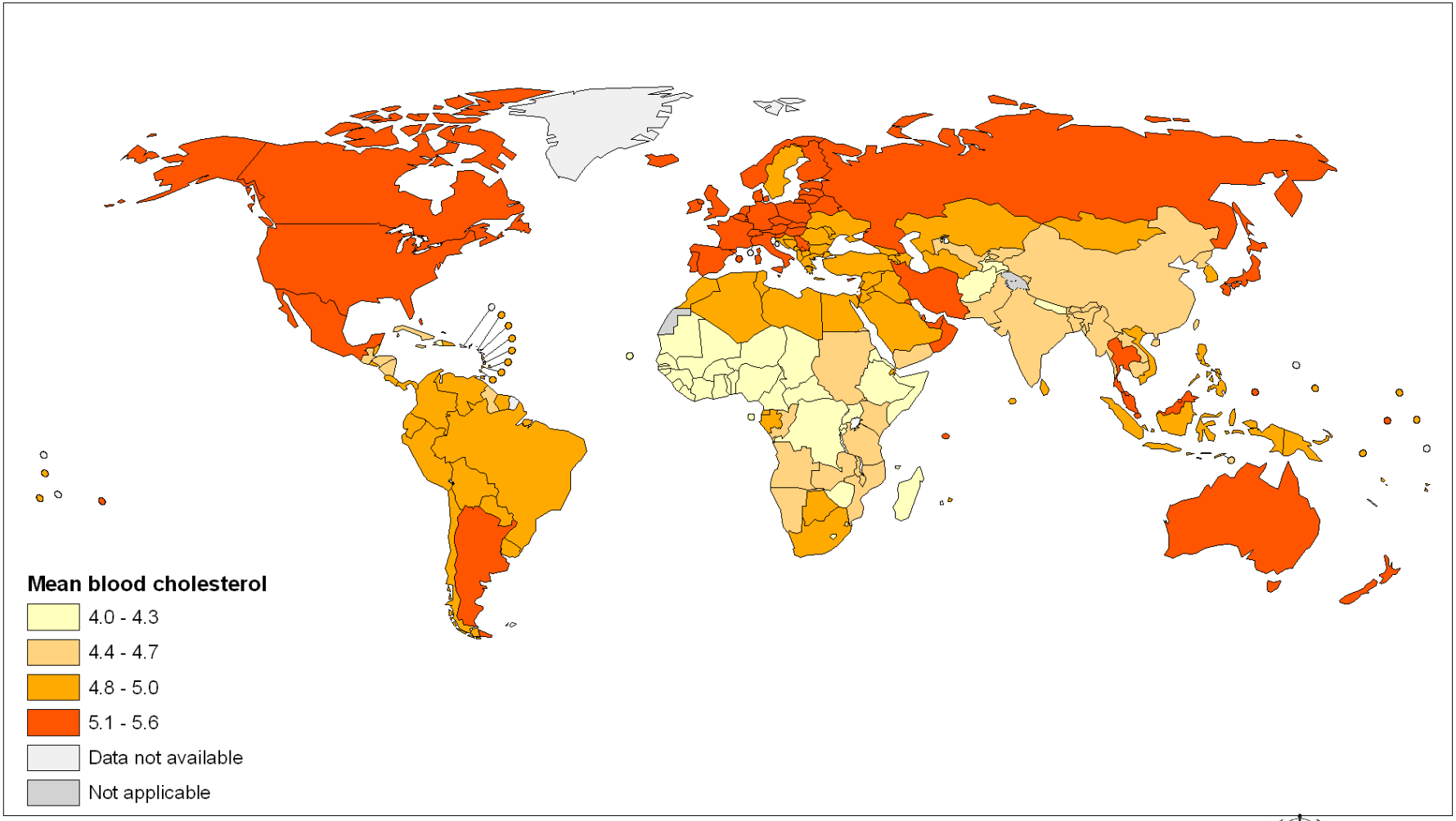
Average Daily Per Capita Calories Consumed
1970 to 2009

Percent of Caloric Growth

- Added Sugars
- Fats & Oils
- Flour & Cereal Products
- All Other

Source: U.S. Department of Agriculture, Economic Research Service. 2011. Calories: average daily per capita calories from the U.S. food supply, adjusted for spoilage and other waste. Loss-Adjusted Food Availability Data.

Mean blood cholesterol (mmol/L), ages 25+, age standardized
Females, 2008



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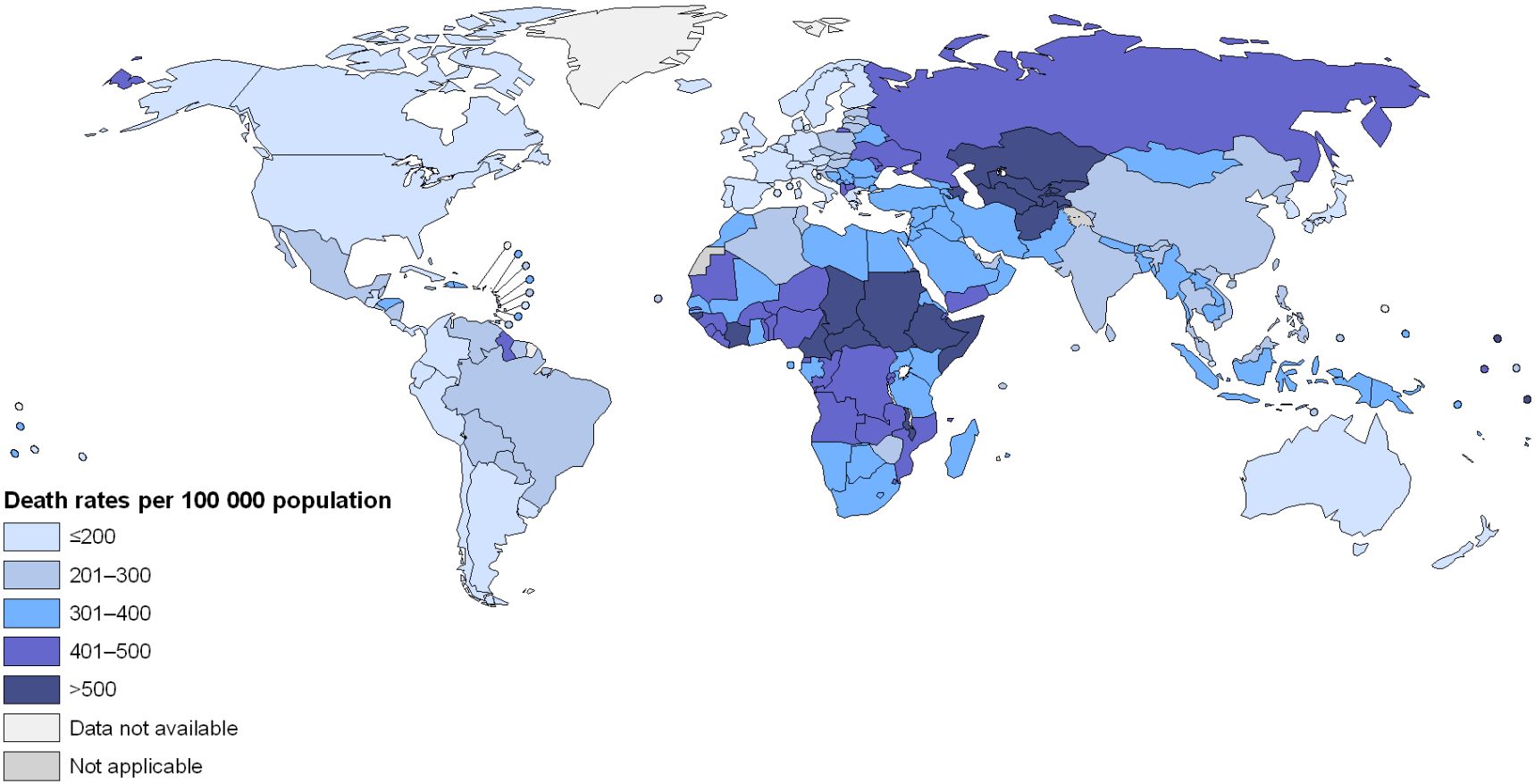
Cardiovascular diseases and diabetes, death rates per 100 000 population, age standardized
Females, 2008



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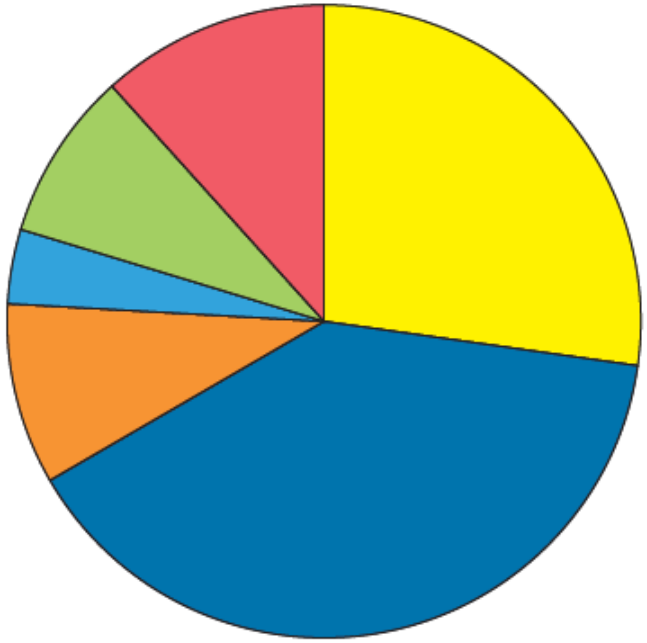
Proportion of Global NCD Deaths

under the age of 70, by cause of death, 2008



- Cancers
- Cardiovascular disease
- Chronic respiratory diseases
- Diabetes
- Digestive diseases
- Other noncommunicable diseases

- ✓ 60% of deaths worldwide are due to NCDs
- ✓ NCDs associated with
  - Low intake of dietary fibers
  - High intake of high calorie foods

WHO, 2011

Mycotoxins and Cereals

- In many parts, maize has become the preferred cereal for food, feed and industrial use, displacing traditional cereals such as sorghum and millets. However, it was found to be significantly more colonized by aflatoxin-producing Aspergillus spp. than either sorghum or millet… *(Afr J Micro Res 5(5):459-466, Hell & Mutegi, 2011)*
- Maize is one of the cereals most susceptible to aflatoxin contamination… *(Mycopathologia 161, 101-107, Wilson et al, 2006)*
- Peanut CRSP investigators have reported mycotoxins (aflatoxin and fumonisin) in maize being associated with 1) suppressed immunity leading to decreased vitamins A and E, and increased malaria infection, and 2) modified immunity in HIV suggesting rapid progression and higher transmission through increased TB in HIV patients, increased maternal anemia and more underweight children under 5 years old… *(Applying Peanut CRSP Research to USAID Initiatives, Williams, J.T., October 19, 2011)*

So What Have We Seen?

- Cereals alone do not provide enough micronutrients and energy – so those with higher portion of diet in cereals (> 20-25%) have greater risk of dietary deficiencies
- Production of cereals of African-origin are not increasing
- Shortage of food in Africa and Southern Asia
- More needs will be in urban areas with greater dependence on infrastructure, transportation and processing

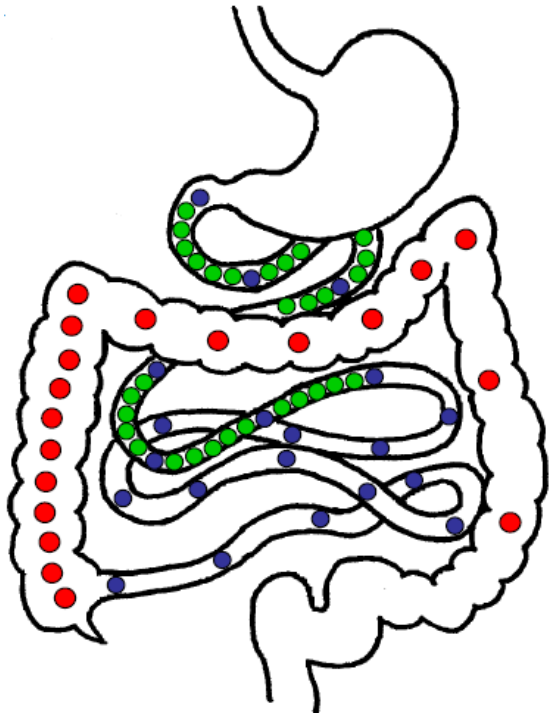
Some More

- Even as there are high death rates due to NCDs in Africa and Asia, BMI values are trending up
- As daily energy consumption increases, ratio of refined versus whole cereal consumption will need to be monitored to prevent obesity and elevated LDL cholesterol levels
- High dependence on cereals especially maize may increase chronic exposure to mycotoxins

Nutritional Aspects

- Contain varying levels of numerous antioxidant phytochemicals, including phytates, phenolic compounds, tannins, avenanthramides and avenalumic acid
  - *Inhibition of cancer cells growth and starch digestion are areas of study for these compounds*
- Contain varying levels of bioactive compounds, including lignans, phytosterols, β-glucan soluble fiber and unsaturated fatty acids
  - *Influence of compounds in regulating serum cholesterol and colon health are areas of study for these compounds*
- Contain varying levels of rapidly digestible starch, slowly digestible starch and resistant starch (RS)

Starch Digestion



Rapidly digestible starch - RDS

Slowly digestible starch - SDS

Resistant starch - RS

RS has been shown to

- lower blood glucose levels and associated insulin response
- ferment slowly in the colon releasing short-chain fatty acids and enhancing production of desirable bacteria belonging to *Bacteroidetes* phyla
- be associated with greater satiety when consumed on equal amount as digestible starch
- affect levels of flatus during gut fermentation

http://www.resistantstarch.com/NR/rdonlyres/D4F47B33-DD39-4601-BB77374A5C420694/0/TheRoleofIngredientstoReducetheGIValue.pdf

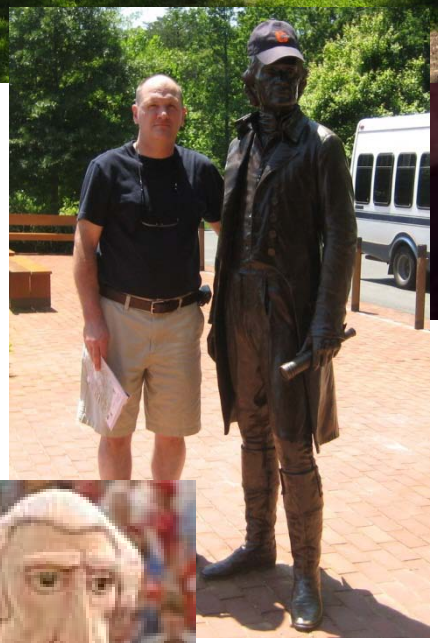
Thought for the Future

- Research is now only beginning to reveal the relationships between cereals in the diet, gut micro flora, metabolism, and health
- Future development projects in cereal value chains (and breeding programs) may want to include long-term health implications as a part of their rationale and justification in addition to agronomic factors

SEE THE FUTURE
FEED
CHANGE

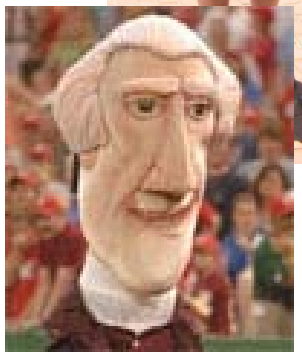
Where We Have Been

- Reviewed cereal grains grown around the world, their origin, and their typical uses;
- Compared their nutritional and agronomic similarities and differences; and
- Presented evidence to help frame debate on their appropriate end uses, and roles in crop diversification and development investments.



Charles Wilson Peale, 1791

Courtesy of Thomas Jefferson Foundation



Courtesy of Washington Nationals

"I think our governments will remain virtuous for many centuries; as long as they are chiefly agricultural." *(to James Madison in 1787)*

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