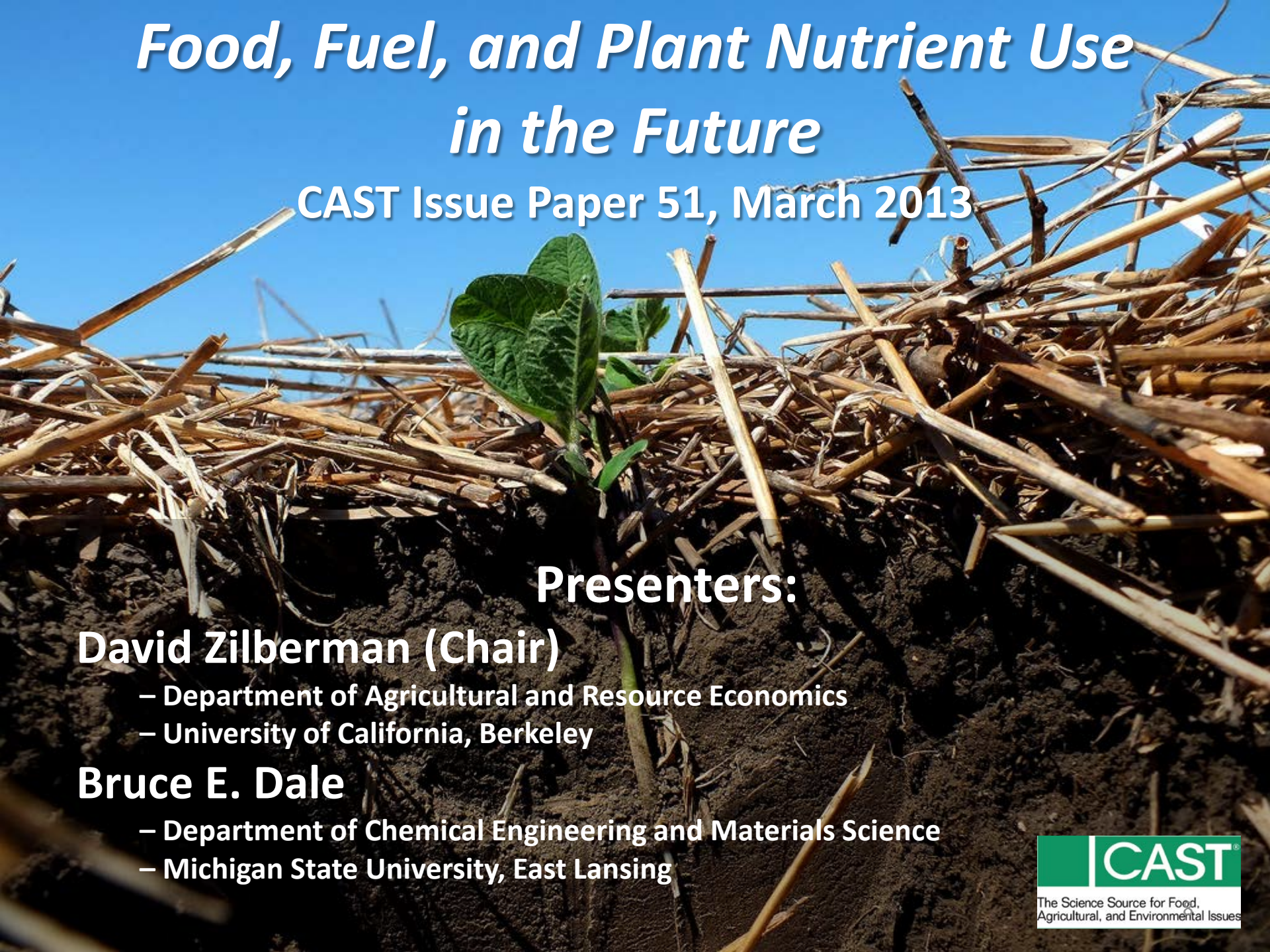

Food, Fuel, and Plant Nutrient Use in the Future

CAST Issue Paper 51, March 2013

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Challenges Facing U.S. and Global Agriculture

- Feeding growing population (9-10 billion in 2050 with growing income)
- Providing sustainable fuels and chemicals
- Contributing to positive U.S. balance of trade and energy independence
- Increasing agricultural production within a constrained footprint (in terms of land, GHG emissions, water, among others)
- Overcoming emerging constraints on nutrient availability

Objectives of Study

- Quantify trends that govern the evolution of agriculture and the national and global implications for agricultural production, land use, and resource utilization
- Understand and quantify the factors affecting fertilizer and nutrient requirements and availability
- Identify the challenges to agricultural production systems and their implication for research, technological progress, and policy

The Educational-Industrial Complex is a Foundation for Agricultural Growth

- The unique system of public-private partnership in the U.S. has been an engine of growth for agriculture and other sectors
- Publicly funded research supported the creation of basic knowledge transferred to the private sector
  - It fed the growth of the life science, agribusiness, and agricultural sectors
  - Resulted in increased productivity and sustainability, but much more progress is needed
- The agricultural bioeconomy sectors point to the potential

Agricultural Biotechnology has Already Made a Major Difference

- Emerged in the early 1990s, taking advantage of the discovery of the genome

Crop	Global Production Share (2010)	Increased Supply	Reduced Prices
Corn	25%	6-15%	10-16%
Soybean	81%	12-32%	15-22%
Cotton	64%	18-37%	15-40%

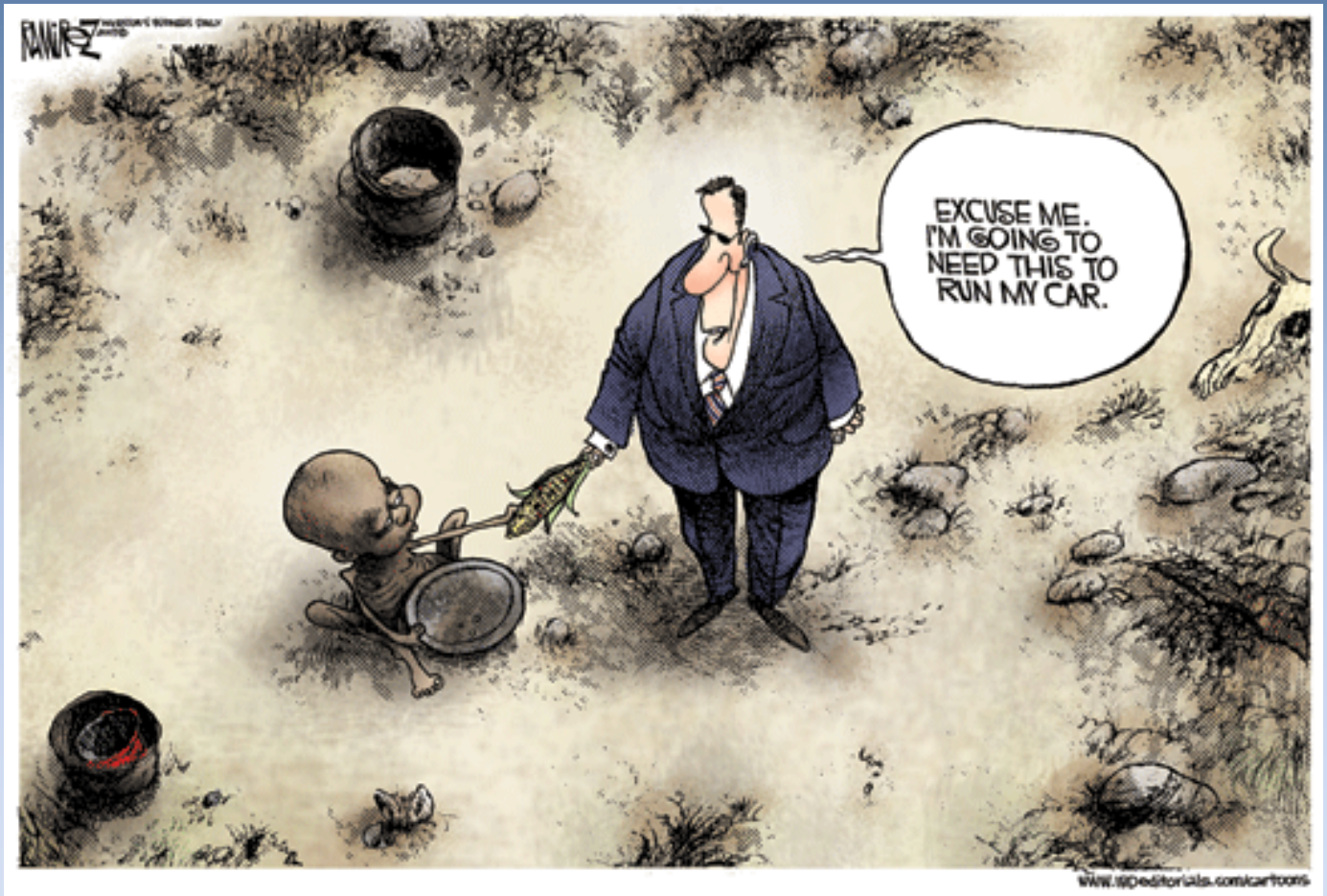
- Reduced GHG emissions and toxic chemical use
- Impact on prices and supply will be much greater with expanded adoption
- Potential is much larger with sound research and regulation

Biofuels Are a Work in Progress

- Corn and sugarcane ethanol are economically viable
- Corn ethanol contributes to balance of trade, energy security, farm income, and higher food prices
- Learning occurs
  - Cost of corn ethanol decreased 70% from 1980 to 2000
  - Cost of sugarcane ethanol decreased 70% from 1976 to 2005
- There are limitations on first-generation biofuels, but second-generation biofuels from straw and grasses will figure in the U.S. agricultural future

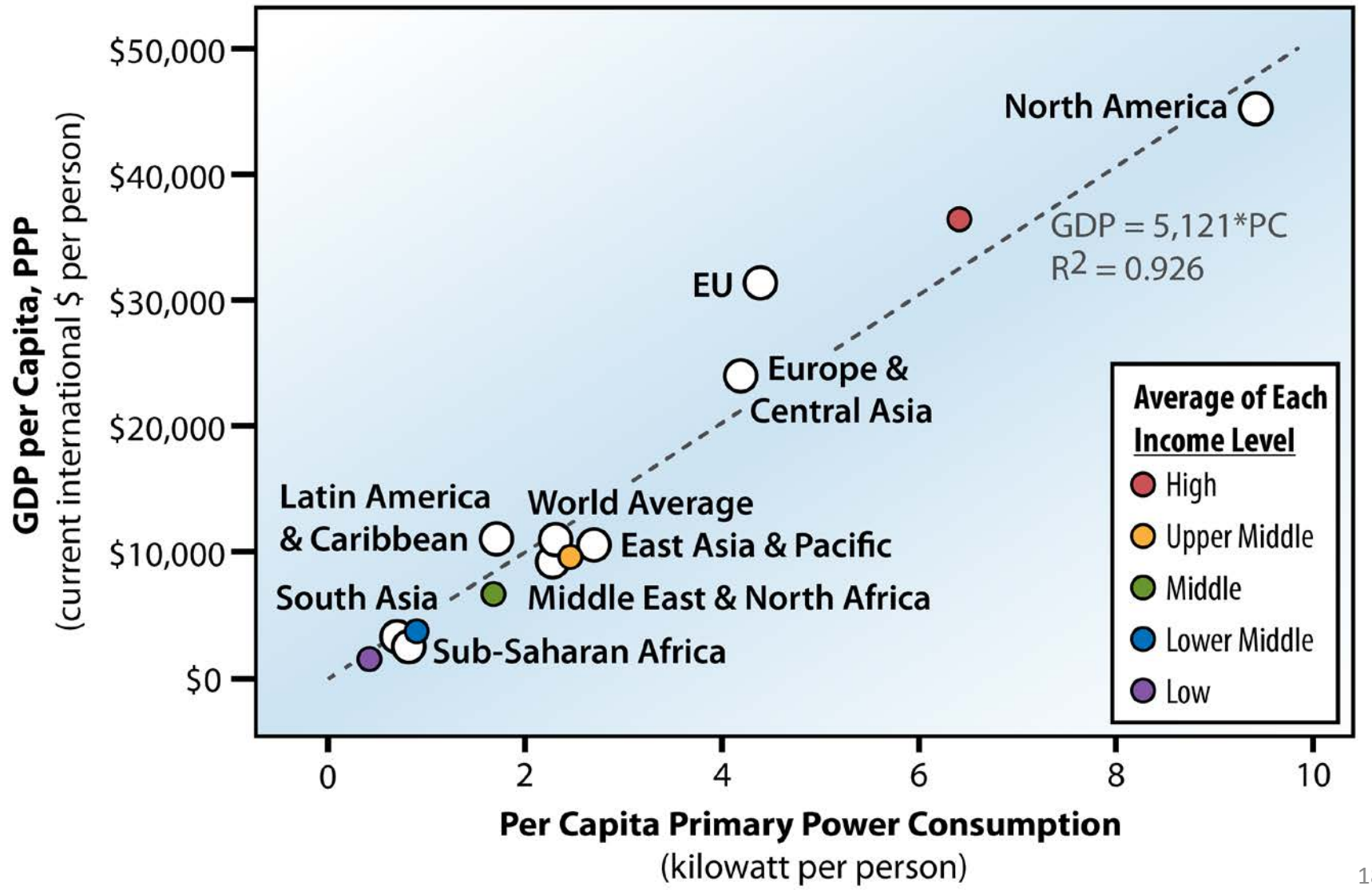
If we only had a brain:
Resolving the apparent food vs. fuel conflict by using our heads

Biofuels: A crime against humanity?



- "[I]t's a crime against humanity to convert agricultural productive soil into soil...which will be burned into biofuel."
  - Jean Ziegler, UN Special Rapporteur, 2007

Power Consumption and GDP (World Regions)



Renewable Power Is Critical for Human Well-being

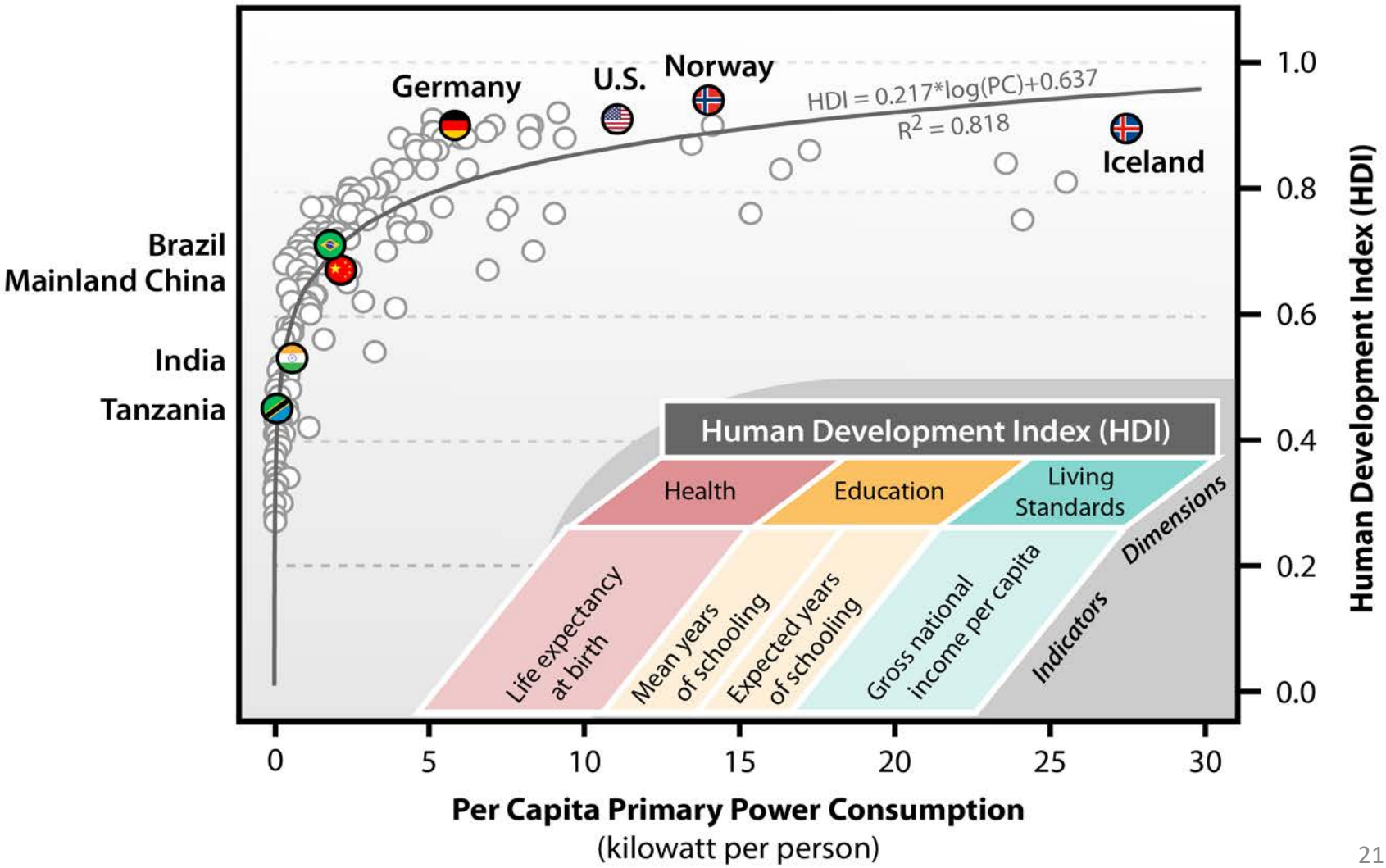
- Rate of energy use (power consumption) strongly affects (determines?) national wealth, life expectancy, and education levels
- All rich societies use a lot of energy (~33% oil)
- "Energy efficiency" helps but is not an answer in itself
- ***Fossil energy use makes us rich today—what energy sources will make our grandkids rich?***
- ***How will the billions of poor people in the world ever access enough fossil energy to develop their human potential?***
- Of all forms of energy, liquid fuels are the most valuable and most problematic in terms of supply, price, and price volatility
- *"Peak oil" has already arrived--2005 by my rear-view mirror*
- Only large-scale, low-cost, low-carbon energy sources can reduce GHGs and provide energy security and long-term wealth
- *Thus cellulosic (and other sustainable) biofuels are not optional—we must have them*
- **How can we develop sustainable biofuel pathways?**

Essay on the Principle of Population

Thomas Robert Malthus
1766 - 1834

"The power of population is so superior to the power of the earth to produce subsistence for man, that premature death must in some shape or other visit the human race…"

Energy Consumption Strongly Affects Human Well-being and Life Expectancy



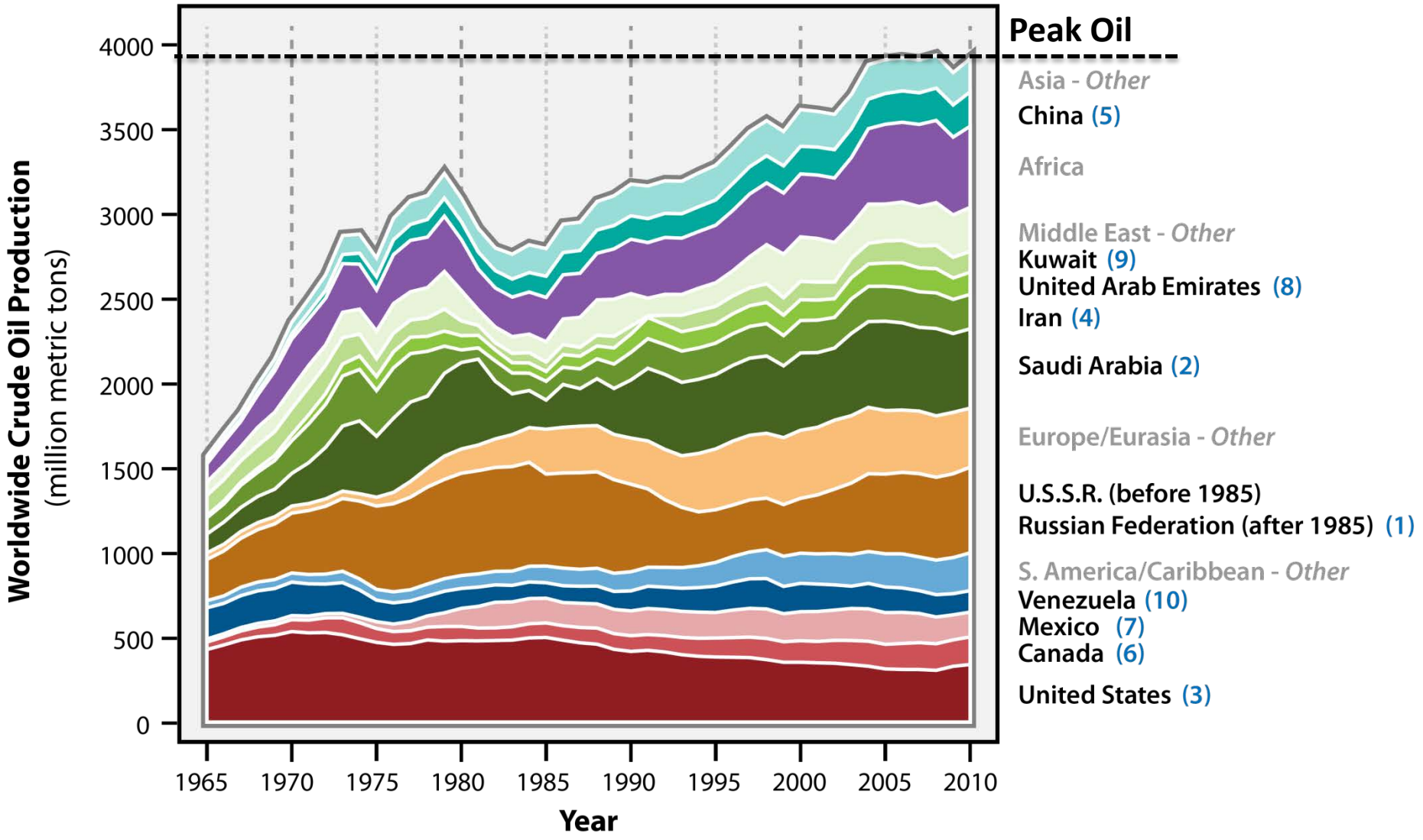
Some Basic Energy Facts: *Why Liquid Fuels Are So Important*

- Services we need from energy (current primary sources of these services)
  - Heat (natural gas, coal)
  - Light/electricity (coal, natural gas, hydro/nuclear)
  - Mobility (liquid fuels from oil—96%, some ethanol and CNG)-- **most commerce**

Some Basic Energy Facts: *Why Liquid Fuels Are So Important*

- **All energy services (all BTU, ergs, GJ) are not created equal—we value mobility (= oil) above all other energy carriers**
- Electricity/batteries can never provide more than about half of mobility needs—and they cannot support commerce at all
- Commerce moves by trucks, ocean shipping, rail, and jet aircraft
- Economic chaos results when liquid fuel demand exceeds supply
- *Liquid fuels, not "energy," is the key economic security issue—and right now liquid fuels means refined oil products*
- *The only potentially sustainable, very large-scale source of renewable liquid fuels is cellulosic biomass—nonfood plant matter (grasses, straw, wood chips, some parts of municipal wastes, etc.)*

Worldwide Crude Oil Production – Subdivided into World Regions and Top 10 Producers in 2010



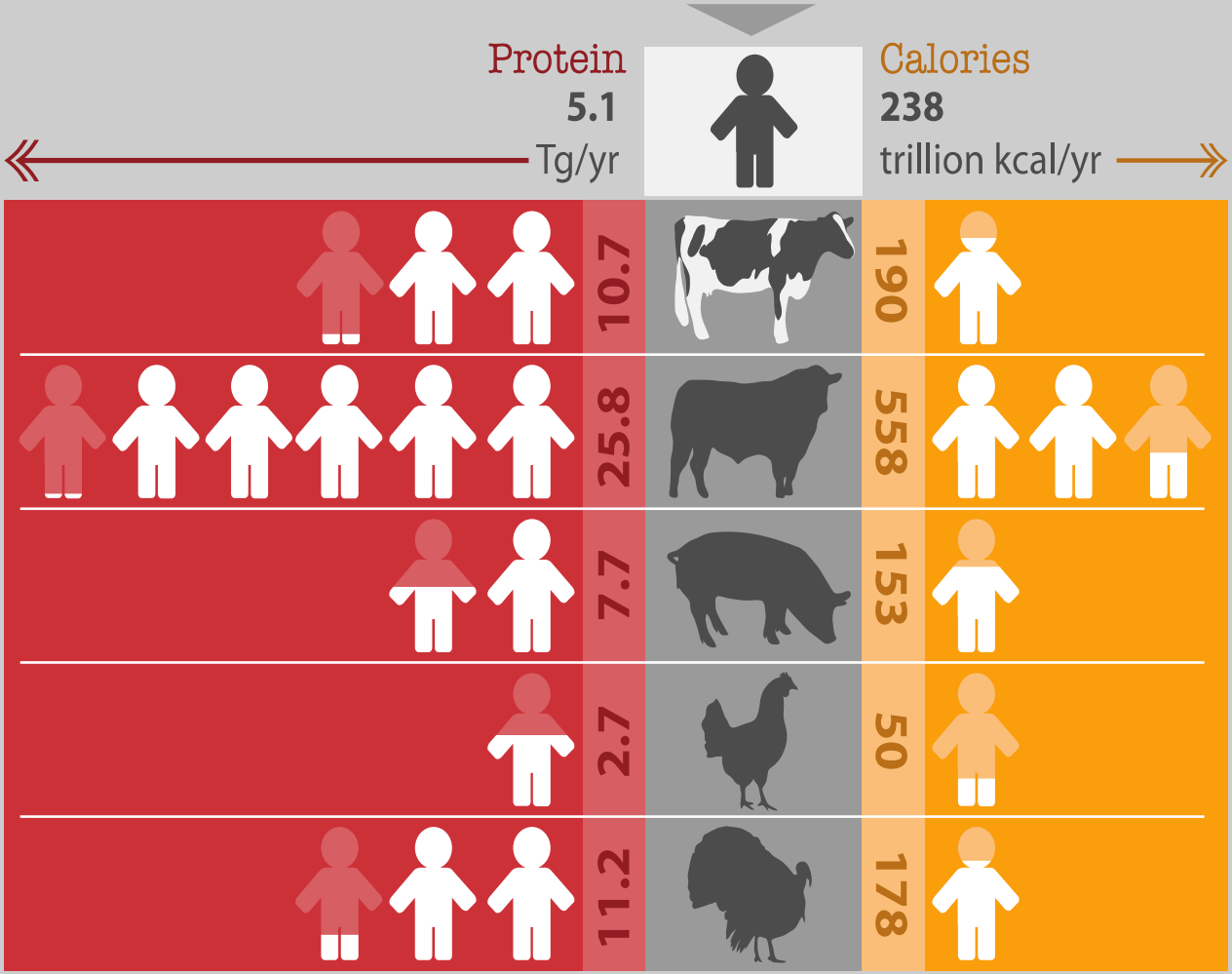
Land-Efficient Animal Feeds Enable Large Environmental and Energy Benefits

- Most human use of land for agriculture is to produce animal feeds—not food directly
- By "redesigning" agricultural systems, we can achieve large environmental and energy benefits
- Use land more efficiently (and more sustainably) to produce food, feed, fuel, and large environmental services
- By producing the same amount of food/feed on existing land, we avoid the indirect land use change (iLUC) issue
- ***And, oh, by the way, we don't "grow food"!***
- ***(About 85% of our land used in agriculture is for animal feed)***

Nutritional Requirements: **Livestock** vs. **Human**

NUTRITIONAL REQUIREMENT OF ALL U.S. LIVESTOCK IN TERMS OF THE...

NUTRITIONAL REQUIREMENT OF THE ENTIRE U.S POPULATION



U.S. livestock consumes

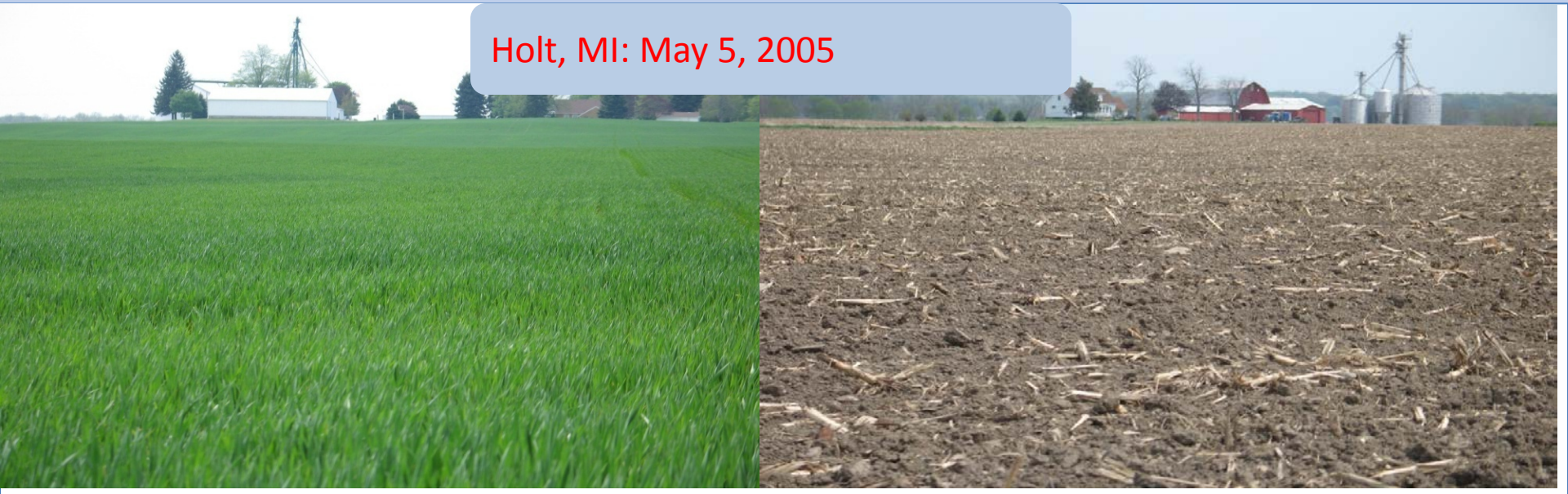
11.4 X and **4.8 X**

the amount of PROTEIN and CALORIES that would **fulfill** the nutrtitional requirements of the U.S. population

All data from 2010/2011. Livestock population data from USDA-NASS, human nutrition from USDA/USDHHS, U.S. population data from U.S. Census Bureau and animal nutrition from Dale et al., "Protein feeds coproduction in biomass conversion to fuels and chemicals".

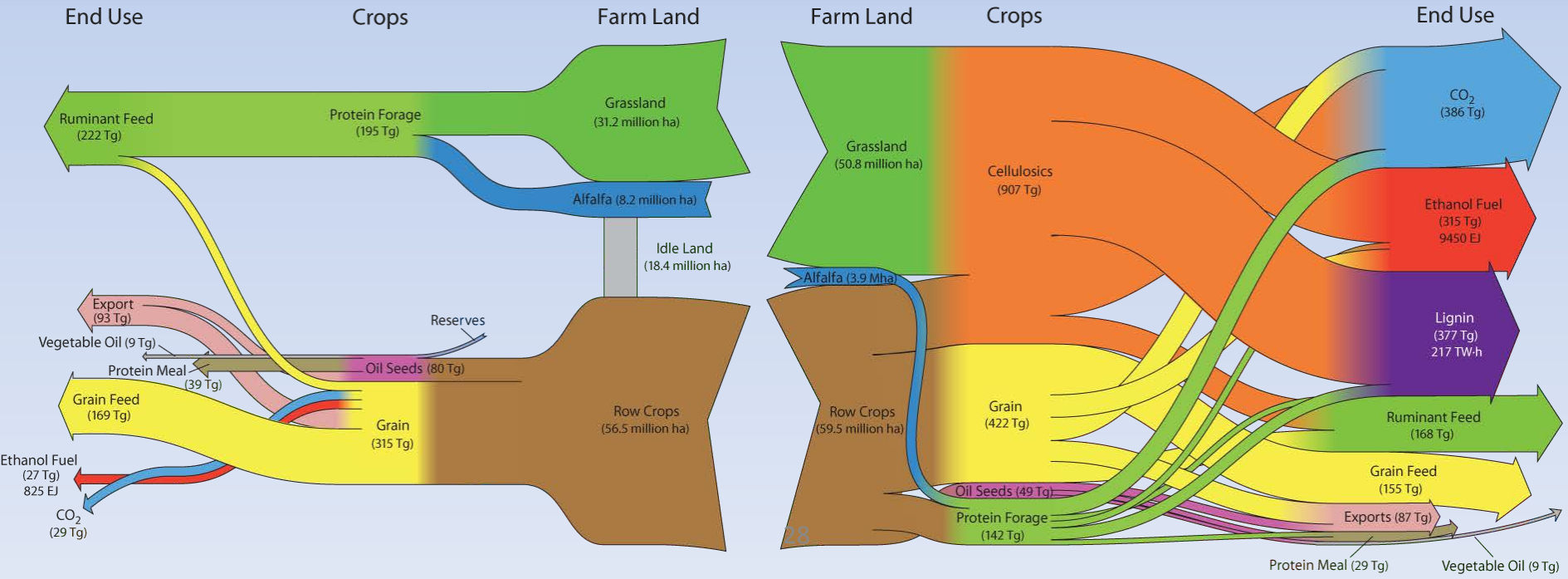
Double Cropping

- Grow crops (grasses) over winter and spring on corn or soy land while still growing corn/soy
  - Does **NOT** require new land
  - Increases sustainable corn stover harvest rate
  - Biomass can be used for biofuels, protein, animal feed, etc.



Current vs Possible Land Use

- Total plant matter produced increases by 2.5-fold on same land area
  - Displaces 50% of U.S. gasoline and 5% of U.S. electricity
  - Reduces U.S. GHGs by more than 10% and nitrate losses by 75%
  - Food and feed production remain the same--*no iLUC*



Some Thoughts on the Sustainability Transition

- We are in a time of profound transition in how the world will be fueled and fed–*we cannot continue forever along our current pathways, we must change and the sooner the better*
- The changes required will be far reaching, profound, revolutionary, upsetting, painful, exciting…pick your adjective
- *Liquid fuels from plant matter (biofuels) are an essential part of the sustainability transition—this will cause a huge impact on the economic, physical, and social "landscapes"*
- We should be seeking large, complementary, beneficial changes: *we need food (feed) and fuel and sustainability and rural economic development and better social outcomes*
- This will not happen by accident—we must envision (use our heads) and design (do the research) sustainable biofuel systems to achieve multiple objectives…then implement these systems

We Can Meet the Challenges

- By
  - Redesigning agricultural production systems
  - Improving crop varieties
  - Recycling nutrients
  - Adopting advanced processing technologies
- The U.S. can help meet growing food and energy demand and overcome the nutrient scarcity and other environmental challenges
- It requires continuous commitment to agricultural and life science research and sound regulation

Questions/Discussion

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Food, Fuel, and Plant Nutrient Use in the Future

Predictions of a world population of nine billion by 2050 necessitate careful stewardship of current food, fuel, and plant assets; a major part of that challenge involves managing what is beneath the surface. (Photo by Colette Kessler, USDA Natural Resources Conservation Service.)

Abstract

Current conditions and future trends show that adequate food production will require increases in the use of fertilizer nutrients. With a growing population, dwindling arable land, and an increased demand for *biofuels*,[1] the world cannot count on an expansion of harvested area to fill the demands. Scientists and food producers need to look at the way land is currently used to feed the world's growing population and look into the best practices for how to move forward.

To meet global food demand, the use of genetics to improve crop productivity, promote soil conservation and management, and use nutrients efficiently is necessary. The key to these endeavors lies in supporting research and development in these areas.

This paper looks at the background leading to the current situation and addresses the resulting requirements as world food production develops during the next 40 years.

Because of various circumstances, grain production will need to increase by approximately 50% during the next four decades. Current U.S. growth rates in cereal yields should meet 2050 demands, but greater cereal yields per unit land area require increases in fertilizer nutrient use, advances in genetics, and improved soil and crop management technologies.

Other topics in this paper include issues dealing with *cellulosic* biofuel production. According to projections, land availability is not a constraint to biofuel production, and the United States has the capabilities to decrease

[1] Italicized terms (except genus/species names and published material titles) are defined in the Glossary.

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