Agriculture Technologies & Transitions

The Role and Trends of Agricultural Mechanization on Commercial and Smallholder Farms

Purdue University

John Lumkes

Humanity's Top Ten Problems (next 30 years)

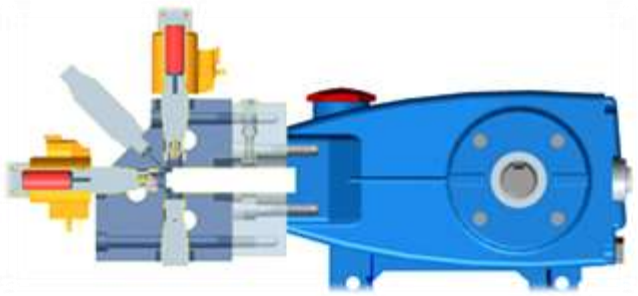
- ENERGY
- WATER
- FOOD
- ENVIRONMENT
- POVERTY
- TERRORISM & WAR
- DISEASE
- EDUCATION
- DEMOCRACY
- POPULATION

2000	6	Billion People
2012	7	Billion People
2025*	8	Billion People
2050*	8.3-10.9	Billion People

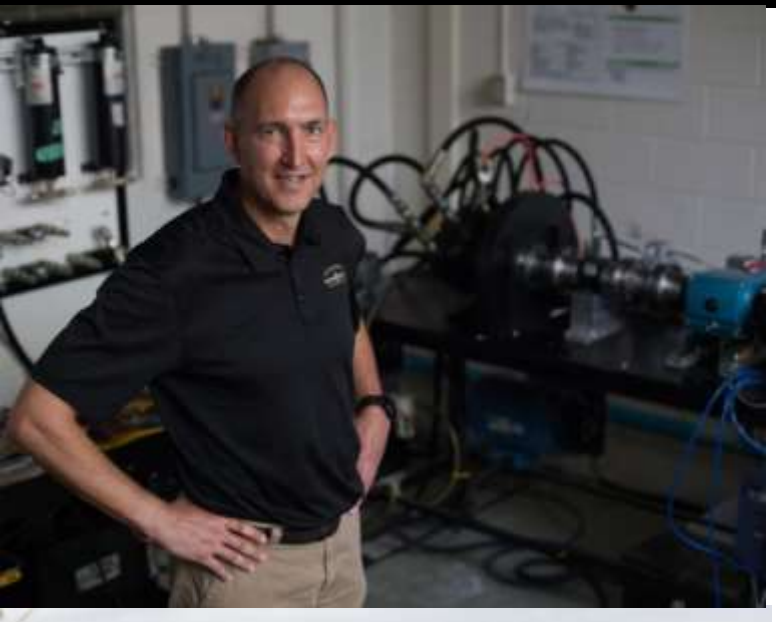
*UN News Centre, June 14, 2013

Source: R. E. Smalley, Rice University, 2005

Research Activities



- Agricultural Mechanization for Smallholders
- Agricultural Robotics
- Fluid Power (digital hydraulics)
- Mechatronics



Design of Machines and Systems to Improve Efficiency and Productivity

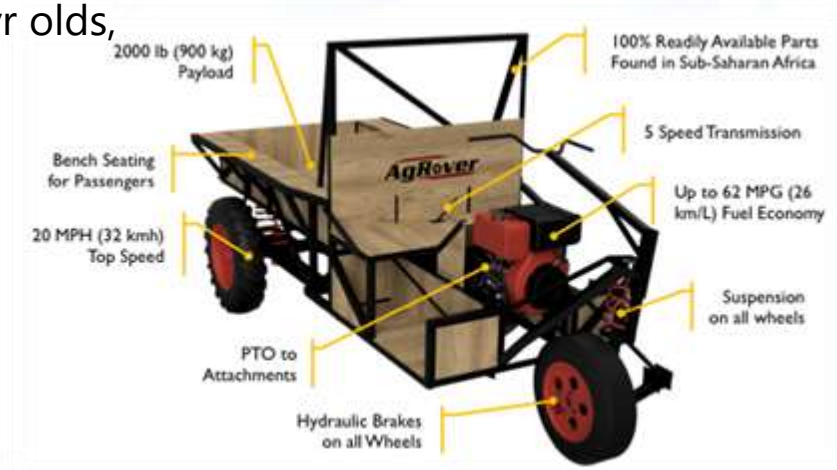
- **Key Research Questions**
- What machines and systems are necessary to enable smart and efficient agriculture?
- How can new technologies sustainably intensify global food production, particularly in emerging economies?
- **Our Approach**
- Develop and apply state-of-the art design and simulation tools for the innovation of new agricultural machines.
- Improve machinery efficiency and productivity through automation, robotics, and intelligent machines.
- Engage international partners and develop globally competent students through international collaborations and co-design activities.
- **Impact**
- Development of new agricultural machines and robotics for sustainable intensification of food production.
- Enable ‘plant by plant’ care where each plant receives optimal care (water, nutrients, pest management, etc.)




Power and Transportation for Smallholder Farmers

Impact farm mechanization, power for attachments, rural transportation, field work, and market access

- Cameroon (11 vehicles, 3 sold, multiple uses daily, partnership with NGO)
- Columbia (AgRover built at university, Farmer to farmer technical training)
- Guinea (AgRover fitted with rice harvester head, capacity building)
- Kenya (AgRover and 3 miniPUPs built at technical school for 8-17 yr olds, technical skills training)
- Nigeria (MAPS producing vehicles, 2 sold, for-profit joint venture)
- Uganda (2 AgRovers at Makerere University, partnership)



Activities demonstrated in the field: transportation, water pumping, maize grinding, threshing, rice harvesting, garbage collection, light tillage, and planting.

Development activities at Purdue: three-wheel personal-size tractor, electric driveline, remote monitoring and data collection system, maize grinder, light tillage attachments, no-till planter, electrical power generation, and welding.

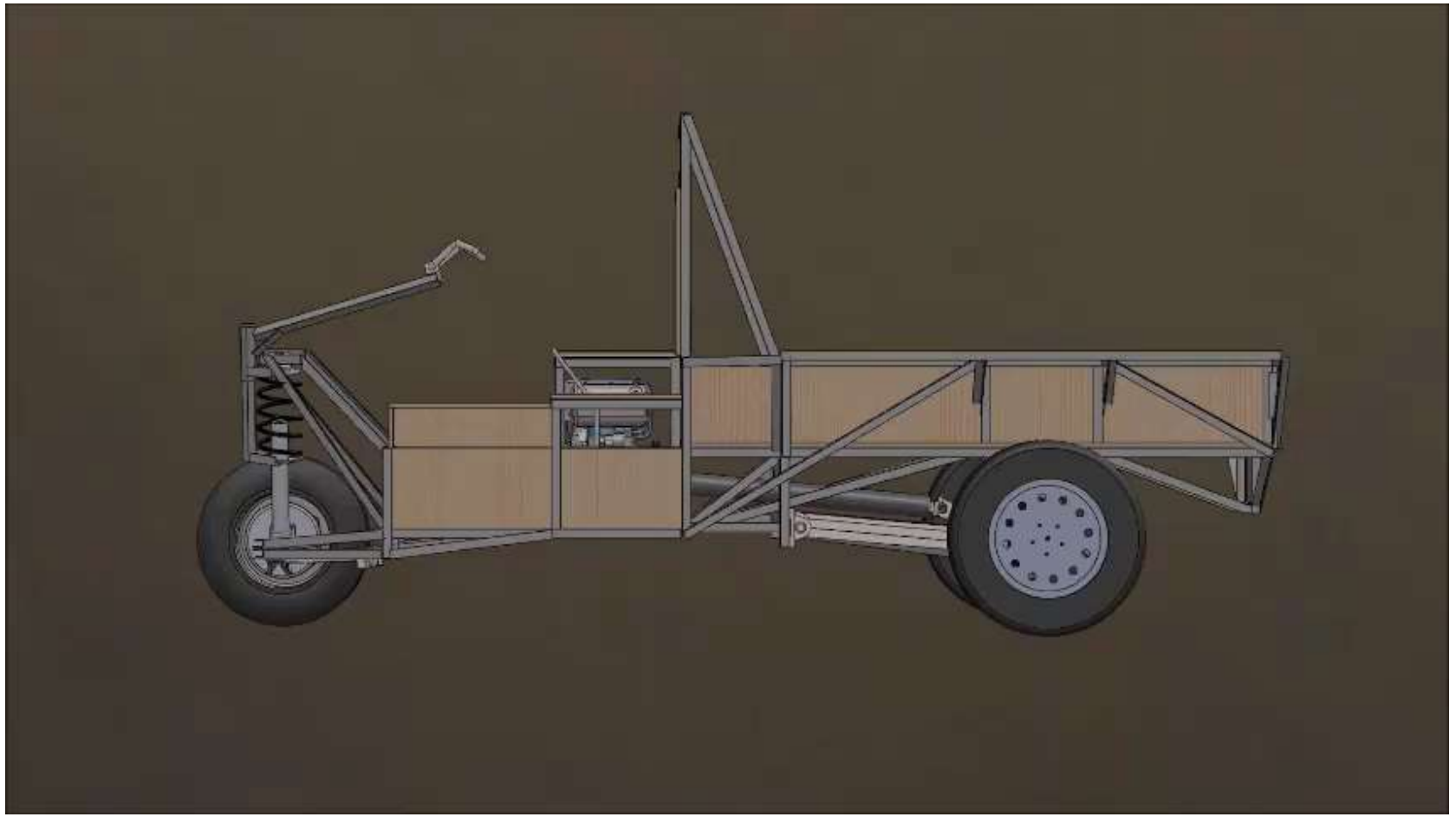
PUP

Purdue Utility Project
John Lumkes
(lumkes@purdue.edu)
engineering.purdue.edu/pup/

AgRover

MAPS INTERNATIONAL

Lumkes, Purdue University



Attachments and Implements

Multigrain Thresher

Tillage and Planting

Water Pumping / Irrigation

Food Processing / Maize Grinder


TEAM
10

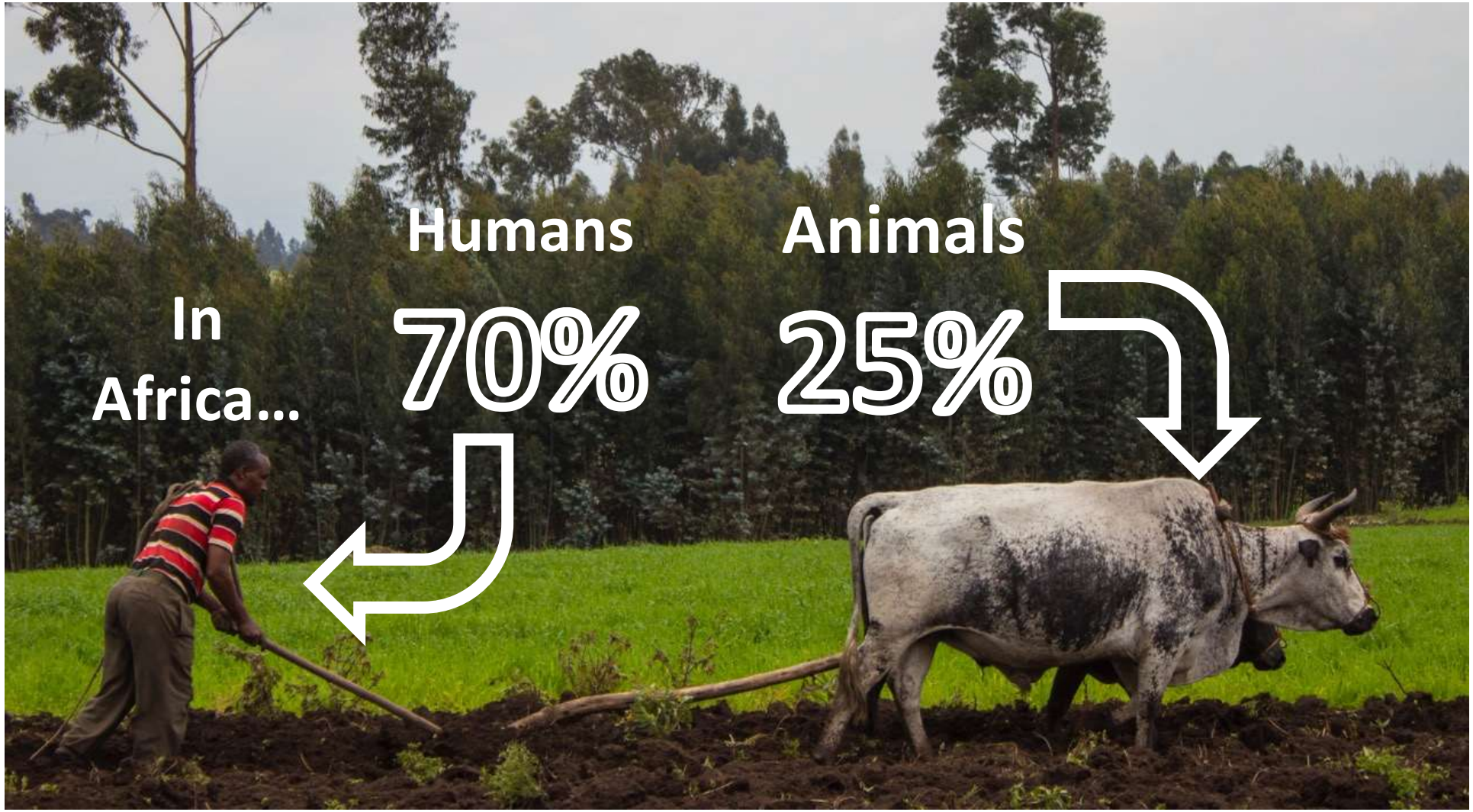
What do you see?

Where does agriculture fit?

- Agriculture Inputs
  - 70% of water used is in the global food value chain
    - And 30% of greenhouse gas emissions, 40% of employment
  - Mechanized agriculture is growing, but in the process has become dependent on fossil fuels
    - Fertilizers, Pesticides and Herbicides are increasingly dependent on fossil fuel
      - Nitrogen, the key to the first Green Revolution and the most important nutrient limiting yields, requires energy to produce urea using the Haber-Bosch conversion
    - Mechanization—tillage, cultivation, spraying, harvest, irrigation, drying grains, transport of goods, etc.
- Very few countries are able to achieve rapid economic growth apart from growth in agriculture
  - Michael Lipton, economist at University Sussex “No country has achieved mass poverty reduction without prior investment in agriculture”
- ~400-500million farms (<2ha), about 1/3 of the worlds population are dependent on these farms

Challenge: Transportation

Challenge: Farm Power



Smallholder Farmer Challenges

- Gender Inequalities
- Food (Economic) Insecurity
- Subsistence Farming
- Inadequate Transportation
- Inadequate Access to Water
- Inadequate Agricultural Power
  - Inefficient harvesting/processing
  - Lack of refrigerated transport/storage
- Inadequate Access to Technology
- Unfavorable Policies/Governance
  - Venture capital is almost non-existent

Majority of small-holder farmers are women
And they provide 90% of the labor in processing food

~65% of Africa's labor force is employed in agriculture, and ~32% of GDP

Average farm size is decreasing

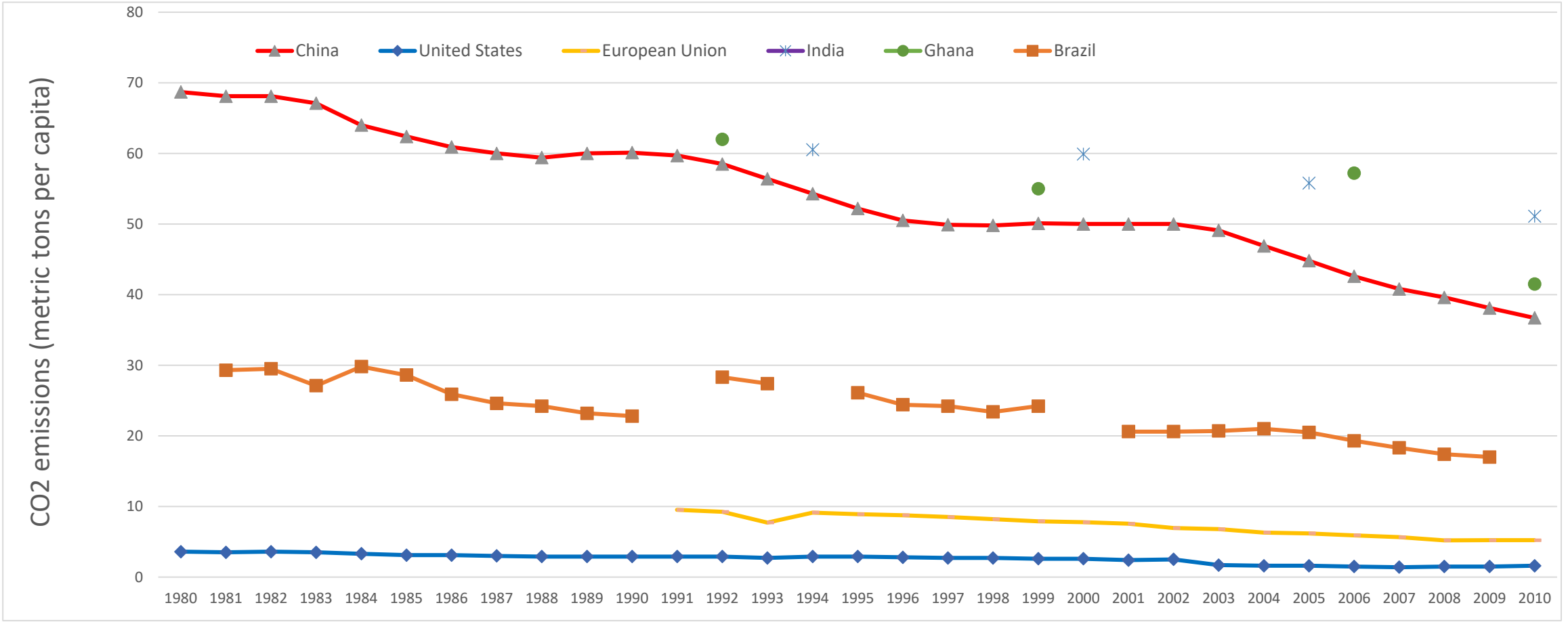
Still have significant land that is not cultivated

Trends in United States Agriculture

- Farm and ranch families comprise just 2 percent of the U.S. population
  - 70-80% of the population in 1870's
  - 21 million American workers (15 percent of the total U.S. workforce) produce, process and sell the nation's food and fiber
- Farmers now produce 262 percent more food with 2 percent fewer inputs (labor, seeds, feed, fertilizer, etc.), compared with 1950
- In 2010, $115 billion worth of American agricultural products were exported around the world
- One in three U.S. farm acres is planted for export
- Nearly 50 percent decline in erosion of cropland by wind and water since 1982.
- Last 30 years: Conservation tillage has grown from 17% to 63% (acreage)
- Last 30 years: Total land used for crops declined by 15% (70 million acres).
- Crop rotation is standard practice

American Farm Bureau, 2012
Fast Facts about Agriculture

Agricultural Employment Trends

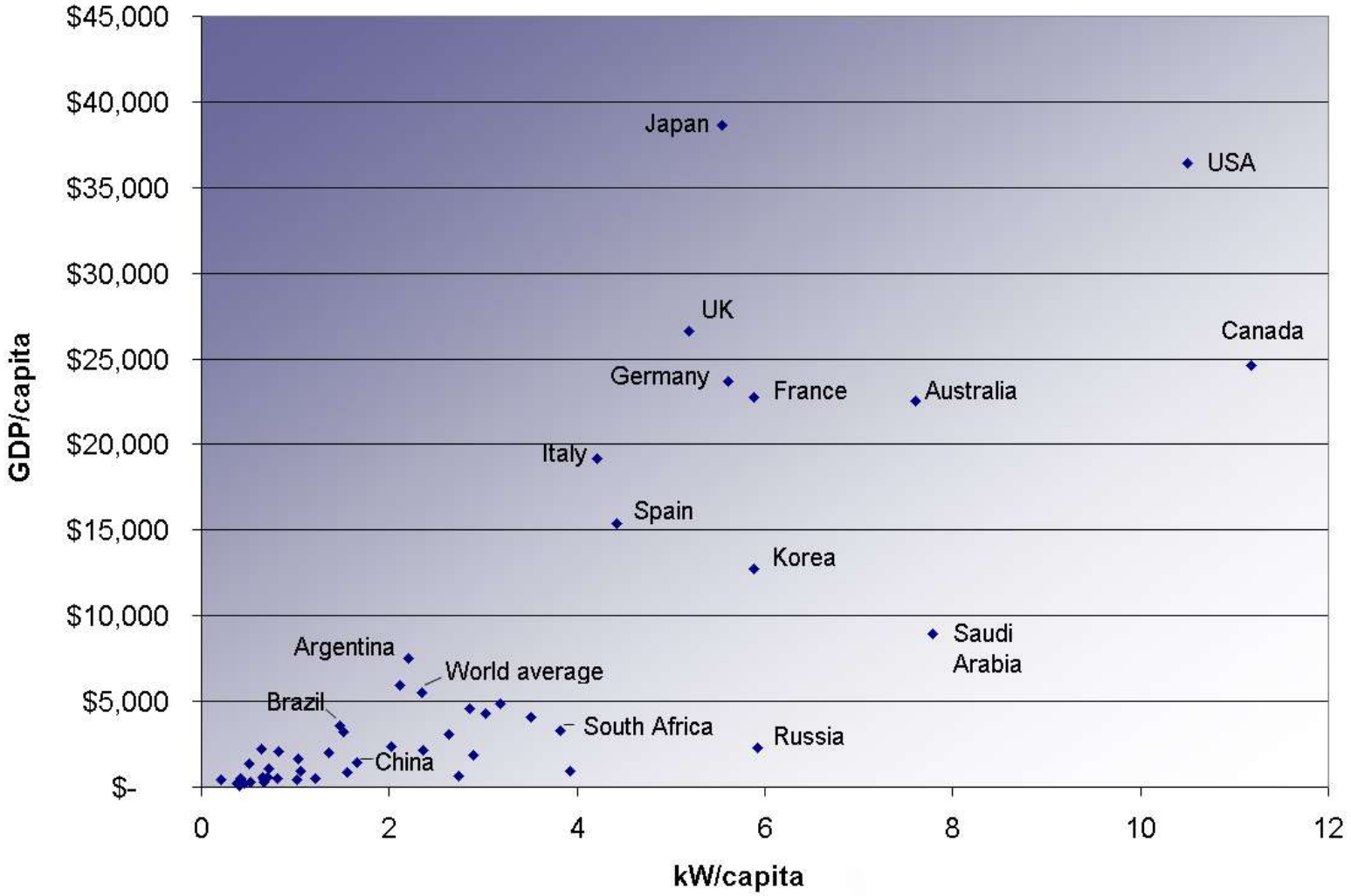


http://data.worldbank.org/indicator

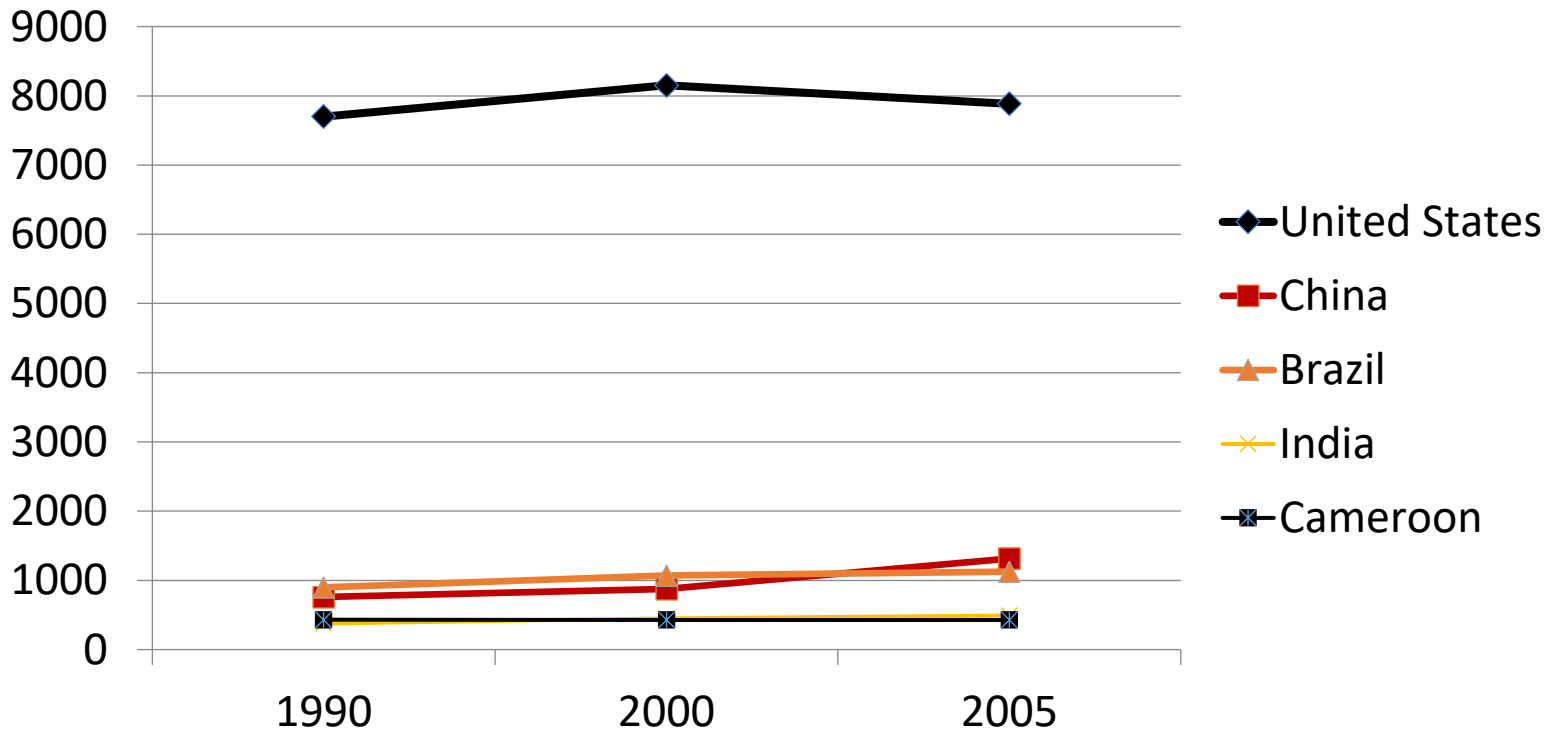
Energy Opportunities/Privileges…

- Energy (sources?)
  - Land preparation and maintenance, farm equipment, mechanization
  - Greenhouses
  - Water pumping, control of drip irrigation
  - Harvesting and processing
  - Transportation and drying
  - Refrigeration/storage, cooled field storage for fruits & vegetables to avoid field losses
  - Agricultural sensors (wireless) to monitor fertilizers & other inputs, traceability, GPS for precision agriculture
- Developing countries
  - 96 kg of oil equivalent/capita/ha (Kgoe) of arable land
- Industrialized countries
  - 312 kg of oil equivalent/capita/ha (Kgoe) of arable land

Energy consumption per capita versus the GDP per capita (2006)

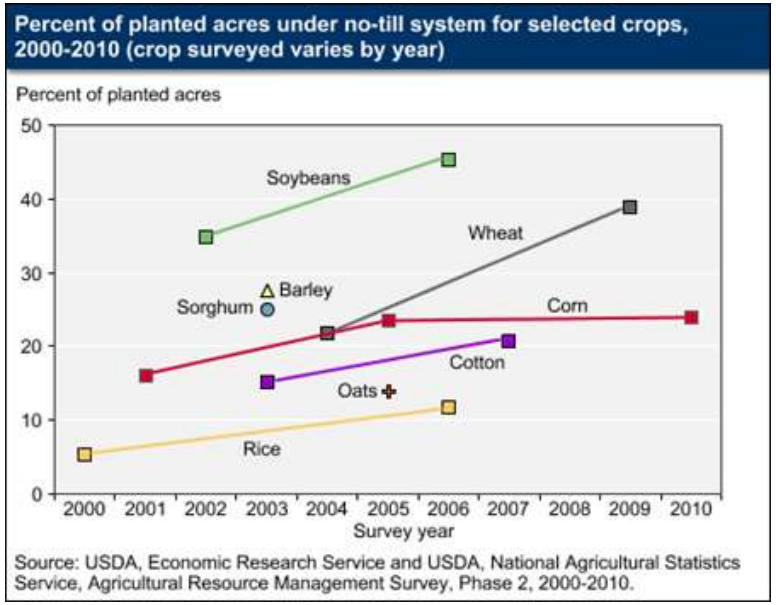


Kilograms of oil equivalent (kgoe) per person



Trends in United States Agriculture

- No Till / Strip Till (Conservation Agriculture)
  - Approximately 65% of soybean and 25% of corn acres
  - 35% of all cropland, increasing 1.5%/yr
  - Correlation with fuel prices



Soybeans grown into corn stalks in a no-till field in Union County, Iowa (USDA)

Trends in United States Agriculture

http://ryegrasscovercropblog.com

- Cover crops
  - Aerial seeding on standing corn and beans ($30/acre total)
  - Rye grass, clover, winter peas, radishes, turnip, etc.
  - Reduces erosion and fertilizer runoff
  - The root base breaks up hard packed soil, adds organic material to soil, attracts earthworms, etc.
  - Less nitrogen is needed (especially if legumes are used)
- Iowa went from 10,000 acres in 2009 to 300,000 acres in 2013

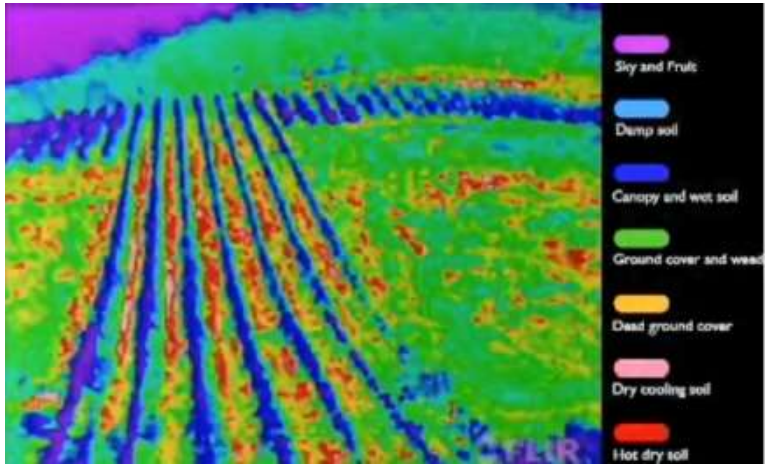
Trends in United States Agriculture

- Precision Agriculture
  - RTK GPS provides centimeters of accuracy
  - Started with auto-steer, moving to autonomous, and planning for site-specific delivery of all inputs
    - Goal: place what is needed, when it is needed, where it is needed…
      100 millions tons of Nitrogen was produced in 2005
      but only 17% was taken up by crops
      (Conway, 2012)
- Big Data
  - Everything has sensors, collects data, now what?

John Deere Machine Sync, deere.com

Trends in United States Agriculture

- Big Data
  - Everything has sensors, collects data, now what?



http://aerobotservices.com/precision-agriculture.html

farmprogress.com

headwallphotonics.com

http://corn.agronomy.wisc.edu/Management/images/L005/L005_z1.JPG

Trends in United States Agriculture

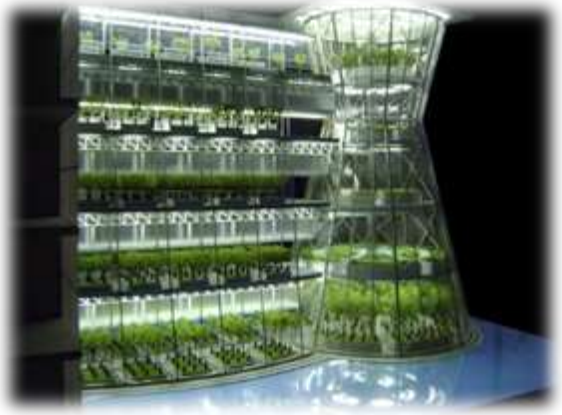
- Robotics
  - Assistive robotics / labor shortages
    - Some industries rely on migratory workers (harvest time)
    - Already: milking cows, cleaning and sorting eggs, semi-autonomous tractors, combines, etc.
    - Research: selectively harvesting fruits and vegetables, food processing (deboning chickens), weeding, etc.

Orange harvester. Photo credit: Vision Robotics Corporation.

DeLaval Milking Station. via Wikimedia Commons.

Urban agriculture/vertical farms

- More Automation and Technology
- Sensors/IOT/Robotics
- LED lighting, energy constraints
- Hydroponics, Controlled Environments
  - Converting city buildings



ecofriend.com/urban-farming-food-insecurity.html

https://www.machinedesign.com/motion-control/farm-robotics-are-taking-giant-automated-leap-forward

We Need a Globally Inclusive Paradigm Shift

Enabling the Doubly Green Revolution

What are the enablers?

- How does nature optimize production?

- Can we develop data-driven systems that enable plant-by-plant care?
- Will it be globally effective?

"Connecting the data to the food…"

- Agriculture robotics/automation
- Energy impact of agricultural automation (**Electrification**)
- Smart actuators and machines
- Mechatronic systems for agriculture
  - IOT
  - Data Science
  - Crop Technology

Conclusions

- Poverty is a major cause of hunger (just growing more food will not solve this)
  - On average, enough food is already produced
    - But are we currently sustainable?
  - Reducing post-harvest losses in some areas is crucial
- We need to holistically manage our natural resources
  - Technology can help, but only one piece of the puzzle
  - Research is needed on biotechnology, farming techniques like CA, growing more with less water, improving our soils over the long term, etc.
- Government policies are critical

Questions / Discussion

John Lumkes
Agricultural & Biological Engineering

Discussion Time

- Within the framework of Energy – Water – Food (i.e. Agriculture), and for this exercise, let's focus on access to energy through electrification
  - Question/Discussion – where do you see the challenges and opportunities regarding sustainable agriculture in your home location?
  - What is your ROI?

ROI for Projects

- Return On Investment (think in terms of project)
  - What are all of your investments?
    - Time (everyone's), Expenses, Resources
  - What is the return?
    - Not only, or doesn't have to be monetary (will be for some projects)
      - Monetary could be measure as cost saving compared with existing
    - Besides financial, what other ways can your project provide/add value (i.e. a return)
    - Impacting users/customers, increased learning, environmental, etc.

Reporting Back to the Group

- Within the framework of Energy – Water – Food (i.e. Agriculture), and for this exercise, let's focus on access to energy through electrification
  - Question/Discussion – where do you see the challenges and opportunities regarding sustainable agriculture in your home location?
  - What is your ROI?