Sustainability
A Scientist's View

Mark Alley
W. G. Wysor Professor Emeritus
Virginia Tech

Why Sustainability?

Nourish,
Replenish,
Grow

Why Sustainability?

- Sustainability Initiatives
  - Walmart: walmartstores.com/sustainability/
  - Pepsico: www.pepsico.com/Investors/Sustainability-Efforts.html
  - Coca Cola www.thecoca-colacompany.com/citizenship/index.html
    - "Live Positively is our commitment to make a positive difference in the world by redesigning the way we work and live so sustainability is part of everything we do."
  - ADM :www.adm.com/en-US/worldwide/us/Pages/Sustainability.aspx
  - Cargill:www.cargill.com/news-center/news-releases/2009/NA3009946.jsp
    - "First Cargill palm plantation certified sustainable by RSPO (Roundtable on Sustainable Palm Oil Certification)
  - United Nations
    - United Nations Sustainability Portal http://193.194.138.42/en/Sustainability-Claims-Portal/

Sustainability*

- "Capable of being sustained"
  - of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged <*sustainable* techniques>
  - of or relating to a lifestyle involving the use of sustainable methods <*sustainable* society>

FROM

- Sustain
  - "To endure", "to hold up", "to provide sustenance"

*http://www.merriam-webster.com/dictionary/sustainable

Sustainability Synonyms*

- Defendable
- Defensible
- Justifiable
- Maintainable
- Supportable
- Tenable

*http://www.merriam-webster.com/dictionary/sustainable

Sustainability

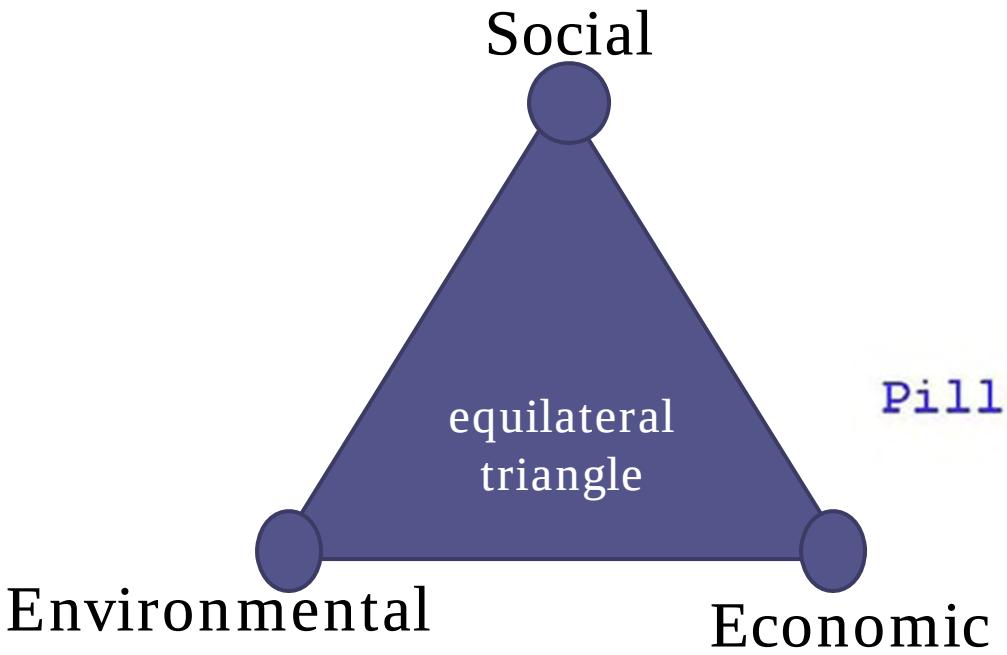
- Brundtland Commission Definition:

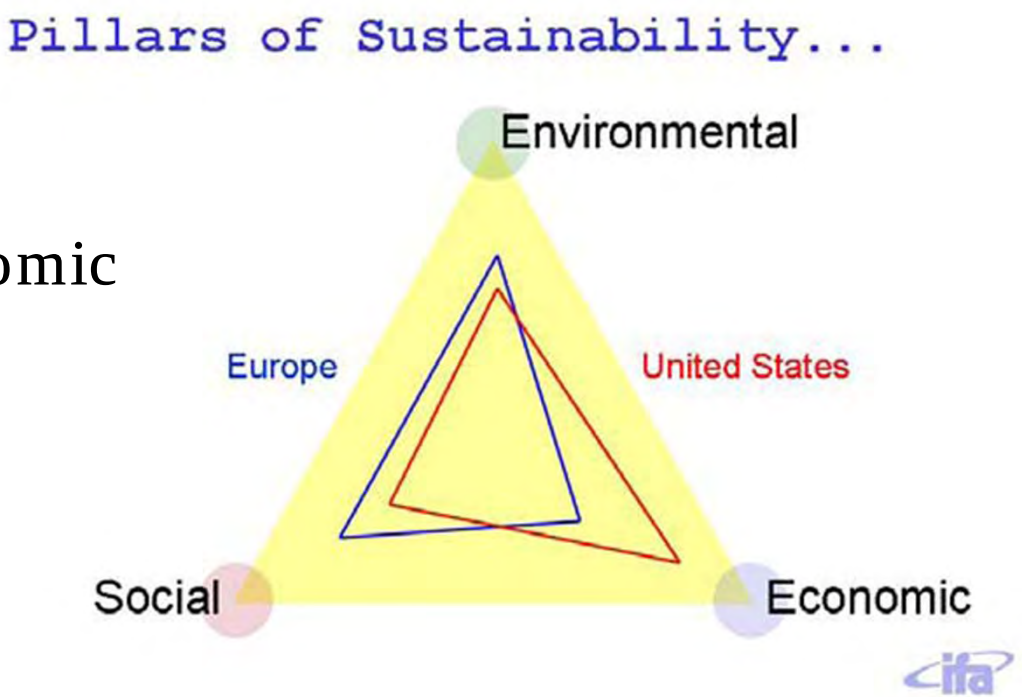
"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

From: *Our Common Future. 1987.* World Commission on Environment and Development. Oxford University Press.

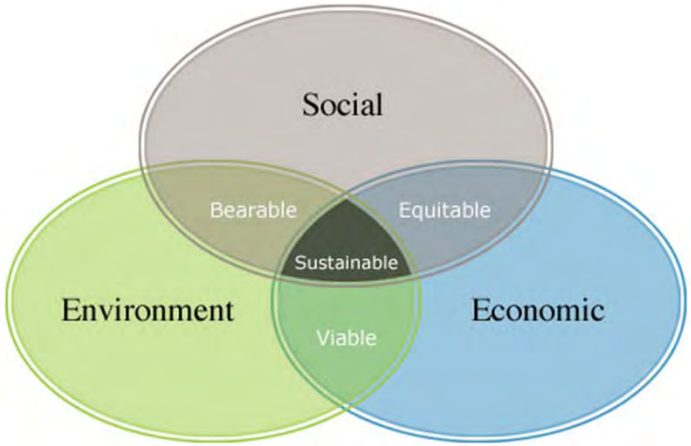
- Commission created in 1983 by United Nations
  - Reflect about ways to save the human environment and natural resources and prevent deterioration of economic and social development.

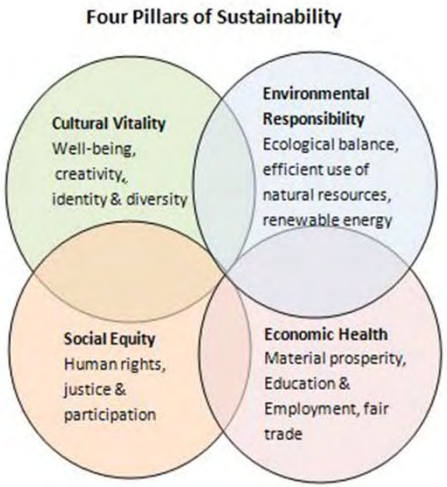
Pillars of Sustainability

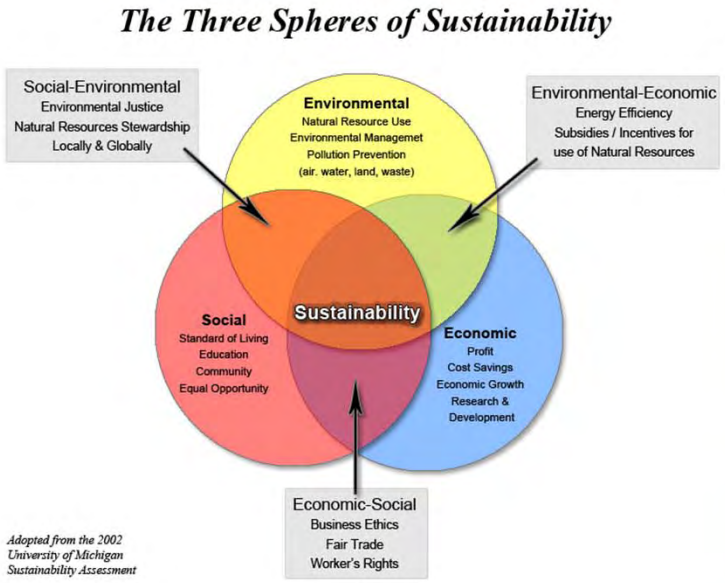


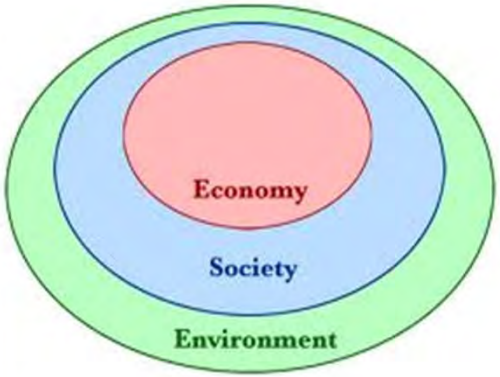


Pillars of Sustainability – Different Views







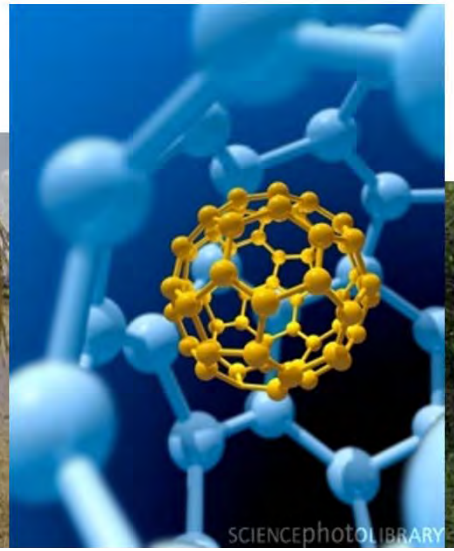


Science

- The observation, identification, description, experimental investigation, and theoretical explanation of phenomena
- Methodological activity, discipline, or study
  - For example, *the science of agronomy*
- An activity that appears to require method and study, as in *the science of purchasing*.
- From the Latin *scientia*, to know

Science

- Measuring
- Defining relationships
- Investigating
- Inventing

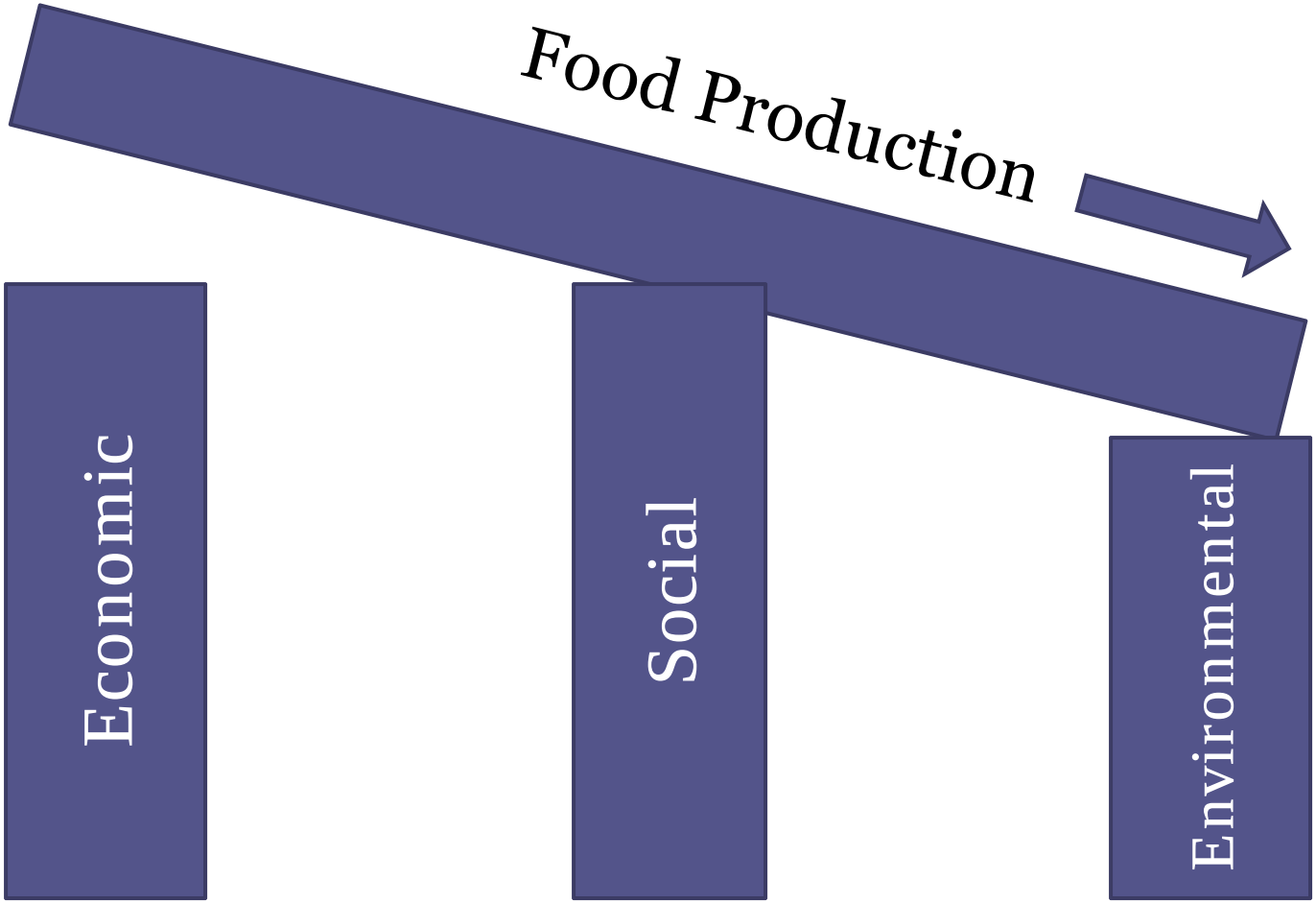


Science Fiction

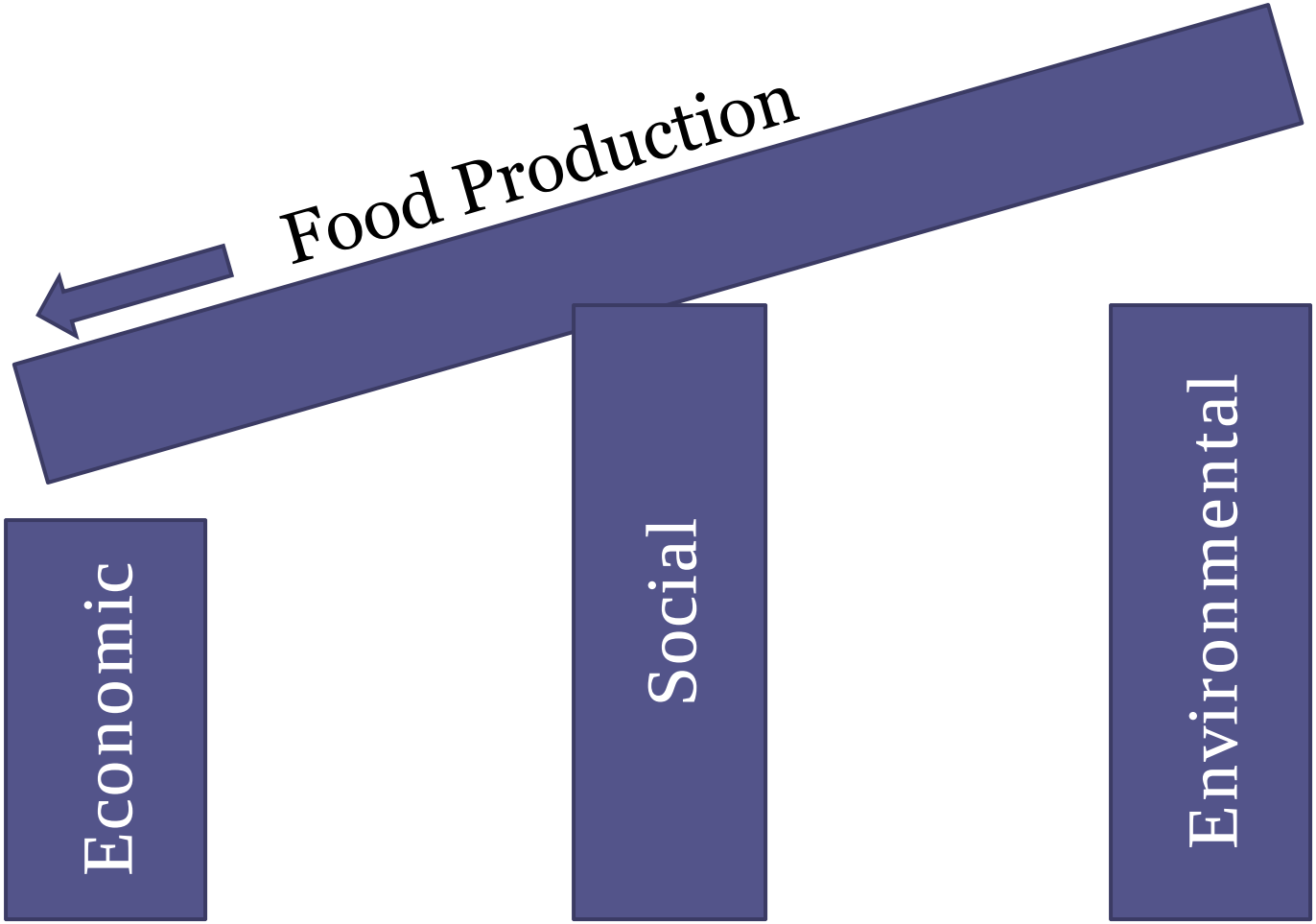
- A literary or cinematic genre in which the plot is typically based on **speculative scientific** discoveries, environmental changes, space travel, or life on other planets.

Agricultural Sustainability Brundtland Commission Pillars

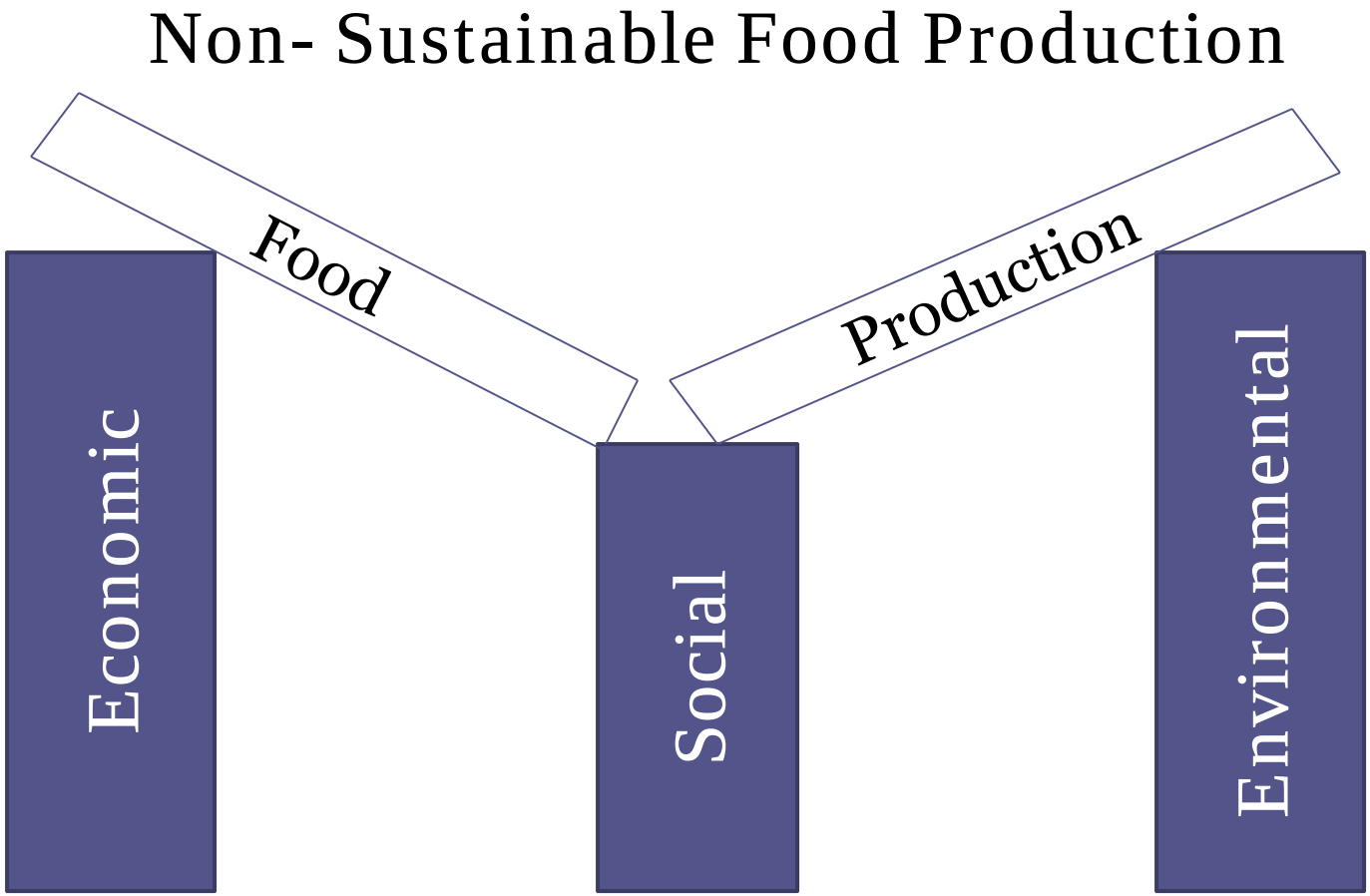
Agricultural Sustainability



Agricultural Sustainability



Agricultural Sustainability



Sustainability of Systems at Low Levels of Plant Nutrient Availability

Country	N	P	K
	----------Kg/ha/year----------		
Ethiopia	-47	-7	-32
Nigeria	-34	-4	-31
Rwanda	-60	-11	-61

- Degradation (erosion) increases as soil organic matter levels decrease
- Local and regional water balances change with less infiltration of limited rainfall
- Technology solutions
  - Standard fertilizers
  - Conservation agriculture techniques
  - Improved seeds
  - Major constraints:
    - education
    - infrastructure – physical and institutional

Agricultural Sustainability

- Agro-ecosystems that can produce the needed food in perpetuity
- Agro-ecosystems that do not degrade associated natural systems and perhaps enhance "eco-system services."
  - Clean water
  - Clean air
  - Carbon and nutrient cycling
  - Bio-diversity

Agricultural Ecosystems Realities

- Increased food production
  - Quantity and quality of food production
  - Increased demand associated with income rises in many countries.
- Less land per person
- Less fresh water per person
- Impact of agricultural practices on water and air quality???

Collapse
*How Societies Choose to Fail or Succeed**

- Past Societies-Reasons for Failure
  - Deforestation and habitat destruction
  - Soil problems
    - Erosion
    - Salt damage
    - Soil fertility losses
  - Water management
  - Over hunting
  - Over fishing
  - Effects of introduced species on native species
  - Human population growth
  - Increased per-capita impact of people
- Past Societies – Not all collapsed!

*Jared Diamond, UCLA

Collapse
*How Societies Choose to Fail or Succeed**

- Modern Societies -- Additional Reasons
  - Human-affected climate change
  - Buildup of toxic chemicals in the environment
  - Energy shortages
  - Full human utilization of earth's photosynthetic capacity
- Examples of modern society collapses
  - Somalia
  - Rwanda

*Jared Diamond, UCLA

Collapse
*How Societies Choose to Fail or Succeed**

- A society's response to its environmental problems depends on the following:
  - Political institutions
  - Economic institutions
  - Social institutions
  - Cultural values
- "if environmentalists aren't willing to engage with big businesses, which are among the most powerful forces in the modern world, it won't be possible to solve the world's environmental problems."

*Jared Diamond, UCLA

Science and Sustainability

- Measurements to define relationships
  - Atmospheric sulfur content declining, increased potential for sulfur fertilizer responses by crops
- New technologies to increase crop production efficiency
  - More people with adequate, nutritious food
  - Increased value in the production chain
  - Decreased potential adverse environmental impacts
- Strengthened social institutions that enable increased standards of living and more peaceful societies

The Fertilizer Industry










Specific Technological Developments

- Defining essential elements for plant nutrition
  - Late 1800's and early 1900's
  - Carbon, Hydrogen, Oxygen – From air and water
  - "Mineral Nutrients"
    - N, P, K, Ca, Mg, S – Macronutrients
    - Zn, Cu, Fe, Mo, Mn, B, Cl, Ni

Technological Developments In the Fertilizer Industry

- Acid treatment of phosphorus sources
  - Patented by Lawes in England in 1842 – Superphosphate
- Haber Bosch Reaction for Producing Ammonia
  - Industrial Scale Production – BASF 1913
- Potash mining
  - Mining in several areas of Germany in the 1860's
    - KCl, K_2SO4
  - Large scale Canadian production in 1960's
- Triple superphosphate
  - 1890's with major production after 1950
- Ammonium phosphates
  - First introduced in the United States in 1916 by American Cyanamid
  - Large scale fertilizer production in 1960's

Phosphate Fertilizer Production in the United States*

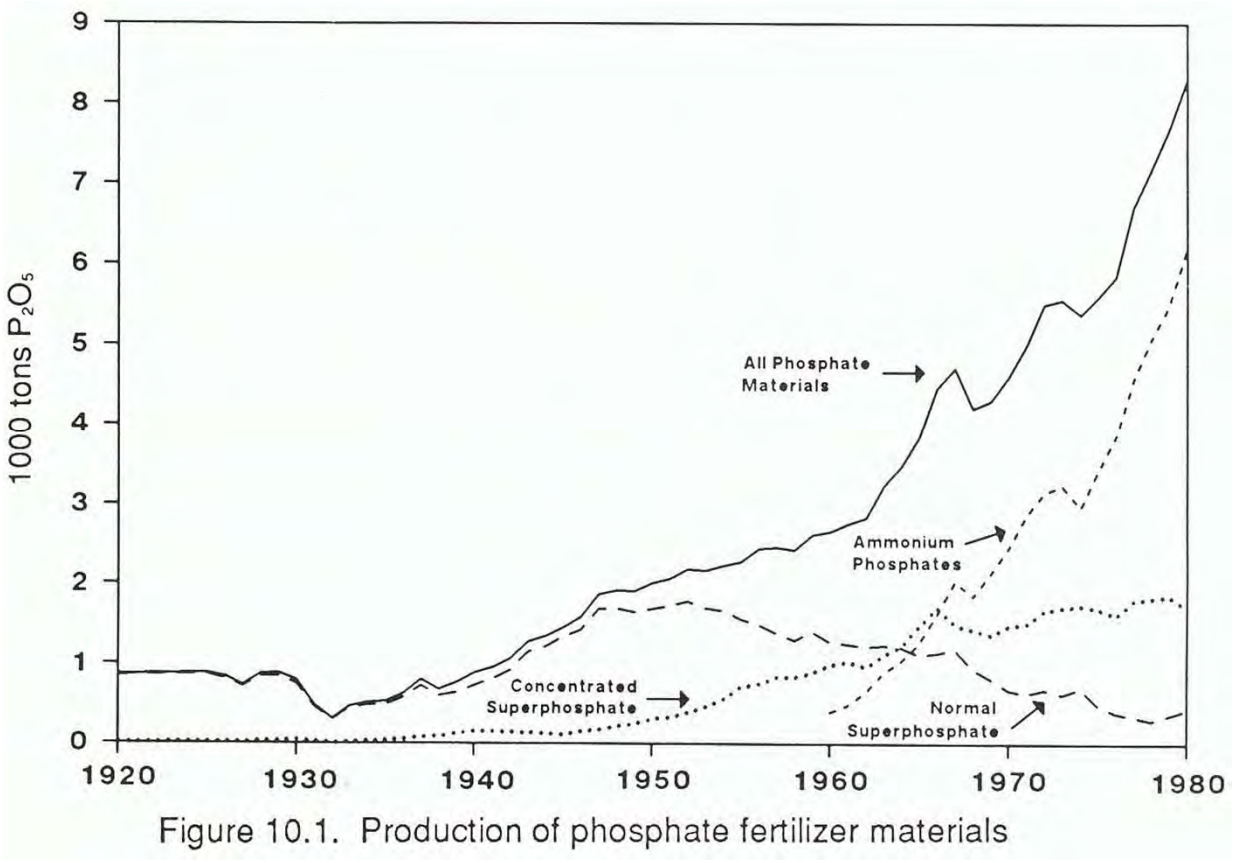


Figure 10.1. Production of phosphate fertilizer materials

*Nelson. 1990. History of the U.S. Fertilizer Industry

Science and Technology for Increased Food Production

- Fertilizers account for 50% of increased food production in the world today
- Do we live longer (even with our “bad” diets” in the developed world)?
- Can not argue that science has increased the carrying capacity of the planet since “hunting and gathering” era
  - Medicine
  - Sanitation
  - Education
  - FOOD PRODUCTION!!

Developing an Approach to Sustainability

- Sustainability of what?
  - Business
  - Farmers we serve
  - Soil productivity
  - Water quality
  - Air quality
  - Food we help produce
  - Natural ecosystems

Sustainability of Agro-Ecosystems

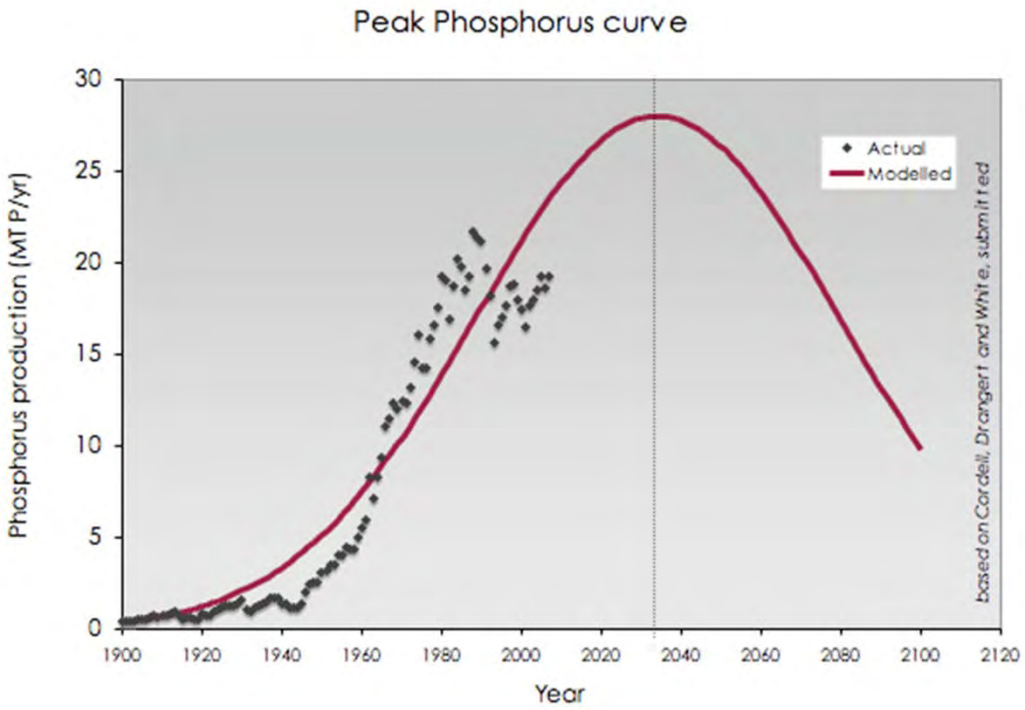
- Enlightened self-interest
  - Increased grain yields = Increased N use?
  - Increasing N use
    - At what rate relative to yield increases?
    - Is N use efficiency of 25 to 50% acceptable?
  - Example:
    - Maize in North China Plain*
      - Average N application: 249 kg N/ha (56 to 600 kg N/ha)
      - Average yield: 6 – 8 t/ha (120 to 160 bu/ac)
      - Soil nitrate levels: 275 kg N/ha (0-90 cm depth); 213 kg N/ha (90-180 cm depth)
      - 49% of 80 groundwater samples exceeded 45 mg NO_3 / L

*Cui, et al. 2008. Agron. J.; Meng et al. 2010, Field Crops Research (in review).

Sustainability of Agro-Ecosystems

- Peak* Phosphorus Discussion

***30 or 200 years, same problem**



*Cordell et al. 2009. Global Envir. Change 19:292-305

Fertilizer Development for the Future

- Virtual Fertilizer Research Center
  - http://www.ifdc.org/Alliances/VFRC
    - Fertilizers critical to world food security
    - Efficiency of currently used fertilizers is low
    - Fertilizers produced with non-renewable resources
    - Majority of current fertilizer sources developed between 1930 to 1960 by the NFDC (which no longer exists)

Fertilizer Industry Focus

- Efficiency
  - Mining
  - Production
    - "De-bottlenecking"
    - Decreased energy use per unit of production
    - Decreased water use
  - Transportation and distribution
  - Financing
- Focus has created an extremely effective system for producing and distributing fertilizers throughout the world – Fertilizer is truly a "globalized" industry

Future Scientific Involvement For a Sustainable Fertilizer Industry

- New energy sources to reduce carbon footprint and cost of production
- More effective use of essential nutrients
  - N -- Plenty of N_2 in atmosphere
  - P –200 (or 30?) years of phosphate rock reserves
  - K – Plenty (but is that a reason to not use it efficiently)
- Issue is what are we doing with what we make and what are the collective "we" doing to "our environment" as we use these nutrients.
  - I can also make the argument that our effects with nutrients are negligible compared to the effects of many "consumer" goods that are being made today.

Future Scientific Involvement For a Sustainable Fertilizer Industry

- Increase the capture of nutrients applied to fields to produce crops
  - N use efficiency – 33 to 65%
  - P use efficiency – 14 to 50%
  - K use efficiency – Balanced fertilization!
- Refine the values for nutrient concentrations of food grains that optimize human and animal nutrition.
  - Determine the fertilizer sources that can supply these nutrients to various crops in specific locations

Future Scientific Involvement For a Sustainable Fertilizer Industry

- Increased yield levels
  - 4 R's program
    - Do we have the right source, rate, place and time for 18.9 tons/ha (300 bu/acre) corn?
    - Amounts of nutrients if we maintain the same nutrient content in the grain
      - May or may not be happening – starch content of corn grain and associated protein content
    - Same growing season, increased nutrient uptake rates
      - Transport through soil
      - Uptake through roots
      - Other ways to get needed nutrients to plants efficiently

Future Scientific Involvement For a Sustainable Fertilizer Industry

- Nutrient recovery and reuse
  - Livestock wastes
  - Municipal wastes
  - How many times can your company sell the same phosphate, nitrogen, and K molecules?
- EPA Targeted Watersheds and NRCS Mississippi River Basin Initiative
  - N, P, and Sediment Reduction in Water
  - Millions of dollars but most, if not all, is for cost-share of practices.
  - How do we get the investment in research?

Future Scientific Involvement For a Sustainable Fertilizer Industry

- Case study*
  - EMBRAPA – Brazil's agency for ag research
  - Extremely successful in developing the technologies need to produce crops in Brazil's unique and diverse soils and climates.
  - Did not mention the precursor to the institution
    - Trained group of individuals to populate the institution
    - Current Director trained at U. of WI and U. of CA

*Cremaq, P. The miracle of the cerrado. Brazil has revolutionised its own farms. Can it do it for others? The Economist. 26 Aug 2010.

Future Scientific Involvement For a Sustainable Fertilizer Industry

- US Agency for International Development Graduate Student Training Program*
  - 1989 – Over 11,000 graduate students
  - 2006 – Approximately 900
  - Europe, Canada, Japan, and Australia have all had extensive graduate student training programs
- Industry needs must be articulated to begin reinvesting in the human capital that will be needed to "sustain" our industry in various regions of the world.

*Rob Bertram, Ag Development and Economic Growth, US Agency for International Development, Washington, DC

SUSTAINABILITY

- Economic
  - Demand (not just need for food) is increasing.
  - Industry appears to be entering a period of greater economic return due to increased demand
  - Investment in research and development for new molecules and technologies is needed for “long-term” economic sustainability

SUSTAINABILITY

- Social
  - Food production is essential for society, and we as an industry have done “good things” in terms of supply, quality and safety.
  - Perhaps we have been “to good” at our jobs and thus we are under appreciated. (GET OVER IT!)
  - The un-intended consequences of our production systems sometimes put us in conflict with society.
  - Continued efforts needed on education of society about what we do, as well as our being socially aware of our actions.

SUSTAINABILITY

- ENVIRONMENT
  - Continue reducing the environmental impacts of nutrients
  - Most, if not all, gains in reducing environmental impacts of nutrients should increase fertilizer production efficiency and crop production efficiency.
    - Quantification of the increases in efficiency should have a value that can be shared by the fertilizer industry and growers, i.e. more value in the system.
  - We must be seen as proactive in this area, or we have the potential to be regulated greatly in specific areas.