Imbalance in phosphorus applications rates

Kg P per hectare

Western Kenya  North China  Midwest U.S.

Vitousek et al. 2009
% of global reserves (orange slices) in P-rich countries

Roberts and Stewart 2002
Estimated life of P reserves remaining based on extraction costs and current extraction rates

Roberts and Stewart 2002
Diminishing P reserves

- The U.S. and China have 25-40 years of economically viable (current value) domestic reserves remaining

- Global Peak Phosphorus could happen by 2033

- The majority of countries have little to no economically meaningful P reserves
Other sources of P?

“meteorites easily could have provided more phosphorus than naturally occurs on Earth -- enough phosphorus to give rise to biomolecules which eventually assembled into living, replicating organisms.”

Innovations report 8-04
P fertility in pre-industrial agriculture

P added
weathering, dust

P lost
erosion, leaching

food harvest

Soil organic matter

P
P fertility in agroecosystems

P added
weathering, dust

P lost
erosion, leaching
food harvest

Soil organic matter
P
Perennial wheatgrass

Annual wheat

ROOTING DEPTH

2.5 m

J. Glover
P fertility in pre-industrial agriculture

**P added**
- weathering, dust

**P lost**
- erosion, leaching
- food harvest

Soil organic matter
Reintegration of livestock into crop agriculture

Cycling of humanure onto cropland
Feeding growing populations is essential but is not enough. Attention to social factors that help stabilize populations and carefully measured economic development are also crucial.
Population (billions)

- Less Developed Countries
- More Developed Countries

Changes in P applied per capita
1962-2002

Kg P per capita

India            China            U.S.A.

Changes in P applied per capita
Changes in % grain supply fed to livestock from 1962-2002

India

China

U.S.A.

% grain supply fed to livestock

- India
- China
- U.S.A.

Years:
- 1962
- 1982
- 2002

Bar graph showing the percentage of grain supply fed to livestock for India, China, and the U.S.A. from 1962 to 2002.
Changes in per capita protein consumption: 1962-2002

Changes in per capita protein consumption: 1962-2002

India

China

U.S.A.
Changes in P applied per capita 1962-2002

Kg P per capita

India           China           U.S.A.

Years: 1962, 1982, 2002
High wow factor ratings from this talk

- Our food production ceiling used to in part determined by the rate at which rocks and soil minerals weathered.
- The fossil fuel bonanza is VERY recent, and it has allowed us to at least temporarily de-couple from these weathering rates.
- The Green Revolution could not have happened without this de-coupling.
- Economically useful P reserves are finite and diminishing.
- Modern trends in meat production and consumption present significant challenges that the movement in sustainable agriculture can help address.
Can Sustainable Agriculture Feed the World?
“All that we can do is to keep steadily in mind that each organic being is striving to increase in a geometrical ratio; that each at some period of its life, during some season of the year, during each generation or at intervals, has to struggle for life and to suffer great destruction.”

Charles Darwin
The Origin of Species
Chapter 3
Evolutionary hangovers?

**Less Developed Countries**
- Population increase

**More Developed Countries**
- Increase in food consumption (especially meat and sugar)
970 million
Malnourished
850 million

Increase in total malnourished people 1950 – 2004 according to Pimentel et al. (2007)

Figure 1 | Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.
Change in fertilizers applied in Cuba following the break-up of the Soviet Union

1000 tons applied yr⁻¹

1988

1994
Legend

- Phosphate Rock Reserves - Top Five Countries (% of global reserves)
- These 8 countries account for 85% of global sulphuric acid production
Concentrating P in time
Annual wheat (on left in each panel) and Perennial wheatgrass.
Washington State University: perennial wheat

Texas A&M: perennial wheat

The Land Institute: perennial sorghum, sunflower, wheat, +

University of Manitoba: (potentially) perennial rye, wheat

Yunnan Academy of Agricultural Sciences: upland rice

Michigan State University: perennial wheat & wheatgrass

FFI-CRC: perennial wheat

World perennial grain programs