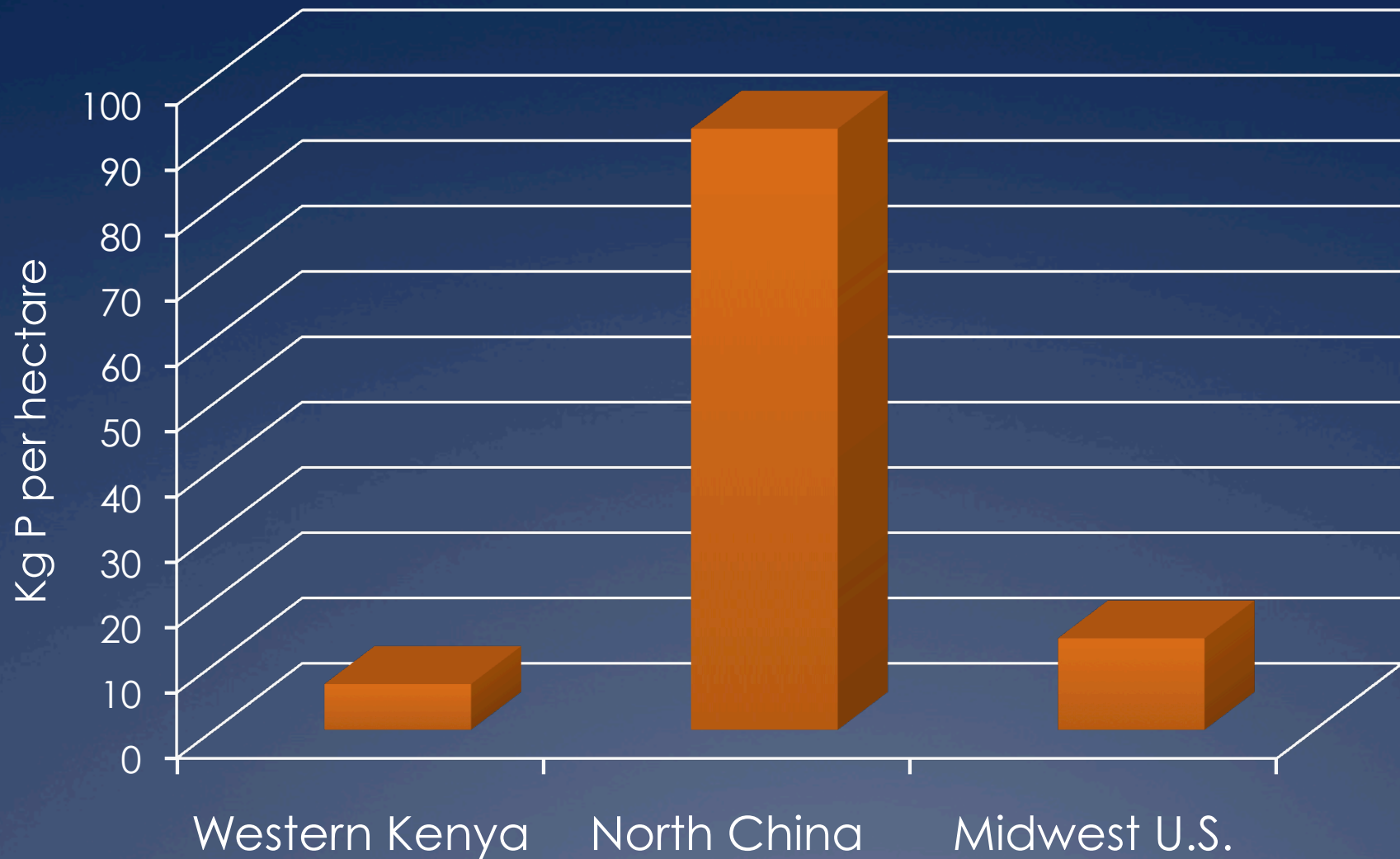
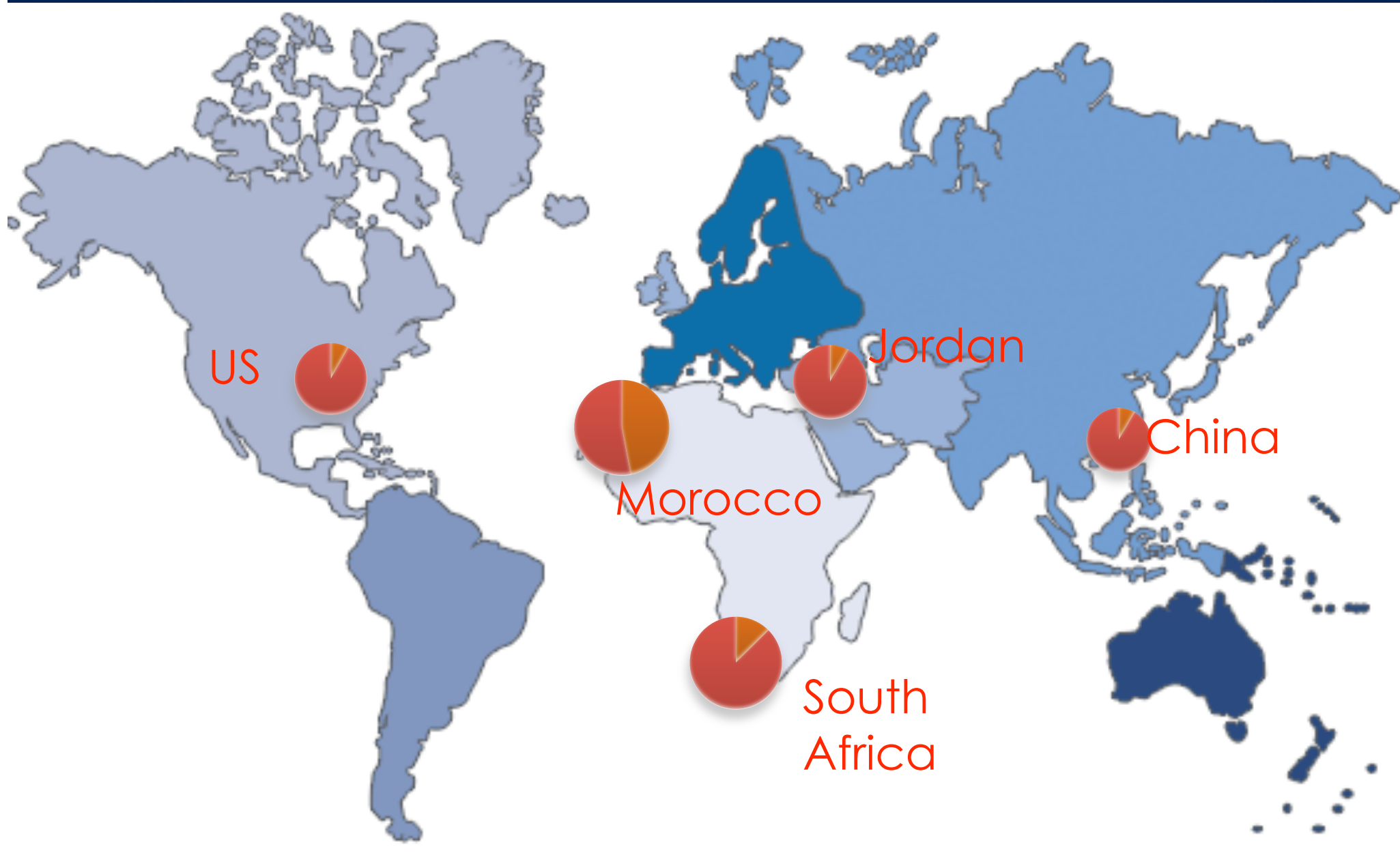




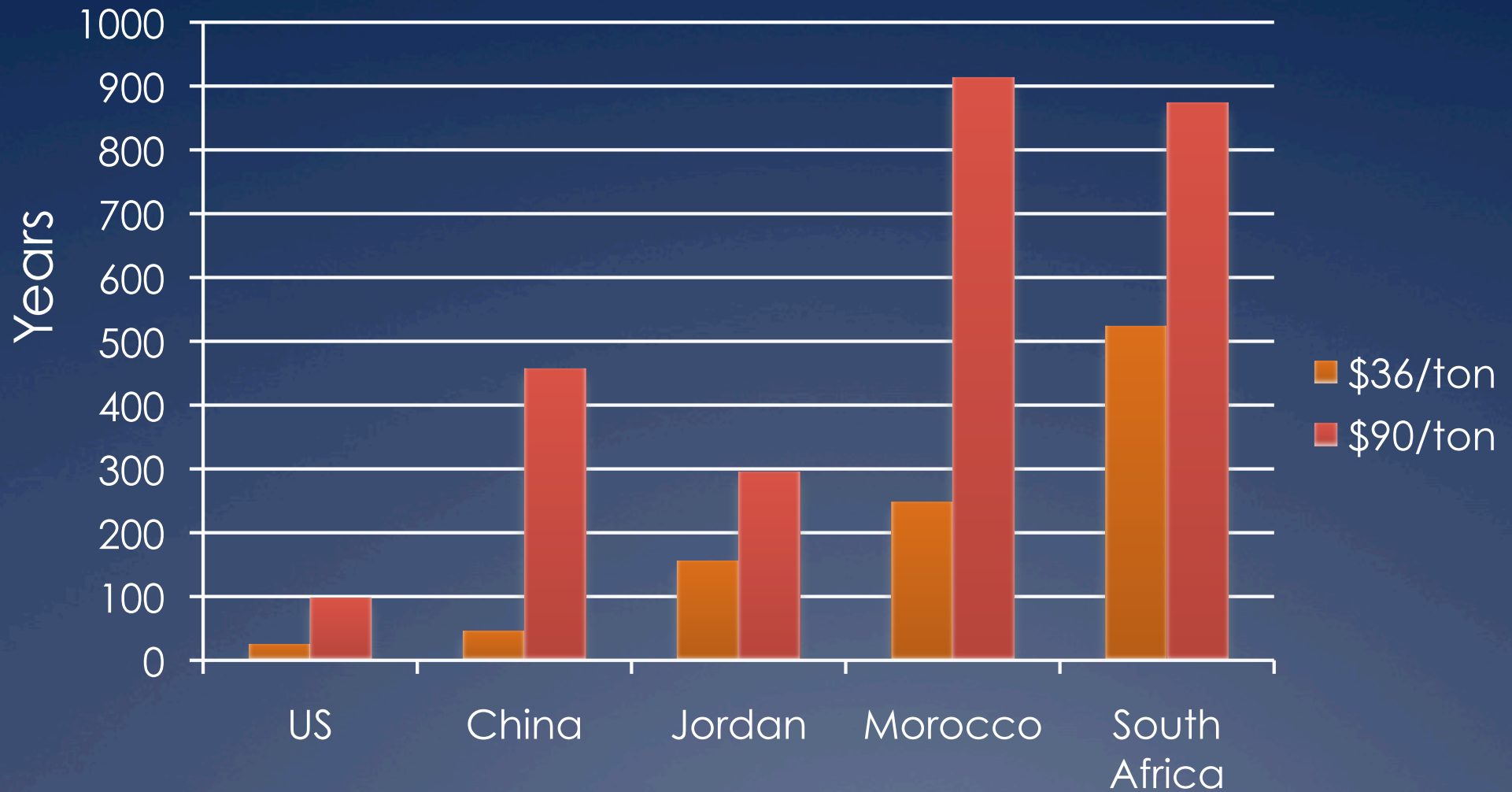
Imbalance in phosphorus applications rates



% of global reserves (orange slices) in P-rich countries



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



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

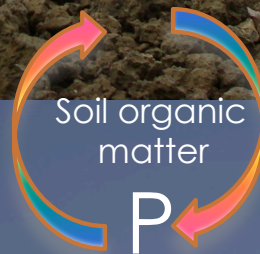
P added
weathering,
dust



P lost
erosion,
leaching



food harvest



P fertility in agroecosystems

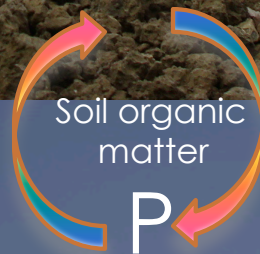
P added
weathering,
dust



P lost
erosion,
leaching



food harvest

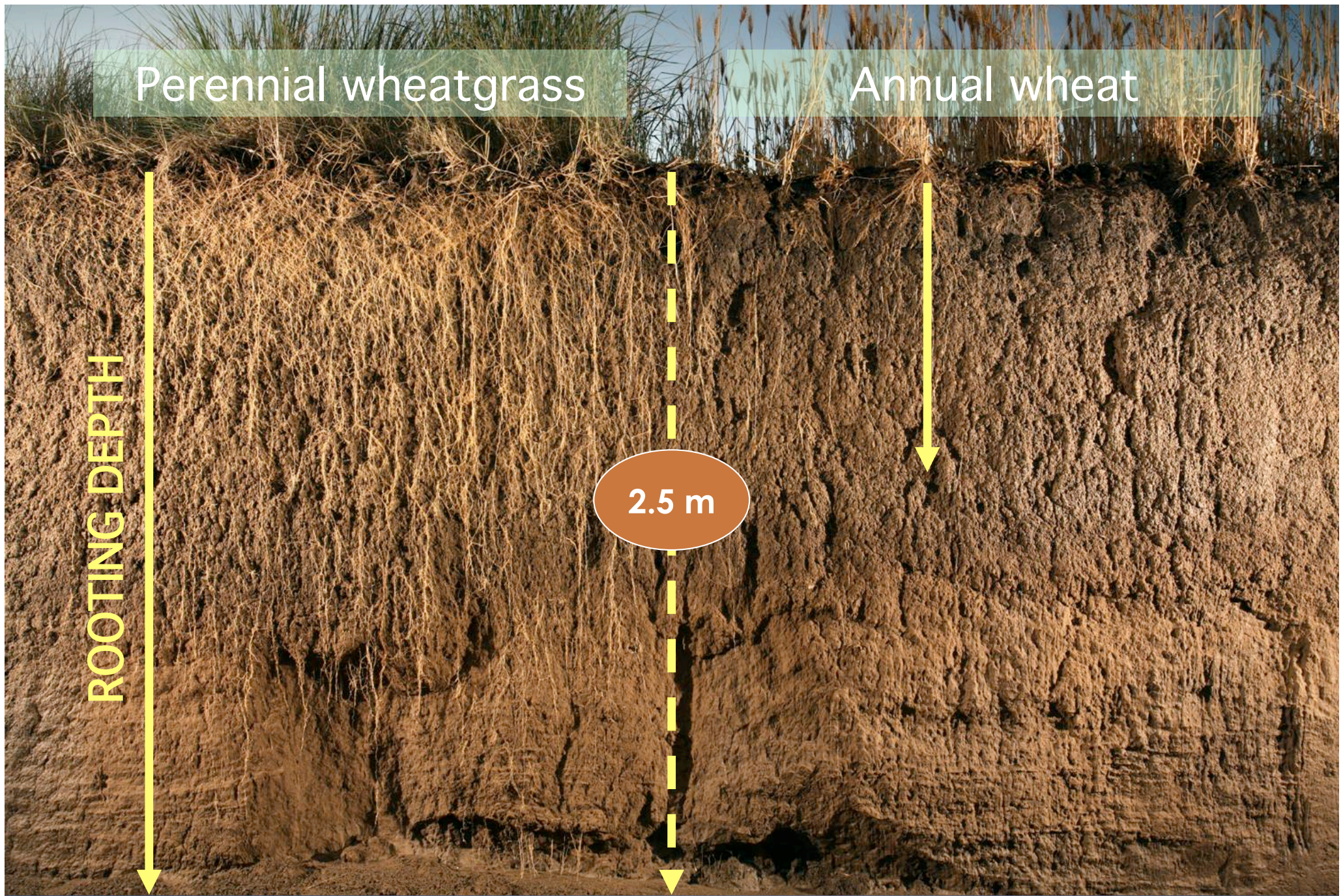


Perennial wheatgrass

Annual wheat

ROOTING DEPTH

2.5 m



P fertility in pre-industrial agriculture

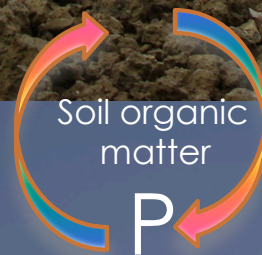
P added
weathering,
dust



P lost
erosion,
leaching



food harvest



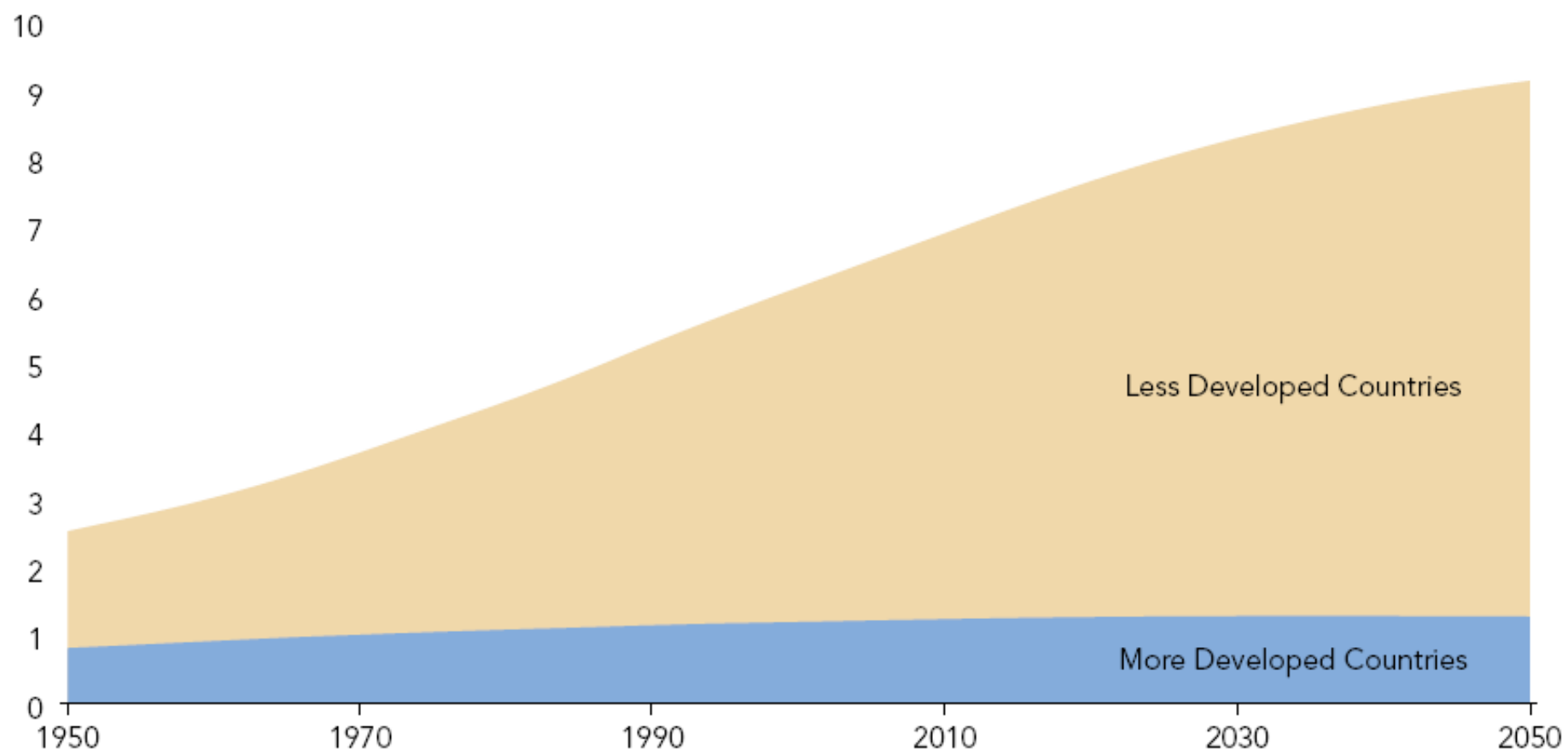


Reintegration of
livestock into crop
agriculture

Cycling of humanure
onto cropland

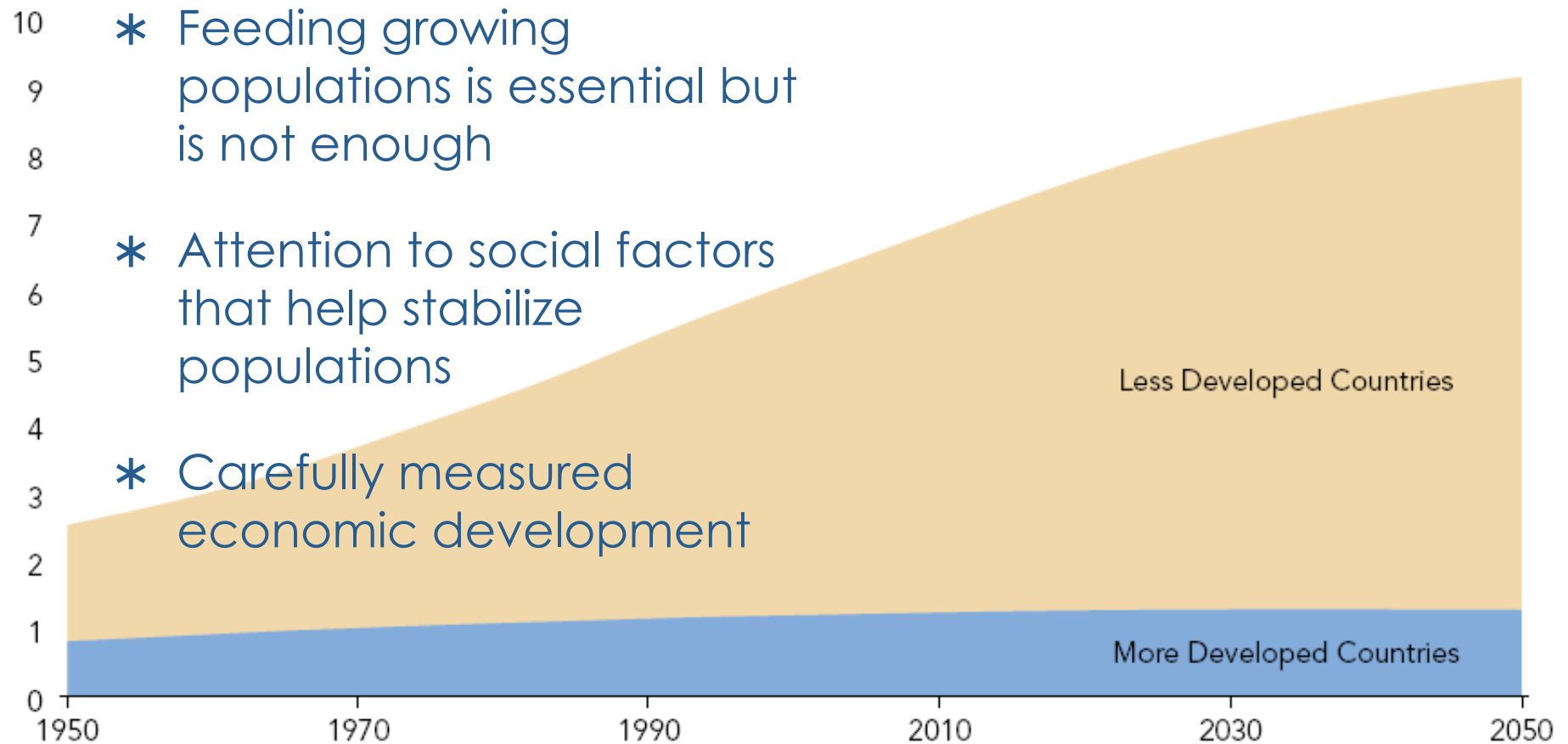


Population (billions)



SOURCE: UN Population Division, *World Population Prospects: The 2008 Revision*, medium variant (2009).

Population (billions)

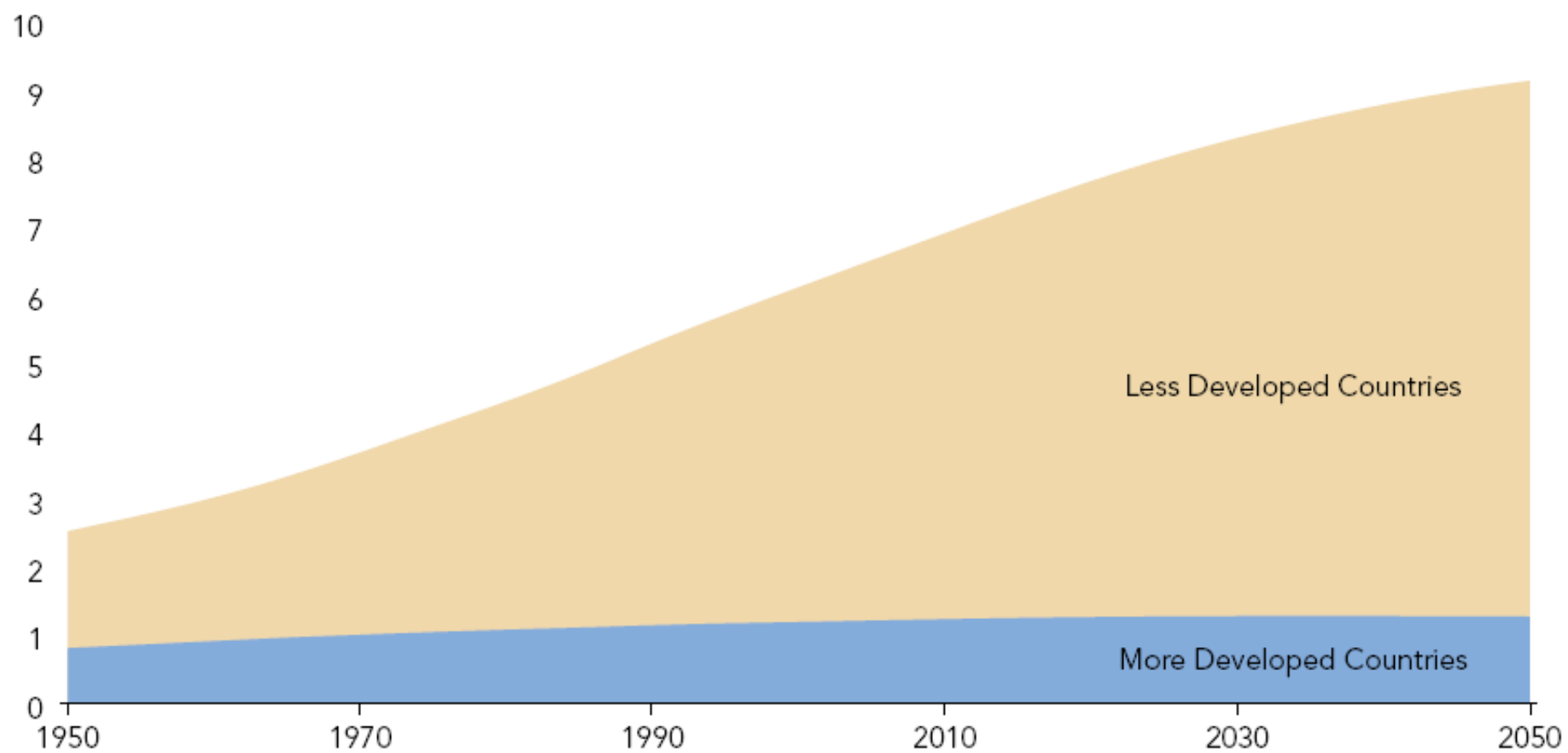


Less Developed Countries

More Developed Countries

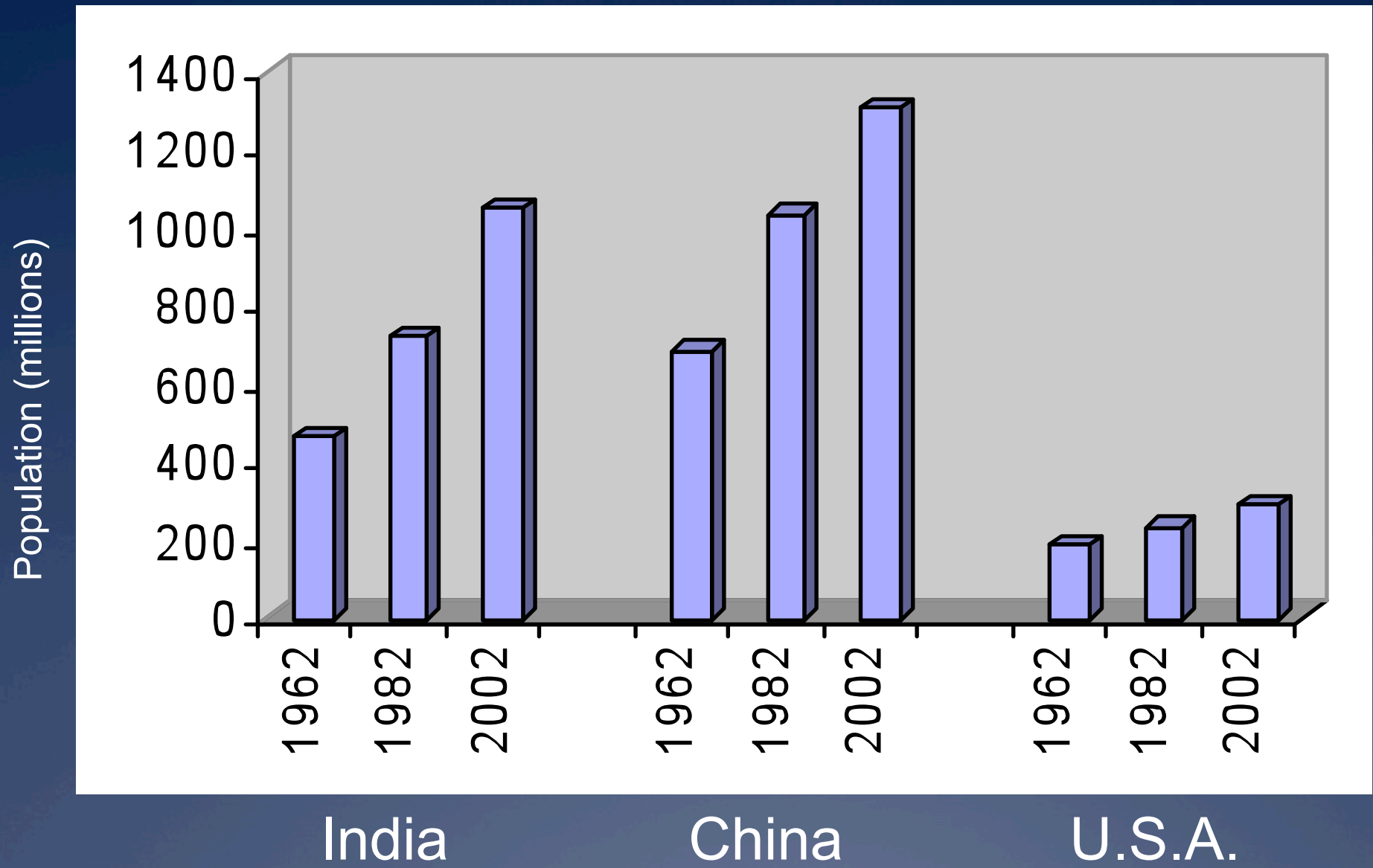
SOURCE: UN Population Division, *World Population Prospects: The 2008 Revision*, medium variant (2009).

Population (billions)

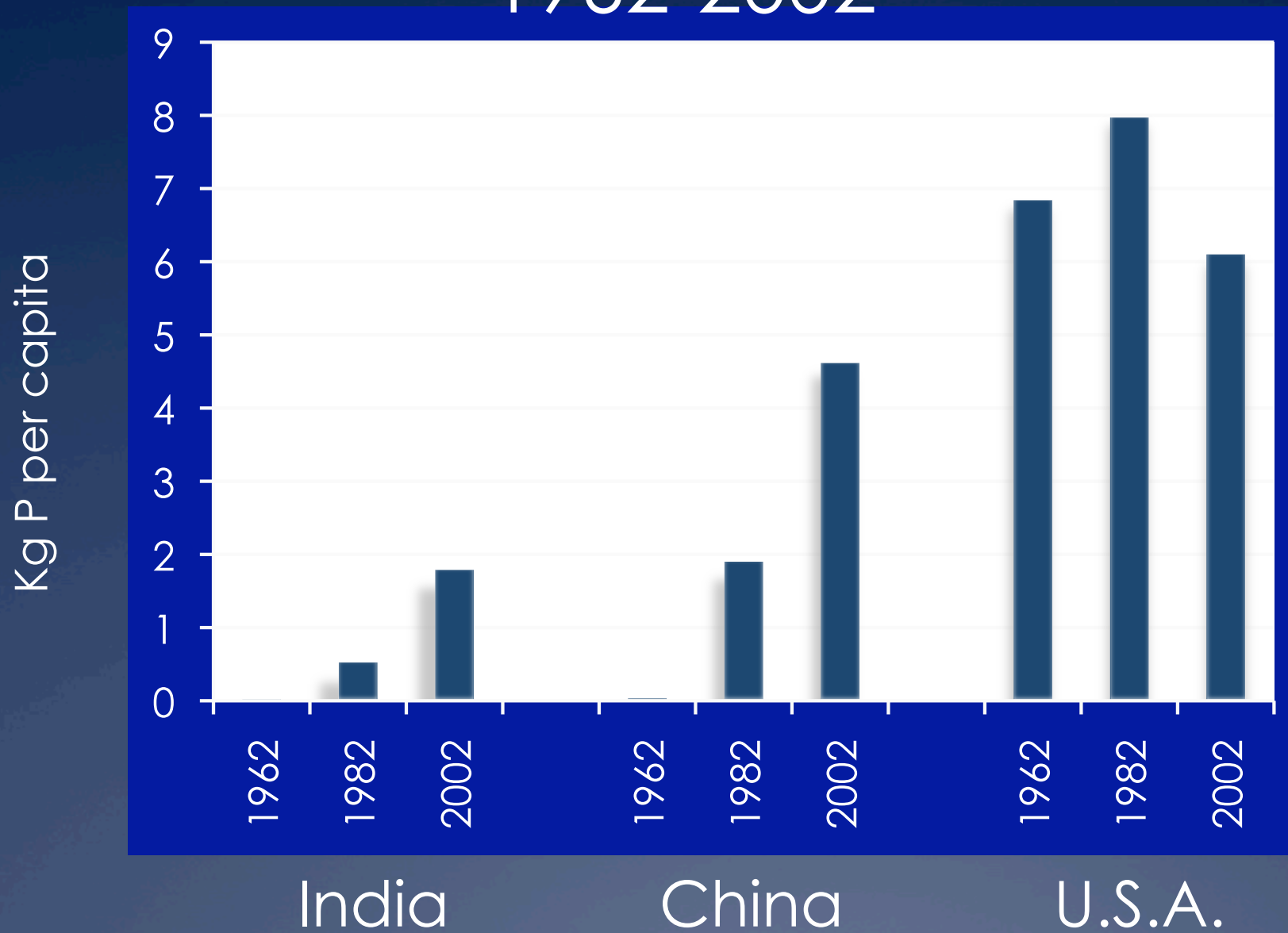


SOURCE: UN Population Division, *World Population Prospects: The 2008 Revision*, medium variant (2009).

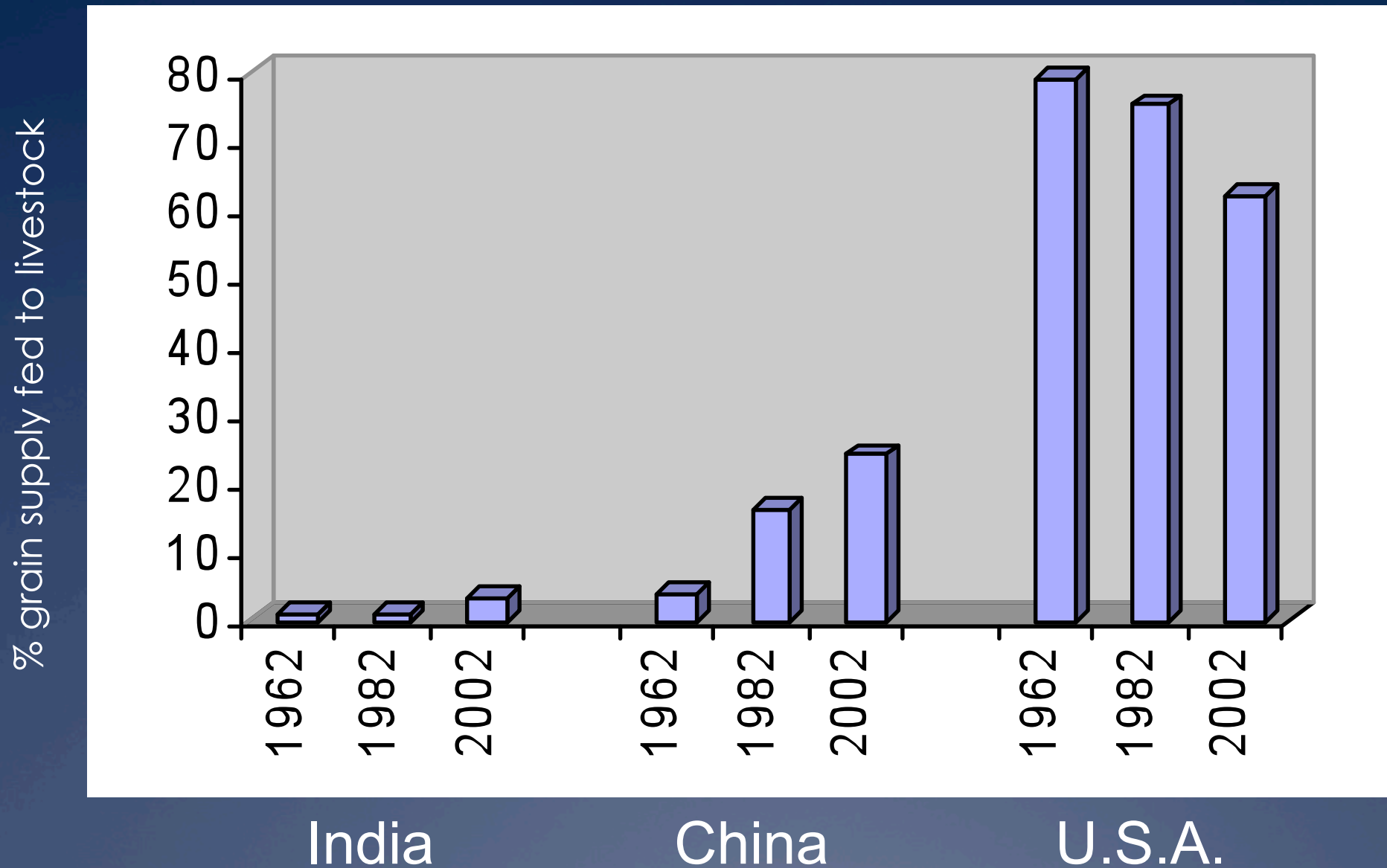
Population changes 1962-2002



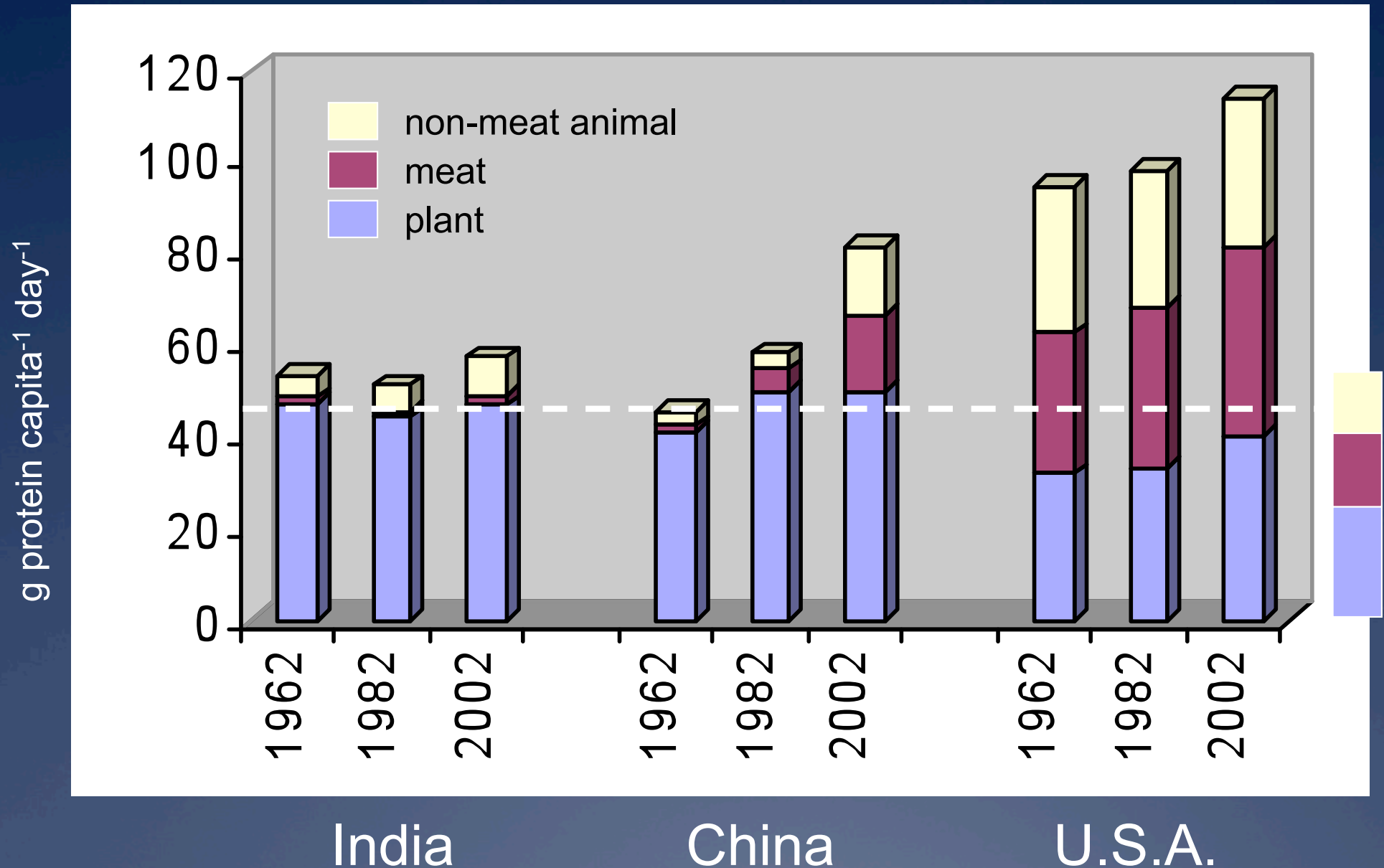
Changes in P applied per capita 1962-2002



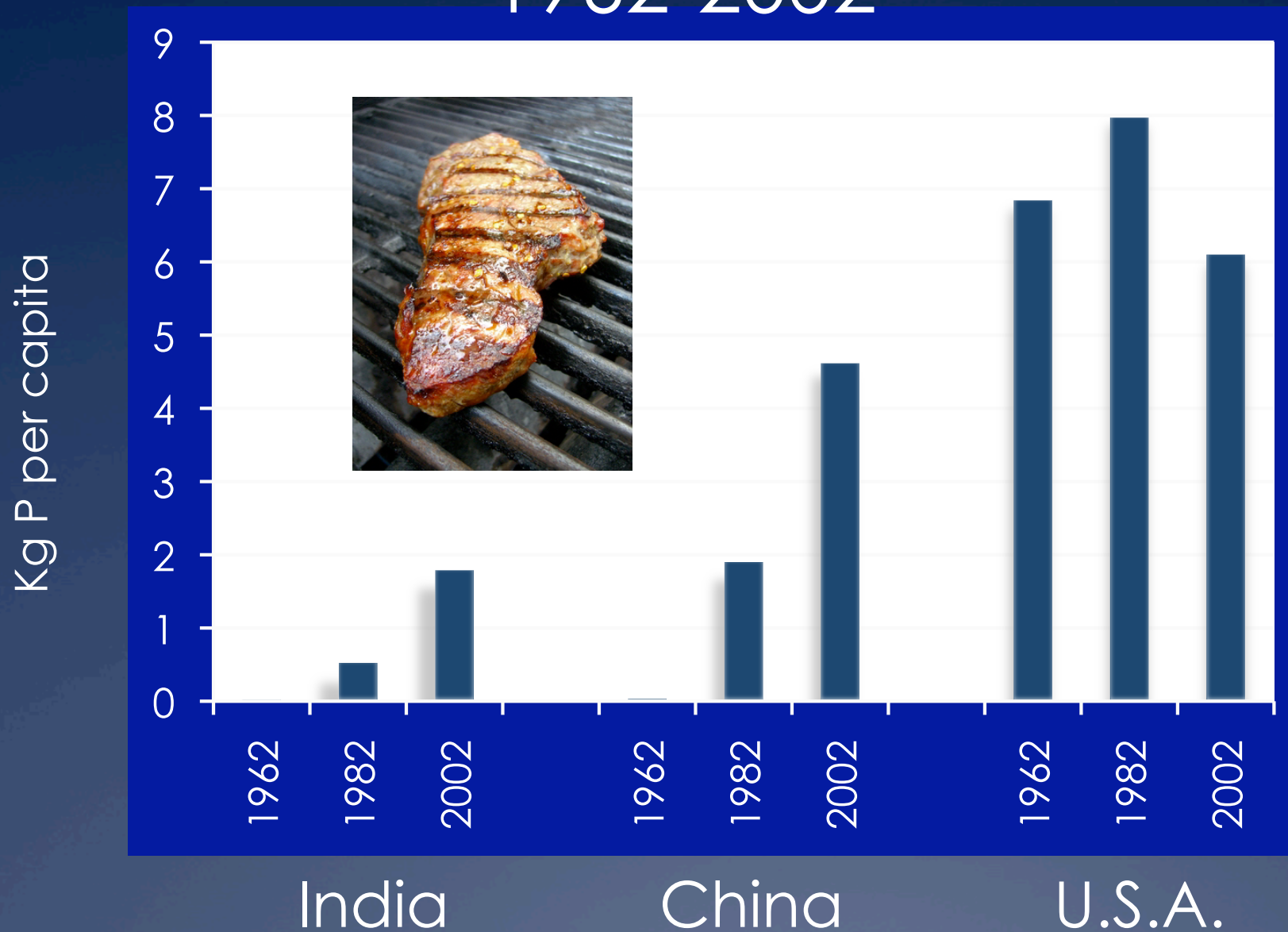
Changes in % grain supply fed to livestock from 1962-2002



Changes in per capita protein consumption: 1962-2002



Changes in P applied per capita 1962-2002



High wow factor ratings from this talk

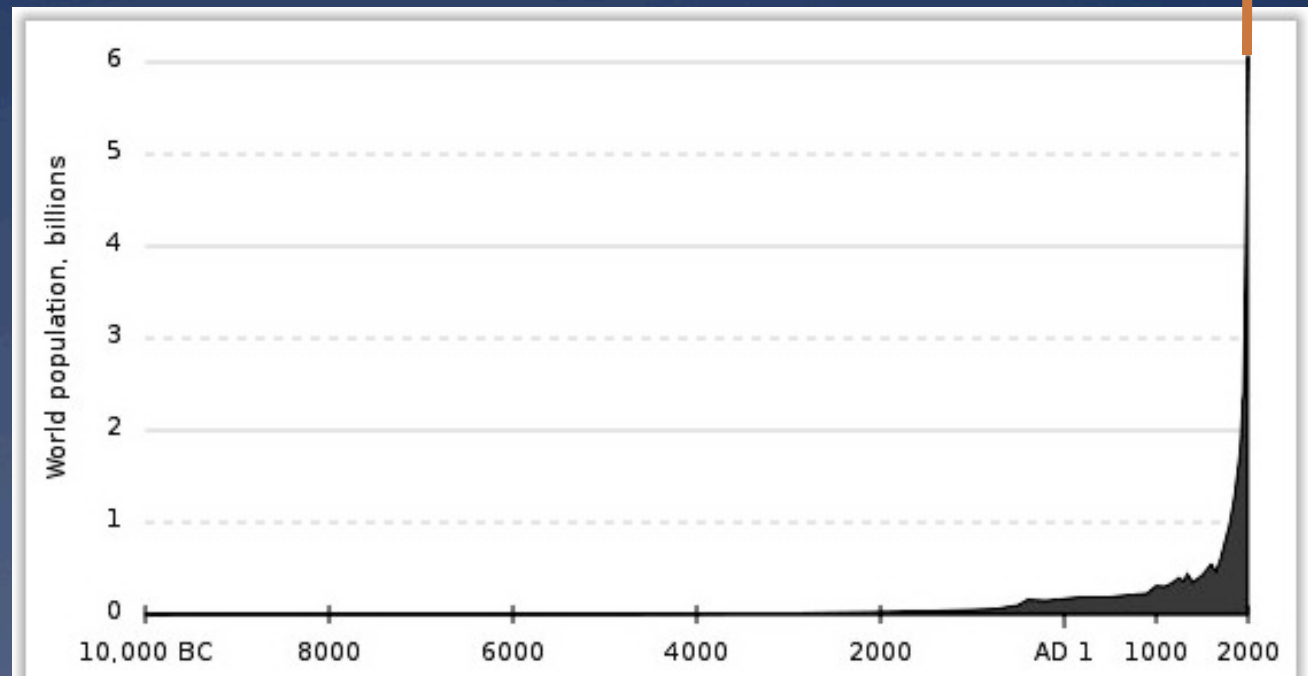
- * Our food production ceiling used to in part determined by the rate at which rocks and soil minerals weathered.
- * The fossil fuel bonanza is VERY recent, and it has allowed us to at least temporarily de-couple from these weathering rates.
- * The Green Revolution could not have happened without 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?

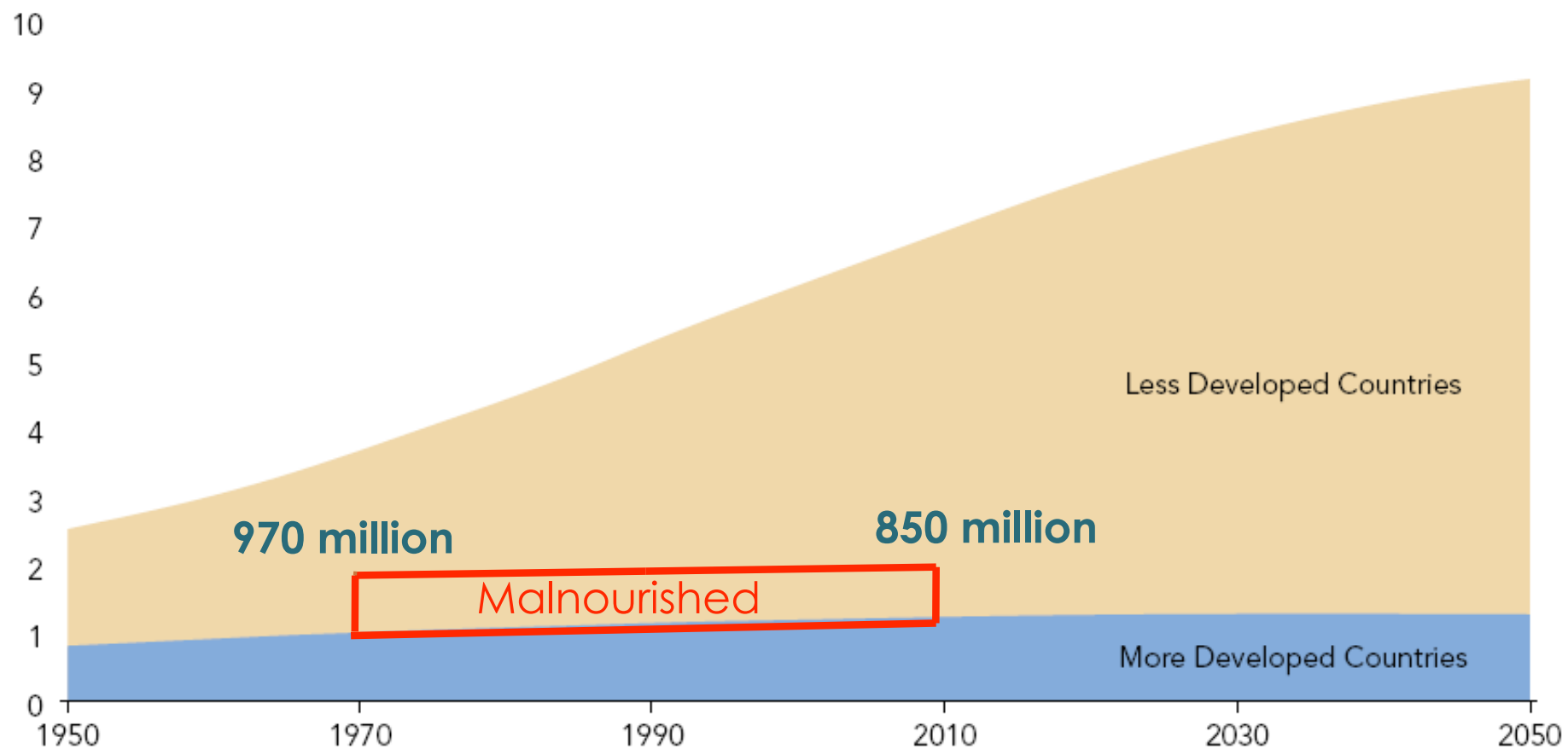
Less Developed Countries

- * Population increase

More Developed Countries

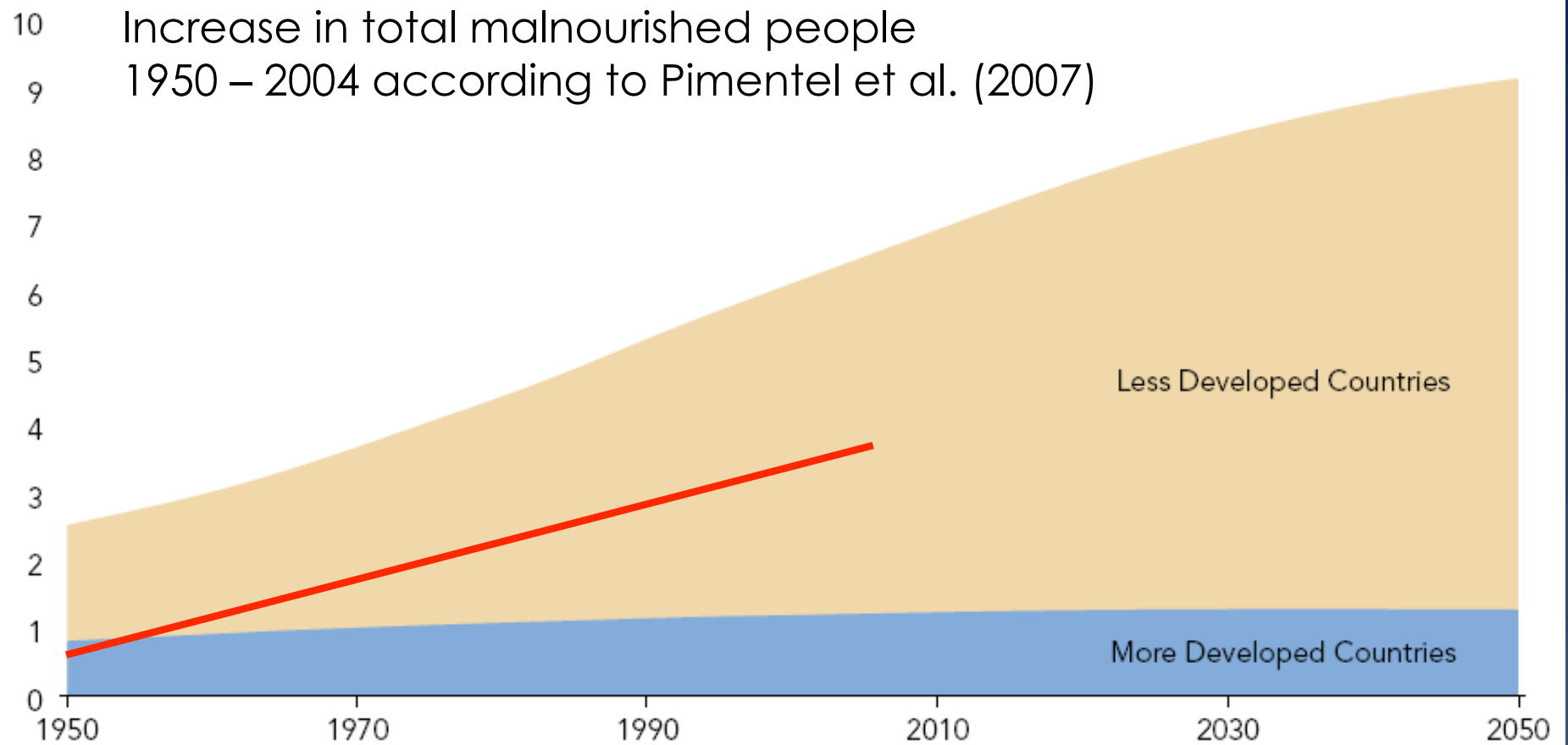
- * Increase in food consumption (especially meat and sugar)

Population (billions)



SOURCE: UN Population Division, *World Population Prospects: The 2008 Revision*, medium variant (2009).

Population (billions)



SOURCE: UN Population Division, *World Population Prospects: The 2008 Revision*, medium variant (2009).









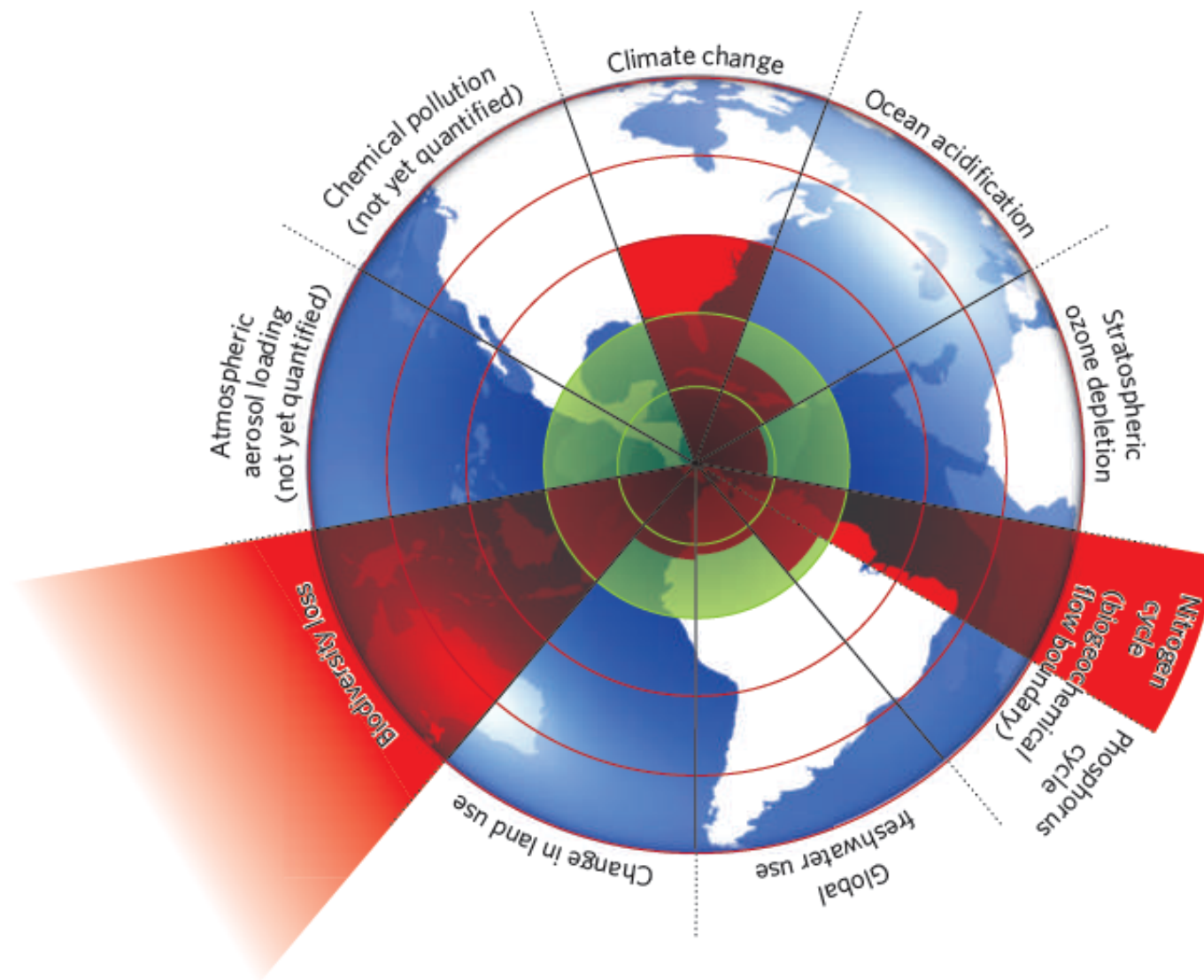
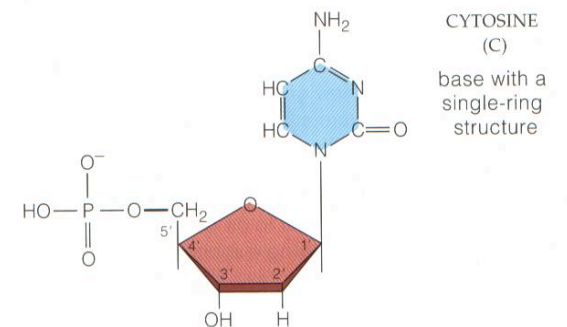
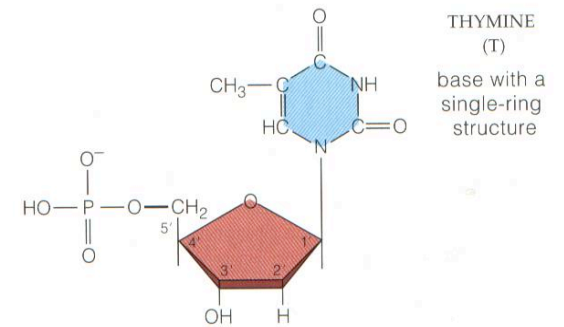
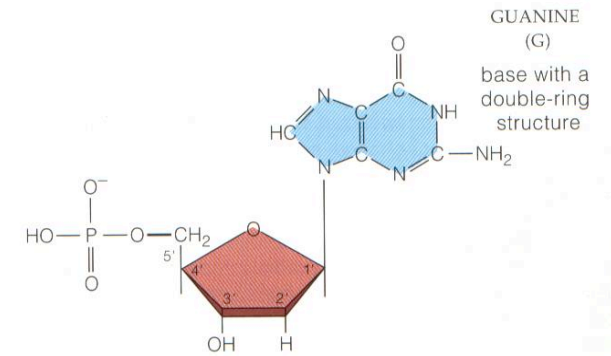
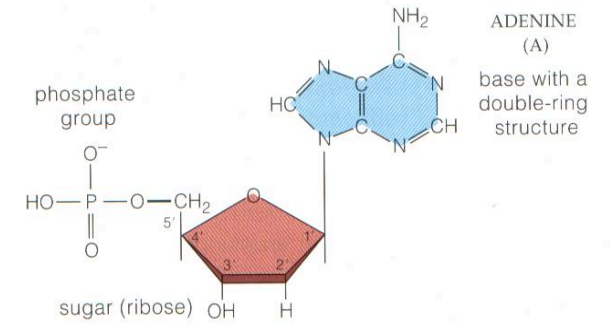
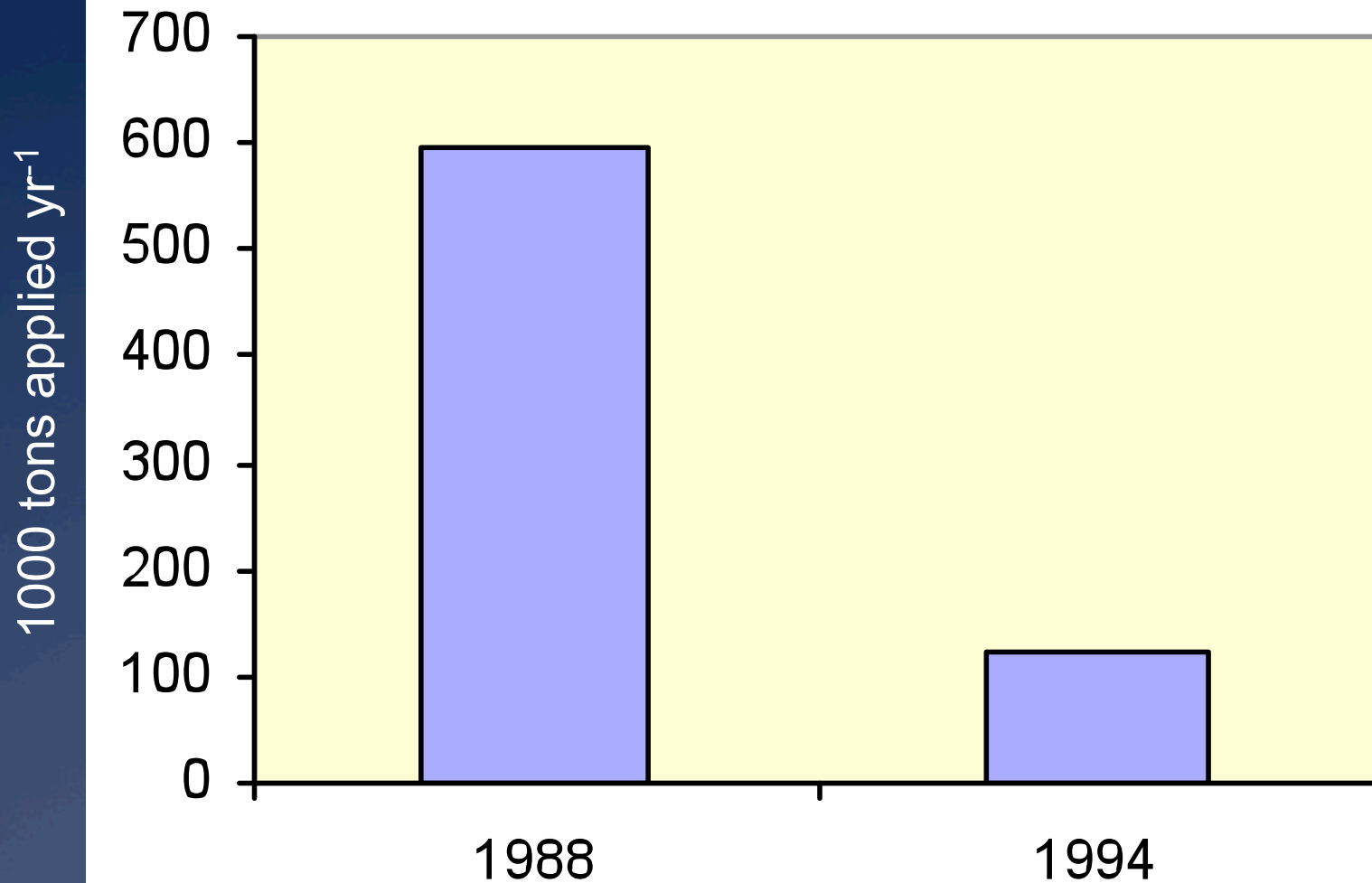


Figure 1 | Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference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

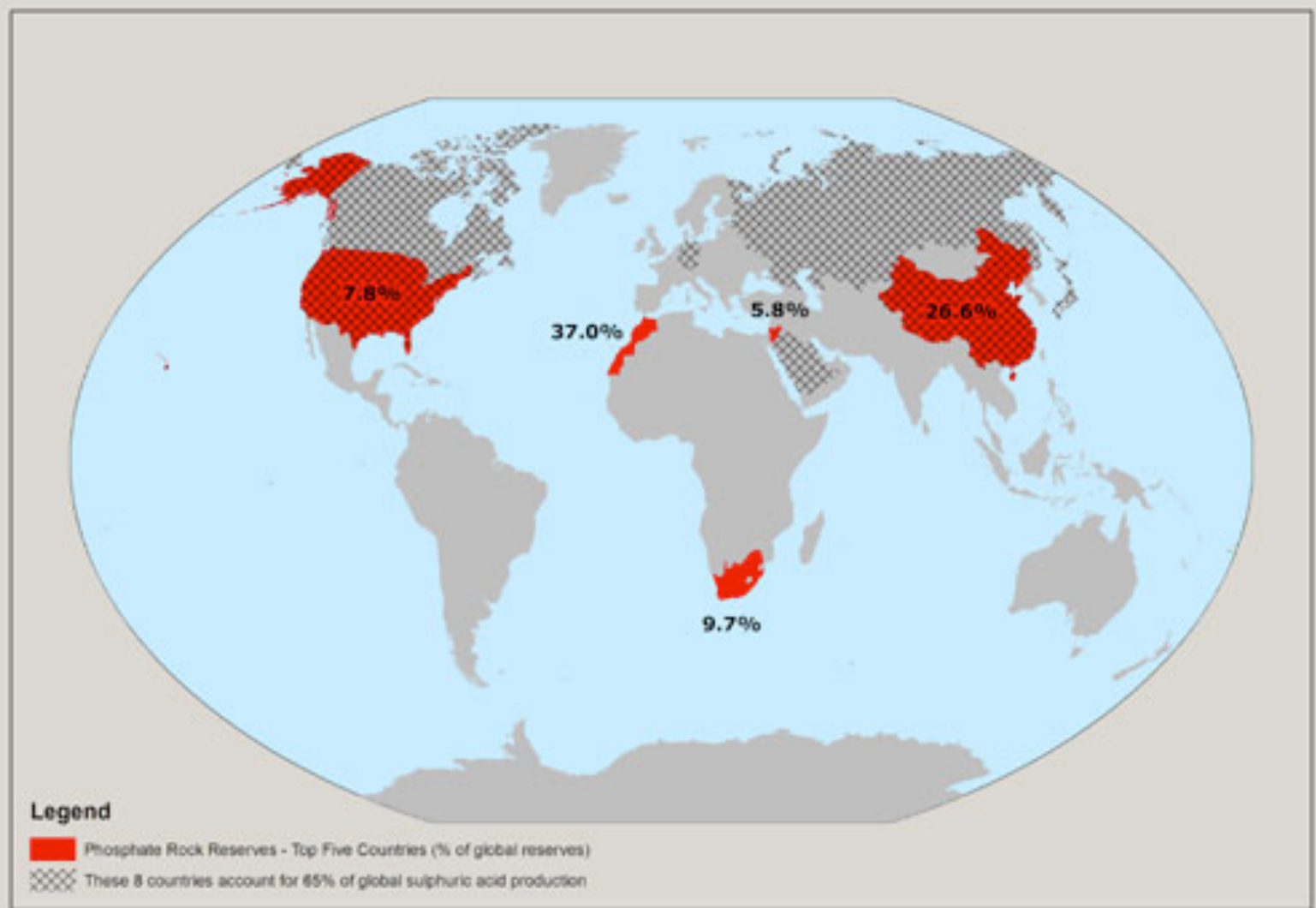


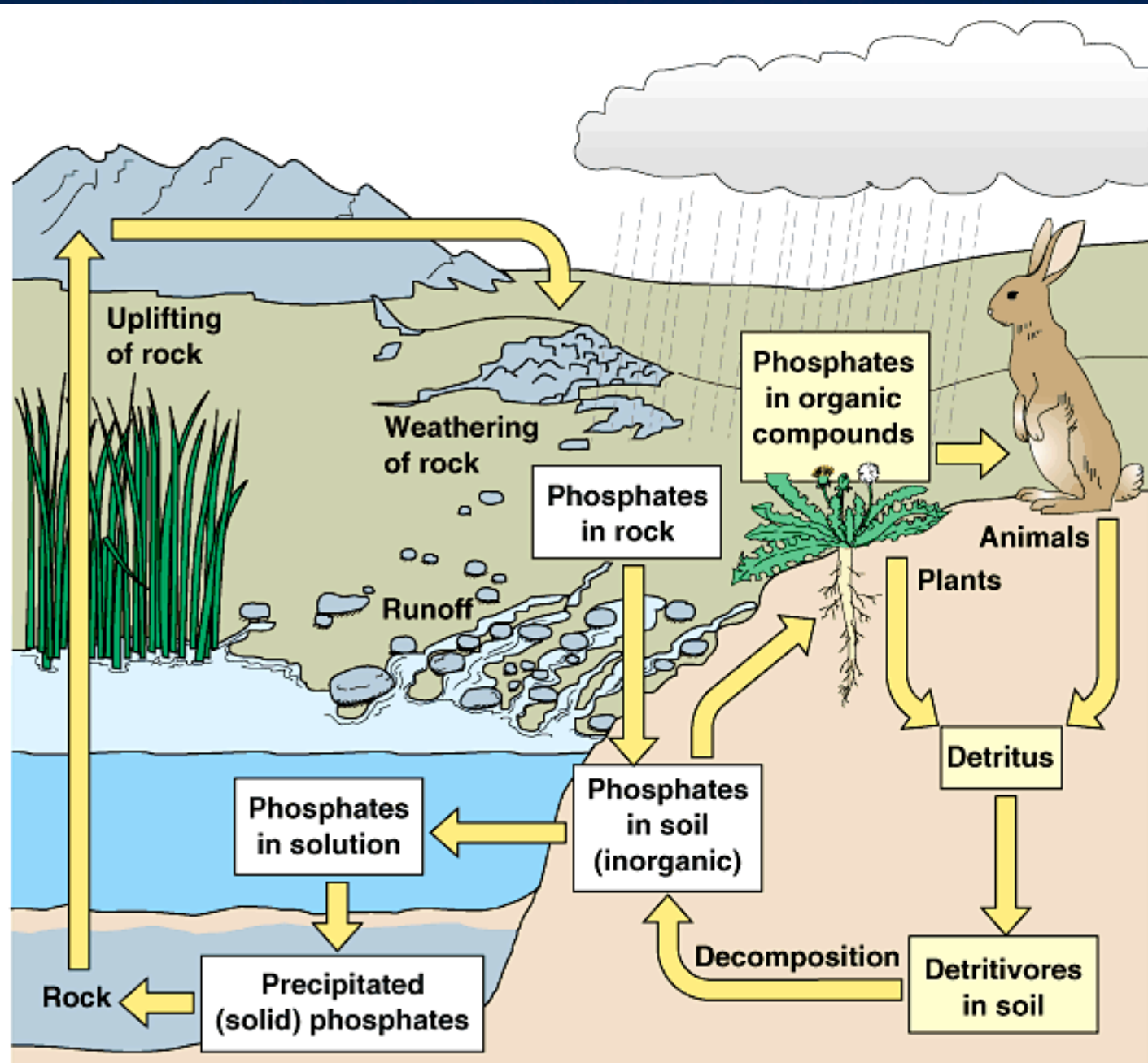


Change in fertilizers applied in Cuba following the break-up of the Soviet Union



World Phosphate Rock Reserves



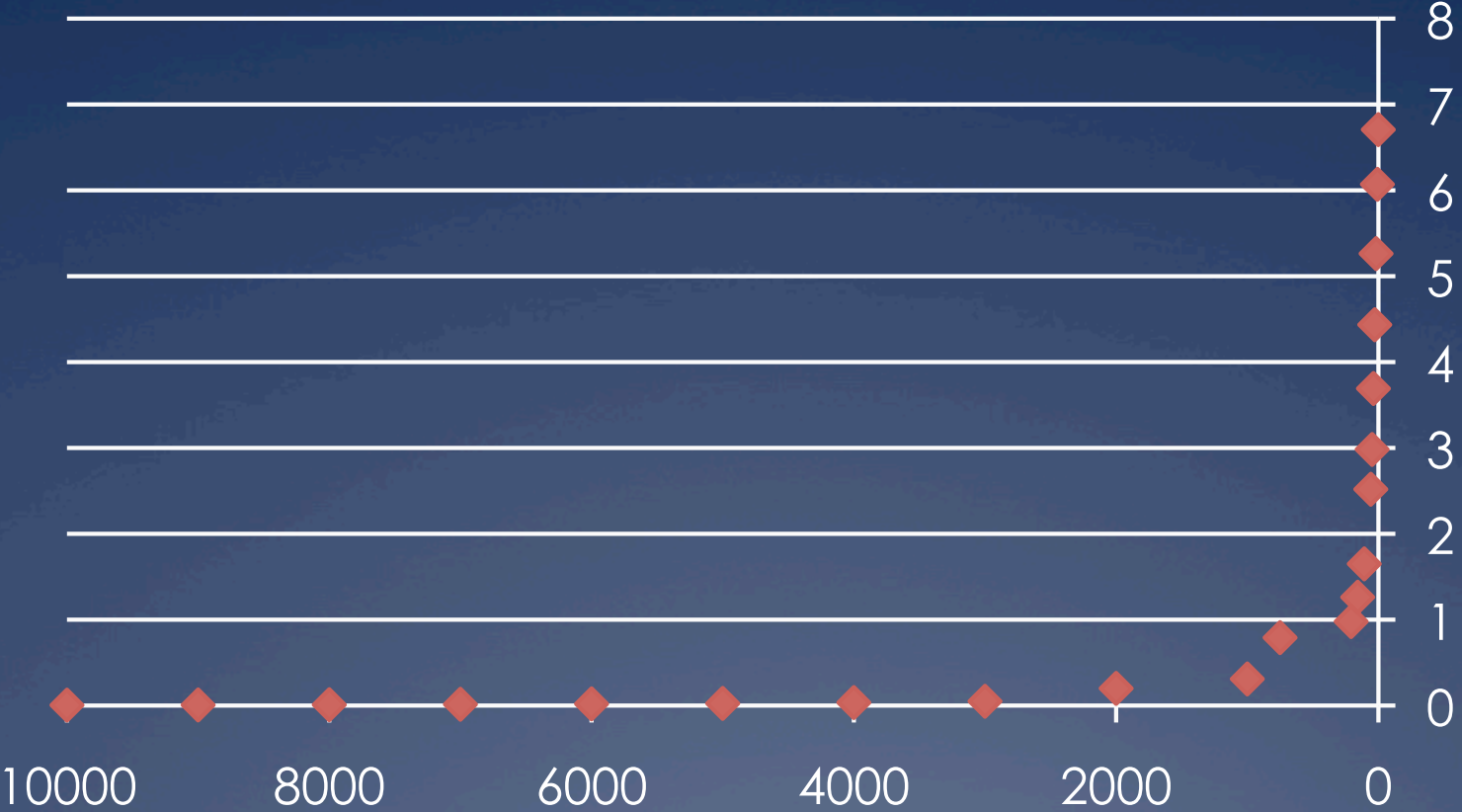


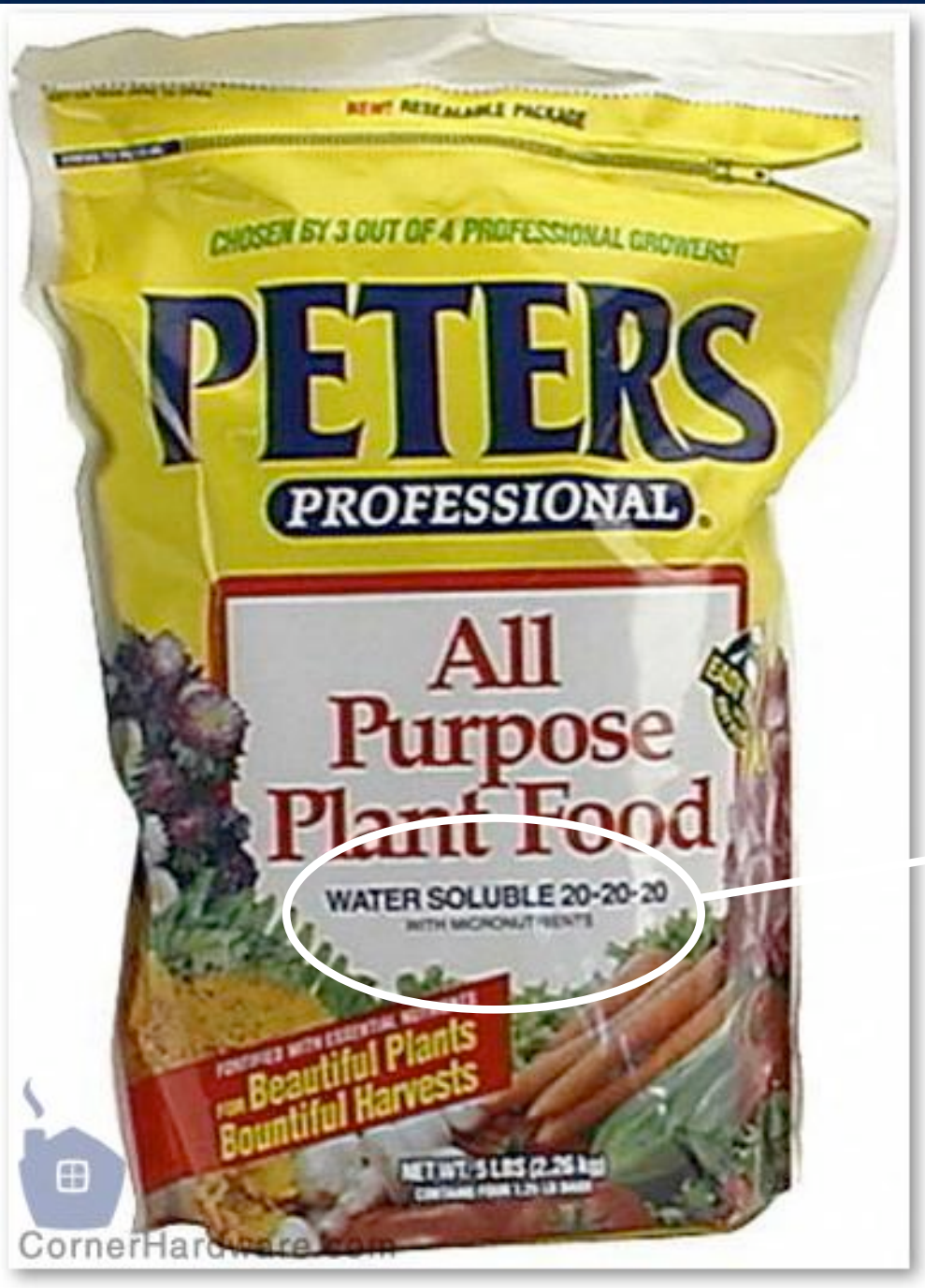
Concentrating P in time





billions





Nitrogen
Phosphorus
K--potassium



Sept

Dec

March

June

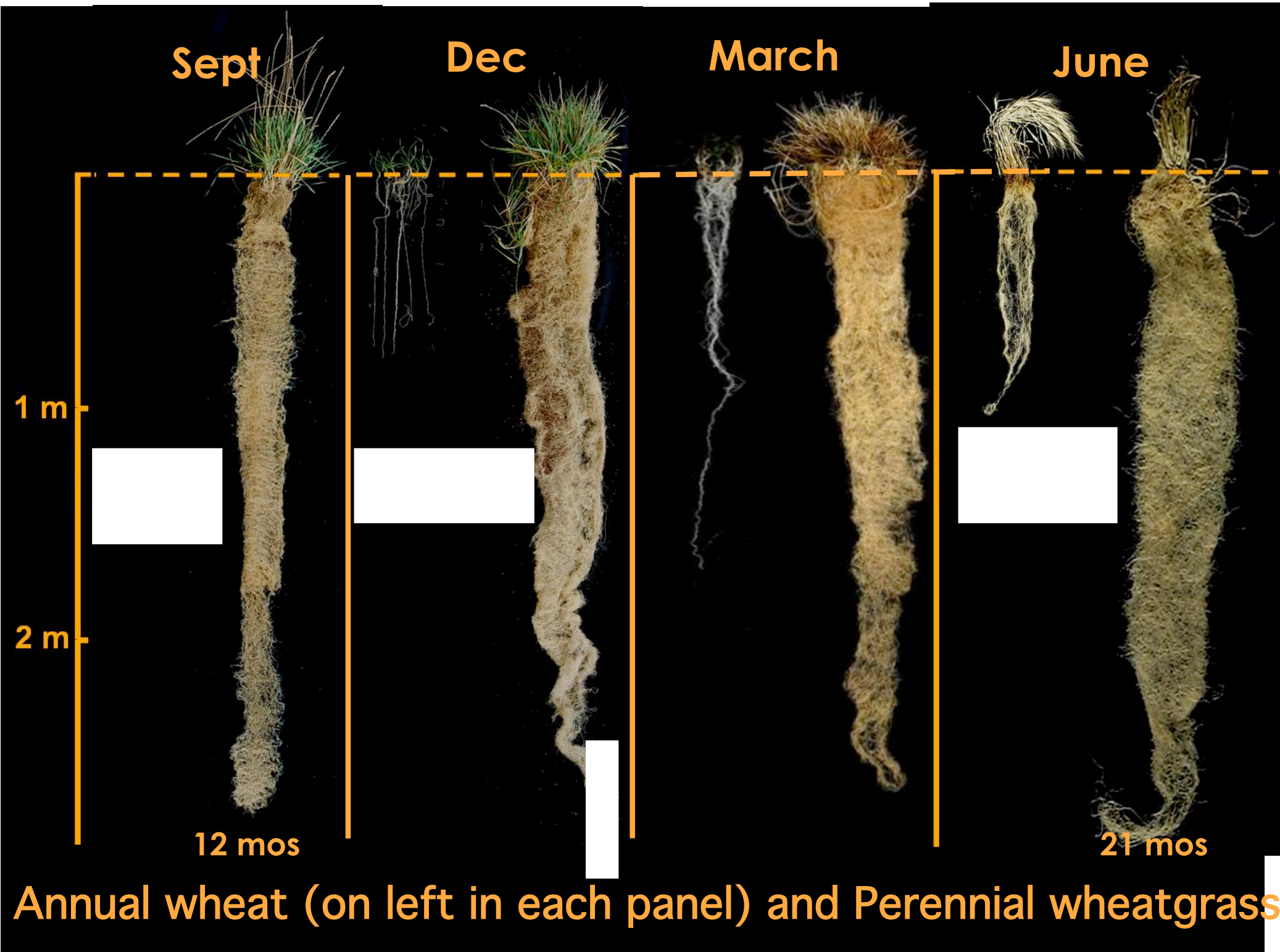
1 m

2 m

12 mos

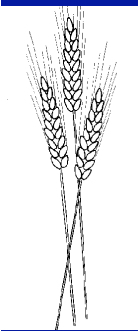
21 mos

Annual wheat (on left in each panel) and Perennial wheatgrass





Washington State University: **perennial wheat**



U&M: **perennial wheat**



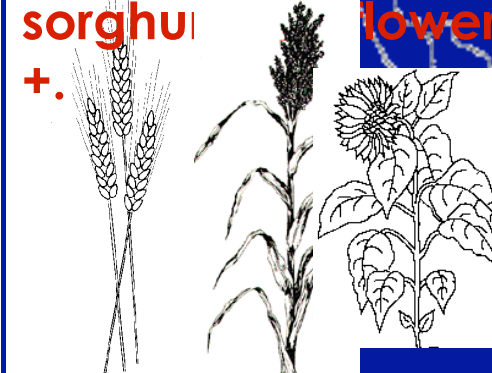
University of Manitoba: (potentially)
perennial rye, wheat

Yunnan Academy of Agricultural Sciences:
upland rice



Michigan State University:
perennial wheat & wheatgrass

The Land Institute: **perennial sorghum, lower, wheat, +.**



FFI-CRC:

perennial wheat

World perennial grain programs

