
ASPEN GLOBAL
CHANGE INSTITUTE

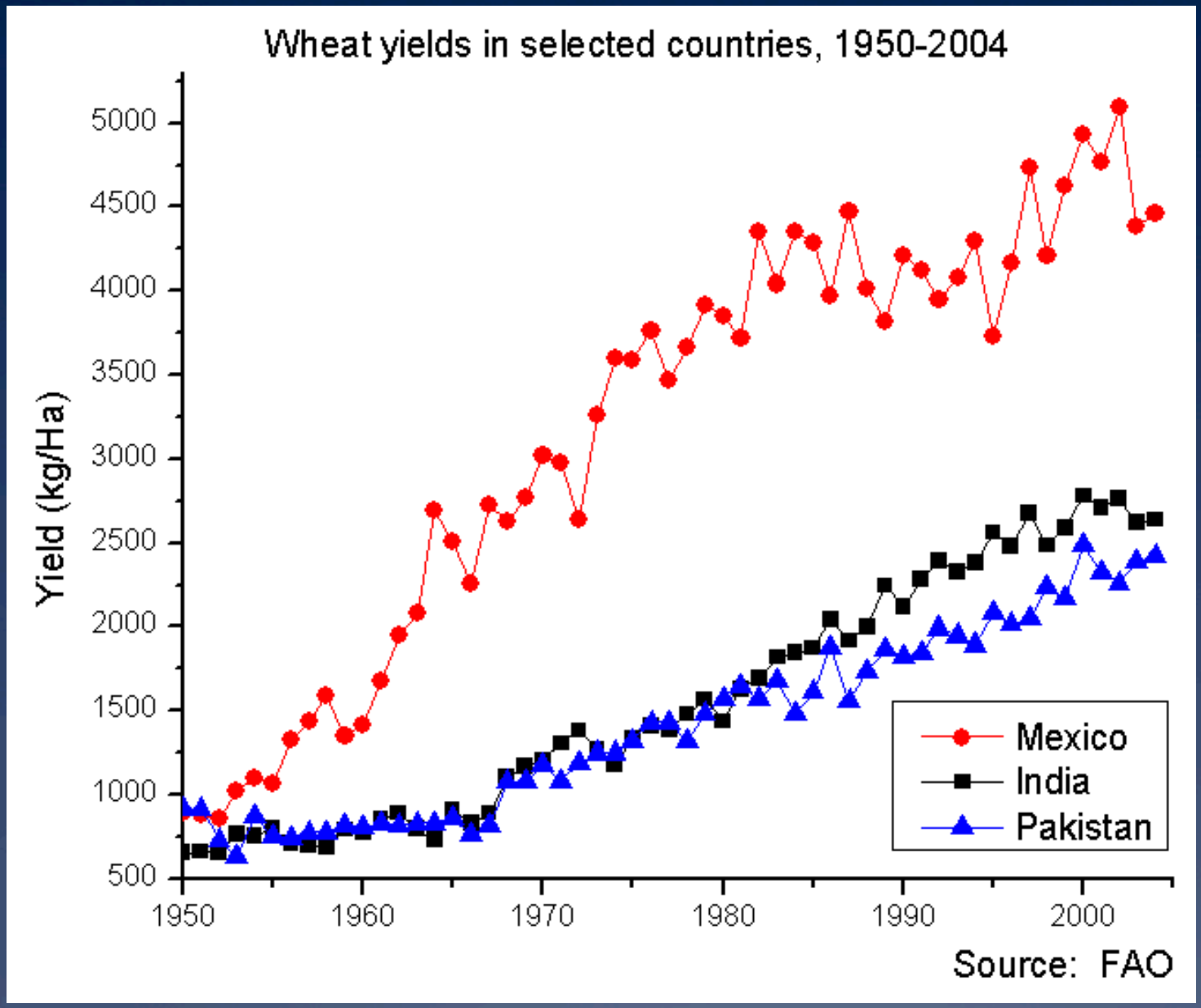
Agriculture after Normal Borlaug

Can Sustainable Agriculture Feed the World?

Tim Crews
Prescott College

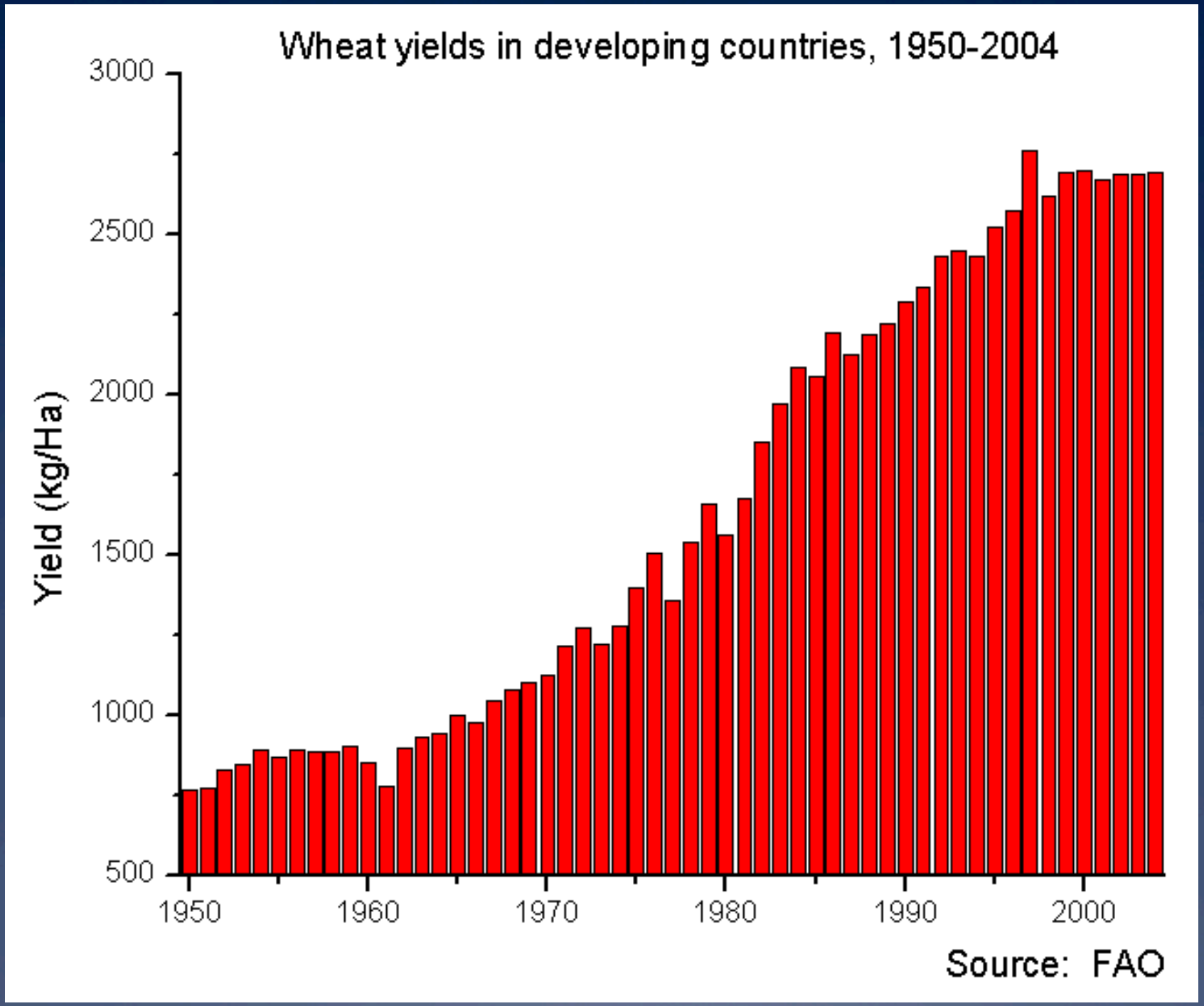

BLVD.
DR. NORMAN E. BORLAUG
PEMEX
FRANQUICIA

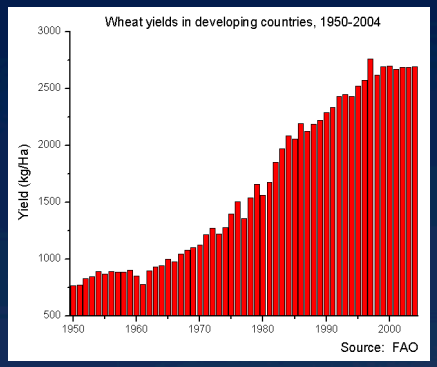

Tijuana
Ensenada
Mexicali
Laguna Salada
UNITED STATES
Ciudad Juarez
Isla Guadalupe
Hermosillo
Guaymas
Chihuahua
Gulf of California
Yaqui Valley
Nuevo Laredo
Topolobampo
Torreón
Culiacán
Monterrey
Matamoros
Gulf of Mexico
La Paz
CUBA
NORTH PACIFIC OCEAN
Mazatlan
San Luis Potosí
Tampico
Aguascalientes
Progreso
Cancún
Puerto Vallarta
León
Querétaro
Tuxpan
Mérida
Guadalajara
MEXICO
Bahía de Campeche
Morelia
Chapingo
Caribbean Sea
ISLAS REVILLAGIGEDO
Manzanillo
Toluca
Coatzacoalcos
Lázaro Cárdenas
BELIZE
Acapulco
Oaxaca
Salina Cruz
GUAT.
HONDURAS
NIC.
0 200 400 km
0 200 400 mi


Wheat yields in selected countries, 1950-2004
Yield (kg/Ha)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
1950
1960
1970
1980
1990
2000
Mexico
India
Pakistan
Source: FAO

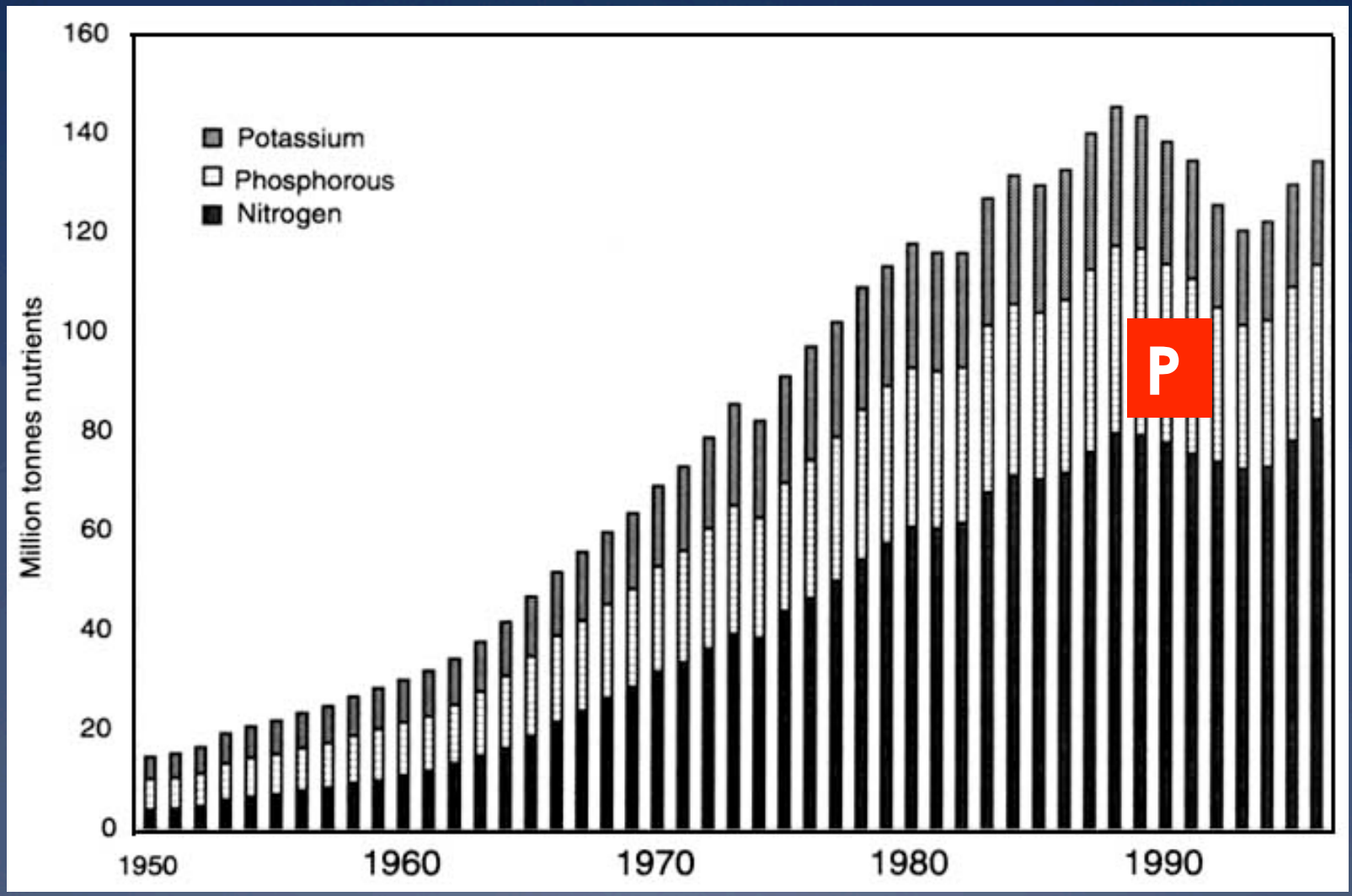
Almost certainly, however, the first essential component of social justice is adequate food for all mankind. Food is the moral right of all who are born into this world.

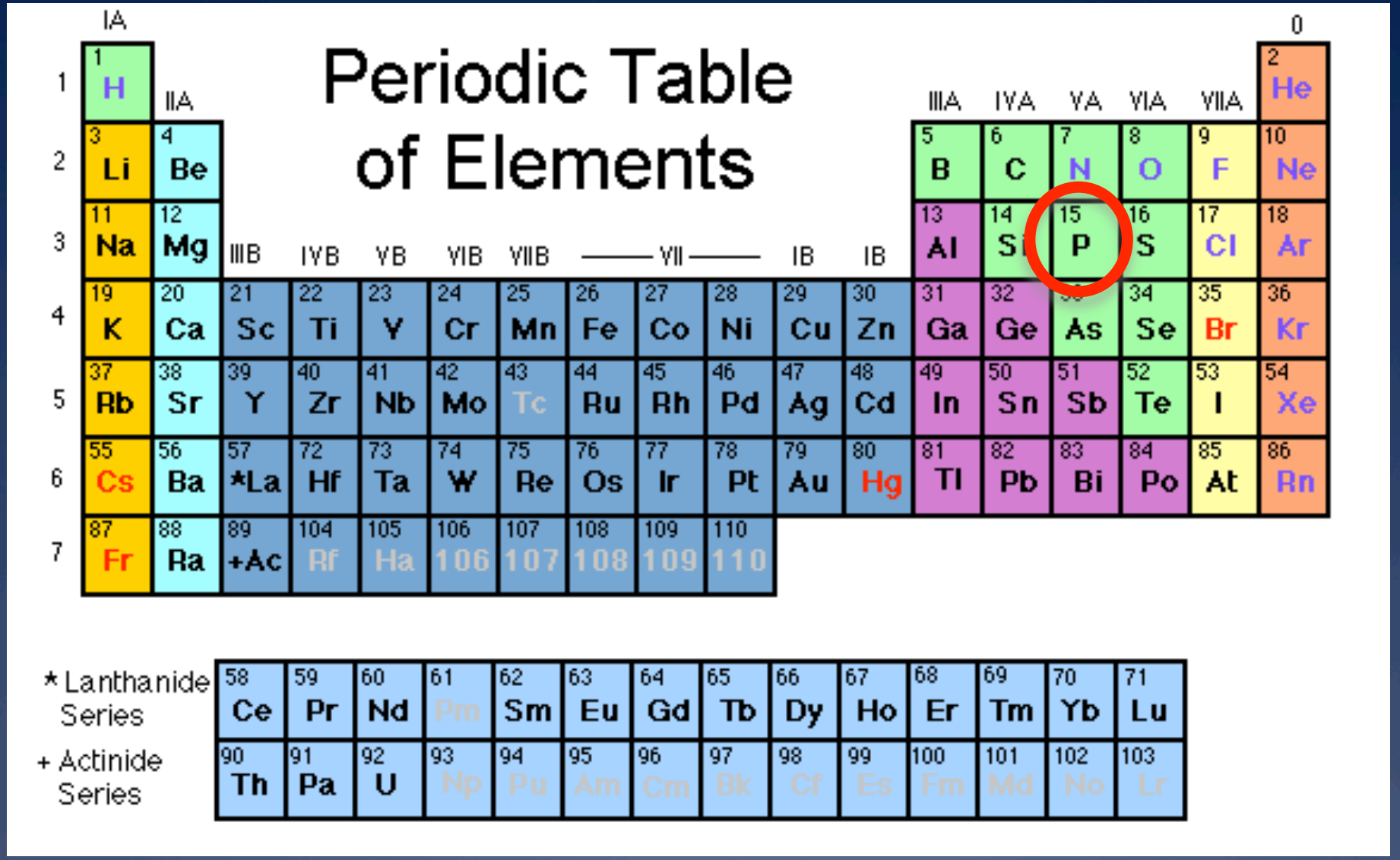
Nobel Lecture, Dec. 11, 1970


Wheat yields in developing countries, 1950-2004
Yield (kg/Ha)
3000
2500
2000
1500
1000
500
1950
1960
1970
1980
1990
2000
Source: FAO



Global applications of N,P,K fertilizers 1950-2000




Periodic Table of Elements
IA
IIA
IIIB
IVB
VB
VIB
VIIB
VII
IB
IB
IIIA
IVA
VA
VIA
VIIA
0
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
57 *La
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
89 +Ac
104 Rf
105 Ha
106 106
107 107
108 108
109 109
110 110
* Lanthanide Series
+ Actinide Series
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr

- energy production and storage molecules
- DNA and RNA
- enzymes and hormones
- buffers pH
- bone
- cell membranes

Phosphorus

N

P K Ca Mg

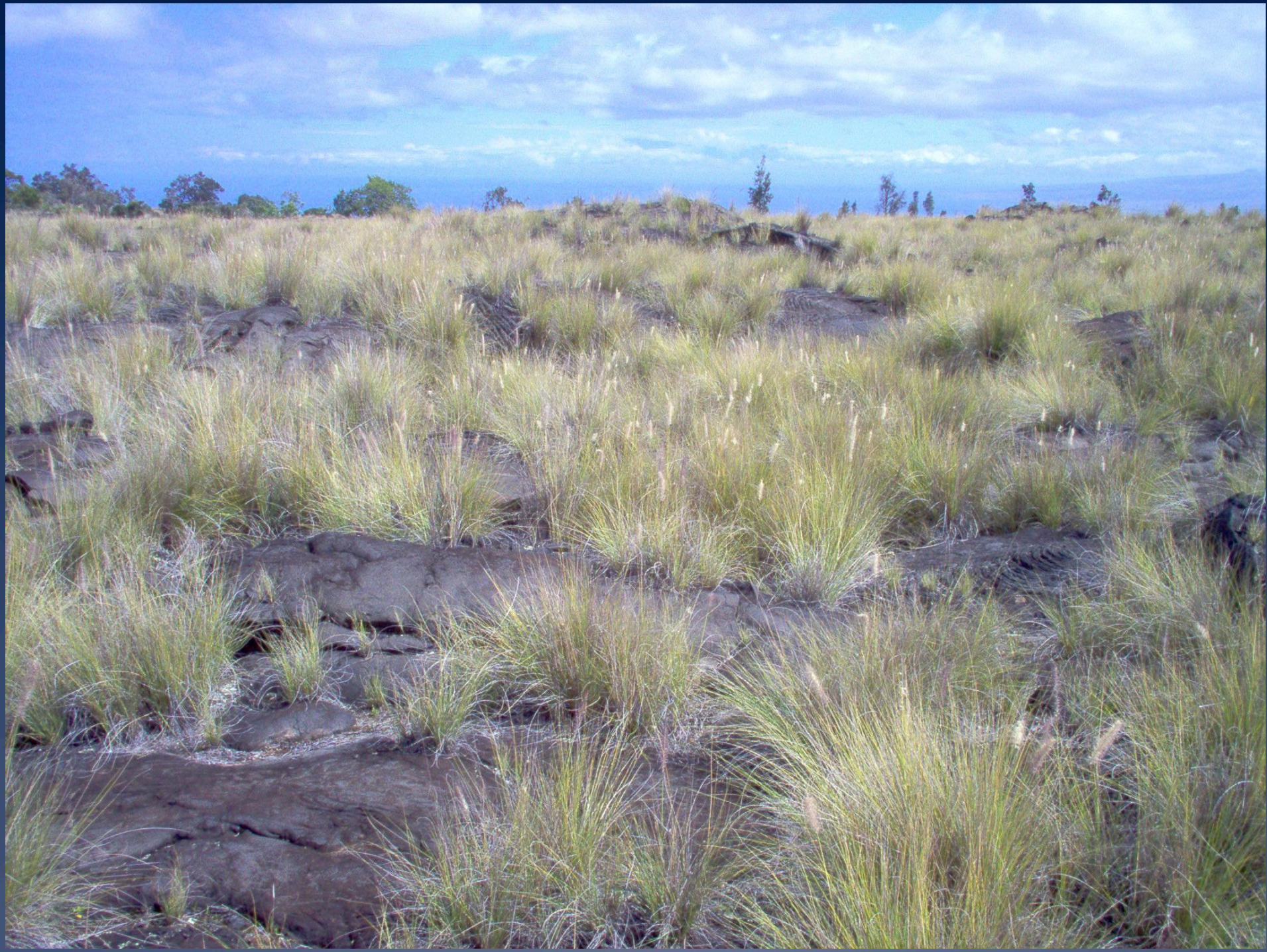
S Mn B

Zn Cu Ni Cl

Mo Fe

Productivity

Phosphorus



P fertility in native ecosystems

P fertility in native ecosystems

P lost
erosion,
leaching

Soil organic matter
P

P fertility in native ecosystems

P added
weathering,
dust

P lost
erosion,
leaching

Soil organic
matter
P

P fertility in pre-industrial agriculture

P fertility in pre-industrial agriculture

food harvest

Soil organic matter

P

P fertility in pre-industrial agriculture

P lost
erosion,
leaching

food harvest

P fertility in pre-industrial agriculture

P added
weathering,
dust

P lost
erosion,
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P fertility in pre-industrial agriculture

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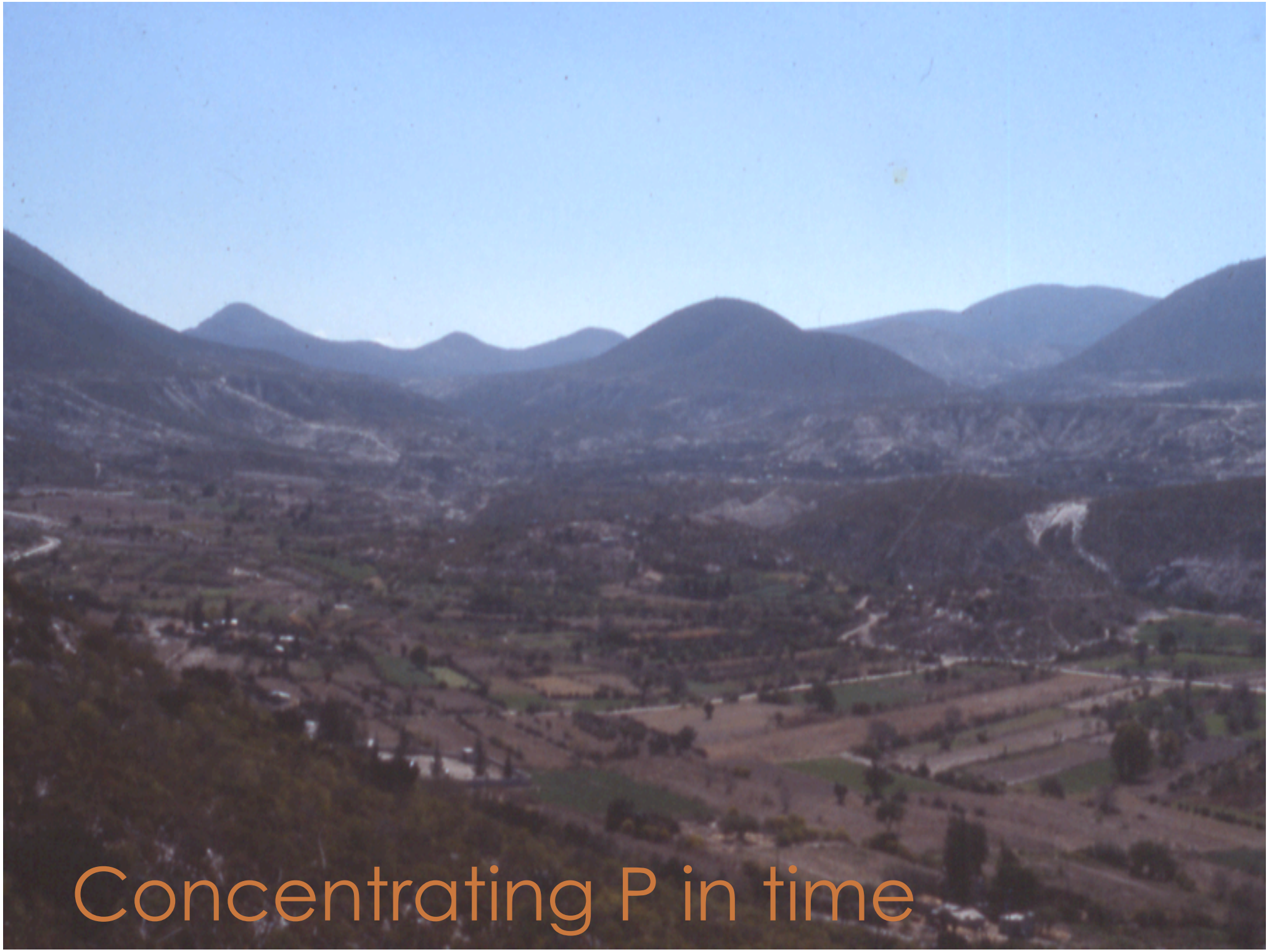
weathering,
dust

P lost
erosion,
leaching

food harvest

Rate of P weathering ≈ rate of removal

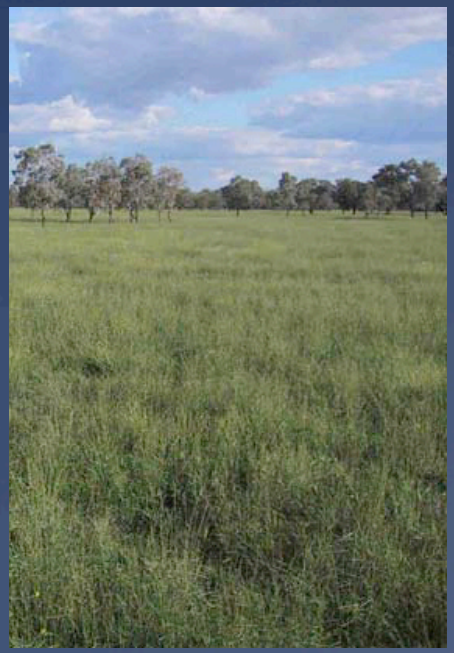
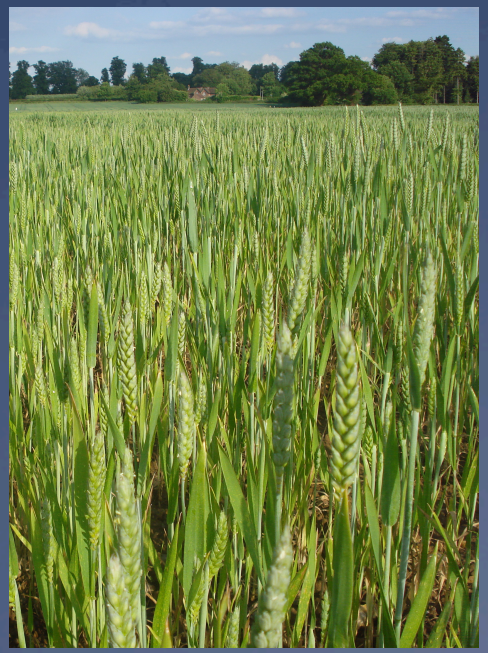
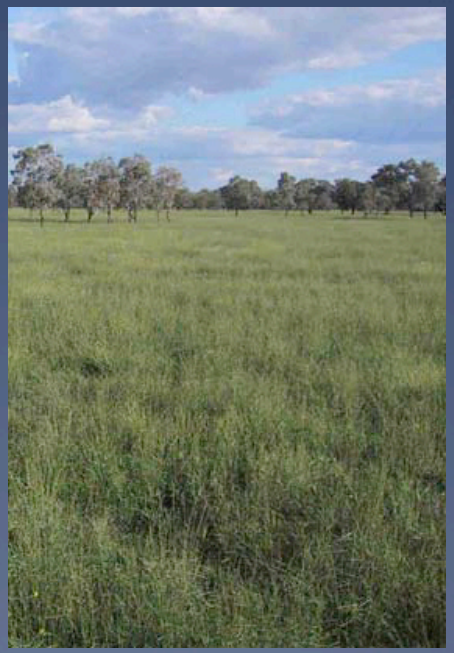
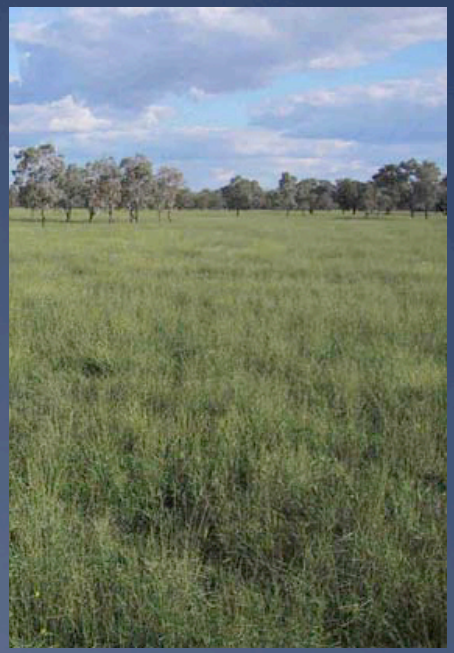

Concentrating P in time

Cover crop "banking" weathered P

Crop fertilized with 2 years of weathered P

Four year rotation: Annual grain crop 1 year, Perennial pasture 3 years

Perennial pasture	Crop	Perennial pasture	Perennial pasture

Concentrating P in time: swidden agriculture

A. Cortes

Concentrating P in time:

Fifteen year swidden rotation involving 2 years of cropping

Forest re-growth	**CROP**	**CROP**	**Forest re-growth**	**Forest re-growth**
Forest re-growth	**Forest re-growth**	**Forest re-growth**	**Forest re-growth**	**Forest re-growth**
Forest re-growth	**Forest re-growth**	**Forest re-growth**	**Forest re-growth**	**Forest re-growth**

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Concentrating P in time:

Fifteen year swidden rotation involving 2 years of cropping

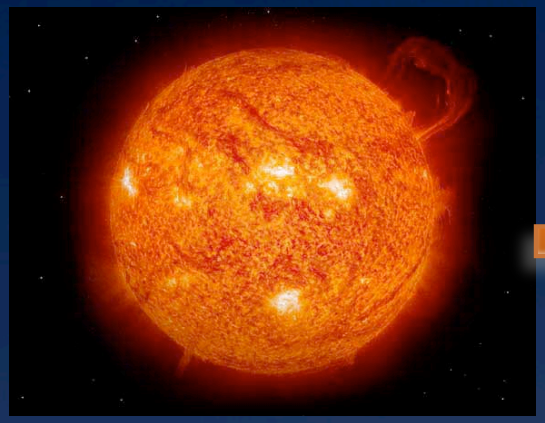
Forest re-growth	Forest re-growth	Forest re-growth	CROP	CROP
Forest re-growth	Forest re-growth	Forest re-growth	Forest re-growth	Forest re-growth
Forest re-growth	Forest re-growth	Forest re-growth	Forest re-growth	Forest re-growth


Concentrating P in space

Concentrating P in space: harnessing gravity

Sierra Madre runoff diversion

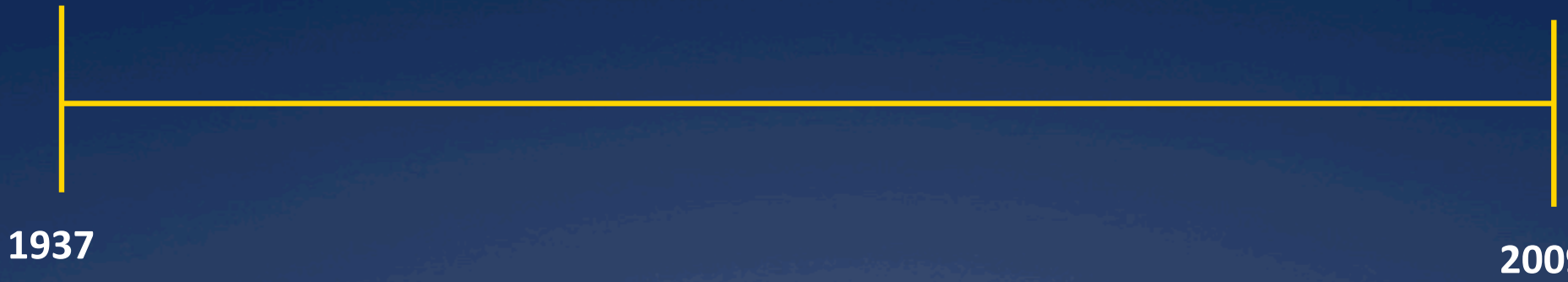
Nile river floodwater deposition



Colonel Edwin Drake's oil well

Titusville, Pennsylvania

August 1859

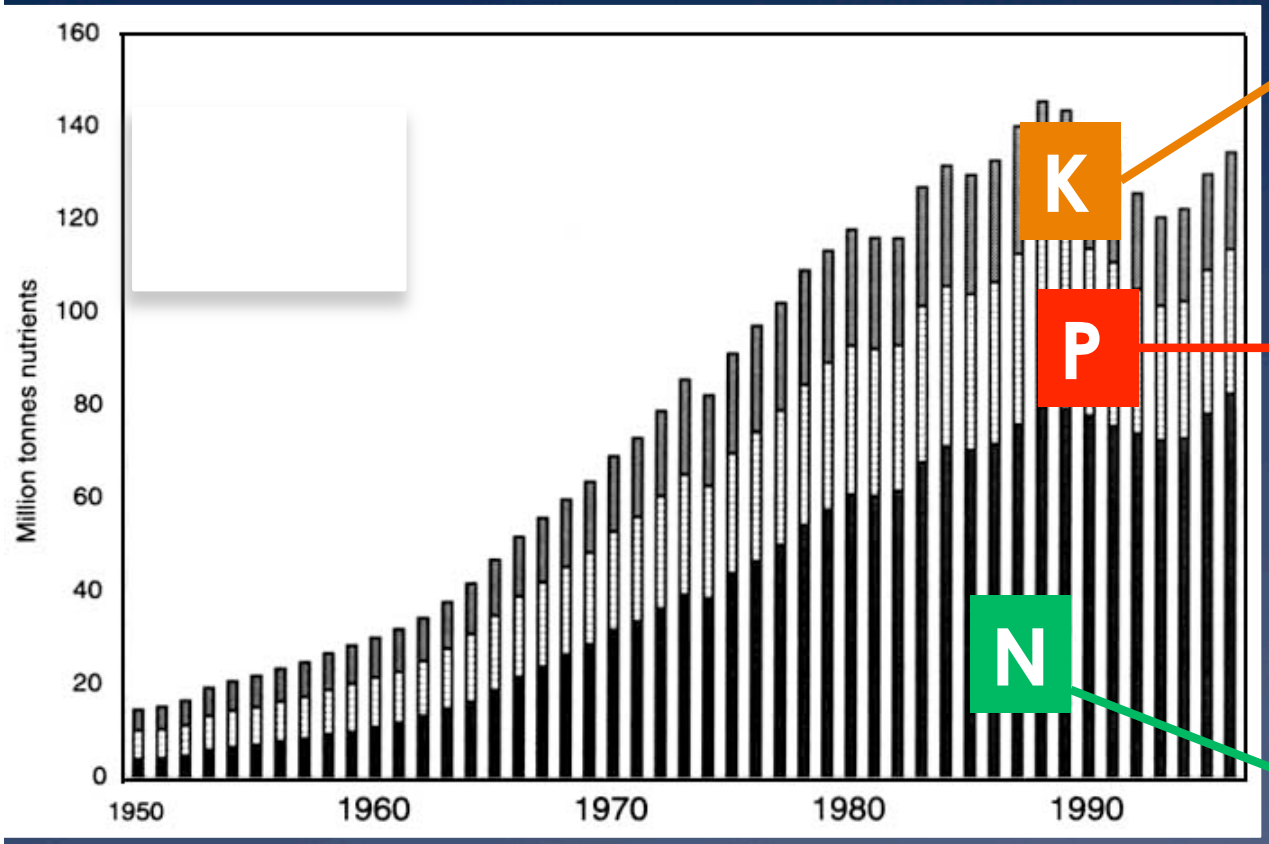


In the lifetime of a 72 year old, >97% of all oil ever consumed has been burned

Agriculture with fossil fuel energy

- Farming methods no longer bound by solar energy
- Discover and exploit highly concentrated reserves of P and other elements—and use them once.

Global increases in potassium, phosphorus, and nitrogen fertilizer applications 1950-1996



Photos: Mikkelsen IPNI

Example of a P balance for modern wheat production

P inputs	kg ha^{-1} yr^{-1}	
Soil mineral weathering	0.3	
Atmospheric deposition	net 0	
Fertilizer	25	
Total		25.3

P outputs	kg ha^{-1} yr^{-1}	
Leaching	0.4	
Soil erosion by water	0.5	
Soil erosion by wind	net 0	
Harvested grain	19	
Straw	3	
Total		22.9

Newman (1997)

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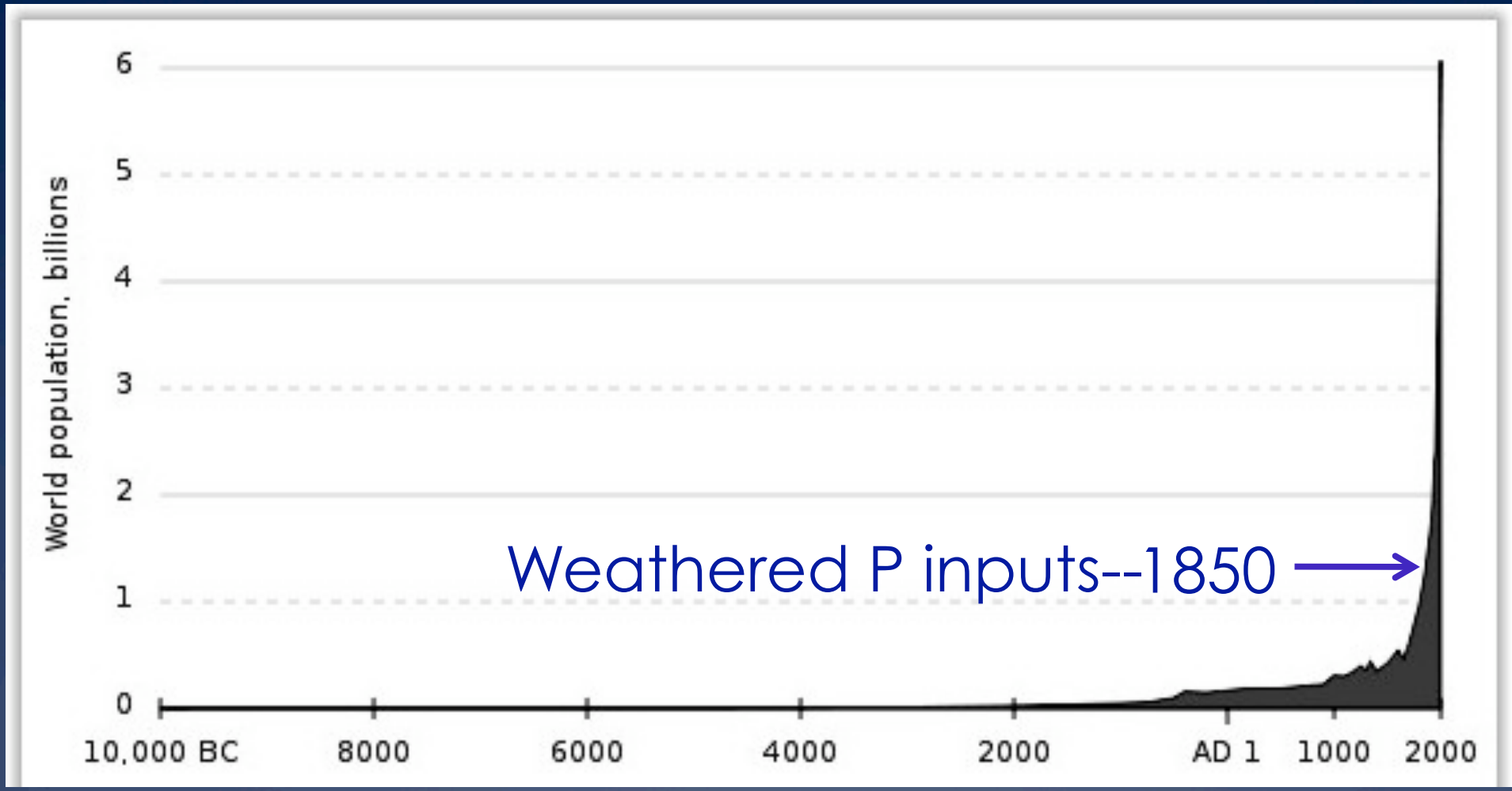
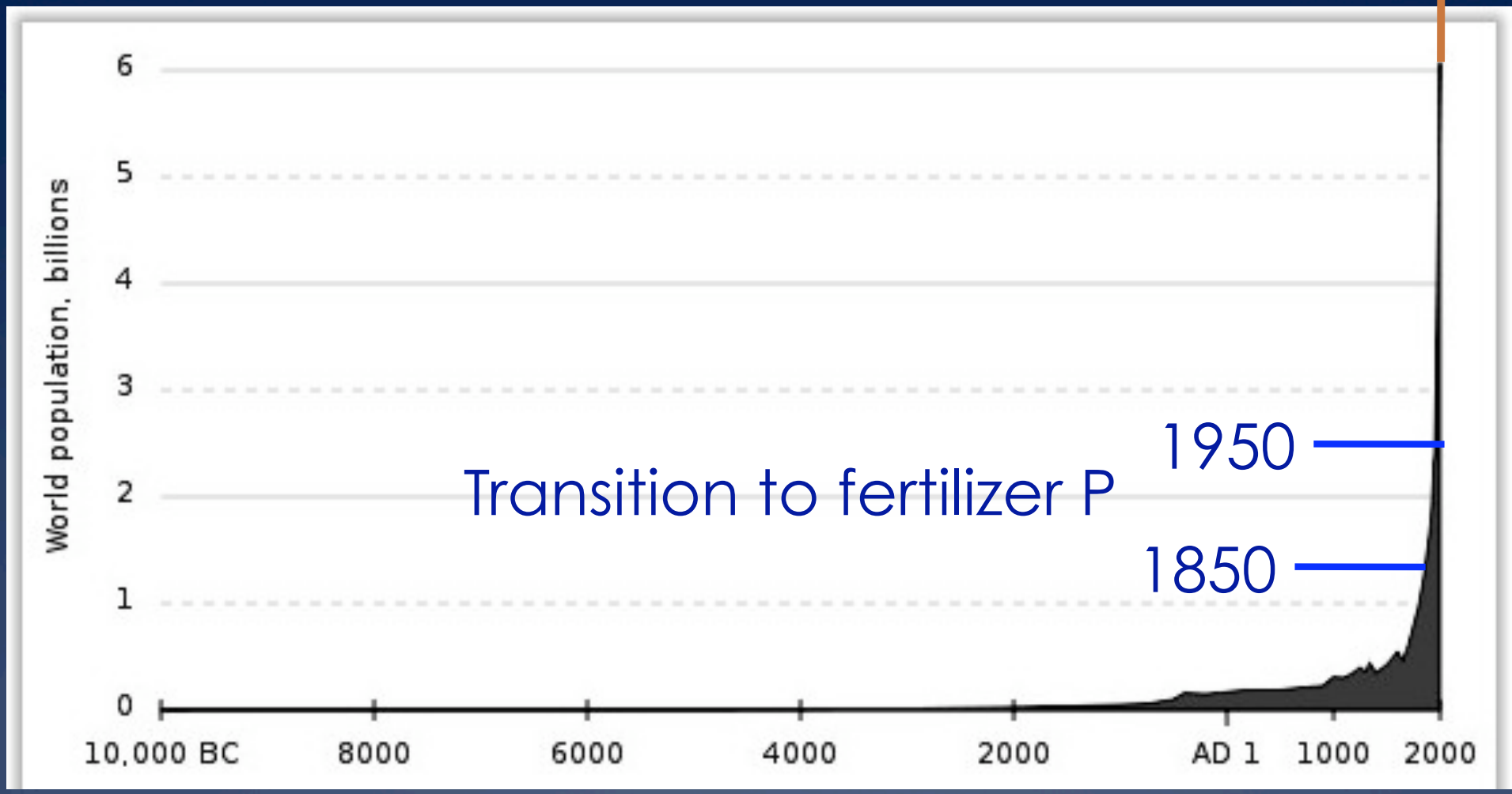

World population, billions
6
5
4
3
2
1
0
10,000 BC
8000
6000
4000
2000
AD 1
1000
2000
Weathered P inputs--1850


Current 6,790,062,216
World population, billions
6
5
4
3
2
1
0
10,000 BC
8000
6000
4000
2000
AD 1
1000
2000
1950
1850
Transition to fertilizer P

P fertilizer and sustainability

The Goldilocks Conundrum

Does too much + too little = just right?

Too Much P

Surface erosion

Leaching

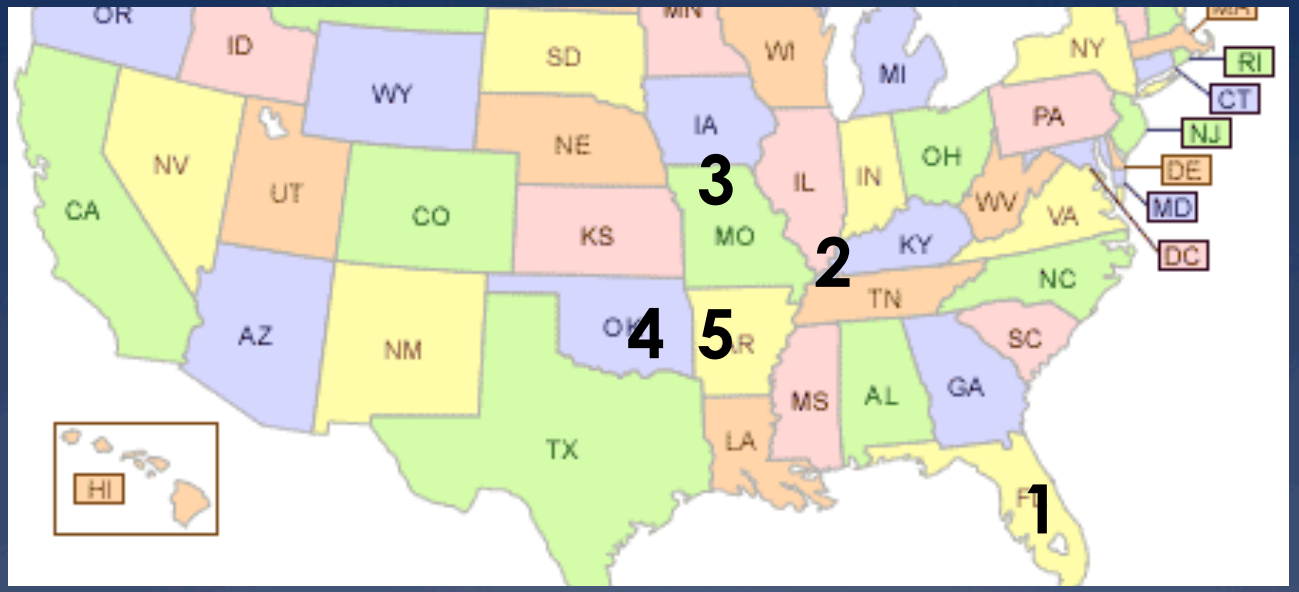
Drinking water, biodiversity, fishing, recreation

Eutrophication


1


2


3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The Morning News (Arkansas)
Saturday, September 19, 2009

Local News for Northwest Arkansas
Poultry Litter Industry Trial Set To Begin Thursday In Tulsa Court

By Doug Thompson
THE MORNING NEWS

FAYETTEVILLE — The Oklahoma attorney general's case against Arkansas-based poultry companies comes down to who's responsible for the safe disposal of chicken litter, both sides agree…….

Now an estimated 345,000 tons of chicken waste each year is produced in 1,800 poultry houses in the 1 million-acre watershed. Farmers dispose of the bulk by spreading it in the hilly watershed as fertilizer. Phosphorous feeds algae, bacteria and other undesired growth, damaging water quality and clarity.