Impact of Agricultural Chemicals on Environment in China , India, The Philippines and Thailand

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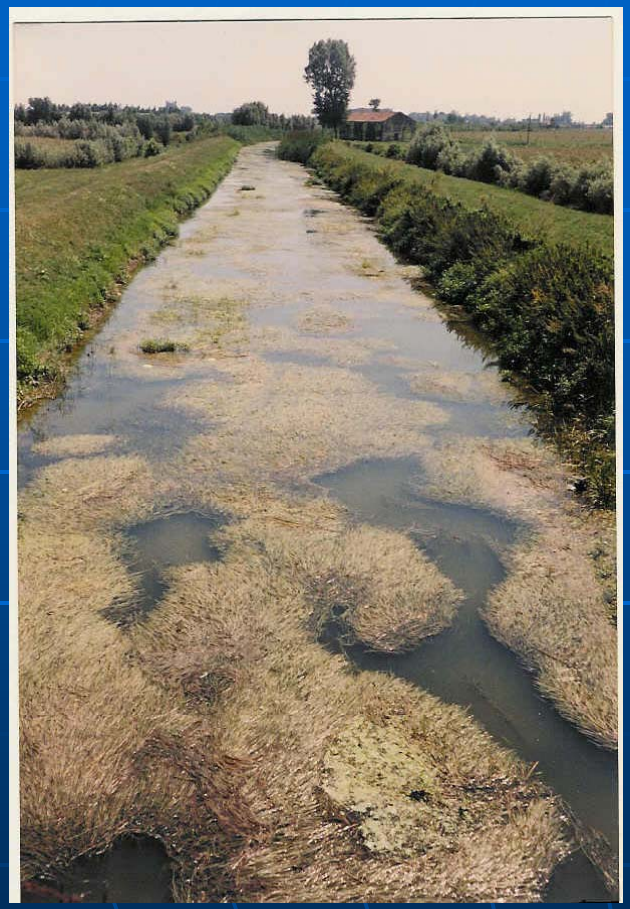
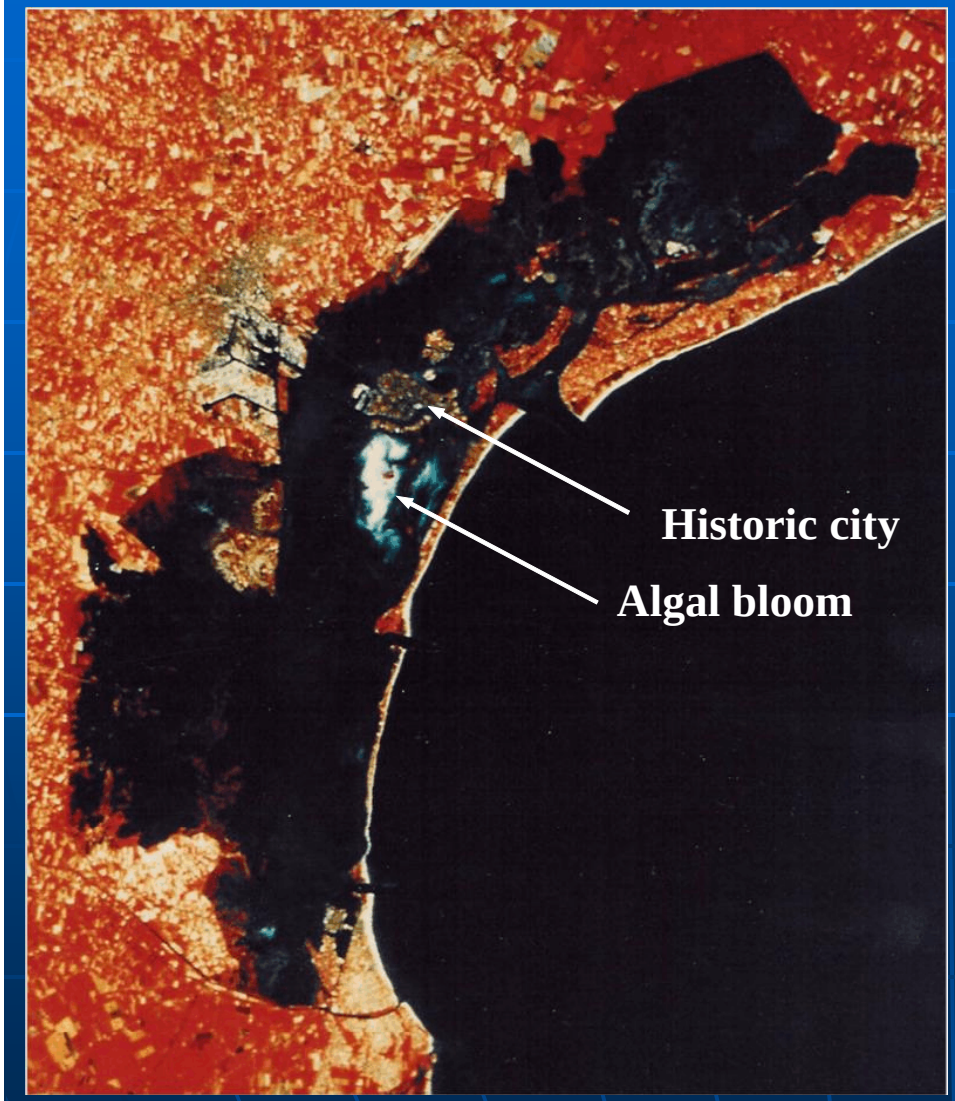
Lagoon of Venice (IT) Problems



Agricultural drainage

- Drainage of wetlands
- Intensive agriculture industrial fertilizers and pesticides
- Wastewater outfall from fertilizing manufacturing on the shore of the lagoon
- Urbanization and transportation
- Tide barrier ?

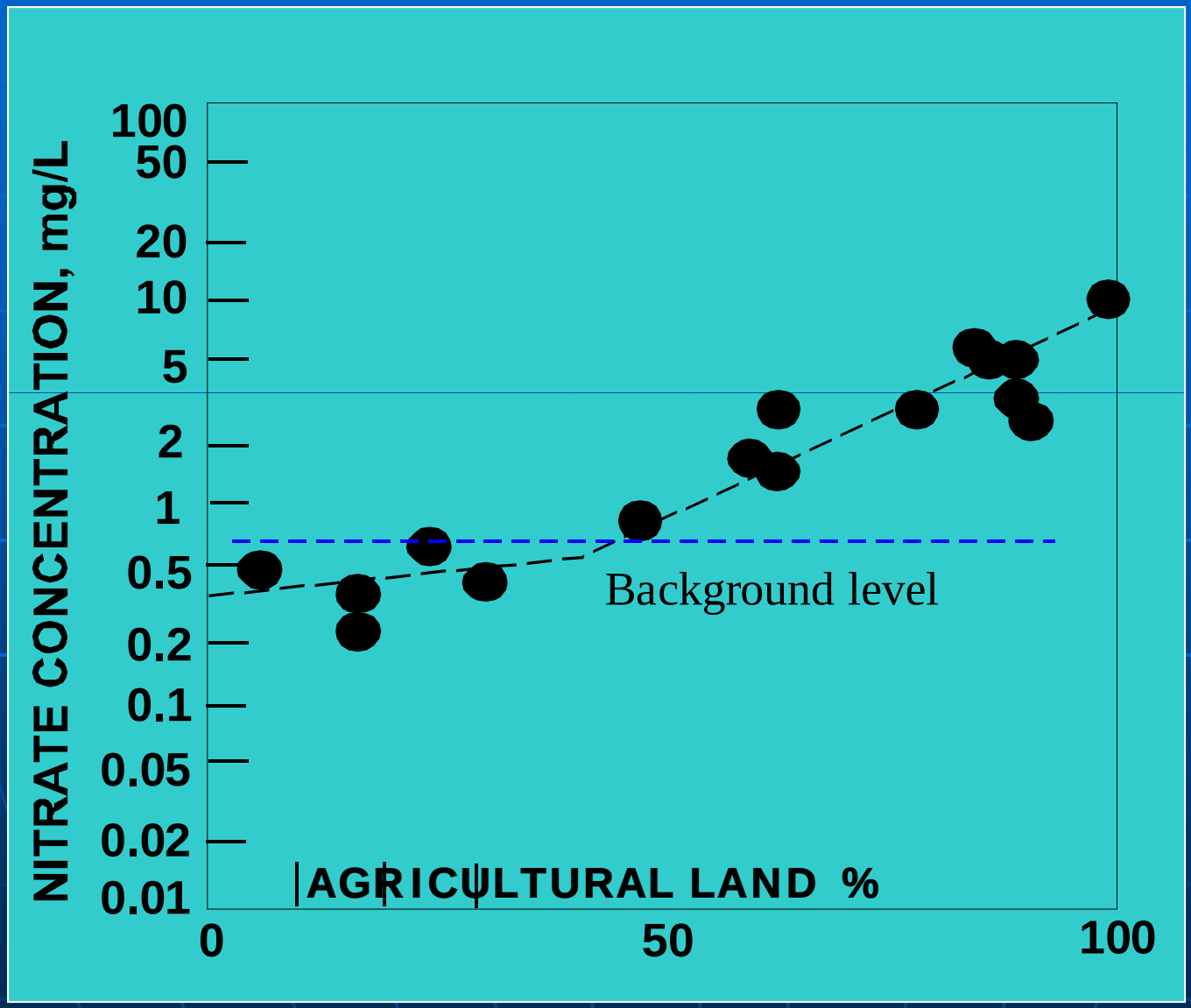


Algal bloom in the Lagoon of Venice in 1980s attributed partially to nutrient discharges from agriculture

Other areas of large scale problems

- Chesapeake Bay
  - Susquehanna River
- Gulf of Mexico
  - Mississippi River
- Black Sea
  - Danube River
- North Sea
  - Elbe

AGRICULTURAL LAND USE INCREASES NUTRIENT CONCENTRATIONS IN RECEIVING WATERS

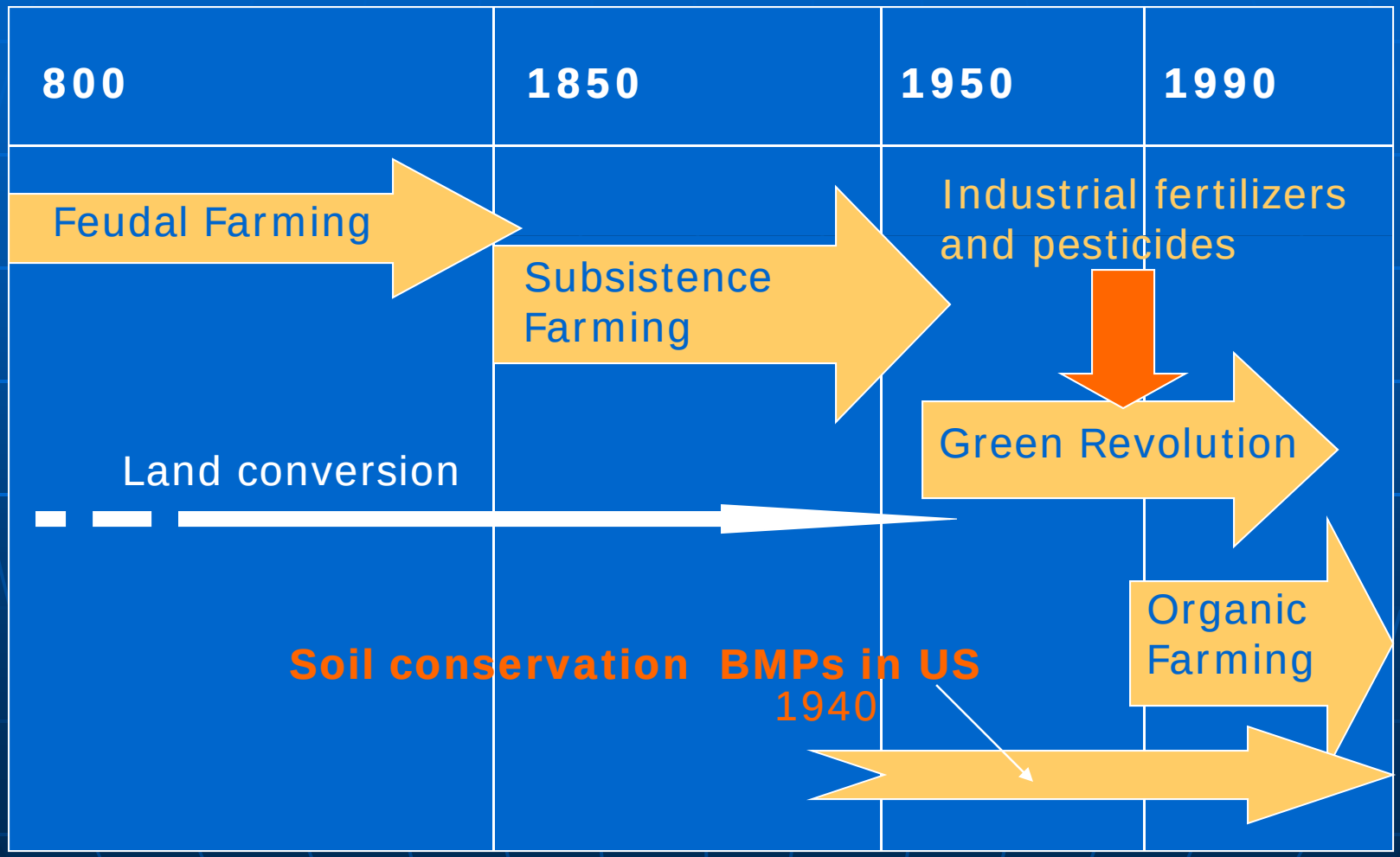


Remaining land use is mostly forest

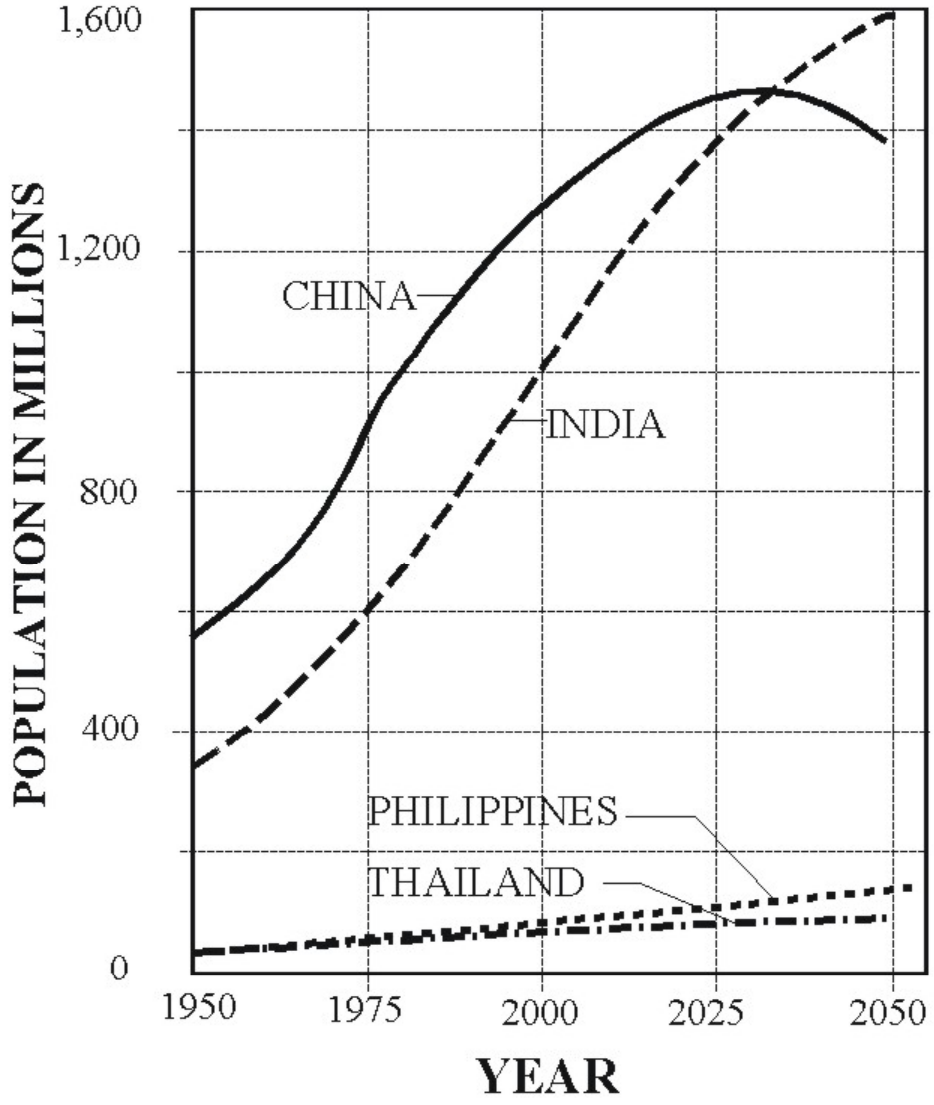
Source USGS

Willamette River Basin, OR

Important Periods of Change of Agriculture



Population in four Asian countries



Population in millions

	1950	2005	2050
CHINA	554	1 315	1 392
INDIA	358	1 103	1 593
PHILIPPINES	20	83	127
THAILAND	20	64	75

Source: GeoHive

Green Revolution

(Intensive Agriculture)

N.E. Borlaug

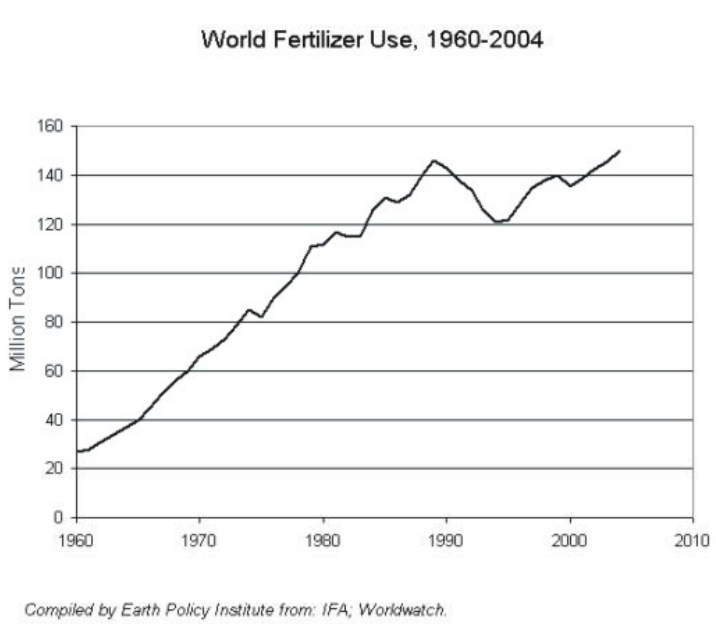
- New crop cultivation methods
- Developing new cop varieties
- Irrigation
- Dramatically increased chemical fertilizer and pesticide applications
- Mechanization

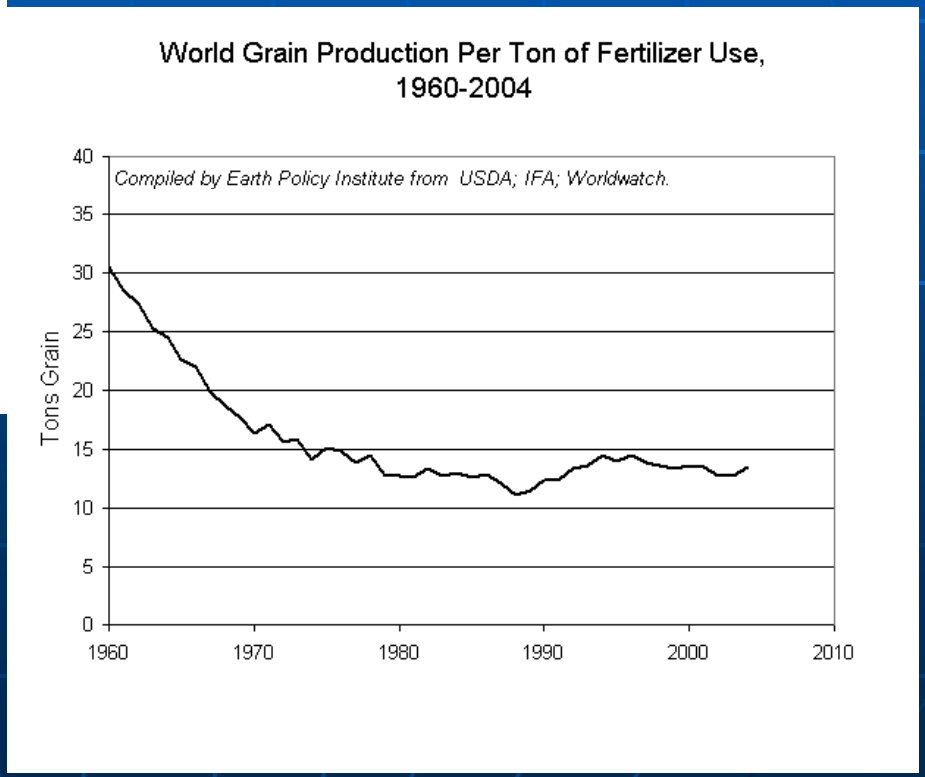
Green revolution

- Has increased crop yields
  - More land would have to be converted to agriculture without green revolution
  - It brought increased standard of living
- Made traditional family farms economically unsustainable
- Diffuse pollution dramatically got worse
- Farm subsidies encourage large intensive operations

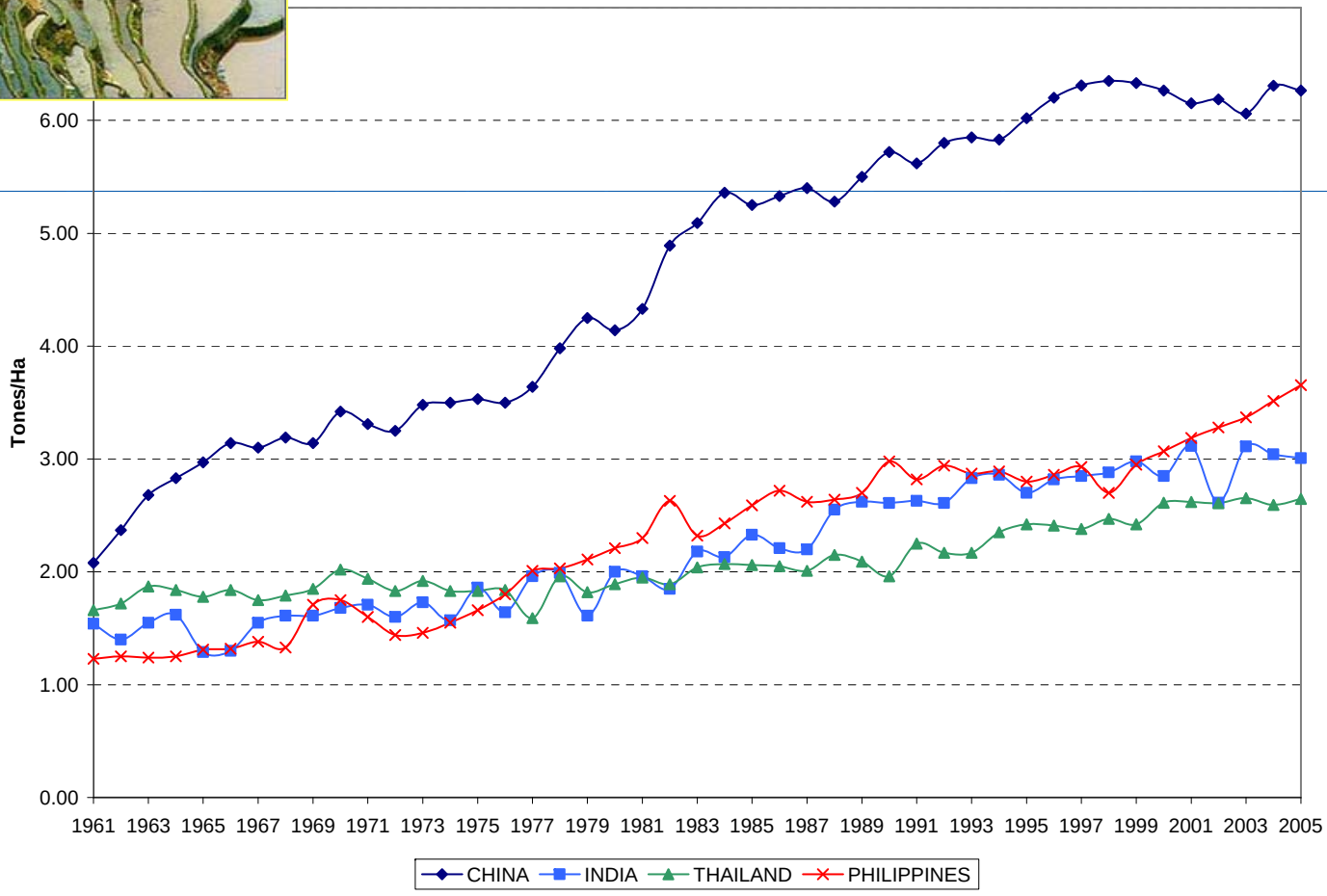
- Borlaug (father of Green Revolution) estimated that if green revolution had not occurred then additional 1.8 billion hectares would have been needed to satisfy the current needs of population
- This “new” agricultural land would come from converted rain forest (tropical humid countries) or from marginal more erosive lands (China)

Worldwide increase of fertilizer use and effect on crop production

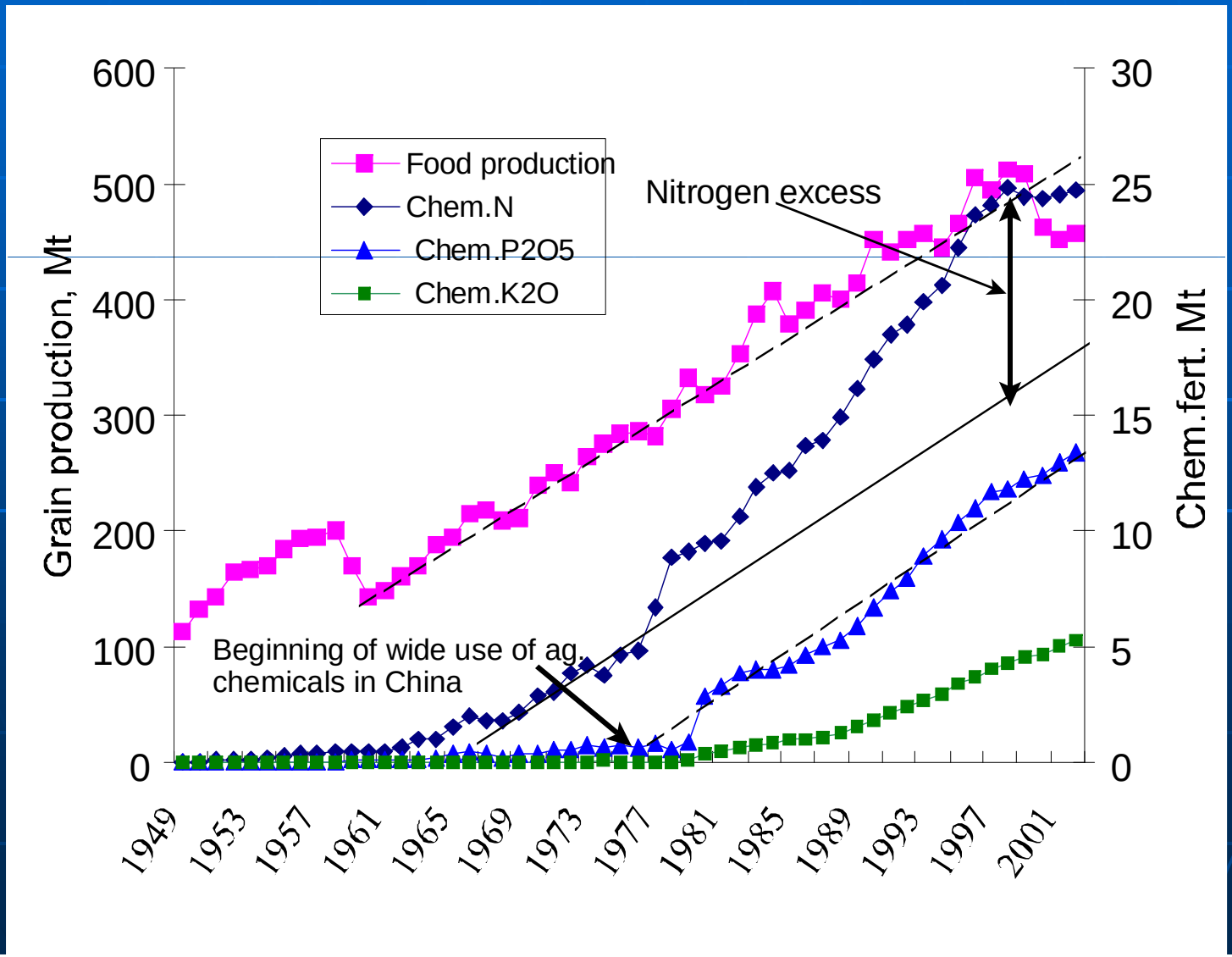




Increased yields of rice



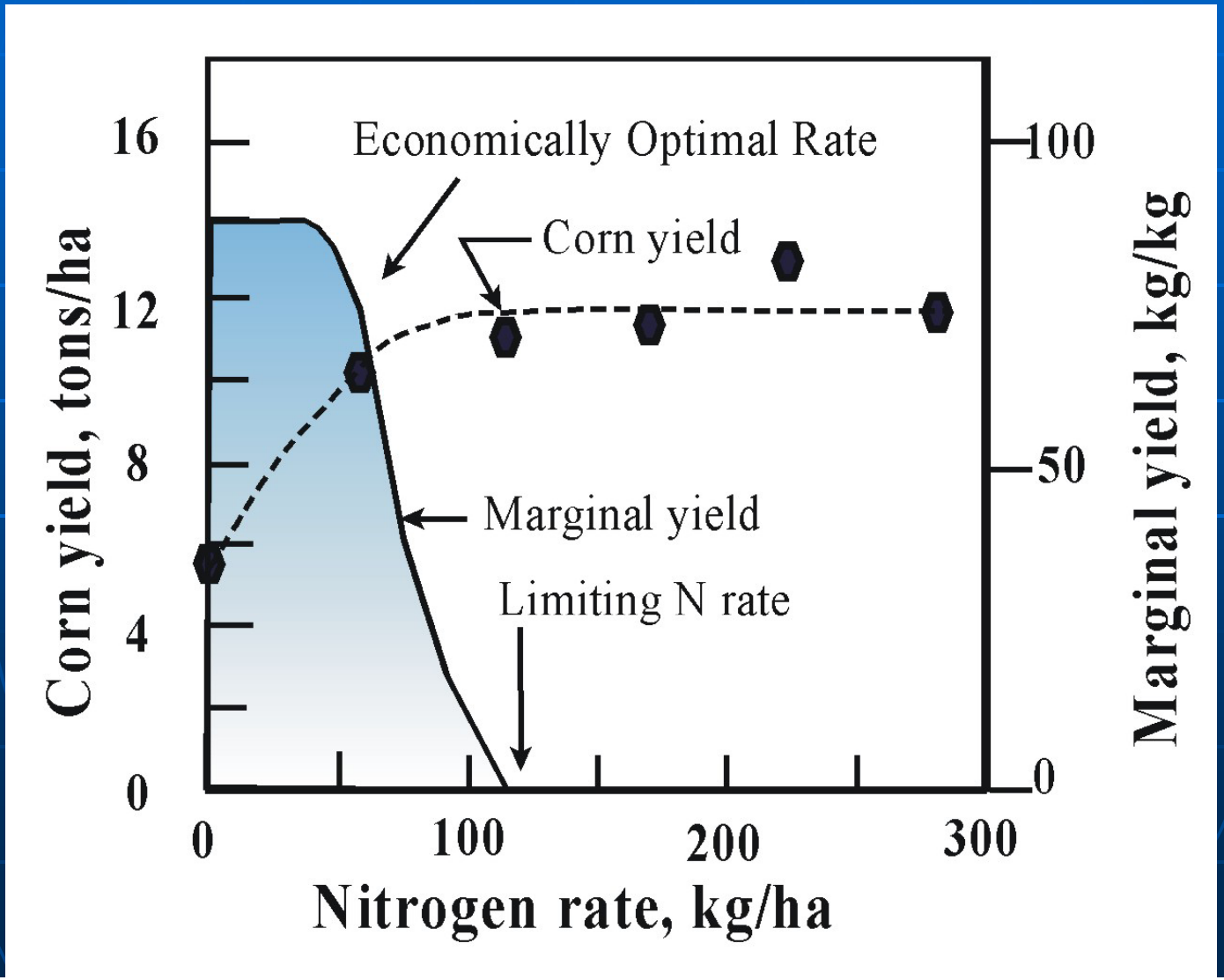
Food production and chemical applications in China



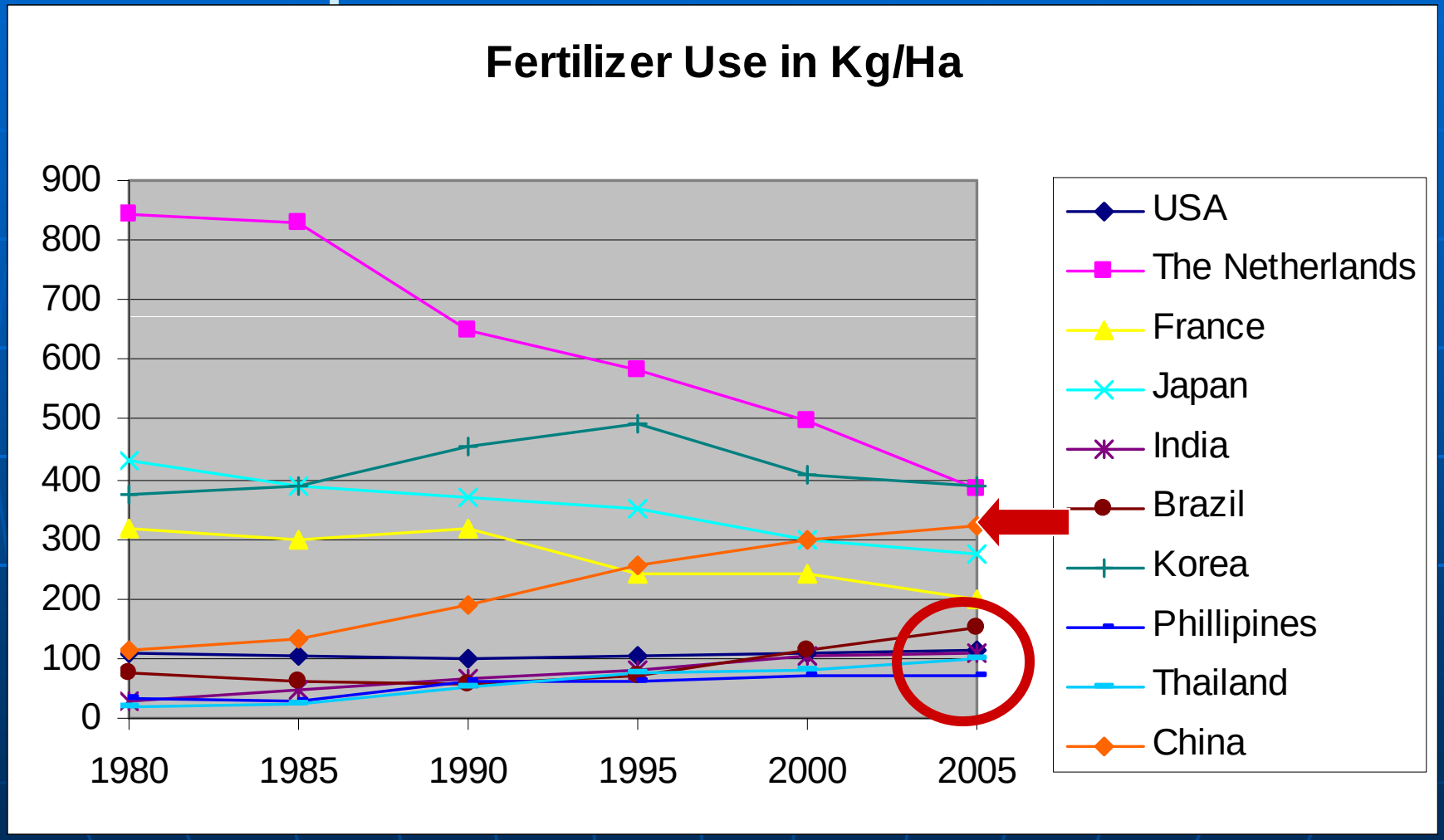
NOTE

The increase of food production is limited by phosphate applications. Nitrogen is in excess

Is increasing of fertilizer application bringing increased yields?



Comparison of fertilizer use



USA, India, The Philippines, and Thailand are at the optimum

Why US is at the optimum range

- Most mechanized agriculture operate with modern agronomic practices
- Crop yields are high
- Agricultural Extension Services are very active and farmers follow the advice.
- US farms are typically large (>5O ha) and many large farmers have college education

Result: Nitrogen concentrations in receiving waters are generally less than 5-10 mg/L

Problems in China

- Small farms operated by less educated farmers
- Very high fertilizer application rates (>300 kg/ha)
- Unbalanced N/P/K ratio – excess N but deficiency of P and K (also in India, Thailand and Philippines)
- Because the plant growth is related to the nutrient in the short supply (e.g., phosphorus) large losses of nitrogen into ground and surface waters occur
- Nitrate is not likely to originate from rice paddies because of reduced (anoxic) conditions in the paddy soils

Can we achieve optimal fertilizer application?

Assumption #1

Groundwater or surface water irrigation, 600 mm of irrigation water in a season with 10 mg/L of TN and 1 mg/l of P

Crop wheat irrigation	N (kg/ha)	P (kg/ha)
Optimum application	120	60
N and P from irrigation water*	- 60	- 6
Organic fertilizer 100 kg/ha of N+P+K**	- 60	-24
From inorganic fertilizer	0	30
Total 30kg/ha		

*The contaminated groundwater containing high concentrations of nitrogen is legacy pollution that can be turned into a resource lasting for several years. This nitrogen recycle is the basic characteristics of sustainable management that emphasizes reuse.

**The proportion of N : P in the organic fertilizer (manure or compost) is 100:30

Assumption # 2

Rain fed field receiving 600 mm of rainfall with 1mg/L of Total N and 0.15 mg/L of P

Crop wheat – rain water	N (kg/ha)	P (kg/ha)
Optimum application	120	60
N and P from rain	-6	-1
Organic fertilizer 100 kg/ha of N+P+K	-60	-24
From inorganic fertilizer or credit[1]	54	35
	Total 90 kg/ha	

[1] No till planting typically requires increased application of herbicides. It can be effectively used for reducing erosion on medium slope fields but the need for more herbicide may offset the benefits of reducing nutrient requirement.

- It is far more preferable to use organic balanced fertilizers that provide organic carbon, nitrogen, phosphorus and potassium, than to use monofertilizer industrial chemical compounds.
- If the carbon is not provided, soil carbon that also nurtures a healthy soil microbiological population will be reduced.
- Dried (pasteurized) sludge from biologic municipal waste water treatment plants can also be used to provide organic fertilizer (N content 5%, phosphate content 2.6%, potassium 0.4 %)*

*http://www.milorganite.com

Pesticide application

Country	Pesticide Application rate kg/ha-year
Costa Rica	51
Columbia	18.5
Japan	13
China	**9.4**
Korea	9
Thailand	**7.3**
United Kingdom	5.3
France	5.1
Switzerland	3.5
Germany	3.0
Philippines	**2.1**
South Africa	1.1
Brazil	1.1
Pakistan	0.6
India	**0.32**
Bangladesh	0.23

South America

(bananas and citrus) is the highest

Severe effects on plantation workers

Pollution from animal operations

- Change of animal operations from small scale family animal husbandry and pasture to concentrated feedlots made possible by green revolution with hundreds (cattle) or thousands (pigs, chickens, turkeys) animals in a small space
- Consequences:
  - Large increase of diffuse pollution on top of the nutrient losses from fields
  - Poor disposal into soils
  - Soil overloading, disposal on frozen soils

- There is no optimal use of pesticides
- Pests (insects) can get acclimated and resistant to a pesticide, leading to ever increasing doses
- Farmers mix pesticides in a cocktail
- Most of severe health damages occur in pesticide handling and storage by family members (mostly women) not familiar with the dangers
- Integrated pest management is slowly being implemented in India, The Philippines and Thailand

- Integrate Pest Management includes
  - Use of pest resistant varieties of crops;
  - Timing of sowing and planting, crop rotation, better water management, targeting the fertilizer application to plant needs so that strong and resultant plants would be grown;
  - Pest monitoring by insect traps and careful observations;
  - Biological controls such as Bacillus thuringensis (Bt);
  - Natural pesticides such as neem;
  - Proper storage and handling;
  - Education of farmers.

Accumulation in soils and aquatic systems

- 20% of applied phosphorus and 50% of applied nitrogen to land reach receiving waters (NAWQA)
- Accumulation rate of phosphorus ranges 3 to 18 kg ha^{-1} $year^{-1}$
- Highest accumulations of nutrients from fertilizers and waste application
  - Japan
  - EC Community
  - US
- Fertilizer use on suburban lawns in the US is several times larger (per unit area) than that on farms

Water quality impacts

- Increased phytoplankton, periphyton and aquatic macrophyte growth, characterized as primary productivity, to a level that they become overwhelming and a nuisance.
- Turbidity increases and transparency decreases. Secchi disc depth measurements in eutrophic waters are less than 1 m.
- Eutrophication increases oxygen consumption in the system that can lead to short term toxic levels (e.g., less than 3 mg/L) due to DO concentration fluctuations by photosynthesis and respiration During night and/or cloudy hours, oxygen can drop to a lethal level and cause fish kills.

- Eutrophication can have deleterious consequences in estuaries even when DO levels are not toxic. These changes include loss of diversity, and changes of both planktonic and benthic communities. Seagrass beds and coral communities are especially vulnerable .
- Harmful algal blooms by cyanobacteria that produce toxins and change biota.
- Rash and gastrointestinal diseases to swimmers.
- Deteriorating water quality of freshwater used for human consumption, increased cost of treatment, taste and odor problems or even taking drinking water supplies out of providing potable water to the population and economy.
- Adverse impact on aesthetics.

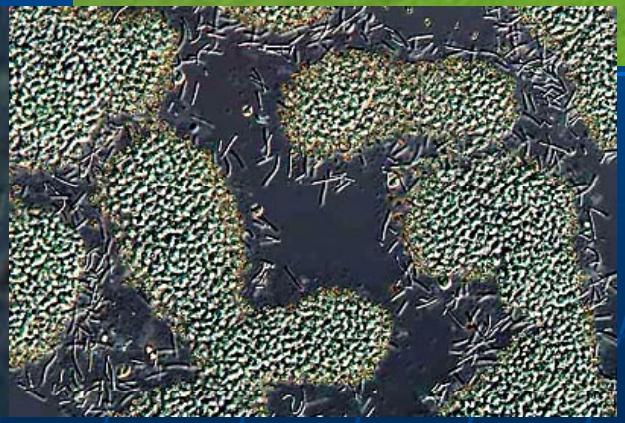
Consequence – Algal blooms by cyanobacteria (blue – green algae)

- Algal bloom defined as 10^6 organisms /ml
- Cyanobacteria prefer higher temperatures
- The oldest surviving organisms on earth
- Form akinetes and spend winter in sediments where they get a lot of nutrients

Orlik reservoir on Vltava River in Czech Republic

Blue – Greens in Czech Republic

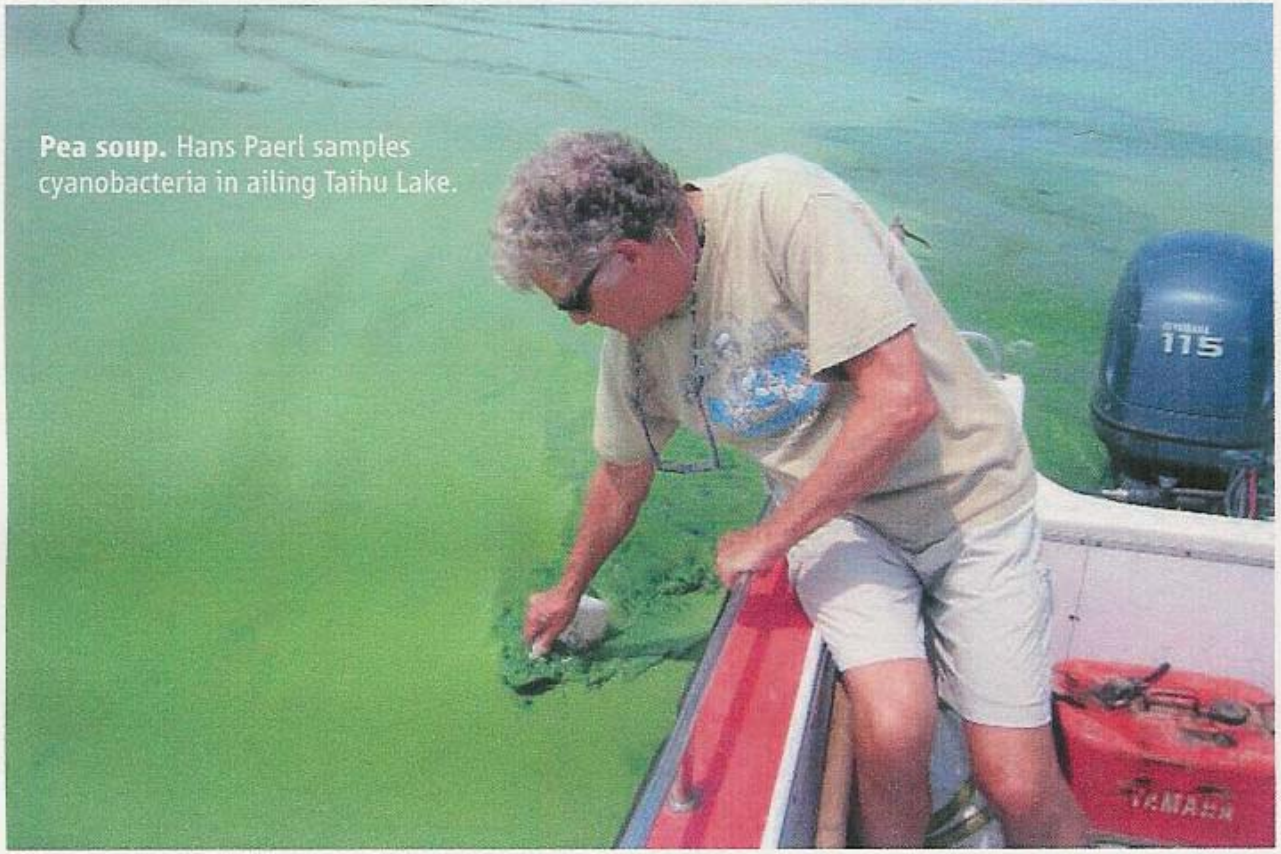
Orlík



Sedlice

75% or reservoirs in Czech Republic have been infected

PEA SOUP IN CHINA



Pea soup. Hans Paerl samples cyanobacteria in ailing Taihu Lake.

ECOLOGY

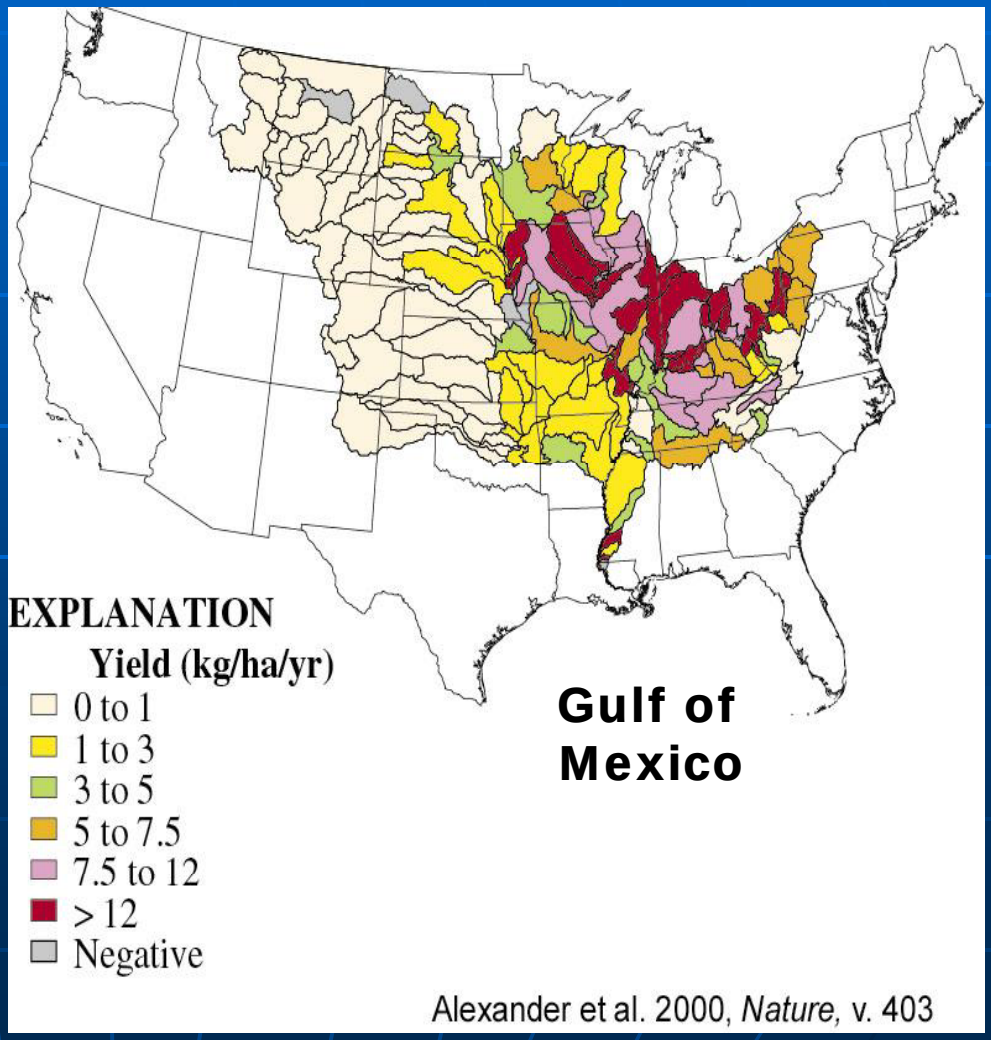
Doing Battle With the Green Monster of Taihu Lake

In attempting to subdue a vicious algal bloom, scientists aim to restore the health of

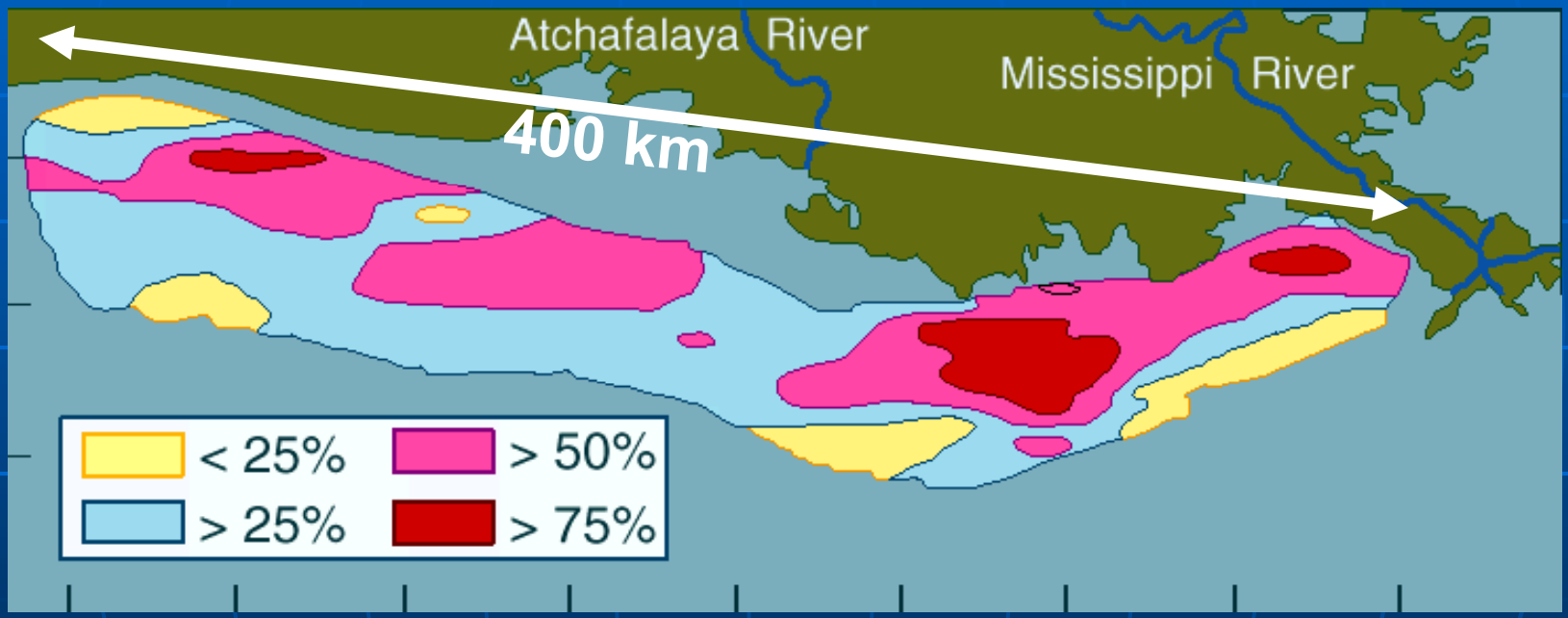
IMPACT OF AGRICULTURE

- Intensive agriculture in the “Bread/Corn basket of America”
- High nutrient loads to the river and the Gulf of Mexico
- Nitrogen is the limiting factor for the eutrophication problems in the Gulf of Mexico

Nutrient yield in the Mississippi River



Extent of Hypoxia in the Gulf

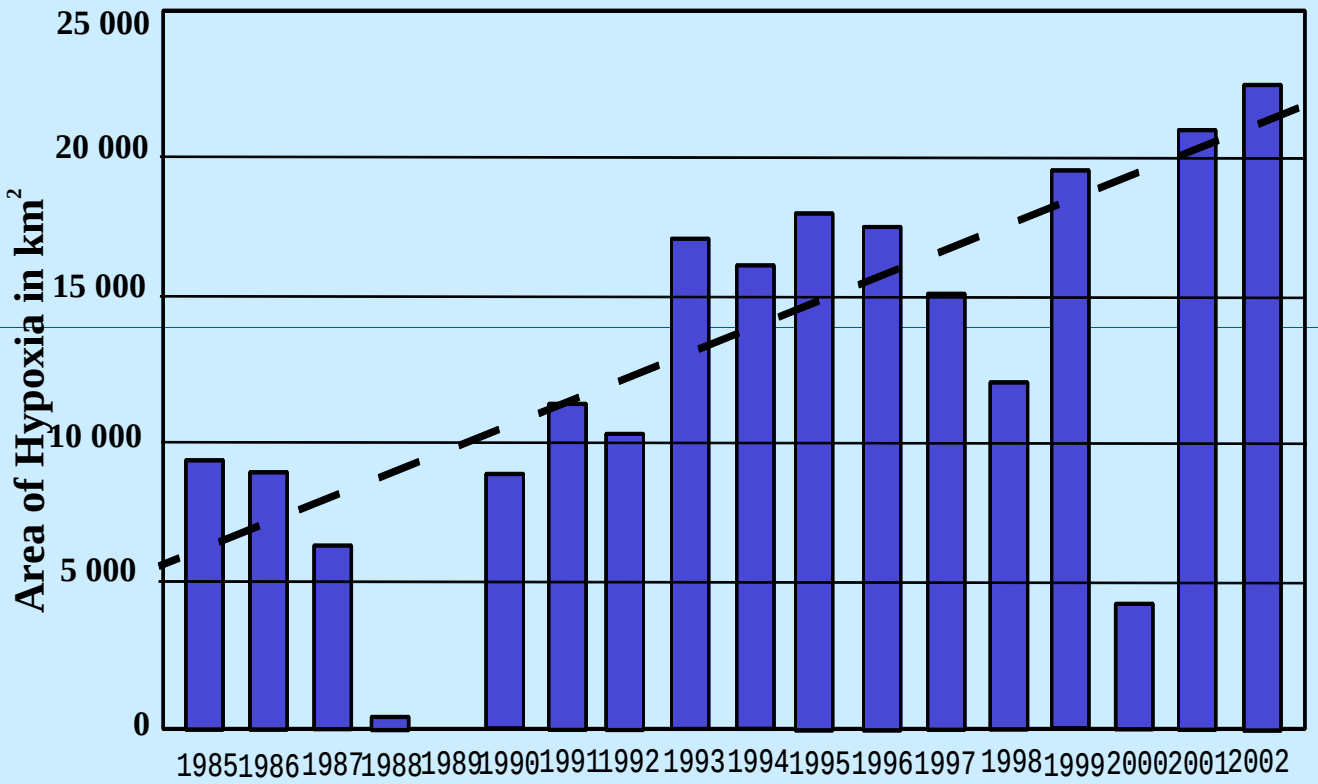


Frequency of Occurrence 1985 - 1999

Rabalais, et al.

Distance Paris to London = 490 km

Area of hypoxic zone 1985 - 2002

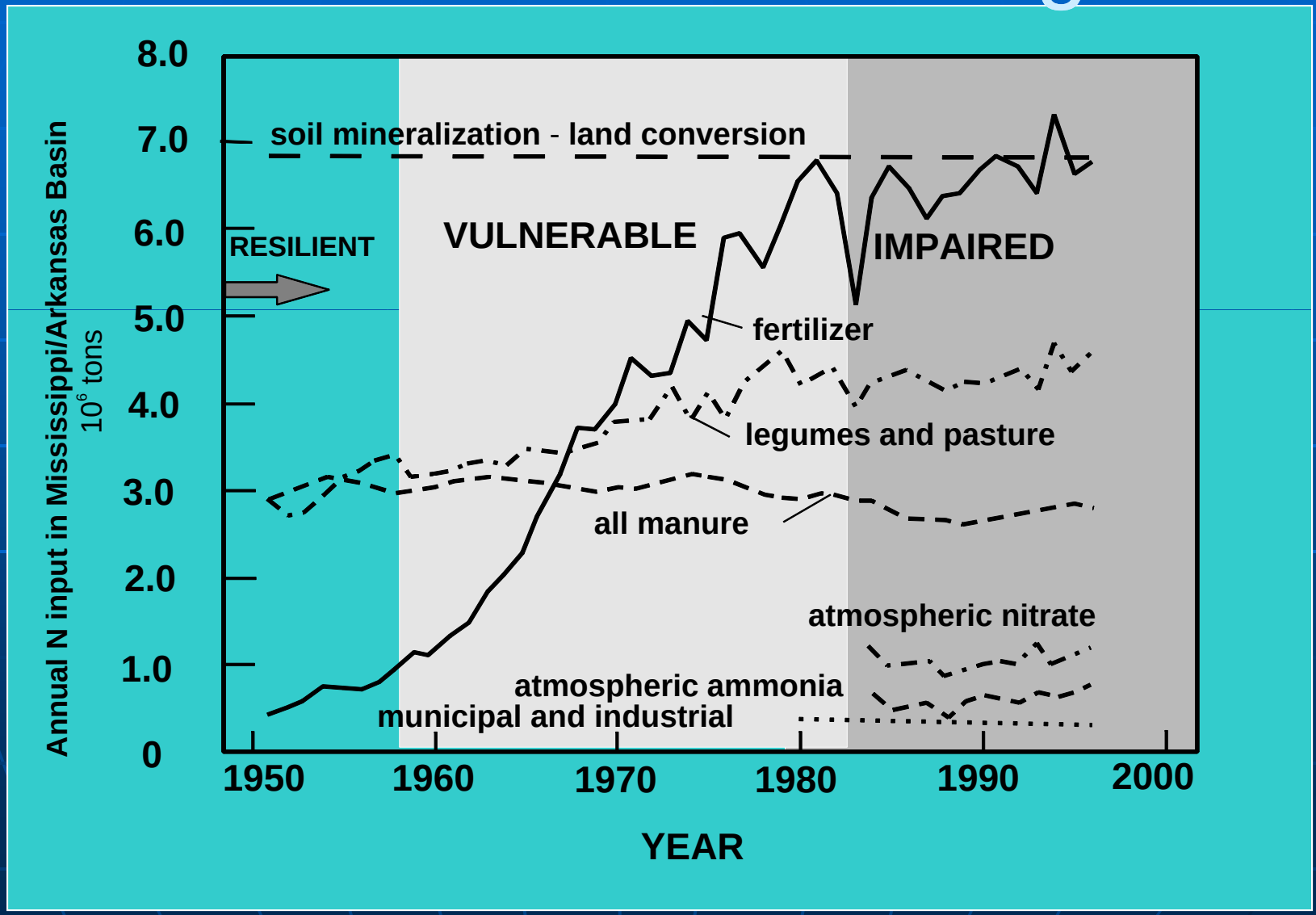


Note: Hypoxia in the Gulf is defined as less than 2 mg/L of DO

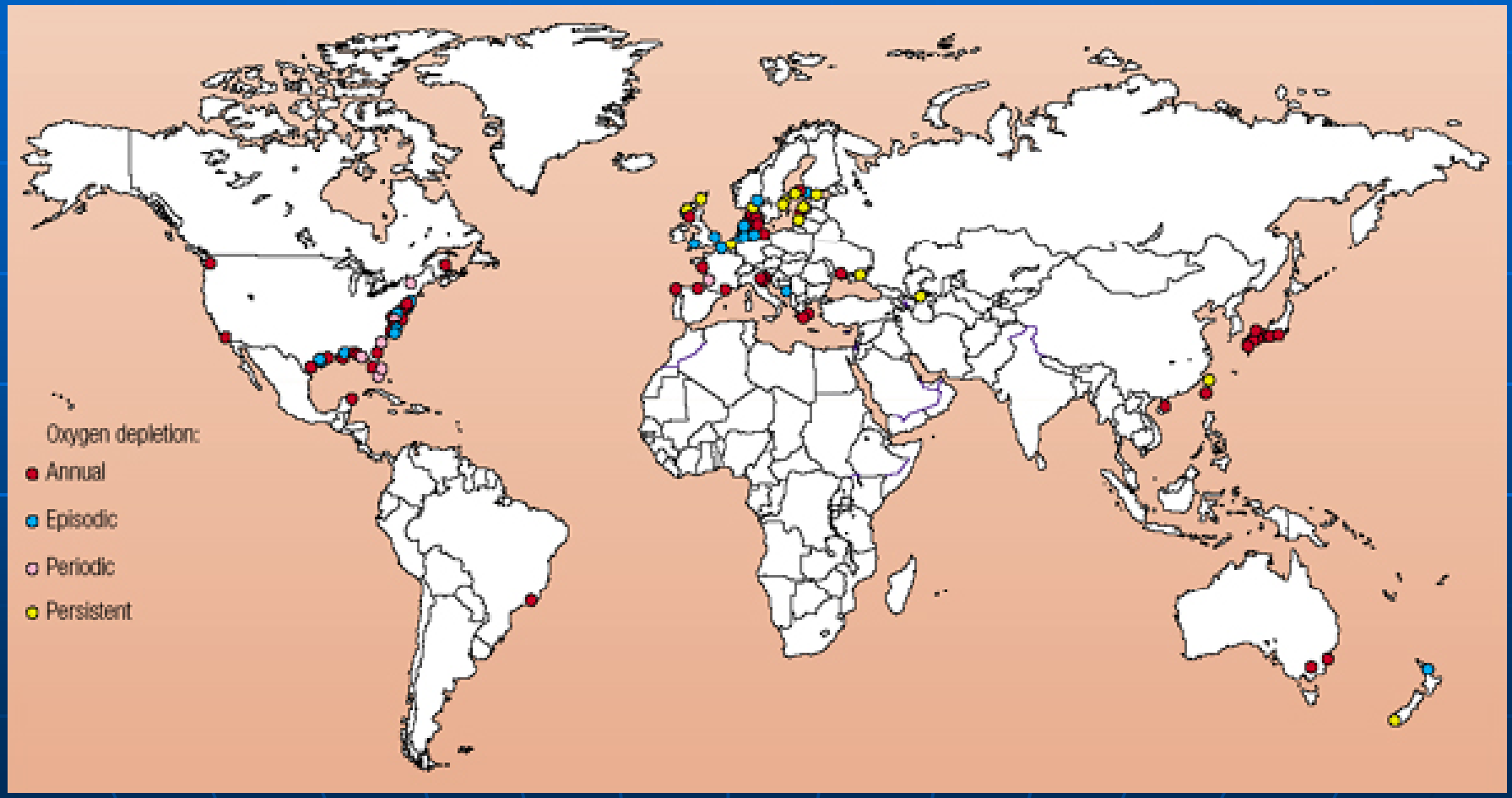
Source Rabalais et al.

By interpolation, hypoxia problems started around 1960

Overall balance of nitrogen



Worldwide hypoxia locations



Community response

- Intensive research and development of BMPs
  - Soil conservation (since mid 1930s)
  - Integrated pest management
  - Buffer strips and field borders
  - Animal feedlot management
  - Targeting fertilizer needs of crops
  - Incorporation and restoration of wetlands
- Grass root movement to organic farming
- Taking polluting agricultural lands out of production

Three types of farming

- Subsistence (mostly small family farms)
  - Expanded by land conversion
  - Without education and some incentives hardly environmentally sustainable (slash, burn, farm and move away)
  - Subsistence farmers in developing countries often may not reason beyond providing food for their families
- Commercial (Large industrial farms and animal operations)
  - High reliance on fertilizers and pesticides, mostly monocultural
  - Large increase of nutrient inputs into receiving waters

Organic Farming

- Ecologically manageable systems
- Still relatively small
- Dramatic growth in Europe and US
- Is it sustainable and/or less polluting?

Converting the entire agriculture sector to organic farming is a challenge and only a long term goal

Sustainable Agriculture?

Shortest definition of sustainability:

A sustainable agriculture is one that, over a long term, (1) enhances environmental quality and the resource base on which agriculture depends, (2) provides for basic human food and fiber needs, (3) is economically viable, and (4) enhances the quality of life for farmers and the society as whole

American Society of Agronomy

Dream, Conflicting or Achievable?

Three Types of Farming

Parameter	**Subsistence**	**Commercial**	**Sustainable (organic)**
Social identity	Family	Corporation	Family or Community
Nature of change	Uncontrolled	Controlled	Planned and anticipated
Government support	Education and grants for BMPs	Subsidies for production and set- aside land	Same as subsistence
Relation to environment	Vulnerable	Control over	Anticipatory
Natural resources	Finite; consume; relocate when exhausted	Develop and and consume	Finite; conserve and preserve
Role of government	Undeveloped and unstable	Coordination, protect rights and needs of land owners	Regulate
Knowledge base	Tradition	Science and technology	Science and technology
Impact on diffuse pollution	Localized, could be significant over long term	Significant and widespread	Small, often none
Cost of externalities	Medium	Large	None

From Novotny (2003) and Padgitt and Petrzelka (1994)

Conclusions

- Over the last 50 years there has been a dramatic shift from subsistence family farming to commercial large scale farms and feedlots with a consequence of large losses of fertilizers into receiving waters (diffuse pollution)
- More environmentally sustainable farming is emerging
- Ecologically sustainable (minimum diffuse pollution) farming may emerge by a conversion of large farm operations to more sustainable farming. This can only be achieved by regulation and rethinking or eliminating subsidies