Knowing the Hazards:
Extinction and Loss of Ecosystem Services II

Class 14

Critical Ecosystem Services

1. Climate and Biogeochemical Cycles
2. Regulation of Hydrologic Cycle
3. Soils and Erosion
4. Biodiversity and Ecosystem Functions
5. Mobile Links
6. Balance of Diseases Transmission

Mobile Links

- "**Mobile links**" are animal species that provide critical ecosystem services and increase ecosystem resilience by connecting habitats and ecosystems as they move between them (Gilbert 1980; Lundberg and Moberg 2003)
- Ecosystems connections via:

1) Gene flow

- Pollinators and dispersers

2) Processes

- Trophic process: pray-predator, scavengers-infected carcasses
- Nutrient process: nutrient in animals and birds droppings
- Physical processes (ecosystem engineers): beavers, woodpeckers

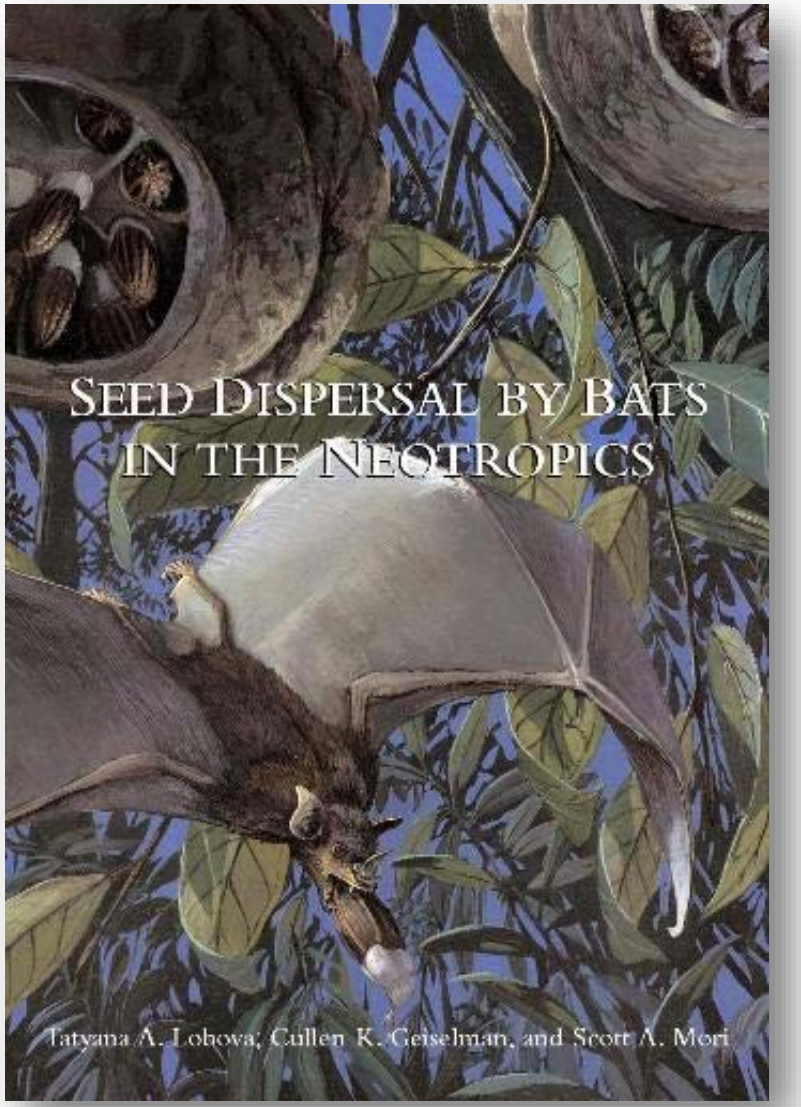
3) Resource links

- Long-distance migration

Seed Dispersal

Seed dispersal is thought to benefit plants in three major ways (Howe and Smallwood 1982):

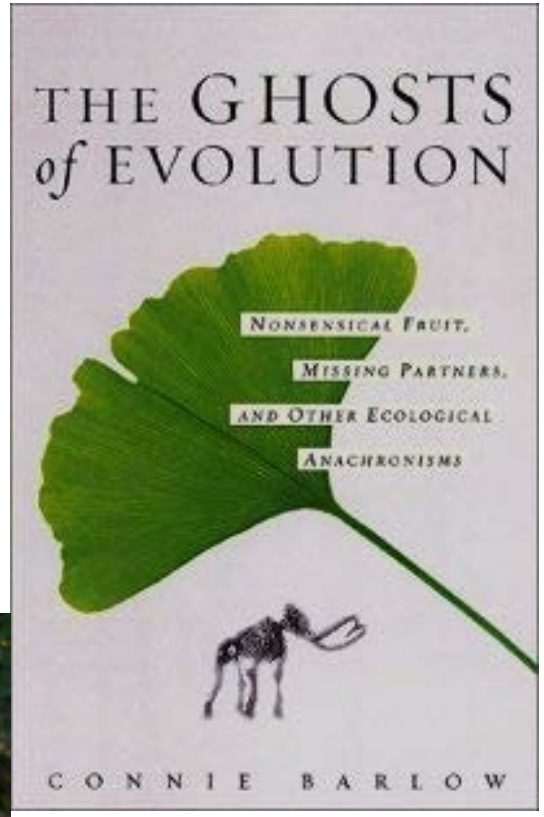
1. Escape from density-dependent mortality caused by pathogens, seed predators, competitors, and herbivores (Janzen-Connell escape hypothesis)
2. Chance colonization of favorable but unpredictable sites via wide dissemination of seeds.
3. Directed dispersal to specific sites that are particularly favorable for establishment and survival.



Missing Seed Dispersers

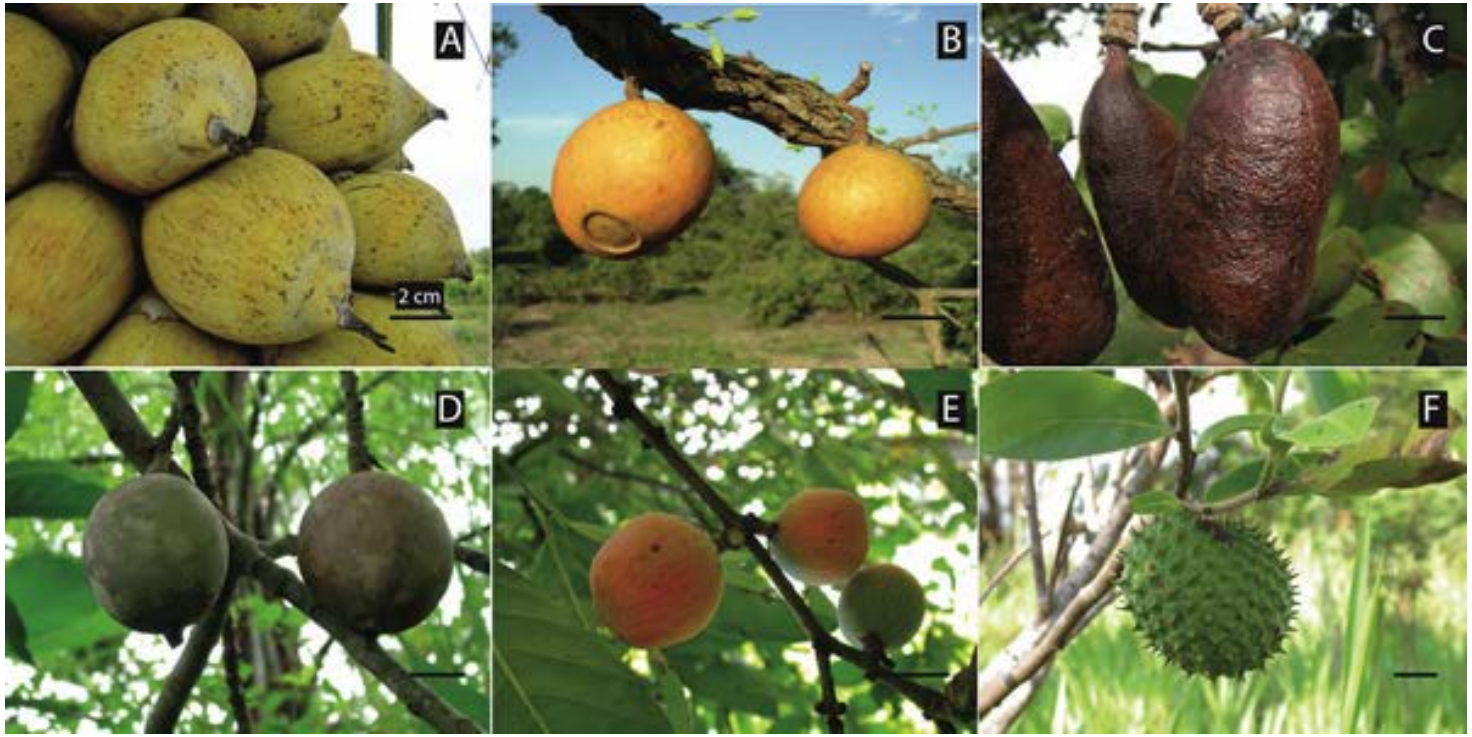
Overhunting
Loss of habitat
Habitat fragmentation

Loss of Biodiversity
Poor Forest Regeneration

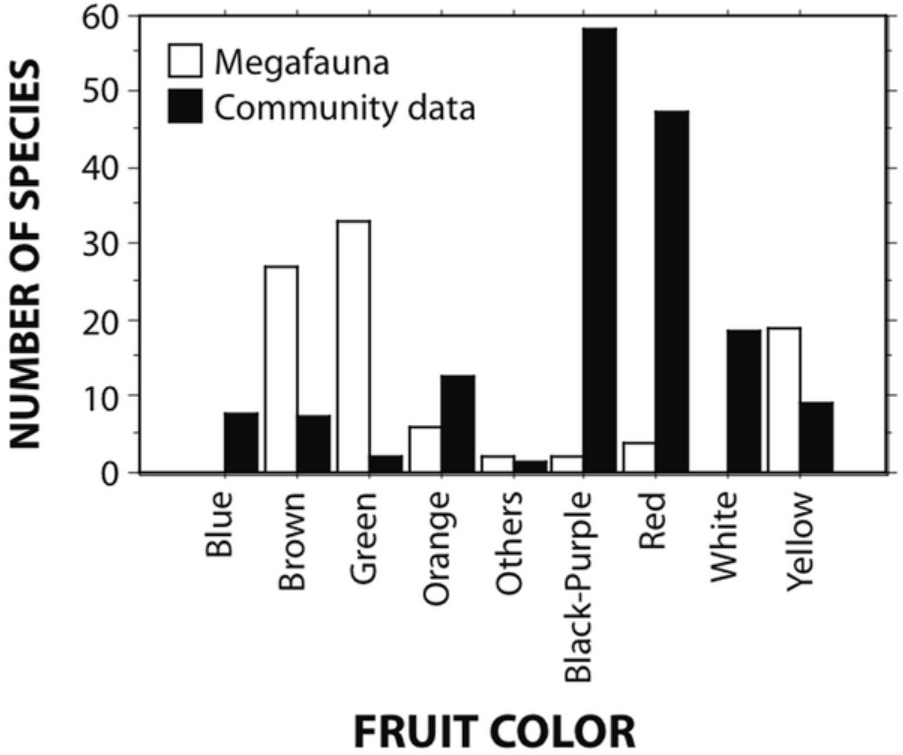


Missing Seed Dispersers

Fleshy fruited megafaunal-dependent species illustrating size, shape, and color variation.



Frequency of megafauna species with different fruit colors (blank bars) compared to the summed frequency in different communities (filled bars).



Guimarães PR Jr, Galetti M, Jordano P (2008) Seed Dispersal Anachronisms: Rethinking the Fruits Extinct Megafauna Ate. PLoS ONE 3(3): e1745. doi:10.1371/journal.pone.0001745
http://journals.plos.org/plosone/article?id=info:doi/10.1371/journal.pone.0001745

PLOS | ONE

Pollination

- 98% of tropical trees are animal pollinated
- More than 1,200 vertebrate and about 289,000 invertebrate spp are involved in pollinating over 90% of flowering plant spp and 95% of food crops (Nabhan and Buchmann 1997).
- 75% of globally important crops rely on animal pollinators, providing up to 35% of crop production (Klein et al. 2007)

Missing Pollinators

Habitat Loss
Habitat modification
Pesticides

Extreme risk of relying on a single pollinator for crops

Bees pollinate 2/3 of flowering plant spp and ¾ of food crops, that provide us with dietary diversity

Mobile Links

- "Mobile links" are animal species that provide critical ecosystem services and **increase ecosystem resilience** by connecting habitats and ecosystems as they move between them (Gilbert 1980; Lundberg and Moberg 2003)
- <u>Protection of mobile links should be a top conservation priority to prevent collapses in ecosystem services</u>:
  - Seed dispersers,
  - Pollinators,
  - Scavengers,
  - Predators,
  - Nutrient depositors

Critical Ecosystem Services

1. Climate and Biogeochemical Cycles
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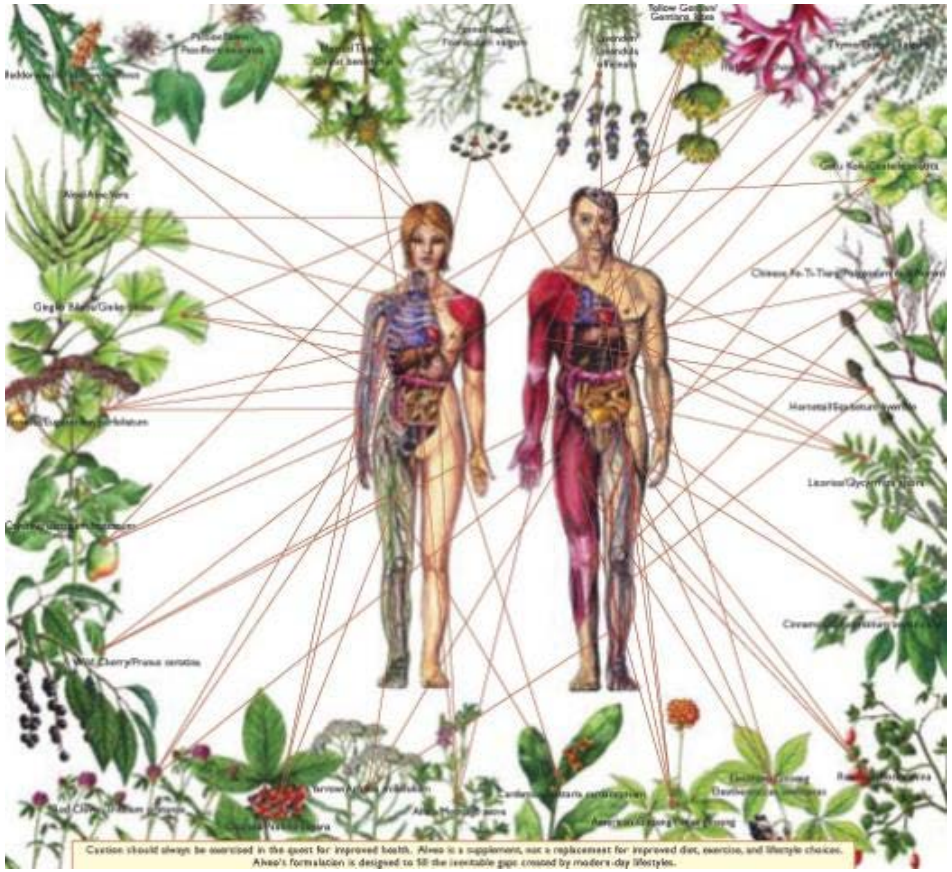
Nature heals and hurts

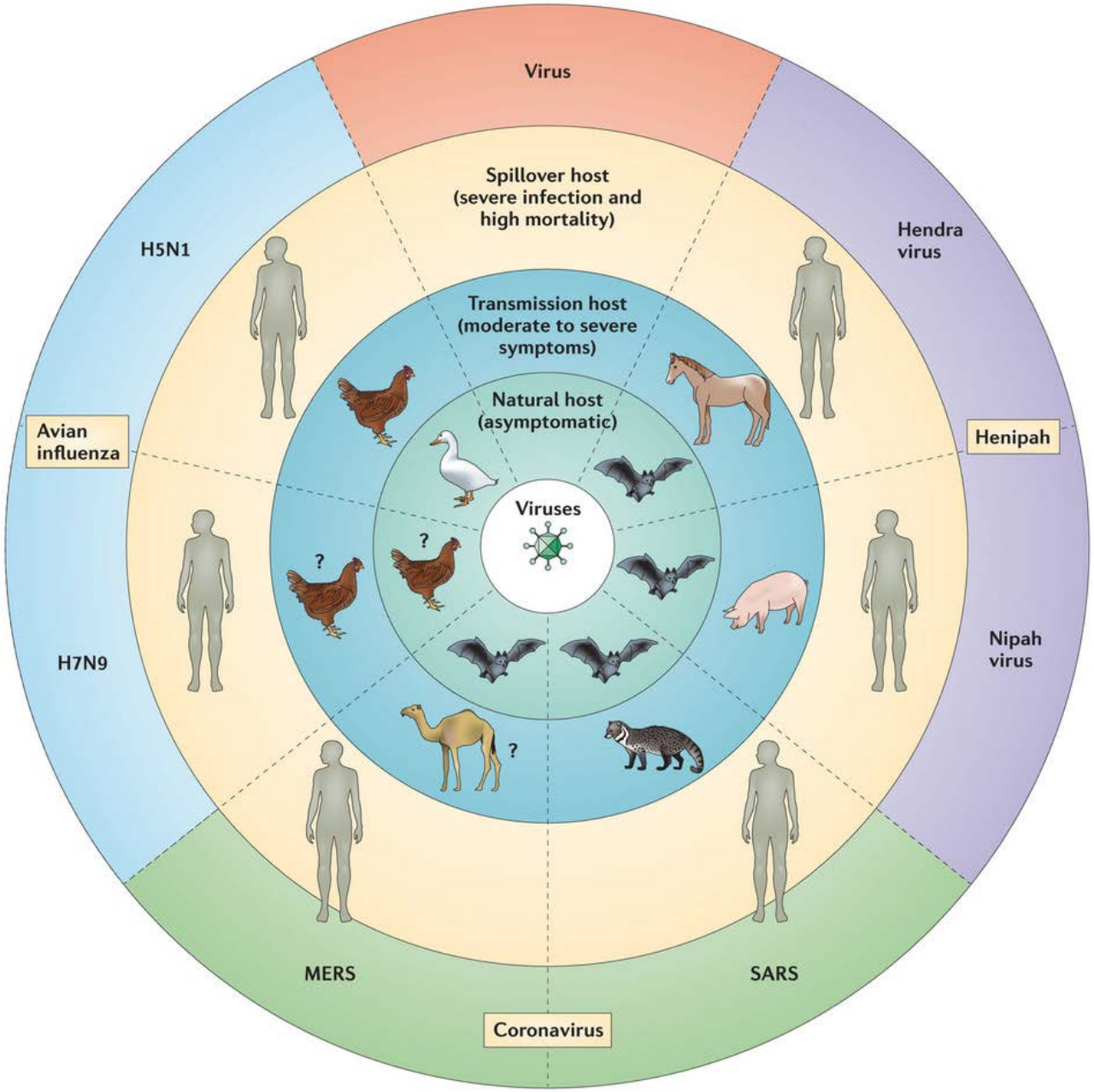
- 40% of our prescription medicine comes from plants
- Of the 3,000 plants identified by the US National Cancer Institute as active against cancer cells, *70%* come from *rainforests*
- The planet's organisms also include countless diseases, many of which are making the *transition to humans* as people increasingly invade the habitats of the hosts of these diseases and consume the hosts themselves.
- ¾ of human diseases might have origin in *domestic* or *wild animals*
- Monkeypox, malaria, HIV and Ebola have came from African primates to people that killed, butchered and consumed them



Zoonotic Diseases

Zoonotic Diseases are diseases that can be passed between animals and humans.

- Viruses, bacteria, parasites, and fungi can cause zoonotic diseases.



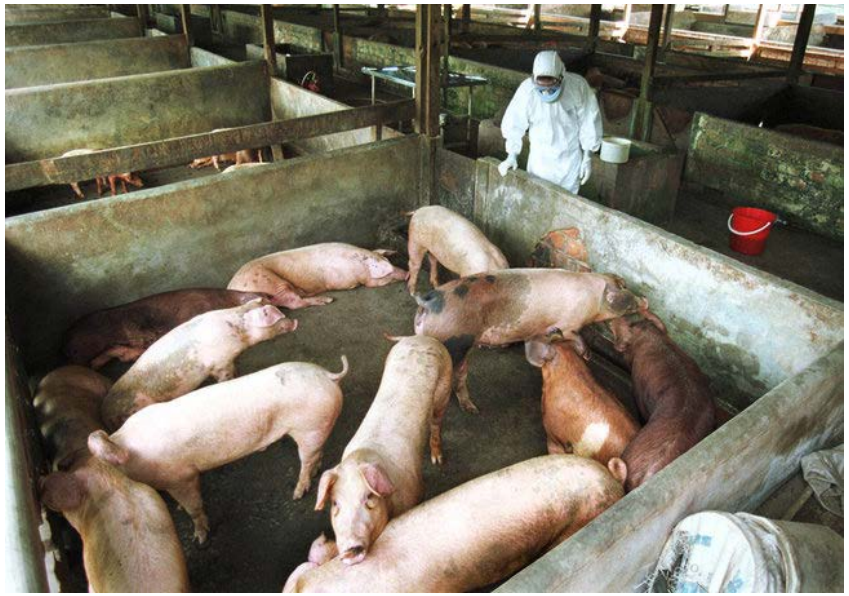
Nature Reviews | Immunology

Emerging Diseases: Nipah

Nipah Virus, Malaysia 1998

- New, high fatality rate
- Misdiagnosed as Japanese encephalitis
- Aggressive control measures were unsuccessful
- Ethnic Chinese farmers sold pigs and spread disease
- Virus isolated after 6 months
- Farmers thought government indifferent to their welfare and health
- Ended with culling of >1M pigs, with devastating effects on farmers' livelihoods
- 265 cases, 105 fatal

15



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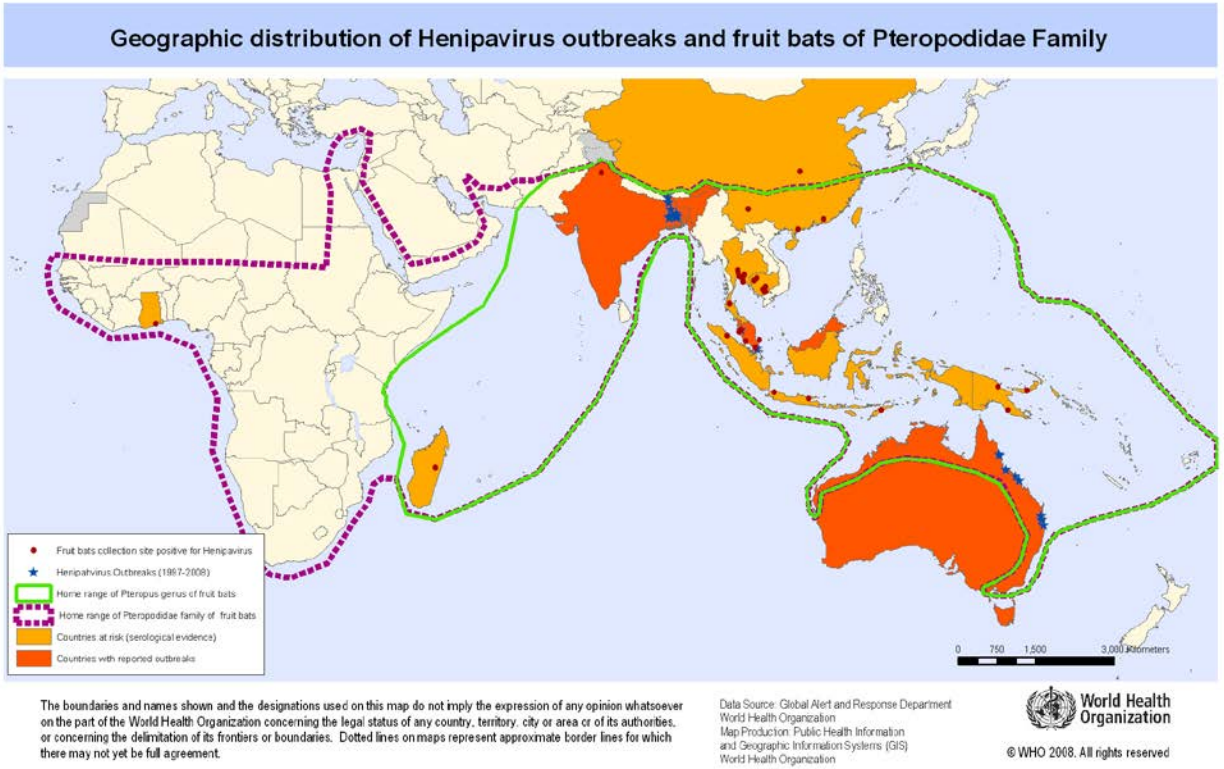
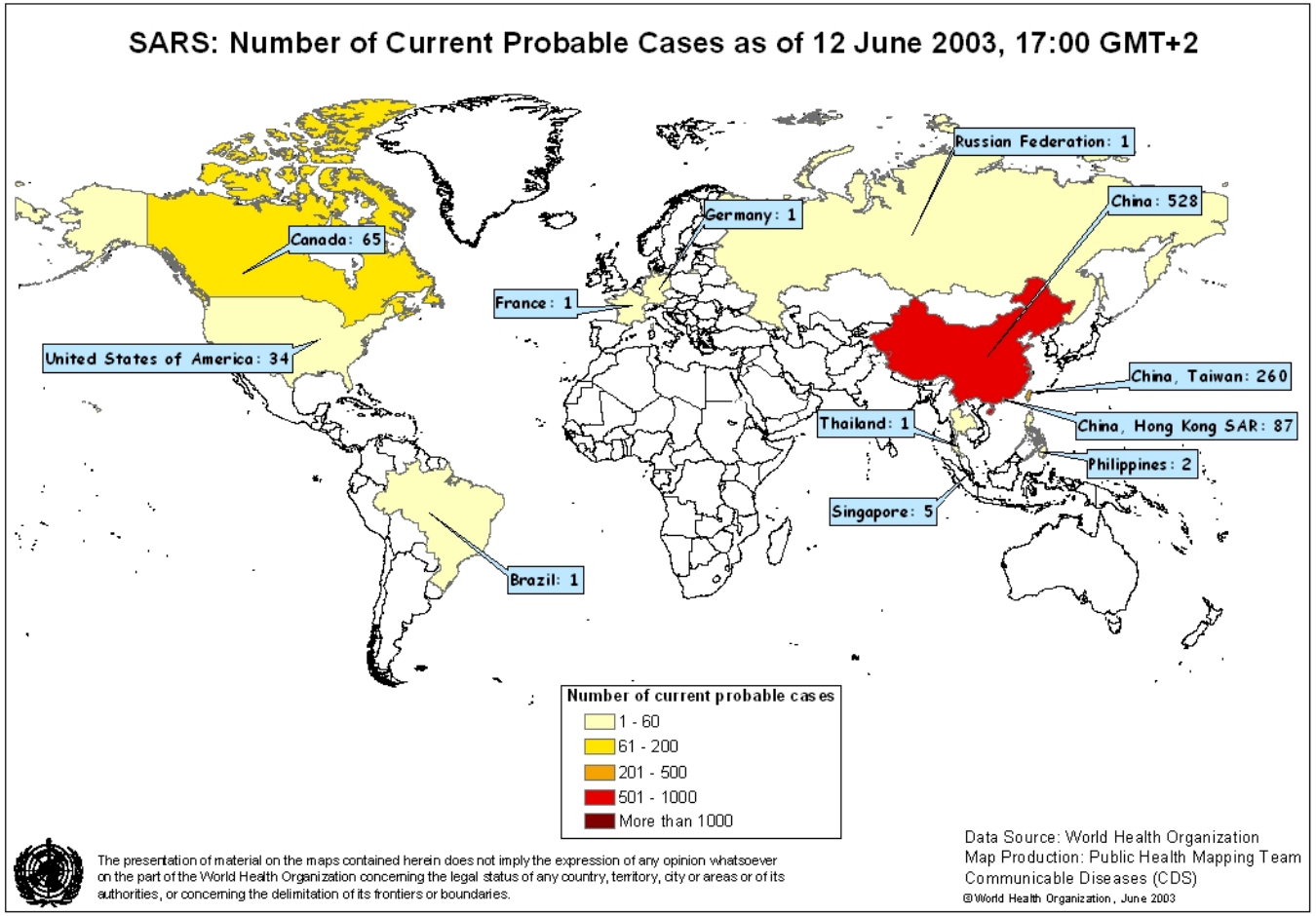
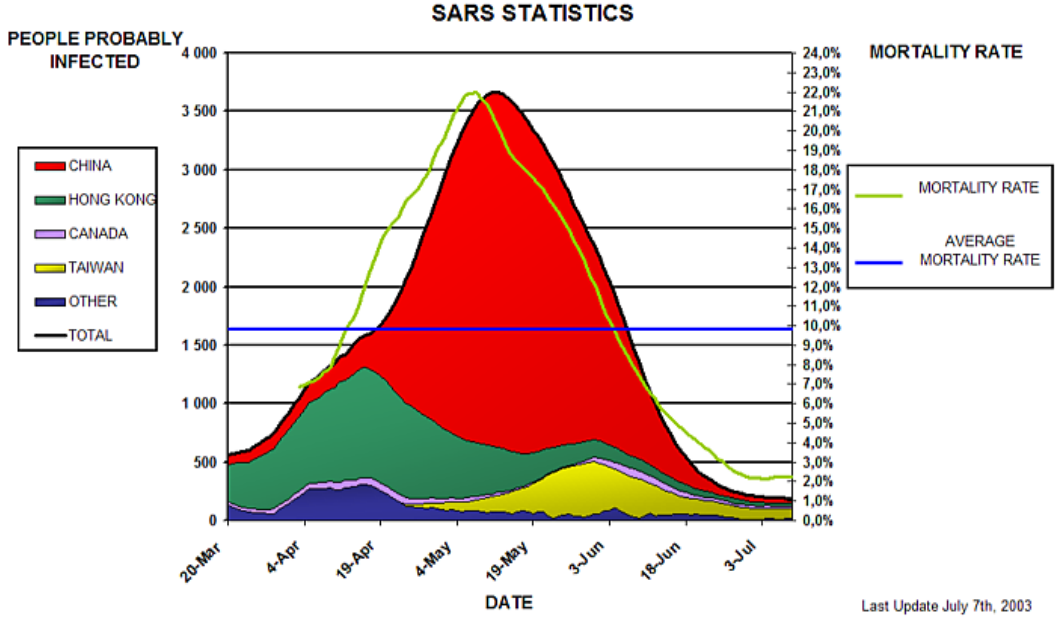
Emerging Diseases: Nipah

- Massive forest fires in 1997-1998 in SE Asia → forest destruction and smoke → forced fruit bats to feed on fruiting orchards, mainly mangoes → pigs were farmed among the fruiting trees and ate mangoes from the ground → bats are hosts to Nipah virus → passed to pigs → passed to people (Chivian, 2002)



Emerging Diseases: SARS



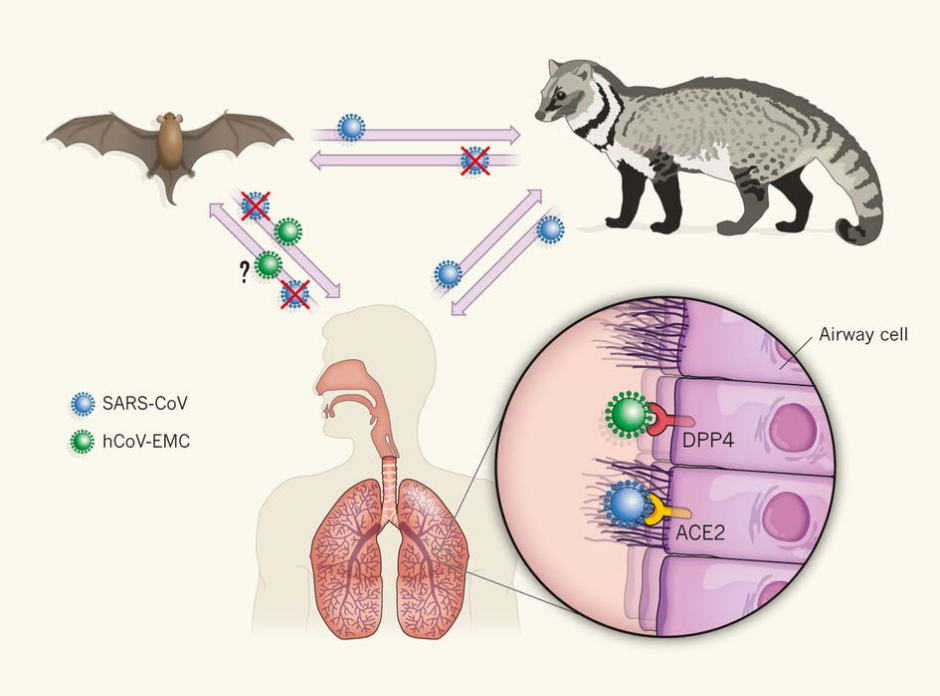


Emerging Diseases: SARS

Fruit bats are native hosts → partially eaten fruits → wild frugivorous animals, like civets and raccoon dogs → passed to other animals in wildlife market → people eat wild animals

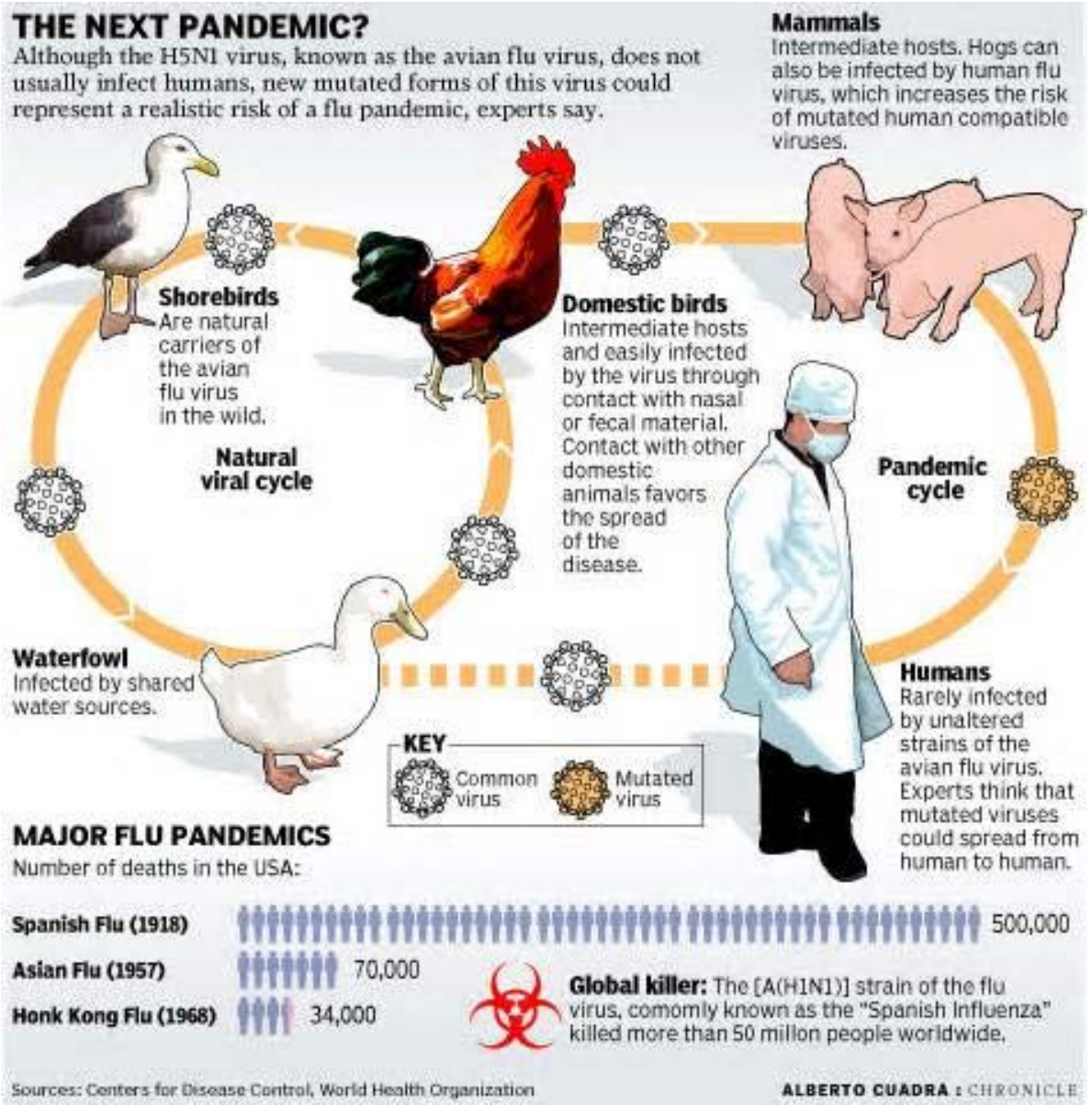
SARS originated from China

Avoid Traveling to: China, HongKong



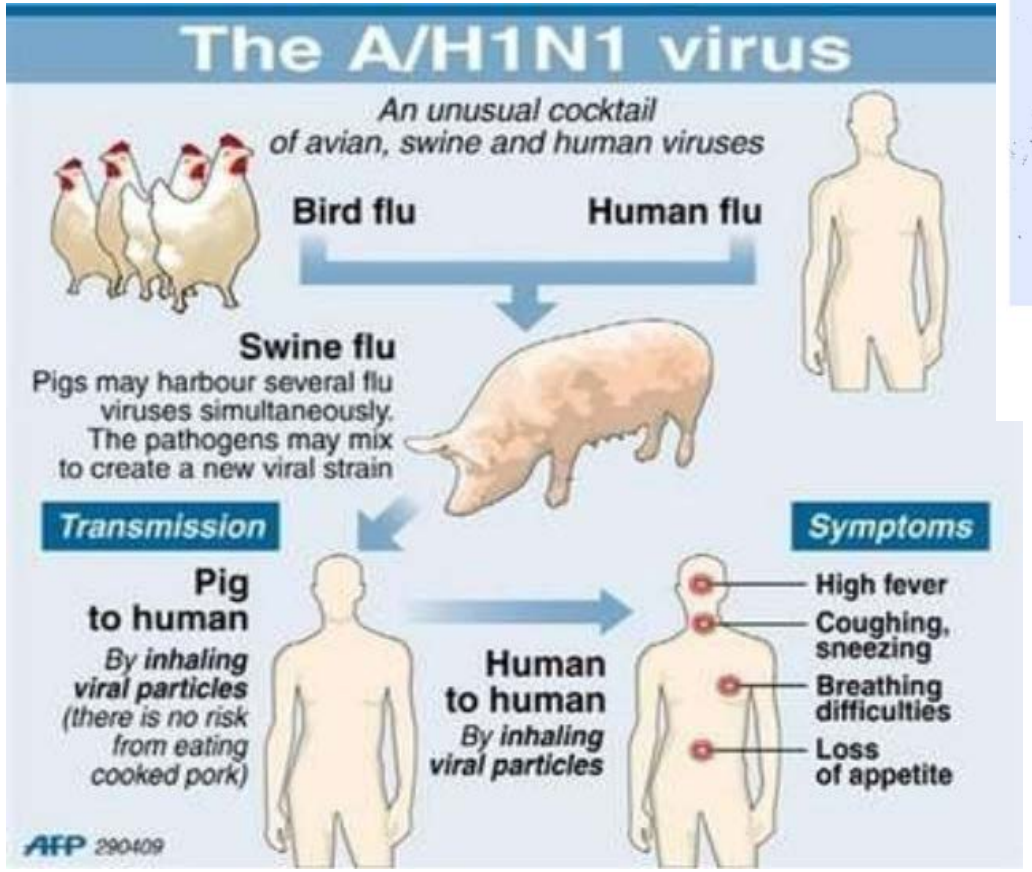
Emerging Diseases: Avian Flu

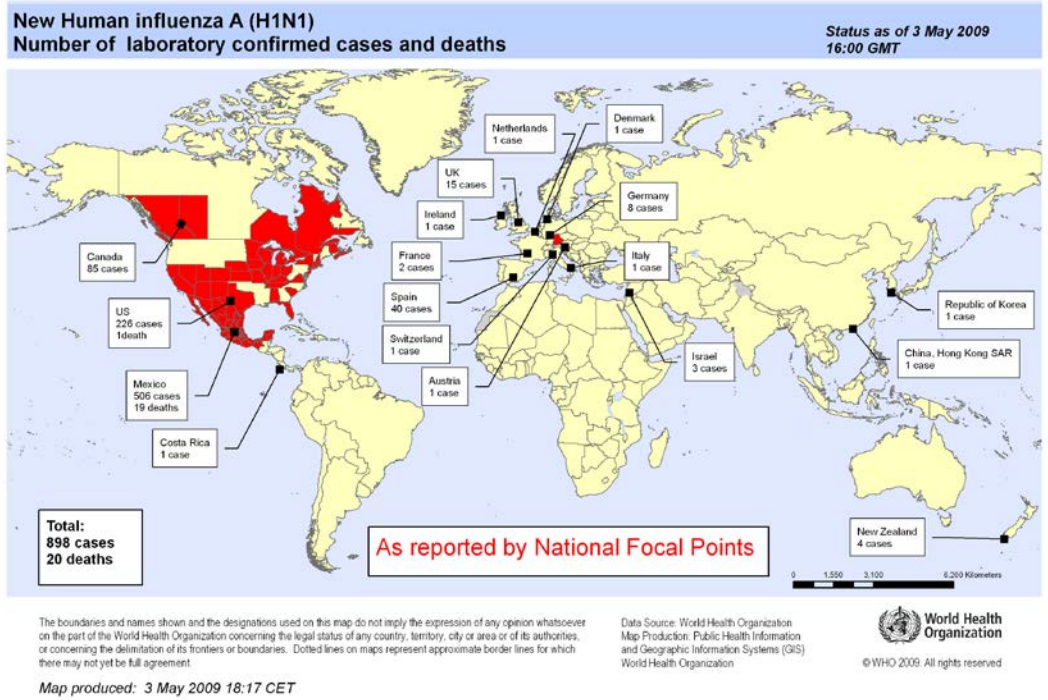
WHO data indicate 60% of cases classified as H5N1 resulted in death



Emerging Diseases: Swine Flu

Declared a pandemic in 2009 →May 30, 2010 more than 214 countries and overseas territories have confirmed cases and over 18,138 deaths (WHO) → vaccination in 2010

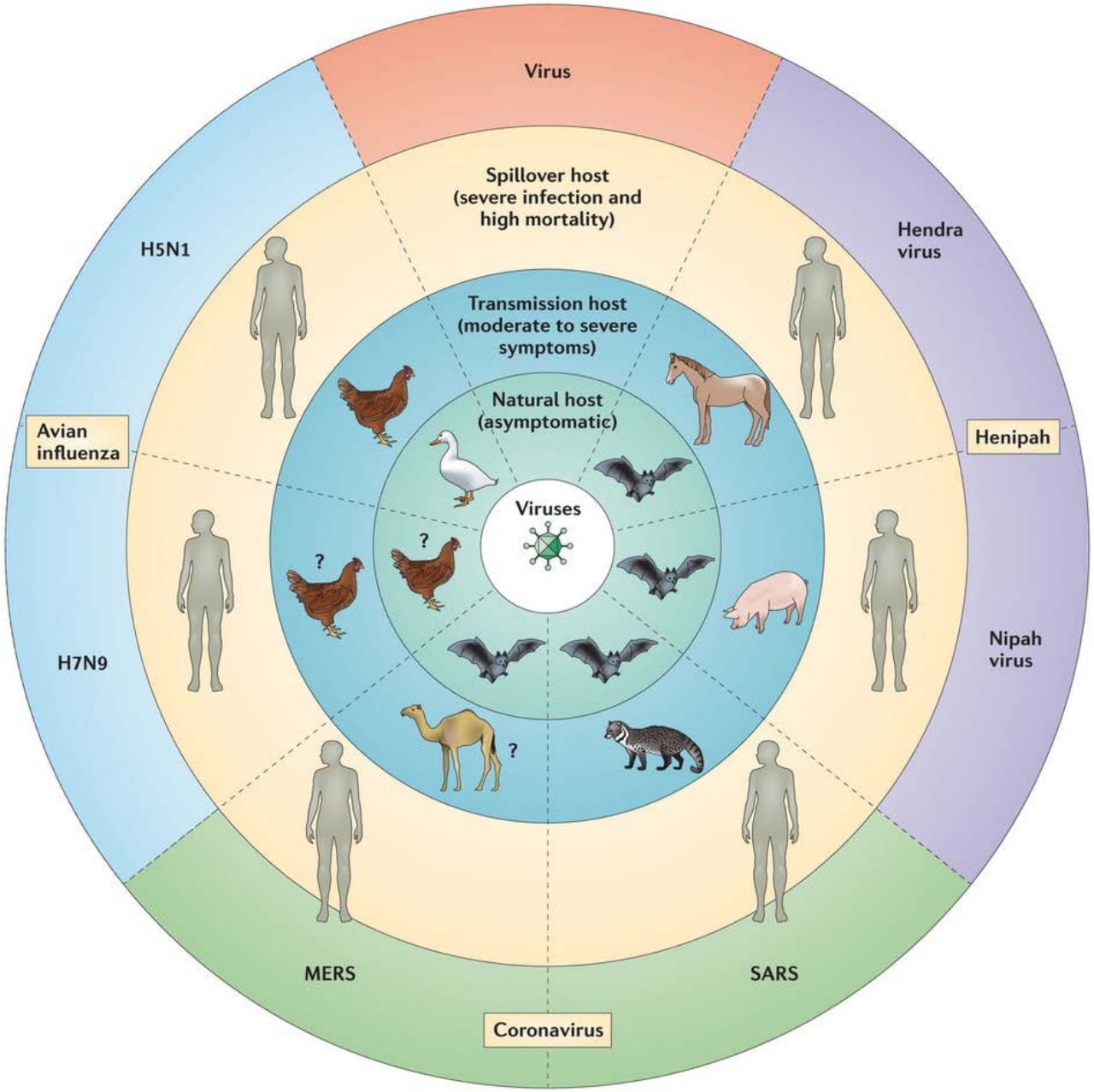




Zoonotic Diseases

- Tropical deforestation, combined with climate change, human migration, agricultural intensification, and animal trafficking create the **perfect storm** for the emergence of new diseases as well as the resurgence of old ones.

- In the face of rapid global change, **ecologically intact and relatively stable communities** may be our best weapon against the emergence of new diseases.



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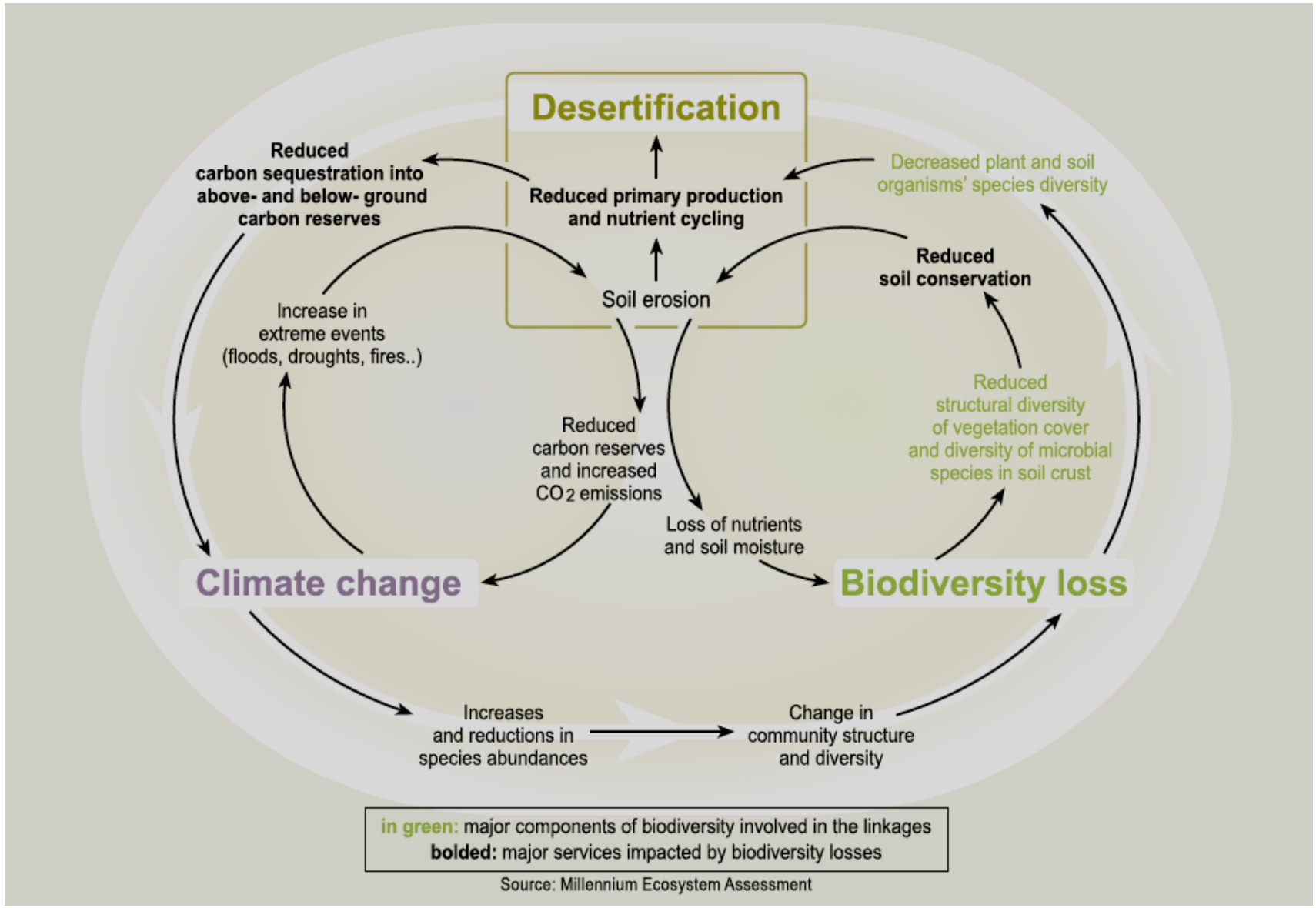
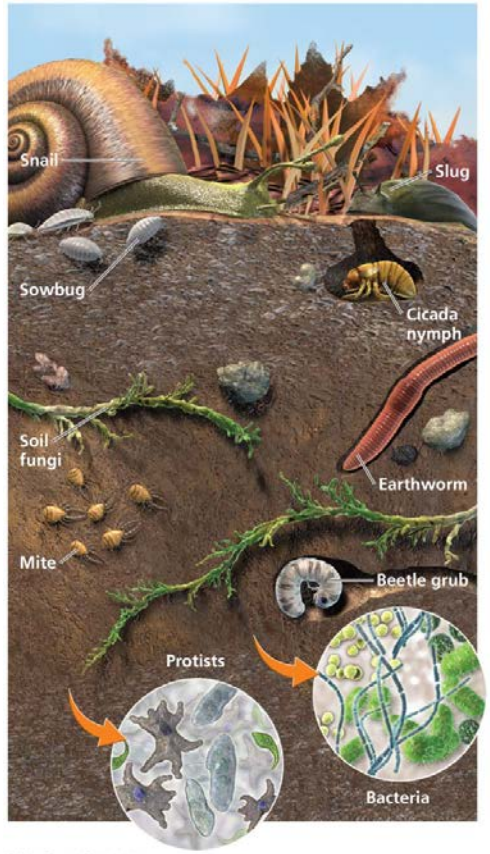
Linkage and Feedback Loops



Soils

- Soil consists of mineral (50%), organic matter (5%), air, and water → composed of interacting living and nonliving matter → considered ***an ecosystem***
- *Most critical and most underappreciated ecosystem*
- Provides 6 major ecosystem services:
  - ✓Moderating the hydrologic cycle.
  - ✓ Physical support of plants.
  - ✓ Retention and delivery of nutrients to plants.
  - ✓ Disposal of wastes and dead organic matter.
  - ✓Renewal of soil fertility.
  - ✓Regulation of major element cycles.



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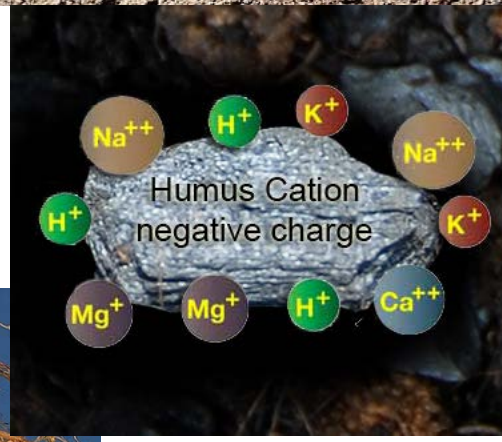
Soils Ecosystem Services

- Nutrient delivery to plans (nutrient cations) → hydroponic systems cost >$250K per ha
- Healthy soil harbors an astonishing diversity of microorganisms, e.g., nitrogen-fixing bacteria → cost at least $320 billion/year to replace with nitrogen fertilizers

- Soil serves as greenhouse gases sink → per area soils stores x1.8 more C and x18 more N that plants can;
  - in peatlands x10 greater C than plants



Regional differences in soils affect agriculture

- In rainforests the nutrients are in plants, **not** in the soil
  - Rain leaches minerals and nutrients, reducing their accessibility to roots
  - Rapid decomposition of leaf litter results in a thin topsoil layer with little humus
- *Swidden* agriculture *(=cut-and-burn)* -- traditionally used in tropical areas
  - After short-time cultivation, a plot is left to regrow into forest
  - *Swidden* agriculture is **not sustainable** at high population densities

Differences in regional agriculture

(a) Tropical swidden agriculture on nutrient-poor soil

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(b) Industrial agriculture on Iowa's rich topsoil

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- Temperate prairies have lower rainfall and less nutrient leaching
- Dead plants return nutrients to the soil
- Thick, rich topsoil of temperate grasslands can be farmed repeatedly for many years

Soil erosion

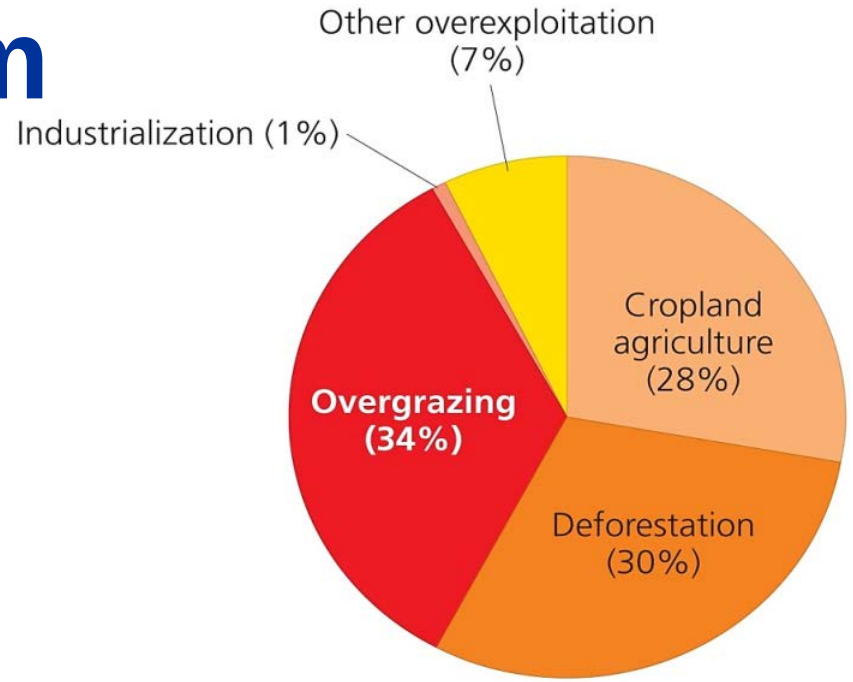
- **Soil degradation**: loss of soil quality and productivity
  - 17% of the Earth's vegetated land surface (Oldeman 1998) or 23% of all land used for food production has experienced soil degradation since 1945
  - Water retention capacity is reduced after intensive cultivation → flood, erosion, pollution
  - **Erosion**: removal of material from one place to another by wind or water → happens faster than soil formation

Direct costs of erosion ~US$250 billion/year and the indirect costs (e.g. siltation, obsolescence of dams, water quality declines) ~$150 billion/year (Pimentel et al.1995).
Sufficient preventive measures would cost only 19% of this total (Pimentel et al. 1995).

We lose 5–7 million ha (size of WV) of productive cropland each year

Soil erosion is a global problem

- Humans are the primary cause of erosion
  - It is occurring at unnaturally high rates
- In Africa, erosion could reduce crop yields by 50% over the next 40 years
- The U.S. loses 5 tons of soil for every ton of grain harvested



(b) Causes of soil degradation

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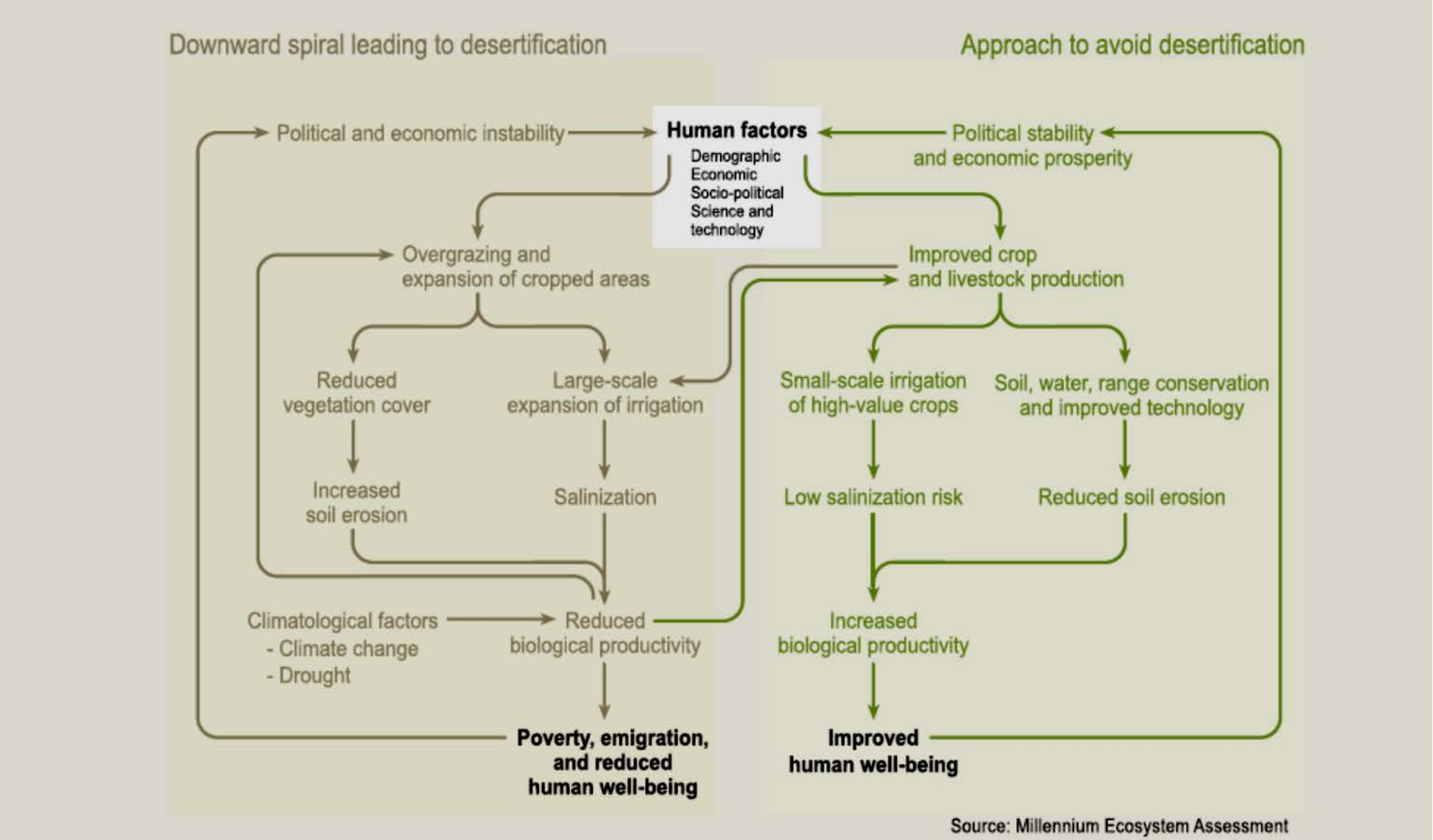
Degradation of topsoil and decreased crop yields, added to population growth are leading agriculture's future to a crisis situation

The Dust Storms

- In late 1800 and early 1900, USA farmers and ranchers:
  - Grew wheat, grazed cattle
  - Removed native grasses
- **Dust Bowl**: 1930s drought and erosion caused “black blizzards” of sand
- **Dust Storms:** On the global scale happens x10 more frequently now than 50 y.a.

(a) Kansas dust storm, 1930s

Potential development in different scenarios



Protecting soil: terracing and intercropping

- **Terracing**: level platforms cut into steep hillsides
  - This “staircase” contains rain and irrigation water

- **Intercropping**: planting different crops in alternating bands
  - Increases ground cover
  - Decreases pests and disease
  - Replenishes soil

(c) Terracing

(d) Intercropping

Protecting soil: shelterbelts and reduced tillage

- **Shelterbelts** (*windbreaks*): rows of trees planted along edges of fields
  - Slows the wind
  - Can be combined with intercropping

- **Conservation tillage**: reduces the amount of tilling
  - No-till farming disturbs the soil even less

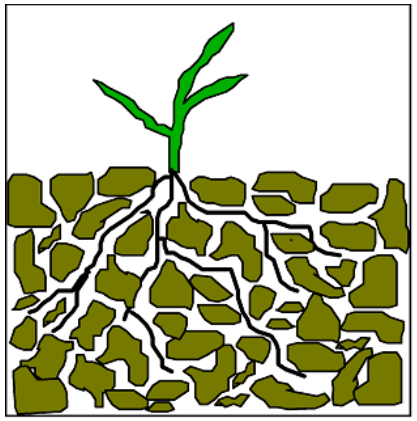
(e) Shelterbelts

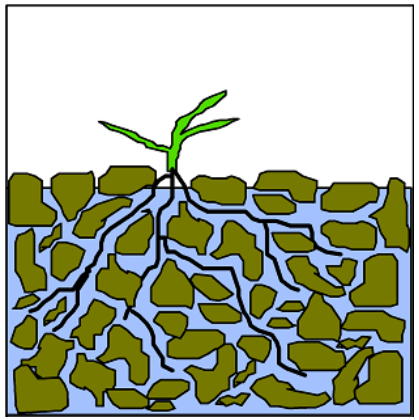
(f) No-till farming

Irrigation: productivity with problems

- **Irrigation**: artificially providing water to support agriculture
  - Unproductive regions become productive farmland
- **Waterlogging**: water suffocates roots in overirrigated soils

(a) Conventional irrigation





Irrigation: productivity with problems

- **Salinization**: the buildup of salts in surface soil layers
  - Worse in dryland areas

Salinization inhibits production of 20% of irrigated cropland, costing over $11 billion/year

Sustainable approaches to irrigation

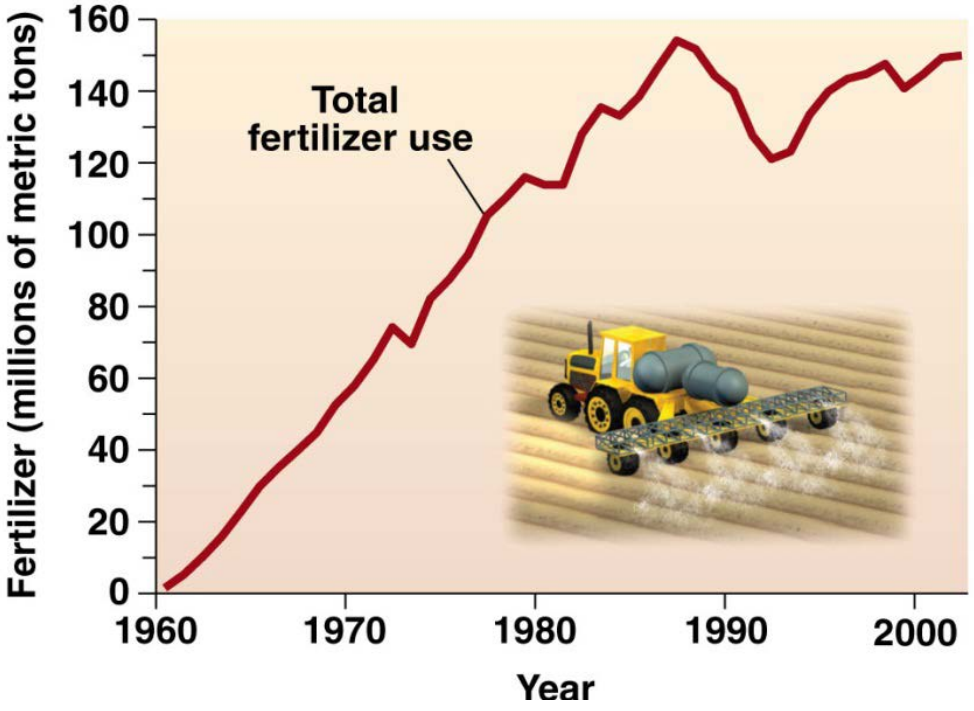
- Match crops and climate
  - Don’t plant water-guzzling crops in dry areas
  - Plant beans or wheat, not rice
- Subsidies make irrigation water artificially cheap
- Drip irrigation delivers water directly to plants

(b) Drip irrigation

Drip irrigation works best on smaller plots with perennial plants (fruit trees)

Inorganic fertilizers cause problems

- Inorganic fertilizers have boosted production
  - But also severely pollute
- Leaching and runoff of inorganic fertilizers causes:
  - Groundwater contamination
  - Dead zones in water systems
  - Air pollution from evaporated nitrates



Inorganic fertilizer use has skyrocketed worldwide

Sustainable fertilizers

- Sustainable approaches to fertilizing delivers nutrients directly to plant roots and avoids overapplication
  - Add fertilizers to drip irrigation water
  - No-till or low-till systems inject fertilizers with seeds
  - Monitor soil nutrients and add only when they are low
  - Strips of vegetation along field edges and streams capture nutrient runoff
- Organic fertilizers add nutrients and organic matter
  - Improving soil structure, nutrient and water retention
- ***Solution***: <u>Integrate inorganic and organic fertilizer systems</u>

(a) Inorganic fertilizer

(b) Organic fertilizer