Teórica 14:
Metabolismo ecosistémico 3:
Ciclo de nutrientes

Refrescando la memoria...
Teórica 12: Productividad primaria

- Las plantas capturan energía mediante fotosíntesis, sosteniendo a todos los niveles tróficos.
- La productividad primaria (PP) varía geográficamente
- Principales limitantes de PP:
  - Mar: N y Fe, y P en menor medida. Luz y temp. no suelen limitar.
  - Agua dulce: luz y temp., junto con P y N.
  - Tierra: luz (radiación), temp., humedad, N y P.
- La diversidad de especies y la productividad primarias están íntimamente relacionadas.

Refrescando la memoria...

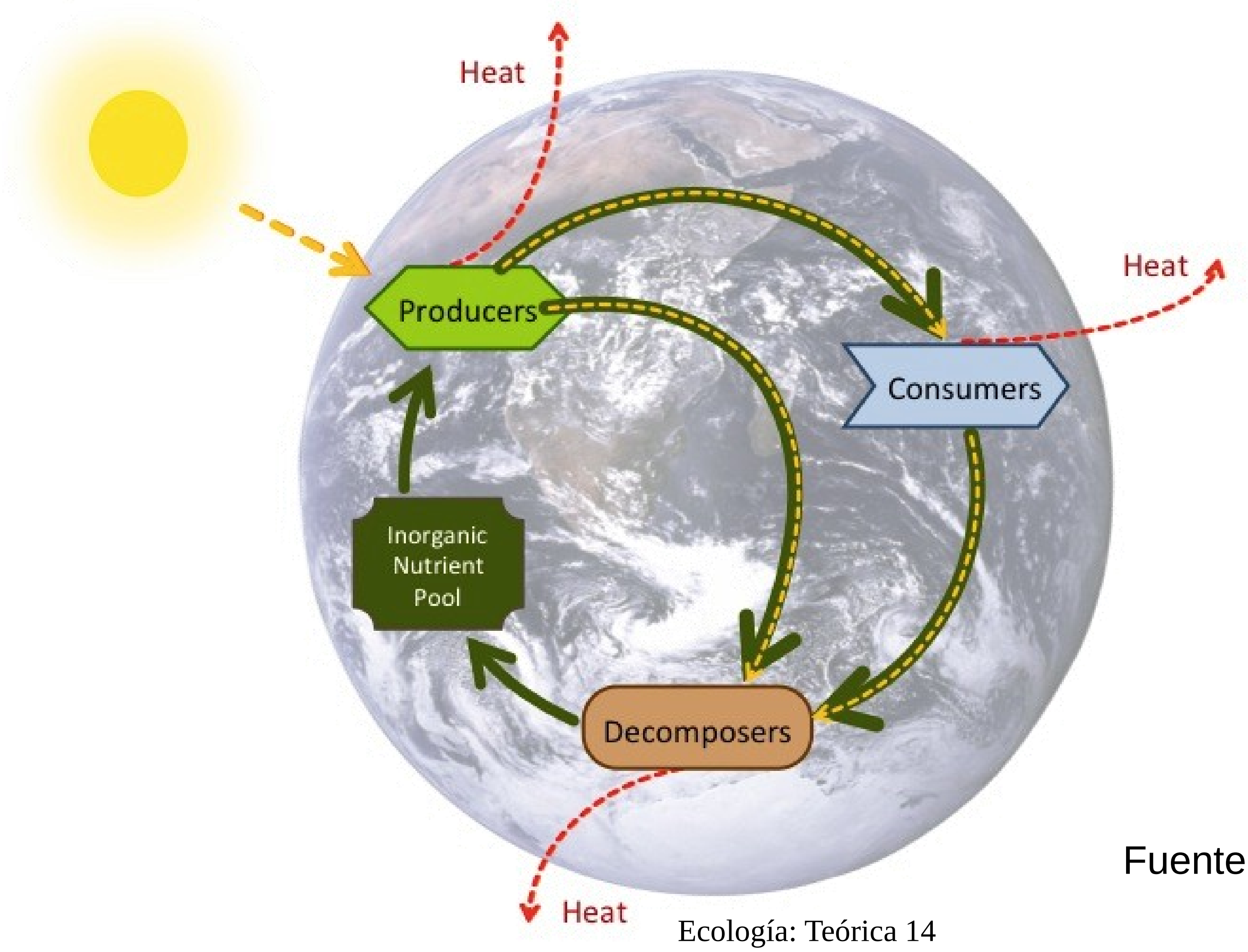
Teórica 13: Productividad secundaria

- La energía fijada por las plantas fluye a los herbívoros o al detrito, o se pierde en la respiración
- La proporción de PP consumida varía entre tipos de ecosistema; en general es mayor en ambientes acuáticos que en terrestres
- En general hay baja eficiencia en la transferencia de energía entre niveles tróficos
- La PS está limitada por la PP
- La teoría metabólica de la ecología es un intento de relacionar procesos fisiológicos de los individuos con procesos poblacionales y ecosistémicos

Teórica 14: Esquema conceptual

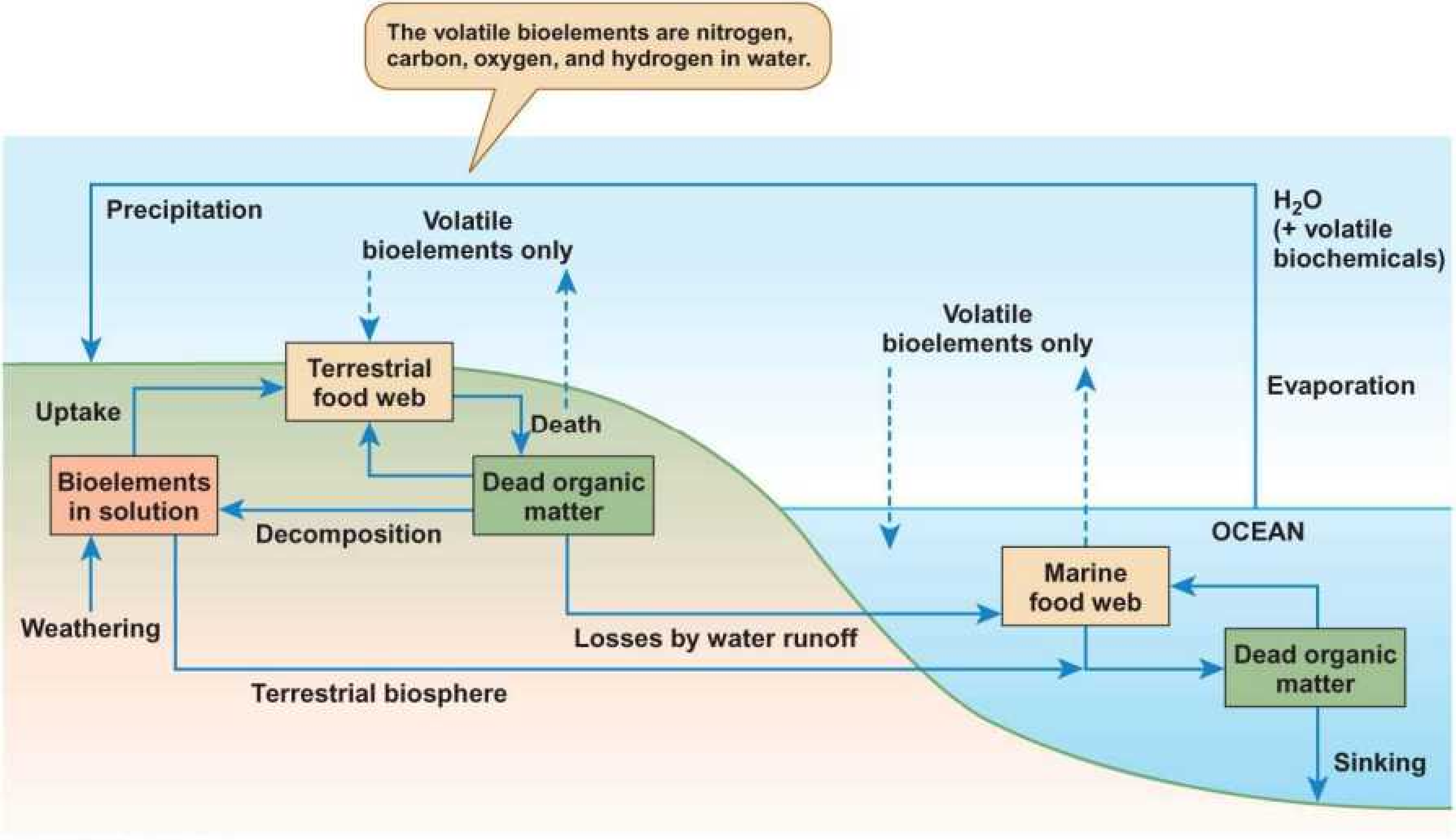
- Generalidades
- Ciclo de nutrientes en ambientes dulceacuícolas
- Ciclo de nutrientes en bosques
- Eficiencia en el uso de nutrientes
- Lluvia ácida y el ciclo del azufre
- El ciclo del nitrógeno

Ciclo de nutrientes general a nivel global

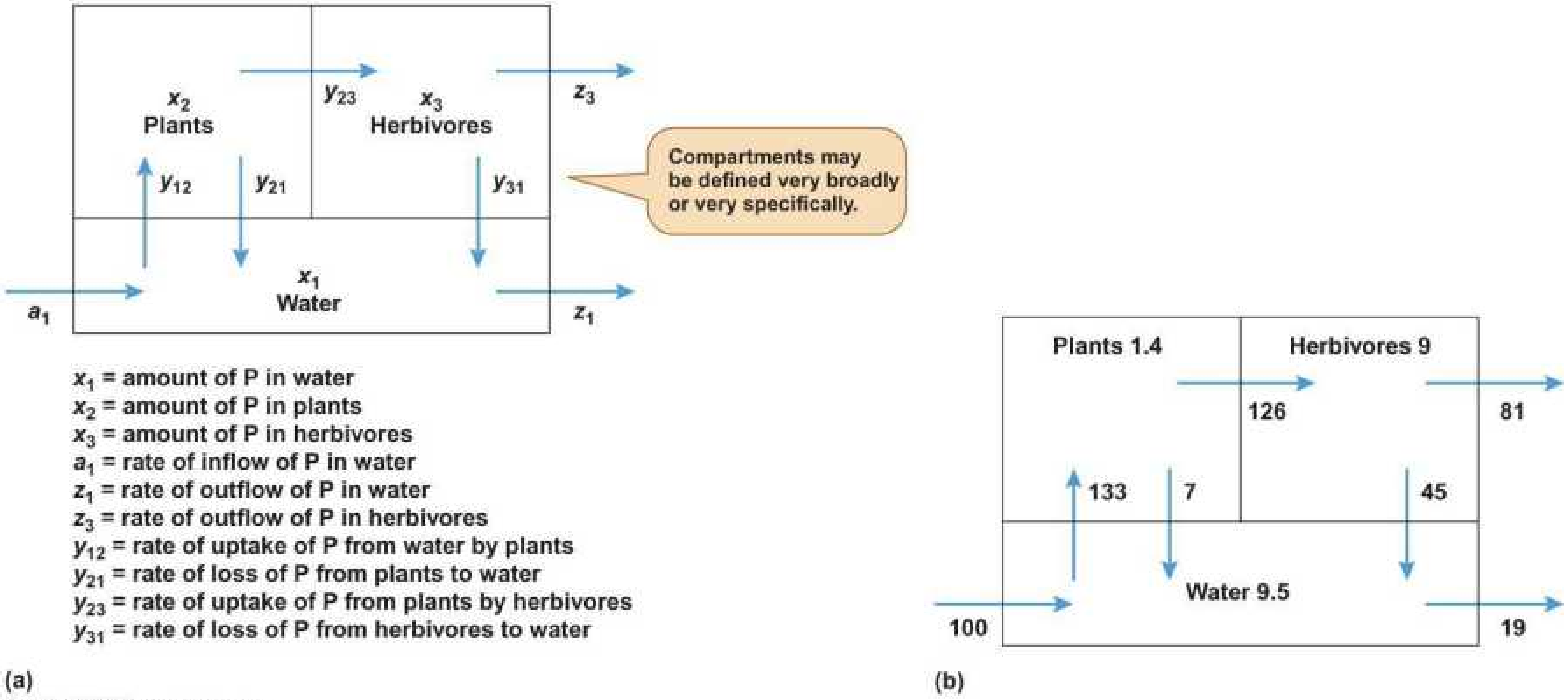


Fuente: khanacademy.org

Ciclo de nutrientes general a nivel global



Ciclo de nutrientes en ambientes de agua dulce:
Ejemplo hipotético para un lago



Compartments may be defined very broadly or very specifically.

x_1 = amount of P in water
x_2 = amount of P in plants
x_3 = amount of P in herbivores
a_1 = rate of inflow of P in water
z_1 = rate of outflow of P in water
z_3 = rate of outflow of P in herbivores
y_{12} = rate of uptake of P from water by plants
y_{21} = rate of loss of P from plants to water
y_{23} = rate of uptake of P from plants by herbivores
y_{31} = rate of loss of P from herbivores to water

(a)

(b)

Figure 2 Hypothetical nutrient cycle for phosphorus in a simple lake ecosystem composed of three compartments: plants, herbivores, and water. (a) Definition of compartments and flux rates (inflow or outflow). Compartments are standing crops or amounts. (b) Hypothetical distribution (mg) and flux rates (mg/day) of phosphorus after equilibration to a constant input rate of 100 mg/day. (After Smith 1970.)

Ciclo de nutrientes en ambientes de agua dulce:
Peces piscívoros y ciclo de P

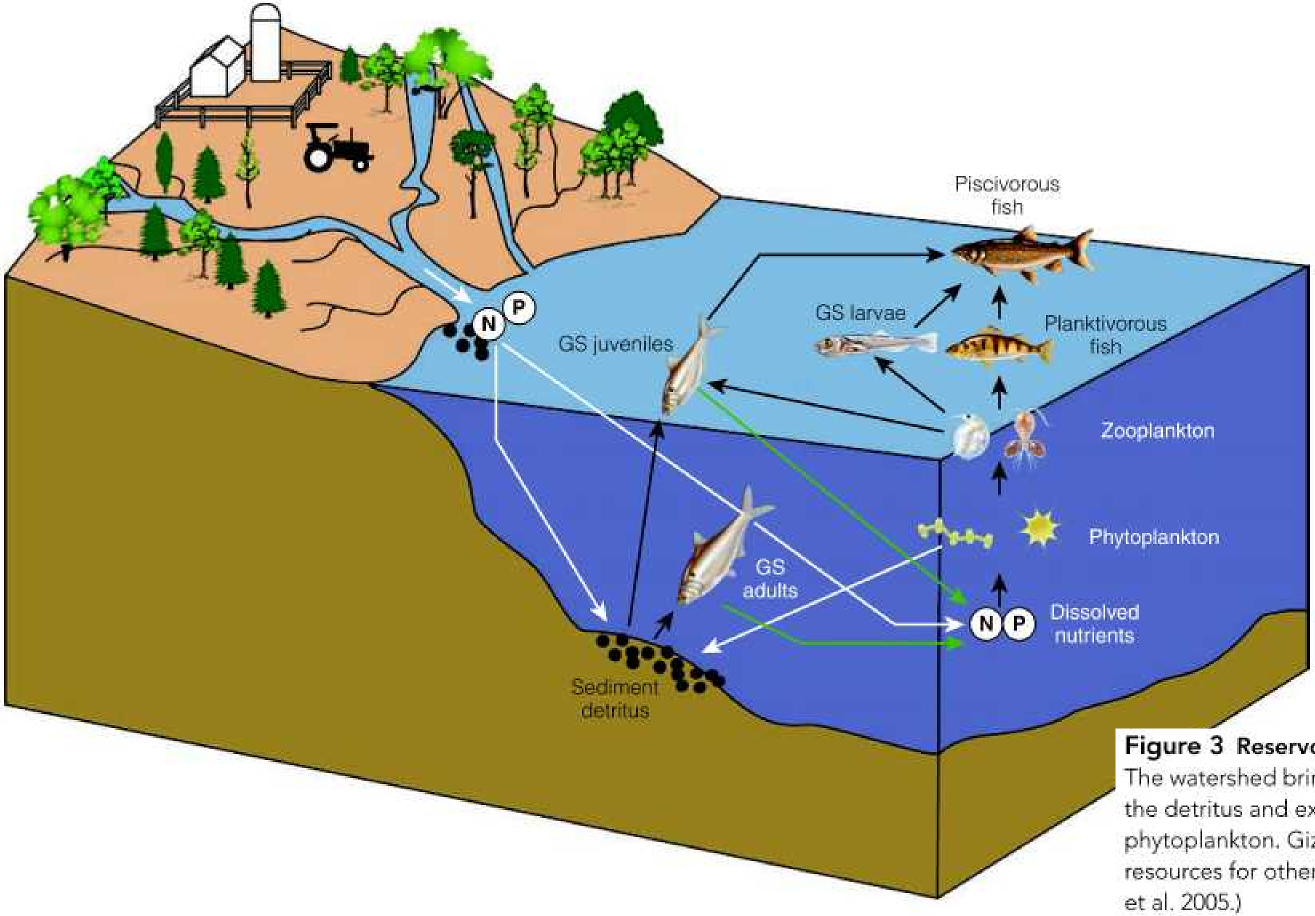
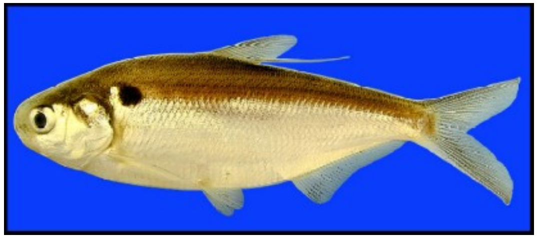
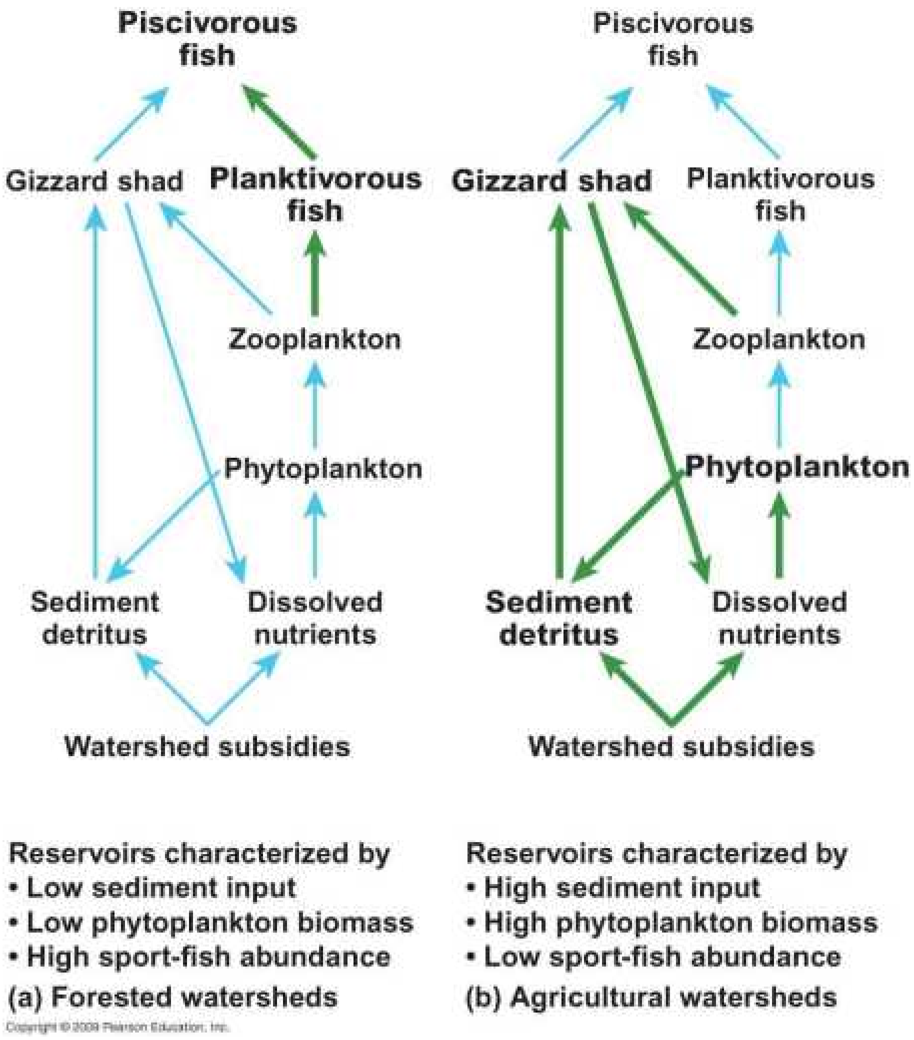


Figure 3 Reservoirs in eastern North America are often dominated by gizzard shad. The watershed brings detritus and nutrients into the reservoir, and gizzard shad feed on the detritus and excrete nitrogen and phosphorus (green arrows) that stimulate the phytoplankton. Gizzard shad juveniles feed on zooplankton and reduce zooplankton resources for other fish. N = nitrogen, P = phosphorus, GS = gizzard shad. (From Vanni et al. 2005.)



Dorosoma cepedianum
(Gizzard shad, GS)

Ciclo de nutrientes en ambientes de agua dulce:
Peces piscívoros y ciclo de P



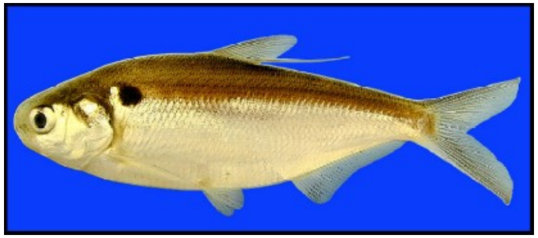
Reservoirs characterized by
- Low sediment input
- Low phytoplankton biomass
- High sport-fish abundance

(a) Forested watersheds

Reservoirs characterized by
- High sediment input
- High phytoplankton biomass
- Low sport-fish abundance

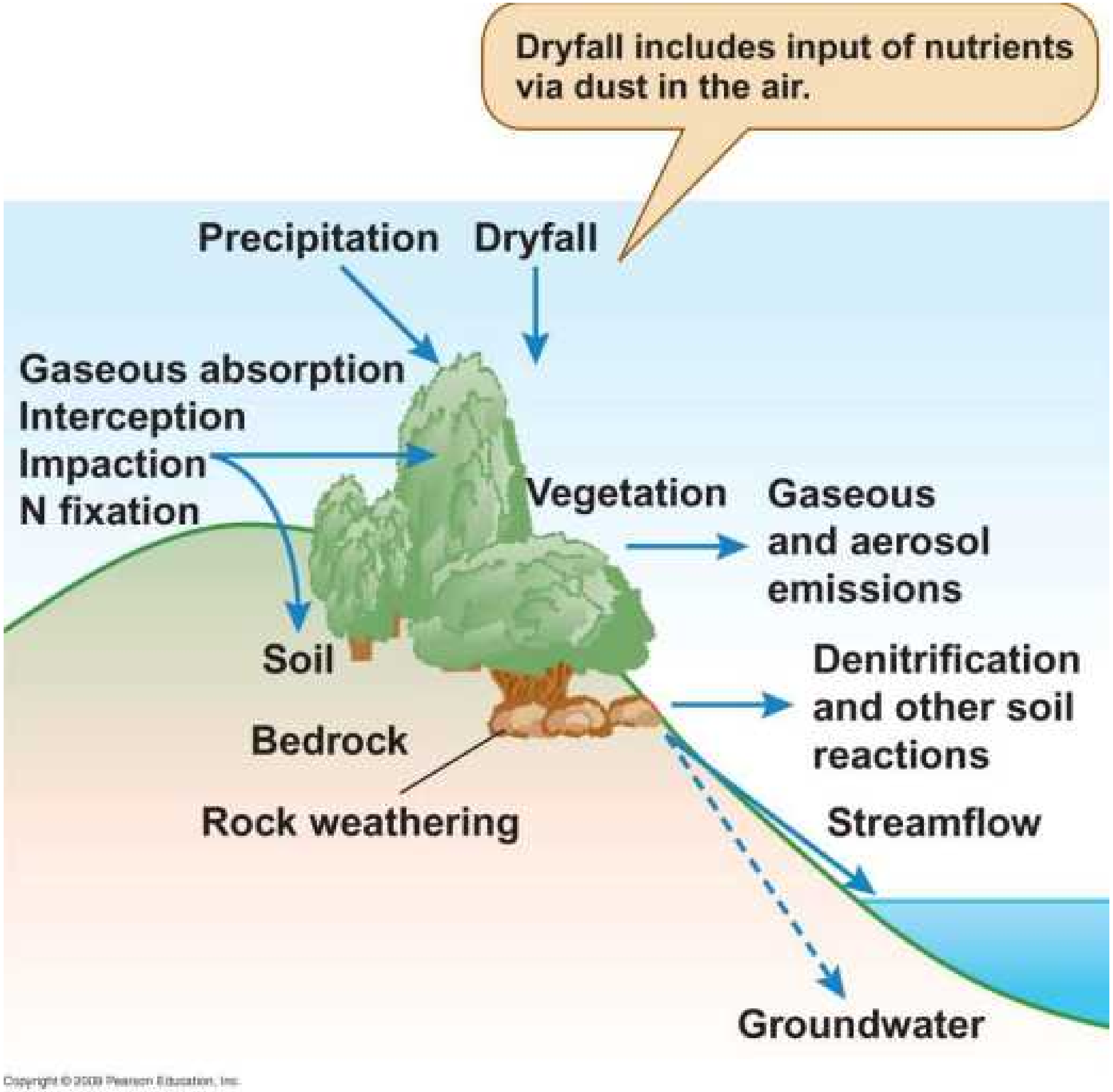
(b) Agricultural watersheds

Figure 5 Food webs of reservoirs in which the surrounding landscape is (a) primarily forest or (b) primarily agricultural land. The nutrient and energy flows are indicated by the thickness of the arrows, and the larger print indicates the dominant species. These are not alternate stable states because they depend on the continued input of different levels of nutrients and detritus from the watersheds. (After Vanni et al. 2005.)

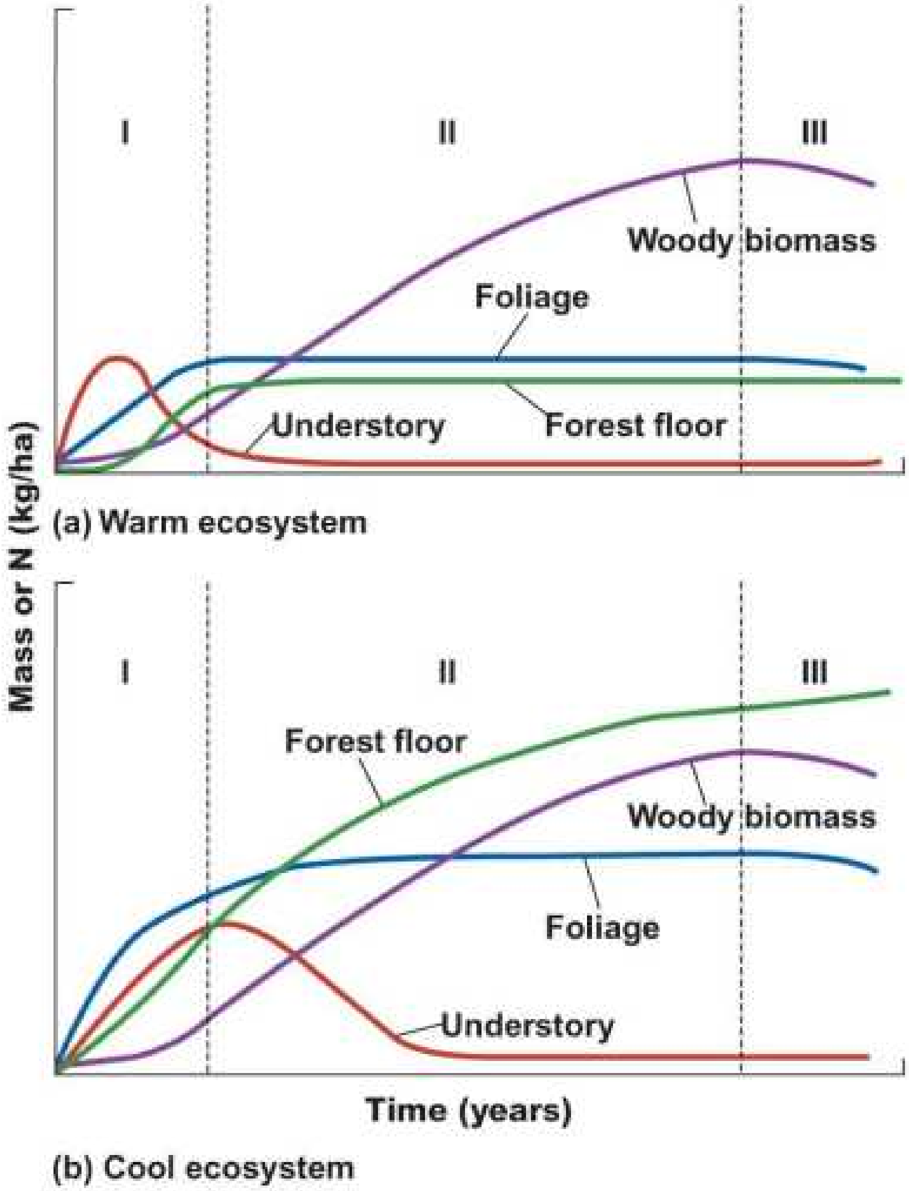


Dorosoma cepedianum
(Gizzard shad, GS)

Ciclo de nutrientes en ambientes terrestres



Ciclo de nutrientes en ambientes terrestres



(a) Warm ecosystem

(b) Cool ecosystem

Figure 13 Schematic representation of changes in nitrogen pools during the development of a forest stand in (a) a warm ecosystem in which the forest floor litter compartment reaches a steady state, and (b) in a cool or cold ecosystem in which the litter continues to accumulate. Three phases can be recognized. In Phase I the understory has much of the nitrogen and plays a major role in cycling. In Phase II the forest canopy closes and the understory pool declines. In Phase III senescence of the forest stand occurs and tree mortality may ensue. (From Johnson 2006.)

Ciclo de nutrientes en ambientes terrestres

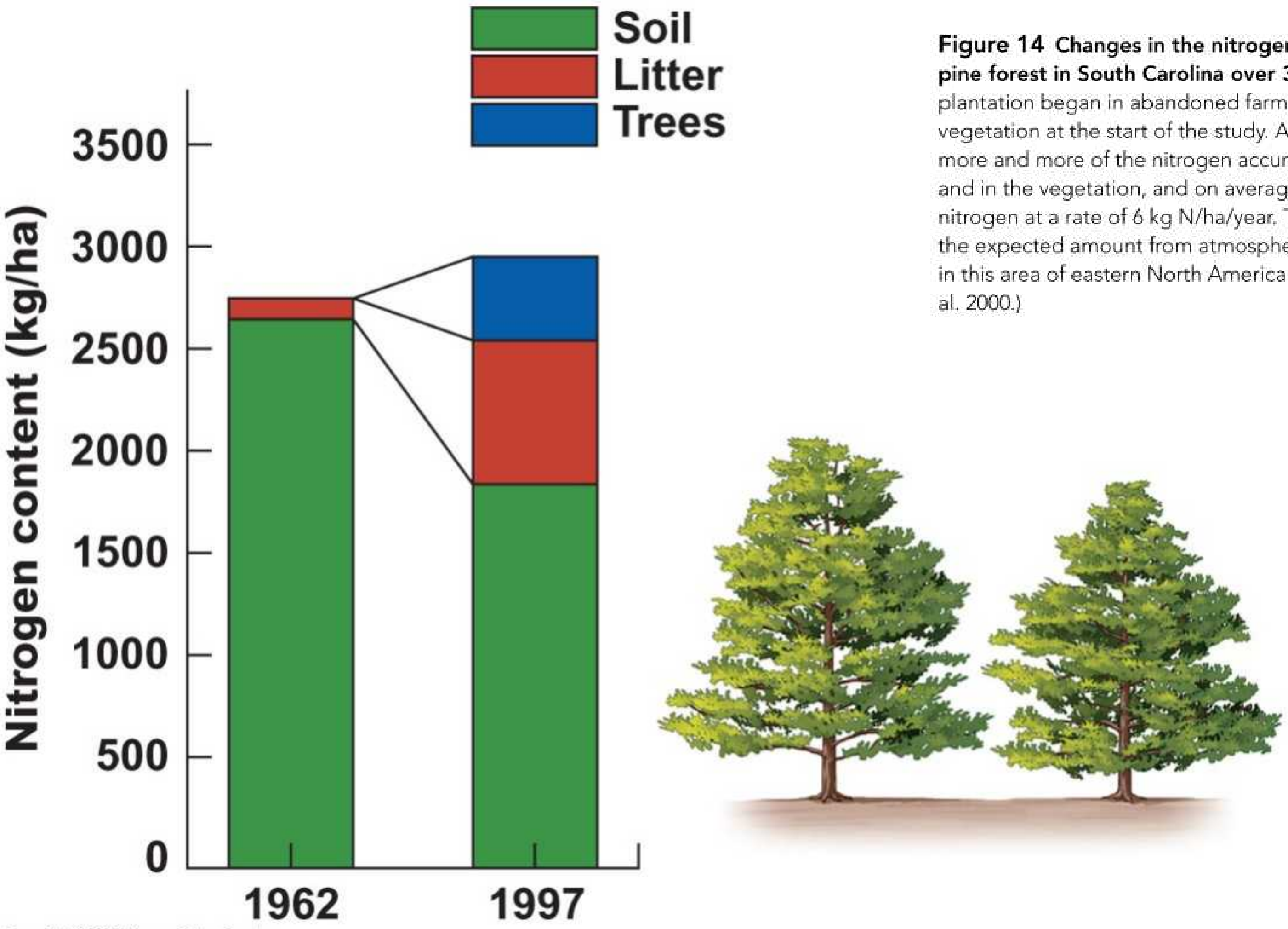


Figure 14 Changes in the nitrogen content of a loblolly pine forest in South Carolina over 35 years. This forestry plantation began in abandoned farmland so there was no vegetation at the start of the study. As the forest developed, more and more of the nitrogen accumulated in the litter and in the vegetation, and on average the site accumulated nitrogen at a rate of 6 kg N/ha/year. This is approximately the expected amount from atmospheric deposition per year in this area of eastern North America. (Data from Binkley et al. 2000.)

Ciclo de nutrientes en ambientes terrestres

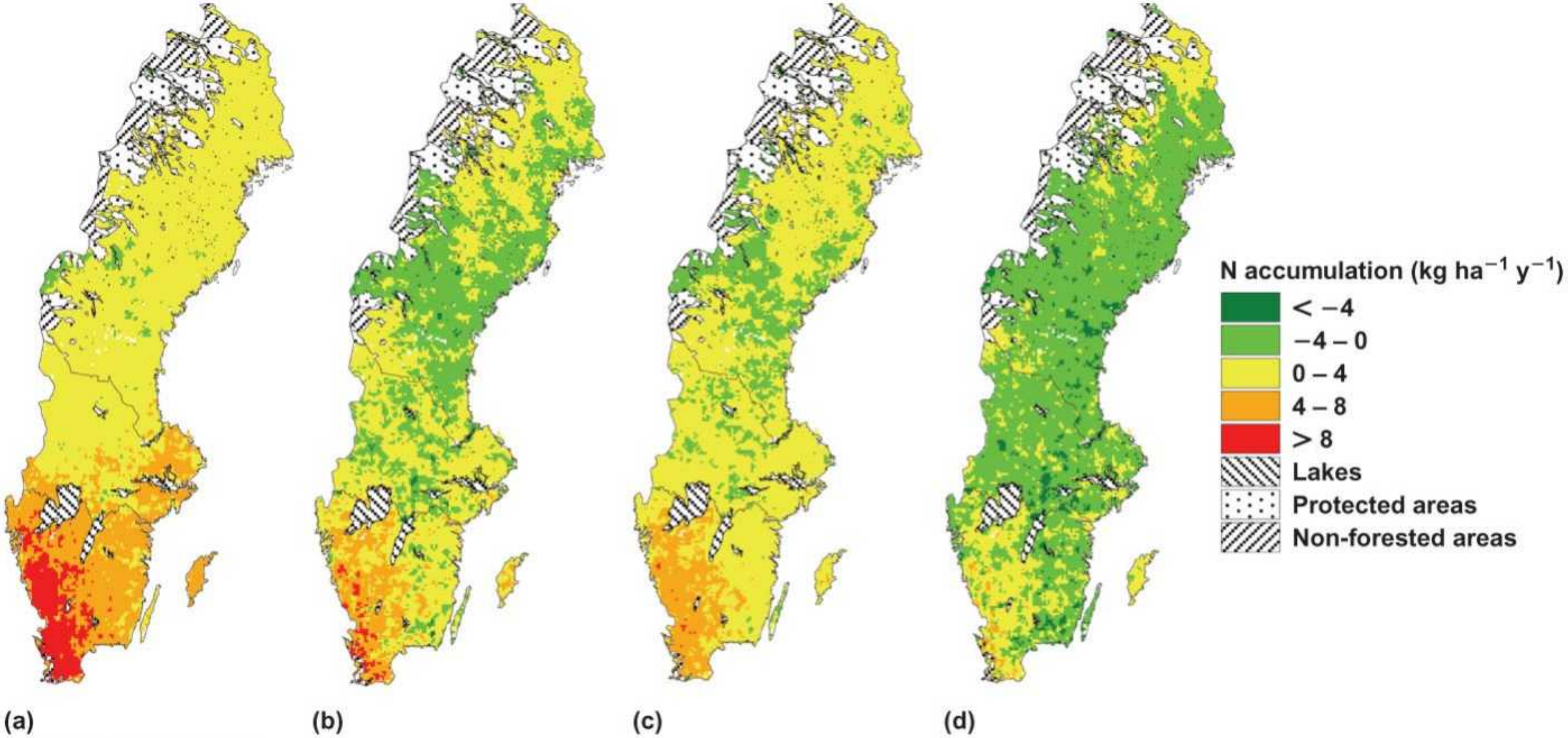
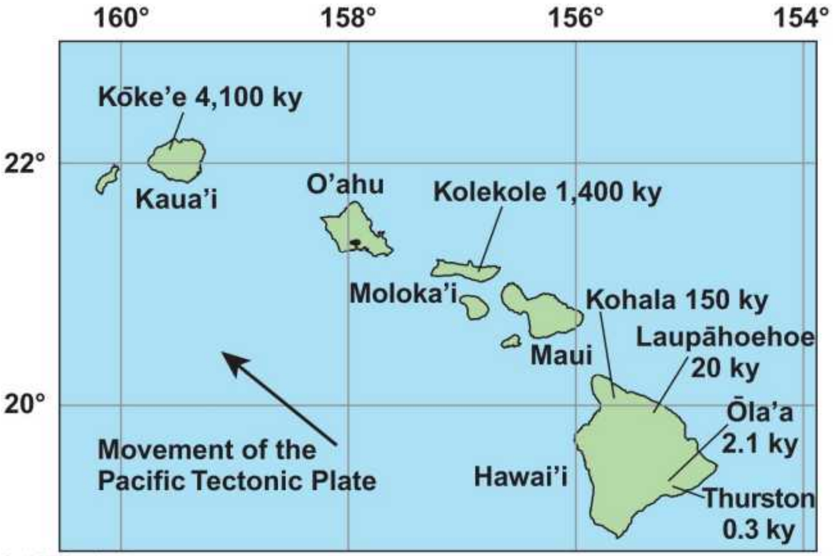
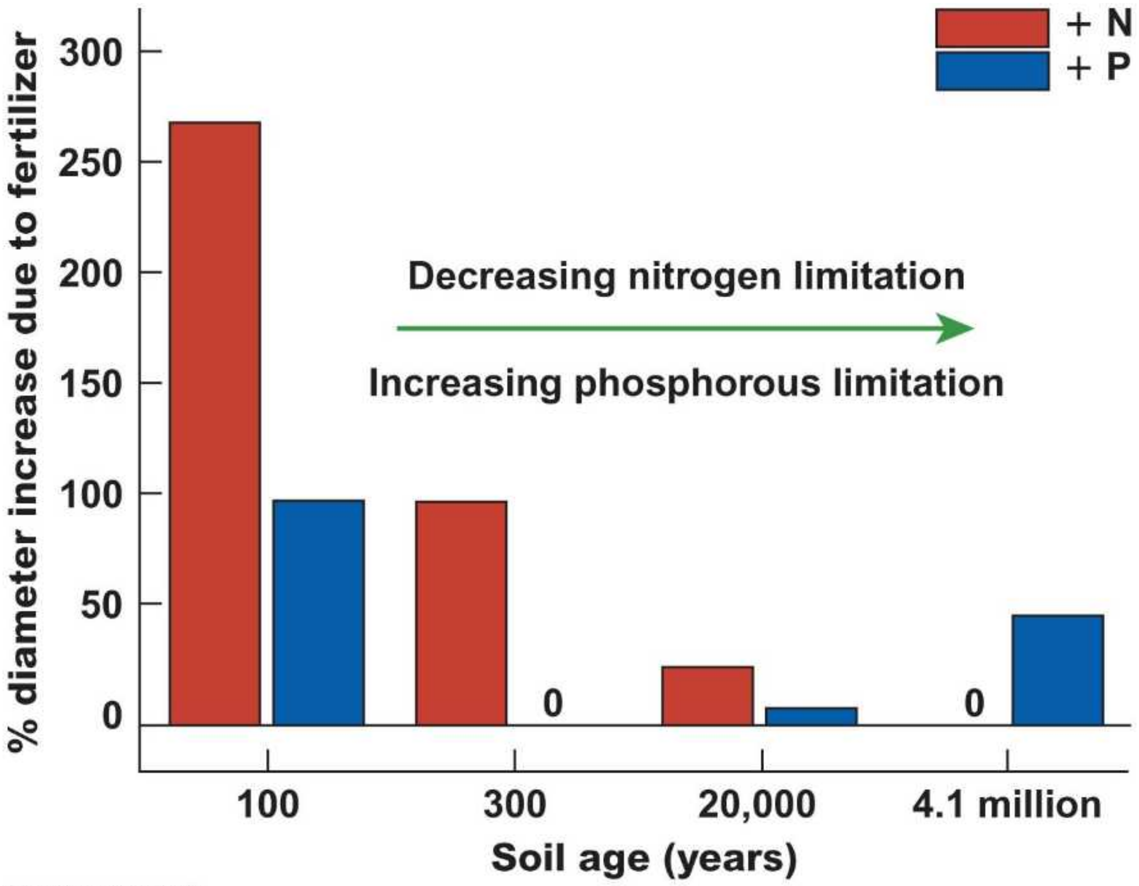


Figure 15 Nitrogen accumulation in Swedish forests according to four possible future scenarios. (a) Nitrogen aerial deposition levels of 1998 and harvesting of only the tree stem. (b) Nitrogen deposition of 1998 and harvesting of the entire tree. (c) Decreasec aerial deposition of nitrogen by 2010 and tree stem harvesting. (d) Decreased aerial deposition of nitrogen by 2010 and whole tree harvesting. Southern Swedish forests have no need for nitrogen fertilization, but central and northern Swedish forests require some fertilization to replace losses due to forest harvesting. (From Akselsson et al. 2007.)

Ciclo de nutrientes en ambientes terrestres





Ciclo de nutrientes en ambientes terrestres

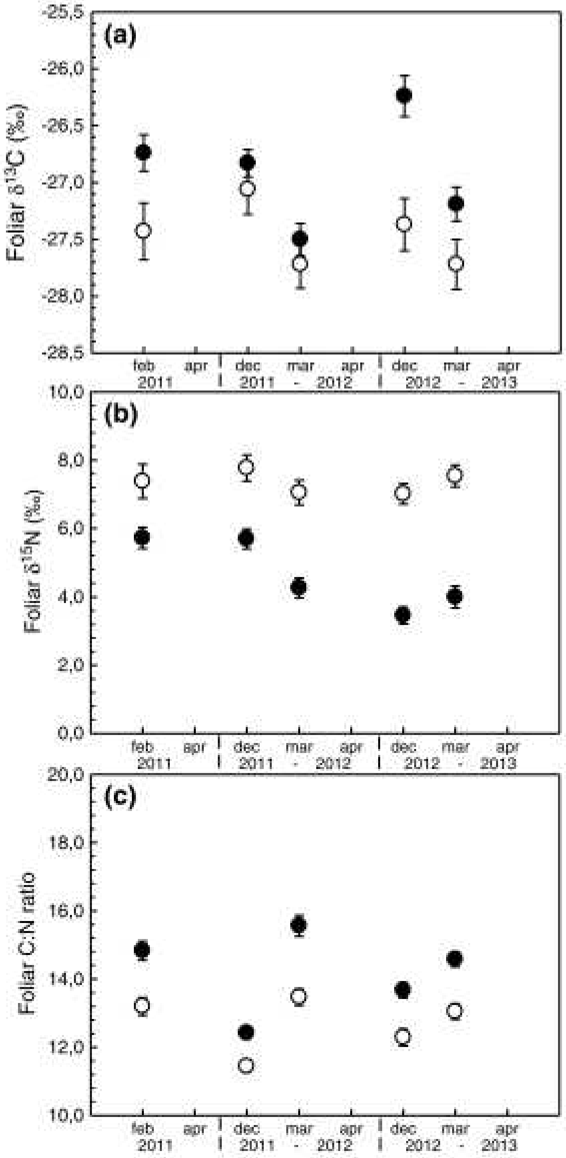


Figure 6. Relative abundance of stable isotopes of carbon (a) and nitrogen (b), and their carbon to nitrogen ratio (c) in leaves of *P. flexuosa* for control woodlands (*filled circles*) and livestock stations (*open circles*) during the experimental period. Symbols are means ± 1 s.e.m.

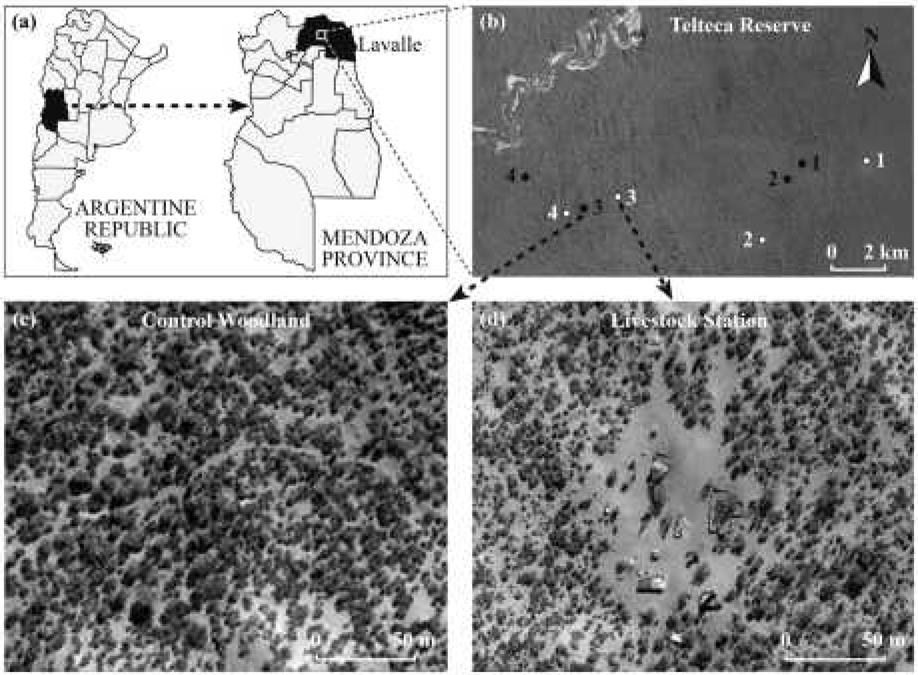
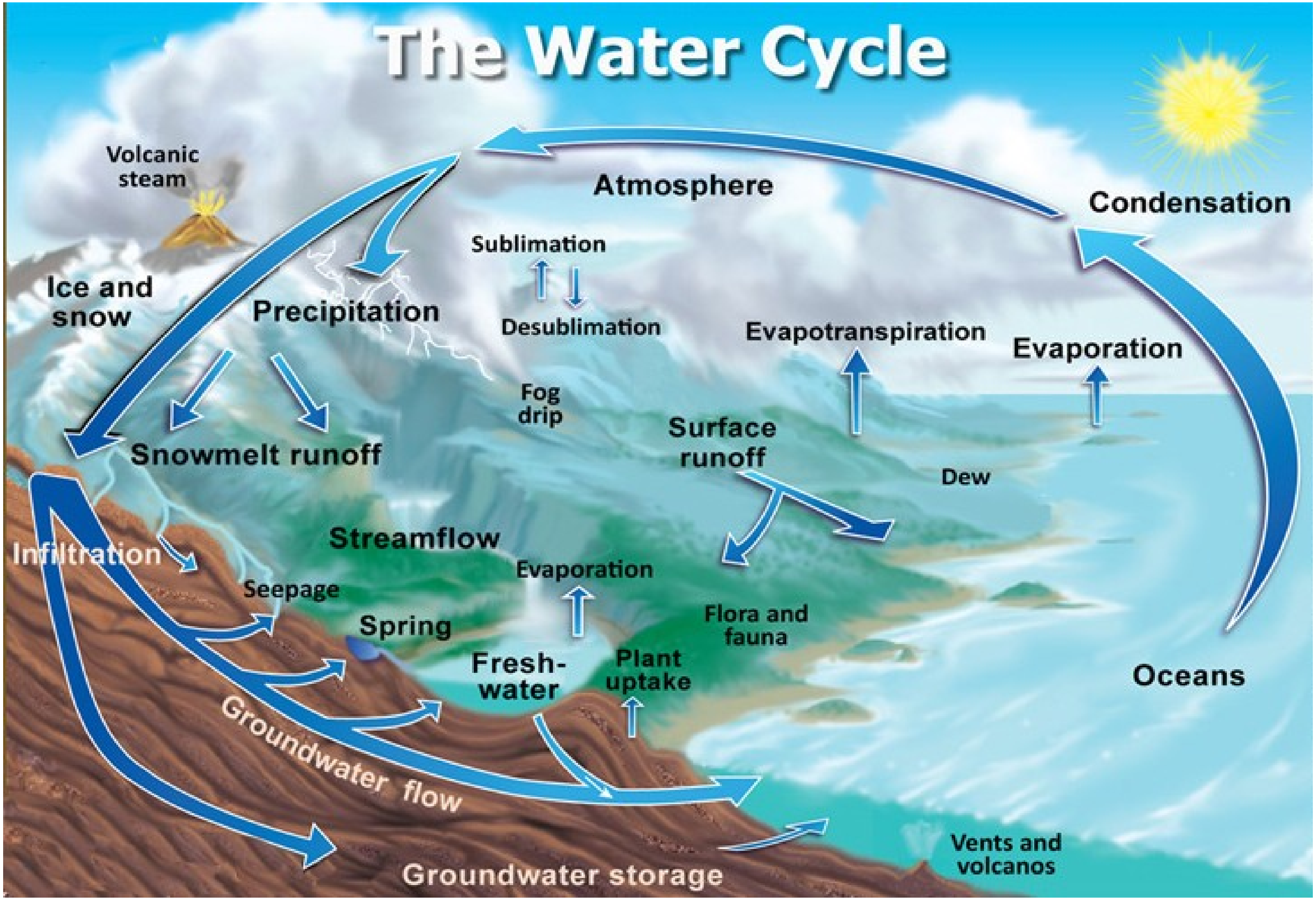


Figure 1. Maps of the Argentine Republic (a) and Mendoza Province (b). A satellite image marks the location of the control woodlands (black mark) and the livestock stations (white mark) in the Telteca Reserve (c). Satellite images with zoom of a control woodland (d) and of paired livestock station (e). Source for the satellite images was Google Earth http://earth.google.es.

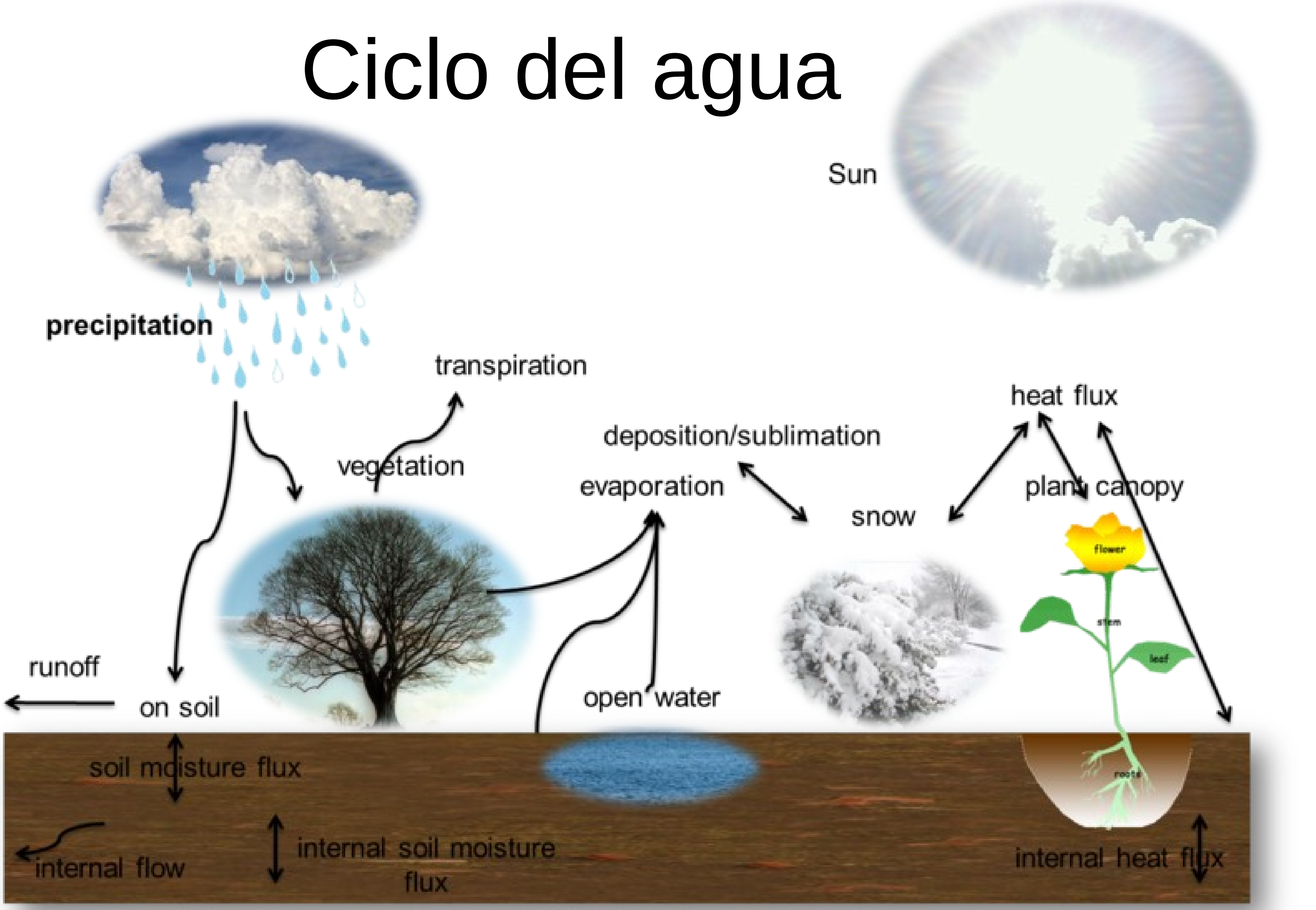
Fuente: Meglioli et al. (2015) Ecohydrology

Ciclo del agua



Fuente: Wikipedia

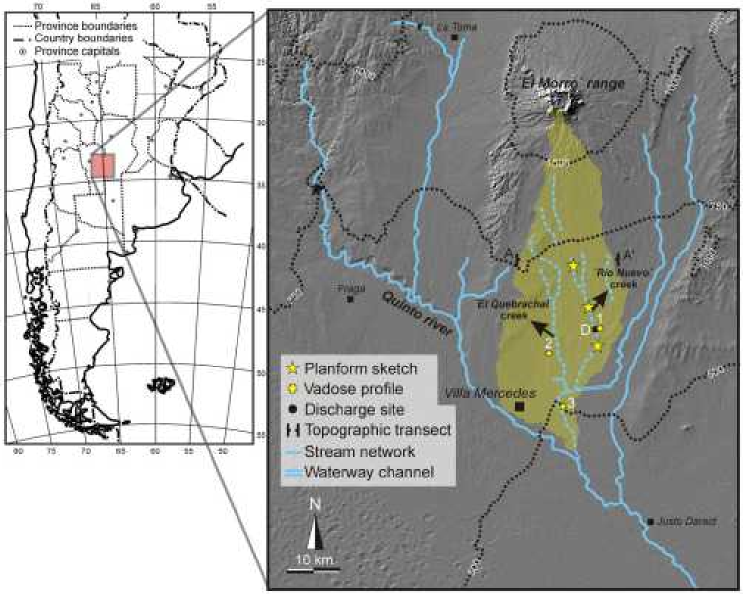
Ciclo del agua



(Chen et. al., 1996, 1997; Chen and Dudhia, 2001; Ek et. al., 2003; Koren et. al., 1999)

Fuente: Wikipedia

Ciclo del agua



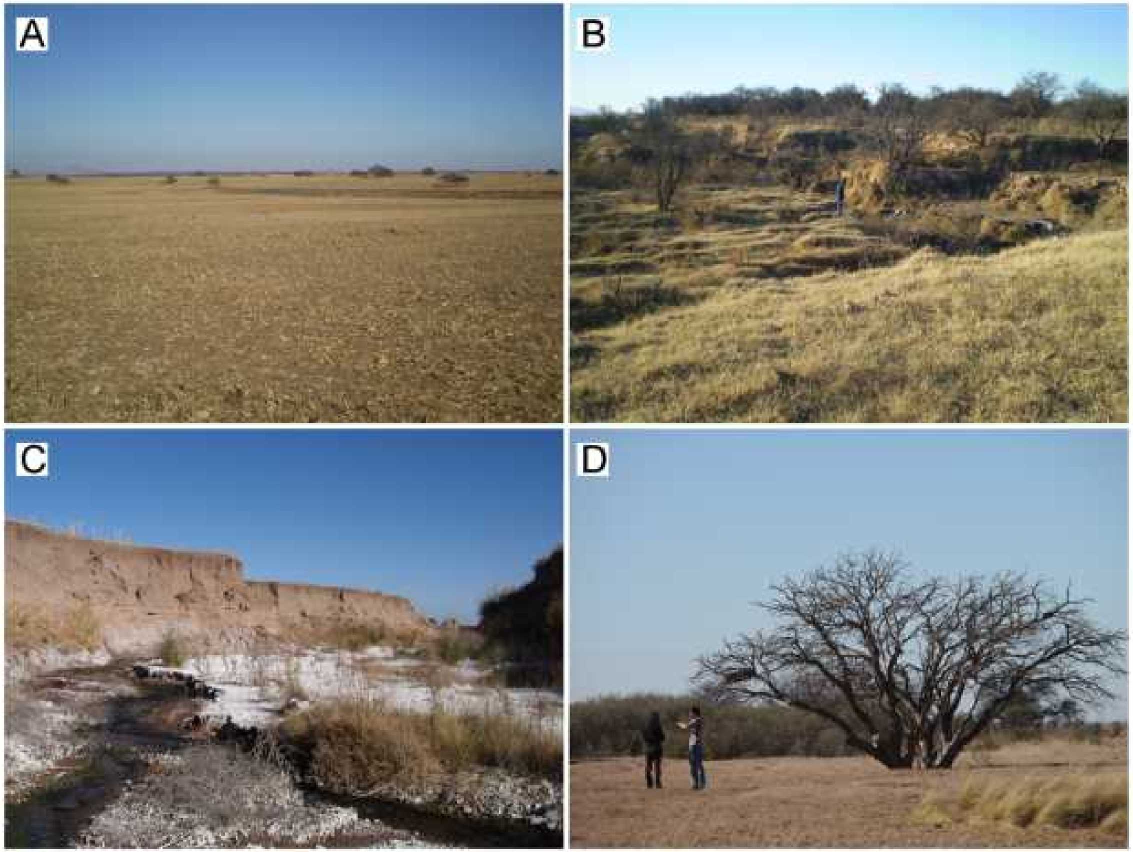


Figure 6. (A) Agriculture stands in the upper section of the catchment with a small surface water body resulting from the groundwater rise, (B) deep-seated mass failures driven by subsurface erosion processes along the new stream banks ('Río Nuevo' creek), (C) new stream channels at the upper section of the catchment ('Río Nuevo' creek) with 6 m vertical side walls and secondary salinity signals and (D) soil embankment in the middle section of the catchment (depth of the new sediments is estimated ~1.5 m).

Fuente: Contreras et al. (2013)
Ecohydrology

Ciclo del agua

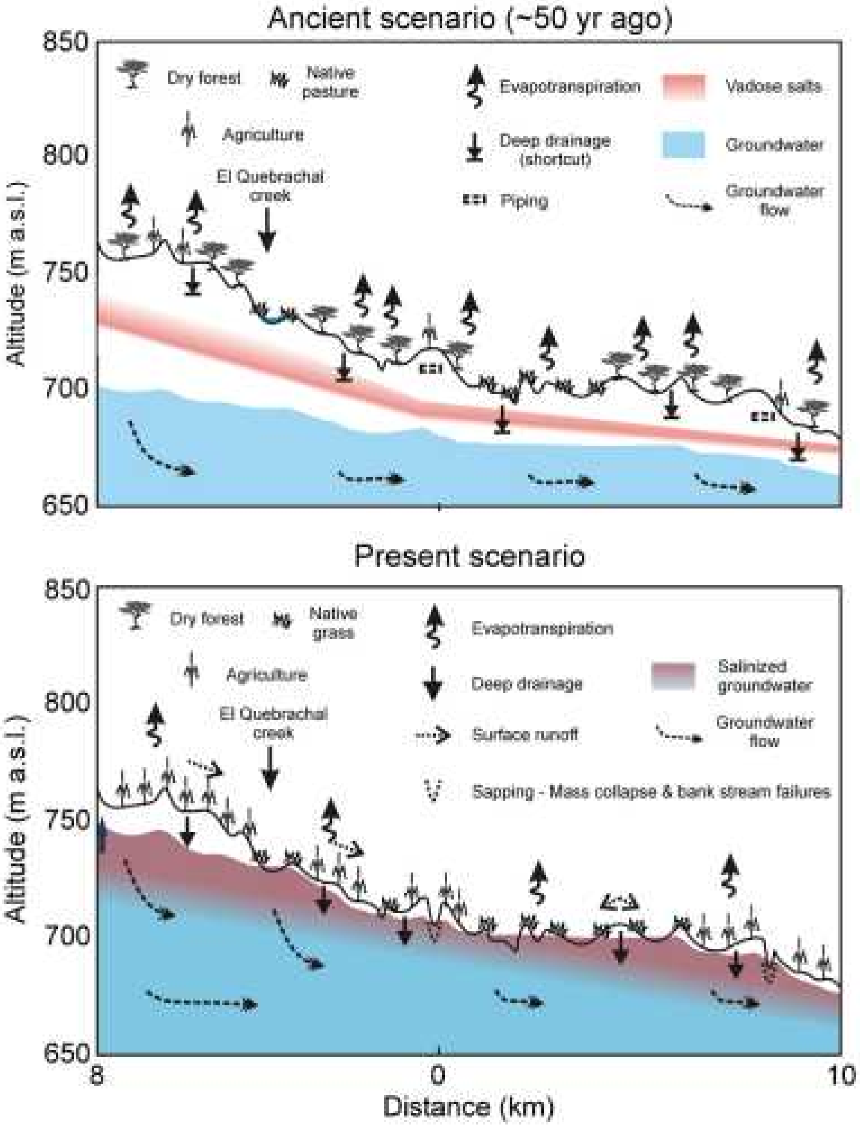
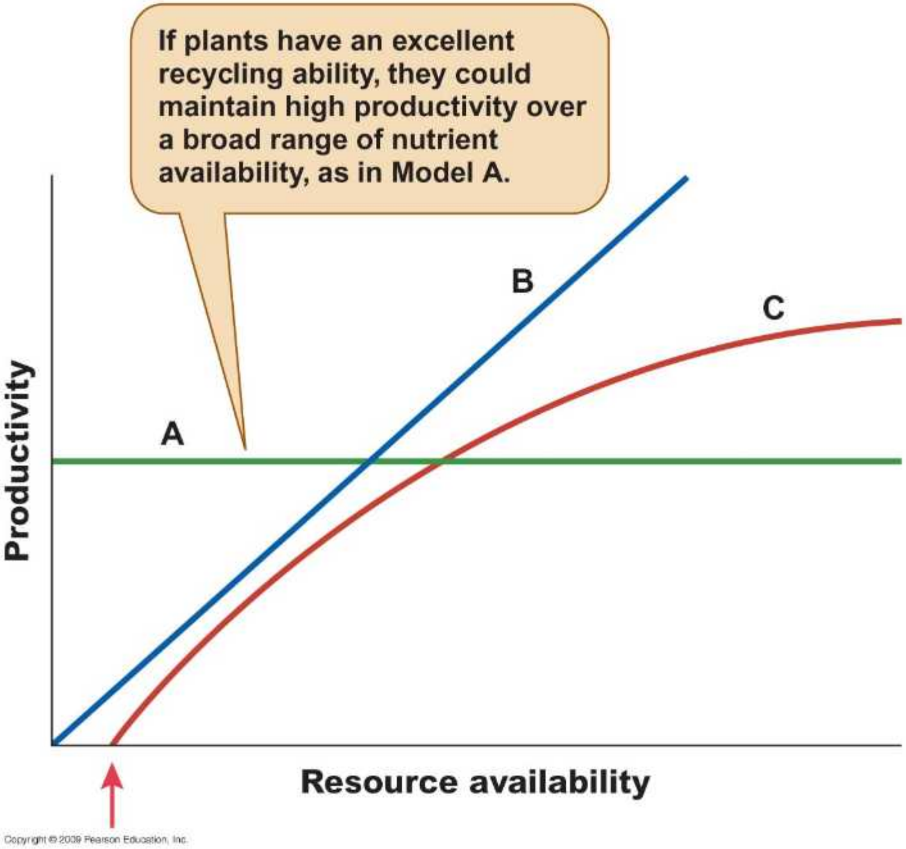


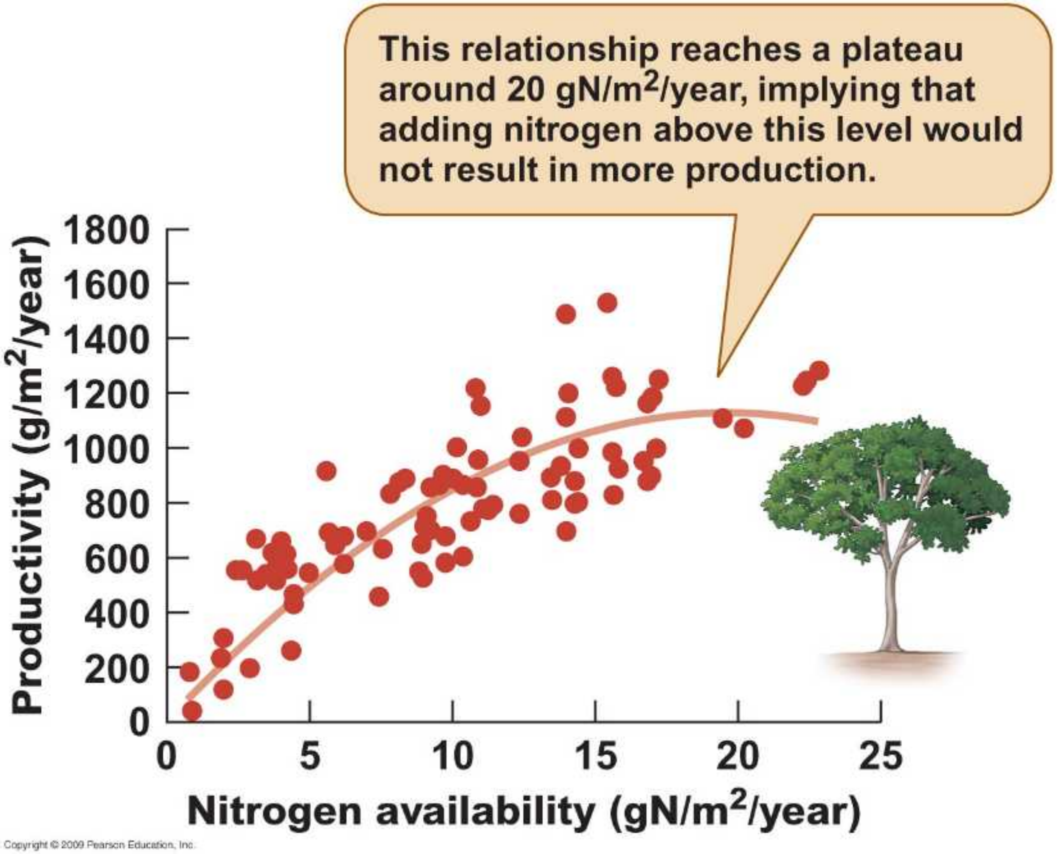
Figure 7. Conceptual model showing the processes and mechanisms involved in the hydro-geomorphologic evolution of the catchment. The profile section, located at the transition between the loessic–sandy and sandy plains, is at scale and shows the local tectonic depression where most of the new canyons and watercourses originate (transect A–A′ in Figure 1). An ancient scenario with a dense dry forest coverage was characterized by the non-flow condition with dry and salty vadose profiles, and deep groundwater levels. After the conversion of native vegetation into agriculture (present scenario), recharge was enhanced resulting in water table level rises, activation of subsurface erosion processes (piping and sapping) and abrupt appearance of lagoons and new watercourses. Once these canyons and watercourses were formed, their expansion was controlled firstly by streambank erosion and lateral mass failures led by sustain groundwater seepage inflows and secondly, by surface runoff following intense rainfall events.

Fuente: Contreras et al. (2013) Ecohydrology

Eficiencia en el uso de recursos

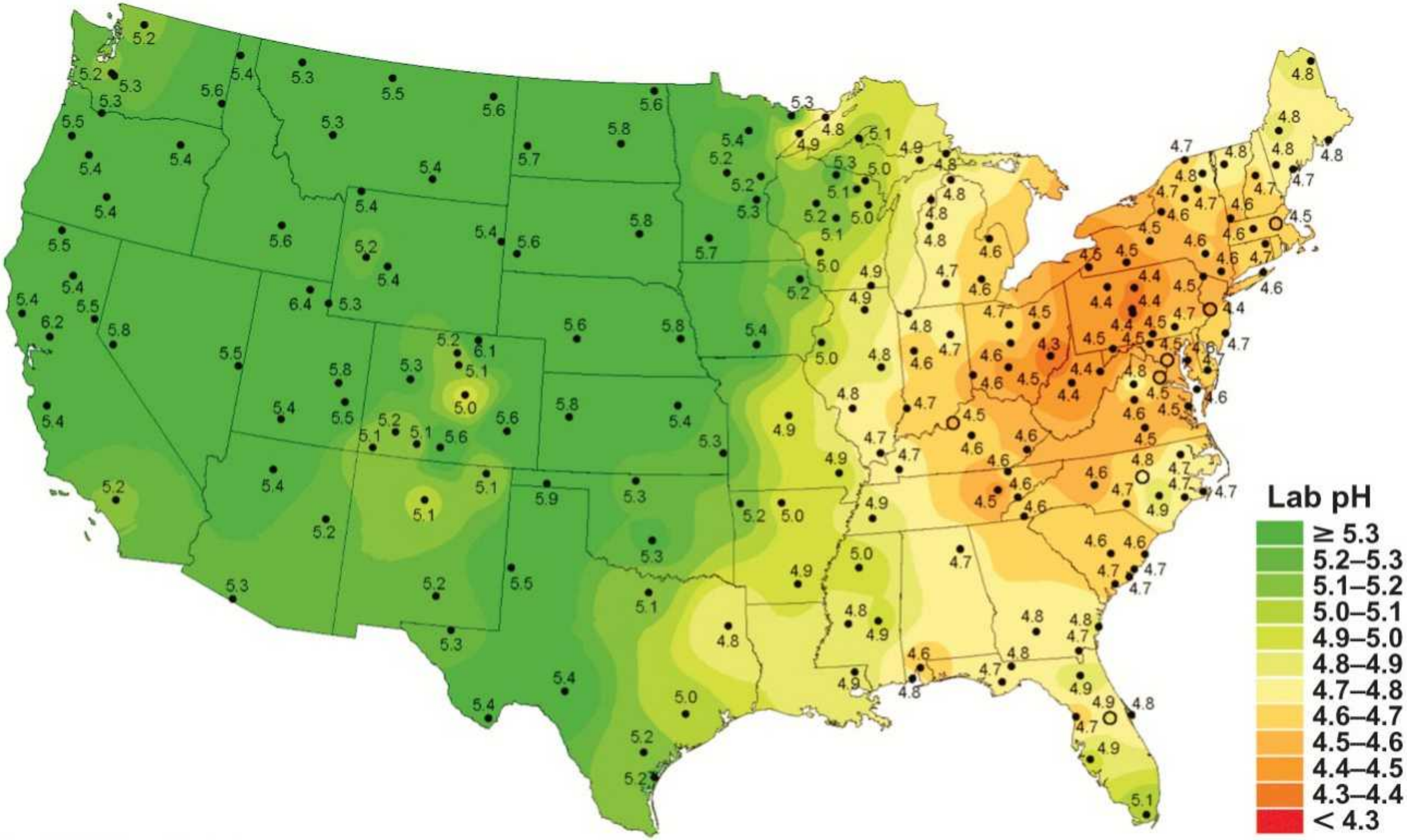


If plants have an excellent recycling ability, they could maintain high productivity over a broad range of nutrient availability, as in Model A.

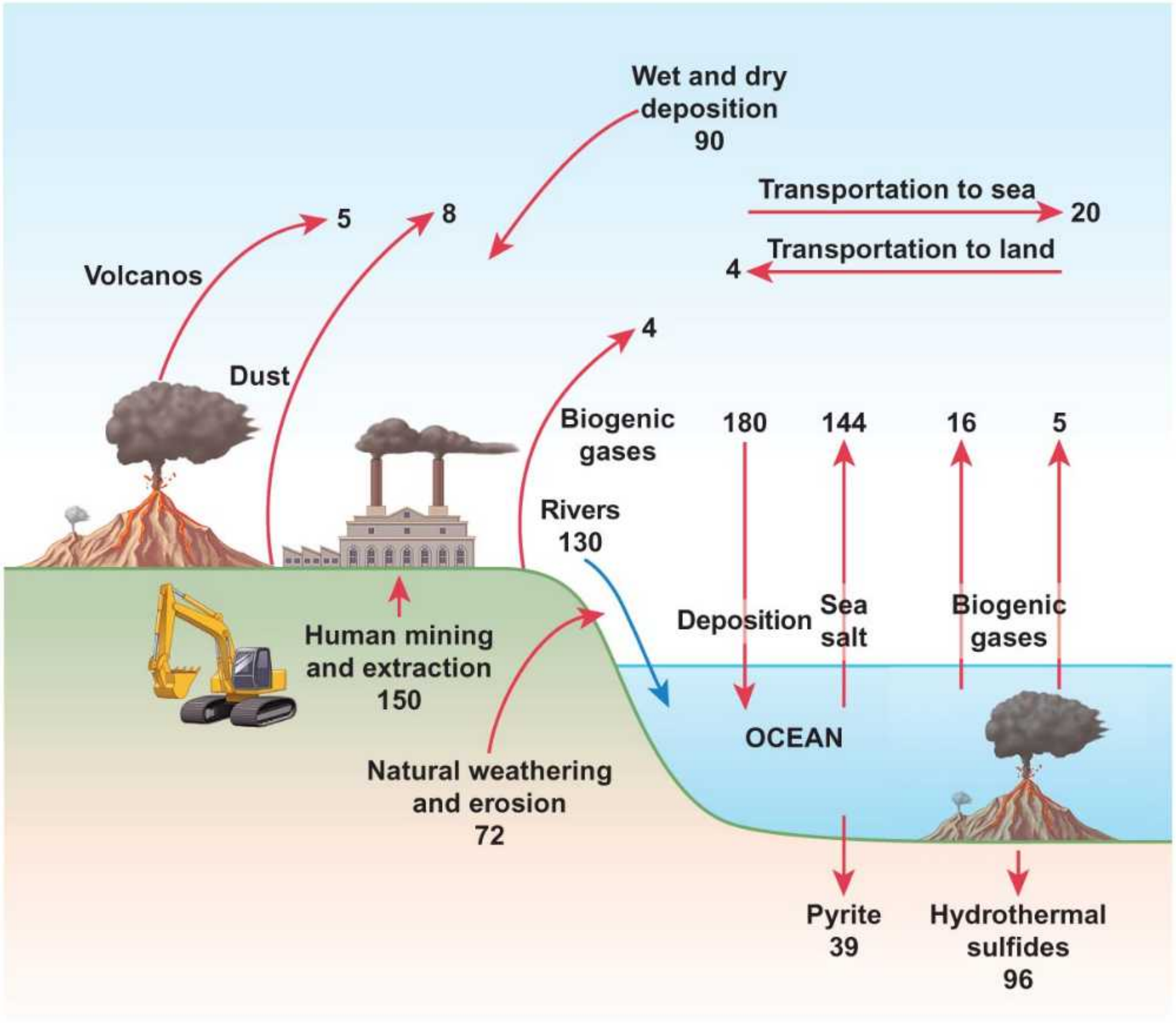


This relationship reaches a plateau around 20 gN/m^2/year, implying that adding nitrogen above this level would not result in more production.

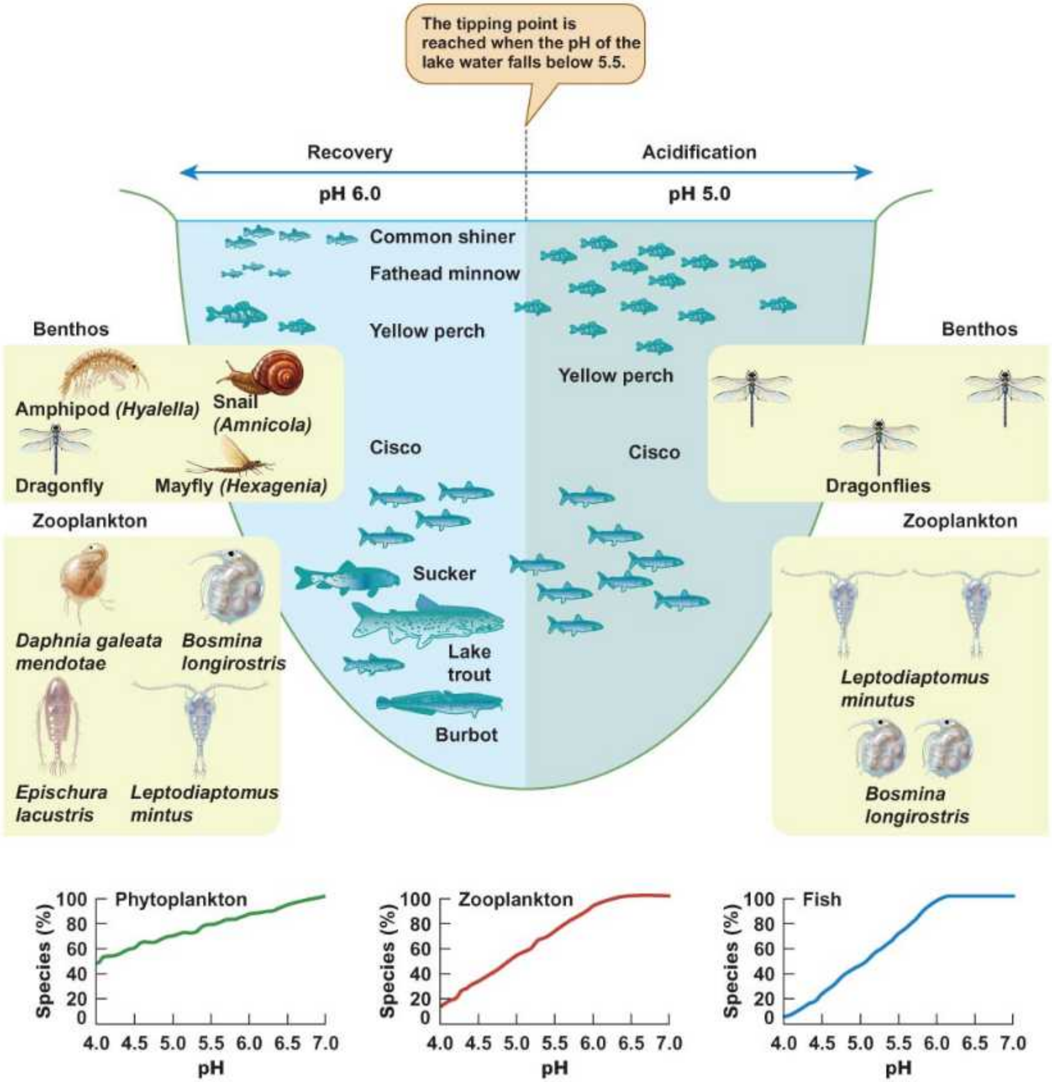
Lluvia ácida y el ciclo de azufre



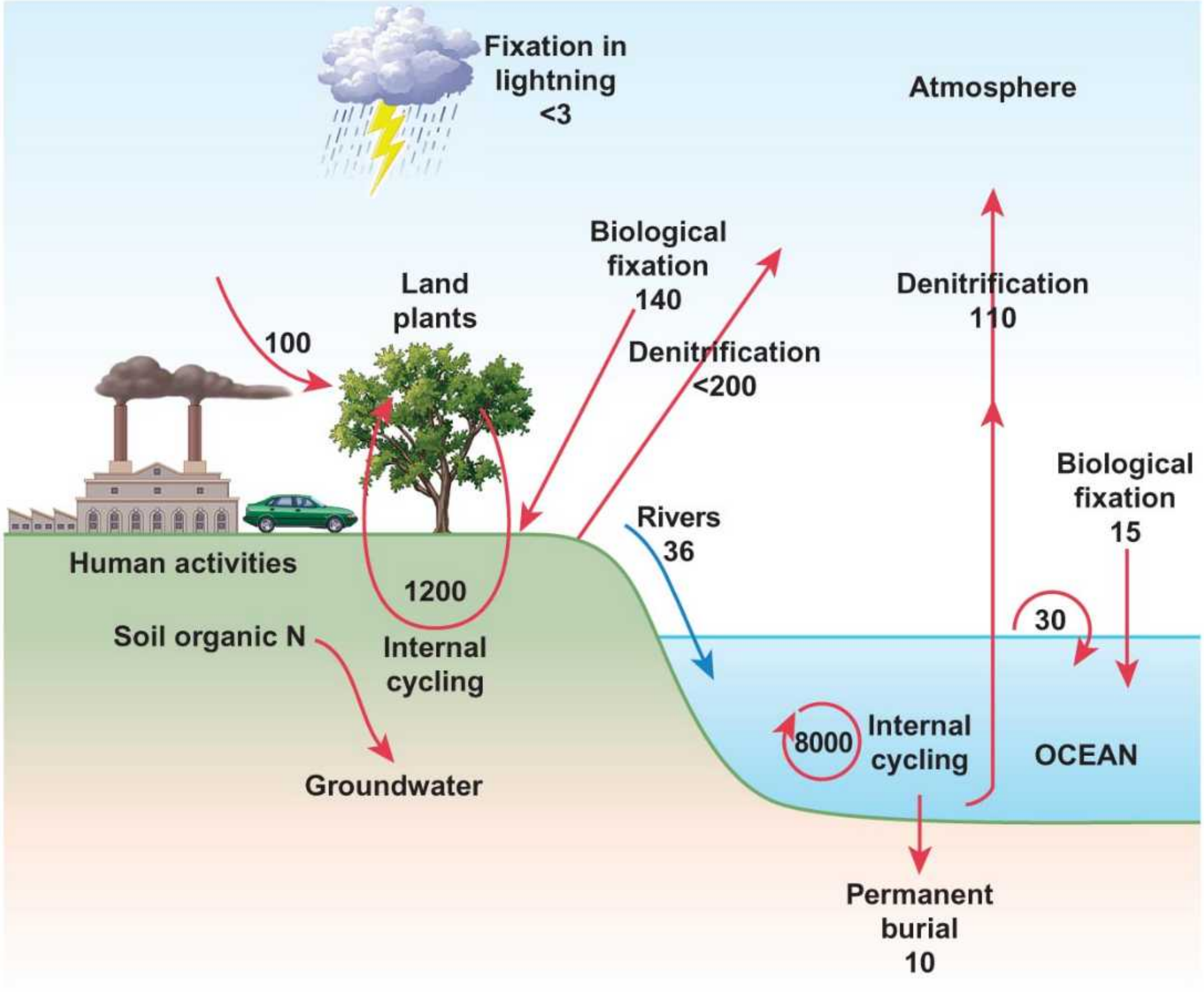
Lluvia ácida y el ciclo de azufre



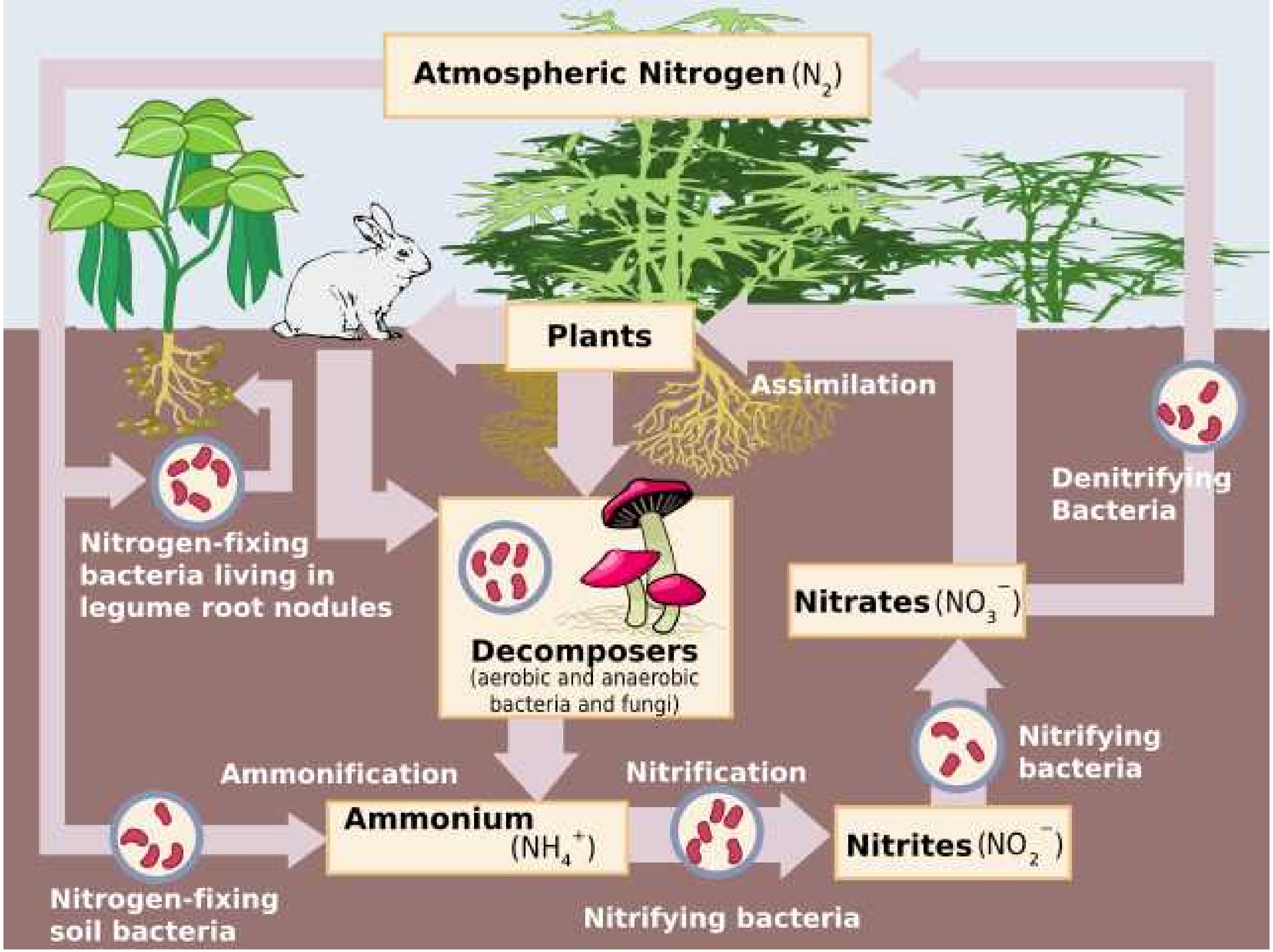
Lluvia ácida y el ciclo de azufre



El ciclo del nitrógeno



El ciclo del nitrógeno



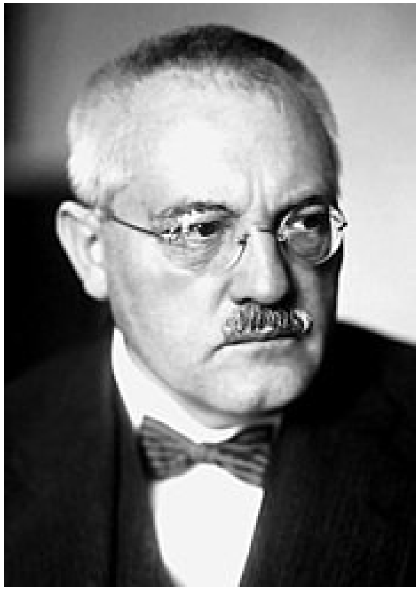
Fuente: Wikipedia

El ciclo del nitrógeno

El proceso Haber-Bosch

$$\underbrace{\mathrm{N_2} + 3\,\mathrm{H_2}}_{\Delta H^\circ = -91.8\,\mathrm{KJ}} \longrightarrow \underbrace{2\,\mathrm{NH_3}}_{\Delta H^\circ = -45.8\,\mathrm{KJ{\cdot}mol^{-1}}}$$

Fritz Haber



Carl Bosch

Fábrica de fertilizante industrial

Fuente: Wikipedia

El ciclo del nitrógeno

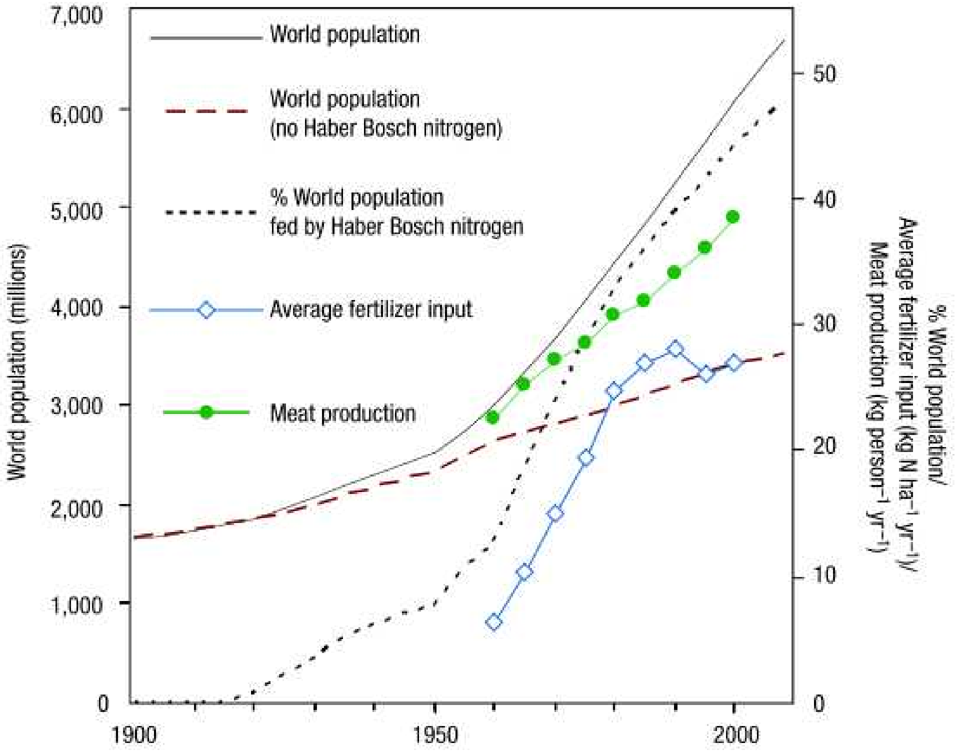


Figure 1 Trends in human population and nitrogen use throughout the twentieth century. Of the total world population (solid line), an estimate is made of the number of people that could be sustained without reactive nitrogen from the Haber–Bosch process (long dashed line), also expressed as a percentage of the global population (short dashed line). The recorded increase in average fertilizer use per hectare of agricultural land (blue symbols) and the increase in per capita meat production (green symbols) is also shown.

Fuente: Erisman et al. (2008)
Nature Geosc 1: 636-639

El ciclo del nitrógeno

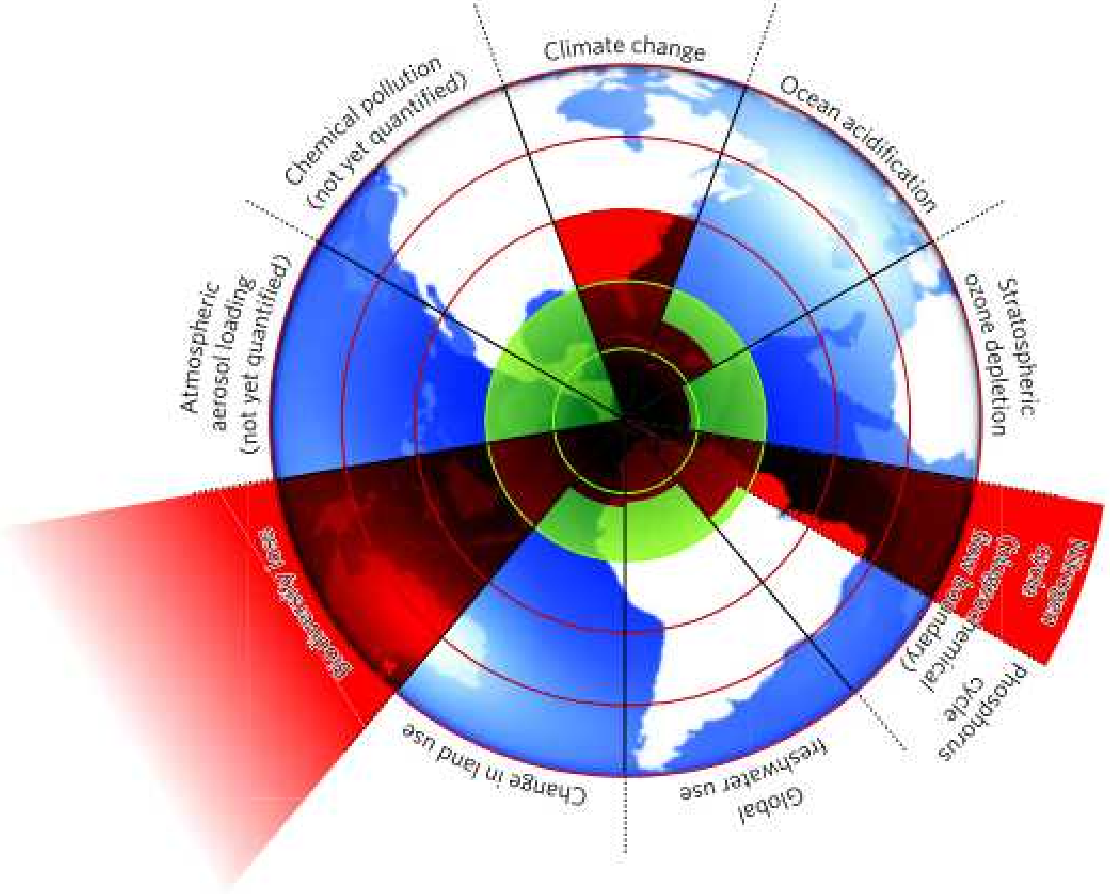


Figure 1 | Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference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

Fuente: Rockström et al. (2009)
Nature 461: 472-475

El ciclo del nitrógeno

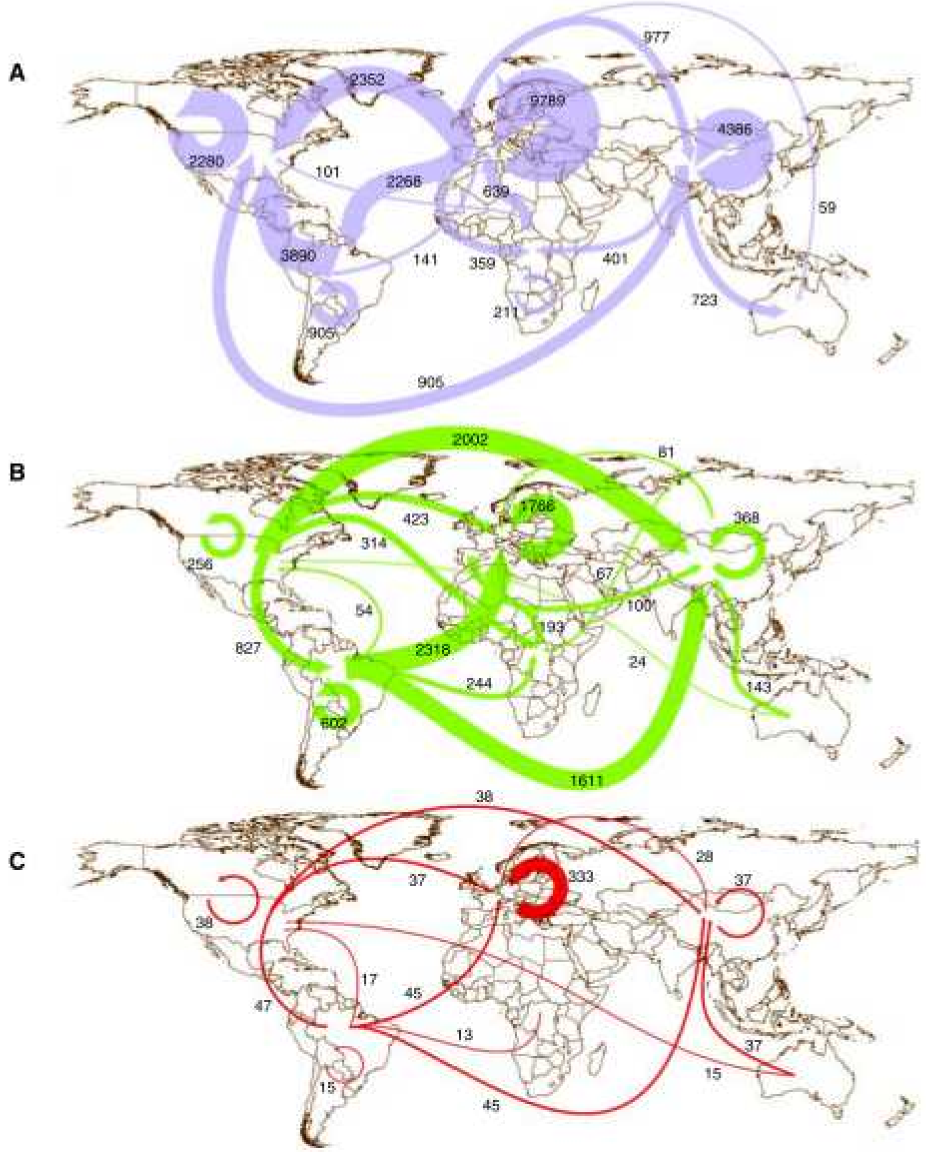


Fig. 1. N contained in internationally traded (**A**) fertilizer (31 Tg N), (**B**) grain (12 Tg N), and (**C**) meat (0.8 Tg N). Data are for 2004 and are in units of thousand of tons. Minimum requirements for drawing a line are 50,000 tons N, 20,000 tons N, and 10,000 tons N for fertilizer, grain, and meat, respectively (*42*).

Fuente: Galloway et al. (2008)
Science 320: 889-892

El ciclo del nitrógeno

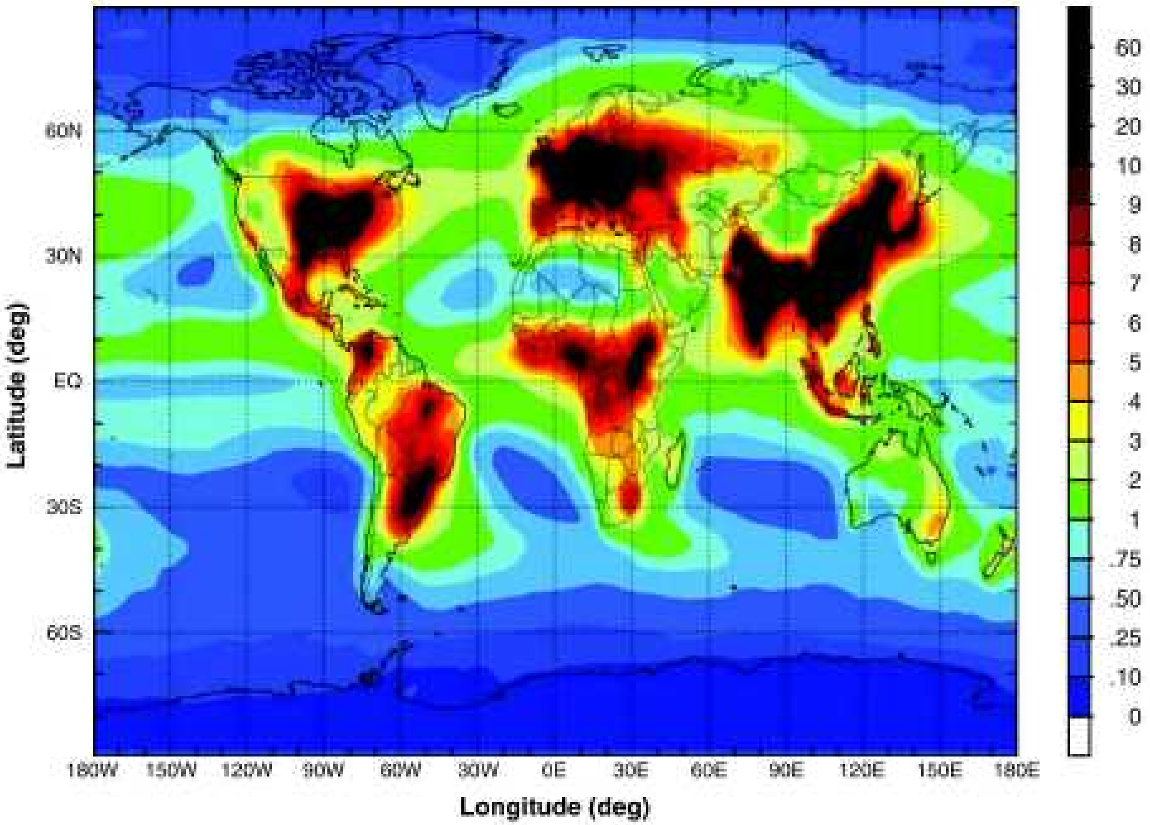


Fig. 2. Estimated N deposition from global total N (NOy and NHx) emissions, totaling 105 Tg N y^{-1}. The unit scale is kg N ha^{-1} y^{-1}, modified from the original units (mg m^{-2} y^{-1}) (*16*).

Fuente: Galloway et al. (2008)
Science 320: 889-892

El ciclo del nitrógeno

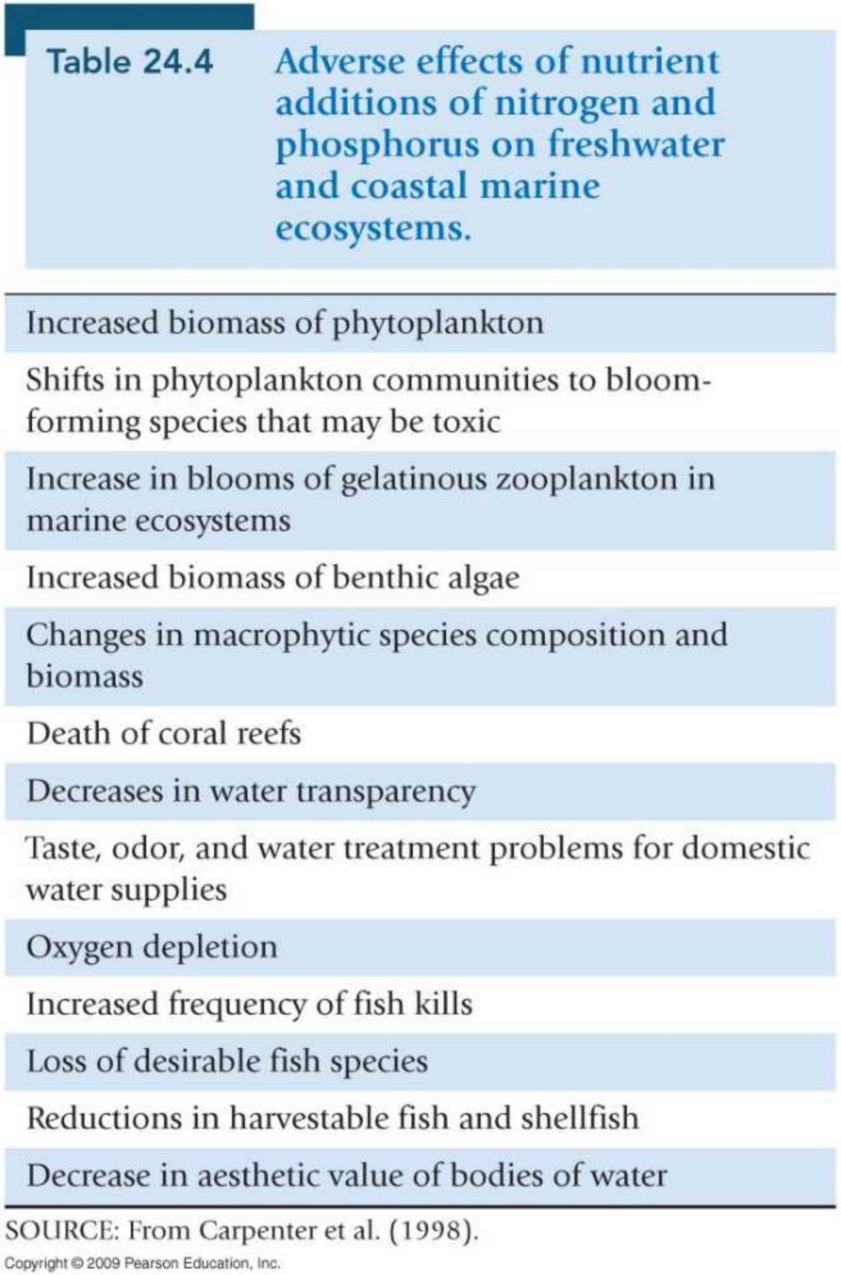
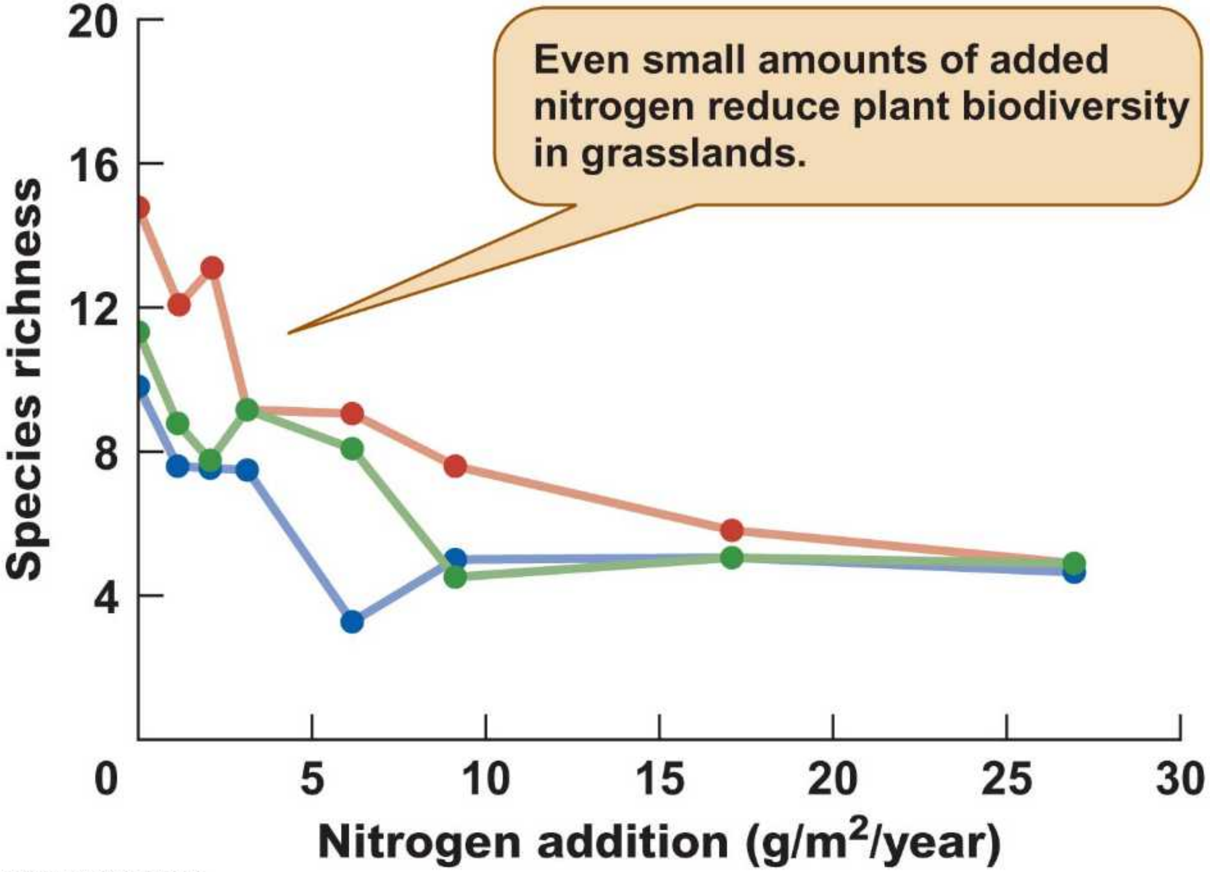


Table 24.4 Adverse effects of nutrient additions of nitrogen and phosphorus on freshwater and coastal marine ecosystems.

Increased biomass of phytoplankton
Shifts in phytoplankton communities to bloom-forming species that may be toxic
Increase in blooms of gelatinous zooplankton in marine ecosystems
Increased biomass of benthic algae
Changes in macrophytic species composition and biomass
Death of coral reefs
Decreases in water transparency
Taste, odor, and water treatment problems for domestic water supplies
Oxygen depletion
Increased frequency of fish kills
Loss of desirable fish species
Reductions in harvestable fish and shellfish
Decrease in aesthetic value of bodies of water

SOURCE: From Carpenter et al. (1998).

El ciclo del nitrógeno



Even small amounts of added nitrogen reduce plant biodiversity in grasslands.

Figure 26 Vegetation responses to 12 years of nitrogen fertilization in Minnesota grasslands. Three fields were used, and six replicates were used for each level of nitrogen addition. Biodiversity declines dramatically as more nitrogen is added to these grasslands. (From Wedin and Tilman 1996.)

El ciclo del nitrógeno

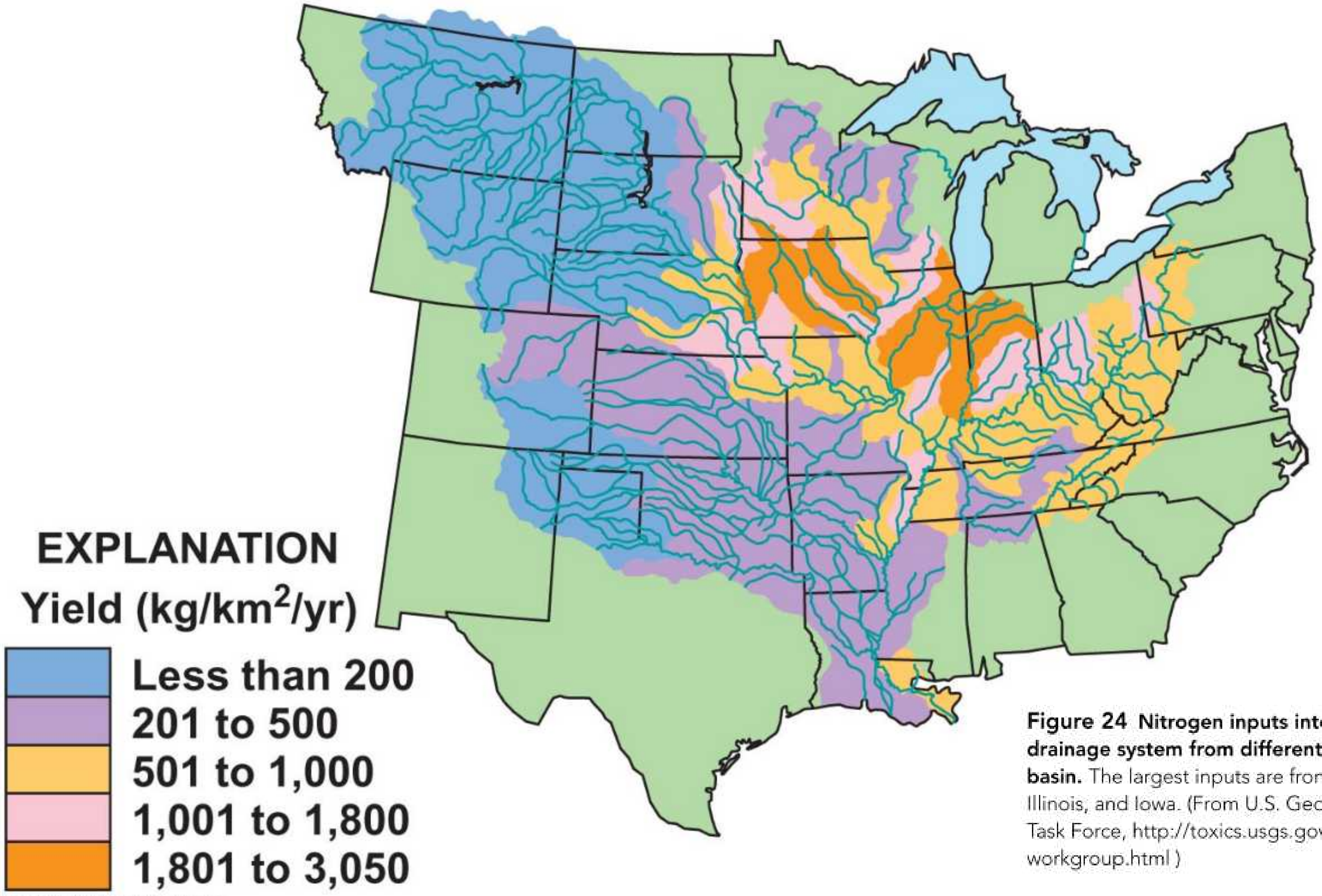


Figure 24 **Nitrogen inputs into the Mississippi River drainage system from different parts of the drainage basin.** The largest inputs are from the corn belt of Indiana, Illinois, and Iowa. (From U.S. Geological Survey, Hypoxia Task Force, http://toxics.usgs.gov/hypoxia/task_force_workgroup.html)

El ciclo del nitrógeno

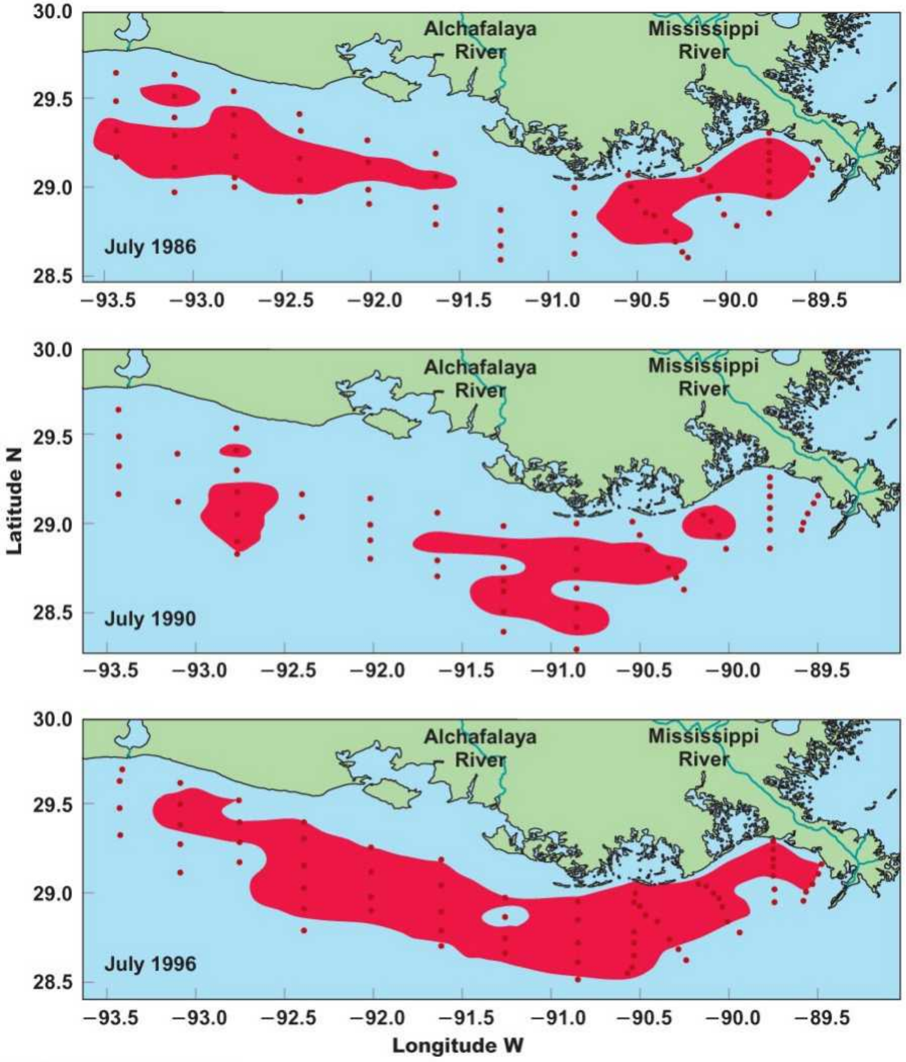


Figure 25 Size of the hypoxia zone (red) off the Mississippi River mouth in midsummer 1986, 1990, and 1996. The dots are the sampling stations in the Gulf of Mexico. Nitrogen-rich water coming down the Mississippi River increases primary production in coastal waters so much that decomposition causes all the oxygen to be depleted in summer in the red zones. (Modified from Rabalais et al. 2002.)

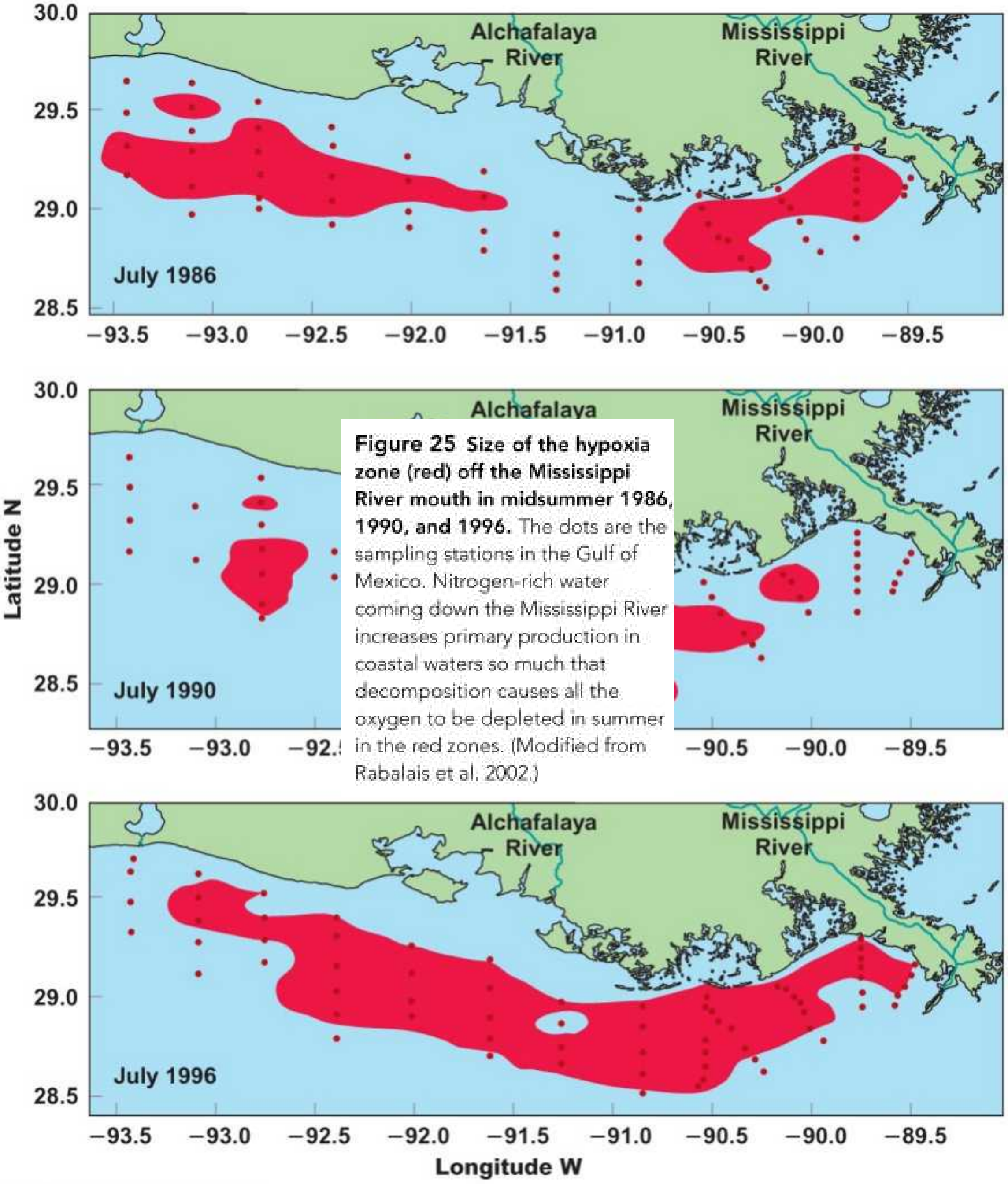


Figure 25 **Size of the hypoxia zone (red) off the Mississippi River mouth in midsummer 1986, 1990, and 1996.** The dots are the sampling stations in the Gulf of Mexico. Nitrogen-rich water coming down the Mississippi River increases primary production in coastal waters so much that decomposition causes all the oxygen to be depleted in summer in the red zones. (Modified from Rabalais et al. 2002.)

Teórica 14: Conclusiones

- El ciclo de nutrientes es un proceso fundamental en los ecosistemas.
- El ciclo de nutrientes depende de los distintos componentes de los ecosistemas y del aporte externo.
- Las actividades humanas pueden afectar fuertemente los ciclos de nutrientes a nivel regional y global.