Physical environment

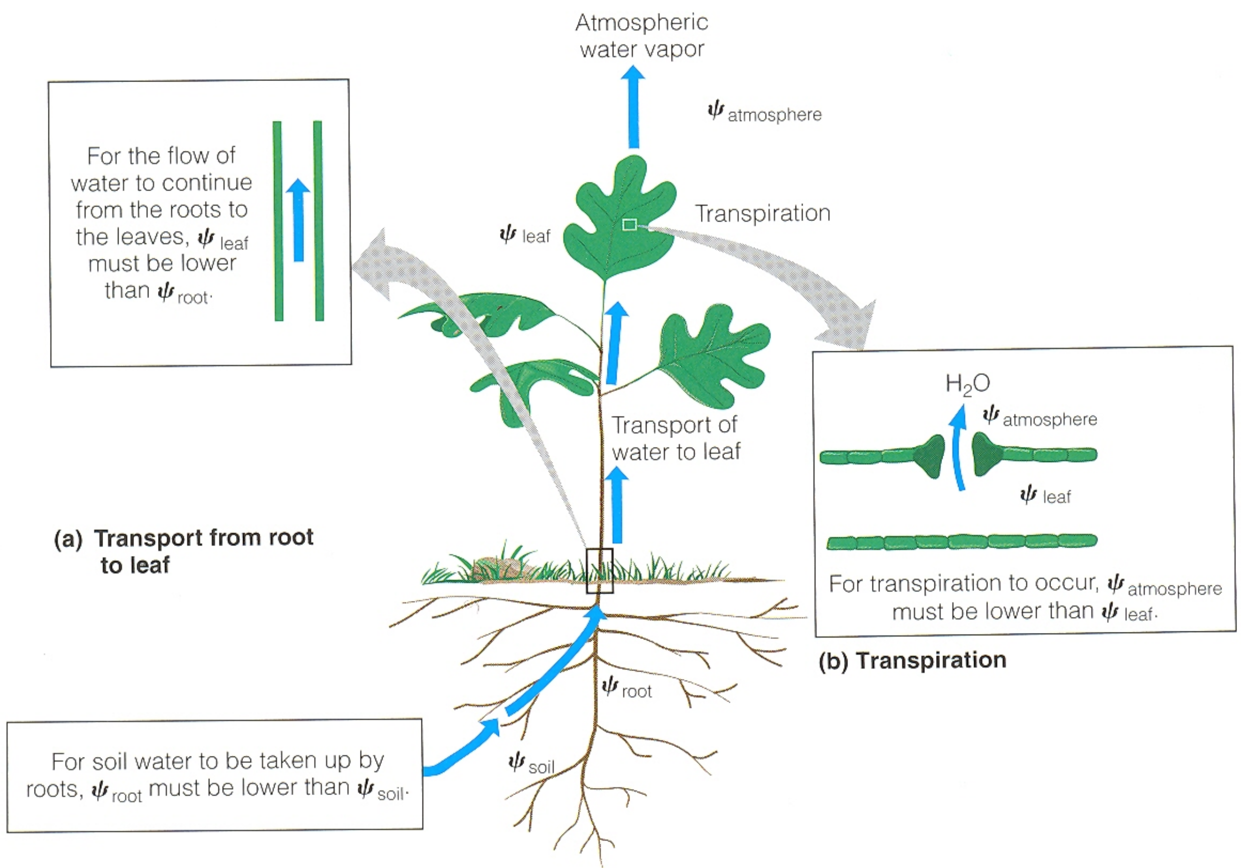


Figure 6.4 | Transport of water along a water potential (ψ) gradient from soil to leaves to air. **(a)** As long as the osmotic potential of the roots is lower than that of the soil, ψ_{root} will be lower than ψ_{soil}, and the roots will continue to take up water from the soil. **(b)** As long as the vapor pressure of the atmosphere (relative humidity) is lower than that of the air inside the leaf, $\psi_{atmosphere}$ will be lower than ψ_{leaf}, and transpiration will continue.

Smith and Smith, 2006

Physical environment

Moisture stress on plants: mortality

Croplands

http://soilcrop.tamu.edu/photogallery/cornsorghum+/images/drought%20stress%203.jpg

Pinyon pine in SW

Photo by Craig Allen - USGS

Physical environment

Water balance controls on tree species distribution in PNW

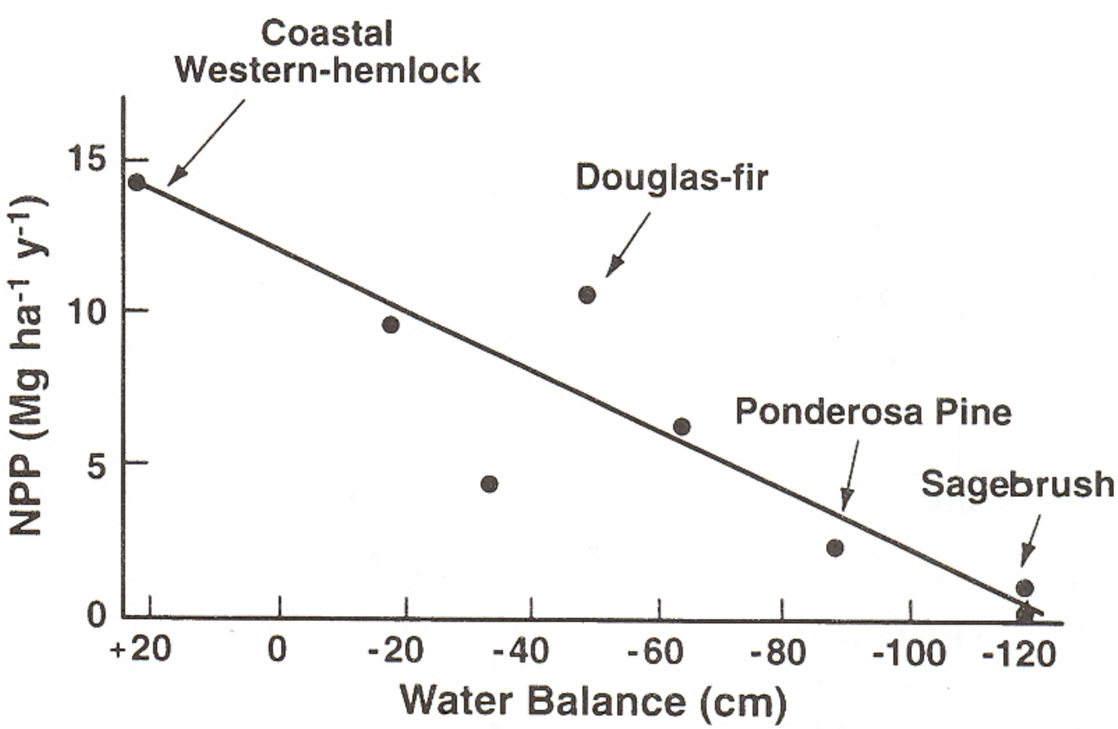
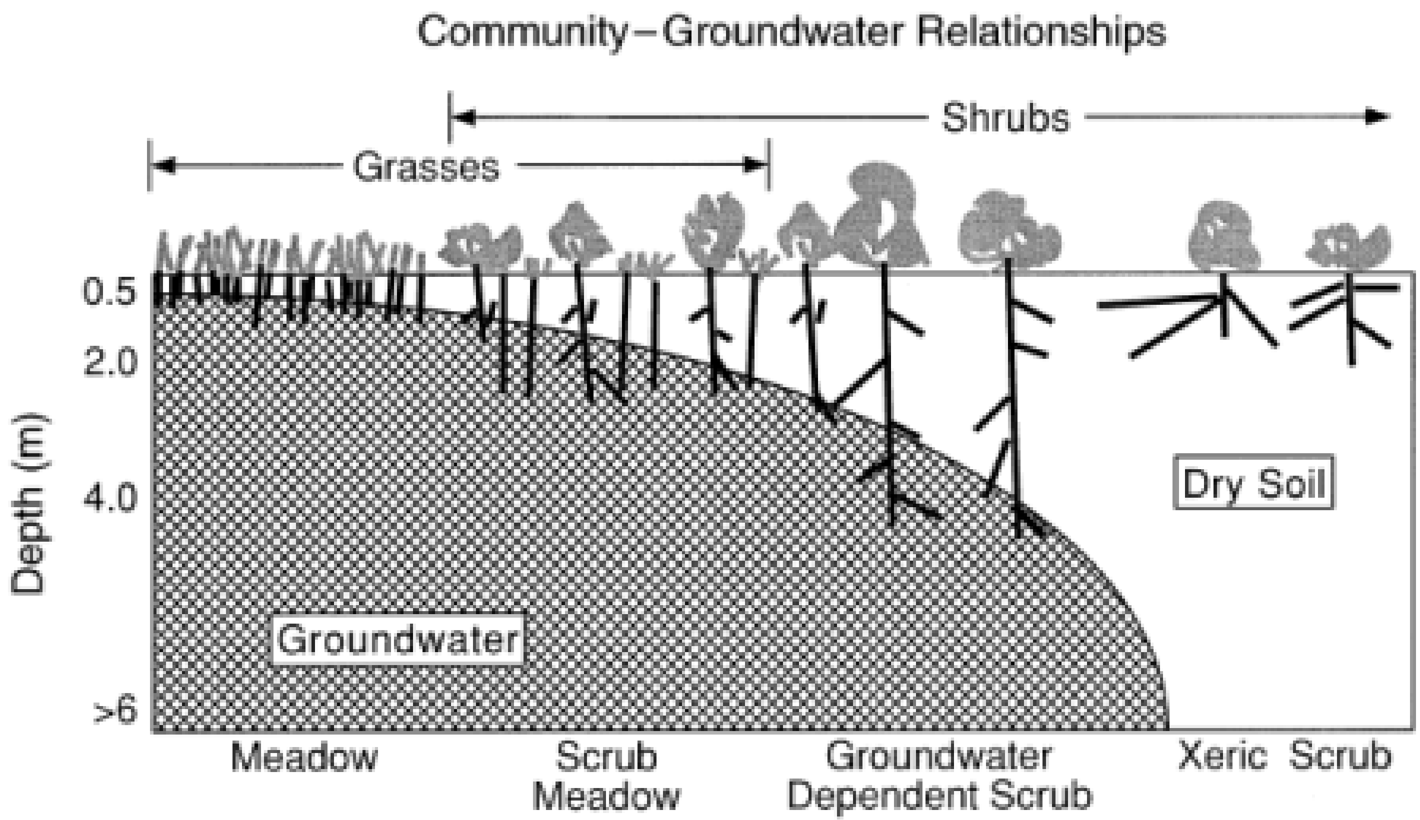


Figure 18.15. The water balance and aboveground net primary productivity (ANPP) of ecosystems in the Pacific Northwest. The relationship between water balance and ANPP emphasizes the idea that increases in water availability along climatic gradients in mountainous regions relate to an increase in net primary productivity. (After Gholz, 1982. Reprinted with permission of the Ecological Society of America.)

Barnes et al., 1998

Physical environment

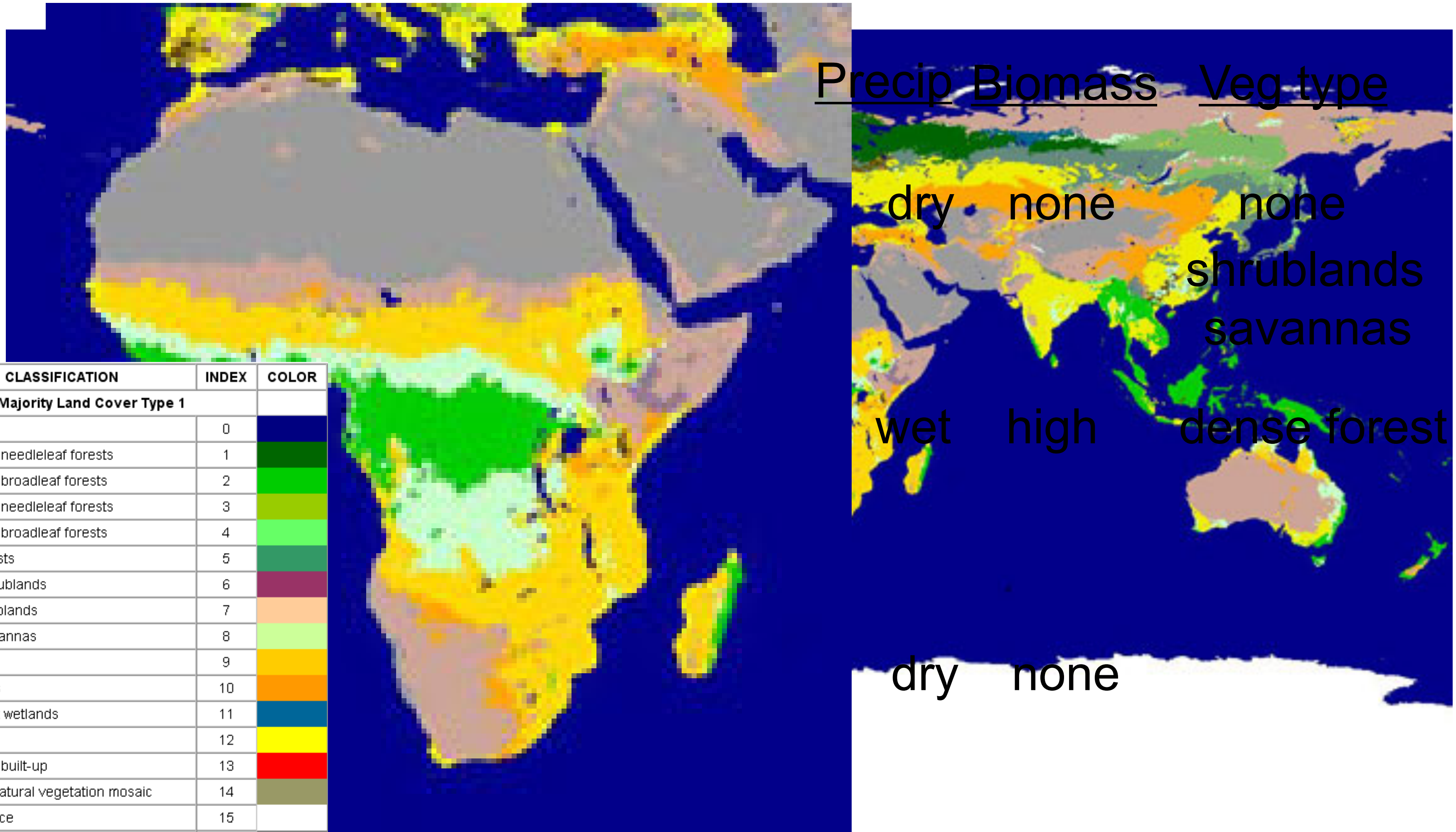
Rooting depth in arid landscape controls species distribution



Elmore et al., 2003

Physical environment

Controls of water balance at larger scale



CLASSIFICATION	INDEX	COLOR
Majority Land Cover Type 1		
water	0	
evergreen needleleaf forests	1	
evergreen broadleaf forests	2	
deciduous needleleaf forests	3	
deciduous broadleaf forests	4	
mixed forests	5	
closed shrublands	6	
open shrublands	7	
woody savannas	8	
savannas	9	
grasslands	10	
permanent wetlands	11	
croplands	12	
urban and built-up	13	
cropland/natural vegetation mosaic	14	
snow and ice	15	
barren or sparsely vegetated	16	
unclassified	254	

Friedl et al.

Physical environment

Plant adaptations to deal with drought: 1. Escapees

- Perennials (dormancy)
- Annuals ("emphemerals")

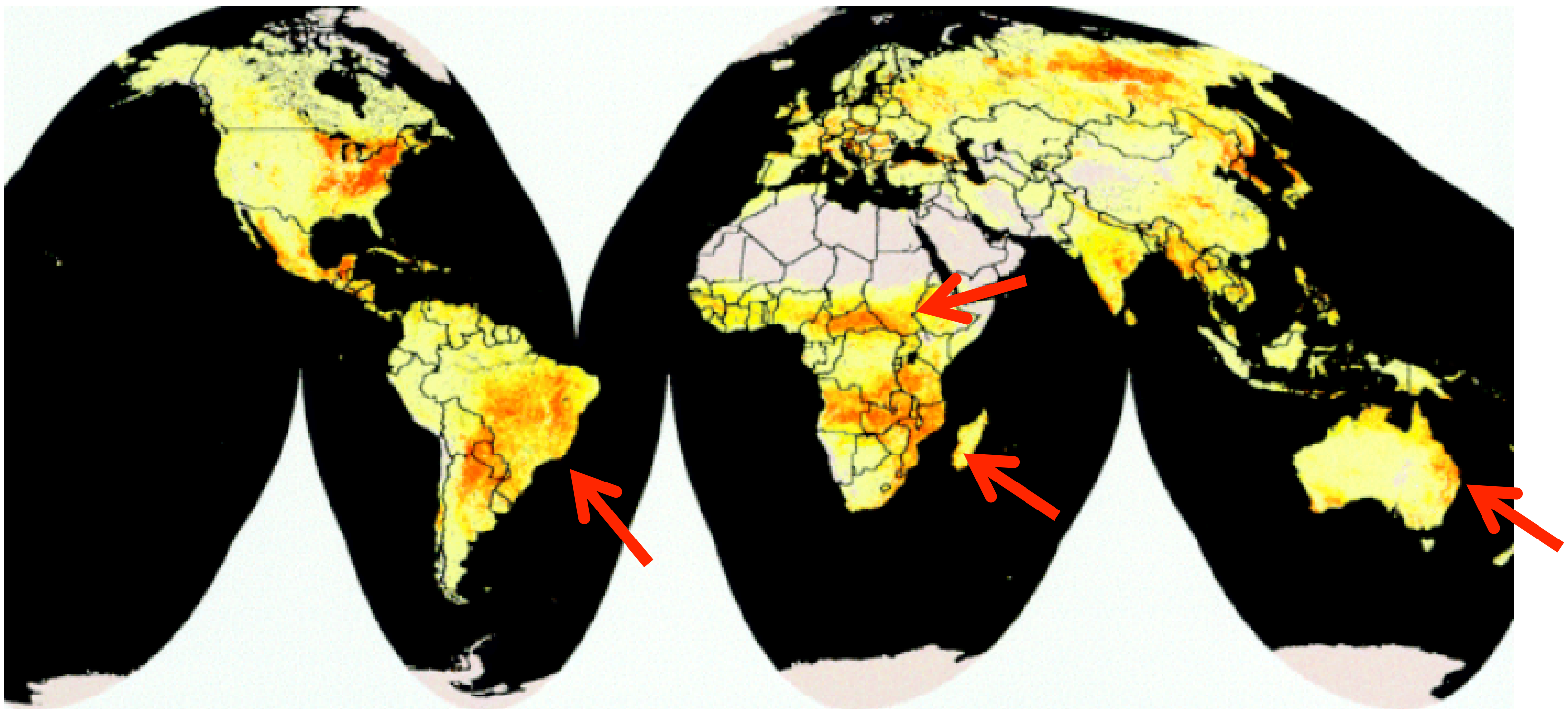
Still very dry and nothing is blooming yet, photo from Anza Borrego Desert State Park on Jan. 1, 2007

www.desertusa.com/wildflo/wildupdates.html

Physical environment

Plant adaptations to deal with drought: 2. Avoiders

another strategy: shed leaves (drought deciduous)
focus on subtropical forests with high % deciduous



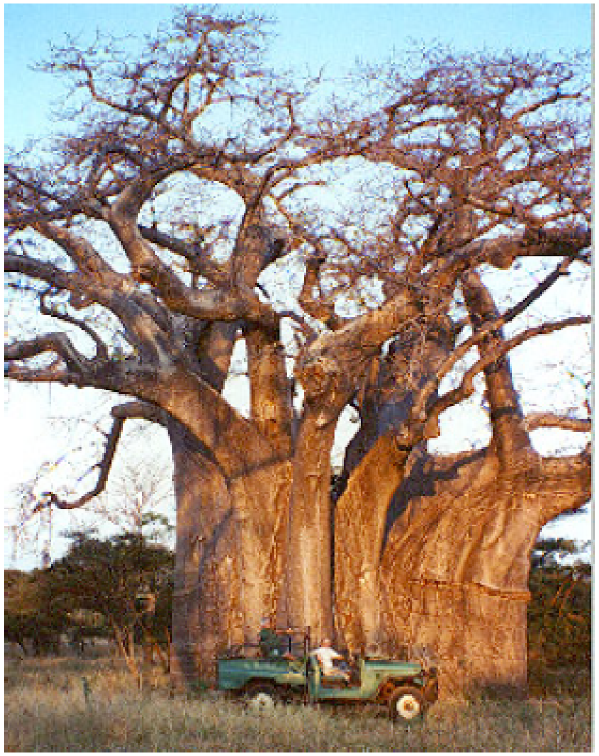
Slide courtesy C. Still

DeFries et al., 2000

Physical environment

Plant adaptations to deal with drought: 2. Avoiders

store water in the trunk
(up to 120,000 liters!)



http://www.safari-tours.com/pgbs/images/lodges/baobab.jpg

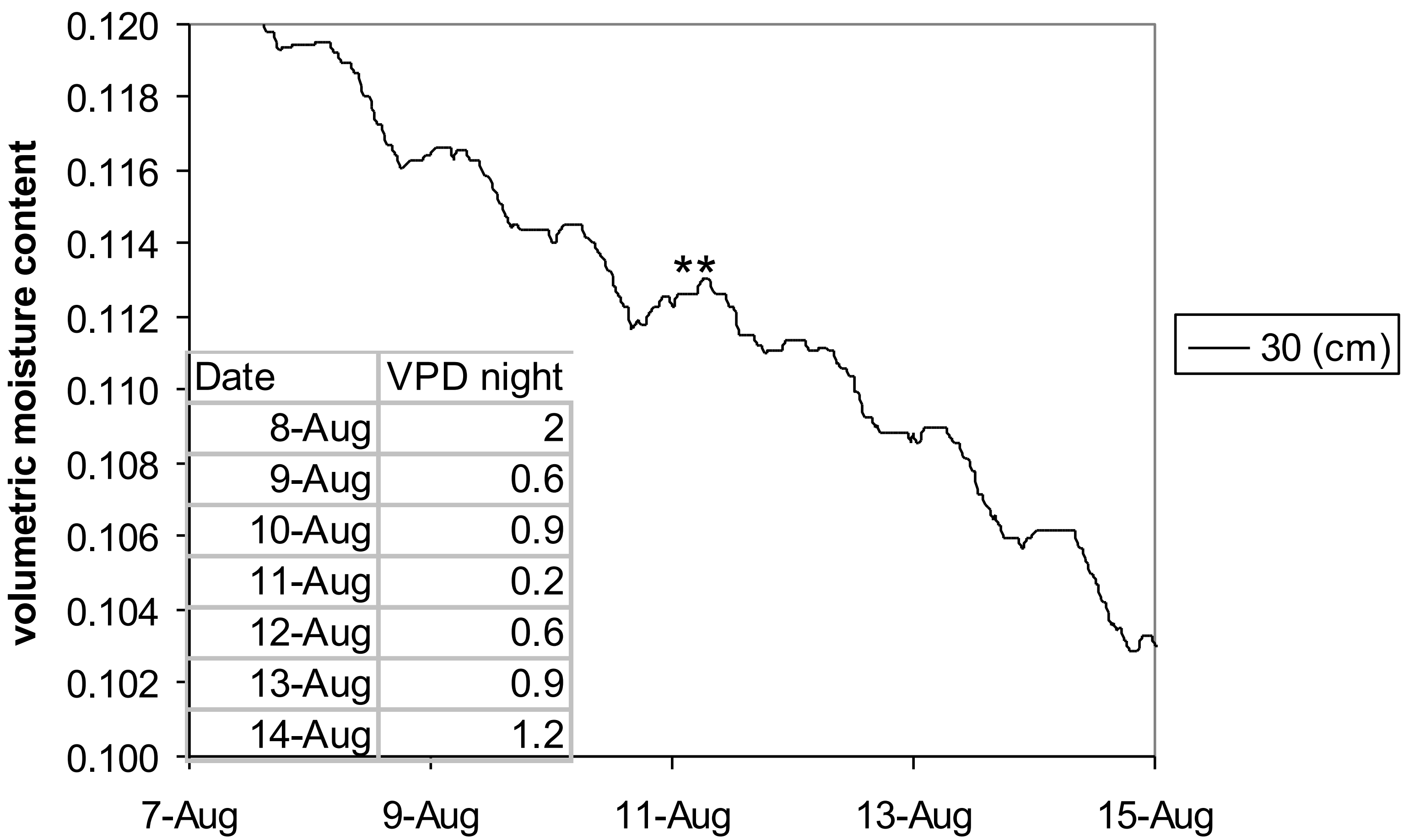
have deep roots (*Larrea tridentata* roots measured to 53 m!)

Slide courtesy C. Still

Physical environment

Adaptation to low moisture conditions: Idaho forest

Soil water redistribution-water flows uphill!



Date	VPD night
8-Aug	2
9-Aug	0.6
10-Aug	0.9
11-Aug	0.2
12-Aug	0.6
13-Aug	0.9
14-Aug	1.2

slide courtesy of K. Kavanagh

Physical environment
Annual water balance

Sierra Nevada, CA: Coniferous

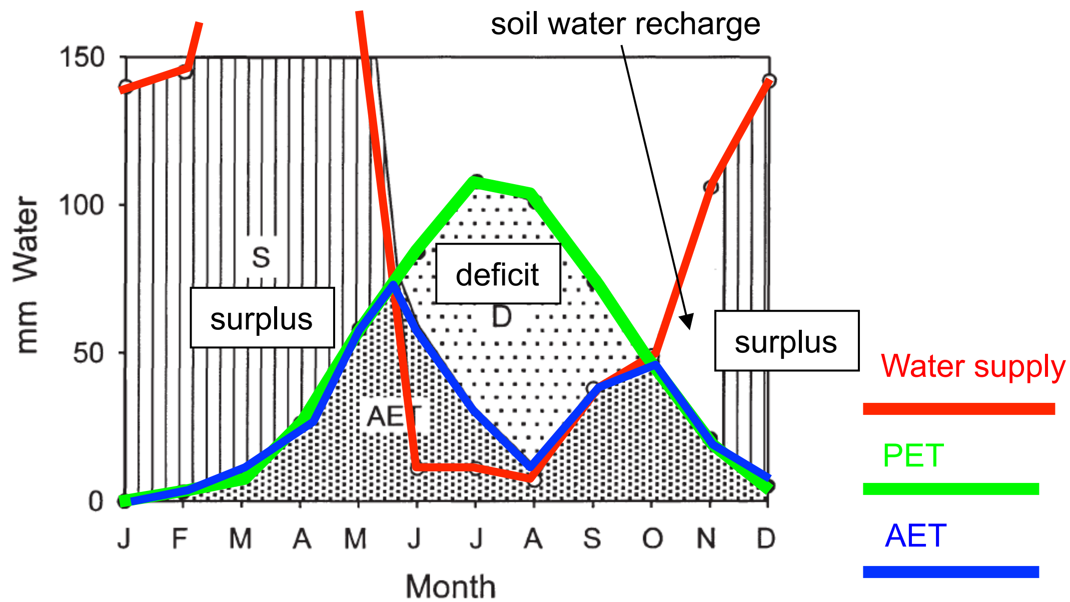


FIG. 1. The annual water balance of a site on level ground, soils of 0.5 m depth, at 2000 m elevation, and in the wet Kaweah watershed of the southern Sierra Nevada (data from Stephenson, 1988). From October through May, water supply (rain plus snowmelt, ○) exceeds evaporative demand (potential evapotranspiration or PET, ●); during this period, actual evapotranspiration (AET, *dense stippling*) equals PET. In October and November, excess water replaces soil water used during the summer; the white area between the water supply and PET curves represents soil–water recharge. From November through May, after soil water has been replenished, the difference between water supply and PET is surplus (S, *vertical stripes*). From June through September, PET exceeds water supply. During this period, AET equals water supply plus water extracted from the soil (which is shown as the curve between the water supply and PET curves). Deficit (D, *light stippling*) is the difference between PET and AET.

Stephenson, 1998

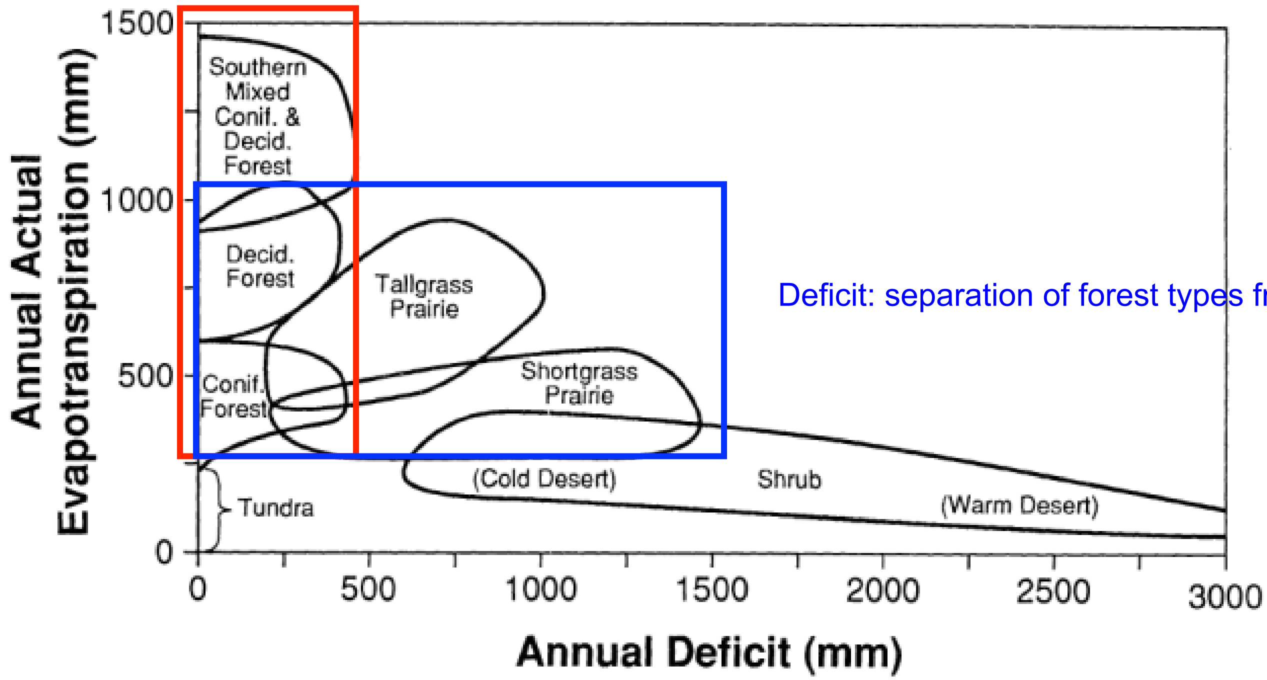
Physical environment

Distribution of major N. America plant formations

AET: separation of different forest types

higher growth

Plant productivity



Deficit: separation of forest types from prairie

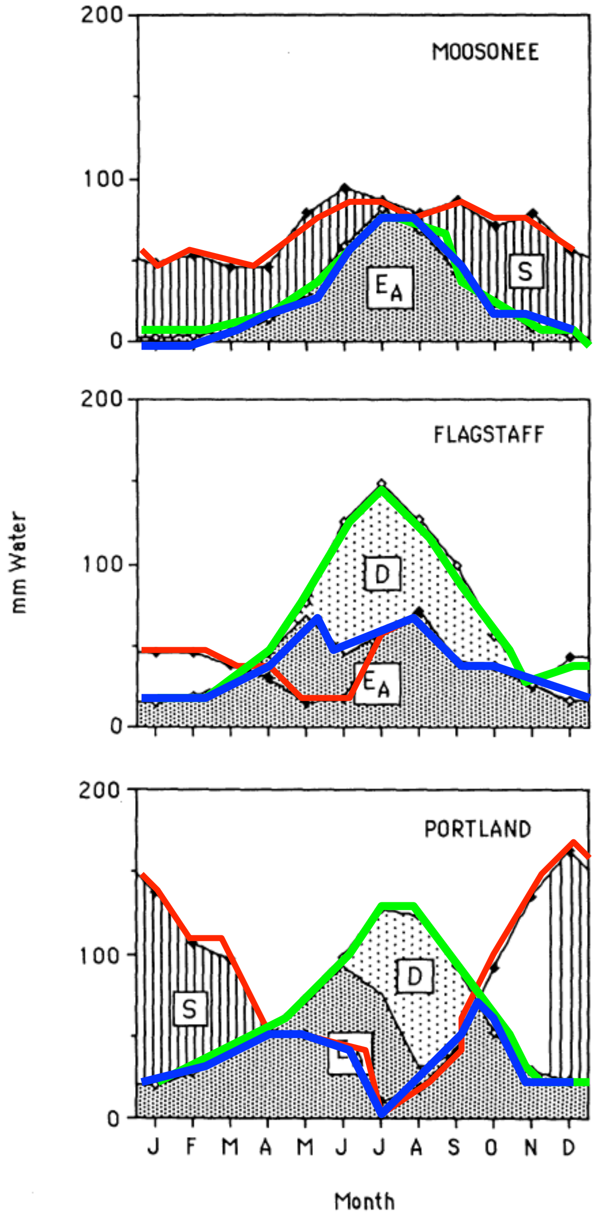
Moisture limitation

higher growth

FIG. 3.—Mean annual actual evapotranspiration and deficit of the major North American plant formations. The denominator of the following fractions is the number of sites within each formation; the numerator is the number of the sites that fell within the boundary indicated for the formation. Southern mixed coniferous and deciduous forest, 34/34; deciduous forest, 60/62; coniferous forest, 28/29; tundra, 5/5; tallgrass prairie, 17/22 (17/18 when coastal prairie sites of Texas and Louisiana are eliminated; see the text); shortgrass prairie, 31/33; shrub 17/17. For clarity, the three transition formations (northern mixed forest, woodland and savanna, and shrub steppe) were not plotted. Values of actual evapotranspiration and deficit for the transition formations usually fell within the range of the formations that the transition formations physiognomically bridged (Stephenson 1988).

Stephenson, 1990

Deciduous trees have higher photosynthetic rates; therefore outcompete conifers in unstressed conditions



Three situations when conifers dominate over deciduous trees:

energy limited: low PET => low AET/growth

Precipitation

PET

AET

water limited: low precip => low AET/growth

S = surplus of water (hatched)
D = deficit of water (stippled)

asynchrony in energy, water supplies => low AET/growth

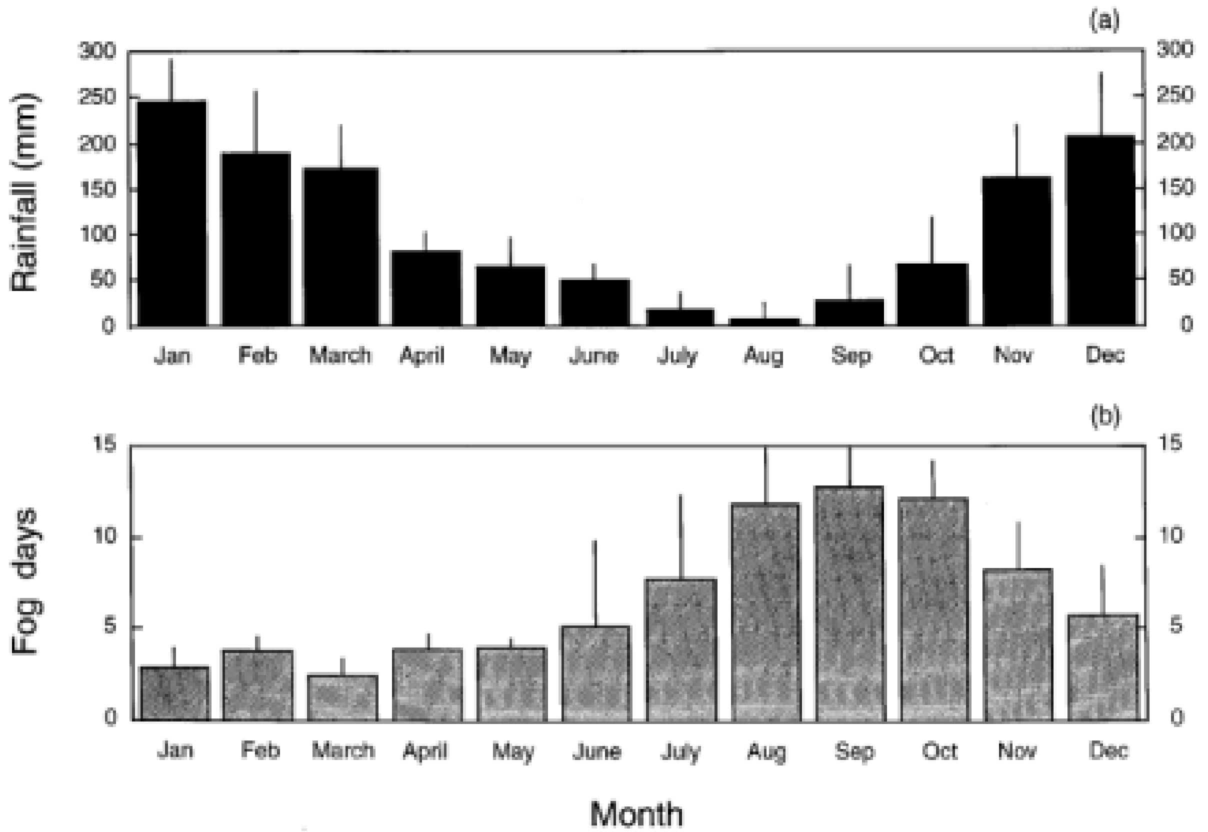
FIG. 4.—The water balances of three North American localities supporting coniferous forest (data from Eagleman 1976). Annual actual evapotranspiration (E_A, *dense stippling*) is less than 600 mm because of energy limitation (Moosonee, Ont.), water limitation (Flagstaff, Ariz.), or asynchronous timing of the energy and water supplies (Portland, Oreg.). See figure 1 for a further explanation of water-balance diagrams. *Solid diamonds*, precipitation; *open diamonds*, potential evapotranspiration.

Stephenson, 1990

Physical environment

Rain isn't everything: N. California coastal forest

Fig. 1 Rainfall (mm) (**a**) and the number of fog-days (**b**) each month for the coastal redwood forest between Arcata and Crescent City, California. Each bar represents an average (±SD) for that month calculated from records obtained from the Arcata and Crescent City airports (35-year record for Arcata, 17-year record for Crescent City). A fog-day is defined as a day when visibility is 0.8 km (0.5 mile) or less for at least 8 h (an average fog-day is generally between 12–17 h)



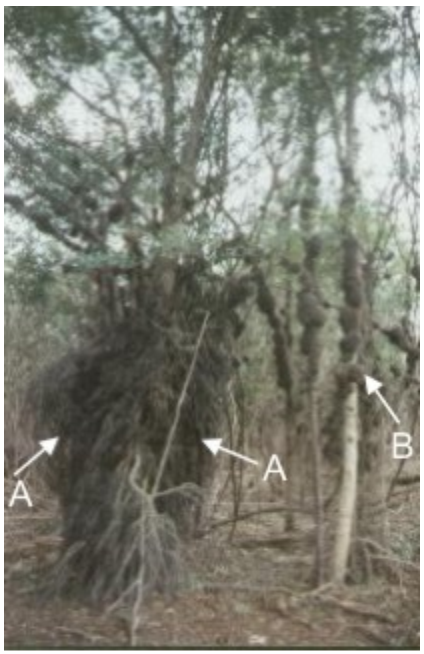
fog is 22-46% of hydrologic inputs; timing is everything!

Dawson 1998

Physical environment
Extremely wet soils

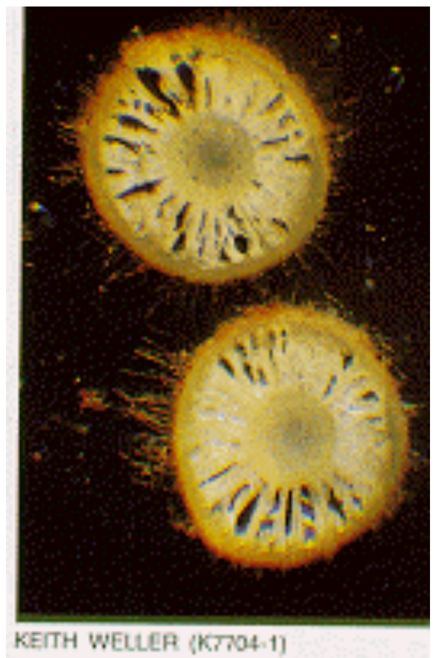
Adaptations:

adventitious roots



www.mpil-ploen.mpg.de/mpiltppa.htm

longitudinal air spaces



www.sprrs.usda.gov/aerenchy.htm

aerating roots

Mangroves (*Avicennia*)

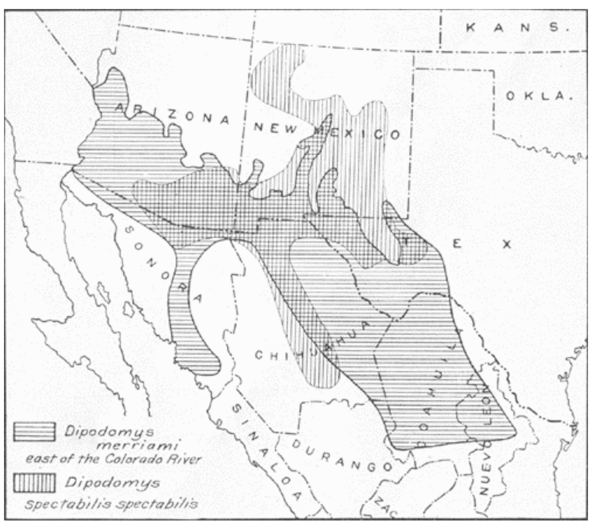
en.wikipedia.org/wiki/Root

Physical environment

Adaptations to low water availability

kangaroo rat (*Dipodomys spectabilis)*

- can live entirely on dry food without ever drinking free water
- 100 g dried seed => 54 ml of water through oxidation
- only very small quantities of feces, urine
- do not sweat; little evaporation
- nocturnal behavior
- during milk production, females need to eat green and moist plants



Vorhies, 1922

museum.utep.edu/chih/theland/animals/mammals/dipospect.gif

Physical environment

Adaptations to low water availability

Namib Desert beetle (*Onymacris unguicularis*)

morphology adaptations to capture fog:
- bumps on back
- channels to mouth
- head down behavior

can capture 40% of body weight in one morning

www.nacoma.org.na/Pictures/Photos/Beetle.jpg

http://www.biomechanics.bio.uci.edu/_html/nh_biomech/namib/beetle.htm

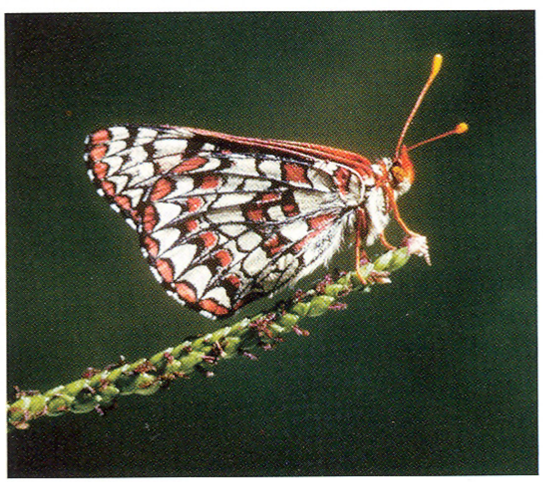
Physical environment

Soil type controls on species distributions

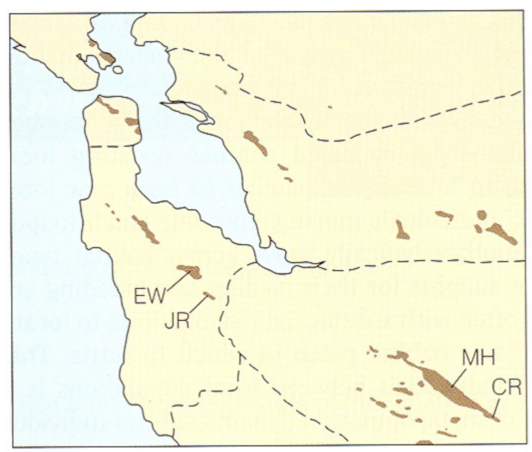
Example: Serpentine soils

- dry and nutrient poor
- toxic to most plants
- support grasses adapted to these conditions

as a result, associated animals are also located in these areas



(a)



(b)

Physical environment

Soil fertility influences plant species distribution: Tolerance to calcium

% of total basal area within stand

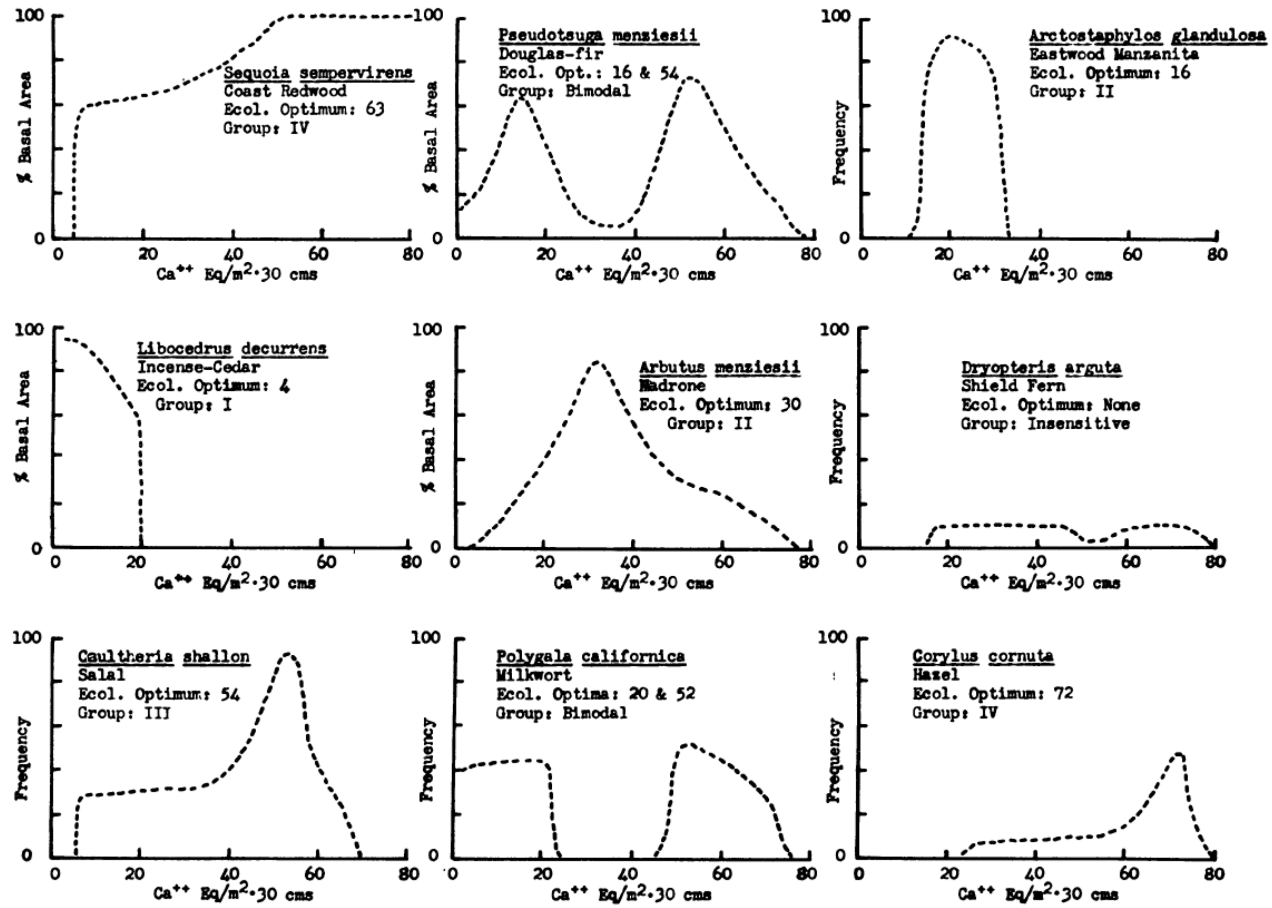


FIG. 7. Distribution of selected species in relation to a quantitative nutrient gradient of replaceable calcium (Eq/m^2 .30 cms).

Replaceable calcium

Waring and Major, 1964

Physical environment

Soil texture (moisture) effects on distributions

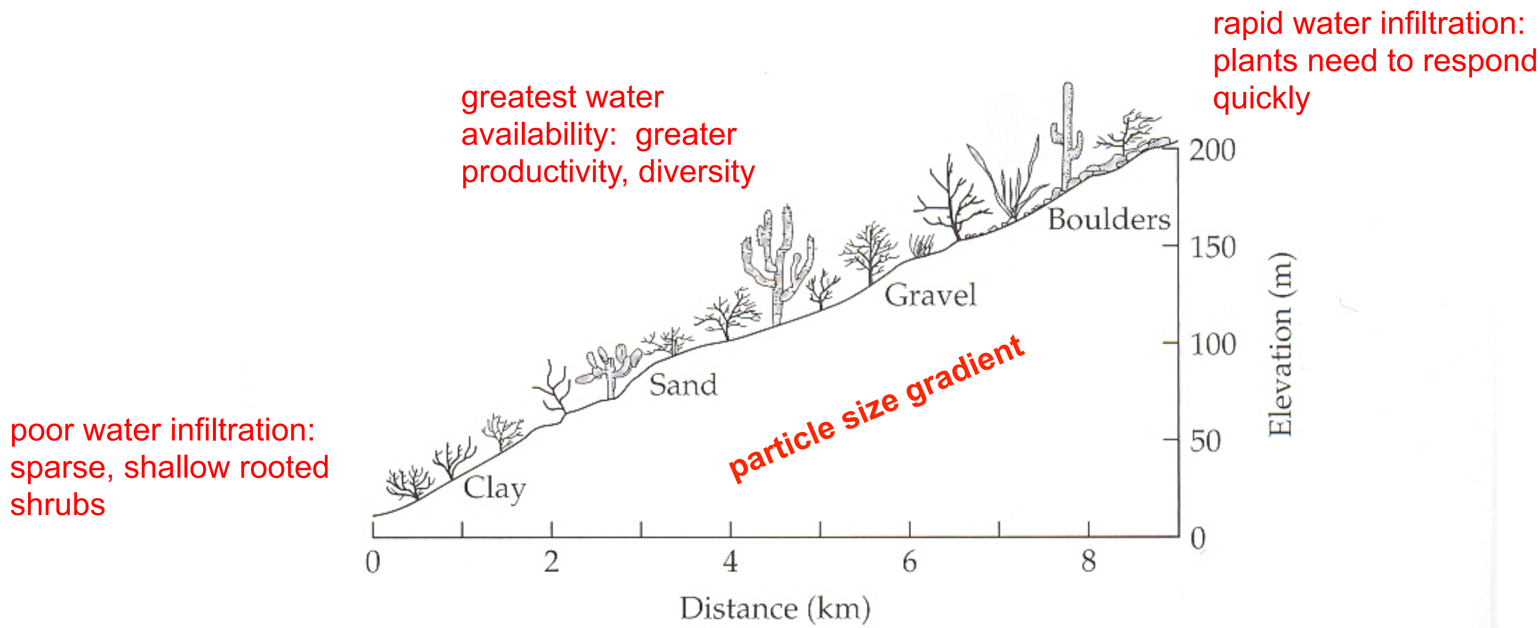


FIGURE 3.13 Schematic representation of the local elevational distribution of soil particle size and vegetation on a desert bajada on the Sonoran coast of the Gulf of California (Sea of Cortez). At the upper end of the alluvial fan, where large boulders have been deposited, the vegetation is dominated by cacti and other succulents that can take up water rapidly before it percolates below the root zone. At the lower end, where water infiltration is poor and the existing water is tightly bound by fine clay particles, the vegetation consists of sparse, shallowly rooted shrubs. The greatest water availability, productivity, and species diversity occur at intermediate elevations, where the soils are sandy, infiltration is high, and water is not tightly bound by soil particles.

Physical environment

Soil texture influences on biogeography

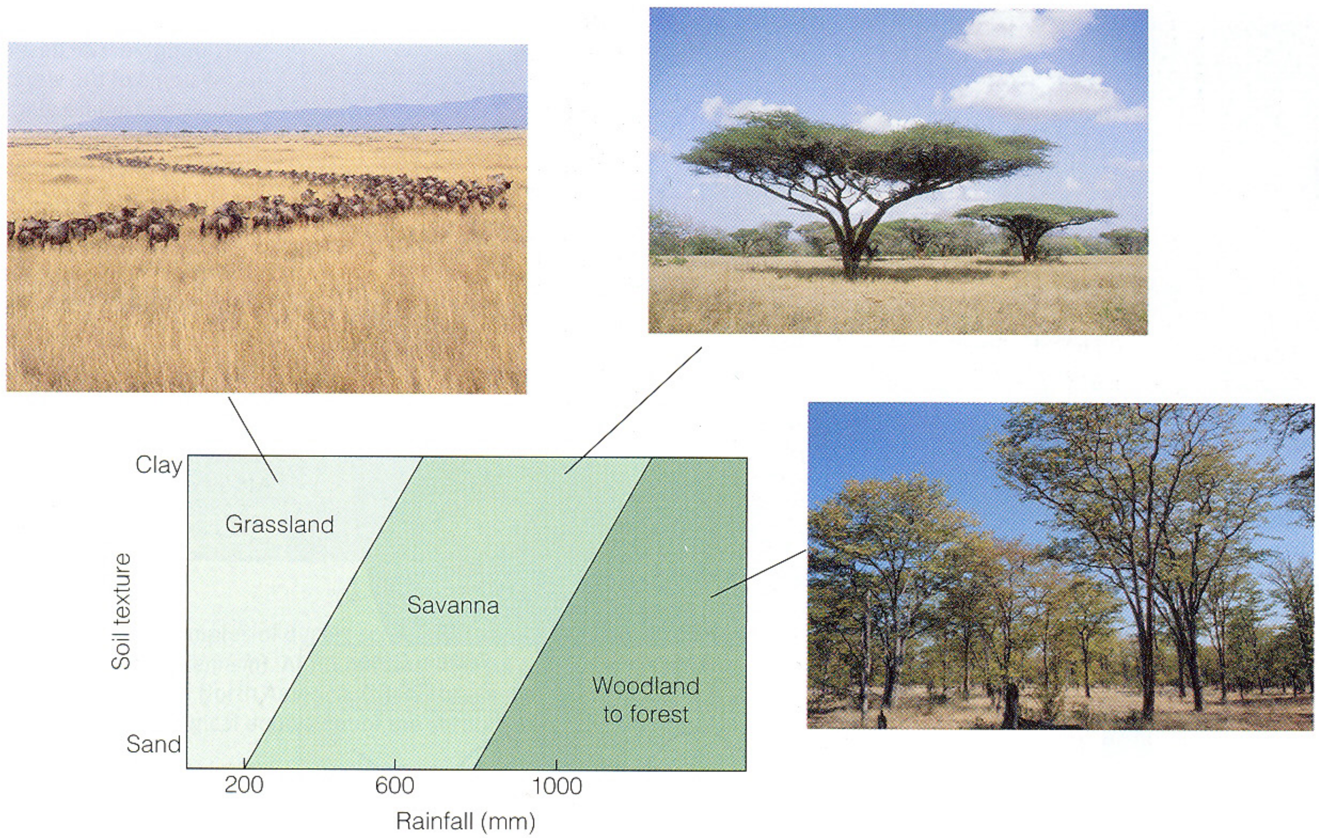


Figure 23.11 | Diagram showing the interaction between annual precipitation and soil texture in defining the transition from woodland to savanna and grassland in southern Africa. Access by plants to soil moisture is more limited on the heavy textured soils (clays) than on the coarser sands, requiring a greater annual precipitation to support the productivity of woody plants.

Smith and Smith, 2006

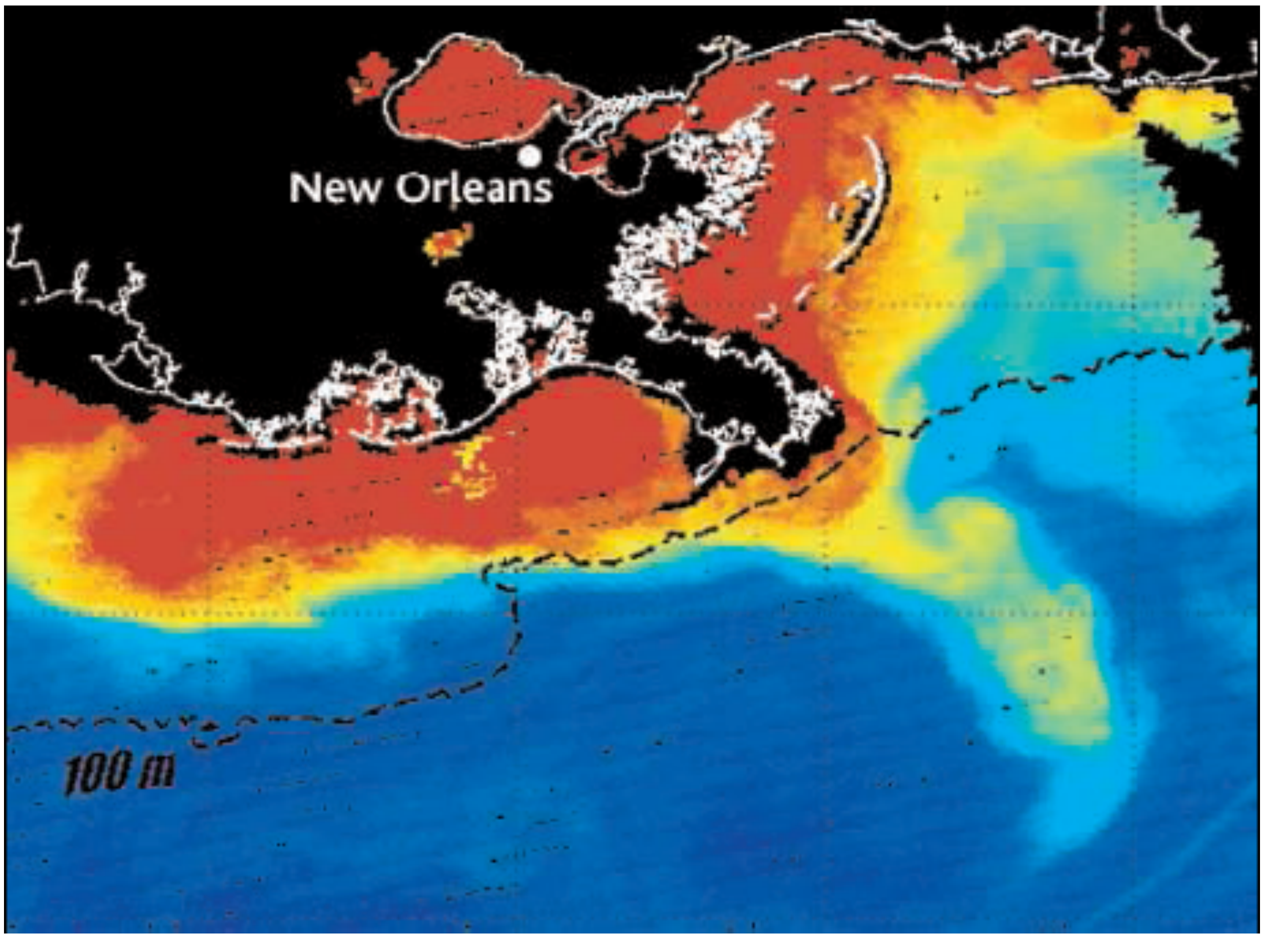
Physical environment

Anoxic conditions

Excess fertilizer => phytoplankton blooms => zooplankton blooms => decomposer bloom => O_2 depletion

Result from:

- lack of plants
- lack of mixing



Ferber 2004

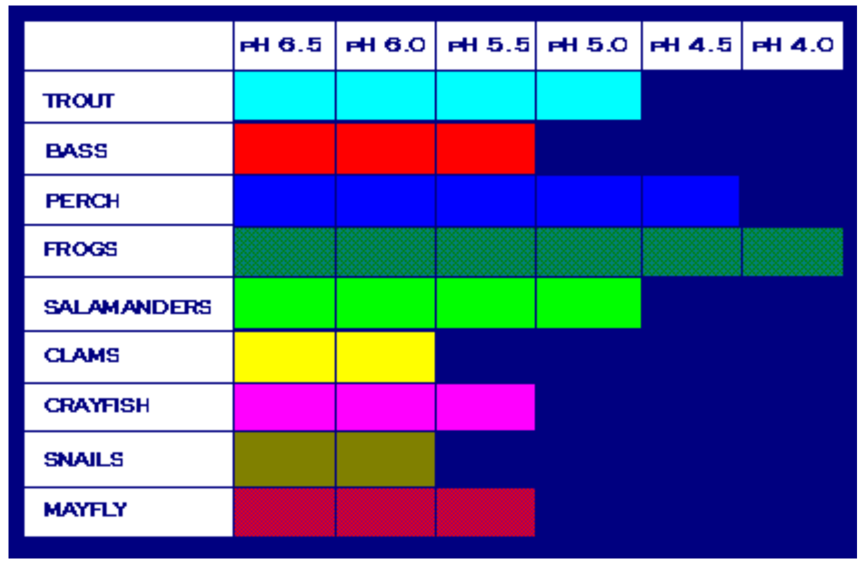
Physical environment

Acid rain

www.terradaily.com/reports/
Acid_Rain_And_Forest_Mass_Another
_Perspective.html

Tolerance of acidification within lakes

Little Echo Pond



Increasing acidification

www.epa.gov/acidrain/effects/surface_water.html

Physical environment

What factors limit white spruce at its northern and southern extent?

Summer temperatures

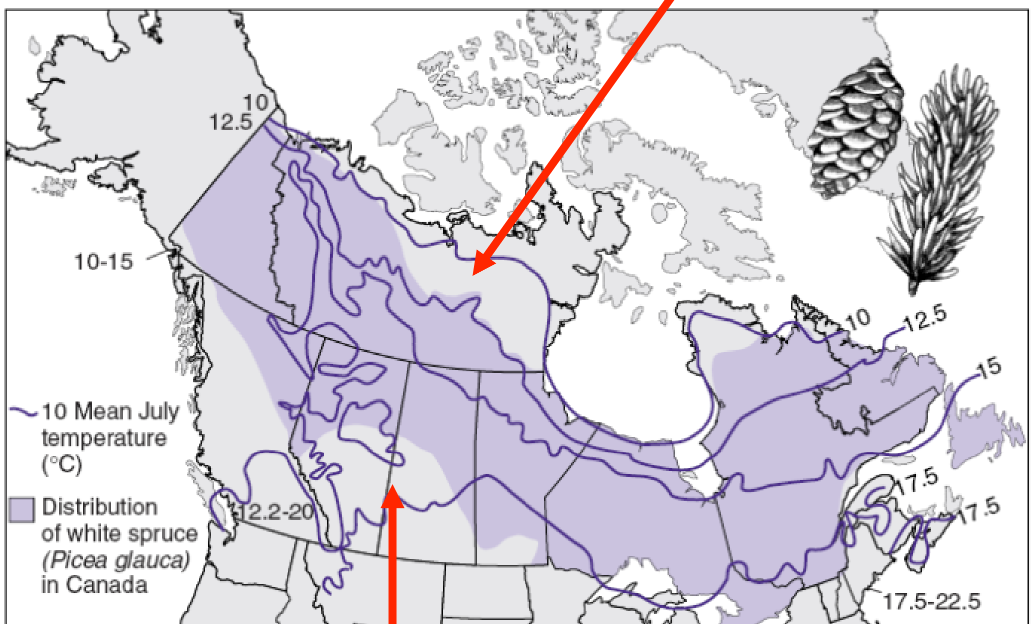


FIGURE 3.4 The relationship between the northern limits of spruce and July temperatures in Canada.

Moisture stress (high summer temps, low precip)

Physical environment

Range and density

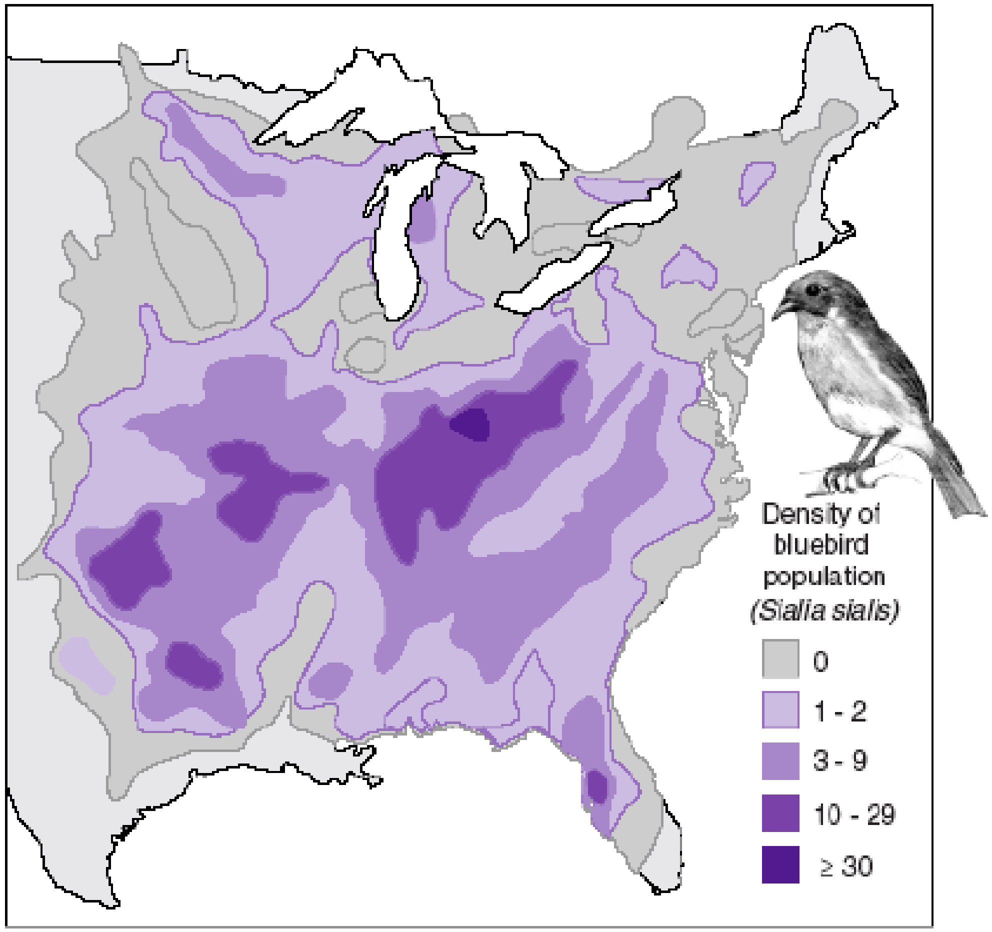


FIGURE 3.12 The range and population density of eastern Bluebird *(Sialia sialis)* in North America. Notice how population density is greatest in patches near the center of the geographic range (after Bystrak, 1979 and Brown and Gibson, 1983).

Physical environment

Population density follows physiological functioning (which is controlled by environment)

Gradients in physiological functioning often follow Gaussian distribution

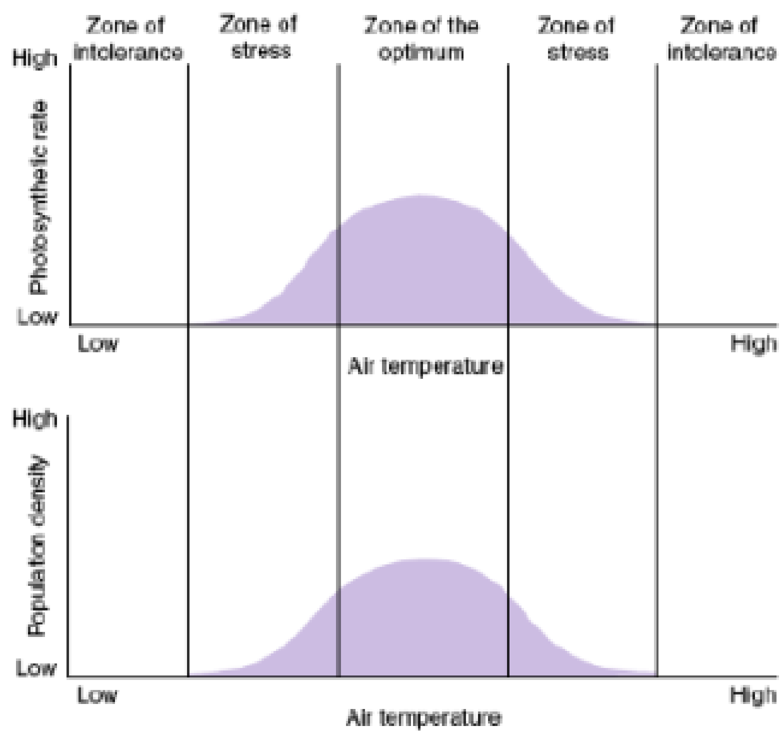


FIGURE 3.13 The photosynthetic rate and population density of a hypothetical plant species along an environmental gradient of low to high air temperature.

Environmental gradient

Physical environment

Environmental gradients control niches

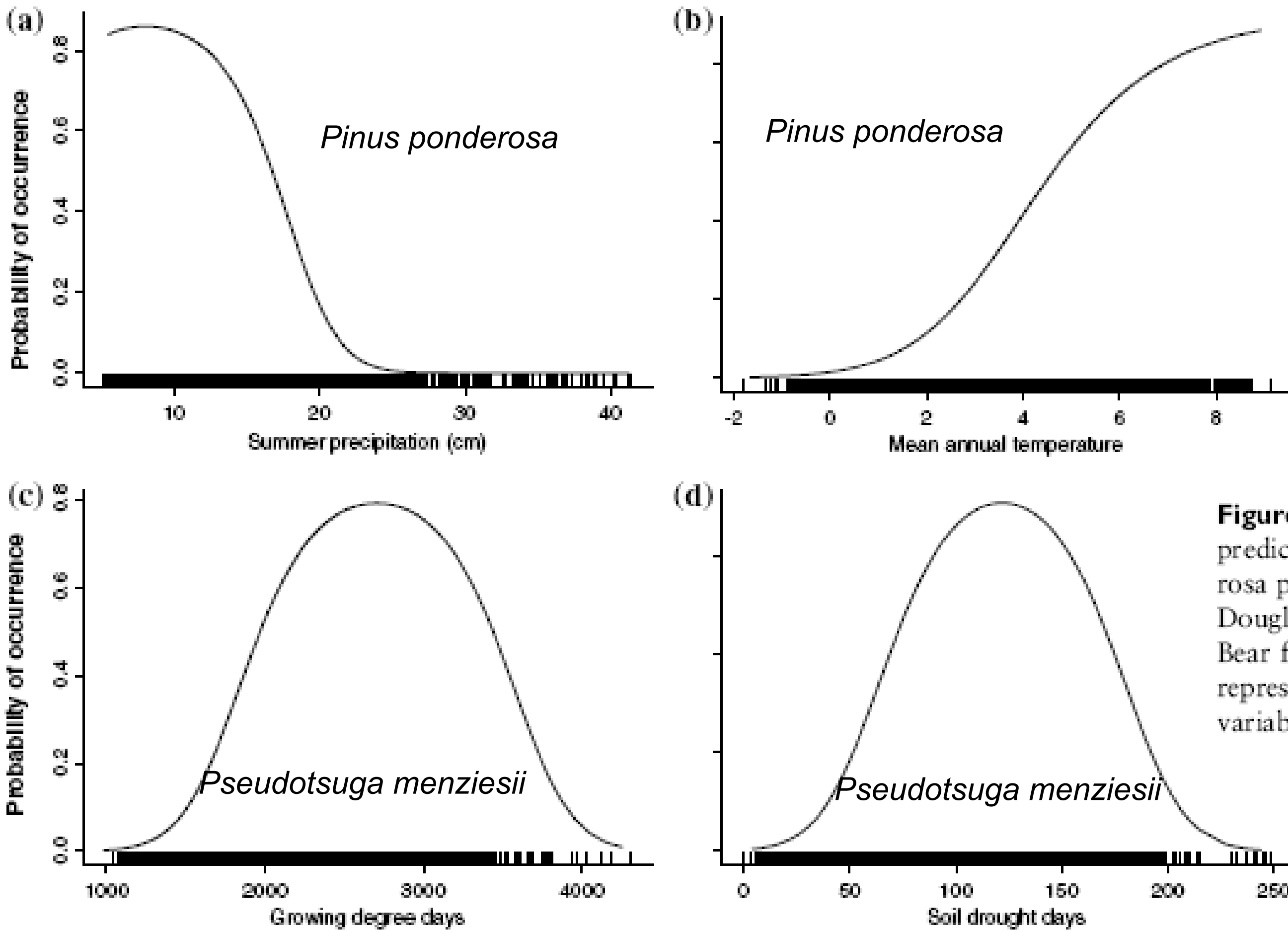


Figure 2 Unimodal/Gaussian responses are predicted by the models. (a) and (b) ponderosa pine on the Wenatchee NF. (c) and (d) Douglas-fir on the Wenatchee and Grizzly Bear forests. Density bands along the *X*-axis represent individual values of the predictor variables.

McKenzie et al., 2003

Physical environment

Variability among species in tolerance to environmental conditions

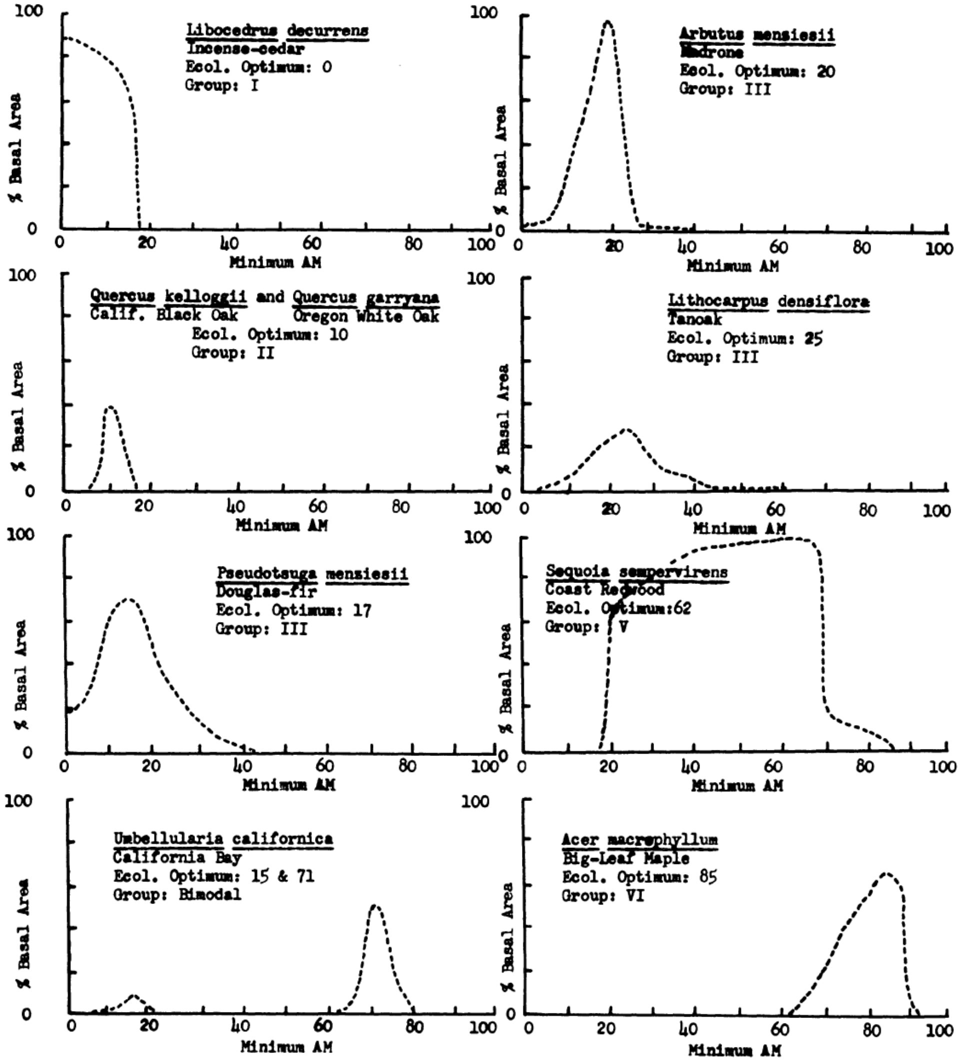


FIG. 3. Distribution of selected species in relation to the Minimum Available Moisture (Minimum AM).

Redwood (*Sequoia sempervirens*): large range of ecological optimum

Others: narrow range

Which are generalists? Specialists?

Waring and Major, 1964