Climate, Vegetation and Plant Life Forms

I. Global climatic zones

A. Solar heating of the Earth, the Earth's rotation and seasonal tilt-progression (Figs. 1-3) result in similar climatic regions at about equivalent latitudes N and S of equator on all continents; the extent of development of climate zone depends on land mass size (Fig. 4)

B. Associated with specific climate zones are particular vegetation types and soil types in a good one-to-one correspondence (Fig. 5)

C. Vegetation types can be ordinates of **precipitation** and **temperature** as axes (Fig. 6)

D. Along transects through Fig. 6 there are continuous changes in species composition, physiognomy (an index of "form"), and the dominant plant life forms

E. In our next lecture we will explore finer-scale factors that also impact vegetation changes; elevation, aspect (Fig. 7), edaphic factors (e.g. salinity, heavy metal composition, ultramafic soils, etc.), etc. can all play roles an can complicate simply temperature / precipitation correlations.

II. Classification of climate using the climate diagram

Climate can be classified according to the two major parameters - temperature and precipitation; their combination effects evapotranspiration.

A. Basics of climate diagram as first developed by Heinrich Walter (Fig. 8A, B)
1. months along x-axis
2. mean monthly temperature (°C) along left-side of y-axis; **offset 6 months in southern hemisphere**
3. mean monthly precipitation (mm) on right-side y-axis
4. name of site, mean annual temperature, and mean annual precipitation along the top of climate diagram. Other info in the caption/key of Fig. 8B.

B. Ecological interpretations of climate diagram

1. a **drought** period occurs when temperature curve is above the precipitation curve; the magnitude of the drought is proportional to the height difference between the two lines; plant growth is presumably retarded under drought conditions
2. A **water surplus** period occurs when precipitation curve exceeds the temperature curve; plant growth is presumably not water limited at these times

C. **Advantages** of climate diagrams
1. Quick visual inspection of important climatic factors
2. Easy, reliable comparisons between climates
3. A scale of 10°C = 20 mm precipitation corresponds to potential evaporation rates
4. Allows quick inspection of the lengths of wet and dry periods

D. **Disadvantages** of climate diagrams
1. Daily range of temperatures is not presented - yet for most zones this is a minor problem
2. No indication of solar radiation is presented - yet this is well correlated with temperature
3. Variability of temperature or precipitation is not presented – yet, globally basic trends exist

E. Water inputs other than rainfall (e.g., fog and cloudwater) are not usually accounted for but have been shown to be extremely important (Fig. 9 / Table 1 after Dawson 1998).

F. Advances have been proposed by Stephenson (1990, 1998) and others that take simple Temp. vs. Precip. relationships and recasts them in terms of inputs, transformations and deficits or – Actual Evapotranspiration (AET) vs. Deficit (D). Such a scheme accounts for "solar" influences on water availability via evaporation (Fig. 10) and is biologically more meaningful.

G. Holoclimates in different parts of the world can be easily identified and characterized with climate diagrams (Fig. 11)

F. Consequences of geographical clines on climate are easily seen with climate diagrams (Figs. 12 / 13)

III. Plant "life form" variation and climate

Early natural historians and plant geographers saw that there appeared to be a correspondence between broad climate zones and the dominant plant life forms in these zones regardless or continent or what plant family the plants were members of. This lead to an area of research aimed on designing classification schemes based on common and shared characteristics. The APPENDIX shows one of the very first classifications schemes that is still used by some European botanists. There are been other schemes proposed and rather than 'memorize' these now, they will be introduced as we move along through the course. Most relevant here is the linkages that began to be made between "climate" and life forms.

A. Comparison of plant communities in <u>**different**</u> climates (from Cain, 1950)

	wet tropical (Seychelles)	hot desert (Death Valley)	cold tundra (Alaska)
phanerophyte	**61**	26	1
chamaephyte	6	7	23
hemicryptophyte	12	18	**61**
geophyte	5	7	15
therophyte	16	**42**	1

B. Comparison of communities in <u>**similar**</u> climates (from Cain, 1950)

	Death Valley California	Salton Sea California	El Golea C. Sahara	Ghardaia N. Africa
phanerophyte	26	33	9	6
chamaephyte	7	6	13	16
hemicryptophyte	18	14	15	20
geophyte	7	0	7	3
therophyte	**42**	**47**	**56**	**58**
number of species	294	81	169	300

C. similar holoclimates on different continents have more similar life form patterns than adjacent but different climates on the same continent (Figs. 8-9)

APPENDIX: Climate and plant life forms (linking physical and biological sciences)

A. Raunkiaer life form system -- developed in early part of 20th century by the botanist Raunkiaer (1934); based on location of perennating bud (see figure, page). Why did Raunkiaer choose perennating buds? It represents a measure of the kind and degree of protection offered to meristematic tissues against unfavorable season ("resting period")

philosophical basis - plants have different ecological amplitudes (more or less limited in their capacity to endure different environmental conditions)

guiding rules - character must be structural and essential; character must be sufficiently obvious that one can easily see in nature to which life form it belongs; life form employed must constitute a homogeneous system (represent a single point of view or aspect of plants, e.g. leaf size, leaf duration)

On an abiotic basis - would expect no selection for any one type in environments where there is no harsh season. However, for biotic reasons (competition), we might expect to find particular forms in habitats where there is no harsh season;

phanerophyte -	>0.5 m
chamaephyte -	0-0.5 m
hemicryptophyte -	on surface
geophyte -	in soil
therophyte -	seed
helophyte -	in ground underwater (marsh)
hydrophte -	in water column

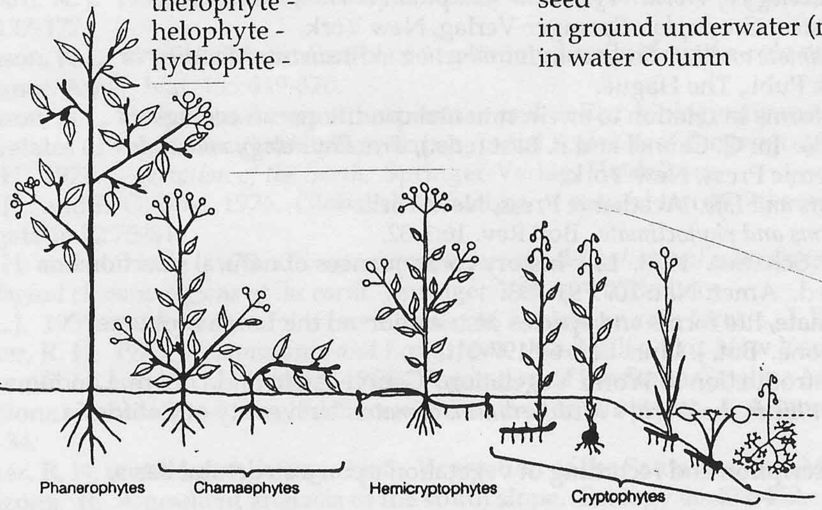

Figure 1.3 Physiognomic classification of plants according to the relative position of perennating parts. The untoned parts of the plants die back during unfavourable periods of the year but the other parts of the plant persist and give rise to new growth the following season. Therophytes, which persist only as seeds, are omitted. (After Raunkiaer, 1934.) (From C. Raunkiaer, *The Life Forms of Plants and Statistical Plant Geography*, 1934; by permission of Oxford University Press.)

B. An alternative consideration for classification could be based on using leaves, specifically leaf sizes (not all features are independent between classifications)

Raunkiaer leaf size classification (mm^2);

leptophyll	<25
nanophyll	25-200
microphyll	200-2,000
mesophyll	2,000-18,000
macrophyll	18,000-160,000
megaphyll	>160,000

Leaves are often further classified according to their <u>structure</u> :

1. **compound** = dissected into smaller components
2. **malacophyllous** = herbaceous
3. **coriaceous** = leathery
4. **sclerophyllous** = mechanically reinforced and stiff
5. **succulent** = juicy
6. **aphyllous** = lacking leaves
7. **pubescent** - with trichomes

Leaves may also be classified according to their life expectancy or **duration** :

1. **evergreen** = lasting one year or longer
2. **semi-evergreen** (tardily deciduous) = becoming deciduous only under extreme drought
3. **drought-deciduous** (raingreen) = persisting only during moist periods
4. **winter-deciduous** (summergreen) = persisting from spring through late summer
5. **winter-green** = persisting from spring through winter
6. **suffrutescent** - multi-branched from woody base
7. **ephemeral** = lasting only a short period of time

Some Literature related to Climate and Plant Life Forms

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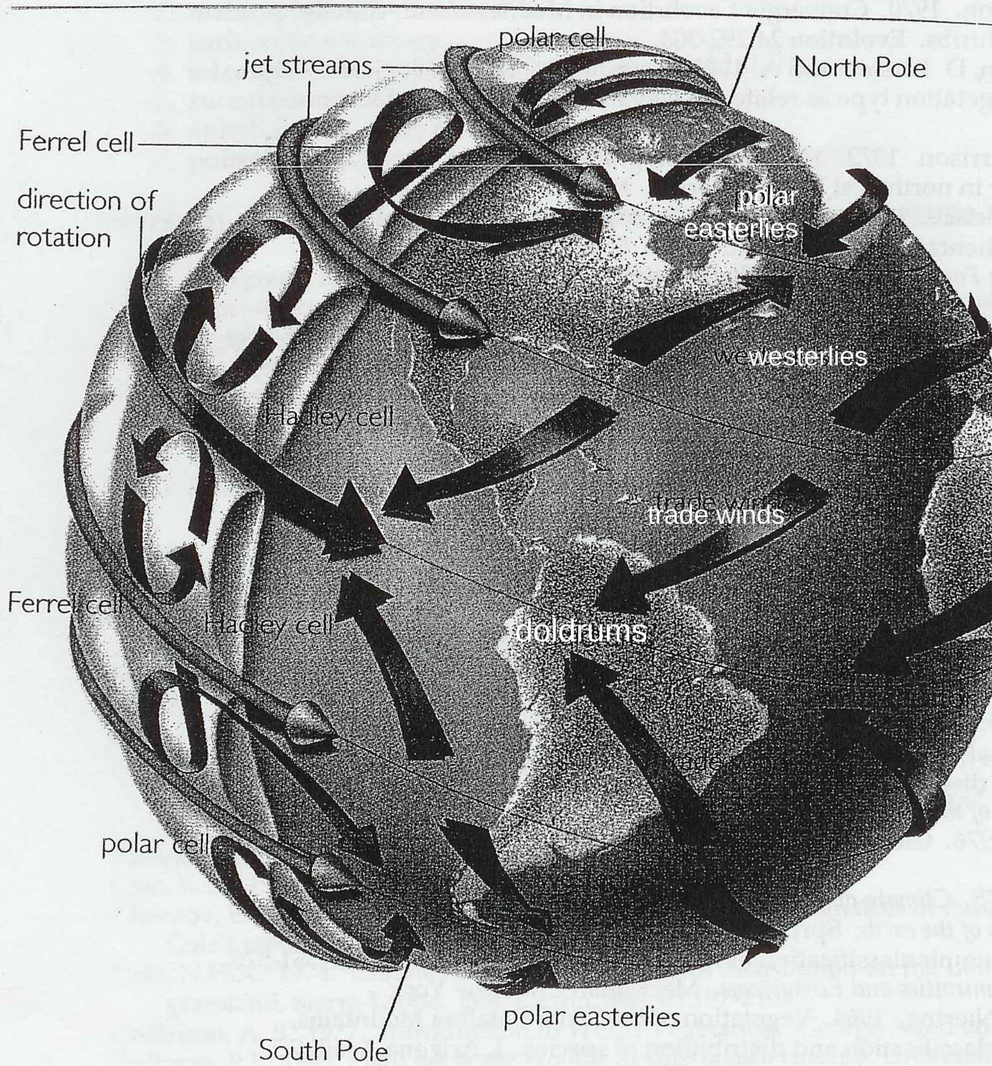

polar cell
jet streams
North Pole
Ferrel cell
direction of rotation
polar easterlies
westerlies
Hadley cell
trade winds
Ferrel cell
Hadley cell
doldrums
polar cell
polar easterlies
South Pole

Fig. 1

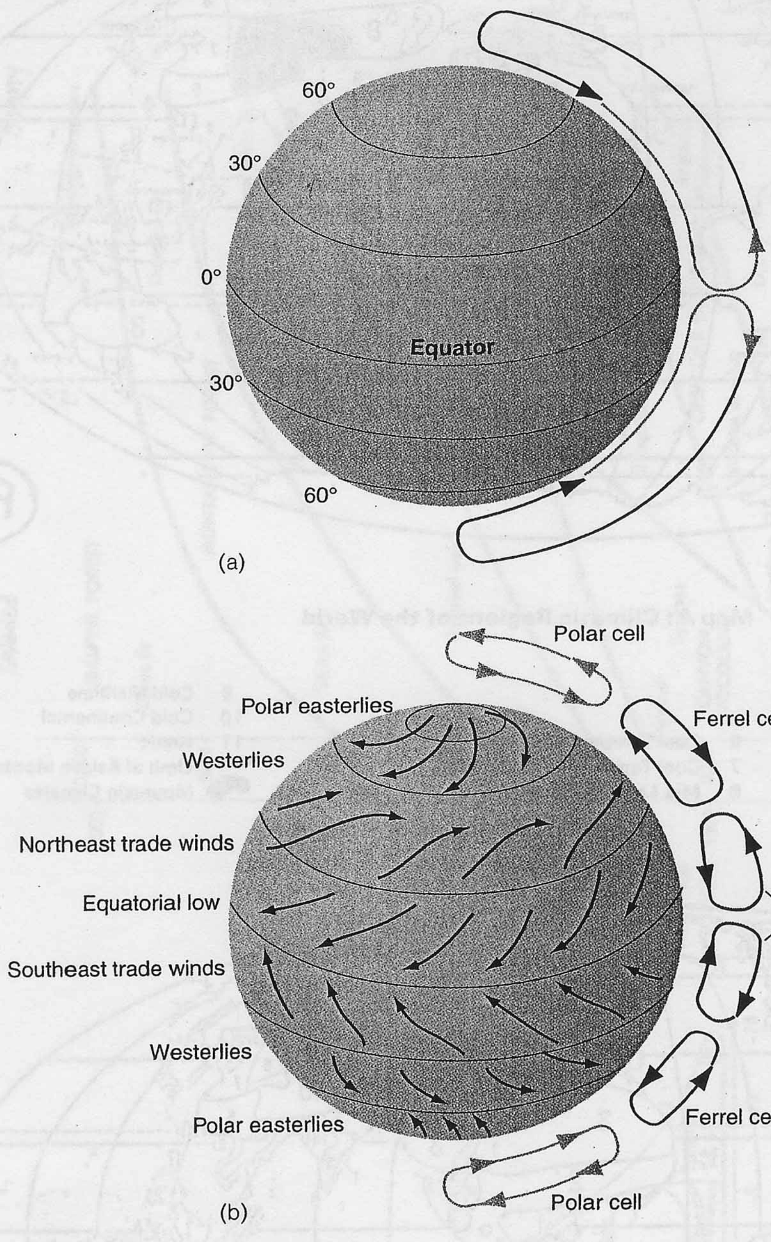


FIG. 2

Circulation of air cells and prevailing winds (a) on an imaginary, nonrotating Earth and (b) on the rotating Earth.

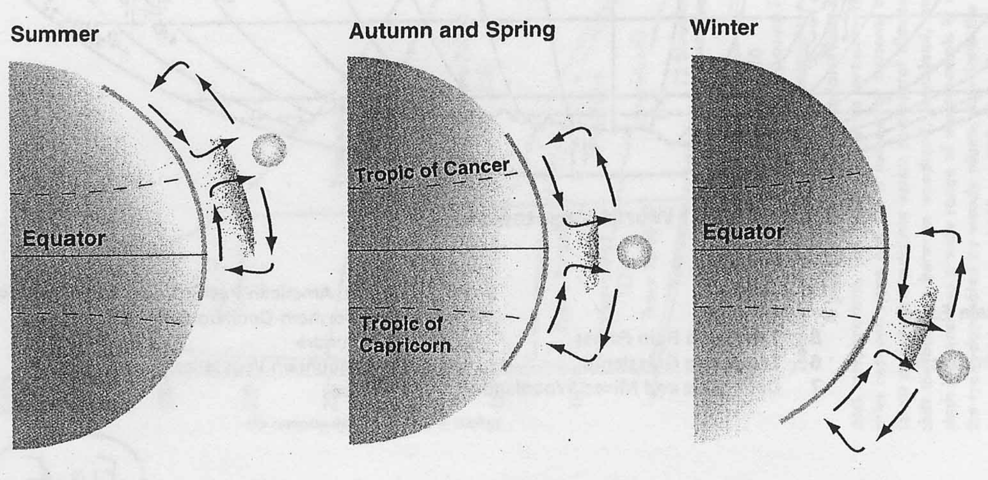


FIG. 3

Shifts of the intertropical convergence, producing rainy seasons and dry seasons. Note that as the distance from the equator increases, the dry season is longer and the rainfall is less. These oscillations result from changes in the altitude of the sun between the equinoxes and the solstices as diagrammed in Figure 2.7. (From H. Walter 1977.)

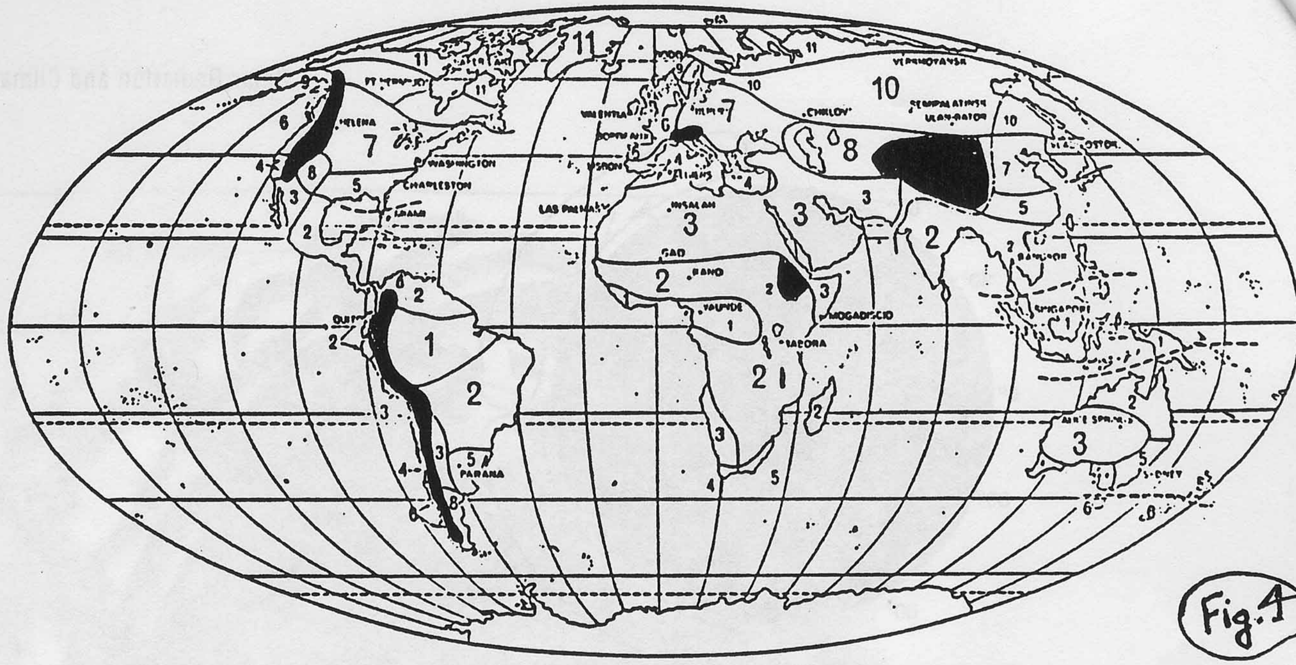
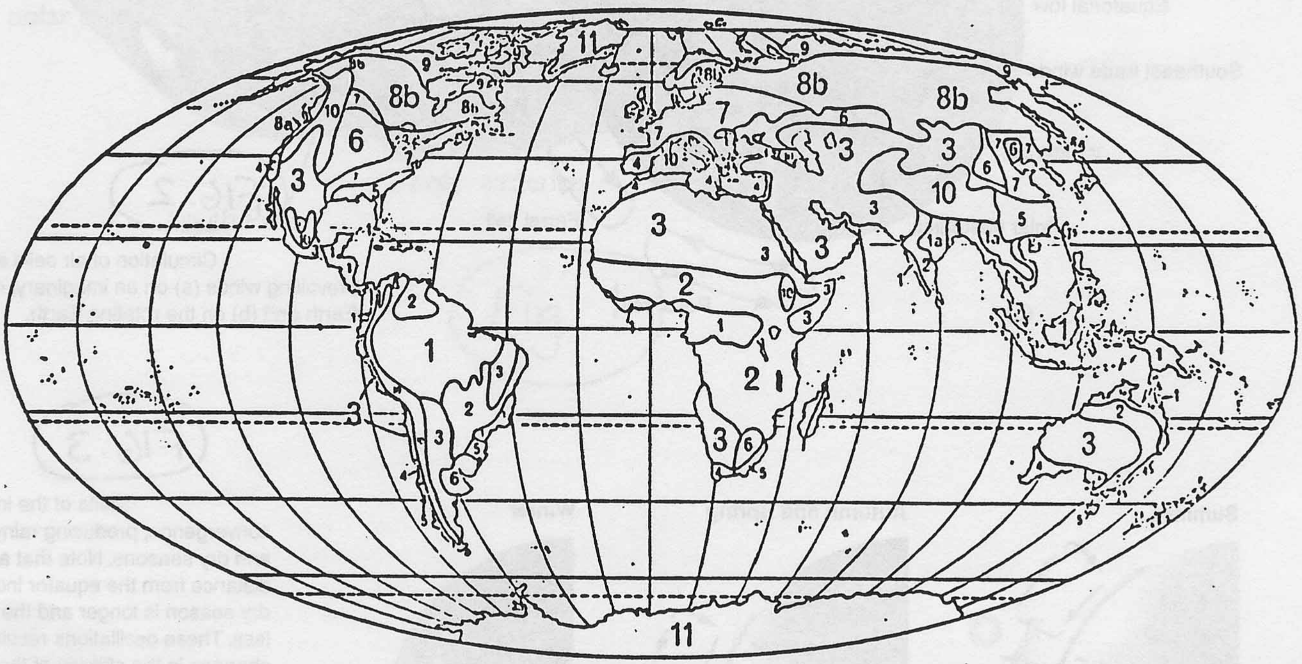


Fig. 4

Map A: Climatic Regions of the World

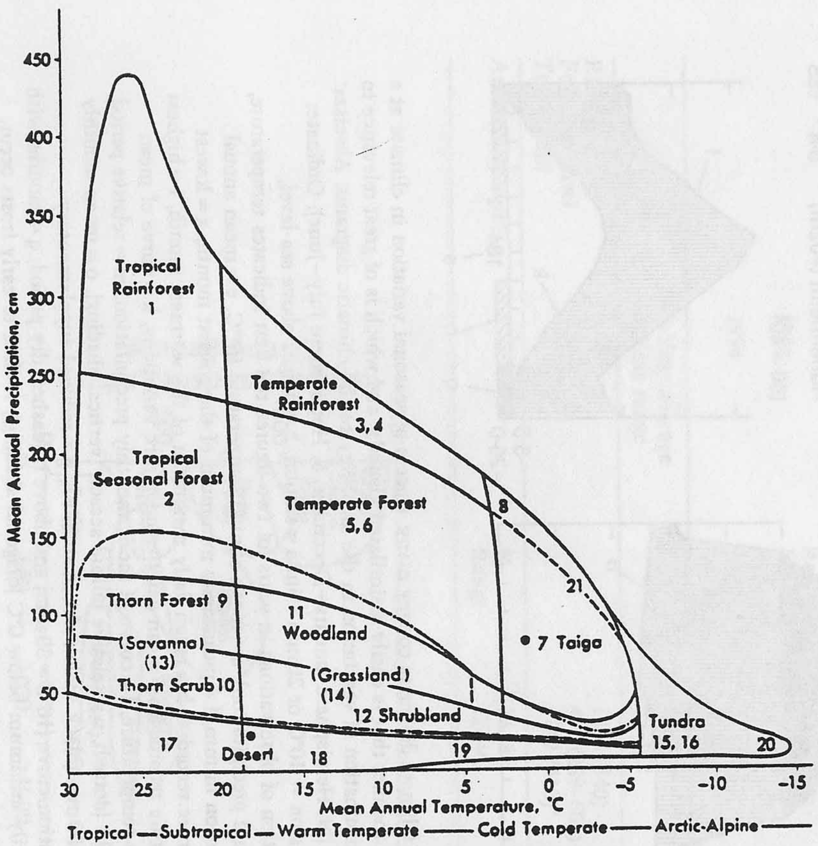
1 Equatorial
2 Tropical
3 Hot Desert
4 Mediterranean
5 Subtropical Summer Rain
6 Cool Temperate Maritime
7 Cool Temperate Continental
8 Mid Latitude Desert
9 Cold Maritime
10 Cold Continental
11 Arctic
Limit of Asiatic Monsoon
Mountain Climates



Map B: World Vegetation

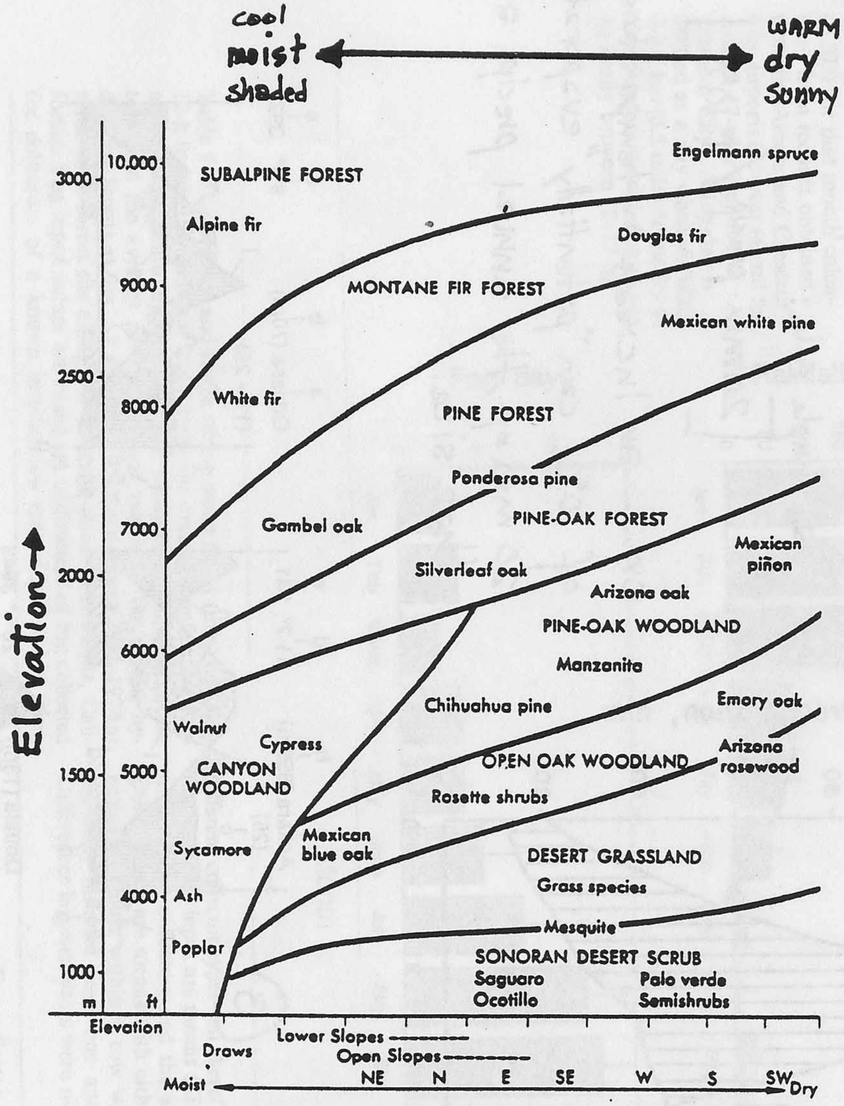
1 Tropical Rain Forest
1a Monsoon Semi-evergreen Rain Forest
2 Savanna
3 Thorn Scrub, Semi-desert and Desert
4 Mediterranean
5 Temperate Rain Forest
6 Temperate Grassland
7 Deciduous and Mixed Woodlands
8a N. American Pacific Coast Coniferous Forest
8b Northern Coniferous Forest
9 Tundra
10 Mountain Vegetation
11 Ice

Fig. 5



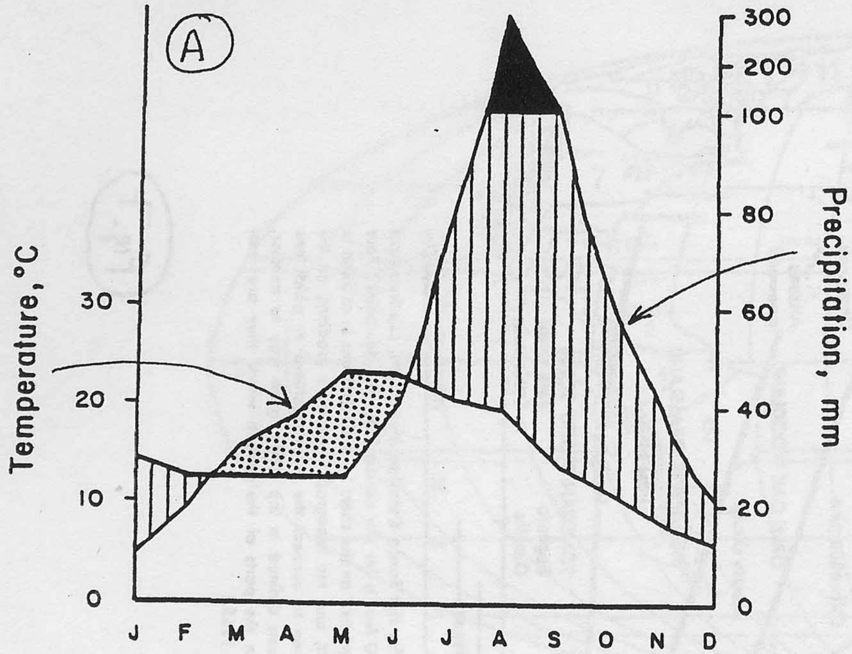
A pattern of world formation-types in relation to climatic humidity and temperature. The numbers refer to formation-types described in the text. Boundaries between types are, for a number of reasons, approximate. In climates between forest and desert, maritime versus continental climate, soil effects, and fire effects can shift the balance between woodland, shrubland, and grassland types. The dot-and-dash line encloses a wide range of environments in which either grassland, or one of the types dominated by woody plants, may form the prevailing vegetation in different areas. (Cf. Dansereau, 1957, p. 100, Lieth, *Ber. Deut. Bot. Ges.*, 69:169, 1956, and Holdridge, *Science*, 105:367, 1947.)

Fig. 6



A vegetation chart for the Santa Catalina Mountains, southeastern Arizona. (The pattern above 9,000 feet is for the nearby Pinaleño Mountains.) Four hundred vegetation samples were plotted on the chart by their positions in relation to the elevation gradient, on the left, and the topographic moisture gradient, on the bottom. Boundary lines were drawn to connect the mean positions at which one community type, as these had been defined in this study, gave way to another. Dominant species are indicated in the parts of the pattern where they are most important. [Whittaker and Niering, 1965.]

Fig. 7

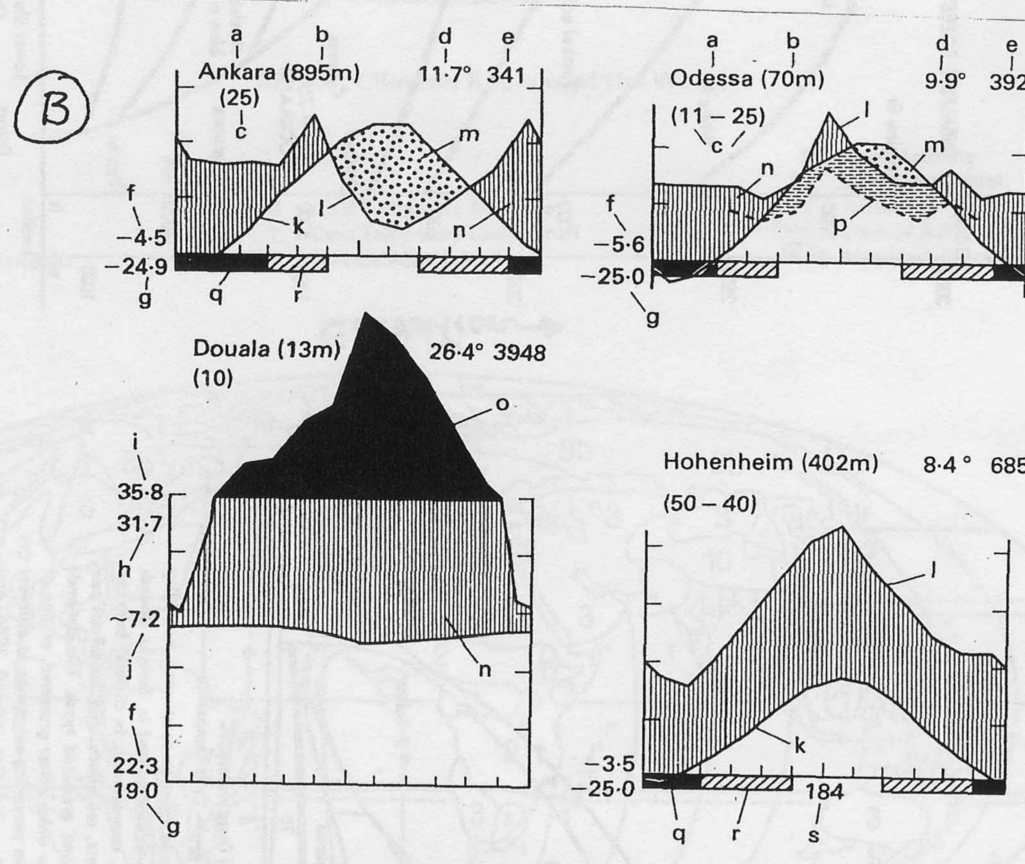


Such diagrams can be used in a very course way to estimate the potential evaporation by a simple rule:

[20mm precip / ↑ 10°C]

Or... an increase in temperature of 10°C can "potentially" evaporate 20 mm of the annual precip. at that site.

Fig. 8



Climate diagrams convey many aspects of seasonal variation in climate at a site in a manner that is easily assimilated visually, and which is of great relevance to the determination of vegetation in the area. Key to the climatic diagrams. Abscissa: months (N. Hemisphere January–December, S. Hemisphere July–June); Ordinate: one division = 10°C or 20 mm rain. a = station, b = height above sea-level, c = duration of observations in years (of two figures the first indicates temperature, the second precipitation), d = mean annual temperature in °C, e = mean annual precipitation in mm, f = mean daily minimum of the coldest month, g = lowest temperature recorded, h = mean daily maximum of the warmest month, i = highest temperature recorded, j = mean daily temperature variations, k = curve of mean monthly temperature, l = curve of mean monthly precipitation, m = relative period of drought (dotted), n = relative humid season (vertical shading), o = mean monthly rain > 100 mm (black scale reduced to 1/10), p = reduced supplementary precipitation curve (10°C = 30 mm) and above it (dashes) dry period, q = months with mean daily minimum below 0°C (diagonal shading), r = late or early frosts occur, s = mean duration of frost-free period in days. Some values are missing, where no data are available for the stations concerned (h–j are only given for diurnal types of climate). After Walter [5].

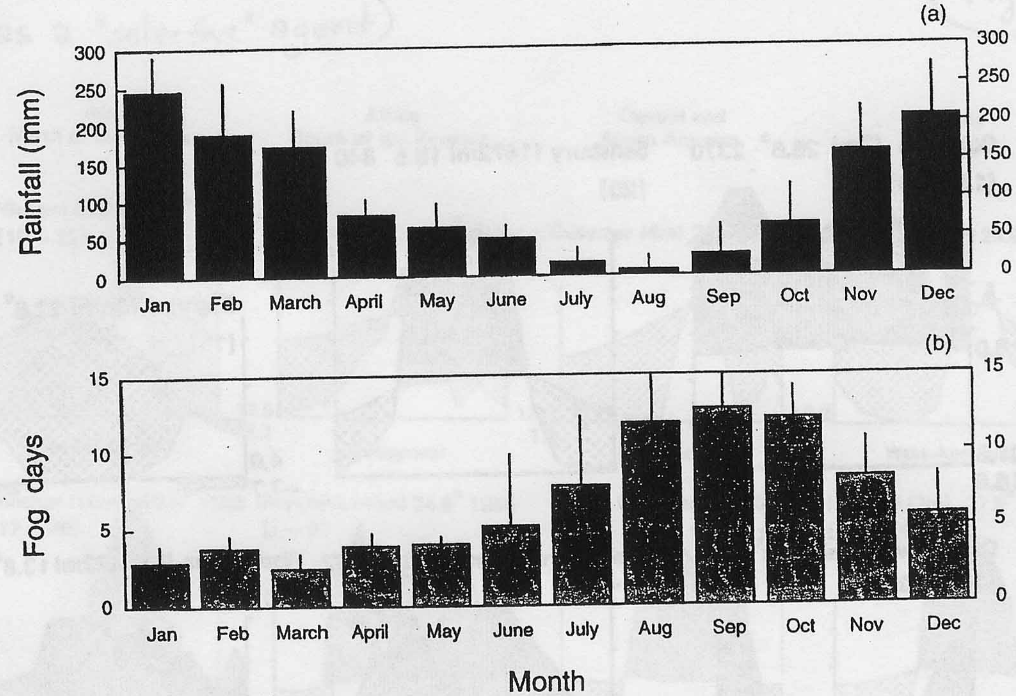


Fig. 9 Rainfall (mm) (**a**) and the number of fog-days (**b**) each month for the coastal redwood forest between Arcata and Crescent City, California. Each bar represents an average (±SD) for that month calculated from records obtained from the Arcata and Crescent City airports (35-year record for Arcata, 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)

Table 1 The average and range of fog water input (mm) during a 12-h fog-day by different 'collectors', the average rainfall, fog drip and total moisture inputs to the sites occupied by different collectors, and the average percentage (and range) of the annual hydrologic inputs as fog. All data were obtained during 1992–1994 at a redwood forest site along the Klamath River near Requa, California. Fog input values are based on millimeters of fog collected for collectors of a known interception area. Input values from different collector types can therefore be compared directly. Values for fog water input are means (SD) from seven interception or ten artificial fog collectors and the same number of 12-h 'fog-days'. Other values are means with either SDs or ranges shown in parentheses. Values within a row with different supercripts are significantly different from one another ($P < 0.05$; Students t-test). Differences between years were not tested (but see Table 3)

	Year		Off trees (interception)	Fog collector in the forest	Fog collector in the open
Fog water input	1992	Average	93 (21)[a]	55 (17)[b]	42 (13)[c]
		Range	63–128	37–73	25–71
	1993	Average	104 (26)[a]	62 (20)[b]	40 (22)[c]
		Range	55–132	39–70	33–69
	1994	Average	93 (21)[a]	60 (18)[b]	51 (21)[c]
		Range	59–130	38–66	29–60
	3-Year average		**98 (23)[a]**	**59 (18)[b]**	**46 (19)[c]**
	3-Year range		55–132	37–73	25–71
Rainfall (mm)			1315 (340)	1315 (340)	1315 (340)
Fog-drip (mm)			447 (289–605)	303 (17–434)	224 (79–368)
Total (mm)			1762 (413)[a]	1618 (292)[a,b]	1540 (325)[b]
Annual fog input		%	**34 (8)[a]**	**23 (7)[b]**	**17 (10)[b]**
		Range	22–46	13–33	6–28

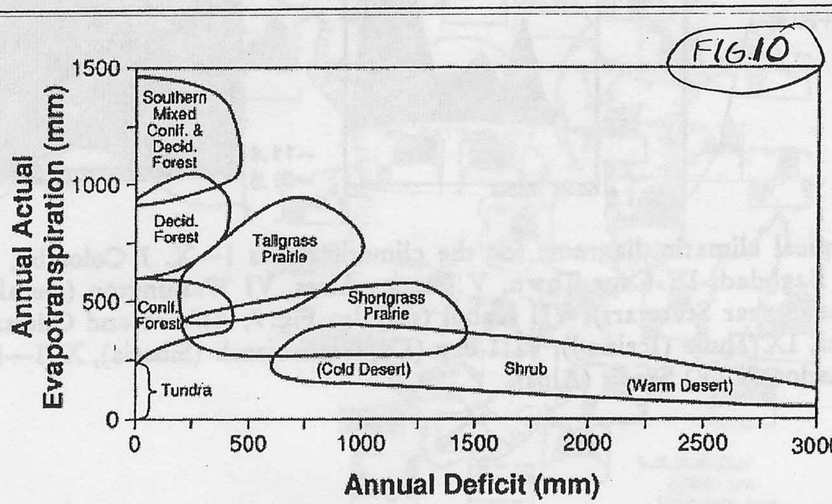
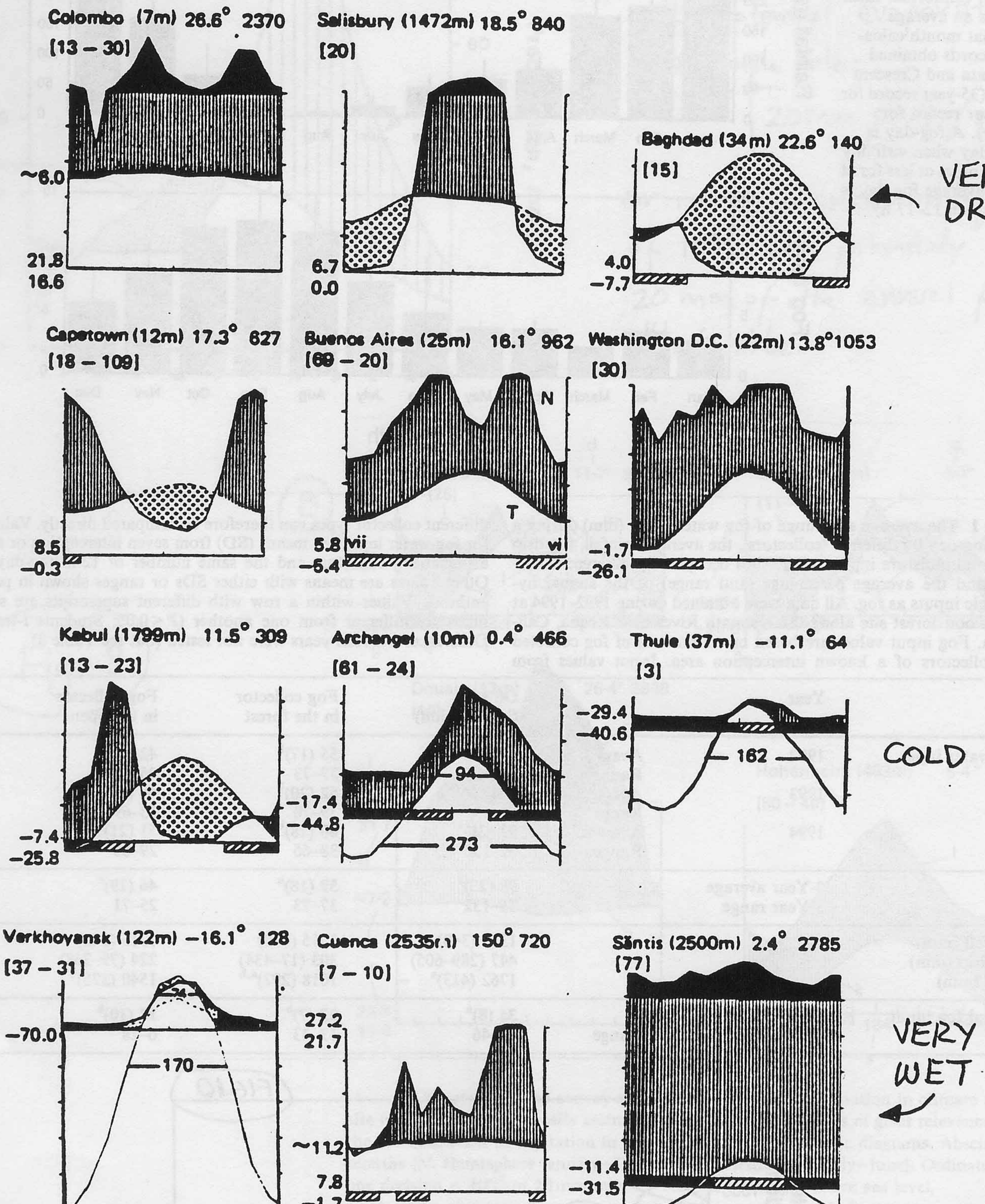


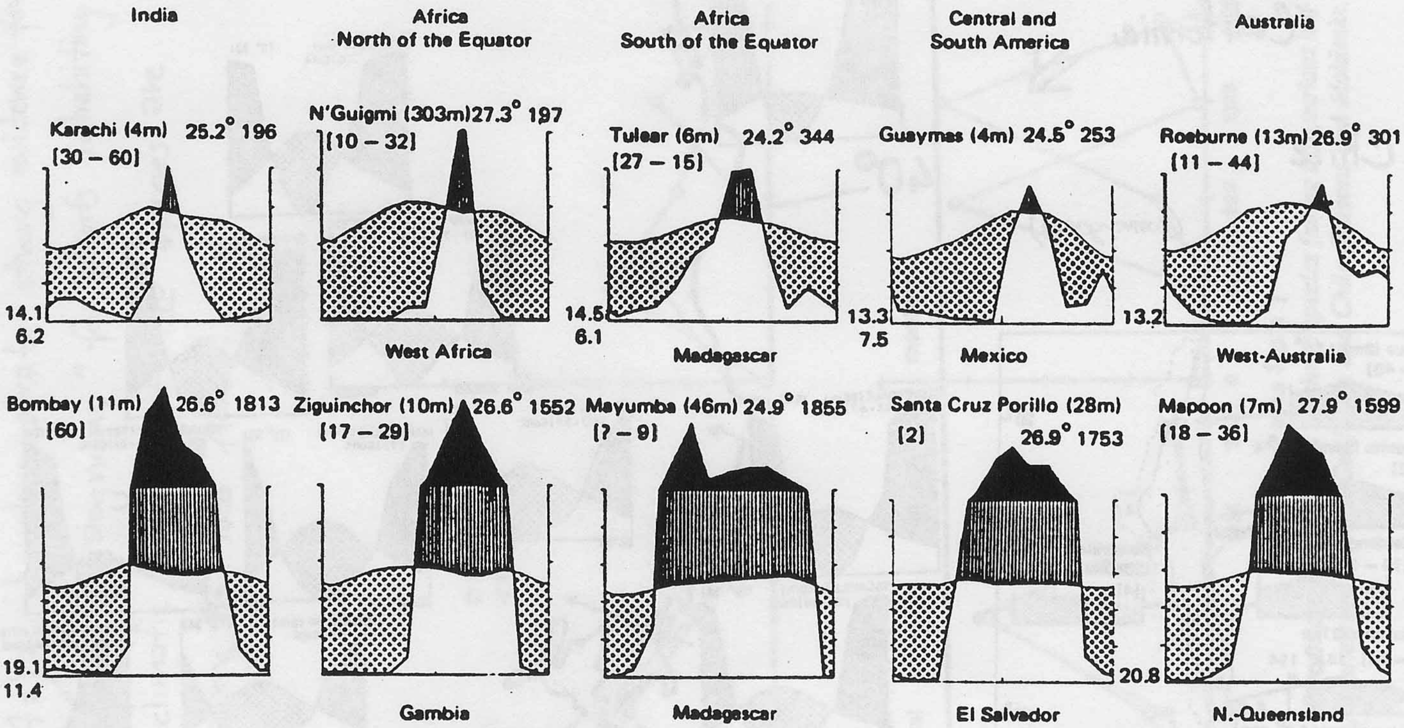
FIG. 10 The distribution of the major North American plant formations relative to annual AET and D (from Stephenson, 1990).

Fig. 11



Typical climatic diagrams for the climatic zones I—X. I Colombo, II Salisbury, III Baghdad, IV Cape Town, V Buenos Aires, VI Washington (see also Fig. 7 Hohenheim near Stuttgart), VII Kabul (see also Fig. 7, Ankara and Odessa), VIII Archangel, IX Thule (Iceland), VIII dry (IX) Verchojansk (Siberia), X (I—II) Cuenca in Ecuador, X (V) Säntis (Alps).

Convergence (as a "selective" agent)

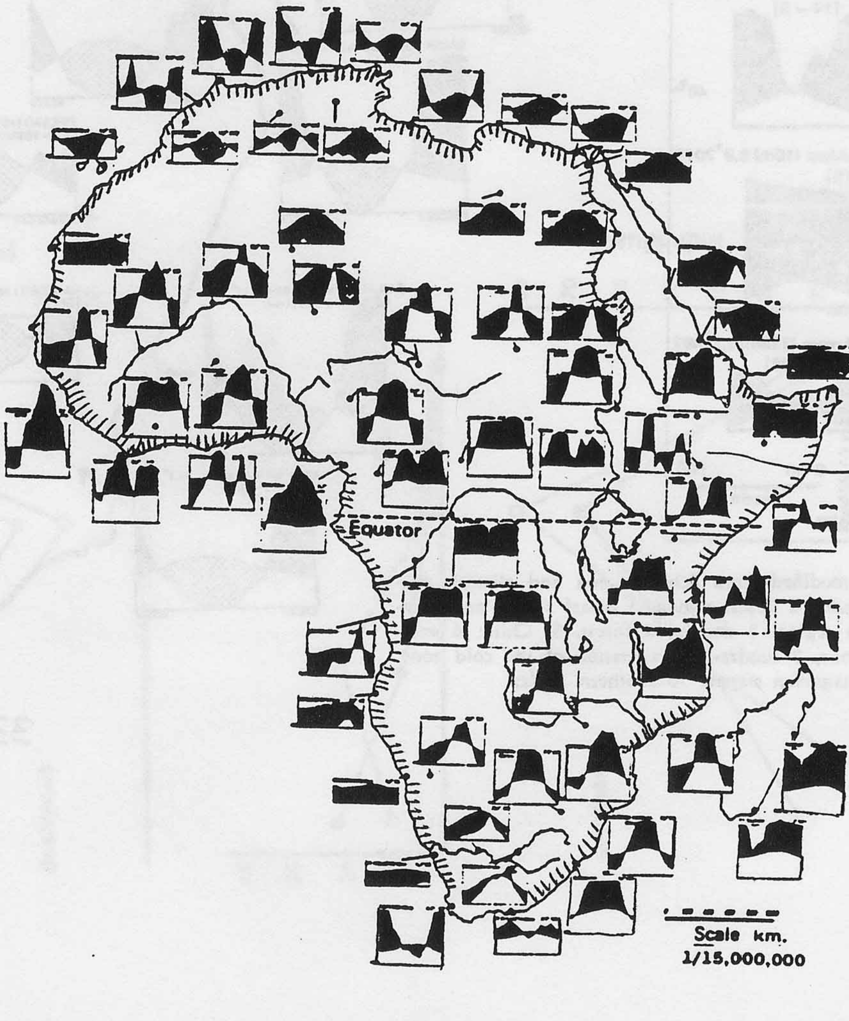


Homoclimes, on other continents, of the Indian stations Karachi and Bombay.

- Example of a climatic diagram-map showing a few stations. Climatic zones from north to south: IV-III-II-I-II-III-IV, although north of the equator the east is too dry (monsoon), to the south, however, too wet (S. E. Trade Winds).

Clines:

e.g., in Africa



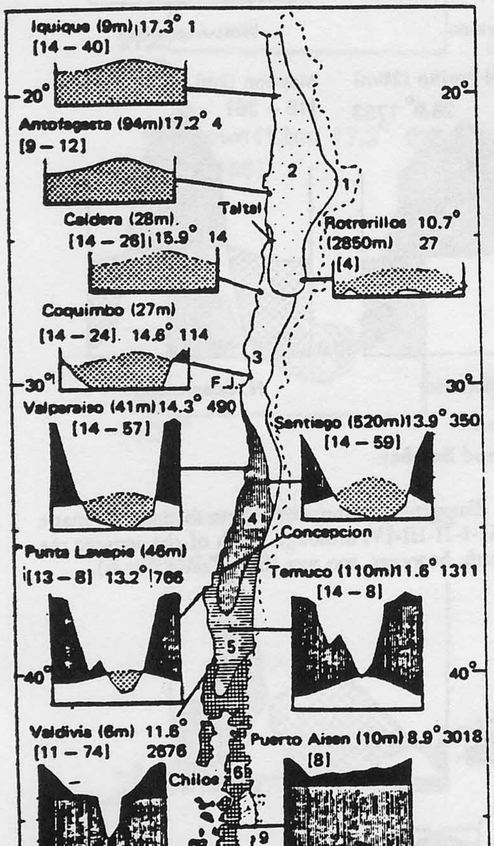
bimodal monsoons.

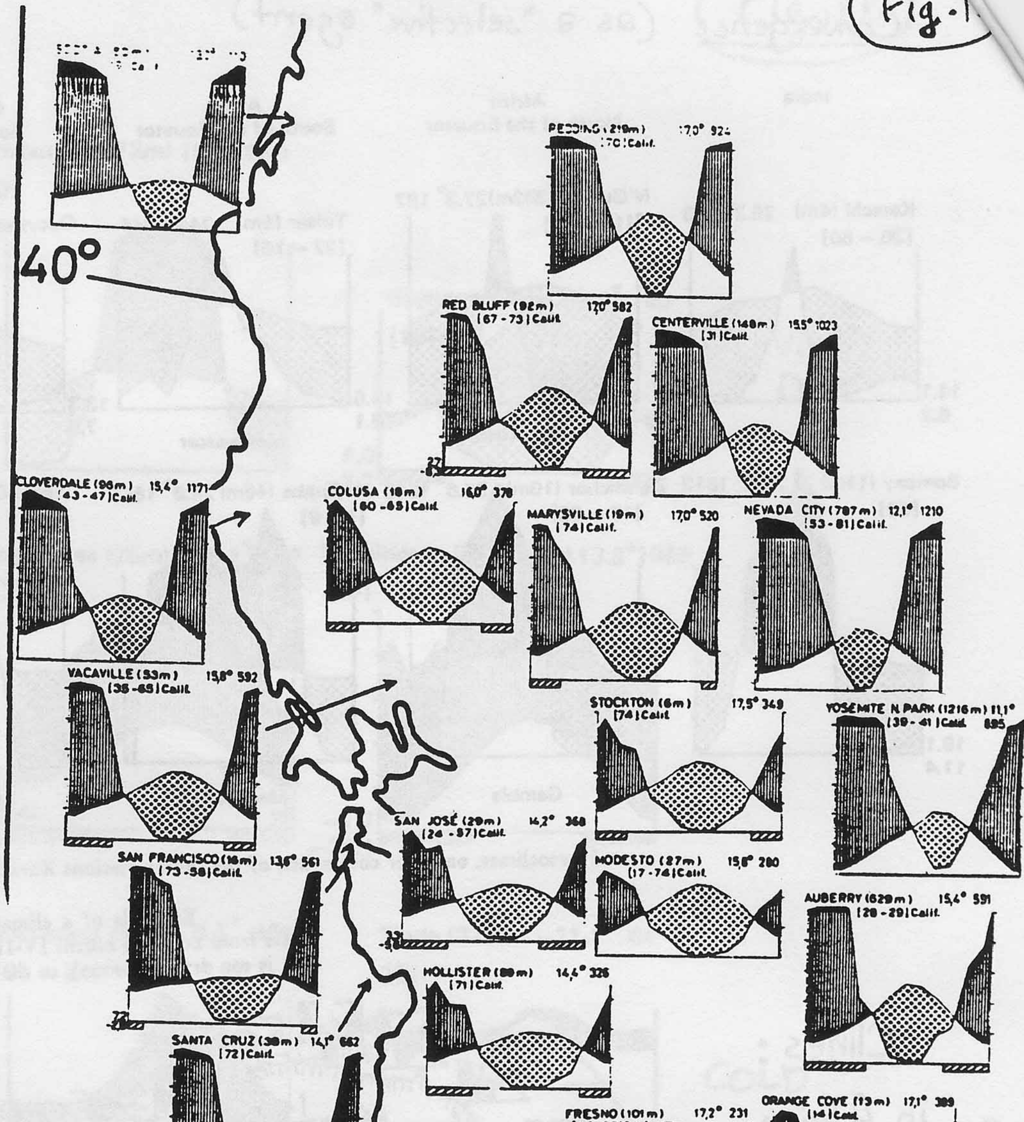
Fig. 1

California

Chile

(convergence)





Vegetation of Chile (modified from Schmithüsen) and climatic dia-
rams. N-Chile: 1 northern High Andes, 2 desert region, 3 dwarf shrub- and xero-
hytic shrub-region, 4 sclerophyllous region, 5 deciduous forest. S. Chile: 6 ever-
reen rainforests of the temperate zone, 7 tundra-like vegetation of the cold zone,
: subantarctic deciduous forest, 9 Patagonian steppe, 10 southern Andes.

Figures 14a & b demonstrate strong evidence for convergence in "physiognomy" for plants inhabiting similar climatic zones, yet NO species are shared among the two floras!

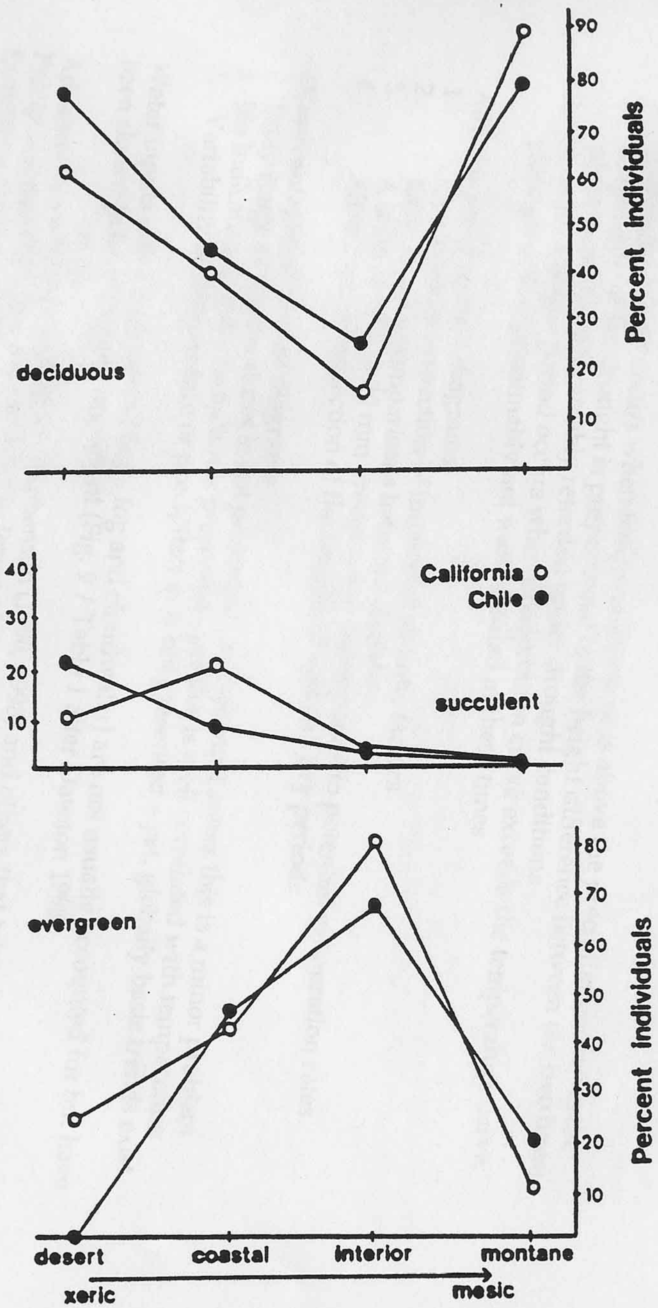


FIGURE 14a *Percentage of shrub individuals with deciduous, evergreen, and succulent habits at four pairs of matched sites in California and Chile (Parsons and Moldenke, 1975).*

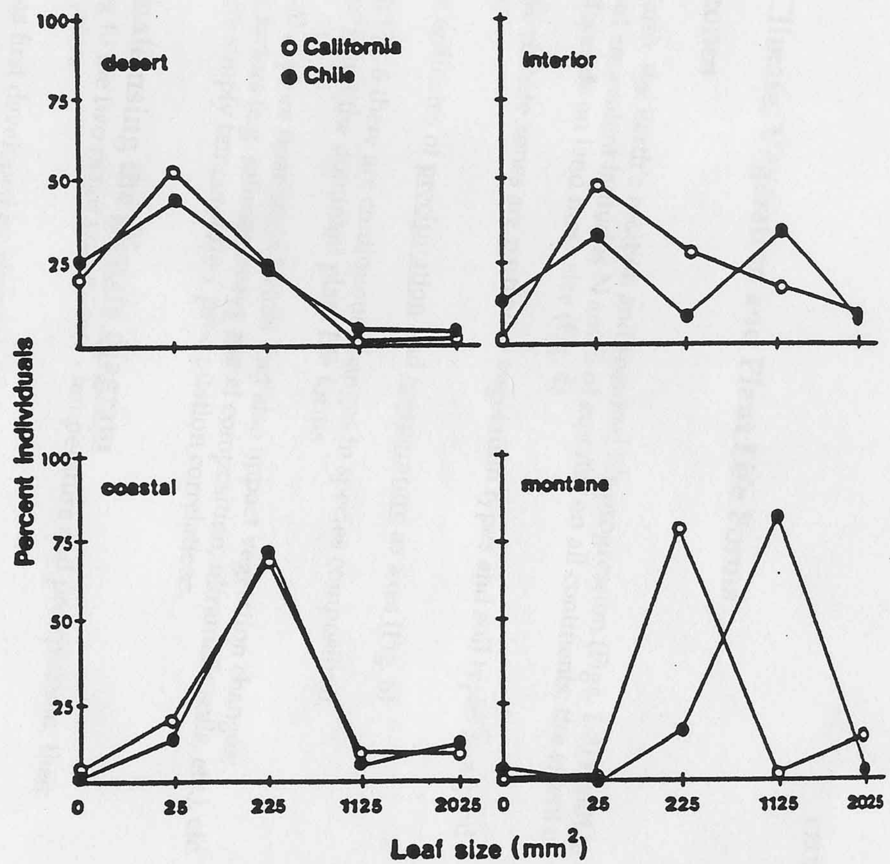


FIGURE b. *Percentage of individuals of shrub species falling into various leaf-size categories, at matched sites in California and Chile (Parsons and Moldenke, 1975).*