Environmental Studies 30 -- The Global Ecosystem
P.J. Richerson

LECTURE 9: Mediterranean Biome

I. Climates

The warm temperate Mediterranean climates are differentiated from other temperate climates by having winter rain and summer drought (Figure 9.1). To those of us raised in California, this pattern seems a normal thing, nicely conducive to outdoor activities. Actually, Mediterranean climates are quite anomalous. Warm air carries much more water vapor than cold air, and the more intense sunlight of summer tends to cause more energetic uplift of air to produce precipitation. Most climates with seasonal rainfall thus have a summer rainy season. The areas of the Mediterranean zone are small in four of the five cases (California, Chile, South western Cape Province in South Africa, and Southwestern and South Australia). Only the Mediterranean area proper is a large biome. In addition, Mediterranean climates are geologically young, existing only since the beginning of the Pleistocene.

The winter rain-summer drought pattern results from the west coasts of continents at mid-latitudes receiving the normal temperate-zone patterns of cyclonic storms driven by the mid-latitude jet in the winter, but lacking these storms in the summer. During the summer, the subtropical high pressures moves far north of its winter-time location on the eastern sides of oceans, and the mid-latitude cyclones are diverted to the north. At the same time, tropical storm tracks are south of the highs and tend to move out to sea on the west side of continents; we also lack this source of moisture, so important at equivalent latitudes on the other side of the continent. Occasional tropical storms do reach California, giving intense and damaging rainfall in Southern California. Likewise, the rare mid-latitude cyclone reaches the northern part of this biome in summer, giving us a little rain in Davis in the odd year.

The Mediterranean type of climate seems to have developed with the increasing coolness of the poles during the Pleistocene. More intense atmospheric and oceanic circulations have become necessary to balance the earth's heat budget, giving greater seasonal shifts in characteristic latitudinal weather belts and stronger, colder offshore currents on the east side of oceans. Both the shift of the subtropical high and the cool offshore waters contribute to the summer drought (the "real" Mediterranean climates of the Mediterranean basin have shorter and less extreme summer drought than California because the Mediterranean Sea is quite warm, giving enough moisture for some summer showers). The immediate coast of California also has summer fog conditions, reminiscent of the fog deserts of Peru and Namibia, because of the cold current.

The two main types of variation within Mediterranean climates are the severity of the summer drought (California and Chile are the most extreme), and total annual precipitation. The summer drought rainfall pattern includes quite dry deserts (Northern Baja California, North Africa) on equatorward sides of the core Mediterranean Biome proper as it grades into the Subtropical Desert, which more typically has summer rain. On the poleward side in the Northern Hemisphere and in Chile, it grades into various moist-temperate climates. On our coast, the winter rainfall maximum is still pronounced as far north as Vancouver, B.C., but the summer drought is considerably reduced.

In some classifications, the whole winter rainfall region is included in the term "Mediterranean" and is applied either to climate or biomes. More commonly only the core semi-arid area with quite dry summers is considered Mediterranean (e.g. California, excluding the North Coast and most of Baja California).

Temperatures also vary within Mediterranean areas, though less than one might think from north to south and more from the coast inland. Mediterranean climates are maritime, more so near the ocean. Temperature seasonality increases inland, as you all know from your experience in California.

Typically, but not always, Mediterranean climates are characterized by light frosts in the winter season, and warm to hot summers. All Mediterranean climates have much milder winters than equivalent latitudes on the east side of continents. Under the influence of prevailing westerly winds, cold continental polar air seldom reaches these biomes. The east sides of continents suffer the intrusion of very cold polar air to quite low latitudes. This is especially true of Eastern North America where there are no significant mountains to retard the flow of frigid continental air from Central Canada in the winter time.

II. Other Physical Factors

A. Soils

The older soils of Mediterranean biomes developed under the warmer and wetter climates of the pre-Pleistocene. They are heavily leached red soils, often laterities. Such soils may be seen in the foothills of the Sierras on level to rolling topography. The Mediterranean biomes of Africa and Australia are dominated by such soils. You can see these soils exposed in road cuts. They are especially pronounced S.E. of Sacramento on the road to Jackson. By contrast, the Mediterranean, California and Chile variants are in mountainous areas where most soils are either shallow residual on the slopes or alluvial in the valleys. Both types are a result of active erosion and so are young and unleached.

B. Fire

The long summer drought and relatively high standing crop of vegetation makes the Mediterranean biomes as prone to fires as savannas and steppes. Many plants here are fire-adapted. Modern human settlement has greatly reduced fire frequency, partly because the historic wildfires were dangerous to life and property. The problem is that fire suppression is difficult in the long run because fuel build-up generates even more fire prone landscapes until the inevitable accident produces real catastrophes.

III. Plant Adaptations

A. Annuals

Annual plants are very diverse in the Mediterranean Biomes. Annuals make up a larger proportion of the species list than in any other biome. This growth habit seems to be favored by the relatively long growth season, made possible by the mild, wet winters, and by the occurrence of the drought period in the hot season. Unlike most perennials, almost all annuals maintain a large number of seeds in the soil, only a portion of which germinate in any given year. The uncertain timing and extent of rains and frosts greatly influences competition in any given year, and the seed bank ensures against local extinction.

Annuals sprout in the Fall, grow slowly in the Winter, and are in a position to use much or all of the shallow water in the Spring. Most of these annuals are the product of recent evolution.

B. Perennials

When in competition with annuals, especially when disturbed, perennial grasses have a difficult time extracting enough water to survive the long dry summer, even in a dormant stage. Perennial bunch grasses were once very common in California grassland, before destructive grazing and plowing were introduced. The turf-forming grasses that rather effectively exclude annuals in the savannas and steppes are absent in Mediterranean biomes.

C. Sclerophylls

The dominant woody vegetation of the Mediterranean biomes is evergreen and sclerophyllous. The deep, extensive root systems of these trees and shrubs find sufficient water to continue photosynthesis at a reduced rate during the summer, and to take immediate advantage of the fall rains. One might expect drought-deciduous plants, reminiscent of the tropical deciduous forest to be more common in Mediterranean environments (there is one in California -- California buckeye); perhaps the ability to use the variable fall rains while temperatures are still warm and favorable for photosynthesis, despite the cost of summertime maintenance of leaf tissue, is decisive. It is important to note that where ample water is available year-round (e.g. riparian vegetation), the predominant habit is winter-deciduous, including maple, cottonwood, sycamore, ash, walnut and others in California.

Under extreme and prolonged drought, the sclerophylls will lose their otherwise evergreen leaves. If extreme conditions continue, the branches and stems may die off down to the root crown. When moisture returns, the plant is then able to resprout from the crown.

The sclerophyll habit was not historically evolved for the Mediterranean climate. Rather, it was recruited to the new Mediterranean Biomes at the beginning of the Pleistocene from the mountains of Mexico where it was adapted to the wetter margins of the Subtropical Desert with summer rain and cool, lightly frosty winters. The closest relatives of many California sclerophylls still inhabit such regions in the "encinal" belt (the cooler semi-arid mountain sides of the moister deserts of Arizona, New Mexico, and Northern Mexico).

Interestingly enough, the Mediterranean Biomes have great ecological resemblances despite their independent history and very recent evolution. The exception is Australia, where Eucalyptus dominance gives the vegetation a very different aspect.

D. Fire Adaptations

Protection from recurrent fire can be achieved in several ways. Annuals are automatically protected by their rich seed bank. Trees are protected by thick layers of bark which catch fire with difficulty and insulate the living cambium layer underneath -- California Redwoods and the Mediterranean Cork Oak are examples. Shrubs often "stump-sprout" after fires from thick subterranean root crowns. Many Manzanitas and Chamise have this habit. A few conifers adapt to fire by carrying their seeds in cones that only open when burned. Knobcone pine in California is a specialist of this type. It is short-lived and bears cones when only 6 to 7 years old. Rather than surviving fires, it is adapted to rapidly recolonize areas with a fire frequency interval of 40 to 50 years.

E. Shrubs

Shrubs are a dominant Mediterranean adaptation on shallow residual soils. The closed-canopy chaparral communities of California, dominated by Manzanita, Ceanothus and Chamise in California is characteristic of other Mediterranean biomes as well. On shallow soils, the shrub roots penetrate the parent rock to find enough water to survive. On better soils the shrubs give way either to grasslands or savanna-like communities (hotter, drier, or wind-blown sites) or forests (cooler, moister or more protected sites). Where soils and topography are complex, the chaparral community may be interwoven with forest and grassland in a most complex manner (forming a mosaic).

IV. Animal Adaptations

Very few animal adaptations are characteristically associated with the Mediterranean Biome. The complex interweaving of community types from forest to grassland has led to a recruitment of animals whose characteristic distributions are far outside the Mediterranean Biome. Animal biogeographers often ignore it for this reason. California, for example, has a moderately diverse animal fauna, but relatively few endemic ones. The open grassland communities once supported ungulate herds characteristic of the steppes. The chaparral and forest still support species characteristic of woodlands outside the Mediterranean biome.

V. Human Adaptations

A. Hunting and Gathering

Hunting and gathering societies prospered in the Mediterranean Biomes. Resources were diverse, particularly in the more rugged examples like Southern Europe and California, and the relatively open country was favorable for hunting. Hunters characteristically are unable to store much food because their extensive resource extraction system requires too frequent movement, and without draft animals, very little can be carried. Consequently, many different kinds of resources available in a relatively small area is especially favorable for this mode of life. Aboriginal California had quite high population densities for a pure hunter-gather system.

B. Agriculture

The Mediterranean Basin was probably the earliest center of agricultural development. The wheat-olive-grape, and sheep-cattle-goat complexes began to develop there about 10,000 years ago. Most of the population were peasant agriculturalists by 5,000 years ago. The classic adaptation is winter rainfall agriculture, although irrigation pushed the complex into the arid margins of the biome quite early. The core adaptation is still quite recognizable in California, Chile and the Mediterranean Basin today. Even California agribusiness owes much to its classical ancestry despite the adoption of a large number of extra-Mediterranean domesticates. Most of these newer crops are dependent on summer irrigation.

Human impacts have also been severe from antiquity. George Perkins Marsh, the 19th Century pioneer of the environmental preservation movement, was greatly impressed by the havoc he observed in the Mediterranean when he was the U.S. Ambassador to Italy. The most severe problems were the destruction of upland soils from overgrazing and wholesale deforestation. Steep slopes in semi-arid regions are prone to catastrophic soil loss because the pioneering annual plants are slow to stabilize the soil against rapid losses from early winter rains. California and Chile face this problem today.

The industrialization of agriculture and the spread of irrigation bring with them a series of new environmental problems, none especially characteristic of the Mediterranean Biome, but often very intense here because of the suitability of the climate and soils for intensive irrigated agriculture. Soil salinization, mentioned previously in the case of deserts, pesticide use and the extirpation of wild communities are conspicuous examples.

VI. <u>Ecotones</u>

A. Ecotone with the Mid-latitude Desert

As total annual rainfall decreases, the sclerophyllous tree-dominated communities are gradually restricted to more and more favorable sites, while grasslands and shrublands expand. Finally, the closed canopy shrublands disappear entirely and the open shrubby desert communities begin to occur. Along the coast of California and Baja California, the Mediterranean communities persist for a while at higher elevations, whereas the transition inland across the mountains is more abrupt.

B. Ecotone with the Temperate Forest Biome

In mild-winter temperate regions, the dominant vegetation is evergreen trees. On the west sides of continents these may be either conifers (needle leaf evergreens) (North America) or mainly broadleaf evergreens (Chile).

In California, the transition is a function of elevation and maritime exposure. Communities representative of the evergreen conifer biome occur as belts in the mountains where cooler temperatures and higher rainfall reduce the impact of summer drought, or along the coast where the cool, foggy climates have a similar effect. The coastal Redwood forests and the montane Yellow Pine belt exemplify the transition from the tropical Mediterranean sclerophylls to the transitional, mildly summer-drought tolerant conifers.

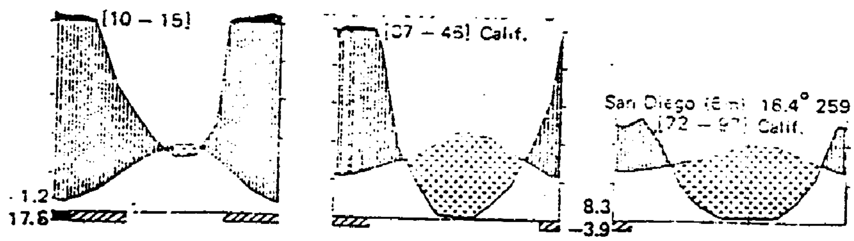
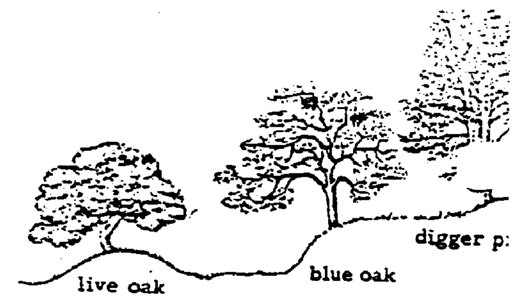
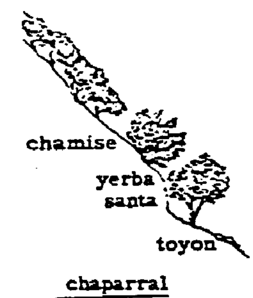


Fig. 52. Climatic diagrams of stations on the Pacific coast of N. America (from north to south) in the coniferous forest-region, sclerophyllous forest-region and the region transitional to the desert.

CALIFORNIA



OAK WOODLAND & SAVANN.



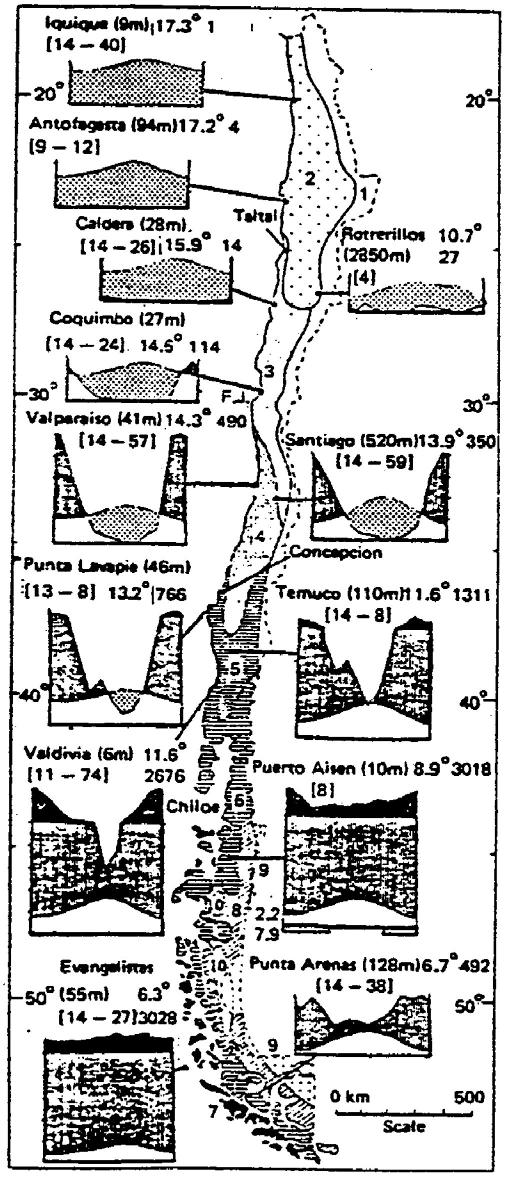
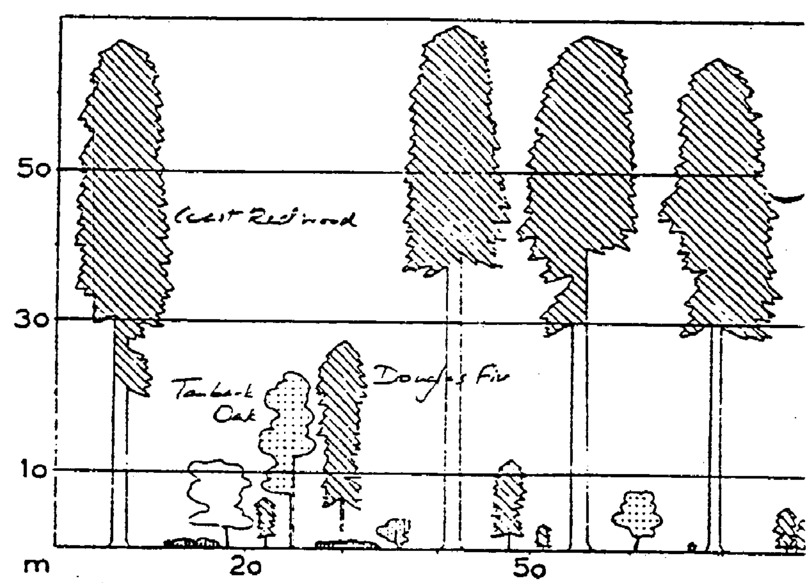


Fig. 53. Vegetation of Chile (modified from Schmithüsen) and climatic dia-ms. N-Chile: 1 northern High Andes, 2 desert region, 3 dwarf shrub- and xero-ic shrub-region, 4 sclerophyllous region, 5 deciduous forest. S. Chile: 6 ever-n rainforests of the temperate zone, 7 tundra-like vegetation of the cold zone, bantarctic deciduous forest, 9 Patagonian steppe, 10 southern Andes.



CALIFORNIA COASTAL REDWOOD ASSOCIATION

FIGURE 9.1

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Name: ____________________

MIDTERM EXAM

This exam is worth 90 points.

I. <u>Short answers</u>: Answer any three for 15 points each.

1. How do the movements of the ITCZ produce the seasonally rainy tropical climates poleward from the ever-rainy equatorial rain forest climates?

2. Water vapor is one of the main vehicles for moving heat in the earth heat engine. How does water vapor transport heat?

3. What is the mechanism of community evolution by competitive exclusion?

4. What is the potential evapotranspiration to rainfall ratio? Why is it a useful index of the aridity of climate from the point of view of plants?

Name: ____________________

II. Biome Problems: 5 points for each part.

1. First Biome:

a. Name this biome:

b. Draw a typical climate diagram for this biome. Indicate cold seasons (if any) with bars for freezing and frosty weather.

c. Describe the soil forming processes that are active in this biome. Are the resulting soils good or poor for agriculture?

2. Second Biome:

a. Name this biome:

b. Draw a typical climate diagram for this biome. Indicate cold seasons (if any) with bars for freezing and frosty weather.

c. Is this biome likely to support high or low biomass of large herbivores <u>relative</u> to plant biomass? Why?

3. Third Biome:

a. Name this biome:

b. Draw a typical climate diagram for this biome. Indicate cold seasons (if any) with bars for freezing and frosty weather.

c. Are poikilothermous animals relatively important or unimportant in this biome? Why?