Climatic limitations on plant growth evaluated by

Balancing Soil Moisture

against evaporation and transpiration

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Crop selection and soil management practices can be based on accurate estimates of evapotranspiration—water loss from the soil by direct evaporation and by plant transpiration—derived from climatic analysis. Growth of crop plants is dependent on the three major factors of soil, climate and management. Soil and management have been studied more thoroughly and are better understood than the factor of climate.

Recent studies with irrigated crops have shown that flowering and production of seed or fruit are strongly affected by day and night temperatures. The choice of crops and their management may be controlled by these factors. However, where crops depend upon rainfall and soil moisture storage for their water supply, crop selection and management may be still more restricted.

The moisture limitation on plant growth can be computed for a soil of any water holding capacity and for any length of growing season by a simple and rapid method using climatic data. The procedure is based on a system of bookkeeping wherein the gains in soil moisture from rain or irrigation are balanced against the losses through evaporation, transpiration, surface runoff, or deep percolation.

The water balance calculated from climatic data for Sacramento is illustrated by the graphs on this page. The potential evapotranspiration—the amount of water which would be lost to the atmosphere from the soil with a continuous plant cover if the soil were kept continually moist—is calculated month by month from mean temperature data, and compared with mean monthly rainfall.

In the Sacramento area, when rain falls on a soil which can store up to 4″ of moisture in a form available to plants, there is a large rainfall deficiency from June to October. However, in November there is more rain than evapotranspiration and some moisture is left in the soil at the end of November. December rains add more moisture to the soil, and by mid-January the soil is wet to its full storage capacity of 4″. From January through March, rainfall continues to exceed the evapotranspiration, but as the soil is filled to its full water storage capacity, the excess must be lost through surface runoff or by percolation through the soil beyond the reach of the plant roots.

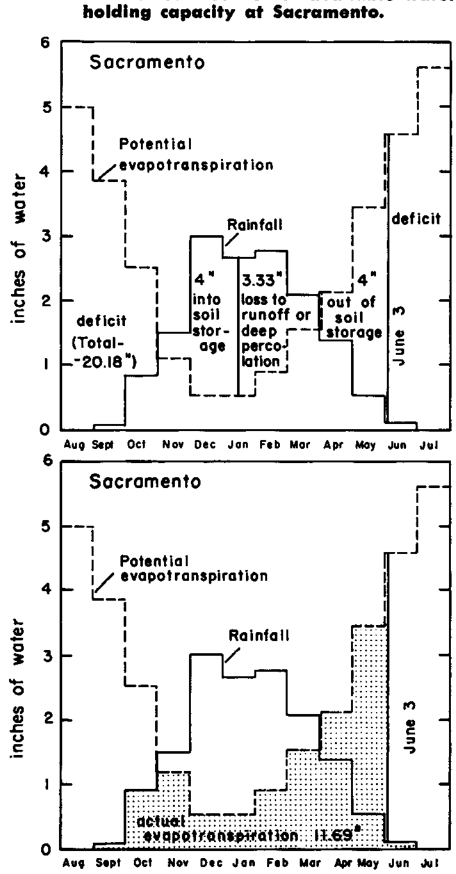
Beginning in April, potential evapotranspiration exceeds the rainfall and the soils begin to dry out. By early June, the 4″ of water in soil storage is exhausted. Plant growth is stopped by a shortage of water.

The total calculated actual evapotranspiration in the Sacramento area—indicated by the dotted area in the lower left graph—amounts to 11.69″. If 20.18″ of water were supplied by irrigation to overcome the deficit—indicated in the upper left graph—the actual evapotranspiration would equal the potential evapotranspiration of 31.87″.

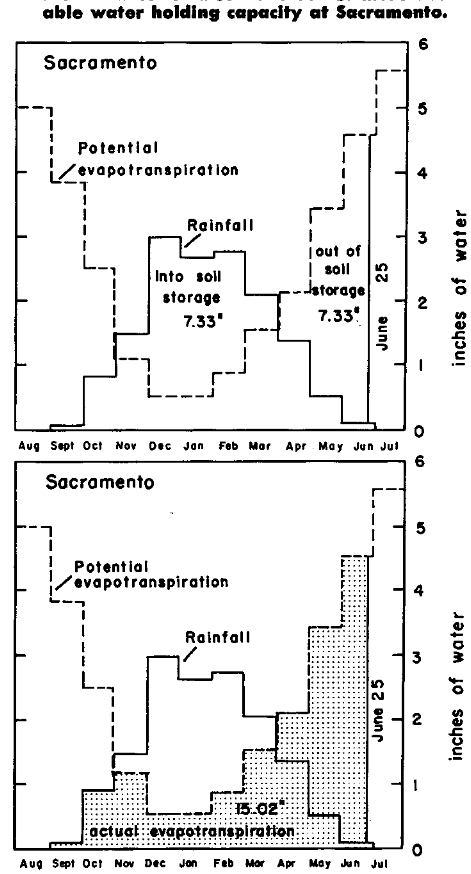
The upper and lower graphs on the right indicate what happens in a soil with a large water storage capacity. There is no water lost through runoff or deep percolation so the calculated actual evapotranspiration is increased by an amount equal to the 3.33″ lost where the soil had only 4″ of water storage capacity.

Experiments have shown that vegetative growth of plants is directly proportional to the water transpired. In California, transpiration accounts for about 55% of the actual evapotranspiration. Thus it is evident that plant growth is

Water balance for a soil of 4″ available water holding capacity at Sacramento.



Water balance for a soil of 7.33″ or more available water holding capacity at Sacramento.



also proportional to the actual evapotranspiration.

At Sacramento the potential evapotranspiration is 2.7 times as great as the actual evapotranspiration, so an increase of total annual plant growth of nearly 300% should result from a change from dry-farmed land to irrigation, if other factors were equal.

Actual and potential evapotranspiration can also be calculated for the frost free growing season as well as for the entire year. For instance, at Soda Springs, the average frost free period between 32°F frosts is only 72 days—from June 18 to August 28—which reduces the actual evapotranspiration from

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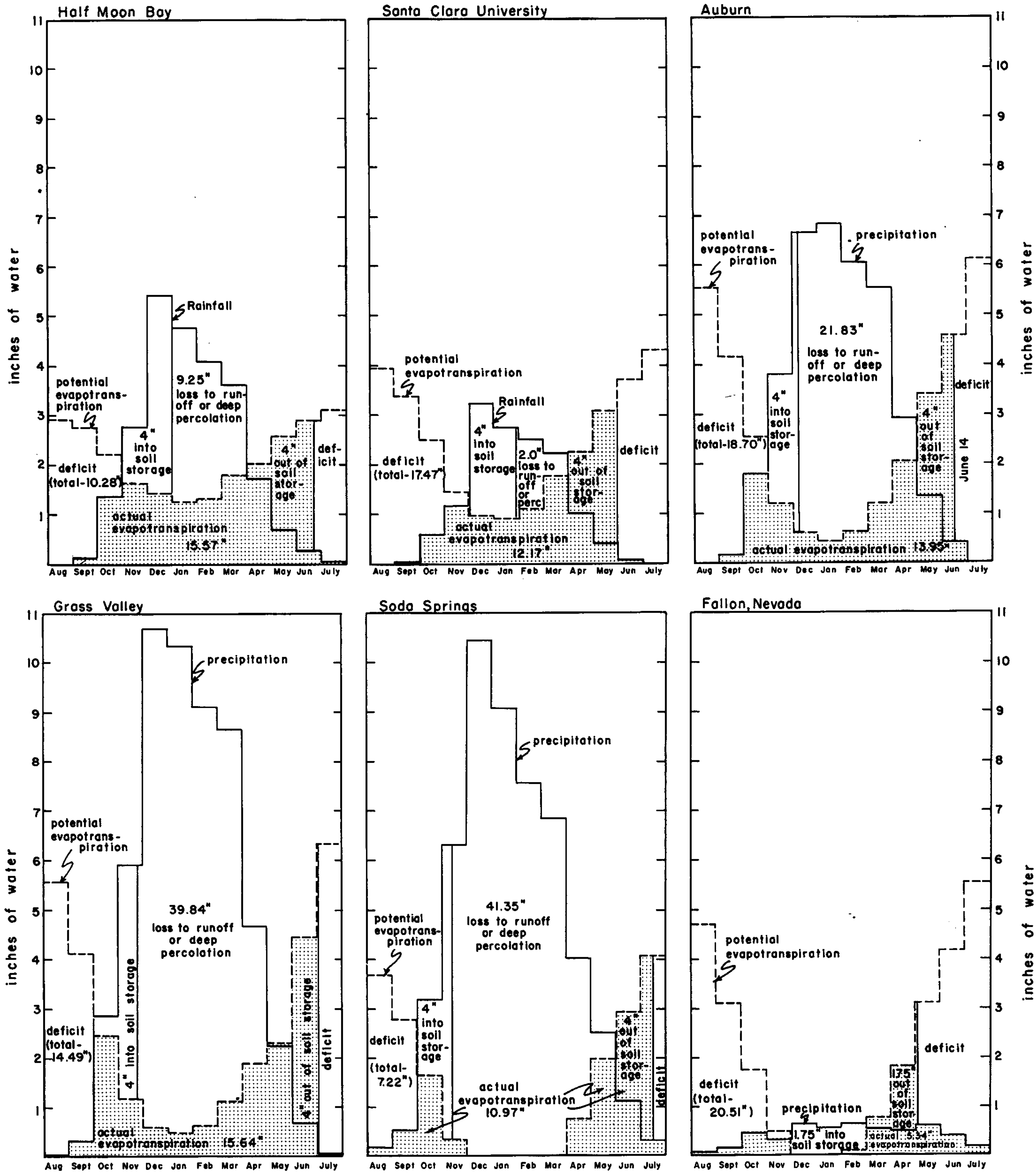
The water balance for soils of 4" available water holding capacity at six stations along a traverse from the Pacific Coast near San Francisco, eastward into western Nevada.



WATER BALANCE

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10.97″ for frost tolerant crops to only 4.07″ for frost sensitive crops.

The water balance can also be computed on a day to day or week to week basis, as a guide to irrigation practice. However, atmometers or evaporation pans are necessary for calculating potential evapotranspiration for such short intervals of time.

To study the application of the water balance method of climatic analysis to land classification, the water balance for soils of 4″ available water holding capacity was calculated for a number of stations along a traverse extending from the Pacific coast near San Francisco, inland into western Nevada. The annual values for actual evapotranspiration are high—more than 15″—along the coast, decline to about 12″ in the interior valleys and rise again to more than 15″ at Grass Valley and decline again to about 11″ in the colder high mountains at Soda Springs. At Fallon, Nevada, because of low rainfall, actual evapotranspiration is about 5″.

The growth of frost tolerant range grass follows the calculated actual evapotranspiration very closely. Perennial grasses grow well along the coast near Half Moon Bay and in the Sierra Nevada foothills at Grass Valley, but only annual grasses which can utilize the winter moisture do well at Sacramento. At Fallon, Nevada, the native cover is mainly widely spaced desert shrubs with a little grass in wet years only.

Thus for unirrigated natural vegetation, the calculated annual actual evapotranspiration is a measure of the expected growth of frost tolerant plants. For dry-farm crops, the soil is usually cultivated between harvest and planting time, so little or no water is transpired and more can be stored in the soil for the growing season. However, the water balance for all the stations calculated—except Fallon—indicates that there is sufficient rainfall to fill 6″ or more of soil water storage capacity. For crops such as dry-farmed barley, the value of summer fallowing is not the conservation of moisture for the spring growth but rather, the beneficial effects summer fallow has on plant nutrients in the soil.

Distribution of Annual and Seasonal Values of Evapotranspiration on Statewide Traverse.

Station	Calculated potential evapotranspiration			Caclulated actual evapotranspiration*		
	Annual	Frost free season: above 32°F	Frost free season: above 28°F	Annual	Frost free season: above 32°F	Frost free season: above 28°F
	inches	inches	inches	inches	inches	inches
Half Moon Bay	25.80	24.68	25.80	15.57	14.45	15.57
Santa Clara Univ.	29.64	26.05	28.51	12.17	8.64	11.04
Sacramento	31.87	31.10	31.63	11.69	10.92	11.45
Auburn	32.65	30.72	32.15	13.35	5.93	9.02
Grass Valley	31.13	28.07	29.95	15.64	12.58	14.46
Soda Springs	18.19	8.53	12.03	10.97	4.07	5.52
Fallon, Nevada	25.75	13.82	17.06	5.34	0.64	1.05

* For soils of 4″ available water holding capacity.

The total potential evapotranspiration along the traverse is high in the Sacramento Valley—more than 30″—and the large deficit of more than 20″ indicates the tremendous value of irrigation in that area. The total potential at Half Moon Bay—25.8″—is somewhat less than at Sacramento and more uniformly distributed through the year because of warmer winter temperatures. However, the summer moisture deficit is much less—10.28″—indicating that less irrigation is needed for maximum production. Artichokes will grow in the Half Moon Bay area without irrigation, but some irrigation is needed for good commercial production.

Auburn and Grass Valley also have high total potential evapotranspiration—more than 30″—but the summer deficit is less than at Sacramento because of higher rainfall. However, at Auburn and Grass Valley a great deal of water is lost through surface runoff or deep percolation, and water available for plant growth increases only slightly, and not in proportion to the rainfall. The water lost from runoff is even greater at Soda Springs, where the calculated actual evapotranspiration amounts to approximately one fifth of the average annual rainfall of 52″.

At Fallon the annual potential evapotranspiration is about the same as at Half Moon Bay—25.75″—but the water deficit is much greater—21.51″—and equal to the deficit of Sacramento. In arid regions, there is little moisture available for soil storage so it is of little importance to plants whether the soil water holding capacity is 2″ or 10″.

Water balance calculations are being prepared for every weather station in the state recording both temperature and rainfall. Maps being prepared show the distribution of the annual and seasonal values of potential and actual evapotranspiration. The water balance approach to climatic analysis has many uses in irrigated and in nonirrigated agriculture: for land classification, crop selection, land management and for planning the most profitable distribution of water for irrigation.

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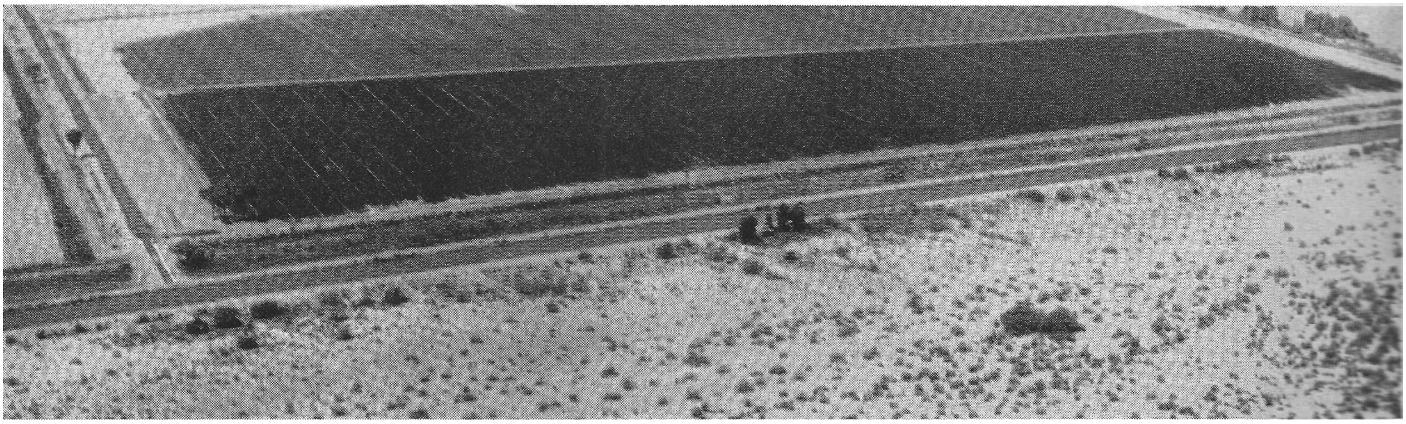

Water needs of desert land balanced in irrigated crop shown in the background. Unbalanced water needs illustrated by desert vegetation in foreground.