or less green grass can be found deep in the heart of each bunch. At all events cattle manage to keep in good condition during the dry season.

What would be the result if summer showers came with such frequency that turf grass survived. The answer is not positive, but it is probable. Turf grass and bunch grass cannot live in the same locality. The great root development of turf grass crowds out the bunch grass and exterminates it. Turf grass is highly nutritious as fodder; but after it turns brown, a single shower leaches the nutrition out of it. Cattle starve unless otherwise fed.

Now here is a delicate balance of rainfall which permits bunch grass and cattle to survive; at the same time it prevents the survival of turf grass. One cannot say positively that the grazing industry would be eliminated if the rainfall should increase to an amount that permitted turf grass to survive. Certain it is however, that the grazing industry would be powerfully affected.—*Jacques W. Redway.*

## THE CLIMATE OF SAN FRANCISCO: AN OUTSTANDING ANOMALY.

There are two strikingly anomalous features in the climate of San Francisco which deserve some attention. One is the extraordinarily cold summer both for the latitude, and in comparison with the terrific summer heat in the interior of California. The other is the occurrence of the highest mean monthly temperatures as late as September and October, although the significance of this is much reduced by the very small annual range of temperature at San Francisco, and the small change from month to month. Now the unduly small annual range of temperature on the Pacific coast of the United States is the result of prevailing on-shore winds, and very remarkable is the contrast in this respect with the Atlantic coast of the States, where the westerly air movement carries a continental range of temperature right to the shore, and some way out to sea. But to get at the root of the two above mentioned anomalies in the local condiions of the city of San Francisco it is necessary to go into closer detail. The summer at San Francisco is cool, partly because of the peculiar insularity of its site (which reference to a map will indicate) and partly, because throughout the warmer months cold west or north-west winds prevail, which roll in frequent fogs from the sea. In other words the sun does not get a chance of heating up he coastal belt to a temperature level suitable to so low a latitude, and the mean temperature of the air in July at San Francisco is only 58° F., or some 5°, less than that of London. It is only occasionally when the sea-wind fails that the temperature rises to a high level at San Francisco with maxima near 100° F. and the city gets a reminder of the proximity of the hot interior valley of California. In the western States the summer thermal gradient is very steep inland from the Pacific, and the July isotherms of 60°, 70°, 80° and even 90° run very close together. The seasonal anomaly, shown in the accompanying table, of the highest mean temperature occurring in September with October second, instead of in July with August second, is at first sight perplexing. In a maritime region it is, of course, usual to find a two-monthly lag in the seasonable extremes of temperature behind the solstice instead of only a one-monthly lag as in a continental region, and in any case one would expect August to be the warmest month at San Francisco. But why September, and then October? The explanation seems to be this: in July and August the Californian coast is kept unduly cool by the strength and persistence of the cold sea winds which are undoubtedly largely governed by the general summer pressure régime char-

acterized by a High over the Pacific Ocean and a Low over the North American Continent; but in September and October the rapid cooling of the land mass permits the summer pressure régime to relax with some decrease in the strength and persistency of the Californian sea-wind, so that the autumn sunshine has a better chance to warm up the coastal belt. Thus the local autumnal warming of the San Francisco coast might be regarded as an indirect result of the general cooling of the interior valleys of California. Little paradoxes of this kind are commonly met with in climatological analysis. This explanation seems to be supported by the fact that the mean total wind movement is less in both September and October than in any month after March, the highest value being for July, according to data at hand for San Francisco. The summer in-draught of air along the Californian coast is no doubt a sort of magnified sea-breeze intensified by the high pressure over the Pacific, and by the effect of the Coast Range of mountains. In winter the local winds at San Francisco are more variable, and the frequent SW. winds, which bring rain from the ocean, are associated with North Pacific cyclonic systems.

The following table of mean temperature and rainfall affords a very instructive comparison between San Francisco on the Pacific coast and Washington on the Atlantic coast, on approximately the same latitude, about 38° N. The dates are based on the period,* 1871–1918, and are taken from pamphlet publications courteously sent to me by the U. S. Weather Bureau.

| | San Francisco. | | Washington. | |
|---|---|---|---|---|
| | Average Temp. °F. | Average Rainfall inches | Average Temp. °F. | Average Rainfall inches |
| Jan. | 50.0 | 5.13 | 33.7 | 3.38 |
| Feb. | 52.3 | 3.56 | 34.7 | 3.26 |
| Mar. | 53.7 | 3.27 | 42.5 | 3.84 |
| Apr. | 55.2 | 1.58 | 53.4 | 3.23 |
| May | 56.6 | 0.78 | 64.3 | 3.59 |
| June | 58.3 | 0.15 | 72.4 | 4.23 |
| July | 58.4 | 0.02 | 76.8 | 4.57 |
| Aug. | 59.0 | 0.02 | 74.7 | 4.26 |
| Sept. | 60.8 | 0.31 | 68.0 | 3.36 |
| Oct. | 60.1 | 0.96 | 56.7 | 2.98 |
| Nov. | 56.3 | 2.53 | 45.1 | 2.47 |
| Dec. | 51.2 | 5.30 | 36.1 | 3.26 |
| Year | 56.1 | 22.70 | 54.9 | 42.43 |

It will be seen that the summer heat of Washington is very much like that of southern Europe, but that San Francisco shows the typically Mediterranean feature of a rainless summer and wet winter. The rather heavier summer than winter rainfall at Washington, and the seasonal direction of the winds (not indicated in the above table) show that the Atlantic sea-board of the United States has something of a "Monsoon" climate though not in so marked a degree as the east coast of Asia. For instance, the mean direction of the surface wind at Washington for seven months in the year is NW. or from land to sea, whereas during the 5 hot months May to September it is from S. The interpretation is no doubt this: that during the cold months the monsoonal influence reinforces the general westerly drift of the atmosphere in Temperate latitudes, and during the hot months it acts in opposition. A sectional analysis of surface winds would probably show that during the summer months due S. winds are not

* San Francisco rainfall from 1849.

necessarily more frequent than those from other directions, but that easterly directions from the sea representing the monsoonal effect are about as common as westerly directions due to the general circulation. For seven months, that is on the balance of the year, the general westerly movement asserts itself.

San Francisco has on the whole a rather tame climate, storms being infrequent. Snowfall is rare, and thunderstorms are both rare and feeble, occurring generally during the wet winter period. The variability of the liberal winter rainfall, however, is rather great, the January average of 5.13 inches being represented by a maximum of 24.36 inches in 1862, and a minimum of 0.58 inches in 1853.

At Washington heavy snowfalls occur during the winter; and summer thunderstorms are frequent, the average number of days being: April, 2; May, 5; June, 6; July, 7; Aug., 5; Sept., 2, the months May to August standing out as in most places with great prominence.—*L. C. W. Bonacina.*

London, England.

## AIMS.

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