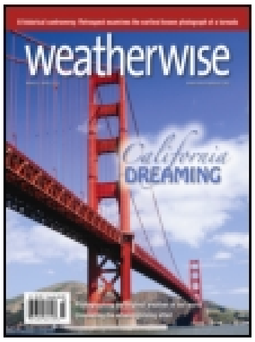

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Keeping Track of Crop Moisture Conditions, Nationwide: The New Crop Moisture Index

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Fig. 1. Yield prospects in a corn field a few miles northeast of Gettysburg appeared to be zero on 23 July 1966. The CMI for the area was −4.9, just one week after the last point shown in Fig. 2.

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HOW extensive is the drought in the winter wheat areas? How serious is it? What portion of the cotton belt is being affected by surplus moisture? Questions like these are frequently asked by government agencies and other groups with wide regional or national interests in consistent week-to-week appraisals of crop moisture conditions. One would think such questions would be fairly easy to answer, but they are not. The drought questions have been particularly difficult.

When viewed in any detail, the agricultural drought problem appears hopelessly complicated. Local differences in soils, types of crops, rooting depths, stages of crop development, and precipitation amounts seem to preclude any meteorological approach to the development of useful information. Actually, if one's interests require a knowledge of detailed local variations in crop responses, available meteorological information is completely inadequate, to say nothing of the lack of the other types of necessary information. However, if one looks at the problem from a different viewpoint, it does not appear nearly so hopeless.

If one's interests require answers to broad questions such as: What is the crop moisture situation in the soybean producing regions? The meteorological approach can provide useful information. In such cases there is no interest in or need for details as to the situation in individual fields. The Crop Moisture Index was designed to provide information in response to the broad-scale general questions rather than the localized questions. It is based on the available meteorological information: namely, reports of mean temperature and total precipitation for each week.

The Drought Problem

In its simplest terms agricultural drought is a transpiration deficit. However, if one uses computed potential evapotranspiration [1] as an estimate of maximum moisture need by crops, the subhumid and semiarid regions turn out to have evapotranspiration deficits much of the time during summer. Maps drawn on the basis of such computations reflect climate as much or more than they show weather. Maps become more meaningful if one bases them on the *abnormal* evapotranspiration deficit.

The computer printouts for the Palmer Drought Index [2] provide a measure of the weekly abnormal evapotranspiration deficit for each climatological division. (Most states are divided into a number of divisions—usually five to ten—which are more or less homogeneous, climatologically.) This abnormal evapotranspiration deficit is a computed value, an estimate of the amount by which the actual weekly evapotranspiration falls short of the "expected" weekly evapotranspiration. The actual evapotranspiration takes account of the actual temperature and precipitation during the week as well as the computed amount of soil moisture, both topsoil and subsoil, existing at the start of the week. The "expected" evapotranspiration is an adjusted normal value; i.e., the long-term mean value is adjusted upward or downward depending on the departure of the week's temperature from normal. Successive weekly values of this computed abnormal evapotranspiration deficit have been combined into an index (usually negative) of the evapotranspiration anomaly which is a measure of the cumulative severity of agricultural drought. In other words, as the accumulated evapotranspiration deficit gradually increases from week to week during dry weather, the crop moisture situation becomes progressively more serious. Figure 2 illustrates the gradual increase in negative index values during several consecutive weeks of abnormally dry weather in various climatic zones. All three cases resulted in crop failures. Figure 1 shows the sorry state of a cornfield northeast of Gettysburg, Pennsyl-

SELECTED DRY SPELLS WHICH CAUSED CROP FAILURE

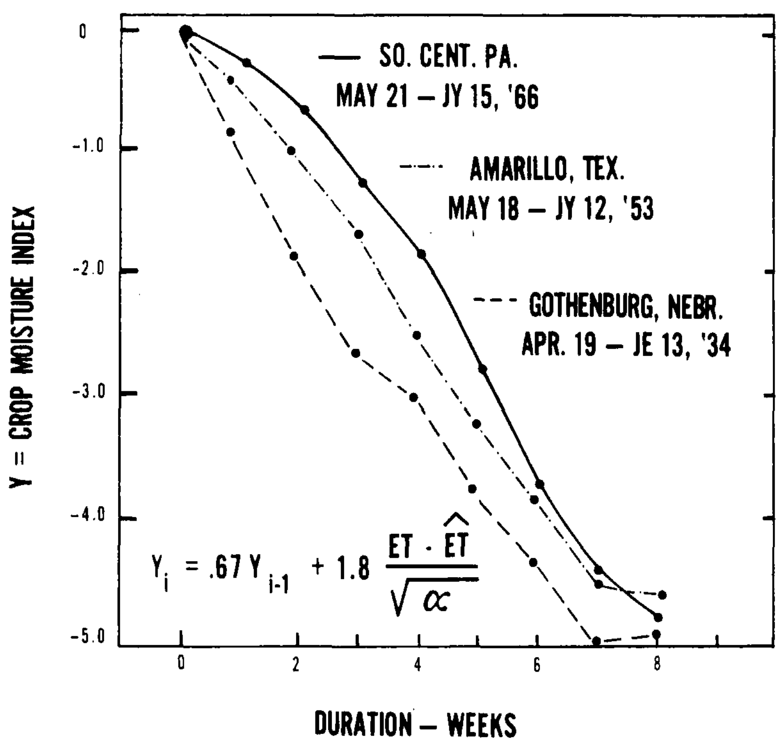


Fig. 2. A number of instances of extremely dry weather which caused crop failures in various climatic regions were used to develop empirical equations for computing a crop moisture index. This figure shows the equation for the relative evapotranspiration anomaly index and the results of applying it to the data from three different regions. Note particularly that the Index comes out about the same in all three cases.

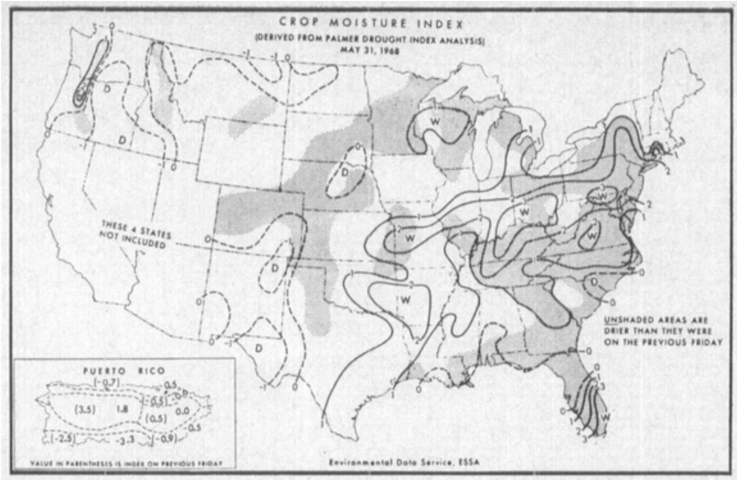
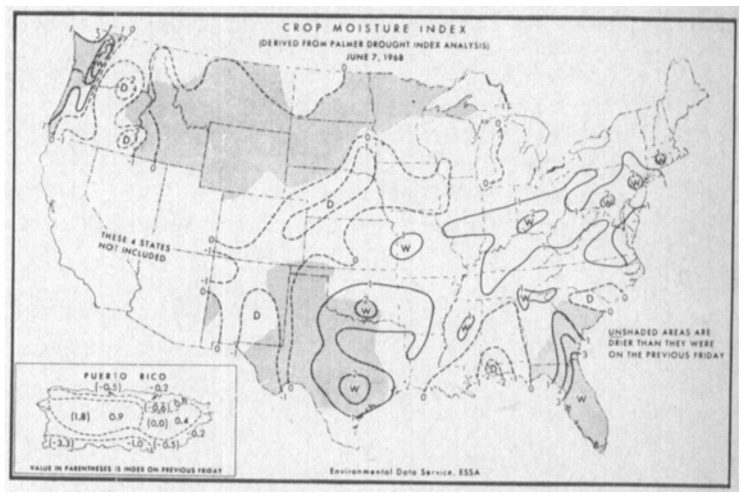
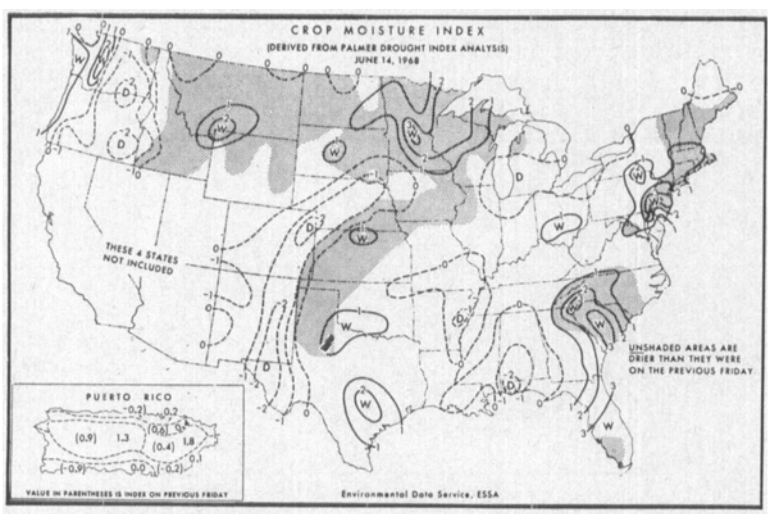
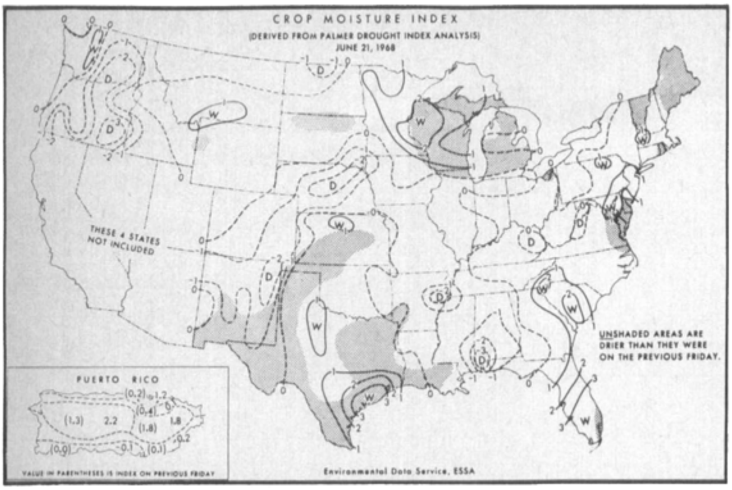
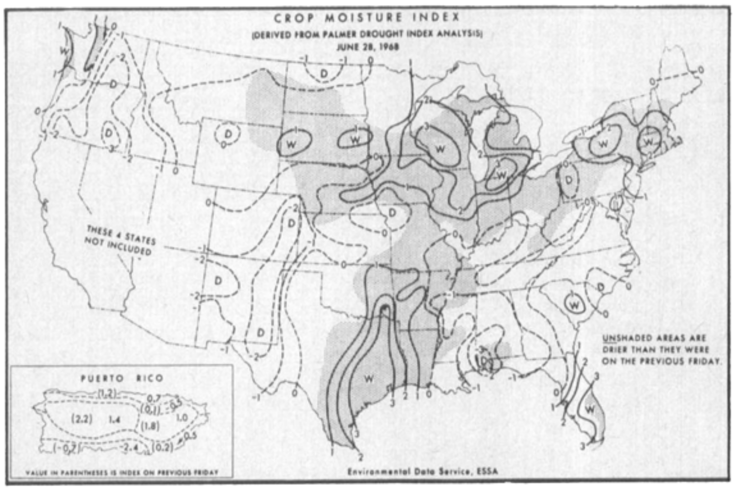


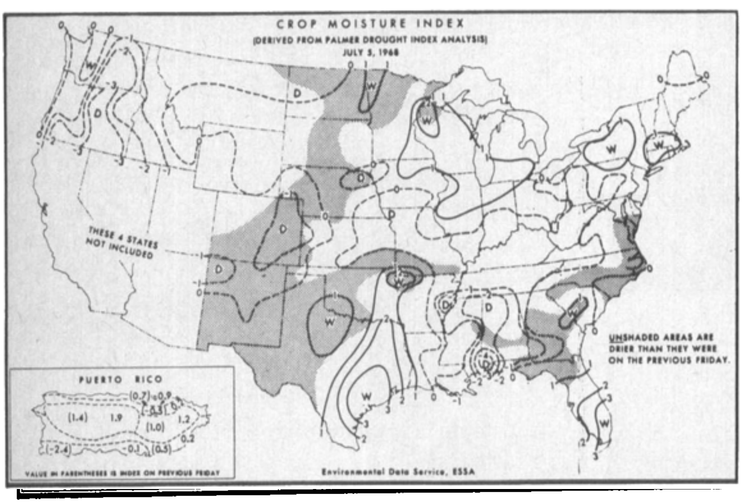
Fig. 3. Maps show week-to-week developments in the crop moisture situation from 31 May through 5 July 1968. The shading shows where enough rain fell during the week to *increase* the CMI. Dashed lines show Index value in dry areas, and solid lines indicate wet areas. Such maps are published each week from April through October in the *Weekly Weather and Crop Bulletin,* a joint publication of the U. S. Dept. of Agriculture and Dept. of Commerce.






CROP MOISTURE INDEX
(DERIVED FROM PALMER DROUGHT INDEX ANALYSIS)
JUNE 21, 1968
THESE 4 STATES NOT INCLUDED
UNSHADED AREAS ARE DRIER THAN THEY WERE ON THE PREVIOUS FRIDAY.
PUERTO RICO
VALUE IN PARENTHESES IS INDEX ON PREVIOUS FRIDAY
Environmental Data Service, ESSA


CROP MOISTURE INDEX
(DERIVED FROM PALMER DROUGHT INDEX ANALYSIS)
JUNE 28, 1968
THESE 4 STATES NOT INCLUDED
UNSHADED AREAS ARE DRIER THAN THEY WERE ON THE PREVIOUS FRIDAY.
PUERTO RICO
VALUE IN PARENTHESES IS INDEX ON PREVIOUS FRIDAY
Environmental Data Service, ESSA


CROP MOISTURE INDEX
(DERIVED FROM PALMER DROUGHT INDEX ANALYSIS)
JULY 5, 1968
THESE 4 STATES NOT INCLUDED
UNSHADED AREAS ARE DRIER THAN THEY WERE ON THE PREVIOUS FRIDAY.
PUERTO RICO
VALUE IN PARENTHESES IS INDEX ON PREVIOUS FRIDAY
Environmental Data Service, ESSA

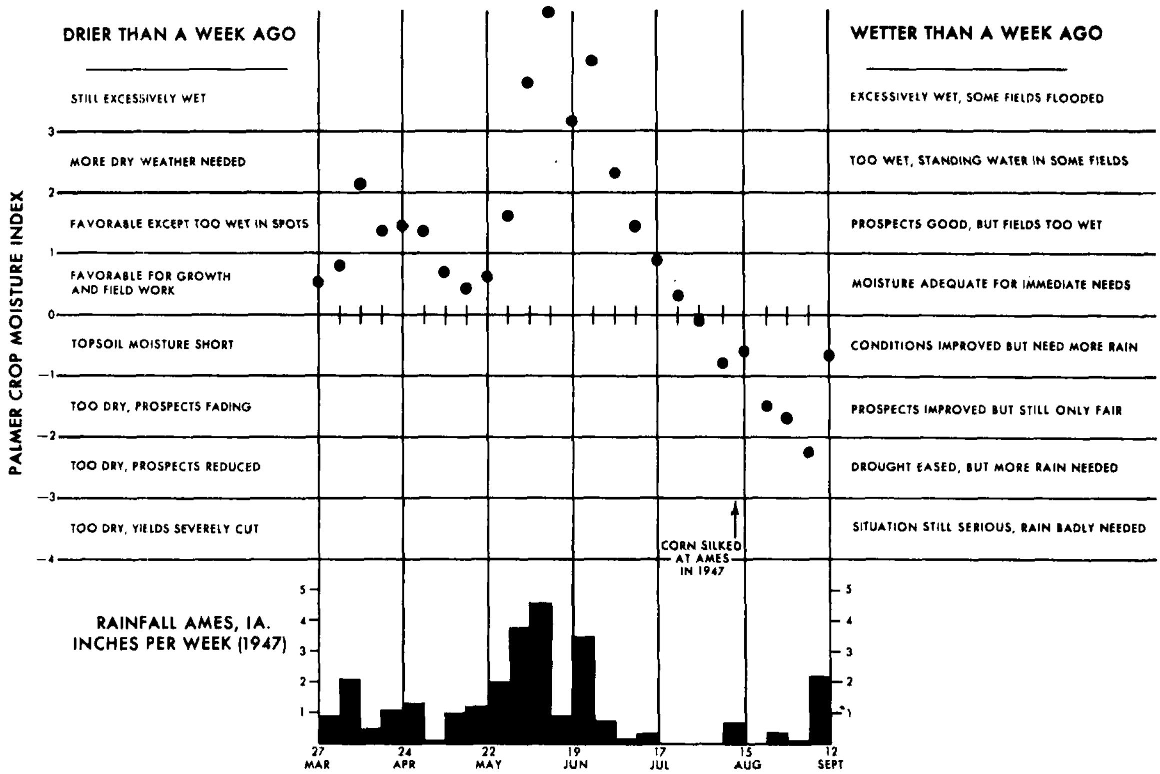


Fig. 4. Rainfall at Ames, Iowa, during the very unsatisfactory growing season of 1947 was twice normal for the first three months and a third of normal during July and August. Use the legend on the left for weeks that decreased the Index: the points at 3 July and 5 Sept. Use the legend at the right for weeks that increased the Index, as on 5 June and 15 Aug. Note that the Index does not indicate drought at Ames until early in August, about a month after the heavy rains ended. Central Iowa corn yields were reduced about 50 per cent in 1947.

vania, at the time the Crop Moisture Index curve for that area (see fig. 2) reached −4.9.

Basically, the computed severity of agricultural drought at the end of any week depends on the severity at the start of the week and the evapotranspiration deficit or soil moisture recharge during the week. Thus, the duration of dry spells, as well as the showers which interrupt them, are both taken into account.

Wet Weather

Of course, the weather is sometimes too wet for crops just as it is sometimes too dry. Too wet often means soils are too wet to permit timely field operations or rains have been so heavy that fields are actually flooded. In the weekly printouts of the Palmer Drought Index analysis, heavy rains in excess of the maximum weekly water use by the crops produce positive values of R (soil moisture recharge) until the soils reach field capacity, then any excess water shows up in the RO (runoff) term. These two measures of "excess" moisture have been combined into a wetness index which is always positive or zero.

The Final Index

The final Crop Moisture Index (CMI) is the algebraic sum of the two numbers described above; namely, the evapotranspiration anomaly index and the wetness index. The CMI stands at or near zero at the start of the growing season, remains near zero so long as the crop moisture supply—and the weather—are near normal, and returns to near zero at the end of the growing season. Figure 4 illustrates the sort of changes that can occur in the CMI during a particularly unusual growing season.

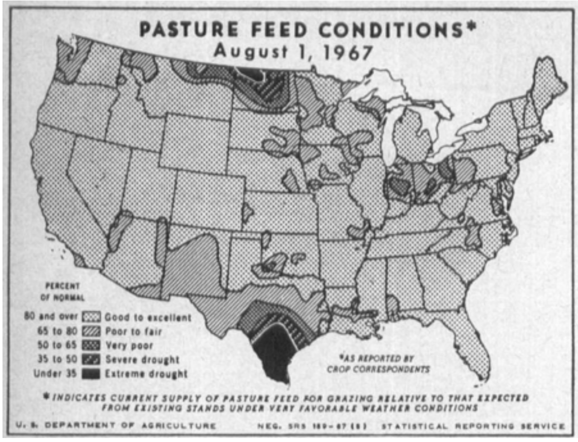


Fig. 5. U. S. Dept. of Agriculture map represents the concensus of reports of pasture conditions from thousands of crop correspondents all over the Nation. At this time of year sub-normal pasture feed supplies reflect shortages. Compare with Fig. 6.

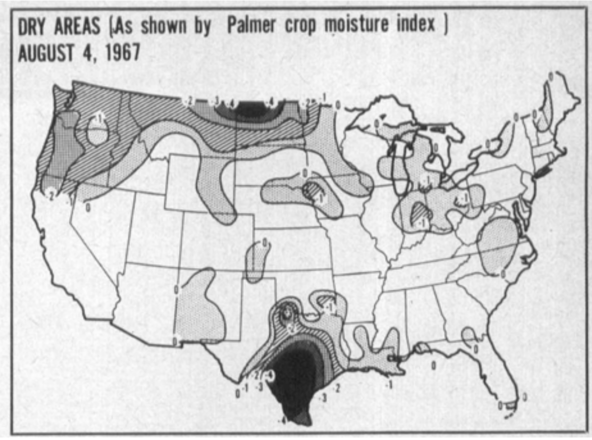


Fig. 6. The map is a companion to Fig. 5. It was independently computed from temperature and rainfall reports. For clarity only the negatives values of CMI are shown. The similarities with Fig. 5 are more striking than the differences.

Interpreting the Results

Negative values of CMI always mean that evapotranspiration has been abnormally deficient. However, positive CMI values mean that either actual evapotranspiration exceeded the expected amount, or recent rainfall exceeded the moisture requirements of crops and the additional moisture was added to the soil or was regarded as runoff.

Weekly maps, such as those in figure 3, are based on areal mean values of both temperature and precipitation from about 10 individual observations from each of 325 climatological divisions. A computed index value is therefore applicable to mean conditions over an area (about 8000 sq. mi., on the average) rather than to conditions at a point. In total, of course, each map is based on observations of temperature and rainfall from some 3000 points over the country.

The legend for the map is in two parts because an index value that occurs as an area becomes drier can also occur as the area becomes progressively wetter after having been very dry. The interpretation is different in the two cases. The map is shaded where conditions have changed little or become wetter during the past week; i.e., the index has *not* decreased during the week. Thus, the map shows both the trend and the status of the moisture situation. The legends are to be applied primarily to growing rather than matured vegetation. Interpretation of the effects on crops and native vegetation must, therefore, take account of the stage of growth as well as the status and trend of moisture conditions.

These CMI maps present a generalized picture; local variations caused by the occurrence or absence of heavy rain or by soil differences are not shown. Shallow rooted crops and crops in areas with poor soils are likely, on occasion, to suffer more than indicated. Conditions may be better than shown in areas having exceptionally good soils. Centers of relative maximum and minimum index values are marked for easier recognition—W for wet and D for dry. In irrigated regions the index values merely reflect departures from ordinary irrigation requirements.

References

1. Palmer, W. C., and A. V. Havens, 1958: A graphical technique for determining evapotranspiration by the Thornthwaite method. *Monthly Weather Review,* **86,** 123–128.
2. Palmer, W. C., 1965: Meteorological drought. *Weather Bureau Research Paper No. 45,* 58 p.