EFFECTIVENESS OF DROUGHT PREDICTIONS

by Lewis Moore *

Drought is really a diabolical subject; its like some of life's other unpleasant things; we generally don't anticipate it until we've got it and then its a little too late to do much about it. Drought is hard to define (until it gets out of hand) and when it does get established, there's no telling when it will break. This is the bad news, but the rest is even worse; there's no predicting drought -- a least nothing you'd want to bet the farm on.

From the Record,the first person to successfully make and verify a long-range drought/famine forecast was Joseph back in about 1880 B.C. You'll recall at that time Joseph was the Pharaoh's prisoner, doing time for some trumped up charges by Potiphar's wife. When referred by some of his jailhouse contacts, Joseph was summoned to interpret the Pharaoh's dreams of fat and thin cattle and heads of grain. Joseph then relayed God's second long-range weather forecast -- for the next 14 years -- which verified in spades and Joseph's government career was made. (Genesis 41:25-30)

There were other long-range forecasts recorded in the Bible, the most famous of which was the widespread flood advisory given to Noah earlier in Genesis. Later, about 1000 years after Joseph's Egyptian famine forecast, Elijah relayed God's first conditional drought forecast, for "two or three years (which ever I choose)" to Ahab and Jezebel. (1 Kings 17:1)

The forecasts mentioned above were precisely accurate according to the biblical account, but since that time and many more forecasts handed down by a variety of seers, the verification rate has really deteriorated. In fact, drought predictions are now so bad that it is questionable whether any of them should be taken seriously. But that doesn't mean people haven't continued to believe that we can foretell drought and harbor the notion that somewhere out there -- there's a voice crying in the wilderness with a silver bullet for forecasting drought. [1]

I think there are two reasons we keep trying to foretell drought: for survival and science. Drought continues to top the hierarchy of natural disasters which modern science and technology has not been able to neutralize. Drought puts a lot on the line: money, security, power and the ability to hold nations and civilizations together; this is even more true as populations swell and we depend evermore on technological fixes to remedy global overload.

The second reason we hang onto the hope of drought prediction is a little more intellectual because there must be a reason when

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the rain stops. Consequently we're constantly hearing about drought cycles, obscure associations, and celestial determinants which supposedly control weather (or foretell drought).

Why do we try to attribute drought to something other than a completely random event - an "Act of God" in legal parlance? A lot of us would like to see the same periodicity in the weather that is present in the orbits of the planets and the changing of the seasons and in our quest, we tend to draw out pseudo correlations between weather and heavenly bodies. For instance, when I was (a lot) younger and out on the farm, I learned from my father that a "wet" crescent moon was one that "the hunter could hang his powder horn on" (because the "hunter" (Orion? -- Daniel Boone?) obviously didn't want to hunt in the rain -- I guess).

Sure enough, I could easily see this correlation in the "cupped" new moon and precipitation, or so it seemed until I got old enough to read that this orientation of the new moon was actually "dry" because its bowl-like tilt would actually catch the rain which might otherwise fall. I mention this because in meteorology, just like in economics and psychology, it is easy to construe data as supporting any particular predictive notion so long as it isn't subjected to both rigorous definition and statistical analysis.[2]

<u>Why We Haven't Progressed in Drought Prediction</u>

We haven't been making drought forecasts like the ones handed down by Joseph and Elijah because (1) obviously God hasn't taken a direct role in the prediction business and (2) specific weather predictions by mortals are limited by the chaotic motion of the atmosphere which cannot be predicted for much more than a week. Lorenz discovered this over 30 years ago [3] when he let a simple computer model of the atmosphere run into extra innings. He found that only infinitesimal rounding errors in the input data caused wide divergences in the longer-range model predictions.

Lorenz realized the profound significance of these divergent forecasts; because it was always impossible to specify exact initial conditions for input into atmospheric models, output from those models would not be accurate for more than a few day's time. Extending the length of the prediction would only magnify the magnitude of the error. Consequently, atmospheric models now produce good short-term predictions, but they are fed new data every few hours and run again to keep in contact with reality. The National Weather Service does issue monthly and seasonal outlooks for temperature and precipitation, but these are trend forecasts and aren't intended to give the specificity which is the goal of the operational atmospheric forecast models.

The basis of this unpredictability in the atmosphere is the sporadic occurrence of turbulence or chaotic flow which is random and unpredictable.[4] These "turbulent bursts" which are present in all scales of atmospheric motion from the curling smoke of a cigarette to the buckling of the jet stream create the unpredictable events which in turn make long-term weather an enigma.

Jet streams, the globe-girdling high level winds, control (or at least define) patterns of moisture and drought. When their meanders change, which can happen suddenly, so do the patterns of precipitation and drought on the Earth's surface. Just like river systems, the meanders of the jet stream can seemingly become entrenched, producing long periods of stable weather patterns. But suddenly, these flow patterns can break down in a turbulent burst and reform in a completely new pattern which may be accompanied by a totally different surface weather regime.

It would be wonderful if we could predict these spasms in the jet stream, but right now we can't. The best we can do is to hedge our bets on climatology and trends, while making maximum use of short-range weather predictions which are useful for periods of up to a week.[5] And, we need to continue the search for useful correlations or "teleconnections" which may someday make long-term drought probabilities less murky.

It's tempting to believe that weather fluctuations or periodic shifts in meteorological patterns can be correlated to other more ordered events and lots of effort has gone into this search. While most of these supposed "relationships" break down with larger samples of data and more statistical scrutiny, a few do not. One phenomenon currently exciting climatologists is the surprising association between high level wind shifts (Quasi-Biennial Oscillation -- QBO) over the equatorial regions and surface temperature trends at some stations. While this correlation appears to be highly significant, it appears to be predictive of temperature rather than precipitation.[6]

A generation ago much meteorologic research focused on the possibility of "weather typing" or attempting to forecast weather by "reading the plays" or identifying analogous weather conditions in the past and extrapolating or forecasting future weather events based on these past weather records. Generally this technique fails for the same reason atmospheric modelling fails -- it is impossible to duplicate the exact present initial conditions in any past weather sequence. Just like snowflakes -- there are no two weather situations that are exactly alike.[7]

<u>What Has Been Done in Operational Long-Term Forecasting</u>

With the chaotic behavior of atmospheric motion and the inability to specify how the aggregate perturbances will form storms in one track and suppress precipitation in another zone, it seems a little remarkable that anyone would venture a long-range prediction. However, the National Weather Service's Climate Analysis Center has been doing this since the 1950s. Although the forecasts are general monthly and seasonal outlooks (above, normal or below average) and the accuracy is generally less than 10 percent over what could be expected using pure climatology and statistical analysis, there is some "skill" in the forecasts and that means potential value depending on how these outlooks are applied to business decisions.

NOAA's monthly and seasonal outlooks vary greatly in their skill as outlined below:

- Temperature advisories are about twice as accurate as those for precipitation;
- The skill scores for individual stations are highly dependent on location and season; and
- Winter forecasts are generally best.

While most of the temperature and almost of the precipitation advisories are less than amazing, there is a high degree of accuracy for temperature forecasts above and below normal in the Southeastern United States. NOAA categorizes its longer-term forecasts on two (above or below) or three (above, normal or below) classes as is the case in Table 1. These forecasts are graded by skill scores which can range from 100 percent for total accuracy down to negative percentages depending on the magnitude of the "busted" forecast. As indicated above, the ability to foretell future precipitation is hardly worth mentioning and may be even worse than useless overall for monthly spring precipitation forecasts.

Table 1: Climate Analysis Center Forecast Skill Scores

$$\text{skill} = \frac{(\#\text{ forecasts correct} - \#\text{ expected correct})}{(\text{total }\#\text{ forecasts} - \text{expected }\#\text{ correct})} \times 100$$

Monthly Forecasts	Summer	Fall	Winter	Spring
Temperature	10.3	10.9	18.3	9.0
Precipitation	4.1	1.6	10.7	-2.3
Seasonal Forecasts (3 months)				
Temperature	7.8	7.6	14.7	3.2
Precipitation	4.4	2.5	6.6	3.2

Source: E. Kalnay and R. Livezey, "Weather Predictability Beyond a Week: An Introductory Review", in Turbulence and Predictability in Geophysics, 1985. p.340

The procedure for these forecasts is to generate the forecast of the 700 millibar pressure level which is the height of an imaginary surface of constant pressure above approximately 30 percent of the Earth's atmosphere. Next, the Climate Analysis Center specifies temperature and precipitation anomalies associated with the pressure surface contours. Finally, the forecasters assign probabilities to the expected variations in temperature and precipitation based on predictability, skill, agreement and the perceived strength of the above predictors.[8] Obviously this is a mixture of science and judgement.

As weak as the long-term NOAA forecasts are, judgement still figures heavily in the forecasts as is also probably the case with the Farmer's Almanac. Assuming the Almanac is not based on "scientific" forecasting, it still manages to show a slight degree of skill on the order of one to three percent when graded by NOAA's skill test. This is such a low level of skill it may not be statistically significant, but as Robert Livezey of the Climate Analysis Center has pointed out, this level of "skill" can be achieved by compensating for the non-normal distribution of weather data, trends in the data, and the length and size of the data record.[9] In other words, a statistician could probably have done as well as the Almanac without the benefit of meteorology.

Table 2: Farmer's Almanac Skill Scores

	Monthly (960 forecasts)	Seasonal (320 forecasts)
Temperature	50.7% (1.4 skill score)	53.2% (6.4 skill score)
Precipitation	51.9% (3.8 skill score)	51.5% (3.0 skill score)

After J.E. Walsh and D. Allen, "Testing the Farmer's Almanac", Weatherwise, 34: 212-215, 1981.

No Free Lunch in the Future

Beyond the statistical analysis of weather and the rather crude dynamical models used in actual forecasting, there have long been many efforts to find climatic analogs or "teleconnections" to foretell future changes in weather patterns. Probably the most suspect teleconnection has been the solar cycle and the many attempts to correlate sunspots with drought.

One such study involved the Great Plains droughts which were studied by Murray Mitchell of the National Oceanographic and Atmospheric Administration (NOAA) about a decade ago.[10] 'Mitchell approached this task as an agnostic rather than trying to "prove" a particular correlation of the weather with the solar cycle. Somewhat to his surprise, he found that about 10 percent of the variation in rainfall on the Plains could be forecast by some unexplained correlation with the solar cycle or roughly, the number of sunspots. This was certainly a significant finding, but it does not help too much so long as the remaining 90 percent of the variation doesn't appear correlated without any other predictable phenomenon.

After Mitchell's work correlating the solar cycle and tendency toward expanding drought, various claims of lunar influence upon weather events have also been claimed, but not explained, although there is some speculation as to the significance of a superpositioning of the solar and lunar cycles.[11]

Still, weak statistical correlations do not yield the bases for future predictions which people would want to bet money on. It's likely the sun, moon, and maybe the stars do have a an influence on Earth's weather, but determining just how these influences work and how they blend into the other, unknown determinants of future weather are still a mystery.

The correlation of drought and sea surface temperature is another theoretical climatic connection, but data to support the various water-weather connections are very sparse and as yet, insufficient for practical forecasting.[12] The El Nino Southern Oscillation (ENSO), a dramatic shift in the warm and cold ocean currents off the northwest coast of South America, has been a recent subject of intense interest as a potential teleconnection portending climatic shifts in the United States. However, this data base is relatively short and the correlation of Pacific sea surface temperatures with American weather is cloudy at best.

Back to Basics

Beyond determining what causes drought or even what is associated with drought and therefore could be used for prediction, there's the messy problem of just what is a drought. Many times drought is as much qualitative as a quantitative phenomenon. Timing of precipitation is everything for dryland farming and just as it is for water supply and flood control operations.

Likewise the areal extent of precipitation events and total quantity of precipitation falling in a watershed has been a problem because of the sparsity of gaging sites and the degree to which data from these sites can be extrapolated over the watershed. The common practice of averaging precipitation of all stations in an area to get an index of drought severity may blend away the local nature of drought and dilute the significance of other correlations which might be investigated. So along with the problems of predicting a deficit of precipitation, there is the added problem of having to predict the significance of that deficit.

Sidestepping Drought

Rather than trying to predict drought, we may have to be content in trying to sidestep its effects -- at least for the foreseeable future. A lot can be learned from climatology: the means, standard deviations, and extremes of climate. Given a large data base of weather data from a station, we can compute the probabilities of certain weather changes or the likelihood that drought will become a problem. [13]

One proactive approach is Stephen Schneider's "Genesis Strategy" based on Chapter 41 of that book of the Bible and Joseph's guidance for the Pharaoh. [14] This is simply saving up for a not-so-rainy day. It works with grain, money, water, and even political favors, but it carries the burden of huge overhead expenses and attendant bureaucracies; still, it works for nations rich enough to afford the cost of storage.

Another approach is the "Response Farming" strategy as articulated by J.I. Stewart. [15] This is a dynamic practice of varying cropping based on climatology and the present weather. If farmers can change planting and crops quickly in response to available moisture, Response Farming should boost total production, but it must be combined with a Genesis Strategy to be effective in offsetting the effects of prolonged and severe drought.

Conclusions

Long term prediction of drought is not now and may never be a viable technique. Determinants of weather patterns and the duration of those patterns are largely unknown and/or unpredictable. While some weak correlations of drought and other natural phenomena have been discovered, we have virtually no skill in connecting these predictors with the really severe droughts which we would most like to predict. For the foreseeable future, the best defense against drought would appear to be contingency planning and storage of surplus agricultural production.

References

1. See a variety of tongue-in-cheek sources, for instance, Leo Rosten, "The Myths by Which We Live", Address presented at the Opening General Session of the 20th National Conference on Higher Education, March 7, 1965, p.2.

"One of the difficulties of being a writer or a teacher or a physicist is that people project magic onto you, and they think that you know the answer to a problem, and they want the answer, simple, incontrovertible, absolute, permanent and universal. Men can't stand uncertainty. They want certitude because they need reassurance against their own uncertainty, their own anxiety, their own fears of the unknown, and they never come to terms with the horrifying fact that some things may never be known but life can go on with honor and in truth."

2. e.g. see H.C.S. Thom, "A Statistical Method of Evaluating augmentation of Precipitation by Cloud Seeding", Final Report of the Statistical Advisory Panel to the Advisory Committee on Weather Control, Washington: 1957 p. 5-25.

3. E.N Lorenz, "Deterministic Nonperiodic Flow", Journal of Atmospheric Sciences, 20:130-141, 1963, as referenced in A.A. Tsonis and J.B. Elsner, "Chaos, Strange Attractors, and Weather", Bulletin of the American Meteorological Society, Vol. 70: Nr. 1, January 1989, p.17, 19.

4. C.S. Ramage, "Prognosis for Weather Forecasting", Bulletin of the American Meteorological Society, 57:1, January 1976, p.4.

5. Richard A. Kerr, "Telling Weathermen When to Worry", Science, June 9, 1989, p.1137.

6. Anthony G. Barnston and Robert E. Livezey, " A Closer Look at the Effect of the 11-Year Solar Cycle and the QBO on Nothern Hemisphere 700mb Height and Extratropical North American Surface Temperature", paper submitted for publication, May 1989.

7. Robert Pool, "Chaos Theory: How Big an Advance?", Science, Vol. 245:26, July 1989, p. 26.

8. E. Kalnay and R. Livezey, "Weather Predictability beyond a Week", Turbulence and Predictability in Geophysical Fluid Dynamics and Climate Dynamics, Bologna: Soc. Ital. di Fisica, 1985, p.342.

9. Robert E. Livezey, "Caveat Emptor! The Evaluation of Skill in Climate Predictions" in Uwe Radok ed. Toward Understanding Climate Change, Boulder: Westview Press, 1987. p 131-162.

10. Murray Mitchell, interview at the National Center for Atmospheric Research, October 1978.

11. Richard A. Kerr, "The Moon Influences Western U.S. Drought", Science , May 11, 1984. p 587.

12. William K, Stephens, "Scientists Link '88 Drought to Natural Cycle in Tropical Pacific", New York Times, January 3, 1989, p. C1.

13. Nathaniel B. Guttman, "Statistical Descriptors of Climate", Bull.of the Am. Meteorological Soc., 70; Nr. 6, June 1989, p. 602.

14. Stephen Schneider with Lynne E. Mesirow, The Genesis Strategy, New York: Plenum, 1976.

15. J.Ian Stewart, "Response Farming in Rainfed Agriculture", Davis, California: The WHARF Foundation Press, 1988.