Monitoring Drought in Chihuahua

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Photos courtesy of Chihuahua's Ecology Institute Drought Research Center

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The Drought in Chihuahua

Drought is recurring and irregular and is part of the variation of all climates on the planet, from the arid to the tropical. It is caused by a persistent anomaly in the hydrological cycle manifested in a severe deficit of rain for a sufficiently long period. It has negative repercussions in society, on the environment and on economic activity. Generally, a drought is defined in relation to the decrease in the amount of rain compared to long-term average historical precipitation. This natural disaster is slow; it does not have an epicenter or a defined trajectory and tends to extend in an irregular fashion through time and space. Its severity depends on the level of lack of humidity, its persistence and the size of the affected area. It is also important to differentiate drought from aridity: the former is a temporary, negative deviation from the norm, while the latter is a permanent characteristic of certain climates like the one that exists in most of the state of Chihuahua. When both events are present simultaneously, the problem, naturally, is greater.

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The state of Chihuahua is currently still suffering from the effects of a severe drought that took place in the last decade. This can be seen, for example, in the levels of water stored in the state's main reservoirs: in 1992, the average level of the reservoirs was 100 percent of capacity; one year later it dropped by 35 percent; and in 1995, they were down to only 19 percent of capacity (see graph 1). Today, the reservoir at the La Boquilla Dam, Chihuahua's largest, is at 25 percent of capacity. The drought has caused a lack of water for 75 percent of Chihuahua's irrigated land. In general, the length of the drought has critically damaged production in agriculture, animal husbandry and forestry, as well as water supplies for human consumption.

In the state's arid and semi-arid areas, as well as in other areas, maintaining life and economic activity depends on the surface water flows and the flow through aquifers.[1] The water supply in these regions is limited in quantity and duration and may not coincide with demand.

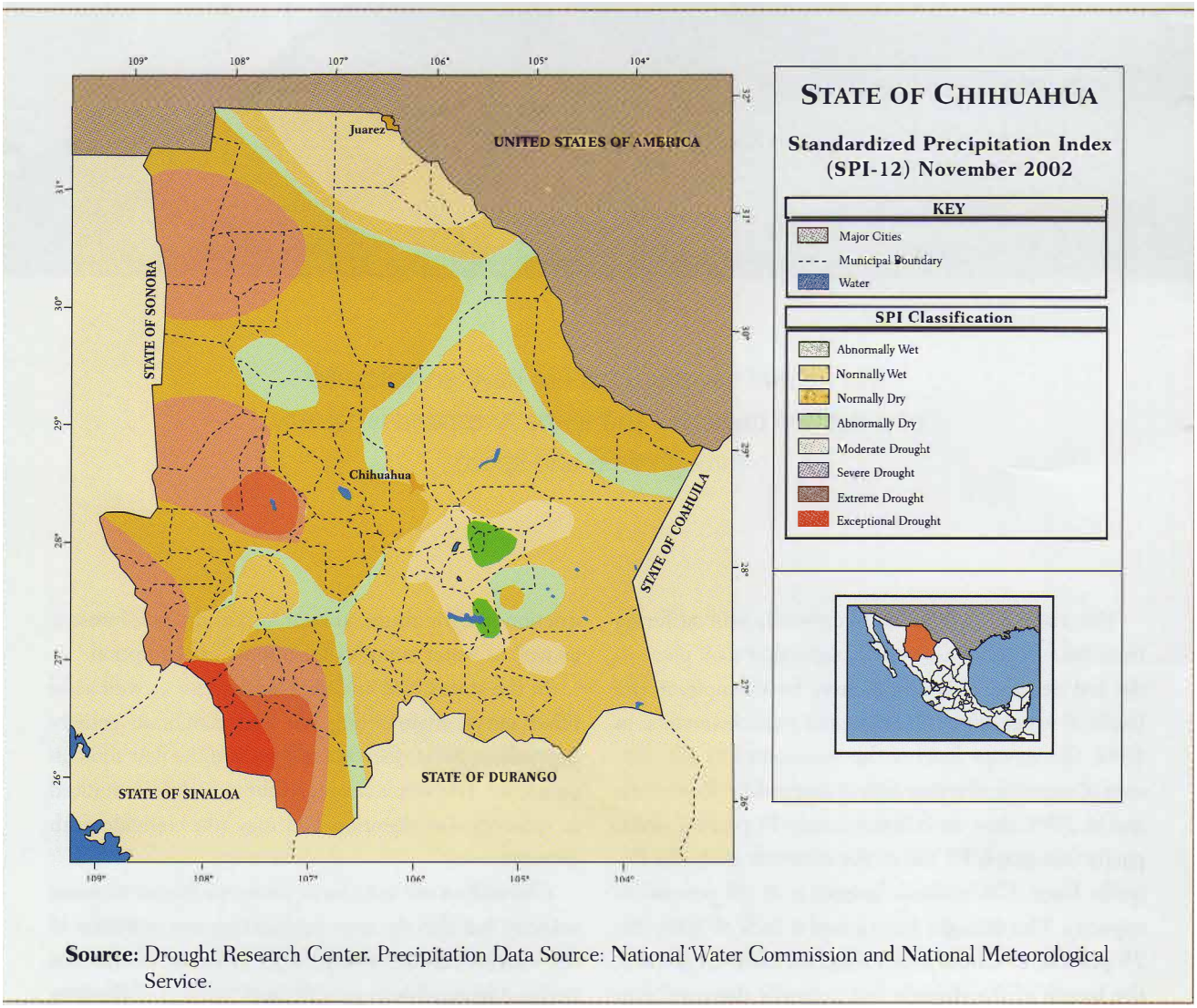
Chihuahua not only faces severe problems of water scarcity, but also the over-exploitation and pollution of the water it has and a serious lag in infrastructure that makes it impossible to provide basic services of drinking

water and sewage to its entire population and to increase supply to agricultural areas with potential.

This is why studying how the drought functions is important for developing strategies for using and managing water. Taking into account all the factors involved, drought studies are carried out with meteorological, hydrological, soil use and socio-economic focuses. The meteorological focus compares the decrease in rain with prior years. The hydrological viewpoint studies the periods of precipitation and how the water behaves on the ground. The soil usage slant analyzes the kind of production in the region where there is drought. Finally, the socio-economic focus combines elements of the previous ones.

Monitoring Chihuahua's Drought

Despite the importance of carrying out permanent monitoring of the drought to lessen its effects, until recently, state- and nationwide, we did not have an up-to-date method with which to do so. Now, Chihuahua's drought monitoring makes it possible to see when the phenomenon begins and ends. It also allows us to determine its intensity and geographic extension with greater precision (see map). Having this information makes it possible to implement more sophisticated preventive and corrective measures to counteract the drought and, above all, to be able to adapt to it.



Source: Drought Research Center. Precipitation Data Source: National Water Commission and National Meteorological Service.

Methodology

The methodology for monitoring Chihuahua's drought includes the Standardized Precipitation Index (SPI) developed in 1993 by Thomas B. McKee, Noland J. Doesken and John Kleist at Colorado State University. The Drought Research Center (CEISS) of the Ecology Institute in Chihuahua designed a computer program to calculate the SPI and other analyses of climate information using historical data on total monthly precipitation issued regularly by the National Water Commission and the National Meteorological Service.

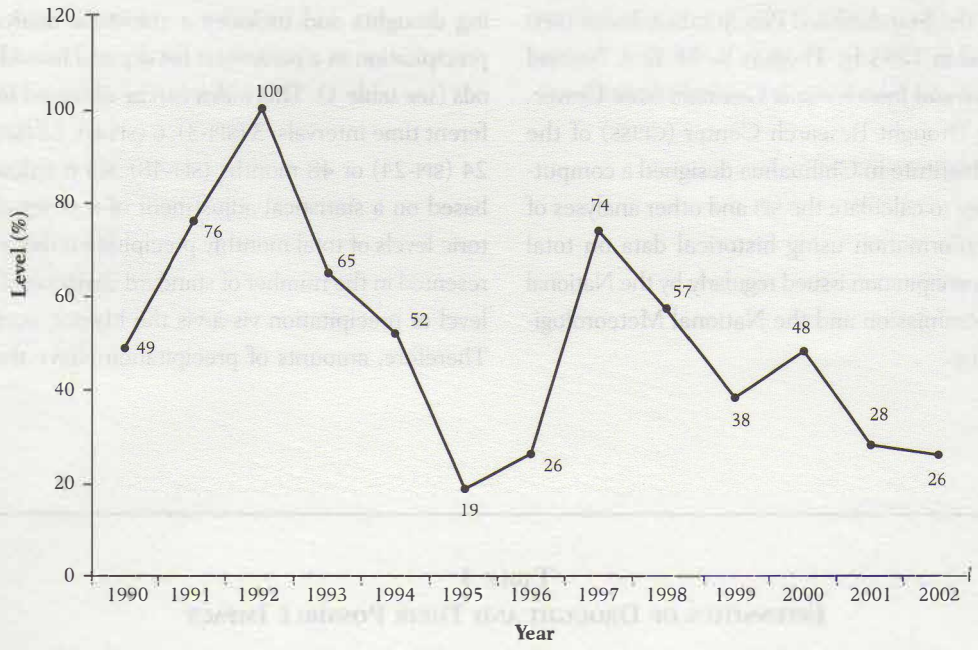
This procedure is linked up with a system of geographical information for the state. The SPI is an advanced methodology used internationally for studying droughts and includes a statistical analysis of precipitation as a parameter for dry and humid periods (see table 1). This index can be obtained for different time intervals: 3 (SPI-3), 6 (SPI-6), 12 (SPI-12), 24 (SPI-24) or 48 months (SPI-48). SPI is calculated based on a statistical adjustment of a series of historic levels of total monthly precipitation that is represented in the number of standard deviation of each level of precipitation vis-à-vis the historic average.[2] Therefore, amounts of precipitation above the his-

Table 1
Intensities of Drought and Their Possible Impact

Category	Possible impacts	SPI interval*
Normally dry	Normal conditions of precipitation.	—
Abnormally dry	The drought begins; a short period in which crops dry slowly. Crops and grasslands begin to be at risk for fire; there is some water deficit; pasture lands and crops do not completely recover.	-0.5 to -0.7
Moderate drought	Certain damage to crops and grazing land; high risk of fire. Streams, reservoirs and wells are low. Imminent scarcity of water. Requests to protect the water supply are necessary.	-0.8 to -1.2
Severe drought	Crops and grasslands are probably lost; high risk of fire. Water scarcity is common and restrictions on water use are imposed.	-1.3 to -1.5
Extreme drought	Greater loss of crops/grasslands; extreme danger of fires; extensive restrictions on water use.	-1.6 to -1.9
Exceptional drought	Exceptional, extended loss of grasslands and crops; exceptional risk of fire; water scarce in streams and wells; declaration of a state of emergency.	-2.0 or <

Note: CEISS modified the index of classification of drought severity developed by the U.S. National Drought Mitigation Center (NDMC).
*SPI = Standardized Precipitation Index.

Graph 1
Average Levels (%) of Chihuahua Water Reservoirs (May 2002)



Source: National Water Commission, 2002.

toric average in a given month will give positive SPI values, representing conditions of humidity. To the contrary, amounts of precipitation below the historic average in a given month will make for negative SPI values, which will indicate a particular intensity in the deficit of humidity (see example of SPI-12 in graph 2). We have monitored the monthly evolution of conditions both of the drought and of humidity in the state of Chihuahua.

In general, we can say that a drought begins when, over time, there is a marked tendency toward continual negative SPI values. The drought ends when the SPI value reaches positive values. The length of a drought can be pinpointed over time as a function of detecting its initial stages until its final stage.

This system is applied in countries like the United States and Australia. In Mexico, Chihuahua is the first state that has this technology to follow this silent but destructive natural phenomenon.

Benefits of Monitoring

Everyone whose activity depends on rainfall is a potential user of the information gleaned from monitoring.

For this reason, we use the statistics to make SPI graphs and a monthly map to disseminate the information through different media, like our web page (www.sequia.edu.mx). Recently, we have given the maps made based on our monthly monitoring to different federal and Chihuahua state government agencies involved in the sustainable use of natural resources so they can become accustomed to using this new cartography and the information it provides in their battle to mitigate the negative effects of this recurring climatic event. Having access to this information is key, particularly for agencies involved in water management. The maps are also given to private farmers and cattle ranchers, along with advisory services about their use and usefulness.

Soon, the information will be available for all the states in northern Mexico that border on the Rio Bravo basin.

Main Findings

In general, the CEISS has found that the droughts in the state of Chihuahua operate unequally, with different intensity, locations, coverage and duration. Nevertheless, we have discovered that the most severe, persistent droughts tend to begin in the Southwest, in the region of Guadalupe y Calvo, Morelos, Batopilas and Guachochi, an area of 3,838,489 hectares, or 15 percent of the state territory (see map). The SPI-12 results for the month of November 2002 in that area show that 59 percent of the state's forests were suffering from severe to exceptional drought. This seems to be the result of the accelerated fragmentation over many years of the forest ecosystems located in the high parts of the Conchos River basin, which have been seriously altered by human activity.[3] This has made for rapid soil erosion and the decrease in replenishment of both the underground aquifers and the surface water supply to the Conchos River medium basin, which is the reason the reservoirs do not recover the levels required to satisfy the state and international demand for what has been called "transparent gold." As a result, planning the use of surface and underground water must be done as a function of its availability and drought expectations.

The decrease in humidity levels in the environment caused by drought favors forest fires which, in turn, cause ecological damage, in addition to financial losses in commercial forests. The SPI is a very useful tool used with other variables to determine the probability of fires. It has been observed that the quantity of heat points detected in Chihuahua bears an important relation to the intensity of the drought in short spans of time.[4] SPI-3, which reflects only three months' deficit in precipitation, is particularly useful since it practically coincides with the fire season in the region. Thus, during the dry season and when there are severe to exceptional droughts, the number of potential fires is greater than in areas where the drought is less intense.

On the other hand, at the end of August, in a corn- or bean-growing area, the SPI-3 could tell us precipitation trends during the important reproductive stage and the early development of the grain. At the end of May, SPI-3 would give us an indicator of soil humidity when the plant growing season begins.

By contrast, SPI-12 indicates long-term precipitation patterns and correlates to water flows, reservoir levels and even levels of underground water in the long term. Therefore, the knowledge obtained when using the SPI-12 in continual monitoring of drought can help us more effectively administer water resources.

In general, early detection of drought will help in making preventive decisions in water reserve management given the probability of its advancing toward the interior of the state of Chihuahua.

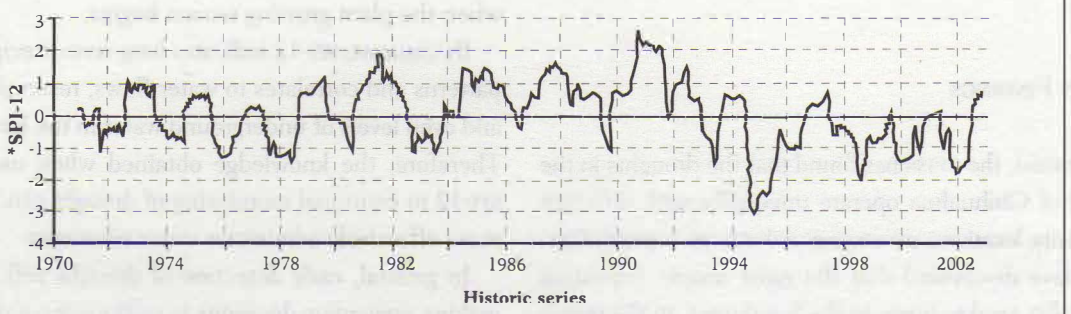
The U.S.-Mexico Treaty

Considered overall, the International Treaty on Borders and Water signed in 1944 with the United States may favor certain Mexican states like Sonora, which receives an annual guaranteed volume of 1.850234 billion cubic meters of water from the U.S. This is not Chihuahua's case, however, since the treaty dictates that it must send the United States 431.721 million cubic meters of water a year. This water comes mainly from the Conchos River, which runs through the state. If the quota is not covered because of what the treaty calls —but does not define— "extraordinary drought," the debt is cumulative and transferred to the following five-year cycle. But, if the extraordinary drought makes it difficult for the United States to give Mexico the water it is committed to, it will reduce its delivery in the same proportion that it reduces its own consumption.

The prolonged drought that has affected Chihuahua for the last decade has meant that for several years Mexico has not been able comply with treaty stipulations. Its current accumulated debt is over 1.936 billion cubic meters of water.

This has spurred a sharp dispute between state governments on both sides of the border. Mexico intends to pay its water debt over the next five years, supplying 682 million cubic meters instead of the 432 million cubic meters it would normally deliver every year. But the fact is that no one knows how to get the water to pay this debt if Chihuahua's reservoirs continue at

Graph 2
Historical Fluctuation of SPI-12 in Delicias City



* SPI: Standard Precipitation Index.

their current low levels. The authorities are counting on the drought ending, making it possible to comply with the 1944 commitments.

With this panorama, it would be fundamental to be able to, firstly, precisely define what the 1944 treaty means by "extraordinary drought." Today it is possible to define this rather vague term with the drought indices being used both in the United States and Mexico. In the case of the SPI ratings, an equivalent of "extraordinary drought" could be something between what are technically considered "extreme drought" (-1.6 to -1.9) and "exceptional drought (-2.0 or greater). Once the term is defined, it is fundamental to pinpoint the locale where the drought originates and monitor its intensity, the geographical area it covers and its duration. In general, it must be studied throughout the basin and its zone of influence. It is also absolutely necessary to consider time parameters. Short periods of extreme or severe droughts cause an important change in the hydrological balance of a basin. However, long periods of moderate droughts can cause the same change in a basin's hydrological balance. Therefore, the combination of different intensities and durations of drought must be taken into consideration.

It is important to remember that a drought may technically come to an end, but its effects can continue for several more years. What is more, if drought is recurring and it happens again in an area key for surface flow or replenishing of the aquifers such as in the case of the high and medium basin of the Conchos River, then its effects will be even more prolonged. With monitoring, in recent years we have found recurrent droughts that vary from severe to exceptional in the forest region of Chihuahua's Southwest. This may explain in part the reservoirs' low levels in the Conchos medium basin; it affects agricultural productivity in this area and diminishes the amount of water that can be sent to the United States to pay the debt agreed to in the international treaty. In short, thanks to the new research and monitoring instruments, it is possible to propose an appendix to the 1944 treaty with cutting-edge technical specifications for monitoring drought, as well as to define under what environmental conditions an extraordinary drought may occur and therefore be able to make or not make the payments of the debt to the United States. VM

Notes

[1] An aquifer is a water-bearing bed or stratum of permeable rock, sand or gravel capable of yielding considerable quantities of water to wells and springs.

[2] The standard deviation is a measure of the variation within a set of data, calculated as the square root of the variance, a measure of the dispersion of values around a mean.

[3] A hydrological basin is an area whose water has been drained or fed into a water conduit.

[4] Heat points are places with a surface soil temperature greater than 40 degrees Centigrade in the daytime and 25 degrees Centigrade at night.