Advanced Agro-Hydro- Meteorology

A MSc course for students of Atmospheric Sciences

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Lecture 7: Drought Monitoring and Planning for Mitigation

7.1 Introduction

Drought is a climatic hazard that occurs in almost every region of the world. It causes physical suffering, economic losses, and degradation of the environment. A drought is a creeping phenomenon, and it is very difficult to determine when a dry spell becomes a drought or when a severe drought becomes an exceptional drought. It is slower and less dramatic than other natural disasters, but its effects are long lasting and widespread. A drought results in less water in the soil, streams, and reservoirs, less water for livestock and wildlife, and poor crops and pastures. A chain of indirect effects follows which may include depressed farm income, closure of farm-supporting industries, and reduced hydroelectric power. A drought often induces malnutrition, disease, famine, population migration, and a chain of consequences for farm families. According to a WMO definition "drought is a sustained, extended deficiency in precipitation."

7.2 Types of drought

1. Meteorological drought is an expression of rainfall departure from normal over some period of time. Meteorological drought definitions are usually region specific and are based on a thorough understanding of the climatology of the region.
2. Agricultural drought occurs when there is not enough soil moisture to meet the needs of crops at a particular time.
3. Hydrological drought refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow and as lake, reservoir, and groundwater levels.

7.3 Meteorological indicators of drought

Drought conditions are basically due to a deficit of water supply in time and/or space. The deficit may be in precipitation, stream flow, or accumulated water in storage reservoirs, ground aquifers, and soil moisture reserves. In describing a drought situation, it is important to understand its duration, spatial extent, severity, initiation, and termination. Depending on the areal extent, a drought can be referred to as a point drought, small-area drought, or a continental drought. The point and small-area drought frequency are very high but are not major sources of concern at the national scale, unless they continue for a prolonged period. The National Drought Mitigation Center has done a detailed comparative evaluation of the most widely used indices and those proposed during the recent past.

- **Percent of Normal**

The percent of normal precipitation is one of the simplest measurements of drought for a location. It is calculated by dividing actual precipitation by the normal (considered to be a 30 or more years mean) and multiplying by 100. The percent of normal is calculated for a variety of time scales. Usually the time scales range from a single month, to a group of months representing a particular season, to an annual climatic year.

- **Deciles**

It is a technique of ranking rainfall values as an indicator of drought. The rainfall occurrences over a long-term precipitation record are divided into sections for each ten percent of the distribution. Each of the sections is called a "decile." The first decile is the rainfall amount not exceeded by the lowest 10 percent of the precipitation occurrences. The second decile is the precipitation amount not exceeded by the lowest 20 percent of occurrences. These deciles continue until the rainfall amount identified by the tenth decile is the largest precipitation amount within the long-term record. By definition, the fifth decile is the median, and it is the precipitation amount not exceeded by 50 percent of the occurrences over the period of record. The deciles are grouped into five classifications, as shown in Table 7.1.

Table 7.1 Decile ranges and moisture thresholds

Decile range	Percent values	Classification
Deciles 1-2	Lowest 20% values	Much below normal
Deciles 3-4	Next 20% values	Below normal
Deciles 5-6	Middle 20% values	Near normal
Deciles 7-8	Next highest 20% values	Above normal
Deciles 9-10	Highest 20% values	Much above normal

- **Dependable Rains (DR)**

  Dependable rains (DR) is defined as the amount of rainfall that occurs in four of every five years (statistically, not consecutively). The index has been applied to the African continent. Dependable rains have potential for use in agricultural planning outside of Africa as well, especially in comparatively dry regio. The concept is, however, not a very good drought-monitoring index.

- **National Rainfall Index (RI)**

  The National Rainfall Index compares precipitation patterns and abnormalities on a continental scale. The index is calculated for each country by taking a national annual precipitation average weighted according to the long-term precipitation averages of all the individual stations. The country-size scale is designed to correlate with other countrywide statistics, especially agricultural production. The RI allows comparisons to be made between years and between countries. Because it is weighted by annual rainfall, those stations in wetter areas of a country have a greater influence on the RI than stations in naturally drier areas.

- **Palmer Drought Severity Index (PDSI)**
  The Palmer Drought Severity Index (PDSI) uses readily available temperature and precipitation data to estimate relative dryness. It is a standardized index that generally spans -10 (dry) to +10 (wet). Maps of operational agencies like NOAA typically show a range of -4 to +4, but more extreme values are possible. The PDSI has been reasonably successful at quantifying long-term drought. As it uses temperature data and a physical water balance model, it can capture the basic effect of global warming on drought through changes in potential evapotranspiration. [see Table 7.2].

Table 7.2 Palmer Drought Severity Index classifications for dry and wet periods

Index value	Classification
–4.00 or less	Extreme drought
–3.00 to –3.99	Severe drought
–2.00 to –2.99	Moderate drought
–1.00 to –1.99	Mild drought
–0.50 to –0.99	Incipient dry spell
0.49 to –0.49	Near normal
0.50 to 0.99	Incipient wet spell
1.00 to 1.99	Slightly wet
2.00 to 2.99	Moderately wet
3.00 to 3.99	Very wet
4.00 or more	Extremely wet

- **Bhalme and Mooley Drought Index (BMDI)**

The BMDI is a simplified version of the Palmer Index. The calculations of BMDI need only precipitation data, but its performance is comparable to that of PDSI. The index expresses situations that vary from extreme drought to extreme wet (Table 7.3). BMDI = <–4 for extreme historical drought and proportionally increases to higher values. For normal conditions, BMDI = 0, and for extreme wet, BMDI = >4. The simplicity of the calculations is the major merit of this index.

Table 7.3 Bhalme and Mooley Drought Index based drought categories

Index value	Character of the weather
Greater than 4	Extremely wet
4 to 3	Very wet
3 to 2	Moderately wet
2 to 1	Slightly wet
1 to –1	Near normal
–1 to –2	Mild drought
– 2 to –3	Moderate drought
– 3 to –4	Severe drought
Less than – 4	Extreme drought

- **Surface Water Supply Index (SWSI)**

SWSI is an indicator of surface water conditions. They described the index as "mountain water dependent," in which mountain snowpack is a major component. The SWSI incorporates both hydrological and climatological features into a single index value resembling the Palmer Index for each major river basin in a state. These values would be standardized to allow comparisons between basins. The inputs required are snowpack, stream flow, precipitation, and reservoir storage. Because it is dependent on the season, the SWSI is computed with only the snowpack, precipitation, and reservoir storage in the winter. During the summer months, stream flow replaces snowpack as a component within the SWSI equation.

- **Standardized Precipitation Index (SPI)**

The Standardized Precipitation Index (SPI) is based on the fact that a deficit of precipitation has different impacts on the groundwater, reservoir storage, soil moisture, snowpack, and stream flow. The SPI quantifies the precipitation deficit for multiple time scales (3, 6, 12, 24, and 48 months). These time scales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale, while groundwater, stream flow, and reservoir storage reflect the longer term precipitation anomalies. SPI is calculated by taking the difference of the precipitation from the mean for a particular time scale and then dividing by the standard deviation. A classification system is used to define drought intensities resulting from the SPI (Table 7.4). A drought event occurs any time the SPI is continuously negative and reaches intensity when the SPI is –1.0 or less. The event ends when the SPI becomes positive. Therefore, each drought event has a duration defined by its beginning and end and its intensity for each month that the event continues. An accumulated magnitude of drought can also be measured. It is called the drought magnitude (DM) and is the positive sum

Table 7.4. Standardized Precipitation Index

SPI value	Moisture category
2.0 and above	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
0 to –0.99	Near normal
–1.00 to –1.49	Moderately dry
–1.50 to –1.99	Severely dry
–2.0 or less	Extremely dry

Crop Moisture Index (CMI)

The Crop Moisture Index (CMI) was developed by Palmer in 1968 and uses a meteorological approach to monitor week-to-week crop conditions from procedures he used to calculate the PDSI. Whereas the PDSI monitors long-term meteorological wet and dry spells, the CMI was designed to evaluate short-term moisture conditions across major crop-producing regions. It is based on the mean temperature and total precipitation for each week and the CMI value from the previous week (Table 7.5).

Table 7.5 Crop Moisture Index (CMI)

CMI values when index increased or did not change from previous week		CMI values when index decreased from previous week	
3.0 and above	Excessively wet, some fields flooded	3.0 and above	Some drying, but still excessively wet
2.0 to 2.99	Too wet, some standing water	2.0 to 2.99	More dry weather needed, work delayed
1.0 to 1.99	Prospects above normal, some fields too wet	1.0 to 1.99	Favorable, except still too wet in spots
0 to 0.99	Moisture adequate for present needs	0 to 0.99	Favorable for normal growth and field work
0 to –0.9	Prospects improved, but rain still needed	0 to – 0.9	Topsoil moisture short, germination slow
–1.0 to –1.99	Some improvement, but still too dry	–1.0 to –1.99	Abnormally dry, prospects deterio-rating
–2.0 to –2.99	Drought eased, but still serious	–2.0 to –2.99	Too dry, yield pros-pects reduced
–3.0 to –3.99	Drought continues, rain urgently needed	–3.0 to –3.99	Potential yields se-verely cut by drought
–4.0 and below	Not enough rain, still extremely dry	–4.0 and below	Extremely dry, most crops ruined

Drought Exceptional Circumstances

When drought conditions are so intense and protracted that they are beyond those that can reasonably be factored into normal risk management strategies, they are termed drought exceptional circumstances. In practice, this is a drought of such rarity and severity that it occurs no more than once in every 20 to 25 years and is more than 12 months in duration.

Remote Sensing

Satellite data can be directly related to land cover (vegetation and soil) status. Remotely sensed data are unsurpassed in supporting the formulation of drought indicators because they are actual observations of landscape status and its performance. Obtaining a time series of remotely sensed images allows information to be extracted regarding the location and duration of below-average biomass and below-average soil moisture. Normalized Difference Vegetation Index (NDVI) data are used to monitor vegetation health and to fine tune regional differences. Remotely sensed data (visible, thermal, etc.), geographic information system (GIS) data layers (soils, geology, etc.), and point-based measurements (climate, biomass, etc.) all have space and time dimensions and can be integrated for a better appreciation of the environment. This information can then be combined with other necessary information, such as agronomic, economic and social data, which allow drought exceptional circumstances to be determined objectively.

A Drought Mitigation Plan

Effective drought mitigation should be based on a comprehensive view of drought, because drought is not simply a deficiency of rainfall but is a more complex phenomenon that influences the whole society. Strategies to minimize the impact of drought at a farm scale are different from those needed at the state or national level. Strategies normally adopted at the farm level are based on local experience. Combating drought at the national or state level is a three-stage process. The first stage is monitoring the drought development in terms of spread and intensity as realistically as possible. In the second stage, the monitored information is used as an early warning system. Activation of a readily available drought mitigation plan is the third step of the process.

Three groups of people are the key players in tackling a drought situation.

(1) In the first group are climatologists and others who monitor how much water is available now and in the foreseeable future.
(2) The second group includes natural resource managers and others who determine how the lack of water is affecting various interests, such as agriculture, municipal supplies, and recreation.
(3) The third group of people is comprised of high-level decision makers who have the authority to act on information they receive about water availability and the drought’s effects.

Drought Mitigation Procedures

A drought plan has three primary organizational tasks: monitoring, impact assessment, and response and mitigation. Each task is assigned to a separate group or a committee, but the groups need to work together well, with established communication channels.

The monitoring committee includes representatives from agencies with responsibilities for forecasting and monitoring the principal meteorological, hydrological, and agricultural indicators.

An impact assessment committee represents those economic sectors most likely to be affected by drought. The impact committee considers both direct and indirect losses as drought effects ripple through the economy. It is responsible for determining impacts by drawing information from all available reliable sources.

The drought task force (group of senior-level officials) acts on the information and recommendations of the impact assessment committee and evaluates the state and federal programs available to assist agricultural producers, municipalities, and others during times of emergency. During periods of severe drought, the committee makes recommendations to the government about specific actions that need to be taken.

Desertification

The appearance of desert like conditions that were nonexistent previously in an area is termed desertification. More specifically, desertification may be defined as land degradation in arid, semiarid, and subhumid areas resulting from climatic variation and human activities. Desertification is a widespread and discrete process of land degradation. With desertification, the fraction of bare soil increases, and vegetation is reduced to small patches. With more bare soil, fine mineral and organic material is rapidly removed by wind. Gully and sheet erosion by occasional heavy rainfall tends to accumulate the eroded material on the low-lying areas or the valley floors.

More than 250 million people in 110 countries are directly affected by desertification, while more than 1 million people are threatened by it. Six million hectares each year are affected worldwide by desertification, causing famine, death of livestock, and the loss of cultivated land. According to another estimate, approximately 70 percent of the susceptible drylands are undergoing various forms of land degradation. The West African Sahelian region is one example of increasing desertification and its impact. In this region, original field data show that forest species richness and tree density have declined in the last half of the twentieth century.