7. Drought and Heat Waves
Heat Waves

✓ Prolonged period of excessive **heat**, often accompanied by excessive **humidity**

✓ Weather is noticeably warmer than normal for the specific time of year and climate.

✓ The unusual weather continues for a prolonged period of time.

✓ The weather will most likely bring about some sort of increase risk to humans and animals, and may place an increased strain on power supplies.
HEAT AND DISCOMFORT INDEX

HUMIDEX INDEX OF APPARENT TEMPERATURE (degree C)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>25%</th>
<th>30%</th>
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<th>40%</th>
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</table>

Up to 29°C: No discomfort
From 30 to 34°C: Slight discomfort sensation
From 35 to 39°C: Strong discomfort. Caution: limit the heaviest physical activities
From 40 to 45°C: Strong indisposition sensation. Danger: avoid efforts
From 46 to 53°C: Serious danger: stop all physical activities
Over 54°C: Death danger: imminent heatstroke
Cause of Heat Waves

- High Pressure weather systems (fair weather, sunny skies) becomes quasi-static/stationary over a region (blocking high).
- Subsiding air in High Pressure result in warming of surface air.
Why are they dangerous?

- Heat kills by taxing the body beyond its’ normal abilities.
- People who live in urban areas are at a greater risk from heat wave effects:
  - Stagnant atmospheric conditions trap pollutants
  - Poor air quality aggravates health problems
  - Asphalt and concrete store heat longer, which results in higher nighttime temperatures (urban heat island effect).
- Called the “silent disaster” because it develops slowly
Figure 1. Time series of annual mean temperature (departure from the average for 1906–1925) at Tokyo and Hachijo Island for 1906–2006.
Atlanta, Georgia, USA
There are a number of factors that contribute to the relative warmth of cities:

a) During the day in rural areas, the solar energy absorbed near the ground evaporates water from the vegetation and soils. Thus, while there is a net solar energy gain, this is compensated by evaporative cooling. In cities, where there is less vegetation, the buildings, streets and sidewalks absorb the majority of solar energy input, releasing it as sensible heat.
b) Waste heat from city buildings, cars and trains is another factor contributing to the warm cities. Heat generated by these objects eventually finds its way into the atmosphere. This heat contribution can be as much as $\frac{1}{3}$ of that received from solar energy.

c) The thermal properties of buildings add heat to the air by conduction. Tar, asphalt, brick, and concrete are better conductors of heat than the vegetation or the rural areas. The higher thermal capacity also allows the city to remain warmer than the surroundings during the night.

d) The canyon structure that tall buildings create enhances the warming. During the day, solar energy is trapped by multiple reflections off the buildings while infrared heat losses are reduced by absorption.
Some consequences of heat islands on the local climate:

a) The urban heat island may increase cloudiness and precipitation in the city, as a thermal circulation sets up between the city and surrounding regions.
b) In the summer months, the heat island effect results in an increased demand for electric power (air conditioners). In Los Angeles, the electric power demand increase by 4% for every 1°C increase in daily maximum temperature. Peak power demand rises 5% for every 0.5°C in daily temperatures. This extra energy use tends to increase the city temperature even more, while further adding greenhouse gases to the atmosphere.
c) Smog is created by photochemical reactions of pollutants in the air, and these reactions are temperature dependent. It has been noted that in Los Angeles the probability of smog increases by 10% for every 0.5°C increase in daily maximum temperature above 20°C.
2003 Heat Wave in Europe

Temperature Anomalies across Europe in summer of 2003
Europe summer temperatures

Exceptional heat wave and drought of 2003 was a major extreme made more likely by global warming: 30K+ deaths

From P. Jones
Temperature Distribution in Europe – summer 2003

![Graph showing temperature distribution for June, July, August, and Summer in Europe during the summer of 2003. The graphs display frequency against temperature with standard deviations and mean temperatures for each month.](image-url)
✓ Temperature regularly exceeded 40°C for 10 days
✓ Air conditioning uncommon in Europe
✓ Close to 50,000 deaths across Europe
✓ Mainly elderly, children, people with respiratory illness
✓ Heat wave hit during August, when many doctors and hospital staff take vacation
✓ Crop shortages
✓ Forest fires
How will Global Warming Impact Heat Waves?
2003 Heat Wave in Europe may be very common in future
More New Record Highs Than Low Temps in U.S.

Expectations in absence of global warming

1950s

- Record Highs: 52%
- Record Lows: 48%

2009

- Record Highs: 56%
- Record Lows: 44%

2010

- Record Highs: 70%
- Record Lows: 30%

1950s data from Meehl et al., all other data from NOAA

2011

- Record Highs: 73%
- Record Lows: 27%

2012 to date

- Record Highs: 90%
- Record Lows: 10%
Beat the HEAT
How to Protect Yourself Against the Dangers of Hot Weather This Summer

A Publication of the National Weather Service, Raleigh, NC

Hydrate.
Keep yourself hydrated with frequent drinks of water, even if you're not thirsty.

Educate yourself.
Keep up with the current and forecast temperatures and heat index.

Act quickly.
Get immediate medical attention at the first signs of a heat illness. Delays can be deadly.

Take it easy.
Anyone working or exercising outdoors should avoid overexertion in hot weather. Take frequent breaks in air conditioning.

Heat waves kill an average of 175 people each year... more than any other weather disaster.
Don't let yourself or a loved one be a statistic this summer.

Get the latest temperatures, heat index readings, and forecasts at www.erh.noaa.gov/rah/heat

Get the Word out!

TOP TIPS TO BEAT THE HEAT

H₂O to go
Take a bottle of cold water with you when you're out and about.

Avoid
Alcohol, tea, coffee and hot, spicy and salty foods can make dehydration worse, so think about avoiding them during hot weather.

Be cool
Make use of fans or air conditioners set to cool.

Dress down
Wear lightweight, light coloured, loose-fitting clothes made from natural fibres, like cotton or linen.

Enjoy
Try eating more cold foods, like salads and fruits. They contain water and are more refreshing in hot weather than hot foods.

Rest
Make sure you get enough sleep and rest if you feel tired.

Soak
Take a cool shower or bath to help you cool down when you feel hot.

Shade
Wear a hat or take an umbrella with you for shade. If you're outside on a hot day.

WATCH OUT
- Be on the lookout for any symptoms of heat-related illness.
- See your GP if you are unwell.
- In a medical emergency, call 1021.

www.amanfoundation.org
Drought

3 kinds of drought

1. Meteorological: absence of rain

2. Agricultural: absence of soil moisture

3. Hydrological: absence of water in rivers, lakes and reservoirs
Dimensions of Drought

**Meteorological Drought**
- Precipitation deficiency accompanied by high temps, winds, low RH, increased sunshine, reduced cloud cover

**Hydrologic Drought**
- Increased evapotranspiration and reduced infiltration, runoff, deep percolation, and groundwater recharge

**Agricultural Drought**
- Soil moisture deficits
  - Plant stress, crop losses, reduced biomass, plant diseases, insect infestations

**Social, Economic, and Environmental Impacts**
Natural Climate Variability

- Precipitation deficiency (amount, intensity, timing)
  - Reduced infiltration, runoff, deep percolation, and ground water recharge
- High temp., high winds, low relative humidity, greater sunshine, less cloud cover
  - Increased evaporation and transpiration

Soil water deficiency

- Plant water stress, reduced biomass and yield
  - Reduced streamflow, inflow to reservoirs, lakes, and ponds; reduced wetlands, wildlife habitat

Time (duration)

- Meteorological Drought
- Agricultural Drought
- Hydrological Drought

Economic Impacts  Social Impacts  Environmental Impacts
Droughts are among the most complex natural hazards

- Drought is a creeping phenomenon with slow onset
- It is difficult to define when it begins and when it ends
- That makes prediction and hence early warning so difficult
- The definition and the impact of droughts is highly depending on regional or even local geographic and meteorological conditions
Timescales of Drought

Droughts span an enormous range of time scales, from short-term “flash droughts” that can have major agricultural impacts to multi-year or even decadal droughts (1930s, 1950s, etc.).

- **30 DAYS**
  - Heat Waves
  - Floods
  - Storm Track Variations
  - Madden-Julian Oscillation

- **1 SEASON**
  - El Niño-Southern Oscillation

- **3 YEARS**
  - Decadal Variability
  - Solar Variability
  - Deep Ocean Circulation

- **10 YEARS**

- **30 YEARS**
  - Greenhouse Gases

- **100 YEARS**
METEOROLOGICAL DROUGHT INDICATORS

Deciles of Precipitation (DI)

Monthly precipitation totals from a long-term record (~30 years) are used for comparison with monthly rainfall in five precipitation classes:

- **0-20%** much below normal
- **20 to 40%** below normal
- **40 to 60%** near-normal
- **60 to 80%** above-normal
- **80 to 100%** much above normal

DI is used widely in Australia for drought relief programme.

**Advantages:** DI is simple to calculate, requires only precipitation data and fewer assumptions.

**Disadvantage:** Too simplistic to inform about gravity of the problem in different sectors.
Precipitation Departure from Normal

Meteorological drought described from rainfall departure from its long term averages and meteorological drought defined on weekly/monthly basis.

Departure of annual rainfall from normal (%)

<table>
<thead>
<tr>
<th>Departure</th>
<th>Drought</th>
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<tr>
<td>0 or above</td>
<td>No drought</td>
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<tr>
<td>0 to –25</td>
<td>Mild drought</td>
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<tr>
<td>–26 to –50</td>
<td>Moderate drought</td>
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<tr>
<td>–50 or more</td>
<td>Severe drought</td>
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</tbody>
</table>

When >50% area of the country gets moderate or severe drought, the country becomes severely drought-affected; if 26-50% area is affected, country becomes moderately drought-affected.

**Advantage:** Simplicity

**Disadvantage:** Average precipitation is not always the same as the median precipitation. Also, distribution or time-scale of rainfall is not specified.
Palmer Drought Severity Index (PDSI)

PDSI, popular in the US, uses data on precipitation, temperature and local available water content (AWC) of soil, and calculates the difference between Climatically Appropriate For Existing Conditions (CAFEC) rainfall and actual rainfall as a drought indicator. PDSI generally varies between -4.0 (extreme drought) and +4.0 (adequate moisture condition). Drought categories are:

<table>
<thead>
<tr>
<th>Index value</th>
<th>Class for drought</th>
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<tbody>
<tr>
<td>- 1.00 to -1.99</td>
<td>Mild drought</td>
</tr>
<tr>
<td>- 2.00 to -2.99</td>
<td>Moderate drought</td>
</tr>
<tr>
<td>- 3.00 to -3.99</td>
<td>Severe drought</td>
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<tr>
<td>&lt; - 4.00</td>
<td>Extreme drought</td>
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</table>

**Advantage:** PDSI quantifies abnormality of weather in a region, and includes measurements of temperature and soil moisture. It can well be used for spatio-temporal variability of drought.

**Disadvantage:** The index values do not always reflect the true drought situation, and soil moisture data are not always available.
Palmer Hydrological Drought Index
Long-Term (Hydrological) Conditions

June 2013

National Climatic Data Center, NOAA

- extreme drought
  -4.00 and below

- severe drought
  -3.00 to -3.99

- moderate drought
  -2.00 to -2.99

- mid-range
  -1.99 to +1.99

- moderately moist
  +2.00 to +2.99

- very moist
  +3.00 to +3.99

- extremely moist
  +4.00 and above
Standardized Precipitation Index (SPI)

SPI, based on probability of precipitation for any time scale, is calculated as:

$$ SPI = \frac{X - Xm}{\sigma} $$

Where $X$ = Precipitation for the station
$Xm$ = Mean precipitation
$\sigma$ = Standardized deviation

SPI Drought Classes

- Less than -2.00: Extreme drought
- -1.50 to -1.99: Severe drought
- -1.00 to -1.49: Moderate drought
- -0.99 to -0.00: Mild drought

Advantage:
- Can be computed for different time scales
- Can provide early warning of drought
- Can help assess drought severity
- Is less complex than PDSI

Disadvantage:
- Groundwater, stream flow, and reservoir storage reflect longer-term precipitation anomalies. So, SPI is calculated for 3, 6, 12, 24, and 48 month time scales.
Standardized Precipitation Index
One Month

June 2013

National Climatic Data Center, NOAA
HYDROLOGICAL DROUGHT INDICATORS

**Groundwater and Reservoir Level**
Monitoring of all reservoir water levels and groundwater table through a closed well observation network is important.

**Standardized Water level Index (SWI)**
An index based on water level probability for any time scale.

\[
SWI = \frac{(W_{ij} - W_{im})}{\sigma}
\]

where, \( W_{ij} \) is the seasonal water level for ith and jth observation, \( W_{im} \) its seasonal mean, and \( \sigma \) is its standard deviation.

**Advantage:**
- SWI can be computed for different time scales
- Can provide early warning of water storage
- Can help in assessing hydrological drought severity
Surface Water Supply Index (SWSI)

Designed for river basins with a component of mountain snow input. Integrates reservoir storage, stream flow and snow and rain into a single index.

\[ SWSI = \frac{aP_{\text{snow}} + bP_{\text{prec}} + cP_{\text{strm}} + dP_{\text{resv}} - 50}{12} \]

where \( a, b, c, \) and \( d \) are weights for snow, rain, stream flow and reservoir storage, respectively; while \( (a+b+c+d) = 1 \), and \( P_i \) = probability (%) of non-exceedence for each of the four water balance components. Calculated at monthly time step.

**Disadvantages:** Unique to each basin or region, so difficult to compare across basins or regions.

Changes in water management in a basin, necessitates redevelopment of the algorithm.

Extreme events cause a problem if events surpass historical time series.
Aridity Index (AI)
Moisture Adequacy Index (MAI)
Crop Water Stress Index (CWSI)
Normalized Difference Vegetation Index (NDVI)
Global warming

- Heating ↑
- Temperature ↑ & Evaporation ↑
- Atmosphere water holding capacity ↑
- atmospheric moisture ↑ & soil moisture ↓
- greenhouse effect ↑
- Droughts
Drought potential worldwide

2000–2009

PDSI

DRY

WET
Predicted Change in Drought Potential

2000–2009

2030–2039
Climate Change and Agriculture

Today’s agriculture sector faces a complex challenges:

- produce more food while using less water per unit of output;
- contribute in a productive way to the local and national economy by understanding local indigenous customs;
- protect the health of the ecosystem and ensure environmental sustainability through “eco-farming”, such as developing cultivation skills in soil regeneration, nitrogen fixation, natural pest control and agro-forestry.
- reduce food shortages, famine, and hunger while coping with changing climate and the increasing frequency of natural hazards that threaten our water supplies and agricultural resources.
Impacts of Drought

Droughts are often defined by their impacts. Impacts, in turn, are dependent upon the severity and duration of the drought, coupled with society’s vulnerability.

Awareness  Preparedness  Societal Vulnerability  IMPACTS  Drought Condition  Duration Severity
Why Should We Monitor Drought Impacts?

Impact assessment is critical for reducing drought risk.

- Drought is a **normal** part of the climatic cycle
- **Impacts** are directly tied to **vulnerability**; vulnerabilities to droughts are **dynamic**
Drought as a Billion-Dollar Disaster


![Bar graph showing US losses due to natural disasters from 1980-2007. The graph indicates that tropical storms/hurricanes caused the most losses, followed by heat waves/droughts and non-tropical floods. Other types of events, such as severe weather, fires, freezes, blizzards, ice storms, and Nor’easters, also contributed to losses.](image-url)
Possible public health hazards

- Health Hazard
  - Insufficient safe water for consumption
  - Insufficient water for hygiene purposes

- Threat to agriculture and economy
  - Lack of water for animals and crops
  - Resultant decrease in public health funding resources for intervention
  - Power loss exacerbates problem

- Malnutrition due to lack of water

- Loss of electrical power from hydroelectric generation
Possible public health hazards

• Environmental Hazards
  – Wildfire
  – Desertification
  – Chemical exposures
    • Silo gases
    • Improper water treatment
    • Polluted water
Desertification as impact of droughts

✓ Desertification refers to the process whereby poor resource management leads to overgrazing, over cultivation, and deforestation (generally adjacent to desert regions).
✓ Leads to the degradation of ground cover and soils.
✓ This deterioration of the land surface is a produce of both local (population pressure and economy) and external (global economy, commodity prices) factors.
Desertification can amplify droughts

- Soils become less productive
- Exposed and eroded topsoil can be blown away by wind or washed away by rain
- Exposing the sand and rock increases the albedo (brighter surface), decreases temperature and amplifies subsidence of air (High pressure cell).
- This amplifies drying, and drought
- Removing moisture at surface (plants) also reduces evaporation and enhances drying of air.
- The arid regions grow
Desertification can amplify climate change

- The exposed soils can cause dust storms and air pollution.
- Desertification plays a role in altering the sources and sinks of greenhouse gases.
- Degradation of vegetation can result in a net carbon source.
- Poorly fed cattle may result in enhanced methane emissions.
- However, dry soils act as a methane sink, so the effect on methane emissions is not clear.
Global Warming

Climate
- Arid-semi arid
- Extreme
- Variability
- Drought

Soils
- Soil liable to salinity and alkanization
- Loose
- Sandy soils

Ecological System

Vegetation
- Semi desert
- Steppes
- Savannas

Topography
- Precondition leading to erosion hazards

Desertification Process in Nigeria

Environmental Effects
- Reduction in river flow and ground water level
- Formation of dunes
- Destruction habitat and loss of biodiversity
- Soil erosion

Socio-Economic Effects
- Food security
- Decline in cash crop for exports
- Migration
- Poverty
- Resource use conflicts

Source: Adapted from Medugu (2007)
Homework