Drought Risk Assessment:
Mapping the Vulnerability of Agricultural Systems

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Disaster Risk Assessment Specialist
Session Outline

• Understanding the Concept of Vulnerability
• Mapping the Agricultural System in GIS
• Developing Vulnerability Functions for Drought Risk Assessment
• Mapping the Vulnerability of Agricultural Systems
What is Vulnerability?

- Concept
- Typology
- Conceptual Models
What is Vulnerability?

Vulnerability = Degree or extent of potential damage or loss

Vulnerability = Ability or capability to anticipate, cope with, resist, recover from the impacts of a natural hazard

Vulnerability = Conditions or situation with increase the susceptibility of a system

Vulnerability = Exposure

Training Workshop on Drought Risk Assessment for the Agricultural Sector – Ljubljana, Slovenia, Sept. 20-24, 2010
The term ‘**Vulnerability**’ is now used in such a loose and widespread manner that it is in danger of becoming as useless as the term ‘**Sustainability**’, and so some precision is needed to rescue it.” (T. Cannon, 2006)
What is Element Vulnerability?

• Element Vulnerability refers to the degree of potential physical damage to the target elements at risk, such as buildings, facilities, infrastructure, and lifelines in response to a hazard event of a given intensity.
Measurement of Element Vulnerability

\[ V_{\text{element}} = \text{DamageRatio} = \frac{\text{Cost}_{\text{repair}}}{\text{Cost}_{\text{element}}} \]
Early Warning on Damage

Flood Duration: Sector Mean

Source: Penning-Rowsell et al 2003: ch. 3
Vulnerability Functions
Fragility Function/Curve

The graph shows the fragility function for different building classes and materials. The y-axis represents the mean damage factor in percentage, and the x-axis represents the intensity level.

- **EMS class B**
- **Curve used for the scenario**
- **S&C brick masonry**
- **EMS class C**
- **Curve used for the scenario**
- **S&C with ringbeams**
- **S&C RC frames**
- **EMS class E**

The lines indicate the relationship between damage factor and intensity for each category, allowing for the assessment of potential damage under varying intensity levels.
What is System Vulnerability?

- System Vulnerability refers to the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of an anthropogenic system to the effect of hazards.

- System Vulnerability is the extrinsic property of an anthropogenic system that can be defined by the susceptibility, coping capacity, and resilience of the system.
Measurement of System Vulnerability

\[ V = f(S, C, R) \]

- **S** - Susceptibility
- **C** - Coping Capacity
- **R** - Resilience
- **V** - Vulnerability

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System Vulnerability: DM Perspective

System Vulnerability

Susceptibility
- Risk Profile
- Disaster Profile
- Risk Perception

Coping Capacity
- Governance
- Contingency plan
- Search & Rescue
- Safe haven/shelter
- Stockpiles
- EWS
- Evacuation plan
- Healthcare

Resilience
- Recovery plan
- Resource Availability
- Expertise & Skills
- Insurance
System Vulnerability: 5S’ Model

Community Vulnerability
(5S’ Principles, Granger (2002))

Socio-economics
- CBDMO
- Vulnerable pop.
- Household size
- Econ. Diversity
- Income struct.
- Landuse planning

Structure
- Vul. Houses
- Public buildings
- Infrastructure
- Cultural sites

Security
- Risk awareness
- EWSs
- Emergency services
- Safe haven
- Contingency plan

Sustenance
- Self-support
- External support
- Health care
- Power supply
- Phy. Accessibility
- Com. Accessibility

Setting
- Haz. environment
- Res. protection
Pressure & Release (PAR) Model

(Wisner, et al., 2003)
Mapping the Agricultural System in GIS

- Identifying & categorizing elements at risk
- Analysis of inter-dependency & criticality
- Inventory mapping
Categorization of Elements at Risk

- For Crops
  - Rice, wheat, corn, cotton, bean, etc.
- For Livestocks
  - Cattle, goat, poultry, etc.
- For Services
  - Water supply, energy supply, etc.
- For Resources
  - Farmers, soil, water, etc.
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**Total importance**: 71 10 31 37 68 62 66 29 24 11 25 70 26 25 28 67 67
### How to Characterize HS?

#### Important Sectors
- Water supply
- Gas and oil supply
- Sanitary drainage
- Storm drainage
- Electricity supply
- Telecom services
- Highways
- Railways
- Ports
- Airports
- Media
- Fuel supply
- Fire fighting
- Buildings
- Health care
- Food supply

#### Dependent Sectors
- Water supply
- Gas and oil supply
- Sanitary drainage
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- Highways
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### Table: Support Item vs Dependent Item

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Inventory Mapping

• Requirements
  – Resolution and seasonality
  – Data format
  – Analysis unit

• Mapping Methods
  – Proxy-based approach
  – Geo-referenced approach

• Data sources
INFORMATION SHEEP, DECEMBER 31, 2002

Inventory
- 1500 and Over
- 1000 - 1499
- 500 - 999
- Less than 500
- Not Published

Source: 2002 Census of Agriculture

Samples

Crop & Lamb Inventory

Training Workshop on Drought Risk Assessment for the Agricultural Sector – Ljubljana, Slovenia, Sept. 20-24, 2010
Inventory Mapping: Samples
Developing Vulnerability Functions for Drought Risk Assessment

- Loss-Intensity Matrix for Drought
- Vulnerability Functions
Vulnerability Functions: Flood

![Graph showing vulnerability functions for flood depth and degree of loss for different asset categories.](image-url)
# Drought Intensity Index

<table>
<thead>
<tr>
<th>Name of Index</th>
<th>Origin</th>
<th>Overview</th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Percent of Normal</td>
<td>N/A</td>
<td>Simple calculation used by TV weathercasters and general public</td>
<td>Useful for comparing single regions or seasons</td>
<td>“Normal” depends on long-term averages and may not correspond to expected outcomes</td>
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<tr>
<td>Palmer Drought Severity Index (PDSI)</td>
<td>Developed by W.C. Palmer in 1965</td>
<td>Soil moisture algorithm based on homogeneous regions</td>
<td>First comprehensive drought index developed in the U.S.</td>
<td>Not as useful for heterogeneous regions; not effective as an early drought detection tool</td>
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<td>Crop Moisture Index (CMI)</td>
<td>Developed by W.C. Palmer in 1968</td>
<td>A PDSI derivative used to assess moisture supply in the short term across major crop-producing regions</td>
<td>Identifies potential agricultural droughts</td>
<td>Not designed to assess long-term droughts</td>
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<td>Surface Water Supply Index (SWSI)</td>
<td>Developed by Shafer and Dezman in 1982</td>
<td>Designed to complement PDSI for use in Colorado, based on snowpack, streamflow, precipitation, and reservoir storage</td>
<td>Represents water supply unique to each river basin</td>
<td>New algorithms must be calculated if there are any changes in data collection or water management; too specific to compare river basins</td>
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<td>Standardized Precipitation Index (SPI)</td>
<td>Developed at Colorado State University in 1993</td>
<td>Based on the probability of precipitation for any time scale</td>
<td>Less complex than PDSI; effective as an early drought detection tool</td>
<td>Values based on preliminary data may change</td>
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<tr>
<td>Reclamation Drought Index (RDI)</td>
<td>Developed by the Bureau of Reclamation in Oklahoma</td>
<td>Similar to SWSI except that it incorporates temperature</td>
<td>Temperature component accounts for evaporation</td>
<td>Too specific to compare river basins</td>
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</table>

Table 1. Major Drought Indices Used in the United States. Data Source: NDMC 2006c.
Changing Drought Intensity

Palmer Drought Severity Index Values

(a) January 1987
(b) September 1987
(c) June 1988
(d) October 1988

PDSI Values
- < -0.99
- -0.99 - 0.00
- 0.01 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 6.00
- 6.01 - 7.00
- > 7.00

0 375 750 1,500 Miles

N
Loss-Intensity Matrix for Drought

Corn

Loss Ratio (%)

Duration (months)

Drought Intensity Index
## Analysis of Historic Losses

### Table: Drought Event and Element at Risk

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Intensity</th>
<th>Duration</th>
<th>Regular Crop Yield</th>
<th>Lost Crop Yield</th>
<th>Loss Ratio (%)</th>
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Dr01 - Cotton

Dr02 - Cotton

Dr03 - Cotton

Dr01 - Rice

Dr02 - Rice

Dr03 - Rice

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*Training Workshop on Drought Risk Assessment for the Agricultural Sector – Ljubljana, Slovenia, Sept. 20-24, 2010*
Mapping the Vulnerability of Agricultural Systems

- Conceptual Model
- The Process
- The Method

Training Workshop on Drought Risk Assessment for the Agricultural Sector – Ljubljana, Slovenia, Sept. 20-24, 2010
Agricultural System Vulnerability (Drought Disaster)

Susceptibility
- Risk Profile
- Impact Profile
- Risk Perception

Coping Capacity
- Governance & Coord.
- Contingency plan
- Drought Monitoring
- Early Warning
- Emergency Response
- Technical Assistance
- Public Awareness/Education
- Demand Reduction Measures

Resilience
- Recovery plan
- Resource Availability
- Expertise & Skills
- Insurance
Vulnerability Analysis: NDMC Approach

• A 3-step process:
  – Identify the impacts of drought
  – Rank the impacts
  – Analysis the causes of the impacts

NDMC Site:
http://www.drought.unl.edu/risk/vulnerabilityanalysis.htm
Cause Analysis: Impacts Tree

Income Loss Due to Crop Failure
Why did you have income losses from crop failure?

Crop failure
Why the crop failure?

Lack of crop insurance
Why the lack of crop insurance?

Inadequacy of relief assistance
Why inadequacy of relief assistance?

High Cost

Lack of water
WHY?

Poor crop selection
WHY?

Climate
No Irrigation

Other seeds are expensive
Farmer preference
Government incentives
No drought warning

Lack of research and relief program coordination

Inefficient “blanket coverage”
WHY?

Conflicting relief programs
WHY?

Too slow
WHY?
Summary

- Vulnerability can be classified into Element Vulnerability and System Vulnerability.
- Vulnerability functions are created to calculate potential damage or loss to a given element at risk against a specified event intensity.
- System vulnerability provides a framework for identifying the social, economic, and environmental causes of disaster impacts. It directs attention to the underlying causes of vulnerability rather than to its result, the negative impacts.
Any Questions?