A multicriteria approach in drought risk assessment

Problems and Options

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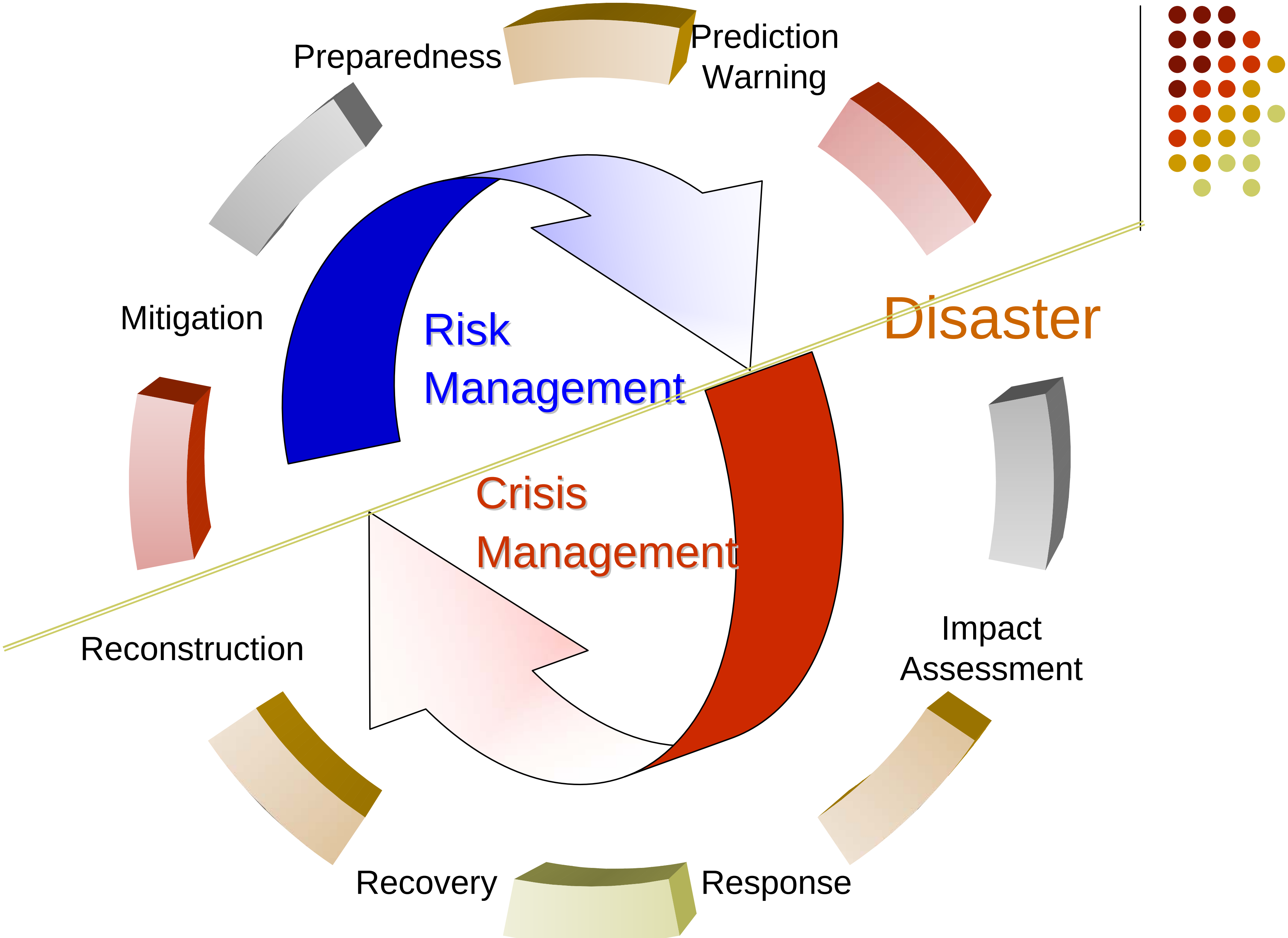
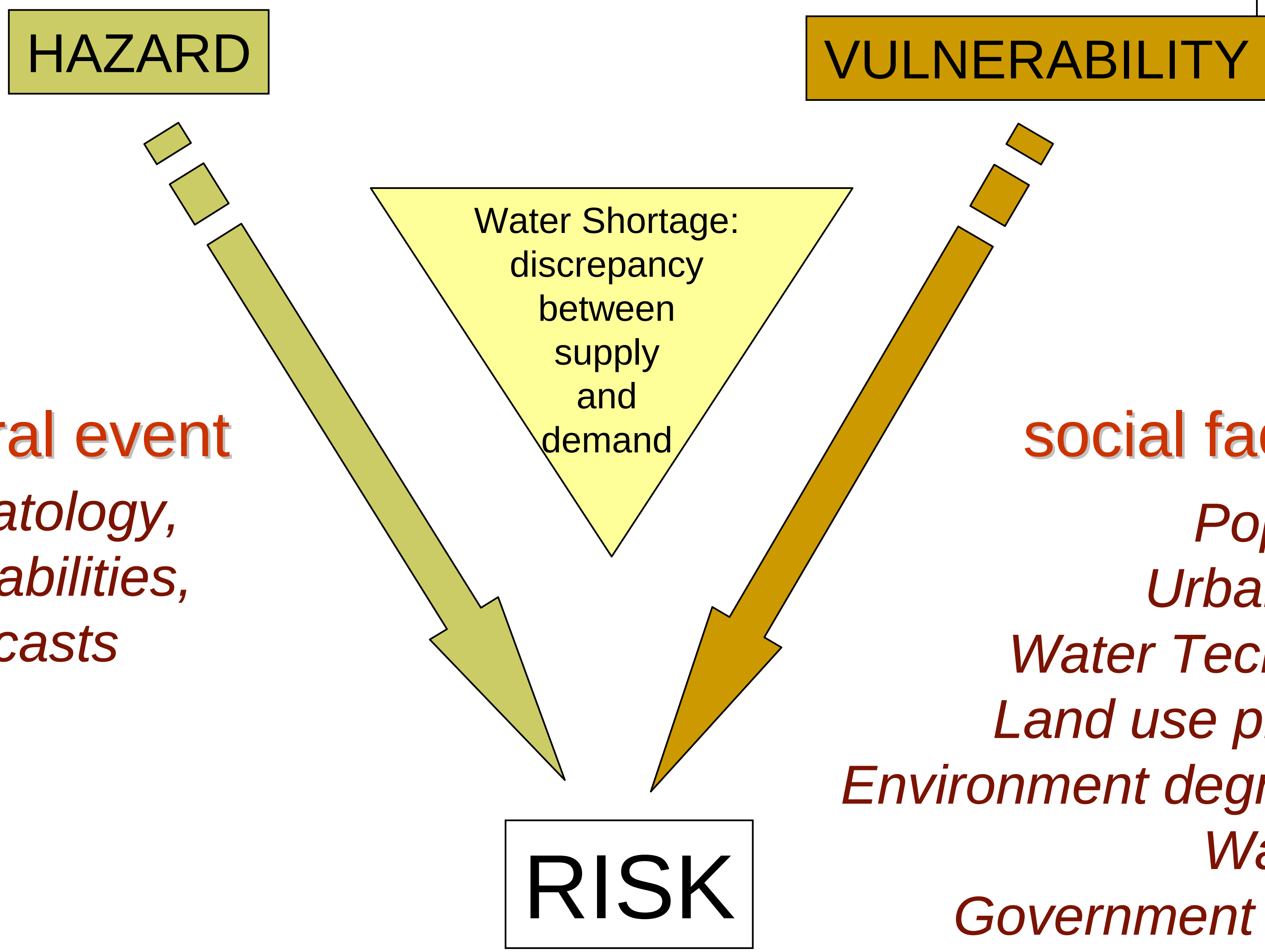
1. Introduction Risk Assessment – why and how ?
2. Multiple Dimensions of Droughts
3. Indicators to specify socio-economic impacts
4. Conclusions


Preparedness
Prediction
Warning
Mitigation
Risk
Management
Disaster
Crisis
Management
Reconstruction
Impact
Assessment
Recovery
Response

Definition of Risks



natural event

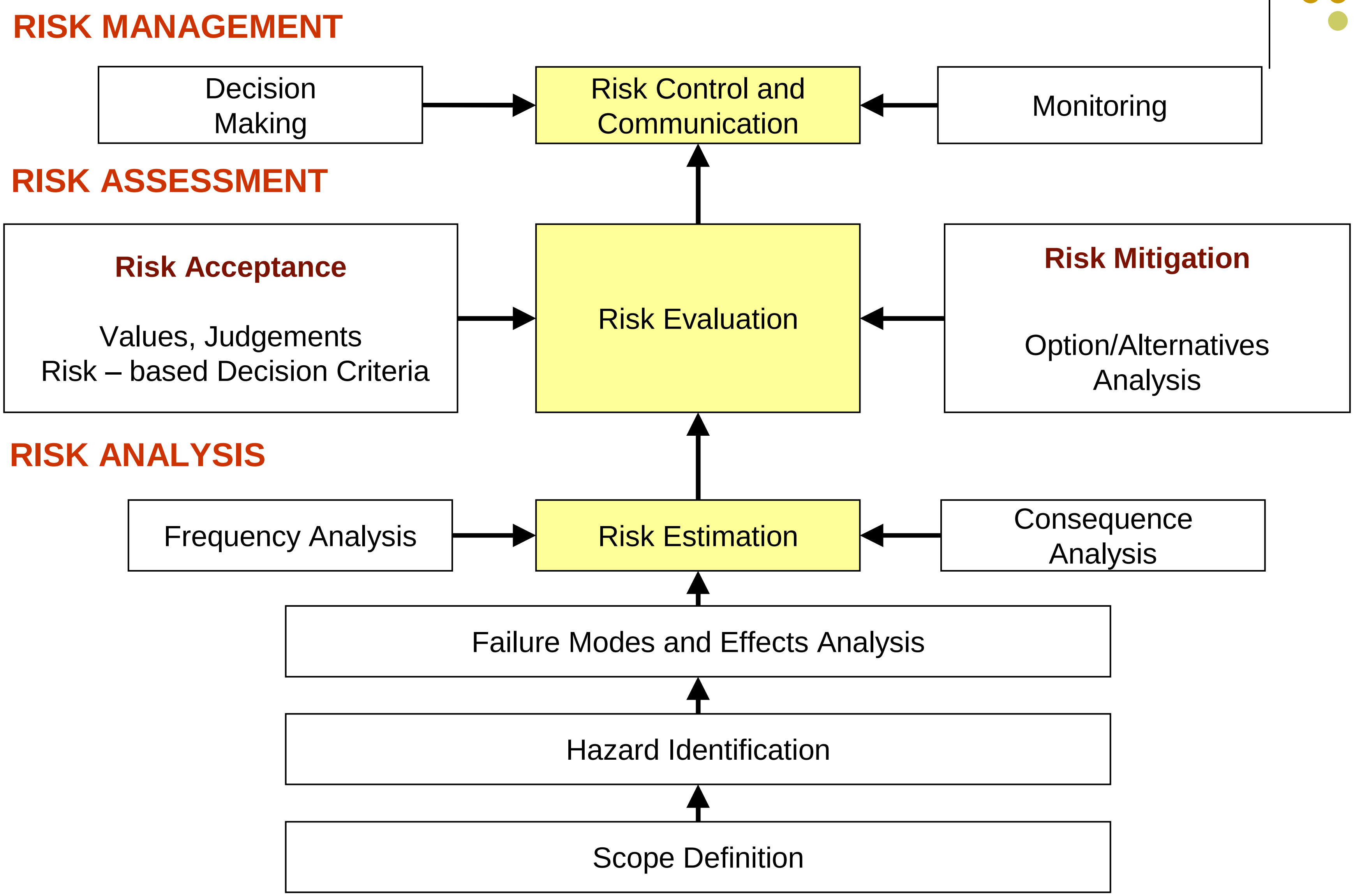
Climatology,
Probabilities,
Forecasts

social factors

Population
Urbanization
Water Technology
Land use practices
Environment degradation
Water use
Government policies

Risk Management Process

(adapted from FELL & HARTFORD, 1997)



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Drought Definitions

Most general: drought originates from a deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector.

- **Meteorological drought** – degree of dryness specified by deficiencies of precipitation and the duration of the dry period

- **Agricultural drought-** agricultural impacts resulting from deficiencies in the water availability for agricultural use

- **Hydrological drought-** significant lack of surface and subsurface water in relationship to the normal conditions over a long time period (results from meteorological drought)

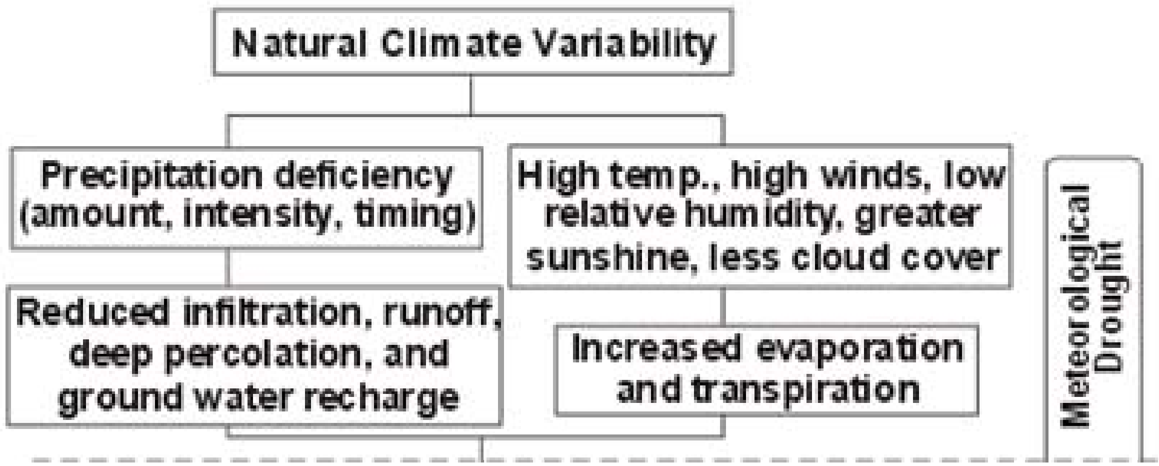
Socioeconomic Drought

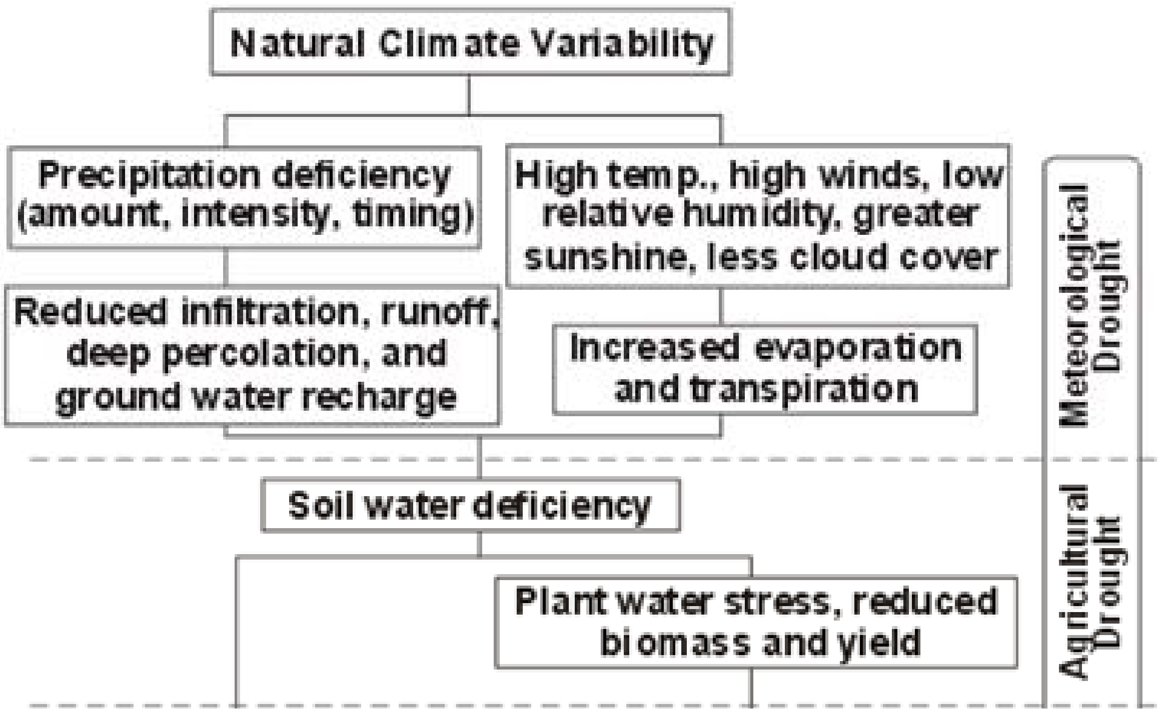
- Gap between supply and demand of economic goods such as
  - water,
  - food,
  - raw materials,
  - hydroelectric power,
  - transportation

  as a result of a weather-related shortfall in water supply

- differs from other types of drought because its occurrence depends on the time and space processes of supply and demand

Example:
If a hydrological drought reduces hydroelectric power production:
more expensive fossil fuels have to be used
energy conservation measures have to be implemented
Industrial and private consumption has to be reduced
Energy intensive production is declining.


Natural Climate Variability
Precipitation deficiency (amount, intensity, timing)
High temp., high winds, low relative humidity, greater sunshine, less cloud cover
Reduced infiltration, runoff, deep percolation, and ground water recharge
Increased evaporation and transpiration
Meteorological Drought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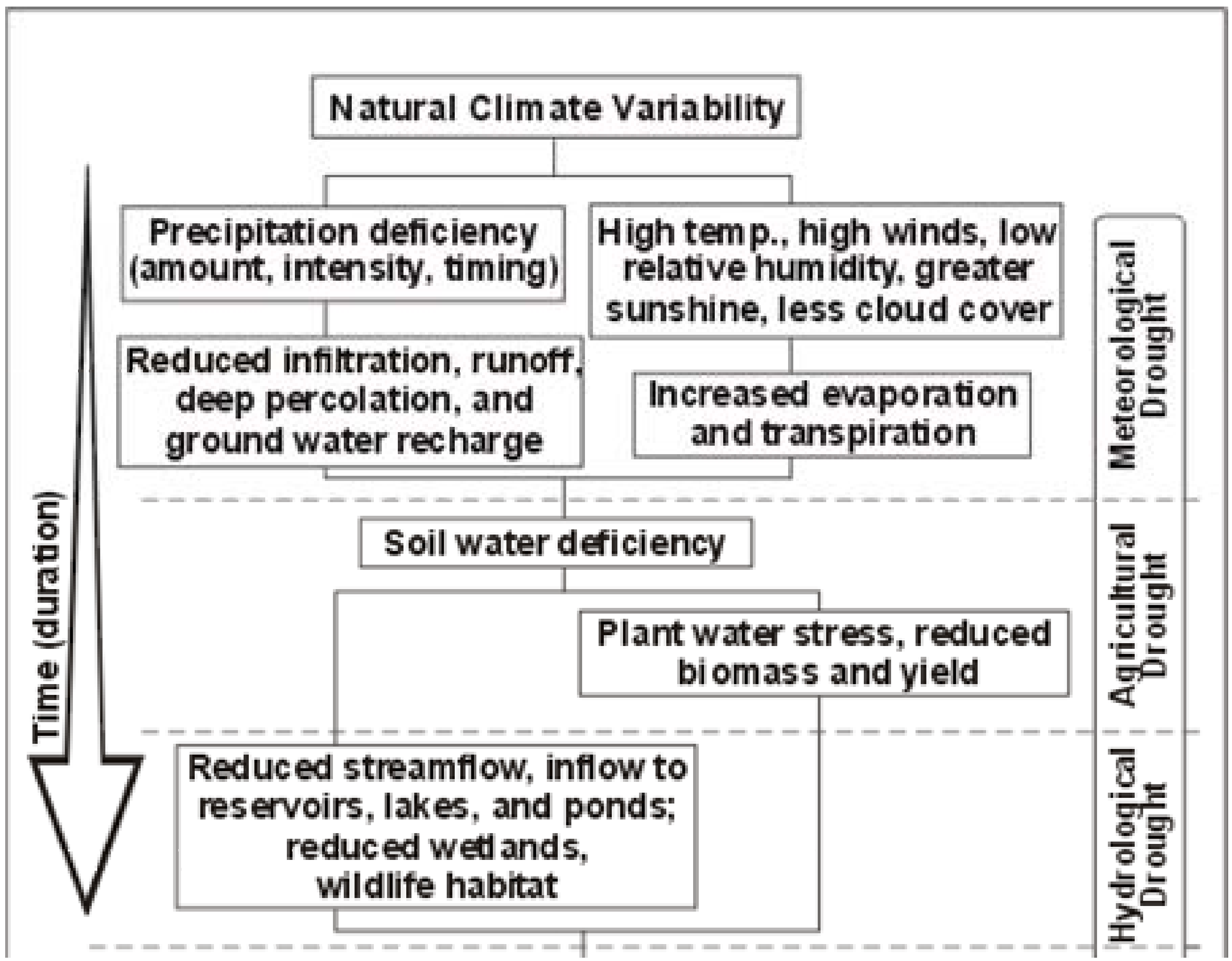
Soil water deficiency
Plant water stress, reduced biomass and yield
Meteorological Drought
Agricultural Drought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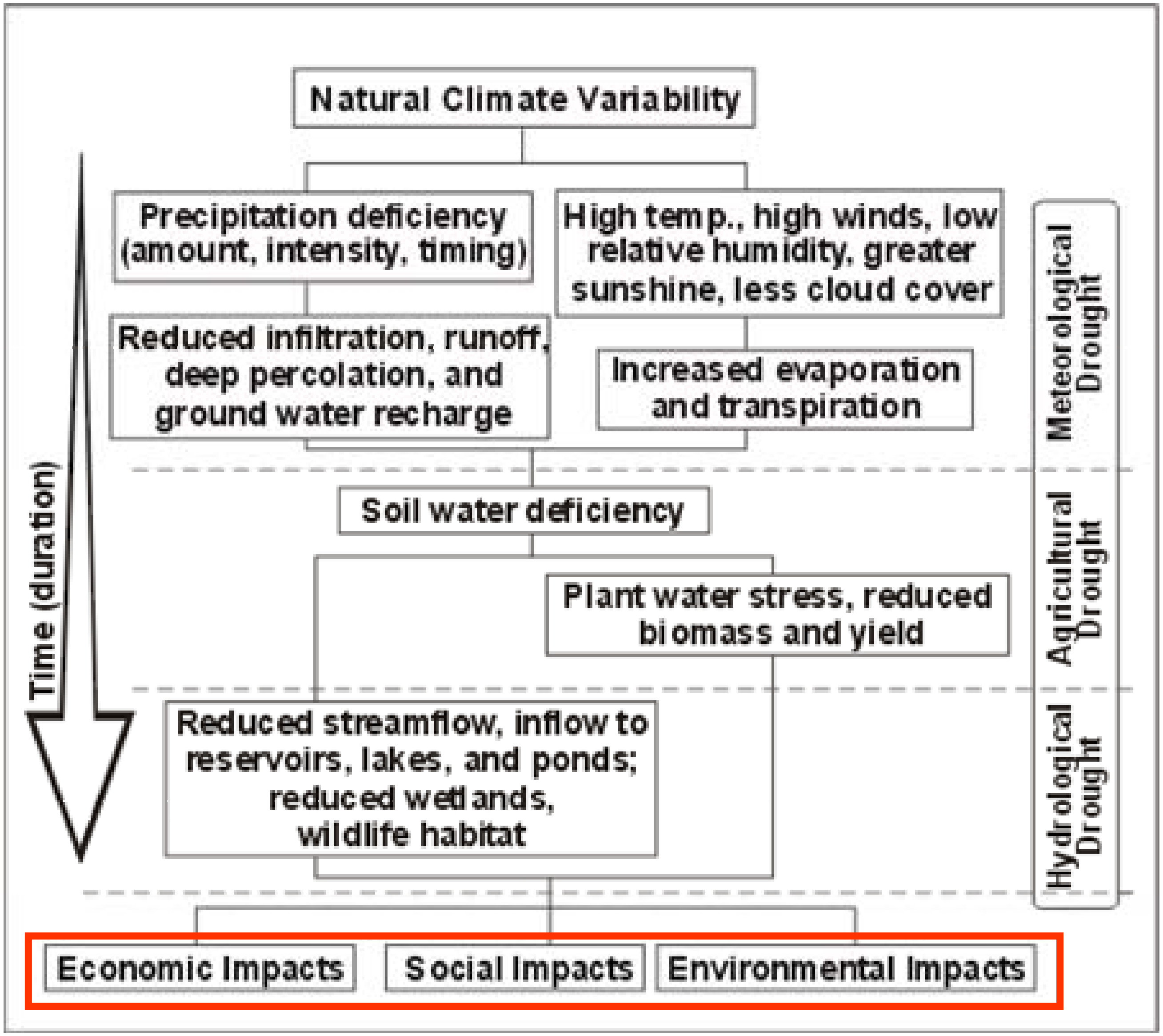
Reduced streamflow, inflow to reservoirs, lakes, and ponds; reduced wetlands, wildlife habitat
Time (duration)
Meteorological Drought
Agricultural Drought
Hydrological Drought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Economic Impacts
Social Impacts
Environmental Impacts
Time (duration)
Meteorological Drought
Agricultural Drought
Hydrological Drought

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Economic impacts
Agriculture, Forestry, Fishery

- **Additional costs and losses to agricultural producers**
  - Annual and perennial crop losses
  - Damage to crop quality
  - Income loss for farmers due to reduced crop yields
  - Reduced productivity of cropland (wind erosion, long-term loss of organic matter, etc.)
  - Plant disease
  - Increased irrigation costs
  - Cost of new or supplemental water resource development (wells, dams, pipelines)
- **Additional costs and losses to livestock producers**
  - Reduced productivity of rangeland
  - Reduced milk production
  - Forced reduction of foundation stock
  - High cost/unavailability of water for livestock
  - Cost of new or supplemental water resource development (wells, dams, pipelines)
  - High cost/unavailability of feed for livestock
  - Increased feed transportation costs
  - High livestock mortality rates
  - Disruption of reproduction cycles (delayed breeding, more miscarriages)
  - Decreased stock weights
- **Loss from timber production**
  - Wildland fires
  - Tree disease
  - Impaired productivity of forest land
  - Direct loss of trees, especially young ones
- **Loss from fishery production**
  - Loss of fish and other aquatic organisms due to decreased flows

Economic impacts

- **General economic effects**
  - Decreased land prices
  - Loss to industries directly dependent on agricultural production (e.g., machinery and fertilizer manufacturers, food processors, dairies, etc.)
  - Unemployment from drought-related declines in production
  - Strain on financial institutions (foreclosures, more credit risk, capital shortfalls)
  - Revenue losses to federal, state, and local governments (from reduced tax base)
  - Fewer agricultural producers (due to bankruptcies, new occupations)
  - Rural population loss
- **Loss to recreation and tourism industry**
  - Loss of income by reduced tourism
  - Loss to manufacturers and sellers of recreational equipment
  - Losses related to curtailed activities: hunting and fishing, bird watching, boating, etc.
- **Energy-related effects**
  - Increased energy demand and reduced supply because of drought-related power curtailments
  - Costs to energy industry and consumers associated with substituting more expensive fuels (oil) for hydroelectric power
- **Water Suppliers**
  - Revenue shortfalls
  - Cost of water transport or transfer
  - Cost of new or supplemental water resource development
- **Transportation Industry**
  - Loss from impaired navigability of streams, rivers, and canals
- **Decline in food production/disrupted food supply**
  - Increase in food prices
  - Increased importation of food (higher costs)

Environmental Impacts

- **Hydrological effects**
  - Lower water levels in reservoirs, lakes, and ponds
  - Reduced flow from springs
  - Reduced streamflow, hydro-morphological changes
  - Loss of wetlands
  - Estuarine impacts (e.g., changes in salinity levels)
  - Increased groundwater depletion, land subsidence, reduced recharge
  - **Water quality effects (e.g., salt concentration, increased water temperature, pH, dissolved oxygen, turbidity)**
- **Damage to animal species**
  - Reduction and degradation of fish and wildlife habitat
  - Greater mortality due to increased contact with agricultural producers, as animals seek food from farms and producers are less tolerant of the intrusion
  - Disease
  - Increased vulnerability to predation (from species concentrated near water)
  - Migration and concentration (loss of wildlife in some areas and too many wildlife in other areas)
  - Increased stress to endangered species
  - Loss of biodiversity
- **Damage to plant communities**
  - Loss of biodiversity
  - Loss of trees from urban landscapes, shelterbelts, wooded conservation areas

Social Impacts

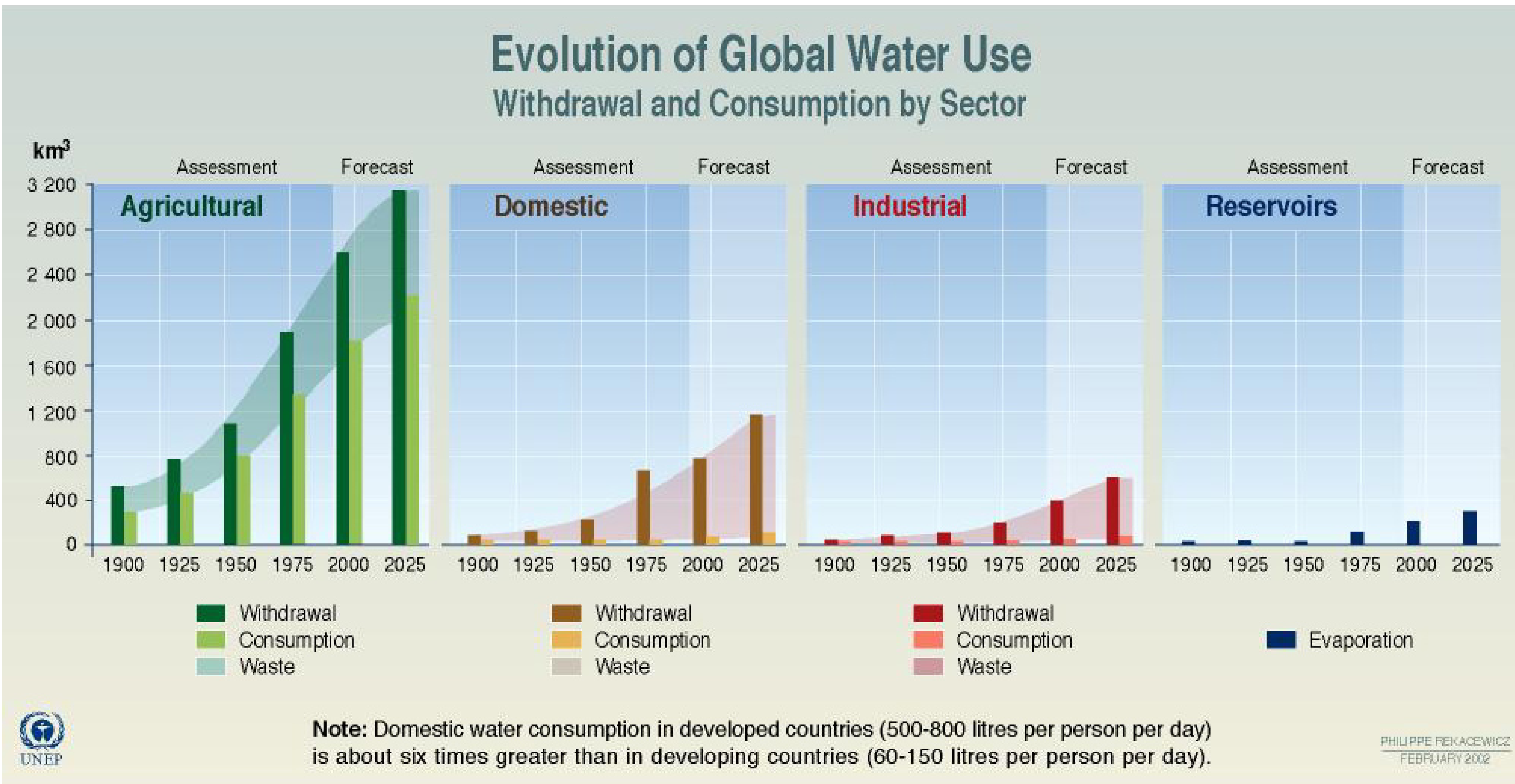
- **Health**
  - Mental and physical stress (e.g., anxiety, depression, loss of security, domestic violence)
  - Health-related low-flow problems (e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations, reduced fire fighting capability, etc.)
  - Reductions in nutrition (e.g., high-cost food limitations, stress-related dietary deficiencies)
  - Loss of human life (e.g., from heat stress, suicides)

- **Increased conflicts**
  - Water user conflicts
  - Political conflicts
  - Management conflicts
  - Other social conflicts

- **Reduced quality of life, changes in lifestyle**
  - Increased poverty in general
  - Population migrations (rural to urban areas, migrants into other countries)

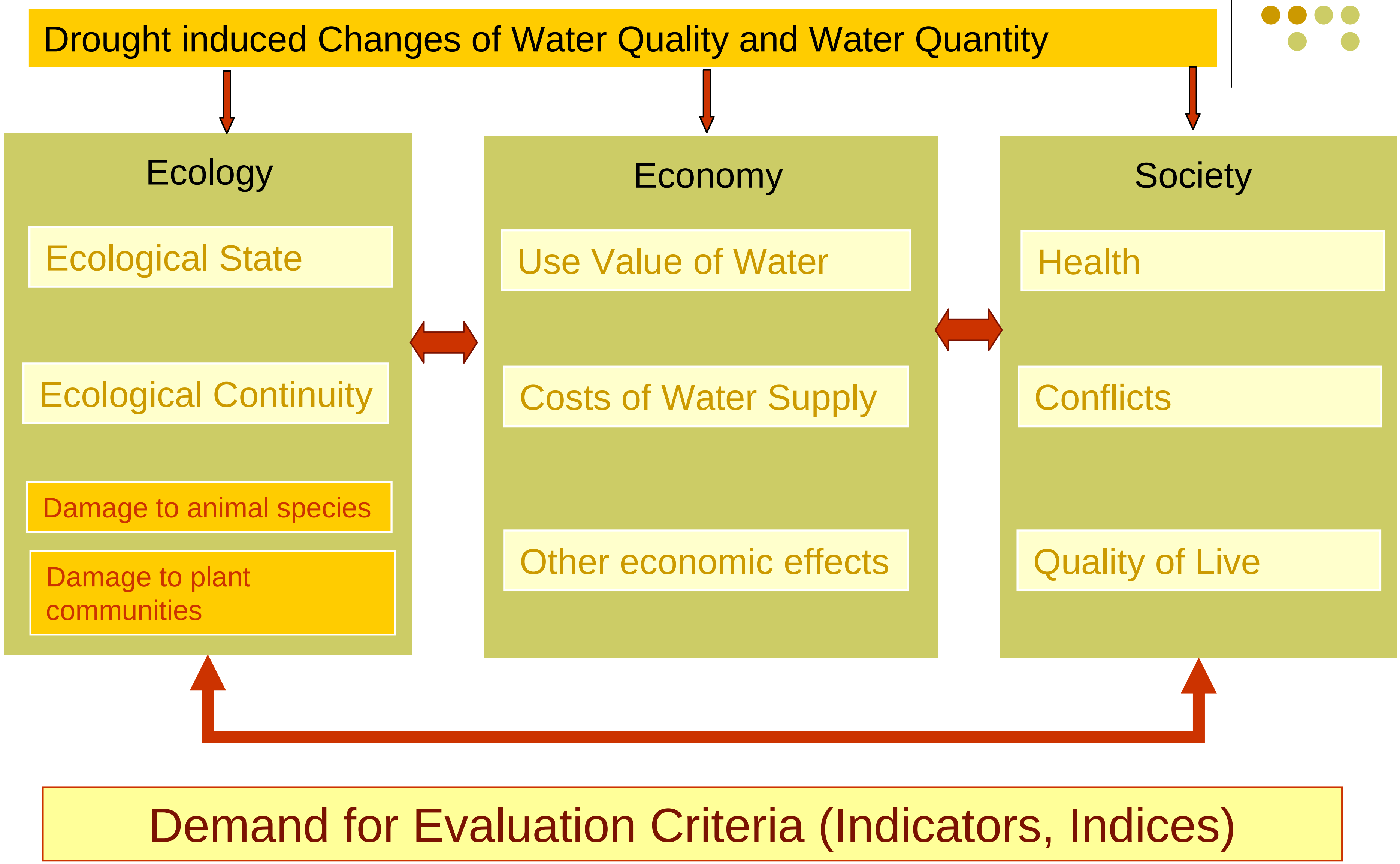
Trends in Drought Impacts

- Impacts are increasing in response to growing vulnerability resulting from increased pressure on limited water resources, increasing population etc.
- Post-impact response increases vulnerability.



Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999.

Interdependencies of Impacts



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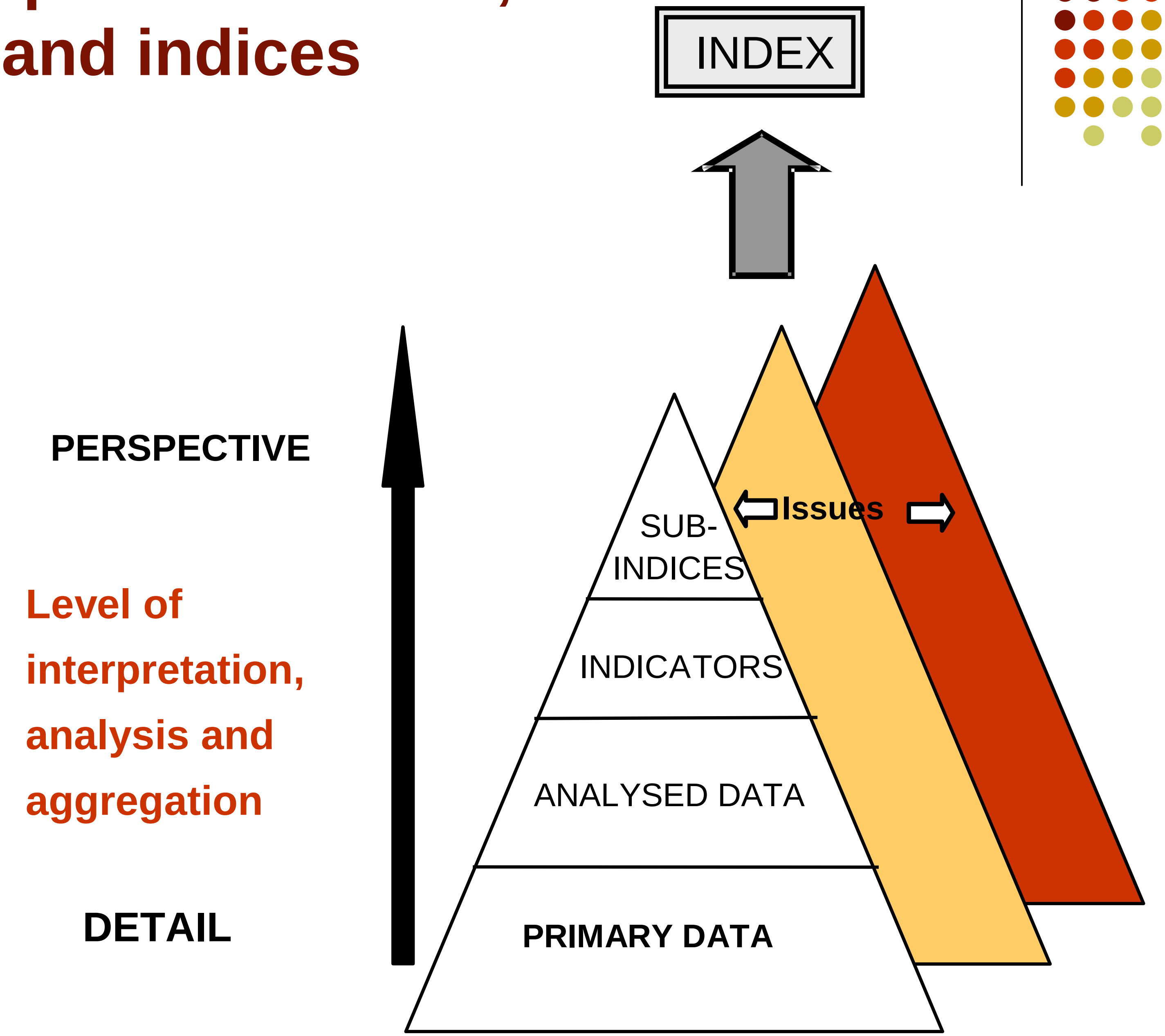
Relationship between data, indicators and indices

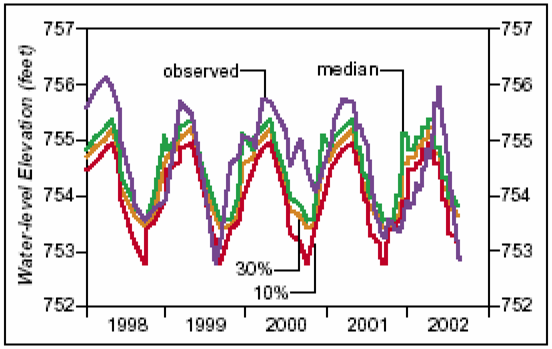


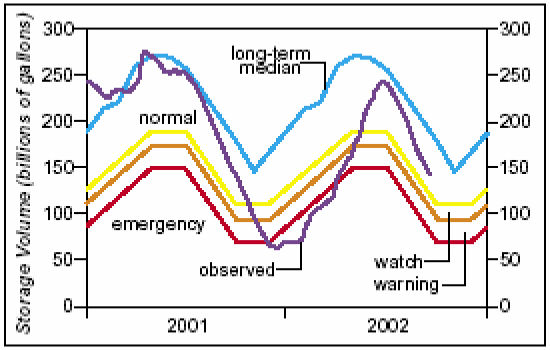
Primary Data for Meteorological, Agricultural or Hydrological Drought Indicators

- Climate variables (e.g., precip., temp.)
- Reservoir and lake levels
- Soil moisture
- Ground water
- Snow pack
- Stream flow
- Vegetation

Common Meteorological, Agricultural or Hydrological Drought Indices

- Percent of Normal
- Deciles
- Palmer Drought Index
  - PDSI, PHDI, CMI
- Surface Water Supply Index
- Standardized Precipitation Index
- Vegetation indices (NDVI, VCI, SVI)
- U.S. Drought Monitor
  - Composite index approach





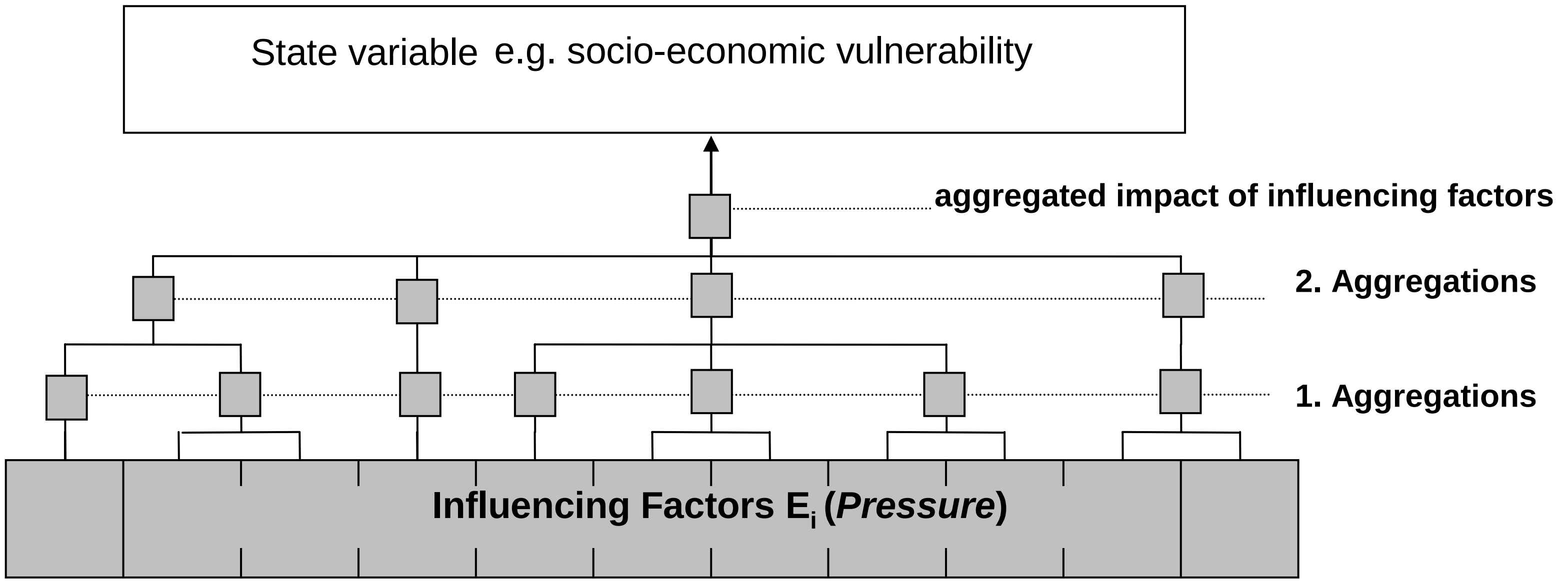
Problems to define Drought Impact Indicators

- **Creeping phenomena**
- **Spatial Heterogeneity**
- **Severity**
- **Vulnerability**
- **Long-Term Variability**
- **Averaging**
  - Often temporal averages instead of critical periods
  - Often local problems are hidden by spatial averaging

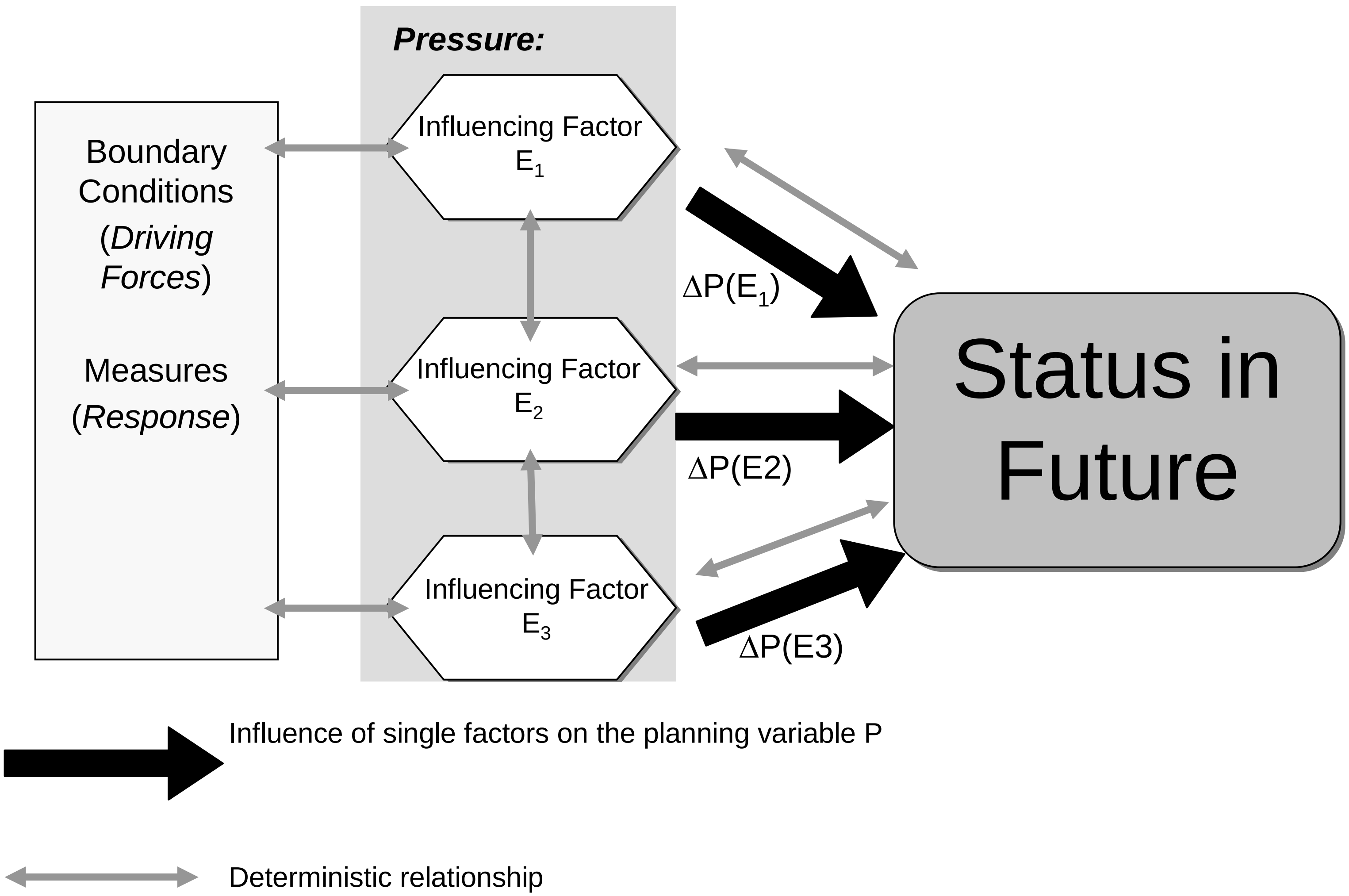
RISK ASSESSMENT

Risk Acceptance Values, Judgements Risk – based Decision Criteria	→	Risk Evaluation	←	Risk Mitigation Option/Alternatives Analysis

Indicators have to be related to influencing factors



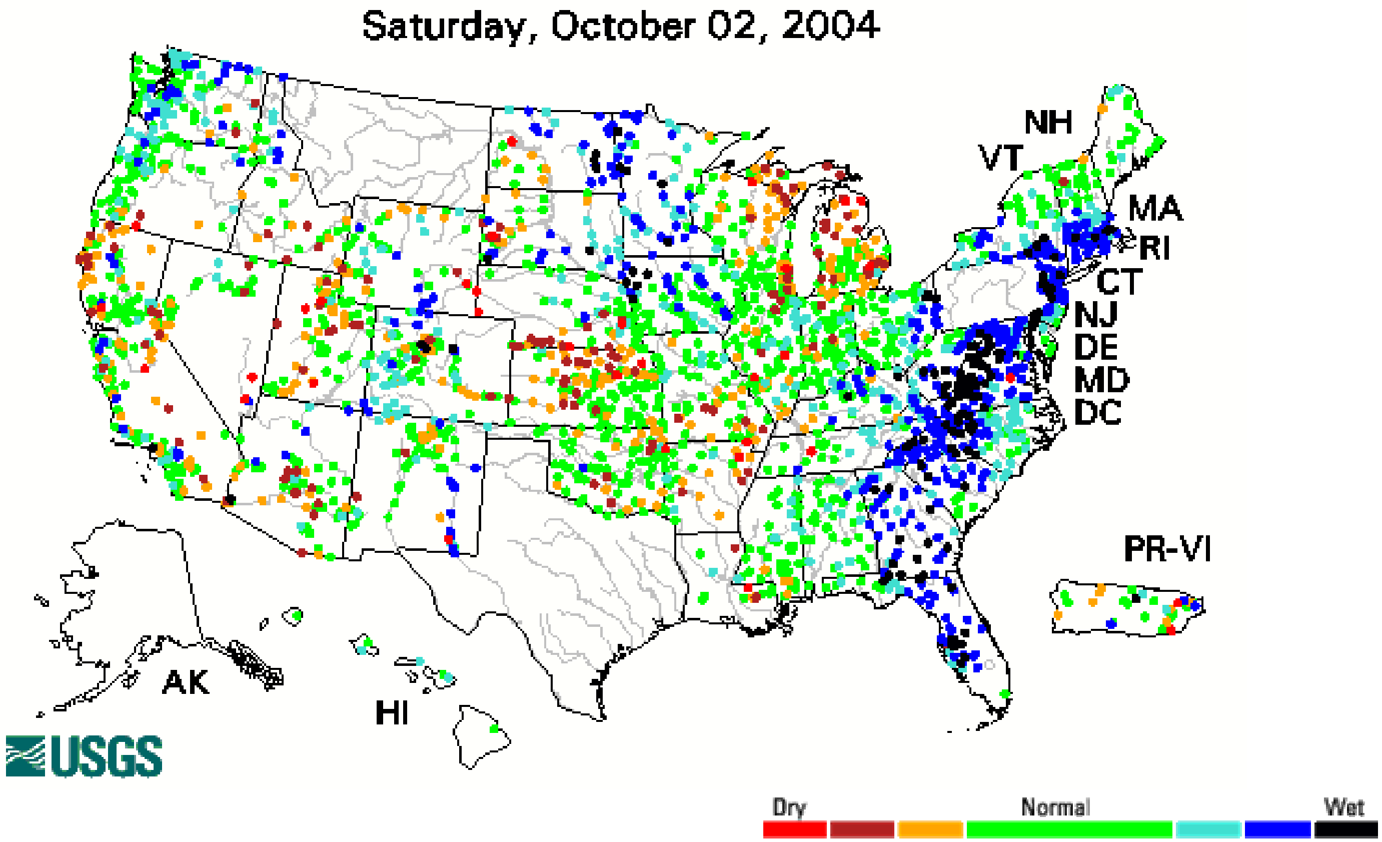
Effects of future developments of pressures should be reflected



Aggregation in Space and Time

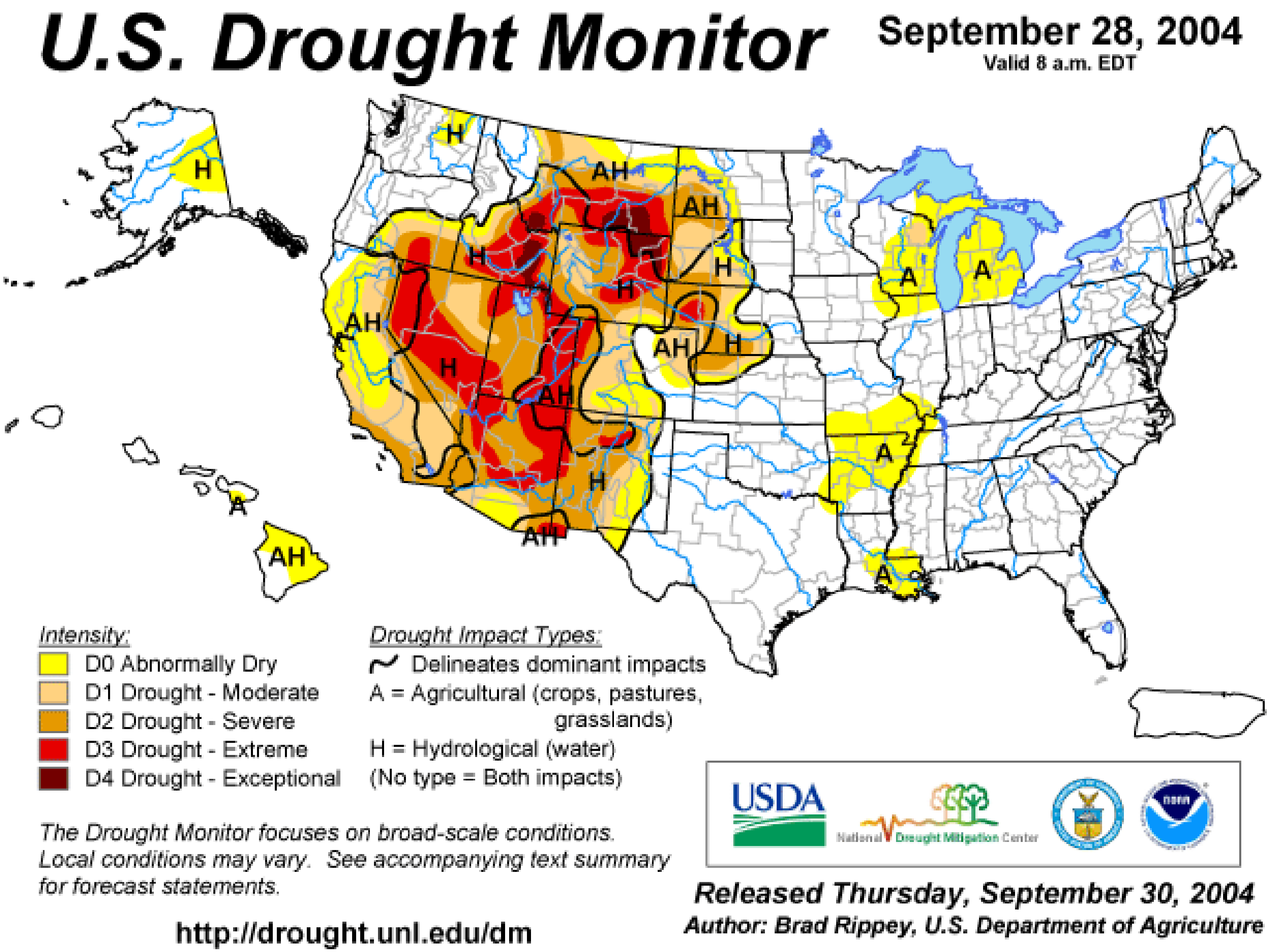
- **Frequencies (risks, reliabilities)**
- **Durations**
- **Spatial Extent**

As impacts differ within and between spatial scales, risk indicators should reflect who and what is at risk and why.



Explanation - Percentile classes						
●	●	●	●	●	●	●
New low	< 10	10 - 24	25 - 75	76 - 90	> 90	New high

USGS: Map of 7-day average streamflow compared to historical streamflow for the day of the year (United States)


U.S. Drought Monitor
September 28, 2004
Valid 8 a.m. EDT
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
A = Agricultural (crops, pastures, grasslands)
H = Hydrological (water)
(No type = Both impacts)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
http://drought.unl.edu/dm
USDA
National Drought Mitigation Center
Released Thursday, September 30, 2004
Author: Brad Rippey, U.S. Department of Agriculture

Risk, Reliability Vulnerability – indicators to characterize temporal variability

- **Reliability**

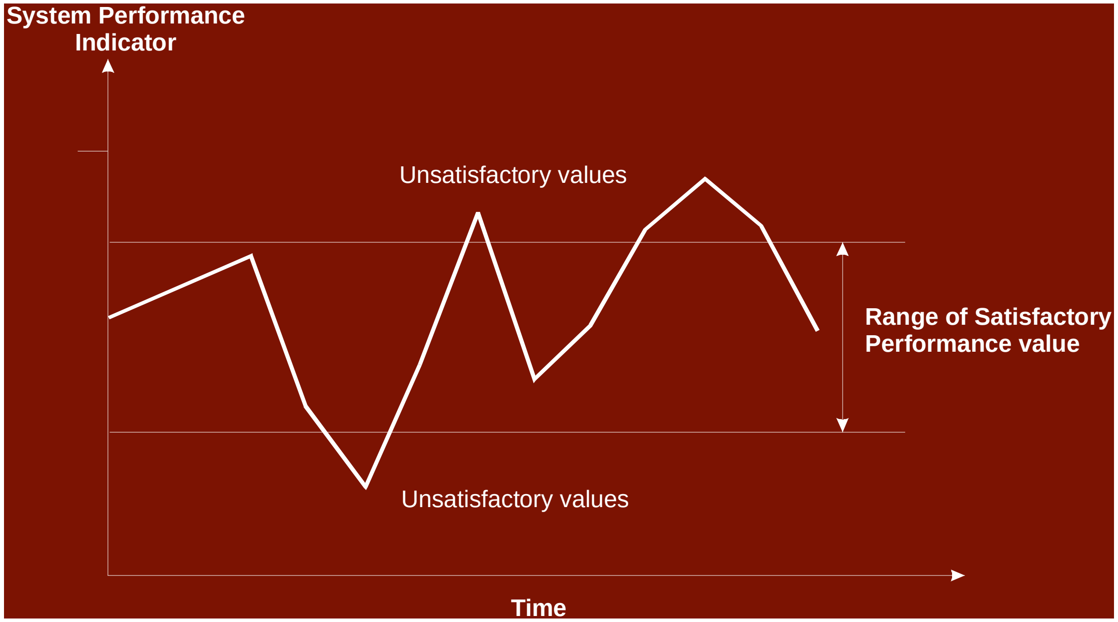
  probability that a criterion value stays within a predefined range of satisfactory values

- Resilience

  number of times a satisfactory value follows an unsatisfactory value related to the total number of all time steps

- Vulnerability

  statistical measure of the extent or duration of failure



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Actions to mitigate drought impacts

- Monitoring and assessment
- Water augmentation/reuse
- Public awareness/education
- Demand reduction/water conservation
- Water use conflict resolution
- Legislation

Information needed to define mitigation strategies

Data Management and Analysis

- **Supply Augmentation**
  - **Water transfer (inter/intra-basin)**
    - **Existing Transfer**
    - **Possible Conflicts**
    - **Costs**
    - **Degree of utilization**
    - **Availability of local resources**
  - **Improved storage**
    - **Existing Storage Capacity**
    - **Reliabilities**
    - **Cost- Benefits**
  - **Desalination**
    - **Costs**
  - **Water re-use**
    - **Costs**
    - **Technical feasibility**
    - **Social aspects**

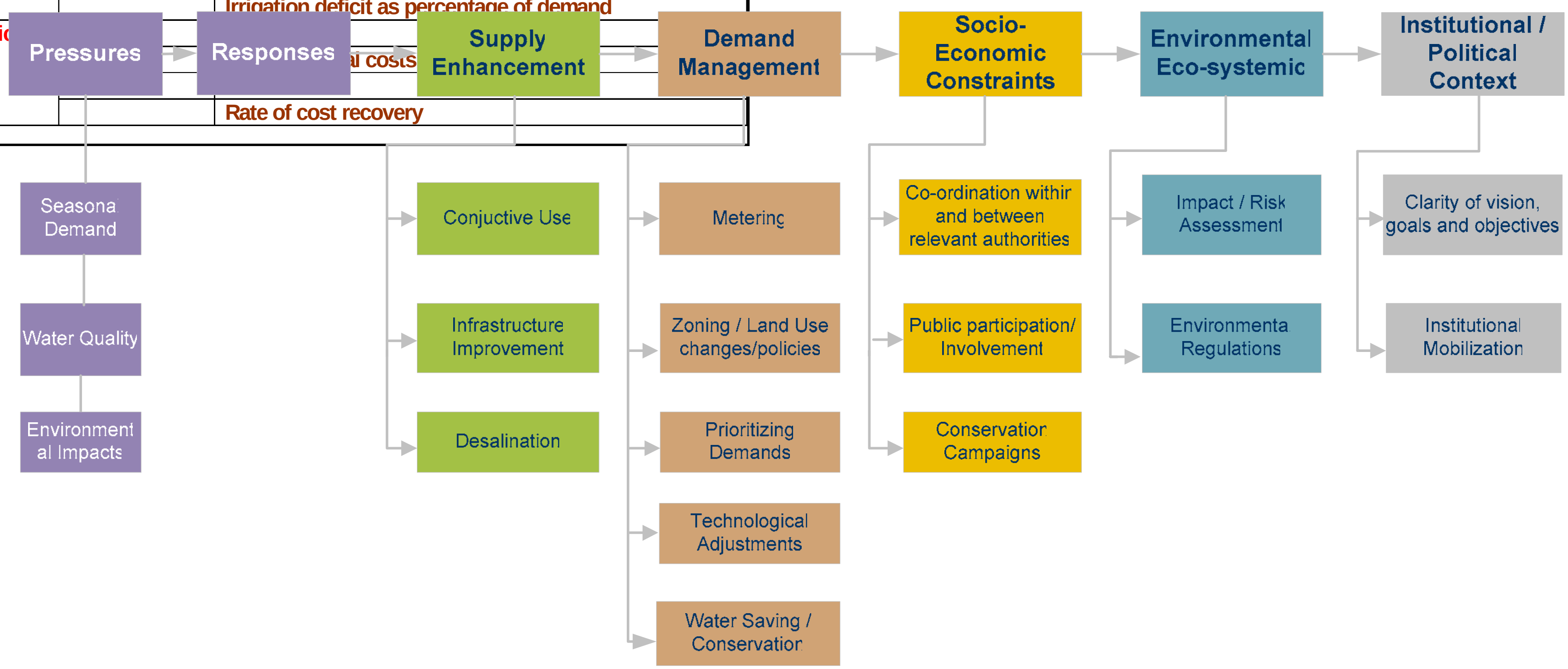
- **Demand Management**
  - **Existing Water Use Efficiency**
    - **Ownerships**
    - **Infrastructure**
    - **Efficiency of water use**
  - **Economic incentives**
    - **Political System**
    - **Ownerships**
    - **Control of water use**
  - **Polluter-pays-principle**
    - **Control**
    - **Social aspects**

- **Socio-Economic Options**
  - **Public participation**
  - **Effects of conservation campaigns**
  - **Environmental standards**

- **Environmental Options**
  - **Environmental standards**
    - **Ecological status**
    - **pressures**
  - **Enforcement of existing legislation**
  - **Impact assessment**
    - **modelling**
    - **experience**
  - **Legal and administrative mandates**
    - **Stakeholders**

WSM DSS- Approach for Water Management Planning

		Indicator
Environment Resources	Exploitation	Total Water production
		Groundwater exploitation index
		consumption index
		Non-sustainable gw production
	Dependencies	Dependence on inter-basin water transfer
		Anthropogenic water produced/total water production
	Water quality	Percentage of treated urban water
		Share of primary treatment
		Share of secondary treatment
		Share of tertiary treatment
Social Indicators	Pressures	Agricultural demand per ha
		Tourist per inhabitant
		Water abstractions per capita
	Deficits	Domestic deficit as percentage of demand
		Industrial deficit as percentage of demand
		Environmental deficit as percentage of demand
		Hydropower deficit as percentage of demand
		Irrigation deficit as percentage of demand
Economic		
		...al costs
		Rate of cost recovery



Thank you for your attention !