FLORIDA A&M UNIVERSITY

VISTA and CISTA frameworks for vulnerability assessments in food-water nexus

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NSF's NRT Grant No. 1735235

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

Outline – VISTA & CISTA frameworks – food/water …

Background (Who cares & why?) → **Methodology** (VISTA/CISTA) → **Results Summary**

Contents lists available at ScienceDirect

Journal of Hydrology 557 (2018) 460–474

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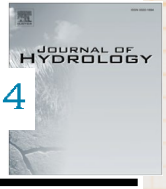
journal homepage: www.elsevier.com/locate/jhydrol



Research papers

Vulnerability assessment of water resources – Translating a theoretical concept to an operational framework using systems thinking approach in a changing climate: Case study in Ogallala Aquifer

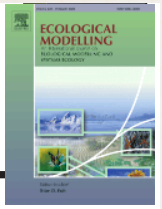
Aavudai Anandhi [a,b,*], Narayanan Kannan [c]

Contents lists available at ScienceDirect

Ecological Modelling 345 (2017) 41–55

ELSEVIER

journal homepage: www.elsevier.com/locate/ecolmodel



CISTA-A: Conceptual model using indicators selected by systems thinking for adaptation strategies in a changing climate: Case study in agro-ecosystems

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Change can be uncertain and unknown

Increasing population, urbanization

Limited resources

More food

More water

Impacting essential resource – food, water, energy…

Vulnerable and creating a need to adapt/mitigate…

Utilize the benefits of change/reduce the harmful effects…

Conceptual models…

- Collate, visualize, understand and explain the issues and problems relating to actual or predicted situations and how they might be solved.

- organizational diagrams, which bring together and summarize information in a standard, logical and hierarchical way.

Patrício etal 2016

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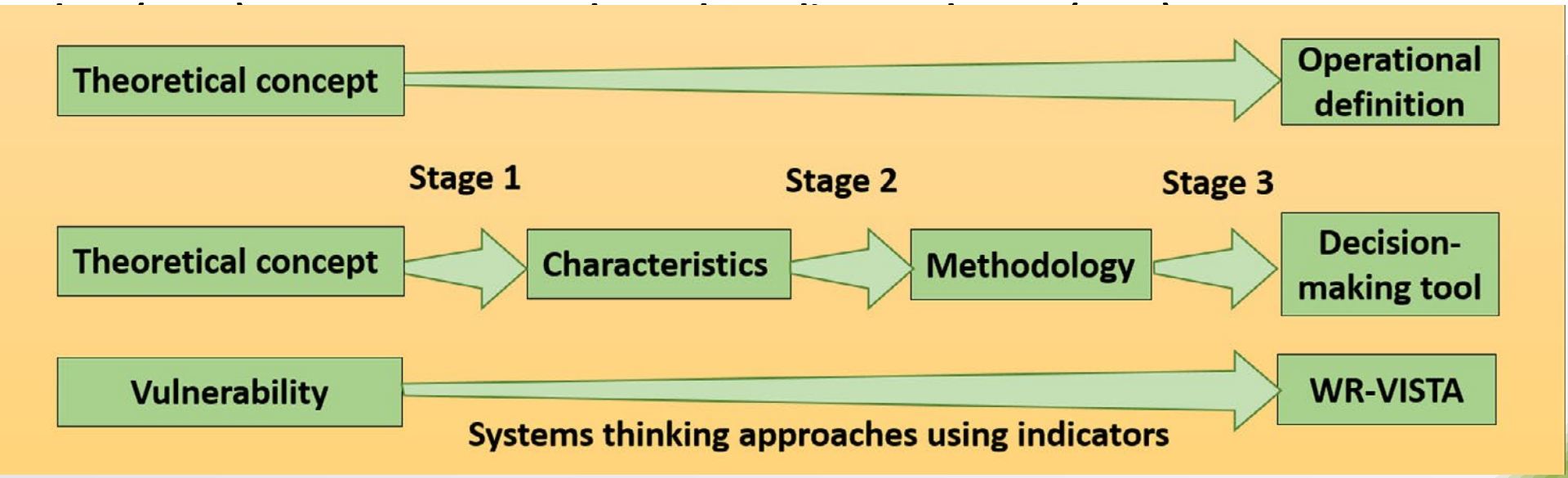
VISTA: Vulnerability assessment conceptual model using Indicators selected by System's Thinking Approach

Vulnerability – "the degree to which the system is susceptible to and is unable to cope with adverse effects of change" - IPCC



Stage 1

Characteristics Examples of characteristic from literature

Stage 1

Theoretical concept → **Characteristics**

Characteristics

- Target system/unit
- System division into components
- Spatial scale(s)
- Temporal scale(s)
- Level of detail
- Data source
- Framework(s)
- Indicator
- Normalization
- Weights
- Aggregation

Stage 2

Characteristics → **Methodology**

Characteristics

- Target system/unit
- System division into components
- Spatial scale(s)
- Temporal scale(s)
- Level of detail

Step 1

Step 2

Step 3

Step 4

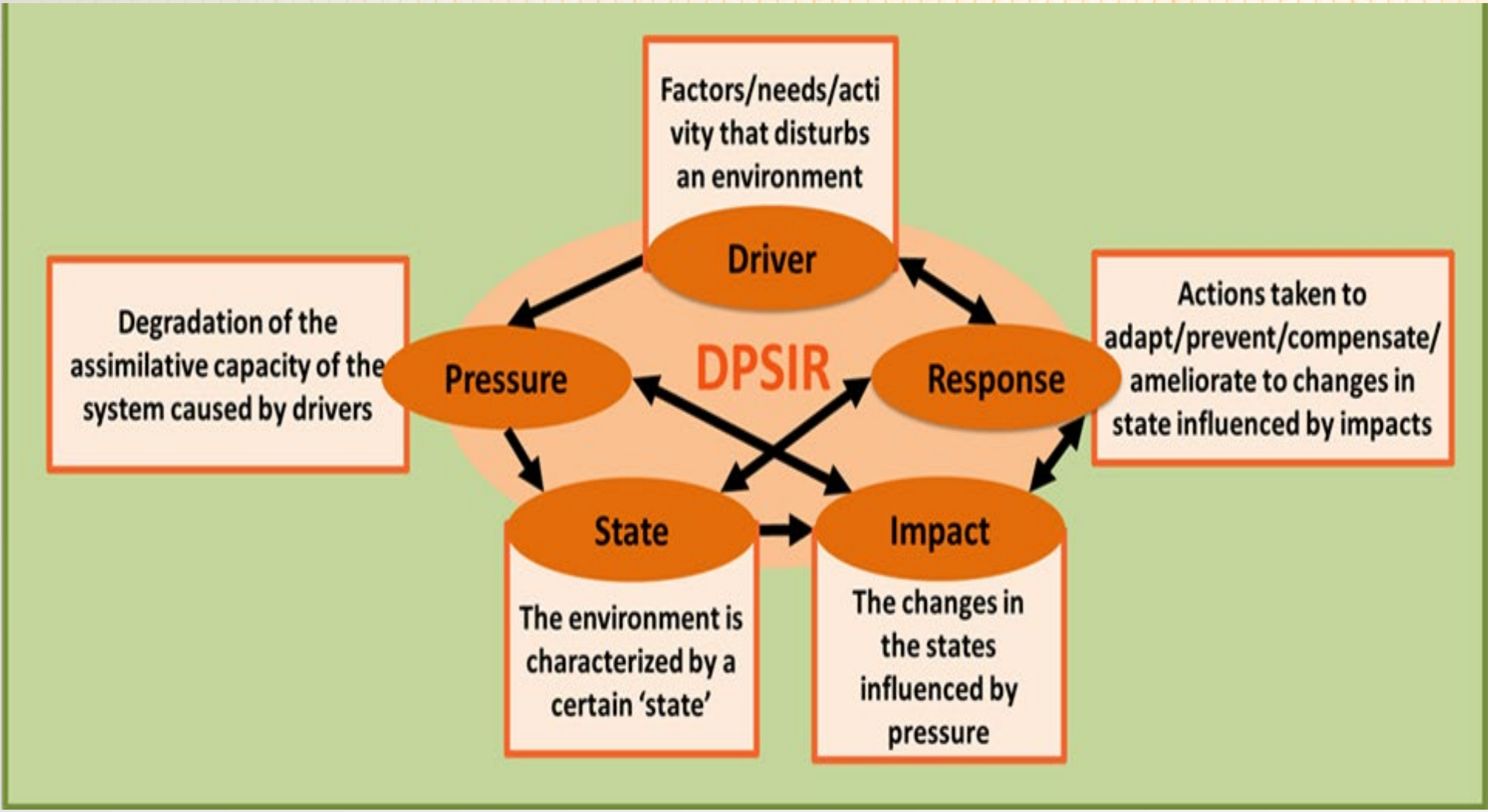
Step 5

Step 6

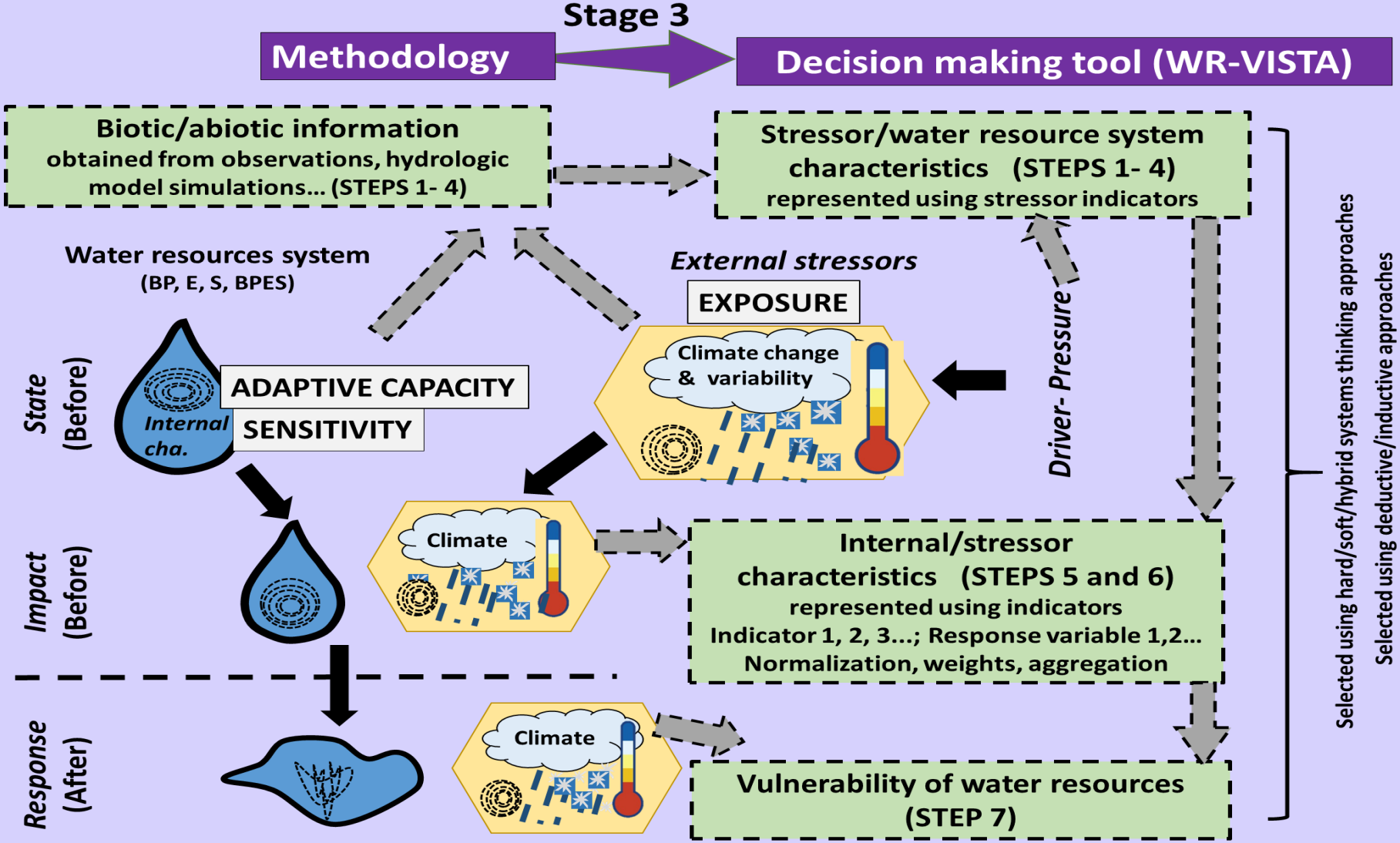
Step 7

- Data source
- Framework(s)
- Indicator
- Normalization
- Weights
- Aggregation
- Develop vulnerability index

Step 5: Frameworks



IPCC Vulnerability = *f* (exposure, sensitivity, adaptive capacity)



WR-VISTA : Modeling tool

IPCC - Framework (grey solid box-capital text): Exposure, Sensitivity, Adaptive capacity

DPSIR - Framework (Italics text): *Driver-Pressure-State-Impact-Response;*

Drop - Target system (water resource system); Hexagon – Stressors (climate change & variability);

Dotted spiral - characteristics of stressor & water resource system;

Black arrows - conceptual model flow; Dotted grey arrow/green box – estimation method

Adapted from Anandhi et al., 2016, Bar et al. 2015; Gallopin, 2006.

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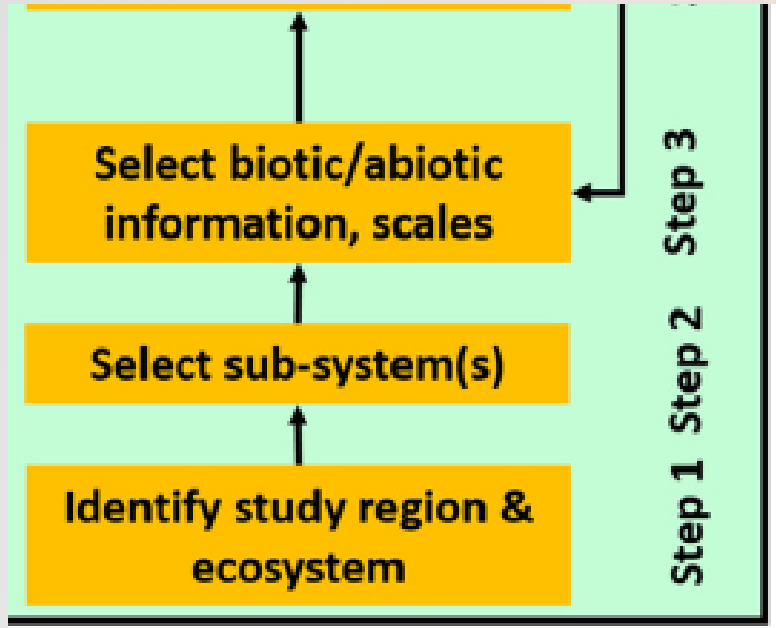
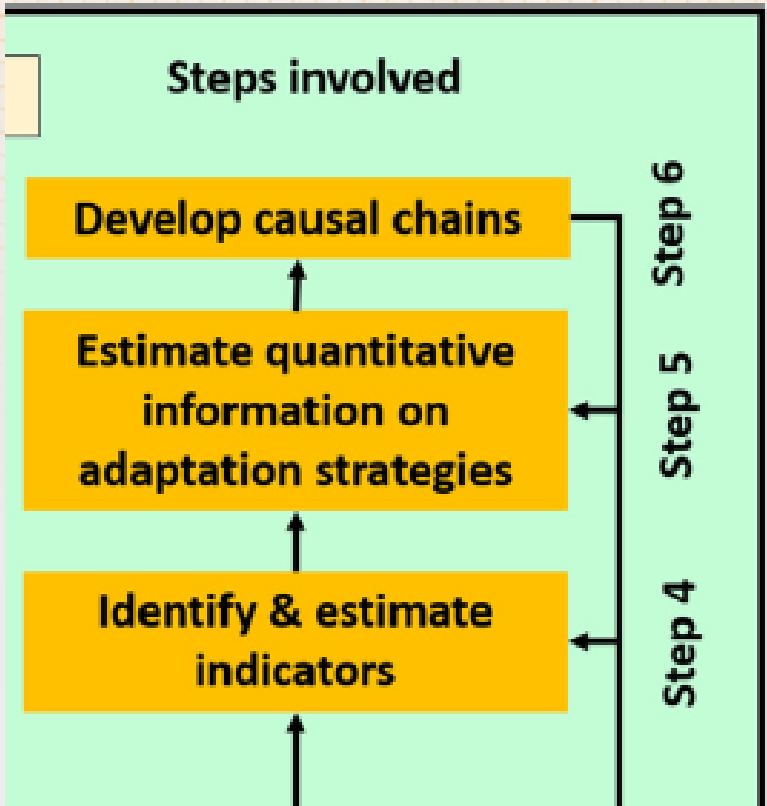
CISTA: Conceptual model using Indicators selected by System's Thinking Approach for agroecosystems





CISTA-A

Triple complexity-adaptation of AS in a changing climate

End Layer

Levels of adaptation (quantitative adaptation strategies)

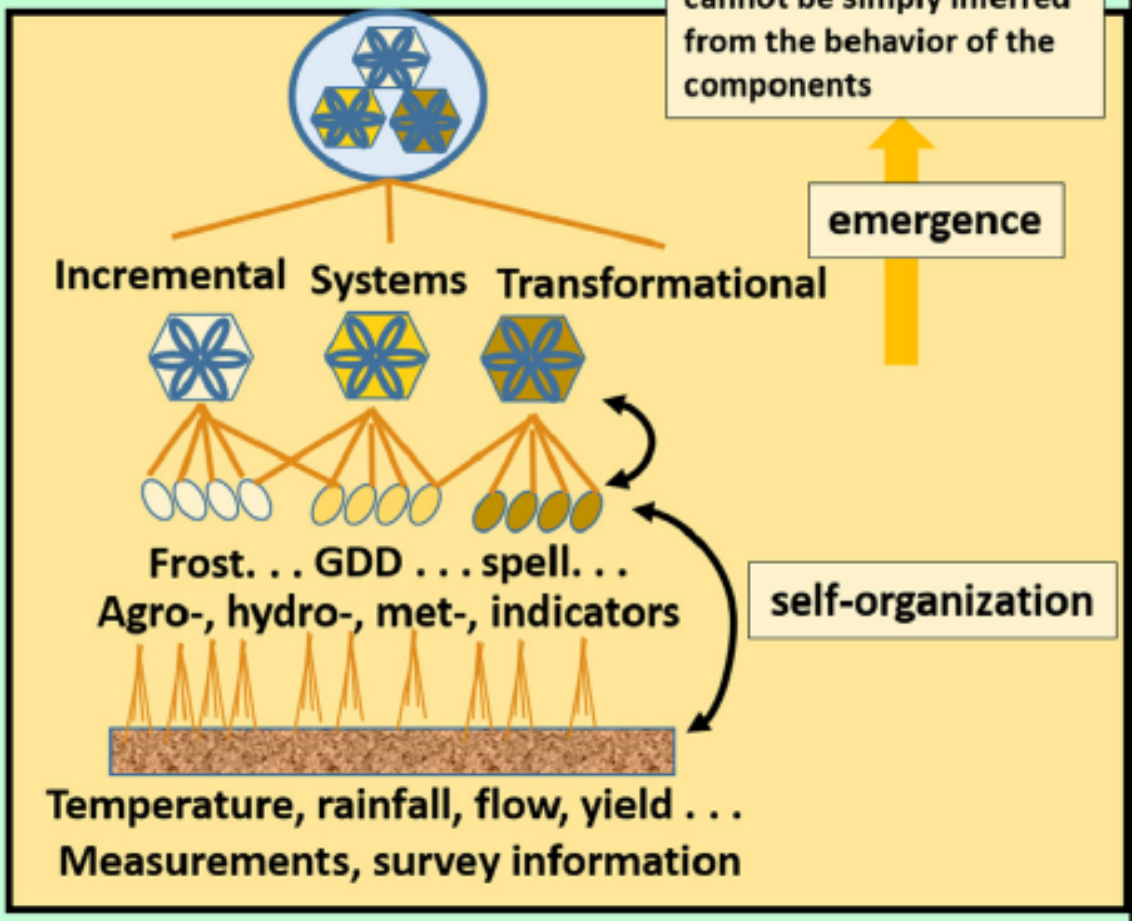
Intermediate Layer

Components (indicators)

Base Layer

Elements (biotic/abiotic information)

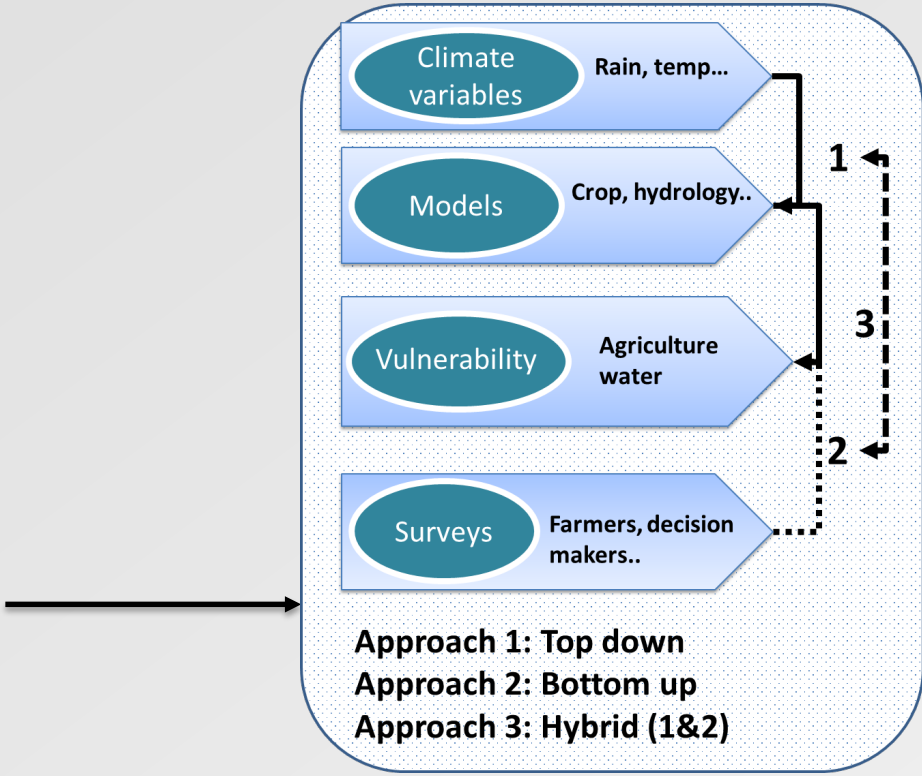
Multiple spatial & time scales



Indicators

Tools

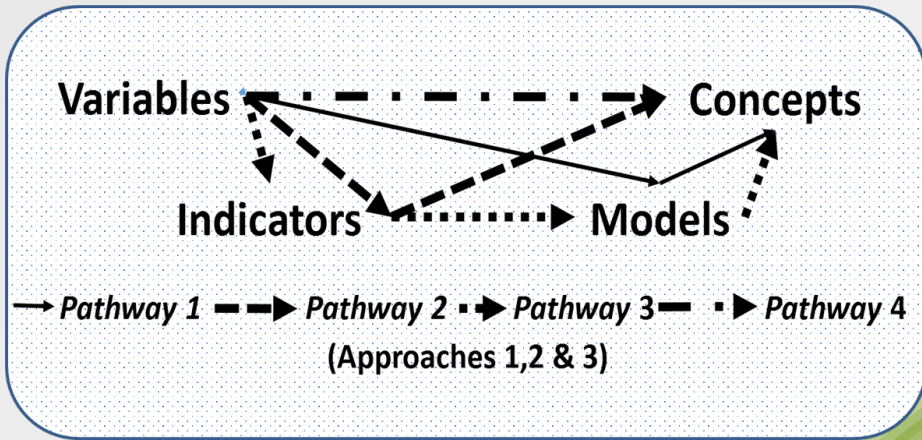
Interrelationships



Spell/ Duration

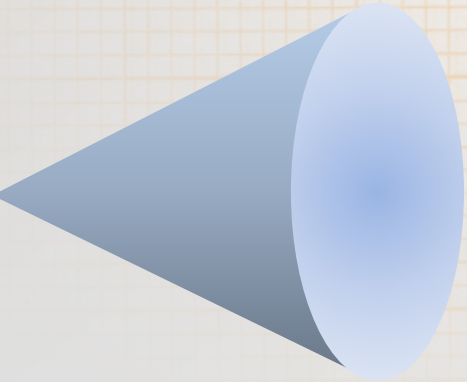
CC Impacts

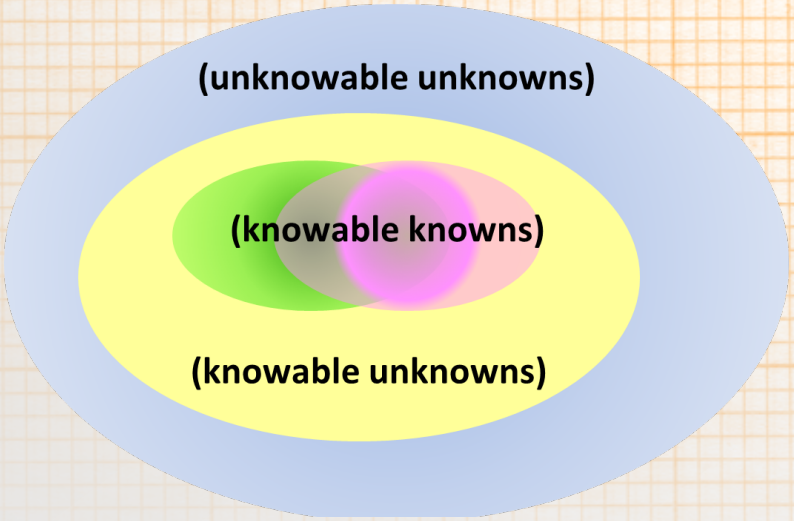
Frost



Climate (C) → **Indicators *f* (.)** → **Analysis** → **Complexity**

Scenario funnel





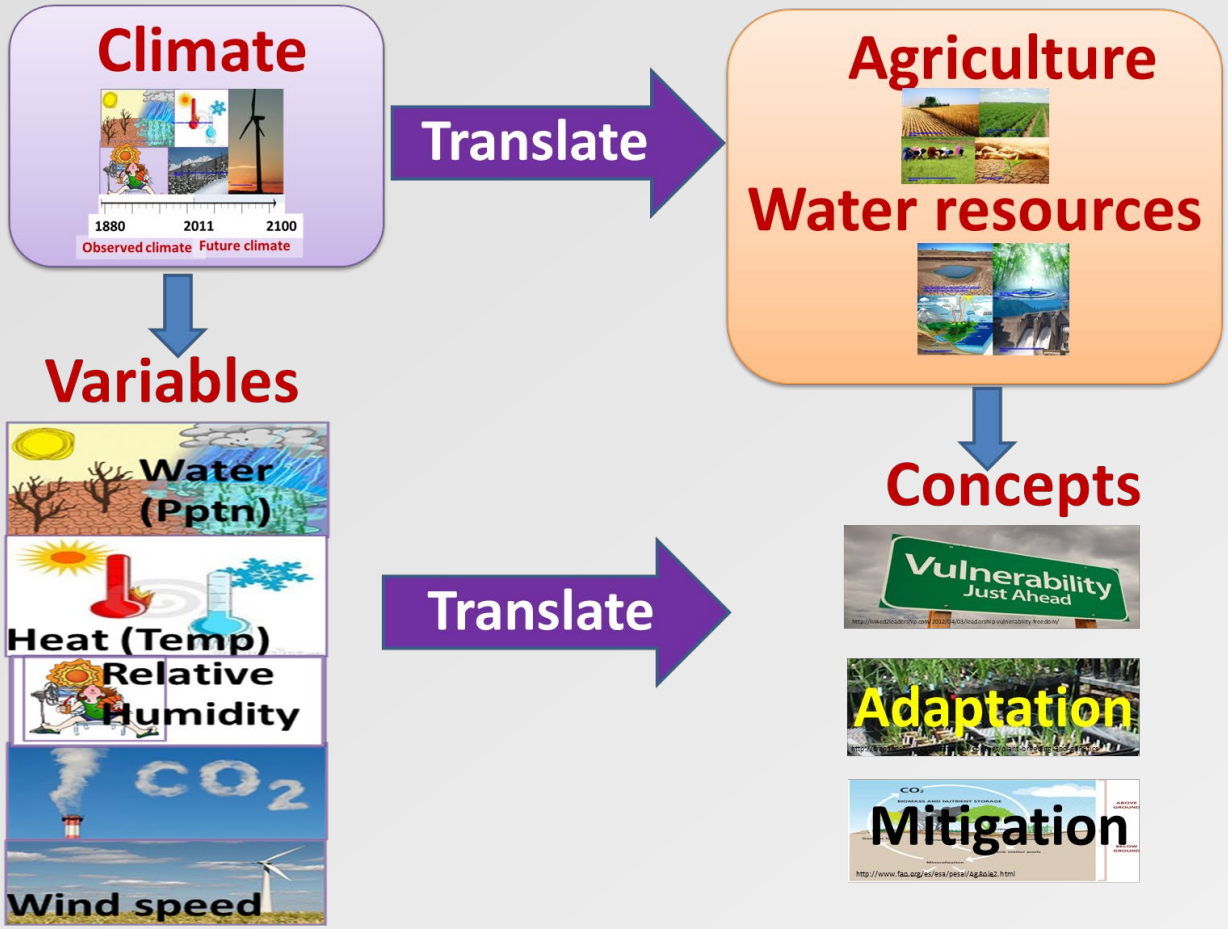
$$EI_i = \frac{\text{Average value of } CF \text{ for } a \text{ period}}{\text{The actual value of } CF \text{ for } a \text{ year}} = \frac{\dfrac{\sum_{k=1}^{Ns} W_{k,j} \sum_{j=1}^{Nc} \sum_{i=1}^{Ny} C_{k,j,i}}{Ny}}{C_{k,j,i}}$$

Rainfall (r)
Temperature (t_{min} , t_{ave}, t_{max}) → ***f*** **(r, t_{mix} , t_{ave} t_{max}.....)** → ***Trends, uncertainty, scenarios***

Vulnerability – "the degree to which the system is susceptible to and is unable to cope with adverse effects of change"

Adger (2006)-Intergovernmental Panel on Climate Change (IPCC)

….. A theoretical concept



Outline – VISTA & CISTA frameworks – food/water …

Background
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Methodology
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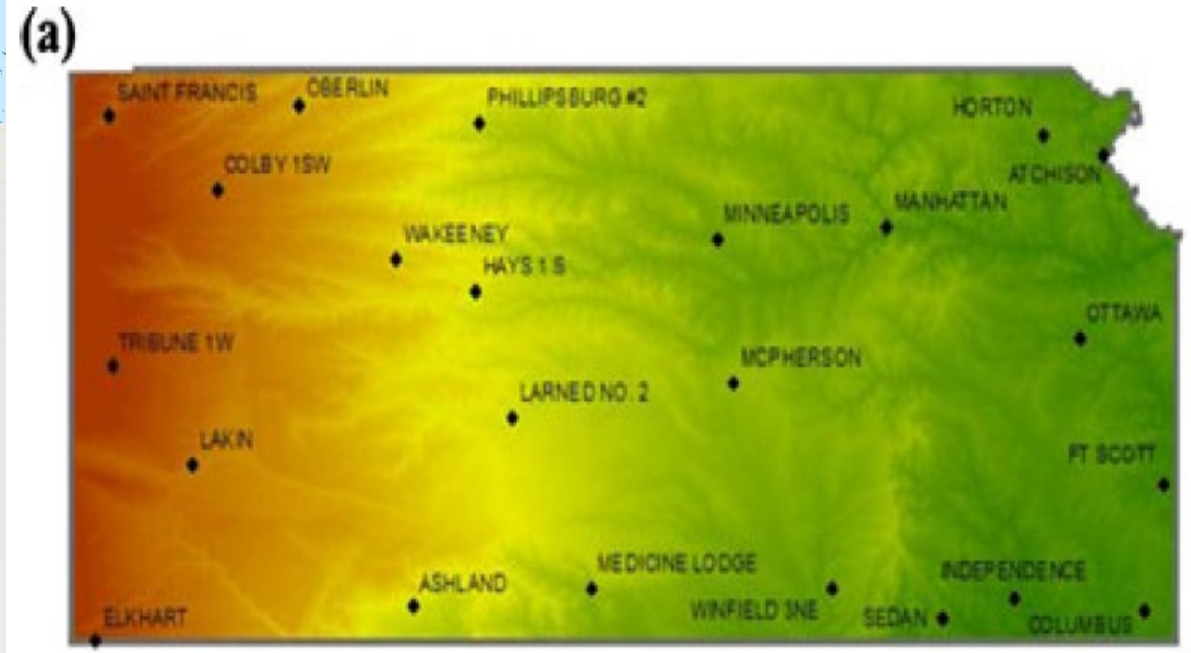
Results
Summary

Study region: **Kansas, USA**



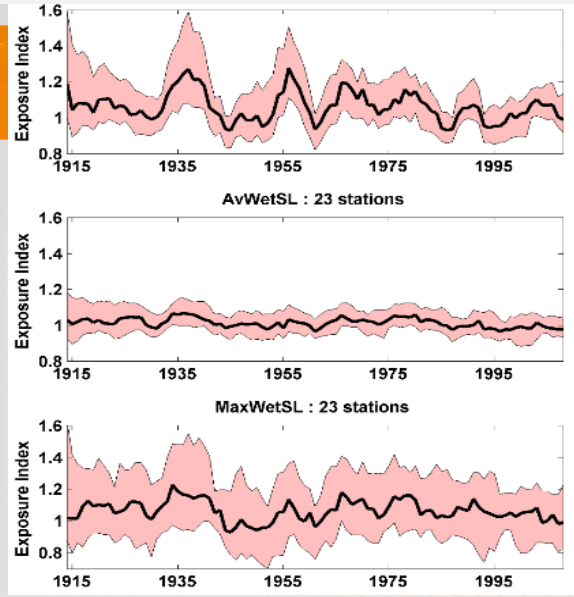
Data: Kansas, USA

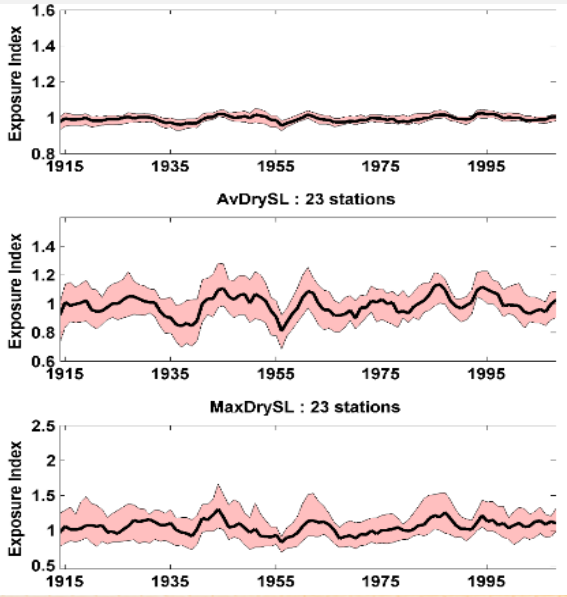
Variable name	Spatial scale (Temporal scale)
Precipitation, air temperatures (maximum and minimum)	Point, 26 weather stations data (Daily). Details in Fig. S1, Table S1, Anandhi, et al. (2016a), and Anandhi et al. (2013a)
Evapotranspiration (ET), runoff	8-Digit HUC-Hydrologic Unit Code, 90 HUC for Kansas, (Annual)
Stream flow	Point, Model setup, calibration and validation during 1960–1965, 1951–1980, and 1971–2000 respectively
ET	8-Digit HUC-Hydrologic Unit Code annual ET for the period 1971–2000 is compared to corresponding published estimates
Topography	Gridded-input to SWAT model (one time)
Land cover	Gridded- input to SWAT (one time)
Soil	Gridded-input to SWAT (one time)
Area	County-wise (one time)
Population	County-wise data for the period 1980–2012 (annual)
Water use, acres irrigated	County-wise data for the period 1980–2012 (annual)
Standard Precipitation Indexes (SPI)	Nine climate divisions in Kansas from 1895 to 2012 (1-, 3-, 6-, 9-, 12-, and 24-month referred as SPI 1, SPI 3, SPI 6, SPI 9, SPI 12, SPI 24)

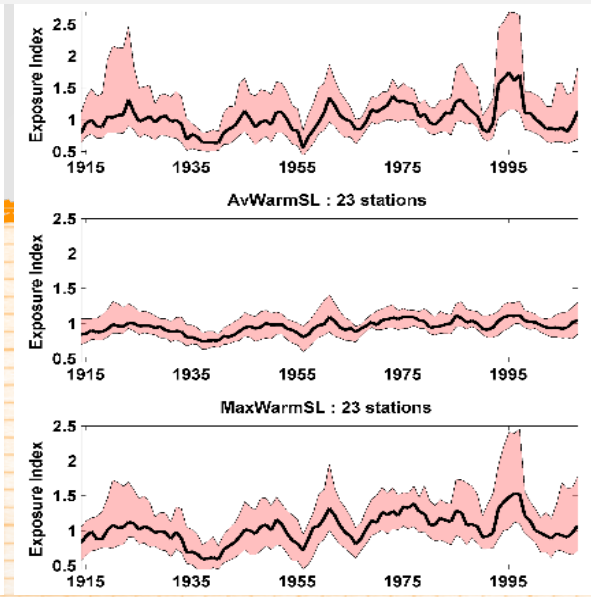
Indicators: VISTA/CISTA components

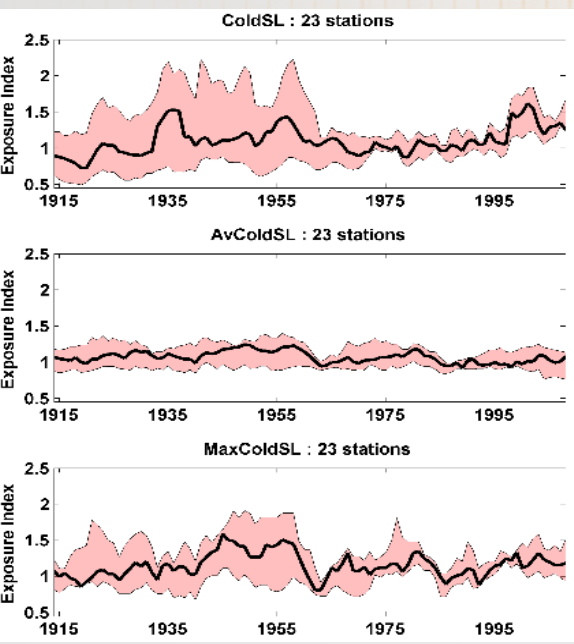
1	Water resources variation (WRV)	0.3–0.96
2	Irrigation coverage	0.0–2.25
3	Water resources scarcity (WRS)	0.35–1.0
4	Population density	0.05–34.0
5	Average population change	4.0 to 7.2
6	Average annual precipitation (RF)	411–1006 mm
7	Average annual runoff	11–300 mm
8	Average annual evapotranspiration (ET)	400–806 mm
9	Wet Spell Length (WetSL)	0.8–1.6
10	Average WetSL (AvWetSL)	0.9–1.2
11	Maximum Consecutive Wet Days (MaxWetSL)	0.7–1.6
12	Dry Spell Length (DrySL)	0.95–1.1
13	Average Dry Spell Length (AvDrySL)	0.75–1.2
14	Maximum Consecutive Dry Days (MaxDrySL)	0.75–1.5
15	Warm Spell Days (WarmSL)	0.50–2.5
16	Average Warm Spell Days (AvWarmSL)	0.50–1.5
17	Maximum Warm Spell Days (MaxWarmSL)	0.50–2.5
18	Cold Spell Days (ColdSL)	0.50–2.5
19	Average Cold Spell Days (AvColdSL)	0.90–1.5
20	No. of coldSL	0.50–2.0
21	Maximum Cold Spell Days (AvColdSL)	0.75–2.0
22	Average Maximum temperature (Tmax)	0.99–1.01
23	Average Minimum temperature (Tmix)	0.99–1.01
24	Average temperature (Tave)	0.99–1.01

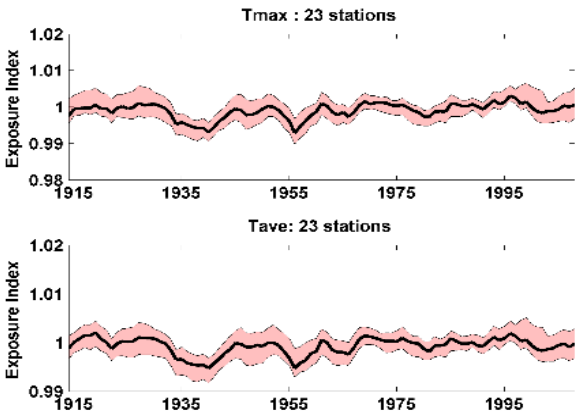
Time series plots

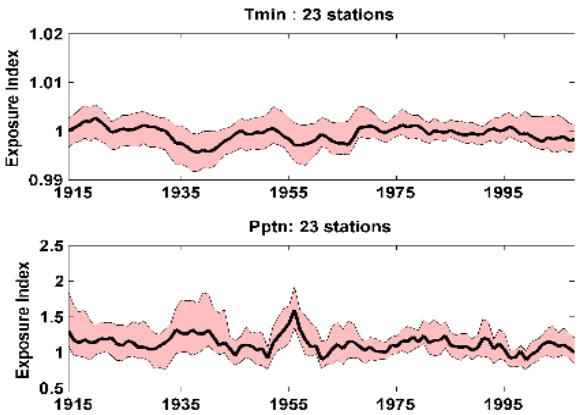


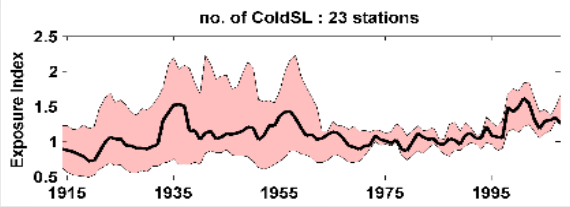


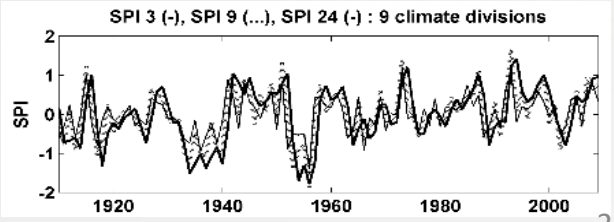




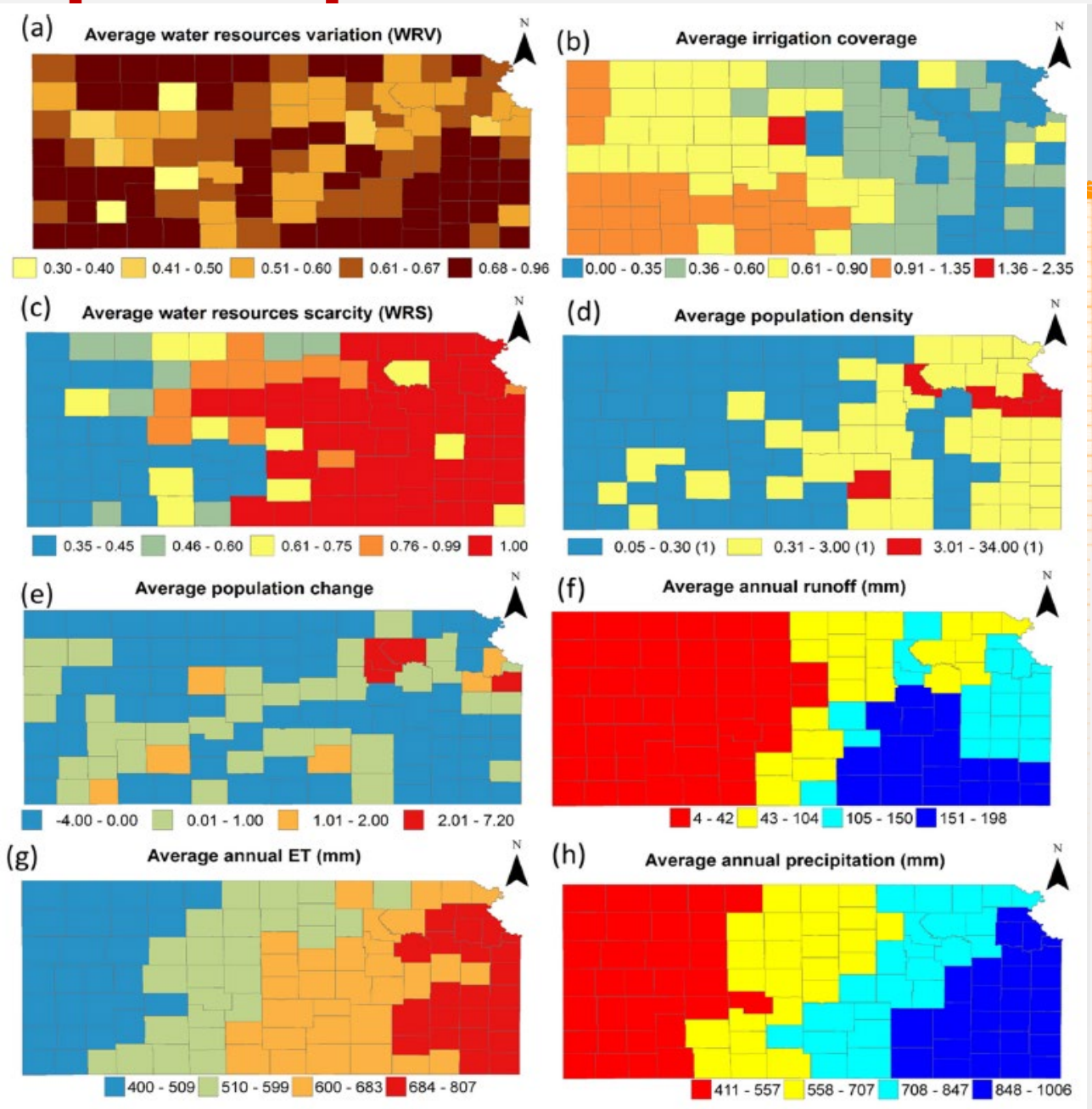






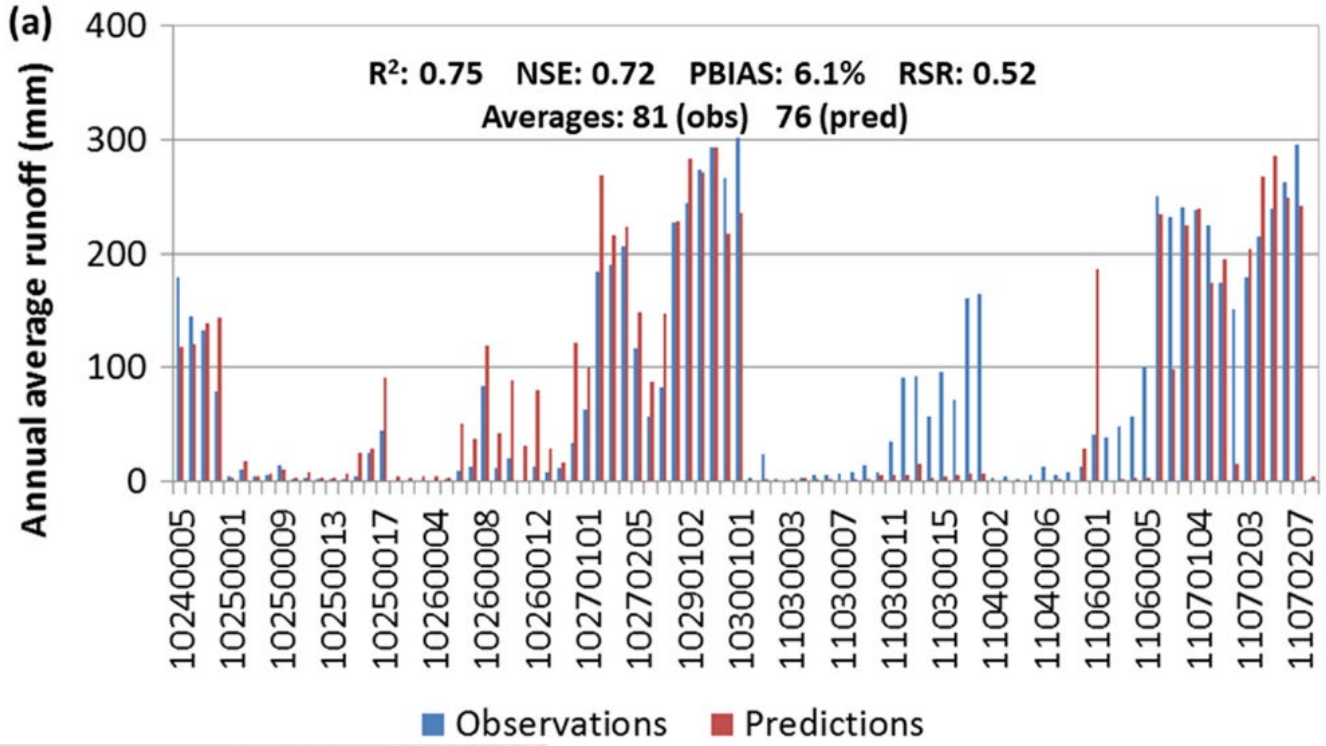


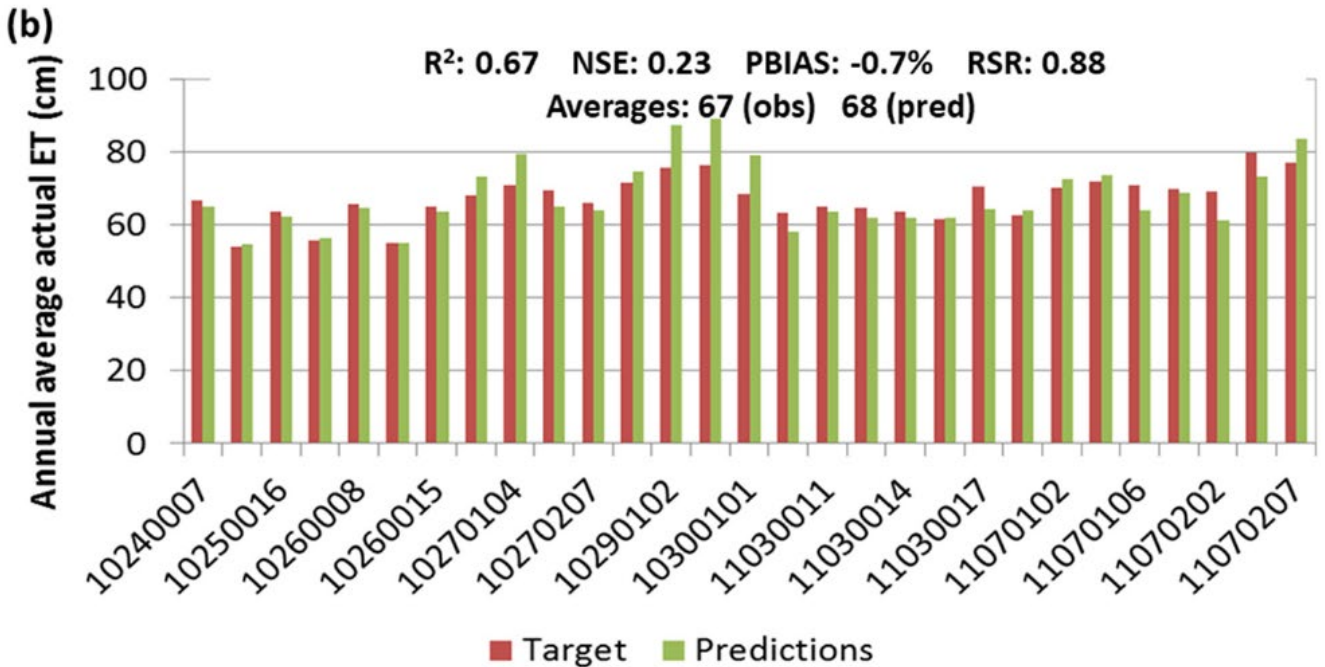
Spatial plots



- Knowledge representation
- Uncertainty representation
- Learning

Model: Runoff, ET

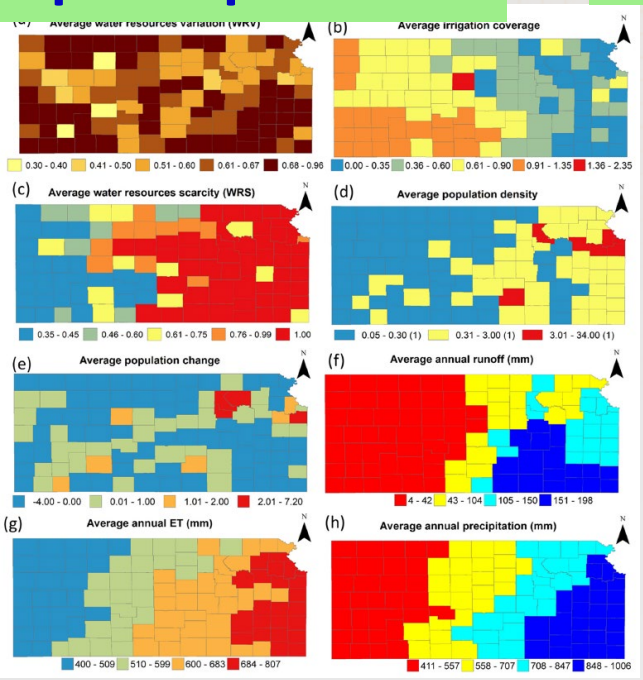




Vulnerability index (EI_i)

$$EI_i = \frac{\text{Average value of } CF \text{ for } a \text{ period}}{\text{The actual value of } CF \text{ for } a \text{ year}} = \frac{\dfrac{\sum_{k=1}^{Ns} W_{k,j} \sum_{j=1}^{Nc} \sum_{i=1}^{Ny} C_{k,j,i}}{Ny}}{C_{k,j,i}}$$

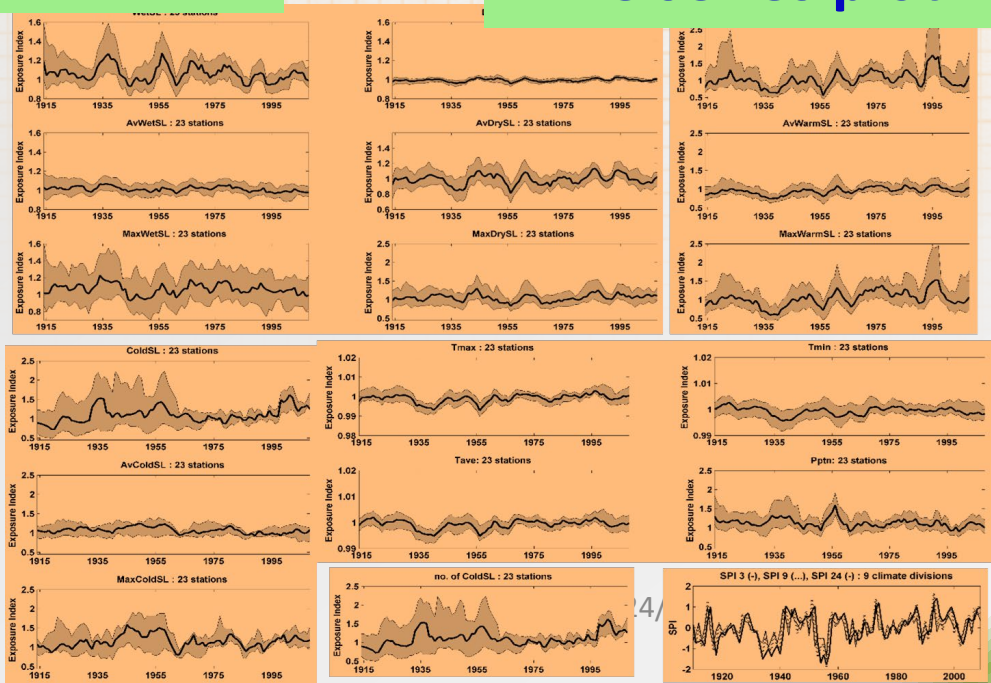
Spatial plot



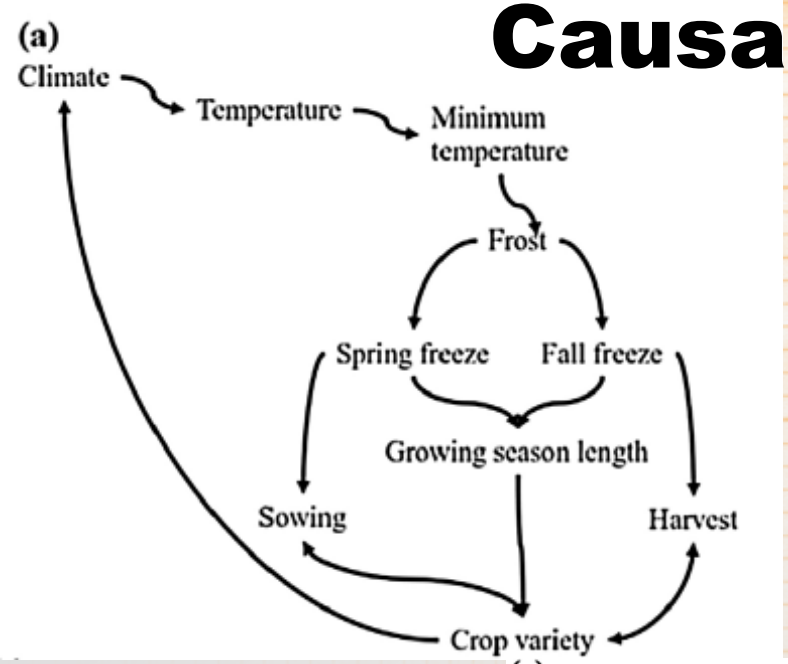
Trends

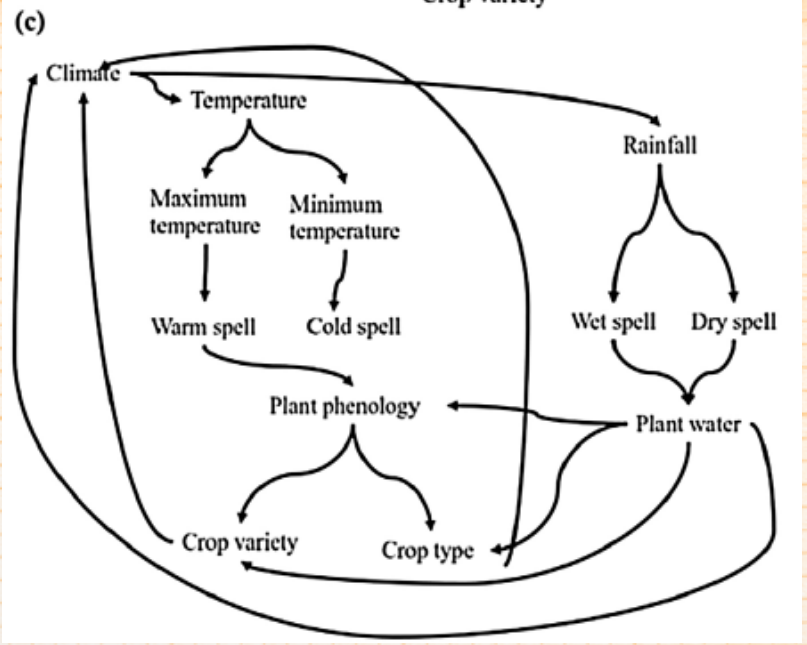
Scenarios

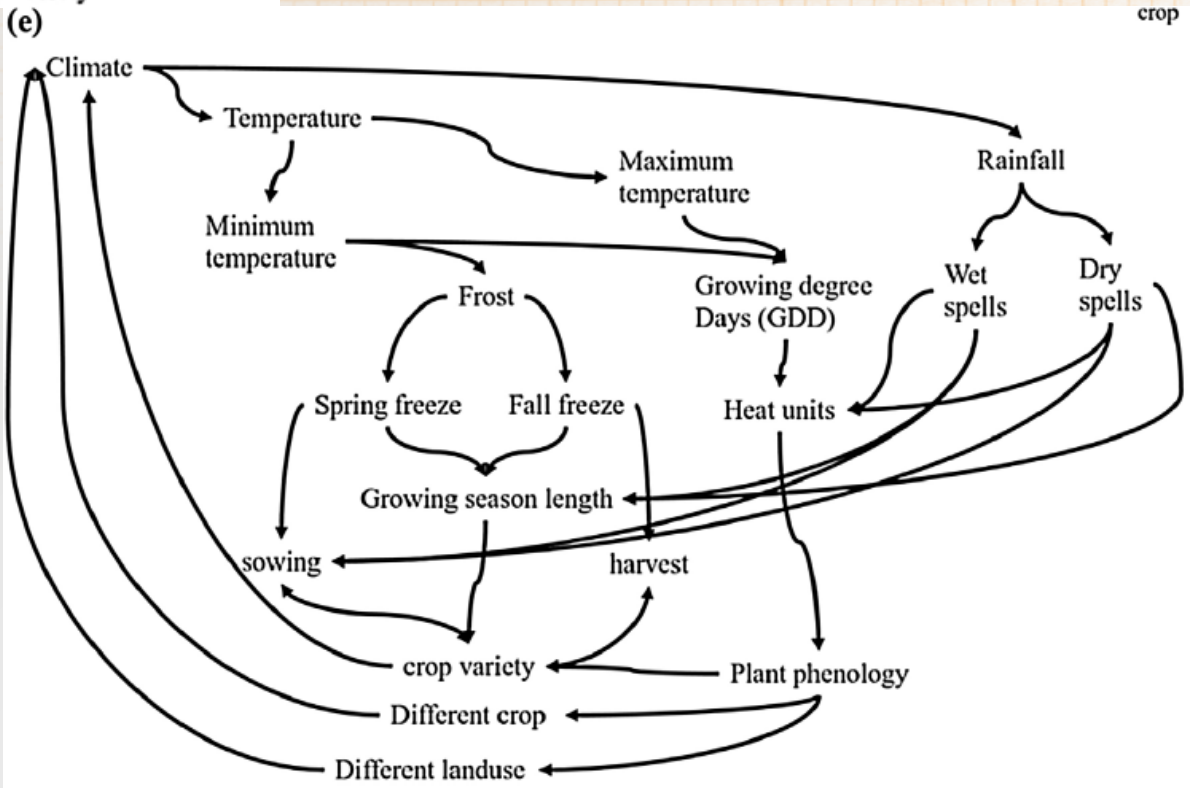
Time series plot



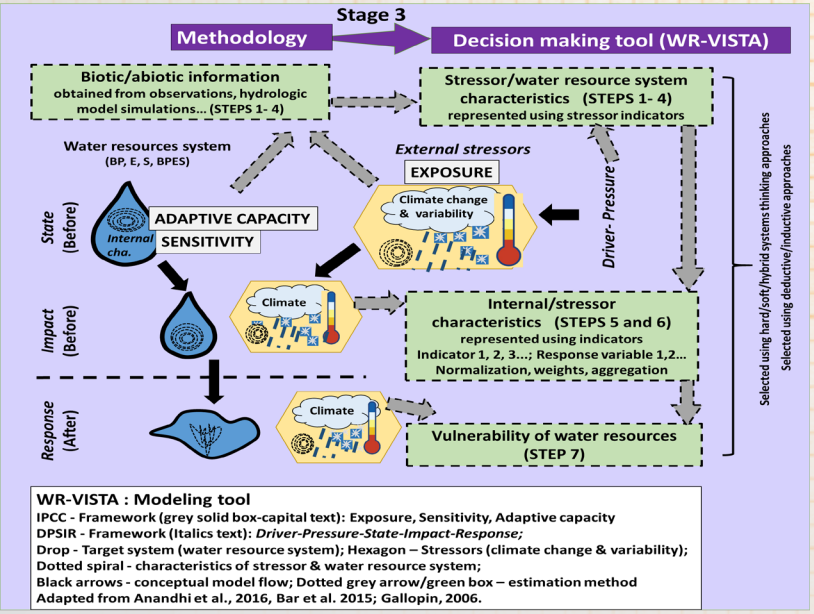
Causal loops



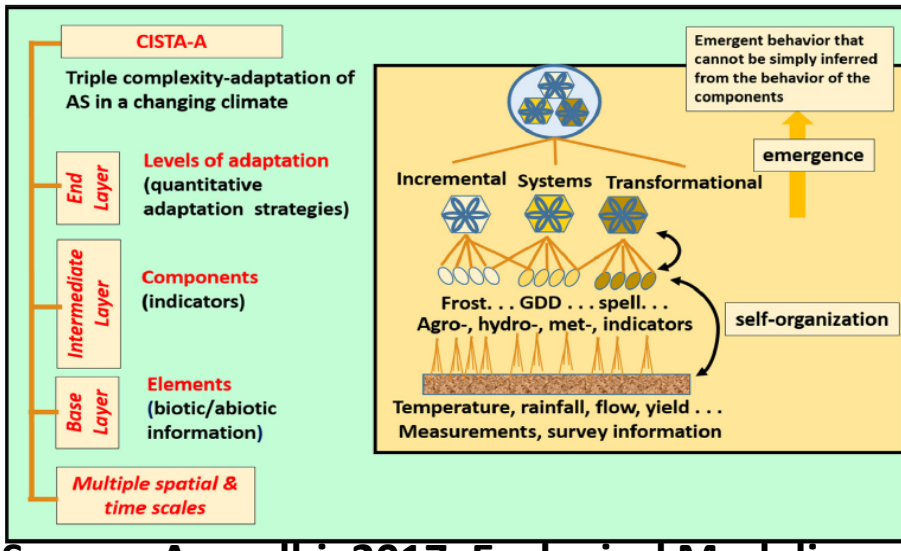




Summary & next steps



Source: Anandhi & Kannan, 2018, J. Hydrology

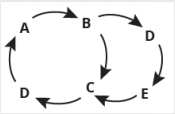


Source: Anandhi, 2017, Ecological Modeling

- Indicator ?
- Aggregation method?
- No validation data

Next steps….

- Unknown, known …
- Mathematical representation
- Food-Water-Energy nexus



Discussion/Questions ?...

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Assistant Professor
Biological systems engineering
Florida A & M University


NO
Water
Life


NO
Plants
Life


Change is an inevitable constant