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

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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

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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

70%

More water

57%

Impacting essential resource – food, water, energy…
Vulnerable and creating a need to adapt/mitigate…
Utilize the benefits of change/reduce the harmful effects…

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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 et al. 2016*
Outline – VISTA & CISTA frameworks – food/water ...

Background
(Who cares & why?)

Methodology
(VISTA/CISTA)

Results
Summary
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

Theoretical concept → Characteristics

Characteristics

Examples of characteristic from literature
Stage 1

Theoretical concept

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
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.
CISTA: Conceptual model using Indicators selected by System’s Thinking Approach for agroecosystems
CISTA-A

Triple complexity-adaptation of AS in a changing climate

Levels of adaptation (quantitative adaptation strategies)

Components (indicators)

Elements (biotic/abiotic information)

Multiple spatial & time scales

Emergent behavior that cannot be simply inferred from the behavior of the components

Incremental
Systems
Transformational

Frost... GDD... spell...
Agro-, hydro-, met-, indicators

Temperature, rainfall, flow, yield...
Measurements, survey information

self-organization

emergence
Indicators \( f(\cdot) \) analysis:

- Rainfall \( (r) \)
- Temperature \( (t_{\text{min}}, t_{\text{ave}}, t_{\text{max}}) \)

\[ EI_i = \frac{\text{Average value of } CF \text{ for a period}}{\text{The actual value of } CF \text{ for a year}} = \frac{\sum_{k=1}^{N_s} W_{k,j} \sum_{j=1}^{N_c} \sum_{i=1}^{N_y} C_{k,j,i}}{Ny \cdot C_{k,j,i}} \]

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
(Who cares & why?)

Methodology
(VISTA/CISTA)

Results
Summary
Study region: Kansas, USA
<table>
<thead>
<tr>
<th>Variable name</th>
<th>Spatial scale (Temporal scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation, air temperatures</td>
<td>Point, 26 weather stations data (Daily). Details in Fig. S1, Table S1, Anandhi, et al. (2016a), and Anandhi et al. (2013a)</td>
</tr>
<tr>
<td>(maximum and minimum)</td>
<td></td>
</tr>
<tr>
<td>Evapotranspiration (ET), runoff</td>
<td>8-Digit HUC-Hydrologic Unit Code, 90 HUC for Kansas, (Annual)</td>
</tr>
<tr>
<td>ET</td>
<td>8-Digit HUC-Hydrologic Unit Code annual ET for the period 1971–2000 is compared to corresponding published estimates</td>
</tr>
<tr>
<td>Topography</td>
<td>Gridded-input to SWAT model (one time)</td>
</tr>
<tr>
<td>Land cover</td>
<td>Gridded-input to SWAT (one time)</td>
</tr>
<tr>
<td>Soil</td>
<td>Gridded-input to SWAT (one time)</td>
</tr>
<tr>
<td>Area</td>
<td>County-wise (one time)</td>
</tr>
<tr>
<td>Population</td>
<td>County-wise data for the period 1980–2012 (annual)</td>
</tr>
<tr>
<td>Water use, acres irrigated</td>
<td>County-wise data for the period 1980–2012 (annual)</td>
</tr>
<tr>
<td>Standard Precipitation Indexes (SPI)</td>
<td>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)</td>
</tr>
</tbody>
</table>
### Indicators: VISTA/CISTA components

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

- Knowledge representation
- Uncertainty representation
- Learning
Vulnerability index \((EI_i)\)

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

Spatial plot

Trends

Scenarios

Time series plot
Summary & next steps

Next steps....
- Unknown, known ...
- Mathematical representation
- Food-Water-Energy nexus

Indicator?
Aggregation method?
No validation data

Discussion/Questions ?...
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Change is an inevitable constant