A trans-disciplinary framework for predictive disease ecology based on cross-scale interactions: Insights from long-term data

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Objective
Our goal is to develop a strategy and operational framework for agricultural grand challenges requiring big data and trans-disciplinary scientific expertise based on spatio-temporal modeling of cross-scale interactions coupled with human and machine learning. The utility of our approach is illustrated using vesicular stomatitis (VS) and West Nile (WN), infectious diseases of livestock that lead to economic costs, quarantines, and restrictions to international trade.

Step 1: Trans-disciplinary team formation

Step 2: Develop disease system understanding

Step 3: Develop hypotheses; identify variables and sources of data

Hypotheses:
1. Local abundance of VS cases = (fair temp, distance to stream flow, precipitation, vegetation, density of hosts)
2. Persistence of VS from one year to the next = (winter minimum temperature)
3. Spatial contagion of VS = (local animal abundance, local insect-host interactions, dispersal distance of insects, distance to previous VS cases)

Step 4: Data harmonization and integration

The data cube has a value for each variable for the same grid area (1 km²) as each VS case on either a daily, seasonal, or annual time step (with time lags) to represent the >1M km² area of the western US where VS occurs.

Step 5: Analysis and interpretation of results

The following example of analyses and results showcase the diverse insights made about VS incidence from the trans-disciplinary team:

Constructing early warning system: Mean VS onset month can be calculated for any location in the region based on latitude, elevation, and long-term precipitation.

Environmental conditions preceding occurrence are different in outbreak vs expansion years. (Peters et al., 2020)

Step 6: Apply to other vector-borne diseases: West Nile

Insights & recommendations for next trans-disciplinary projects
1. Define a clear problem statement to guide data gathering, harmonization, and analysis.
2. Strategically identify a trans-disciplinary team of technical and scientific experts that include a person who can integrate the disciplinary interests.
3. Recognize the importance of the interactive process needed to build a meaningful data cube (Data + Metadata + Scientific Expertise + Technical Expertise).
4. Focus on pattern + process relationships to guide data variable selection and analyses.
5. Identify products and stakeholders of the information and results early in the project, and develop new products as the project evolves.
6. Regular face-to-face meetings and collaboration among scientists with new skills are needed to maintain a successful trans-disciplinary project through time.