Exploring the Nexus between LCLUC, Socio-Economic Factors, and Water for a Vulnerable Arid US-Mexico Transboundary Region

2024 NASA LCLUC Science Team Meeting
Gaithersburg, MD (4/2/2024)

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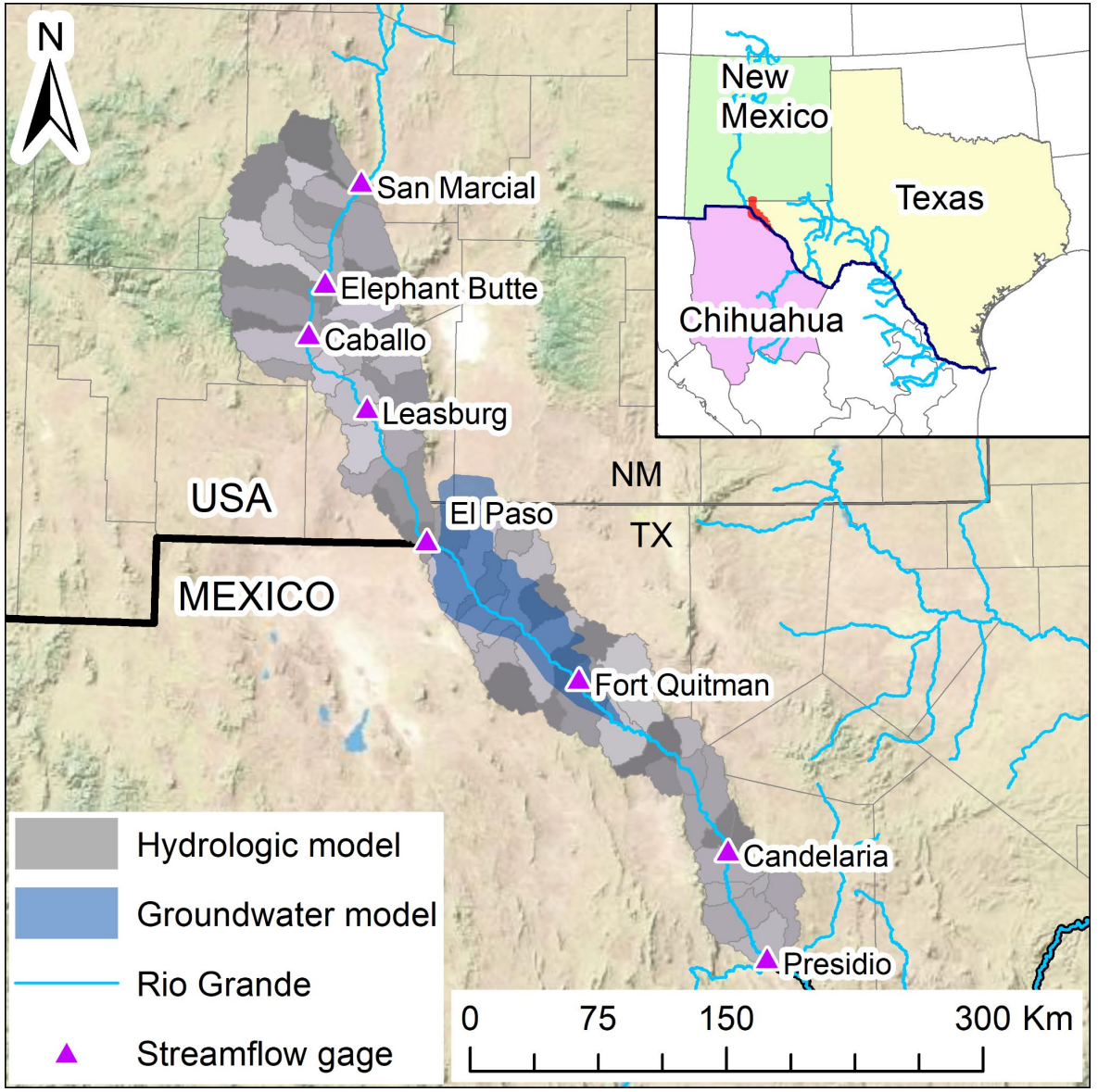
Study Area

- Over 2 million people
- Highly managed river
  - 85% water use in Ag
- Groundwater rapidly depleting
  - Limited Recharge
  - Salinization
- Urbanization
- Ag intensification



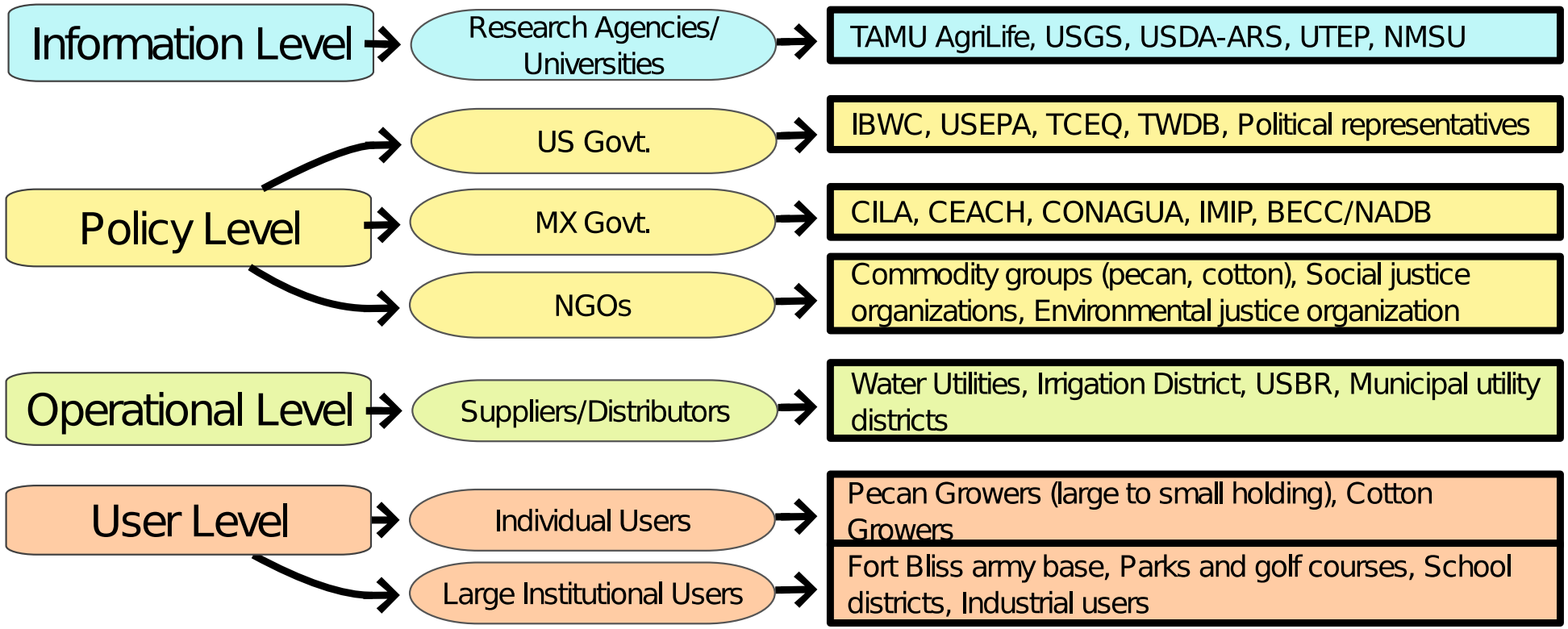
LCLUC pressures

Water is a critical common pool constraint for LCLUC

- Dwindling supplies
- Increasing demand
  - Cities
  - Agriculture
  - Environmental Services
- Segmented Governance
  - Two countries
  - Three states

The Stakeholders

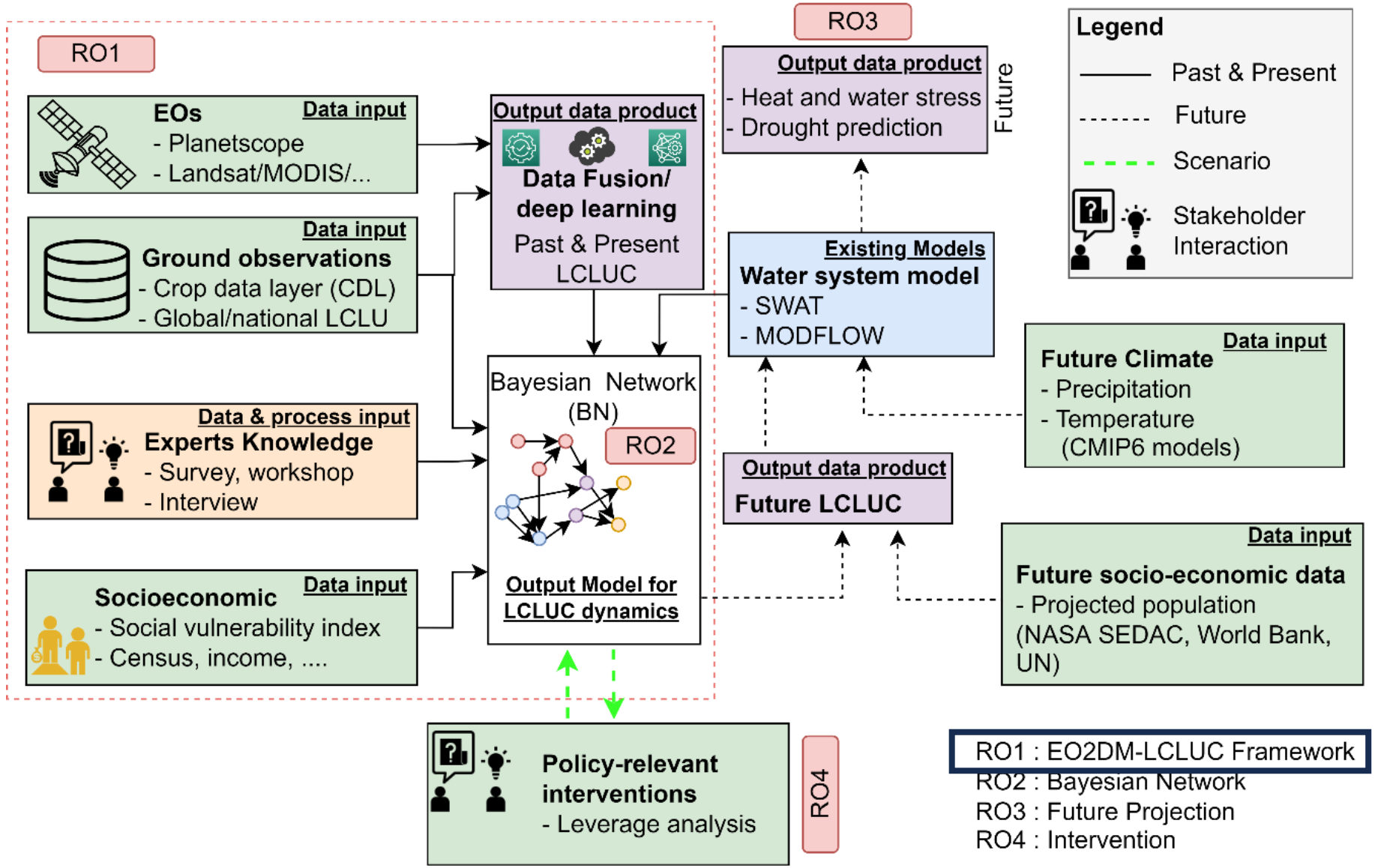
PERMANENT FORUM OF BINATIONAL WATERS

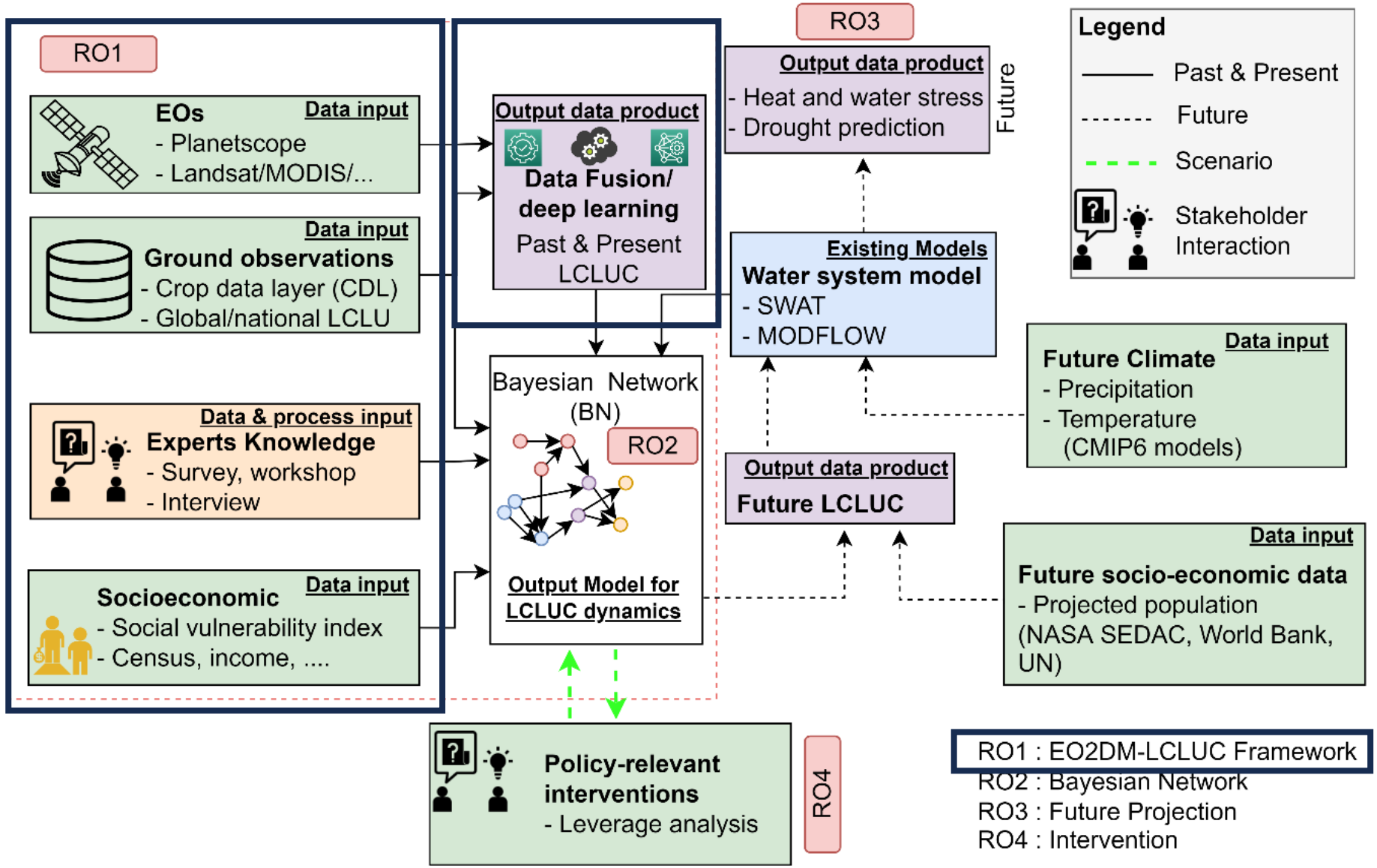


A Comprehensive Process for Stakeholder Identification and Engagement in Addressing Wicked Water Resources Problems
Hargrove and Heyman Land 2020, 9(4), 119; https://doi.org/10.3390/land9040119

Science Question

How natural and human systems interact to influence the LCLUC when **constrained by a critical common-pool natural resource** [water availability]


RO1
EOs
Data input
- Planetscope
- Landsat/MODIS/...
Data input
Ground observations
- Crop data layer (CDL)
- Global/national LCLU
Data & process input
Experts Knowledge
- Survey, workshop
- Interview
Socioeconomic
Data input
- Social vulnerability index
- Census, income, ...
Output data product
Data Fusion/
deep learning
Past & Present
LCLUC
Bayesian Network
(BN)
RO2
Output Model for
LCLUC dynamics
RO3
Output data product
- Heat and water stress
- Drought prediction
Future
Existing Models
Water system model
- SWAT
- MODFLOW
Data input
Future Climate
- Precipitation
- Temperature
(CMIP6 models)
Output data product
Future LCLUC
Data input
Future socio-economic data
- Projected population
(NASA SEDAC, World Bank,
UN)
Policy-relevant
interventions
- Leverage analysis
RO4
Legend
Past & Present
Future
Scenario
Stakeholder
Interaction
RO1 : EO2DM-LCLUC Framework
RO2 : Bayesian Network
RO3 : Future Projection
RO4 : Intervention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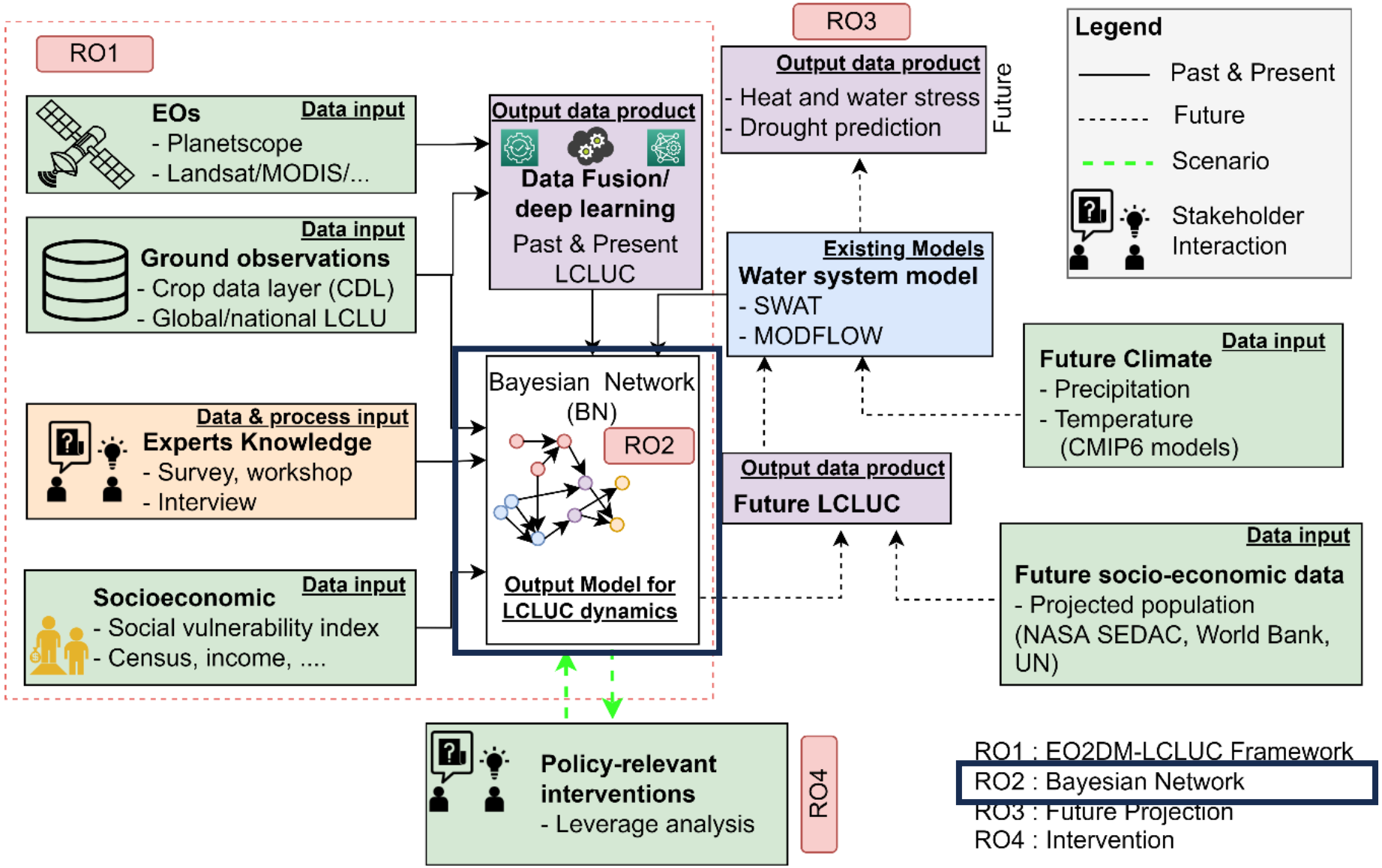
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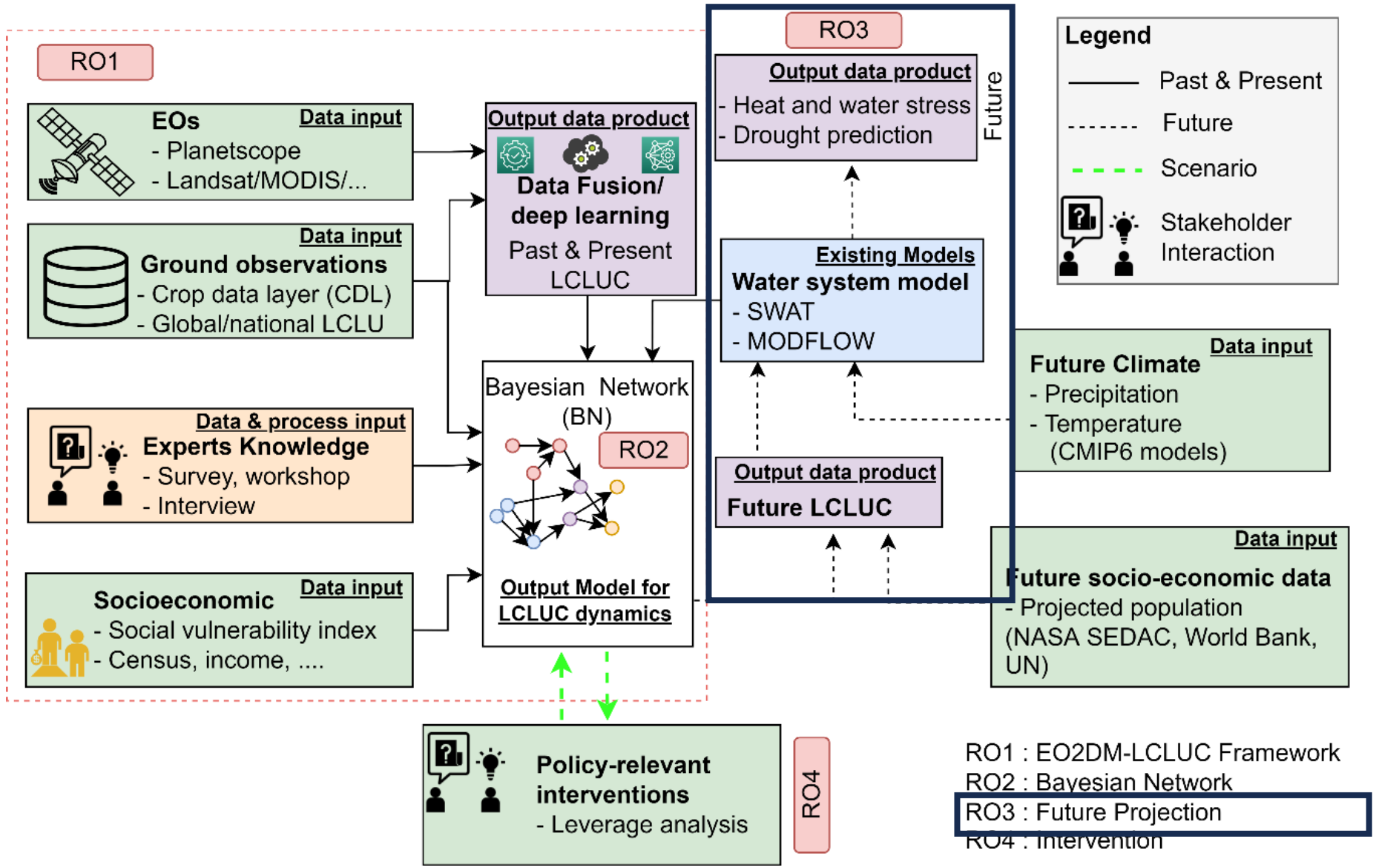
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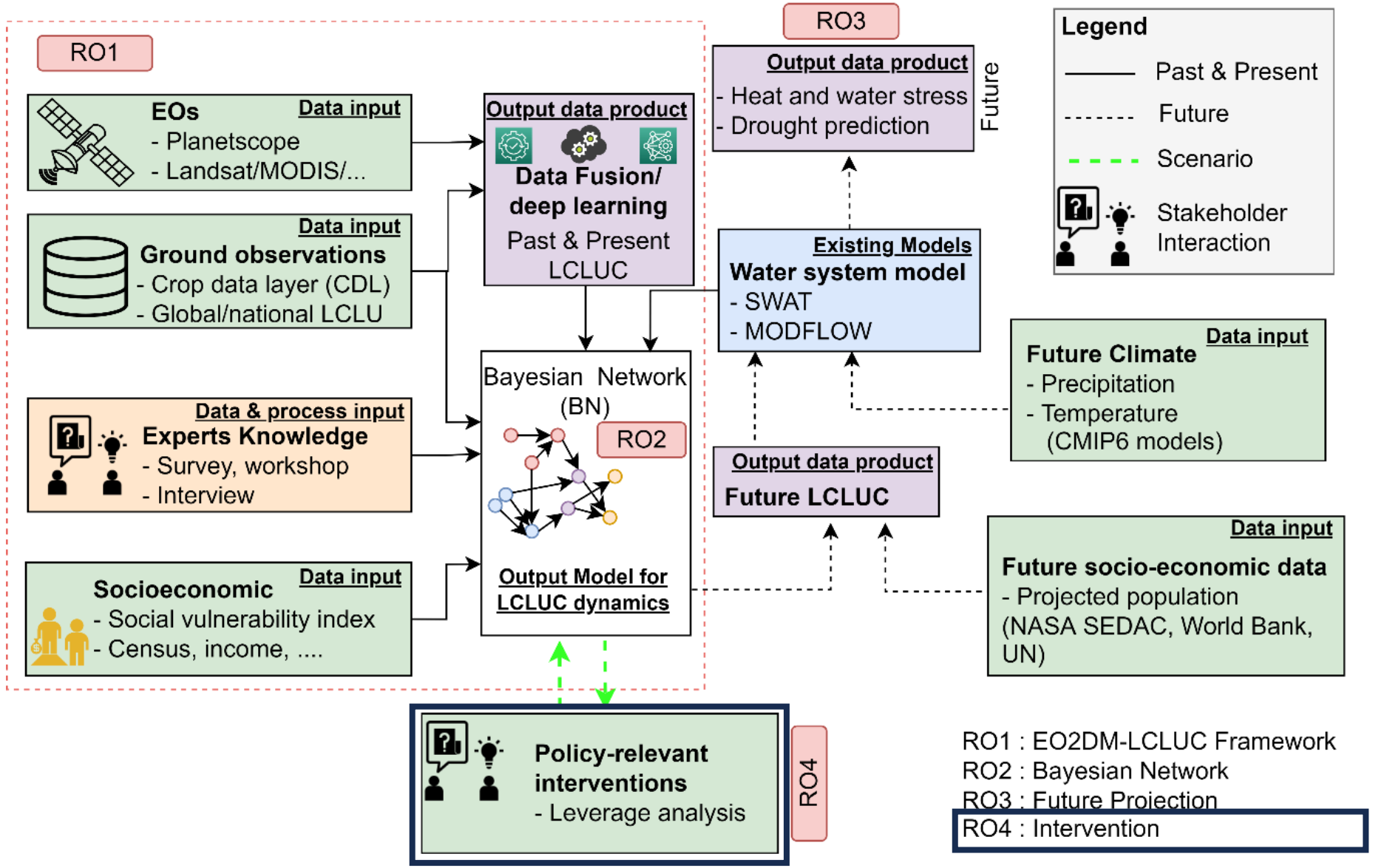
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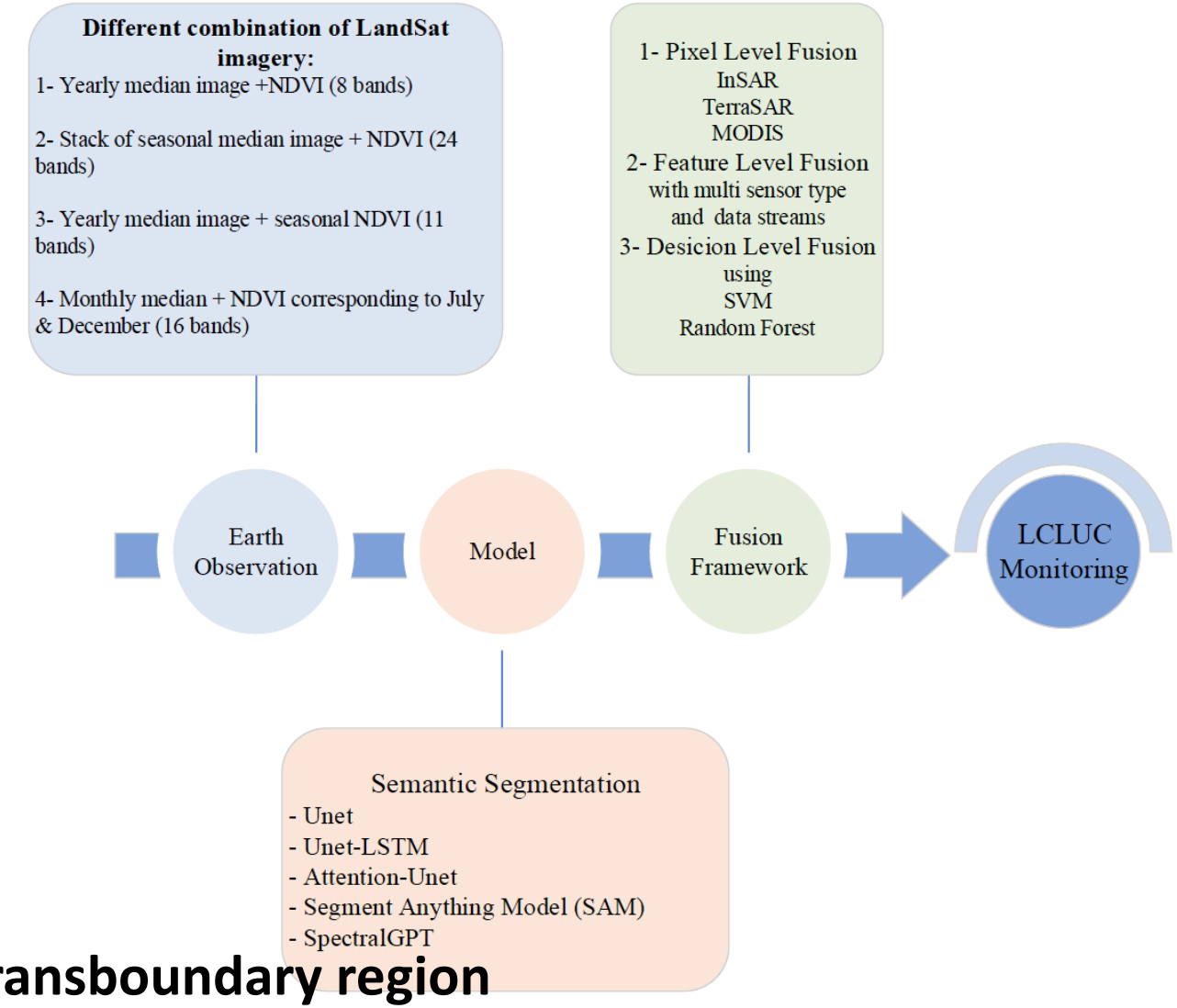
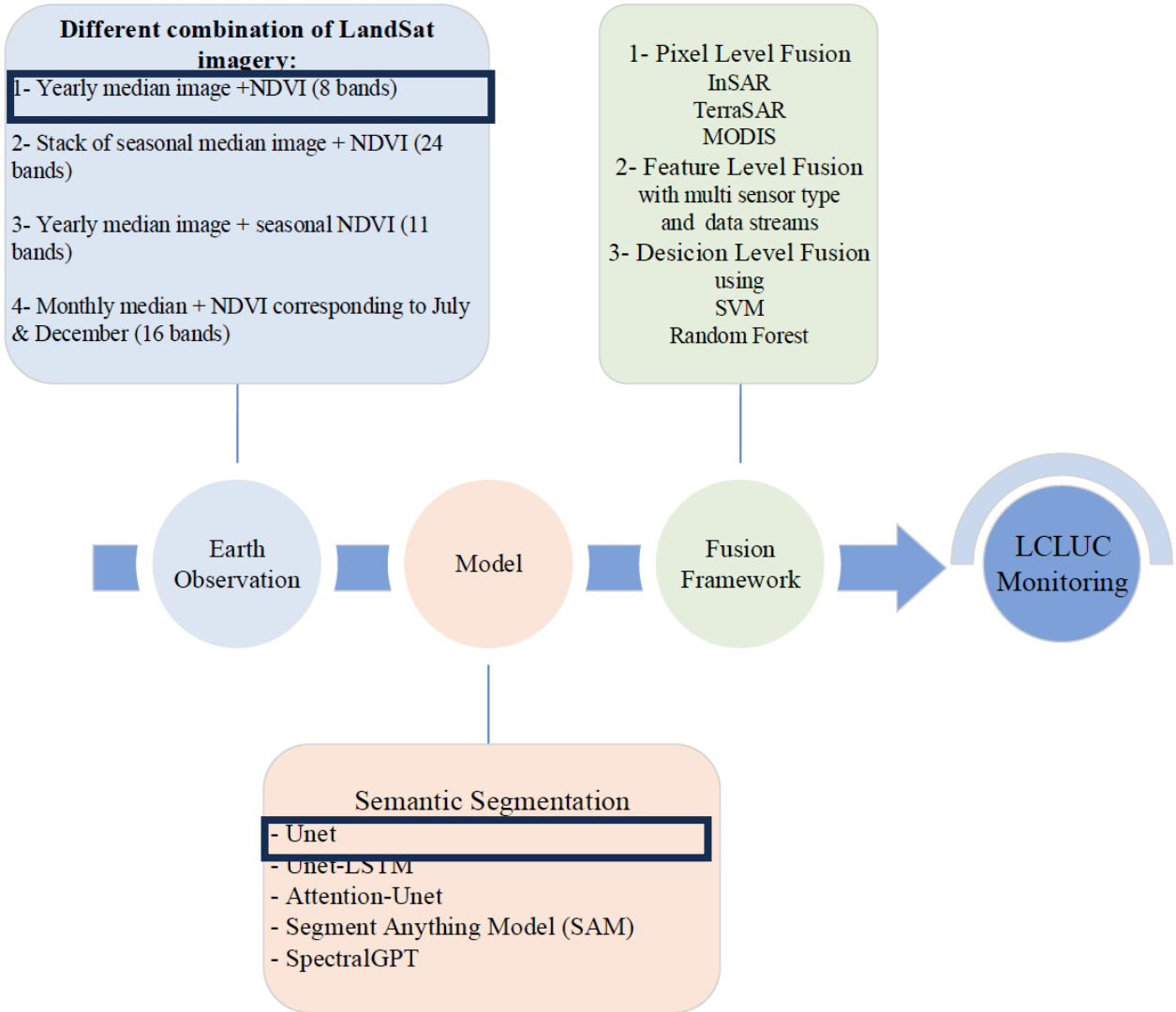
Progress Year 1

RO1-LCLUC data for the region

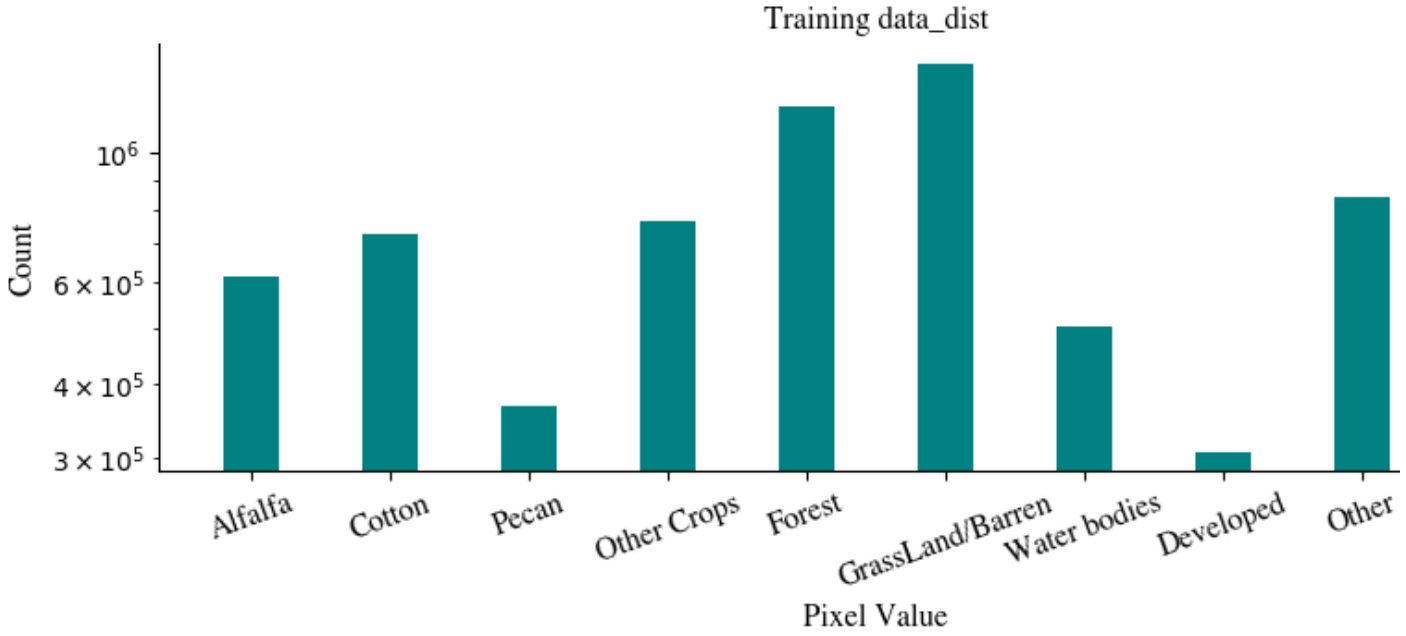


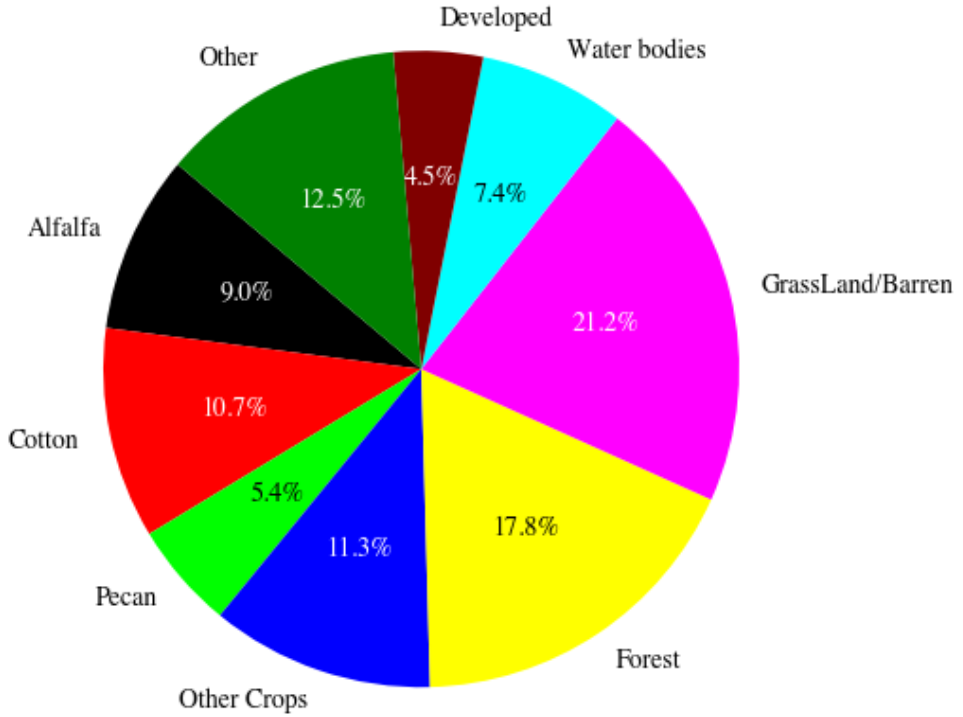
Robust LC and LU time series for the transboundary region

- Handle small-size lots (0.4 ac to 1400 ac)
- Quantify likely GW Usage

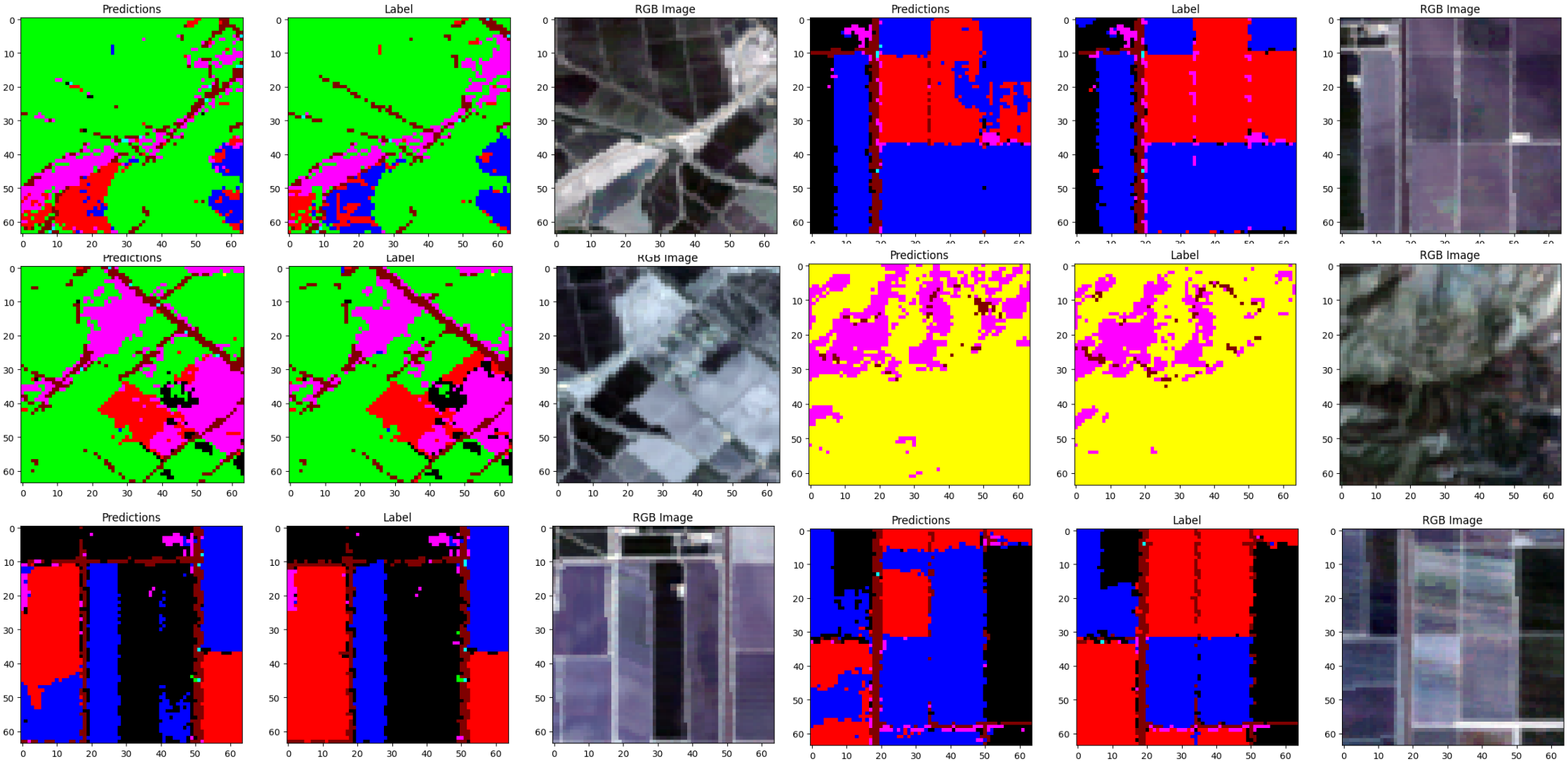

Different combination of LandSat imagery:
1- Yearly median image +NDVI (8 bands)
2- Stack of seasonal median image + NDVI (24 bands)
3- Yearly median image + seasonal NDVI (11 bands)
4- Monthly median + NDVI corresponding to July & December (16 bands)
1- Pixel Level Fusion
InSAR
TerraSAR
MODIS
2- Feature Level Fusion
with multi sensor type
and data streams
3- Desicion Level Fusion
using
SVM
Random Forest
Earth Observation
Model
Fusion Framework
LCLUC Monitoring
Semantic Segmentation
- Unet
- Unet-LSTM
- Attention-Unet
- Segment Anything Model (SAM)
- SpectralGPT

Training data statistics

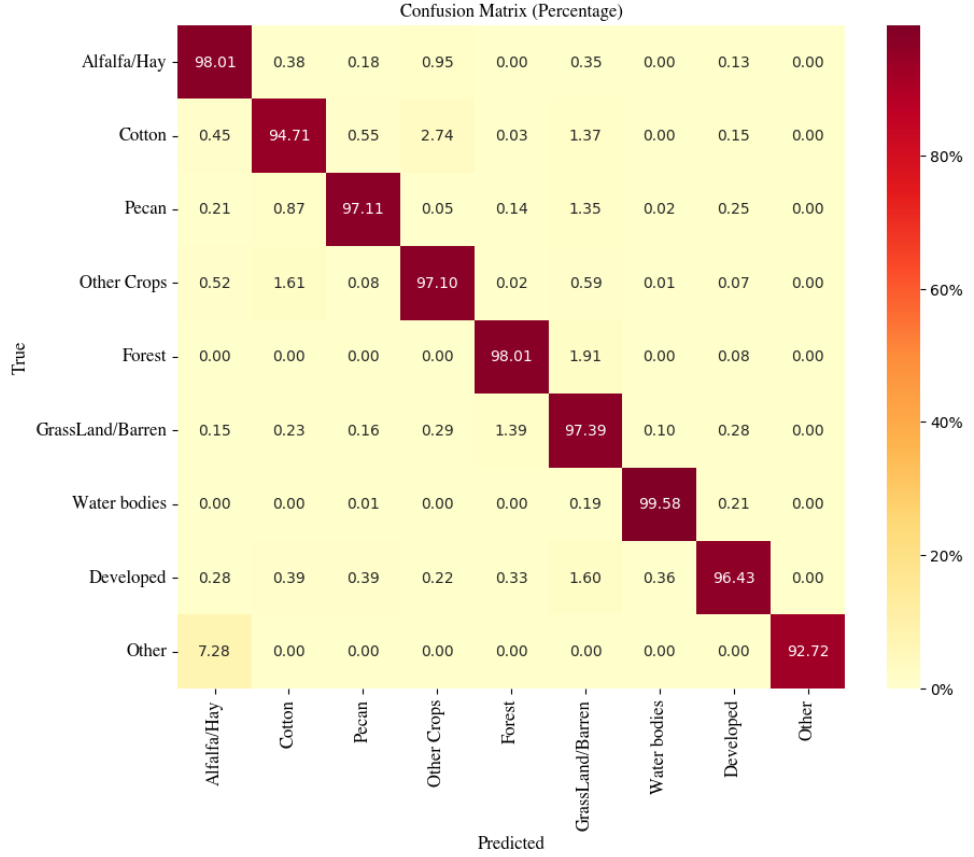




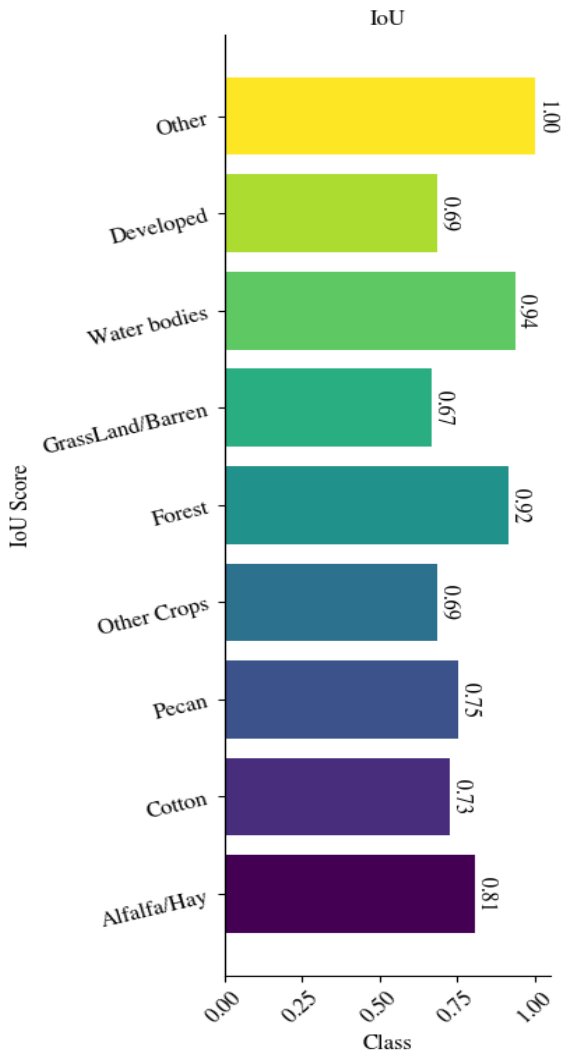
Test Image Visualization



Model Evaluation 1



Model Evaluation 2



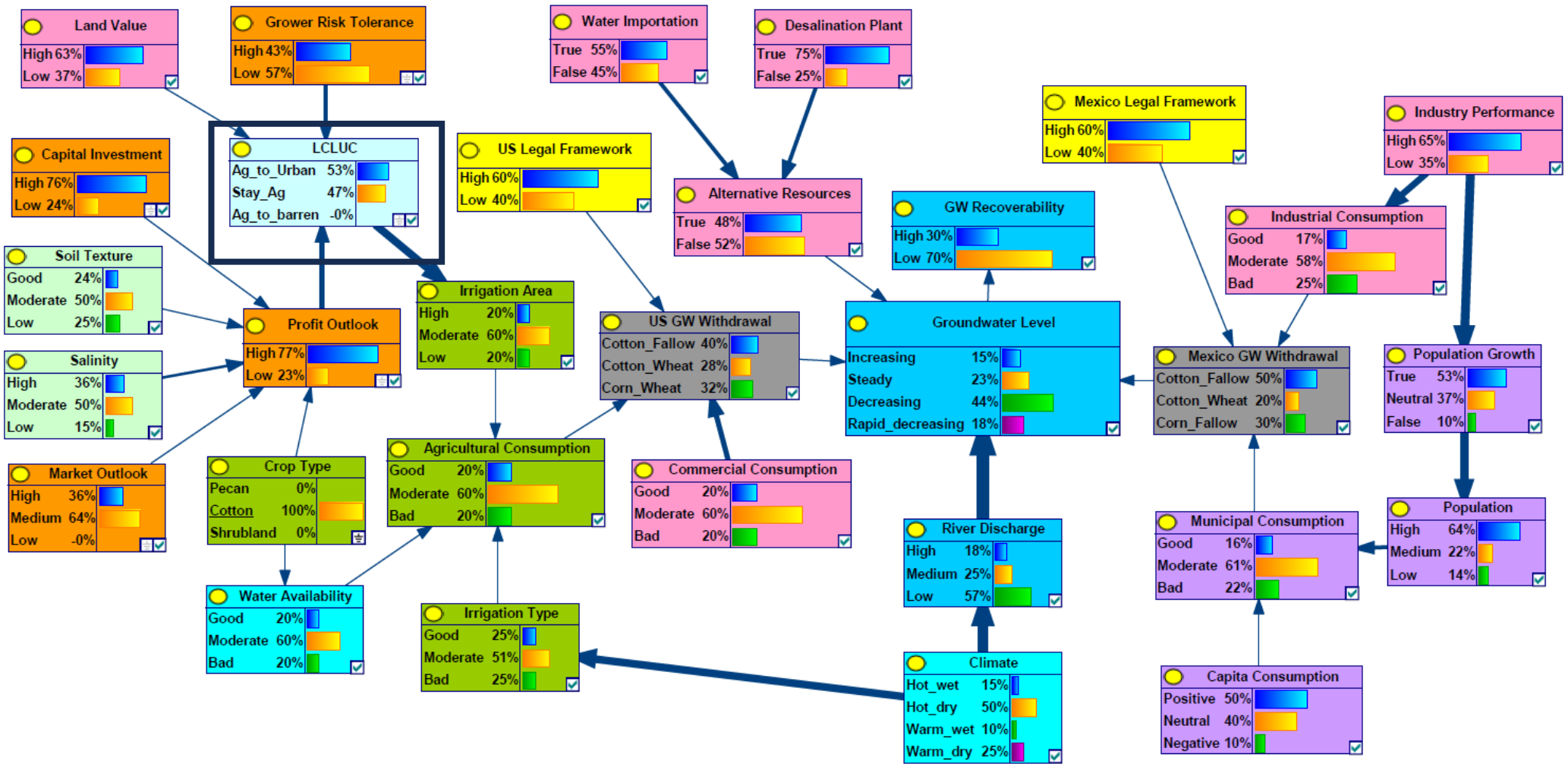
$$IoU = \frac{TP}{(TP + FP + FN)}$$

$$AUC = \frac{\sum Rank(+) - |+| \times (|+|+1)/2}{|+|+|-|}$$

where:
$\sum Rank(+)$ is the sum the ranks of all positively classified examples
$|+|$ is the number of positive examples in the dataset
$|-|$ is the number of negative examples in the dataset

Training time	epoch	Precision	Recall	IoU (average)	multi class AUC (average)
3hrs	400	0.88	0.88	0.81	0.987

Other Data Sets



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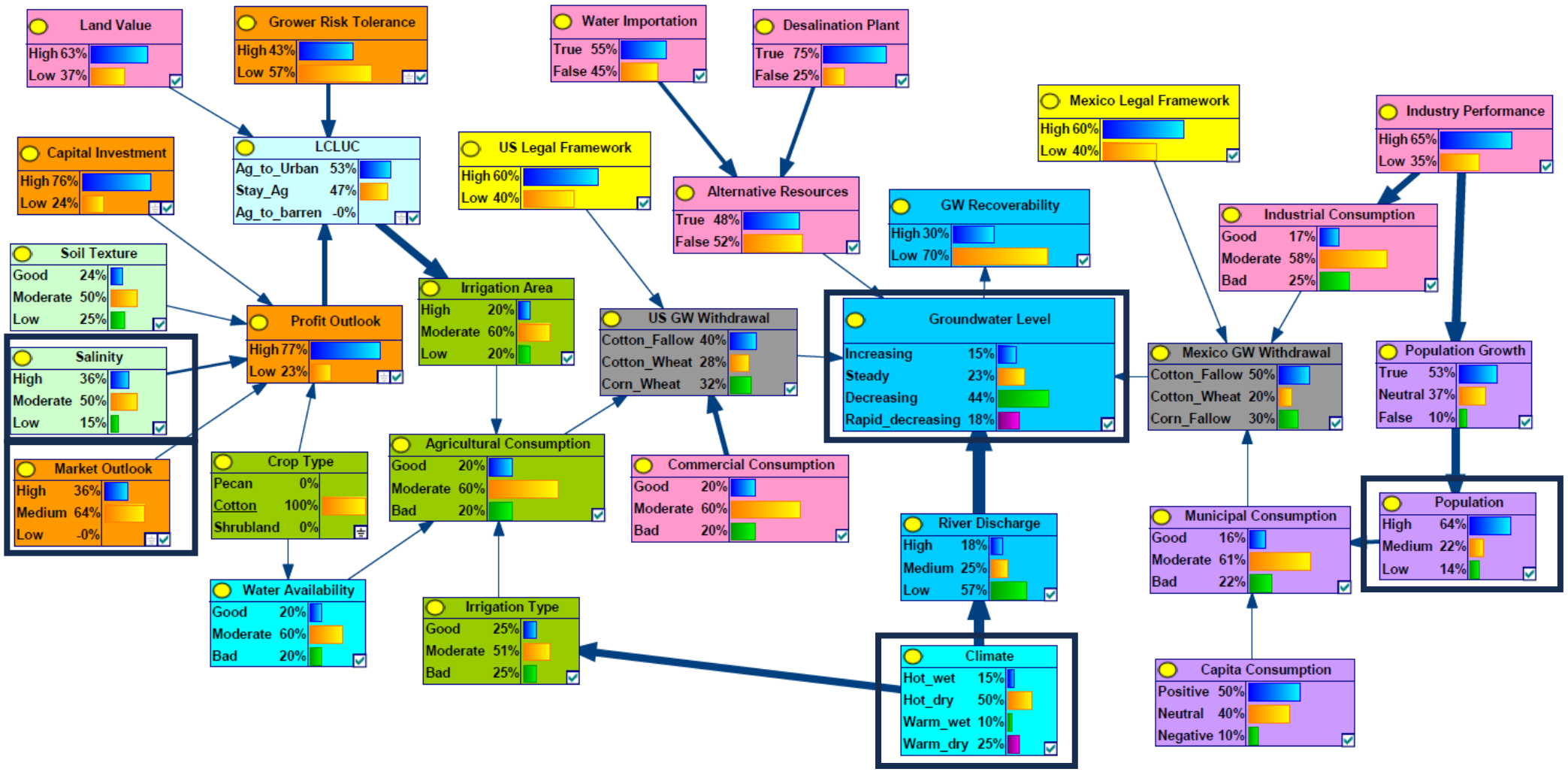
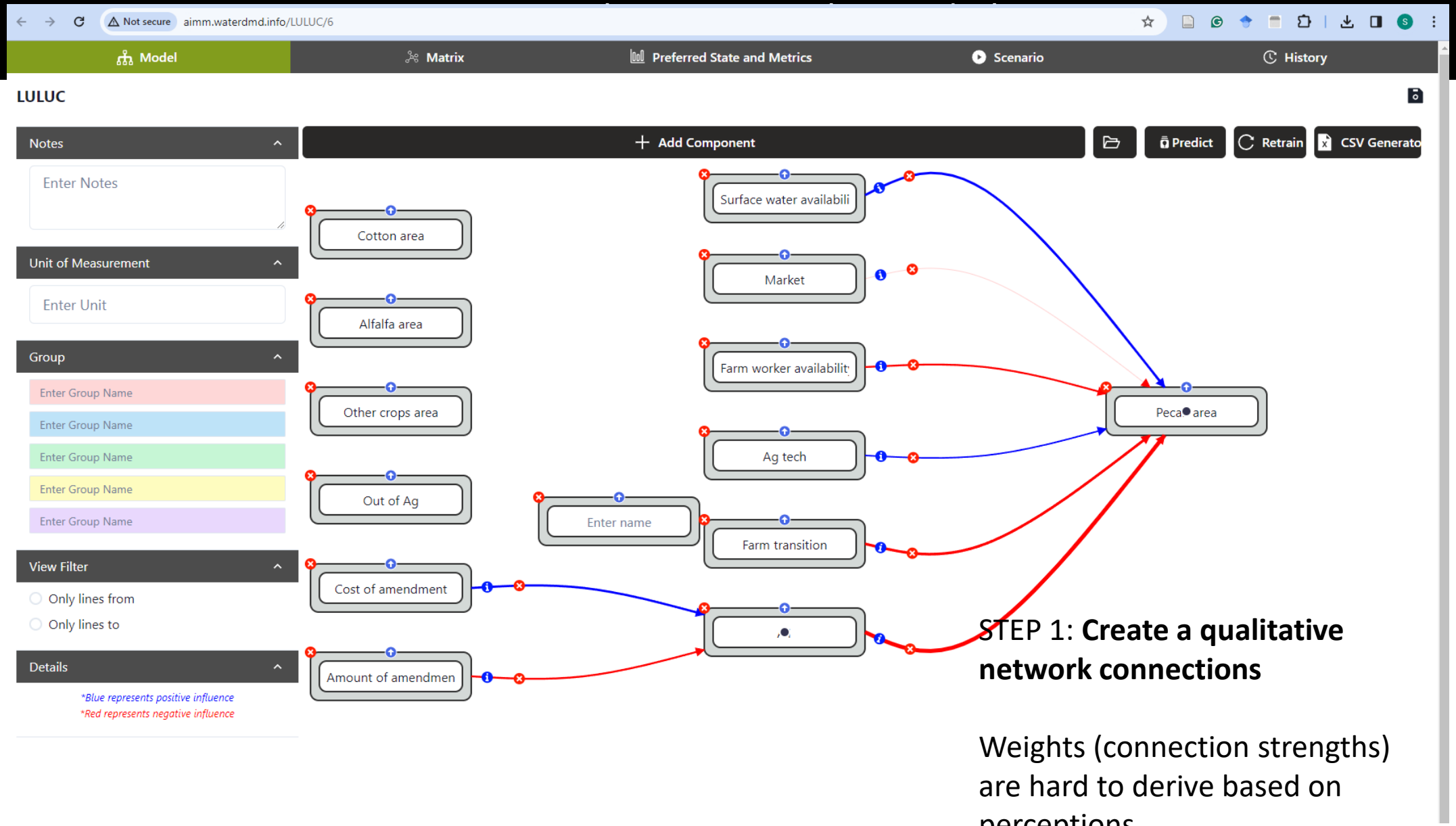


Time Series Data to Mental Models



STEP 1: **Create a qualitative network connections**

Weights (connection strengths) are hard to derive based on perceptions

STEP 2: **How have factors changed?**

- Create data on a graph
- Use existing observations
- Alter existing observation

STEP 2: **Set weights trainable?**

- Set to zero for no connection
- Set to a fixed value if there is a perception
- Other weights are trained

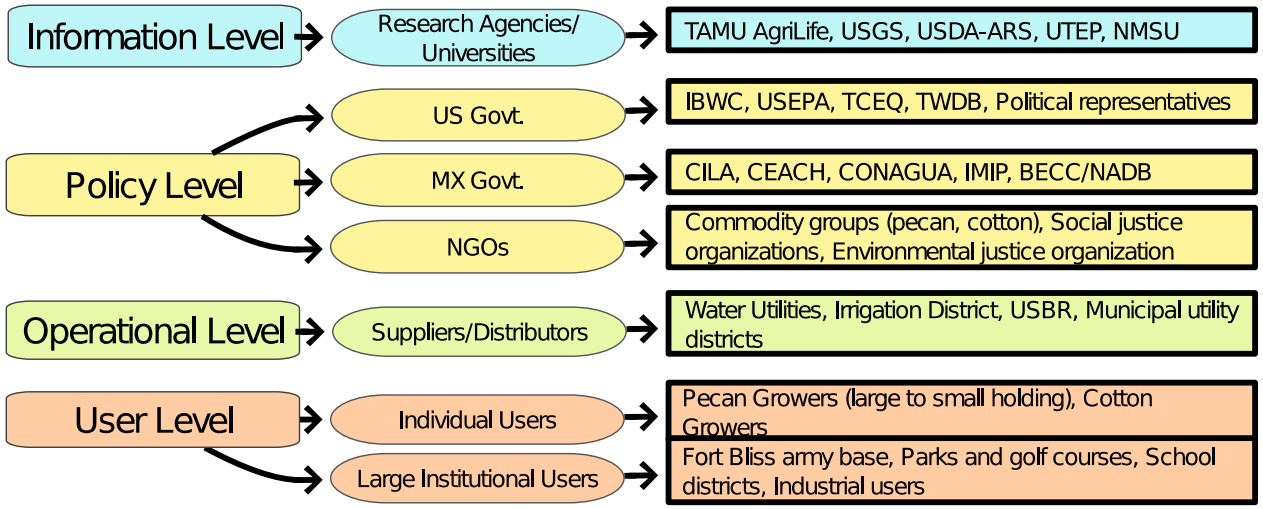
More on the Network for AI-MM

- Implementation of the Network
  - Custom Connections
    - Fully connected with zero weights
  - Trainable/Not trainable weights
  - Conv 1D on time
  - Trained using standard backpropagation
    - Weights are of importance

- See concordance and discordance in the MM of different stakeholder groups
- Web-based platform→Users can see each other's models and analyze the future based on different models

Year 2 and 3

- RO 3. Predict future LCLUC transitions
  - Different MMs
  - Convergent MM
- RO 4. Leverage analysis



Compare Mental Models

Quantify Concordance/ Discordance Distance Weights

Policy Relevant Leverage Points

Interdisciplinary Team Working on the Project

Arizona State University

Saurav Kumar, PI

Raquel Neri, PhD student, Bayesian Networks

Saman Ebrahimi, PhD Student, LCLUC Analysis

Shanfer Majeed, MS Student, AI-MM Development

Texas A&M AgriLife

Rosario Sanchez, Co-I, Lead at A&M

Beth Racine, Co-I

PERMANENT FORUM OF BINATIONAL WATERS

Marisol Dominguez, Research Scientist, Stakeholder Engagement

JSU Jackson State University

Rocky Talchabhadel, Co-I, Lead at JSU

Sunil Bista, PhD Student, Hydrologic Modeling