SPATIOTEMPORAL DYNAMICS OF CHLOROPHYLL-A IN THE POTI COASTAL ZONE: A MULTI-ECOSYSTEM APPROACH (2023–2026), *Preliminary results*.

Integrating Sentinel-2 Imagery and In-Situ Monitoring for Coastal Management.

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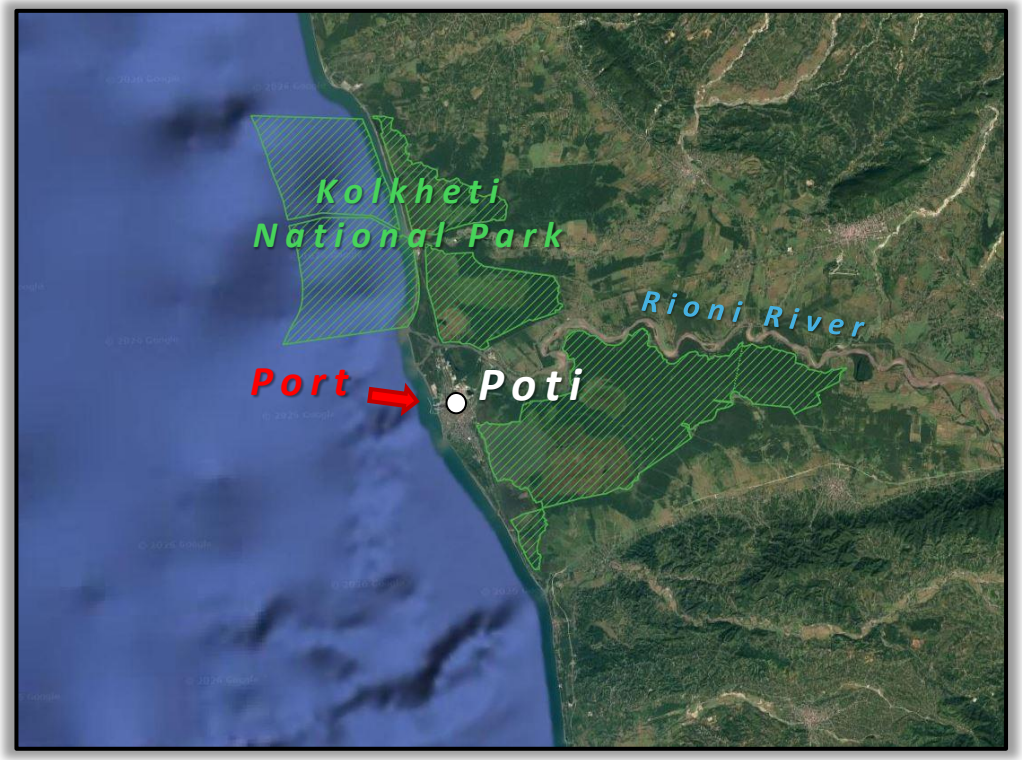
Research motivation and The Study Area

Why Poti ?

- ***The "Hydrological Crossroads" of Georgia.***

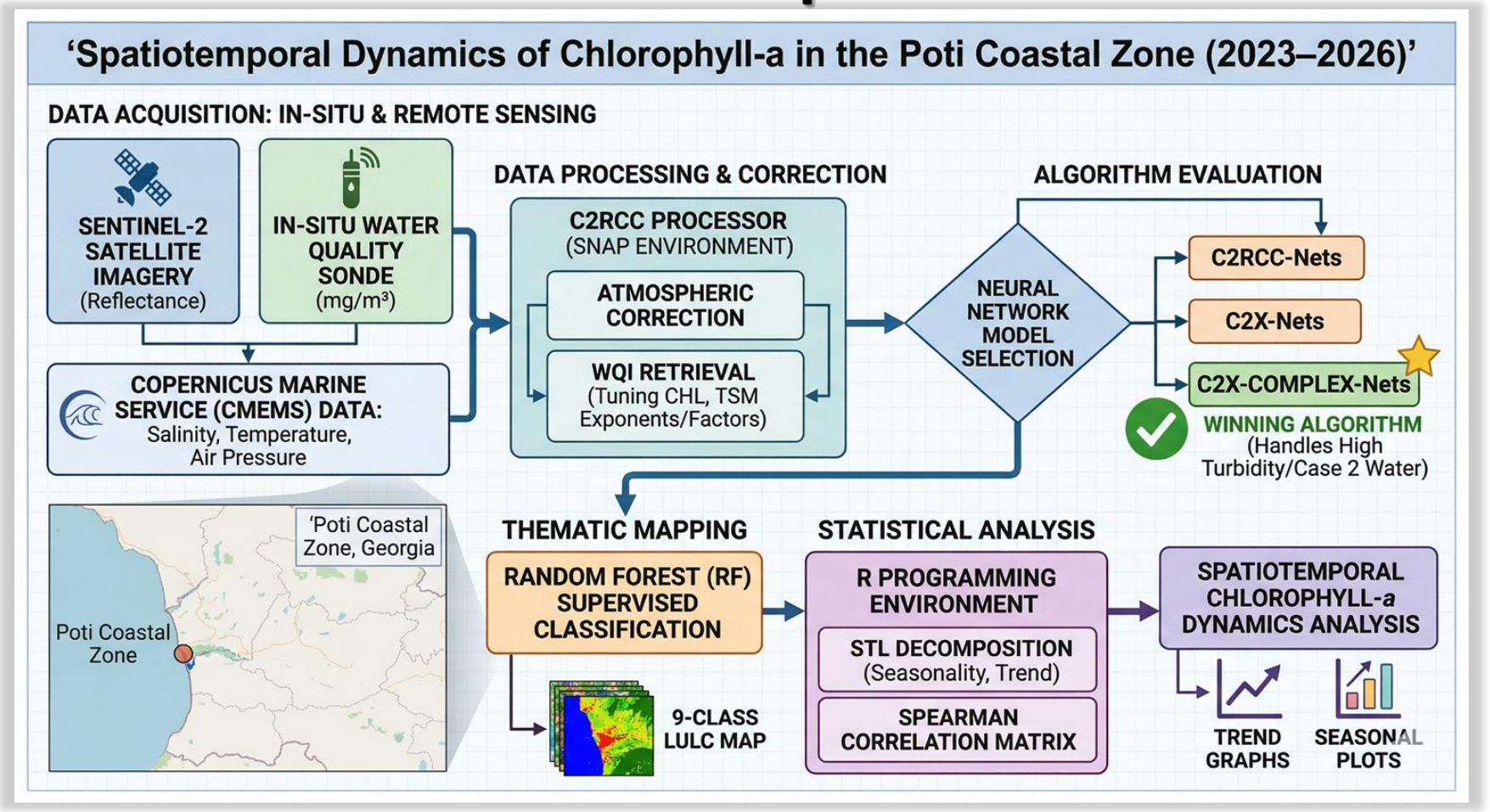
  - *Highly complex coastal system.*
  - *One of the most ecologically valuable territory .*

- ***Goals: Quantifying human impact (Port/City) vs. natural dynamics (Wetlands/MPAs).***



Key topics: Anthropogenic, Estuarine Dynamics, High Conservation Value

Data Fusion: Space vs. Sea



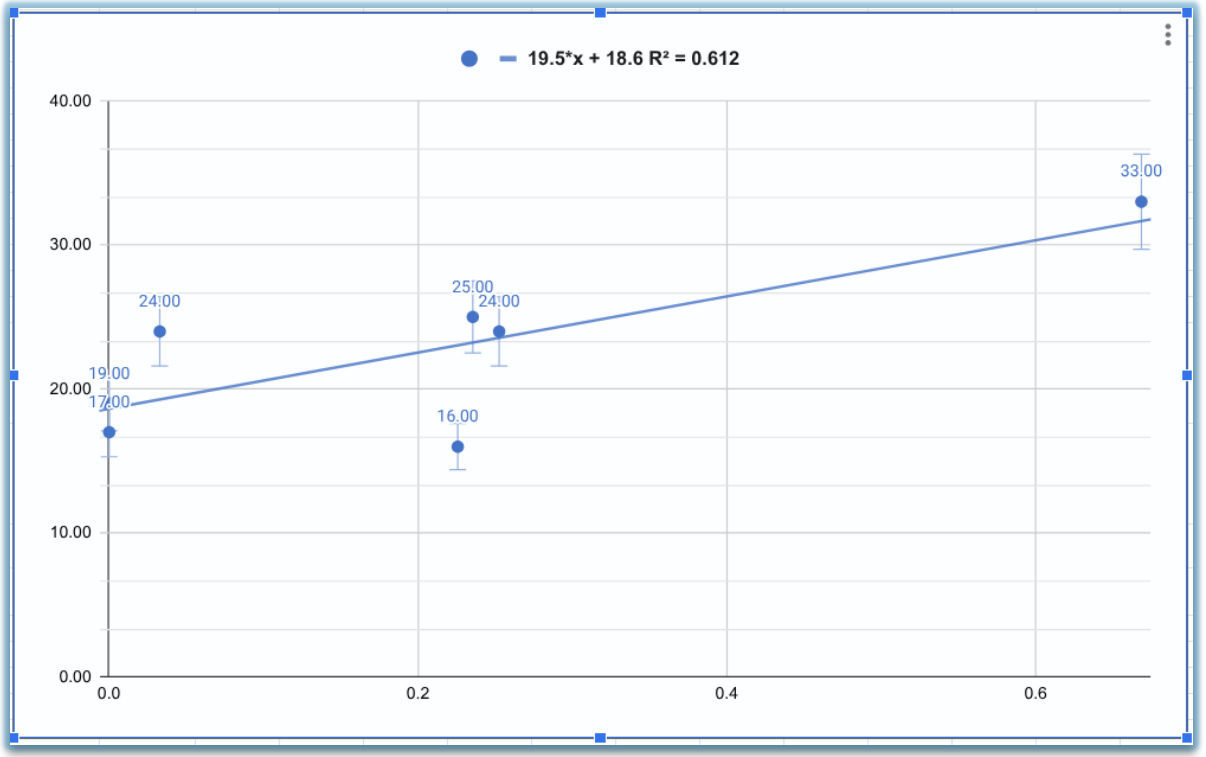
Sentinel-2 (Images) + In-Situ Sonde (The "ground truth").

Key topics: Ground Truth, Optically complex, Neural Networks.

Calculation the specific CHL Exponent and CHL Factor

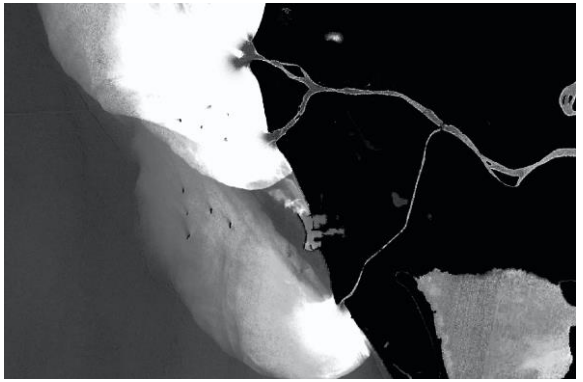
Calibration Workflow:

1. *Input (x): IOP_apig (Sentinel-2 Satellite Signal)*
2. *Target (y): In-situ Chlorophyll (Field Measurements)*
3. *Method: Log-Log Linear Regression (ln transformation)*
4. *Outcome: Site-specific Slope & Intercept for calibration (CHL Factor and CHL Exponent)*

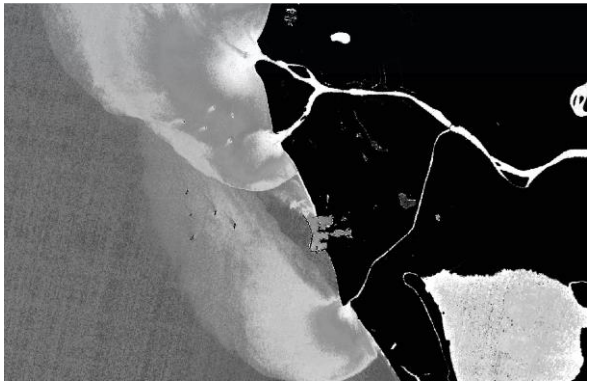


The scatter plot shows the linear correlation between the original Chl-a raster and the in-situ data R^2=0.612

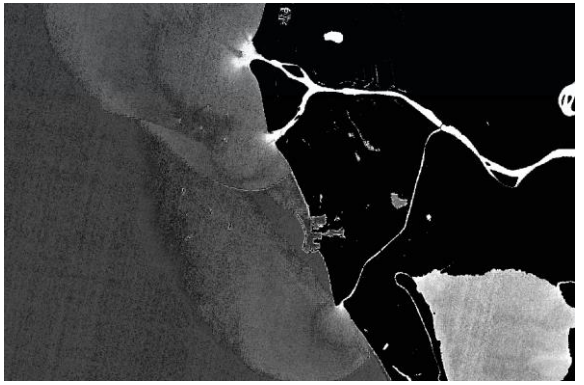
The "Winning" Algorithm (C2RCC)



C2RCC-Nets



C2RCC-C2X-Nets

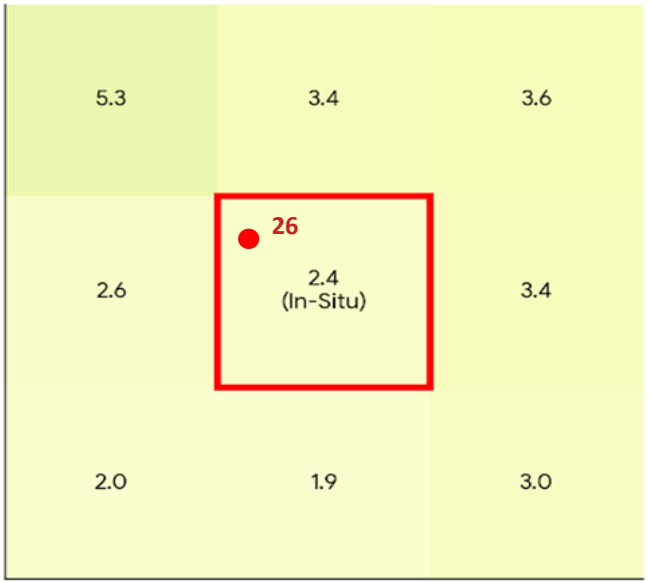


C2RCC-COMPLEX-Nets

- *Comparison of C2RCC-Nets, C2X, and C2X-COMPLEX.*
- *The C2X-COMPLEX-Nets emerged as our 'winning' algorithm.*
- *C2X-COMPLEX Specifically designed for extreme coastal conditions where light scattering and absorption are very high.*

Calibrated Model Validation

1.Original Raster
(No Calibration)



Relative Error (Mean): 88.2%

2.Calibrated Raster
(Factor/Exponent Applied)

Relative Error (Mean): 24.2%

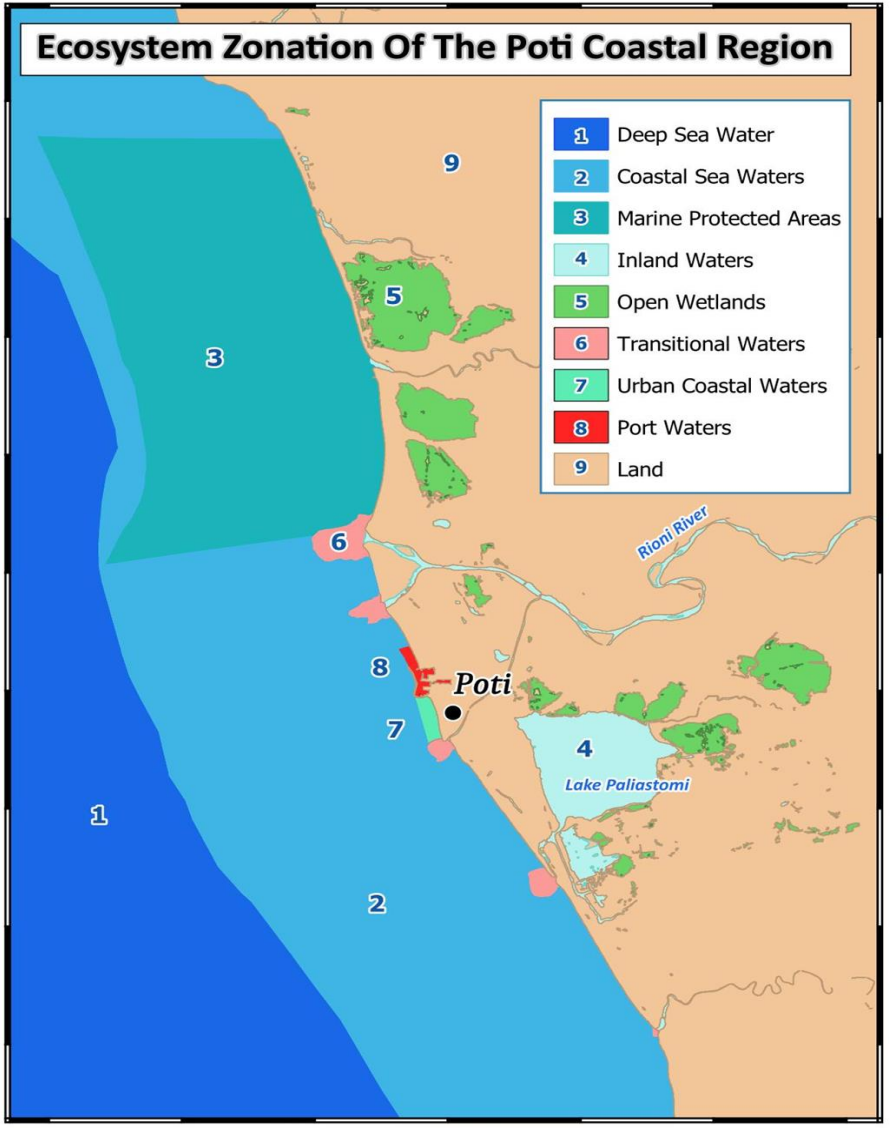
Comparison of Pixel Matrices in a 3 × 3 Grid (Sonde Value: 26 mg/m³)

Machine Learning Zonation

A map showing the 9 classes:

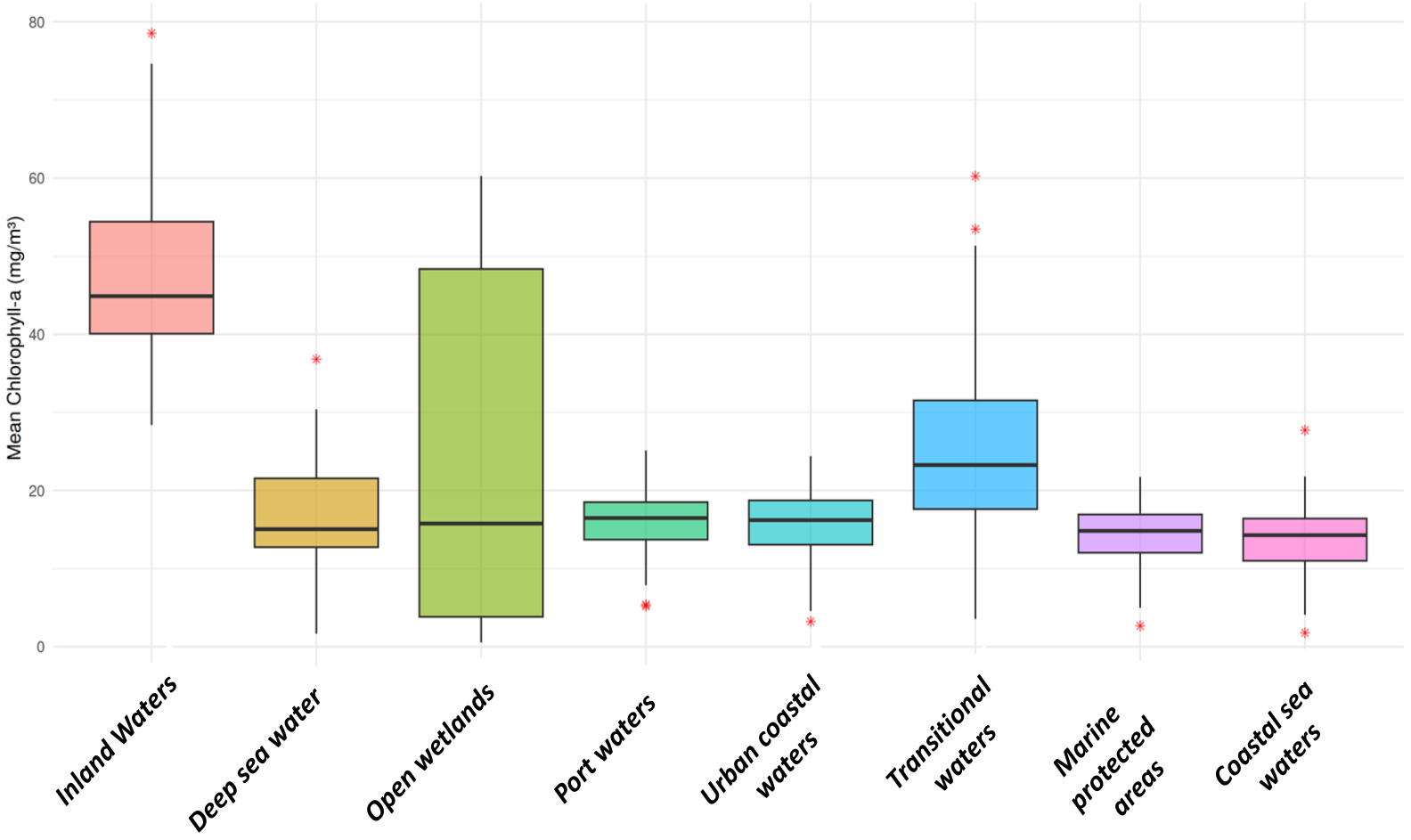
1. *Deep sea water,*
2. *Coastal sea waters (10 km),*
3. *Marine protected areas,*
4. *Inland waters ,*
5. *Open wetlands,*
6. *Transitional waters,*
7. *Urban coastal waters,*
8. *Port waters.*

- ***Random Forest (RF) Supervised Classification.***
- ***Spectral Signatures (muddy water vs. clear water)***
- ***Delineation (defining the boundaries of an area)***

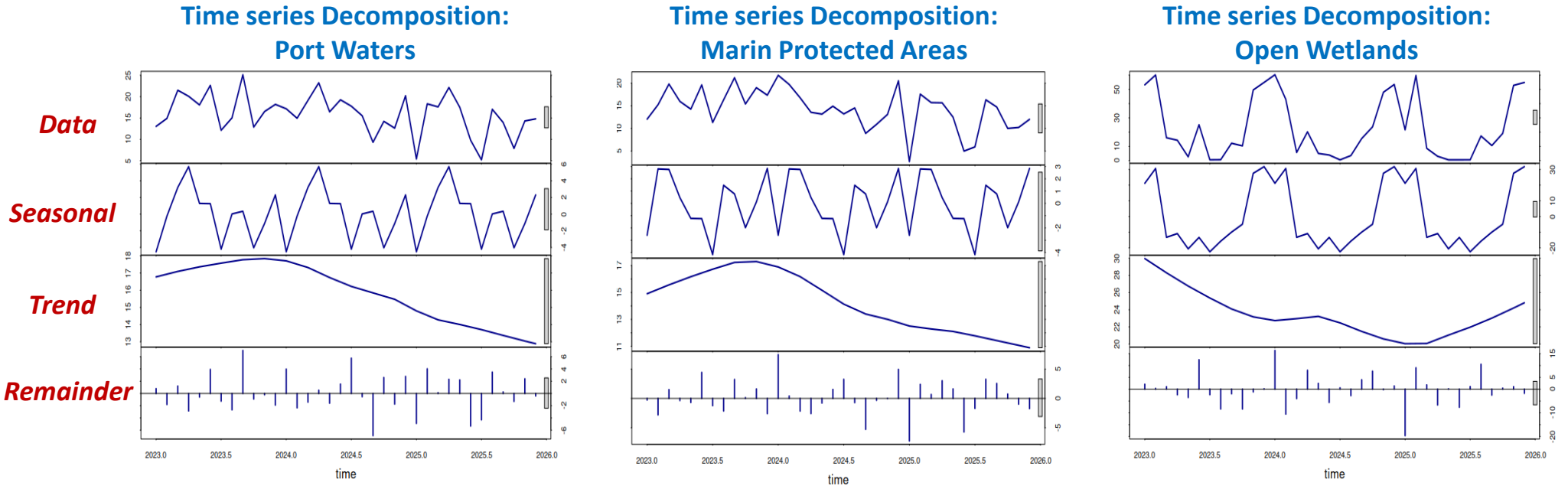


Statistical Summary (The Boxplots)

Chlorophyll-a Variability Across 8 Aquatic Zones (Poti Coastal Area (2023-2023)



The Seasonal Pulse (STL Decomposition)



Data: ***The top panel represents the Raw Data or Observed signal.***

Seasonal: ***The Seasonal component represents the repeating patterns that occur at fixed intervals, such as daily, monthly, or yearly rhythms.***

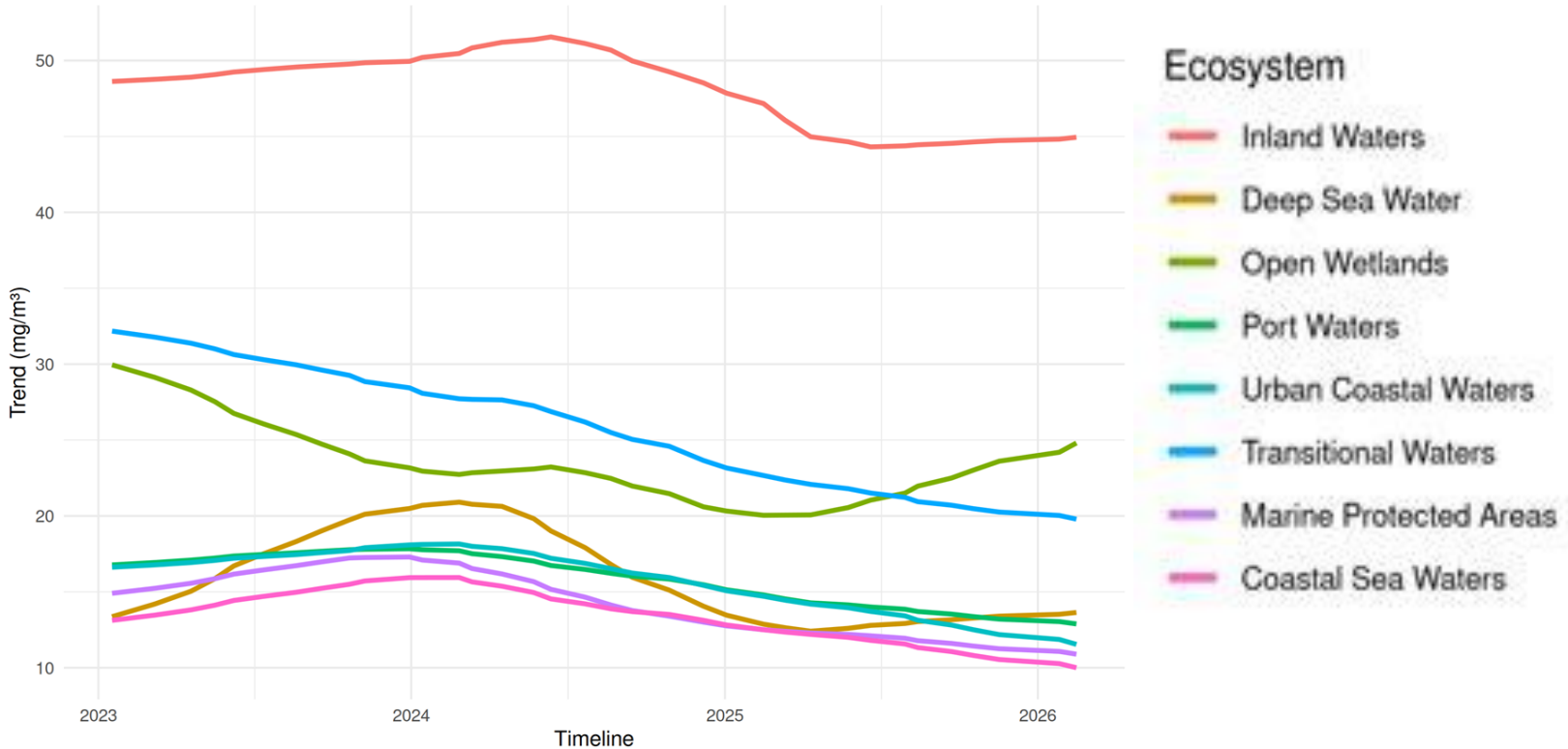
Trend: ***The Trend component shows the long-term direction of the data.***

Remainder: ***The Remainder (Residual) represents what is left over after the Trend and Seasonal components are subtracted from the raw Data.***

Long-Term Trends

Long-term Chlorophyll-A Trends by Ecosystem

Removing seasonal noise to reveal the true environmental direction

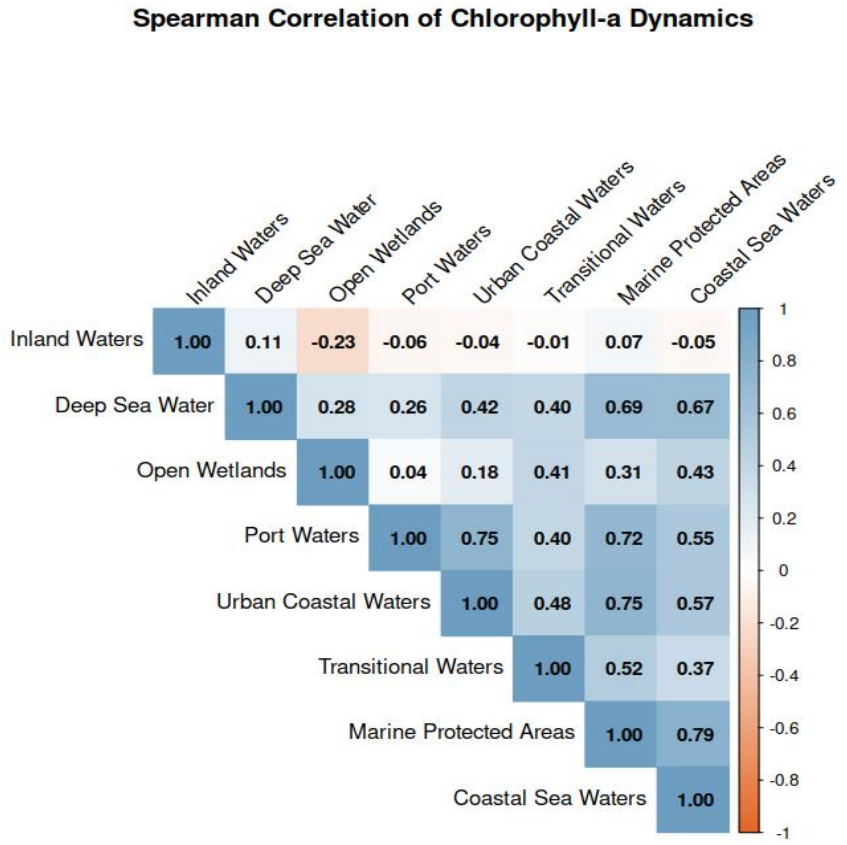


.Is the water getting cleaner? Discuss the "Trend" lines from R. Note any significant upward or downward slopes.???

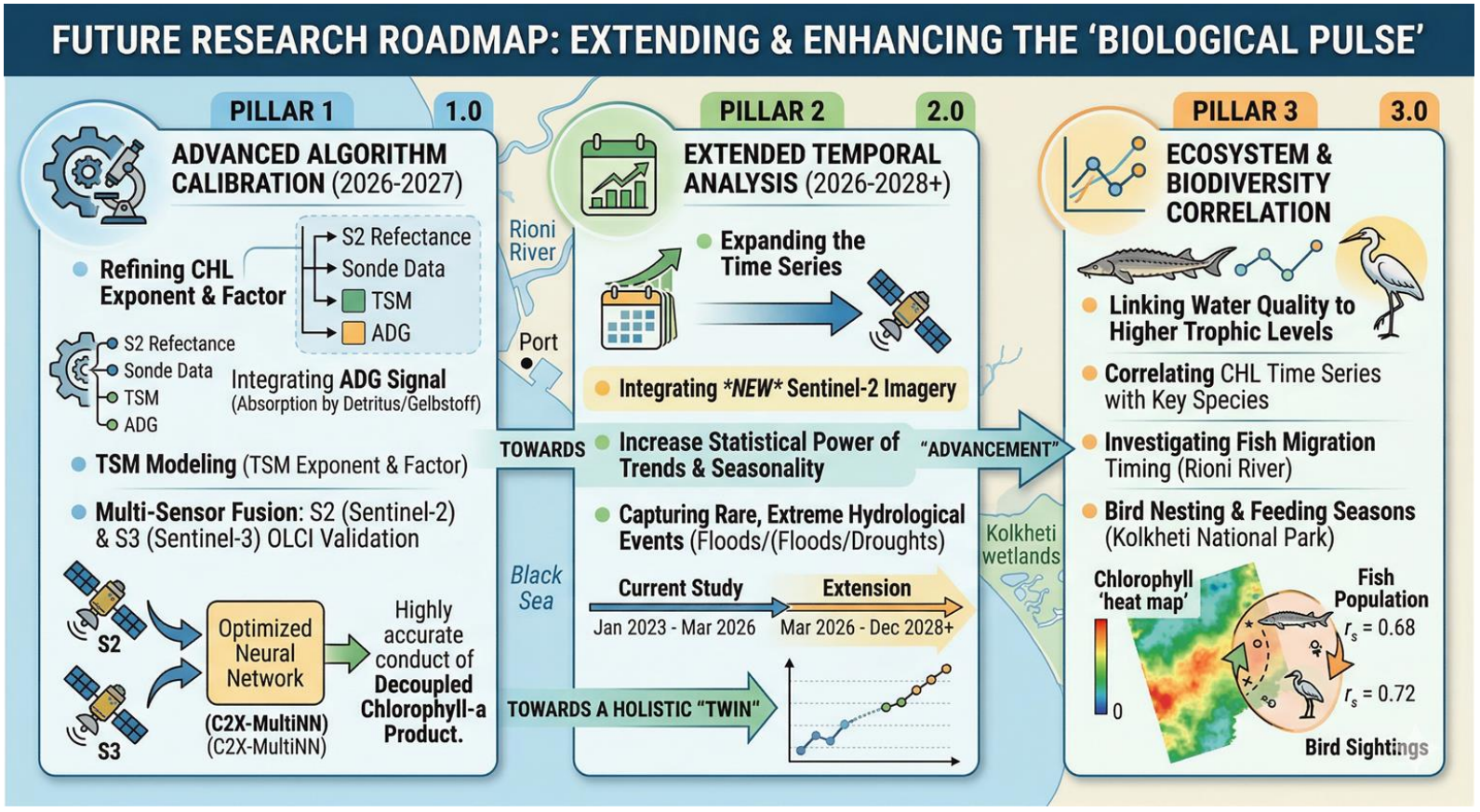
The Connectivity Matrix (Spearman)

- ***The Mystery: Explain the negative correlation between Open Wetlands and Inland Waters.***

- ***"When the river floods (high Inland flow), it may increase turbidity so much that it shades the light, or the wetlands might peak during low-flow summer months when the water is stagnant and warm."***

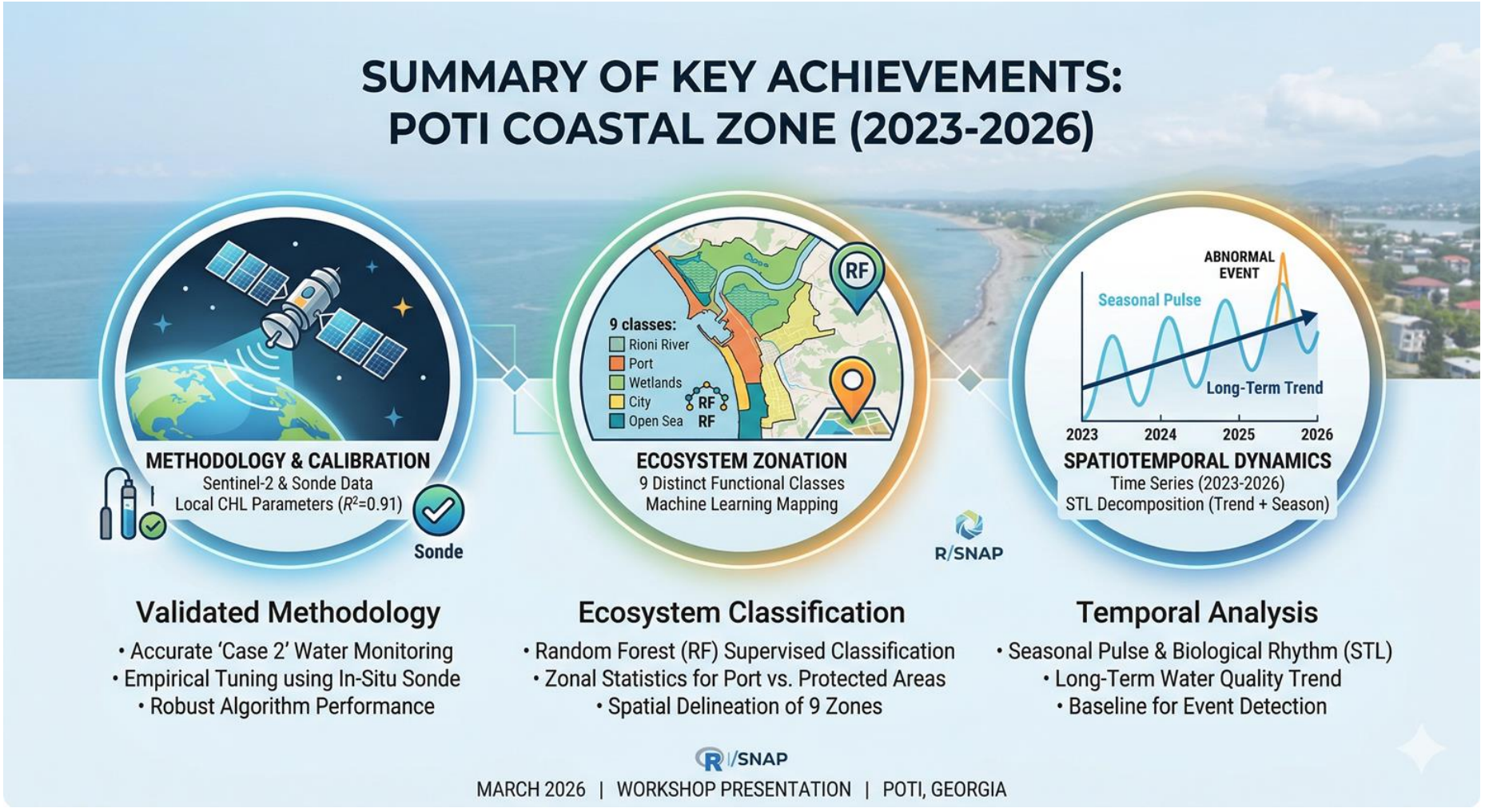


Next Steps & Improvements



Pillar 1: Calibration 2.0 (The Technical Gear); Pillar 2: Expanded Time Series (The Timeline) ; Pillar 3: Ecological Correlation (The Life)

Conclusion


SUMMARY OF KEY ACHIEVEMENTS:
POTI COASTAL ZONE (2023-2026)
METHODOLOGY & CALIBRATION
Sentinel-2 & Sonde Data
Local CHL Parameters (R^2=0.91)
Sonde
9 classes:
Rioni River
Port
Wetlands
City
Open Sea
RF
RF
ECOSYSTEM ZONATION
9 Distinct Functional Classes
Machine Learning Mapping
R/SNAP
ABNORMAL EVENT
Seasonal Pulse
Long-Term Trend
2023
2024
2025
2026
SPATIOTEMPORAL DYNAMICS
Time Series (2023-2026)
STL Decomposition (Trend + Season)
Validated Methodology
• Accurate 'Case 2' Water Monitoring
• Empirical Tuning using In-Situ Sonde
• Robust Algorithm Performance
Ecosystem Classification
• Random Forest (RF) Supervised Classification
• Zonal Statistics for Port vs. Protected Areas
• Spatial Delineation of 9 Zones
Temporal Analysis
• Seasonal Pulse & Biological Rhythm (STL)
• Long-Term Water Quality Trend
• Baseline for Event Detection
R/SNAP
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