University of Sri Jayewardenepura
ශ්‍රී ජයවර්ධනපුර විශ්වවිද්‍යාලය
ஸ்ரீ ஜயவர்த்தனபுர பல்கலைக்கழகம்

Development of a Hybrid Spatio-Temporal Skill Verification Framework for Weekly Rainfall Forecasting Models in Sri Lanka

Presented by :   **A.H.M.L.S. Senavirathna**
Index No   :   **AS2021393**

Department :   **Statistics**
Degree   :   **B.Sc. (Honours) Degree in Applied Science**

List of Content

1. Background and Significance

Sri Lanka's Agricultural Dependency

❏ **25% of workforce** engaged in farming dependent on rainfall patterns

❏ Major crops (paddy, tea, rubber) rely on monsoon timing and intensity

❏ Four key seasons: Southwest Monsoon, Northeast Monsoon, and two Inter-Monsoon periods

Current Gap

❏ **Short-range forecasts (1-3 days) are reliable**

❏ **Sub-seasonal forecasts (1-4 weeks) critically lacking**

❏ **Essential for fertilizer application, irrigation scheduling, and harvest timing**

2. Models in Use & Their Limitations

Model	Source	Strengths	Weaknesses
NCMRWF	India	Regional expertise	Monsoon placement errors in later weeks
ECMWF	Europe	Excellent Week 1 performance	Dry/wet biases after Week 2
NCEP CFSv2	USA	Global coverage	Rapid skill degradation after Week 2
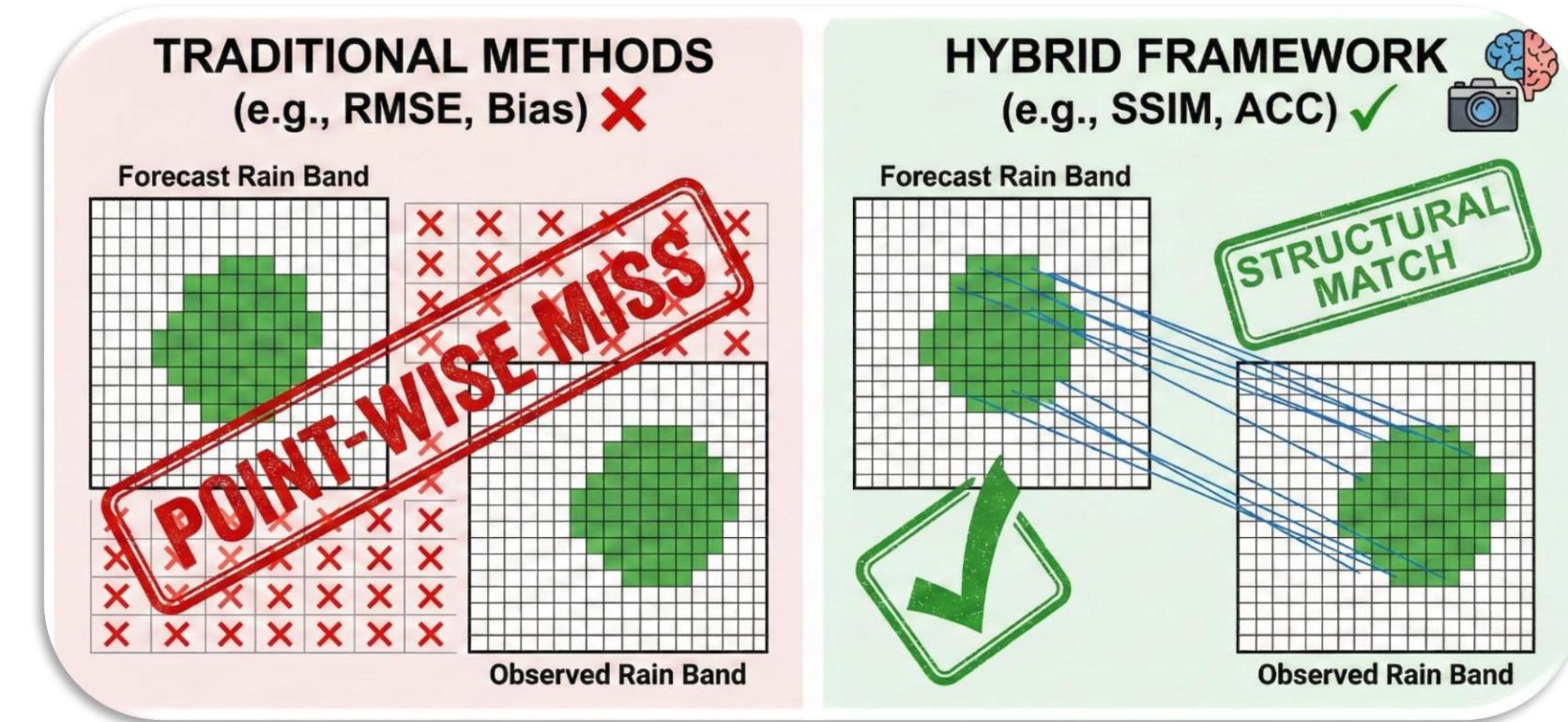
Key Issue

❑ Biases and spatial displacement errors over Sri Lanka's complex terrain, especially in Weeks 3-4

3. Innovation and Verification Method

TRADITIONAL METHODS (e.g., RMSE, Bias) ❌ — Forecast Rain Band / Observed Rain Band — POINT-WISE MISS

HYBRID FRAMEWORK (e.g., SSIM, ACC) ✓ 📷 — Forecast Rain Band / Observed Rain Band — STRUCTURAL MATCH

Agricultural Relevance:
❑ Farmers need to know WHERE and WHEN rain will fall, not just rainfall amounts

Traditional Methods ❌

❑**RMSE & Bias:** Measure point-wise errors

❑Fail to account for spatial displacement

❑Miss overall pattern similarities

❑Example: Forecast predicts rain in Colombo, but falls in Negombo. It marked as total failure.

Hybrid Approach ✓

❑**Classical Stats:** ACC, FSS, SAL for meteorological accuracy

❑**Computer Vision:** SSIM, IoU for spatial patterns

❑Treats rainfall maps as images

❑Captures structural accuracy of rain bands

Research Objectives

Main Objective →

❑ To evaluate weekly rainfall forecast skill of **NCMRWF, ECMWF**, and **NCEP** models over Sri Lanka and identify the most reliable model for agricultural decision-making during monsoon seasons

Specific Objectives →
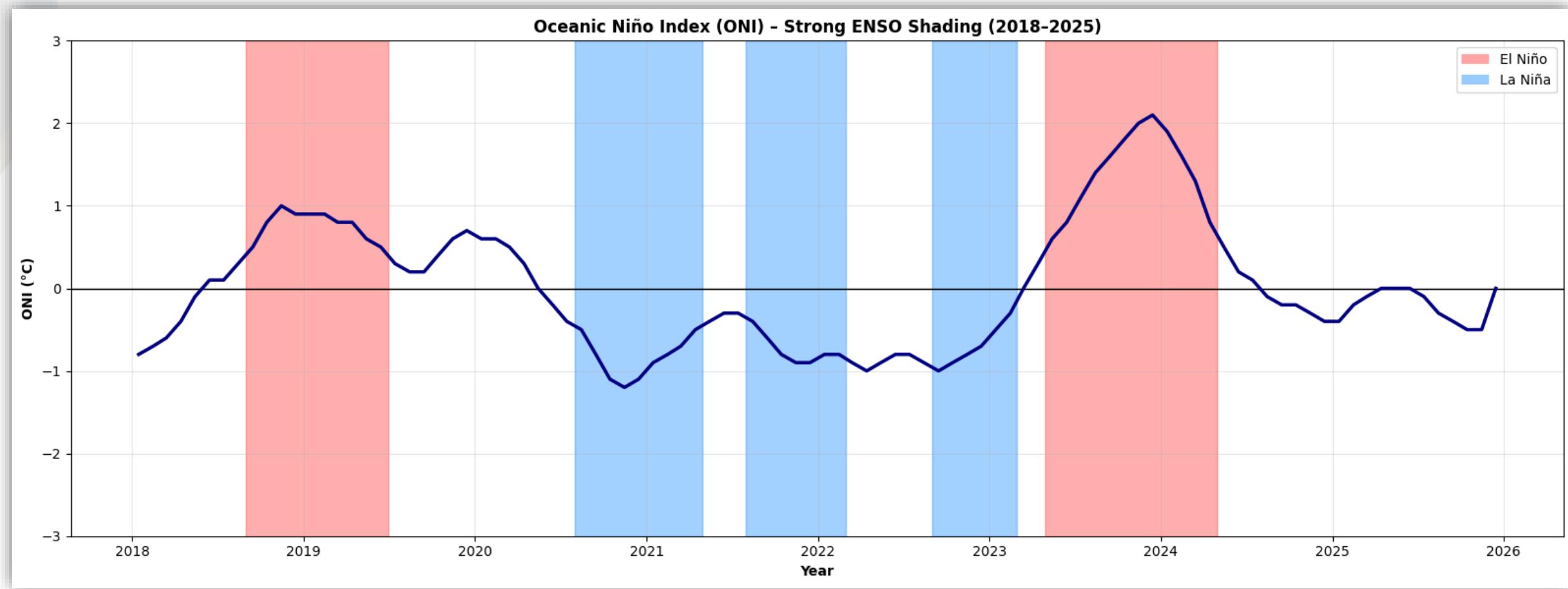
❑ Verify model performance across **all monsoon seasons** using spatial and statistical metrics against blended satellite-gauge observations

❑ Quantify **spatial displacement errors** and skill degradation over the 4-week forecast lead time using hybrid methods

❑ Develop **model recommendations** tailored to different lead times and agro-climatic zones for operational use

Research Design

Retrospective Quantitative Analysis Period:

❏ January 1, 2018 – December 31, 2025 (8 years)

Oceanic Niño Index (ONI) - Strong ENSO Shading (2018-2025)

Why 8 Years?

ENSO Coverage

❏ 2+ El Niño events (2018-19, 2023-24)
❏ 2+ La Niña periods (2020-22 "triple-dip")
❏ Multiple neutral phases

Data Availability

❏ Consistent model hindcasts
❏ All major monsoon seasons
❏ Robust climate representation

Data Collection Method

Two primary Datasets

1. Observational Data

Resolution:
❑ 0.05° high-resolution daily rainfall grids

Sources:
❑ 400+ Department of Meteorology stations
❑ NASA GPM IMERG satellite data

Method: Cressman objective analysis blending

2. Forecast Data

Models:
❑ NCMRWF Coupled Unified Model

❑ ECMWF Ensemble Prediction System

❑ NCEP Global Forecast System

Output: Weekly accumulated precipitation

Innovation
Land mask + buffer-weight map ensures station data dominates over land while satellite fills spatial gaps

https://lakshithasenavirathna.github.io/rainfall-merging-viz/

Analysis Workflow

Phase 01 : Observational Data Preparation

- ❑ Cressman successive correction objective analysis blending station + satellite data on 0.05° grid with land mask

Phase 02 : Classical Skill Verification

Metrics:
- ❑ Bias
- ❑ ACC (>0.6 threshold)
- ❑ FSS (neighborhood verification)
- ❑ SAL (structure-amplitude-location)

Phase 03 : Computer Vision Analysis

- ❑ **SSIM:** Structural similarity for rain band quality
- ❑ **IoU:** Intersection over Union for heavy rain events

Phase 04 : Model Optimization

- ❑ Weighted scoring combining ACC + SSIM

    → Recommendation matrix by week and monsoon season

Key Metrics Explained

Metric	Type	What It Measures	Threshold
ACC	Classical	Pattern correlation between forecast and observed anomalies	>0.6 = Skillful
FSS	Classical	Neighborhood-based spatial accuracy across scales	Higher = Better
SAL	Classical	Decomposes errors: Structure + Amplitude + Location	Near 0 = Perfect
SSIM	Computer Vision	Perceptual similarity: luminance, contrast, structure	0-1 scale
IoU	Computer Vision	Overlap of heavy rain areas (>50mm/week)	0-1 scale

Project Timeline

Task / Phase	Nov 2025	Dec 2025	Jan 2026	Feb 2026	Mar 2026
Literature Review	Nov 1-30				
Research Proposal Writing		Dec 1-15			
Cressman Analysis Preparation		Dec 16-31	Jan 1-15		
Implement Cressman Analysis			Jan 16-31		
Classical Skill Verification				Feb 1-14	
Computer Vision Metrics				Feb 15-28	
Model Comparison & Optimization				Feb 15-28	
Thesis Writing					Mar 1-31

Computational Platforms

Languages: Python (Cressman analysis, CV metrics) + R (geostatistics)

Platform: Visual Studio Code, R Studio
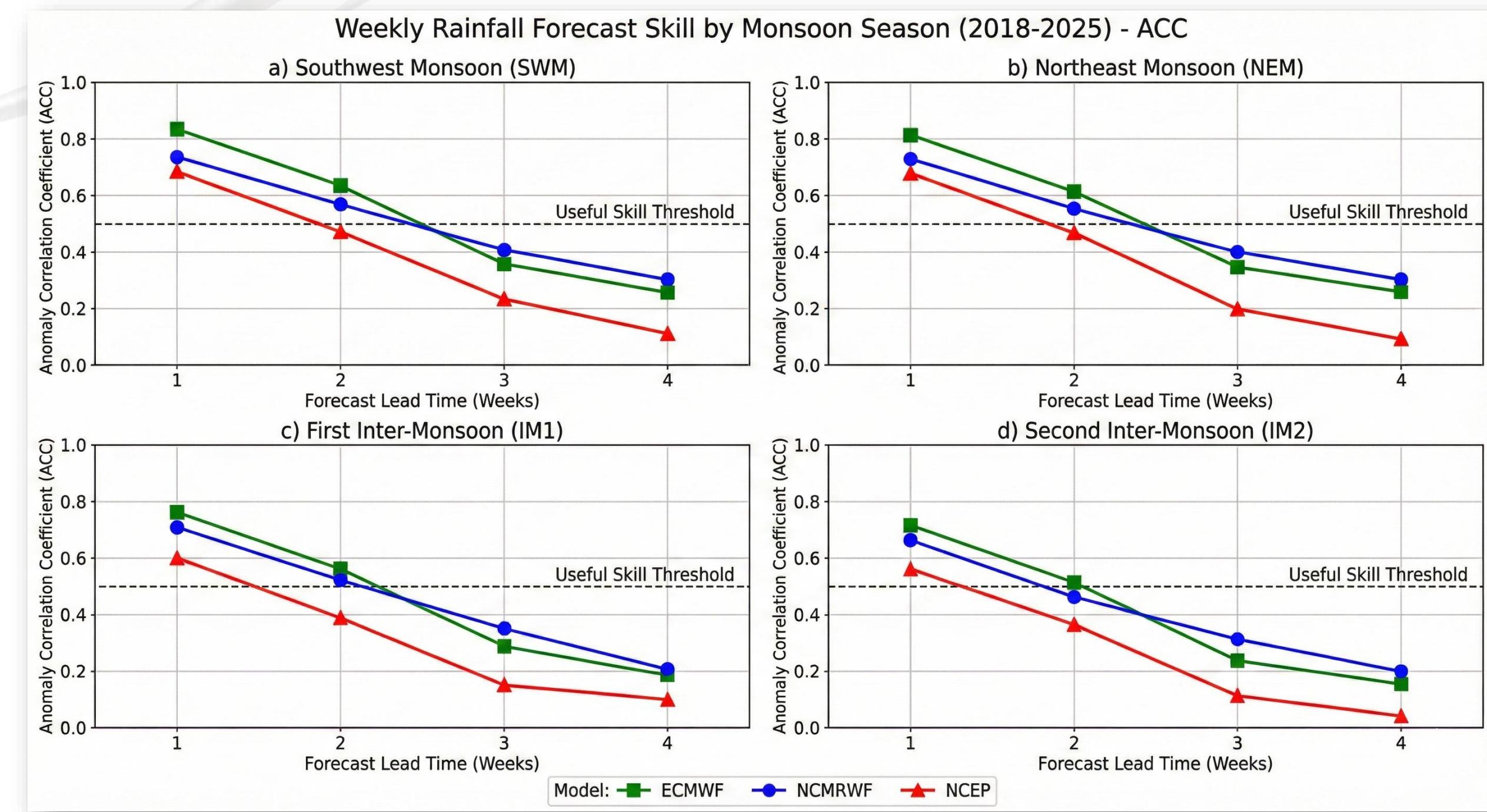
Software: Open-source tools only

Funding: No external funding required

Expected Outcomes

1. Comprehensive Model Evaluation:
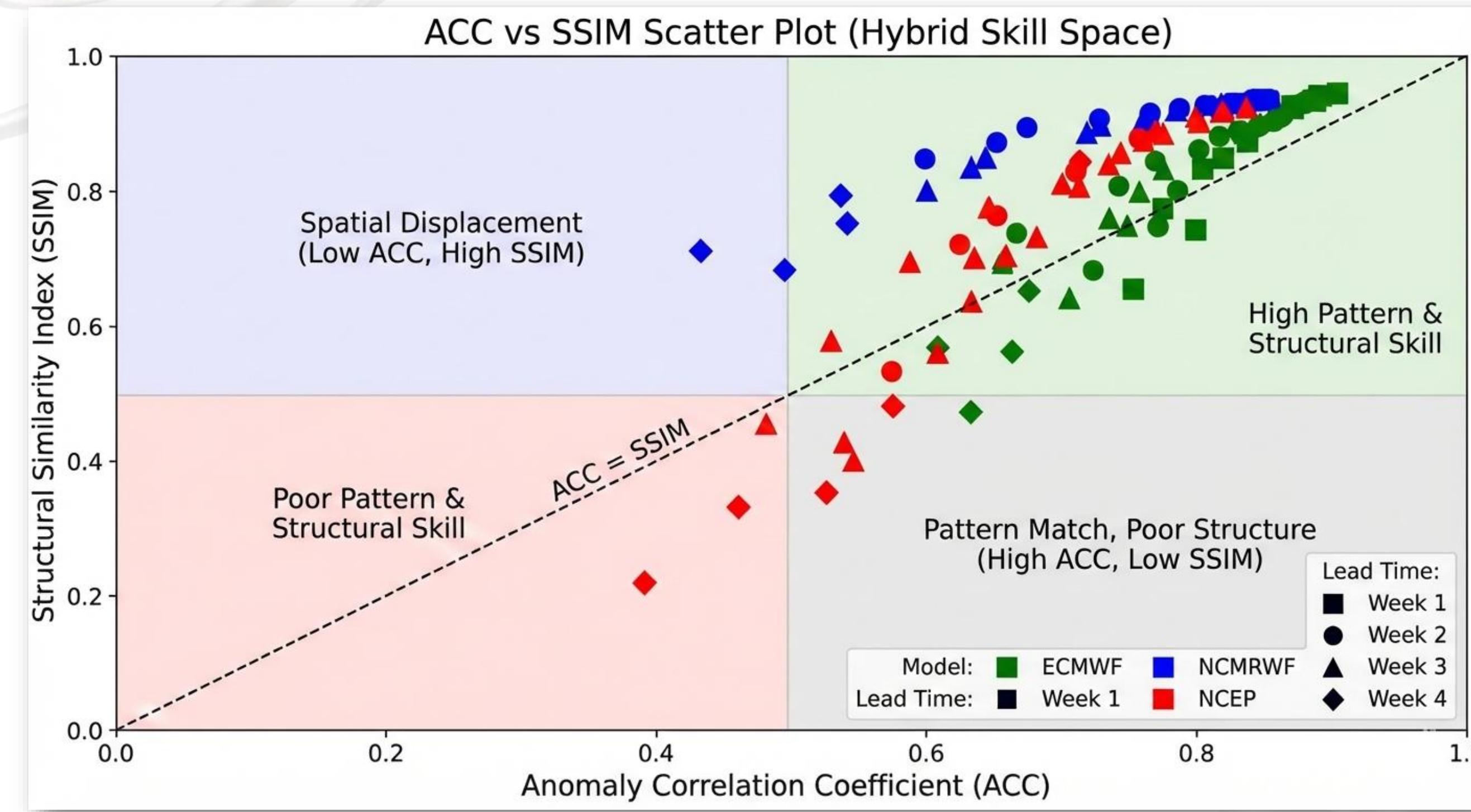
Detailed skill profiles for all three models (2018-2025) identifying strengths and weaknesses across monsoon seasons

Weekly Rainfall Forecast Skill by Monsoon Season (2018-2025) - ACC

Expected Outcomes

2. Hybrid Verification Framework:
Reusable Python codebase combining ACC, FSS with SSIM, IoU—applicable beyond this study
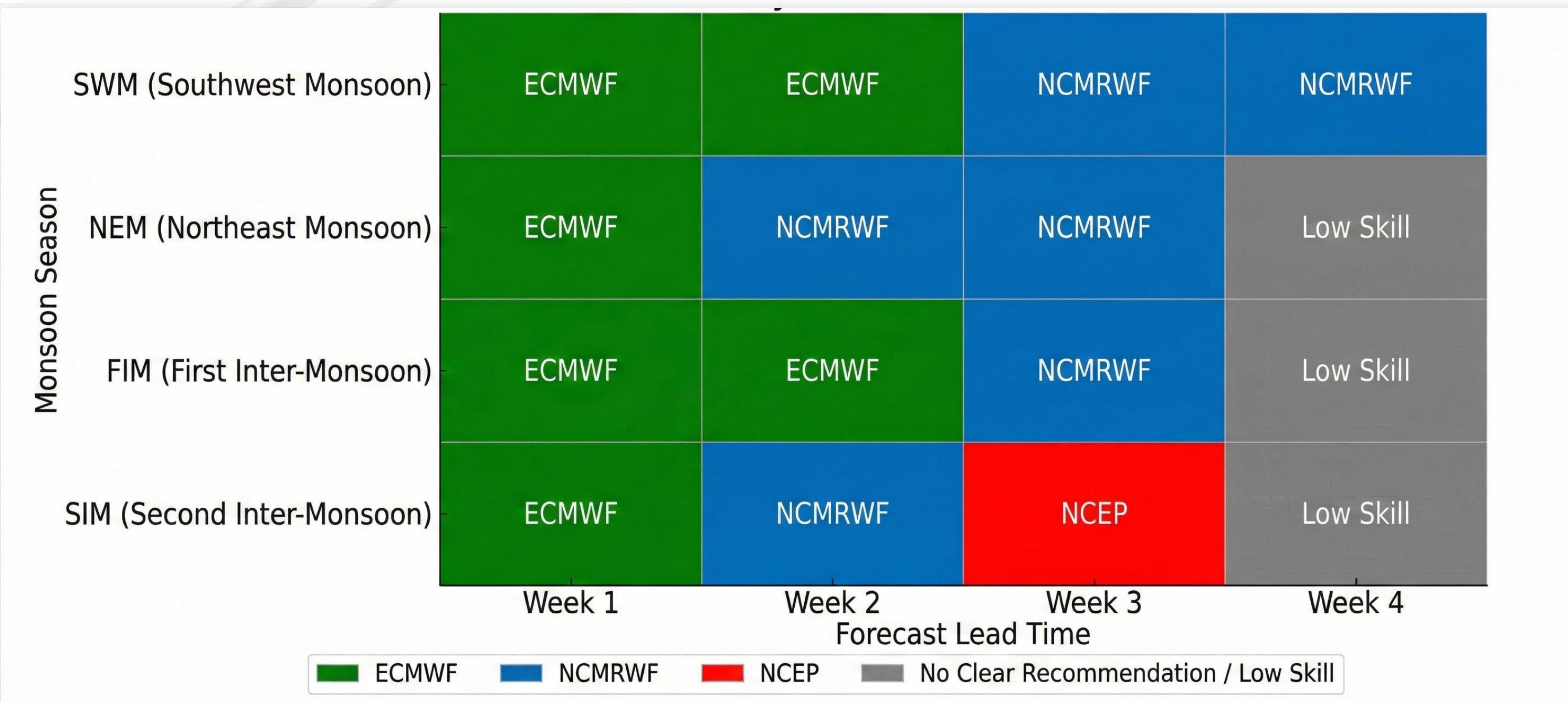
Expected Outcomes

3. Operational Recommendation Matrix:
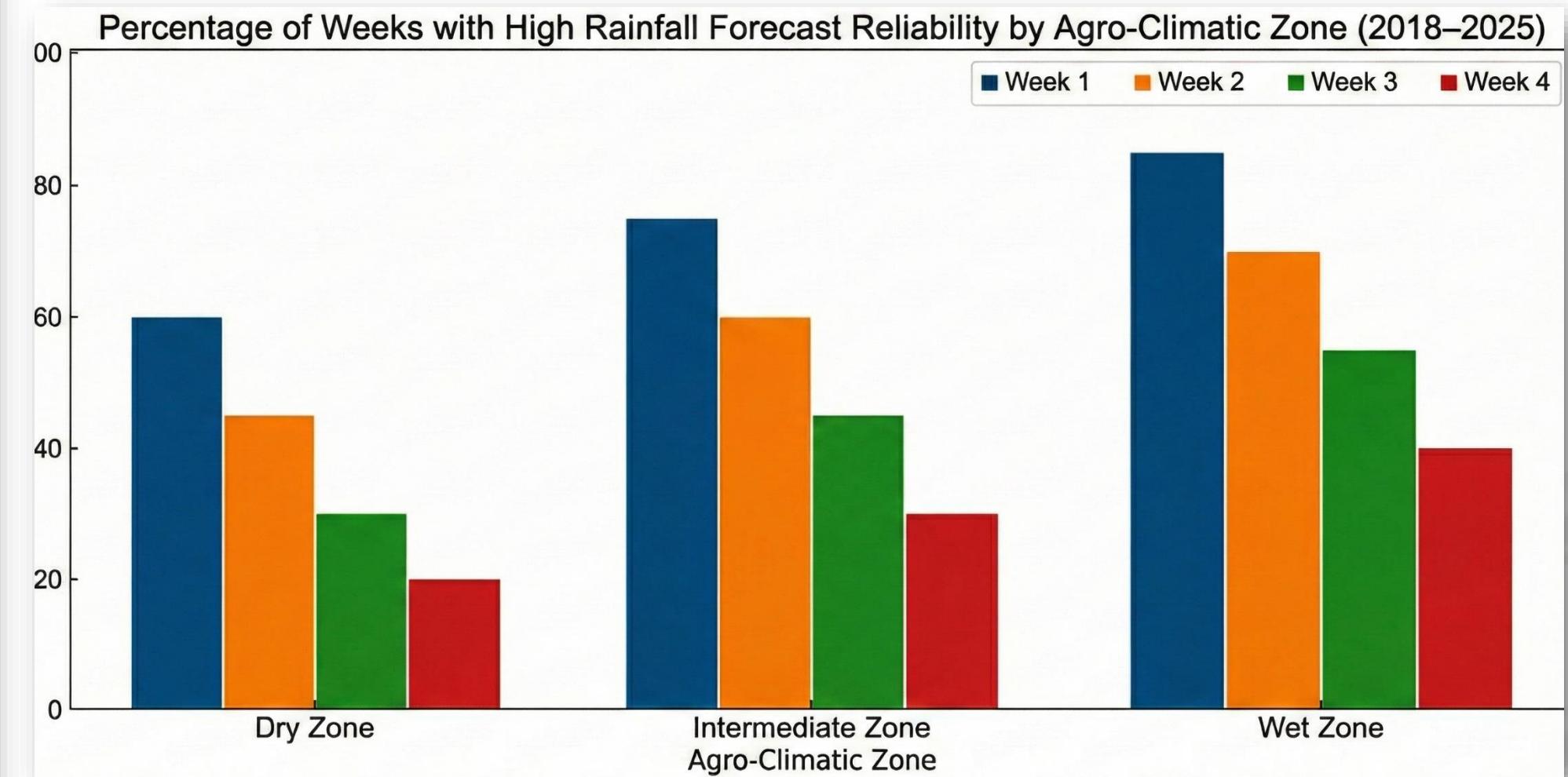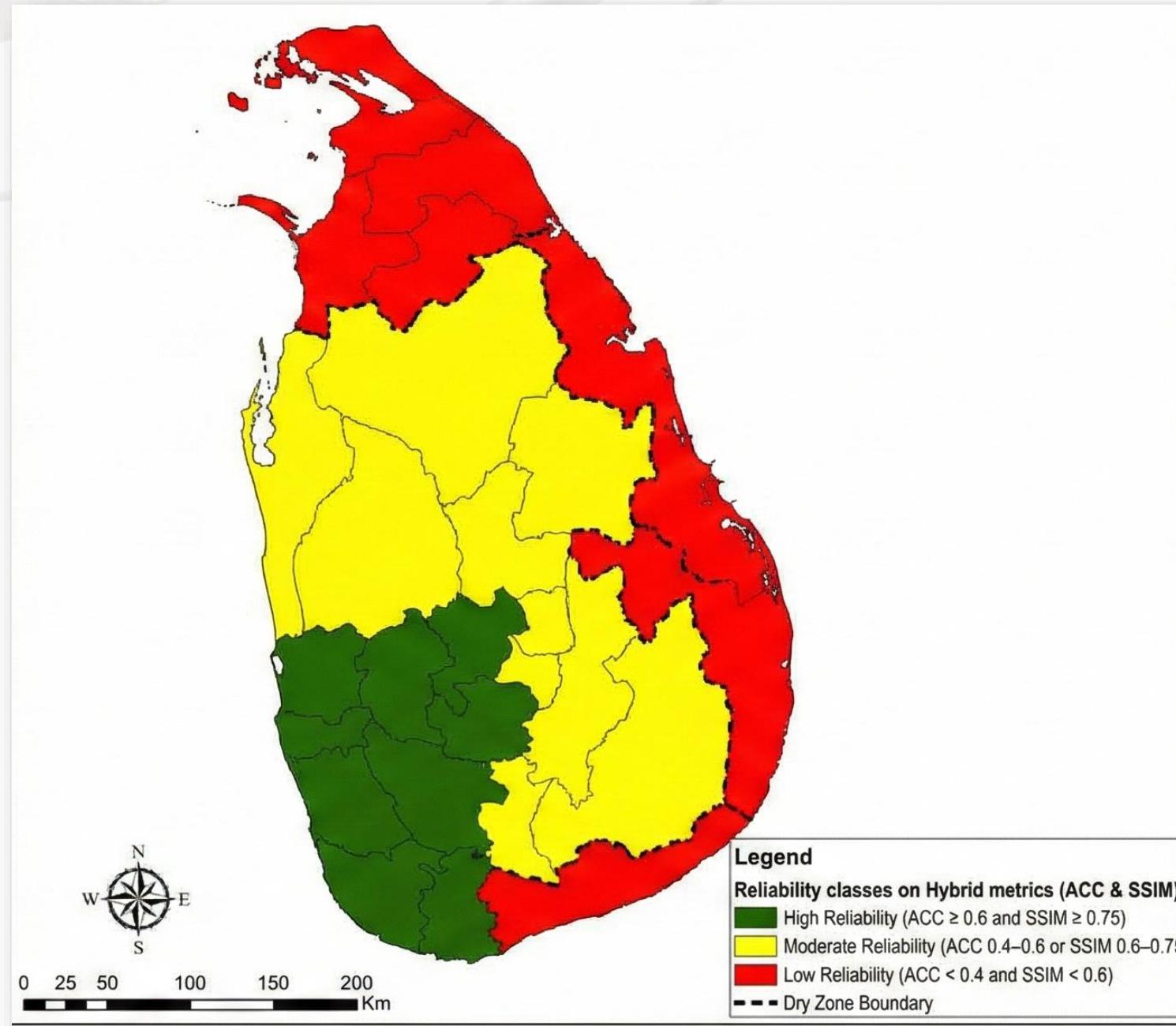
Practical guidelines: e.g., "SWM Week 1-2: ECMWF; Week 3-4: NCMRWF " for optimal model selection

Expected Outcomes

4. Agricultural Decision Support:

Enhanced weekly rainfall bulletins(a brief report) with reliability ratings for farmers in rainfed areas (Dry Zone)

Better Forecasts = Better Decisions = Improved Food Security

Thank You