Upsampling GRACE in the Senegal River Valley using XGBoost regression model

†Jemima O'Farrell[1,3], Michael Geever[1,3], Dualta Ó Fionnagáin[1,3], Patricia Codyre[2,3], Charles Spillane[2,3], Aaron Golden[1,3]

[1]School of Natural Sciences, [2]School of Biological & Chemical Sciences, [3]Ryan Institute College of Science and Engineering, University of Galway, Galway, Ireland, H91 TK33

TAPAS
AI for Climate Action

Upsampling GRACE to 0.25° Resolution

Numerous recent national and international aid interventions have focussed on the intensification of rice production in the Senegal River Valley (SRV) [1,2], which has had a major impact on land cover changes in the region. This study focuses on overcoming the limitations of the coarse spatial resolution of the Gravity Recovery and Climate Experiment (GRACE), set at 1° (~111km), which provides little spatial variation and limits the study of the local dynamics driving changes in Terrestrial Water Storage (TWS) across the SRV.

To overcome the limitations of the relatively low spatial resolution of the GRACE observations, the data has been downscaled from 1-degree resolution to 0.25-degree resolution using a machine learning (ML) pixel-based XGBoost regression model. The increase in resolution is visually demonstrated in *Figure 1.*

The data was preprocessed and extracted using the Google Earth Engine Python API, which leverages Google's cloud processing and open-access data to reduce the computational cost. The model is trained on GLDAS-2.2 climate variables, MODIS NDVI, MNDWI and GPM precipitation, resampled to the spatiotemporal resolution of GRACE data.

The current iteration of the model has a satisfactory R^2 score of 0.91 following 10-fold shuffled split cross-validation. The scatter plot in *Figure 2.* depicts the prediction accuracy of the model on the training set.

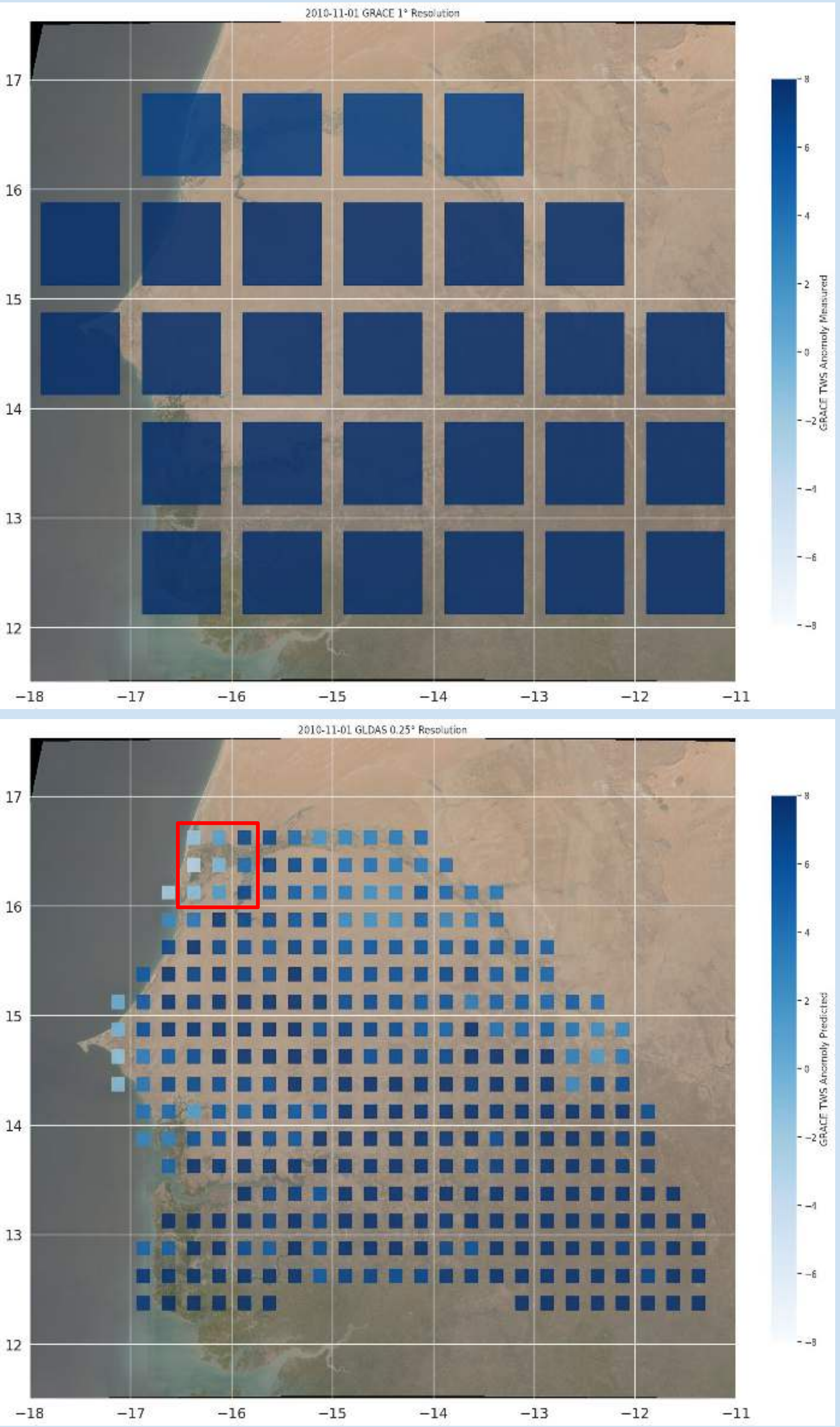

Fig 1. *Sample of the output resolution pixels clipped to Senegal compared with the nominal scale of GRACE pixels*

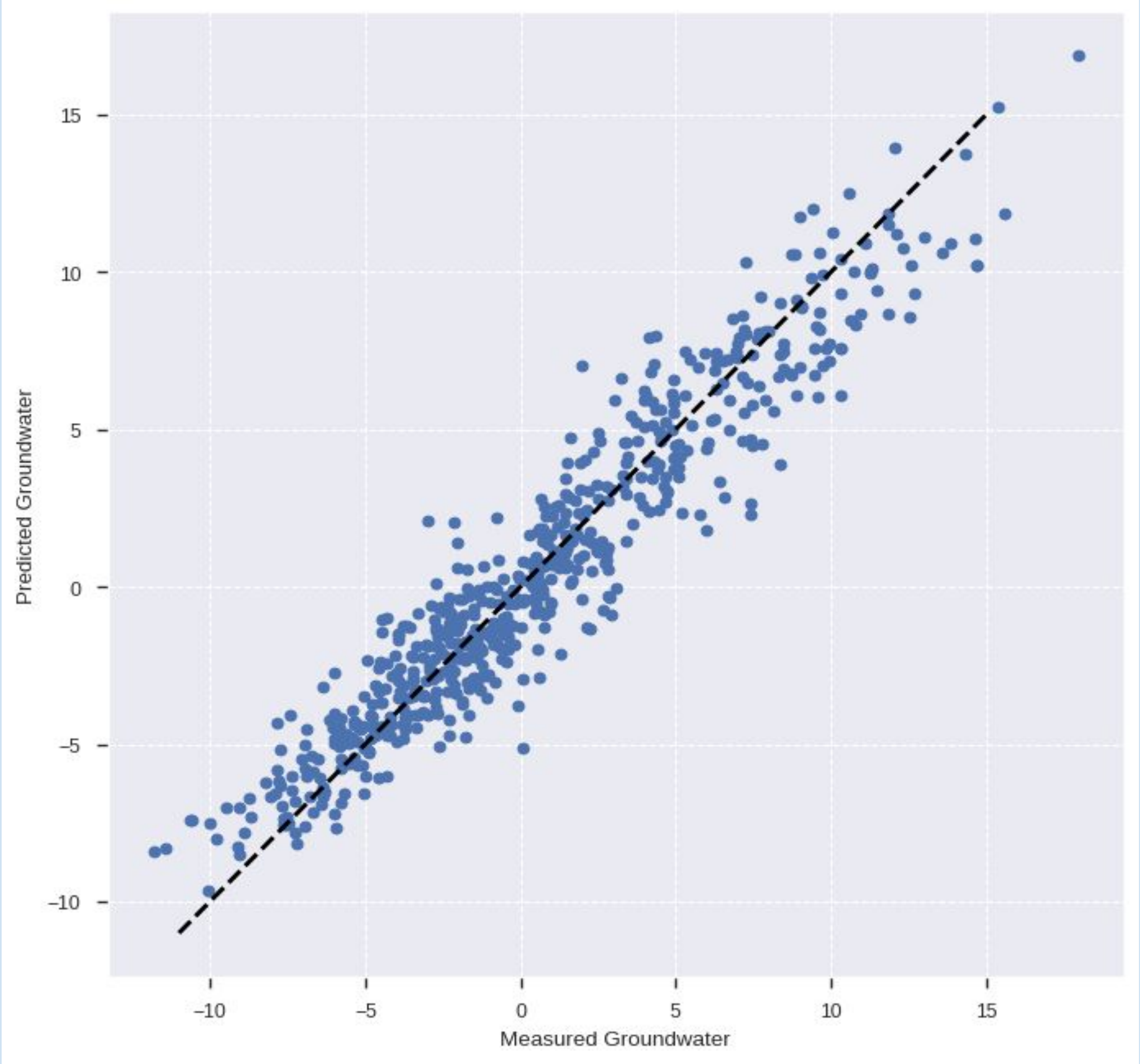

Fig 2. *Predicted Vs. Measured scatter plot*

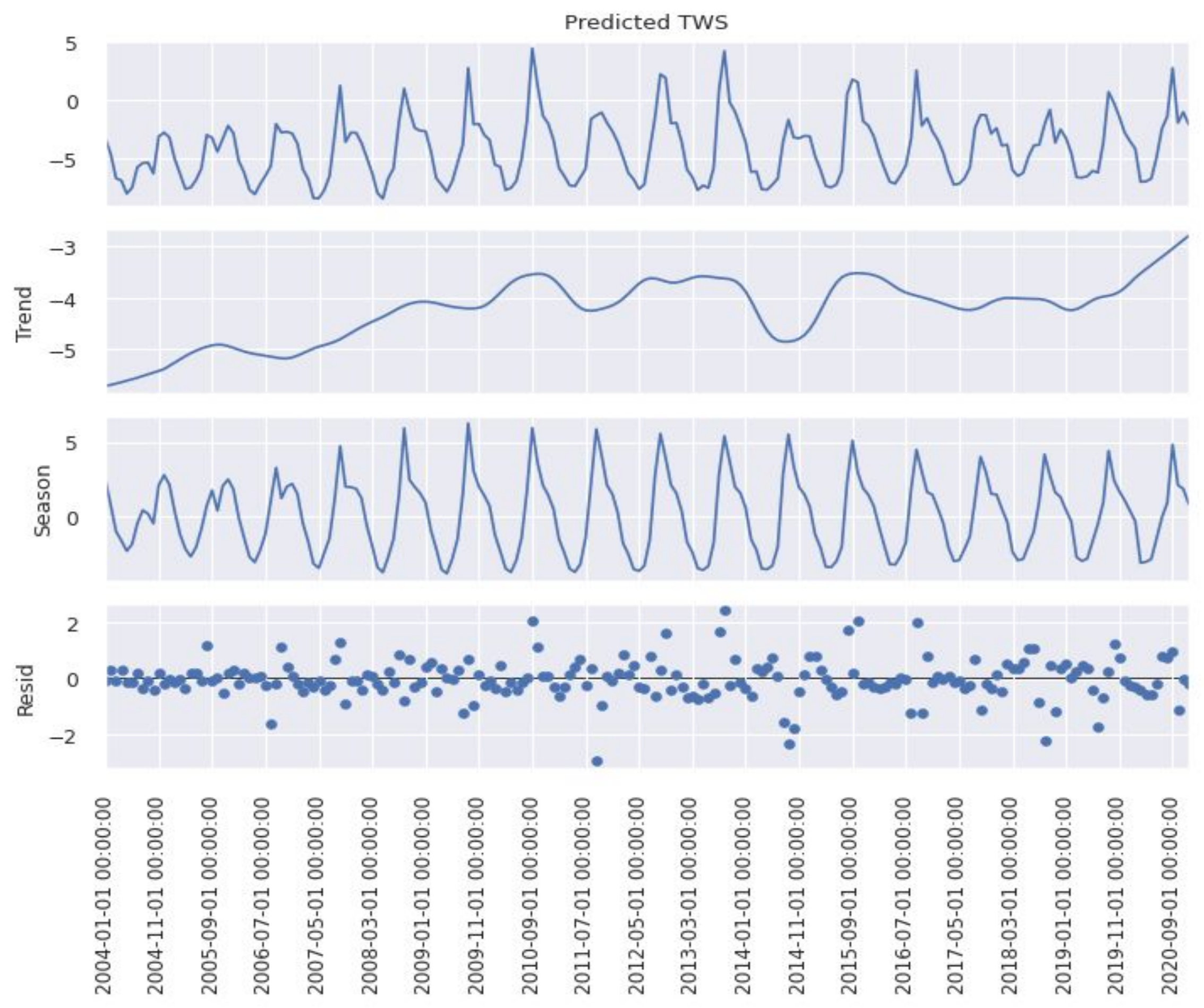

Fig 4. *Seasonal decomposition results for pixel ID (-66,64) including trend, seasonal component and residuals.*

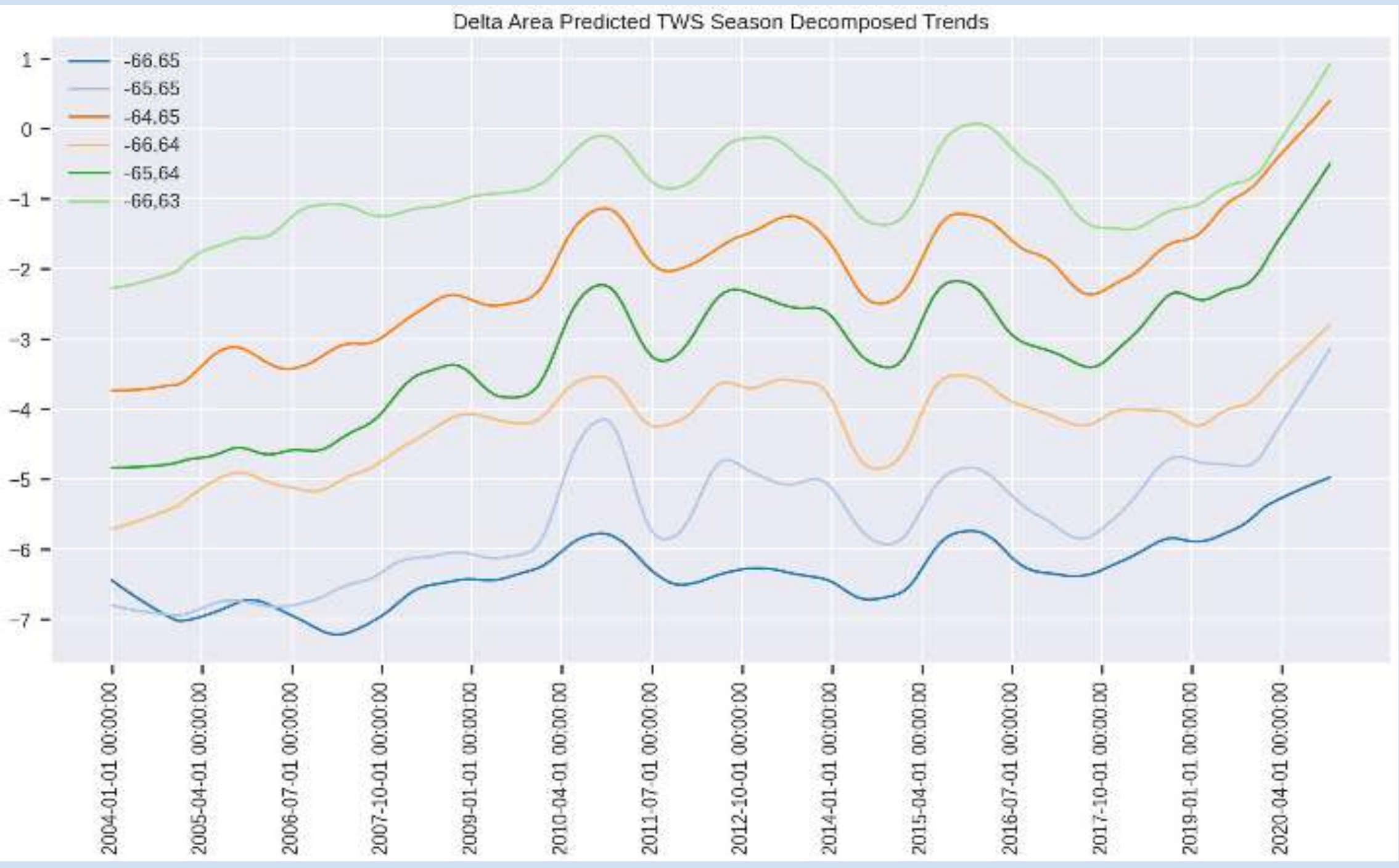

Fig 5. *Trend result for all Delta Pixels from seasonal decomposition to demonstrate positive trend in study period*

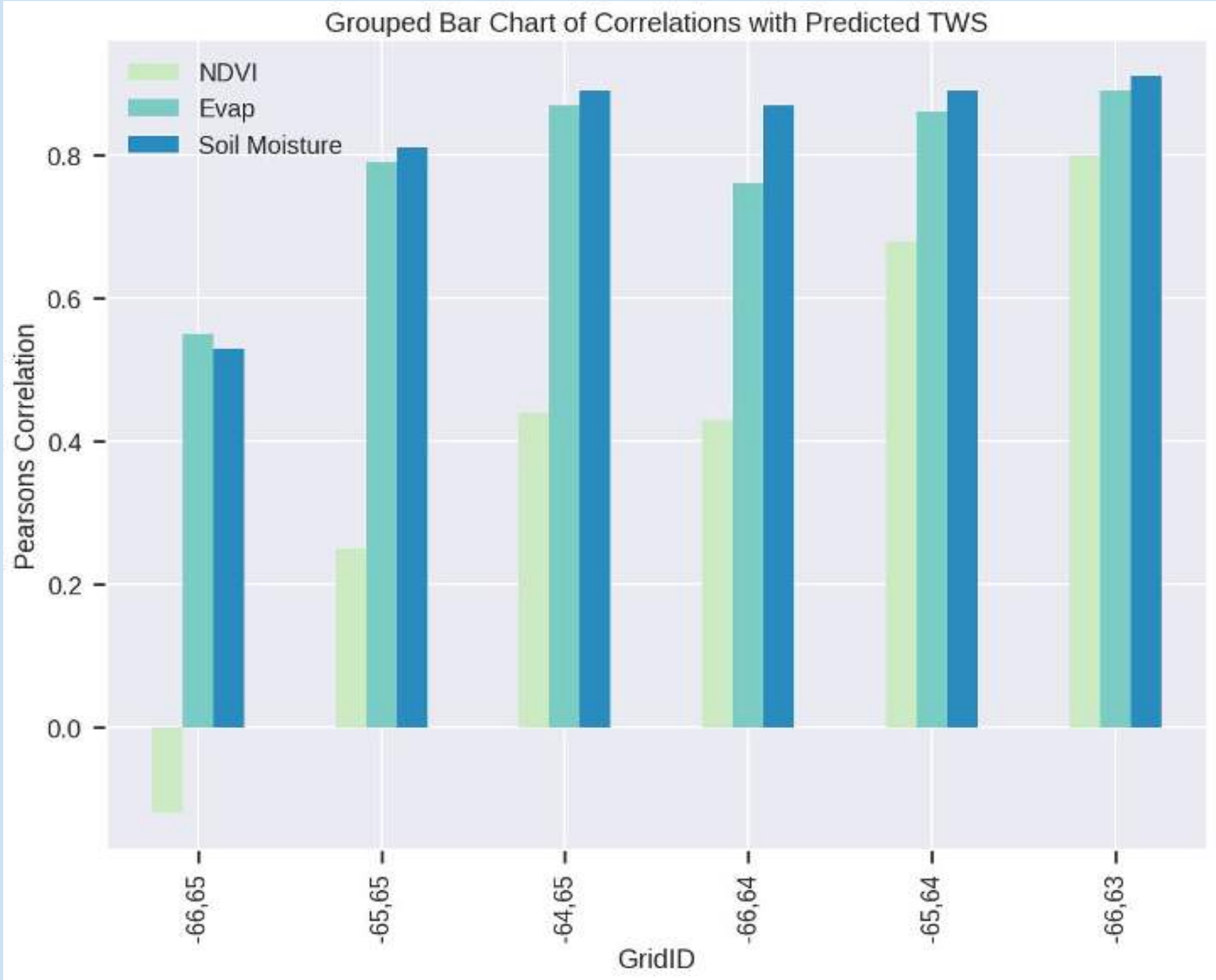

Fig 6. *Grouped bar chart of the Pearson's correlation results when comparing the output of the model to input features for individual Delta Pixels.*

Trends in TWS and Correlation with Input Features

To analyse underlying trends in the output of the ML model, seasonal decomposition was applied to the time series of 6 pixels that intersect with the region of interest depicted in *Figure 3*, an example of the output is depicted in *Figure 4.* Overall the selected pixels in the region see a significant positive trend in TWS, which can be observed in the trend time-series in *Figure 5.* An estimated overall increase of 2.24-4.34 cm is observed over the entire study period (January 2004 - 2020) for our region of interest.

Climate shock events can also be observed in the underlying trends, such as high precipitation (2010) and droughts (2011, 2014). This indicates that the groundwater availability in the region is particularly vulnerable to such impulsive events, as groundwater storage (GWS) has a very strong correlation (0.982-0.991 R^2) with TWS locally and makes up the majority of available water resources in the arid climate of Senegal. This resource insecurity will be exacerbated by ongoing climate change, which will drive higher groundwater abstraction demand, higher evapotranspiration demand, seawater intrusion and more erratic precipitation patterns.

From a correlation study of the output of the model against the input variables, depicted in *Figure 6.*, we examined some of the primary drivers of TWS fluctuations in the SRV. We chose to include NDVI in our model as a proxy for vegetation, which plays an important role in the hydrological cycle at a local scale. As a result, we saw a marginal improvement in the overall model accuracy, while also observing some interesting insights into the relationship between vegetation and TWS anomalies.

In the sparsely vegetated regions where NDVI represents the natural flora that is supported by seasonal rainfall, we observe a high correlation between NDVI and TWS. However, in regions where agriculture is heavily supported by irrigation from groundwater, this relationship weakens and predicting TWS using the GLDAS 2.2 climate model is much less reliable. This can be attributed to the complex contribution of irrigation practices to the natural hydrological cycle and provides motivation for closer study of the impact of intensive irrigated agriculture on TWS at a regional scale.

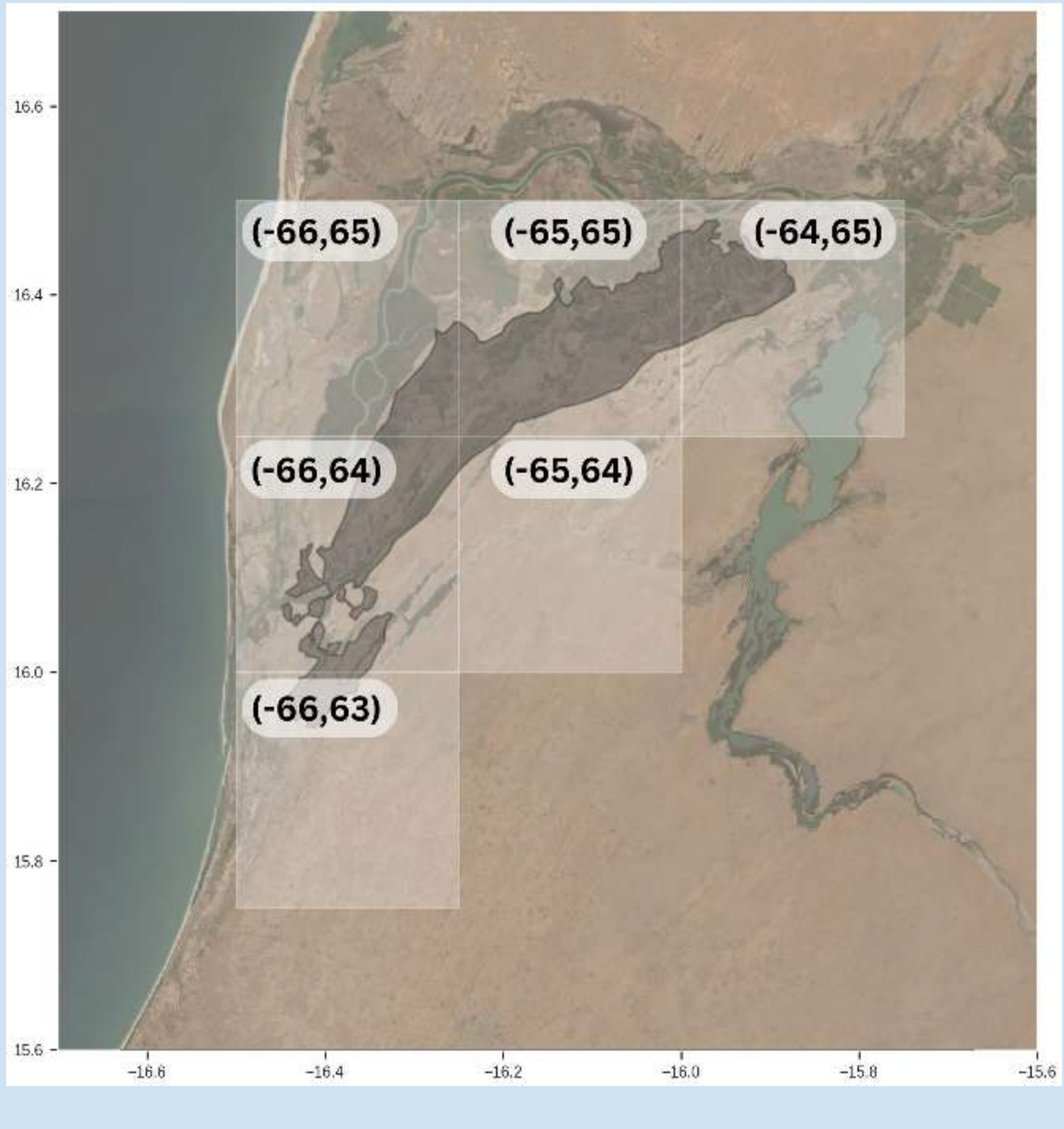

Fig 3. *Area of interest highlighted in the red square in Figure 1, the Senegal River Valley outlined in black, overlayed the scale and projection of 0.25 degree pixels in white, labeled with Grid IDs*

Science Foundation Ireland For what's next

Ollscoil na Gaillimhe University of Galway

References

[1] - Evaluation of the Irrigation and Water Resource Management Project in Senegal: Interim Evaluation Report (July 10 2019) Mathematica. Available at: https://shorturl.at/BELOQ

[2] - Project on Improvement of Rice Productivity for Irrigation Schemes in the Valley of Senegal in Republic of Senegal (March 2014) Available at: https://shorturl.at/dqRU3