International Conference of Environmental & Public Health Issues in Asian Mega-cities 2024

# Predicting urban tree locations: A case study of Daegu

By Joonwoo Lee, Hyeyun Kang, and Chulmin Jun*



GeoDB Lab 공간데이터베이스연구실 | 서울시립대학교 UNIVERSITY OF SEOUL

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# Introduction

Accurate estimation of carbon sinks
within urban settlements is crucial

# Climate Crisis & Carbon Neutrality

- Intensifying climate crisis
  - The earth is facing a global climate emergency
  - IPCC 6th Assessment Report indicates:
    - A 1.1 °C increase in global surface temperature since 1850–1900s due to human activities
    - A 54% rise in carbon emissions since 1990s

- Global commitment to action
  - 2015 Paris Agreement(United Nations) adopted by 195 countries, including South Korea
    - Replace the Kyoto Protocol
  - Emphasizes:
    - The critical role of forests and vegetations as carbon sinks
    - The importance of transparent greenhouse gas emission and absorption statistics

# Importance of Carbon Sink Estimation

- Role of urban vegetation in carbon neutrality
  - Achieving carbon neutrality requires precise estimation of carbon emissions and absorptions
  - Urban vegetation serve as significant carbon sinks
  - Accurate location data of individual trees in urbanized area is essential for estimation

- Challenges in South Korea
  - Lack of a clear definition for “settlements” or urban areas
  - LULUCF sector greenhouse gas inventory:
    - Calculation methods not fully adapted to domestic conditions
    - Insufficient location data for accurate estimations in the settlement sector[1)]
    - Leads to gaps in greenhouse gas statistics

- Need for improved estimations methods
  - Satellite imagery and vegetation indices offer potential solutions

1) Choi, W. J., Han, S. H. & Ahn, S, J. (2022). Current status and implications of the LULUCF calculation system for building a greenhouse gas inventory. *NIGT Brief*, 1–14.

# Objectives



## Estimating the location of carbon sinks within urban areas:

Focus on urbanized cities

Utilize vegetations indices derived from satellite imagery

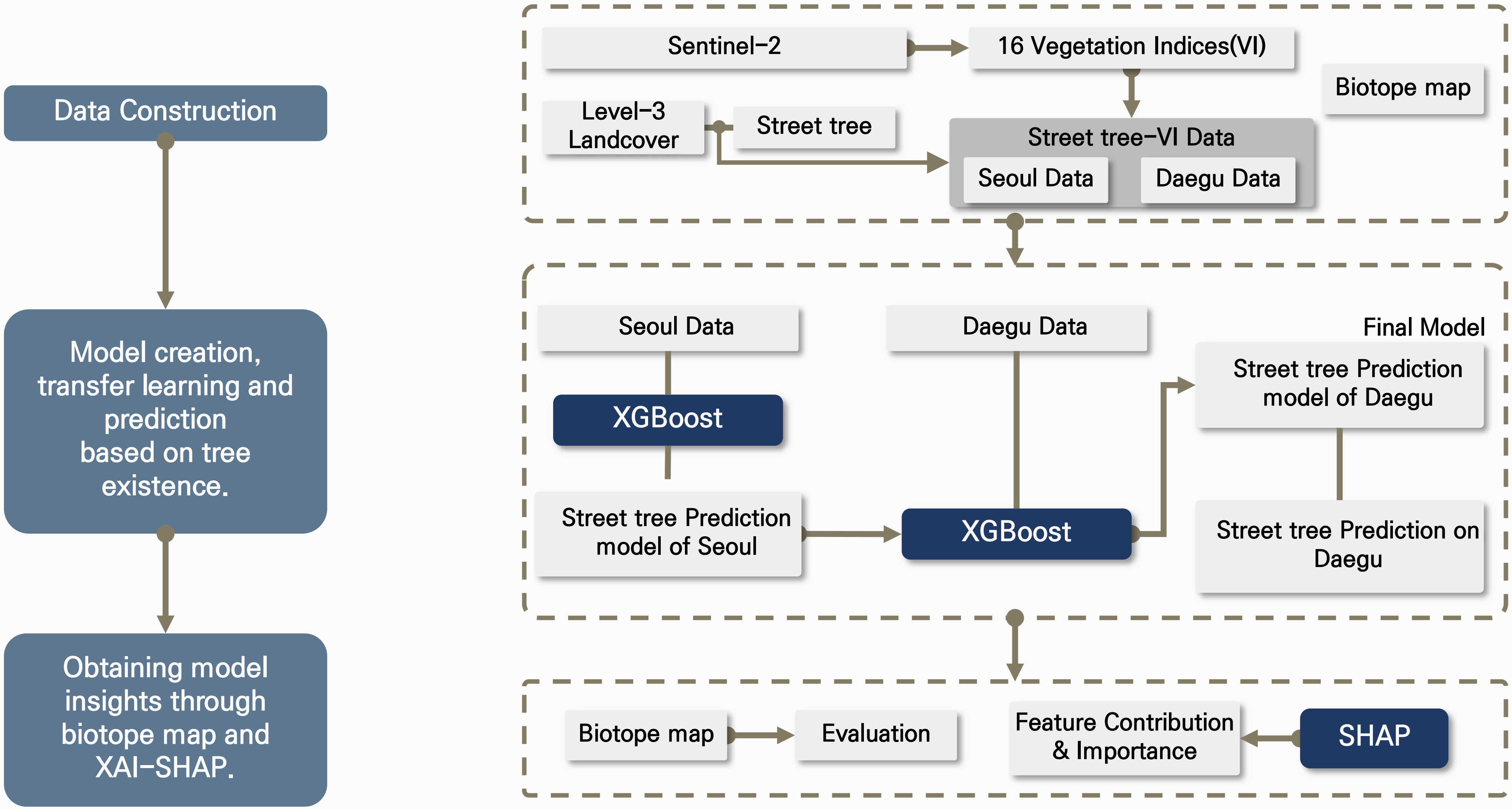
Understand the relationship between vegetation indices and carbon sinks

Utilizing
advanced modeling to reveal
urban carbon sink potential

# Methodology

# 02

# Flow Chart



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# Study Area



- Focuses on two major urban areas in South Korea — Seoul and Daegu.
- Due to the lack of a clear definition for “settlements” in South Korea, ad ministrative boundaries were used to delineate study areas in both Seou l and Daegu




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# Data

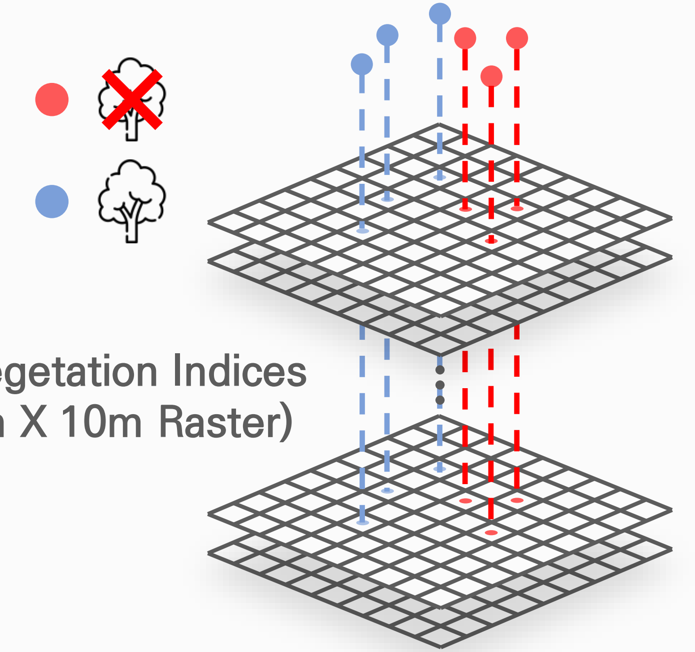
- Street tree location data in Seoul(planted in 2002–2003)
- Street tree location data in Daegu(planted in 2002–2003)
- Subdivision Land Cover Map (2023)
- Biotope Map(Daegu, 2024)
- Satellite images (Sentinel–2, captured in 2024)

- 16 Vegetation Indices

| Vegetation Index | Formula | Vegetation Index | Formula |
|---|---|---|---|
| PSRI | $\frac{Band\ 8}{Band\ 4}$ | EVI | $\frac{2.5 \times (Band\ 8 - Band\ 4)}{(Band\ 8 + 6 \times Band\ 4\ - 7.5 \times Band\ 2) + 1}$ |
| RVI | $\frac{Band\ 4}{Band\ 8}$ | SAVI | $\frac{Band\ 8 - Band\ 4}{(Band\ 8 + Band\ 4 + 0.428) \times 1.428}$ |
| NDVIre1 | $\frac{Band\ 8 - Band\ 5}{Band\ 8 + Band\ 5}$ | NDMI | $\frac{Band\ 8 - Band\ 11}{Band\ 8 + Band\ 11}$ |
| NDVIre2 | $\frac{Band\ 8A - Band\ 5}{Band\ 8A + Band\ 5}$ | MSI | $\frac{Band\ 11}{Band\ 8}$ |
| NDVIre3 | $\frac{Band\ 8A - Band\ 6}{Band\ 8A + Band\ 6}$ | NDWI | $\frac{Band\ 3 - Band\ 8}{Band\ 3 + Band\ 8}$ |
| NDVIre4 | $\frac{Band\ 8A - Band\ 7}{Band\ 8A + Band\ 7}$ | GCI | $\frac{Band\ 9}{Band\ 8} - 1$ |
| NDVI | $\frac{Band\ 8 - Band\ 4}{Band\ 8 + Band\ 4}$ | LCI | $\frac{Band\ 8 - Band\ 5}{Band\ 8 + Band\ 2}$ |
| NDRE | $\frac{Band\ 8 - Band\ 7}{Band\ 8 + Band\ 7}$ | SIPI | $\frac{Band\ 8 - Band\ 4}{Band\ 8 + Band\ 2}$ |

# Structured Data Generation Process

- Create locations without street tree using subdivision land cover map
- Spatial Join vegetation indices values to both street tree locations and non–street tree locations
- Generate data where tree existence is the dependent variable, and vegetation indice values are independent variables
- Seoul: 108943 locations, Daegu: 12627 locations

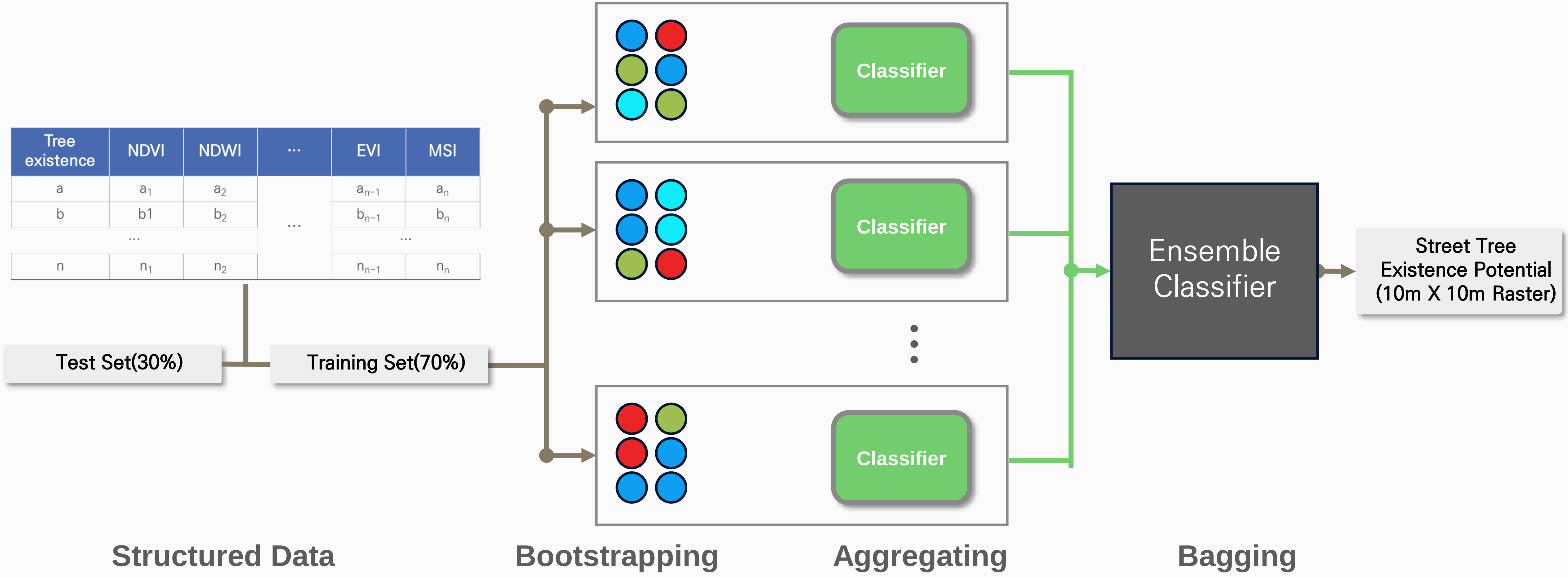



## Structured Data

| Tree existence | NDVI | NDWI | … | EVI | MSI |
|---|---|---|---|---|---|
| 0 | $a_1$ | $a_2$ | | $a_{n-1}$ | $a_n$ |
| 1 | b1 | $b_2$ | … | $b_{n-1}$ | $b_n$ |
| | … | | | … | |
| 1 | $n_1$ | $n_2$ | | $n_{n-1}$ | $n_n$ |

# XGBoost

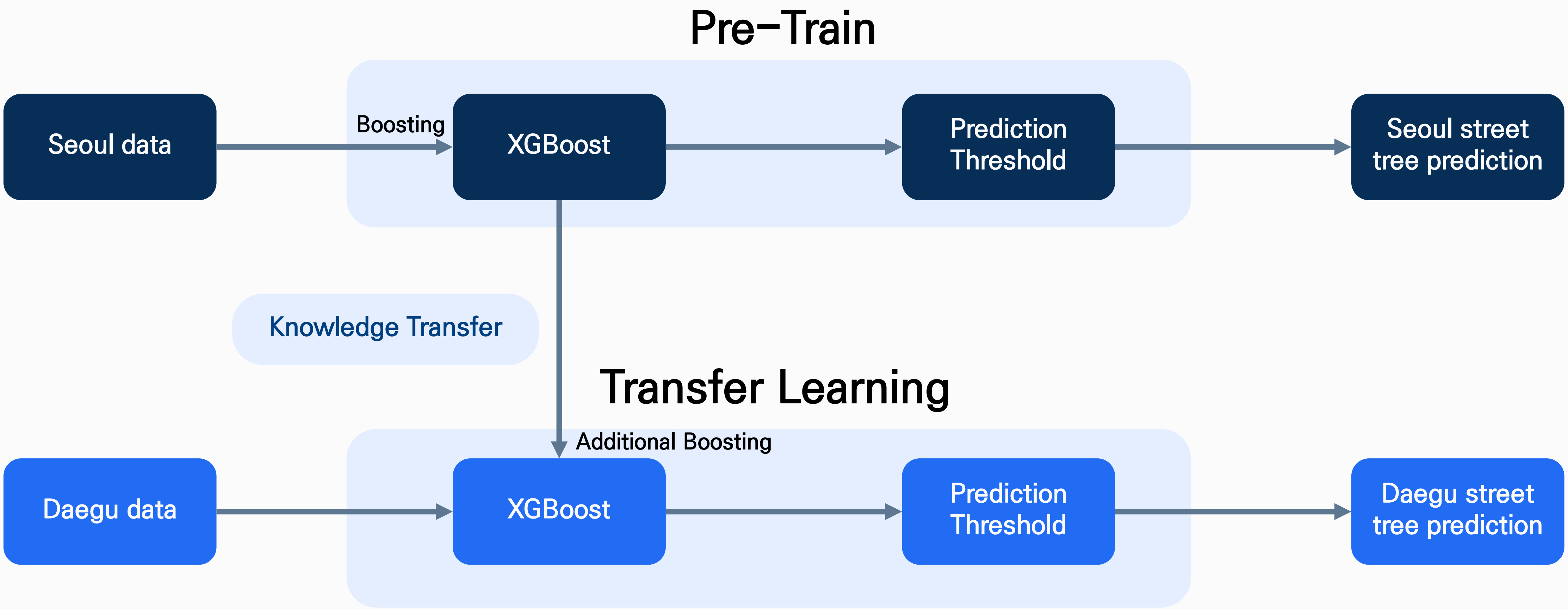
- Basic architecture of XGBoost classifier



# Transfer Learning



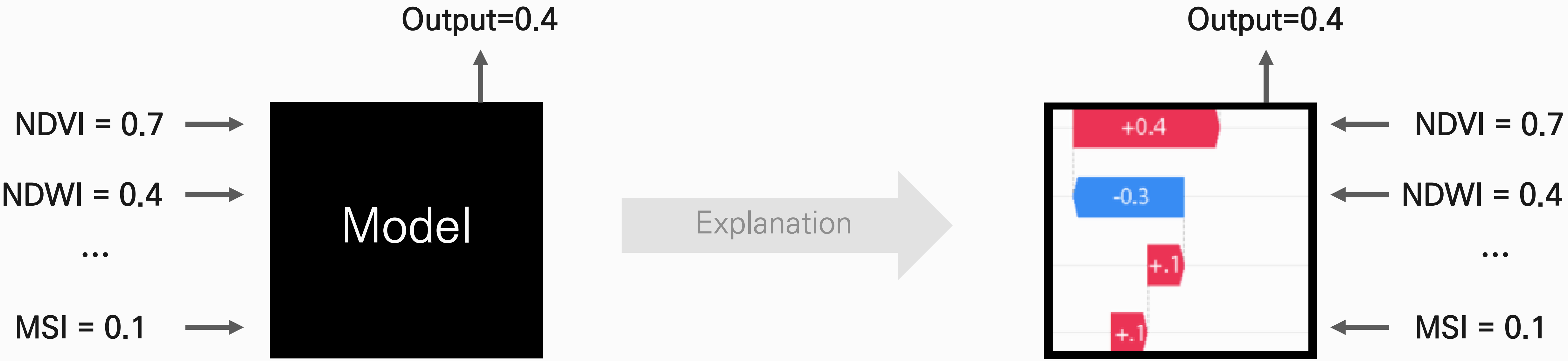
- Transfer learning process used in this study



# SHapley Additive exPlanations



- XAI-SHAP




- XAI method that uses Shapley values to analyze the impact of features on the model
- Deterministic method, considering even the negative impact of features on the model
- Vulnerable to outliers



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# Results

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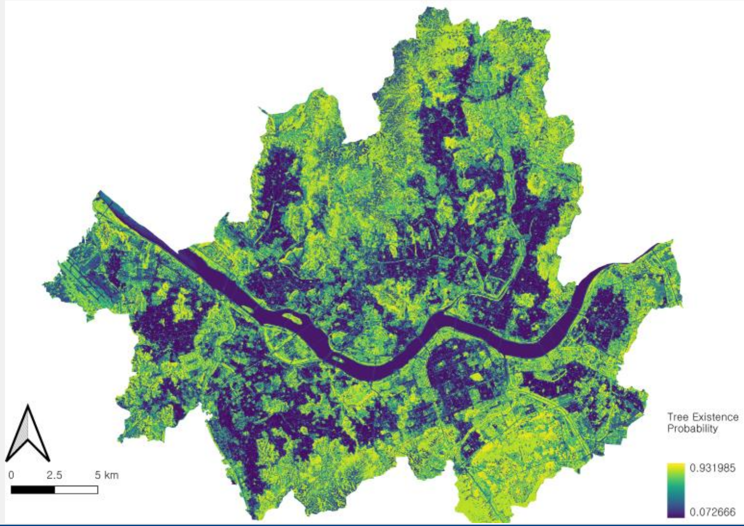
Delivering insights through precise urban carbon sink predictions

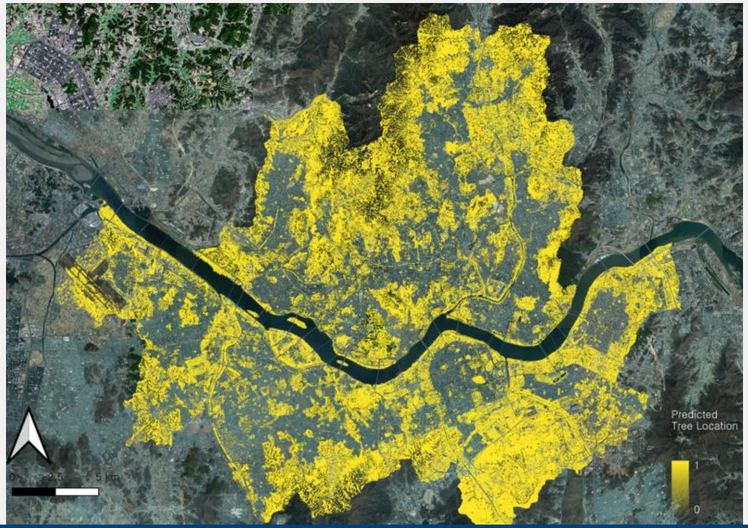
# Street Tree Prediction Model of Seoul

- XGBoost classifier model training results
  - Boosting: 100
  - Accuracy: 0.8383
  - Precision: 0.8226
  - F1-Score: 0.8378
- Probability of tree existence predicted using the XGBoost model trained only on Seoul data




Street Tree Existence Probability of Seoul

- To predict tree existence based on probability of tree existence, a threshold between 0.5 and 0.9 was compared and analyzed
- Final threshold of 0.6 was applied to generate the tree existence prediction map for Seoul




Predicted Street Tree Location of Seoul



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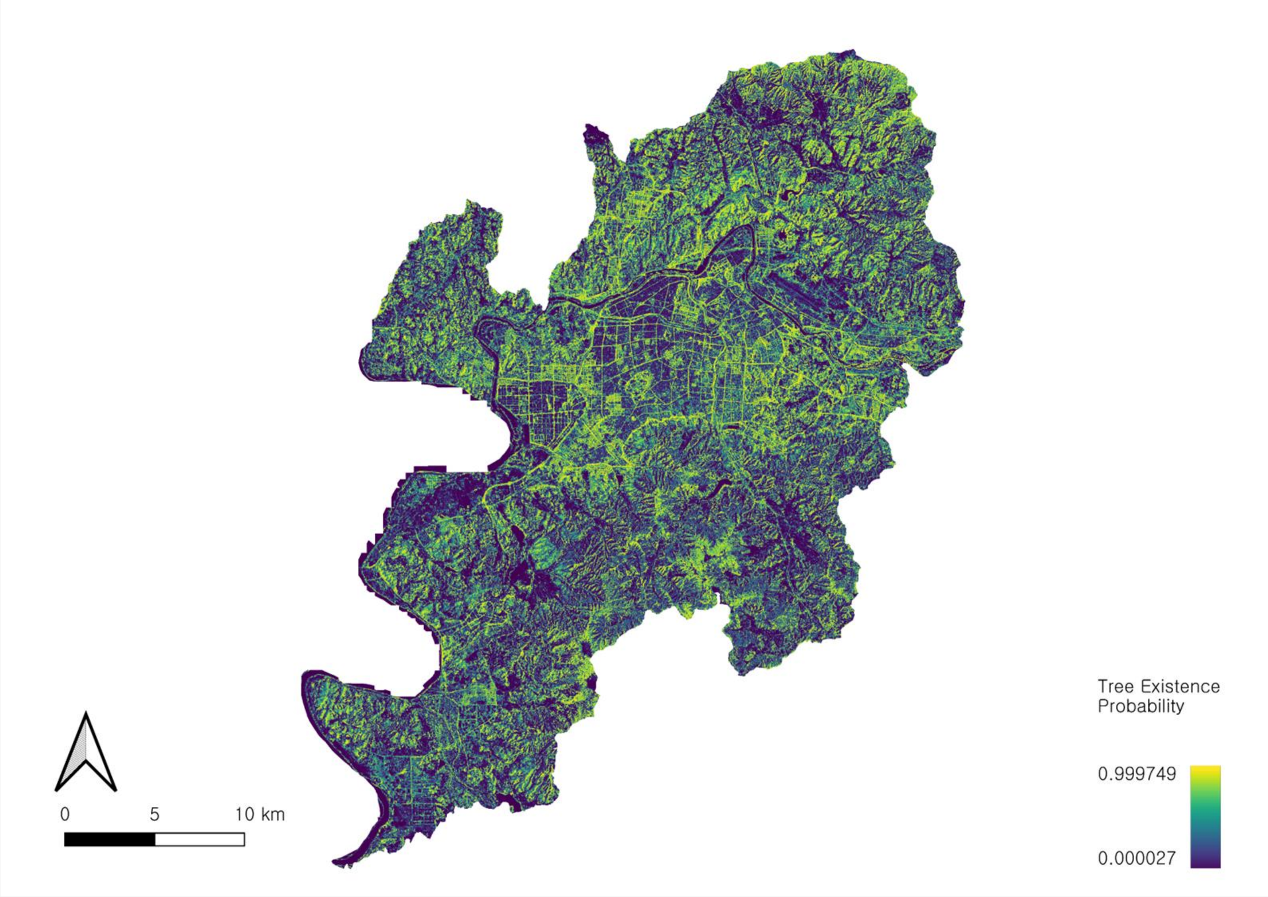
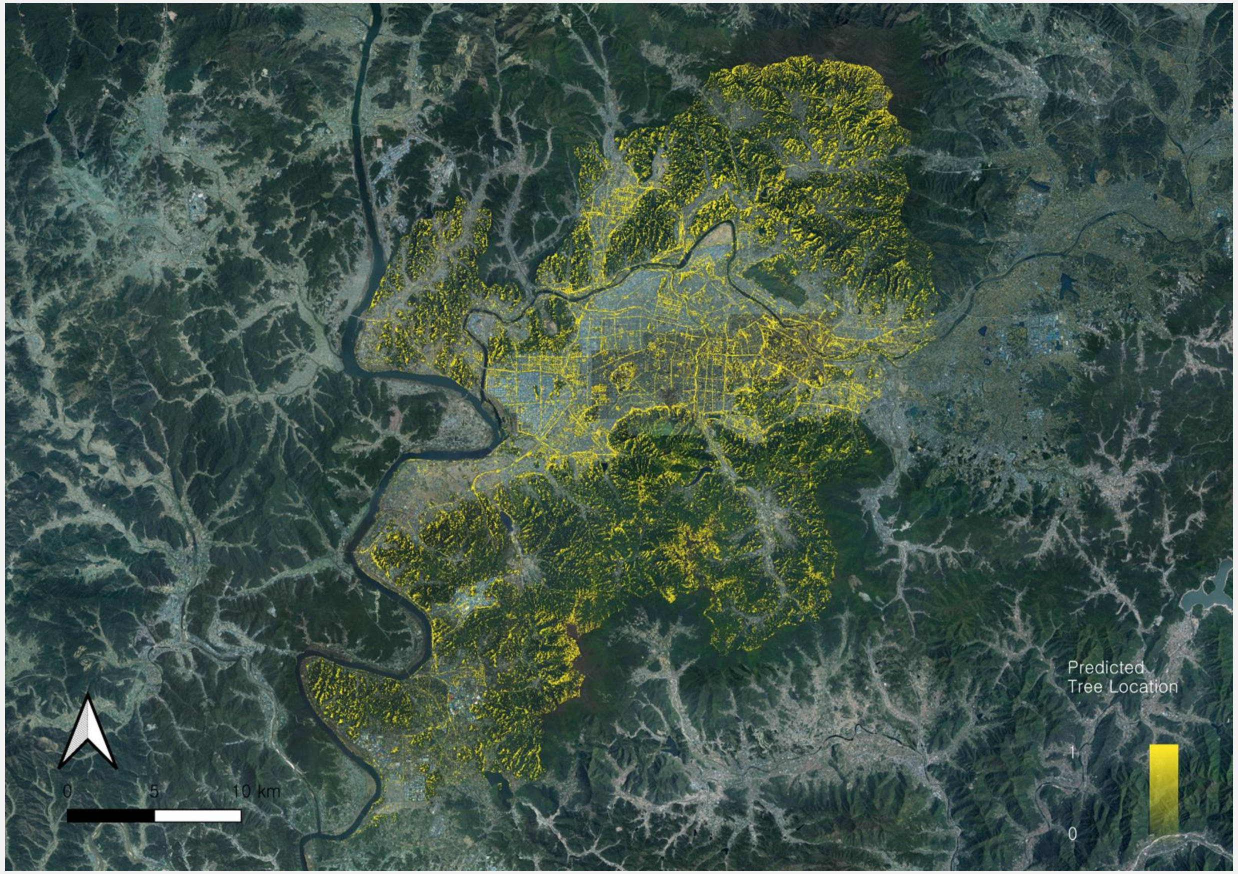
# Street Tree Prediction Model of Daegu




Street Tree Existence Probability of Daegu

- Transfer Learning Results
  - Boosting: 100
  - Accuracy: 0.8232
  - Precision: 0.7978
  - F1-Score: 0.8145
- The left image shows the predicted probability of tree presence in Daegu City, using a final XGBoost model trained through transfer learning.
- While there was no significant improvement over the pre-trained model, the model demonstrated consistent performance post-transfer learning, indicating reliable consistency

# Tree Prediction on Daegu




Predicted Tree Location of Daegu

- The left image shows the estimated locations of street trees in Daegu City using a threshold value of 0.6
- Validation of predicted map was limited through high proportion of non-urban areas within Daegu's administrative bound and lack of ground-truth data
- Concentrating on urban areas, evaluation was conducted through biotope map of Daegu City



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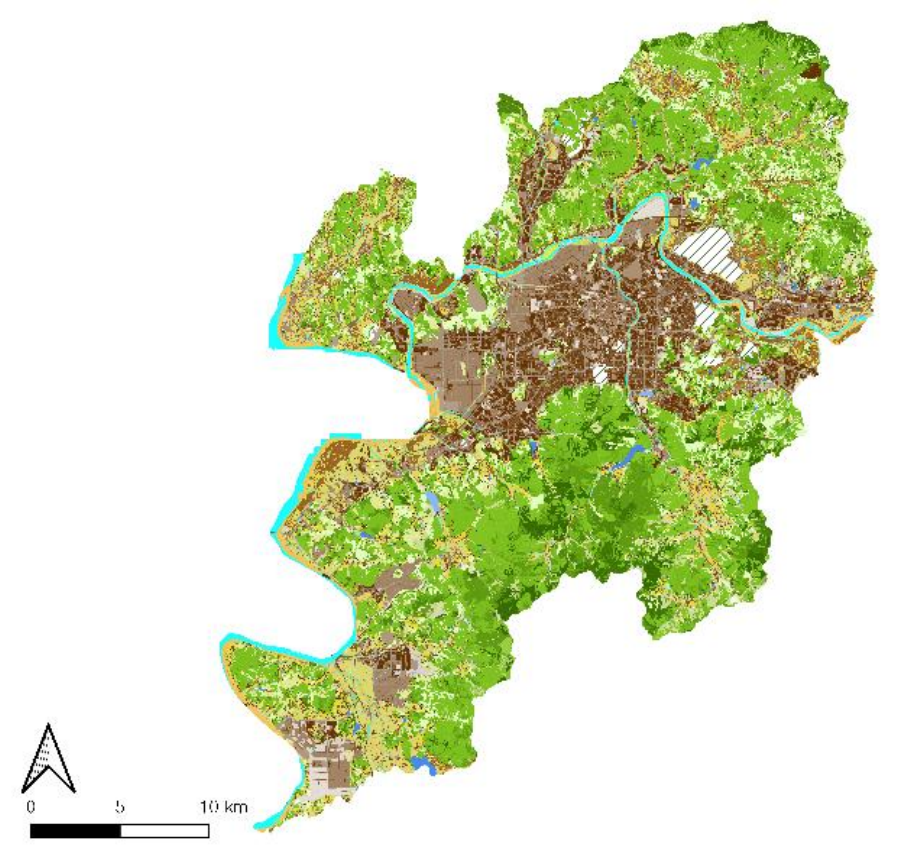
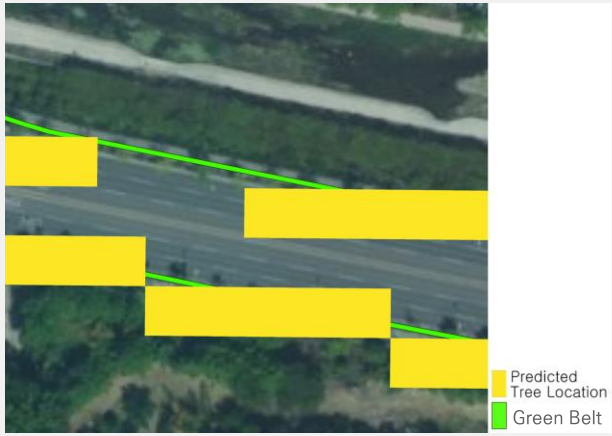
# Evaluation




(A) Daegu's Urban Ecological Maps (biotope map)




(B) Example of Green Belt and Predicted Carbon Sinks

| Constructed Green Space | Road Green Space | Green Belt |
|---|---|---|
| 17% | 31% | 50% |

(C) Area Ratio of Estimated Carbons Sinks in Biotope Map

Evaluation through Biotope map of Daegu

- Street trees in the biotope map are classified as constructed green space (major category), road green space (sub-category), and green belt (detailed category)
- To verify the estimation performance of street tree estimation map, the area ratio of estimated as a carbon sink for each biotope category has been calculated
- Constructed and road green spaces within settlements include various biota, excluding street trees, which limits the predicted area of carbon sinks to be high-proportion
- Although 50% of green belt areas were predicted as carbon sinks, slight location errors, due to shrub-centered spatial settings, resulted in some areas not being predicted as carbon sinks
- some limitations exist due to different spatial settings and other factors, the model was relatively effective in identifying street tree locations



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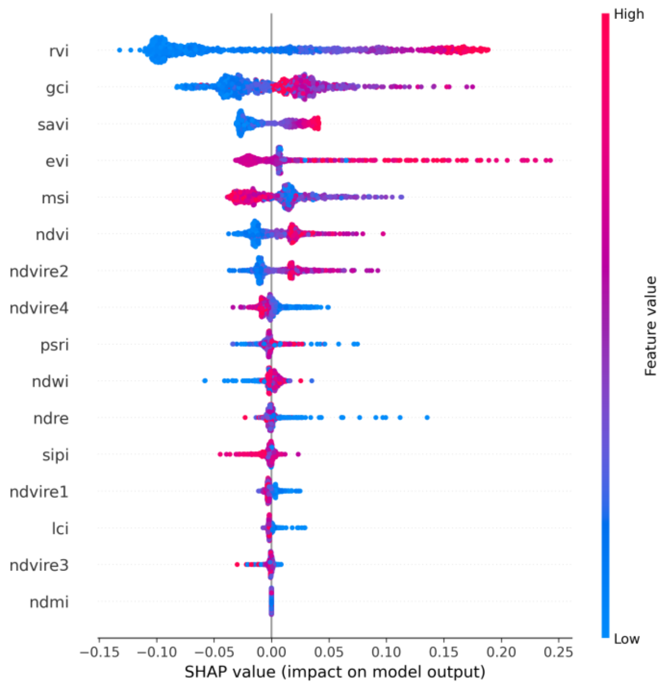
# Model Insight

## Pre-Trained Model




**Postive Correlation**

- RVI, GCI, SAVI, NDVI, NDVIre2

**Negetive Correlation**

- MSI, NDVIre4, NDRE, NDVIre1, LCI

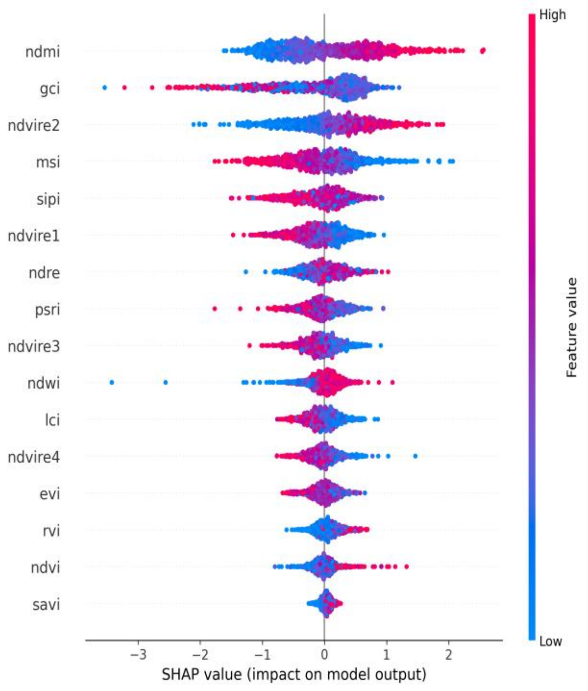
**Low Contribution**

- NDMI, NDVIre3, LCI, NDVIre2

**Additional Analysis Needed**

- GCI, SAVI, etc.

## Final Model




**Postive Correlation**

- NDMI, NDVIre2, NDWI, RVI, NDVI

**Negetive Correlation**

- GCI, MSI, NDVIre1, PSRI, LCI, NDVIre4

**Low Contribution**

- SAVI, NDVI, RVI, EVI

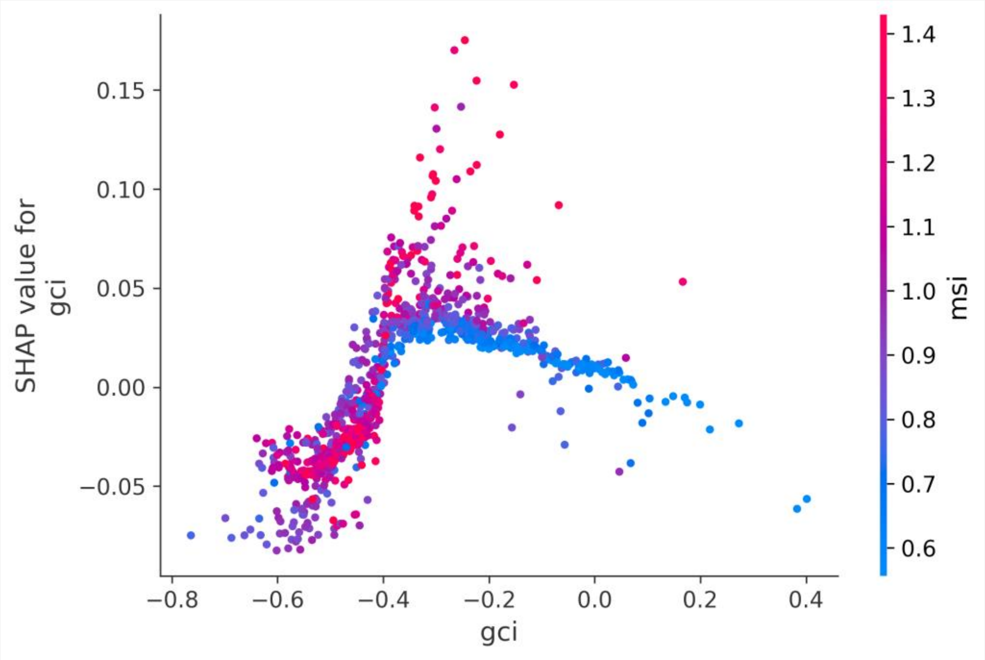
**Additional Analysis Needed**

- SIPI, NDRE, etc.

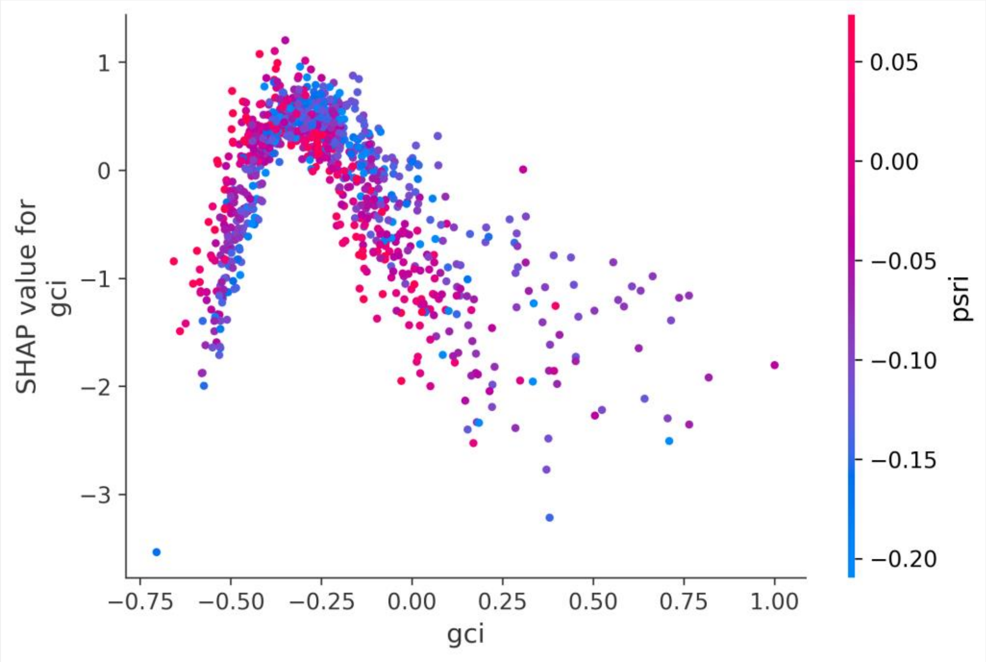
# Model Insight



- Pre-Trained Model
  - Relationship between GCI and SHAP value is more linear than final model




- Final Model
  - Distinct non-linear pattern emerges, showing more complex interactions involving GCI



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04

# Conclusion

Driving forward with data-driven strategies for a sustainable future

# Conclusion

- **Significance of Urban Carbon Sink Estimation:** Accurate prediction of carbon sinks in urban areas is essential for achieving carbon neutrality and addressing climate change. Urban vegetation plays a crucial role, requiring reliable estimation methods
- **Model Performance & Adaptability:** The XGBoost model demonstrated strong predictive capabilities, with consistent accuracy across Seoul and Daegu datasets. Transfer learning proved effective, highlighting the model’s adaptability to various urban environments
- **Key Insights & Future Directions:** Vegetation indices like NDMI, NDVIre2, and RVI showed positive correlations with carbon sinks, while indices like GCI and MSI revealed complex, non-linear interactions. Further analysis of specific indices will enhance model precision
- **Next Steps:** Expanding validation efforts with additional ground-truth data, refining vegetation index analysis, and exploring advanced machine learning techniques can further improve urban carbon sink estimation accuracy

# Acknowledgment

This research was supported by the Carbon Neutrality, a specialized program of the Graduate School through the Korea Environmental Industry & Technology Institute(KEITI) funded by Ministry of Environment (MOE, Korea)



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# Thank you for listening


Joonwoo Lee, Hyeyun Kang, Chulmin Jun*

- Tel: 02-6490-5456
- Email: leejoon924@uos.ac.kr