ESGI195 Challenge: Estimating Carbon Capture from Satellite and Environment Data in NEOM Nature Reserve

This ESGI195 challenge is sponsored by NEOM Nature Reserve: neom.com/nature

Overview

NEOM is restoring vegetation in the hyper-arid deserts of Tabuk Province in Northern Saudi Arabia. A core goal is to monitor and quantify carbon capture from these regreening efforts. Satellite NDVI[1] data (10m resolution, weekly) are freely available, but translating NDVI to carbon estimates is non-trivial: the relationship varies with vegetation type and local conditions, and satellite resolution may be too coarse for heterogeneous planted vegetation.

The challenge comprises three tasks: (1) to establish NDVI-to-carbon calibration from extant literature, (2) to explore integration of satellite imagery with high-resolution drone data, and (3) to explore modelling of species-specific carbon yield and guide the follow-up regreening efforts

TASK 1: NDVI-to-Carbon Calibration

Participants will: Review published NDVI-to-carbon models for dryland and arid vegetation, identify and apply a simple mathematical model to the provided satellite NDVI data to map carbon uptake across NEOM subregions, and apply statistical techniques for uncertainty quantification. Challenge outcomes can include carbon uptake GIS layers, including uncertainty estimates and documentation of the modelling approach.

TASK 2: Multi-Resolution Data Fusion

Existing drone survey imagery (cm-scale, sparse) offers high-resolution ground truth data. This task explores how to fuse sparse drone data with regular coarse satellite NDVI data to refine carbon model calibration and reduce uncertainty. Participants will review multi-resolution remote sensing fusion methods, propose a mathematical framework to integrate and calibrate sparse high-resolution drone data with spatially complete low-resolution NDVI data, and update carbon estimates from task 1. Challenge outcomes can include documentation of a data-fusion framework, refined

[1] Normalized Difference Vegetation Index

carbon estimates from task 1 and assessment of value-of-information of drone survey data.

TASK 3: Species-Specific Modelling

Using experimental plot data published in Alhashim et al. (2025), explore whether species-level carbon yield functions, and other environmental data, including irrigation regime, and weather information, climate indices, can be used to predict biomass carbon trajectories (for 2030/2040/2050) under climate and management scenarios . This requires estimating total species composition from provided data and modelling species growth and survival and carbon yield as functions of environmental conditions. Outcomes can include species carbon yield curves under different climates and soil conditions, and updated carbon from tasks 1 and 2, and projected carbon maps under different climate scenarios.

Data:

- Satellite NDVI: Public web tool (10m, weekly).
- Alhashim et al. (2025) species/survival data: spreadsheet publicly available (CC BY 4.0).
- Environmental data: e.g., ERA5 climate reanalysis (public), topography (public).
- Drone survey imagery