Addressing Societal Challenges with Earth Observation and Foundation Models

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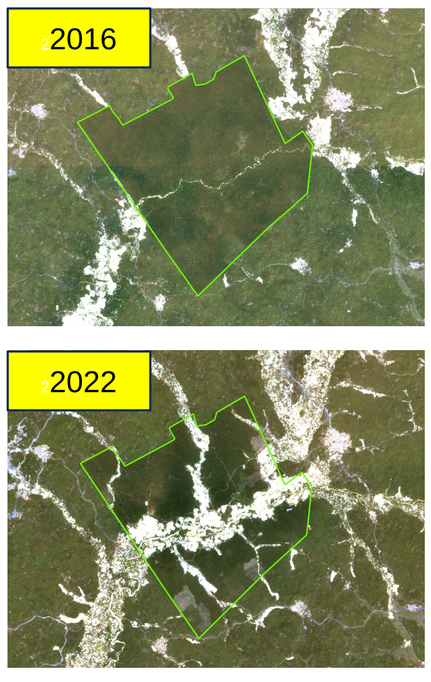
Abstract

The rapid growth of data in today's era has increased the complexity of data-driven issues in science and engineering. This has led to a paradigm shift in Artificial Intelligence (AI), with a focus on unsupervised/self-supervised learning for vast data volumes, and multimodal learning for integrating diverse data sources, enhancing decision-making and insights across various applications. Embracing this AI shift for societal challenges, DLR, IBM, FZJ, and KP Labs have proposed a Geo-foundation Model framework, FAST-EO, for multiple applications. This manuscript introduces two of these applications, to be provided by DLR, targeting specific challenges in agriculture and forestry.

Monitoring Expansion of Mining Fields into Farmlands

Challenges:

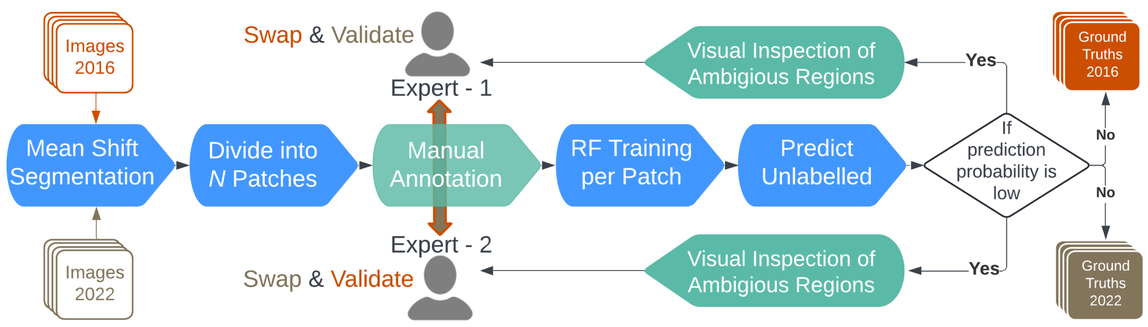
- In Ghana, unregulated quests for gold threatens natural resources [1] like cocoa farmlands.
- Small scale mining (SSM) activities reduced overall agricultural productivity and increased rural poverty in mining areas [2].



Goals:

- Develop a benchmark dataset by integrating publicly available cocoa maps with annotations of mining and non-mining areas.
- Train Machine Learning and Deep Learning models to establish performance baselines for change detection.
- Compare the performance of baseline models with Foundation Model (FM)-based fine-tuning specifically applied to this issue.

Dataset Creation Approach:



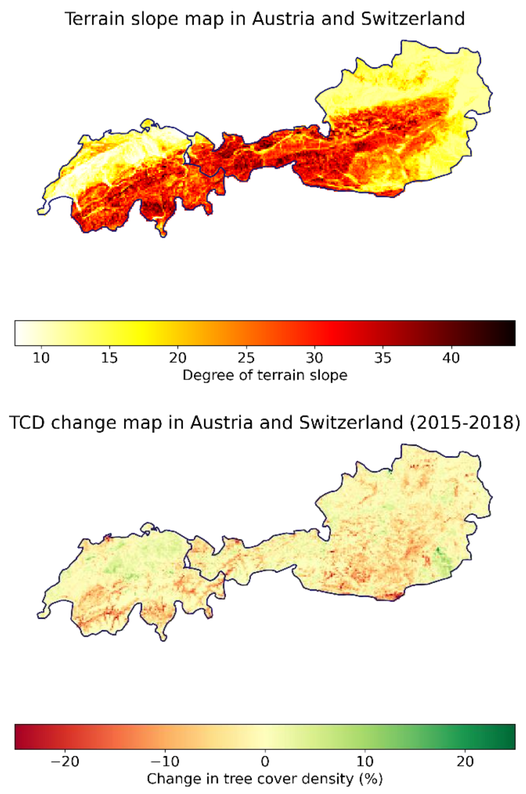
Preliminary Annotation Results:

- Random Forest (RF) model achieved an average F-score and accuracy of ~94% during cross-validation training on manually labeled data.
- The RF model predicted ground truth labels (mining / non-mining) for the entire 2459 km² study area in mosaic 2016 and 2022 Sentinel-2 images. Visual assessment confirmed high accuracy predictions.

Monitoring Changes in Forest Above-Ground Biomass

Challenges:

- In mountainous regions such as the Alps, and Pyrenees, the accuracy of biomass predictions (e.g. carbon stock, tree cover, tree height) using AI4EO significantly decreases [3].
- Deforestation mostly happens in the terrains up to 50 degree slope
- Reforestation mostly happens in flatter regions.

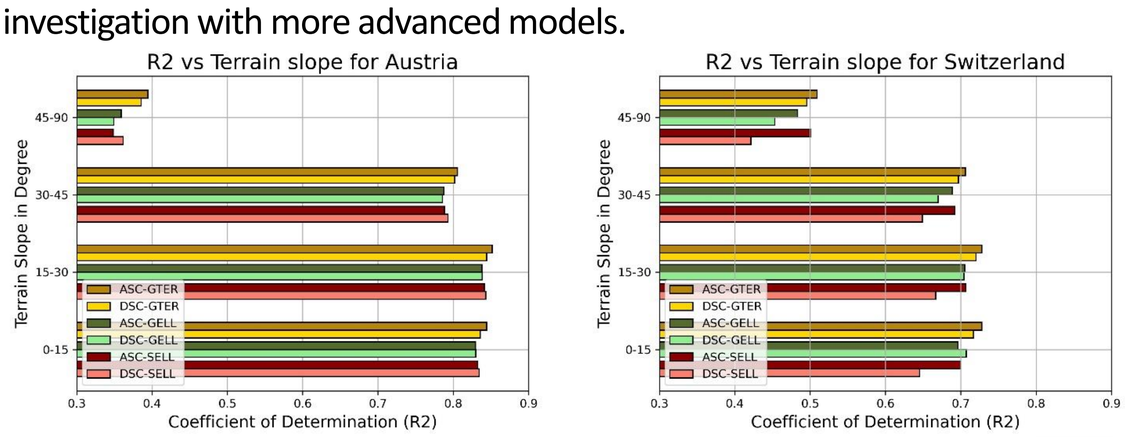


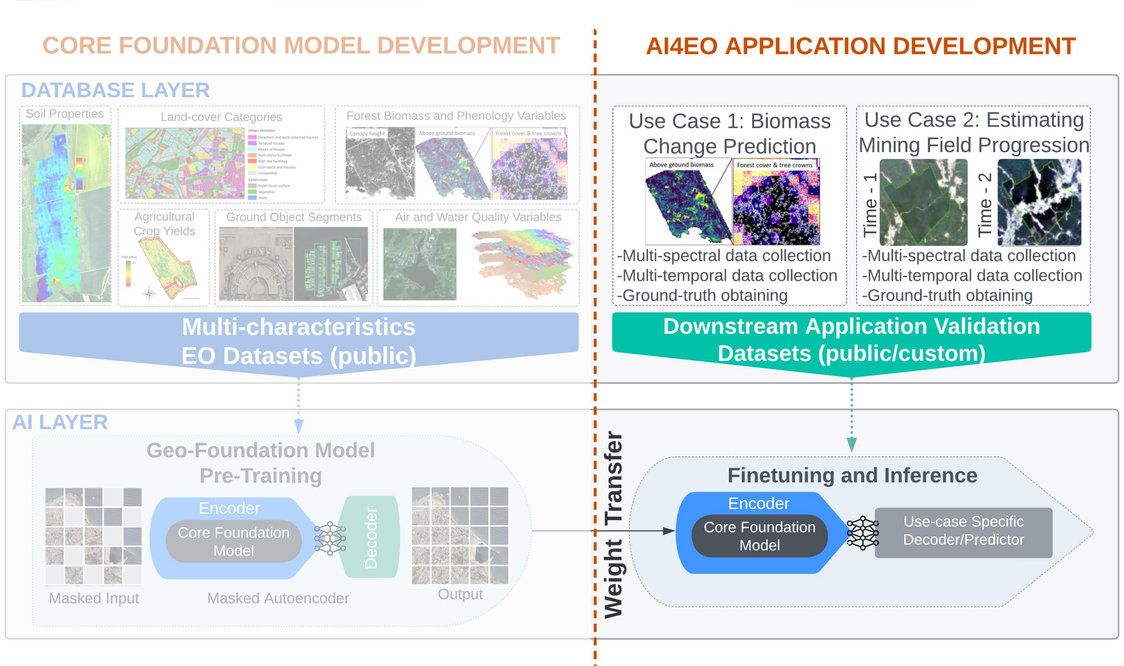
Goals:

- Incorporate auxiliary data, such as elevation models, in training for domain adaptation.
- Utilize multiple data sources to assess the potential for improvement.
- Expand the test area to evaluate generalizability across varied topographies, including both flat and mountainous regions.
- Compare the existing models implemented for this problem (U-Net variants) with FM-based fine-tuning applied to this specific issue.

Preliminary Results:

U-NET-based benchmarking validates the variations in model performance across topographic changes when using Sentinel-1, encouraging further investigation with more advanced models.





Conclusion and Future Work

As illustrated in the left image, this initiative aims to target the application side of Foundation Models and benchmark them against other state-of-the-art architectures. The intent is to develop broader solutions for the societal challenges previously mentioned, as part of the FAST-EO project funded by ESA, under Contract No. 4000143501/23/I-DT.

References

[1] Gilbert, Danyo. "The Effects of Illegal Small-scale Gold Mining in Ghana: A Threat to Food Security." (2022): 84-98.
[2] Aragon, Fernando, and Juan Pablo Rud. "Mining, pollution and agricultural productivity: evidence from Ghana." (2012).
[3] Dostálová, Alena, et al. "European wide Forest Classification based on Sentinel-1 Data." *Remote Sensing* 13.3 (2021): 337.