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Transfer learning for smallholder field delineation and field size estimation in sub-Saharan Africa

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Abstract

Agricultural monitoring based on Earth observation is challenging in tropical smallholder landscapes, due to the spatially fragmented and dynamic nature of the agricultural systems leading to region-specific and diverse portfolios in terms of crops, productivity, and land management. These complexities are particularly prevalent in sub-Saharan Africa (SSA), where a large fraction of the agricultural land is managed by semi-subsistence smallholder farmers, which operate under constrained access to capital and inputs. As a consequence, the spatial distribution of agricultural fields, field sizes, crop types, and productivity remains an empirical blind spot for most parts of SSA. In this study, we combine state-of-the-art deep learning models with very-high spatial resolution satellite imagery to produce accurate delineations of individual smallholder fields. We make use of transfer learning by fine-tuning deep learning models trained in France and India for use in northern Mozambique and southwest Nigeria. We experiment with different strategies for fine-tuning models across regions based on human-annotated training data and investigate options for self-supervision to facilitate model transfer while reducing reference data requirements. We test the performance of pre-trained and fine-tuned models for object-level field delineation and site-level field size estimation based on the median intersection over union (mIoU) and mean site-level RMSE (mRMSE), respectively using independent reference data.

Our results indicate i) good performance of the pre-trained model in both field delineation (mIoU: 0.699) and field size estimation (mRMSE: 0.071 ha), ii) consistent performance improvements for all fine-tuning experiments compared to the pre-trained model (mIoU increases: 0.045–0.058, mRMSE decreases: 0.008 ha–0.031 ha), revealing substantial improvements achieved by regional fine-tuning, and iii) comparable performance increases for supervised and self-supervised approaches, with low differences in object-level (ΔmIoU: 0.014), and site-level performance scores (ΔmRMSE 0.017), indicating a great potential for self-supervised transfer learning in reducing reference data requirements. This study presents a stepping stone for overcoming the persisting data gaps in smallholder agriculture of SSA by producing detailed field delineations at scale, which support field-level crop type and yield estimation, and allow for field size estimation in smallholder regions.

Keywords: Deep learning, geospatial, land management, machine learning

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