Mapping oil palm density at country scale: An active learning approach

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Abstract

Accurate mapping of oil palm is important for understanding its past and future impact on the environment. We propose to map and count oil palms by estimating tree densities per pixel for large-scale analysis. This allows for fine-grained analysis, for example regarding different planting patterns. To that end, we propose a new, active deep learning method to estimate oil palm density at large scale from Sentinel-2 satellite images, and apply it to generate complete maps for Malaysia and Indonesia. What makes the regression of oil palm density challenging is the need for representative reference data that covers all relevant geographical conditions across a large territory. Specifically for density estimation, generating reference data involves counting individual trees. To keep the associated labelling effort low we propose an active learning (AL) approach that automatically chooses the most relevant samples to be labelled. Our method relies on estimates of the epistemic model uncertainty and of the diversity among samples, making it possible to retrieve an entire batch of relevant samples in a single iteration. Moreover, our algorithm has linear computational complexity and is easily parallelisable to cover large areas. We use our method to compute the first oil palm density map with 10 m Ground Sampling Distance (GSD), for all of Indonesia and Malaysia and for two different years, 2017 and 2019. The maps have a mean absolute error of ±7.3 trees/ha, estimated from an independent validation set. We also analyse density variations between different states within a country and compare them to official estimates. According to our estimates there are, in total, >1.2 billion oil palms in Indonesia covering >15 million ha, and >0.5 billion oil palms in Malaysia covering >6 million ha.
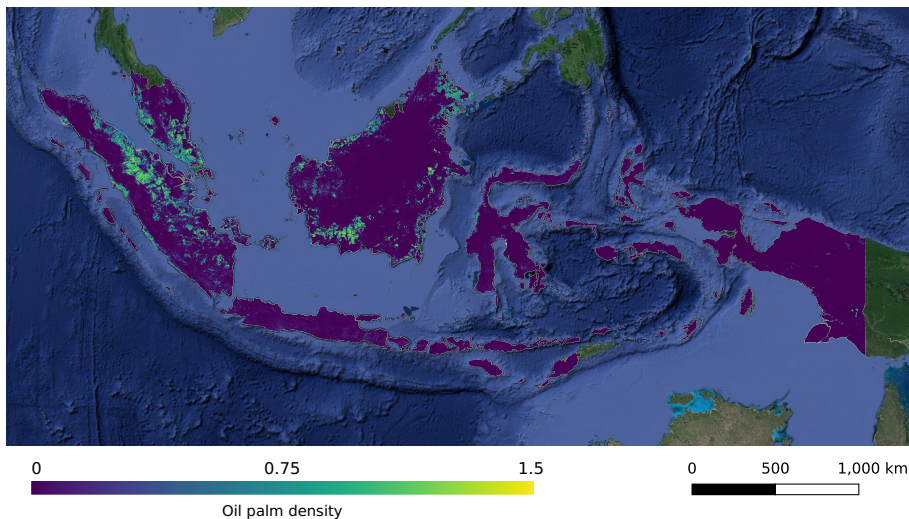
Figure 1: Oil Palm Density Map over South-east Asia in 2017 using our proposed method. We estimate a total of 1.7 billion oil palms in Indonesia and Malaysia. We present the average density over 10m pixels for illustration.