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Extensive unreported non-plantation oil palm in Africa

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Abstract

The extent of oil palm in non-plantation settings in Africa remains unknown despite its considerable socio-economic, nutritional, and cultural importance. Non-plantation oil palm includes wild or semi-wild stands that grow in forest, agroforest, and garden contexts and appear dispersed or forming clusters with irregular arrangements. Based on stratified sampling and sub-meter satellite imagery, we estimated 6.53 ± 0.99 Mha of non-plantation oil palm in Africa, largely unreported in official statistics, but widespread in West and Central African villages. This previously undocumented oil palm highlights the potential role of such oil palm in supporting local livelihoods and informal food systems. Our findings are relevant for better informed policies on African food and land-use systems.

Introduction

African oil palm (*Elaeis guineensis* Jacq.) is a tropical species native to Africa with a broad distribution across the humid areas of the continent[1]. Palm oil produced from oil palm had been used for millennia in West Africa[2]. Despite its widespread local production, regional production appears insufficient to meet current regional demand, and most African countries have become net importers of palm oil[3]. This mismatch between demand and supply reflects the limitations of the various local production systems. In Africa, palm oil is produced in contexts ranging from intensively-managed plantations to semi-wild and wild oil palm, with the latter two growing outside plantation settings and primarily used for subsistence[4]. Plantations include large-scale industrial and smallholder settings cultivated as monocultures in organized patches of similar age. Non-plantation oil palm grows in forest, agroforest and garden contexts, appearing dispersed or forming clusters with irregular arrangements, often integrated into temporary fields, groves, or forested areas[5].

Non-plantation oil palm in Africa is mainly of the *Dura* variety, which produces lower yields than the hybrid *Tenera* used in modern plantations[4]. Despite this, many farmers prefer *Dura* because it casts less shade, making it more suitable for intercropping[6]. Unrefined palm oil, typically produced from Dura, is a valued staple in African cuisine and often sells at higher prices in local markets than refined oil[7]. Oil palm also provides other products such as palm wine[1]. In rural areas, artisanal mills commonly process fruit bunches to meet local demand[8]. Most of the resulting palm oil is consumed locally[4], highlighting the importance of oil palm in supporting subsistence and informal economies in the region.

Despite its local importance, non-plantation oil palm appears underestimated in official statistics. Food and Agriculture Organization (FAO) data, based on individual country reports, focus on commercial plantations and neglect mixed gardens and wild and semi—wild foods[9]. In the case of oil palm, FAO reports 6.76 million hectares (Mha; equivalent to 10^6 ha) in Africa in 2021, but this only considers harvested areas. A previous study using radar satellite data estimated the African oil palm area at 1.08 Mha in 2021, but this estimate included only closed-canopy monoculture plantations and excluded non-plantation oil palm[10]. To date, only one report provides an estimate for non-plantation oil palm for the entire African continent, suggesting a much larger area of 6.67 Mha[5]. This study considers oil palm integrated into agroforestry systems or managed natural groves, where communities harvest fruits, sap, and kernels for local processing into oil, soap, and palm wine. However, this study combined country-level inventories from different years with varying accuracy. More robust estimates require consistent and statistically sound approaches.

Knowing the extent of non-plantation oil palm is important for evaluating its contribution to food security. The 2008 FAO and World Health Organization consultation recommended that, for a healthy life, each person requires that fat provides 20–35% of total energy intake with consumption below the 20% threshold being problematic[11]. Another study found that fat consumption in West and Central Africa falls below this 20% threshold[12], creating a "fat gap". However, we believe this analysis overlooked various sources of fat that are often neglected in official statistics and therefore considered "invisible", including various forms of non-plantation oil palm[13].

Here, we present the first robust and spatially consistent estimate of non-plantation oil palm in Africa. By integrating an objective continent-wide sampling strategy with sub-meter satellite imagery, we aim to quantify the extent of this overlooked resource. Our goal is to improve the evidence base for policymaking and interventions related to food security, land-use planning, and trade, while also enabling researchers to more accurately consider available sources of fat in their assessments of nutrition and land systems.

Method

1. Overview

Our aim was to estimate the area of non-plantation oil palm in Africa and its presence in and around villages. First, the primary analysis in our study involved estimating the extent of plantation and non-plantation oil palm across the African continent. We randomly selected 11,800 points across an area of 618.83 Mha (Supplementary Fig. 1), covering all African regions where oil palm could potentially occur. For each point, we visualized sub-meter resolution satellite images in Google Earth and identified if plantation or non-plantation oil palm was present based on the identification and spatial arrangement of the palms. This sampling allowed us to estimate the total oil palm canopy area with confidence intervals. Second, we randomly selected 1,100 villages and used their mapped boundaries to determine if non-plantation oil palm was present within the village or in their surroundings. This approach aimed to identify villages with non-plantation oil palms and their distribution.

2. Simple random sampling for country-wide estimation of oil palm area

2.1. Delimitation of the sampling area

We used the potential oil palm distribution map from a previous study[14], which defined areas suitable for oil palm growth based on their climate. This potential distribution was used to constrain the spatial extent of our sampling. The potential oil palm distribution combines 19 bioclimatic variables from WorldClim with the spatial extent of known industrial oil palm plantations from IUCN. A location was considered climatically suitable if at least 17 of the 19 variables matched the conditions observed in the IUCN plantations. Within this potential distribution, we masked out and thus excluded non-vegetated land cover, including water, bare land, and impervious surfaces using the European Space Agency WorldCover 2021 v2 land cover map. This mask constrained the sampling area and helped reduce uncertainty in the area estimates. Then, we subdivided the potential distribution into undisturbed forest, inhabited, and uninhabited areas. First, we defined the undisturbed forest using the JRC Tropical Moist Forest (TMF) dataset[15], which defines undisturbed forest as evergreen or semi-evergreen forest, with no signs of degradation or deforestation, as observed in the Landsat data. Then, outside the undisturbed forest, we defined inhabited areas as pixels within a 100-meter of those classified as inhabited in any of two datasets, the Global Human Settlement Layer and the World Settlement Footprint 2015. Areas outside the inhabited buffer zone were classified as uninhabited. In addition, we buffered the potential oil palm distribution area by 100 kilometers and extended the buffering area in West Africa across the coast up to Senegal, where non-plantation oil palm has been reported[5]. We did not exclude any pixel using additional masks in the buffering area in West Africa. In summary, the sampling area consisted of four classes: 1) undisturbed forest, 2) inhabited and 3) uninhabited areas outside the undisturbed forest and within the potential distribution, and 4) buffering area of the potential distribution. The total sampled area was 618.83 Mha.

The purpose of subdividing the sampling area was to apply different sampling densities based on the likelihood of oil palm presence. Inhabited areas are more likely to contain human-managed oil palm, while uninhabited areas, undisturbed forests, and regions outside the potential distribution are less likely to do so. This permitted a stratified approach in which we applied a higher sampling density: 20 points per Mha in inhabited areas, 10 points per Mha in uninhabited areas and buffered regions within the potential distribution, and 5 points per Mha in undisturbed forests. Higher densities lead to narrower confidence intervals. For example, in a 100-Mha region where 10% of the sampled points are oil palm, the estimated oil palm area is 10.0 Mha. The corresponding 95% Wilson score confidence intervals[16] are ±1.1 Mha for a sample size of 2,000 points (20 points per Mha), ±1.5 Mha for 1,000 points (10 points per Mha), and ±2.1 Mha for 500 points (5 points per Mha). These sampling densities were selected based on preliminary tests and expert knowledge to balance sampling effort and expected oil palm occurrence, while keeping the total number of points feasible for manual interpretation.

Despite our care in determining our sample region according to where oil palm might grow, we acknowledge scattered observations outside the sampled area. For example, we did not include isolated patches of oil palm that have been reported in Central and Southern Angola, Zambia, and Mauritania[17]. These regions present sparse populations with an oil palm area that is only a small fraction of that found within the potential distribution range[1], and therefore negligible in the context of our analysis. Moreover, there is no oil palm reported in these three countries by FAO and a previous study on non-plantation oil palm in Africa[5].

2.2. Definition of oil palm types

We distinguished plantation from non-plantation oil palm based on spatial patterns visible in sub-meter satellite imagery. Plantation oil palm refers to large, regularly spaced, intensively managed stands. In contrast, non-plantation oil palm includes dispersed, irregular, and smallholder-managed palms, as well as wild or semi-wild stands that are not part of organized plantations. A more detailed explanation is provided below:

1) **Plantation oil palm:** Structured monoculture plantations with homogeneous oil palm age. The plantation has a regular planting pattern and optimal spacing to maximize productivity. These plantations can be corporate-managed (industrial plantations) or owned by small businesses, families, or local communities (smallholder plantations). Plantation oil palm can be identified in sub-meter satellite images because of the high planting density and a linear arrangement of palms (Fig. 1). While industrial plantations show similar characteristics such as large coverage, long linear well-defined boundaries, and dense and equidistant trails placed for optimal harvesting, smallholders are a heterogeneous group with different planting settings. Here, in this category, we include any smallholder contexts with a systematic layout, planting rows, and standardized spacing. We used a minimum mapping unit of 40.1 m^2, which corresponds to the area occupied by five oil palm trees planted in a triangular pattern with a standard spacing of 9 meters.
2) **Non-plantation oil palm**: oil palm that grows dispersed or in clusters, with irregular arrangement and lack of strict planting patterns (Fig. 1). This includes a) wild oil palm, which grows in naturalized settings coexisting with native vegetation or other plant species, creating a mixed structure that resembles a natural vegetation type rather than a cultivated plantation. This includes truly wild oil palm which was mapped elsewhere[17]; b) smallholder or community-based oil palms that grow close together but lack systematic layout, planting rows, or standardized spacing. In these groves, oil palms grow in irregular patterns due to spontaneous seedling emergence or informal planting methods without planned organization; c) Dispersed oil palms in anthropogenic landscapes: individual or scattered oil palm growing within human-modified environments, such as agricultural fields, villages, roadsides, or mixed-use lands. Our definition of non-plantation oil palm does not distinguish between land where oil palm grows entirely wild and land owned and managed by smallholders, as this information cannot be directly determined from satellite data.

2.3. Visual interpretation of satellite data

We visually interpreted land cover type using sub-meter resolution satellite imagery at 11,800 randomly selected points across tropical Africa. This manual interpretation allowed us to identify the presence or absence of oil palm and distinguish between plantation and non-plantation types based on canopy structure, planting patterns, and contextual landscape features.

Oil palm is a distinctive plant and can usually be distinguished from other palm and plantation types with reasonable confidence based on specific features visible in sub-meter resolution satellite images. To identify oil palm and differentiate it from other species, we collected 175 sub-meter resolution images paired with Google Street View data. We sampled locations until the visual information collected became redundant. Supplementary Fig. 2 provides examples from six locations. We analyzed the sub-meter resolution satellite images and qualitatively identified the key features that distinguish oil palm from other palms and crop types. Supplementary Text 1 describes the key visual features used to identify oil palm in sub-meter resolution imagery and provides further details on the protocol followed for the visual interpretation of satellite data. A single interpreter visually inspected the 175 points to test the replicability of interpretation. All land cover types were correctly identified, indicating 100% replicability.

Plantation and non-plantation oil palm can be identified based on the spatial arrangement of the oil palms (Fig. 1). Plantation oil palm presents a homogeneous density and is typically planted in rows using a triangular spacing arrangement[1]. Rectangular spacing is also used in oil palm, although this spacing type is more common in coconut plantations. Non-plantation oil palm, on the contrary, does not follow rows and occurs at variable densities or scattered across the land.

Sub-meter resolution imagery in Google Earth is updated regularly, but availability varies by location. The available imagery corresponds to different acquisition years depending on the location. Therefore, our area estimates represent the distribution of oil palm over recent years, not a single reference year. This is a minor issue, as oil palm is a perennial species whose spatial distribution changes slowly over time. For points without satellite imagery, we assigned the label 'no satellite data' and grouped them under the 'Other' class in subsequent analyses. This decision reflects the fact that these points were mostly located in remote, forested areas with a low probability of containing oil palm.

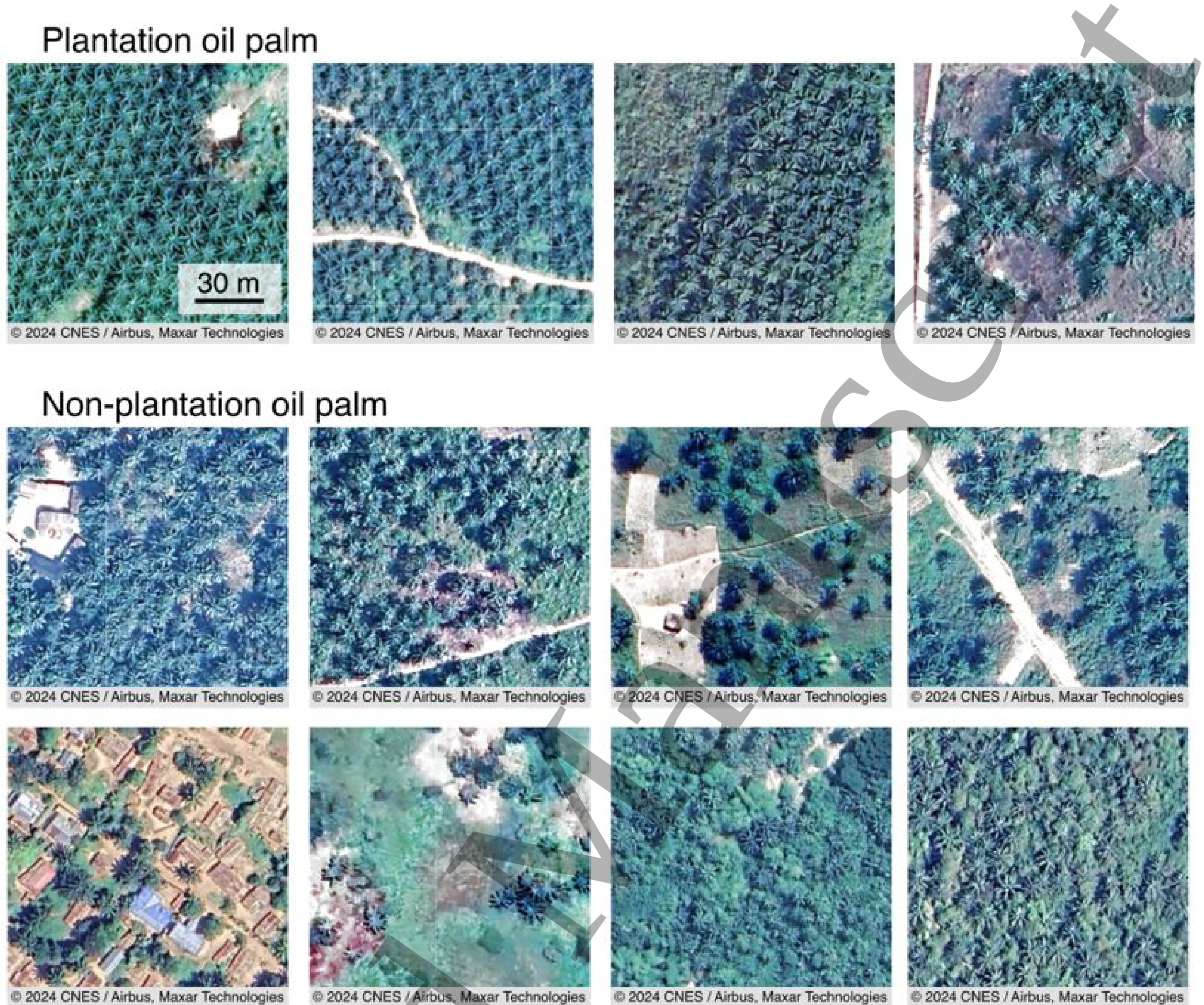

Figure 1. Sub-meter resolution satellite images showing plantation and non-plantation oil palm. Plantation oil palm is usually planted in a linear arrangement and high planting density. On the contrary, non-plantation oil palm grows without standardized spacing around villages and crops or in semi-natural and wild contexts. The satellite images are the sub-meter resolution imagery displayed as the base layer in Google Earth © Google.

2.4. Estimation of oil palm canopy area

We used the Wilson score[16] to estimate the proportion of sampled points with plantation and non-plantation oil palm. The Wilson score provides an accurate approximation of the binomial distribution, particularly when estimating low proportions, which is the case in our study; the proportion of points labelled as oil palm was below 5% in many countries. The center of the Wilson score interval $\check{p}$ was calculated with Eq. 1:

$$\check{p} = \frac{p+\frac{z^2}{2n}}{1+\frac{z^2}{n}} \quad \text{(Eq. 1)}$$

where *p* is the observed proportion of points with oil palm (either plantation or non-plantation oil palm separately), *n* is the total number of points sampled, and *z* is the critical value from the standard normal distribution for a desired confidence interval. In this study, we used a 95% confidence interval and, thus, a *z* value of 1.96. The formula for the Wilson Score Interval (Eq. 2) provides the confidence interval of $\check{p}$.

$$CI = \frac{\check{p}+\frac{z^2}{2n}\pm z\sqrt{\frac{\check{p}(1-\check{p})}{n}+\frac{z^2}{4n^2}}}{1+\frac{z^2}{n}} \quad \text{(Eq. 2)}$$

The oil palm area estimate (*AE*) was calculated by multiplying the total sampled area by the proportion of oil palm points (Eq. 3). Similarly, the confidence interval of the oil palm area estimate (CI_{AE}) was obtained by multiplying the total sampled area by the confidence interval of the proportion of oil palm points (Eq. 4). Sampled points were classified as oil palm only if they fell within the oil palm canopy. Thus, our area estimates represent the oil palm canopy area, defined as the ground area covered by the vertical projection of the oil palm fronds.

$$AE = Total\ sampled\ area \times \check{p} \quad \text{(Eq. 3)}$$

$$CI_{AE} = Total\ sampled\ area \times CI \quad \text{(Eq. 4)}$$

We used different density of points that differed by country and sampling area classes. Thus, the estimation of the oil palm area (Eq. 1 and 3) and its confidence interval (Eq. 2 and 4) were calculated separately for each country and sampling area class. To obtain country-wide area estimates (*AEcountry*), we summed the oil palm area estimates for the inhabited area (*AEinhab*), uninhabited area (*AEuninhab*), buffered potential distribution (*AEbuffer*), and undisturbed forest (*AEforest*) (Eq. 5). For the confidence intervals, we used the propagation of uncertainty to aggregate the uncertainty at the country scale (Eq. 6):

$$AEcountry = AEinhab + AEuninhab + AEbuffer + AEforest \quad \text{(Eq. 5)}$$

$$CItotal = z\sqrt{\frac{CIinhab}{z^2}+\frac{CIuninhab}{z^2}+\frac{CIbuffer}{z^2}+\frac{CIforest}{z^2}} \quad \text{(Eq. 6)}$$

where *CIinhab, CIuninhab, CIbuffer,* and *CIforest* represent the confidence intervals for the inhabited area, uninhabited area, buffered potential distribution, and undisturbed forest for a given country. *CItotal* represents the confidence interval of the country-wide area estimate (*AEcountry*).

2.5. Comparison with official and satellite-derived statistics

We compared our oil palm area estimates with official statistics from FAOSTAT and USDA Foreign Agricultural Service, as well as satellite-derived estimates from a global oil palm map[10]. We extracted the oil palm area from these datasets for the year 2021. These datasets have different definitions of what constitutes oil palm. The official statistics from FAO and USDA include oil palm areas that have been harvested. In contrast, the global oil palm map[10] only includes closed-canopy monoculture oil palm plantations, whether it was harvested or not, but excludes young plantations and oil palm that grow sparsely. For Nigeria, we also compared our estimates with previous studies on plantation and non-plantation oil palm (Supplementary Text 2).

3. Determining the occurrence of non-plantation oil palm within the proximities of villages

The second approach focused on determining the proportion of villages with non-plantation oil palm growing within the village and in their surrounding areas. We mapped the surroundings of the villages using OpenStreetMap (OSM) data. Specifically, we used all settlement boundaries in West and Central Africa included in OSM. To enhance the reliability of the village boundaries, we also used the Open Buildings 2.5D Temporal Dataset and excluded villages with fewer than 10 or more than 1,000 buildings.

Because the density of villages varies across Africa, we created a 100 x 100 km grid and randomly selected 100 villages within each grid cell. This approach prevented oversampling areas with high village densities. Finally, from the selected villages, we randomly selected 400 village boundaries in West Africa and 700 in Central Africa. The boundaries in Central Africa were subdivided into 500 within the Congo forest and 200 outside it. The villages in the Congo forest were selected based on the regions classified as tropical and subtropical moist broadleaf forests in the RESOLVE Ecoregion dataset. For each selected village, we visually inspected sub-meter resolution imagery within the village boundary and within a 100-meter buffer surrounding the boundary. We considered that oil palm was present if it appeared in natural groves, clustered formations, around houses, or in non-plantation settings. Supplementary Fig. 3 shows a village with non-plantation oil palm. In cases where oil palms appeared scattered, we considered that the village contained oil palm if there were at least five palms within the inspected area.

While the point sampling covered all African countries where oil palm is expected to grow, the analysis in small villages focused on West and Central Africa, excluding East Africa for three reasons. First, FAO and previous studies on non-plantation oil palm report that oil palm is scarcely present in East Africa[1,5]. Second, preliminary analysis indicated that oil palm was virtually absent around villages in East Africa. Third, the estimated oil palm area in East African countries, based on our sampling points, represents only 1.0% of total oil palm area in Africa. This suggests that oil palm is less prevalent in East Africa, although it may have local importance in regions such as Kigoma in western Tanzania and Bundibugyo in western Uganda.

Results

Based on our sample, we estimated the total oil palm area at 8.43 ± 1.11 Mha in Africa. This is significantly larger than reported by FAO (6.76 Mha), USDA Foreign Agricultural Service (4.58 Mha), and satellite-based estimate (1.08 Mha) in 2021[10]. Most, 77.4% (6.53 ± 0.99 Mha) consisted of non-plantation oil palm, with just 22.6% (1.90 ± 0.51 Mha) in plantations. Our area estimates for plantation oil palm by country are similar to those reported by FAO and USDA data, except in Nigeria (Fig. 2). Supplementary Text 2 and Supplementary Fig. 4 compare our oil palm area estimates for Nigeria with previous studies, which report similar values and thus challenge the reliability of the figures reported by FAO and USDA for the country.

The Democratic Republic of the Congo (DRC) holds the largest area of non-plantation oil palm, with 2.50 ± 0.69 Mha, followed by Nigeria with 1.89 ± 0.54 Mha. We also assessed oil palm density. Sierra Leone showed the highest density of non-plantation oil palm, covering 6.6% ± 2.5% of the sampled area, compared to 1.2% ± 0.3% in the DRC. Non-plantation oil palm commonly occurred near villages across most of the surveyed region (Fig. 3) though there were exceptions (e.g. the interior of Côte d'Ivoire). In the Congo rainforest, 79.1% of the sampled villages had non-plantation oil palm within the village and in their vicinity. In the rest of Central Africa, this proportion was 61.0%, and in West Africa, 51.3%.

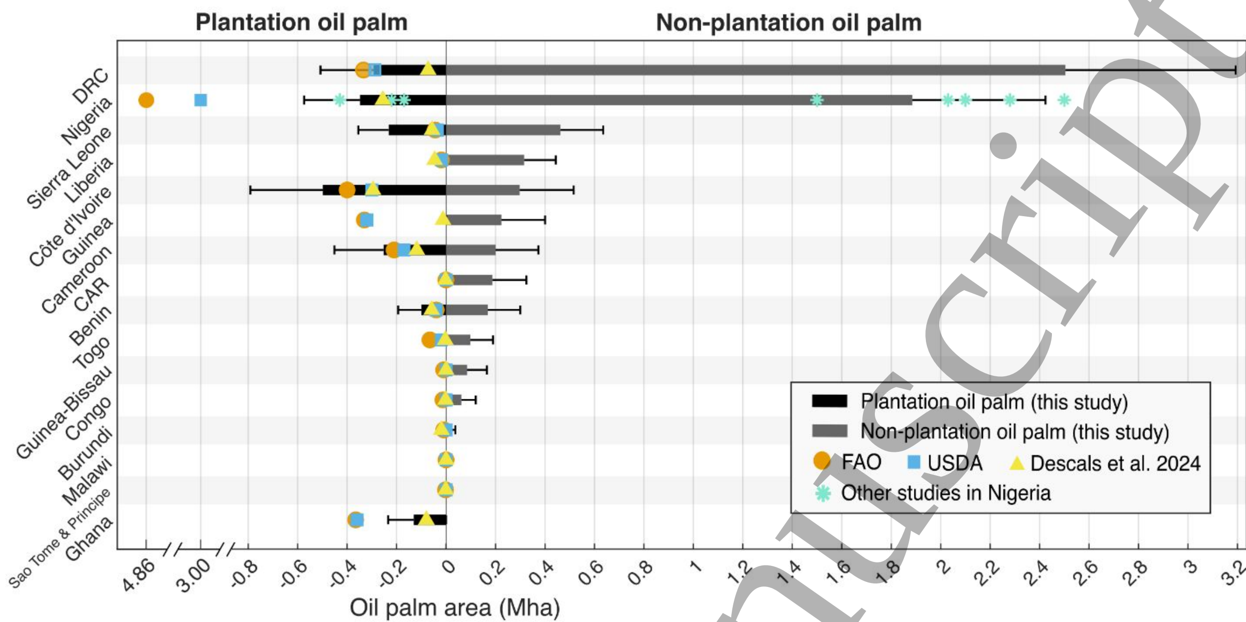

Figure 2. Comparison of plantation and non-plantation oil palm areas in million hectares (Mha) in African countries with estimated oil palm area greater than 0. The full list of countries sampled in this study is shown in Supplementary Table 1. The figure shows areas from various sources: this study, FAO, USDA, and Descals et al., 2024 for the year 2021. Points in cyan represent other studies reporting plantation and non-plantation oil palm in Nigeria. Black lines indicate 95% confidence intervals for the estimates of this study.

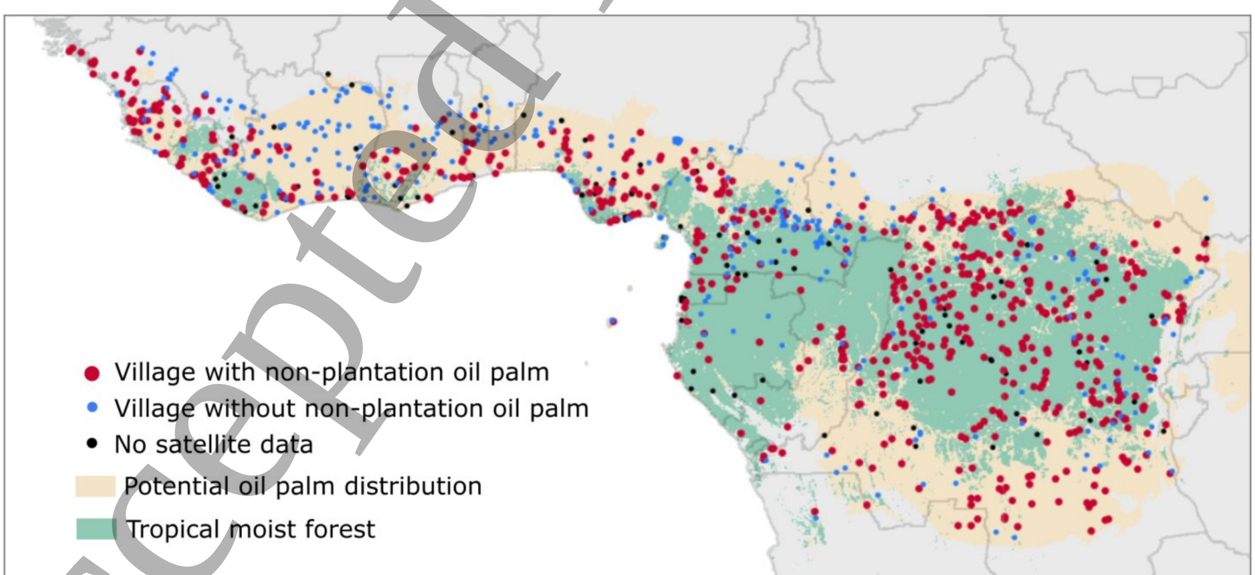

Figure 3. Spatial distribution of villages with (red circles) and without (blue circles) non-plantation oil palm across the oil palm potential distribution in West and Central Africa.

Discussion

We observe that much of the rural population in our African study area has access to non-plantation oil palm. While we should be cautious in drawing assumptions, the results suggest that more people may be able to meet their nutritional requirements than had been believed—though we would also underline that this interpretation needs further assessment. While much of the oil palm has been largely "invisible" to official observation and documentation until now, this oil palm has important implications for food security, by potentially addressing the assumed "fat gap" in these areas that had been based on limited data[12]. The presence of non-plantation oil palm does not necessarily mean that palm fruits are harvested and used, but its frequent occurrence near isolated villages combined with field knowledge from the region suggests that local harvesting is widespread. Field surveys, as conducted in specific regions[18], are needed to confirm this and to distinguish between subsistence use and trade-oriented production.

The extent of non-plantation oil palm revealed in our observations suggests a significant source of nutrition and income as has been noted locally in previous studies[5,19]. This raises questions concerning potential deforestation. The presence of oil palm indicates that the land is suitable for this crop and that villagers likely have the relevant knowledge to manage, harvest, and process the crop[5,8]. These factors may facilitate commercial intensification of oil palm cultivation to better meet regional and global demand[13]. Smallholder-driven oil palm expansion may occur at the expense of old-growth forests if suitable policies and regulations are not implemented[18,20]. On the other hand, oil palm yields more than other oil crops and if crop expansion is needed to meet demand, the use of oil palm may spare land[13].

Detecting oil palm in dense forests is challenging, and some palms may have been missed[17]. Non-plantation oil palm has been reported outside the sampled area, for example, in Angola, Zambia, and Mauritania[1]. Additionally, distinguishing oil palm from other palm species or irregularly arranged plantations introduces classification uncertainty. Despite these caveats, the methodology for generating area estimates is reliable for the following reasons. First, the non-sampled regions contain sparse oil palm populations, with oil palm areas that represent a small fraction of the total oil palm area found within the potential distribution range[1]. Second, the identification of key spatial features in palm and cultivation types relied on 175 sub-meter resolution satellite images paired with Google Street View (Supplementary Fig. 2). The identification of land cover types in these 175 locations was 100% replicable. Third, we replicated the visual identification of oil palm five times and determined the result using a majority vote (See Methods). Finally, the alignment of our plantation oil palm estimates with FAO statistics, except Nigeria, supports the accuracy of our methods. We discuss the FAO and USDA estimates in Nigeria in the Supplementary Text 2.

The challenge of quantifying the presence and access to oil palm illustrates a broader issue in understanding food security, particularly for communities living near forests or maintaining mixed gardens. While satellite imagery can help estimate some distinctive crops, such as oil palm and coconut, many other food sources remain difficult to observe and quantify. These include crops such as taro (*Colocasia* spp.) and yam (*Dioscorea* spp.) that thrive in forest margins, fallows and gardens, fruiting trees such as *Dacryodes edulis* H.J. Lam, *Allanblackia* spp. and *Irvingia* spp., as well as seasonal mushrooms, and other plants such as bananas (*Musa* spp.) and false banana (*Ensete ventricosum* (Welw.) Cheesman), which are often integrated into complex multi-layered gardens that often merge and persist within the secondary forest. Similarly, bushmeat continues to be a crucial yet poorly documented source of protein and fat. The importance of these food resources follows seasonal patterns, with communities relying on different items throughout the year and involving a spectrum between wild harvest and cultivation depending on needs, availability, and local knowledge. These often 'messy' landscapes and dependencies - neither purely agricultural nor purely wild - pose challenges for agricultural monitoring and food security assessment methods despite their potentially crucial role in local nutrition and resilience. To address such issues, it is essential to map all crops and farming practices, including other overlooked food species such as groundnut, rice, cassava, sorghum, and millet and subsistence value chains, which also play significant roles in forest loss, climate change, and biodiversity loss[20]. Understanding and accurately mapping all crops and agricultural practices is critical to effectively address the social and environmental impacts of agriculture.

Conclusion

Our findings indicate that most oil palm in Africa grows outside plantations in wild and semi-wild contexts, often near villages and in landscapes organized by smallholder activities. This non-plantation oil palm, which is virtually invisible in current official statistics, covers an estimated 6.53 ± 0.99 Mha and is likely to play an important role in local livelihoods and food systems. Although its presence does not prove it is being used in each case, the abundance of non-plantation oil palm near rural villages, and the long established importance of palm oil throughout the region, indicates a key role in subsistence and informal production. This is important as it means that the nutritional deficit that had been previously identified with many people not having access to sufficient fat to address their dietary needs is likely to be less widespread and severe than had been thought—though such conclusions now require further evaluation. The past neglect of this resource raises questions concerning food security, nutrition, and land use in Africa. Our findings contribute to improving the information required for food and land-use policies in Africa.

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Data Availability. The Zenodo repository (https://doi.org/10.5281/zenodo.14754653) contains: (i) the 11,800 randomly sampled points used to estimate oil palm area; (ii) the 175 sub-meter resolution images paired with Google Street View data; (iii) the 1,100 randomly selected village boundaries in West and Central Africa; and (iv) the points indicating where oil palm was found within and near villages. Village boundaries were queried from OpenStreetMap https://www.openstreetmap.org/ using QGIS. Sub-meter resolution images were visualized in Google Earth Engine https://code.earthengine.google.com/. The JRC Tropical Moist Forest can be downloaded at https://forobs.jrc.ec.europa.eu/TMF/data, the ESA WorldCover 10m v200 at https://doi.org/10.5281/zenodo.7254221, the Global Human Settlement Layer at https://doi.org/10.2905/2FF68A52-5B5B-4A22-8F40-C41DA8332CFE, the World Settlement Footprint 2015 at https://doi.org/10.6084/m9.figshare.12424970, the building dataset developed by Google. We also used the Open Buildings 2.5D Temporal Dataset (https://sites.research.google/gr/open-buildings/temporal/), and the RESOLVE Ecoregion biome layer (https://ecoregions.appspot.com/). Official oil palm statistics were obtained from FAOSTAT (https://www.fao.org/faostat/en/) and USDA-FAS (https://fas.usda.gov/).

Competing Interests. Serge Wich is a member of the IUCN Oil Crops Task Force. Erik Meijaard chairs and has received funding from the IUCN Oil Crops Task Force, and he has done work paid for by the Roundtable on Sustainable Palm Oil.

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