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Supplementary Methods

Prospecting for Peat

We used multiple satellite products as to infer the presence of peat on the basis of proxies for hydrology, topography, and vegetation. The satellite products cover three different types of data: L-band radar which provides information on vegetation structure and ground moisture; optical data which provides surface spectral information related to vegetation type; and a Digital Elevation Model (DEM), giving information on absolute elevation. Each of the three input types is discussed in detail below:

1. L-band radar from the Advanced Land Observation Satellite (ALOS) Phased Array L-band Synthetic Aperture Radar (PALSAR) satellite is provided as 2 bands, HH and HV, from the pre-processed ALOS PALSAR 50 m Orthorectified Mosaic Product[49]. Over tropical forest, such dual polarisation radar data can be used to distinguish between the relative contribution of the two main scattering components of radar data: double bounce (energy returning to the satellite through interacting with tree stems and then the ground), and volume scattering (energy randomly scattered in between canopy elements)[50]. While both HH and HV polarisations will contain elements of both, only volume scattering has a tendency to change the polarisation. Therefore, in HH double bounce dominates and in HV volume scattering dominates. The absolute magnitude of the volume scattering term will increase with forest above-ground biomass, up to some saturation limit[51], whereas the double bounce term will increase with biomass up to a lower saturation limit and then decrease as the ground is masked, but also increase as soil moisture increases. In order to take full advantage of the

structural information provided by these two polarisations, a third term is calculated: the ratio of HV/HH. This allows a differentiation of the increasing magnitude of both within increasing forest biomass, and the change in ratio between the two as vegetation structure changes and soil moisture increases.

2. Optical satellite data gives spectral information only from the top of the canopy, so unlike radar data contains little or no information about the soil surface. However, as dominant species and canopy cover, and thus reflectance characteristics, vary between the major vegetation types, it is useful in delineating different vegetation types here. We used optical data from Landsat Enhanced Thematic Mapper (ETM+) bands 4 (detecting in near infrared; NIR), 5 and 7 (detecting in mid infrared; MIR)[52]. The internal structure of leaves tend to strongly reflect NIR radiation and therefore forested areas should appear brighter in band 4, whereas areas of lower leaf area should appear brighter in band 5 and 7. Different vegetation types and species groupings can have subtly different spectral reflectances in these bands, allowing some ability to differentiate between vegetation types even at full canopy cover, but the main use of these data at this stage was to differentiate between areas of different levels of tree canopy cover.

3. We used the Shuttle Radar Topography Mission (SRTM) 3-arc second (~90 m resolution) Digital Elevation Model (DEM)[53] to look for depressions within the landscape where water might pool. Typically the SRTM C-band radar measures the ground surface elevation; however in forested regions C-band radar does not fully penetrate the forest canopy. Therefore depressions in the landscape could be attributable to a decrease in elevation but also a decrease in canopy height or an

increase in canopy openness, which would allow greater penetration of the radar signal through the forest canopy. Whilst the last two scenarios are not suggestive of the direction of water flow, they could still be indicative of peat, as spatial patterns in hydrology and nutrient status across a peatland are often reflected in lower stature vegetation and sometimes vegetation successions. Therefore subtle depressions in the DEM gave us a reasonable indication as to where peat might be formed.

Radiocarbon Dating

Due to the very humified nature of the peat, and a lack of macrofossils for dating, bulk samples were used, with details given here. Each sample was sieved at 200 µm to remove fine roots and pretreated with HCl-KOH-HCl, then dried, ground and combusted with CuO. The C was recovered by converting to graphite by Fe/Zn reduction and dated by accelerator mass spectrometry. To calibrate the radiocarbon ages we used the INTCAL13[54] calibration curve in R package clam version 2.2[55]. Sieved bulk peat dates can incorporate material of different ages, e.g. decomposed root material intruded from above into the peat matrix; Wust et al. (2008) showed that the maximum age discrepancy between dates on bulk material and pollen extracts was <1000 ^{14}C yrs in Indonesian Holocene material[56]. Consequently, our dates may slightly underestimate the true age of peat in our samples.

Peat accumulation rates were estimated by dividing peat thickness (mm) by basal radiocarbon date (years; Table 1; Extended Data Table 3). To estimate the long-term rate of carbon accumulation (LORCA) of the peat, first the peat accumulation as dry mass (g m^{-2} yr^{-1}) was calculated as the accumulation rate scaled by its measured bulk density, then the LORCA was calculated as the accumulation rate scaled by the measured mean carbon concentration of that core[57] (Table 1; Extended Data Table 3).

The markedly younger age of basal peat at Ekondzo (2,155 cal yrs BP *vs* ≥7,137 for all other basal dates) and considerably higher peat accumulation rates (at least four-fold higher than all other transects) are very difficult to explain, strongly suggesting that this sample has been contaminated by younger material and does not reflect the true age of the material. Thus, the Ekondzo basal date and results derived from it (peat accumulation, LORCA) are not included in the main text, but are listed in Extended Data Table 2 and Extended Data Table 3 for completeness. Alternatively, it is possible that the site represents later peat initiation, potentially lateral peat expansion. Further radiocarbon dates will be necessary to confirm or refute this interpretation.

Water-Table Levels

Cumulative Increase in the Water Table (CIWT) calculation: For each sensor CIWT was calculated by first using a 24-hour period window smoothing (R package Zoo[58]), to remove high frequency, low amplitude, signals (likely attributable to atmospheric tides causing 12-hour atmospheric pressure cycles[59], and evapotranspiration-driven water table draw-down causing 24-hour cycles). Following this, all negative changes in the water table were filtered out, and positive changes summed for each calendar month to obtain CIWT. Only months where the water table was always above the surface were used, as large apparent increases in the water table, unrelated to water inputs, can occur due to peat specific yield effects[60], the Lisse Effect and the Reverse Wieringermeer Effect[61], but these only affect water tables when they are below the peat surface. CIWT was then compared to rain gauge data from the area (Epena station) and monthly TRMM 3B43 data (Extended Data Fig. 1), showing a lack of additional water to the system via flood waves.

Peatland Area Estimates

The eight satellite products used to map the five land cover classes, detailed in Extended Data Table 5, were of three different types of data: L-band radar; optical data and two layers derived from a DEM. Each of the three input types is detailed below:

1. Given its ability to differentiate between areas of high and low soil moisture (see Prospecting for Peat section), three ALOS PALSAR products were used; the mean values of HH and HV, from four annual mosaics, 2007-10, and the ratio of HV/HH from the mean HV and HH values.

2. Optical satellite data is the standard product used for land cover classification. We used optical data from Landsat ETM+ bands 3 (detecting in the visible red), 4 (detecting in the NIR), and 5 (detecting in the MIR; rather than 4, 5 and 7 as in our prospecting for peat phase) as a pre-processed, cloud-free, uniform mosaic for the entire Cuvette Centrale was available for these bands from OSFAC[62]. Visual analysis comparing 3-4-5 and 4-5-7 composites confirmed that similar features could be distinguished, and we expect that similar maps would have been produced had band 7 been available instead of band 3. Ideally more bands would have been used, but previous experience suggests diminishing marginal returns for each additional Landsat band, and the OSFAC mosaics were preferred over alternatives as they had very good cloud removal and radiometric continuity across the mosaics.

3. We used the SRTM DEM as it was the highest accuracy DEM available for the study area. Though the ASTER GDEM v2 has a higher resolution and does not penetrate vegetation, giving a more consistent surface model (the reasons for its use in attempting to detect domes), it is a less consistent product when used across wide

areas as it has stripe artefacts between scene boundaries, and has occasional small-scale artefacts due to cloud cover. With the release of the SRTM 1-arc second DEM, the elevation data used in the classifications was of a higher resolution (~ 30 m resolution) than was available when prospecting for peat. Slope was calculated and included, as low slope values are more likely to be associated with peatlands, with steeper slopes associated with river levees or higher ground supporting *terra firme* forest, thus it may assist the algorithm in distinguishing peat and non-peat vegetation.

Below-ground Carbon Stocks

Integrating our new peatland C stock estimates into pan-tropical estimates: We used our below-ground carbon stock results to update the most recent pan-tropical total peat C stock estimate[2]. Page et al. (2011) provide a best estimate of peat C stocks for each country in the tropics, and their sum as the total tropical peat C stock[2]. To obtain a new total tropical peat C stock estimate, we substituted the best estimate of Page et al. (2011) for the ROC and DRC with our best estimate C stock (30. 6 Pg C) and accounted for likely net C losses resulting from ongoing South East Asian peatland degradation in the ~23 years since that data was collected at ~0.5 Pg C per annum[24] (data on peat extent were collected in 1990 in Indonesia, and 1992 in Malaysia and Papua New Guinea, which account for most of the SE Asia peat area reported[2]). Page et al. (2011) do not report confidence intervals for their country or total tropical peat C estimate, but rather report a minimum and maximum estimate[2]. Therefore, we replace their minimum and maximum peat C stock estimates for the ROC and DRC with our Cuvette Centrale lower and upper 95% CIs, and again account for net C losses from South East Asian peatlands, assuming that the losses per year were low, at 0.25 Pg C yr^{-1}, or high at 0.75 Pg C yr^{-1}, for the maximum and minimum estimates respectively, to estimate updated minimum and maximum total tropical peat C stock estimates.

Above-ground Carbon Stocks

Aboveground carbon (AGC) stocks were based on inventory plots, and allometric equations, described here. For Dicots AGC (kg) of each tree was calculated using a common allometric equation, including diameter, wood density and tree height[45], assuming 47% carbon content[46]. Wood specific gravity values were from the Global Wood Density Database[47, 48] following commonly used methods[42]. The *in situ* tree height measurements (n=510) were used to compute a height-diameter allometry allowing height to be estimated from diameter for trees with no height measurement, following recommendations in[43]:

$$H=27.4-18.1*\exp(-\exp(-7.78)*D\wedge^{2.15})$$

with height, H, in m, and diameter, D, in cm.

For Monocots, we used a generic tropical palm equation including height when available[44] and an alternative when no height was available[44].

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