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Mapping peat soil moisture under oil palm plantation and tropical forest in Sarawak

Laura D. Ngau[1], Sim S. Fong[1], Kho L. Khoon[2,6], Elisa Rumpang[2],
Harri Vasander[3], Jyrki Jauhiainen[3], Kim Yrjälä[3,4], Hanna Silvennoinen[5]

[1] Faculty of Resource Science & Technology, Universiti Malaysia Sarawak, Sarawak, Malaysia
[2] Peat Environment & Biodiversity Unit, Malaysian Palm Oil Board, Kajang, Selangor, Malaysia
[3] Department of Forest Sciences, University of Helsinki, Finland
[4] State Key Laboratory of Subtropical Silviculture, Zhejiang A&F University, Hangzhou, China
[5] Norwegian Institute of Bioeconomy, Aas, Norway
[6] Economic Planning Unit Sarawak, Chief Minister's Department, Kuching, Sarawak, Malaysia

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SUMMARY

Water table conditions in drained peatlands affect peat decomposition, fluvial carbon and greenhouse gas emissions, and plant growth in oil palm plantations. This study illustrates the spatial heterogeneity of soil moisture profiles in cultivated tropical peat under oil palm plantation and uncultivated secondary forest, using maps. At a study plot under each land use the geographical coordinates of sampling points, tree locations and other features were recorded. Peat soil samples were taken at depths of 0–50 cm, 50–100 cm, 100–150 cm and 150–200 cm, and their moisture contents were determined. Overall, soil moisture content was higher in secondary forest than in oil palm plantation due to land management activities such as drainage and peat compaction in the latter. Significant differences were observed between the topsoil (0–50 cm) and deeper soil layers under both land uses. Soil moisture maps of the study plots interpolated using geographical information system (GIS) software were used to visualise the spatial distributions of moisture content in soil layers at different depths (0–50 cm, 50–100 cm, 100–150 cm, 150–200 cm). Moisture content in the 0–50 cm soil layer appeared to be inversely related to elevation, but the correlation was not statistically significant. On the other hand, there was a significant positive correlation between soil moisture content and the diameters of oil palm trunks. Palm trees with negative growth of trunk diameter were mostly located in subplots which were relatively dry and/or located near drains. The results of this study indicate that soil moisture mapping using GIS could be a useful tool in improving the management of peatland to promote oil palm growth.

KEY WORDS: Geographical Information System, GIS, map, tropical peatland

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INTRODUCTION

Peat consists of partially decomposed organic materials which have accumulated primarily due to waterlogged and anoxic conditions in the soil (Page & Baird 2016, Tubiello *et al.* 2016). It is found on every continent and across tropical, temperate, boreal and (sub)arctic regions. Tropical peatlands make up 90–170 million hectares (Mha) of the 186–423 Mha of peatlands throughout the world (Gumbricht *et al.* 2017, Xu *et al*. 2018) and are located mainly in South America, Central Africa and South East Asia. Most of the peatlands in South East Asia are found in Malaysia and Indonesia (Hooijer *et al*. 2012, Veloo *et al.* 2015) and they cover 8 % (2.7 Mha) of the total land area of Malaysia (Mutalib *et al*. 1991, Abat *et al*. 2012). A large proportion of these peatlands have been cleared and converted for agricultural development to grow plants including oil palm (*Elaeis guineensis* Jacq.), sago palm (*Metroxylon sagu* Rottb.) and pulpwood trees (Purwanto *et al*. 2002, Miettinen *et al.* 2012, Carlson *et al*. 2015).

Peat is formed when the accumulation rate of organic material exceeds its decomposition rate in an oxygen deficient environment (Hoyt *et al.* 2019). Undisturbed peatlands often function as carbon (C) sinks with capacity to store organic matter in flooded conditions characterised by low redox potential, where only relatively slow anaerobic decomposition of organic matter - resulting in C-loss in the form of methane (CH_4) - can occur (Cobb *et al*. 2017, Manning *et al*. 2019). When the peatland is converted for agricultural use, permanent lowering of the water table through drainage is required to create an aerated zone suitable for the growth of crop roots. This simultaneously raises the soil redox potential, increasing oxygen availability and enhancing the release of C from organic matter decomposition primarily as carbon dioxide (CO_2) (Husen *et al*. 2013, Carlson *et al*. 2015, Page & Baird 2016, Tonks *et al*. 2017, Hoyt *et al*. 2019). Attention has also been drawn to the increased loss of C in the form of dissolved and particulate organic carbon carried away in drainage waters (Moore *et al.* 2011, Moore *et al.* 2013, Evans *et al*. 2016, Yupi *et al.* 2016, Cook *et al.* 2018). It is expected that more than half of this carbon will also contribute to the total greenhouse gas emission because it will undergo mineralisation and be released as CO_2 (Moore *et al*. 2013, Wit *et al*. 2015, Carlson *et al.* 2015). Evans *et al*. (2016) reported that draining peatlands could significantly increase the fluvial C-loss, as evidenced by the observation of Cook *et al*. (2018) that dissolved organic carbon (DOC) fluxes were higher in an oil palm estate with deep drains than in one with shallower drains.

Soil water content plays a critical role in the decomposition of peat, regulating the carbon loss and influencing nutrient availability (Teh *et al*. 2005, Jauhiainen *et al*. 2008, Carlson *et al*. 2015, Hashim *et al*. 2019). In drained peatlands the water table conditions influence peat decomposition, fluvial carbon losses, greenhouse gas emissions and the growth of oil palm. Lim *et al*. (2012) regarded water table level as the most important factor affecting plant growth and crop yield on peat. Hashim *et al*. (2019) highlighted the importance of water table management in nutrient regulation. In that study, four-month-old oil palm seedlings planted in lysimeters mimicking the field conditions of drained tropical peatland with water table depths of 25, 40, 55, 70 and 85 cm displayed significant differences in nutrient (Ca, Cu, K, Mg, P) concentrations. Moreover, the rate of nutrient leaching was dependent on water table depth; the lysimeter with the highest water table (25 cm) showed the greatest nutrient losses while the one with the lowest water table (85 cm) showed the smallest nutrient losses. Oil palm seedlings grew fastest at a water table depth of 55 cm, corroborating the findings of Melling *et al*. (2007).

The majority of oil palm roots are found in the uppermost 50 cm of the peat soil profile (Henson & Chai 1997, Melling *et al*. 2009) and a water table depth of 40–60 cm is currently recommended for oil palm plantations to ensure that the palm roots are not waterlogged. A water table positioned above or below the recommended range relative to the rooting zone may negatively affect both nutrient uptake and the production of fresh fruit bunches (Henson *et al*. 2008, Lim *et al*. 2012).

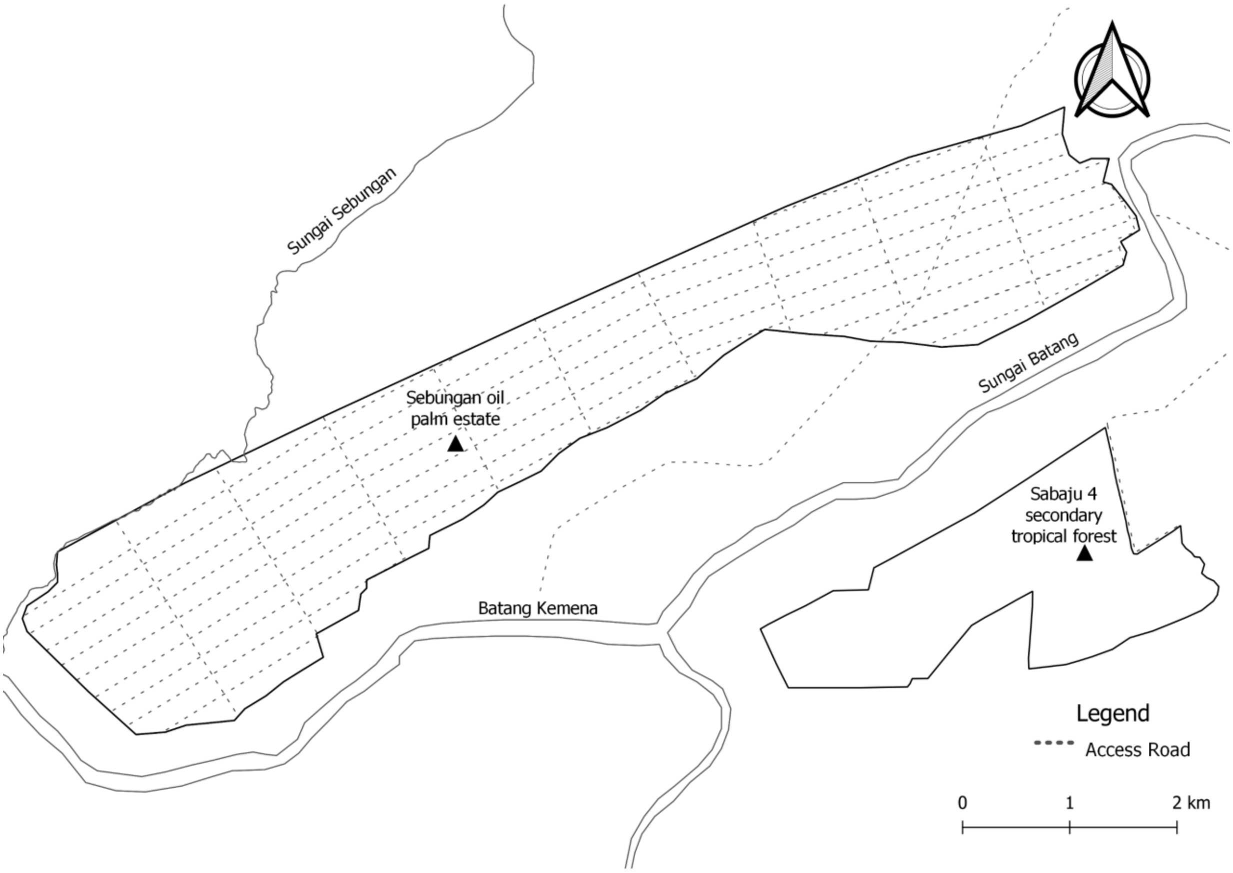
Mapping has played a significant role in determining the spatial extent of peatland and providing credible estimates of peat carbon stocks. Maps have also been useful in facilitating decision making on peatland management (Aitkenhead 2016, Minasny *et al*. 2019, Vernimmen *et al*. 2020). A study conducted by Wösten *et al*. (2008) used spatial maps of groundwater to visualise the correlations between groundwater level and other factors such as vegetation type, and as a basis for planning land utilisation and restoration employing a hydropedological modelling approach. These authors concluded that “water management is a key element in the wise use of peatlands”.

Despite the significance of water table conditions in drained peatlands and the prominent role of maps as data visualisation tools, to the best of our knowledge the spatial variability of moisture in tropical peatlands has not previously been illustrated. In this study we illustrate soil moisture profiles under two different land uses (oil palm plantation and uncultivated secondary forest) by mapping them using a geographical information system (GIS). This enables us to show and compare the spatial heterogeneity of moisture profiles under the two different land uses, and thus to gain insights about how the management of water table level in the oil palm plantation modifies the spatial distribution of peat moisture relative to the situation in nearby, mostly unchanged, forest peat.

METHODS

Study sites

Fieldwork was conducted at the Sebungan oil palm estate (03° 09' 58.32" N, 113° 21' 15.43" E) and the Sabaju 4 forest (03° 09' 58.32" N, 113° 24' 21.32" E), located approximately 40 km east of the town of Bintulu in Sarawak, Malaysia (Figure 1). The climate in this region is generally warm (annual mean temperature 26–27 °C) and humid with annual precipitation >3000 mm (MET Malaysia 2019). The Sebungan Estate is situated on peatland between the two rivers Batang Kemena and Sungai Sebungan (Cook *et al.* 2018). Peat depth ranges from 1 m to more than 3 m. According to previous studies (Cook *et al*. 2018, Sim *et al*. 2019), the artificial drainage network established in the estate prior to planting with oil palm in 2007 (MPOB 2006) confines the water table between 30 cm and 60 cm below the soil surface. At the time of our study the semi-mature oil palm trees had partially closed canopies that provided some shade for the peat surface (Figure 2a). A one-hectare study plot divided into 25 subplots of dimensions 20 m × 20 m was established in the plantation, and a similar study plot was set up in the nearby Sabaju 4 tropical forest. Sabaiu 4 is a closed-



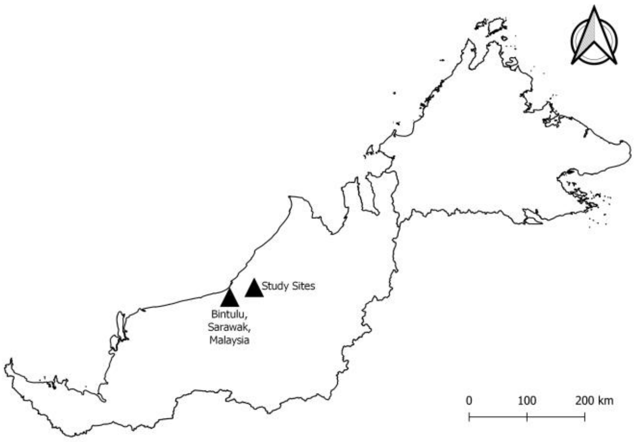


Figure 1. Maps showing the locations (filled triangles) of the two study plots in relation to the plantation, rivers and access road (above) and the study area within Sarawak (right).

canopy secondary forest which has undergone up to two cycles of logging in the past (Figure 2b). We expected that the water table here would be higher than in the plantation, given its unregulated condition. The Sabaiu 4 study plot was approximately 500 m from the closest drain, which ran alongside the access road to the east of the forest (Figure 1).

Peat sampling and laboratory measurements

Peat soil sampling was conducted over the course of four weeks in July 2019, during the period of influence of the southwest monsoon (May to August) which is drier than the northeast monsoon season (October to January) (MPOB 2006). Peat samples were taken from four depths (0–50 cm, 50–100 cm, 100–150 cm and 150–200 cm) at both sites using a peat auger (Eijkelkamp, core diameter 5.2 cm, length 50 cm) with an extension rod. The samples were removed from the auger, sealed tightly in zip-lock bags and kept below 4 ℃ before analysis in the laboratory.

At the Sebungan oil palm estate, samples were taken from each of the 25 subplots selecting three management zones namely the harvest path (HP), frond pile (FP) and palm base (PB). In Sabaju 4, samples were taken from three points (L1, L2, L3) placed randomly within each subplot except that flat and open surfaces between trees were preferred to

Figure 2. Photographs of vegetation in the study plots at (a) the Sebungan oil palm estate and (b) the Sabaju 4 secondary tropical forest.

minimise the chance of the corer contacting impenetrable woody material. In total, 600 samples (4 depths in the peat profile × 3 sampling points × 25 subplots × 2 study sites) were collected, including 75 samples from each peat depth at Sebungan Estate (total 300 samples) and 300 samples from Sabaju Forest. During sampling, the geographical coordinates of subplot borders, sampling points and trees (oil palm or forest) were recorded using a hand-held GPS (Garmin GPSMAP 64s). Data recorded as part of plantation and forest management by the Malaysian Palm Oil Board (MPOB) indicated that the diameters of the trees ranged from 10.0 cm to 63.7 cm and their heights from 7.8 m to 31.4 m. For the forest trees, only those with diameter more than 10 cm were mapped. Elevation data for both study plots were obtained from Google Earth.

In the laboratory, the peat samples were weighed and dried to constant mass in an oven at 55 ℃. Gravimetric soil moisture content was then calculated according to the standard method (ASTM D 2974-87):

$$\text{Moisture Content (\%)} = \frac{(A-B)}{A} \times 100 \qquad [1]$$

where A = mass of the wet peat soil (g) and B = mass of the oven-dried peat soil (g).

Data analysis and spatial interpolation

Statistical analyses were conducted using SPSS (Statistical Package for the Social Sciences), mainly for Pearson product-moment correlation and Analysis of Variance (ANOVA) as well as for comparing means using Tukey's test at $p < 0.05$.

The study site features and peat soil characteristics including subplot borders, trees, soil depth, sampling points, moisture and elevation were assigned as attribute features to corresponding geographical coordinates in CSV (comma-separated values) files. The CSV files were imported as point layers to QGIS (Quantum Geographical Information System) 3.20 software. Peat soil moisture was spatially interpolated using inverse distance weighted (IDW) interpolation which is a built-in tool in QGIS. IDW interpolation uses points with known values to predict the values at unmeasured points. In determining a predicted value, points with known values that are closer to the prediction location have higher influence than those farther away (Liu *et al.* 2021). The influence of known values depends on the distance coefficient, p, which was kept at $p = 2$ for all the maps in this study.

RESULTS

Variation of soil moisture with land use and depth in the peat profile

In Sebungan Estate, the average soil moisture values at depths of 0–50 cm, 50–100 cm, 100–150 cm and 150–200 cm were 83.9 %, 86.9 %, 87.4 % and 88.9 %, respectively (Table 1). In Sabaju Forest, the average soil moisture was 89.6 %, 91.2 %, 91.4 % and 91.1 % for the same sequence of layers. Considering the plantation and the forest separately, in both cases soil moisture in the 0–50 cm layer was significantly different ($p < 0.05$) from that in the other three layers, and the increase of soil moisture with depth indicated that the deeper peat was submerged below the water table. However, the soil moisture values were significantly lower in the oil palm plantation than in the secondary forest. The values measured in Sebungan Estate (range 83.9–88.9 % across four layers spanning the depth range 0–200 cm) were all lower than the value for topsoil in Sabaju

Table 1. Layer-by-layer average soil moisture in Sebungan (oil palm estate) and Sabaju 4 (tropical secondary forest) peat. Depth is measured from the soil surface downwards. There are no significant differences ($p > 0.05$) between values with the same superscripted letter; s.d. = standard deviation.

Location	*n*	Depth (cm)	Soil moisture (%) [mean ± s.d.]
Sebungan Palm Oil Estate	75	0–50	83.88 ± 3.91^{a}
	75	50–100	86.86 ± 2.10^{b}
	75	100–150	87.44 ± 4.39^{b}
	75	150–200	88.88 ± 3.55^{c}
Sabaju Secondary Forest	75	0–50	89.57 ± 2.85^{a}
	75	50–100	91.24 ± 1.84^{b}
	75	100–150	91.37 ± 1.74^{b}
	75	150–200	91.06 ± 2.02^{b}

Forest (89.57 % at 0–50 cm). Comparing soil moisture in individual layers between the two land uses revealed significant differences for all depths ($p < 0.05$). Finally, a comparison of soil moisture between the different management zones (HP, FP, PB) across the 25 subplots in the oil palm plantation showed that the average soil moisture values were 84.9 ± 1.7 % for HP, 84.3 ± 3.14 % for FP and 82.5 ± 5.6 % for PB, with no significant differences between zones.

Spatial variation of soil moisture and elevation

The layer-by-layer spatial distributions of soil moisture in Sebungan Estate are mapped in Figures 3 and 4. In the 0–50 cm layer, soil moisture varied between 82 % and 87 % in most areas. At 50–100 cm the distribution of soil moisture content was more homogeneous than in the surface layer, with values between 85 % and 91 % throughout the study plot. In the deeper horizons (100–150 cm and 150–200 cm), soil moisture content ranged from 85 % to 94 % and the measurements at 100–150 cm exhibited a pattern similar to that at 0–50 cm.

According to the Google Earth data, the average elevation (above mean sea level) in the Sebungan (plantation) study plot was 16.8 ± 0.5 m (SE = 0.046, 95 % CI = 16.86–16.86) with a minimum of 16 m and a maximum of 18 m. The average elevations of the three different management zones HP, FP and PB were 16.7 ± 0.5 m, 16.8 ± 0.7 m and 16.7 ± 0.5 m, respectively, and showed no significant differences. The spatial distribution of elevation was rather homogenous in most parts of the plot (Figure 5a). Pearson product-moment correlation indicated an inverse relationship between average moisture content at 0–50 cm and elevation, although it was not statistically significant ($r = -0.169$, $p = 0.147$, $n = 75$).

At Sabaju Forest the moisture content of soil below 50 cm depth was between 85 % and 94 % (Figures 6 and 7). The top layer (0–50 cm) had a slightly lower moisture content of 76–88 % with a few wetter spots (up to 94 %). The average elevation in the forest was 20.01 ± 1.62 m above mean sea level (SE = 0.153, 95 % CI = 19.71–20.31), which was significantly different from the elevation of the estate. In the 0–50 cm soil layer, moisture content appeared to be higher in lower-lying areas (compare Figures 6a and 5b) and this impression was confirmed by correlation analysis which showed that the average soil moisture content at 0–50 cm depth was inversely correlated with elevation although (as for the plantation) the values were not statistically significant ($r = -0.124$, $n = 75$, $p = 0.289$). Similar results were obtained for the correlation between average soil moisture and number of trees by subplot ($r = -0.09$, $n = 25$, $p = 0.966$). In addition, a significant inverse correlation was observed between the average elevation and number of trees by subplot ($r = -0.561$, $n = 25$, $p = 0.003$).

Correlation of soil moisture with the growth of oil palm

The soil moisture map was correlated with palm growth data for 2014 to 2018 recorded as part of plantation management by the Malaysian Palm Oil Board (MPOB). There was a significant positive correlation between soil moisture content at 0–50 cm and the average trunk diameter of 156 oil palms ($r = 0.413$, $n = 25$, $p = 0.04$). Figure 8 illustrates the percentage growth in diameter of palms and the average soil moisture of subplots. Some palms exhibited negative growth in trunk diameter and most of these were located in relatively drier subplots or close to the drain (Figure 9).

DISCUSSION

Our observations are consistent with the previous finding of Sim *et al*. (2019) that the peat soil at depths ≥ 100 cm is fully submerged, in both the plantation and the forest. The surface soil in forest (moisture content 69.3 %) and plantation (66.7 %) was drier when observed by these authors in 2017 than during the current study. This may be due to environmental factors such as the temporal distribution of precipitation and the dynamics of groundwater level (Qiu *et al.* 2001, Lee *et al.* 2018). Water table data collected at Sebungan Estate in 2018 and 2019 and at Sabaju 4 in 2017 and 2018 were obtained from MPOB (Figure 10). These showed that water table depth varied seasonally, fluctuating within the range 17–95 cm (below soil surface) in Sabaju 4 and 52–179 cm in Sebungan Estate. The water table recorded in both the forest and the oil palm plantation was at its lowest level in June–September 2018 and 2019 respectively, which are typically the driest months in Malaysia. The annual range of water table level seemingly varied. The average water table depth recorded at Sabaju 4 in 2017 (April to December) was 31.3 ± 19.2 cm and in 2018 it was 66.3 ± 28.4 cm, suggesting that climate conditions affect water table fluctuation in the forest (Wakhid *et al.* 2018). Water table depth recorded in Sebungan Estate was 58.86 ± 12.28 cm in 2018 and 93.55 ± 43.18 cm in 2019. The average water table depth at the time of peat soil sampling in July 2019 was 151.98 ± 12.43 cm, which was much lower than the target range of 30–60 cm. This may have resulted in very dry soil, even in the deepest horizon investigated during this study.

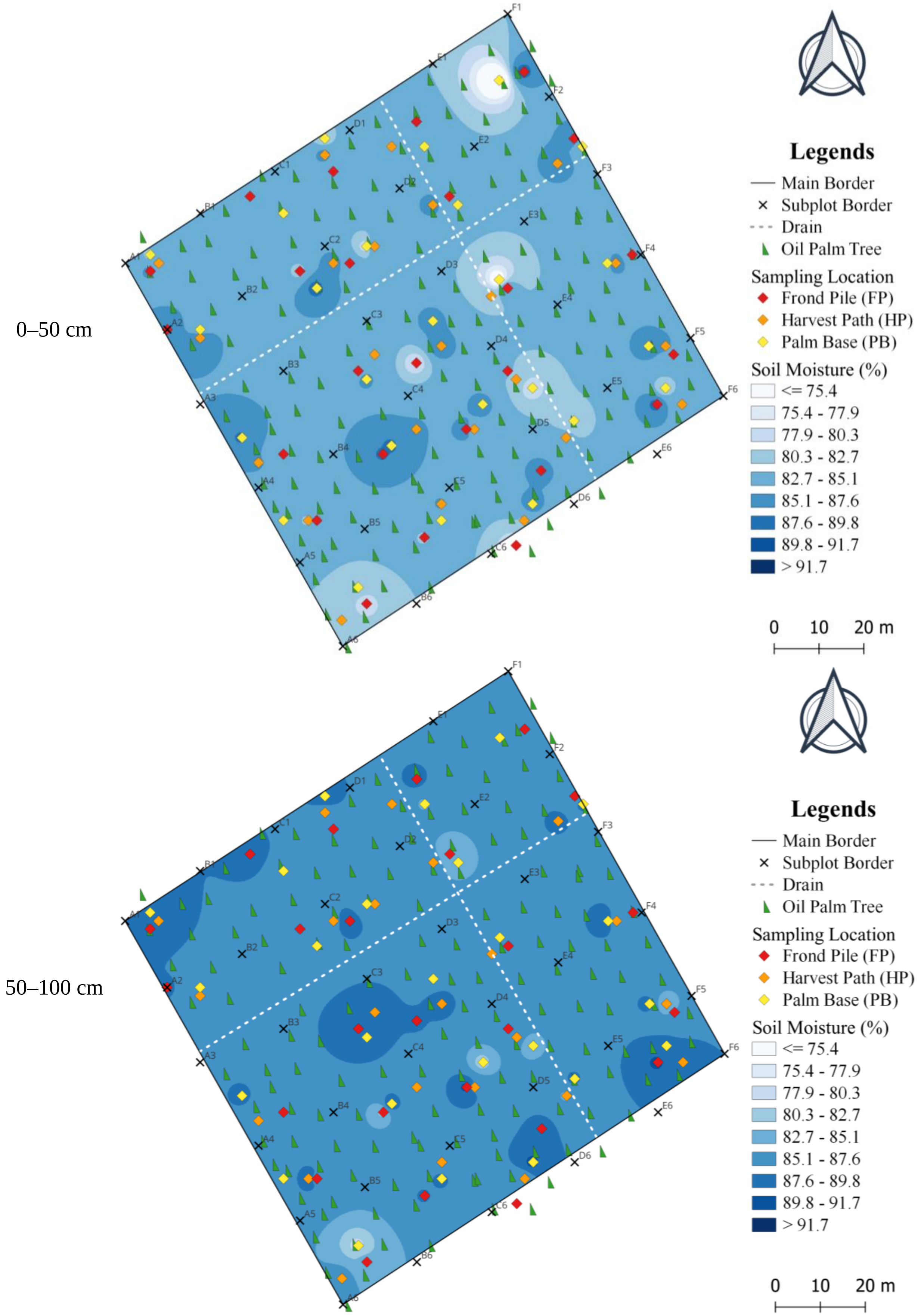


Figure 3. Maps showing the spatial distributions of subplots, sampling points, trees, drains and moisture content in shallow (0–50 cm and 50–100 cm) soil layers at Sebungan Estate oil palm plantation.

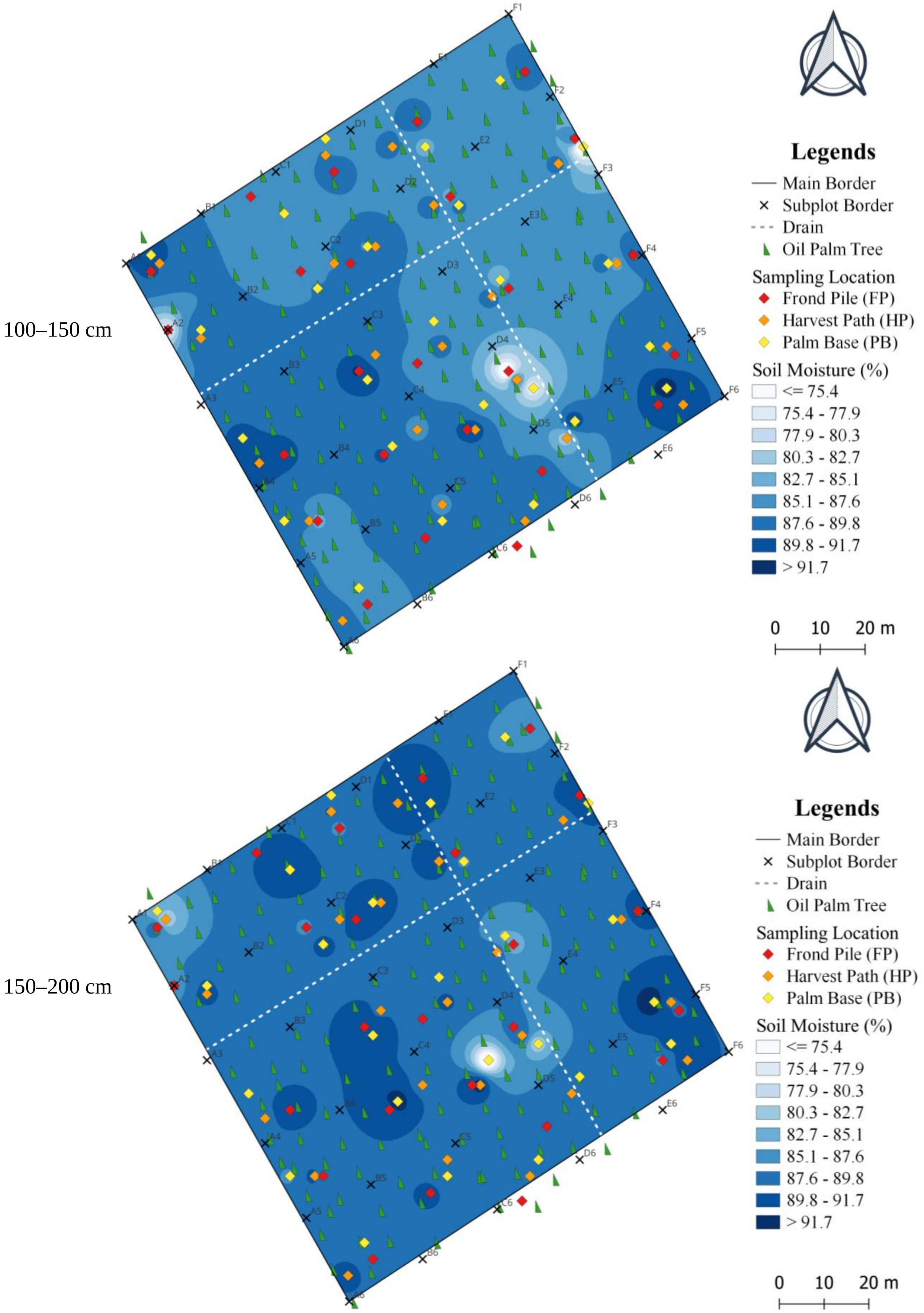


Figure 4. Maps showing the spatial distributions of subplots, sampling points, trees, drains and moisture content in deeper (100–150 cm and 150–200 cm) soil layers at Sebungan Estate oil palm plantation.

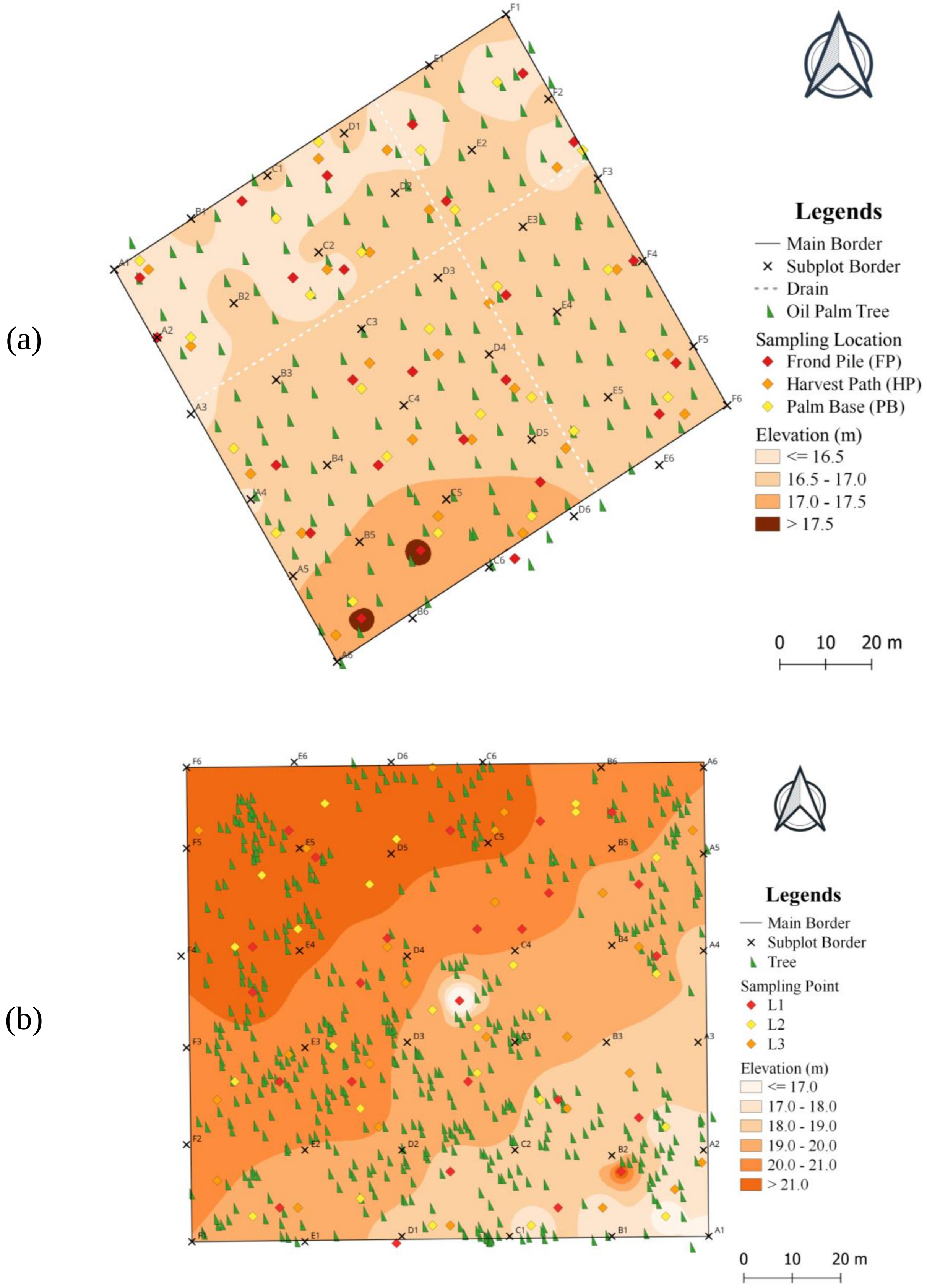


Figure 5. Maps showing the distributions of subplots, sampling points, trees and ground elevation in (a) Sebungan Estate oil palm plantation and (b) Sabaju secondary tropical peat swamp forest.

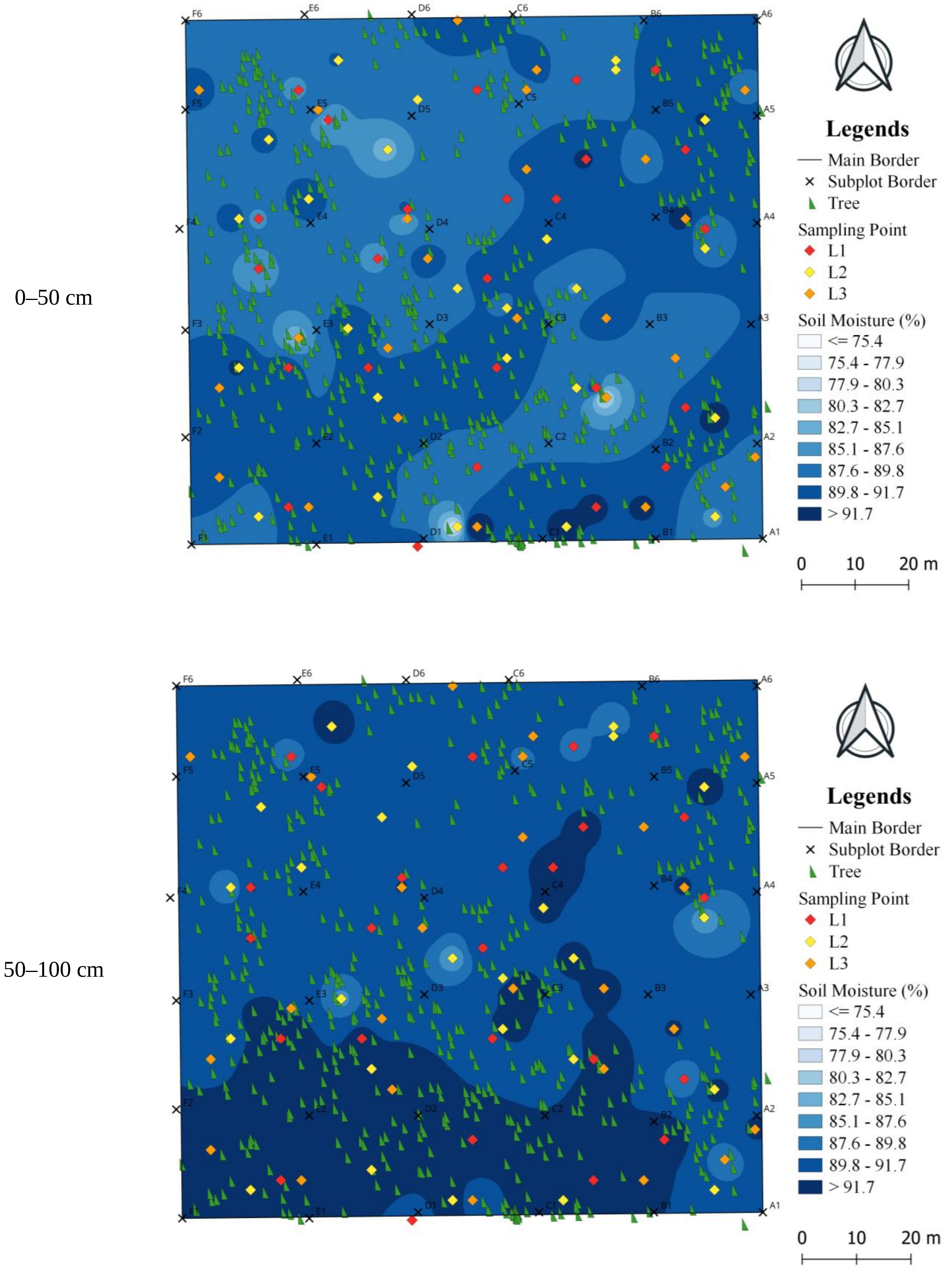


Figure 6. Maps showing the spatial distributions of subplots, sampling points, trees and moisture content in shallow (0–50 cm and 50–100 cm) soil layers at Sabaju secondary tropical peat swamp forest.

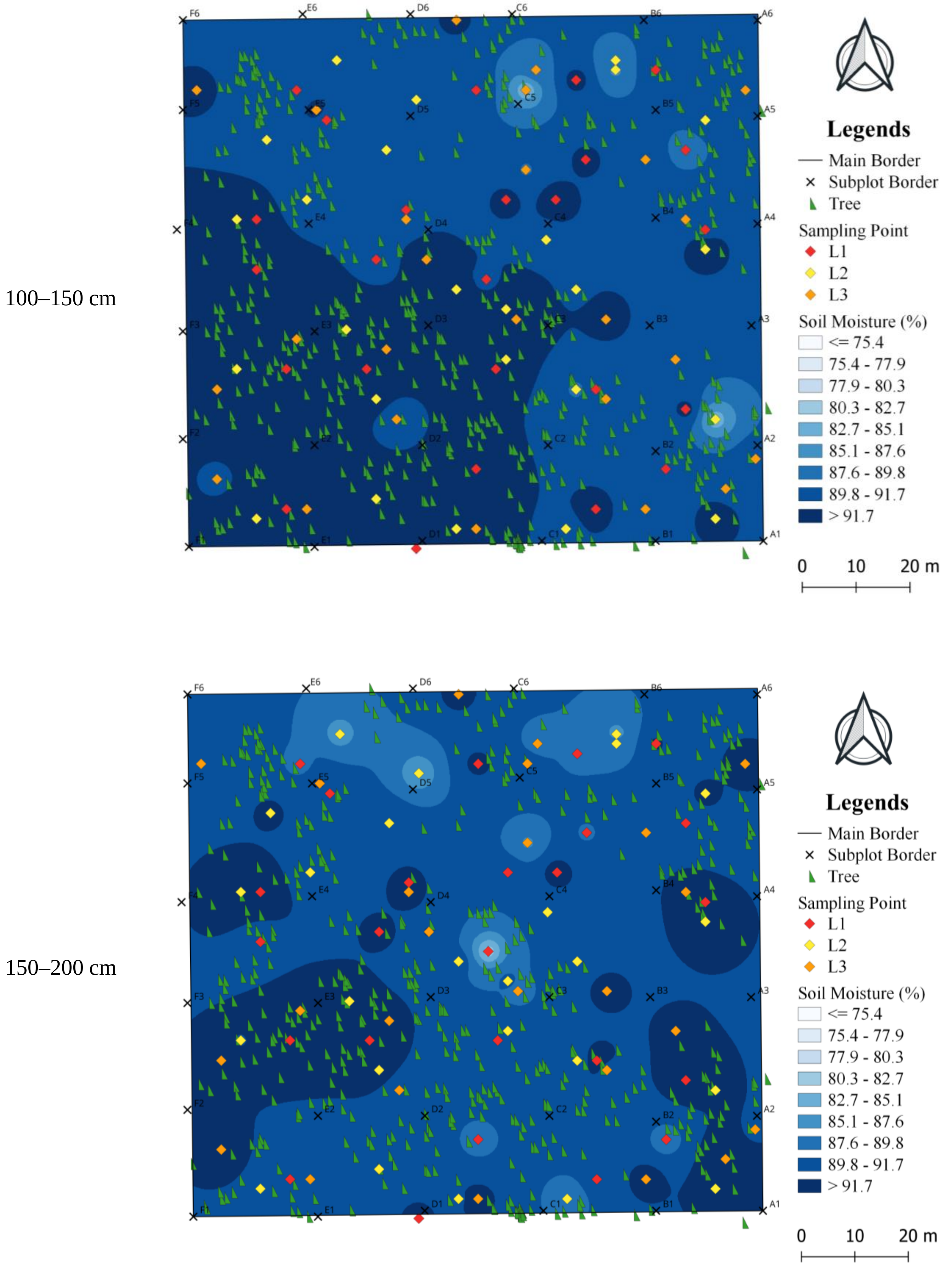


Figure 7. Maps showing the spatial distributions of subplots, sampling points, trees and moisture content in deeper (100–150 cm and 150–200 cm) soil layers at Sabaju secondary tropical peat swamp forest.

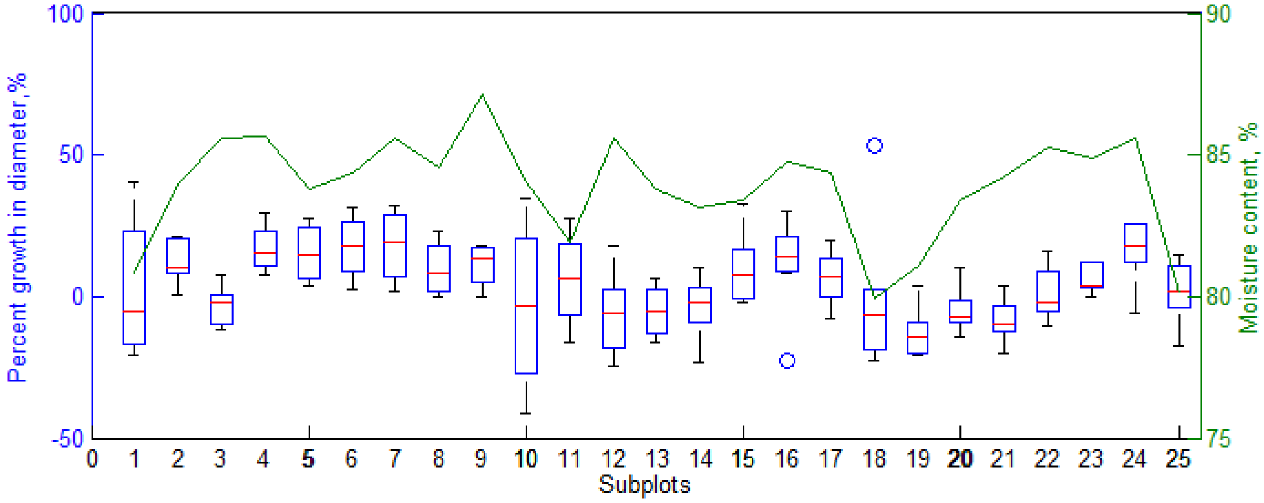


Figure 8. Percent growth of oil palm trunk diameter based on data from 2014–2018 (box-and-whisker plots) and soil moisture content in the 0–50 cm layer (green line) in the 25 subplots at Sebungan Estate. The number of oil palms per subplot ranged from 4 to 10.

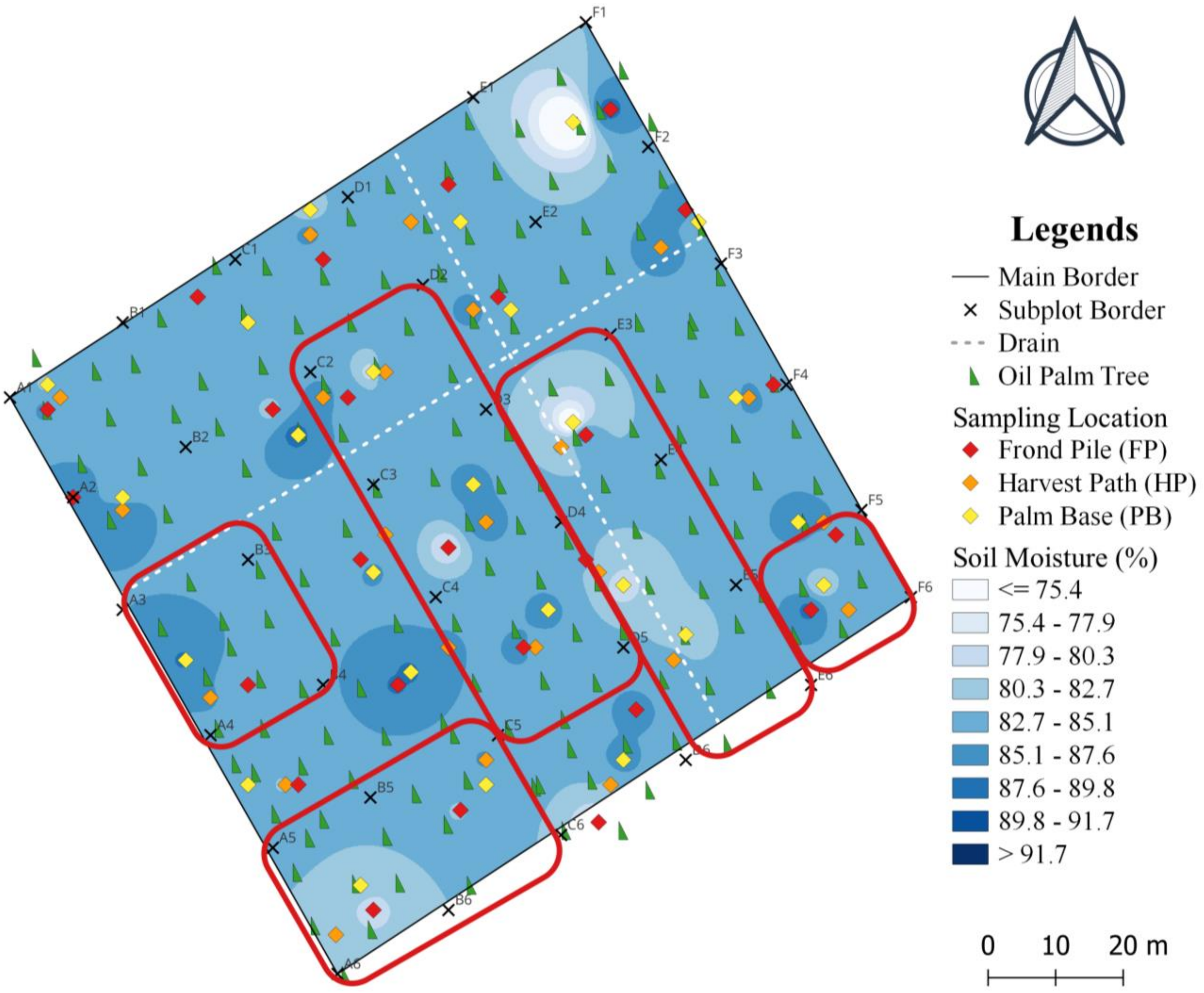


Figure 9. The spatial distribution of moisture content in the 0–50 cm soil layer at Sebungan Estate oil palm plantation (from Figure 4) with subplots where oil palm trees showed negative growth in trunk diameter identified (within the red boxes).

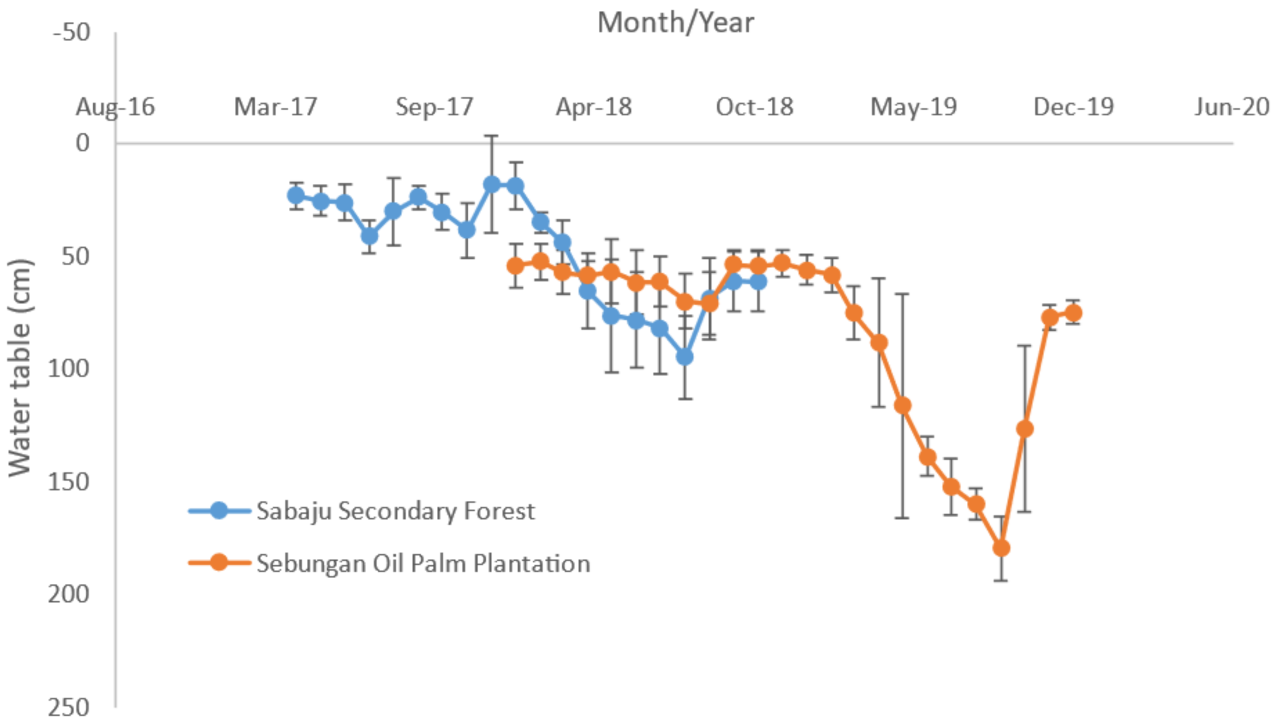


Figure 10. Monthly water table data collected in Sebungan Estate oil palm plantation (2018–2019) and Sabaju secondary tropical peat swamp forest (2017–2018).

Our data are consistent with the findings of Tonks *et al*. (2017), who reported higher moisture content in the surface soil layer of secondary forest compared to a mature 10–15-year-old oil palm site. Oil palm plantation has larger gaps in the canopy and lower cover of ground vegetation than secondary forest (Hooijer *et al*. 2012, Dommain *et al*. 2018). This in turn exposes the ground to more intense solar radiation, leading to increased soil surface temperature (Wösten *et al*. 2008, Jauhiainen *et al*. 2014, Wang *et al*. 2014). Thus, it is likely that the lower moisture levels in the shallowest soil layer at Sebungan compared to Sabaju was a result of drier and hotter microclimate in the oil palm plantation (Anamulai *et al*. 2019). A similarly drier microclimate in cultivated peatland was observed by Ludang *et al*. (2007) in Central Kalimantan, Indonesia. The wetter soil in Sabaju Forest would be fostered by the greater ground cover of vegetation and leaf litter, along with the microtopography of the forest floor.

Another factor tending to make the soil in the oil palm estate drier is the lowering of the water table by drainage and the resulting compaction of the soil. This contributes to increasing the bulk density of the peat (which results in lower moisture content), especially in the topmost soil layer (Wösten *et al*. 1997, Huat *et al*. 2011, Tonks *et al*. 2017). Bulk density data collected from the same plots at Sebungan Estate and Sebaju Forest in 2017 (Sim *et al*. 2019) were examined to demonstrate their relationship with gravimetric soil moisture content. Plotting bulk density (y) against moisture content (x) for 200 samples collected from four depths (0–100, 100–200, 200–300, 300–400 cm) showed an inverse relationship, $y = -0.01986x + 1.9728$ with $R^2=0.94$ (Figure 11). The bulk densities of surface (depth 0–100 cm) soil from the forest (0.64 g cm^{-3}) and oil palm plantation (0.65 g cm^{-3}) were comparable. Moving down the profile, bulk density decreased under both land uses but the plantation soil showed higher bulk density than the forest soil. The plantation soil was drier at 300–400 cm (89.4 %) than the forest soil at 100–200 cm (93.6 %), indicating a trend similar to that observed in the current study where the deeper peat horizons in the plantation were drier than the surface peat in the forest.

Although the differences were not significant, the descending order of moisture content in the different management zones of the plantation (HP > FP > PB) agrees well with that reported by Manning *et al*. (2019). Peat soil near palm bases (PB) was drier than that in harvest paths (HP) and frond piles (FP), which might be due to water uptake by the palm roots (Safitri *et al*. 2018).

The maps revealed that the spatial distribution of soil moisture was more heterogeneous in the Sabaju 4 forest than in the oil palm plantation. This is probably

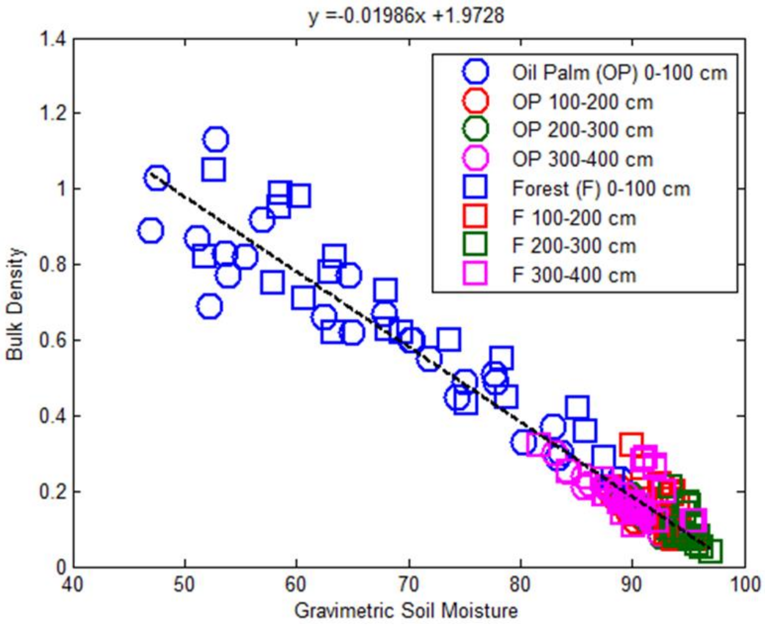


Figure 11. Inverse relationship between bulk density and gravimetric soil moisture based on the data of Sim *et al.* (2019).

due to the random distribution of above-ground vegetation and the microtopographical heterogeneity of the forest floor. The forest peat samples were taken preferentially from flat, open surfaces rather than next to or in between trees where depressions would be present and the peat auger would often land on hard, undecomposed wood below 50 cm depth; although the latter choice of sampling spot was unavoidable in some subplots.

It is believed that the spatial distribution of soil moisture is controlled by the topographic elevation (Qiu *et al*. 2001, Yang *et al.* 2017), and our results based on Google Earth elevation data are consistent with this contention. More elevated sites may be better drained and thus be characterised by lower soil moisture. A study conducted by Wang *et al.* (2017) on roadways in the United States of America reported that the accuracy of Google Earth elevations is satisfactory and comparable to that of elevation data from other sources (root mean square error = 2.27 m, standard deviation = 2.27 m, mean absolute error = 1.32 m). Rusli *et al.* (2014) verified that the elevations of flat surfaces extracted from Google Earth demonstrate a strong positive correlation with the satellite elevation obtained from the Shuttle Radar Topography Mission 90 (SRTM 90).

Soil moisture content directly affects the growth of oil palm. Diurnal fluctuations of trunk diameter have been well documented in literature (Junjittakarn *et al*. 2011, Chan *et al*. 2016), but continuously decreasing diameter - as observed in our study - has not been extensively reported in the case of oil palms. Negative trunk growths are commonly associated with measurement errors in the early years of planting (Lesser & Kalsbeek 1999, Pastur *et al.* 2007). However, consistent reverse annual growth might be caused by a decrease in water content of the stem which results, in turn, in contraction of the trunk at different rates (Baronasa *et al*. 2001, Pastur *et al*. 2007, Itaka *et al.* 2014).

Thus, in addition to demonstrating that land use activities involving the drainage and compaction of peat soil can modify soil-water dynamics, the results of our study indicate that there are significant implications for the growth of oil palm. The visualisation of soil moisture in cultivated peatland using GIS shows considerable promise as a tool to help improve our understanding of which land management factors are crucial for stable oil palm growth.

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AUTHOR CONTRIBUTIONS

Conceptualisation: LDN, SSF, KLK; Funding acquisition: HV, JJ, KY, KLK, HS, SSF; Sampling and data curation: LDN, SSF, ER; Data analysis: LDN, SSF, ER; Map generation: LDN; Writing - original draft: LDN and SSF; Writing - reviewing & editing: KLK, HV, JJ, KY, HS. All authors approved the final manuscript.

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Author for correspondence: Laura Dines Ngau, Faculty of Resource Science & Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia.   E-mail: lauradines31@gmail.com