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Interactive comment on “A cost-efficient method to assess carbon stocks in tropical peat soil” by M. W. Warren et al.

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Response to Referee #1

The Referee expresses concern about limitations of the data sets used in this analysis, and suggests that a more comprehensive analysis is necessary which better represents the tropical peatlands of Southeast Asia. This concern is reiterated in the specific comments, and the referee suggests that the paper would benefit from broader analysis of the literature. To establish the relationship between bulk density and carbon density, our literature review was limited to peer-reviewed publications (including one PhD dissertation) which include measurements of bulk density and carbon content obtained from induction furnace C analysis. Literature with estimates of peat carbon density based on loss on ignition (LOI) or Walkley-Black wet combustion are not included,

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because these are measurements of soil organic matter and rely on an assumed constant for %C which is known to vary among tropical peat samples. Furthermore, both techniques lose precision when organic matter content is very high. Data provided by Hooijer et al. (2012) were also excluded in our study, because a default C content (55%) was assumed for all calculations of C density. These criteria limited our dataset somewhat, however all known studies were included after extensive research of the peer-reviewed literature. Based on the reviewer's concern, we will revise our analysis to include data from Neuzil (1997), which were originally excluded as the data were published in conference proceedings. In fact, published information on peat characteristics is very limited, as indicated by the Page et al. (2011) review. With the addition of Neuzil (1997) data, the two primary data sources for Indonesian peat characteristics cited in the Page et al. 2011 review (Page et al. 2004 and Neuzil 1997) will be included in our analysis.

Due to the paucity of data on tropical peat characteristics, Page et al. (2011) estimate global tropical peatland carbon stocks by establishing a default value for bulk density: "In the absence of sufficient information on peat BD across the tropics we used a single best estimate of 0.09 g cm⁻³ that is a combination of the weighted means of 0.08 g cm⁻³ (Page et al., 2004) for peatland in Central Kalimantan, Indonesia and 0.13 g cm⁻³ for Central Kalimantan, 0.08–0.13 g cm⁻³ for Sumatra and 0.09–0.13 g cm⁻³ for West Kalimantan (Neuzil, 1997)." The Page et al. (2004) and Neuzil (1997) data used by Page et al. (2011) to establish a bulk density default value for all tropical peats are from single peat cores in a few peat deposits in Indonesia (12 total cores), yet are accepted because they are within values reported for other tropical peat deposits.

The reviewer also expresses concern: "Determination of bulk density (Bd) is the principle methodology used in this paper, yet very few actual Bd values are presented, thus the research is somewhat abstract and, on the basis of the data currently presented, unverifiable. At the very least, a table is required that presents the average values and other key statistics like range for each of the 3 regions (Danau Sentarum, Sabangau,

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Berbak), and of the literature sources, as a function of depth. The same table is also needed for carbon content. In its present form, it is impossible to judge if the numbers presented are supported by other studies.” We used a total of 678 bulk density and %C measurements (including 94 published values) to derive the relationship between bulk density and carbon density. We feel that the sample size of 678 measurements is sufficient to establish the strong linear relation between bulk density and carbon density, as indicated by the high R^2 (0.96) and narrow confidence intervals of the equation presented. Bulk density values in our analysis ranged from 0.021 to 0.37 g cm⁻³ which covers the broad range expected for tropical peat, and 64% of the bulk density values were within the 0.08–0.13 g cm⁻³ average values considered in the Page et al. 2011 review. All data used in this study are from original data sources and listed in Table 1. Contrary to the referee’s comments, our analysis did include a limited number of data points from Riau province (Brady 1997), and data from Riau will be expanded with the inclusion of Neuzil (1997) data in the analysis. Another issue mentioned by the reviewer is a high number of data points used in our analysis are from Danau Sentarum, which may not be representative of other coastal and sub-coastal peatlands. While we agree Danau Sentarum is unique, we do not believe specific differences in peat properties from Danau Sentarum significantly affect the relationship between bulk density and carbon density. Furthermore, the large number of samples included from Danau Sentarum help broadens the overall dataset, to partially overcome the geographic bias of published peat characteristics. We understand the extent of the overall dataset used in our analysis is not clearly presented in the paper. We will address this issue by following the reviewers’ suggestions and adding tables including average bulk density, %C, and C density for each peat formation, along with totals.

The reviewer suggests inclusion of data from Hooijer et al. (2012) would strengthen the analysis because it “presents results from double the amount of data presented in this analysis”. While we agree that the large dataset presented by Hooijer et al. (2012) is a very valuable contribution to understanding how drainage and subsidence affect peat characteristics, the statement is somewhat inaccurate and fails to recognize the

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objective of our study. In the Hooijer et al. (2012) study, incremental peat samples were taken from within acacia and oil palm plantations in Riau and Jambi provinces using a pit sampling method to assess the impacts of deep drainage on the bulk density of surface peat layers, above the water table. Three replicates were taken from each sample depth within each pit, with 22 pits in acacia plantations and 10 pits in oil palm plantations. Therefore, much of the overall data generated was from sub-sampling within each depth layer of each pit (location). In total, Hooijer et al. (2012) sampled 32 pit locations which is the exact number of sample locations included in this study. However, our sampling approach and methods were different than those of Hooijer et al. (2012) to accommodate a very different research question. Our sampling method aimed to capture variation throughout the vertical profiles of less disturbed peatlands of varying thicknesses, in three important peat formations of Indonesia (un-drained excluding Sebangau, where shallow canals are dug for timber extraction, not agricultural conversion). Hooijer et al. (2012) were seeking to detect small differences in surface bulk density caused by compaction and consolidation, and therefore applied a more focused sampling effort within selected plantation sites; they do not present bulk density data for forested un-drained peatland, and did not sample deep in the profile with the assumption bulk density below the water table does not vary, and is representative of surface peat before drainage.

Finally, the reviewer indicates significant sources of error from vertical peat coring: “A) compresses the peat (increasing sample Bd; this is especially a problem in peat with high wood content as is the norm in SE Asia) and B) carries the risk of retrieving incomplete samples with air/water pockets (decreasing sample Bd).” Where a sharpened steel cylinder-type auger inserted vertically into the peat could significantly compact the peat core, the Russian peat sampler (Jowsey 1966) used for peat sample collection in this study is designed to obtain saturated peat samples with minimal disturbance. Most values reported in the literature for peat bulk density have been obtained using the same type of auger, allowing for greater comparability among values.

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We respectfully disagree with the reviewer's statement that the vertical auger method is "...widely known to be sub-optimal and sometimes very inaccurate...". To our knowledge, no comparative study has been published demonstrating the inaccuracy of vertical coring using a "Russian" peat sampler, or an improved method for obtaining deep, saturated peat samples. Currently, the "Russian" type auger is the only practical option for obtaining samples from deep, waterlogged peat and is considered standard. The pit sampling approach used by Hooijer et al. (2012) is more similar to standard BD measurements for mineral soils, and involves digging a soil pit and horizontally sampling peat with sharpened steel cylinders at different depth intervals. This approach may be desirable for sampling surface layers of drained, consolidated peat where the water table has been artificially lowered, however it is important to bear in mind that these measurements are limited to the practical depth at which an intact soil pit can be dug, and water pumped out if it is below the water table. The pit method may not be logistically possible (certainly not practical), when attempting to sample peat several meters below the water table, which is usually less than 30cm deep in un-drained peat swamp forest. In addition, the pit method requires a significant amount of heavy equipment (large pump, generator, hoses, and gasoline) which cannot be easily deployed in remote forested areas. For sampling deeper in the peat profile, the method could be very dangerous if the pump or hoses fail, or if the wall being sampled collapses, which is highly likely given its waterlogged, unconsolidated condition. In fact, we are unaware of any study that demonstrates the pit method can be used in intact peat swamp forest (Hooijer et al. 2012 do not present bulk density data for un-drained, forested sites). For these reasons, the pit method cannot be recommended in place of vertical coring for bulk density measurements in un-drained sites, although it may be an appropriate method for sampling deeply drained sites when comparisons with un-drained sites are not necessary.

We appreciate the valuable comments and understand concerns expressed by the reviewer. These concerns will be considered in the revised manuscript, and the limitations of our dataset will receive more attention. However, we feel that the data and

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methods used in our study do not preclude the research objective, which is to establish a useful equation to estimate carbon density from bulk density for tropical ombrotrophic peatlands.

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