

Carbon Storage of Caimpugan Peatland in Agusan Marsh, Philippines and its Role in Greenhouse Gas Mitigation

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ABSTRACT

Globally, peatlands have a high potential in mitigating climate change, but no study has been done on this in the Philippines. This study estimated the amount of stored carbon (C) in the Caimpugan peatland, Agusan Marsh. In Tall Pole Forest, Intermediate Forest, and the Pygmy Forests in two locations in the peatland, the aboveground C stocks were measured in standing trees, understorey, herbaceous vegetation, and litter. In addition, belowground C stocks were also measured in peat soils at different horizons. Non-destructive sampling was done for trees > 5 cm dbh using allometric equations. Total soil organic C was determined using Flash Elemental Analyzer 1112 Series Carbon Analyzer. A two-way ANOVA was used to compare estimated stored C among selected vegetation types with location as the replication. The estimated aboveground C stock of Caimpugan peatland was 22.9 M t of C within its 5, 487 ha of area with an estimated 3,000-6,000 t of C on a per hectare basis. The estimated mean belowground C stock (4,659 t C ha⁻¹) was much higher than the mean aboveground C stock (53 tC ha⁻¹). With the substantial amount of stored C in Caimpugan peatland, its protection is fundamental to enhance its role in mitigating CO₂ emissions.

Key words: peatland, C sink, greenhouse gas (GHG) mitigation

INTRODUCTION

Peatlands all over the world cover only three percent or some 4 M km² of the Earth's land area (Parish *et al.* 2008). However, these ecosystems store a large fraction of the world's terrestrial carbon resources up to 2,000 Giga tons of CO₂ (Verwer *et al.* 2008), equivalent to 30% of terrestrial carbon, 75% of all carbon in the atmosphere, 90% of all carbon stored in global plant biomass and twice the carbon stored in forests (Parish *et al.* 2008). Meanwhile, C storage in Southeast Asian peatlands is estimated to be at least 42,000 M MT assuming a carbon content of 60 kg m⁻³ (Hooijer *et al.* 2010 as cited by Davies during the Peatland Assessment Training Workshop, 2010).

Peatlands constitute the top long-term carbon stock in the terrestrial biosphere due to its waterlogged and acidic condition. This ultimately slows down the process of decomposition over production resulting to net accumulation of peat. This long term ability of peatlands to absorb CO₂ from the atmosphere means that they play a major role in moderating atmospheric CO₂ concentrations. Tropical peatlands, in comparison to boreal and temperate peatlands, make a significant contribution to terrestrial carbon storage because of their relatively faster peat and carbon accumulation rates resulting to considerable thickness and higher carbon content (Immirzi and Maltby 1992).

However, at both regional and local levels, peatlands have been subjected to degradation which puts into compromise its regulatory ecosystem function as a C sink. In the Philippines, Caimpugan peat area in Agusan Marsh is relatively intact but is recently under threat of clearance,

conversion to agricultural land and ecotourism developments. Considering the potential anthropogenic disturbances that the Caimpugan area faces, it is vulnerable to become a net carbon source. The study estimated the C storage of Caimpugan peatland. Specifically, it determined the aboveground C storage of the peatdome in the following pools: trees, understorey herbaceous vegetation litter and soil.

MATERIALS AND METHODS

The sampling for the study to estimate the C storage of the Caimpugan peatland was done in the peat forest from May 24-28, 2010. The period of sampling was during the dry months of the Caimpugan peatdome for the purpose of accessibility and safety. The assumptions and methods employed for the analysis are conservative, or err on the side of conservativeness in the face of statistical or lack of regional-specific data.

Stratification of the Study Area

The Caimpugan peatdome had three vegetation zones/phasic communities namely: the tall pole forest (TPF); the intermediate forest/transition zone (IF); and the pygmy forest (PF) based on the previous works of IFAD-GEF (2006) in their descriptions of the phasic communities/vegetation types within the peatland. Stratification was based on the vegetation types since these three zones characterize the whole peatland. The goal was to attain estimates for each vegetation zone in order to come up with an estimate for the whole peatland. It was observed during the site visit that the

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three vegetation types were very distinct from each other.

Identification of C Pools to Measure

The selection of C pools was in accordance to the salient features of the area. For aboveground C, standing trees, understorey herbaceous vegetation and litter were measured while the peat soil at different horizons represented belowground C.

Type, Number and Location of Sampling Plots

Nested rectangular plots were used in this study after a preliminary survey identified that the area consists of tree stands with a wide range of tree diameters and stem densities. Nested plots are composed of three full plots (large, medium, small) whereby each is viewed as separate. Each plot size was appropriated for measuring different ranges of tree dbh. The largest and the outermost plot (50 x 20 m), was for the measurement of trees with dbh >50cm. The medium sized plot within the large plot, (35 x 17 m), is for the measurement of trees with 20-50 cm dbh while the small plot within the medium plot (10 x 5 m) was for trees with 5-20 cm dbh range (**Figure 1**). All measurements of the large, intermediate, and the small sampling plots were based on the recommended sampling plot measurements from the Sourcebook for Land-Use Change and Forestry Projects of BioCF and Winrock International (Pearson, Walker and Brown 2005).

The positioning and location of 1x1 m frame in **Figure 1** is hypothetical since their actual positions were dependent

on the conditions in the field. Three nested plots were established in every vegetation zone to serve as replicates in increasing reliability of results. Three nested plots were established per vegetation type in each of the two opposite areas where the three vegetation zones, at its typical phasic order, were encountered; for a total of 18 nested plots. This was based on the premise that typical peatdomes exhibit similar pattern of phasic communities across opposite directions from the peat periphery inward to the pygmy forest. It has to be noted that soils in the peatland were under severe waterlogged condition even during the dry summer months and this has been a primary limitation in determining the locations of the sampling plots. In this case, the estimates derived from the field were considered case study estimates and that an inference to the whole of Caimpugan peatland cannot be made. The relative positions of the plots within Caimpugan peatland is illustrated in **Figure 2**.

Aboveground C Pools

Standing trees. For tree biomass, the study used non-destructive sampling for trees with dbh ranging from 5 cm onwards. In all the plots established, species name, dbh, and total height were obtained. Brown's (1997) general biomass equation was used for wet (>4,000 mm rainfall, the average annual rainfall in the area is 4,600 mm) tropical forests with maximum dbh of 112 cm (which is observed to be the case in Caimpugan peatland), since local species-or-site-specific biomass equations were absent. Biomass equation formula was: $\text{Biomass} = 21.297 - 67.953 \times \text{dbh} + 0.740 \times \text{dbh}^2$. The individual tree biomass values computed using the biomass

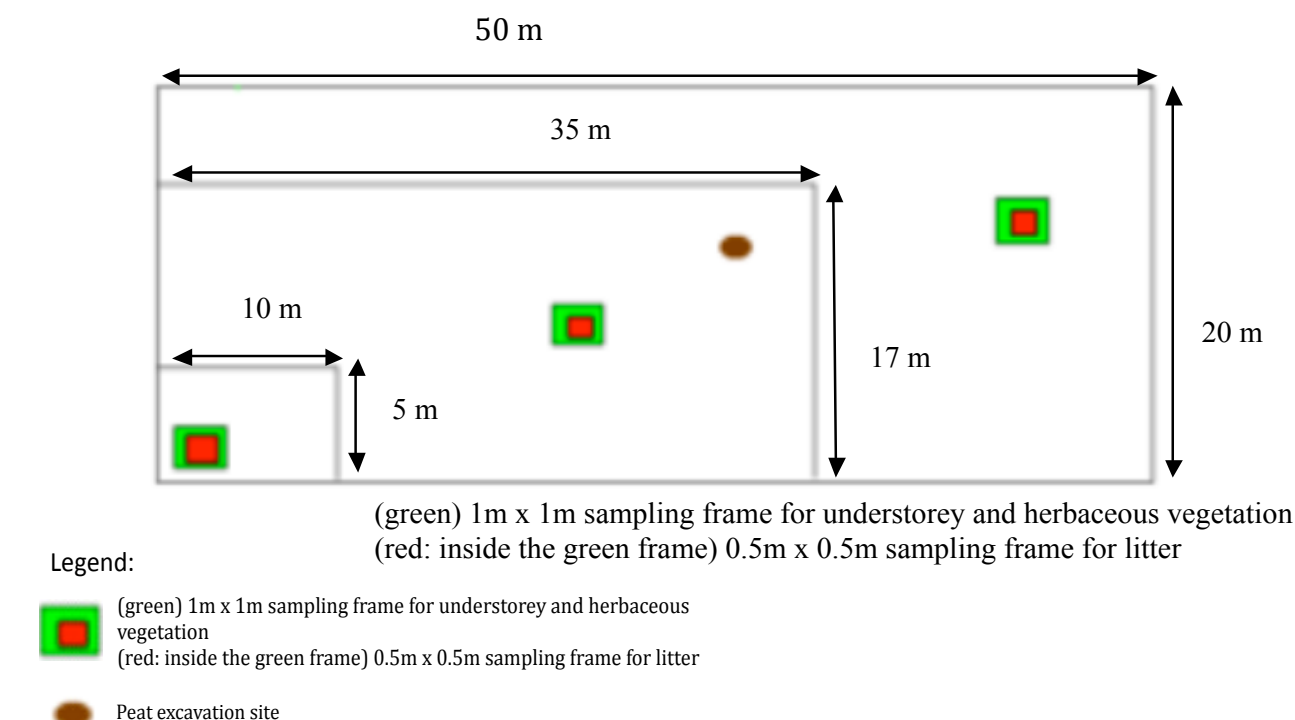


Figure 1. Measurements of the nested rectangular plots and dimensions of its individual plots for trees at varying dbh, understorey herbaceous vegetation, litter and soil.

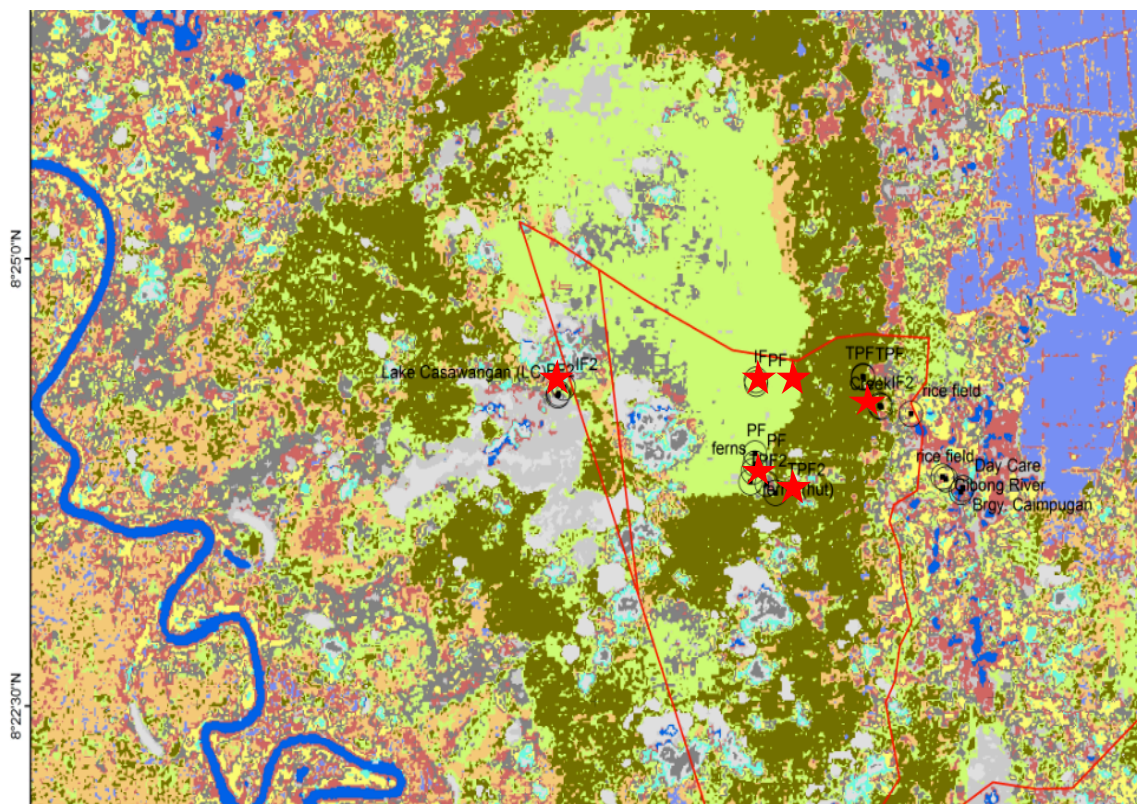


Figure 2. Relative positions (★) of nested plots across the transect line in Caimpugan peatdome.

regression equations were summed to give the total tree biomass stock in the sampled area. The total tree biomass was multiplied with the average C content of wood (default value of 45%) in calculating for its equivalent C stock.

Understorey and herbaceous vegetation. A one square sampling frame (1 m x 1 m) was laid out inside each of the large, intermediate, and small plots in accessible areas. All herbaceous and woody vegetation with less than 5 cm dbh inside the frame were collected. Fresh weight of each samples were determined before subjecting them to oven-drying. All herbs and woody plants found inside the quadrant, with diameters less than 5 cm were clipped using pruning shears. The total fresh weights were immediately determined using a portable weighing scale. Subsamples of about 300g were placed in labeled plastic bags and were then transported to the laboratory. The subsamples were oven-dried at 80°C until constant weight was achieved.

Litter. Coarse or standing litter is defined as any tree necromass with less than 5 cm diameter and/or 50 cm length, with undecomposed plant materials, as well as unburned leaves and branches. Inside the sampling frames used for measuring understorey and herbaceous vegetation, a square frame (0.5 m x 0.5 m) was established for the litter collection. The total fresh weight of all samples was taken, after which about 300 g were subsampled for air and oven drying. Samples were oven-dried at a temperature of 80°C for 72 hours or until weights of the samples became constant.

Data and analyses at the plot level for standing trees, herbaceous vegetation and litter, were extrapolated to the area of a full hectare after carbon stocks estimates were made. Extrapolation was done by calculating the proportion of a hectare (10,000 m²) occupied by a given plot using expansion factors (Pearson, Walker and Brown 2005). The expansion factor was calculated as the area of a hectare in square meters divided by the area of the sample in square meters.

A total of six peat profiles were examined which represented the three vegetation zones at two different sampled locations. All the peat profiles examined accounted for the change in peat depth as profiles approach the pygmy forest. The highly waterlogged condition limited the examination of deeper horizons of the peat profiles. Peat layers were identified with respect to its different levels of decomposition. Samples were taken from each horizon and were subjected to Total Organic Carbon (TOC) tests using Flash Elemental Analyzer 1112 Series Carbon Analyzer in the Analytical Service Laboratory of the International Rice Research Institute (IRRI).

Belowground Pools

C Estimates of Peat Soils at Different Horizons. Total Organic Carbon (TOC) contents per observed horizon of all the six profiles were taken from the laboratory. During the field sampling, the differentiating factor for each horizon was its observed degree of decomposition in accordance to Von Post Scale of Humification.

Table 1. Depths (in cm) at which three replicates of peat samples were collected from each observed horizon in the profiles examined.

Horizon	TPF (1)	TPF (2)	IF (1)	IF (2)	PF (1)	PF (2)
1	1-9	1-14	1-9	1-15	1-4	1-14
2	9-15	14-30	9-20	15-30	4-13	14-35
3	15-235	30-270	20-350	30-340	13-560	35-400

All three levels of decomposition were observed in all the organic soil profiles within the peatland namely: fibric (early stage of decomposition); hemic (moderate/intermediate decomposition); and sapric (most advanced stage of decomposition). Hi, He, and Ha stand for Fibric, Hemic and Sapric, respectively, recognizing the degree of organic material decomposition based on the Soil Taxonomy of U. S. Department of Agriculture (*Soil Taxonomy 1999*). Wet bulk density values of fibric (<0.1 , hence the use of 0.09 g m^{-3}), hemic ($0.07\text{-}0.18$, hence the use of 0.18 g m^{-3}) and sapric (>0.2 , hence the use of 0.25 g m^{-3}) soil materials based on FAO soil taxonomy data were used for the extrapolation of TOC values into C estimates in a ton/ha basis. The amount of carbon per unit area is given by: $C (\text{t ha}^{-1}) = [(\text{soil bulk density } (\text{g m}^{-3}) \times \text{soil depth } (\text{cm}) \times \text{C content})] \times 100$.

Data Analysis. The study employed a two factor factorial in complete randomized experimental design where vegetation and location were the two factors considered. The mean aboveground C contents were compared among the combinations of these two factors. Duncan's Multiple Range Test was used to locate which means are different from each other and by how much.

Null Hypotheses:

1. There is no significant difference in C storage for standing trees between the three vegetation zones in the two sampled locations.
2. There is no significant difference in C storage for understorey vegetation between the three vegetation zones in the two sampled locations.
3. There is no significant difference in C storage for litter between the three vegetation zones in the two sampled locations.
4. C stocks in the peat soil of Caimpugan peatland does not significantly differ from the aboveground C stocks.

Two-way ANOVA test was employed to determine the mean C stocks of aboveground pools. Factor(s) which were known to cause significant difference between means based on test statistic values (F-computed) were then subjected to pairwise comparison through Duncan Multiple Range Test. C estimates for standing trees for each vegetation were obtained by calculating for its weighted means since the individual sampling plots measure different ranges of dbh. The area of each plot was divided by the total area of the three plots with the nested plot multiplied by the mean C

stock of each individual sampling plot. The sum of the three values for each individual plot is the weighted mean C stock for the vegetation zone. Meanwhile, descriptive analysis was used to come up with statistics that would describe the C content of each soil profile within the three vegetation zones sampled at two different areas.

RESULTS AND DISCUSSION

Aboveground Pools

Standing trees. Vegetation type was a highly significant factor in the difference of C estimates for standing trees as test statistic values (F computed). Among the three vegetation zones, the tall pole forest (TPF) had the highest mean C stocks of 87.01 t ha^{-1} for standing trees followed by the intermediate forest (IF) with 14.42 t ha^{-1} , and the pygmy forest (PF) with 1.18 t ha^{-1} (**Figure 3**). Pairwise comparison through Duncan Multiple Range Test (DMRT) showed that the TPF had significantly higher means from the large and the intermediate plots, thereby means from the IF and PF do not significantly differ in the said sampling plots. Meanwhile, means from the IF, which were highest in the small plots, were not significantly higher than the TPF. This means that the means from the small plots in the PF was significantly lower than the other two. Significant difference is observed in the means of C stocks for standing trees across the three vegetation zones. This was because the average size and height of trees in each vegetation zone was distinctly different, hence the names tall pole, intermediate and pygmy forests.

Understorey herbaceous vegetation. Location was a significant factor in the difference of C estimates for understorey and herbaceous vegetation across all the individual plots while vegetation type is the significant factor for the small plots. Test statistic values (F computed) for the location factor showed to be highly significant. Mean C stock in the understorey herbaceous vegetation was $0.66\text{-}2.33 \text{ t ha}^{-1}$ (**Figure 4**) which indicate that the means of C stocks across the three vegetation zones in the first location sampled did not significantly differ, however, the means of the two locations sampled, with the same kind of vegetation, was significantly different.

Mean understorey C estimate for location 1 (2.33 t ha^{-1}) was significantly higher than the mean estimate for location 2

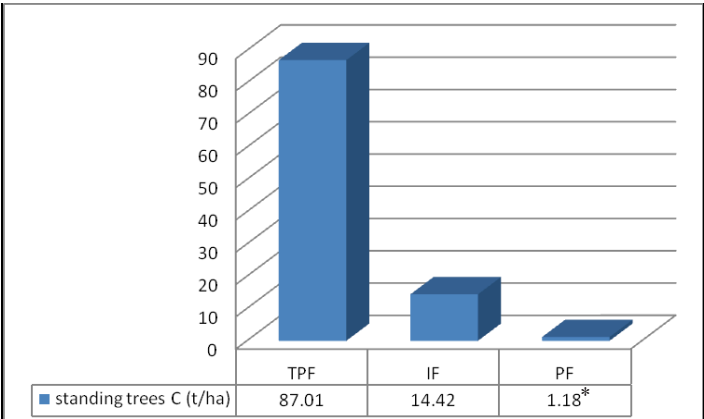


Figure 3. Mean C stocks of standing trees across the three vegetation zones in Caimpugan peatland.

*emphasizes the extremely low estimates for the PF case study plots due to the non-inclusion of standing vegetation with dbh <5cm within the 10 x 5 m plots for standing trees.

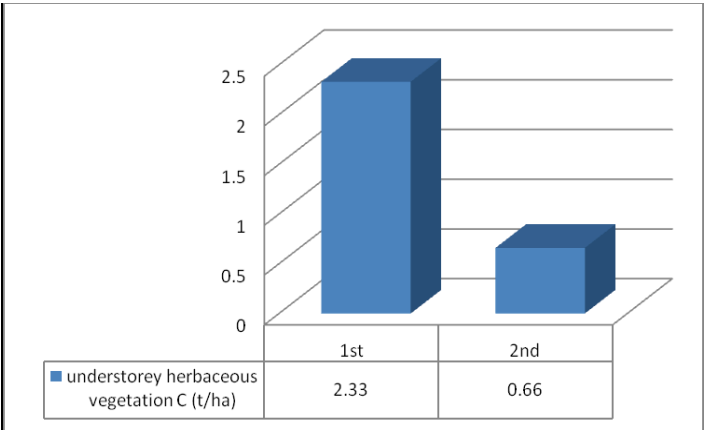


Figure 4. Mean C stocks of understorey herbaceous vegetation in the two locations sampled.

(0.66 t ha⁻¹). However, vegetation and its interaction with the location were considered factors of the observed difference in the C estimates of the sampled understorey herbaceous vegetation in the small plots. It was observed during field sampling, that the abundance of understorey herbaceous vegetation across the three different vegetation zones in one location was similar. The second location sampled was observed to have been cleared and was at the stage of recuperation which could explain its lower understorey and herbaceous biomass. Pairwise comparison through Duncan Multiple Range Test (DMRT) was employed to verify the observations in the small plots. With vegetation as a factor, the 1st PF has the highest mean and is significantly different from all other vegetation types sampled within the two locations. Furthermore, in terms of interaction of the area and vegetation, the 1st TPF and the 2nd IF showed significant interactions.

Litter. The interaction between the vegetation type and the location was a significant factor in the C estimates for litter in all the individual plots, with test statistic values (F-computed) depicting a significant difference in small plots and a highly significant difference in the large and medium

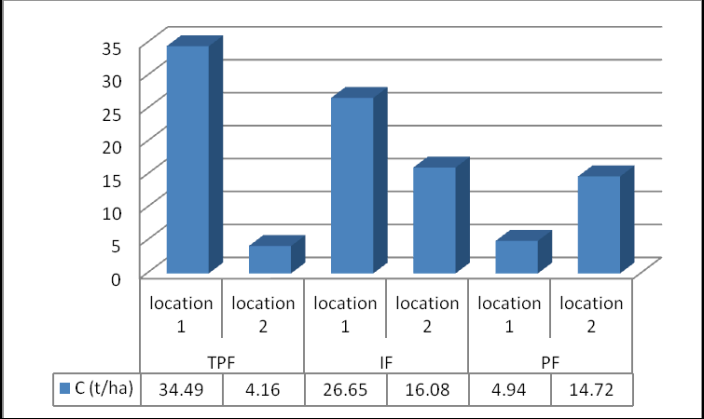


Figure 5. Mean C stocks of litter in the three vegetation zones at two locations.

plots. Mean C stocks in litter was 4.16-34.49 t ha⁻¹ (**Figure 5**). Pairwise comparison through Duncan Multiple Range Test (DMRT) was used to verify which area and vegetation have significant interactions. There is significant interaction in the large plots of both IFs from the two different locations as well as in the 2nd PF. Moreover, location and vegetation had significant interactions in the medium and in the small plots with for the 2nd IF and 2nd PF. Since the mean C estimates for litter was highly influenced by the interaction of the vegetation and location, the means for each vegetation across locations was used for calculating the total aboveground C stock. With this, TPF in locations 1 and 2 have mean C stocks of 34.49 t ha⁻¹ and 16.08 t ha⁻¹, respectively. Meanwhile, the IF in locations 1 and 2 had mean C stocks of 26.65 t ha⁻¹ and 4.16 t ha⁻¹, respectively and the PF in locations 1 and 2 had mean C stocks of 4.94 t ha⁻¹ and 14.72 t ha⁻¹, respectively.

Total Aboveground C Stock. With the assumption that the sampled areas within the peatland have similar characteristics with those not sampled, the sum of all the means for each aboveground C pool measured from each plot, was used as an estimate for the total aboveground C stock in the Caimpugan peatdome. Shown below is the formula:

$$\text{Aboveground C stock (t ha}^{-1}\text{)} = \text{tree C stock (t ha}^{-1}\text{)} + \text{understorey herbaceous C stock (t ha}^{-1}\text{)} + \text{litter C stock (t ha}^{-1}\text{)}$$

TPF had the highest total aboveground C stock (91.83-123.83 t ha⁻¹), followed by the IF (31.16-43.4 t ha⁻¹) and lastly, the PF (8.34-16.56 t ha⁻¹) (**Table 2**). The mean total aboveground C is 52.53 t ha⁻¹. C storage estimated for the aboveground C stocks in the Caimpugan peatland are however, lower than the average 150-250 t ha⁻¹ estimates of *Rieley (2008)* for tropical peatlands.

The difference in C storage of each aboveground C pool in the three vegetation types sampled at two locations was illustrated in **Figure 6**. Standing trees had the highest C storage in the TPF (87.01 t ha⁻¹), while litter has the highest C storage for both IF (16.08-26.65 t ha⁻¹) and PF (14.72-

Table 2. Total aboveground C stocks.

Mean C Stocks of Aboveground Pools (t ha ⁻¹)				
Vegetation	Standing Trees f (V)	Herbaceous Veg f (L)	Litter f (V*L)	Total aboveground C stocks
Tall Pole Forest	87.01	0.66(L2)-2.33(L1)	4.16(L2)-34.49(L1)	91.83(L2)-123.83(L1)
Intermediate Forest	14.42	0.66(L2)-2.33(L1)	16.08(L2)-26.65(L1)	31.16(L2)-43.4(L1)
Pygmy Forest	1.18	0.66(L2)-2.33(L1)	14.72(L2)-4.94(L1)	8.45(L1)-16.56(L2)
Mean				52.53

f(V): function of vegetation; f(L): function of location; f(V*L):function of the interaction of vegetation and location

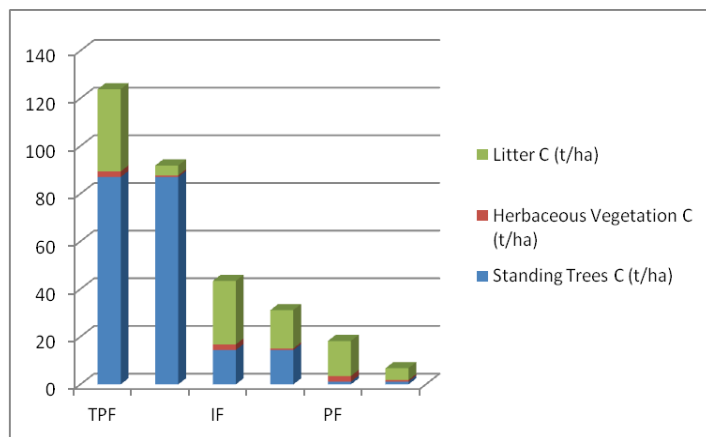


Figure 6. Estimated aboveground C stocks for the TPF, IF and PF in Cairmpugan peatdome.

4.94 t ha⁻¹). The very low C estimates for standing trees in the PF was due to the non-inclusion of standing trees within the 10 x 5 cm plots with less than 5 cm dbh. Litter had the highest C stocks in both IF and PF since both vegetation zones had relatively shorter trees as compared with the TPF. Litter in the TPF and IF was usually composed of fallen leaves, sedges, and other grasses. However, it was noted that litter in the PF was dominantly composed of remains from mosses which has formed mats on the peat surface. These aboveground estimates are lower than the ~150-250 t C ha⁻¹ estimates of *Rieley (2008)*.

It was crucial to identify which aboveground C pools were most substantial in each vegetation zones so that specific protection and preservation measures will be done to maintain its present C stock as well as ensure its ability to further store C. Aboveground C pools were more tangible than belowground C pools and this made it more vulnerable to anthropogenic disturbances.

Belowground C Pools

C estimates of peat soils at different horizons. The PF had the highest mean belowground C stock of 6,195.34 t ha⁻¹ followed by the IF with 4,632.97 t ha⁻¹ and TPF with 3,149.88 t ha⁻¹ (**Figure 7**). These sampled profiles across the three vegetation zones at two different locations, had different horizon expressions in terms of its specific degree of decomposition. However, all the three broad levels of decomposition were apparent in these sampled profiles. It

was further assumed that soil forming factors within each vegetation zone of the two areas within the peatland were similar. With this, the study utilized the means of C stocks from each level of decomposition which characterize peat horizons located within a particular vegetation zone. The mean bulk densities, depths, and C contents of horizons from a certain level of decomposition in a particular vegetation were determined to calculate the mean C stocks of each observed horizon. Means for each horizon were then summed to come up with the total C stock of the profile representing each vegetation zone. It was noticeable that the deeper the profiles, the higher were its C stocks. C storage estimated for the belowground C stocks within the sampled locations in the Cairmpugan peatland were within the average ~250 to >5,000 t ha⁻¹ estimates of *Rieley (2008)* for tropical peatlands.

Though the sampled PF of the Cairmpugan peatdome had the lowest aboveground C stock, it had the highest belowground C stock (**Figure 7**). This was due to its considerable peat depth of 400 cm and 560 cm in the two areas sampled. Estimated peat depths in the IF were 340 cm and 350 cm while depths in the TPF were 235 cm and 270 cm. It was also observed in the Hi, He, and Ha horizons that all the peat profiles are arranged in increasing depths. This means that most of the peat layers in the Cairmpugan peatdome were of sapric materials. The sapricity of the organic materials in the control sections of the profiles

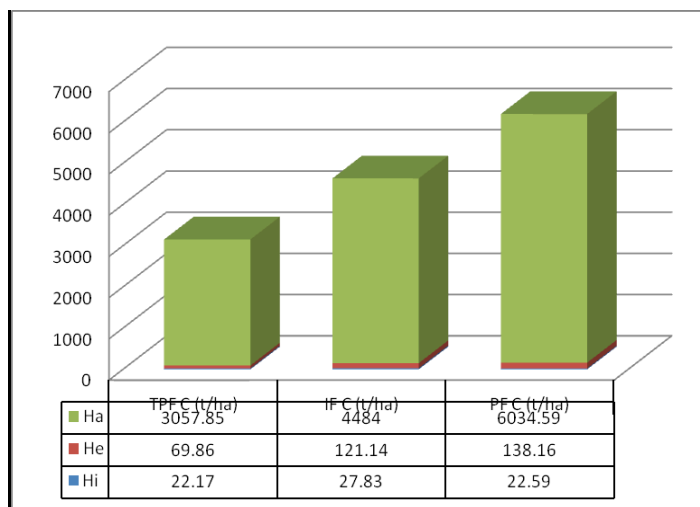


Figure 7. Mean C stocks at different peat horizons of the three vegetation zones.

signify that the peats examined were already in its advanced stages of decomposition implying periodic fluctuations in the watertable. Once organic soil materials are in contact with oxygen as watertable subsides, rate of decomposition was enhanced. This aerobic decomposition naturally releases C in the atmosphere. These soil materials have the highest bulk densities and water holding capacities (implication of a high water holding capacity for example to drainage). Peat accumulated at a rate of 1-3 mm year⁻¹ and decomposed at a rate of 2-5 mm year⁻¹ (*Peatland Assessment Training and Workshop 2010*). This means that the rate of destruction was approximately 10 times the rate of its formation. Its inherent sensitivity to drainage was a threat to this significant C pool.

Belowground vs. Aboveground C Pools. The C stocks in peat soil was higher than all the aboveground C stocks combined for all the three vegetation zones (**Figure 8**).

The stocks in peat soil was 25-34 times higher than the aboveground C in the TPF, with belowground C of 3,148.88 t ha⁻¹ as compared to its aboveground C of 91.83-123.83 t ha⁻¹ (**Table 3**). Moreover, C stocks in peat soil was 106-148 times higher than the aboveground C in the IF, with belowground C of 4,632.97 t ha⁻¹ as compared to its aboveground C of 31.16-43.4 t ha⁻¹. Peat soil C stocks in the PF (6,195.34 t ha⁻¹) was meanwhile 374-733 times higher than its aboveground C (8.45-16.56 t ha⁻¹) This means that peat soil stored the highest C content in all the C pools sampled for this study. It should be further understood that the peat had been storing C ever since the deposition of its organic materials which have accumulated through time. The mean total belowground C is 4, 659.06 t ha⁻¹ compared to the mean total aboveground C of 52.53 t ha⁻¹.

Total C Stocks per Vegetation Zone. The PF had the highest mean C stock (6,207.805 t ha⁻¹) followed by the IF (4,670.25 t ha⁻¹) and then the TPF (3,256.71 t ha⁻¹) (**Table 4**). Carbon storage estimates on a per ha basis for each vegetation zone

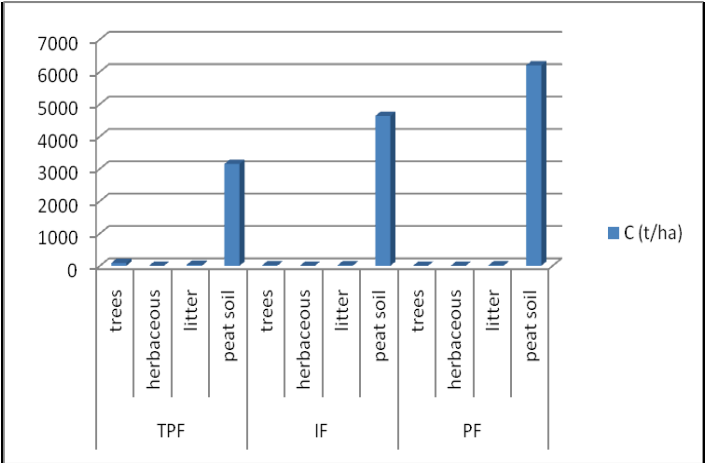


Figure 8. C stocks of aboveground and belowground C pools in the three vegetation zones of Caimpugan peatdome.

in the Caimpugan peatland, were higher than the estimates for other land use types in the Philippines, which was 113.7 t ha⁻¹ for protection forest (*Lasco and Pulhin 2000*), 111.1 t ha⁻¹ for second-growth forest (*Lasco and Pulhin 2000*), 55.6 t ha⁻¹ for tree plantations (*Lasco and Pulhin 2000*), 50.3 t ha⁻¹ for agroforestry (*Lasco and Pulhin 2000*), 35 t ha⁻¹ for brushlands (*Lasco and Pulhin 2000*) and 5 t ha⁻¹ for grasslands (*Lasco and Pulhin 2000*), all of which as cited by *Banaticla (2003)*.

This means that unlike other forest types, where aboveground C has the highest C stock among the pools, peatlands stored huge amount of C in the soil. Therefore, there is an urgent need to identify peat areas in the Philippines in order to protect the C which has already been stored by these ecosystems for a long time. Indonesia has already learned that conversion of peatlands to any other use requiring drainage, will not be profitable nor appropriate considering the long term effects of peatland conversion. Although the Caimpugan Peatdome is not yet largely threatened by land conversion, land clearance has already been prevalent along the periphery of the peatland where the TPF is situated. If such activities are left uncontrolled, the peat area will decline and may open the PF to easy access. This research would like to highlight that during the field sampling in the PF within the second location, evidences of patched forest fires, believed to be man-made, were seen.

Total C Storage of Caimpugan Peatland. Assuming that the sampled vegetation zones are of similar characteristics all throughout the entire peatland, C estimates for each vegetation type was multiplied by the area of these vegetation zones resulting to a total estimate of 22.86-22.99 M t/ Megatons. It should however be noted that only C estimates of the TPF and the PF were used since only these two

Table 3. Comparison of C stocks t C ha⁻¹ in both aboveground and belowground C pools.

Vegetation	Total Aboveground C t C ha ⁻¹	Total Belowground C t C ha ⁻¹	Difference
Tall Pole Forest	91.83-123.83	3,148.88	25.42-34.29
Intermediate Forest	31.16- 43.4	4,632.97	106.75-148.68
Pygmy Forest	8.45-16.56	6,195.34	374.11-733.17
Means	52.53	4,659.06	

Table 4. Total C stocks per vegetation zone in Caimpugan peatland.

Vegetation	Mean total C stocks (t ha ⁻¹)
Pygmy Forest	6,207.805
Intermediate Forest	4,670.25
Tall Pole Forest	3,256.71

distinct vegetation zones can be discerned in the satellite images. Quantum Geographic Information System (QGIS) calculations of both land cover types showed that the area for TPF is 3,771.33 ha while PF has 1,715.31 ha for a total land area of 5,486.64 ha (**Table 5**). Differential light reflectance of both readily perceived vegetation types in the satellite image was used as basis for these land area estimates. Among the limitations considered in the satellite image analysis were the presence of clouds and cloud shadows over the peatland. These areas were included in the area of TPF since it did not fall within the central portion of the peatland, which appears to be a distinct stunted forest.

For a ton per hectare basis, TPF and PF C storage estimates are within the range of estimates of *Rieley (2008)* for tropical peatlands. However, only the estimates for TPF were within the 2,200-3,500 t C ha⁻¹ estimates of *Page (2010)* for Southeast Asian peatlands. It should be noted that C estimates were exceedingly high in countries such as Indonesia and Malaysia due to its large confirmed peat areas. The Philippines was still at its initial stages of identifying peat areas but as far as field surveys by the Department of Environment and Natural Resources (DENR) as of 2011, the hectareage of confirmed peat is unprecedentedly increasing. The C storage of the Caimpugan peatland may not yet be highly significant in global scenarios for mitigating GHG emissions, but it stands as an important C storage for the Philippines. Case study estimates of this peatland area are remarkably higher than any other studied forest types in the country. The peatland was also considered an active site in storing C and if conditions for its perpetuation are maintained, can serve as an efficient long-term C sink.

Table 5. Estimation of total C storage of Caimpugan peatland.

Vegetation Zone	Area (in ha)	C Storage estimates (t ha ⁻¹)	Total C Storage estimates (tons)
TPF	3,771.33	3,256.71	12,282,128.12
PF	1,715.31	6,207.805	10,648,309.14
	5,486.64		22,930,437.26
*Total C storage estimates in million tons			22.9 Mt

Response to Hypothesis: General Findings

The study rejected the first null hypothesis since there was a significant difference in the C stock estimates for standing trees across the three vegetation zones. C stocks in standing trees were significantly higher than the two other vegetation zones. This is because only trees were distinctly different across the three vegetation zones. The bigger the biomass values of trees, the higher its C storage. Furthermore, the study rejected the second null hypothesis since there was a significant difference in the C stock estimates for undersorey and herbaceous vegetation between the two locations sampled. The first location had a higher C stock compared to the

second location. It was observed in the field that the herbaceous vegetation was characterized by the abundance of sedges and grasses. However, it was observed in the second location that there were relatively lesser sedges. The forest floor was relatively drier in the second location and this served as a limiting factor to the growth of abundant sedges. Ferns were also observed to thrive most in the second PF forest compared to the first PF. The possible implication of the existence of ferns in the second PF was its current state of early succession species. The said PF seemed to have been burned previously as evidenced by the burnt down wood in the forest floor. This study also rejected the third null hypothesis since there is a significant difference in C stock estimates for litter as a factor of the interaction between vegetation type and location. This can be explained by the fact that vegetation was influenced by edaphic factors in a particular location. The kind and amount of litter on the forest floor depends on the vegetation growing in the said area. Although this biotic and abiotic interaction is also true in standing trees and herbaceous vegetation, it was significantly observed in the litter. Differences in C stock estimates in other aboveground C pools such as herbaceous vegetation and litter were affected by other factors such as location and the interaction of both vegetation and location, respectively. Lastly, the study also rejected the fourth null hypothesis because the belowground C stock estimates for the peat soil was higher than all the combined aboveground C stocks. This can be understood in light of the difference of peat soils from mineral soils. Mineral soils store their C only in its organic matter fraction which was far lesser than the organic matter content of peat soils. The depth of peat profiles in the Caimpugan peatdome also implies large C deposits since it has been storing C ever since its formation, unless drainage episodes took place in the past that caused the release of stored C by way of organic matter oxidation.

CONCLUSION AND RECOMMENDATION

With the assumption that the three vegetation zones sampled in this study were similar in other portions of the peatland, the 5,487 ha Caimpugan peatland was estimated to store 22.9 M t of carbon. The Caimpugan peatdome was found to be a substantial and space efficient C store compared to other forest types in the country. The most important C pool in the system was the peat soil since its C storage estimates were exceptionally higher than any of the aboveground pools combined. Conservation priority concerns for the peatland should primarily be focused in maintaining the conditions necessary for peat soils to keep from being oxidated. Considering its role as a significant C sink, stringent measures must be done to protect and conserve these areas. Peat soils in the country should no longer be treated as miscellaneous or marginal lands among literatures in the country. Indeed, human activities around the Caimpugan peatdome must be monitored to keep the

ecological integrity of the peatland. Aside from the contribution of new knowledge, peat swamp forests will finally be included in the accounting of C storage in the Philippine forests through the C storage estimates derived from this study.

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