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Carbon sequestration potential of the secondary growth forest along the Abuan watershed at Ilagan, Isabela

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Abstract
The Abuan watershed had experienced deforestation due to illegal deforestation, poaching and land conversion. This has resulted to the loss of its ecosystem services. In the watershed area, restoration efforts showed encouraging results where secondary forest is flourishing. Secondary forest growth provides tremendous potential for large amounts of carbon sequestration.

This study aimed to determine the carbon sequestration potential of the secondary growth forest along Abuan watershed in Ilagan, Isabela. Specifically, it was conducted to identify the tree species present in the area and estimate the amount of carbon sequestered annually by the above ground carbon cover of the trees in the study area. Ten (10) sampling points measuring 20m x 20m were established using Point center quarter method (PCQM). Tree census was conducted and identification was done up to its species level. The amount of carbon sequestered by the trees was measured.

Twenty six (26) species was documented. The above ground carbon by the trees in the watershed is calculated at 18,452 kg. The species *Shorea concorta* (White lauan) has the highest amount of carbon sequestered while *Dipterocarpus validus* (Hagakhak) species sequestered the lowest. The age, height and DBH are directly proportional to the amount of carbon sequestration. Thus, the younger the tree, the higher the amount of carbon sequestered and the older the tree, the lower the amount of carbon sequestration. In addition, the taller and wider the tree, the higher carbon sequestration potential per year. It is recommended that below ground potential including the carbon-sink function of the soil be included in estimating the carbon sequestration potential of the secondary growth forest to understand fully this ecosystem function.

Keywords: Carbon sequestration, carbon sequestration potential, secondary growth forest

Introduction
Terrestrial ecosystem plays a key role in climate change as they may act both as a source or sink for carbon dioxide (Trexler and Haugen, 1994) [8]. Deforestation has resulted in about one third of the rise of CO2 in the atmosphere. Mature and particularly old forest contain large store of carbon that gets locked up in the live and dead wood for long period of time (IPCC, 2000) [2]. This carbon is released into atmosphere due to deforestation thereby acting as a source for carbon emission. On the other hand plant sequesters carbon during photosynthesis, which is the elemental base for carbon (C) accumulation, growth, and biomass production of plants. Photosynthetic responses to rising global mean temperature of terrestrial plants can potentially alter ecosystem C balance and cycling (Gunderson *et al*. 2010 [3]; Rustad *et al*. 2001) [6]. Forest not only sustains its own carbon but also has the potential to absorb carbon from the atmosphere. Reduction of photosynthesizing biomass through indiscriminate deforestation constitutes damage to the self-regulating mechanism that removes carbon dioxide from the atmosphere combustion. Global emissions of carbon have been increasing for about 140 years since the beginning of the Industrial Revolution. The sharpest increase is observed during the most recent 50 years, principally from accelerated use of fossil fuels. Concentration of carbon dioxide in the atmosphere has increased by about 25% from pre-industrial levels and will approach 360 ppm by end of year 2000 (Tomson and Jensel, 2002). It is estimated that future doubling of atmospheric co_2 concentration to about 700 ppm will risk an accompanying greenhouse rise of approximately 1.5-4.0ºC in mean global surface temperature.

Trees remove carbon dioxide from the atmosphere through the natural process of photosynthesis and store the carbon (C) in their leaves, branches, stems, bark and roots.

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They convert carbon dioxide into sugar, cellulose and other carbon containing compounds that they use for growth and development. Approximately half the dry weight of a tree's biomass is carbon. They are effective at capturing particulate pollution from the air and also help lower concentrations of other air pollutants. Trees help reduce excess runoff and water pollution by capturing and filtering storm water. Trees are unique in their ability to lock up large amounts of carbon in their wood, and continue to add carbon as they grow (Shin *et al*., 2007) [7].

According to De Witt (2004), trees in the forest, at an age of 10-30 years old, can sequester carbon at a maximum rate. At age 30 years, about 200 to 520 tons CO_2 are sequestered per hectare in forests with productivity ranging from low to high. After this age, if the trees are not harvested, the sequestration rate slows gradually until maturity at about 80 to 100+ years of age, and flattens out from then on as growth is balanced by decay.

Due of deforestation, the Abuan watershed has lost its ecosystem services, one of which is the sequestration of carbon. Recognizing the role of watersheds in maintain the integrity of the ecosystem, both the government and non-government agencies in partnership with the communities along the watershed area planted trees in an attempt to restore forest cover. Hence, the study was conducted to determine the above ground carbon sequestration potential of the secondary growth forest along the Abuan watershed in Ilagan, Isabela.

Materials and Methods
Description of the Study Area
The study area lies within the western buffer zone of the Northern Sierra Madre Natural Park (Fig 1). It is located at the Midwest of the province of Isabela (17°11'12"N, 122° 7' 12"E). The land area consists of an approximate 63, 754 hectares that supports the livelihoods of some 2900 farming households. The lower sub-catchments consist of farm lands, residual forests and brush lands with an area of 19,000 hectares (or 31%) of the watershed area.

The soil in most areas in the watershed is known as mountain soil. The rolling areas has loam soil while the hilly region are characterized sandy loam soils. The upper catchments are predominantly forest (89%) with more than 56,000 hectares. Agricultural crops (4.4 percent) are planted in the lower sub catchments of almost 3000 hectares. Such agricultural crops are mostly planted with maize. Kaingin or Swiden farming with a total area of 287.5 hectares are in patches within the watershed.

The watershed is named after the Abuan River, which, together with the smaller Bintacan River, drains into the Pinacanauan de Ilagan River, before merging with the Cagayan River.
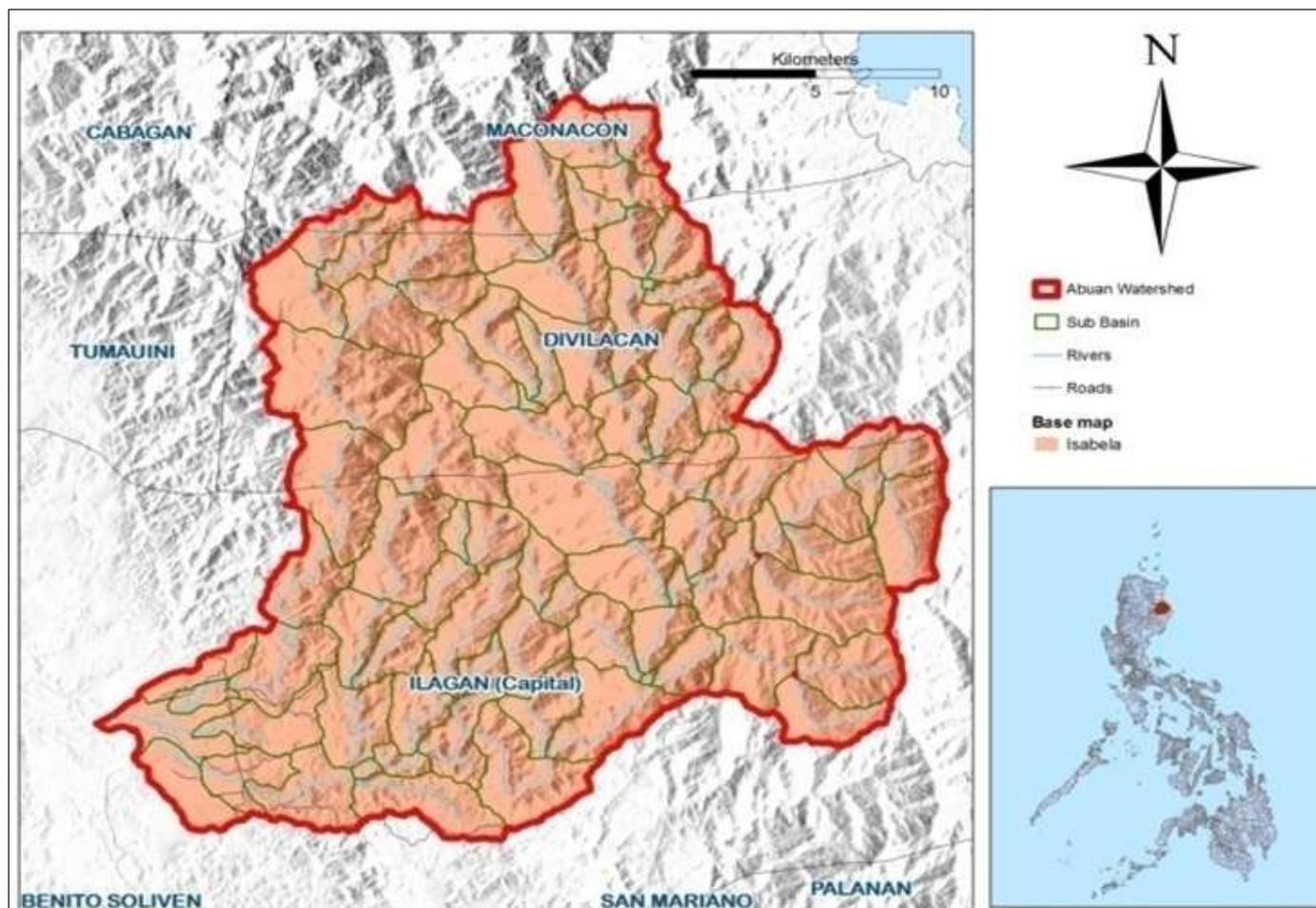

Fig 1: Map of the Abuan watershed.

Sampling Methods
The point center quarter method was used in establishing the sampling points for the study. The layout of a 20 x 20 m each plot is shown diagrammatically in Figure 2. Ten (10) plots were established in the study area. An arbitrary straight line through the S-N direction measuring 400 m was laid. Sampling points were established every 20 m with a 20 m interval between sampling points.
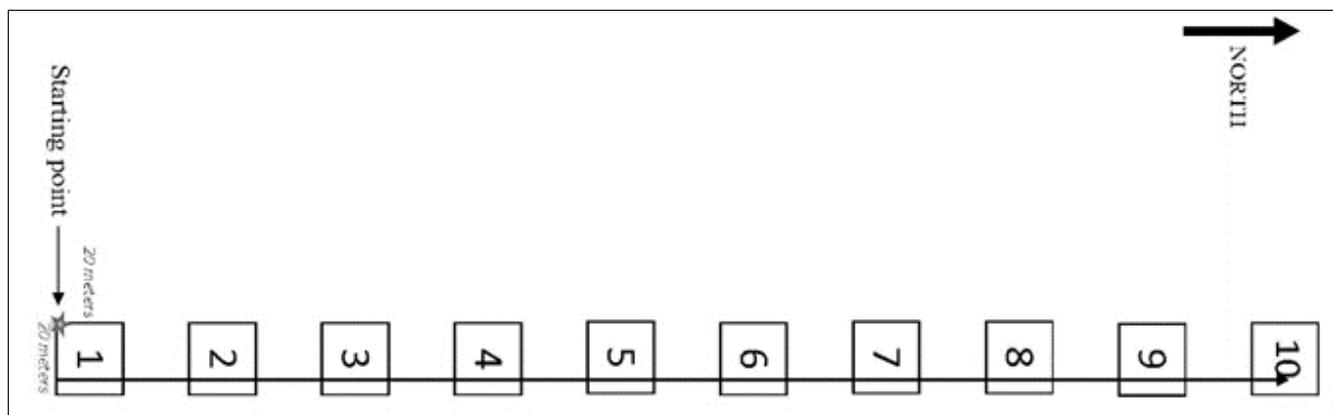
Fig 1: Layout of the study area in the Abuan watershed.

Tree Census and Tree Tagging

All free standing woody stems with a diameter at breast height (at 1.3m) of ≥ 5cm are included in the census. Saplings and vines were not included in the census. Tags made of aluminum are attached to all trees (and stems, for branching trees) that are included in the census. The label includes the quadrat number and the tree number. The tags are attached with a copper wire/nylon (for small stems), or nailed to the tree (for big stems). The diameter of the tree is measured at 1.3m from the ground, using the diameter tape. For big trees, an improvised caliper was used. Tree caliper was used for small diameter trees. The measurement is then recorded on the data sheet.

Species Identification

Trees were identified up to its species level. Identification is made based on dried voucher specimens collected from the field. Photo-documentation of trees used was also done and used to facilitate identification. Dichotomous key for identification was utilized. Literature and on-line resources were also used to validate identification.

Data Gathered

Calculation of the Amount of CO_2 Sequestered in a tree was calculated following Raison and Myers (1992) [5], and Attiwill et al. (1994) [1] as follows:

1. The total (green) weight (w) of the tree was determined as follows:
   for trees with DBH < 11; $W = 0.25D^2H$
   for trees with DBH> 11; $W = 0.15D^2H$

2. where: W is the Above-ground weight of the tree in pounds;
   DBH is the diameter at breast height;
   H is the height of the tree

3. The dry weight of the tree was derived using the following constants recommended by the University of Nebraska (2002):
   dry weight of the tree = weight of the tree x 72.5%

4. where: dry matter accounts to 72.5% while moisture of the trees is 27.5%

5. The weight of carbon in the tree. The average carbon content is generally 50% of the tree's total volume. Hence, weight of carbon in the tree was determined by multiplying the dry weight of the tree by 50%.

6. The weight of carbon dioxide sequestered in the tree was determined by multiplying the weight of carbon in the tree by 3.6663. The value of 3.6663 was obtained by computing for the molecular weight of CO_2. The atomic weight of Carbon is 12.001115. The atomic weight of Oxygen is 15.9994. The weight of CO_2 is C+2*O = 43.999915. The ratio of CO_2 to C is 43.999915/12.001115 =3.6663.

7. The weight of CO_2 sequestered in the tree per year was calculated by dividing the weight of carbon dioxide sequestered in the tree by the estimated age of the tree.

Results and Discussions

Tree Species Composition of the Abuan Watershed

There were 26 tree species documented. Of the 26 tree species, twenty five (25) species belonged to class Magnoliopsida. These species are *Pipturus argenteus* (Agandong) of family Vebenaceae, *Dipterocarpus grandiflorus* (Apitong) of family Dipterocarpaceae, *Homalanthus populneus,* (Balanti) of family Juglandaceae, *Fenilleae dulcis* (Dulawen) of family Anacardiceae, *Dipterocarpus validus* (Hagakhak) of family Dipterocarpaceae, *Laucaena leucocephala* (Ipil Ipil) of family Fabaceae, *Coffea Arabica* (Kape) of family Rubiaceae, *Wringtia pubescens* (Lanite) of family Apocynaceae, *Palaquim philippense* (Malak malak) of family Sapotaceae, *Dracontomelon edule* (Manaring) of family Anacardiaceae, *Ficus religiosa* (Maragawid) of family Moraceae, *Kleinhovia hospital* (Marakapas) of family Malvaceae, *Coffea africantes* (Marakape) of family Ribiaceae, *Shorea squamata* (Mayapis) of family Dipterocarpaceae, *Pterocarpus indicus* (Narra) of family Fabaceae, *Artocarpus camansi* (Pakak) of family Annonaceae, *Shorea negronensis* (Red Lauan) of family Dipterocarpaceae, *Macaranga tanarius* (Samak) of family Euphorbiaceae, *Sandoricum koetjape* (Santol) of family Meliaceae, *Shorea polysperma* (Tanguile) of family Dipterocarpaceae, *Ficus nota* (Tibig) of family Anacardicaea, *Schefflera actinophylla* (Umbrella Tree) of family Araliaceae, *Shorea concorta* (White Lauan) of family Dipterocarpaceae, *Antidesma bunius* (Wild Bignay) of family Phyllanthaceae, and *Nephelium lappaceum* (Wild Rambutan) of family Sapindaceae. One (1) species belonged to class Liliopsida; the *Saribus rotundifulius* (Anahaw) of order Arecales presented in Table 1.

Table 1: Trees Species Composition of the Forest Trees Community in Abuan Watershed.

Class	Order	Family	Species	Common Name
Magnoliopsida	Vebenales	Vebenaceae	*Pipturus argenteus*	Agandong
	Malvales	Dipterocarpaceae	*Dipterocarpus grandiflorus*	Apitong
	Malpighiales	Juglandaceae	*Homalanthus populneus*	Balanti
	Sapindales	Anacardiceae	*Fenilleae dulcis*	Dulawen
	Malvales	Dipterocarpaceae	*Dipterocarpus validus*	Hagakhak
	Fabales	Fabaceae	*Laucaena leucocephala*	Ipil-ipil
	Gentianales	Rubiaceae	*Coffea arabica*	Kape
	Gentianales	Apocynaceae	*Wringtia pubescens*	Lanite
	Ericales	Sapotaceae	*Palaquim philippense*	Malak-malak
	Sapindales	Anacardiaceae	*Dracontomelon edule*	Manaring
	Rosales	Moraceae	*Ficus religiosa*	Maragawid
	Malvales	Malvaceae	*Kleinhovia hospita*	Marakapas
	Gentianales	Ribiaceae	*Coffea africantes*	Marakape
	Malvales	Dipterocarpaceae	*Shorea squamata*	Mayapis
	Fabales	Fabaceae	*Pterocarpus indicus*	Narra
	Rosales	Annonaceae	*Artocarpus camansi*	Pakak
	Malvales	Dipterocarpaceae	*Shorea negronensis*	Red Lauan
	Malpighiales	Euphorbiaceae	*Macaranga tanarius*	Samak
	Sapindales	Meliaceae	*Sandoricum koetjape*	Santol
	Malvales	Dipterocarpaceae	*Shorea polysperma*	Tanguile
	Sapindales	Anacardiceae	*Ficus nota*	Tibig
	Apiales	Araliaceae	*Schefflera actinophylla*	Umbrella Tree
	Malvales	Dipterocarpaceae	*Shorea concorta*	White Lauan
	Malpighiales	Phyllanthaceae	*Antidesma bunius*	Wild Bignay
	Sapindales	Sapindaceae	*Nephelium lappaceum*	Wild Rambutan
Liliopsida	Arecales	Aracaceae	*Saribus rotundifulius*	Anahaw

Above-Ground Carbon Sequestration Potential of the Tree Species in Abuan Watershed

A total of 144,464 kg was computed as the total sequestered carbon and 18,452 kg sequestered carbon per year by all of the tree species in the ten (10) plots in Abuan Watershed (Table 2). Plot 5 got the highest carbon sequestered with a twenty 27,072 kg and the lowest sequestered carbon was found in plot 10 having 3,527 kg.

Table 2: Above – Ground Carbon sequestration potential of the tree species in Abuan watershed.

Plot	Total Weight (kg)	Dry Weight (kg)	Carbon Weight (kg)	Sequestered Carbon Dioxide (kg)	Sequestered Carbon Dioxide per Year (kg)
1	7015	5086	2543	9323	2603
2	12142	8803	4402	16138	2146
3	5418	3928	1964	7200	1457
4	4791	3474	1737	6368	1925
5	20369	14768	7384	27072	1847
6	15919	11541	5770	21156	1990
7	11535	8363	4182	15331	2137
8	16642	12066	6033	22118	1642
9	12213	8854	4427	16231	2272
10	2654	1924	962	3527	433
Total	108699	78807	39403	144464	18452

The Individual carbon sequestration of the tree species was shown in Table 4. It was found out that *Shorea concorta* (White Lauan) species sequestered the highest amount of carbon having 13,524 kg and *Dipterocarpus validus* (Hagakhak) species sequestered the lowest amount of carbon with 1,954 kg. Moreover, the carbon sequestration per year by the individual tree species can be affected by age of the trees. Species *Ficus nota* (Tibig) sequestered the highest amount of carbon per year with 963 kg and *Dipterocarpus grandiflorus* (Apitong) sequestered the lowest amount of carbon per year with 91 kg.

Result shows that age, height and DBH are directly proportional to the amount of carbon sequestration. Thus, the younger the tree, the higher the amount of carbom dequestered and the older the tree, the lower the amount of carbon sequestration. In addition, the taller and wider the tree, the higher carbon sequestration potential per year. Many studies has already been conducted to understand the carbon sequestration potential of forest trees. In the study of Juwarkar

et al. (2011) [4] in India, they have found out that *Tectona grandis* showed the highest tree diameter of 26cm and average height of 19.85m while the lowest tree diameter and height of 10.35cm and 8.25m was shown by *Ziziphus glaberrima*, respectively. The claimed further that the total above and belowground biomass of the trees in the natural forest of Tadoba Andhari Tiger Reserve were observed to be 178.09 Mg/ha and 46.30 Mg/ha respectively. They also found out that the the carbon stock accumulated in vegetation was found to be 112.19 MgC/ha.

Terakunpisut *et al.* (2016) also conducted a study on carbon sequestration potential in aboveground biomass of Thong Pha Phum National Forest, Thailand. They found out that carbon sequestration among varied different types of forests. Tropical rain forest had higher carbon stock than dry evergreen forest and mixed deciduous forest with 137.73 ± 48.07, 70.29 ± 7.38 and 48.14 ± 16.72 ton C/ha, respectively. The ≥ 4.5 - 20 cm trees potentially provided a greater carbon sequestration in tropical rain forest and dry evergreen forest while the size of

> 20 - 40 cm gave potentially high carbon sequestration in mixed deciduous forest. In conclusion, the greatest carbon sequestration potential is in mixed deciduous forest followed by tropical rain forest and dry evergreen forest in Thong Pha Phum National Forest. This evidence indicates the potential for growth to reach the climax stage of succession in the near future. These smaller trees do not have the highest carbon sequestration potential but they are relevant in terms of their future potential to grow up.

Table 4: List of tree species with the highest carbon sequestration in Abuan watershed.

Species	Age (yr)	Plant height (ft)	Diameter (in)	Sequestered carbon dioxide (kg)	Sequestered carbon dioxide per year (kg)
Laucaena leucocephala – Ipil Ipil	5	30	38	3927	785
Dracontomelon edule – Manaring	20	75	20	2714	316
Dipterocarpus grandiflorus – Apitong	23	65	19	2084	91
Dipterocarpus validus –Hagakhak	10	50	21	1954	195
Shorea concorta – White Lauan	35	120	35	13524	386
Shorea concorta – White Lauan	30	120	23	5617	187
Ficus nota – Tibig	7	36	46	6617	963
Shorea squamata – Mayapis	25	95	20	5957	238
Shorea concorta – White Lauan	10	90	23	4212	421
Dipterocarpus grandiflorus – Apitong	13	95	15	2011	154

Conclusion
There were 26 taxa documented consisting of 26 tree species; 25 species belonged to class Magnoliopsida and nne (1) species belonged to class Liliopsida. The most abundant tree species in the area was *Macaranga tanarius* (samak tree) with a total population of 68. This was followed by *Shorea concorta* (White Lauan) and *Dipterocarpus grandiflorus* (Apitong) and *Nephelium lappaceum* (Wild Rambutan) with a population of 46 and 16, respectively.

A total of 144,464 kg was computed as the total sequestered carbon and 18,452 kg sequestered carbon per year by all of the tree species in the ten (10) plots in Abuan Watershed. Plot 5 got the highest carbon sequestered with a twenty 27,072 kg and the lowest sequestered carbon was found in plot 10 having 3,527 kg. It was found out that *Shorea concorta* (White Lauan) species sequestered the highest amount of carbon having 13,524 kg and *Dipterocarpus validus* (Hagakhak) species sequestered the lowest amount of carbon with 1,954 kg. Moreover, the carbon sequestration per year by the individual tree species can be affected by age of the trees. Species *Ficus nota* (Tibig) sequestered the highest amount of carbon per year with 963 kg and *Dipterocarpus grandiflorus* (Apitong) sequestered the lowest amount of carbon per year with 91 kg.

Moreover, it can be deduced from the foregoing result of the study that the above-ground biomass of the secondary growth forest along the Abuan watershed has the potential to serve as a carbon sink due to its carbon sequestration activity. It can also be concluded that age, height and DBH are directly proportional to the amount of carbon sequestration. Thus, the younger the tree, the higher the amount of carbom dequestered and the older the tree, the lower the amount of carbon sequestration. In addition, the taller and wider the tree, the higher carbon sequestration potential per year.

The carbon sequestration potential of the above-ground biomass of the secondary forest along Abuan watershed. Hence it is recommended that below ground potential including the carbon-sink function of the soil be included in estimating the carbon sequestration potential of the secondary growth forest to understand fully this ecosystem function.

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