INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 22, No. 6, p. 101-108, 2023
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Carbon sequestration potential of Sago (*Metroxylon sagu* Rottb.) plantation in Aklan State University, Banga, Aklan, Philippines

Raffy L. Tano*, **Melba L. Raga-as, Roberto L. Saladar, Jane Iris I. Rola**

Forestry Department, College of Agriculture, Forestry and Environmental Sciences, Aklan State University, Banga, Aklan, Philippines

Article published on June 11, 2023

Key words: Soil organic carbon, Rosette, Aboveground and belowground, Soil sampling, Global climate change, Biophysical data

Abstract

Global climate change is a widespread and growing concern that has to extensive discussion and negotiations. Thus, this study was conducted to evaluate the carbon sequestration potential of sago plantation. In this study, the simple random sampling was carried out to collect the biophysical data of Sago. The samples were taken randomly of which each sample is given a chance of being selected. The site was measured by the use of meter tape. The area was sub-divided into six quadrats, and it was labeled from Q1 to Q6 of which, each sample quadrats has a dimension of 20m x 38m. Two growth stages of Sago such as rosette and flowering stages were surveyed through destructive sampling and the soil organic carbon was determined through soil sampling. The result showed stages, both the frond and leaves with 0.06kg/plant for rosette and truck/bole with 168.9kg/plant at flowering stage has the highest carbon content stored. Moreover, the total average carbon content at the rosette stage was 0.16kg or 35.68kg/ha. Furthermore, rosette stage has a carbon content of 0.04 t/ha and 23.29 t/ha for the flowering stage. The results showed that older the age of sago the more carbon being sequestered. Soil organic carbon showed that there were 11.6 t/ha stocked in the soil within the area. The total aboveground and belowground carbon is estimated to be 34.93 t/ha. Thus, Sago plantation contains a substantial amount of carbon and plantation endeavor is essential mitigation and adaption measure for climate change.

***Corresponding Author:** Raffy L. Tano ✉ rltano@asu.edu.ph

Introduction

Global climate change is a widespread and growing concern, prompting extensive debate and negotiation. This impact is directly related to climate change because CO_2 emissions have the potential to influence global climate temperature changes and subsequent changes in climate patterns (IPCC 2021). Responses to this concern have focused on reducing greenhouse gas emissions, particularly carbon dioxide, as well as measuring carbon absorbed and stored by forests, soils, and oceans.

Carbon sequestration is one option for slowing the rise of greenhouse gas concentrations in the atmosphere, and thus potential climate change. Furthermore, capturing carbon dioxide (CO_2) from the atmosphere or anthropogenic (human) CO_2 from large-scale stationary sources such as power plants before it is released into the atmosphere. Thus, by conserving existing carbon reservoirs, improving carbon storage in vegetation and soils, and substituting biomass for fossil fuels in energy production, land-use and forestry have the potential to significantly reduce the amount of carbon dioxide in the atmosphere (Pacala & Socolow, 2004). Forest and soil are potential sinks for increased CO_2 emissions and are on the list of acceptable offsets (Simegn *et al*., 2014). Basically, trees are particularly important in the terrestrial biosphere. trees absorb carbon dioxide from the atmosphere through photosynthesis and store it in their leaves, branches, stems, barks, and roots. Carbon accounts for roughly half of a tree's dry weight. Trees in forests, if well-stocked, typically sequester carbon at a maximum rate between the ages of 10 and 20-30 years; at 30 years, approximately 200 to 520 tones co2-e are sequestered per hectare in forest, with productivity ranging from low to high (Johnson and Coburn, 2010).

Aside from trees, palm species provide an excellent carbon sink with a density of 55 t/ha-1 accumulated over time (Pulhin *et al*., 2000). The Sago (*Metroxylon sagu* Rottb) palm is another excellent carbon-sequestering palm. In Malaysia and Indonesia, they promote the planting of sago palm to address and solve the problem of land use and land cover change, and this species emits the least CO_2 with 214.75kg CO_2 eq compared to oil palm and paddy, which emit 406.88kg CO_2 eq and 322.03kg CO_2 eq, respectively (Bintoro *et al*., 2018; Uda *et al*., 2020).

The sago palm flourishes in a moist environment and is therefore found along riverbanks, water holes, and swampy areas. It is an indigenous species of the Southeast Asia region, specifically Malaysia, Indonesia, Papua New Guinea, and the Philippines (Amin *et al*., 2019). Different regions have different accessions and names for sago (Dewi, 2015). Morphological characteristics such as shoot color, size, density, hardness, spine position, leaf rachis color, trunk diameter, height, and starch color can distinguish these accessions (Bintoro, 2008).

The sago palm plant grows to a medium height of 20 to 25 m, has 6 to 9 m long pinnate leaves, and a smooth trunk that measures 40cm in diameter. Furthermore, it has frequently been referred to as a "poor man's crop" (Flach & Schuiling, 1989). It provides numerous ecosystem services, including service provision and service regulation Sago starch and fronds have been used as raw materials for provisioning services (Toyoda, 2015), fiber as animal feed, and sago weevil as food (Chanta, 2017). Sago starch, in particular, has been used as a raw material in a variety of industries, including food, paper, adhesives, textiles, plywood and cosmeceutical, all of which generate revenue for the country of origin (and also has long been a staple food for humans, and nearly all other parts are used for subsistence. Sago is also a good source of lactic acid, which is used as a preservative in dyeing, adhesives and pharmaceutical (Hirao *et al*. 2018; Ohmi 2015).

The sago palm is becoming more popular as a food source in southern Vietnam, Thailand, and the Philippines (Novero, 2012). Furthermore, sago contributes to environmental protection by protecting swamps and dry lands, as well as preventing floods and forest fires. It contributes to the reduction of the greenhouse effect and global warming caused by the release of carbon dioxide into the atmosphere. The sago plant absorbs a large amount of CO2 in order to produce a large amount of starch (Singhal *et al.*, 2008). According to a local supply chain analysis study, the Philippines Lack an established sago industry (Abello, 2021). Despite enormous claims about its carbon sequestration capacity, no research has been conducted to determine the amount of carbon stored by Sago species, particularly in the Province of Aklan. As a result, this study was carried out to fill a data gap on Sago's carbon sequestration potential. Thus, the carbon sequestration potential of a Sago plantation was assessed in this study.

Material and methods

Study Site/Location and/or materials

The research was carried out at Aklan State University's Banga Campus in Aklan's Sago Research Area. The location faces North East and has coordinates of 11.63248°N and 122.33019°E, as well as an elevation of 45 meters. This study area is 230m long and 20m wide, with a total area of 4,600m2. The location was chosen due to the ease of transportation and the availability of sample plants. The Aklan State University manages this Sago plantation, which is frequently used for educational and scientific purposes.

Experimental Treatment and Lay-out

The biophysical data of Sago were collected using simple random sampling in this study. The samples were chosen at random, and each sample has a chance of being chosen. The site was measured with meter tape. The area was divided into six quadrats and labeled Q1 through Q6, with each sample quadrat measuring 20m x 38m. Three quadrats were chosen at random for the collection of sample data, with three Sago plants at the rosette and mature stages. Three representative soil samples were also taken from the quadrats.

Data Gathering

To determine the biomass density of Sago, the following measurements were taken:

Aboveground Fresh Biomass Determination

This includes the trunk, fronds, and its leaves.

Rosette stage

Three plants were collected from each of the quadrats selected. Using a Biltmore stick, the height was measured from the base of the trunk to the highest leaf tip. Using a bolo, the sample plants were harvested and cut into three parts (truck, fronds, and leaves). All of the fronds were removed from the trunk, and the leaves will be stripped away. To facilitate weighing, the trunk was cut into sections/small parts. The fresh weight of each cut trunk, leaf, and frond was recorded in a record book. A kilogram sample of each plant part was placed in a brown envelope and dried in the oven.

Mature stage

The inflorescence stage was chosen, and destructive sampling was performed. Similarly, to the rosette stage, the height was measured with a meter tape from the base of the trunk to the highest leaf tip. A tree caliper was used to measure the diameter of the trunk. The sample plants were divided into four sections (trunk, fronds, leaves, and flowers). The fronds were removed from the trunk, and the leaves were stripped away. Each trunk was also subdivided into small pieces for ease of weighing. The fresh weight of each cut trunk, leaf, and frond was recorded in a record book. A one-kilogram sample of each plant part will be placed in a labeled brown envelope for oven drying.

Dry Matter Yield

All the representative sample plant tissues that were collected both above and below ground were oven dried at 100°C three days or until constant weight was achieved.

Estimation of Number of Rosette and Mature Sago Growth Stage in a hectare at Natural Stand

The determination of the number of rosette and mature growth stage of Sago is done through conducting an inventory at three (3) sites namely ASU Banga Aklan. It is done by counting the present rosette and mature growth stage in every site.

Soil Collection

Pith with a dimension of 1m x 1m was marked from representative sample quadrats to be used n gathering soil samples. Soil samples were dug with the use of shovel. Soils that were collected from each pit was mixed thoroughly then air-dried for one week.

Carbon Content Determination

Rosette and Flowering Stage

For the sago palm parts (leaves, frond, trunk, flowers and roots) of the rosette and flowering stage, carbon stored was determined using the formula:

Carbon = Biomass values x 45%

Where: Biomass values – Total oven dried weight 45% - the average percent carbon contained in tree species (Pulhin *et al.,* 2000).

Source: 45% C of tree species – constant value – Lasco & Pulhin, 2000; Urquila, 2000.

Biomass values for the trunk, fronds, leaves, and roots were calculated using following formula:

Total oven dried weight (ODWt) = TWF- (TFW* (SFW – SODW)/SFW

Where: ODWt – total oven dry weight

TFW – total fresh weight

SFW – sample fresh

SODW – sample oven-dry weight

Soil Organic Carbon

One kilogram of the air dried representative soil sample was taken and properly labeled for analysis at the Regional Soils Laboratory in Iloilo City, Iloilo, Philippines.

To determine the soil organic carbon ton per hectare (t/ha) the following formula was being used:

Soil Organic Carbon t/ha =% Organic Carbon x Cut soil

Cut soil = Bulk density x Volume

$$\text{Bulk density} = \frac{\text{Cut soil}}{\text{Volume}}$$

Volume = Area x Depth

Result and discussion

Fresh biomass (kg/plant) of Metroxylon sagu

The presented results in Table 1 provide the average biomass values for different parts of *M. sagu* plants at two growth stages: rosette and flowering. In the rosette stage, the roots have an average biomass of 0.2kg, while the leaves and fronds exhibit biomass values of 0.36 and 1.18kg, respectively. The truck biomass is reported as 0.72kg. However, no biomass value is provided for the flower at this stage. The total biomass for the rosette stage is calculated as 2.46kg. In flowering stage, the leaves exhibit a significantly higher biomass of 18.4kg, followed by the fronds with a biomass of 91kg. The trunk is reported to have a much larger biomass of 826kg, indicating substantial growth and development during this stage. The flowers have a biomass value of 30.93kg. The total biomass for the flowering stage is calculated as 965.33kg.

Table 1. Average fresh biomass (kg/plant) of the different parts of Sago under different growth stage.

Growth Stage	Roots	Leaves	Frond	Trunk	Flowers	Total
Rosette	0.2	0.36	1.18	0.72	-	2.46
Flowering	-	18.4	91	825	30.93	965.33

Dry Matter Yield of Metroxylon sagu Rottb

Table 2 presents the dry matter yield of various parts of the *M. sagu* palm under different growth stages. The dry matter yield values are expressed in kilograms per plant. Indicating the amount of plant material obtained after removing moisture. In the rosette stage, the roots have a dry matter yield of 0.04kg per plant, while the leaves and fronds yield 0.13kg and 0.14kg, respectively. The trunk shows a dry matter yield of 0.08kg, but no value is provided for the flowers. The total dry matter yield for the rosette stage is calculated as 0.39kg per plant.

The flowering stage, the leaves exhibit a significantly higher yield of 11.35kg per plant, indicating substantial biomass production. The fronds show a yield of 52.38kg, indicating their contribution to the overall dry matter production. The trunk demonstrates a substantial increase in yield, reaching 375.04kg, highlighting its growth and development during this stage. The flowers have a yield value of 18.05kg. The total dry matter yield for the flowering stage is calculated as 456.80kg per plant.

Table 2. Dry matter yield (kg/plant) of different parts of sago under different growth stages.

Growth Stage	Roots	Leaves	Frond	Trunk	Flowers	Total
Rosette	0.04	0.13	0.14	0.08	-	0.39
Flowering	-	11.35	52.38	375.04	18.05	456.80

The results presented in Fig. 1 & 2 highlight the dry matter yield and moisture content of different parts of the M. sagu palm at the rosette and flowering stages. At the rosette stage, the fronds were found to contribute an average of 35.9% of the dry matter yield, followed by the leaves at 33.3%, the trunk at 20.5%, and the roots at 10.3%. On the other hand, at the flowering stage, the trunk/bole exhibited the highest dry matter yield at 82.1%, followed by the fronds at 11.5%, the flowers at 3.9%, and the leaves at only 2.5%.

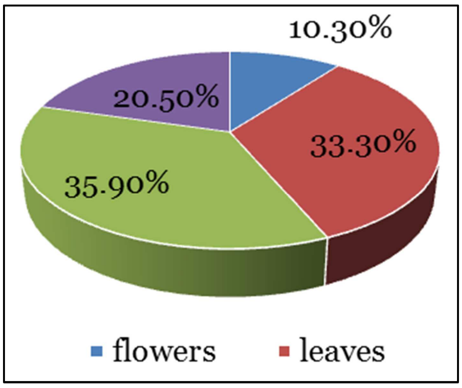

Fig. 1. Percentage of dry matter yield of different plant parts at rosette stage.

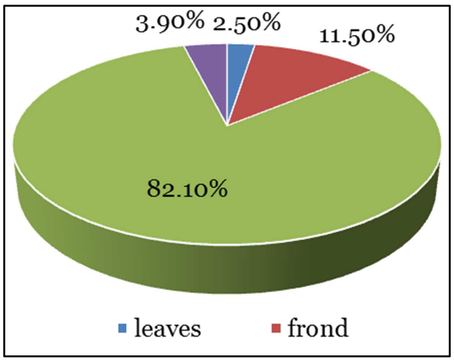

Fig. 2. Percentage of dry matter yield of different plant parts at flowering stage.

Carbon Content at Different Parts of M. sagu

The carbon content of various parts of the *M. sagu* palm at different growth stages, specifically the rosette stage and the flowering stage.

The study shows that the carbon content varies significantly depending on the growth stage and the specific plant part being analyzed. At the rosette stage, the average carbon content of the *M. sagu* palm is 0.26kg per plant.

Among the different plant parts, the leaves and fronds have the same carbon content of 0.06kg, followed by the trunk with 0.03kg, and the roots with the lowest carbon content of 0.01kg. In contrast, at the flowering stage, the *M. sagu* palm exhibits much higher carbon content. The average carbon content at this stage is 207.92kg per plant.

The trunk/bole has the highest carbon content of 168.90kg, followed by the frond with 23.75kg, flower with 8.11kg, and leaves with only 7.16kg. Analyzing the percentage of carbon in relation to dry matter yield, during the rosette stage, the carbon content ranges from 6.25% to 37.5% on average. Considering similar dry matter yields, both leaves and fronds display the same carbon content of 37.5% (0.06kg), followed by the trunk with 18.75%, and the roots with 6.25%. Regarding the flowering stage, the percentage of carbon varies from 3.44% to 81.23%. notably, the trunk exhibits the highest carbon percentage of 81.23% (168.9kg), followed by the frond with 11.42%, flowers with 3.91%, and leaves with only 3.44%.

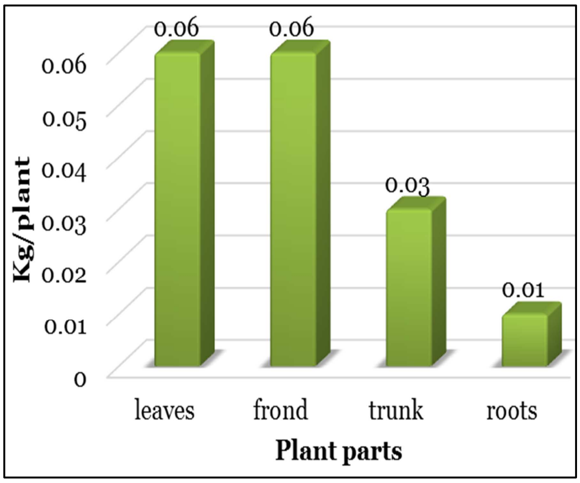

Fig. 3. Average Carbon content (kg/plant) of different plant parts at rosette stage.

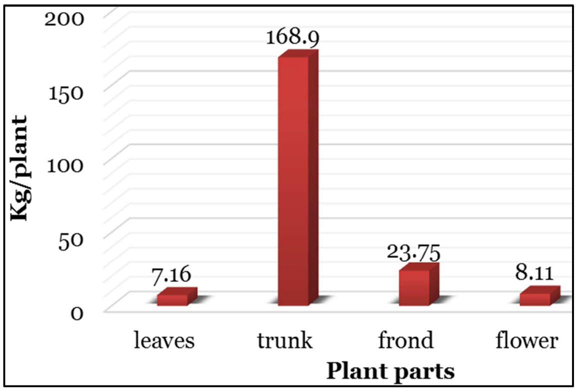

Fig. 4. Average carbon content (kg/plant) of different plant parts at flowering stage.

Soil Carbon Content

Based on the soil analysis data provided in Table 3, several observation can be made. The soil organic matter (SOM) content is measured at 1.0%, indicating a relatively low concentration of organic matter in the sample area. The pH value of 5.64 indicates a moderately acidic environment. Soil pH influences nutrient availability and microbial activity in the soil. The potassium (K) concentration is measured at 200 ppm, indicating a high concentration of potassium in the soil. The phosphorus (P) concentration is measured at 33 ppm, indicating a medium level of phosphorus in the soil. Additionally, the data mentions a soil organic content of 11.6 t/ha (tones per hectare), which is relatively low. This can be attributed to the low percentage of soil organic matter (1.0%) and carbon (0.0058%). Higher soil organic matter content generally correlates with improved soil fertility, water-holding capacity, and nutrient availability.

Table 3. Soil analysis data.

Soil Test Data			
pH	OM (%) SA Wildes	P (ppm) Olsen's Method	K (ppm) Cold H_2SO_4
5.64	1.0	33	200

Discussion

These findings are significant in terms of the distribution of dry matter across the *M. sagu* at various stages of development, the sagu palm. The absence of flower data during the rosette stage suggests that they are either absent or have a low dry matter yield. According to Yamamoto *et al.* (2016), flowers may be absent or have a low dry matter yield during the rosette stage of *M. sagu* Rottb. However, the available literature indicates that the dry matter yield of The *M. sagu* palm variety varies depending on factors such as age and trunk diameter. For example, Ehara *et al.* (2000) discovered a variety of morphological characteristics and estimated pith dry-matter yield at 13 to 34% and 55%, respectively. The variation in pith dry-matter yield is primarily attributed to trunk diameter and biomass production.

The findings also show a positive relationship between fresh biomass and dry matter yield. Higher fresh biomass corresponds to higher dry matter yield, indicating that the amount of dry matter produced increases as the plant grows and accumulates more biomass. This relationship can be seen in both the rosette and flowering stages, where the parts with the freshest biomass also have the most dry matter yield.

In terms of moisture content, the fronds have the highest percentage, accounting for 31.32% of the plant's fresh biomass during the rosette stage. This indicates that the fronds retain a substantial amount of moisture in relation to their weight. During the flowering stage, the trunk/bole part has the highest moisture content percentage (36.19%), indicating that it has a greater capacity to retain moisture than other plant parts.

Soil organic matter (SOM) is also important for soil fertility and nutrient cycling. The study emphasizes the significance of SOM and its influence on soil health and nutrient availability. Soil organic carbon (SOC) functions as a reflector.

Conclusion

Based on the findings of the study, it is evident that Sago (*Metroxylon sagu* Rottb.) can contribute significantly to carbon sequestration, thereby potentially playing an important role in mitigating climate change. The study indicates that *M. sagu* palm have the capacity to sequester substantial amounts of carbon in both aboveground biomass and soil organic carbon.

The study reports that at the rosette stage, *M. sagu* palm can sequester approximately 0.04 t/ha (tones per hectare) of carbon through aboveground biomass. However, at the flowering stage, the carbon sequestration potential increase significantly to approximately 23.29 t/ha, resulting in a total carbon content of 23.33 t/ha, including soil organic carbon.

Furthermore, the study highlights a specific case in Aklan, where a *M. sagu* plantation with a mass of 410.37 t/ha has the potential to sequester a substantial amount of carbon. This suggests that large-scale cultivation of *M. sagu* palm in the region can significantly contribute to carbon sequestration efforts.

Recommendations

Based in these findings, it can be recommended that the cultivation of *M. sagu* palm, particularly at the flowering stage, be considered as a potential climate change mitigation strategy. *M. sagu* plantations can be established in suitable regions with favorable climatic and soil conditions, taking into account factors such as land availability, water resources, and socio-economic considerations.

It is important to note, however, that additional research and evaluation are required to validate and generalize these findings. Regional differences, specific management practices, and potential trade-offs with other environmental or socioeconomic aspects must all be carefully considered.

As a result, additional research, such as long-term monitoring and field trials, would be beneficial in providing more robust evidence and informing practical implementation strategies for using the *M. sagu* palm as a tool for carbon sequestration.

References

Abellomm. 2021. Study eyes package of technologies for sago production. Magazine Agriculture.

Amin N, Sabli NM, Izhar S, Yoshida H. 2019. Sago Wastes and Its Applications. Peranika Journal of Science & Technology **27(4),** 1841-1862 (2019).

Bintoro HMH, Nurulhaq MI, Pratama AJ, Ahmad F, Ayulia L. 2018. Growing area of sago palm and its environment. In "Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods". pp. 17-29. Springer Nature.

Chanta S. 2017. Sagp palm in Thailand: Status knowledge and sustainable management guidelines. Higher Education Research Promotion and National Research University Project of Thailand, Office of the higher Education Commission. [Thai].

Dewi RK, Bintoro MH, Sudradjad S. 2016. Morphological Characteristics and Yield Potential of Sago Palm (*Metroxylon* spp) Accessions in South Sorong District, West Papua. Journal Agronomi Indonesia **44(1),** 91-97.

Ehara H, Susanto S, Mizota C, Hirose S, Matsuno T. 2000. Sago palm (*Metroxylon sagu*, Arecaceae) production in the Eastern Archipelago of Indonesia: Variation in Morphological characteristics and pith dry-matter yield. Economic Botany **54(2),** pp. 197-206. 2000.

Flach M, Schuiling DL. 1989. Revival of an ancient starch crop: A review of the agronomy of the sago palm. Agrofor.Syst. **7,** 259-281.

Hirao K, Kondo T, Kainuma K, Takahashi S. 2018. Starch properties and uses as food for human health and welfare. Sago Palm: Multiple contributions to food Security and Sustainable. Springer Nature, Singapore. DOI: 10.1007/978-98-10-5269-9_21

Johnson I, Coburn R. 2010. Trees for Carbon Sequestration. Primefacts for Profitable, Adaptive and Sustainable Primary Industries. www.industry. nsm.gov.au/pdf p5-6

Lasco RD, Pulhin FB. 2000. Forest Land-Use Change in the Philippines and Climate Change Mitigation. Mitigation and Adaptation Strategies for Global Change **5,** 81-97.

Novero A. 2012. Recent advances in sago palm (*Metroxylon sagu* Rottb.) Micropropagation (Book chapter). pp 60-66 in the e-book “frontiers on recent developments in plant science”, Goyala and Maheshwari p, eds., Bentham Publishers Ltd., Lethbridge, Canada. ISBN: 978-1-60805-403-9: 2213-2708;

Ogle SM, Olander L, Wollenberg L, Rosenstock T, Tubiello F, Paustian K, Buendia L, Nihart A, Smith P. 2014. Reducing greenhouse gas emissions and adapting agricultural management for climate change in developing countries: providing the basis for action. Global Change Biology **20(1),** 1-6.

Ohmi M. 2015. Starch properties and uses. In: Society of Sago Palm Studies (Eds). The Sago Palm: The Food and Environmental Challenges of the 21st Century. Trans Pacific Press, Kyoto.

Pacala S, Socolow R. 2004. Stabilization wedges-solving the climate problem for the next 5 years with current technologies: Science, vol. **305,** pp 968-972. https://www.undeerc.org/pcor/sequestration/whatis sequestration.aspx

Paulinoa V. 2014.How can I convert present soil organic matter into soil carbon.

Pulhin BF, Lasco RD, Urquiola JP. 2014. Carbon Sequestration Potential of Oil Palm in Bohol, Philippines. Ecosystems & Development Journal **4(2),** 14-19. April 2014. ISSN 20012-3612.

Santillan JR. 2013. Mapping the Starch-rich Sago palm through maximum likelihood classification of Multi-source data. Proceeding of the 2nd Philippine Geomatics Symposium PhilGEOS: Geomatic for a Resilient Agriculture and Forestry November 28-29. University of the Philippines, http://www.dge.upd.edu.ph.philgeos2013

Simegn TY, Soromessa T, Bayable E. 2014. Forest Carbon Stocks in Lowland Area of Simien Mountains National Park: Implication for Climate Change Mitigation. Science, Technology and Arts Research Journal **3,** 29-36.

Singhal RS, Kennedy JF, Gopalakrishnan SM, Kaczmarek A, Knill CJ, Akmar PF. 2008. Industrial production, processing, and utilization of Sago palm-derived products. Carbohydrates Polymers **72(1),** 1-20.

Toyoda Y. 2015. Diversity of Used. In: Society of Sago Palm Studies (Eds). The Sago Palm: The Food and Environmental Challenges of the 21st Century. Trans Pacific Press, Kyoto.

Uda SK, Hein L, Adventa A. 2020.Towards better use of Indonesian peatlands with paludiculture and low-drainage food crops. Wetl. Ecol. Manag **28(3),** 509-526. DOI: 10.1007/s11273-020-09728-x

Uda SL, Hein L, Adventa A. 2020. Towards better use of Indonesian Peatlands with Paludiculture and Low-drainage food crops. Wetl. Rcol. Manag **28(3),** 509-526. DOI: 10.1007/s11273-020-09728-x.

Yamamoto Y, Omori K, Nitta Y, Kakuda K, Pasolon YB, Rembon FS, Gusti RS, Arsy AA, Miyazaki A, Yoshida T. 2016. Dry matter production and distribution after trunk formation in Sago palm (*Metroxylon sagu* Rottb.). Tropical Agriculture and Development **60(2),** 71-80.