Ecosystems & Development Journal 4(2): 14-19
April 2014 ISSN 2012-3612

Carbon Sequestration Potential of Oil Palm in Bohol, Philippines

Florencia B. Pulhin[a,b] ,
Rodel D. Lasco[b], and
Joan P. Urquiola[b]

ABSTRACT

The enactment of the Philippine Biofuels Act in 2006 led to rising interest in biofuels and the potential to help mitigate the negative impacts of climate change in view of the ability of plant biomass to sequester carbon from the atmosphere. The carbon sequestration potential of oil palm has been recognized for several years but no study has been done in the country to assess the amount of carbon in its biomass. This paper presents the amount of carbon stored in different parts of Elaeis guineensis, commonly known as African oil palm, in plantations with different ages. The carbon content of one plant each from oil palm plantation with ages two, five, six, seven, eight, and nine years was assessed. Results indicate that among different parts, trunk with frond butts and the fronds stored the highest amount of carbon per plant. The data also indicate that the carbon content of oil palm leaves does not vary with plantation age. Moreover, calculations show that a nine-year-old oil palm plantation in the Philippines could sequester 6.1 t $ha^{-1} yr^{-1}$ of carbon, with an estimated carbon density of 55 t ha^{-1}. Older oil palm plants contain more carbon than those that are relatively younger. The study's findings could help policy and decision makers craft climate change mitigation policies and programs in the Philippines.

Keywords: oil palm, biofuel, Elaeis guineensis, carbon sequestration, climate change mitigation

INTRODUCTION

The most recent report of the Intergovernmental Panel on Climate Change (IPCC, 2007) concludes that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Impacts of climate change, particularly warming, can be harmful both on the environment and human population. Cognizant of these potential adverse impacts, the global community signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. Ratified by 195 countries (UNFCCC 2013), the UNFCCC primarily aimed to stabilize greenhouse gas (GHG) concentrations at safe levels.

During the Third Conference of Parties (COP-3), the Kyoto Protocol was drafted to set legally binding obligations on developed countries to reduce, by year 2008-2012, their overall GHG emissions by about 5% of the 1990 levels. One way by which this was to be done was by supporting projects in developing countries through the Clean Development Mechanism (CDM) such as afforestation/reforestation, methane capture, and fuel switching, among other things. The Kyoto Protocol was amended on December 8, 2012 and this paved the way for the second commitment period from 2013-2020 (UNFCCC 2013).

[a]*Scientist II, Forestry Development Center, CFNR, UPLB, College, Laguna 4031, Philippines*
[b] *World Agroforestry Centre (ICRAF), College, Laguna 4031, Philippines*
**Corresponding author: yaybpulhin@yahoo.com; f.pulhin@irri.org; f.pulhin@cgiar.org*

In recent years, attention focused on the possible use of biodiesel to help mitigate climate change. According to Lin *et al.* 2006, biofuels produce less harmful emissions than fossil fuels when used in generating electricity. The use of biofuels in place of fossil fuels results in GHG emissions savings of 30% (Zah *et al.* 2007) to 41% (Hill *et al.* 2006).

One of the potential crops that can be used as source of biofuel is *Elaeis guineensis*, commonly known as African oil palm. *E. guineensis* is a tropical forest palm native to West and Central Africa. Compared with other oil crops, *E. guineensis* produces three to eight times more oil (Sheil *et al.* 2009). This suggests that less area is needed to produce the same quantity of oil compared with rapeseed, sunflower, coconut, cottonseed, ground nut, and sesame seed. In addition, *E. guineensis* has many uses. For instance, the crude palm oil is used in various non-edible products such as detergents, cosmetics, plastics, surfactants, herbicides, and a broad range of other industrial and agricultural chemicals. When refined, the oil is used for frying, making margarine, and as cocoa butter substitute. The fibers from the fruit and the empty bunch can be used as raw materials for particle board, pulp, and paper. The shell can be utilized to produce carbon briquette and as raw material for fiberboard while the trunk can be used in manufacturing furniture and particle board (Wahid *et al.* 2005).

The rising interest in biofuels in the Philippines was encouraged by the enactment of the Biofuels Act in 2006 (Maruyama *et al.* 2009). The act mandated that in 2011, there should be a 2% biodiesel blend and 10% bioethanol blend in diesel and gasoline, respectively (Stromberg *et al*. 2011).

Several biofuel processing plants were constructed all over the country to meet the expected demand. The biofuel crops that have mainly been used are sugar cane and coconut, but there are efforts to tap other crops such as cassava, sweet sorghum, jatropha, and corn.

According to Pamplona (2011), area planted to oil palm in the Philippines is about 43,000 ha. He reported that the Philippines had been importing USD 150 million worth of palm oil annually and the worth could rise to USD 280 million by 2020. The high level of interest in planting oil palm in the southern island of Mindanao is an encouraging development as this will help reduce the country's level of African palm oil import.

Aside from the GHG savings that can be derived from using oil palm as biofuel source, *E. guineensis* also sequesters carbon from the atmosphere, which helps to reduce GHG. Results of studies conducted in Indonesia revealed that a mature oil palm has a carbon density of 90 t ha^{-1} (Tomich *et al.* 2002; Casson *et al.* 2007). In the Philippines, no study had been undertaken to assess the amount of carbon of *E. guineensis*. Hence, this study was conducted to help fill the data gap. Several life cycle analyses have shown mixed results in terms of mitigating GHG emissions with the use of biofuels from oil palm. In general, planting oil palm in non-forested land results in lower GHG emissions compared to clearing forests for oil palm planting as the latter uses fossil fuels and the burning of which leads to higher GHG emissions (Reijnders and Huijbregts 2008; Hassan *et al.* 2011; Siangjaeo *et al.* 2011).

This study was conducted to determine the amount of carbon stored in *E. guineensis,* specifically the carbon contents of different oil palm parts and to estimate the amounts of carbon stored over a period of time.

METHODOLOGY

Study Area

The study was conducted in the plantation of the Philippine Agricultural Land Development and Mills, Incorporated (PALM, Inc.) located in the Municipality of Carmen, Bohol, Philippines in November 2010. The municipality falls under Corona Climate Type IV, which is characterized by evenly distributed rainfall throughout the year. It is influenced by northeast monsoon from October to January; by trade winds from the Pacific from February to April; and the southeast monsoon from May to September. Its topography is generally gently sloping to rolling with slope of 3-18%. The most prevailing soil type is Ubay clay, which is a residual soil from shale, sandstone, and conglomerates.

Sampling

Six oil palm plants were used in the study: one oil palm from each plantation site aged two, five, six, seven, eight, and nine years were destructively sampled to assess the amount of carbon stored in the oil palm parts, similar to the procedure used by Syahrinudin (2005) in determining carbon sequestration of oil palm in Indonesia. The sample oil palms were felled using a chainsaw. Each oil palm sample was measured for total height and cut into six parts (trunk, fronds, leaves, fruits, flowers, and roots) which were weighed and collected for laboratory analysis.

All the fronds were cleared off from the trunk leaving only the frond butts attached (Figure 1). The trunk was subdivided into small parts for convenience of weighing. Length and diameters at both ends of each cut trunk were recorded. Fresh weight of each cut trunk was also taken and recorded. A sample weight of a kilogram was placed in a labelled plastic bag and taken to the University of the Philippines Los Baños for oven drying and analysis. To ensure that all the sections of the trunk were represented in the collected sample for laboratory analysis, small portions from each felled trunk were taken.

All the leaves were stripped off from the fronds (Figure 2). All butts were cut into small sizes for convenience of weighing. All fronds were collected and placed in one big bag and weighed to obtain the total fresh weight.

A sample of the fronds weighing approximately one kilogram was placed in a labelled bag for oven drying and analysis. Similar to the trunk, it was ensured that all portions of the fronds were represented in the sample taken for analysis.

Figure 1. A staff from PALM, Inc. removes fronds from the oil palm trunk

Figure 2. Laborers remove the leaves from the oil palm frond

All the leaves that were stripped off the butt were collected and placed in a bag. Total fresh weight was obtained and recorded. A sample of about one kilogram was also taken for analysis and oven drying.

Fruits and flowers were also collected and separated from the butts. Fresh weights of the fruits and flowers were taken separately and recorded. Sample of the fruits and flowers each weighing about a kilogram were also taken for analysis and oven drying.

In the older plantation (nine-years-old), a small back hoe was used to excavate the roots for estimation of root biomass. In young stands, roots were dug out manually. Soil attached to all roots was removed using a mesh sieve. All roots collected were placed in a bag and weighed to get the total fresh weight. A sample weight of about one kilogram was collected, labelled, and taken to the laboratory for oven drying and analysis.

Prior to oven drying of samples, the collected samples were air dried for one week to shorten oven drying time. Air dried samples were placed in labelled paper bags and taken to the laboratory. The samples were oven dried at a temperature of 100°C for three days or until the weights of the samples became constant. Biomass values for the trunk, fronds, leaves, flowers, fruits, and roots were calculated using the following formula:

ODWt = TFW – (TFW*(SFW-SODW))/SFW

Where:

ODW = total oven dry weight
TFW = total fresh weight
SFW = sample fresh weight
SODW = sample oven-dry weight

Total biomass of the oil palm was estimated by summing the biomass values derived for each of the plant parts: trunk, fronds, leaves, flowers, fruits, and roots.

To determine the percentage of carbon contained in each part of the palm, oven dried leaf samples were taken to the Analytical Service Laboratory (ASL) of the International Rice Research Institute (IRRI). For the other parts of oil palm, default carbon value was used (Lasco and Pulhin 2000, Labata *et al. 2012*). The amount of carbon stored in the leaves was determined by multiplying the biomass values with the derived percentage of carbon. For the rest of the oil palm parts, carbon stored was determined by multiplying the biomass values with 45%, the average percent carbon contained in tree species in the Philippines (Lasco and Pulhin 2000).

In calculating total biomass, total carbon stored in the whole oil palm plant is derived by adding the carbon stored in each of the plant parts.

RESULTS AND DISCUSSION

Biomass of Individual Oil Palm and its Parts

Biomass of the oil palm studied ranged from 0.021- 0.90 mt per individual plant. As expected, the largest amount of biomass was observed in the nine-year-old oil palm while the smallest value was obtained with the two-year-old plant (Figure 3). Since the oil palms studied are still in their early years, it is highly possible that more carbon will be fixed by the plant if left in the area for 10 years or more.

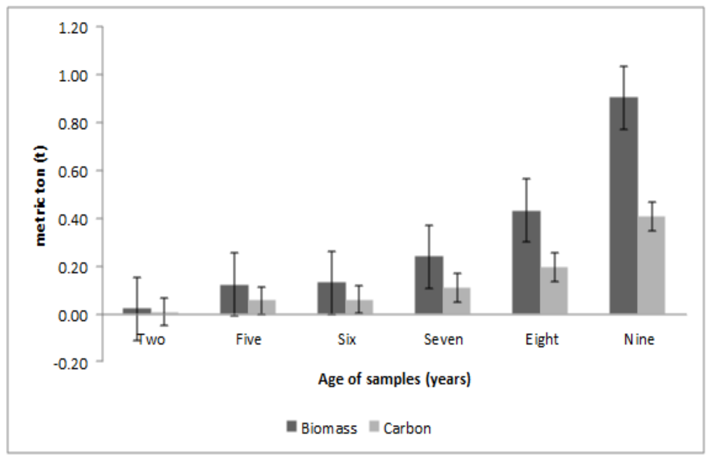

Figure 3. Biomass and carbon of the oil palm at different ages

Trunk with frond butts and fronds accounted for most of the total biomass. For oil palm with ages two, six, and seven years, large percentage of the biomass was found in the fronds (Figure 4). For the remaining oil palm studied (ages five, eight, and nine), the trunk with frond butts showed the largest percentage of biomass. Meanwhile, leaves and fruits usually accounted for the lowest biomass percentage.

Contribution of Different Parts of Oil Palm to Total Carbon Stored

The results indicate that most of the carbon stored was observed in the trunk with frond butt, ranging from 19.20% to 54.49%, and in the fronds, ranging from 35.82% to 60.62% (Table 1). Around 2% to 20% was found in the leaves while approximately 3% to 9% was observed in the roots. Lastly, around 0.2% to 10% of the total carbon stored in the oil palm was found in the flowers and fruits.

Carbon Content of Oil Palm Leaves

Only carbon present in the leaves of oil palm was determined through laboratory analysis. For the other parts, default carbon value of 45% was used. Carbon content of oil palm leaves ranges from 44.7% to 49.1% or an average of 47.47%. This is close to the findings of Syahrinudin (2005) who obtained 43.7% for leaf carbon content.

The leaves of the eight-year-old oil palm were observed to contain the highest percentage of carbon while the lowest value was observed in the leaves of the nine-year-old oil palm. Percentage of carbon measured in the leaves of the seven-year-old oil palm was almost the same as that obtained from the eight -year-old. Leaves of the two-year-old oil palm contained 48.2% carbon while five- and six-year-old plantations have 47.0% and 46.8% carbon, respectively (Table 2). Results indicate that carbon present in the leaves did not vary with oil palm plantation age. This is similar to the results of Syahrinudin (2005) who found that plantation age does not affect the carbon content of aboveground compartments particularly the leaves.

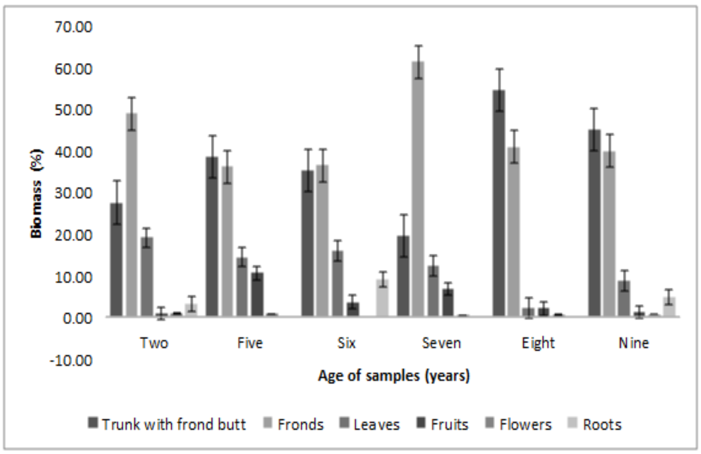

Figure 4. Biomass of different oil palm parts at different ages

Amount of Carbon Stored in Different Parts of Individual Oil Palm

As indicated in Figure 3, the amount of carbon stored in the given pool was proportional to the amount of biomass in that carbon pool; that is, the higher the biomass, the higher the amount of carbon stored. Because of their higher biomass contents, the older oil palm plants contained more carbon than the younger ones. For instance, the two-year-old oil palm showed a total carbon content of 0.009 metric ton while the nine -year-old oil palm showed a total carbon content of 0.407 metric ton. The five- and six-year-old oil palms showed nearly similar total carbon contents, 0.055 and 0.060 metric ton, respectively. On the other hand, the seven-year-old and eight-year-old oil palms showed total carbon contents of 0.109 metric ton and 0.194 metric ton, respectively.

Trunk with frond butt was observed to contain 0.0592 metric ton of carbon, the highest carbon content among the oil palm parts measured. The fronds ranked next with a mean carbon amount of 0.0589 metric tons per oil palm. Leaves ranked third with an average of 0.0124 metric tons of carbon per individual. Meanwhile, the roots gave a mean carbon value of 0.083 metric tons per individual, fruits with 0.0039 metric tons per oil palm, and flowers with merely 0.0008 metric tons per individual plant on the average.

The data indicate that the amount of carbon stored in different oil palm parts did not increase as the plantations increased in age. For instance, the amount of carbon measured in the trunk with frond butt and the fronds of a five-year-old oil palm was higher than that of a seven-year-old. In terms of leaves, eight-year-old oil palm exhibited lower amount of carbon than five-, six- and seven-year-old oil palms. Also, the fruit of a seven-year -old oil palm was observed to contain higher amount of carbon than that of eight- and nine-year-olds (Figure 5). Flowers of five -year-old oil palm contained greater value of carbon than the seven-year-old. However, the amount of carbon of the roots was observed to increase with the increasing sample age.

Table 1. Carbon contents of different oil palm parts

Sample Age (years)	Trunk With Frond Butt	Fronds	Leaves	Fruits	Flowers	Roots
	------------ Oil palm parts ------------					
	------------ percent of total ------------					
2	27.13	48.28	20.08	0.75	0.75	3.01
5	38.20	35.82	14.92	10.42	0.64	-
6	34.97	36.25	16.31	3.55	-	8.92
7	19.20	60.62	13.27	6.66	0.26	-
8	54.49	40.75	2.40	1.99	0.38	-
9	45.10	39.84	8.65	1.08	0.62	4.71
Standard error	**5.13**	**3.87**	**2.55**	**1.54**	**0.09**	**1.76**

Table 2. Carbon contents of oil palm leaves at different ages

Sample Age (years)	Percent Carbon
2	48.2
5	47.0
6	46.8
7	49.0
8	49.1
9	44.7
Average	**47.47**

Carbon Sequestration Potential of Oil Palm Plantation

Assuming a plantation of 135 oil palm plants in a hectare of land, the results can be extrapolated as follows: plantations with ages two, five, seven, and nine years can have carbon sequestration and storage potentials of 1.22, 7.43, 14.72, and 55.00 metric tons ha^{-1}, respectively. In terms of rate of sequestration, results indicate that on the average, oil palm can sequester approximately 2.5 mt C $ha^{-1}yr^{-1}$. The data for the two- and nine-year-old plantations showed carbon sequestration rates of 0.64 and 6.10 metric tC $ha^{-1}yr^{-1}$, respectively.

The computed values for carbon storage of the two- to seven-year-old oil palm plantations are lower than the findings in other countries (Table 3). For instance, three-year-old oil palm plantations in Indonesia can store around 12.3 to 16.6 metric tC ha^{-1} (Syahrinudin 2005). These are higher than the computed carbon storage rates for the Philippines, ranging from 1.22 to 14.72 metric tC ha^{-1} (Table 3).

Table 3. Carbon sequestration potential of oil palm in other countries

Oil Palm Plantation Age (years)	Country	Carbon Storage (tC ha^{-1})	Sequestration Rate (tC ha^{-1} yr^{-1})	References
3	Indonesia	16.6	5.5	Syahrinudin, 2005
8	Indonesia	12.3	5.5	Lamade and Setiyo, 2002
9-10	Malaysia		9.74	Henson, 1999
10	Indonesia	49.4	4.9	Syahrinudin, 2005

In terms of the carbon storage of the eight- to nine-year-old oil palm plantations, higher values were obtained in the Philippines than in other countries. For instance, carbon storage of an eight-year-old oil palm plantation in Indonesia was observed to be 12.3 metric tC ha^{-1} (Lamade and Setiyo 2002), which is only half of the value obtained in the Philippines.

A 10-year-old plantation in Indonesia could store 49.4 metric tC ha^{-1} (Syahrinudin 2005) while in the Philippines, a nine-year-old plantation could store 54.95 metric tons of carbon ha^{-1}. The differences in the amount of carbon storage could be attributed to the variation in physical conditions of the study areas.

Oil palm plantation in the Philippines has a carbon density of 55 metric t ha^{-1}. This is higher than the carbon density of teak plantation in the country, which is only 35 metric t ha^{-1} (Lasco *et al.* 2000). In terms of carbon sequestration rate, oil palm plantations in the Philippines outdo coconut (*Cocos nucifera* L.) plantations which sequester at 6.1 t ha^{-1} yr^{-1} and grasslands at less than 1 t ha^{-1} yr^{-1} (Brakas and Aune 2011).

CONCLUSIONS AND RECOMMENDATIONS

Oil palm can play a very important role in mitigating climate change since it sequesters substantial amount of carbon. Results of this study indicate that a nine year old oil palm plantation in the Philippines can sequester 6.1 tC $ha^{-1}yr^{-1}$ and has a carbon density of 55 t ha^{-1}. So, converting 1 million hectares of grasslands into oil palm plantation will store about 55 million metric tons of carbon. This value represents carbon taken out of circulation from the atmosphere, a saving which is in addition to carbon prevented from being emitted when oil palm is used as biofuel. It should be noted, however, that its role in climate change mitigation is only meaningful when barren areas not classified as forests are converted into an oil palm plantation because there is additional amount of carbon gained. Conversion of an existing forested forestland will lead to a carbon debt because carbon stored in existing forests is much bigger than that in an oil palm plantation. For instance, a second growth forest contains around 208 metric t ha-1 while mature mixed dipterocarp plantation has as much as 126 metric t ha^{-1} (Lasco *et al.* 2004).

Further research is recommended to enhance and validate the results of the study. Since only one sample in each plantation site was taken, increasing the sample size and employing statistical design could help provide more accurate computations for carbon sequestration and storage potential of oil palm plantations in the Philippines. The study's findings could help policy and decision makers craft climate change mitigation policies and programs in the Philippines.

REFERENCES CITED

Brakas, S.G. and Aune, J. B. 2011. Biomass and carbon accumulation in land use systems of Claveria, the Philippines. In: Kumar, B.M. and Nair, P.K.R. (eds.). Carbon sequestration potential of agroforestry systems: opportunities and challenges, Vol. 8, Advances in Agroforestry. Dordrecht, Heidelberg, London, New York: Springer. pp. 163-175.

Casson, A., Tacconi, L., Deddy, K. 2007. Strategies to reduce carbon emissions from the oil palm sector in Indonesia. Paper presented at Indonesian Forest Climate Alliance. Jakarta, Indonesia .

Hassan, M. N. A., Jaramillo, P., Griffin, W. M. 2011. Life cycle GHG emissions from Malaysian oil palm bioenergy development: The impact on transportation sector's energy security. *Energy Policy*. 39(5):2615-2625.

Henson, I.E. 1999. Comparative ecophysiology of oil palm and tropical rainforest. In: Singh, G., Huan, L.K., Leng, T. and Kow, D.L., (eds.). Oil palm and the environment: a Malaysian perspective. Kuala Lumpur. pp. 9-39.

Hill, J., Nelson, E., Tilman, D., Polasky, S., and Tiffany, D. 2006. Environmental, economic, energetic costs and benefits of biodiesel and ethanol biofuels. In: Snyder, et al., eds . Proceedings of the National Academy of Sciences of the United States of America. 103:11206–11210.

International Panel for Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC. Cambridge, New York: Cambridge University Press.

Labata, M.M., Aranico, E.C., Tabaranza, A.C.E., Patricio, J.H.P., Amparado, R.F.Jr. 2012. Carbon stock assessment of three selected agroforestry systems in Bukidnon, Philippines. *Advances in Environmental Sciences*. 4(1): 5.

Lasco, R.D. and Pulhin, F.B. 2000. Forest land-use change in the Philippines and climate change mitigation. *Mitigation and Adaptation Strategies to Global Change Journal*. 5: 81-97.

Lasco, R.D., Pulhin, F.B., Visco, R.G., Racelis, D.A.; Guillermo, I.Q., and Sales, R.F. 2000. Carbon stocks assessment of Philippine forest ecosystems. Paper presented at Science-policy workshop on terrestrial carbon assessment for possible carbon trading. Bogor, Indonesia .

Lasco, R.D., Guillermo, I.Q., Cruz, R.V.O., Bantayan, N.C., and Pulhin, F.B. 2004. Carbon stocks assessment of a secondary tropical forest in Mt. Makiling Forest Reserve, Philippines. *Journal of Tropical Forest Science*. 16(1): 35-45.

Lamade, E. and Setiyo, I.E. 2002. Characterisation of carbon pools and dynamics for oil palm and forest ecosystems: application to environmental evaluation. Paper presented at International Oil Palm Conference. Bali, Indonesia .

Lin, Y.C., Lee, W.J., and Hou, H.C. 2006. PAH emissions and energy efficiency of palm-biodiesel blends fueled on diesel generator. *Atmospheric Environment*. 40 (21): 3930–3940.

Maruyama, A., Aquino, A.P.; Dimaranan, X.B., and Kai, S. 2009. Potential of biofuel crop production in the Philippines: A Preliminary Analysis. *HortResearch*. 63: 67-76.

Pamplona, P.P. 2011. Promoting Oil Palm Farming in the Philippines: Possible Benefits. 2011. http://ppdci.org/wp-content/uploads/2011/06/Promoting-Oil-Palm-Farming-in-the-Philippines...pdf

Reijnders, L., and Huijbregts, M.A.J. 2008. Palm oil and the emission of carbon-based greenhouse gases. *Journal of Cleaner Production*. 16(4l):477-482.

Sheil, D., Casson, A., Meijaard, E., van Nordwijk, M. Gaskell, J., Sunderland-Groves, J., Wertz, K. and Kanninen, M. 2009. The impacts and opportunities of oil palm in Southeast Asia: What do we know and what do we need to know?. Occasional paper no. 51. CIFOR, Bogor, Indonesia.

Siangjaeo, S., Gheewala, S.H., Unnanon, K., and Chidthaisong, A. 2011. Implications of land use change on the life cycle greenhouse gas emissions from palm biodiesel production in Thailand. *Energy for Sustainable Development*. 15(1): 1–7.

Stromberg, P.M., Esteban, M., and Gasparatos, A. 2011. Climate change effects on mitigation measures: The case of extreme wind events and Philippines' biofuel plan. *Environmental Science and Policy*. 14(8): 1079 – 1090.

Syahrinudin. 2005. The potential of oil palm and forest plantations for carbon sequestration on degraded land in Indonesia. In: Vlek, P. et al ., eds. Ecology and Development Series 28. Germany.

Tomich, T.P., de Foresta, H., Dennis, R., Ketterings, Q., Murdiyarso, D., Palm, C., Stolle, F., Suyanto, S., and van Noordwijk, M. 2002. Carbon offsets for conservation and development in Indonesia? *American Journal of Alternative Agriculture*. 17: 125-137.

United Nations Framework Convention on Climate Change (UNFCC). 2013. First steps to a safer future: Introducing the United Nations Framework Convention on Climate Change. http://unfccc.int/key_steps/the_convention/items/6036.php

Wahid, M.B., Abdullah, S.N.A., and Henson, I.E. 2005. Oil palm achievements and potential. *Plant Production Science*. 8: 288-197.

Zah, R., Böni, H., Gauch, M., Hischier, R., Lehmann, M., Wäger, P. 2007. *Ökobilanz von Energieprodukten: Ökologische Bewertung von Biotreibstoffen* (Environmental impacts of biofuels). Empa, St. Gallen, Switzerland.

Figure 5. Oil palm fruits (a) and trees (b)