

Greenhouse gas reduction potential due to smart palm oil mill residue treatment

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Abstract

Indonesia has recently become the world largest palm oil producer. It has produced approx. 21 million tonnes in 2009 (USDA 2010). Increasing global demand for palm oil - partly driven by subsidies for biodiesel - is mainly covered by increasing production in Indonesia and is likely to increase in coming years. The production of 1 million t crude palm oil requires 5 million t of fresh fruit bunches (FFB). On average processing of 1 million t FFB in palm oil mills generates 230,000 t empty fruit bunches (EFB) and 650,000 t palm oil mill effluent (POME) as residues. These residues cause considerable environmental burdens, particularly greenhouse gas (GHG) emissions. Advanced treatment and utilisation of those residues by co-composting can reduce GHG emission from 120,000 t CO_{2eq} up to approx. 7,000 t CO_{2eq} per million t FFB if treatment of POME in open pond systems and returning EFB to the plantation is regarded as state-of-the-art in Indonesia. Consequently the GHG reduction potential of the Indonesian palm oil industry has been approx. 12 million t CO_{2eq} in 2009. More than 25 palm oil mills in Indonesia have already realised co-composting plants for EFB and POME, some of them with CDM. The revenue from CDM could be in the range of 100 to 250 million € per year if the proposed residue treatment is realised on a national scale.

Keywords: GHG reduction, POME, EFB, palm oil, composting

Introduction

Palm oil is an important source for edible oils, as raw material for cosmetics and detergents and more recently for biodiesel production (Wicke, 2008; de Vries, 2010, Hirsinger, 1995; Stalmans, 1995, Lim, 2010). Palm oil is mainly exported in contrast to other biomass products that are mainly consumed locally in the countries of production (Heinimo, 2009). Increasing demand for palm oil is driven by increasing consumption of vegetable oils due to growing human population

(Corley 2009) but also by biodiesel consumption due to recent policy targets in Europe and the US (Wahid, 2008).

Over the past decade, many industrialised countries have introduced policies to stimulate renewable energy, which has led to an increased import of biomass particularly palm oil for biodiesel production. Therefore palm oil production has grown rapidly and that has led to growing concern about its environmental and ecological impacts. Increasing global demand for palm oil is mainly covered by increasing production in Indonesia and is likely to increase in coming years. Indonesia has recently become the world largest palm oil producer. It has produced approx. 21 million tonnes in 2009 (USDA 2010).

The competition for palm oil between food, feedstock for chemicals and biodiesel has put palm oil in the limelight and resulted in an extremely controversial debate around the world (Reijnders, 2008; de Vries, 2008; Verwer, 2008). Sustainability of palm oil is crucial if this versatile crop is to become the leading vegetable oil in this world (Tan, 2009). This multipurpose oil needs to be cultivated in a proper manner to ensure sustainable development in terms of economic, social and environment. Environmental sustainability of palm oil is determined by land use or land use change, maintenance of soil quality and genetic diversity. One of the most significant factors of sustainability, however, is nutrient management on palm oil plantations (Chan 2005), hence sound fertiliser management practises are vital for commercial palm oil production.

The production of 1 million t crude palm oil requires 5 million t of fresh fruit bunches (FFB). On average processing of 1 million t FFB in palm oil mills generates 230,000 t empty fruit bunches (EFB) and 650,000 t palm oil mill effluent (POME) as residues. These residues cause considerable environmental burdens, particularly greenhouse gas (GHG) emissions but potentially they can replace fertiliser and help to reduce costs.

Traditionally POME is stored in pond systems; from those ponds approx. 6.6 kg methane per t FFB is emitted into the atmosphere. The EFB is either dumped or returned to the palm oil plantation. The latter can cause all sorts of problems, just

to name a few logistic, handling and hygienic problems. Alternatively POME and EFB can be treated in a compost plant, where the residues are stabilised under controlled conditions so that anaerobic conditions are avoided.

Technology

The total POME will be added to the chopped EFB during composting process in open windrows, which are turned regularly by a turning machine. The temperature in windrows raise up to 70 °C, at this stage of the composting process more than 3.5 m³ POME/t EFB can be evaporated within 6 to 8 weeks.

The composting process includes several activities such as: (a) the chopping of the EFB using a cutting mill; (b) forming of longitudinal heaps; (c) turning of the heaps using a self driving windrow turning machine; (d) watering of the heaps using waste water (POME) in order to balance the high water evaporation and (e) finishing step.

The produced compost can be either used directly on the plantation or it can be sold after finishing (screening) depending on the market demand.

Life Cycle Assessment (LCA)

The first set of results show the environmental impacts of four palm oil mill residue treatment options. The LCA modelling has been carried out in GaBi 4.3 (PE Europe 2003), using the CML 2001 method for estimating the environmental impacts (Guinée 2002). Updated IPCC characterisation factors for GHG are used to calculate the GWP. Just the GWP is calculated and discussed in detail below; other environmental impacts are neither shown nor discussed in this study.

Results and discussion

Traditionally POME is stored in open (anaerobic) pond systems; from those ponds approx. 6.6 kg methane per t FFB is emitted into the atmosphere. The EFB is either dumped or returned to the palm oil plantation. The latter can cause all sorts of problems, just to name a few logistic, handling and hygienic problems. Alternatively POME and EFB can be treated in a compost plant, where the

residues are stabilised under controlled conditions so that anaerobic conditions are widely avoided.

Fig. 1 shows a life cycle diagram of a palm oil production system. It encompasses input materials like fertiliser and pesticides including transport but also diesel consumption for mechanisation, the operations within the palm oil mill, the heat and power plant as well as the waste management.

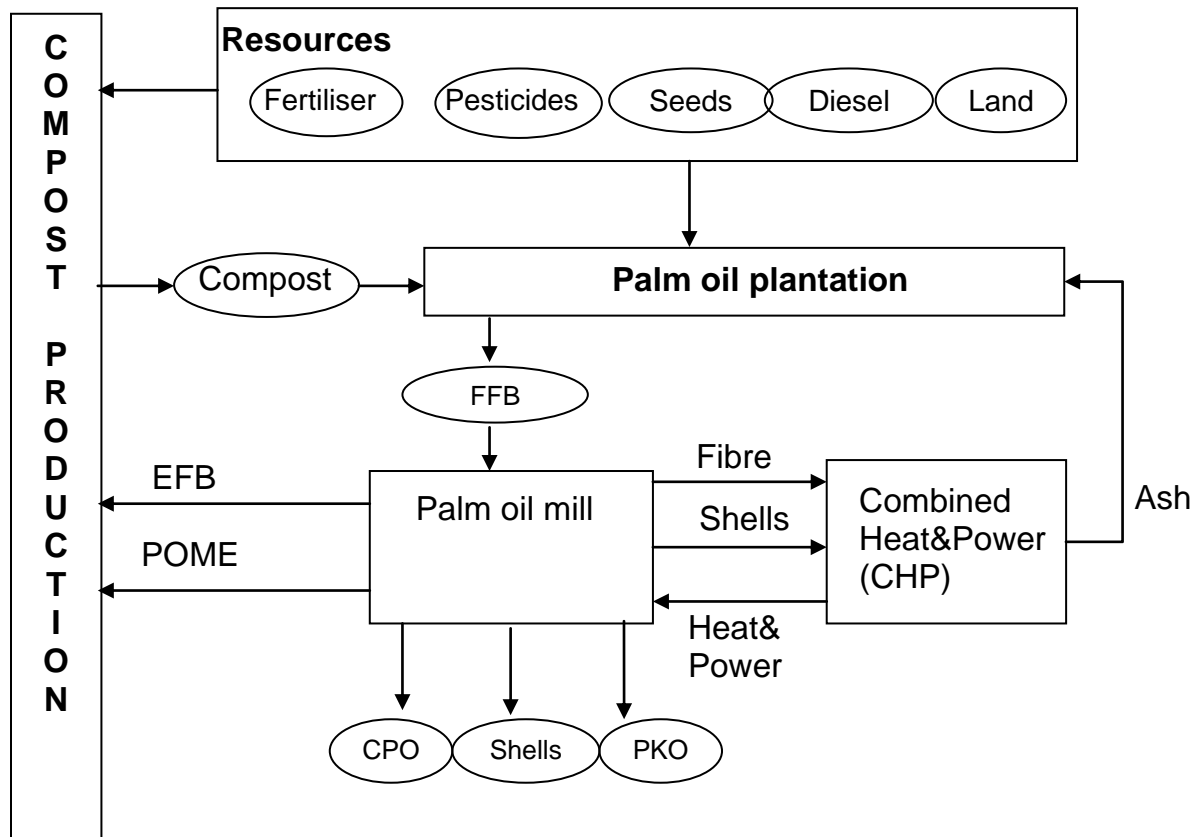


Fig. 1: Life Cycle diagram of palm oil production systems

In Tab. 1 the most relevant input-data are shown for both systems, the conventional system, where EFB is dumped and POME is stored in ponds and the advance system using co-composting for treating the residues.

Table 1: Most important life cycle inventory data

t per million t of FFB	EFB-dumping and pond system	Co-composting system
N-fertiliser	14,300	11,600
Other fertiliser	18,900	5,000

Pesticides	5,000	5,000
Transport distance	750 km ocean transport 500 km road transport	750 km ocean transport 500 km road transport
CHP-efficiency	72%	72%
EFB	230,000	230,000
POME	650,000	650,000

The plantation and the waste treatment contribute most to the GWP. The production and treatment of one million tonne FFB causes approximately 460,000 tonne CO_{2eq} in the conventional system and 110,000 t CO_{2eq} when the co-composting technique is used. Despite the considerable transport distances assumed for this study its contribution to the GWP is almost negligible (<1%). Results of both systems are shown in Fig. 2. The GWP is mainly caused by methane; the treatment of POME in ponds causes approx. 130 kg per t FFB. This value is based on own measurements and in accordance with generic data provided by the IPCC.

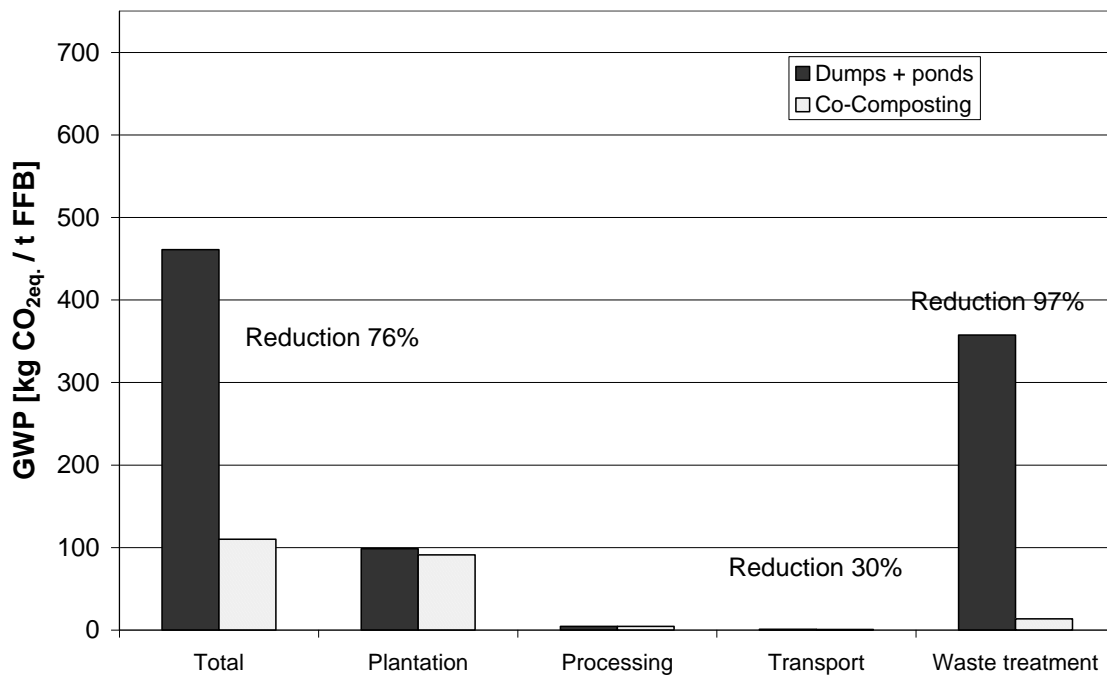


Fig. 2: Global warming potential (GWP) of two palm oil production

Unfortunately no measurements or literature data are available for EFB-dumping sites. IPCC suggests 80% anaerobic conditions; this is obviously a worst case assumption. We have investigated two scenarios (0.5% and 5% nitrous oxide) for EFB-dumping depending on the degree of anaerobic conditions. The formation of methane is calculated as 49% of biodegradable carbon. In Fig. 3 results are shown. For this analysis we have assumed approx. 5% anaerobic conditions and a nitrous oxide production of 0.5% in order not to overestimate the effect of the co-composting process. The GWP varies between 245 and 470 kg CO_{2eq} per tonne FFB; for this analysis 245 kg CO_{2eq} per tonne FFB has been assumed.

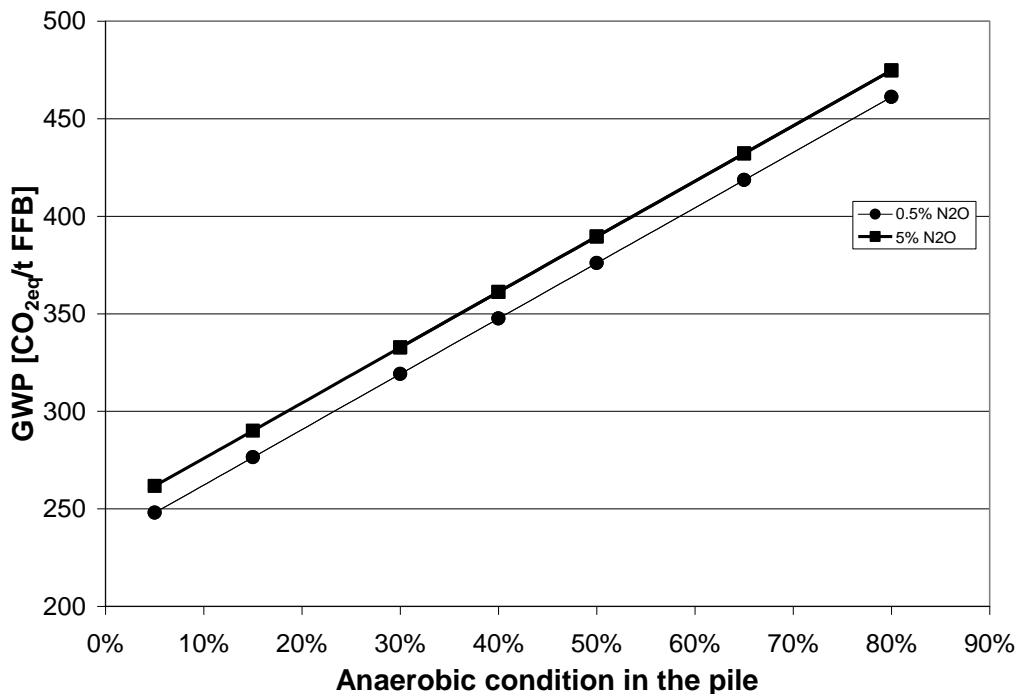


Fig. 3: Global warming potential due to EFB dumping depending on the degree of anaerobic conditions

Approx. 6 million hectares are used for palm oil plantations in Indonesia in 2005 and the area is growing constantly. Assuming an average yield of 20 t FFB per hectare and a GWP between 470 and 245 kg CO_{2eq} per tonne FFB for the conventional residue treatment system and 7 kg CO_{2eq} per tonne FFB for the advanced composting system, then the GWP reduction potential can be calculated according to:

$$GWP \text{ reduction potential} = \text{yield FFB / hectare} * \text{area} * \text{factor}_{\text{management}} * \Delta GWP / t \text{ FFB}$$

wherein the factor_{management} represent the proportion of palm oil plantation still using conventional palm oil mill residue treatment management. The factor_{management} is assumed to be between 0.25 and 0.60; meaning 25% or 60% respectively of the existing palm oil plantation in Indonesia dump EFB and store POME in open ponds. The GWP saving potential is enormous, provided that 25% of the palm oil mills in Indonesia treating residue conventionally between 6 and 11 million t CO_{2eq} per anno and be avoided and if it is 60% then the reduction potential is between 15 and 22 million t CO_{2eq} per anno. At a price of 14 € per tonne CO₂ the overall value of using the composting technique is considerable.

Summary

Due to co-composting of EFB and POME nutrients from EFB and POME are recovered, which is not just environmental beneficial but it also saves costs. The produced compost can be returned to the plantation and 39% Mg, 55% K, 40% P and 18% N is recycled based on the functional unit. Furthermore a significant amount of carbon is returned to the soil. The monetary value of the main nutrients of POME and EFB is about 218,457 €/a for an oil mill with a capacity of 30 t/h or 120,000 t FFB input a year (Schuchardt, 2002).

Additionally composting reduces the GHG-emissions from palm oil mill residue treatment significantly. On a national scale between 7 and 22 million t CO_{2eq} per anno can be saved depending on the total area used, the proportion of palm oil mills still using conventional residue treatment and emissions from EFB dumps... When 60% of the palm oil mills still dump EFB and store POME in open ponds then 17 million t CO_{2eq} emissions form Palm oil mills can be reduced in Indonesia through wide application of co-composting. The shift to advanced palm oil mill residue treatment can generate approximately 240 million € per year if accepted as Clean Development Measure (CDM).

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