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Letter to the editor

The bio-fuel debate and fossil energy use in palm oil production: a critique of Reijnders and Huijbregts 2007

The sustainability of bio-fuel production systems [1] is under intensive debate. Often, such systems are seen as a threat to food security and the environment, while their capacity to reduce greenhouse gas emissions is unclear. Here I refer to 'bio-fuels' as liquid transportation fuels from solid biomass.

Debating the pros and cons of bio-fuels is important: a clear picture will assist policy makers in deciding whether or not to encourage certain developments. Core issues in the debate are the energy and carbon balances of bio-fuel production. Energy captured in bio-fuels should exceed the fossil energy required during their production and net greenhouse emissions of bio-fuels should be less than those of conventional fuels; driving on bio-diesel should give reduced emissions of greenhouse gases as compared with driving on ordinary diesel.

Fossil energy use, hence some emission of CO_2, is almost unavoidable during production of bio-fuels since it is used for powering agricultural machinery and industrial processing facilities, and for production of fertilizers and pesticides. Greenhouse gas emissions also occur from agricultural soils and industrial wastewater in the form of N_2O and CH_4. Numerous scientific studies have analyzed the energy balance and environmental emissions from bio-fuel production systems [2–5]. But the figures and assumptions used in such studies are still hotly debated. For example, the magnitude of emissions from agricultural soils of N_2O, a greenhouse gas 296 times more potent than CO_2 [6],[1] is controversial [7,8]. Outcomes of the discussion imply that production and use of some bio-fuels could aggravate rather than reduce greenhouse gas emissions. Getting both the numbers right, and good estimates of uncertainty in these estimates, is essential to provide solid arguments on which to base policies relating to development of the bio-fuel sector. In this context I comment on the recent analysis of Reijnders and Huijbregts [9].

Reijnders and Huijbregts [9] rightfully point out that, in considering the capacity of bio-fuels based on palm oil to reduce greenhouse gas emissions, due account should be taken of carbon emissions from conversion of forests into plantations and from oxidation of peat soils, the methane emissions from wastewater and N_2O emissions from the soil. They also estimate carbon emissions linked to fossil fuel use in palm oil production, making a number of assumptions that I believe to be incorrect. Reijnders and Huijbregts state that fossil fuels are often preferred as energetic inputs in palm oil production, citing a paper of Prasertsan and Sajjakulnukit [10]. Prasertsan and Sajjakulnukit do not explicitly make this claim, nor provide sufficient grounds for it. The preference for fossil fuels assumed by Reijnders and Huijbregts is then applied to palm oil production across the whole of Southeast Asia, while Prasertsan and Sajjakulnukit [10] only considered palm oil production in Thailand. Palm varieties, growth conditions and plantation management in Thailand are substantially different from those in Malaysia [11] and production of palm oil in Thailand represents only 2% of the joint production of Malaysia and Indonesia [12]. Nevertheless, I examined the theoretical consequences of the assumptions made by Reijnders and Huijbregts.

Reijnders and Huijbregts assume that the energy input in plantation cropping, local transport and processing is $\sim$11 GJ/ton of palm oil. They assume that fossil fuels provide 75% of the energy input in palm oil production, hence 8.25 GJ/ton. Prasertsan and Sajjakulnukit [10], estimate the energy necessary for industrial processing at $\sim$8 GJ/ton palm oil, meaning that plantation agriculture requires some $11 - 8 = 3$ GJ/ton palm oil. These inputs usually consist of diesel, fertilizers and pesticides and hence, at least currently, can safely be assumed to be of fossil origin: thus using the assumption of Reijnders and Huijbregts, $8.25 - 3 = 5.25$ GJ/ton palm oil of the fossil energy is spent in industrial processing. Therefore $5.25/8.25 = 64\%$ of the energy in processing would be of fossil origin. This is not in line with reports from Malaysia [13] and Indonesia [14] that indicate that palm oil mills rely almost exclusively on combustion of oil palm crop residues (fibres and shells). Already in 1991, Wood and Corley reported that fruit fibre (and often the shells) was used to raise most of the processing energy required; Hai [15] reported that '*fibre and shell are currently the main sources of energy in the palm oil mill; their combustion in boilers produces more than sufficient energy to meet the mills energy demand*'. Similarly, in a PhD thesis on clean production technology for

[1] Over a 100-year time horizon.

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the crude palm oil industry in Thailand, Chavalparit [16] discusses energy balances of 5 wet oil palm mills[2] representative of different locations and production strategies in Thailand. In the energy balances presented, not more than 2% of the energy required in oil extraction and purification was provided by fossil energy: representing the small amount of electricity used for starting the boilers. This corresponds with the findings of Wood and Corley [17].

If we assume that plantation agriculture uses only fossil energy, and that in the processing industry 2% of the energy inputs are from fossil origin, then Reijnders and Huijbregts overestimate fossil fuel use by 5.1 GJ/ton oil, equivalent to 0.54 ton carbon/ha, if all fossil fuel used was mineral oil. Since the final total global warming impact score in ton CO_2 equivalent per ton of palm oil estimated by Reijnders and Huijbregts ranges from 2.6 to 18.2, the relative effect of such an overestimation on the end result ranges from 3 to 21%.

As a final note, improved production efficiencies of, for example, fertilizers in the past decades have probably reduced fossil energy consumption in oil palm cultivation compared with the still-widely-used estimates of Wood and Corley [17]. For production of nitrogen fertilizer, Wood and Corley [17] used a production energy requirement of 78.13 GJ/ton from Mudahar [18,19], dating back to the early 1980s. Nowadays 40–50 GJ/ton is more realistic [20–22]. Energy requirements for packaging [23] and transport [22], as were taken into account by Mudahar [18,19] are negligible. With a nitrogen application rate of 88 kg/ha [17], an energy reduction in palm oil production of $88 \times (78.13 - 45) = 2.9$ GJ/ha hence from 19.1 [17] to 16.2 GJ/ha is feasible. However, whether it is actually achieved depends on current fertilization practices and the state of the fertilizer industry in Southeast Asia.

A comprehensive update on palm oil energy balance and environmental emissions would be a great asset. And it is likely that recent knowledge of people from the sector would be more valuable in making such an update than that of scientists working thousands of miles away from the nearest plantation.

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[2] Dry mills are not used in large-scale production because the mixed oil resulting from it is not suitable for downstream processes [11].