Measuring Impact of Exports of Palm Oil Biodiesel on Direct and Indirect Land Use Changes in Malaysia

Chakrin Utit*; Mohd Yusof Saari** and Azman Hassan**

ABSTRACT

Palm oil biodiesel is often regarded as a renewable energy source with the potential to lower emissions of carbon dioxide (CO_2). However, exports of this product may face non-tariff trade barriers that are directed towards its role in bringing undesirable impacts to the environment. This article examines the impact of exports of palm oil biodiesel for the period 2010-2012 on direct and indirect land use changes in Malaysia. Data from a national economic survey alongside export data of palm oil biodiesel, crude palm oil production and land use for oil palm, rubber, cocoa, paddy and forests are utilised to calculate the extent of direct and indirect land use changes. In 2010, the effect of direct land use changes is recorded to be equal to -0.000156%, increasing to -0.000008% in 2012. For indirect land use changes, the highest effect recorded is for land planted with cocoa which is equal to 0.000292% in 2010, decreasing to 0.000016% in 2012. These results indicate that exports only contribute in a small way towards direct and indirect land use changes.

Keywords: palm oil biodiesel, land use changes, input-output, exports.

* Institute of Agricultural and Food Policy Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.

** Faculty of Economics and Management, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
E-mail: chakrin_utit@upm.edu.my

INTRODUCTION

Nowadays, the world depends heavily on the use of crude oil, petroleum and natural gases to run economic activities. These energy sources are non-renewable and will be completely depleted someday. To prolong the life-span of the energy reserves in Malaysia for future security, the government in 1980 initiated the National Depletion Policy (Oh *et al*., 2010). This policy shows that the government has been aware of the depleting problem as early as in the 1980s. During the 8th Malaysia Plan (2000-2005) period, the consumption rate of petroleum products grew at 4.5% annually, and increased to 6.1% in the 9th Malaysia Plan (2006-2010) period (Rahim and Liwan, 2012). Looking at this trend, it is expected that the demand for petroleum will keep on increasing, and that this will surely put a great deal of pressure on its supply.

On the other hand, the use of fossil fuel energy is said to be the major contributor of the climate change phenomenon. The use of fossil fuels in production processes contributes to the emission of greenhouse gases (GHG), namely, water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Too much of GHG contributes to the issue of global warming. A report by the Intergovernmental Panel on Climate Change (2007) showed that with GHG, the current global mean earth's surface temperature is about 14°C which is higher than the necessary temperature of -19°C that can be found at the altitude about 5 km above the surface. In order to control emission levels worldwide, the Kyoto Protocol (which is an agreement that commits every nation by setting internationally binding emission reduction targets) was adopted in 1997, and came into force in 2005. For Malaysia, the National Policy on Climate Change was enacted in 2010, focusing on sustainable development and taking into account environmental protection.

As awareness in global environmental issues is spiking globally, people are now turning to the alternative energy sources. Research and development (R&D) activities are vigorously conducted around the world to produce environmental-friendly and sustainable energy, such as and especially biofuel. In palm oil-producing countries such as Malaysia and Indonesia, this commodity is utilised for processing into biodiesel. After harvest, the fresh fruit bunches of oil palm undergo the processes of cooking, mashing and pressing to produce crude palm oil (CPO). At a later stage, palm oil biodiesel is derived by processing CPO into methyl ester, which can then be used directly. Blending it in a certain proportion with petroleum diesel will form Envo Diesel (Lim and Teong, 2010). Basically, oil palm which is a perennial crop is a better choice as the source for the production of biodiesel because it has a higher yield compared with soyabean, rapeseed and sunflower seed (Mekhilef *et al.*, 2011). According to the Malaysian Palm Oil Board (MPOB), the harvesting process starts 30 months after field planting, and thereafter the crop is harvestable all year long. All these characteristics show that oil palm is a good choice for biodiesel production.

A study on renewable and non-renewable energy consumption in Romania (Shahbaz *et al.*, 2011) shows that non-renewable energy that is used in the manufacturing sector contributes to the rising CO_2 emissions. These emissions are the worst externality cost in the consumption of this type of energy. In comparison with non-renewable energy, biofuels especially palm oil biodiesel are often mentioned as the incentive to lower GHG. A study by Sanjid *et al.* (2013) shows that biodiesel combustion tends to emit less GHG and produce less noise in an unmodified diesel engine. The presence of oxygen in biodiesel leads to more efficient combustion. This will produce less CO_2, particulates and smoke. For diesel engines, the use of biodiesel will help to reduce CO_2, carbon monoxide (CO), ozone-forming hydrocarbons, hazardous particulate matter (pm), and acid rain causing sulphur dioxide emissions (Dincer, 2008). However, biodiesel is said to contribute to indirect land use changes (iLUC). In the case of oil palm (*Elaeis guineensis*) in Malaysia, the amount of palm oil production in 1985 was 4.1 million tonnes, and this has continued to increase, reaching 18.9 million tonnes in 2011. Based on these statistics, the claim that a large amount of land has been converted to oil palm planted areas may not be rejected outright.

In the present context, iLUC usually refers to the conversion of land from its current use into use for the cultivation of energy crops. In the past few years, this conversion activity has been discussed extensively in some literature (*e.g.* Searchinger *et al.*, 2008; Bindraban *et al.*, 2009). Land conversion is carried out to support the increasing demand for the energy crops that are used in the production of biodiesel (Overmars *et al.*, 2011). The iLUC is widely recognised as and is a major discussion topic on the cause of increasing GHG. Expansion of planted area is needed to produce the raw material for biodiesel production. From 1985 to 2011, the statistics compiled by MPOB indicate that the size of oil palm planted areas in Malaysia increased from 1.5 million to 4.9 million hectares. A study proved that accelerating demand for palm oil contributed to the 1.5% annual rate of deforestation of tropical rainforests (Fargione *et al.*, 2008). Thus, this gives a clear indication that energy crops, especially oil palm, play an active role in contributing towards iLUC.

The effort to produce palm oil biodiesel in Malaysia started in the early 1980s. From 1984 onwards, MPOB in collaboration with Petronas has been able to produce 3000 t of palm oil methyl ester annually (Lim and Teong, 2010). However, this output is only used for laboratory testing, stationary engine evaluation and field trials as described by Mukti *et al.* (1986). Even though extensive research and trials have been conducted, no major breakthroughs were made, and this situation continued until the announcement of the Fifth Fuel Policy under the 8th Malaysia Plan (2000-2005) (Lim and Teong, 2010). With this policy enforced, the production of biodiesel in Malaysia increased by 168.49 million litres from 2006 to reach 521.76 million litres in 2008. Production in 2009 then experienced a huge reduction by 280.45 million litres from the amount in 2008, and continued to drop to the lowest level of 55.44 million litres in 2011. According to Oh *et al.* (2010), production was targeted mainly for export purposes, with exports increasing from 345.67 million litres in 2006 to 630.46 million litres in 2008. There were drastic decreases in the years that followed years, leading to the lowest record of 31.52 million litres in 2012.

Based on a report prepared by the United States Department of Agriculture (2013), the European Union (EU) became the highest importer of palm oil biodiesel from Malaysia in 2011, with an amount equal to 38 811 t or 77.62% of the total export value. In the following year, the export value was 21 832 t or 75.32%. The slight reduction in export value was caused by the imposition of a non-tariff trade barrier on palm oil biodiesel. This is because one litre of biodiesel can only reduce 17% of its life cycle GHG emissions; however, the requirement to be recognised as a renewable fuel is a reduction by at least 20% (Szulczyk, 2013). The same study also stated that the trade barrier imposed is a way to protect the rapeseed biodiesel industry in EU.

To demonstrate the contribution of palm oil biodiesel to iLUC, the input-output technique is employed. This technique is used extensively by environment researchers especially in impact studies (*e.g.* Munksgaard *et al.*, 2005; Turner *et al.*, 2007). In the case of land use, a study was conducted in China using the input-output model to find out how changes in the economy and society affected future land use at a regional level (Hubacek and Sun, 2001). Another study by Labandeira and Labeaga (2002) used this technique to obtain data on energy-related CO_2 emission in Spain. By using this technique, the results show a great variety of input-output model applications in the environmental field. The input-output technique is also known for its ability to take into account all inter-industry activities. It can demonstrate the drag effect in an economy if changes occur in any industry. This is because the output of one industry is the input of another.

METHODOLOGY AND DATA

Extended Input-Output Model for iLUC

Input-output analysis is a modeling technique that is frequently used by economists to study the relationship between different sectors. Basically, this technique shows the interdependency between production sectors in the economy. Interdependency means production sectors will purchase goods and services from other sectors as intermediate input for their production, and in turn produce output which are then sold to other sectors and consumers.

With the capability of capturing the interdependency of different sectors, input-output analysis is best applied for the calculation of the total requirements of environmental resources for a unit of final demand (Matete and Hassan, 2005). With this analysis, the total requirements (direct and indirect) of the input to satisfy final demand can be assessed. One example of the application of input-output analysis in the case of environmental resources is the study by Velazquez (2006). This study in Andalusia tried to determine which economic sectors consumed the greatest quantities of water and the extent by which water may become a limiting factor in the growth of certain production sectors. In Taiwan, a study using input-output structural decomposition analysis was done to examine the trends of emission and the effects from the changes in CO_2 emission by various industries over the period 1981-1991 (Chang and Lin, 1998). In the case of land, Hubacek and Giljum (2003) applied the input-output analysis to calculate the requirements of land for producing exported goods from the European countries to the rest of the world. The vast application of input-output analysis in studies on the environment has become the main motivation for this modeling technique to be used in this study.

The dataset for the analysis in this study is the Malaysian 2005 input-output table. Modeling for iLUC requires the construction of an extended input-output table which accounts for the changes in land use for planting oil palm and residuals. *Table 1* shows an ordinary input-output table that is extended by including land and residuals in physical units.

The demand and supply of intermediate input among the production sectors are denoted by the matrix Z (*nxn*). Final demand on the other hand is separated into two matrices, namely, domestic demand f^D (*nxd*) and export f^E (*nxe*). The vector for total output is represented by x, and it is equal to total input, x'. Matrix M (*mxn*) refers to the land input in the production sectors expressed in physical units. In addition, these land input can be further disaggregated based on categories. In the vector for residuals, Matrix N (*n* x *k*) explains how much of the output in the form of GHG (*e.g.* CO_2, NO_x, SO_2) is released into the environment from the production sectors.

Based on the structure of *Table 1*, to obtain the output for sector *j x* , the vector for final demands which consist of f^D and f^E can be multiplied by the inverse matrix. The standard model formulation that shows how the model is linked to environmental analysis is expressed as follows:

$$x=(I - A)^{-1}(f^D+f^E) = L(f^D+f^E) \qquad (1)$$

where I is the identity matrix, and A ($A=Z\hat{x}^{-1}$) is the domestic input coefficient matrix. Matrix A represents the direct requirements of commodity *i* needed per physical unit of commodity *j's* production. Matrix $(I - A)^{-1}$ represents the total production every sector must generate to satisfy the final demand of the economy. In input-output modeling, final demand is treated as an exogenous variable. By changing the level of this vector, the economic impacts of the policy variables can be analysed.

To account for land use change and pollution generated, the consumption of land input and pollution are assumed to be linearly related to output. Thus, this assumption can be expressed as the following equations:

$$R^* = R(I - A)^{-1}(f^D + f^E) = RL\,(f^D + f^E) \qquad (2)$$

where $R=M\hat{x}^{-1}$, with the equation expressed in the physical unit per ringgit of the land use change.

$$Q^* = Q(I - A)^{-1}(f^D + f^E) = QL\,(f^D + f^E) \qquad (3)$$

where $Q=N'\hat{x}^{-1}$, with the equation expressed in the physical unit per ringgit of the pollution generated.

In Equation (2), R* represents the amount of land that is required directly and indirectly to deliver a ringgit worth of sector *j*'s output to meet final demand. The Q* in Equation (3) indicates the amount of pollution generated directly and indirectly in the process of delivering a ringgit worth of sector *j*'s output to meet final demand.

Econometric Model

The extended input-output modeling gives the means for measuring the extent of iLUC resulting from palm oil biodiesel export. However, to look at the relationship between palm oil production with land use change, we have to explore the econometric modeling. Before that, we will have to conduct the Dickey-Fuller unit root test to determine whether the time series variables used in this study are stationary when using an autoregressive model. If no unit root problem is detected, then multiple regression analysis by using ordinary least squares (OLS) will be done. The relationships between CPO production and different land types are then tested. Land type includes land planted with rubber, paddy, or cocoa, and forested land. The economic

TABLE 1. EXTENDED INPUT-OUTPUT FLOWS

Input-output matrix	Production activities	Final demand		Total output	Residuals
		Domestic	Export		GHG
Production activities	Z	f^D	f^E	-	N
Value-added	-	v	-	x	
Imports	-	e	-	-	
Total input	-	x'	-	-	
Land use	M				

Note: For clarity, matrices are indicated by bold, upright capital letters; vectors by bold, upright lower case letters and scalar by italicised lower case letters. Vectors are columns by definition, so that row vectors are obtained by transposition, indicated by a prime (*e.g.* x'). A diagonal matrix with the elements of vector x on its main diagonal and all other entries equal to zero are indicated by a circumflex (*e.g.* $\hat{x}$).

function of land use change is shown as follows:

Land use area=f(crude palm oil production) (4)

The multiple regression model is shown below:

$$log\ e = \beta_0 + \beta_1 \log x_i + \varepsilon \quad (5)$$

where:

log e = natural logarithm of land use area;
β_0 = constant;
β_1 = coefficient for crude palm oil production;
$\log x_i$ = natural logarithm of crude palm oil production; and
ε = error term

Data

Three sets of data were used for this study. First data set was the 2005 input-output table derived from the Department of Statistics Malaysia (DOSM). It consists of 120 sectors and is classified according to the Malaysia Standard Industrial Classification (MSIC) (Department of Statistics Malaysia, 2010). The input-output table was utilised to measure the impact from the increase in exports of palm oil biodiesel on land use change. The biodiesel sector was also broadly classified under the sector for oils and fats in the input-output table for further analysis.

For the land use change scenario, the planted area data which includes oil palm, rubber, cocoa, paddy and forests are derived from DOSM. The data range from the year 1980 to 2012. All of these data are recorded in hectares of planted area, and were used to show the changes in the size of the oil palm planted area. With biodiesel production data being only available for the period 2006-2013, CPO production data from MPOB were used as the proxy. These data were recorded in tonnes. The same type of data has been used by Wicke *et al.* (2011) in a study to explore land use change and the role of palm oil production in Indonesia and Malaysia. By using both of these data, any relationship that exists between palm oil biodiesel production and land use change by land type can be investigated.

The third data set was also derived from MPOB. Data on exports from the palm oil biodiesel sector, in the period from 2008 to 2013, were used to calculate the extent by which the sector contributed to land use change. These data are available in the forms of tonnes and ringgit. To look further into the impact of exports of palm oil biodiesel on land use change, analysis was done using the extended input-output model as described in the earlier part of the methodology.

With respect to the objective of this article, an aggregation problem was identified. The use of CPO as the proxy for biodiesel only provided a rough estimate of the relationship between biodiesel production and land use change. This is because CPO was also utilised for the production of products other than biodiesel. Nevertheless, this article is able to provide a general idea of the extent of the land use change caused by palm oil biodiesel exports.

RESULTS AND DISCUSSION

Impacts on production

For further discussion on the impact of palm oil biodiesel on iLUC, we first need to take a look at the export data of biodiesel in Malaysia. *Table 2* shows that from the years 2008 to 2009, the export quantity increased by 24.90% from 182 108 to 227 457 t. With price adjustment using 2009 as the base year, it can be seen that the income from these exports increased by 23.89% from RM 488.94 million to RM 605.75 million. Over the subsequent years (2009-2012), both the export quantity and output decreased significantly because of the world economic crisis that hit most countries, especially those in the EU zone which is the biggest importer of palm oil biodiesel. According to a report by the United States Department of Agriculture (2013), the reduction particularly in 2012 was also caused by the export tariff differential between Malaysia and Indonesia. For the period 2012 to 2013, 503.9% of growth in export quantity was recorded due to an adjustment in export duties and lower CPO prices. The adjustment has made Malaysian biodiesel

TABLE 2. EXPORTS OF PALM OIL BIODIESEL

Year	Tonnes	RM
2008	182 108	488 942 330
2009	227 457	605 750 000
2010	89 609	105 002 206
2011	49 999	39 505 578
2012	28 983	12 543 410

Note: RM figures use 2009 as the base year.
Source: MPOB (2012).

exports more competitive and boosted their export quantity and income considerably.

In order to quantify the impact on iLUC from palm oil biodiesel, the export data were utilised to determine the changes in the total output for the aggregated industry. As land type used in this study was categorised according to land under oil palm, rubber, paddy, cocoa, and land for forestry and logging, the output value of each sector was extracted from the agricultural industry. To compute these values, the share of production for each sector from the total output in the 2005 input-output table was multiplied by the total output in the agricultural industry. Based on these calculations, the oil palm sector held a share of 0.36, followed by rubber 0.10, cocoa 0.02, paddy 0.02 and forests 0.15. *Table 3* shows the output of each sector from the years 2009 to 2012, after also taking into account the contribution of palm oil biodiesel exports to the economy. The changes in output were then calculated from *Table 3*. From 2009 to 2010, the output from each land type decreased by 0.02%, and kept on decreasing until 2012 when it reached 0.001%. However, the output value increased by 0.015% in the year 2013 due to changes in policy as described in the earlier part of this section.

Before going into details on the effects on iLUC, let us take a look at the elasticity for each land type. For oil palm, the elasticity is 0.7979, followed by rubber at -0.4355, paddy 0.0006, cocoa -1.4969 and forests 0.2325. The elasticity for forests, for example, can be interpreted as follows: a 1% increase in CPO production leads to an increment by 0.2325% in iLUC.

Finally, the extent by which palm oil biodiesel contributed to iLUC was calculated. To derive the percentage values of the impact, the output changes that had been calculated as described before were multiplied with the elasticity for each land type. From *Table 4*, it is proven that the contribution of palm oil biodiesel towards iLUC is rather small. This shows that EU had wrongly assumed that their imports of palm oil biodiesel had induced iLUC. The study done by Fargione *et al*. (2008) only showed that the accelerating demand for palm oil contributed to an increasing rate of deforestation. In our study, the use of palm oil as both food and biodiesel was included. The study by Oh *et al.* (2010) showed that the increase in palm oil biodiesel production was achieved through yield increase and production efficiency rather than by increasing the size of the planted area.

Impacts on iLUC

As the Dickey-Fuller unit root test indicated that all the variables used were stationary, *i.e.* the values of the augmented Dickey-Fuller (ADF) test-statistics were greater than the critical

TABLE 3. TOTAL OUTPUT OF DIFFERENT CROPS (RM) BY YEAR

Year	Oil palm	Rubber	Cocoa	Paddy	Forests
2009	70 340 678	18 980 752	3 555 460	3 337 242	29 433 545
2010	70 326 944	18 977 046	3 554 765	3 336 590	29 427 798
2011	70 325 148	18 976 561	3 554 675	3 336 505	29 427 047
2012	70 324 408	18 976 362	3 554 637	3 336 470	29 426 737

Source: Computed from Equation (1).

TABLE 4. EFFECTS OF LAND USE CHANGES

Section	Oil palm	Rubber	Cocoa	Paddy	Forests
A. Change in land use (ha)					
2010	-756.1528	86.3242	5.6747	-0.0839	-820.9550
2011	-101.9049	11.2665	0.7855	-0.0111	-106.9011
2012	-42.5955	4.8528	0.3417	- 0.0046	-44.2302
B. Change in land use (%)					
2010	-0.000156	0.000085	0.000292	-0.000000	-0.000045
2011	-0.000020	0.000011	0.000038	-0.000000	-0.000006
2012	-0.000008	0.000005	0.000016	-0.000000	-0.000002

Source: Computed from Equation (2).

values, OLS was then conducted. The null hypothesis that stated the variable has a unit root can thus be rejected. *Table 5* shows that oil palm, rubber, cocoa and forested land were statistically significant at the probability level of 5%. All the null hypotheses were rejected, showing that the increased production of CPO did bring about the conversion of active agricultural land into oil palm planting. These findings can be supported by a few past studies. Based on the study done by the working group of the Roundtable on Sustainable Palm Oil (2013) in Peninsular Malaysia, 0.59 million hectares of the newly planted areas of oil palm in 2006 were converted from ex-rubber land, while 0.36 million hectares were converted from forested land. The finding relating to the forested land is also supported by Clay (2004) and Fitzherbert *et al*. (2008) who claimed that there is a direct relationship between deforestation and the expansion of oil palm planted area, especially in the South-east Asian region.

Paddy land was the only land type that was not statistically significant at the 5% probability level. The null hypothesis failed to be rejected, showing that paddy land had not been converted into oil palm plantings. However, the results for a similar study by the Roundtable on Sustainable Palm Oil show that approximately 0.10 million hectares of land relating to paddy, coconut, horticulture and other food crops had been converted into oil palm land in Sabah. At the regional level, the conversion might have happened, but the scale is too small to affect the whole nation. The same applies for the finding by Feintrenie *et al.* (2010) which shows that paddy land had been converted into oil palm land in the case of Bungo district in Indonesia. This land conversion which happened in Bungo is just a case under one specific district and may not represent the situation in Indonesia as a whole.

CONCLUSION

This article analysed the contribution of palm oil biodiesel exports towards indirect land use changes in Malaysia. Data from the input-output table and on the exports of palm oil biodiesel were utilised for the analyses. Results suggest that the impact on indirect land use changes from palm oil biodiesel is lower than what had been claimed by EU. They prove that the production and export of palm oil biodiesel do not pose a really big threat to the environment. Historical data may have suggested that palm oil biodiesel does contribute towards land use changes, but over the years advancements in oil palm planting technology have enabled the increases in production and exports of palm oil biodiesel without having to increase the planted area (Edwards *et al*., 2010).

Despite the usefulness of this article in showing the contribution of palm oil biodiesel towards land use changes, the limitation of data has been the main obstacle for further analysis. The production and export data of the Malaysian biodiesel industry have only existed for a short time period, *i.e.* from 2006 to 2013. Within this period, it is somehow difficult to analyse whether the increases in biodiesel production and exports do contribute to land use changes. The use of data on CPO as a proxy for biodiesel production only provided a rough estimate of the land use change scenario as CPO is also processed for other purposes. Regardless of this limitation, the article is able to give an insight into the relationship between the Malaysia biodiesel industry and land use changes.

TABLE 5. IMPACTS ON iLUC

Land type	Constant	Coefficient	t-statistic	P-value	R^2	Dr-W stat
Oil palm	2.0732	0.797912*	56.6579	0.0000	0.9904	1.9601
Rubber	21.1236	-0.4355*	-13.0827	0.0000	0.8467	0.3245
Paddy	13.4156	0.0006	0.0853	0.9326	0.0002	0.8160
Cocoa	35.4006	-1.4969*	-8.0867	0.0000	0.6784	0.1214
Forests	12.9400	0.232514*	4.9279	0.0000	0.4393	0.4362

Note: * Statistically significant at 5% level.
Source: Computed from Equation (5).

REFERENCES

BINDRABAN, P S; BULTE, E H and CONIJN, S G (2009). Can large-scale biofuels production be sustainable by 2020? *Agricultural Systems, 101(3)*: 197-199.

CHANG, Y F and LIN, S J (1998). Structural decomposition of industrial CO_2 emission in Taiwan: an input-output approach. *Energy Policy, 26(1)*: 5-12.

CLAY, J (2004). Palm oil. *World Agriculture and the Environment: A Commodity-by Commodity Guide to Impacts and Practices*. Island Press, Washington, DC. p. 203-235.

DEPARTMENT OF STATISTICS, MALAYSIA (2010). *Input-output Tables Malaysia 2005*. Department of Statistics, Malaysia, Putrajaya.

DEPARTMENT OF STATISTICS, MALAYSIA (2013). *Malaysia Economics Statistics-Time Series 2013*. Department of Statistics, Malaysia, Putrajaya.

DINCER, K (2008). Lower emissions from biodiesel combustion, energy sources: part A. *Recovery, Utilization, and Environmental Effects, 30(10)*: 963-968.

EDWARDS, R; MULLIGAN, D and MARELLI, L (2010). Indirect land use change from increased biofuels demand. *Comparison of Models and Results for Marginal Biofuels Production from Different Feedstocks.* EC Joint Research Centre, Ispra.

FARGIONE, J; HILL, J; TILMAN, D; POLASKY, S and HAWTHORNE, P (2008). Land clearing and the biofuel carbon debt. *Science, 319(5867)*: 1235-1238.

FEINTRENIE, L; CHONG, W K and LEVANG, P (2010). Why do farmers prefer oil palm? Lessons learnt from Bungo district, Indonesia. *Small-Scale Forestry, 9(3):* 379-396.

FITZHERBERT, E B; STRUEBIG, M J; MOREL, A; DANIELSEN, F; BRÜHL, C A; DONALD, P F and PHALAN, B (2008). How will oil palm expansion affect biodiversity? *Trends in Ecology & Evolution, 23(10)*: 538-545.

HUBACEK, K and GILJUM, S (2003). Applying physical input–output analysis to estimate land appropriation (ecological footprints) of international trade activities. *Ecological Economics, 44(1)*: 137-151.

HUBACEK, K and SUN, L (2001). A scenario analysis of China's land use and land cover change: incorporating biophysical information into input–output modeling. *Structural Change and Economic Dynamics, 12(4)*: 367-397.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (2007). What factors determine earth's climate? Retrieved from https://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-1.html.

LABANDEIRA, X and LABEAGA, J M (2002). Estimation and control of Spanish energy-related CO_2 emissions: an input–output approach. *Energy Policy, 30(7)*: 597-611.

LIM, S and TEONG, L K (2010). Recent trends, opportunities and challenges of biodiesel in Malaysia: an overview. *Renewable and Sustainable Energy Reviews, 14*(3): 938-954.

MPOB (2012). *Malaysian Oil Palm Statistics 2012*. MPOB, Bangi.

MATETE, M and HASSAN, R (2005). An ecological economics framework for assessing environmental flows: the case of inter-basin water transfers in Lesotho. *Global and Planetary Change, 47(2)*: 193-200.

MEKHILEF, S; SIGA, S and SAIDUR, R (2011). A review on palm oil biodiesel as a source of renewable fuel. *Renewable and Sustainable Energy Reviews, 15(4)*: 1937-1949.

MUKTI, M A A; YUSUF, M Z M and ALI, A R (1986). Palm oil as alternative fuel diesel engines. *PORIM Bulletin No. 9*: 22–34.

MUNKSGAARD, J; WIER, M; LENZEN, M and DEY, C (2005). Using input output analysis to measure the environmental pressure of consumption at different spatial levels. *J. Industrial Ecology, 9(1-2)*: 169-185.

OH, T H; PANG, S Y and CHUA, S C (2010). Energy policy and alternative energy in Malaysia: issues and challenges for sustainable growth. *Renewable and Sustainable Energy Reviews, 14(4)*: 1241-1252.

OVERMARS, K P; STEHFEST, E; ROS, J P and PRINS, A G (2011). Indirect land use changes emissions related to EU biofuel consumption: an analysis based on historical data. *Environmental Science & Policy, 14(3)*: 248-257.

RAHIM, K A and LIWAN, A (2012). Oil and gas trends and implications in Malaysia. *Energy Policy, 50*: 262-271.

ROUNDTABLE FOR SUSTAINABLE PALM OIL (2013). Land use changes in Malaysia. Retrieved from http://www.rspo.org/file/GHGWG2/7_land_use_change_Malaysia_Rashid_*et_al*.pdf.

SANJID, A; MASJUKI, H H; KALAM, M A; RAHMAN, S A; ABEDIN, M J and PALASH, S M (2014). Production of palm and jatropha based biodiesel and investigation of palm-jatropha combined blend properties, performance, exhaust emission and noise in an unmodified diesel engine. *J. Cleaner Production, 65*: 295-303.

SEARCHINGER, T; HEIMLICH, R; HOUGHTONS, R A; DONG, F; ELOBEID, A; FABIOSA, J; TOKGOZ, S; HAYES, D and YU, T H (2008). Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science, 319(5867)*: 1238-1240.

SHAHBAZ, M; ZESHAN, M and TIWARI, A K (2011). Analysis of renewable and nonrenewable energy consumption, real GDP and CO2 emissions: a structural VAR approach in Romania. MPRA Paper No. 34066. Retrieved from http://mpra.ub.uni-muenchen.de/34066.

SZULCZYK, K R (2013). The economics of the Malaysian palm oil industry and its biodiesel potential. *Social Science Research Network 2309130*.

TURNER, K; LENZEN, M; WIEDMANN, T and BARRETT, J (2007). Examining the global environmental impact of regional consumption activities – Part 1: a technical note on combining input–output and ecological footprint analysis. *Ecological Economics, 62(1)*: 37-44.

UNITED STATES DEPARTMENT OF AGRICULTURE (2013). Malaysia. Biofuels Annual. Retrieved from http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Kuala%20Lumpur_Malaysia_7-9-2013.pdf.

VELAZQUEZ, E (2006). An input–output model of water consumption: analysing intersectoral water relationships in Andalusia. *Ecological Economics, 56(2)*: 226-240.

WICKE, B; SIKKEMA, R; DORNBURG, V and FAAIJ, A (2011). Exploring land use changes and the role of palm oil production in Indonesia and Malaysia. *Land Use Policy, 28(1)*: 193-206.