ISSN 1327-8231

ECONOMICS, ECOLOGY AND THE ENVIRONMENT

Working Paper No. 159

The Production of Biofuels: Welfare and Environmental Consequences for Asia

by

Clem Tisdell

September 2009

THE UNIVERSITY OF QUEENSLAND

ISSN 1327-8231
WORKING PAPERS ON

ECONOMICS, ECOLOGY AND THE ENVIRONMENT

Working Paper No. 159

The Production of Biofuels Welfare and Environmental Consequences for Asia[*]

by

Clem Tisdell[†]

September 2009

---

[*] A paper presented at the International Workshop on Climate Change Growth in Asia organized by the Griffith Asia Institute and the Asia-Pacific Centre for Sustainable Enterprise, Griffith University and to be held at Robertson Gardens, Robertson, Brisbane on 8 September, 2009.

[†] School of Economics, The University of Queensland, St. Lucia Campus, Brisbane QLD 4072, Australia
Email: c.tisdell@economics.uq.edu.au

WORKING PAPERS IN THE SERIES, *Economics, Ecology and the Environment* are published by the School of Economics, University of Queensland, 4072, Australia, as follow up to the Australian Centre for International Agricultural Research Project 40 of which Professor Clem Tisdell was the Project Leader. Views expressed in these working papers are those of their authors and not necessarily of any of the organisations associated with the Project. They should not be reproduced in whole or in part without the written permission of the Project Leader. It is planned to publish contributions to this series over the next few years.

Research for ACIAR project 40, *Economic Impact and Rural Adjustments to Nature Conservation (Biodiversity) Programmes: A Case Study of Xishuangbanna Dai Autonomous Prefecture, Yunnan, China* was sponsored by the Australian Centre for International Agricultural Research (ACIAR), GPO Box 1571, Canberra, ACT, 2601, Australia.

The research for ACIAR project 40 has led in part, to the research being carried out in this current series.

For more information write to Emeritus Professor Clem Tisdell, School of Economics, University of Queensland, St. Lucia Campus, Brisbane 4072, Australia.

The Production of Biofuels:
Welfare and Environmental Consequences for Asia

ABSTRACT

The production of biofuels has been supported by many conservationists and environmentalists on the grounds that it reduces greenhouse gas emissions and is a renewable energy substitute for non-renewable fossil fuels, mainly oil. More recently the domestic production of biofuels (and the domestic supply of other forms of alternative energy) have been welcomed by several nations as ways to reduce their oil imports and increase their energy self-sufficiency, as for example, has happened in the United States. India also which is very dependent on oil imports has also begun to produce biofuels in Kerala and elsewhere. However, doubts have been raised about the effectiveness of biofuel use as a means to reduce the accumulation of greenhouse gases and elementary economics teaches us that it is likely to have opportunity costs. For example, increased cropping to provide biofuels can be at the expense of the production of food and natural fibres thereby adding to their prices. It may also increase the conversion of natural areas to agricultural use and consequently, add to biodiversity loss and an increase in greenhouse gas in the atmosphere. For example, in Borneo, forests are being converted to grow oil palm, partly used for biodiesel production in developing countries. These issues are discussed generally and their economic welfare implications are given particular attention in relation to Asian nations. Amongst the different situations examined from economic welfare and environmental points of view are the following:

1. Asian nations producing biofuels for their own use from home-grown crops, as is the case of India and China.
2. The external trade of Asian countries in feedstock for biofuels, such as palm oil in Indonesia and Malaysia and in biofuel itself.
3. Possible Asian ventures to grow crops for biofuels abroad or import biofuels.
4. The economic consequences for Asian countries of decisions by higher income countries, such as the United States (which also happens to be a major global exporter of food and natural fibre), to raise their production of biofuels.

Analysis is provided that casts doubts on the likelihood that the introduction of biofuels will reduce greenhouse gas accumulation in the atmosphere.

The Production of Biofuels:
Welfare and Environmental Consequences for Asia

1. Introduction

The use of biofuels has been supported by many environmentalists (for example, the German Green Party) as a way to reduce global warming. This paper expresses doubts about their potential to do this and focuses on the production of liquid biofuels (primarily ethanol and biodiesel) taking into account the implications of the rapid expansion in the global production of these fuels for Asian nations. Further substantial increases in the production of biofuels (stimulated by government subsidies and economic incentives) are expected in coming decades as available supplies of mineral oil begin to decline and the long-term real price of mineral oil rises.

Economic growth in Asia, particularly in China and India, has accelerated the demand of Asian nations for oil and this trend can be expected to continue as the number of motor vehicles in Asia escalates. Asia has insufficient oil to meet its demand and is heavily reliant on imports, and its oil deficit is expected to magnify. The oil deficit situation of Asian countries varies. Japan is completely dependent on imported oil, both China and India have a high degree of reliance on imports, and even Indonesia is now a net importer of oil. Given the pivotal role of oil in providing fuel for transport purposes in modern economies, the possibility of substituting biofuels for fuels derived from mineral oils seems *on the surface* to be an attractive option for Asian countries.

There are several reasons why Asian nations might want to produce biofuels. These include:

(1) to increase their economic and defence security;

(2) to reduce local air pollution;

(3) to make some contribution towards reducing the intensity of their greenhouse gas (GHG) emissions. However, Yan and Lin (2009, p. S4) suggest that this is not yet a high priority for most Asian nations;

(4) Asian countries may also want to ensure that they have accumulated experience and knowledge in producing biofuels before the price of mineral oil rises substantially; and

(5) some Asian nations believe that the production of biofuel feedstock will boost agricultural incomes.

Nevertheless, as discussed below, Asian countries face several constraints in increasing their production of biofuels and for most, substantial production of biofuel by them is not an attractive economic option.

Opportunity costs are involved in producing biofuels. These are discussed generally and then the pattern of global biofuel production is outlined along with economic measures that have been adopted by governments to support it. Subsequently, attention focuses on the production of biofuels by Asian countries for their own use, their exports and imports of biofuels and of biofuel feedstock, as well as associated foreign direct investment. Some of the economic consequences for Asian countries of higher income countries expanding their production of biofuels are also considered as well as their own decisions to increase their production of biofuels. Note that Asian countries in this article refer only to those in east and south Asia.

2. The Opportunity Costs of Producing Liquid Biofuels

Neoclassical economists placed considerable stress on the importance of the concept of 'opportunity cost'. They argued that, in general, because of resource scarcity, an increase in the production of one commodity can only be obtained by forgoing the availability of some other commodity or set of other commodities. Trade-off is required and the amount of the trade-off indicates the opportunity cost of increasing the supply of the focal commodity which in this case could be a biofuel or a collection of biofuels.

However, economists also recognized that the need for trade-off could be avoided as a result of productivity enhancing technological progress, by reducing allocative inefficiency or X-inefficiency, or both, if they are present. Technological progress moves the production possibility frontier to the right and a reduction in the two types of inefficiencies mentioned moves production closer to an economy's production possibility frontier.

Neoclassical economists also envisaged capital accumulation as an additional means to bring about economic growth and push the production possibility frontier to the right. However, neo-Malthusian economists argue that the process may eventually result in unsustainable economic growth because capital accumulation tends to reduce the stock of natural capital Tisdell (1997; 2005, Ch.11; 2009, Ch. 7). Although the feedstock for biofuels is renewable, when the whole production cycle of biofuels is considered some non-renewable resources can be expected to be used up in the process and also a major expansion in biofuel production is liable to result in biodiversity loss both as a result of agricultural intensification and extension. This is clear in the case of production of first generation biofuels. These are being produced now using agricultural feedstock such as maize, wheat and so on.

The supply of feedstock for the production of first generation biofuels is likely to be at the expense of food production, in some cases natural fibre production such as cotton, rubber and other cultivated crops. Ethanol and biodiesel are the two main liquid biofuels produced today. Ethanol is produced from starch and sugar from several sources, for example, maize, sugar cane or sugar beet, wheat, and less frequently, sweet sorghum. Except for the latter, these are used for human consumption and also their grains are utilized to produce feed for livestock. Biodiesel is manufactured from natural oils. The main oils used for this purpose are canola (rapeseed), soy, palm and coconut. These are all edible oils and many have additional uses, for example, palm oil is used in manufacturing margarine and many soaps.

India has plans to extract oil from jatropha (*Jatropha curcus*) to produce biodiesel. Jatropha has a high (inedible) oil content and "can grow in arid and semi-arid regions, tropical and subtropical areas and grow even on barren and wastelands, degraded soils having low fertility and moisture but cannot stand heavy frost" (Punia, 2007). It fruits after 2 years and continues to do so for 30-40 years. Punia (2007) estimates that 40 million ha. of wasteland could be developed in India to grow jatropha. However, it is unclear whether these so called 'wastelands' currently perform ecological functions of economic value or have some direct use, for instance for light grazing by livestock. If so, the opportunity cost of using them to grow jatropha may not be zero. Secondly, there is not guarantee that the growing of jatropha will be confined to wastelands in India. Depending upon the profitability of growing it, it may displace existing crops in some areas or livestock production.

Second generation biofuels are being developed which rely on the use of cellulose and lignocellulose in plants. Conversion to ethanol or biodiesel is possible but still remains very expensive. However, the costs involved are expected to fall as scientific research progresses. Several scientists agree that the opportunity cost involved in supplying feedstock for producing second generation biofuels is likely to be eventually much lower than for first generation biofuels. Fast growing grasses, unmerchantable forests and timber and cellulosic wastes from farms, timber mills and household garbage could in theory be converted to these biofuels. Their advocates argue that they will have a low degree of competition with existing crops for land use and that they may reduce pollution associated with the disposal of some cellulosic wastes.

Once again, however, there is no guarantee that this feedstock will not be grown in some areas used today to produce food, fibre and other agricultural products. Lack of substitution cannot be assumed. Furthermore, a greater and more extensive use of land to provide feedstock for second generation of biofuels can be expected to bring about a further reduction in biodiversity and may actually increase GHG emissions.

Questions have also been raised about the contribution of biofuels to GHG reductions. In some instances, when the whole cycle of production is considered, they may even add to greenhouse gas emissions, as in the case of the production of ethanol from maize in the United States. This is probably also the case for biodiesel production from palm oil in cases where expansion occurs by the clearing of tropical forest. In addition, there is considerable loss of biodiversity. The same may be said of the expansion of soybean production in the Amazon to produce soya oil for the manufacture of biodiesel. While it is claimed that second generation biofuels will result in a greater reduction in GHG than first generation biofuels, their overall effectiveness in that regard has been questioned, for example, by Colin Hunt (2009, Ch. 6).

Yan and Lin (2009, p. S1) observe that "some biofuels, especially those linked to first generation biofuels, have received considerable criticism recently – most notably the biofuel potential to increase food prices; their relatively low greenhouse gas (GHG) abatement capacity yet high marginal carbon abatement costs; their continuing need for significant government support and subsidies; their direct and indirect impacts on land use change; and related greenhouse gas emissions". Even in the case of second generation biofuels produced from forest resources, there is debate about their likely net impact on the stock of GHG in the atmosphere. While fuel from petroleum emits more CO_2e than biofuel obtained from wood, reduced stands of wood (and similar substances) reduce their capacity to sequester carbon. Therefore, even in this case, total CO_2e in the atmosphere may rise as a result of the production of these biofuels. In any case, if economic growth continues globally (and particularly in significant Asian countries), there may be little or no reduction in the total uses of petrol and diesel in the near future as a result of the increased supply of biofuels. In fact, total GHG emissions could actually increase because the combustion of biofuels still emits GHG gases even if these are lower than for mineral fuels. Switching to biofuel is likely to be induced eventually by increasing scarcity of mineral oil and the long-term increase in its price rather than the reputed environmental advantages of biofuels. At least this seems likely to be so for most Asian countries.

3. The Pattern of Global Biofuel Production and of Economic Measures to Support it.

3.1 The distribution of global biofuel production

In 2006, 40 billion litres of ethanol and 8.5 billion litres of biodiesel were produced globally (WorldBank, 2007, p.80). The same source indicates that the US was the largest producer of ethanol (producing 45% of the world's supply), followed by Brazil (42%) and the EU (4%) with other countries accounting for 12% of global production. The EU produced 75% of the world's biodiesel in 2006, the US 13% and the rest of the world 12%. We can conclude that Asia (with the exception of China) is still a relatively small player in the production of biofuels. However, its production is expanding and is expected to grow quickly. China is reputed to be the third major producer of ethanol globally accounting for 9% of global supply. As discussed below, Indonesia, Malaysia, Thailand, the Philippines and India have plans to increase their biofuel production, particularly their production of biodiesel.

Currently, Malaysia and Indonesia are producing biodiesel from palm oil and also exporting palm oil. One of its uses in the EU is for the production of biodiesel. The Philippines is producing biodiesel from coconut oil. The feedstock for ethanol production in Asia varies according to geographical region. In the south, sugar cane is mostly used for this purpose but in the north, China has been utilizing corn and wheat and in southern China cassava and tubers (Tian et al., 2009). These are all crops that are also utilized for food, including food for livestock.

Note that because of climatic differences, crops that may be utilized for producing biofuels differ and are likely to continue to differ in some Asian countries from those utilized in the US and Europe. Furthermore, given the ambitious targets of the US and the EU for increasing their production of biofuels, there are doubts about whether their domestic supplies of feedstock are going to be sufficient for this purpose. Therefore, it is likely that they will need to increase their imports of feedstock some of which is likely to come from Asia. Already the EU imports palm oil for this purpose thereby contributing to environmental degradation in Southeast Asia, according to some assessments (Swarna Nantha and Tisdell, 2009).

3.2 Measures to support the production of biofuels

The rapid growth in the production of biofuels has been mainly due to subsidies, government directives, and measure to ensure trade protection for the biofuel industry, particularly in higher income countries. For example, imports of ethanol are restricted in the US and large subsidies are paid for biofuel production and to farmers who produce feedstock for biofuel production. The situation is little different in the EU. For example, price supports are provided to farmers for production of rapeseed (canola) which is widely used to produce biodiesel. Many countries mandate the supply of mixtures of biofuels with fuels derived from mineral oil, and have programmes to increase the proportion of biofuels in the available fuel blends.

Table 1 summarizes information about production of biofuels in selected countries for 2005 and provides some remarks on the policies of these countries.

Table 1: Biofuel profiles of selected countries in 2005

Country	Production (litres)		Leading feedstocks		Blend Mandates/goals?
	Ethanol	Biodiesel	Ethanol	Biodiesel	
United States	15B	290M	Corn	Soybeans	Yes (28.35B litres by 2012)
National energy security large motivator for biofuel programmes; subsidy of 51c per gallon of ethanol used in fuel and a 50c or $1 a gallon subsidy for biodiesel; many subsidies at state level as well.					
European Union	950M	2.3B (2004)	Cereals and sugar beets	Rapeseed	Yes (2% by 2005 (not met) and 5.75% by 2010)
Policy goals: mitigate climate change, secure energy supply, advance technology, and diversify agriculture; land scarcity makes blending goals difficult without imports; tax concessions for bio-energy.					
Brazil	16B	?	Sugarcane	Castorbean oil, soya oil	Yes (20-25% ethanol. 2% biodiesel, 5% in 2013)
World's largest ethanol producer and exporter; produces ethanol at lowest cost; well developed biofuel transportation infrastructure; biodiesel "H-Bio" recently developed and patented by Petrobras.					
Guatemala	64M	?	Molasses	Jatropha	No
Excellent sugar cultivation; investigated by EU for dumping ethanol; Brazilian investors are investing in distillers and hope to create market for flexfuel cars.					
China	3.6B	?	Maize, cassava, rice	Waste cooking oil, vegetable oils	Yes (in certain provinces)
Vehicle ownership increased 600% in last decade driving fuel demand and the need for alternative fuels; China's policy on biofuels will largely determine the development of biofuels on a global scale; incentive programmes for ethanol.					
The Philippines	83M	?	Sugar	Coco-methyl, ester, jatropha	Yes (1% biodiesel, 5% ethanol
Government support to biofuel investment; biofuel production geared to social goal (job creation and related political stability); forthcoming Asian private investments for ethanol processing.					
India	1.6B	?	Molasses	Jatropha	Yes (5% ethanol in certain states, 20% biodiesel by 2012)
World's second largest sugar producer; sweet sorghum & tropical sugar beet investigated as feedstock alternatives to sugar; sugar market heavily regulated; meeting future blending goals predicted to require imports					

Thailand	300M	?	Sugarcane, molasses, cassava	Jatropha, palm oil	Yes (10% ethanol & biodiesel by 2012)
Government-fixed ethanol price and revenue distribution; location, natural resources and government support create potential for ethanol exports, especially to China & Japan.					
South Africa	390M	?	Sugarcane, sweet sorghum, maize	Soya Oil, (Jatropha use under debate)	Yes (since 2006 voluntary blending targets)
Government in the process of finalizing a national biofuels strategy; completing a lead phase out programme in 2007 will expand market for ethanol; government & private sector investigating new energy crops; biofuel production geared to social goals (job creation in rural areas).					

Source: Extracted from UNCTAD (2006, Table 1, pp. 20-21)

Unfortunately, Table 1 does not provide information for Indonesia, Japan and Thailand. Another table (Table 2) in the next section, provides some further information. From Table 2, it will be seem that several Asian countries have adopted systems of mandates and economic incentives to boost their production of biofuels.

3.3 Economic arguments and government support for the production of biofuels

In several circumstances, traditional economic analysis can be used to support the payment of subsidies to industrial production. For example, Pigou (1932) argued that if an industry generates a favourable environmental externality, subsidizing its production could add to economic welfare assuming that the Kaldor-Hicks (or potential Paretian improvement) criterion is adopted. Therefore, if it can be shown that the production of biofuels has a positive environmental externality, that might be used as an economic reason for a subsidy.

It is not, however, clear that the production of all biofuels generates (or always generates) favourable environmental externalities. In estimating externalities the whole life cycle of biofuel production needs to be assessed. Very often estimates of reduction in GHG emissions compared to use of petrol and diesel fail to take account of the whole life cycle, such as changes in land use that may come about as a result of the production of biofuels (see Fargione et al., 2008; Righelato and Spracklen, 2007; Searchinger et al., 2008). Especially when forest is cleared to extend the area growing feedstocks for biofuels, GHG emissions can increase. There is also a loss of biodiversity and ecosystem services. These losses may also result from intensification of agricultural of biomass production to supply extra quantities of feedstock. Figure 1 provides a primitive depiction of life-cycle considerations in assessing the environmental impacts of biofuels.

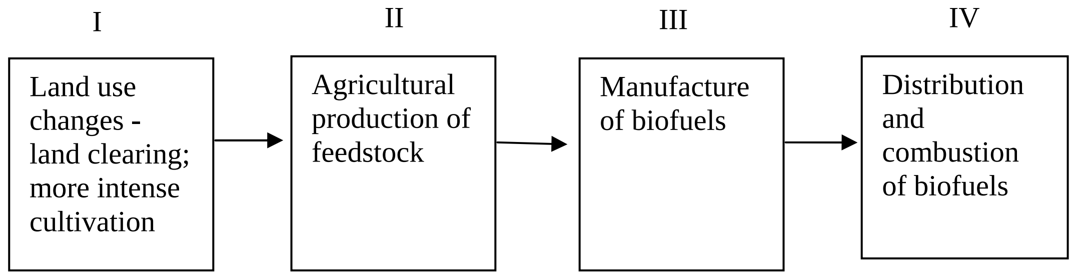

Figure 1 A crude representation of stages in the life cycle of first generation biofuels. When all stages of production of a biofuel are considered, its GHG emissions may exceed that of petrol and diesel or may be minimal. While most studies indicate a reduction in GHG emissions as a result of using biofuels rather than fossil fuels, the reduction is minimal when maize is used as a feedstock to produce biofuel and nearly all studies fail to take adequate account of stage I which reduces the sequestration of GHG. When this is accounted for, biofuels can increase GHG emissions.

Furthermore, it is questionable whether biofuel production ought to be subsidized. Charging for GHG emissions (if these are the main environmental externalities of concern) is an alternative policy instrument. This could in theory be achieved by a cap-and-trade scheme (a system of tradable permits). This is a more direct approach to pollution control than Pigovian-type regulation but the practicality of such a scheme is a different matter.

On the other hand, it could be argued that biofuel production has the status of an infant industry and requires subsidies and trade protection to develop and reach a critical mass. However, infant industries often 'fail to grow up'. How much public financial support is required and for how long can be a contentious matter. The sympathy of some 'green groups' for biofuels (at least, initially) and their simple analysis of their environmental consequences, has opened the way for significant rent-seeking behaviour by those involved in the production of biofuels.

Income distribution arguments, economic security and defence security arguments are also sometimes advanced in favour of the production of biofuels and used as reasons to provide economic support for their production. Yet as discussed later, biofuel production does not always have favourable income distribution consequences and the scarcity arguments also need to be scrutinized carefully because they too can become a ‘smoke screen’ for the extraction of rents.

4. The Production of Biofuels by Asian Nations for their Own Use

4.1 Production goals, achievements and incentives for biofuel production in selected Asian countries

As can be seen from Table 2, a significant number of Asian countries have started producing biofuels and plan to increase their production of these. Furthermore, some Asian countries, such as Vietnam, that are not as yet producing biofuels (except on an experimental basis) are expected to begin commercial production in the not too distant future ((Malik et al., 2009). Except for Japan, all Asian nations producing biofuels have mandated minimum targets for blending biofuels with other fuels and they either have subsidies or plan to introduce subsidies for biofuel production (see Table 3).

Table 2: Biofuels policies in selected Asian countries

Country	Targets for 1st generation biofuels and plans for 2nd generation biofuels	Blending mandate
China	Take non-grain path to biofuel development	Ethanol: trial period of 10% blending mandates in some regions
India	No target identified. Promotion of jatropha	Ethanol blending; 5% in gasoline in designated states in 2008, to increase to 20% by 2017
Indonesia	Domestic biofuel utilization; 2% of energy mix by 2010, 3% by 2015 and 5% by 2025. Seriously considering jatropha and cassava.	Diesel: blending is not mandatory but there is a plan to increase biodiesel blend to 10% in 2010.
Japan	Plan to replace 500 ML/year of transportation petrol with liquid biofuels by 2010	No blending mandate. Upper limits for blending are 3% for ethanol and 5% for biodiesel.
Malaysia	No target identified. Promotion of jatropha, nipa, etc.	Diesel: blending of 5% palm oil in diesel.
Philippines	No target identified. Studies and pilot projects for jatropha.	Ethanol: 5% by 2008; 10% by 2010. Diesel: 1% coconut blend by 2009

Thailand	Plan to replace 20% of vehicle fuel consumption with biofuels and natural gas by 2012. Utilization of cassava.	Ethanol 10-20% by 2008 (Gasohol 95) Diesel: 5% (B5) mix in 2007 and 10% (B10) by 2011.

Source: Extracted from Yan and Lin (2009, Table 1, p.S3)

Table 3: Economic supports for biofuel production in selected Asian countries

Country	**Economic measures**
China	Ethanol: incentives, subsidies and tax exemption for production. Diesel: tax exemption for biodiesel from animal fat or vegetable oil.
India	Ethanol: excise duty concession. Ethanol and diesel: set minimum support prices for purchase by marketing companies.
Indonesia	Diesel: subsidies (at the same level as fossil fuels).
Japan	Ethanol: subsidies for production and tax exemptions.
Malaysia	Diesel: plans to subsidize prices for blended diesel.
Philippines	Ethanol and diesel: tax exemptions and priority in financing.
Thailand	Ethanol: price incentives through tax exemptions

Source: Extracted from Yan and Lin (2009, Table 1, p. S3).

Let us consider the situation of these countries in turn as far as the production of biofuels is concerned. So far China has focused mainly on the production of ethanol and has mostly used corn for this purpose. Some wheat and tubers (e.g. sweet potato) and cassava are the basis of production in a few areas. China is the third largest producer of ethanol globally (Malik et al., 2009, p. S61). As can be seen from Table 4, the use of feedstock in China is influenced by the geographical region in which the production of biofuels occurs.

Table 4: Biofuel plants operated in China. These plants all produce ethanol

Plant	Year Built	Location	Capacity (t/year)	Feedstock
Huarun ethanol Co. Ltd	1993	Heilongjiang	100,000	Corn
Jilin fuel ethanol Co. Ltd	2001	Jilin	400,000	Corn
Tianguan fuel ethanol Co. Ltd	2002	Henan	500,000	Wheat, tubers
Fengyuan group	2002	Anhui	440,000	Corn
COFCO Bioenergy Co. Ltd	2005	Guangxi	200,000	Cassava

Source: Extracted from Tian et al. (2009, Table 2, p. S79)

Currently, all the feedstock used by China for ethanol production consists of food items but possibly of inferior quality for eating. However, even inferior grains such as cassava can be used for feeding livestock. It is interesting that China intends in the future to discontinue its reliance on grains for producing biofuel. Presumably, this is intended to maintain its degree of self-sufficiency in grains. Alternative sources of feedstock that are under investigation are listed in Table 5 along with the regions suitable for their production (Tian et al., 2009). However, these are all agricultural crops and will compete for land use with other agricultural crops or livestock production, especially the latter. Tian et al. (2009) appear to assume that extra feedstocks for biofuel will be supplied by extending the area of cultivated land. The environmental impact of this needs investigation. Li (2007) points out that China is also considering non-food feedstock for its production of biofuels but is aware that this could involve opportunity.

Table 5: Crops suggested by Tian et al. (2009) to provide feedstock in the future for ethanol production to China and regions recommended for their cultivation.

Region	Suitable energy crops
North-east	Sweet sorghum
North China	Sweet sorghum, sweet potato
Loess plateau	Sweet sorghum
Inner Mongolia and Xingiang	Sugar beet, sweet sorghum
Middle and lower Yangtze	Sweet potato
South China	Cassava
South-west	Sweet potato

Source: Extracted from Tian et al. (2009, Table 4, p, S80).

India has been slower than China in developing the production of biofuels and has mainly relied on molasses (derived from sugar cane) to produce ethanol. This year however, it is short of sugar and is importing sugar. It appears to be placing its future hopes on the growing of jatropha as a feedstock for its biofuel.

Indonesia is producing ethanol from cassava and sugar cane and biodiesel from oil palm and jatropha (Kussuryani, 2007). The Indonesian Government has, according to Kussuryani (2007), adopted a fast track programme to create villages that are self sufficient in their supply of energy and promote the regional development of biofuel production. As well, it is establishing special biofuel zones (areas of concentration in biofuel production) in which it provides the land and infrastructure for investors at no cost to them.

Little information is available for Japan about its biofuel production, presumably because biofuel production in Japan is insignificant. However, it is reported to be considering the production of some biofuel from biomass in Japan (see Table 2). Japan is also reported to be investing in biofuel plants in Indonesia, possibly with an eye to supplying some of this production to Japan.

Production of biofuels in Malaysia is focused mainly on the supply of biodiesel using palm oil as feedstock. In 2007, four biodiesel plants were operating in Malaysia, and another four were about to come on line and licenses for many more plants have been issued (Wahid et al., 2007). Until recently, all of Malaysia's biodiesel was exported to the EU and the USA but now blending mandates have stimulated the use of biodiesel in Malaysia. Jatropha and nipa palm are also being promoted as feedstocks in Malaysia.

Thailand is producing biofuel form diverse feedstock. Feedstocks include sugarcane, molasses, cassava and oil palm. Thailand is a major producer of cassava.

The Philippines is using sugarcane, coconut oil and jatropha to produce biofuel and is providing economic incentives for investment in the refining of biofuels.

Of all the Asian countries, Thailand appears to have the most ambitious programme for making use of biofuels. Its target is to supply 20% of its vehicle fuel from biofuels and natural gas by 2012 and to achieve a blend of 10-20% ethanol in petrol. It also envisages the possibility of exporting biofuels, mainly to China and Japan.

4.2 An assessment of biofuel production possibilities in Asia

Asia faces several constraints in increasing the amount of its biofuel production and these constraints vary by country and by regions within each country. Furthermore, Asia spreads over a vast diverse geographical area. This implies, amongst other things, that the feedstocks likely to be used for producing biofuel in Asia are likely to be diverse and to vary by country and region.

Furthermore, the area of land available for expanding biofuel feedstock production in Asia without reducing food supplies, lowering output of natural fibres, decreasing production from trees and livestock production is limited in many Asian countries such as China, India and Japan. Trade-offs are likely to be unavoidable.

Some scientists believe that wastelands can be utilized to grow biofuel feedstock. Wastelands may, however, have some use for livestock and/or provide environmental services. Unfortunately, use of the term 'wastelands' gives a biased perspective on their use. Similarly the clearing of forests to grow biofuel feedstock can involve significant environmental costs and the cleared land may have opportunity costs in terms of lost timber and paper production or the growing of alternative crops. It is also argued by their proponents that second generation biofuels will be able to utilize biomass wastes from garbage and farms. Possibly, this could reduce some pollutants. However, organic farm waste may be better used by adding it to soils to create humus. Soil degradation may accelerate if increased amounts of organic matter are removed from agricultural land and the fertility of the soil can decline.

The production of some crops for supplying feedstock for biofuels requires significant water use, for example, in growing sugarcane and sugar beet. Production of ethanol is very water intensive. Malik et al. (2009) point out that up to four litres of water are needed to produce one litre of ethanol. Water is already in very short supply in parts of Asia. This will constrain possibilities for producing biofuels.

In order to make significant inroads into the use (and projected use) of petrol and diesel, Asian countries would need to allocate a very large area to the growing of feedstock for biofuels. In the absence of spectacular yield increases, this is likely to add to increasing food prices and disadvantage poor consumers. It is probably unrealistic to believe that Asia will be able to supply a large proportion of its liquid fuel by producing biofuels. It is possible that as the scarcity of mineral oil increases, Asian nations will become more reliant on natural gas as a source of energy for transport and other uses. This may explain why China and India have recently made agreements to purchase massive quantities of natural gas from Australia (Lewis, 2009). Although this does not seem to be a high priority for most Asian nations, there is mounting scientific evidence that land conversion to provide feedstock for biofuels actually adds, in many cases, to GHG emissions when the whole life cycle of their production is taken into account (Fargione et al., 2008; Righelato and Spracklen, 2007; Searchinger et al., 2008).

5. Exports and Imports of Biofuels and their Feedstock by Asian Countries and Foreign Investment in the Biofuel Industry

Given the emerging and dynamic nature of the development of biofuel production, only limited information is available on exports, imports and foreign investment in the biofuel industry. Malaysia is exporting biodiesel to the EU and the USA and it exports palm oil to the EU where one of its uses is to produce biodiesel. Indonesia also is an exporter of palm oil, some of which is used to produce biodiesel in Europe. There has also been foreign investment in oil palm plantations in Malaysia and in Indonesia.

Thailand believes that it is likely to be able to export biofuel to China and Japan. I do not have information on the extent to which there has been foreign investment in the development of the Thai biofuel industry. Malik et al. (2009, p. S62) report that “The Thai government is looking at new oil palm plantings as well as growing other energy crops such as *jatropha* to increase supply of feedstock for biodiesel processing. The latter could be initially imported from neighbouring countries like Myanmar (their target is to plant close to 3 million ha of jatropha) and perhaps sourced from Lao PDR and/or Cambodia”.

China, India and Japan are all potential importers of biofuels. However, their imports are likely to be influenced by the comparative prices of biofuels and their substitutes. Nevertheless, they may decide to import some biofuels as a diversification strategy and in order to increase their energy security.

There is a strong possibility that China may invest in biofuel production offshore, especially production of second generation biofuels. It already, for example, has large forest plantations in Brazil. This would reduce pressure on its own land areas and it may be able to use some biomass wastes from its Brazilian operations. Given China's large foreign reserves and its resource requirements, foreign investment to secure its resource needs is likely to be given high priority as China continues to develop. China's demand for imports of energy and natural resource impacts are expected to accelerate (Tisdell, 2009).

6. Economic Consequences for Asian Countries of Increased Production of Biofuels by High-Income Countries and Vice Versa

6.1 Impacts of increased biofuel production by higher income countries

Expansion of biofuel production in higher income countries has significant economic implications for most Asian countries. This is particularly so for expansion in production of ethanol (which has been largely based on corn) by the United States. Production of biodiesel based on soy oil also has economic impacts on Asia.

Asia is a significant export market for corn and soybeans much of which is used for livestock production in Asia, for example in the rearing of pigs. A spike occurred in grain prices in 2008 prior to the deepening of the global recession. A significant proportion of this increased price has been attributed to US subsidies to support ethanol production using corn. The longer-term consequences of this have been highlighted by Searchinger et al. (2008) and concerns have been expressed in publications such as *Lancet* (Boddinger, 2007) about the negative consequences of ethanol production for food supplies.

In practice, it is very difficult to determine exactly the impacts on food prices (for example, grain prices) of increased production of biofuel in higher income countries using agriculturally produced feedstock. This is because several factors can simultaneously influence changes in prices, and their separate impacts are difficult to disentangle empirically. For example, the spike in grain prices in early 2008 (including in Asia) was partly due to the significant expansion in US production of ethanol from corn, the high price of mineral oil, and speculation about future food availability and oil prices. The situation was worsened because several food surplus nations restricted their food exports as a result of their growing concerns about food security. Furthermore, several food deficit countries began 'panic' buying of grains. Brahmbhatt and Christiaensen (2008, pp. 3-4) argue that the rise in international grain prices in the period 2004 to early 2008 can be attributed to 'global factors [which] include rising energy costs, the falling dollar and – most importantly – policies that have induced a sharp increase in biofuel demand for grains, although the impact on rice is more indirect". They point out that World Bank studies covering the period 2004 to early 2008 indicate that rising energy and fertilizer prices contributed 35% of the rise in world food prices *but* increased biofuel demand was the *largest* contributor to increased world grain prices. This was mainly because the United States diverted increasing amounts of its corn output to the production of ethanol. Brahmbhatt and Christaensen (2008, p. 5) observe that "almost all the increase in global maize production from 2004 to 2007 (a period when grain prices rose sharply) went for bio-fuels production in the U.S. while existing stocks were depleted by an increase in global consumption for other uses. Land use changes due to increased use of maize and oilseeds for biofuels led to reduced plantings of wheat, the subsequent depletion of world wheat stocks to record lows, and a surge in wheat prices". They then state that the rise in wheat prices was reflected in higher rice prices "because wheat and rice are substitutes in consumption and imports".

If this scenario is correct (as it appears to be), then consumers (especially those on lower incomes) were adversely affected by the expansion of biofuel production in the US. Although with the onset of the global recession in 2008 and falling prices for mineral oil, grain prices have declined, the long-term consequence of increased production of liquid biofuels is likely to be to keep grain prices (and the prices of other commodities that are land-based) higher than they otherwise would be. Consequently, poorer consumers (including those in Asia) are likely to suffer reduced welfare if biofuel production expands rapidly.

The consensus within the World Bank appears to be that production of biofuels tends to push up food prices. The World Bank (2007, p.70) reported "spurred by subsidies and the Renewable Fuel Standard issued in 2005, the United States has diverted more maize to ethanol. Because it is the world's largest maize exporter, biofuel expansion in the United States has contributed to a decline in grain stocks to a low level and has put upward pressure on world cereal prices. Largely because of biodiesel production, similar price increases have occurred for vegetable oils (palm, soybean and rapeseed)."

While Sexton et al. (2009) do not deny that biofuel production in higher income countries has put upward pressure on food prices, they appear to be hoping for a 'technological fix' to the problem. They argue that "biotechnology and transgenic crops can be powerful drivers of productivity growth, but it demands increased investment and reduced regulation. We argue that biotechnology is essential to reduce land-use changes associated with biofuel demand that not only reduce biodiversity but also release greenhouse gases into the atmosphere" (Sexton et al., 2009, p. 130).

However, one should be wary of their argument. Certainly, advances in biotechnology do not guarantee a reduction in biodiversity loss or a reduction in GHG added to the atmosphere as a result of biofuel production.

Advances in genetic engineering could easily lead to intensification of the culture of feedstock for biofuels and the extension of the utilization of land for providing feedstock thereby adding to biodiversity loss and increasing GHG emissions. Furthermore, the ecological fitness of many genetically modified organisms may not be sustained in the long-term and consequently, sustainability issues can arise (Tisdell, forthcoming). In the long-term, genetically modified organisms may reduce biodiversity. Although mankind has made tremendous scientific and technological progress, biodiversity continues to decline at an alarming rate, mainly due to human economic activity. Given this record, it is not apparent that further technological progress will prove to be a 'silver bullet'. Although technological progress often has the potential to alleviate environmental problems, demands for ever continuing economic growth tends to negate its environmental benefits.

6.2 Asian economic welfare losses as predicted by neoclassical microeconomic theory

Traditional microeconomic theory indicates that Asian nations importing grain (or vegetable oil or oil seeds) are likely to suffer a net economic welfare loss as a result of the expansion of biofuel production in higher income countries. This can be illustrated by Figure 2 for an Asian country that is a net importer of feedstock used in higher income countries to produce biofuel.

In Figure 2, D_1D_1 represents the demand for the Asian country for a commodity which it utilizes for food but which is also used as feedstock for biofuel in a developed country and S_1S_1 represents its domestic supply of that commodity, X. In the absence of biofuel production in developed countries, the import price of the commodity, X, is assumed to be P_1 but once biofuel production takes off in higher income countries (such as the US), the export price of X rises to P_2. As a result, imports of X by the Asian country fall from $X_4 – X_1$ to $X_3 – X_1$. Its domestic production of X rises from X_1 to X_2 and its domestic consumption of X declines from X_4 to X_3.

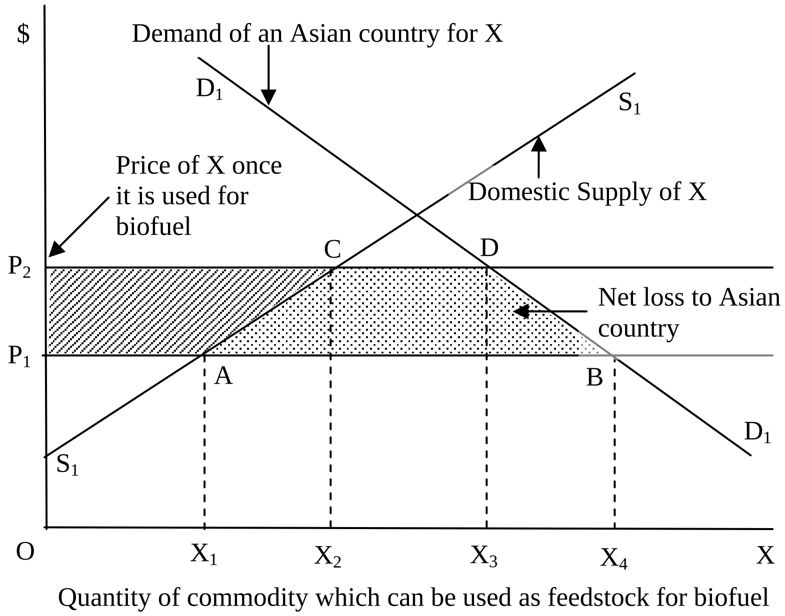

Figure 2: An illustration that high biofuel production in developed countries results in Asian countries that are net importers of commodities used to produce biofuel suffering net welfare loss

As a result of the rises in the price of commodity X due to its use in developed nations to produce biofuel, the surplus of buyers of X in the Asian importing country falls by the area of the hatched quadrilateral plus the dotted quadrilateral. On the other hand, the surplus of domestic suppliers of X rises by the hatched area. Consequently, the net loss to the Asian economy is equivalent to the area of the dotted quadrilateral. Vietnam, for example, is an importer of maize from the USA and also imports soybean much of which is used for its livestock production. Note also that farmers in the relevant Asian country may both intensify and extend their production of X once its import price rises thereby adding to GHG emissions and biodiversity loss.

On the other hand, Asian countries exporting commodities which are used for biofuel production are likely to experience a net economic welfare gain if demand for their feedstock increases in higher income countries. For example, an expansion in the demand for palm oil in higher income countries is likely to bring economic benefits for Malaysia and Indonesia. Using microeconomic analysis, the economic consequences for them can be illustrated by Figure 3. The focal Asian nation is assumed to be an exporter of X which can be used as feedstock to produce biofuel. As before, the demand for X in the focal Asian commodity is indicated by line D_1D_1 and its domestic supply is shown by line S_1S_1. Prior to a hike in demand for X in higher income countries to produce biofuel, the Asian exporting country is assumed to obtain a price of P_3 for its exports of X but after demand escalates due to increased foreign demand for X for biofuel production, the price of X rises to P_4. The Asian country's exports of X rise from $X_3 – X_2$ to $X_4 – X_1$, its consumption of X falls from X_2 to X_1 and its production of X rises from X_3 to X_4.

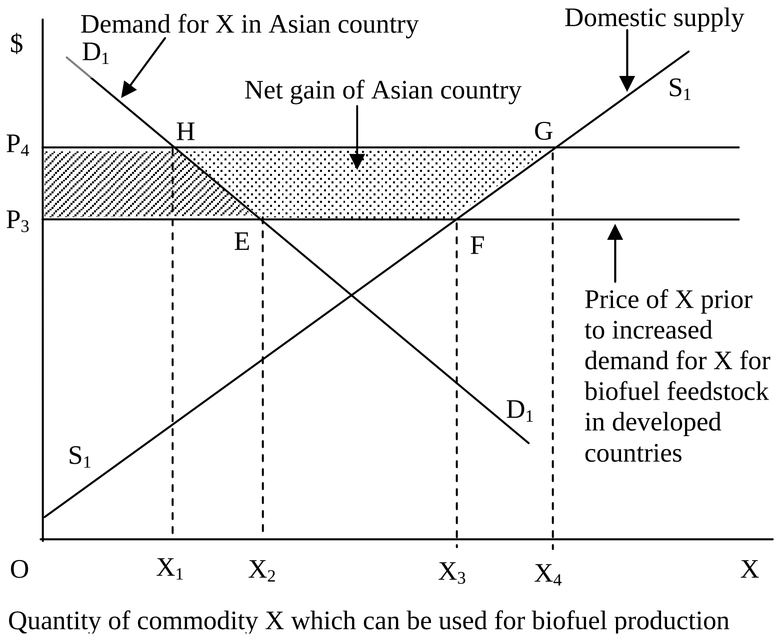

Figure 3: A case in which an Asian country has a net welfare gain as a result of expansion in the foreign demand for its product X which can be used to produce biofuel.

In the case illustrated in Figure 3, the Asian country has a net economic gain as a result of an increase in the export price of X. The surplus of its producers of X rises by the area of hatched quadrilateral plus the dotted one. The surplus of its domestic consumers of X falls by the area of the hatched quadrilateral. Therefore, the net economic benefit obtained by this Asian country increases by an amount equivalent to the dotted area shown in Figure 3, if the Kaldor-Hicks criterion is adopted. Despite this, its increase in production of X is likely to be obtained as a result of both intensification and extension of the area of land allocated to X. This could result in increased GHG emissions and greater biodiversity loss. This is an issue of concern in relation to increased palm oil production in countries such as Malaysia and Indonesia.

6.3 Impacts of increased biofuel production by Asian countries

If Asian countries mandate the increased consumption of biofuel and subsidise its production, this is likely to distort the allocation of their resources. If cropland is used for this purpose, the prices of crops can be expected to rise and if grazing land is used for this purpose the prices of some livestock products are likely to increase. In the short run, there is a misallocation of resources and reduced net economic welfare. Consumers have a reduced surplus but producers are likely to see their economic surplus increase. Traditional economic analysis indicates that the economic loss to consumers can be expected to outweigh the gain to producers. It is also likely that the environmental impacts of such a policy will be negative. However, if the biofuel industry proves to be an infant industry that will 'grow-up' in a reasonable period of time, that could give some economic support to this policy. In the case of Thailand, expansion in its biofuel production may reduce its food exports. Currently Thailand is a net exporter of food and animal feedstock (Malik et al., 2009, p. S62). This policy is likely to have negative economic consequences for countries that currently buy food and animal feedstocks from Thailand.

Note that traditional microeconomic analysis relying in the Kaldor-Hicks principle (potential Paretian improvement principle) ignores the income distributional consequences of policies. Biofuel development could well be detrimental to the economic interests of the poor, even poor farmers. This needs further investigation.

7. Further Discussion and Conclusion

There is little prospect of liquid biofuels replacing current levels of consumption of petrol and diesel (let alone projected levels of use of these substances) without causing severe economic distress. The amount of land that would be required for such substitution would be so large that it would greatly reduce food supplies and other economic uses of the land. For example Rajagopal and Zilberman (2007) found that just offsetting 10% of the oil imports of the US and the EU by biofuels would require 30-70% of their cropland to be allocated to the production of feedstock for biofuel. Hence, offsetting their total oil imports would require at least the use of 4 to 7 times the area of their present cropland to supply biofuels. Such an area is unlikely to be available.

Similarly, the World Bank (2007, p.71) notes the projection that 30 percent of the US maize harvest is likely to be used to produce ethanol by 2015 but that this will supply less than 5 percent of US gasoline consumption. This implies that if all maize production in the US were allocated to the production of ethanol, it would only account for around 15 percent of the gasoline requirements of the United States in 2015.

From the above, it can be concluded that the economic cost in terms of food and other land-based commodities forgone as well as the environmental costs of meeting a high proportion of the world's consumption of gasoline and diesel from biofuels is likely to be very high, even prohibitive. There is also no reason to believe that the costs to Asian countries of substantially increasing their reliance on liquid biofuels will be low and expansion of production of feedstock for biofuels and biofuels themselves in many Asian countries (especially those in southeast Asia) is likely to be achieved at a high environmental cost in terms of lost biodiversity and increased GHG emissions.

It should also not be forgotten that even when the use of biofuels has lower intensity of GHG emissions compared to the use of fossil fuels, their use still adds GHG to the atmosphere. Many natural scientists seem to believe (naively) that if biofuels became available with lower intensity of GHG emissions than fossil fuels, this will lower aggregate GHG emissions. However, economic considerations indicate that this may not happen. It all depends on the rate for which biofuels will be substituted for fossil fuels. It is too simplisitic to believe there will be one-for-one (perfect) substitution.

For example, suppose that the GHG emissions from use of a unit of biofuel are half those from a unit of fossil fuel and that both enable an equivalent performance. The latter is a generous assumption since the distance one can travel on a litre of ethanol is slightly lower than that for a litre of gasoline. It follows that if for every extra two litres of biofuel used there is a reduction of one litre in the use of fossil fuel, the level of GHG emissions remain constant. GHG emissions actually rise if the reduction in the use of fossil fuels is less than a litre for every extra unit of biofuel used. There are many circumstances in which the estimated reduction in GHG emissions for biofuels compared to the use of fossil fuels is less than 50 per cent. In such cases, a greater rate of substitution of biofuel for fossil fuels would be needed to lower GHG emissions.

Given the above, there is a possibility that the introduction of biofuels will add to GHG emissions rather than reduce these. Firstly, there may be insufficient substitution of biofuels for fossil fuels in cases where the latter has a lower GHG intensity resulting in a rise in aggregate GHG emissions. The new technology merely adds to total consumption of fuels. Secondly, natural scientists have shown that processes for producing several types of biofuels add to GHG accumulation in the atmosphere when the whole life cycle of their production is considered.

In addition, some less expensive options to the use of biofuels are likely to be available for Asian nations for many years to come, For example, Australia has extremely large natural gas reserves, especially if gas associated with underground coal seams is included. Furthermore, greater use of electric vehicles and hybrid vehicles can extend options. However, in the long run, as most neo-Malthusians believe, our best hope for coping with increased resource scarcity and growing environmental damages form economic production is to reduce excessive consumption by the richer members of society and limit population growth. China has done the latter but few, if any nations, seem prepared to follow the former path.

8. References

Boddinger, D. (2007). Boosting biofuel crops could threaten food security. *Lancet*, 370, 923-924.

Brahmbhatt, M., and Christiaensen, L. (2008). *Rising food prices in East Asia: Challenges and policy options* World Bank, Washington DC.

Fargione, J., Hill, J., Tilman, D., Polasky, S, and Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. *Science*, 319, 1235-1238.

Hunt, C. (2009). *Carbon Sinks and Climate Change: Forests in the Fight Against Global Warming.* Edward Elgar, Cheltenham, UK and Northampton, MA, USA. (In press).

Kussuryani, Y. (2007). Biofuel development in Indonesia. . Paper presented at USDA Global Conference on Agricultural Biofuels: Research and Economics. Accessed 19 August, 2009, from http://www.ars.usda.gov/meetings/Biofuel2007/files/Intl%20Perspectives%20B-Revised.doc

Lewis, S. (2009, August 19). Chinese sign off on $50B gas deal. *The Courier Mail*, p. 28.

Li, Shi-Zhong. (2007). Non-food feedstock and the road map of China's bioethanol industry. Paper presented at USDA Global Conference on Agricultural Biofuels: Research and Economics. Accessed 19 August, 2009, from http://www.ars.usda.gov/meetings/Biofuel2007/files/Intl%20Perspectives%20B-Revised.doc

Malik, U.S., Ahmed, M., Sombillon, M.A., and Cueno, S.L. (2009). Biofuels production fro smallholder producers in the Greater Mekong Sub-region. *Applied Energy*, 86, S58-S68.

Pigou, A.C. (1932). *The Economics of Welfare* 4th ed. Macmillan, London.

Punia, M.S. (2007). Current status of research and development on jatropha (*Jatropha curcus*). Paper presented at USDA Global Conference on Agricultural Biofuels: Research and Economics Accessed 19 August, 2009, from http://www.ars.usda.gov/meetings/Biofuel2007/files/Intl%20Perspectives%20B-Revised.doc

Rajagopal, D., and Zilberman, D. (2007). *Review of environmental and policy aspects of biofuels*. World Bank Policy Research Working Paper, No. 4341. World Bank, Washington DC.

Righelato, R., and Spracklen, D.V. (2007). Carbon mitigation by biofuels or by saving and restoring forests? *Science,* 317, 902.

Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabissa, J., Tokgoz, S., Hayes, D. , and Yu, T-H. (2008). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science,* 319, 1238-1240.

Sexton, S., Zilberman, D., Rajagupal, and G, Hochman. (2009). The role of biotechnology in a sustainable biofuel future. *AgBioForum,* 12, 130-140.

Swarna Nantha, H., and Tisdell, C. (2009). The orangutan - oil palm conflict: economic constraints and opportunities for conservation. *Biodiversity Conservation,* 18, 487-502.

Tian, Y., Zhao, L., Meng, H., Sun, L., and Yan, J. (2009). Estimation of un-used land potential for biofuels development in China. *Applied Energy,* 86, S71-S85.

Tisdell, C. (1997). Capital/natural resource substitution: the debate of Georgescu-Roegen (through Daly) with Solow/Stiglitz. *Ecological Economics,* 22(3), 289-291. Reprinted in C. Tisdell (2003) *Ecological and Environmental Issues.* Edward Elgar, Cheltenham, UK and Northampton, MA, USA.

Tisdell, C. (2005). *Economics of Environmental Conservation.* 2nd ed. Edward Elgar, Cheltenham, UK and Northampton, MA, USA.

Tisdell, C.A. (2009). *Resource and Environmental Economics: Modern Issues and Applications.* World Scientific, Singapore, New Jersey, London. (In press).

Tisdell, C.A. (forthcoming). The precautionary principle revisited: its interpretations and their conservation consequences. *Singapore Economic Review*.

UNCTAD. (2006). *The Emerging Biofuel Market: Regulating Trade and Development Implications*. UNCTAD/DITC/TED/2006/4. United Nations, New York and Geneva

.

Wahid, M.B., Chao, Y.M., and Lim, W.S. (2007). Technological progress and commercialisation of biodiesel in Malaysia. Paper presented at USDA Global Conference on Agricultural Biofuels: Resource and Economics. Accessed 19 August, 2009, from http://www.ars.usda.gov/meetings/Biofuel2007/files/Intl%20Perspectives%20B-Revised.doc

WorldBank. (2007). *World Development Report 2008: Agriculture for Development*. The World Bank, Washington, DC.

Yan, J., and Lin, T. . (2009). Biofuels in Asia. *Applied Energy*, 86, S1-S10.

PREVIOUS WORKING PAPERS IN THE SERIES
ECONOMICS, ECOLOGY AND ENVIRONMENT

For a list of working papers 1-100 in this series, visit the following website: http://www.uq.edu.au/economics/PDF/staff/Clem_Tisdell_WorkingPapers.pdf or see lists in papers 101 on.

101. Knowledge and Willingness to Pay for the Conservation of Wildlife Species: Experimental Results Evaluating Australian Tropical Species, by Clem Tisdell and Clevo Wilson, May 2004.
102. Antarctic Tourists, Wildlife and the Environment: Attractions and Reactions to Antarctica, by Clem Tisdell, May 2004.
103. Birds in an Australian Rainforest: Their Attraction for Visitors and Visitors' Ecological Impacts, by Clem Tisdell and Clevo Wilson, May 2004.
104. Nature-Based Tourism and the Valuation of its Environmental Resources: Economic and Other Aspects by Clem Tisdell, May 2004.
105. Glow Worms as a Tourist Attraction in Springbrook National Park: Visitor Attitudes and Economic Issues, by Clem Tisdell, Clevo Wilson and David Merritt, July 2004.
106. Australian Tropical Reptile Species: Ecological Status, Public Valuation and Attitudes to their Conservation and Commercial Use, by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, August 2004.
107. Information and Wildlife Valuation: Experiments and Policy, by Clem Tisdell and Clevo Wilson, August 2004.
108. What are the Economic Prospects of Developing Aquaculture in Queensland to Supply the Low Price White Fillet Market? Lessons from the US Channel Catfish Industry, by Thorbjorn Lyster and Clem Tisdell, October 2004.
109. Comparative Public Support for Conserving Reptile Species is High: Australian Evidence and its Implications, by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, October 2004.
110. Dependence of public support for survival of wildlife species on their likeability by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, October 2004.
111. Dynamic Processes in Contingent Valuation: A Case Study Involving the Mahogany Glider by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, November 2004.
112. Economics, Wildlife Tourism and Conservation: Three Case Studies by Clem Tisdell and Clevo Wilson, November 2004.
113. What Role Does Knowledge of Wildlife Play in Providing Support for Species' Conservation by Clevo Wilson and Clem Tisdell, December 2004.
114. Public Support for Sustainable Commercial Harvesting of Wildlife: An Australian Case Study by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, December 2004.
115. Endangerment and Likeability of Wildlife Species: How Important are they for Proposed Payments for Conservation by Clem Tisdell, Hemanath Swarna Nantha and Clevo Wilson, December 2004.
116. How Knowledge Affects Payment to Conserve and Endangered Bird by Clevo Wilson and Clem Tisdell, February 2005.
117. Public Choice of Species for the Ark: Phylogenetic Similarity and Preferred Wildlife Species for Survival by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, March 2005.
118. Economic Incentives for Global Conservation of Wildlife: New International Policy Directions by Clem Tisdell, March 2005.
119. Resource Entitlements of Indigenous Minorities, Their Poverty and Conservation of Nature: Status of Australian Aborigines, Comparisons with India's Tribals, Theory and Changing Policies Globally by Clem Tisdell, March 2005.

120. Elephants and Polity in Ancient India as Exemplified by Kautilya's *Arthasastra* (Science of Polity) by Clem Tisdell, March 2005.
121. Sustainable Agriculture by Clem Tisdell, April 2005.
122. Dynamic Processes in the Contingent Valuation of an Endangered Mammal Species by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, April 2005.
123. Knowledge about a Species' Conservation Status and Funding for its Preservation: Analysis by Clem Tisdell, June 2005.
124. Public Valuation of and Attitudes towards the Conservation and Use of the Hawksbill Turtle: An Australian Case Study by Clem Tisdell, Hemanath Swarna Nantha and Clevo Wilson, June 2005.
125. Comparison of Funding and Demand for the Conservation of the Charismatic Koala with those for the Critically Endangered Wombat *Lasiorhinus krefftii* by Clem Tisdell and Hemanath Swarna Nantha, June 2005.
126. Management, Conservation and Farming of Saltwater Crocodiles: An Australian Case Study of Sustainable Commercial Use by Clem Tisdell and Hemanath Swarna Nantha, August 2005.
127. Public Attitudes to the Use of Wildlife by Aboriginal Australians: Marketing of Wildlife and its Conservation by Clem Tisdell and Hemanath Swarna Nantha, August 2005.
128. Linking Policies for Biodiversity Conservation with Advances in Behavioral Economics by Clem Tisdell, August 2005.
129. Knowledge about a Species' Conservation Status and Funding for its Preservation: Analysis by Clem Tisdell, August 2005.
130. A Report on the Management of Saltwater Crocodiles (*Crocodylus porosus*) in the Northern Territory: Results of a Survey of Pastoralists by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, September 2005.
131. Crocodile Farms and Management of Saltwater Crocodiles in Northern Territory: Results of a Survey of NT Crocodile Farmers Plus Analysis of Secondary Information by Clem Tisdell, September 2005.
132. The Environment and the Selection of Aquaculture Species and Systems: An Economic Analysis by Clem Tisdell, October 2005.
133. The History and Value of the Elephant in Sri Lankan Society by Ranjith Bandara and Clem Tisdell, November 2005.
134. Economics of Controlling Livestock Diseases: Basic Theory by Clem Tisdell, November 2006.
135. Poverty, Political Failure and the Use of Open Access Resources in Developing Countries by Clem Tisdell, November 2006.
136. Global Property Rights in Genetic Resources: An Economic Assessment by Clem Tisdell, November 2006.
137. Notes on the Economics of Fish Biodiversity: Linkages between Aquaculture and Fisheries by Clem Tisdell, November 2006.
138. Conservation of the Proboscis Monkey and the Orangutan in Borneo: Comparative Issues and Economic Considerations by Clem Tisdell and Hemanath Swarna Nantha, March 2007.
139. Economic Change and Environmental Issues: Policy Reforms and Concerns in Australian Agriculture, by Clem Tisdell, April 2007.
140. Institutional Economics and the Behaviour of Conservation Organizations: Implications for Biodiversity Conservation by Clem Tisdell, March 2007
141. Poverty, Policy Reforms for Resource-use and Economic Efficiency: Neglected Issues by Clem Tisdell, May 2007.
142. The State of the Environment and the Availability of Natural Resources by Clem Tisdell, May 2007.
143. Economics of Pearl Oyster Culture by Clem Tisdell and Bernard Poirine, July 2007.
144. The Economic Importance of Wildlife Conservation on the Otago Peninsula – 20 Years on by Clem Tisdell, November, 2007.

145. Valuing the Otago Peninsula: The Economic Benefits of Conservation by Clem Tisdell, November 2007.
146. Policy Choices about Agricultural Externalities and Sustainability: Diverse Approaches, Options and Issues by Clem Tisdell, November, 2007.
147. Global Warming and the Future of Pacific Island Countries by Clem Tisdell, November 2007.
148. Complex Policy Choices about Agricultural Externalities: Efficiency, Equity and Acceptability by Clem Tisdell, June 2008.
149. Wildlife Conservation and the Value of New Zealand's Otago Peninsula: Economic Impacts and Other Considerations by Clem Tisdell, June 2008.
150. Global Property Rights in Genetic Resources: Do They Involve Sound Economics? Will They Conserve Nature and Biodiversity? By Clem Tisdell, August 2008.
151. Supply-side Policies to Conserve Biodiversity and Save the Orangutan from Oil Palm Expansion: An Economic Assessment. By Clem Tisdell and Hemanath Swarna Nantha, September, 2008.
152. The Orangutan-Oil Palm Conflict: Economic Constraints and Opportunities for Conservation by Hemanath Swarna Nantha and Clem Tisdell, October 2008.
153. Economics, Ecology and the Development and Use of GMOs: General Considerations and Biosafety Issues by Clem Tisdell, October 2008.
154. Agricultural Sustainability and the Introduction of Genetically Modified Organisms (GMOs) by Clem Tisdell, February, 2009.
155. Notes on Biodiversity Conservation, The Rate of Interest and Discounting by Clem Tisdell, April, 2009.
156. Is Posner's Principle of Justice an Adequate Basis for Environmental Law? by Clem Tisdell, June 2009.
157. The Sustainability of Cotton Production in China and Australia: Comparative Economic and Environmental Issues By Xufu Zhao and Clem Tisdell, June 2009.
158. The Precautionary Principle Revisited: Its Interpretations and their Conservation Consequences by Clem Tisdell, September, 2009.