Natural vegetation changes resulting from changes in land requirements for increased biofuels production.

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Contents

Line of argument / Summary

1) Increased demand for biofuels will give rise to increased land use, even after taking account of yield increase and co-products. The aggregate increased land use will entail conversion of idle land, grassland or forest to arable crop land

2) In this paper, the type of land used for increased crop demand is determined by matching areas of increased crop land to areas where there are changes in natural vegetation using historic data on the type of land use change for each crop.

3) It is shown that the increasing global demand for meat is being met almost entirely by yield increases and not by land area increases.

4) Therefore from (3) any conversion of grassland to arable land will mainly drive higher yields in the aggregate global production of meat and will only drive small increases in grassland area elsewhere.

5) Therefore from (4) arable crops displacing grassland will not give rise to significant deforestation.

6) It is shown that traded temperate biofuel crops are directly grown on idle land and grassland and are not grown directly on deforested land.

7) Therefore from (5) and (6), temperate crops needed for biofuel production will displace idle land and grassland, but will not directly or indirectly replace forest

8) Deforestation (forest land clearance for other economic uses) is distinct from commercial logging (timber removal) and it is shown that although commercial logging may be associated with deforestation is not the cause of deforestation

9) It is shown that nearly all new palm area has historically been grown in areas of deforestation

10) It is shown that soy is grown primarily for the meal and soy meal is the marginal global high protein animal feed.

11) It is shown that marginal global vegetable oil demand is primarily supplied by palm oil

12) It is shown that increased rape is only being grown in Europe for the EU biodiesel market so rape oil is not equivalent to palm oil.

13) It is shown that the proportion of deforestation attributable to commercial cropping can be accounted for by directly matching areas of increased commercial crop land to areas of deforestation.

14) It is shown that the growth of commercial crops associated with deforestation land is due to increased demand for these crops and there is no evidence that they are being pushed onto using forested land due to land pressure from temperate crops.

15) Therefore from (7), (13) and (14) biofuel crops can be divided into some crops that are not directly or indirectly associated with deforestation and other crops that are.

16) The analyses in (2), (3), (6), (8), (10) (11), (12) and (14) should be confirmed using macro-economic models. The parameters for the macro-economic models must be chosen which enable the models to correctly simulate the actual market behaviour over recent years.

Introduction

As a result of policies, for example in the EU, the increased use of bioenergy for biofuels or for heat and power generation, will be increase demand for bioenergy crops. The use of some crops for biofuel production will give rise to co-products, which will relatively reduce the demand for other crop products substitutes, such as cereals soy meal used for animal feed . The increase in the rate of demand growth for biofuel crops will cause increase the rate of yield growth and rate of land area growth of these crops. For cereal crops, the bulk of the increased demand will be met by yield growth. However, even after taking account of co-products and yield growth, increased land area will be needed for many crops associated with biofuel production.

The land area changes that are needed for any crop, will ultimately result in land use changes of natural vegetation or idle land. In some cases biofuel crops may be grown directly on idle land or land converted from natural vegetation, but in other cases biofuel crops will displace other agricultural crops, which in turn may be grown on idle land or land converted from natural vegetation. Where natural vegetation, or land that has been idle for several years is converted to cropland, this will incur a step reduction in the carbon stock of the land, which will give rise to GHG emissions.

Biofuel suppliers can choose whether they supply biofuels from crops that are being grown on land that has been recently converted from idle land or natural vegetation, or whether to supply from crops that are being grown on mature cropland.

If biofuel suppliers produce biofuels from crops that are being grown on land that has been recently converted from idle land or natural vegetation, they will cause direct land use change (LUC) and will be able to choose appropriate land to grow crops and crop growing practices to minimise adverse GHG emission from LUC.

If biofuel suppliers produce biofuels from crops that are being grown on mature cropland, they will cause indirect land use change (ILUC) and will have to accept factors for GHG emissions from ILUC, which will be determined from the average land use changes that are needed to satisfy the increase in demand for each biofuel crop .

The objective of this paper is to identify, in a transparent way, the average indirect land use changes that take place, for each major biofuel pathway.

Existing macro-economic models

A number of published articles and studies in 2008 (Searchinger 2008, OECD 2008) have determined the implications of biofuel policies on land use changes and the GHG emissions from those changes. These studies have attempted to estimate where indirect land use changes will take place as a result of the changes in agricultural land area, due to increases in the prices of agricultural commodities resulting from biofuel demand. These studies are generally based on macro-economic models and assume that the land changes are based primarily on economics driven by land rents in different countries and different agro-economic zones (AEZ). However, the changes in land use are determined by many factors other than economics. For example: security of food supply, employment and development policies.

Some macro-economic models such as GTAP (CARB 2009) IFPRI (Valin 2009) have aggregated all oilseeds together as a single unit, so it has not been possible for them to model the interactions in the animal feed market between different oilseed crops and with cereal co-products.

Macro-economic models such as GTAP have up to ??? different commodities, which are all affected by the changes in demand of biofuel crop demand changes. This makes the output of the model opaque in trying to determine the reasons for the results.

Land availability for biofuels

Work was done for the Gallagher Review (RFA 2008), which showed that there are large area of idle land where biofuel crops could be grown. Modelling by the International Institute for Applied Systems Analysis (IIASA) indicated that between 790 and 1215 million hectares of suiable land was potentially available globally. The European Envionmental Agency (EEA 2007) has significantly lower estimates of suitable land ranging from less than 50 m ha to about 400 m ha. However, much of the land identified as available for agriculture is not easily accessible and there is no mechanism to ensure that increased crop demand for biofuels will be grown on this spare land. Arable cropland has replaced grassland in Brazil and Australia, while land has increasingly been left idle in the EU, USA and Eastern Europe. Work is therefore needed to determine, where the increased land use for biofuel crops will occur and what type of natural vegetation it will displace.

Countries where land use change take place

Alternative ways have been tried to determine where land use change for biofuel crops will take place in order to be able to determine the GHG emissions from ILUC.

Macro-economic models assume that land area changes are driven by land rents in suitable agro-economic zones. However, there are many other factors that will determine where crops will be grown. For example:

- commercial crops, such as soy bean and sugar cane require extensive supply chains and tend to expand in existing areas in order to utilise the existing supply chain infrastructure and knowhow.
- policies on land use in different countries influence the change of land use e.g. idle land and forest land areas .

Macro-economic models are generally not checked by back-testing, so it is only possible to check the assumptions by comparing the model prediction results and subsequent changes in land use.

Alternatively it is assumed by Fritsche (2008) that land use change will continue to take place in the same countries as they have historically and the type of changes in natural vegetation conversion are averaged over those countries that export biofuel crops. This is used to determine an average GHG emission factor per ha that is then applied across all biofuel crops. However, this approach takes no account of the different types of climate and natural vegetation of land used for growing different crops.

In this paper, the type of land used for increased crop demand is determined by matching areas of increased crop land to areas where there are changes in natural vegetation using historic data on the type of land use change for each crop.
It is assumed, that the land use changes will take place in the same countries as they have historically. This assumption has been tested for different crops and the results are shown in table 1.

Crop Land Area Changes	**Wheat**	**Maize**	**Rape seed**	**Sugar Cane**	**Soy bean**	**Oil Palm**	**Sugar Beet**
Correlation between land area changes from 1991-2001 and 2001 - 2007	0.77	0.93	0.59	0.85	0.93	0.80	0.74

Table 1

These results show that there is a good correlation between land area changes for each crop in between one period and the next. Therefore the relative land area changes in country crop areas over a ten year period provide a good indication of the relative land area changes over future years.

Most biofuel crops are globally traded, so the change in demand for biofuel crops will be reflected in World prices and will affect production globally. However, due to differential logistics costs, there will be a tendency for extra crops to be grown close to the source of extra demand, so a local figure for the type of land use change should be used. For example if there is increased demand for maize in the USA, it is more likely to be met by higher production in the US than that given by a global average figure. Likewise in the EU, the additional demand for biofuel crops, such as wheat, maize, rapeseed sunflower and sugar beet, which are widely grown in the EU, are more likely to be met by increased production within the EU, rather than by increased production in the rest of the World.

Type of land displaced as a result of land use change

The carbon emissions from land use change for biofuel crops will depend on the average type of land it is displacing and will be different for different crops. Typical land types are: existing idle land, other cropland, grassland and forest. Idle land in the EU is former set-aside land and rotational grassland that is not currently being fully utilised for arable crops, while in the USA land stopped being cultivated due to low crop prices and in the former USSR due to the end of soviet farm collectives.

It is assumed in this analysis that the land use changes in each country will displace the same type of natural vegetation as they have historically. This is tested for deforestation, using FAO (2009a) reported data for forest areas of countries from 1995 to 2007. The data for the countries with the highest rates of deforestation are shown in table 2.

Country	Area change 1995-2007 m ha/yr	Fractional change in forest area 1995-2001 %/yr	Fractional change in forest area 2001-2007 %/yr
Brazil	-2.9	-0.55%	-0.65%
Indonesia	-1.9	-1.84%	-2.07%
Sudan	-0.6	-0.82%	-0.86%
Myanmar	-0.5	-1.31%	-1.43%
Zambia	-0.4	-0.98%	-1.04%
Tanzania	-0.4	-1.08%	-1.16%
Nigeria	-0.4	-2.94%	-3.56%
Congo	-0.4	-0.36%	-0.24%
Zimbabwe	-0.3	-1.59%	-1.75%
Mexico	-0.3	-0.50%	-0.40%
Venezuela	-0.3	-0.58%	-0.60%
Bolivia	-0.3	-0.45%	-0.46%
Australia	-0.2	-0.18%	-0.12%

Table 2

It can be seen that the fractional rates of deforestation are similar for the periods 1995-2001 and 2001 to 2007. Using data for all countries, there is a 92% correlation between the fractional change in forest area from 1995 to 2001 compared with the fractional change in forest area from 2001 to 2007. Therefore the historic changes in natural vegetation, over a ten year period provide a good indication of the changes in natural vegetation over future years.

By doing a country or state land balance between areas of forest, grassland and different crops, an estimate can be made of whether changes in the land area of the biofuel related crop are is displacing forest, grassland, idle land or other crops. If the biofuel associated crop is displacing other crops, then the results of that crop displacement are traced to crop area changes in other countries.

For those countries with the largest increases in land area for a crop, the increase in crop areas have been compared with the changes in areas of forest and permanent grassland in those countries. For example in areas where increases in crop land area correspond to decreases in forested area, the increased crop land area is attributed to deforested land.

Many studies have looked at the underlying drivers of global deforestation, and highlight a more complex relationship between social, economic and policy factors contributing to each step of the transition process from undisturbed forest to permanently deforested cropland or other land use. The Eliasch review, published in 2008, provides a helpful literature review and synthesis of several such studies, from which figure 1 is copied.

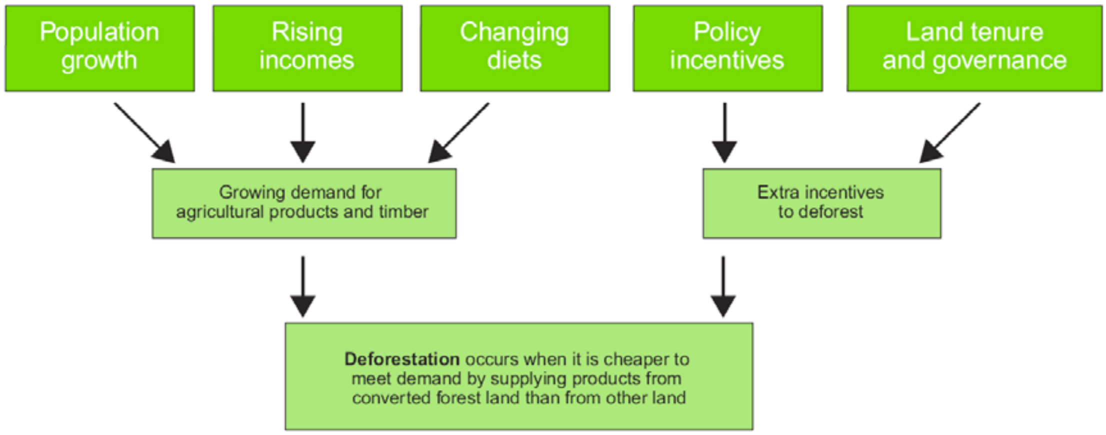

Figure 1

Such models can be used to explain the causes of historic deforestation in individual countries, However the differing importance of social, economic and policy factors in each country means these cannot provide a simple and robust basis for attributing global crop area increases to deforestation and other land use changes. The method proposed in this paper provides such a basis. By attributing crop area increases at a country level based on historic relationships between different land area changes, it recognises the balance of social, economic and political factors contributing to deforestation in each country. It also provides a strong incentive for the main producing countries for each biofuel feedstock crop to ensure that crop area expansion does not proceed alongside high rates of deforestation. The use of 10 year historic factors ensures that a sustained decoupling of crop expansion and deforestation through social and political changes at a country level will feed through into a reduced ILUC impact associated with that country's biofuel and crop exports.

Whilst the analysis used in this paper does not necessarily prove that deforestation is caused by increased in crop area, it enables deforestation to be closely attributed to changes in crop cultivation, such that policies can be developed to reduce deforestation.

Land Use for meat production

The global harvested land area has been increasing from 1995 to 2007 by 0.23%/yr. This cropland area has been obtained by displacing a combination of idle land, grassland and forest. The increase in demand for biofuels will increase the area of cropland required, some of which will be obtained by converting grassland.

It is assumed either explicitly or implicitly in several studies associated with ILUC: Fritsche (2008), Ecofys ???, and in some partial equilibrium macro-economic models, that the conversion of grassland to cropland in one part of the world will inevitably lead to the conversion of forest to grassland in another part of the World. However, no justification has been made for this assumption and so it has been tested below. The analysis is based on the method used in an FAO (2006) study that was done using data up to 2001 and is extended to data up to 2007.

Nearly all grassland and a substantial proportion of cropland is used for the production of meat. A rough estimate of the cropland used for meat production can be estimated as:

Coarse grains: maize, barley, rye, millet, sorghum
Wheat : 50% of European production
Oilseed meals: soya, rape, sunflower,

The proportion of the oilseed crop area attributable to the oil and the meal is determined by a value allocation according to product values. Other crops and crop by-products are also used for animal feed, but the land areas involved are small and will not affect the result of this analysis.

The land areas to provide animal feed and the compound annual growth rates (CAGR) of land use and meat production are shown in table 3

	Land area 2007 mha	CAGR 1995-2007
Grassland area kha	3378	-0.08%
Oil seed area kha	68	3.44%
Cereal area	313	-0.11%
Cropland area	381	0.44%
Total land area	3759	-0.03%
Meat production		2.70%

Table 3 Ref CropProdn/Livestock

It may be seen that the grassland area is about ten times the cropland area used for animal feed production. Global meat production increased by 2.7%/yr from 1995 to 2007, while the total land area decreased by 0.03%/yr. Thus the increased demand for meat production has been met entirely by increases in yield. The major reasons for the increases in meat yield are:

- the move from ruminants to monogastric animals, which are more efficient at meat production
- increased yields of cereal crops, used as animal feed
- increased use of oil meals as feed supplements.

The issue as to the advantages and disadvantages of intensification of meat production do not affect the conclusion from this analysis and is beyond the scope of this paper.

The growth rate of meat production, meat yields and the land area for meat production are plotted over time, from 1961 using four year periods in figure 2. Over a four year period, meat production will be closely equivalent to meat demand.

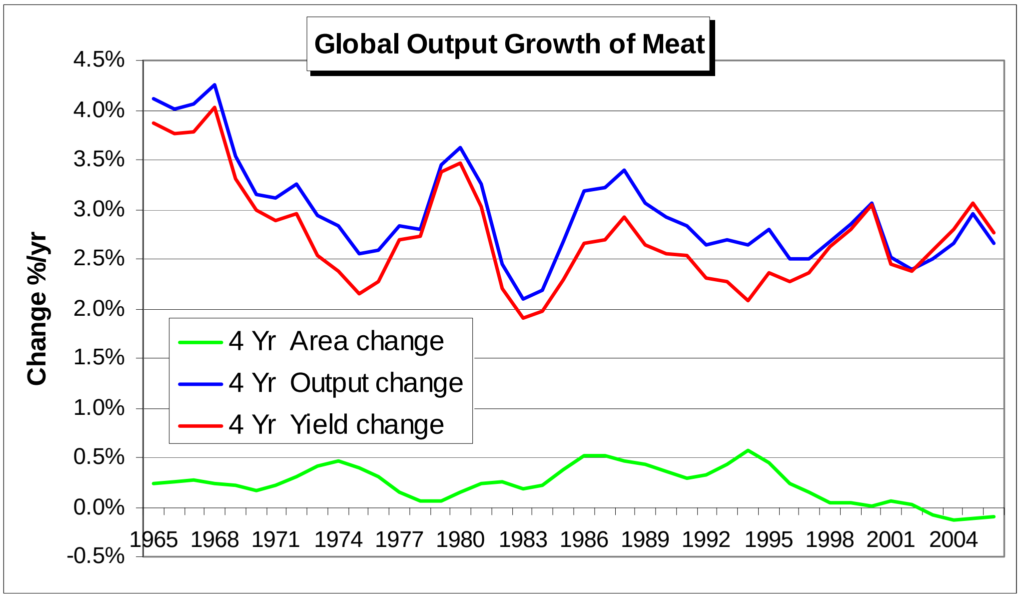

Figure 2

It may be seen that output growth has varied between 2%/yr and 4%/yr according to the growth in demand. This shows that most of the demand growth has been met by yield growth since 1961. It has been even more pronounced over recent years, as shown in table 3 for the period 1995-2007, during which land area growth has been negative. FAO (2006) states that the World has probably passed its peak in the rate of increase in meat demand due to increased demand in developing countries and therefore it is expected that the trend from 1995 to 2007 is likely to continue.

The growth rate of meat yields and the land area for meat production plotted against the growth rate in output over four year periods are shown in figure 3.

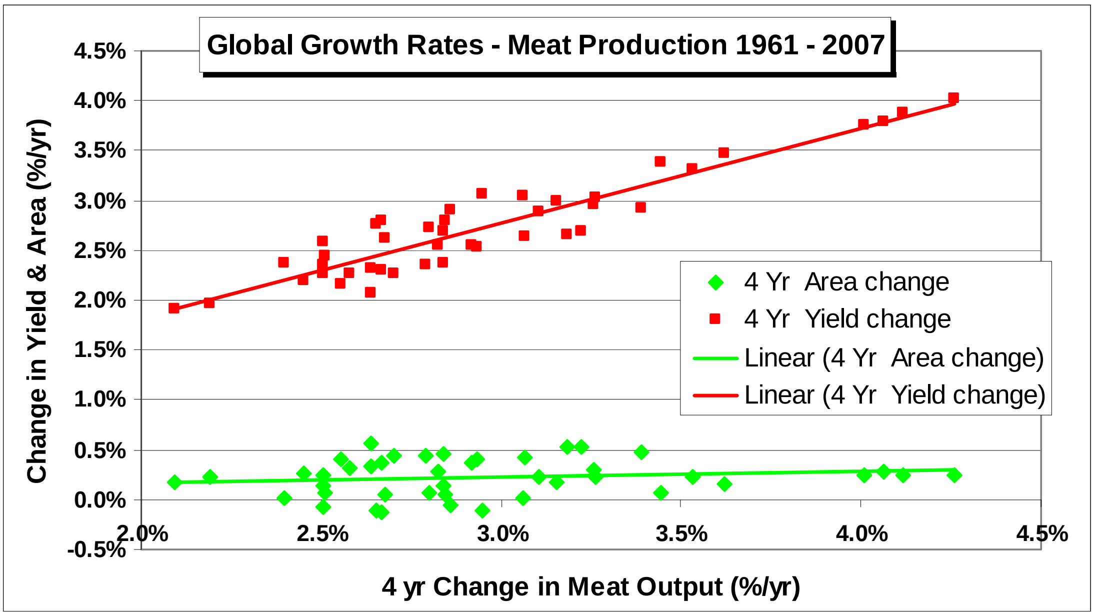

Figure 3

It may be seen that changes in meat demand growth are met entirely by changes in meat yield growth. While there are changes in the growth of land area used for meat production, these are independent and are not related to changes in meat demand growth. Thus while there may be continued conversion of forest to ranchland, this is not being driven by meat demand and is happening anyway.

Any exogenous change in the land area used for meat production will result in a change in meat supply and hence a change in prices. The supply chain will act in exactly the same way to a price change, whether the price change is caused by an exogenous land area change or a demand change, and so will compensate in the same way i.e. by changes in meat yield. Therefore if the increased demand for some biofuel crops displaces grassland, this will be met by increased meat yields and will not drive other land to be turned into grassland. Crops that are grown on displaced grassland in one part of the World will therefore not in turn give rise to deforestation in other parts of the World.

Macro-economic models should also be able to model the effects of exogenous changes in the land area used for meat production. Presumably since these are economic models, they will model the effect of changes in grassland area on meat supply and prices and then model the effect of meat price changes on changes in the meat supply chain. Parameters for macro-economic models must be chosen which enable the models to correctly simulate the actual market behaviour of the meat market over the period from 1995 to 2007 before attempting to predict the effect of increased biofuel demand.

It has been shown above, that conversion of grassland to arable land will drive higher yields in the aggregate global production of meat and will not drive increases in grassland area elsewhere.

Therefore arable crops displacing grassland will not give rise to deforestation and only those crops that are grown in the same country or state where there is deforestation will lead to deforestation.

Therefore, temperate crops needed for biofuel production will directly displace idle land and grassland, but not forest

Increased demand for temperate biofuel crops

Temperate biofuel crops that are widely grown in the EU are: wheat, maize, barley, rye, sugar beet, rapeseed and sunflower. The cereal crops are interchangeable in many areas and crops such as sugar beet and oilseed crops are used as break crops in the cereal rotations. They can therefore be considered together in terms of the type of land they will replace. The global output growth and land area growth of these crops from 1995 to 2007 is shown in table 4.

Temperate biofuel crops	Harvested Area 2007 m ha	Area Growth 1995-2007 mha/yr	CAGR 1995-2007 %/yr
Global	496	-0.13	-0.03%
EU	61	-0.4	-0.56%

Table 4 Ref LandDisp/Summ

Due to increased yields the land area used for these crops has reduced at 0.03%/yr globally and 0.6%/yr within the EU from 1995 to 2007. However, while there has been a reduction in land area in most regions over this period e.g. EU, USA, Canada, Russia and China, there has been an increased area in other regions, for example Australia. There have also been increases in maize in some African countries, but this is generally for subsistence farming and therefore will not be affected by chnages in the traded markets. The reduction in crop areas in some countries has created idle land, for example in Russia, former set-aside land in the EU, or has been converted to grassland in the US. Where there have been increases in the area of temperate biofuel crops, this has displaced grassland, or land that was made idle prior to 1995. In general the area of forest in temperate countries has been increasing and there are no significant examples of forest being displaced by temperate commercial crops.

As the demand for temperate biofuel crops increases, this will cause reuse of idle land in regions that have been creating idle land and will cause increased displacement of grassland in other regions.

FAO (2009b) data for countries or regions with the largest changes is area of temperate biofuel crops from 1995 to 2007 are shown in table 5.

Temperate biofuel crops							
	China	**Argentina**	**Australia**	**Canada**	**EU**	**Ukraine**	**Global**
Change in Land Area kha/yr 1995-2007							
Temperate biofuel crops	-573	-169	387	-261	-355	316	-131
Grassland	0	-6	-3801	-18	-242	30	
All cropland	565	672	317	-163	-355	253	
Ratio Pasture/Cropland area	2.6	4.2	20.0	0.6	0.9	0.4	
Ratio of Historic Land Use Change							**Average**
Global Production							
Grassland	#N/A	100%	100%			11%	**40%**
Idle land	#N/A			100%	100%	89%	**60%**
Local Production							
Grassland						11%	**5%**
Idle land					100%	89%	**95%**
Forest	3261	-150	-244	0	715	17	
Other land	-4585	-260	3294	41	392	35	
ABS		169	387	261	355	316	1488

Table 5 Ref LandDisp/Disp

The estimate of the proportion of increased crop area that will be met by grassland and idle land is estimated by comparing the relative historic changes in areas of cropland and grassland.

The largest reduction in temperate biofuel crop area has been in China. However, these crops have been replaced largely by vegetable crops. It is therefore unlikely that increased demand for biofuel crops will be met by additional planting in China. In Canada and the EU, where the areas of both cropland and grassland have fallen, this has created idle land for reuse. The area of compulsory set aside land in the EU in 2007 was 3.8 m ha and the EU Impact assessment of the 2020 10% target indicated that in the absence of a biofuels policy in the EU, arable land use was expected to continue to fall at a rate of 0.35 m ha /yr.

In Australia the increase in cropland has been obtained by replacing grassland. In the US the land freed up by decreased cropland has been planted for grassland. However, much of this grassland was planted on idle land as part of the conservation reserve program (CRP) program and carbon stocks of this land will be low. In the Ukraine there has been an increase in both cropland and grassland. However CE Delft (2008) quote an FAO assessment that 13 m ha of idle land in the former Soviet Union could be returned to use with little environmental impact and it can be assumed that the recent increased land use in Ukraine is reusing idle land that was created prior to 1995.

There is uncertainty about how much of the EU demand for biofuels will be met by increased EU crop production and how much by increased crop production in the rest of the World. Therefore displacement ratios are shown in the table both for local production and for global production of increased temperate biofuel crops to meet the increased demand in the EU.

Estimates were made by Ecofys (2008) for the Gallagher review that a significant proportion of biofuel crops to meet the EU 2020 target would cause land use change outside the EU. However this analysis did not take account of biofuel co-products, or increased crop yields and assumed a too high ratio of biodiesel to bioethanol to meet the 2020 target. Elsewhere, the Gallagher review (RFA 2008) acknowledged that wheat co-products could offset 60-81% of wheat feedstock area. Work by Ensus (2007) has shown that with expected yield increases and by reuse of former set-aside land in the EU, it would be possible to meet the land requirements for all the expected increase in bioethanol fuel demand, by increased production of cereal crops in the EU. However, there is no guarantee that this is what would happen in practice and while a large proportion could be met by increased EU production, the remainder would be met by reduced exports or by imports.

Calculation of Armington elasticites will be needed to determine the proportions which temperate crops for biofuel production in the EU will be will be supplied by growing crops on idle land within the EU, or on idle land in the former USSR from other parts of the world. These proportions would be expected to depend on the extent and the rate of increase in biofuel use from temperate crops within the EU.

The actual land displacement ratios for temperate crops for EU biofuel production will be between the two bounds for local and global production shown in table 5 and the sensitivity of the results of calculating GHG emissions from ILUC should be determined for these two cases.

It has been shown above that traded temperate biofuel crops are not grown directly on deforested land. Therefore since it is shown in para ?? that displacement of grassland will not lead to deforestation, temperate crops needed for biofuel production will only displace idle land and grassland, but not directly or indirectly replace forest.

EU Sugar Beet

It is not economic to transport sugar beet or beet products over any significant distance, so EU sugar beet can be treated as an isolated market. The sugar production quantity in the EU is fixed by statute and constrained so that it does not compete with other sugar markets. Extra sugar beet for biofuel use will therefore be grown within the EU, and will directly or indirectly reuse idle EU land that has been created over recent years.

Deforestation

Deforestation refers to forest land clearance for other economic uses, while logging refers to commercial timber removal. Deforestation gives a step change reduction in carbon stocks and also prevents the gradual replenishment of future carbon stocks from re-growth of timber. It is claimed in various references ??? that deforestation of tropical forests for use for biofuel crops in Brazil and S E Asia is due to logging. However, no justification is given for this. When timber is removed by selective logging, the forest can be left for new timber to grow naturally, while in plantation woodland, areas of forest are felled for timber and subsequently replanted. In either case the carbon stock of the forest would eventually be replenished. (FAO 2005). For all forests, there is therefore a sustainable rate of timber removal, where the rate of timber removal is less than or equal to the rate of timber growth.

A measure of the relative rate of timber removal is given by the average rate of industrial roundwood removal (FAO 2009c) divided by the growing stock of timber in the forest (FAO 2005). The rate of deforestation is given by the rate of change in forest area between 2000 and 2007 (FAO 2009a). Data on timber removal and deforestation for different countries and regions is given in table 6.

Country/Region	Rate of timber removal %/yr	Rate of deforestation 2000-7 %/yr
European Union	1.4%	-0.5%
USA	1.2%	-0.1%
Canada	0.6%	0.00%
India	0.4%	-0.04%
Russia	0.2%	0.01%
Brazil	0.1%	0.6%
Indonesia	0.6%	2.0%
Malaysia	0.4%	0.7%
Nigeria	0.7%	3.5%

Table 6 Ref LandDisp/Forest

It may be seen that there is no relationship between the rate of commercial timber removal and the rate of deforestation in different countries or regions. For countries such as USA and the EU with good forest management, rates of timber removal of greater than 1%/yr can be achieved with no deforestation. Countries such as Canada, India and Russia, with large areas of unexploited forest, achieve lower timber removal rates between 0.6% and 0.2%/yr with no reduction in forest area. For Brazil, Indonesia, Malaysia and Nigeria, the rates of timber removal are no higher than for other countries, yet there are significant rates of deforestation. In fact the rates of deforestation are higher than the rate of timber removal. This indicates that some deforestation is occurring while only recovering a fraction of the available timber.

Logging is justified by the value of timber that is removed. However, the cost of land clearance for agriculture can only be justified for the purposes of other economic land uses, predominantly agriculture and is driven by the value of crops or livestock that can be grown on cleared land.

When land clearance is associated with logging, only part of the carbon stocks of the land can be attributed to the land clearance and this should be taken account of in the calculation of carbon stock losses as a result of deforestation. However when as shown in table 2 for countries where only a fraction of the available timber is being recovered, the proportion of the reduction in carbon stocks attributable to logging will be small.

It has been shown that deforestation (forest land clearance for other economic uses) is distinct from logging (commercial timber removal) and while timber removal may take place at the same time as land clearance for agricultural use, the deforestation is not caused by the timber removal. The deforestation due to land clearance is driven by the value of the land for other uses.

Palm Oil

The countries with the largest changes in oil palm land area (FAO 2009b) and the respective changes in cropland (FAO 2009b) and natural vegetation (FAO 2009a) is shown in table 7. These countries represent 90% of the increase in oil palm area from 1995 to 2007

	Indonesia	Malaysia	Nigeria	Thailand	Global
Change in Land Area kha/yr 1995-2007					
Oil Palm	274	132	29	22	506
Forest	-1871	-116	-410	-80	
Grassland	-40	0	-67	0	
Cropland	378	94	637	54	
Ratio of Historic Land Use Change					**Average**
Forest	98%	88%	86%	100%	94%
Grassland	2%	0%	14%	0%	2%
Cropland	0%	12%	0%	0%	3%

Table 7

It may be seen that the countries where there has been the largest increase of oil palm land area are countries where there has also been substantial deforestation. For all countries except Malaysia, the decrease in forest area exceeds the increase in oil palm area, so the increased palm area must directly or indirectly be grown on deforested land. It is Indonesian government policy to expand oil palm production into forest and peat land areas. In Malaysia the amount of deforestation from 1995 to 2005 has been lower than the increase in oil palm and there has been no reduction in grassland, so the remaining oil palm has been grown on existing cropland and displaced other crops.

The crops displaced by oil palm in Malaysia are rubber and cocoa beans. These crops have been displaced primarily to Indonesia, Nigeria, Thailand and Ghana, where the land for these crops is provided primarily by deforestation. The change resulting from crops displaced from Malaysia is shown in appendix 1.

The overall split of the type of land used for increased oil palm production after allocation of replaced cropland is shown in table 8

	Indonesia	Malaysia	Nigeria	Thailand	Weighted Average
Ratio of Historic Land Use Change					
Oil Palm	274	132	29	22	
Forest	98%	88%	86%	100%	
Grassland	2%	0%	14%	0%	
Cropland	0%	12%	0%	0%	
Forest displaced via cropland		89%			
Grassland displaced via cropland		4%			
Other land displaced via cropland		7%			
Total ratio of historic LUC					
Forest	98%	99%	86%	100%	97%
Grassland	2%	0%	14%	0%	2%
Other land	0%	1%	0%	0%	0%

Table 8 Ref LandDisp/Disp

It may be seen that nearly all oil palm has either displaced forest in the countries where it is grown or displaced other crops which are grown in other countries where they in turn displaced forest. The net effect is that land for oil palm has historically almost entirely been obtained directly or indirectly by using deforested land.

Global protein meal and vegetable oil demand and supply

The average prices (USDA 2009a) and relative values of vegetable oil and meal from different biofuel oilseed crops is shown in table 9.

		Soy	Rape	Sun	Palm
Average 2001-08					
Oil price US	USD/ton	542	695	858	636
Meal price US	USD/ton	212	168	106	82
Oil yield	t/t crop	0.19	0.410	0.420	0.235
Meal yield	t/t crop	0.74	0.557	0.550	0.028
Oil value	USD/ton crop	102.9	285.1	360.2	149.6
Meal value	USD/ton crop	157.1	93.4	58.1	2.3
Oil value/total product value		**40%**	**75%**	**86%**	**98%**

Table 9 Ref Price Trends/Summ

It may be seen that for rape, sunflower and palm, the vegetable oil is significantly more valuable than the meal and it is generally accepted that the crop is being grown for the vegetable oil. However, in the case of soya bean, the meal has a significantly higher value than the oil and it is important to consider whether soya bean is being grown primarily to provide meal, rather than to provide oil.

The global trade in meals (USDA 2009b) for animal feed is shown in figure 4. and the results are summarised in table 10

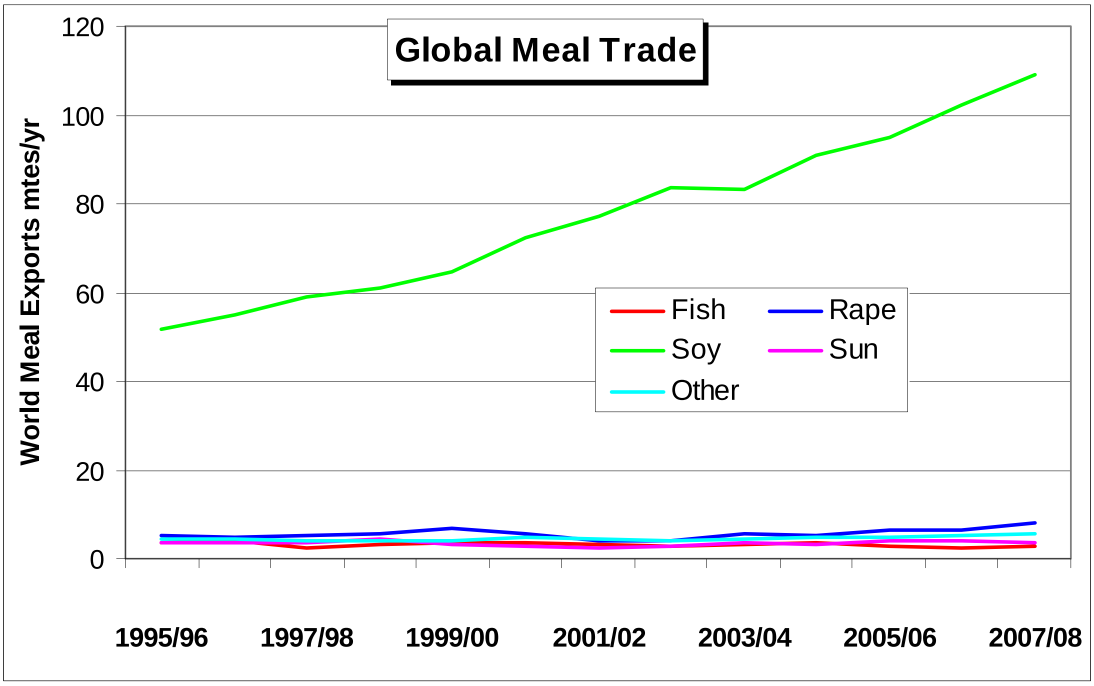

Figure 4 Ref Animal Feed Volumes/USDAOilseed

Global Trade		Soybean	Rape seed	Sunflowe rseed	Palm	Fish Meal
Meal Exports						
Exports Avg 2006-8	mt /yr	102.1	7.1	4.0		2.7
Export growth 1998-2008	mt /yr	50.1	3.0	0.1		0.6
Vegetable oil exports						
Exports Avg 2006-8	mt /yr	10.4	1.9	3.7	28.1	
Export growth 1998-2008	mt /yr	4.4	-0.1	0.2	19.6	

Table 10 Ref Animal Feed Volumes/Summ

It may be seen from figure 4 and table 10 that nearly all the current trade in high protein meals and growth in trade over the last 12 years has been in soy meal and it may therefore be concluded that soy meal is the marginal global source of protein meals to meet the demand for animal feed.

The global trade in vegetable oils is shown in figure 5

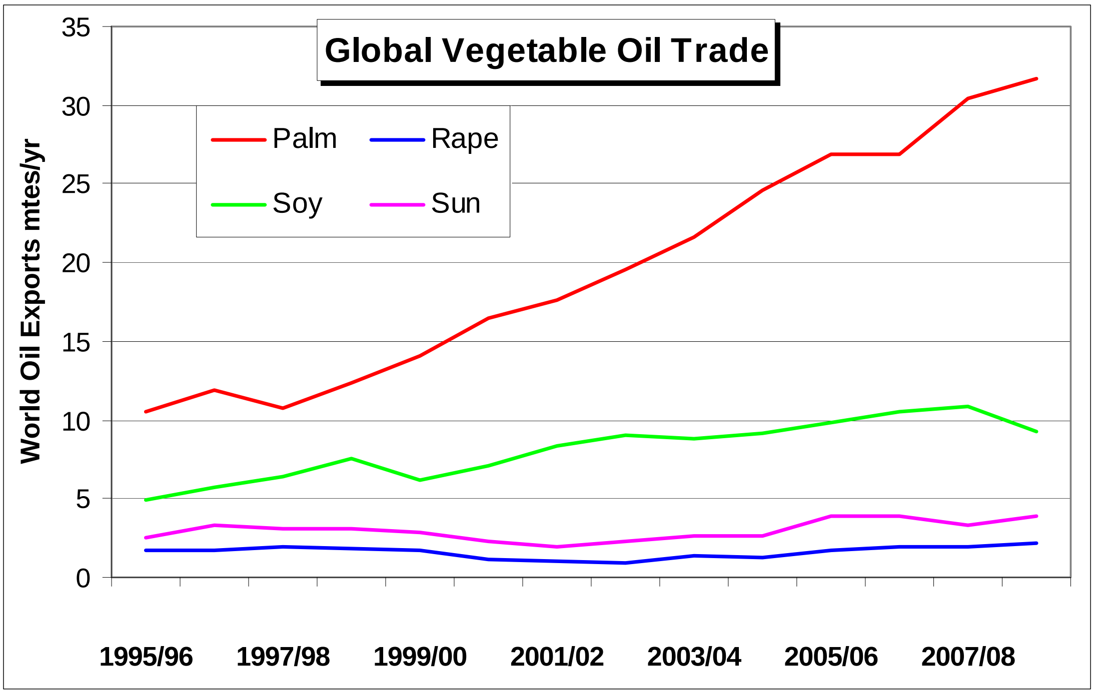

Figure 5

It may be seen from figure 5 and table 10 that while there has been an increase in soy oil exports as a result of the increased production of soya been, most of the increase in trade in vegetable oils 12 years has been from palm oil. It may therefore be concluded that palm oil is the marginal global source to meet the growing demands for vegetable oil.

On the basis of these data it may be concluded that soya bean growth is being driven by the demand for soy meal to meet the global demand for animal feed protein, while palm is being grown to meet the marginal global demand for vegetable oil.

It follows from this that the substitution of biofuel co-products for soy meal will reduce the growth rate of soya bean production. It also follows that the use of soy oil to make biodiesel will not affect the growth rate of soya bean and will be replaced by increased production of palm oil.

Rape seed production

It has been argued that making biodiesel from rape oil (as with soy above) will mean that the rape oil will need to be replaced by palm oil. However, the situations with rape and soy are quite different. The production of rapeseed in the EU is shown in figure 6.

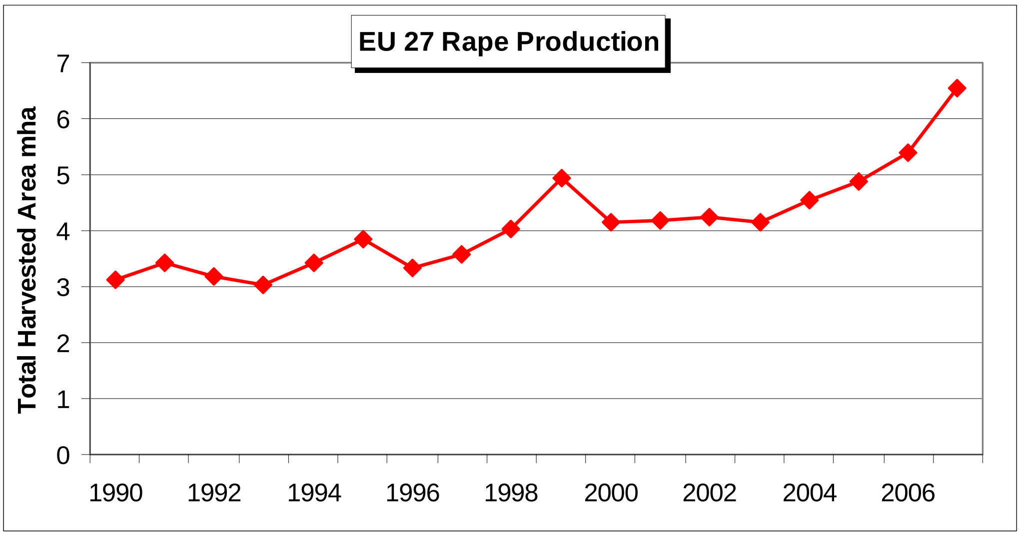

Figure 6 Ref Crop Production/rape

It may be seen that the growth was fairly steady until 2003 with a compound annual growth rate of only 2.3%/yr from 1995 to 2003. Rape was justified as to provide a break crop in some cereals rotations, but economics did not justify additional rape cropping. However, since the introduction of EU biodiesel production in 2003, the CAGR has been 11%/yr to meet the demand for sustainable biodiesel from rape in the EU.

Since the increased growth of rape production in the EU was only as a result of the demand for biodiesel, it cannot be argued that the use of rape oil for biodiesel production in the EU is increasing the demand for palm oil.

Soya bean production

Since as is shown above, soya bean is primarily grown to meet the global meal supply, the type of land used to grow soya bean is important to determine the indirect land use credit for those biofuel co-products that will replace soy meal as animal feed.

The countries with the largest increases in soya bean land area and changes in cropland and natural vegetation in these countries is shown in table 11. These countries represent 91% of the increase in soya bean area from 1995 to 2007.

	Brazil	Argentina	USA	India	Paraguay	Global
Change in Land Area kha/yr 1995-2007						
Soybean	1081	939	354	259	130	3050
Forest	-2941	-150	238	238	-179	
Grassland	340	-6	270	270	25	
Cropland	1431	672	-269	-269	179	
Ratio Pasture/Cropland	3.6	4.2	2.4	2.4	5.4	
Ratio of Historic Land Use Change						**Average**
Forest	50%	16%	0%	0%	50%	27%
Grassland	50%	56%	100%	0%	50%	54%
Cropland	0%	28%	0%	100%	0%	19%

Table 11

The largest increase in land area of soya bean production is in Brazil. In Brazil the growth of soy area is associated with a large rate of deforestation. Work by Themba (2008) and Sparovek (2007) show that while soya bean has historically been grown in the South of Brazil, the more recent tendency has been for increased soya bean production to be in the Amazon Basin. Work by Morton (2006) found that in the Mato Grosso from 2001 to 2004, conversion to pasture accounted for most of the deforestation, while large scale cropland accounted for 17% of new deforestation. Cropland expansion was directly obtained in equal proportions from cerrado, planted pasture and forest. However, since most of the pasture in Mato Grosso is obtained from deforestation, it has been assumed that 50% of the cropland from pasture is indirectly obtained by deforestation. Therefore including the cropland obtained directly from deforestation, 50% of soya meal was attributable directly or indirectly to deforestation. This result for Mato Grosso is assumed to be typical for Brazil, but needs to be checked and the sensitivity of this assumption will need to be tested on the GHG credit for biofuel co-products.

In Argentina the deforestation is taking place in the northern states of Chaco, Santiago del Estoro, Salta and Formosa. The rate of increase of soya bean area in these states from 1995 to 2007 was 154kha/yr (SAGPYA 2009), which closely matches the deforestation rate in Argentina (FAO 2009a). Since the increase in soya bean is greater than the total increase in cropland, some soya bean is displacing cropland. The land area changes for Argentina in FAO statistics, do not balance and it is assumed that the remaining soya bean is replacing grassland area. The data for crop displaced from Argentina and the land they are replaced to is shown in appendix 1.

In Paraguay soya bean has displaced areas of the interior Atlantic forest.
In the USA as in para ??, the marginal land use change is grassland.
In India increased soya bean area is split between grassland and cropland and the data for crops displaced in India and the land they are replaced to is shown in appendix 1.

The overall split of the type of land used for increased soy production after allocation of replaced cropland is shown in table 12

Soy bean summary							
	Brazil	Argentina	USA	India	Paraguay	Average	
Change in Land Area kha/yr 1995-2007							
	1081	939	354	354	130		
Ratio of Historic Land Use Change							
Forest	50%	16%	0%	0%	50%	27%	
Grassland	50%	56%	100%	0%	50%	54%	
Cropland	0%	28%	0%	100%	0%	19%	
Weighted average of displaced cropland							
Forest		7%		34%			
Grassland		30%		50%			
Cropland		17%		16%			
Idle land		45%		0%			
							Normalised
Combined ratio of Historic Land Use Change						**Average**	**Average**
Forest	50%	18%	0%	34%	50%	31%	33%
Grassland	50%	64%	100%	50%	50%	61%	63%
Cropland	0%	5%	0%	16%	0%	4%	0%
Idle land		14%		0%		5%	5%

Table 12

Sugar cane production

The countries with the largest increases in sugar cane land area and changes in cropland and natural vegetation in these countries is shown in table 13. These countries represent 99% of the increase in sugar cane area from 1995 to 2007.

	Brazil	India	China	Global
Change in Land Area kha/yr 1995-2007				
Sugar cane	148	30	15	197
Forest	-2941	157	3261	
Grassland	340	-56	0	
Cropland	1431	245	565	
Ratio Pasture/Cropland	3.6	0.1	2.6	
Ratio of Historic Land Use Change				**Average**
Forest	0%	0%	0%	0%
Grassland	100%	23%	0%	80%
Cropland	0%	77%	100%	20%

Table 13

Although Brazil has the largest increase in sugar cane area as well as a high rate of deforestation, the areas where sugar cane is planted are different from those where there is deforestation. Since the ratio of pasture to cropland in Brazil is high, it can be assumed that as explained in para ?? that the use of pasture to grow sugar cane, will not drive the replacement of forest by pasture.

Increased sugar cane area in India is split between grassland and cropland. Data for crops displaced in India and China and the land they are replaced to is shown in appendix 1.

The overall split of the type of land used for increased sugar cane production after allocation of replaced cropland is shown in table 14

Sugar Cane Summary	Brazil	India	China	Average	Normalised Average
Change in Land Area kha/yr 1995-2007					
	148	30	15		
Ratio of Historic Land Use Change					
Forest	0%	0%	0%	0%	
Grassland	100%	23%	0%	80%	
Cropland	0%	77%	100%	20%	
Weighted average of displaced cropland					
Forest		34%			
Grassland		50%	40%		
Cropland		16%			
Idle land			60%		
Combined ratio of Historic Land Use Change				**Average**	**Normalised Average**
Forest	0%	27%	0%	4%	4%
Grassland	100%	61%	40%	89%	91%
Cropland	0%	12%	0%	2%	
Idle land	0%	0%	60%	5%	5%

Table 14

Summary of land displacement ratios

The results of the ratios of different types of land displaced by different crops is shown in table 15 and figure 7.

There are uncertainties in the calculation of these ratios and it will be important to determination the sensitivity of the GHG emissions from ILUC to these uncertainties.

Better accuracy for historic data may be achieved by using more accurate data for the areas of crop growth and deforestation on a state by state, rather than country by country basis. For temperate crops a better view as to what proportion of increased demand for biofuel crops will be grown within the EU and how much is produced in the World market, may be ale to be determined by macroeconomic models. However this will also depend on other policies made within the EU.

Crop	Palm	Soy	Sugar Cane	Temperate Crops	
Land type				**World supply**	**Local supply**
Forest	97%	33%	4%	0%	0%
Grassland	2%	63%	91%	40%	5%
Idle land	0%	5%	5%	60%	95%

Table 15

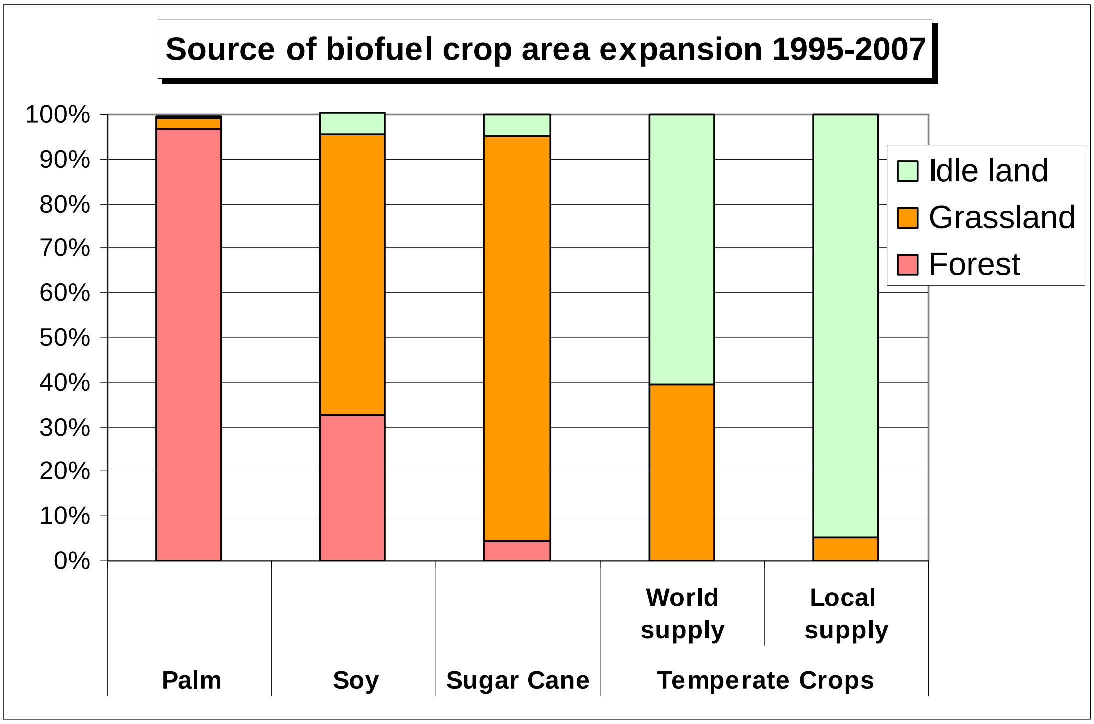

Figure 7

Attribution of deforestation to commercial crops

In the preceding paragraphs deforestation has been attributed to biofuel crops on a crop by crop basis. It is useful to check the results from this analysis by considering the causes of deforestation and the growth of commercial crops that are associated with deforestation, by considering the expected change in crop area in each country, and attributing this to idle land, grassland and forest area changes within the same country, according to the historic ratios of changes in these types of land use.

FAO (1980) (Ecometrica reference) split down the causes of deforestation. The major cause of deforestation was subsistence farming. Subsistence farmers grow cereals and vegetables for their own food do not have the currency to buy traded crops and are not efficient enough to compete with commercial production. Deforestation due to subsistence farming will therefore not be affected by changes in global markets due to biofuels. FAO estimated that 16% of deforestation was caused by commercial cropping. Other significant causes of deforestation were ranching and loss of forest to supply wood for fuel.

An estimate of deforestation attributable to production of commercial crops is shown in table 16. Commercial crops require substantial infrastructure and production scale and include oil palm, soya bean, rubber and coffee. They are not grown as subsistence crops. Deforestation is attributed to different crops by matching increases in areas of crop growth to areas of deforestation as in the analysis above.

Change in Land Area kha/yr 1995-2007	Indonesia	Malaysia	Nigeria	Thailand	Brazil	Argentina	Paraguay	Myanmur	Ghana	Total
Forest	-1871	-116	-410	-80	-2941	-150	-179	-466	-123	-6337
Oil Palm	274	132	29	22					30	
Soya bean			7		541	939	130	7		
Groundnuts	3		5		2			19	32	
Seame seed			6					64		
Rubber	70		5	21	5			3		
Coffee	55				39					
Cocoa bean	13		36						73	
Total Commercial crops	**414**	**116**	**88**	**43**	**587**	**150**	**130**	**92**	**123**	**1743**

Table 16 Ref LandDisp/Summ

Due to the rapid increase in oil palm production in Indonesia, an adjustment has been made to include the increase in immature (i.e. non harvested) area.

Global rates of deforestation since 1995 are:

Deforestation Rates 1995-2007		
Total global deforestation	kha/yr	12787
Total global reforestation	kha/yr	4870
Net global deforestation	kha/yr	7917
Global deforestation to commercial crops	kha/yr	1812
	% of total	23%

Table 17 Ref LandDisp/Summ

The proportion of calculated global deforestation attributable to increases in commercial crops is 14% of total deforestation and 23% of net deforestation. This agrees well with FAO (1980).

It has been shown that the proportion of deforestation attributable to commercial cropping can be accounted for by directly matching areas of increased commercial crop land to areas of deforestation.

Reasons for increased growth of commercial crops associated with deforestation

Crops such as oil palm, rubber, coffee and cocoa have always only been grown in tropical countries and been associated with deforestation. The increased production in these countries is due to increased demand for these crops.

Data for soya been is shown in table 10 The largest supplier of soya bean in 1990 was the US. As the demand for soya bean has increased substantially over the last 20 years, all countries including the US have increased soy land area. Therefore the increase in land area in Brazil, Argentina and Paraguay is due to increased demand for soy, not because of increases in the land area used elsewhere. Indeed cropland has been left idle in the US, while grassland and forest have been converted to grow soy in S America. The growth of soy in S America therefore is not caused by pressure from other crops.

It has been shown that the growth of commercial crops associated with deforestation land is due to increased demand for these crops and there is no evidence that they are being pushed onto using forested land due to land pressure from temperate crops.

Use of macro-economic models

Macro-economic models are used for solving complex world trade problems. For the prediction of natural vegetation changes resulting from changes in land requirements for increased biofuels production, there are a relatively small number of specific issues that need to be resolved.

From the analysis above it can be seen that these issues include:

- to determine the type of land in terms of natural vegetation that will be used to grow increased demand for other biofuel crops and animal feed crops.
- to confirm that changes in meat supply due to changes in available grassland area will be met by changes in meat yield, rather than by indirect land area changes elsewhere.
- to confirm that soy is grown for its meal as a marginal global high protein animal feed.
- to confirm that marginal global vegetable oil demand is supplied by palm oil.
- to confirm that increases in rape is being grown in Europe to supply the EU biodiesel market, rather than to meet the global demand for vegetable oil.
- to confirm that growth of commercial crops grown on deforested land is not due to land pressure from temperate and other crops.

It is clear that In order to resolve these issues a macro-economic model must have the necessary functionality. For example oilseeds cannot be aggregated together.

The macro-economic models will need to show for each of these issues, they are able to simulate actual data over the last 10-15 years, before they are used to predict or confirm the effects of increased biofuel demand on indirect land use change.

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Appendix

Malaysia displaced crops

The changes in the crop areas of different crops in Malaysia is shown in table A1.1.

Malaysia crop changes		Palm	Natural rubber	Cocoa beans	Total
Change in crop area 1995-2007					
	kha/yr	16	-11	-13	-24

Table A1.1

It may be seen that the oil palm has directly or indirectly replaced cocoa beans and rubber. Since the total global demand for these crops has increased, the shortfall of production of these crops in Malaysia has been made up in other countries. The countries with the largest changes in cocoa bean and rubber plantation area and changes in cropland and natural vegetation in these countries is shown in table A1.2

Natural rubber		**Indonesia**	**Viet Nam**	**Thailand**	**Global**	**Average**
Change in Land Area kha/yr 1995-2007						
	Natural rubbe	70	18	21	133	
	Forest	-1871	239	-80		
	Grassland	-40	9	0		
	Cropland	378	199	54		
Total ratio of historic LUC						
	Forest	98%	0%	86%		79%
	Grassland	2%	0%	14%		4%
	Other land	0%	100%	0%		17%
Cocoa beans		**Ghana**	**Nigeria**	**Indonesia**	**Global**	**Average**
Change in Land Area kha/yr 1995-2007						
	Cocoa beans	73	36	13	73	
	Forest	-123	-410	-1871		
	Grassland	-2	-67	-40		
	Cropland	127	637	378		
Total ratio of historic LUC						
	Forest	98%	86%	98%		95%
	Grassland	2%	14%	2%		5%

Table A1.2

It may be seen that the countries where there has been the largest increase in cocoa bean and rubber plantation land area are countries where there has also been substantial deforestation. For all countries except Vietnam the decrease in forest area exceeds the increase in cocoa bean and rubber plantation, so the increased palm area must directly or indirectly be grown on deforested land. In Vietnam the palm is grown on other land and has not given rise to deforestation.

Argentina displaced crops

The main crops displaced from cropland in Argentina are:

Argentina crop changes	Sunflower seed	Cotton seed	Maize	Wheat	Total
Change in crop area 1995-2007 kha/yr	-107	-59	-27	-43	-236

Table A2.1

Wheat, maize, and sunflower are temperate crops and met by displacing a mixture of grassland and idle land as shown in table A2.1. The increases in seed cotton areas and the land they are replaced to is shown in table A2.2

Cotton seed	China	Burkina Faso	Nigeria	Brazil	
Change in Land Area kha/yr 1995-2007					
Cotton seed	68	44	24	20	
Forest	3261	-24	-410	-80	
Grassland	0	0	-67	0	
Cropland	565	174	637	54	
Ratio of Historic Land Use Change					**Average**
Forest	0%	14%	86%	100%	30%
Grassland	0%	0%	14%	0%	2%
Cropland	100%	86%	0%	0%	68%

Table A2.2

The average figures for displaced cropland in Argentina is shown in table A2.3

Average Argentina displaced crops	Sunflower seed	Seed cotton	Maize	Wheat	Average
Change in Land Area kha/yr 1995-2007					
Displaced crop	107	59	27	43	
Ratio of Historic Land Use Change					
Forest		30%			7%
Grassland	40%	2%	40%	40%	30%
Cropland		68%			17%
Idle land	60%		60%	60%	45%

Table A2.3

China displaced crops

China crop changes	Wheat	Rice	Total
Change in crop area 1995-2007			
kha/yr	-753	-294	-1047
Ratio of Historic Land Use Change			**Average**
Grassland	40%		40%
Idle land	60%		60%

Table A3.1

India displaced crops

The main crops displaced from cropland in India are:

India crop changes		Sorghum	Millet	Groundnuts	Total
Change in crop area 1995-2007					
	kha/yr	-230	-132	-114	-477

Table A4.1

Sorghum			
	Nigeria	**Brazil**	
Change in Land Area kha/yr 1995-2007			
Sorghum	98	56	
Forest	-410	-2941	
Grassland	-67	340	
Cropland	637	1431	
Ratio Pasture/Cropland	1.0	3.6	
Ratio of Historic Land Use Change			**Average**
Forest	86%	0%	55%
Grassland	14%	100%	45%
Cropland	0%	0%	0%
Millet			
	Niger	**Mali**	
Change in Land Area kha/yr 1995-2007			
Millet	106	56	
Forest	-31	-100	
Grassland	617	244	
Cropland	249	144	
Ratio Pasture/Cropland	2.1	7.7	
Ratio of Historic Land Use Change			**Average**
Forest	0%	0%	0%
Grassland	100%	100%	100%
Cropland	0%	0%	0%

Groundnuts				
	China	**Ghana**	**Myanmur**	
Change in Land Area kha/yr 1995-2007				
Groundnuts	98	32	19	
Forest	3261	-123	-466	
Grassland	0	-2	-5	
Cropland	565	127	464	
Ratio Pasture/Cropland	2.6	2.1	0.0	
Ratio of Historic Land Use Change				**Average**
Forest	0%	98%	99%	33%
Grassland	0%	2%	1%	1%
Cropland	100%	0%	0%	66%

Table A1.2

Average India displaced crops				
	Sorghum	**Millet**	**Groundnuts**	**Average**
Change in Land Area kha/yr 1995-2007				
Area	230	132	114	
Ratio of Historic Land Use Change				
Forest	55%	0%	33%	34%
Grassland	45%	100%	1%	50%
Cropland	0%	0%	66%	16%

Table A1.3