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FOOD *VERSUS* FUEL:

CAN WE AVOID CONFLICT?

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GENERAL INTRODUCTION TO THE CURRENT FOOD VERSUS FUEL DEBATE

The aims of this chapter are: i) to present the main food versus biofuel debate arguments and the moral/ethical dilemmas, ii) assess the role of the agricultural sector and land use competition, iii) examine the impacts on food prices, subsidies, GHG and energy balance, iv) outline the potential implications of the second generation of biofuels, v) assess sustainability issues, and vi) identify major RD&D gaps.

There is an on-going debate on biofuels which has focused primarily on the overall social and environmental benefits, and land use competition. The food versus fuel debate is not, however, new (e.g. see Rosillo-Calle and Hall, 1987), but it has intensified significantly in 2007 and 2008 partly because the sharp increase in food prices largely blamed on biofuels. Also, new evidence has recently emerged on the overall GHG benefits of biofuels for which there is currently little consensus. In addition, there are widely diverging views on the sustainability of the current and future development of biofuels. These uncertainties are partly the consequence of lack of long term data which can only be addressed by investigating many of the existing R&D gaps, to gain better understanding of the full implication of biofuels.

Unfortunately the general press has highlighted primarily the potential negative effects, ignoring the fundamental message. A common feature of all these studies is that they lack rigorous long term scientific data to back up most of the claims. Production of biofuels is complex given the key role of agriculture, the potential impacts of climate change, increasing demand for food, feed, energy, and other biology-based products, and environmental scrutiny (see Rosillo-Calle and Johnson, 2010).

While biofuels were widely blamed for the surge on food price increases in 2007 and 2008, the reality is that there are complex reasons often little to do with biofuels expansion, e.g. lack of investment in agriculture, short term objectives, speculation, social injustice and poverty, to mention just a few. *Direct land competition* is a myth rather than a reality considering that merely 1% of the global crop land area is currently dedicated to biofuels. There are more than 2 Gha of underexploited land, plus 700 Mha of other type of land that could be used for non-food purposes without affecting food production. As Hazel and Wood (2007) put it *"... more food is produced than needed to feed the entire world population and at prices that have never been so low. The fundamental hunger problem today is one of income distribution rather than food shortages"*.

For decades farmers have seen their income falling as the price of agricultural commodities has kept falling year after year[1]. Agriculture has

[1] For example, in the UK if wheat prices kept pace with inflation over the past century, wheat would now be worth about $1200/t, rather than it current price of $ 190/t. See Biofuels-Some Myths and Misconceptions, National Farmers Union, UK (www.nfuonlie.com).

suffered from chronic under investment in most parts of the world e.g. in the 1980s about 17% of international development aid was for agriculture, but in 2005 this was just 3%. On the whole, the cost of the raw materials play a comparatively small role in the retail of food since price increases are largely determined by traders, speculation and the price of oil, among others.

True, while world demand for energy continues to grow, supply of cheap and clean energy are dwindling; at the same time population also continues to grow and so does the demand for improving living standards. What could therefore be the potential role of agriculture in meeting such demand without jeopardising its primary role of providing food? What would be the economic, social, political, and environmental consequences? How this increasingly complex situation is managed will be crucial in the future.

Biofuels have both the potential for providing many benefits but also many negative impacts if not properly managed. Biofuels are diverse as there are many different feedstocks from which they can be produced, each one with its own pros and cons. It is also fundamental to recognise that biofuels can only provide a fraction of our energy needs and thus any claim that they can provide the majority of our transport fuel needs is without a solid foundation, except in some specific circumstances e.g. Brazil. *Biofuels are not the problem but part of the problem and also part of the solution*. Unfortunately the debate has been driven mostly by politics, moral and ethical issues, and vested interest, rather than science.

THE THREE MAJOR ETHICAL/MORAL DILEMMAS OF BIOFUELS

There are at least three major ethical and moral dilemmas when it comes to biofuels, at least with regard to the first generation: i) should we produce food or fuel, or both and if so to what extent?, ii) to what extent do biofuels cause negative impacts on climate change?, and iii) to what extent do biofuels contribute or not to socio-economic development, wealth generation and distribution. None of these questions are easy to answer.

Should we produce food or fuel?

Opinions are divided and far from being scientifically driven in most cases. For many people it is simply unethical to use land to produce biofuels which benefit mostly the rich. A strong argument is that close to 2 billion people are undernourished in the world. This argument is, however, rather simplistic since the reasons why people go hungry are many and complex, and often have nothing to do with food and land availability or biofuels.

Generally, there is considerable amount of food available, and so if people go hungry is because they simply cannot effort to buy food, particularly the poorer. The root of the problem is social and economic inequality, with or without biofuels. At the same time it is obvious that, given the right conditions (i.e. financing, markets, skills etc.), farmers can deliver far more food than believed by the general public.

Therefore the answer should be yes, we can produce both food and biofuels to a certain extent on a global scale, without affecting food production, with good management practices.

Climate change

The greatest challenge facing humankind is perhaps the potential impacts of climate change. So the question we need to pose is, do biofuels make or not a net positive impact on global warming? On balance, it seems, the overall impacts are positive although evidence is still unclear simply because we do not have the methodology in place to make all the necessary calculations, and therefore much will depend on the specific feedstock and circumstances. The study by Searchinger *et al*. (2008) has raised new questions and challenges, but still leaves many unanswered questions that need to be investigated. Even the questions raised by Searchinger *et al*. are questionable.

The role of biofuels in wealth creation and distribution

For some people biofuels crate and distribute wealth while other disputes this. This argument is rather superficial and unbalanced because biofuels are not *intrinsically* better or worse than any other crop and therefore they need to be analysed within a wider social, economic and political context. For example, critics of biofuels often cite working conditions in the Brazilian sugarcane fields, without taking into account the overall social and economic reality prevailing in that country or region. Actually, in Brazil the working condition of workers in the sugarcane industry is much better than in similar industries such agricultural and forestry. While a very high standard is required for workers in the ethanol industry, the working conditions in other agricultural sectors are simply ignored or overlooked. This is a clear example of double moral judgement.

THE ROLE OF THE AGRICULTURAL SECTOR

Agriculture is extremely important, the key to our survival, not only as the source of our food, feed, energy etc., but also because for many, primarily in the developing world, their livelihood depends on agriculture. Land is finite while our demand on land is increasing continuously, beyond the famous seven "Fs": Food, Feed, Fuel, Feedstock, Fibre and Fertiliser.

The agricultural sector faces therefore its greater historical challenge ever as demand for agricultural-based products and fuels continue to increase due to the combination of growing population, and cultural changes. Modernisation of agriculture, particularly in most of the developing countries, is essential to increase productivity and overall production. Agriculture's increasing global role as potential provider of many raw materials other than food products could, at the same time, attract massive new investment, creating many new opportunities for innovation and diversification which could truly transform agriculture as we know it. For this to be achieved, massive investment is needed in new cultivation techniques, development of new crop varieties that require less water, fertilizer etc.; capacity building, skills, infrastructure etc.

It seems clear that if farmers are provided with the right conditions they will be able to produce far more food, energy and industrial products. Think of the poor African farmer, and specially women, only if he/she[2] could have access to the same conditions farmers have in the industrial countries! This requires many fundamental changes e.g. land ownership, fair land distribution, good educational level, availability of capital, skills, finance, marketing knowledge, and so forth. Farming cannot be seen as a backward activity, but as a science driven industry. Investment on modern scientific research for agriculture led to dramatic yield breakthroughs in the last century e.g. in England wheat yields took nearly 1,000 years to increase from 0.5 to 2 t/ha/yr, but just 40 years to increase to 6 t/ha/yr (Hazel and Woods, 2007).

It is unfortunate that most governments have neglected agriculture for so long. By transforming agriculture and fairer trade of agricultural products (including biofuels) it would be possible to produce far more food and also substitute between 5% and 20% of petrol in transportation by biofuels without affecting food supply. In addition, avoiding post-harvest loses, will be a key factor in increasing food production. What is needed is large investment on R&D, changes in land ownership and rights, the way we produce, transform, and distribute agricultural products and so forth.

Land availability

There remain many unanswered questions with regard to the total land availability that can be dedicated for energy crops and agricultural land due to lack of long term scientific data. Physical availability of land tells us very little without a full analysis of the wider factors. Additional uncertainties include the long-term productivity and sustainability of energy crops production, the effect of population growth and changing diets, global markets for food and animal feed; efficiency of biomass conversion technology, increased need for water and fertilizers, demand for other non-energy uses of land; and climate warming.

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[2] In Africa, most agricultural activities are carried out by women. These women have no capital, knowledge other than empirical, and above all, no governmental support. Empower the women farmer and productivity will increase dramatically. The role of these women is simple ignored.

The most productive land is already used (1.5 Gha[3] arable land, 3.5 Gha grasslands, 0.2 Gha for human settlements, 3.9 Gha forested land and 4.2 Gha consist of deserts, mountains and other unsuitable land for productive use). Doornnbosch and Steelblink, (2007) estimate that the upper technical limit of land for dedicated energy plantation in 2050 would be 440 Mha. However, Hausman (2007) estimates that there are currently more than 700Mha of good uncultivated quality land in 95 countries which could be used for bioenergy production[4].

Bergsma *et al*. (2007) have estimated that replacing 20% of oil (88 EJ) in 2020 by biofuels in the transport sector will require between 150 Mha to 1,000 Mha depending on the technological options adopted for its production. This large difference can be explained by the considerable uncertainty in biofuel production. But estimates by Moreira (2006) show that to meet 30% of ethanol demand in 2070, only between 80 Mha and 250 Mha will be needed, using advanced conventional biofuel production technologies, and sugarcane as the main feedstock. For comparison, current global sugarcane planted area is about 25 Mha while in 2007/08 harvest, about 260 Mha to 270 Mha were dedicated to wheat production (see www.fas.da.gov).

The main long-term difficulty facing bioenergy is not process technology but the costs of the feedstock e.g. for liquid biofuels still represents about 60-65% of total costs for sugarcane, over 70% for corn and more than 85% in the case of biodiesel. It is simply not possible to have a modern and efficient bioenergy industry until the feedstock is available cheaply and in large quantities. And this would not happen until the whole agricultural sector is also modernised to compensate for additional demand.

FAO statistics[5] show there are about 2 Gha of land considered degraded or abandoned which could partly be brought under cultivation with relatively low investment as land is often abandoned primarily due to low prices of commodities, poor management practices, lack of markets, infrastructure, lack finance, capital, skills and so forth.

The largest land area for biofuels could come from underutilised, pastures and grasslands (rather than from forested land as is often portrayed), combined with better utilization of residues. However, based on present trends, it is highly unlikely that large amounts of land would be available for dedicated energy crops without fundamental changes in the agricultural sector. The use of agricultural residues, integrated production and second generation biofuels would probably be the key factor.

The challenge will be how to achieve greater sustainable productivity per hectare/year with the lowest possible inputs. And an even a greater challenge, and uncertainly, is how to deal with the possible potential impacts of climate change. Other limiting factors may be lack of water, soil salinity and erosion, lack of investment, skills, fair play etc. The modernization of bioenergy must be in parallel with educational and agricultural modernization and capacity building.

The case of Brazil and the USA

Brazil and USA are very contracting cases, and the key to the future development of biofuels. Yes, the main feedstock used could not be more diverging, sugarcane and corn, respectively.

Brazil

Brazil is a country with an immense agricultural potential where, excluding a few areas, agricultural modernization is in its infancy. With favourable climatic conditions in large parts of the country and a large program of R&D, Brazilian agriculture will be able to increase productivity and overall production quite dramatically, if there is sufficient market demand, as discussed elsewhere in this book.

The availability of cheap and abundant land has led to extensive agricultural and husbandry practices and consequently to low productivity, thus achieving only a partial production potential.

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[3] 1 Gha = 1,000 Mha.

[4] According to Hausman (2007) today's oil production represents the equivalent of 500 to 1,000 Mha (depending of the assumptions and productivity per ha, of biofuels.

[5] FAOSTAT – Food and Agricultural Organization, UN, Rome.

TABLE 1 Summary of land use impacts with varying estimates.

Corn yield scenario	2015 corn yield, bushel/acre	DG land use credit (percentage)	Range of US land converted, (Mha)
Informa	183.0 (16,459 l/ha)	31%	0.0-2.3
USDA	169.3 (15,225 l/ha)	31%	1.7-4.0
Informa	183.0 (16,459 l/ha)	71%	0
USDA	169.3 (15,225 l/ha)	71%	0

Source: DARLINGTON, 2009.

Take, for example, sugarcane which according to Ministry of Agriculture[6] data the average productivity per hectare increased from 61.5 t/ha in 1990 to 73.8 t/ha in 2005. For comparison, productivity in Colombia is close to 200 t/ha. And in the case of soy bean, based on the same source, productivity increase from 1.7 t/ha to 2.2 t/ha over the same period. Such productivity is low in comparison to major producers of these crops.

USA

The production of large scale ethanol from corn in the USA is the subject of a continuous bitter debate by the pro and anti biofuel lobbies, who continue to put forward a constant stream of arguments to support their views. Unlike sugarcane which offers many clear advantages as a feedstock, corn is far more controversial as the advantages depend on many factors which often depend more on politics than on science[7].

Yet, despite many uncertainties, it is clear that the potential for improving the benefits of ethanol from corn is quite large, either through improvements in the agricultural cycle or better use of by-products in the processing phase. For example, the argument put forward by many detractors of ethanol that most of the agricultural land of the USA would have to be converted to corn, does not stand scrutiny according to the latest studies. For example, (Darlington, 2009) affirms that the increase from *7.5 Bl/yr (2 Bgy) in 2000/01 to about 57 Bl/y (15 Bgy) in 2015/2016 would not result in new forest or grassland conversion in the USA or abroad (p4).* This would be possible throughout agricultural improvement (i.e. higher yields) and better use of by-products in the process phase. Table 1 summarises all land use impacts based on different assumptions and sources. The net land use for ethanol in the US for 2015 range 0 to 4 Mha, or less than 1% of the world's cropland.

The additional area devoted to ethanol would be offset by the reduction in other crops such as wheat and cotton and the CPR (the conservation Reserve Program). There are two fundamental factors. Firstly, increase in yield. According to the Table 1 above, yields will increase from 151.1 bushel/acre (13,590 l/ha) in 2007/08 to 183 bushel/acre (16,459 l/ha) in 2015/16 (Informa) and to 169.3 bushel/acre (15,225 l/ha) according to the USDA. Secondly, are the credits for distillers grains (DGs), a major co-product from ethanol fermentation processing used for animal feed. With the maximum land credit, no additional land is required for ethanol production even so there is a three-fold increase in ethanol production.

What this demonstrates is that even in the case of corn, there is considerable potential for increasing yields and better utilization of co-products if adequate R&D is put in place. If the same principle is applied to sugarcane, the overall potential will be far greater. Of course, it is impor-

[6] Agricultura Brasileira em Números, Secretaria de Política Agrária, Ministério da Agricultura, Pecuária e Abastecimento, March 2009.

[7] There is vast number of studies on this issue and thus this would not be taken any further.

tant to recognise that biofuels, and in particular first generation, have many limitations.

THE IMPACTS OF BIOFUELS ON FOOD PRICES

The potential impacts of biofuels on food prices came dramatically into light from 2007 to mid 2008, after which food price increases began to subside[8]. There has been sharp criticism against biofuels but without fundamental scientific proof. The reasons are many and complex, as there are many influencing factors, including (see Rosillo-Calle and Tschirley, 2010):

- Changed consumption patterns. Improved living conditions, particularly in developing countries such as Brazil, China and India, as growing wealth consumers move away from cereals to meat. This will require more land since, for example, it takes 8 to 10 kg of e g wheat to produce 1 kg of meat.
- Distorted agricultural sector in many countries, especially in the south, caused by rich countries dumping heavily subsidized surplus production on the world market led to very low prices and discouraged investment in agriculture.
- Lack of investment in the agricultural sector. For example, in the 1980s about 17% of international development aid was for agriculture, but in 2005 this was just 3%. This has been exacerbated in the last decade by low commodity prices as farmers struggled to survive and could not invest in new production.
- The increased interest from investors and traders in commodities makes price development much more sensitive. Speculation has been a major factor in prices increase.
- It is simply wrong to affirm that biofuels have played a major role in food price increases. Price increases due to *direct land competition* is a myth rather than a reality as merely about 1% of the global land area is currently dedicated to biofuels.
- Current situation of the agricultural sector. For example, the application of empirical rather than scientific principles, lack of skills, capital etc., are primary factors for low productivity, primarily in many developing countries and in particular in Africa.

Food price increases are therefore the result of a complex web of factors that need to be incorporated in any debate. For example, higher agricultural prices have both positive and negative impacts as higher incomes will allow farmers to invest more in agriculture and bring under cultivation new lands previously abandoned as uneconomic for lack of market. In Western societies consumers have been accustomed to a very low food prices for far too long, and this will become far more difficult to maintain in the future.

In conclusion, it seems clear that food price increases have been exaggerated by the popular press, a strategy often used by critics to scare off consumers. The greatest impacts are caused by oil price increases, as oil is used in the whole production and distribution chain, rather than by biofuels. At the same time, about 70% of the world's poor live in the countryside and could therefore benefit more directly from price increases. However, the urban poor face a grim future if prices are high but this requires, primarily, policy action.

Is goes without saying that this is an area that needs to be further investigated. We need to have a better understanding of the underlying causes of food price increases, rather than the easy solution of blaming biofuels.

SUBSIDIES

Subsidies have been at the core of energy production systems, both for fossil fuels and renew-

[8] While ethanol production in the US increased rapidly in 2007/08, American farmers delivered a bumper harvest for many crops in 2008 despite adverse weather conditions. For example, soybean crop reached 2.96 billion bushels, the forth largest in US history, 11% up from the previous year. As a consequence, agricultural commodity prices fell sharply. This shows that the previous year price increase of corn, who the anti-biofuels lobby blamed on ethanol production, was a myth (see Associate Press: Big harvest, weak demand bring down crop prices, 13 January 2009).

able energy sources. Pouring in vast subsidies is hardly the best way of expending taxpayer money. As with fossil fuels, biofuels development has been sparked off mostly by subsidies and other fiscal incentives rather than by market forces alone. However, the size of energy subsidies varies considerably from country to country.

For example, historically subsidies given by governments to fossil fuels and nuclear energy have been enormous in comparison for biofuels. Larson and Shah (1992) estimated that fossil fuel subsidies were to be more than $ 230 billion. Many these subsidies continue today under different hidden forms.

One of the major problems is how to identify many of the hidden subsidies that fossil fuels receive, directly or indirectly, in a multitude of forms. Take, for example, the US where a report by the General Accounting Office (GAO) shows that the petroleum industry received between $ 135 Bl to $ 150 Bl in tax breaks from 1968 to 2000 alone, excluding foreign investment tax credits estimated to cost de Treasury a further $ 7 Bl per year, compared to $ 7.7 Bl to $ 11.6 Bl given to the ethanol industry from 1979 to 2000 (GAO, 2000; WI, 2007).

US subsidies to the petroleum industry equal to approx. $ 0.003 cents/litre, but when indirect subsidies are included (i.e. military expenditure related to secure oil supplies from the Persian Gulf, which in 2003 amounted to c$ 50 billion), this represents an additional $ 0.30cents/litre of gasoline (see WI, 2007), excluding environmental damage of transport fuels[9]. In 2006 the US Federal energy subsidies totalled approx. $ 74 Bl, of which fossil fuels accounted for $ 49 Bl (66.2%) compared to $ 6 Bl for ethanol (7.6%); see Doornbosch and Steenblik, 2007; <www.earthtrack.net>. However, Pimentel *et al*. (2010) state that current direct subsidies per litre of ethanol from corn in the US is many times greater than gasoline.

Yet, one of the major criticisms against biofuels relates to the subsidies paid by governments to develop this industry which, critics say, distort the market. One would be inclined to think that subsidies provided to fossil would also distort the market. The scrutiny to which bioenergy is being subjected is unprecedented, and critics often forget that, historically, fossil fuels have received, and continue to receive, huge subsidies. While most of these fossil fuels subsidies still continue in different forms, there are increasing calls to remove or reduce subsidies to the bioenergy industry, which are very small by comparison. It is important that further research is carried out to ensure that subsidies are not seen as one sided, but that all pros and cons are fully accounted for, so that we can have a more balanced attitude.

BIOFUELS, CLIMATE CHANGE, GHG AND ENERGY BALANCE

Climate change is potentially the single most important challenge facing humanity. A key issue will be the vulnerability of the agricultural sector and its capacity to respond to climatic changes e.g. shorter growing season for some crops, severe droughts and flooding etc[10]. Climate change will, ultimately, be one of the main factors that will determine the success or failure of biofuels in the long term.

And we need to understand clearly the question, "do biofuels reduce GHG" to answer growing criticism. Further, we need to ask, if biofuels aren't as GHG positive as originally thought, should we reduce the speed of their introduction while allowing at the same time consumption of fossil fuels unchallenged? There is, simply, no perfect fuel!

As with the energy balance, the overall GHG benefits of biofuels are also increasingly being questioned, particularly after the study by Searchinger *et al*. (2008). This is because there are many and varying inputs that have to be accounted for which can lead to very different interpretations. But new studies are constantly challenging old

[9] For example, environmental damaged caused by diesel in the transport sector in 1993 (the year for which data is available), has been estimated at $0.31cents/litre (see WI, 2007).

[10] There is abundant literature on the potential impacts of climate change in agriculture. A particular international institution who is working in this area is the International Agricultural Research Centres. See for example, **Global Climate Change**: Can Agriculture Cope? Available at: <www.cgiar.org>.

persecutions. For example, a recent study carried out by researchers at the University of Nebraska Lincoln, which has quantified the impacts of recent improvements throughout the corn-ethanol production process, has demonstrated that corn ethanol emits about 51% less GHG than gasoline, therefore dismissing those critics who argue corn ethanol offers little potential for improvements[11].

GHG are constantly changing as they are the focus of significant efforts to increase the energy ratio and to reduce GHG. Further, many of the comparisons are with corn and wheat which compare unfavourably with sugarcane as if offers multiple benefits. For example, a study by S&T (2009) shows that GHG emission savings from ethanol production and utilization has more than doubled between 1995 and the projected level for 2015. The study indicates that *"there is a danger of making policy-decision based on historical data without taking into account learning experiences and the potential gains that can be expected as industries develop"* (S&T, 2009 p. iv). There are many ways in which GHG can be reduced as there are still many gaps in our understanding.

Biofuels, has been suggested, could largely be produced from set aside land particularly in EU and USA as a way of reducing competition with food production and reducing GHG. However, this option has also come under scrutiny (see Pineiro *et al*., 2009). The authors state that *"Depending on prior land use C releases from soil after planting corn for ethanol may in cases completely offset C gains attributed to biofuels generation for at least 50 years"*. Also, based on the results of 142 soil studies, soil sequestrated by setting aside former agricultural land was greater than the C credits generated by planting corn for ethanol on the same land for 40 years and greater or equal economic net present value (Pineiro *et al*., 2009).

The energy balance of biofuels production (the ratio of energy contained in the biofuel to the ratio of fossil fuel energy used to produce it), is still a contentious issue, particularly in the case of ethanol from corn, and this is despite numerous studies [e.g. see Wu *et al*. (2006), Shapouri *et al*. (1995), Wang, Wu and Huo (2007)]. It is also an issue often grossly oversimplified given the complex web of economic, social and political factors that need to taken into account; different assumptions/calculations can, therefore, lead to very different results. One of the difficulties is that often old data tend to be used while the continuous improvements in biofuels production and use are not always incorporated into the analysis.

There is also a need to have more comparative analysis of the energy balance of gasoline and biofuels. For example, a study by Sheehan *et al*. (1998), sponsored by the USDA and USDOE, found that the primary energy use for each 1MJ of petroleum diesel requires 1.2007 MJ, corresponding to 83.28% energy efficiency. Petroleum diesel uses 1.1995 MJ to produce 1MJ of the fuel product energy. According to the Greet Model[12] calculations, the fossil energy input per unit of ethanol is 0.78 MBTU[13] of fossil energy consumed per each 1 MBTU of ethanol delivered. This compares with 1.23 MBTU of fossil energy consumed for each MBTE of gasoline delivered (see www.transpsortation.anl.gov/)[14]. The S&T (2009) study shows that the net energy ratio (Joule delivered/J consumed) was for gasoline 3.7961 in 1995 and 3.1174 estimated for 2015; and 1.1851 for corn ethanol in 1995 and 1.9262 estimated for 2015.

Despite considerable disagreement, some consensus is emerging on the overall energy balance. For example for US corn, it is more generally accepted to vary from 1.25 and 1.35, which could be further improved to 2.9 if fossil fuels in industrial processes are switched to biomass-based fuels. The energy balance is not static but changing continuously. Major improvements (i.e. reducing energy consumption, greater energy self-sufficiency, developing new co-products etc.), will

[11] See **Journal of Industrial Ecology**. Available at: <http:dx.doi.org/10.1111/j.1530-9290.2008.00105.x>.

[12] Greet – **The greenhouse gases, regulated emissions and energy e in transportation**, was developed by Dr Michael Wang, **Argonne National Lab's Centre for Transportation Research**, with support from the USDOE.

[13] Million British thermal unit (one Btu = 1.05506 x 10^3J). In this case, 823 MJ for ethanol against 1,298 for gasoline.

[14] See document: **Ethanol** – The complete energy life cycle picture, 2007.

further improve the energy balance. US corn is, however, one of the least efficient feedstocks used in ethanol production e.g. sugarcane in Brazil has a ratio of 8.3 to 10 fold (see Macedo *et al.*, 2004; Walter *et al.*, 2008).

SECOND GENERATION OF BIOFUELS

Considerable hope is being pinned on second generation of biofuels. The current concern with the first generation of biofuels is catapulting RD&D toward the second generation in the hope that it would be possible to produce biofuels in large scale without affecting food production. This could be possible because the feedstock will be mainly cellulose-based, agro-forestry wastes such as straw. The hope is that they will provide clear advantages over the first generation, including:

- avoid direct competition with food crops;
- reduce the level of subsidies;
- provide clear advantages on GHG;
- provide clear environmental benefits;
- reduce deforestation;
- improve biodiversity;
- better utilization of resources e.g. lower quality land, water etc.

Although it remains to be seen if all attributes to the 2nd generation biofuels can become a reality. Firstly, it is not yet clear what impacts will have on land use, secondly the use of poorer land will be reflected in lower yields or higher inputs, thirdly process technology would be more expensive and possibly will have higher disposal problems, and four the overall costs may be much higher because the higher processing costs involved.

For example, currently there are two main conversion routes: i) biochemical (using enzymes and other microorganisms), and ii) thermo-chemical that uses pyrolysis and gasification technologies). None of these technologies seem to offer a commercial advantage despite many years of RD&D. Both pathways offer advantages and disadvantages (see Sims *et al.*, 2009). Thus, there are still serious technological hurdles to overcome not to mention economic ones. Within current financial climate and fluctuating oil prices, it is difficult for foresee when this technology will become commercially viable in large scale, but most probably no before 2020.

SUSTAINABILITY AND CERTIFICATION ISSUES

Considerable amount of work has been done on sustainability issues, but not on a global scale. It is necessary to have a more systematic approach which has greater international acceptance. The problem is how to create a global standard that allows for national and global activities, given the complexity of many of the issues involved. Any sustainability standard must include three key components: economic, social and environmental aspects. Although, a political and institutional new pillar has to be included as many of the issues implied in sustainability are regarded of a political nature (e.g. targets), see Diaz-Chavez and Rosillo-Calle, 2008).

Since the EU Directive on Biofuels in 2003 came into force, there has been a growing concern over the availability of resources and the increasing demand for energy crops to produce them. There has also been a concern for the increasing demand for biofuels imports from developing countries. This increment is expected to come mainly from sugarcane, soya, palm oil, rape seed, wood products and other biofuel feedstock (see Walter and Rosillo-Calle, 2008). It is important to be aware that vegetables oil market is driven primarily by demand for edible oil rather than for the biodiesel market. Often biodiesel is a by-product of the edible oil market.

Currently considerable efforts are being made towards the development of standard and certification systems specifically dedicated to biofuels. However, there are still considerable gaps in out understanding that need further investigation. The main ongoing projects are briefly explained below (see Diaz-Chavez and Rosillo-Calle, 2008 for further details).

1) ***Roundtable for Sustainable Palm Oil (RSPO) system***. This is a global multi-stakeholder initiative, originally produced for the palm oil production with focus on cosmetic and food industry.

2) *Round Table for Responsible Soya (RTRS)*. This is also a multi-stakeholder organisation created in 2004 including producers, industry, trade & financial organisations and civil society organizations. The RTRS is developing a set of standards for the production and sourcing of responsible soy and a verification mechanism to reinforce these standards.
3) *The United Nations Environment Program (UNEP)*. The Working group of UNEP is developing sustainability criteria and standards for the cultivation of biomass used for biofuels. To date this information has not been finalised.
4) *The European Commission with the new Energy Directive*. The recently approved EC Directive states: "Biofuels used for compliance with the targets laid down in this Directive, and those that benefit from national support systems, should therefore be required to fulfil criteria for environmental sustainability" (COM, 2008, p. 17).
5) *The Global Bioenergy Energy Partnership (GBEP)*. Partners include the G8 countries + 5 (Mexico, South Africa, China, India and Brazil) and other UN institutions and associations.
6) *The International Petroleum Industry Environmental Conservation Association (IPECA), Chain of Custody (CfC)*. IPIECA is a global association representing both the upstream and downstream oil and gas industry on key global environmental and social issues. This demonstrates that oil companies are also playing an increasing role in the development of sustainability and accreditation issues.

MAJOR RESEARCH AND DEVELOPMENT GAPS

There are still many gaps in our understanding of first generation biofuels, not to mention the second generation. One of the main reasons for the current agricultural difficulties lays on governmental policy. Many governments, and particularly in developing countries, have given priorities to industrialization and very low priority to R&D in agriculture. This has led, as stated above, to very serious R&D problems in many agricultural activities. These are many ranging from soil preparation to final product. This paper can only highlight the main ones related to implications to food and biofuels. It is clear that the main challenge is to modernize agriculture.

- *Human capacity building*. In many countries (exclude the most advanced ones), many farmers do not have the scientific knowledge to carry out their activities. Many practices are based on "empirical knowledge" which, as fundamental as it is, does not solve the needs of a modern agricultural enterprise. Farming must be scientifically-driven, and not regarded as a backward activity. This requires considerable attention for skills formation. And do not forget to role of women which in many developing rural economies, particularly Africa, are the key to success of failure as they are the backbone of the local economies.
- *Capital and investment*. Farmers need to have access to financial resources and investigating this need will go a long way in solving problems.
- *Marketing*. Often farmers know little on how to market their products leaving them exposed to exploitation by intermediaries and speculators. More R&D needs to be channelled to inform and prepare farmers to market their products.
- *Agricultural best practices*. There is considerable potential to improve agriculture to increase yields, reduce the use of fertilizers and pesticides, reduce GHG impacts and enhance sustainability and biodiversity.
- *Soil preparation*. This is very important, particularly when it comes to soil compaction. Often the machinery used is the wrong one e.g. too heavy for that particular soil. New R&D is needed to develop machinery more adequate to specific soils.

- *Harvesting machinery*. As with soil preparation, harvesters used in sugarcane, for example, are too heavy resulting in unnecessary soil compaction and losses. In many of the poor countries this is a serious problem.
- *Development of new crop varieties more adequate to energy*. Currently almost all R&D is channelled to food production crops.
- *The feedstock*. Feedstock is the main component of costs and thus ensuring the right feedstock is fundamental.
- *Disease and pest control*. Currently only major companies do have R&D in this area. There should be greater support for small farmers.
- *Transportation*. There are still many R&D gaps in the transportation of the feedstocks, particularly the method and costs as they constitute a major component of the final costs. The transportation of the raw material and distribution (end use), need considerable more R&D to avoid losses and reduce GHG emissions and costs (e.g. see Wakeley *et al*., 2009). Also, developing new form of long distance transport (e.g. pipelines, shipping) is essential for trade, particularly international biotrade.
- *Price increase of food*. Price increases have been blamed on biofuels. As we have seen in this paper, there are many diverse reasons, often nothing to do with biofuels. More research should go into this area so that the real "underlying reasons" are fully understood and explained to the wider audience.
- *Land use issues*. It is important to show that biofuels are not responsible for land competition with food crops. Currently only about 1% of the crop land is used for biofuels. The complex relationships between land use and biofuels need to be fully understood and explain to the wider public. Physical availability of land often tells us little, other factors such lack of skills, markets, injustice etc., are at the core of the problem.
- *Subsidies*. The anti-biofuels lobby has criticised the use of tax payer money to prop up biofuels. Subsidies have been, and still are, at the core of most government's energy policy. It is important that this is properly exposed to the general public.
- *Green housegases*. This is a sensitive area that needs considerable research. The pros and cons need to be understood beyond the specialist or experts. There are many ways in which the GHG can be improved in favour of biofuels e.g. using the right feedstock such as sugarcane, better utilization of co-products etc.
- *Energy balance*. There is still no general consensus on this issue for some feedstocks and thus the anti-biofuels lobby continue to argue that "we put more energy in than taken out". While this may be the case in some situations e.g. corn in the USA when new improvements are not taken fully into account, this is not the case if all potential improvements are taken into consideration. Further, sugarcane has a very high energy ratio and this needs to be explained much better than has been the case so far.
- *Co-products*. It is clear that there is a huge potential for the utilization use of co-products. New ways and markets should be investigated.
- *Sustainability and accreditation issues*. It is a major of concern primarily in the major biofuels consumer countries. Producers of biofuels need to have much greater involvement to ensure fair play, and that it is not another barrier to trade.
- *Biodiversity*. A hot topic which huge implications. Monopolistic cultures do not help. However, the system being implemented in Brazil of leaving 10-20% of cane field to preserve biodiversity should be given more prominence.
- *Innovation*. Often R&D fails to support innovative activities that can benefit more

directly the farmers, in this case those producing biofuels.

With regard to the second generation of biofuels, the following are some of the main gaps (far from exhaustive):

- Despite considerable increase in RD&D of recent years, and considering the complexity of the pathways, more RD&D is still need.
- More bridges between first and second generation of biofuels are needed to take full advantage of the transition phase, as this will be an evolutionary rather a revolutionary transition.
- More demonstration plants using greater diversity of feedstocks.
- Environmental performance and certification schemes would have to be developed. Obviously this could greatly be enhanced from current work on first generation.

FINAL CONSIDERATIONS

The food *versus* biofuels issue has been blown out of proportion, a debate driven by vested interests, moral and ethical stand rather than by science. It is important to go the core of the problem. Unfortunately there are still many gaps in our understanding that need to be investigated further.

It seems clear that biofuels, at worst, are only partly responsible of food prices increase, but not the cause. With over 2Gha of idle or semi-idle land and with only 1% of the crop land dedicated to energy crops, biofuels should be seen as part of the problem and also as part of the solution.

It is possible to produce all our food needs and a portion of biofuels without affecting food crops. The modernization of agriculture and good management practices can avoid land competition but fundamental changes are required in the agricultural sector, as explained in this chapter.

The debate on *food versus fuel* must go beyond the narrow confines of vested interests, misinterpretations, and over simplistic arguments. We need to have a balanced and realistic approach and not to overstate or underestimate the potential contribution of biofuels.

Also, it is important to ensure that concern with the environment, sustainability, and biodiversity issues does not lead to the imposition of requirements so stringent that will place biofuels in a considerable disadvantage with fossil fuels, hence hindering (or even preventing) rather than enhancing their development. We need an internationally agreed, traceable and realistic certification and accreditation system that allows a fair playing field for biofuels (Rosillo-Calle and Tschirley, 2010).

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