BIOFUELS: WHAT IMPACT ON CROP PROTECTION AND SEEDS NOW?

Part 2: Sources of feedstocks for first and second generation biofuels

The first article in this series, published in the previous issue of Outlooks on Pest Management, provided an overview of the current status of biofuel production, targets for fossil fuel substitution and the use of crop feedstocks. Here, Alan Baylis, Nuvistix Innovation, reviews the current trends and predictions for the demand for various crop feedstocks in response to biofuel ambitions to 2030 and beyond.

Keywords: Biodiesel, bioethanol, biofuels, crops, feedstocks

Introduction

World production of biofuels is dominated by three countries or regions: the US (43%), Brazil (32%) and, less so, the European Union (15%) (Baylis, 2008). This will continue to be the case, not only because of respective government policies on biofuels addressing, to various degrees, climate change mitigation, energy security and rural development, but also because of the huge areas of productive land which are needed to provide biomass feedstocks for any significant biofuel production.

To date, biofuel feedstocks have been overwhelmingly sourced from materials with high concentrations of carbohydrates or oil in storage organs such as grains and other seeds or roots. This has meant that maize (corn), wheat and sugar beet which could have been used as food and animal feed have been used instead to produce bioethanol. There has been a similar situation in oilseeds, particularly soybeans and oilseed rape (canola), used to produce biodiesel. These are so-called 'first generation' biofuels. However, in general, interest in these crops as feedstocks has been stimulated by 'surplus' production in N. America and Europe.

A comparison of capacities of feedstocks to produce first generation biofuels is shown in Figure 1. These are based on typical yields in relevant areas and efficiency of manufacturing. In both cases, the more productive bioethanol and biodiesel feedstocks are crops from tropical regions where more solar energy is fixed by photosynthesis. However, despite only around 2% of the global grain harvest being used for biofuels (EREC, 2008), recent depletions in the world's food reserves have highlighted the need to move away from the production of first generation biofuels towards 'second generation' biofuels produced from more abundant woody material consisting largely of lignocellulose. Bioethanol produced from lignocellulose is generally referred to as 'cellulosic ethanol'. Biodiesel can also be produced from woody feedstocks by thermochemical processes called biomass to liquid (BTL). There are, however, significant issues around the cost of manufacturing plants, technical feasibility of efficient production and logistics of feedstock supply which mean that for a number of years to come major food crops will still be used to make biofuels.

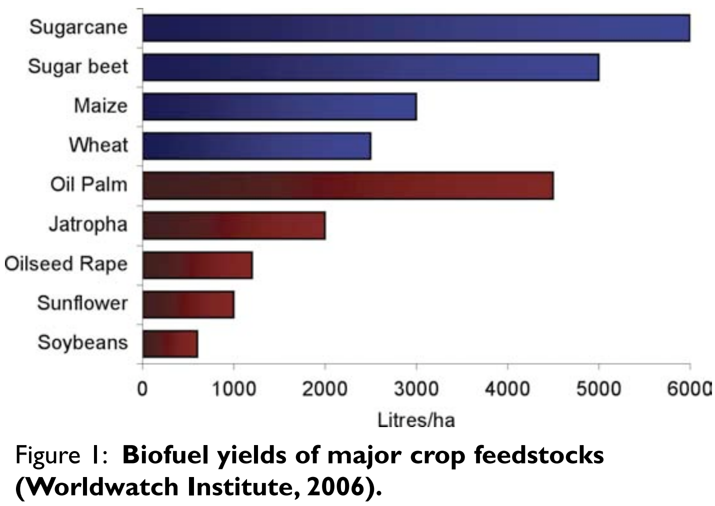

Figure 1: **Biofuel yields of major crop feedstocks (Worldwatch Institute, 2006).**

A different issue arises with the two other major crop feedstocks, sugarcane and oil palm. Although they already have established industrial uses, expansion of these crops in Brazil and South-East Asia, respectively, can involve the destruction of valuable natural eco-systems.

In addition to these crops, several others are of interest as potentially important feedstocks in Asia. China and Thailand are considering cassava and sweet sorghum for bioethanol; India and China are looking at jatropha for biodiesel (Coyle, 2007). Also, conflicts with food and eco-systems are encouraging research into algal feedstocks, in which land-use, at least, will not be an issue. Overall, the need for sustainable sources of biofuel feedstocks has been repeatedly emphasised (eg Gallagher, 2008). So, where will the biomass needed for first, and later, second generation biofuels come from? In the following discussion, crops, cropping trends, locations and challenges will be considered.

Towards 2020

Changes in crops and cropping systems and the impact on agricultural industry sectors over the coming decade will be greatest in the US, Brazil and Europe. Forecasts and implications for crops as feedstocks in these areas are discussed in turn below.

In the US, the consumption of corn as an ethanol feedstock has grown rapidly in recent years (Figure 2). The USDA forecasts that more than 30% of the domestic corn

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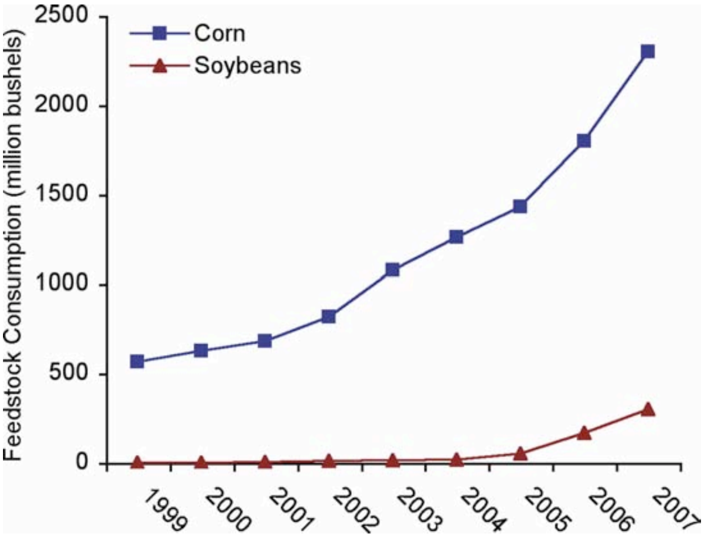

Figure 2: **Consumption of US corn and soybeans as bioethanol and biodiesel feedstocks (Westcott, 2007).**

crop harvested in 2009 will be used for bioethanol production (Westcott, 2007). This reflects the growing production capacity from on-going manufacturing plant construction. According to the Renewable Fuels Association, the number of US bioethanol plants has more than doubled in the past three years. In November 2008, there were 179 bioethanol plants in the US with a further 23 under construction. Although this will result in over 12 billion gallons being produced annually in the US by 2016, and will require almost double the tonnage of corn used in 2007, this will represent less than 8% of gasoline (petrol) consumption. Projected future corn areas are shown in Figure 3. Three companies stand out in terms of manufacturing capacity, each having in excess of one billion US gallons per annum: POET, VeraSun Energy and Archer Daniels Midland.

Biodiesel production capacity and output are currently increasing rapidly in the US, albeit at a much lower level than ethanol (Figure 2). This is projected to level off after 2011 when about 23% of the soybean crop will be used as biodiesel feedstock (Westcott, 2007). However, US soybean areas are forecast to decline slightly by 2016 (Figure 3). The 700 million gallons of biodiesel then produced annually will account for less than 2% of total transport diesel use in the US.

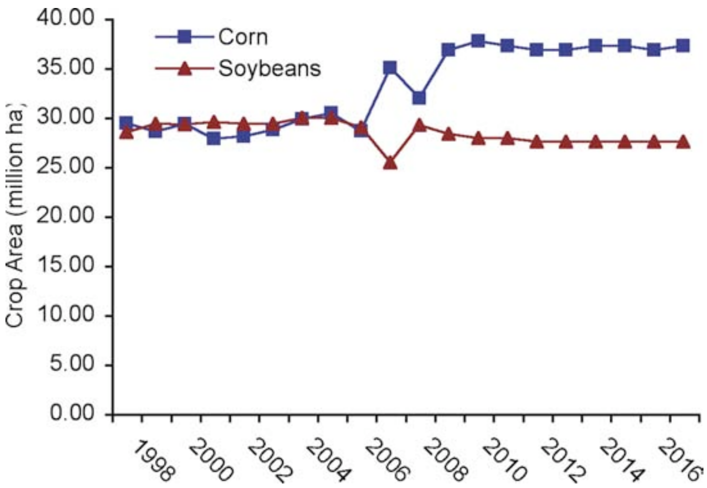

Figure 3: **Historical and future trends in US corn and soybean areas. (Data for 1998-2006 and 2007-2017 come from FAO and USDA, respectively.)**

Second generation biofuels are not expected to make a significant contribution to overall production for perhaps a decade or more. USDA assumes that cellulosic ethanol production will account for only around 200 million gallons by 2013. Whereas, currently, ethanol may be produced from grain at a capital cost of about \$2/gallon, the cost of using biomass as a feedstock would be \$5-10/gallon, so improving the efficiency of conversion is crucial to entice investors (Gray, 2007)

The first commercial cellulosic ethanol plant in the US is being built by Range Fuels at Soperton, Georgia. The plant is expected to come on-stream in 2010 and will eventually produce up to 100 million gallons of ethanol and methanol each year. Range Fuels are using thermochemical technology to make biofuels from syngas (carbon monoxide and hydrogen) under conditions of high temperature and pressure. Verenium, formed by the merger of chemical engineering company Celunol and biotechnology company Diversa in 2007, plans to build its cellulosic ethanol plants using fermentation technology. Verenium already operates an R&D plant in Jennings, Louisiana, capable of processing two tonnes of sugarcane bagasse (the crushed stems remaining after sugar milling) per day for ethanol and is completing construction of a 1.4 million gallon per annum demonstration plant on the same site (Gray, 2007). These facilities are steps towards a 100 million US gallon (380 million litre) plant requiring up to 4000 tonnes of feedstock every day. With corn stover (non-grain residues), for example, the maximum conversion rate to ethanol is about 100 US gallons/tonne, so this size of plant would need to be supplied by about half a million acres (200,000 ha). In practice, Verenium estimate that such a plant sited on N. American prairies would need to source corn stover, or a dedicated energy crop such as switchgrass, from a 20-30 mile radius.

Brazil has a long history of producing ethanol from sugarcane, back to the 1930s. In the early 1970s, the energy crisis prompted the Brazilian government to initiate the 'Proacool' programme of subsidies and tax breaks for the whole supply chain involved in ethanol production. Although cheaper oil in the 1990s resulted in the withdrawal of subsidies, ethanol production has almost doubled since 2004 (RFA, 2008).

The economics of bioethanol production in Brazil are very attractive due to the high productivity of sugarcane in the tropical climate and the ready adaptation of existing sugar mills (Table 1). Consultants McKinsey (Assis *et al*,

Table 1. Bioethanol production costs of major first generation feedstocks in US cents/litre in 2006 before subsidies (Assis et al, 2007).

	Feedstock	Processing	Total
Brazilian Sugarcane	18	5	23
US Corn	25	13	38
EU Wheat	34	18	52

Table 2. Sugarcane cropping, ethanol and sugar outputs in Brazil in 2006 and forecast for 2020 (Unica, 2007).

	2006	2020
Area harvested (million ha)	6.3	13.9
Cane production (million t)	430.0	1038.0
Yield (t/ha)	68.3	74.7
Ethanol output (billion L)	17.8	65.3
Sugar output (million t)	29.7	45.0

2007) estimate that in 2020 Brazilian bioethanol could be available on European garage forecourts at less than 50% of the cost of petrol, all based on late 2006 prices.

Predictions of ethanol production from sugarcane in Brazil in 2020 made by Unica (União da Indústria de Cana-de-Açúcar) show a more than trebling in output from a crop area increasing from around 6 million ha in 2006 to nearly 14 million ha in 2020 (Table 2). At present, sugarcane accounts for a little over 2% of the arable crop area of 300 million ha in Brazil. A further 200 million ha of grazing land could offer up to 28 million ha for sugarcane expansion in areas where good yields (75 t/ha) could be achieved without irrigation. These estimates assume the use of only first generation technology and no production of cellulosic ethanol. Second generation technology would allow considerably greater output or less land required for expansion.

In a more bullish scenario, assuming a doubling in productivity when cellulosic ethanol technology is available, McKinsey believe that, particularly driven by export demand due to very competitive prices, Brazil could be producing nearly 200 billion litres of bioethanol from sugarcane in 2020. If average yields were raised 30% to the level of the current most productive areas, this would require an additional 11 million ha of sugarcane to be grown, increasing the total area to 18 million ha. The areas of soybean and corn harvested in Brazil in 2007 were approaching 21 and 14 million ha, respectively. However, to achieve such levels of production will require large investments in distribution and storage infrastructure (including rail and pipe connections through rainforest) and the number of processing mills increasing from the current 350 to nearly 1000.

In contrast to the US and Brazil, the majority of biofuel production in Europe is biodiesel. By far the biggest feedstock is oilseed rape, but a number of others are used in significant amounts (Figure 4).

Although the 2003 EC Biofuels Directive targeted a 5.75% share for biofuels of the transport fuel market in 2010, this has now been recognised as unachievable and the focus is on the longer term target of 10% share by 2020 (EC, 2007). The means by which this is forecast to be achieved by increasing biodiesel and bioethanol production is shown in Figure 5. The current gap between the two biofuels will start to close as some major projects come to fruition. These include the 400 million litres per annum plant on Teesside, UK, the first of several planned in Europe by Ensus. This plant will use one million tonnes of wheat every year. Abengoa Bioenergy already has a cellulosic ethanol demonstration plant operating near Salamanca, Spain.

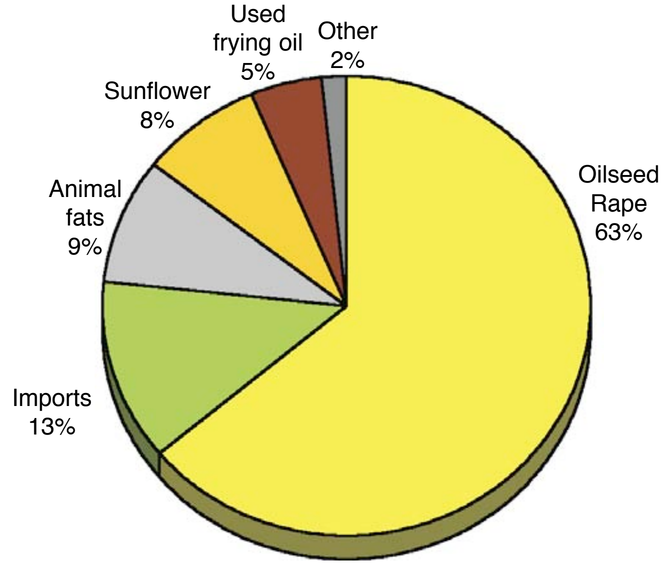

Figure 4: **Sources of feedstock for EU biodiesel in 2005 (Garafalo, 2006).**

The impact of the 10% in 2020 target on European agriculture has been assessed by creating a scenario in which 80% of feedstock demand is satisfied by domestic production (EC, 2007). Under this scenario oil was priced at €48 per barrel – higher prices would make biofuels more competitive and *vice versa*. Important assumptions include that 30% of biofuels in 2020 will be manufactured by second generation technologies either BTL for biodiesel or cellulosic ethanol, and that yields will continue to increase, eg 1% per annum for cereals, 2% for oilseeds and sugar beet. In the case of cereals, the 59 million ha grown in 2006 would be expected to produce an extra 38 million tonnes in 2020. Additional cereal hectares would come from some of the set-aside area together with small shifts from oilseeds and sugar beet. By 2020, energy crops such as miscanthus and short-rotation coppice of willow and poplar are expected to cover a significant area. The EU crop areas forecast for 2020 and the anticipated uses

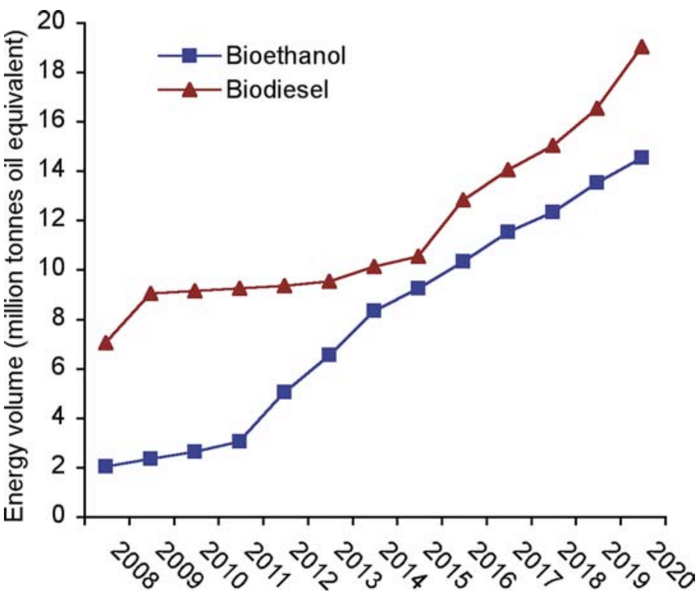

Figure 5: **Predicted growth in EU consumption of biofuels (EC, 2007).**

for food and biofuels are shown in Table 3. Overall, depending on the progress made with second generation biofuels, around 17.5 million ha, some 15% of all arable land, will be required to meet the biofuel target for 2020.

Table 3. Forecast area and distribution of crops between food and biofuel feedstock uses in EU-27 in 2020 (EC 2007).

	Area (million ha)			
	Total	Food	Biofuels	% Biofuels
Cereals	62.5	50.2	12.3	19.7
Oilseeds	8.5	5.6	2.9	34.1
Sugar beet	1.4	0.8	0.6	42.8
Energy crops*	1.7	0	1.7	100.0

* assumed to be all utilised for biofuels rather than heat and power.

On to 2030

Looking a decade further ahead, both the US and the EU have published reviews of their anticipated availability of biomass feedstocks in 2030. It should be noted that these have been compiled on different bases, but are, nevertheless, interesting visions and comparisons. The EU review (BRAC, 2006) considers where biomass will come from in the EU to meet half of a potential target of 25% contribution to transport fuels by biofuels, the other half being assumed to come from imports. The US review (Perlack *et al*, 2005) is a 'bottom-up' discussion of how much biomass could potentially be available from all sources in the US for whatever use in fuels, energy or chemicals. The contributions expected from each feedstock source are shown in Figure 6. Clearly, the EU is expecting to rely more on forestry and perennial energy crops than the US where the main sources will be crop residues and other wastes.

According to the US Departments of Agriculture and Energy (USDA & DOE) 'Billion Ton' report, by 2030 US farmland and forests could supply about one billion tonnes and more than 350 million tonnes of biomass, respectively (Perlack *et al*, 2005). To be consistent with satisfying the need for food, animal feed and fibre, and while noting that soil quality must be sustained, it was calculated that just 9% of agricultural production would come from grain with the wide adoption of second generation manufacturing technology.

Conclusions

Considerable efforts worldwide are being directed at developing biofuels and the impacts on major crops have so far been very significant in some cases, especially US corn and Brazilian sugarcane, but overall small in terms of gross changes in area or crops and cropping systems. Future forecasts have been built on a number of key assumptions about major influencing factors which are surrounded by high levels of uncertainty.

What will the price of oil be in 2020 or 2030? The EC scenario for 2030 discussed above used a price of €48 per barrel (currently $61), but the average price in July 2008 was $133/barrel and by October was down to $77/barrel. Will the 'green credentials' of biofuels continue to be challenged? It has become clear that environmental advantages and net energy gains depend on how crops are grown and processed. Sugarcane ethanol is currently the biofuel with most benefits in this respect (Worldwatch Institute, 2006). Will investments continue to be made into biofuel plants and second generation technologies? One of the 'big three' US bioethanol producers, VeraSun Energy is finding trading

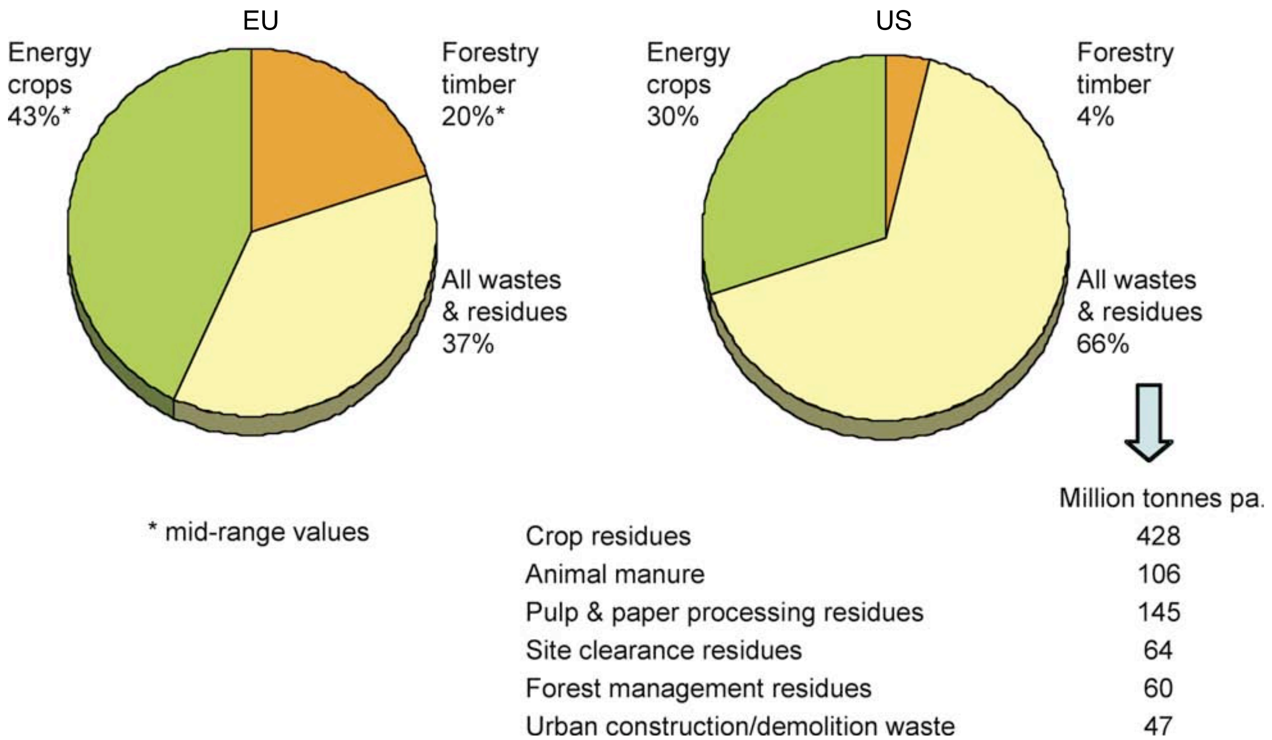

Figure 6: **Sources of second generation biofuel feedstocks forecast in 2030 by EU and US (EU: BRAC, 2006; US: Perlack *et al*, 2005).**

conditions difficult with high corn prices and credit constraints, and the company filed petitions for Chapter 11 relief in the US Bankruptcy Court in October 2008.

The assumptions made in the US 'Billion Ton' report make interesting reading, for they indicate the progress necessary to achieve the vision. They include:

- Yields of corn and wheat will increase by 50% from today's levels
- High biomass soybeans with a straw to grain ratio of 2:1 will be introduced
- Technology for harvesting crop residues will enable 75% removal of straw and stover
- No-till cultivation will be used for all biomass crops
- Perennial energy crops like switchgrass will be grown on 22 million ha – around 75% of the area currently devoted to corn or soybeans

USDA and DOE acknowledge that converting all cropland to no-till may be unrealistic, but, nevertheless, point out that a strong market for bioenergy could be a forceful driver for large increases in no-till acres. This is to avoid degrading soil structure and soil erosion caused by cultivations and the removal of residues which would otherwise have been ploughed-in to increase organic matter levels.

Some things are more certain though. These are the practical issues in supplying the huge biorefineries with the inputs to achieve the necessary economies of scale. Trucking-in 4000 tonnes of low density feedstock every day to a 100 million gallon plant will be a considerable undertaking. Seasonality of supply and storage are big issues. Verenium aim to use not only stover and biomass from energy crops, but a diverse range of waste materials, including food processing wastes like citrus peel and pulp, sugarcane bagasse, forestry thinnings, saw mill waste and urban wastes such as paper, garden plant material and construction timber waste (Gray, 2007).

Having reviewed the current status and forecasts for biofuels and feedstocks – and the all important assumptions – the final article in this series will consider the direct implications and opportunities for the agrochemical and seed sectors.

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Dr Alan Baylis (Nuvistix Innovation) is an independent consultant specialising in support for innovation and new ventures. He is Honorary Secretary of the Society of Chemical Industry's BioResources Technical Interest Group.

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