Nuffield Farming Scholarships Trust

An Oldacre Foundation Award

Agricultural Commodities in a Changing World

Ian Tremain

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Chapter 1 : Acknowledgments

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Disclaimer

The views expressed in this report are entirely my own and do not necessarily represent the views of the Nuffield Farming Scholarships Trust, or my sponsor, or any other sponsoring body.

Chapter 2 : Executive summary and recommendations

The world's food supply is in an increasingly vulnerable state. Fossil fuels are rapidly depleting and food production is more reliant on oil than ever before. In addition, agricultural commodity markets are more prone to rapid movements in price due to the way traders are now allowed to operate.

Here in the UK we are now net importers of oil. We also import significant quantities of our food, much of which we have the capability to produce ourselves.

The last Labour government launched "Food 2030" the UK's first food policy since the Second World War. The main aims of this policy are to increase total food production and at the same time ensure food is produced, processed and distributed to feed a growing global population in ways which:

- use global natural resources sustainably,
- enable the continuing provision of the benefits and services that a healthy natural environment provides
- promote high standards of animal health and welfare,
- protect food safety,
- make a significant contribution to rural communities, and
- allow us to show global leadership on food sustainability.

The UK currently relies on importing 20% of our total food (*source DEFRA*), which is currently affordable and plentiful. However we may become vulnerable to world events and we have placed power in the hands of very few other nations who control the world oil and gas supplies, a major raw material for food production.

Having considered the challenges before us, and explored our current dependence on oil and gas as the raw materials for almost half of the food produced in the world, I believe we should urgently consider building a more resilient food system here in the UK.

Due to changes in regulation and the ability to transmit information around the world in real time, food commodity markets have become more volatile as a result of being opened up to speculators.
New tools need to be used to manage risk and ensure that the producer of the food is paid a fair reward for his investment and work.

I would make the following recommendations: -

- Each business should consider the impact on their business of rising oil and energy costs and prepare budgets with scenario planning which values energy and oil at much higher values than today.
- Managing risks of volatile markets will be essential in a future where price

shocks, and rapid price movements will become more prevalent.

- Secure long term supplies of energy through the use of anaerobic digesters.
- Reduce the UK's dependence on imported feed and food.
- Governments around the world should examine the role of speculators in agricultural commodity markets, as they create more price volatility, which adversely affects the poorest in the world the most.
- The Town and Country Planning system should not be a barrier to exploring new sustainable ways of producing energy and food.
- New technologies will need to be embraced.
- Algae should be considered as a source of fuel, fertilizer and food, for humans, fish and livestock.

By embracing algae and photo bioreactor technology we can achieve all of the ambitions of "Food 2030", and create new jobs and revenue for UK agriculture. This would also make the UK more resilient in the face of future challenges.

Chapter 3 : Introduction

I grew up on a small family dairy farm in South East Cornwall and I was among the first intake of students at the Duchy Agricultural College in 1986. Since leaving college I have always worked in the animal feed supply trade, firstly for WJ Oldacre as a cattle specialist and I was delighted that my sponsor for my Nuffield Scholarship was The Oldacre Foundation. My second employer was Mole Valley Farmers Ltd where I was a raw material and grain trader, and purchaser of feed ingredients for the feed mills and blending plant. Having learnt the necessary trading skills at Mole Valley Farmers, I set up my own feed trading company, Tremains Ltd, in 2001.

More by accident than by design about every seven years I take a new challenge or change job and often this is punctuated by a period of travel or study. It was however made very clear to me that Nuffield does not fund gap years, and that it had a more serious purpose in educating and expanding the minds of the successful candidates. I first became aware of Nuffield Farming Scholarships in 1991 when my colleague at WJ Oldacres, Roger Trewhella, became a scholar. Since then my path has crossed many times with other Scholars and, in 1999, I plucked up the courage to apply for the first time. On that occasion I was not successful but it became an ambition to apply again with a more positive result.

After building my own feed trading business and selling it to BOCM PAULS in 2009, I was at a crossroads in life, not sure of which direction to take and what new frontiers there were to conquer. So ten years after being turned down I tried again, this time with success.

I knew the world was changing fast. Since I was born in 1968 world population has doubled and will increase by the same amount again in the next forty years. So the challenge to feed this growing population is immense, and new solutions will be needed in a world where the twin challenges of peak oil and climate change are a threat to food production. I set off with an idea to look at agricultural commodities, and how market volatility will affect us all, whether we be primary producers, traders, or consumers.

However I came home with a very different set of thoughts. I have explored some new solutions and I am convinced that necessity is the mother of invention.

Chapter 4 : Travel - People and Places

a. Alltech, Lexington, Kentucky, USA

I started my journey in May 2009 and joined a delegation from the UK feed industry attending the Alltech symposium in Kentucky. Alltech are still a relatively new business being formed just 28 years ago by Dr Pearse Lyons who is still as passionate today about the business as he was when he formed the company. Pearse is an Irish American whose background was in brewing and he spotted the niche to supply yeast into the animal nutrition market.

Today Alltech has a turnover of half a billion dollars and rising fast as they position themselves in rapidly growing markets in Asia and expand their product portfolio. All this is driven by making scientific advances in nutrition. Alltech have committed huge budgets in research and have pioneered work in nutrigenomics. This involves mapping the gene of individual animals and then building the nutrition specifically to that animal's ability to respond. This has huge potential to use feed far more efficiently than is currently the case. In some cases we may be over feeding an animal and wasting valuable resources and in other cases not maximizing the potential by under feeding a particular nutrient or mineral.

Another area of Alltech's research is that of algae. In the US a good deal of work is in progress searching for high oil species of algae, which could then be extracted and used as biofuel. This was the first time I had seen algae being grown in a photo bioreactor. Here they were using a series of plastic bags with water being pumped around in a loop system.

Since I have returned home Alltech have acquired Martek Biosciences who specialize in algal Omega 3 products for human and animal diets.

Not only did I get some one to one time with Pearse Lyons but shook the hand of John Y Brown the man who made Kentucky Fried Chicken a global brand, and also saw the great Mohammad Ali. Alltech are surely one of the finest marketeers in agriculture, and I was supremely impressed by their commitment to quality, scientific research, and their ability to add value to their products.

b. Kentucky State University.

While in Kentucky I also made a visit to the State University to look at their algae research work.

Kentucky is naturally rich in coal reserves and as a result has a high proportion of its power produced from coal fired power stations. In turn these emit high levels of CO_2 into the atmosphere and the University are undertaking a number of trials using algae as a way to capture carbon. Here I saw a number of different systems including a British made photo-bioreactor, which was a series of horizontal tubes. They are filled with water and a small amount of algae is added. Then CO_2 is pumped into the system and the algal growth is monitored. While the end product was of interest, the main focus of this work was to sequestrate CO_2 from the atmosphere and therefore reduce any future financial implications of emissions.

c. Fonterra, Auckland, New Zealand

From the US I flew to Auckland, New Zealand where I met representatives from Fonterra, a leading multinational dairy company, owned by 13,000 New Zealand dairy farmers and the world's largest exporter of dairy products. I spent a morning with the recently created risk management team where I gained insights into the way the world dairy markets operate. This team consists of five people and, interestingly, two years before they did not have an especially dedicated team looking at risk management tools and managing the price volatility in markets.

d. Canberra, Australia.

I joined the **Australian Nuffield Global Focus Programme** here in Canberra. To my knowledge I am the first UK scholar to join the full six-week programme, which is designed to give scholars a broad view of the world. This year's group consisted of seven Australians, two Kiwis and myself. We were also from a wide and diverse range of agriculture, representing: fruit, dairy, aquaculture, sheep, beef, and arable including rice and poppy growers. Given this wide range of backgrounds and with myself coming from Europe the discussions between us were of huge value and worth every penny of the cost. Each and every visit, whether it was to a large or small business or research facility or government department, stimulated debate and because we all had different perspectives we were able to go into real depth in our discussions.

The six-week programme was an incredible journey, not just physically as we visited seven countries on four continents with hardly a moment to draw breath between visits. But also in my thinking, having time with nine other people all of whom bring a different understanding. I hope in turn I will have added to the value of the programme by bringing my own perspective on the discussions. Certainly coming from the EU the whole area of subsidies and agricultural support came up more than once, as too did genetic modification technologies, peak oil and managing risks in farm businesses in volatile markets.

Following excellent presentations in Canberra and a dinner at The Houses of Parliament hosted by former Nuffield Scholar and current Deputy Speaker of the House Bruce Scott, we set off for the Philippines**.**

e. IRRI, The Philippines

Here we visited the International Rice Research Institute (IRRI). I had underestimated how crucially important rice is to global food security as half the world's population eats rice every day. The IRRI carries out independent research into the development of rice breeding, and maintains a seed bank of over 120,000 varieties of rice. The information and the seed bank are freely accessible worldwide. One area of research, which involves genetic engineering, was to reduce the cooking time of rice from twelve to eight minutes by manipulating the gelatinization temperature. I wondered how busy you needed to be, to cook your rice in record quick time, however the researcher went on to explain that the saving in energy by reducing the average cooking time by four minutes by half the world's population was significant.

In many Asian countries wood for fires is a scarce resource or the alternative use of bottled gas is an emitter of CO2. So a relatively small change in the cooking time of rice could have a major contribution to reducing greenhouse gas emissions and increase fuel security.

But what to me was most surprising was the major source of the funding for this vital work, the Gates Foundation.

f. China.

From here we flew to Hong Kong and then on by ferry into inland China. The following days have to be some of the most incredible of my entire life, as we saw some of the biggest businesses in the world. We visited the world's largest wool processor, the world's largest prawn farm, and the 2nd largest woven plastics manufacturer. However we also spent time with small farming families and those in the countryside making a living on half an acre of land. We were trying to understand the lives of almost one billion rural dwellers in this country of extremes. On one of the days we were hosted by officials from the Chinese Government at what they call the Long Shua festival. This turned out to be more like an Olympic ceremony with us treated as guests of honour, and in a bizarre moment I was pulled up on stage in front of a crowd of 55,000 people to take part in a mime act. I later discovered this was broadcast live on television across Asia to an audience of half a billion viewers!

g. USA

Still with the Australian Nuffield Global Focus Tour, the next stop was Mississippi. Arriving at Jackson airport after a long flight and two weeks in Asia it was a welcome sight to be met by our hosts from the Natural Resources Conservation Service (NRCS), which is a department of the United State Department of Agriculture (USDA). Here we saw many crops grown in the unique Mississippi Delta.

Catfish is an important industry with over 100,000 acres of fresh water ponds. One of the visits we made was to Tackett Farms, the world's largest catfish producer. This one operation has 8,000 acres of water. Stocking density is 5000 fish / acre. So with a capacity to produce 40 million fish it was no surprise to find they ran their own hatchery producing 150 million fingerlings. 30 million were sold to other producers, and the remainder were used in their own operation. A quick look at the maths and you can see there is a very high rate of mortality in young catfish. It takes 200 days to reach a weight of 1.5lbs. Tackett Farms own their own processing facility and have a part share in the feed mill, which produce the 32% protein feed.

One of the greatest benefits of being a Nuffield Scholar is not just the access to businesses like Tackett Farms but the chance to get beneath the surface of the culture and spend some time with local people. The staff at the NRCS who were our hosts for the week organised a full and hectic program, which allowed us to see so much in just one week. Visits ranged from Mississippi State University, cattle ranches, research farms, the Agriculture & Forestry museum, to Delta Council and the BB King museum.

h. Canada

Another week and another country. In Canada we were welcomed like long lost family by Canadian Nuffielders who opened their homes and their hearts to us. This was a week of many more visits to primary producers and also tours of Indian reservations and Hutterite colonies all of which are a unique part of Canadian culture. Nuffield scholars are highly regarded in Canada and we were treated like celebrities at all the visits and farmer meetings we attended. The Nuffield programme in Canada has not been highly supported in more recent years with only one Scholar representing the whole of Canada this year. However the current board is seeking to

address this with larger bursaries to scholars and by using our visit to lift awareness and by promoting the vast benefits of the Nuffield programme across Canada.

i. Back to the USA

The Global Focus Group then made its way to Washington DC and it was my 3rd entry into the USA since I left home. It seems incredible that we were on Capitol Hill in the USDA buildings looking across the road to the Senate, having meetings with representatives from both Republican and Democrats and also with industry representatives. Although currently there is no Nuffield programme in the USA, we were given a remarkable welcome and access to so many people within government and industry. In an effort to remain healthy 4 of us would endeavor to jog each morning and I shall never forget an early morning run, passing the White House, and reaching the steps of the Lincoln Memorial, to see the sun rise over the city.

j. Ireland

Our final week was spent in Ireland, both North and South of the border. Here our full week's programme had been arranged for us by our fellow 2009 scholars who did a fantastic job and were all generous with their time and arranged a week which money could not buy. Among many highlights was standing in a stable with Galileo, the world's most valuable horse! Our final evening was spent at a reception in the Australian Embassy in Dublin.

When you travel with a group for 6 weeks and share the highs and lows of that experience you get to know people pretty well. I'd be lying if I said everything went smoothly, we suffered sickness, flight delays and lost luggage. We also didn't all agree about the topics we discussed. On long car journeys and in airport lounges we discussed everything from micro algae to God, and all things in between. We came from 3 different countries, we are involved in different areas of agriculture and each of us sees the world differently. And yet, we also had a huge amount in common. All of us were proud to represent our countries and be ambassadors for Nuffield. All of us want to make a difference, and see what we do in feeding the world as important.

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Having completed the **Global Focus Programme** I was now travelling on my own. I felt I had received enough information to last a lifetime, and making sense of it all seemed a big task. So to explore this changing world in a little more depth I headed back to China, but this time instead of flying my wife and I decided to take the train from Bridgwater to Beijing.

k. Russia

We passed quickly from home via euro star to Paris, on to Berlin and then to Moscow without seeing anything except a few days in Berlin to see the sights. This was my first visit to Russia and I was struck by the extremes of this vast country. Wages in Moscow are on average twenty times higher than the rest of the country. Moscow itself is a mixture of expensive shops and areas of complete deprivation. When you

travel by train you see so much more of the countryside and get to understand a bit more than flying over the top of a country. We boarded the Trans Siberian Train ten in Moscow and made the seventy-seven hour journey to Irkutsk in Siberia at an average speed of forty-three miles an hour.

Outside Moscow and many of the larger towns and cities we saw lots of small wooden huts, surrounded by gardens. These are called “Dachas”. It’s a sort of cross between an allotment, weekend holiday home, and beach hut all rolled into one. Many Russians live and work in cities and would have an apartment, often soviet style with little in the way of gardens or beautiful space around them. However at weekends they head out to their dacha where they would have a simple log cabin with very basic facilities, and here they would grow food in the gardens and forage in the countryside for nuts and berries. Many Russians would expect to supply a proportion of their food this way and have far less reliance on buying food from supermarkets than we do here in the west.

Arriving in Siberia four days later we caught a local bus to Listvyanka, a small fishing village on the shore of Lake Baikal, the world’s largest freshwater lake. The lake is home to 1085 species of algae, the majority of which are unique to this region.

l. Mongolia

Of the twelve countries I visited Mongolia has to be one of the most remarkable. We left the train in the capital Ulan Bator and having found a guide headed out into the Mongolian steppe and down to the Gobi desert and spent the following ten days living in traditional gers. In many ways time has stood still here and of the population of three million, half live in cities and half live in gers and are still nomadic. Mongolia is the size of Western Europe, which makes it one of the least densely populated countries on earth at 1.75 people per square kilometer.

Their diet consists of mainly meat and dairy products with very few fresh fruit and vegetables. They also consider pigs and poultry unclean animals and so eating pork and chicken is very rare. As Mongolia is landlocked very little fish is consumed. The five animals that make up the majority of the country are: sheep, goats, cattle, horses, and camels. With a very high fat diet I would have expected to see much more obesity, however all these animals are reared extensively and there is very little in the way of processed foods and certainly there is no use of fertilizers or pesticide on the pastures. One explanation for what is demonstrably a healthy diet is the higher levels of Omega 3 in very slowly reared stock. The intake balance between Omega 6 and Omega 3 is vitally important. Western diets, which include intensively reared stock, high output arable crops and highly processed foods contain a ratio of up to 15 to 1 Omega 6 to Omega 3 (Source: The Center for Genetics, Nutrition and Health, Washington, DC). This compares to a ratio of 1 to 1 in a Mongolian diet.

Some of the highlights of my entire travels were in Mongolia, meeting nomads who have virtually nothing in the way of material possessions yet, as a guest in their home, they offered the best they had to an uninvited visitor and would keep filling my cup with the salty milk tea. But the one memory I shall hold forever is spending time with a nomadic family in the Gobi, collecting camel dung for the fire and milking their camel, before riding across the desert at sunset. Priceless!

m. China

On my second visit to China I spent a further month. After four weeks of travelling slowly east, and seeing very little in the way of large cities it was almost overwhelming to arrive in Beijing during the ten day celebrations to mark sixty years of rule by the communist party. Beijing has population of twenty two million people with very many more visitors in the capital city for the festivities. My view of communist China is very different now I have spent time there. Beijing's public transport is surely one of the most efficient and reliable in the world. The streets and underground are spotlessly clean and we saw no beggars at all. Not being reliant on being re elected in five years, the government are able to invest in some long-term infrastructure such as roads, railways, dams etc. However rural China feels so very different with many areas unchanged for centuries and still almost a billion people living a subsistence lifestyle on just half an acre of land.

From Beijing we took the train northeast to Harbin in Heilongjiang province where I spent a week with Associated British Agriculture (AB Agri), a British food business who have invested in China and now have feed mills and a part share in large sugar beet processing facilities.

As China grows economically so too does it's appetite for a more western diet which includes red wine, meat and dairy products. As Heilongjiang province is naturally more suited to dairy production than many of the hotter more southerly provinces the government target for increased milk production is 9% annually. Many small producers would have between five and ten cows and each day would walk them to the village milking station to be milked. Often these milking facilities are owned by dairy companies who then collect the milk daily. Government dairy advisors are working with these small herd owners to increase production, However this is a very long slow process, so as a result new large dairies of anything between five hundred and five thousand cows and more are being built, often with western expertise and management. AB Agri's investment in sugar beet processing aims firstly to grow more sugar in the Northern provinces of China and secondly provide the sugar beet pulp co-product which is ideally suited for dairy rations. Very little grass is grown here, so the primary source of fibre for cattle is maize stalks, which are low in digestibility.

Therefore sugar beet pulp makes an excellent alternative source of digestible fibre, which is lacking in most Chinese ruminant diets. However, as in many rural situations, change often takes time.

Introducing new crops and changing the way small farmers feed their stock often takes much education. Doing business in China takes many years of building relationships and trust, and I was impressed how AB Agri had committed to this fast growing market with absolute commitment.

In our final two weeks in China to cover more ground we took to the air and flew again seeing many of the sites including the terracotta warriors, the ancient rice terraces of Pingan, and the cormorant fishermen of the Li River.

In my final week I came across a small shop, which was selling little green tablets, very high in protein, as a healthy food supplement. I was fascinated to discover that what this small shop was selling was simply algae. Tasting it for the first time reminded me of grass. It has a very high level of chlorophyll and has a dark green colour.

This for me was my Nuffield moment. Having seen it growing in plastic bags and in tubes, and discussed for hours the uses of algae in aquaculture diets, to see it in a shop on sale for human consumption was the light bulb moment that made me understand that here was a crop which :

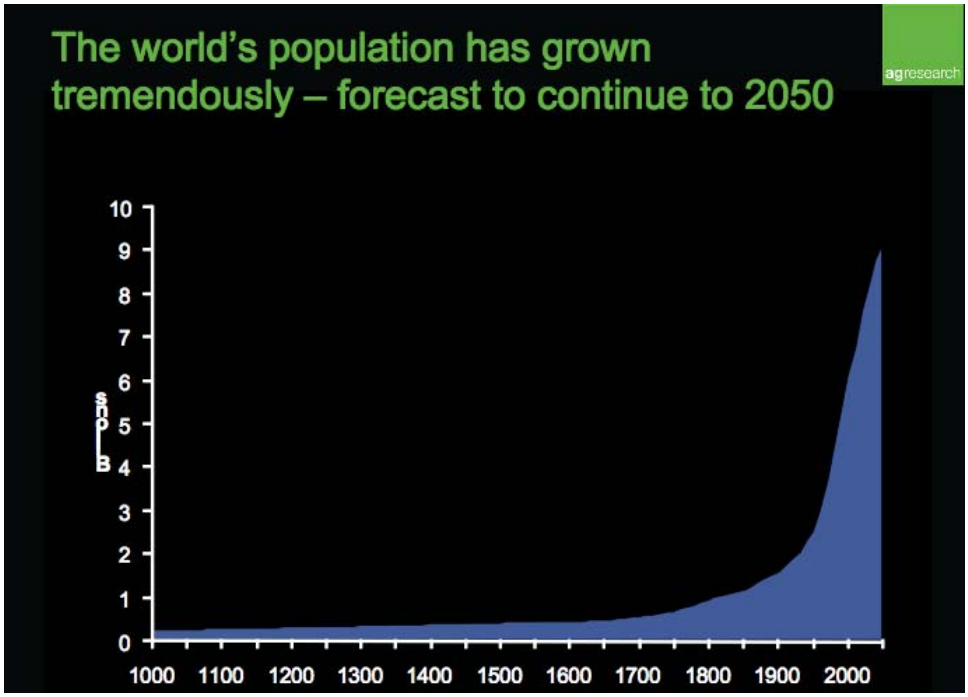
- could be grown anywhere
- is the most efficient plant on the planet
- has almost unlimited potential to feed humans, fish and animals
- in addition to producing oil to replace fossil fuels, and pharmaceutical products.

The small Chinese shop which provided my "Nuffield moment"

Chapter 5 : The Challenge Ahead

a. Rising Global Population and the Green Revolution.

Having completed a synopsis of my travels I will now sum up the implications of what I have seen.



This graph, which will be familiar to many, shows world population over a thousand years. We can clearly see that in the past 100 years we have seen an exponential growth curve. Today the world's population is 6.8 billion people and is increasing by 220,000 every day which is 2.6 persons each second.

In 1798 scholar and theologian Robert Malthus predicted that population growth would exceed our ability to feed ourselves. Malthus has become widely known for his theories concerning population and its increase or decrease in response to various factors. The six editions of his essay on the principle of population published from 1798 to 1826, observed that sooner or later population gets checked by famine, disease, and widespread mortality.

The growth pattern we see in the population graph is completely unique in mammals. Although it is stretched over a longer time frame, the shape of the curve is much more akin to that of insects. At the point where exponential growth begins an insect colony finds a rich and abundant food source, which fuels the rapid increase. Sadly at some point the rich food supply is used up and the population collapses, either entirely or to a point where food supply and numbers of mouths to feed are in balance.

Over the years many technological changes have taken place in world agriculture, which have fuelled further population increases. From the first primitive plough more than 4000 years ago, moving to the horse collar and a heavy plough, through to tractors fully equipped with precision GPS technology today, technical advances have allowed us to produce more food, more efficiently than ever before.

In Britain the process of enclosure of the commons, while deeply controversial at the time, led to new systems of farming and introduction of new crops such as turnips which were fed to livestock which then provided manure for cereal crop. The famous Norfolk four-course rotation (wheat – turnips – barley – clover), meant higher productivity and avoided the need for land to lie fallow between crops by replacing nutrients through both manure and the nitrogen fixing properties of clover and increased cereal yields by 50% by the end of the 18th century.

However the biggest change of all in the supply of food for the human population was first the Industrial Revolution followed quickly by the discovery of crude oil. As the world reached its third billion around 1960 most of the increases in food output had been a combination of mechanical advances and the plentiful supply of affordable nitrogen fertilizer, which gave an excellent return on investment.

The Green Revolution began in Mexico in 1943. Mexico was reliant on importing half of its grain and in response the country's Ministry of Agriculture and the Rockefeller foundation set up a venture called "The Office of Special Studies". There were three elements, which allowed the Green Revolution to succeed.

- Firstly new seed varieties were bred which were insensitive to day length and produced higher yields. An important element of the process was the dwarfing of wheat and rice, reducing the height of the plant and concentrating the energy in the grain. This also enabled the straw not to lodge and fall over under its own weight.

- The second element was the use of inorganic fertilizers. The production of nitrogen, phosphate and potash by the mid 20th century was now possible because of the affordable supply of both natural gas and crude oil.

- The third element was that of irrigation. Most developing countries have a wet and dry season, and while dry season yields are much higher than those in the wet season, lack of rainfall can mean that crops are lost due to water stress. Without proper irrigation crop yields tend to be low and unpredictable – whatever the level of fertilizer application. All of these advances were of course made possible by the mechanisation of agriculture, which had taken place a few decades earlier.

It is widely accepted that Norman Borlaug, who became the director of the Office of Special Studies, is the "Father of the Green Revolution". In 1970 he was awarded the Nobel Peace Prize.

With the experience of the agricultural development begun in Mexico by Norman Borlaug in 1943 judged as a success, the Rockefeller Foundation sought to spread it to other nations. The Office of Special Studies in Mexico became an informal international research institution in 1959, and in 1963 it formally became CIMMYT, The International Maize and Wheat Improvement Center.

In 1961 India was on the brink of mass famine. Borlaug was invited to India by the adviser to the Indian Minister of Agriculture M. S. Swaminathan. Despite bureaucratic

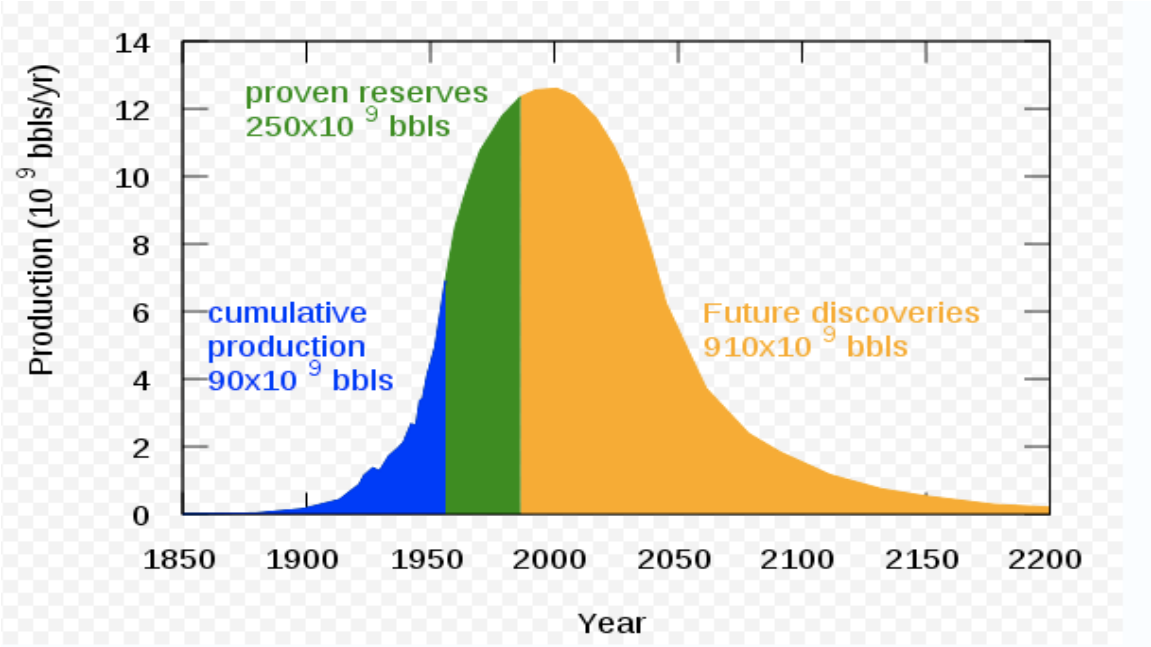
hurdles imposed by India's grain monopolies, the Ford Foundation and Indian government collaborated to import wheat seed from CIMMYT. Punjab was selected by the Indian government to be the first site to try the new crops because of its reliable water supply and a history of agricultural success. India began its own Green Revolution programme of plant breeding, irrigation development, and financing of agrochemicals.

India soon adopted IR8 - a semi-dwarf rice variety developed by the International Rice Research Institute (IRRI) that could produce more grains of rice per plant when grown with certain fertilizers and irrigation. In 1968, Indian agronomist S.K. De Datta published his findings that IR8 rice yielded about 5 tons per hectare with no fertilizer, and almost 10 tons per hectare under optimal conditions. This was 10 times the yield of traditional rice. IR8 was a success throughout Asia, and dubbed the "Miracle Rice". IR8 was also developed into the Semi-dwarf IR36.

In the 1960s, rice yields in India were about two tons per hectare; by the mid-1990s, they had risen to six tons per hectare. In the 1970s, rice cost about $550 a ton; in 2001, it cost under $200 a ton. India became one of the world's most successful rice producers, and is now a major rice exporter.

b. Peak Oil and Climate Change

Peak oil is the point in time when the maximum rate of global oil extraction is reached, after which the rate of production enters terminal decline. This concept is based on the observed production rates of individual oil wells, and the combined production rate of a field of related oil wells. The aggregate production rate from an oil field over time usually grows exponentially until the rate peaks and then declines—sometimes rapidly—until the field is depleted. This concept is derived from the Hubbert curve and has been shown to be applicable to the sum of a nation's domestic production rate, and is similarly applied to the global rate of petroleum production. Peak oil is often confused with oil depletion; peak oil is the point of maximum production while depletion refers to a period of falling reserves and supply.



M King Hubbert created and first used the models behind peak oil in 1956 to accurately predict that United States oil production would peak between 1965 and 1970. His logistic model, now called Hubbert Peak Theory, and its variants have described with reasonable accuracy the peak and decline of production from oil well, field, regions, and countries, and has also proved useful in other limited-resource production-domains. According to the Hubbert model, the production rate of a limited resource will follow a roughly symmetrical logical distribution curve (sometimes incorrectly compared to a bell shaped curve) based on the limits of exploitability and market pressures.

The effects of even a small drop in production can be dramatic. For instance, during the 1970s oil shocks, shortfalls in production as small as 5%, caused the price of oil to nearly quadruple. The same thing happened in California a few years ago with natural gas: a production drop of less than 5% caused prices to skyrocket by 400%.

Fortunately, those price shocks were only temporary, due to the fact that new oil fields were still to be exploited. However if the world is able to extract less oil as time goes on, these price shocks will not be temporary, and in fact we are likely to experience more volatility as time progresses.

If we were to overlay the graph above onto the world population graph I think this would clearly demonstrate the relationship between oil and our ability to feed ourselves.

Today between 30% and 50% of the world's food is produced using nitrogen fertilizer and, once produced, is often shipped and flown around the world, again using fossil fuels in its transportation.

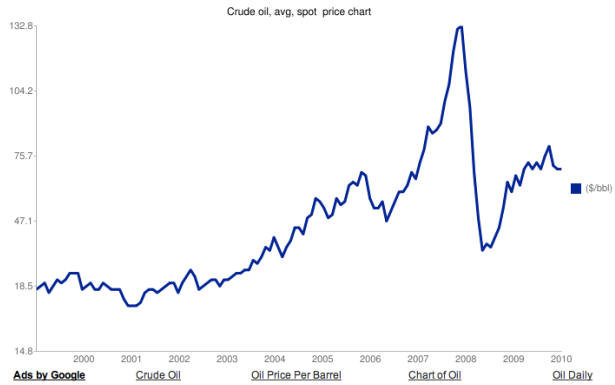
So now we have the challenges of Climate Change and Peak Oil. Together these two issues have been referred to as the “hydrocarbon twins”, we wouldn’t have one without the other. I believe many people think that oil supply in the world is comparable to having a car with a tank full of petrol; the car will continue to run just as efficiently until the very last drop of petrol is used. It is my belief that this is far from the case because of the way our financial and commodity markets operate.

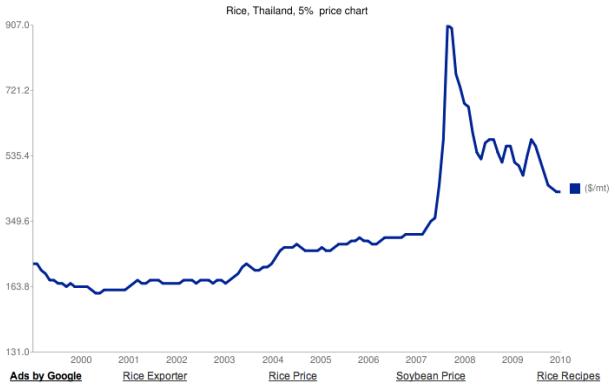
There is a gathering momentum of evidence to suggest that over the next 100 years the rate of use of oil will deplete the remaining viable reserves. In the UK North Sea oil and gas peaked in 1999 and today we are a net importer of fossil fuel.

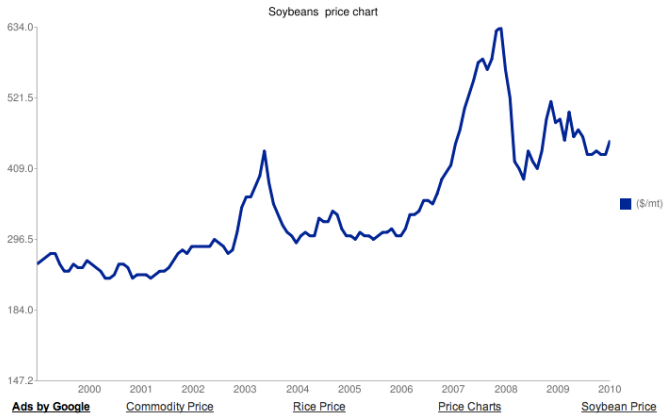
I believe now is a critical time to rethink our current reliance on fossil fuels to produce food.

c. Volatile Commodity Markets

Having spent fifteen years as a feed raw material buyer and commodity trader, I have seen commodity markets become more volatile in recent years. Markets react often disproportionately to the facts. Prices for crude oil and soft commodities such as rice and wheat followed an almost identical pattern in 2008 where there was a “perfect storm” with high oil prices and poor world harvests. This serves as an early warning of the volatile markets, which are going to be inevitable in the future, where food is reliant on crude oil as a raw material in production and for transportation.







The four charts above show the price in US dollars of oil, wheat, rice and soya over the past 10 years and clearly there is a correlation between all four of them. Clearly 2008 was a "perfect storm" for all commodities, but because the cost of food

production is so inextricably linked to oil price, then I believe we are likely to see this pattern continue in the future.

One reason why commodity markets have become more volatile and market reaction is greater than the normal laws of supply and demand might dictate, is that historically farmers have been able to reduce some of the market risk by forward selling some or all of their crop to a trader who may well be acting on behalf of a consumer such as a feed or flour miller. This type of trading conducted in the Chicago Board of Trade has traditionally been subject to tight regulation and all those involved in producing and using agricultural commodities could manage their risk and the system worked well.

However in the mid 1990s a subtle and seemingly unnoticed change took place. After much lobbying by financial institutions these regulations were changed to make it possible for “the funds” (as they are referred to), such as Goldman Sachs, to buy and sell these forward positions. This made agricultural commodities the target of traders who can buy and sell these forward positions many times over. Thus greater swings in prices took place than would otherwise have been the case. Today the funds make vast sums of money by speculating on a position, which becomes a self-fulfilling prophecy.

Chapter 6 : Algae

As I travelled the world I first saw algae being grown in Kentucky both at Alltech and at the State University and this started to get me thinking about it as a crop and also the potential to grow protein.

As I stood in the little shop in China which sold only species of algae as a healthy food supplement I began to see more potential in algae as a source of nutrition. Most of the research in the world is focusing on high oil species algae, which have the potential to be used as a biofuel. Companies like Shell & BP are committing millions of dollars of investment searching for perfect species and a cost efficient method of first drying, and then extracting, the oil from the algae. Like many oilseed crops the residue is naturally high in protein and could well feature in livestock diets. However with current prices of crude oil hovering around $80/barrel the technology has not progressed to a cost effective level. Yet with volatile oil prices and the very real threat that peak oil is either here already or only a few years away, large oil companies continue to invest huge budgets in algal research.

One of my fellow travelers on the Global Focus Programme, Adam Butterworth from South Australia, manages an oyster hatchery in Port Lincoln and his Nuffield topic was seaweed production for use in the oyster industry. As we spent many hours visiting businesses and waiting in airport lounges around the world I spoke at length to Adam about the production of seaweeds and algae, realizing that it was protein that young oysters need and algae was a very efficient and sustainable source.

a. Seasalter, Kent

On my return to the UK I started to investigate the algae industry here and found that the major end usage for algae is as a food source is in the shellfish industry. I visited Seasalter on the Kent coast, which is a commercial oyster farm with 60 acres of open ponds. Seasalter grow micro algae in fresh water to feed the hatchery as very young oysters feed on algae. Here for the first time I saw a low-tech approach to growing algae, which in turn is fed to a high value commodity.

The first thing that struck me was that water had to be pasteurized to inhibit any naturally occurring algae which would grow and maybe out-compete the strains which *were* desirable. If a glass of any water is left for a few weeks after a while it will begin to turn green, either from algae naturally present in the water, or an air borne source.

Open raceway pond at SeaSalter, Kent.

Most of us will be familiar with algae as a nuisance in ponds and lakes and in certain conditions blue green algae blooms on water and causes real problems. Just before the Olympic games in China there was concern that the sailing events could be cancelled due to an algal bloom. I quote overleaf from a sailing spokesman for the Beijing Games organizing committee:

> *"Warmer waters, increased rainfall and high levels of nutrients in the ocean brought about the algae explosion along vast stretches of the 800-kilometer (500-mile) coastline. Qingdao, located 830 kilometers from Beijing, had to mobilize more than 1,000 fishing boats to scoop up the algae and contain the outbreak.*
>
> *"We can only haul the blue-green algae manually and we're doing all we can with our arms full and by the boat-load," said a sailing spokesman for the Beijing Games organizing committee. "All you can see is fishing boats along the coast."*

Qingdao and its algae

b. Algae and seaweeds

Algae can be considered to be non flowering plants of a large group that includes the seaweeds (Macro algae) and single-celled forms (micro algae). Like plants, algae are microorganisms that utilise chlorophyll to convert nutrients, CO_2 and sunlight into sugars. Unlike plants they lack traditional associations such as true stems, roots and leaves. Broadly speaking macro algae form seaweeds and kelps and are usually found in salt water, while micro algae are more common in every single environment on earth. There are many exceptions but, as there are potentially a million or more species of algae, then this is a good guide.

i. Types of seaweed

Globally there are over 9,000 catalogued species of seaweed divided into three major types: green, brown and red. Red is the most species-rich group (6,000) followed by brown (2,000) and green (1,200). Around 600 species are found on UK shores. Like land plants, the vast majority of seaweeds depend on light for growth, so they only occupy the inter-tidal area or relatively shallow photic (light penetrating) zone. Green seaweeds tend to be found towards the top of the shore, browns from the top to deeper waters, and, since they are adapted to photosynthesize at lower lights levels, red seaweeds tend to dominate the deeper, darker waters and also beneath kelp canopies and in shady rock pools.

ii. Seaweed farming

In 2002, world aquaculture production of seaweeds reached over 11.5 million tonnes with a value of over $6 billion, with China accounting for almost 9 million tonnes of that total. In Europe, seaweed cultivation occurs only on a small scale, with France being the only commercial producer in 2002, growing 35 tonnes (Source FAO 2002).

c. Uses of seaweed

Seaweed is not only used as a food source (particularly in Japanese cooking), it has a range of other uses.

- It can be used in agriculture and horticulture as an organic fertilizer and soil dressing
- in beauty treatments, not only as an ingredient in products such as moisturisers but also in seaweed baths
- as a health supplement
- and also as a source of agar and alginates for a range of products including ice cream, yoghurt and pet food.

iv. Agrisea New Zealand

AgriSea Animal Health Nutrition in New Zealand is promoting the use of native seaweed species (Ecklonia Radiata), and herbs, which contains a complex range of bio-available minerals and nutrients to support Animal Health. They also have a large range of soil conditioner product all based on harvested native seaweeds. While I did not visit this company I think they demonstrate that there is a small and growing interest in utilizing seaweeds in soil health and animal nutrition.

v. Micro algae

They are unicellular species, which exist individually, or in chains or groups. Depending on the species, their sizes can range from a few micrometers to a few hundreds of micrometers. Unlike plants, microalgae do not have roots, stems and leaves. Microalgae, capable of performing photosynthesis, are important for life on earth; they produce approximately half of the atmospheric oxygen and use simultaneously the greenhouse gas carbon dioxide to grow photoautotrophically.
The biodiversity of microalgae is enormous and they represent an almost untapped resource. It has been estimated that up to one million species exist of which about 35,000 species are described. Over 15,000 novel compounds originating from algal biomass have been chemically determined. Most of these microalgae species produce unique products like carotenoids, antioxidants, fatty acids, enzymes, polymers, peptides, toxins and sterols. While fish oil has become famous for its omega-3 fatty acid content, fish don't actually produce omega-3s. Instead they accumulate their omega-3 reserves by consuming microalgae or plankton microalgae consumers. One of the most well known species of algae is Spirulina.

vi. Spirulina Algae

Spirulina is a microscopic blue-green algae that exists as a chain forming single celled organism turning sunlight into life energy. Under the microscope, Spirulina is a blue-green colour and has the appearance of a segmented spiral as a long thin thread. Spirulina is exceedingly adaptable and occurs in a wide variety of environments mostly in fresh water but can also grow tropical springs, saltwater and saltpans. Spirulina is full of nutrients and very easily digested once the cell wall has been cracked. Commercially, Spirulina is available as a powder, tablet and capsule or added to foods, pet foods and health tonics. It is available in high street health food shops such as Holland and Barratt.

There are many forms of valuable algae and in the last 40 years Spirulina has been singled out for its nutritional properties. Long before it became a favorite of the health food industry, Spirulina was eaten regularly centuries ago by North Africans and Mexicans. Now many people around the globe realize that Spirulina is a powerful food with huge potential as a whole food source, medicine and biochemical resource.

A great deal of research has concentrated on the cultivation and harvesting of what is affectionately referred to as ‘the green’. It has been described as ‘probiotic’ and a ‘superfood’.

The cultivation of Spirulina has also brought interest because, as with most micro algae, Spirulina is extremely adaptable, often thriving in extreme conditions. With its rich nutritional goodness and ability to grow in adverse conditions, Spirulina has a huge potential to be a food source that will help feed and nourish the world population. Spirulina is incredibly rich containing a balance of nutrients that make it virtually a ‘whole food’ capable of sustaining life without the need for other foods.

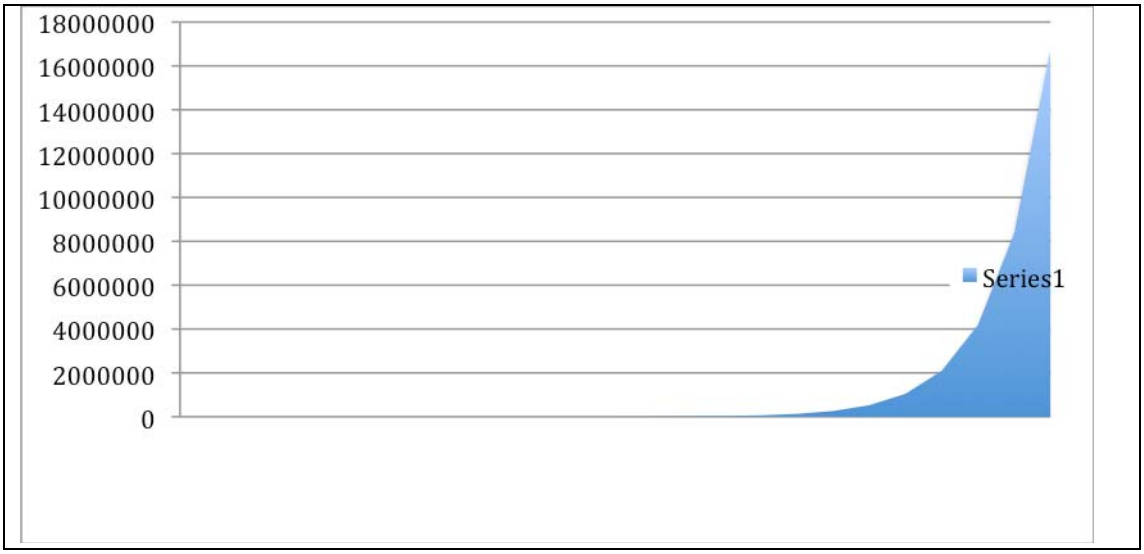
Spirulina is at least 60% protein making it a highly digestible food. It is higher in protein than any other food. Its outstanding nutritional profile also includes the essential fatty acids, GLA fatty acid, lipids, the nucleic acids (RNA and DNA), B complex, vitamin C and E and phytochemicals, such as carotenoids, chlorophyll (blood purifier), and phycocyanin (a blue pigment), which is a protein that is known to inhibit cancer.

How is it grown?

In outdoor systems Spirulina thrives in natural alkaline lakes. The key component in the production of Spirulina is sunlight and attention is given to measurement of temperature and oxygen levels. Because pesticides and herbicides would kill many microscopic life forms in a pond, algae scientists have learned how to balance pond ecology without the use of these harmful substances. This form of production represents one of the solutions needed to produce food while restoring the planet. It can also be grown in controlled photo-bioreactors, which has a much higher capital cost but very much more efficient production and relatively purer products.

Spirulina is one of the most efficient photosynthesizing plants on the planet, and given ideal conditions of heat, light, nutrients and $CO_{2,}$ will divide - therefore doubling - every four hours. This means it will multiply by sixty-four in the first day but will have multiplied by more than Sixteen million after four days.

This chart on the next page shows the growth curve of micro algae in optimum conditions over four days.



Growth of micro algae in optimum conditions over four days

Current research with photo-bioreactors has shown that algal strains can reach maximum growth at four days as the density of the algae blocks light, and movement is restricted.

<u>"Chlorella and Spirulina"</u>.

Both of these algal species are very high in crude protein content and have naturally high levels of omega 3. Both are available in health food shops here in the UK as a human food supplements and have a retail value in excess of £250,000/t.

The use of spirulina is advocated by the "World Health Organisation" (WHO) as a means to alleviate malnutrition in third world countries. They cite the following advantages:

1. Is locally produced at low cost (between 5 an 9 $ per Kg).
2. Has a high nutritional value
3. Contains nutrients in an easily digestible form
4. Is easy to grow and safe to consume
5. Can be dried and conserved for years
6. Requires less water than a vegetable garden
7. Provides more than 20 times more protein per hectare than soya.

"*The best health food for people in 21 century*"
- Confirmed by World Health Organisation.

"The most ideal food in 21 Century"
-Recommended by United Nations FAO.

"The most ideal and sound food for tomorrow"
- Recommended by UNESCO.

vii. Cultivation of algae in open ponds

Cultivation of algae in open ponds such as the ones at Seasalter in Kent is the most common around the world. Open ponds can be categorized into natural waters (lakes, lagoons, ponds) and artificial ponds or containers. The most commonly used systems include shallow big ponds, tanks, circular ponds and raceway ponds. One of the major advantages of open ponds is that they are easier to construct and operate than most closed systems.

- However, major limitations in open ponds include poor light utilization by the cells, evaporative losses, diffusion of CO_2 to the atmosphere, and requirement of large areas of land.

- Furthermore, contamination by nutrient scavenging predators, algae viruses, algae-eating microorganisms and other fast growing heterotrophs have restricted the commercial production of algae in open culture systems to only those organisms that can grow under extreme conditions.

- Also, due to inefficient stirring mechanisms in open cultivation systems, their mass transfer rates are very poor resulting to low biomass productivity.

- Their open plan design also allows any and all environmental contamination to be incorporated within the ponds (e.g. birds, faeces, dust/particulates etc. etc.).

The ponds in which the algae are cultivated are usually called the “raceway ponds”. In these ponds, the algae, water & nutrients circulate around a racetrack. With paddlewheels providing the flow, algae are kept suspended in the water, and are circulated back to the surface on a regular frequency. The ponds are usually kept shallow because the algae need to be exposed to sunlight, and sunlight can only penetrate the pond water to a limited depth.

The ponds are operated in a continuous manner, with CO_2 and nutrients being constantly fed to the ponds, while algae-containing water is harvested at a single point by a dipped conveyer belt.

The biggest advantage of these open ponds is their simplicity, resulting in low production costs and low operating costs. While this is indeed the simplest of all the growing techniques, it has some drawbacks owing to the fact that the environment in and around the pond is not completely under control. Bad weather can stunt algal growth. Contamination from strains of bacteria or other outside organisms often results in undesirable species taking over the desired algae growing in the pond. The water in which the algae grow also has to be kept at a certain temperature, which can be difficult to maintain. Another drawback is the uneven light intensity and distribution within the pond.

In the United States the Aquatic Species Programme (ASP) used open ponds for its experiments and has also favoured the same for the future primarily owing to its economic value. However, many companies today are experimenting with closed pond systems and in many cases, with the much more expensive photo-bioreactors.

viii. Cultivation of Algae in Closed Ponds

An alternative to open ponds is closed ponds where the control over the environment is much better than that for the open ponds. Closed ponds systems cost more than the open ponds' initial capital expenditure, and considerably *less* than photo bioreactors for similar operational footprints.

As a variation of the open pond system, the idea behind the closed pond is to close it off, to cover a pond or pool with a greenhouse. While this usually results in a smaller system, it does take care of many of the problems associated with an open system. It allows more species to be grown, it allows the species that are being grown to stay dominant, and it extends the growing season, only slightly if unheated, but if heated it can produce year round. It is also possible to increase the amount of carbon dioxide in these quasi-closed systems, thus again increasing the rate of growth of algae.

ix. Cultivation of Algae in Photo-Bioreactors

As with closed ponds, algae can be grown in photo-bioreactors, which are closed to the general environment. Photo-bioreactors can be considered to be a network of clear tubing with a shallower light-path length than open ponds. Generally they are mechanically pumped; however airlift systems can be utilised for a fraction of the cost. There is again a higher capital expenditure than for ponds.

Algae from photo-bioreactors however tend to be purer, and more controlled, giving higher growth rates. There is little evaporation loss so up to 99% of the water can be recovered and reused.

x. Algae Harvesting

Gathering algae consists of separating algae from the growing medium, drying, and processing it to obtain the desired product. Separating algae from its medium is known as harvesting. Harvesting methods depend primarily on the type of algae. The high water content of an algae culture must be removed to enable further processing. Macro algae harvesting usually employs manpower, whereas micro algae can be harvested using micro screens, centrifugation, flocculation or by froth flotation. These must be energy-efficient and relatively inexpensive so selecting the right method for certain strains is important.

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xi. Exalga

Since returning home I have become a non executive director of a startup company called “Exalga” and to my knowledge we are the only commercial algae growers in Northern Europe who are producing proteins for use in human and aquaculture diets. We are using an indoor photo-bioreactor, built in a poly tunnel, consisting of a vast array of vertical clear tubes each containing twenty litres of water. After introducing the required algal species it takes just four days to reach the maximum concentration of algae, which we then separate from the water. The water is returned to the tubes and the process starts again. We are still in the early stages of development. However I believe that this model is able to scale up to a size which would bring down costs significantly allowing us to compete with the current imports of algae for human and aquarium use, and create cost effective protein which is completely environmentally sustainable and could be used as an alternative to fishmeal and proteins of vegetable origin.

Exalga photo-bioreactor

Each tube contains twenty litres of water. Seventeen tubes can be fitted on each side of a standard three-metre pallet rack. As each pallet rack has two bars, each with a double row of tubes fitted, a single pallet rack frame can hold sixty-eight tubes of water each containing twenty litres. Therefore each frame can hold 1360 litres of water.

It takes four days to reach maximum density of algal growth of .06% w/w. This means each rack can produce 816 grammes of algae every four days. It is theoretically possible in a full year to repeat this process ninety one times. However with hold up, clean downs and allowing a margin of error, if this process were to be repeated just seventy five times, each rack would produce 61.2kg per annum.

A shed or poly tunnel measuring 7 metres x 30 metres (210 square metres) could accommodate Forty racks and therefore could produce 2,448 kg of fresh algae, with a dry matter content of 36%. Once dried to a dry matter content of 88%, which would allow for longer-term storage, this would give 1,001 kg. The market price has a huge variation dependent on the end use of the product. Values range from £5/kg for pet food diets to £250/kg for human health food supplements, or at the very high end of the value chain, marine aquarium diets at £700/kg. So if an average price of £100/kg could be achieved, the revenue from 1 small poly tunnel could be £100,000pa.

The beauty of this type of modular system is that it is replicable in larger buildings and spaces and as volume produced goes up the costs of production come down, as much of the basic equipment needed such as a centrifuge to separate the algae from the water is shared. Also if the output requirement increases so does the number of tubes proportionally. Once we reach a critical volume, costs can reduce even further as acrylic tubes could be manufactured on site using plastic molding equipment and reducing the thickness of the tubing even further. Unlike ponds there is no height limitation to photo-bioreactors.

The key to efficiency in this type of production system is the correct balance of nutrients, which are small quantities of nitrogen, phosphate and potash. Ample light which can either be natural, or artificial LED light can be introduced cost effectively. CO_2 is needed which can be obtained from the environment or be forced into the system for additional growth. The final element is a constant temperature where the optimum temperature for micro algae to grow is 24°C however growth will occur between 5-40°C albeit at reduced efficiency.

xii. Anaerobic Digesters

The UK is seeing more investment in anaerobic digester (AD) plants as the economics makes them an attractive option for both farms and businesses across the food sector. One of the little utilised by-products from an AD plant is the heat, which is often the one energy source. This is difficult to capture the value of, often by virtue of the fact that a suitable use is too far from the location of the plant.

By locating algae plants alongside AD plants the waste heat can be transferred into high value algal protein, which is easy and cost effective to transport for further processing or there are very real possibilities that on farm uses can be explored for the algal growth. The nutrients required for algae to grow are all available in the digestate and Exalga are doing research to upgrade the digestate to make it more available to the growing algae. Using this stream of waste nutrients will limit waste and minimise any effect on current farming fertilizer demands. In addition $CO_{2,}$ which is emitted from the combined heat and power (CHP) plant can also be utilised to further enhance algal growth.

There is a perfect synergy between AD plants and algae production. While it is possible to use either open or closed ponds, by far the most effective method would be to locate a photo-bioreactor next to an AD plant as this would give the greatest

ability to control both the inputs and the quality of the end product. This type of synergistic relationship has been called up-cycling.

If you were to take the next logical step it would be to also locate a fish farm such as tilapia, which could then feed on the algae. Tilapia is the most farmed fish on the planet and is a perfect way to transfer algal protein into nutritious human food.

Anaerobic digesters such as this one at Kemble Farms, Cirencester, are able to utlilise slurry from the dairy unit and maize grown on the farm to produce electricity for use on the farm and to feed back into the national grid. However it has not so far been possible to capture all the value of the heat which is produced from the plant.

Chapter 7 : Conclusions

1. World population will continue to rise

Having now spent a good deal of time travelling the world and thinking about the challenges ahead of us I can fully understand why 200 years ago Malthus was so concerned about our ability to feed ourselves and why he may have thought that a dramatic reduction of world population was the only answer for humankind. However while there have been many famines and huge losses of life through wars and diseases the underlying trend has still continued to be one of growth. Current estimates from the United Nations is that world population will peak around ten billion sometime around the end of this century. As pressure is put on the food system to provide adequate nutrition for the world I am convinced that we will need to respond to the challenge in the same way that we did when we adopted turnips as a new crop. This enabled the Norfolk four course rotation to increase yields dramatically in Britain. Or, when oil was made available, we suddenly had the ability to produce inorganic fertilizers, which paved the way for Norman Borlaug and the green revolution to boost the food availability to fuel further population growth.

2. The poorest on the planet are most affected by price volatility

Today there are one billion people on the planet who suffer from obesity and the effects of over eating (mainly in the western world), and at the same time one billion people who are suffering from a lack of adequate food and are under nourished, (mostly in the third and developing world). In the western world we have also seen the cost of food as a proportion of our income fall to an all time low of just 10.5%. This compares to 25% just over 25 years ago. In many third world countries food costs account for 70% of income. So the effect of volatile markets affects the poorest on the planet the most. In 2008 when food prices soared many poorer countries suffered civil unrest and food riots were commonplace on the streets of cities across Asia, Africa and South America.

3. There will be serious shortages of food and water by 2030

The government's own chief scientific advisor Prof John Beddington predicted a perfect storm in a speech in March 2009 to the Sustainable Development UK 09 conference.

> *"By 2030 the demand for resources will create a crisis with dire consequences", Prof John Beddington said. "There's not going to be a complete collapse, but things will start getting really worrying if we don't tackle these problems." Prof Beddington said the looming crisis would match the current one in the banking sector. "My main concern*

is what will happen internationally. There will be food and water shortages," he said. "We're relatively fortunate in the UK; there may not be shortages here, but we can expect prices of food and energy to rise."

4. Food and energy security has been largely forgotten in the light of the international financial crisis

The issue of food and energy security rose high on the political agenda in 2008 during a spike in oil and commodity prices. However since then the recession and financial concerns have dominated the headlines and been the main focus of governments around the world. Unless we act, I believe a food supply crisis could be more harmful than the current banking crisis. Now is the time to increase our food security and take a closer look at regulations which allow speculators to profit from rapid fluctuations while causing many of the most vulnerable in the world to suffer. Markets need to be allowed to operate effectively but at the same time strong regulation will secure profitable producers for the long term.

5. All technologies that could potentially help meet this challenge must be explored

There are many potential contributions to help in this enormous challenge and I have seen a range of work including genetic modification, nutrigenomics, precision arable cropping using GPS technology, advances in soil and water management, and animal nutrition and breeding. I have also seen successful organic and biodynamic systems. The challenge ahead is so great that all of these technologies old and new must be explored.

6. Government and industry will need to take a partnership approach to this enormous challenge

If we are to achieve the aims of the “Food 2030” policy, and respond to the concerns of Professor John Beddington, we will need to be more creative and more ambitious in the future than we have been in the past. Government and industry will need to take a partnership approach to this immense challenge.

7. The most exciting potential contributor is algae

For me the most exciting of all the potential contributors to the immense challenges ahead is that of algae. By producing a sustainable source of energy and protein using algae and photo-bioreactor technology the UK and large parts of the world can become more resilient in the face of future challenges.

Here in the UK we will need to adopt photo-bioreactor technology, as we do not have a suitable climate to use open ponds such as those operated in China and Hawaii. We could also reduce our reliance on imported proteins,

and do so in a sustainable way. Algae do not require vast areas of land and therefore will not be using a valuable and finite resource which could otherwise be used for growing food. We can reduce market volatility by removing currency risks by originating this raw material in a sterling based economy. We can reduce our current reliance on fishmeal as a feedstock for aquaculture and the intensive pig and poultry sector. By locating algae farms next to anaerobic digesters, many co-products can be utilised such as waste heat, nutrients from digestate and CO_2 from the CHP plant. Investment in research is critical, as the high capital investment costs will deter individuals and commercial organisations from exploring this exciting new sector until further work is done to confirm it's efficacy.

Algae has a huge part to play in feeding the poor and most vulnerable in the world as they too could grow more of their own nutritional needs making them less dependent on food aid and the volatility of global markets.

Chapter 8 : Recommendations

1. Each business should consider the impact on their business of rising oil and energy costs and prepare budgets with scenario planning which values energy and oil at much higher values than today.

2. Managing risks of volatile markets will be essential in a future where price shocks, and rapid price movements will become more prevalent.

3. Governments around the world should examine the role of speculators in agricultural commodity markets, as they create more price volatility, which adversely affects the poorest in the world the most.

4. Secure long term supplies of energy through the use of anaerobic digesters.

5. Reduce the UK's dependence on imported feed and food.

6. The Town and Country Planning system should not be a barrier to exploring new sustainable ways of producing energy and food.

7. New technologies will need to be embraced.

8. Algae should be considered as a source of fuel, fertilizer and food, for humans, fish and livestock.

Ian Tremain

Pengotton
Gotton
Cheddon Fitzpaine
Taunton TA2 8LL

tel : 07811 198979
email : iantremain@me.com

Postscript

Somerset, December 2010.

It is now two years since I made my initial application for a Nuffield Farming Scholarship and I could not have predicted the journey I would have taken both physically and mentally over this period of time. Having worked in the same industry for over twenty years it is sometimes difficult to step outside of the day-to-day busyness to consider the path ahead. Two years ago I was at a crossroads in life, having sold the business which I had created, and not sure of my future direction. However when I stood in the little shop in China, which only sold algae, a light came on in my mind. (*see foot of page 11*). There have been many "Nuffield moments" and together they are shaping the way I think and how I see the world. As I look back on this journey I can see that I would not have been able to think these thoughts or consider new horizons, unless Nuffield had opened the doors for me. The experience has allowed my to discover more about the world in which I live and more importantly more about myself. I also now realize that the Nuffield experience doesn't end when my report is printed and the presentation is delivered, but rather it continues with life long learning.

The Nuffield Farming Scholarships Trust has made an investment in me, and this has taught me a valuable lesson in investing in myself. I consider myself the most fortunate of all scholars to have had both the time and the additional resources available to spend four months out of the country in addition to many days here in the UK. I hope in the fullness of time my sponsor, The Oldacre Foundation, and Nuffield will consider their investment a good one and that UK agriculture will be a beneficiary of this investment.

One of the valuable lessons for me of the past two years came from Stephen Covey's book, "7 habits of highly effective people", which encouraged readers to "sharpen the saw". The story explains of a young man working really hard to saw down a very large tree with a blunted saw. A passer by stops and they agree how hard the task appears to be, with a saw which has been worn down by use. The passer by suggests that the user goes back to the workshop and sharpen the saw, but the worker replies that he's far to busy to stop and has too much to do to. I can see that by taking the time to sharpen the saw of my mind I will be more effective and have a better contribution to make.

In the Chinese language the word for problem is the same word that is used for opportunity, so as the world faces new challenges, I can now clearly see new opportunities.

For the past six months I have had a full time role working on a BBC initiative called "Village SOS" which has matched business people with village communities who have started social enterprise projects.

I have been living in Mid Wales and providing entrepreneurial advice to a village that has purchased a seven acre derelict market garden, which I am helping to restore to become a local supplier of organic fruit and vegetables. Many of the projects taking part in this rural regeneration initiative will have the results screened on BBC1 in the spring of 2011.

As I complete my commitments to this project I will spend more time in my non-executive directorship role at Exalga (*see further details on page 27*). The Exalga business, even in recent weeks, has taken new steps to turn an idea into commercial reality, and is growing rapidly.

I have no doubt I will continue to see new opportunities in the years ahead.

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Appendix

Reference Books:

The Transition Handbook, Rob Hopkins.
The Feeding of the Nine Billion, A Chatham House Report, Alex Evans.
Integrated Multi-Trophic Aquaculture systems. A Nuffield Report, Adam Butterworth.
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