Why Worry About Food 2?

Going Deeper, information on food issues for those who want to know more

Summary

- The Eco-congregation discussion document entitled Why Worry about Food set out a basic framework to help Church congregations and eco-congregation Groups to discus a range of environmental issues linked to how we produce our food.
- The initial document referred to the science, sociology and economics, which underpins many of these issues but without providing detail. This Document attempts to fill that gap.
- Here we provide additional information on the topics discussed in the Summary Document for those who would like to know more.
- Although paralleling the Summary Document it can be read independently.
- As part of the Eco-congregation material on Food there are additional to the Summary Document and Going Deeper suggested Bible Studies and a listing of places from where further information can be obtained.

The structure of this module

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1. Introduction

The wide spread nature of food production and the numbers of people involved world wide make food issues complex because of their impact on communities and their economies. Inevitably there are significant environmental impacts simply because of scale. However beyond universality, food production impacts on the environment in both positive and negative ways, which are unique. This raises issues related to balance and considerations such adequate food supply to areas of food poverty. Our Current debate is part of discussions on sustainable consumption and the unequal divide of resources between rich and poor nations, and the totality of resource use.[1] It is important to remember that the future is not fixed. Society, as it is now, is a human construct, markets are not sacred, and we can change what we don't like, if we work together.

2. The Importance of Food

a) Agriculture is different

Livestock production is one of the earliest forms of farming mentioned in scripture. Sheep always get a good press. (Genesis 4, 2-5). God valued the lamb brought by Abel more than the fruit of the earth produced by Cain. All industrial activity uses resources and generates and releases Greenhouse Gases (GHG). We consume food; we respire so we release CO2. Agriculture differs from most other industries in a key respect; not only does it produce GHG's it commonly results in the storage of large amounts of C in soil.

Agriculture (including horticulture) and related activities such as forestry and wild life conservation result in plants fixing CO2 from the atmosphere and moving a proportion of that fixed CO2 into the soil. Soil is a mixture of degraded rock and carbon derived from plants and soil microorganisms. Were agriculture to stop and be replaced by a building we would lose its CO2 release but also it's storage of atmospheric CO2 released by agriculture and by our other activities. In some cases this storage can exceed the CO2 foot print of agriculture i.e. the net CO2 footprint can be positive. Different forms of agriculture result in different amounts of C being stored in the soil. Storage is generally highest in systems based on the use of permanent pasture and least in annual crop systems (Table 1). The impact of grazed pasture is complicated by the release of Methane, an active GHG (Table 2), as an inherent feature of rumen fermentation. This results in beef and lamb having significant C footprints (Table 3) [2]. Never the less Grassland soils tend to have high organic matter contents. The types of food we produce and eat and the ways in which they are produced thus affect food productions overall environmental impact.

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[1] Christian Aid (2013) Hungry for Justice: Fighting starvation in an age of plenty p74

[2] CO2 Equivalents The burning of fossil fuels results in the release of CO2 to the atmosphere. CO2 prevents heat, generated on earth from leaving and so results in generalised warming. Other gases released from human activity such as methane work in a similar way but are more potent. The effect of gases such as methane and nitrous oxide are thus given values related to the impact of CO2

b) Environmental Impact

The production of food will always have a major impact on the environment, especially in relation to changed land use and biodiversity. The environmental impact of an intensive production system using fertilisers and processed feedstuffs will be greater than that of a small farm recycling natural resources and using limited mechanisation. Not all soils are equally robust and able to cope with the growth of crops, which deplete carbon and nutrients. In the developing world many soils, as a consequence of geological history, mineralogy and previous land use, are fragile. Some can be damaged more easily when used for exported commodity crops rather than for the producer's local consumption. Food produced distant from consumption incurs transport costs. The environmental impact of our food is thus not just that of what we produce in Scotland it is also that of our impact from food produced elsewhere. Where this involves the replacement of forests for the production of soya environmental impact is high.

We cannot preclude all impact but we can influence its extent. The ways in which the growing of our food impacts upon the environment are summarised briefly in Table 1. The key issues are the amounts of food produced by different types of production, the quantities of carbon stored in the soil as organic matter, biodiversity[3] and the relative efficiencies of crop and of animal production in respect of environmental impact.

Table 1 The environmental impacts of food production

Food production	Key actions	Causes and types of environmental impact
Arable crop production	Establishment	Habitat destruction, significant losses of biodiversity, significant releases of C from soil, initially reduced C capture, changed hydrology
	Fertiliser and chemical use use	Significant energy required to produce fertiliser or pesticides. N2O release from soil following fertiliser use and potential contamination of surface water. Pesticides reduce biodiversity and may modify soil

[3] Biodiversity An indicator of the numbers and range of different living organisms present in a place or within a particular approach to agriculture. It is most commonly used to characterise variation in soil microorganisms or the numbers of other plant species present within an area of land being used for food production. It may also be used to characterise the impact of types of agricultural production on birds or insects

		biological communities
	Managed recycling	Allows for introduction of N fixing and soil N capturing plants as part of a rotation, assists the accumulation of C in the soil, can increase soil and above ground biodiversity
Livestock production	Cattle or sheep	Methane production as a consequence of rumen fermentation, amount of food reduced compared to crop production on good land but produces food from land not capable of growing crops which is important in Scotland and results is significant C storage in the Soil
	Non Ruminants	Usually need significant amounts of feed which other wise might have been for humans,

c) Population Impact: How much Food

At first sight quantifying world food production should be simple and useable as a basis for feeding the world. We have good estimates of world population; we are aware that it is increasing. We have estimates of how much food is being produced in the world, although these tend to be dominated by the food, which is traded, and often ignore that produced on small farms solely for the use of the producers, which is a large proportion of the global total. In addition the contribution of fish and food from allotments and community gardens is commonly omitted. However production can vary greatly in the same country or even in the same area from year to year. For example in 2002 the average wheat yield in the Ukraine was 3 tonnes/ha, in 2003 it was 1tonne/ha and in 2008 4tonnes/ha.[4] Thus in a major world grain producer output can fall by two thirds year to year or increase by a third. This level of variability is not unusual.
Even if we had hard estimates, in which we could have confidence, for both population and production we would still have less than a clear picture of the workings of the world food system. There are significant numbers of the food poor; currently estimated at between 800milllion and 1 billion. However the food poor exist not because of a world shortage of food but because they are unable to pay for food, both that produced locally and what could be imported.
Alternative uses for food complicate the picture. Much of crops such as barley, currently around 40% of production, are fed to livestock. Significant amounts of

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4 www.indexmundi.com/agriculture/?country=ua&comodity=wheat&graph=yield

grain are used as industrial feed stocks or turned into biofuels. Producing fuels in this way of course reduces the amounts of fossil fuels used. On top of all this much food, perhaps 30% of production, is wasted. Changing priorities within these alternative uses could release more for human consumption and reduce the need to produce more in total.

Consideration of issues related to production, distribution and purchasing power need to be rooted in specific situations. It helps to reflect on a single continent. Africa is among the most food poor of all continents[5]. At least a quarter of the world's food poor reside here and numbers have increased over the last two decades; despite increasing world food stocks. Of an estimated 798 million food poor in the developing world, 205 million (27% of the population) are in Africa;[6] In sub-Saharan Africa one in four people live with hunger. [7] In Africa each year around 30-40 million people require emergency food aid. Over recent years food production in Africa has increased by 2.5% while population has increased by 2.8%.

It is helpful to look at Africa to answer the question, would producing more food in total reduce the numbers of the food poor? Under-nutrition is a significant element in 28% of deaths in Africa. Economic growth is needed to fund food imports and home production. Economic productivity requires improved intellectual capacity, which is dependant on adequate nutrition. Food security is related to agricultural productivity; especially from one's own herd or farm. Higher productivity generally reduces food prices and results in a higher availability in the market. In Eastern and Central African countries, the most badly affected areas; there is low and stagnant production and poor purchasing power. Markets are ineffective and the population do not have the wealth to stimulate imports, resulting in under-nutrition. Moving beyond this situation involves changes beyond mere food production. Improvements are needed in basic services such as education. The nutritional status of children in Africa is linked to the educational status of their mothers. Enhancing the educational status of girls is a key issue. Improving nutrition requires both increased local production and improved economic standing, permitting imports from global markets.

There is need to improve agriculture to help both producers and the broader population. Increased production would benefit national economies and so the economic ability to import food. Improving food security requires stimulating economic growth in all sectors. Most crops in Africa are rain fed and so food availability follows a seasonal pattern with high availability immediately post

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5 Who feeds the world? Misereof, IHR hilfswerk

6 FAO (2003) Indicators of food and nutritional security in Africa.

7 Palmer P (2013) Hungry for Change p22-23 in The Bible in transmission; Food Matters

harvest and high prices and food poverty just before the next harvest. Economic development will require that developed countries, like our own, increase our economic engagement and import more, including foods. The fragility of African soils requires that this is done responsibly, avoiding poor environmental care. The easiest approach to this is through the encouragement and development of current social systems based on small farming; those which are marginalised by current systems[8]. In Africa, as in South America, small producers are impacted by international companies deforesting land so as to produce soya, sugar and biofuels. Access to clean water is critical as is access to local crop varieties. Worldwide 70% of the global seed market is in the hands of just 10 companies. Local community interests and international shareholder demands are seldom compatible.

d) Global Climate Change

Global Climate change (GCC) raises questions about the environmental impact of food production. There is consensus that GCC is driven by increasing atmospheric concentrations of Carbon Dioxide (CO2), Methane (CH4) and Nitrous Oxide (N2O), all direct or indirect products of our use of fossil fuels[9]. (Table 2)

Table 2 The principal green house gases.[10]

CO2	Principally from the burning of Fossil Fuels (emission of 6Gt per year), from imbalances of net photosynthesis and plant/animal respiration (usually the fixation of 1.3Gt), the destruction of forests (emission of 1.6Gt per year) and fixation in the oceans (usually the fixation of 2.0Gt per year)
CH4	Produced by microorganisms in natural wetlands, paddy rice and ruminant animals. 25 times the impact of CO2
N2O	Produced by micro-organisms in the soil from natural sources and nitrogen fertilisers 296 times the impact of CO2

All industrial processes release green house gases (GHG's). The make up of the gases released by industry in general, is CO2 86%, CH4 7%, N2O 6%. In food production the profile is the more damaging CO2 11%, CH4 36%, N2O 53%. This difference is largely due to primary production with the on farm component responsible for 67% of this. For most of us our food footprint is around 20% of a western carbon footprint. The UK's annual C footprint due to food is around 170 million tonnes, similar to the impact of our use of fuels and electricity generation.

8 Palmer P (2013)hungry for Change p22 in The Bible in transmission; Food Matters

9 Tinker PB (1993) climate change and its implications pp3-12 in global Climate Change Ed D Atkinson, BCPC, Farnham, Surrey.

10 Newman EI (2000) Applied Ecology and environmental management, Blackwell, Oxford.

The carbon footprint associated with different foods and other activities are shown in Table 3. This allows us to put the carbon footprint of many of the foods we eat into a wider context.

Table 3 Carbon Footprints of Food and Related items. [11]

Primary Food	CO2 Footprint	Processed food or Non Food	CO2 Footprint
Apple	550g/kg	Porridge	82g/bowl (300g/bowl if made with milk)
Banana	480g/kg	Burger	22kg/kg
Strawberry	600g/kg (7.2kg/kg if by air)	Bottled water	160g/l
Asparagus	500g/kg (3.5kg/kg if by air)	Boiled Potato	620g/kg
Tomato	400g/kg (9.1 g/kg average of all)	Train Travel	0.15kg/mile
Rice	4kg/kg (6.1 if N fertiliser used)	Car travel in a small efficient car	344g/mile
Milk	1.3kg/l	An average Christmas	280kg/person
Cheese	12kg/kg	1 tonne of Fertiliser	2.7-12.3 tonnes/tonne depending on efficiency of use
Beef	17kg/kg	Deforestation	500tonnes/ha
Lamb	19kg/kg	Volcano	42million tonnes when active

While crop production has the smallest Carbon footprint within agriculture it is modified by how and where the production occurs. The carbon footprint of crops

[11] Berners-Lee M (2010) How bad are bananas: The carbon footprint of everything. Profile Books London

is influenced by the use of fertilisers; their addition to a single ha of land adds around 2 tones of CO2 to the footprint. Similarly processing adds significant costs. One of the common foods of our era, the burger, has a substantial footprint.

3. Contentious Issues

a) Approaches to Food Production

Because people in different parts of the world eat different foods and different amounts of food per capita then the answers to the questions which farming system feeds the most people and which farming system produces the most food can be rather different[12]. There is a reasonable measure of agreement that small farms, principally based in the developing world, are responsible for feeding between 60 and 70% of the world's current population[13]. These farms base their farming methods on recycling and the use of natural resources and so operate like western organic enterprises. As the food they produce is not traded it is not branded as organic. With improved access to nitrogen, whether as fertiliser or from animal manures or legume fixed nitrogen, such production could be increased.

However estimates that synthetic nitrogen fertiliser supplies 40% of the nitrogen used by crops globally suggests intensive agriculture produces a much greater % of the worlds total food resources than the proportion of people fed would suggest. The use of fertiliser nitrogen is a key element in foods carbon footprint. The Haber-Bosch chemical process used to convert Nitrogen from the atmosphere into nitrate or ammonium N fertilisers, is energy demanding. It has been suggested that the correct use of natural N fixers could, on a world wide basis, provide as much N as is currently produced chemically, but with out the GHG penalty. The technological solutions being developed by the big farm sector aim at sustaining the current business model through producing more with less; the GM Grail of nitrogen fixing perennial wheat is a vision of that model. The alternative vision foresees production linked to what can be sustained through biological cycles.[14]

Current world food production could supply us with enough macronutrients e.g. energy and protein to feed around 14 billion people.[15] We monopolise around 40% of the global land surface, including 25% for the production of food. We

[12] World Watch (2006) in World Watch Magazine19,3
[13] ETC Group (2009) Who will feed us?
[14] IAASTD quoted by Tudge
[15] Heren H Millennium institute Washington Quoted by Tudge

have replaced a third of tropical forest and a quarter of natural grassland.[16] In addition agriculture is responsible for 85% of human water consumption. Asking a simple question like, 'From where does the world's current food supply come?' gets us into controversy. There are no straight factual answers to questions with a substantial policy or political element. Debates about the merits of different ways of producing food have become bitter with the two major standpoints organic or intensive constantly attempting to undermine the claims of the other. Essentially the virtues of the different approaches are different (Table 4.) Consequently they cannot be compared on the basis of simple criteria.

Table 4 Different approaches to food production are associated with different core values which affect the outcome [17]

Intensive Arable	**Organic Rotation**
Maximised yields the primary driving objective. Amount of land per unit production minimised	Optimised Yields; the highest obtainable subject to meeting other core objectives.
Management and labour Costs Minimised through external resource use such as agrochemical use.	Centred on working with biological cycles
High externalities[18] by design. The costs of losses of fertiliser to ground water and unemployment costs of displaced staff funded by others	Product health, including effects on biodiversity and people involvement e.g. labour costs, core objectives
Biodiversity protected but within limits and commonly restricted to headland and refuge areas. Production per unit area may reduce the amount of land needed for food production.	Biodiversity enhancement a design criterion

16 World Resource Institute (2000) Domesticating the world: Conversion of natural ecosystems. earthtrends.wri.org/features/view_feature.php?theme=8&fid=34

17 Modified from Atkinson D and Watson CA (2000) The research needs of organic agriculture: Distinct or just the same as other agricultural research. Proceedings BCPC Conference pest and diseases 151-159.

18 Externality. Originally a term in economics to indicate terms which sat outwith the analysis. It includes costs which are real but which are not borne by the producer such as the impact of GHG's, the costs of removing nitrates from drinking water . It can also include the costs associated with the destabilization of communities or the need for the state to pay benefits to those on low wages.

In temperate agriculture, especially where shortfalls in nutrient supply and water availability are remedied by the use of fertilisers and irrigation, intensive methods normally lead to higher yields. In tropical and hot arid climates the maintenance of soil structure is critical to water supply and thus to crop production. Here organic methods, especially those employed on small farms, lead to increased yields compared to westernised methods. In the west it seems that organic yields are not uncommonly 10-20% lower than those from intensive chemically driven systems. In contrast in developing countries, especially where farming is occurring on fragile soils, yields on organic farms can be close to double those from chemical cultivation especially where water supply to the crop is an issue. Such systems tend to be more resilient economically reducing the risk of debt and so providing better results in bad crop years. In addition in such situations several crops may be grown in a single season either in sequence or simultaneously.

b) Small Farmers and Communities.

With help to improve transport infrastructure, finance for investment and market structures small scale farming in developing countries could increase the production of food by 25-35%. This food would be in the right place to have a real impact on the food poor.

Emphasis on producing a commodity is on maximising efficiency; usually measured in production per worker, per time unit, per area of land or per unit cost. Such an approach can regard other things as externalities. Much modern business aims to maximise the proportion of costs, which are externalised. An increasing number of international bodies are now recognising the importance of moving agriculture away from mere technologies and to methods centred on social and environmental considerations. Mono cropping, a major element in intensive systems reduces biodiversity and can eradicate local species and varieties.[19] Modern varieties are bred to function with inputs such as fertilisers. Alternative systems enhance the role of small-scale farmers and practices such as crop rotations and organic manures. Recently UN agencies have argued that in developing countries organic agriculture can increase productivity and raise incomes using low cost local technologies, which mimic natural processes and so have a minimal environmental impact. A change in the predominant model for production needs to be accompanied by initiatives to create access to markets providing fair returns to producers. These issues are also important to Scottish Farming.

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[19] International Assessment of Agricultural Knowledge Science and Technology for Development (IAASTDI) (2009) Agriculture at the crossroads. Agassessment.org/report/IAASTDI/EN/Agriculture%20at%20a%20crossroads synthesis%report%20

c) Biotechnology

Biotechnology is commonly advocated as the painless way of solving many of our food problems. Biotechnology and its contribution to food production is more wide ranging than just genetically modified (GM) crops although often discussions become reduced to just this. This is unfortunate because some producers have rejected all biotechnologies on the basis of the impact of the first generation of transgenic crops. The topicality of the subject; the UK is currently attempting to get EU rules changed so that GM crops can be grown in UK, suggests the need to look at the potential environmental impact of the currently available GM crops.

GM Crops have been around for 20 years; the first products reached the market, initially in the USA and then in UK.[20] The debate has covered issues related to:

- the safety of GM derived foods; the general consensus is that they are within the normal use of the term, safe,
- their impact upon the environment; the consensus is that they, and associated cultural methods, can have a negative impact on biodiversity.
- effects on the structure and ownership of farming, essentially who farms and how; the consensus is that it will result in more power and influence flowing to multinational companies such as Monsanto, Bayer and BASF.
- Whether claimed benefits are achievable, e.g. Will their be a reduction in vitamin A related eye disorders in parts of the developing world through the consumption of golden rice, which contains vitamin A precursors. Will such rice be affordable by potential target communities?

Key issues in the debate are who controls, the concentration of power and the social and environmental impacts. It is here that Churches and eco-congregation can contribute by asking biblical 'Wisdom' [21] related questions based on a reasoned search for ways to ensure wellbeing and to transmit hard earned knowledge to subsequent generations.[22] In addition whether the food produced by the system has embedded values[23] compatible with scripture is important.

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[20] Bruce D and Bruce A (eds) (1998) Engineering Genesis, Earthscan, London.

[21] Wisdom The Wisdom literature within our scriptures advises us on appropriate things to do and approaches to life. The principles contained here can be applied to new technologies as a way of helping us to decide which of the things we could do we should actually go ahead with.

[22] Crenshaw JL (1998) What is Wisdom? Pp3-9 in Old Testament Wisdom, Westminster John Knox Press, Louisville, Kentucky, USA

[23] Embedded Values. All food which have features which can be measured such as their physical, chemical and microbiological properties. These provide the basis of current food standards. Foods also have a series of embedded properties which relate to how they

Discussion of any new technology must examine present production and the full range of options for meeting future needs. The current and possible future yields obtainable for a food crop, such as wheat (Table 5), provide an approach to considering issues and options.

Table 5 The yield of wheat produced in various systems

Production system	Yield usually attained
Theoretical maximum yields based on basic physical laws and maximum sunlight energy capture	Around 26 tonnes/ha
Small plot yields and target for new Rothamsted breeding programme [24]	20 tonnes/ha
Record commercial yields	15.7 tonnes/ha in New Zealand 14.3 in UK
UK average yields	8 tonnes/ ha. Average for all cereals 7.0 tonnes/ha
Organic yields in UK	5-6 tonnes /ha
Lower quartile and bad year yields in UK	3-4 tonnes/ha
EU average yields[25]	5-6 tonnes/ha

The current situation suggests:

- First, in the UK there is great variation in the yields achievable with a similar genetic base. Genetics is not the sole determinant of yield and production.
- Second, the gap between the yields of poorly performing farms and those producing record yields is similar to that between those producing record yields and theoretical maximum. Approaching the latter requires radical new technology. Applying the practices currently in use on good farms might help the former.
- Third, increasing the average yields of world agriculture and of our less productive farms could increase total food production on the current land

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have been produced i.e. have they been produced in ways which respect the environment, provide a fair recompense to the producer, have been fairly traded and have respected animal welfare standards. Such properties are rarely measurable but are important in respect of environmental footprint.

[24] Jones D (2013) Could wheat be made more like maize? Farmers weekly July 2013

[25] Indexmundi.com/agriculture

area.

- Fourth, there is scope to increase the yields of organic production systems, which produce much of the world's food through a better understanding of limiting factors such as sub-optimal nitrogen supply.
- Fifth, none of this makes allowance for the impact of reducing waste in all systems of production, which can be 50% within the system.[26]

Research to explore all of these potential routes seems wise, but within a balanced research portfolio. Biotechnology could reduce the environmental footprint of western crop production. However economic and power relationships affect land use and communities, especially in the developing world. There is concern that the current patenting of genes related to water use and drought resistance by large international companies[27] could lead to small producers in developing countries being blocked from using such methods. Dependence on the products of international companies has in the past resulted in financial pressures, which have led to poor care of the land, and changes, which have destabilised communities whose investment in the land had resulted in good management.

4) Some helpful science

Food production and processing have a basis in science. A lack of familiarity with the science underpinning production commonly results in people being excluded from the debate. Here we briefly summarise three key areas at the heart of the issues of Section 3.

a) Organic production depends on the recycling of mineral nutrients and on the use of soil microorganisms to provide nutrients for crop growth. However a significant proportion of the nutrients absorbed by crops, even in systems receiving fertilisers are made available by the actions of soil microorganisms.
In organic systems using microorganisms is an alternative to using synthetic fertilisers as the primary source of mineral nutrients. Basing nutrient supply on the activities of living organisms however links nutrient availability to climatic variability. This accounts for much of the yield gaps between intensive and organic systems in both temperate and tropical climates. Relationships between plants and microorganisms have evolved over long periods of geological time; plants and arbuscular mycorrhizas have been associated for 500 million years. Organisms of this type are at the heart of the working of natural plant communities and organic and

[26] Institute of Mechanical Engineers (2013) Global Food: waste not want not.

[27] ETC Group (2008) Patenting the climate genes. Communique99, 1-30, www.etcgroup.org/upload/publication/687/03/etcgroupclimategenesfinal05_08.pdf

biodynamic production systems.[28]
The principle soil organisms involved are:
1. Soil bacteria. Bacteria play a major role in the transformation of plant residues into useable nutrient sources. They release nutrients from organic matter and transform nutrients into forms more easily useable by plants. Some free-living soil bacteria fix nitrogen. The symbiotic relationship between the Rhizobium bacteria in the nodules of leguminous plants and the plant is critical to providing nitrogen for organic systems.
2. Mycorrhizal Fungi. Arbuscular Mycorrhizas are a symbiotic relationship between plant and a fungus where the fungus forms internal structures to facilitate nutrient transfers. The fungus assumes responsibility for much nutrient uptake. It modifies the plant growth, provides some control of fungal diseases and warns the plant of impending droughts or insect attacks.

b) GM crops are created by the use of transgenic technologies, which are claimed to be more effective and quicker than conventional plant breeding. Table 6 compares these two approaches to plant improvement. For almost 10,000 years humankind has been attempting to improve the domesticated species used for food production through the selection of superior genotypes and by the selective crossing of varieties within the same species so as to produce hybrids with improved characteristics. While the effectiveness of methods has improved with better knowledge of the genetic make up of species conventional breeding methods are limited to genes within a single plant genera. Biotechnological approaches, which have been in use for around 30 years seek to increase the range of genes, which can be imported into a species.

Table 6 Plant breeding and related approaches

Attribute	Traditional plant breeding	Biotechnology
History	Has been in use for around 9,000 years	Product of 1980s recombinant technology with first varieties released in 1990s

[28] Balfour EB (1943) The Living Soil, Universe Books, NY

How it works	Based on cross pollination of domesticated plants with the wild varieties to introduce new desirable features. Improved knowledge of plant genomes has improved success and allows marker-assisted breeding. Makes use of natural and induced mutations and changes to the number of chromosomes.	Organisms containing a desirable gene are identified. Genes from any organism can be used. The gene is isolated and incorporated into a recombinant sequence, which includes a marker gene and a promoter. This sequence is inserted into a plant cell. Cells with the new gene are isolated and multiplied.
Achievements	All current varieties of most of our crops have been produced with this technology	Most current commercial GM varieties have been modified to be resistant to herbicides or to a small number of insect pests
Limitations	Restricted to genes which are already present in the genera or in very closely related species	The position of insertion of the new gene can be random and may impact on other genes.
Speed of delivery	Small changes can be introduced in a few years but more significant changes can take much longer	Ought to be faster than conventional breeding but assessing for deleterious effects relating to the random nature of the insertion of the new gene and the need for extensive field-testing limits this advantage.

An aim of genetic engineering has long been a cereal plant which can fix nitrogen. However, rather few plants have a relationship with soil bacteria allowing the fixation of atmospheric Nitrogen. The wisdom question is if the ability to fix N is so important why have so few plants followed this path? Leguminous plants are a minor component of most vegetation types In plants, which can fix nitrogen a large amount of photosynthate, around 40%, is used to power fixation. N fixing plants still need leaves, stems and roots and so the energy for N fixation can only come at the expense of grain unless the leaves are able to fix much more carbon.

c) Biodiversity and why it matters are key issues in the food debate. We share God's planet with a range of other organisms. Many of them have been here much longer than we have. They are vital to the functioning of the processes, which control natural cycles such as those related to the composition of the atmosphere and our supply of clean water. They have value in them selves as something in whose creation God was involved and which God loves and sustains.
Biodiversity is used to describe three different types of variation; genetic variation within single species, the number of individual species in a defined area and the diversity which exists within an area as small as a habitat or as large as a country. Biodiversity can thus refer both to genes or the individual organisms, which we classify as species.