Agro-Ecological
Investment Management

CLIMATE CHANGE AND INVESTMENT IN ECOLOGICAL AGRICULTURE: OUTPERFORMANCE AND OPPORTUNITY

AN ASSET MANAGEMENT UNDERSTANDING



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EXECUTIVE SUMMARY

- Climate change is the largest and most dangerous threat facing human civilisation.

- Agriculture is directly responsible for 13.5% of global greenhouse gas emissions, but based on a lifecycle approach it is responsible for between 25-30% of emissions.

- Ecological/organic agriculture is focussed on the sound stewardship of agricultural soil, protection of the environment and social responsibility. Addressing climate change is therefore implicit within its approach.

- Ecological/organic agriculture can mitigate and adapt to climate change in a multitude of ways; among these, the elimination of synthetic nitrogen fertilisers, creating healthy soils with high organic matter (soil carbon) levels, and pasture based livestock systems are the three principal methods by which superior outcomes are generated.

- These benefits manifest themselves not only in greenhouse gas (GHG) terms but in reduced input costs, more consistent and sustainable production (yield) and potentially superior income flows from environmental markets such as carbon and biodiversity.

INTRODUCTION

In 2004 the UK government's chief scientific advisor Sir David King said that "Climate change is the most severe problem we are facing today" [3]. Since that time the message from the scientific community has become increasingly consistent, urgent and clear; the situation is worse the more that is understood about climate change [8].

It took Professor Lord Nicholas Stern's review on the economics of climate change to forcefully point out that the economic and financial systems are utterly dependent on, not separate from, the natural world (including the climate system), and that addressing climate change was not a luxury, but essential, if humanity was to maintain current levels of prosperity and that failure to act could result in severe economic hardship or worse [37].

Agriculture has a critical role to play in addressing climate change as it is directly and indirectly responsible for a significant proportion of global warming and it will also suffer from its effects [11].

Humankind's response to climate change is divided into two broad categories: mitigation and adaptation [8]. Mitigation is taking action to reduce the amount of global warming, while adaptation involves modifying our activities so that they can continue, under a changing climate. Agriculture will therefore have to undertake mitigation practices while simultaneously adapting to a changing climate. The difficulty of achieving this should not be underestimated, especially, if we are to maintain the level, consistency and diversity of food and fibre supply that we have become accustomed to.

Organic/ecological agriculture has a considerable range of both mitigation and adaptation strategies in-built. In addition, its core approach is to protect and enhance natural systems, so it is fundamentally attuned to making the required changes to further reduce its impact on the climate and the rest of the natural world.

It is also important to appreciate that the only way to understand climate change and the required mitigation and adaptation strategies is to use a systems/holistic approach. The planet's natural systems (see below) are not isolated compartments, they are all actively interlinked. A reductionist approach (the opposite of systems theory and holism), where only one part of a system is considered in isolation, is in large part responsible for climate change and the general ecological damage humanity is causing.

An example of a reductionist approach is the concept of 'food miles'. It is only concerned with the fossil fuel consumed transporting food from the farm to the shop, yet transportation is often a small fraction of the total fossil energy consumed in the complete production and consumption of a food product. There are many examples of food produced close to the point of sale that has low food miles but has a much greater total fossil energy consumption than the same food produced in a second more distant location with higher food miles but much less total energy across its entire lifecycle [30].

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Focusing on fossil energy consumption is also reductionist because burning fossil fuel is not the only way food production can influence global warming. Mitigation and adaptation measures must therefore be very well thought through to ensure that they are not making the situation worse rather than better due to unconsidered 'side-effects'. The gold-standard method for ensuring that everything is taken into account is life cycle assessment (LCA) [14] also known as 'cradle-to-grave analysis'. The results from less thorough methods should be treated with high levels of caution.

To understand how and why organic agriculture is part of the climate change solution it is necessary to understand how agriculture as a whole interacts with the planet's natural systems and why industrial agriculture is both unsustainable and exacerbating the problem of global climate change.

SOIL - THE 'HEART' OF THE PLANET

There is a widely used aphorism among soil scientists "never treat soils like dirt", which is in part a lament, that for many if not most people, soil is both a mystery and something of little or no value. This is exceptionally worrying because soil is probably the most valuable asset humanity controls, as our entire civilisation is dependent on it.

Soil is often likened to the skin of the planet, but this does soil a serious injustice as it has a far more important and extensive role than skin does for a person. The soil is right at the centre, the 'heart', of the planet's natural systems. These systems are categorised into different 'spheres' and include the atmosphere, the hydrosphere (water bodies including rivers and other land based waters as well as the oceans and seas) the geosphere (the rocky interior of the planet), the biosphere (all living things) and the pedosphere (the soil). Matter, i.e. the chemical elements, constantly cycle through these different spheres, for example carbon, which is at the centre of global warming, constantly flows between the atmosphere, the biosphere and the soil (pedosphere) through the world's two most important physiochemical reactions; photosynthesis and respiration (Figure 1).

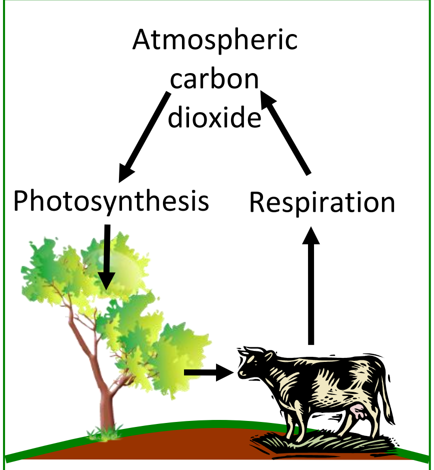

Figure 1. Part of the carbon cycle, where atmospheric CO_2 is converted to carbohydrates by photosynthesis in plants, which are then eaten by animals which convert the carbohydrates back into CO_2 via respiration.

Soil is the 'heart' of the planet because it is the soil that is the interface for all the other cycles. Soil is the main environment for the land biosphere, i.e. as a rule of thumb, soil contains ten times more life, (measured by weight or diversity), than all of the life growing above it. It is also literally and metaphorically the root of all above-ground life as soil is half of the medium in which plants grow, the other half being the atmosphere. Plants are the bridge that links the soil and sky. Soil is also the interface between the atmosphere and the geosphere and the filter through which the hydrosphere flows. It is therefore impossible to overstate the importance of soil as it is the meeting place of all the planetary spheres, and matter cycles.

Soil is the foundation of human civilisation, as it was the activity of soil management, as part of agriculture, that allowed early humans to move away from hunting and gathering to form the first societies, and without productive soil civilisation would simply perish [5][12][20]. Therefore considering the absolute importance of soil to humanity's continued survival and its critical role in the planetary cycles, including climate management, the treatment soil has received in an agricultural context over the last 50 years, can be described as wholly negligent, measurably damaging and potentially catastrophic. Indeed after climate change, the damage done to the world's soils is probably the next most important threat to maintaining society's current levels of prosperity [5]. The protection of soil is the issue upon which organic agriculture was founded and it continues to be a fundamental aspect of its management practice and a key factor in its productive out-performance.

The message is simple: soil is at the heart of planetary systems and its correct management is vital in combating climate change as well as a wide range of other ecological damage. The fundamental objective of organic agriculture is optimal soil management; for industrial agriculture soil is just another resource. It is conspicuously clear that it is ecological/organic management that has the capability and praxis to maintain productive agriculture over an indefinite time scale. The alternative 'consumes' soil, eroding the very basis of its existence, meaning its time is limited, particularly in the face of global climate change.

INDUSTRIAL AGRICULTURE AND CLIMATE CHANGE

Industrial agriculture is the technical name given to the dominant farming system in the developed world because it mimics industrial manufacturing systems. This is also the fundamental fallacy of industrial agriculture in that agriculture is based almost entirely on natural systems (i.e., the pedosphere, hydrosphere etc.) which behave completely differently to the linear mechanical and physical processes underlying industrial manufacturing. There is now growing consensus across the scientific disciplines that agricultural "business as usual is no longer an option" [24].

> "The discourse around food and agriculture that has dominated the past 60 years needs to be fundamentally re-thought over the next few years. New strategies are needed that respond to the daunting challenges posed by climate change mitigation and adaptation, water scarcity, the decline of petroleum-based energy, biodiversity loss, and persistent food insecurity in growing populations. A narrowly-focused 'seed and fertilizer' revolution will not avert recurrent food crises under these conditions; current models of intensive livestock production will be unaffordable; global and national food supply chains will need to be restructured in light of demographic shifts and increasing fuel costs. Future food production systems will not only depend on, but must contribute positively to, healthy ecosystems and resilient communities. Soils and vegetation in agricultural landscapes must be restored and managed in ways that not only achieve food security targets far more ambitious than those committed to under the Millennium Development Goals, but also provide watershed services and wildlife habitat, and sequester greenhouse gases." [26]

The "narrowly-focused 'seed and fertilizer' revolution" [26] that proponents of industrial agriculture continue to push is not only the wrong answer, it is a key part of the problem. The increases in agricultural production over the last half century are mainly due to the increased use of synthetic nitrogen fertilisers, new crop cultivars ('seeds') that can make better use of the synthetic nitrogen fertilisers and irrigation [24]. The farming system this mixture promotes is monoculture, which is ecologically unstable and therefore requires continual propping up by biocides, i.e. pesticides, insecticides, herbicides and fungicides.

This approach has undoubtedly resulted in considerable increases in crop yields over this time [4]. It is however a classic example of flawed reductionism in that the overwhelming aim has been yield increase regardless of the other effects that using synthetic nitrogen, irrigation and biocides cause, such as:

- the degradation, erosion and loss of soil,
- lower nutrient contents of crops,
- evolutionary biocide arms races against pests and diseases,
- pollution of waterways,
- farmer indebtedness,
- loss of biodiversity, and
- biocides in food, etc., etc. [24].

The narrow focus on yield from nitrogen and water ignores the consequent negative downstream effects and also fails to consider the long term sustainability of the whole system, i.e. no questions are asked about upstream issues, e.g. where the nitrogen and water come from and how long they can continue to be obtained.

If these are not sufficient reasons to support investment in organic/ecological farming systems over industrial, then further support is provided by industrial agriculture's significant contribution to climate change, a threat to civilisation of such enormity that business (and investment) as usual is absolutely no longer an option.

Agriculture directly contributes 13.5% of the greenhouse gas emissions responsible for global warming and climate change (Figure 2 and Box 1). However, this analysis excludes many of the up and down stream components of agriculture, e.g. the production of synthetic nitrogen fertilizers, and when these are taken into account using lifecycle assessment, agriculture contributes between 25-30% of all GHG emissions [27].

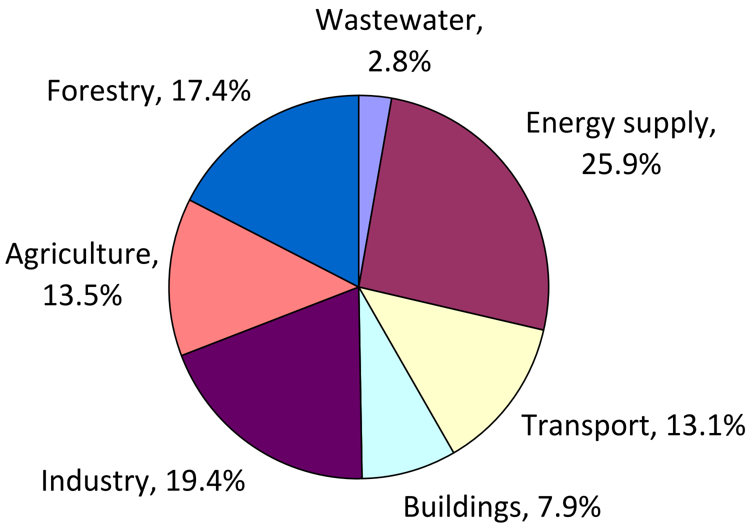

Figure 2. Greenhouse gas emissions (CO_2, CH_4 and N_20 converted to CO_2 equivalents) by sector in 2004 [6].

Box 1. Greenhouse gasses

Greenhouse gases (GHGs) are gases in the atmosphere that absorb and emit radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. The main greenhouse gases in the Earth's atmosphere are water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3) [8].

Carbon dioxide equivalent, (CO_2eq), is an internationally accepted measure that expresses the global warming potential of a GHG in terms of the amount of CO_2 that would have the same global warming potential. Methane has approximately 20 times and nitrous oxide approximately 300 times the greenhouse effect on a unit weight basis compared with CO_2, depending on timescale. [8].

The 13.5% of direct net GHG emissions by agriculture is estimated at between 5.1 and 6.1 gigatonnes (Gt) CO_2eq, in 2005 [6]. This is composed of 3.3 Gt CO_2eq methane, 2.8 Gt CO_2eq nitrous oxide and 0.04 Gt CO_2. The CO_2 figure is small because these are net figures and while there are very large flows of carbon between agriculture and the atmosphere they are mostly cyclical and in balance. However, land clearance for agriculture and soil degradation which do result in substantial CO_2 and other GHG emissions are not counted under agricultural emissions by the International Panel on Climate Change (IPCC) [6][8]. In comparison agriculture is considered to be the main emitter of nitrous oxides and methane, which is additionally problematic as these have approx 300 and 20 times respectively the global warming potential of CO_2 [8] see Box 1.

Nitrous oxide emissions mostly originate from:

- high levels of soluble forms of nitrogen in the soil mostly from synthetic nitrogen fertilisers; and
- animal housing and manure management.

Methane emissions mostly originate from:

- the digestive processes (enteric fermentation) of ruminants (e.g. cows, sheep, goats) (see Box 2);
- anaerobic rice paddies;
- manure management; and
- compaction of soils due to the use of heavy machinery.

The burning of biomass, e.g. from slash-and-burn agriculture, and clearing land for agriculture emits both methane and nitrous oxide [15][27].

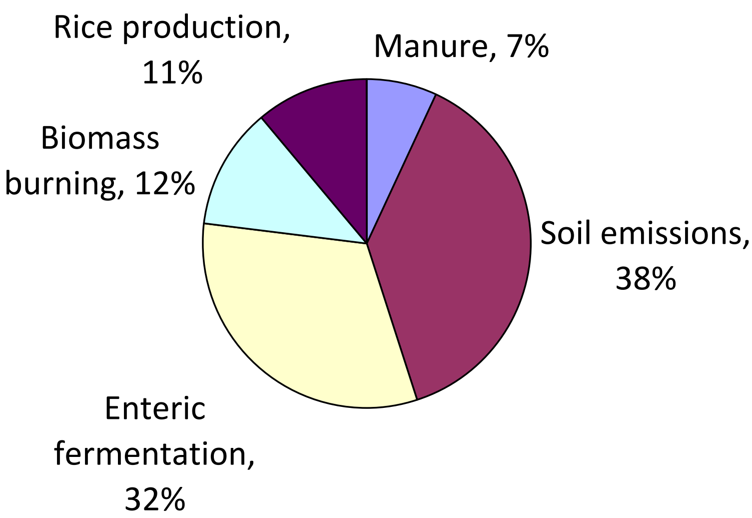

Figure 3. Main agricultural greenhouse gas emissions in 2005 [34].

Box 2. Enteric fermentation

Enteric fermentation is a type of fermentation that takes place in the rumen of Artiodactyla (ruminant) animals such as cows, sheep and goats. The rumen is a specialist, additional stomach that allows ruminants to digest plant materials high in cellulose, by utilising microbes to digest the cellulose for them. One of the by-products of enteric fermentation is methane (CH_4) which has approximately 20 times the greenhouse effect of CO_2 (see Box 1).

While these are the main direct contributions of agriculture to climate change, there are many more indirect and un-accounted for effects. For example the loss of soil organic matter releases carbon from the soil back to the atmosphere. Loss of soil organic matter also degrades soil so it is less productive, with more land required for food production leading to clearing of natural vegetation, which releases more GHGs and/or leads to more nitrogen fertiliser being used, every aspect of which exacerbates global warming. It is fair to say that the prevailing industrial approach to agriculture manifestly contributes to climate change. Ecological/organic agriculture by default has a requirement that it must address climate change and most importantly has many aspects that actively address climate change, and make it a management system better adapted to performing in the face of global climate change.

ORGANIC AGRICULTURE AND CLIMATE CHANGE

Organic agriculture has a much wider set of aims than merely yield maximisation. These aims are based on a broad holistic perspective and understanding. They have been framed by IFOAM (The International Federation of Organic Agricultural Movements) as the four Principles of Organic Agriculture.

Principle of health. Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.

Principle of ecology. Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

Principle of fairness. Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.

Principle of care. Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

[17] See www.ifoam.org for full wording of the Principles.

These principles are the bedrock upon which organic agriculture is based, and cover not just practical agricultural matters but also much wider moral concerns such as inter-generational equity. Therefore, although organic agriculture had been in existence for around half a century before the first inkling that humans may be causing global warming; now that climate change has been recognised, organic agriculture is implicitly required to mitigate and adapt to it.

Not only do the principles mean that organic production is required to address climate change, its eco-literate approach means that many of its practices are already ‘climate friendly’ or at least less harmful than those of industrial agriculture. In the next chapter we consider in some detail, the key contribution of industrial agriculture to climate change and how ecological/organic agriculture differs.

THE HABER-BOSCH PROCESS - HUMANKIND'S MOST SUCCESSFUL FOLLY?

One of the primary climate friendly practices of organic agriculture is its avoidance of synthetic nitrogen fertilisers. It is nitrogen fertilisers that are the primary source of nitrous oxide from agriculture and which are responsible for a little under half of direct agricultural GHG emissions on a CO_2eq basis (see 'Industrial Agriculture and Climate Change' above). This negative impact is extended and compounded by the production of these fertilisers, which is also a major contributor to global warming.

All synthetic nitrogen fertilisers are manufactured by a technique called the Haber or the Haber-Bosch process, discovered exactly a century ago in 1909 by Fritz Haber. Carl Bosch was responsible for the difficult task of scaling up Haber's laboratory equipment to the commercial scale needed for manufacturing. For this they were awarded Nobel Prizes [32].

The process combines elemental hydrogen with atmospheric unreactive nitrogen gas (di-nitrogen) to create ammonia (NH_3) which is the 'primary' reactive nitrogen (Nr) compound from which all others are manufactured. The first problem with the Haber-Bosch process is that the chemical combination of di-nitrogen with hydrogen is very difficult to achieve and requires pressures of 150–250 bar and temperatures of 300 to 550 °C in the presence of a catalyst. These high temperatures and pressures require a significant amount of energy and need large industrial production plants. In addition a source of elemental hydrogen is required, which currently is almost exclusively obtained from natural gas (methane/CH_4) which is a fossil fuel obtained from oil wells. Extracting the hydrogen from methane by steam reforming is also an energy intensive process. The result is that approximately 1% of global energy is used (approximately 5% of world natural gas production) in the manufacture of synthetic nitrogen [33]. However, this figure still excludes the energy used for the rest of the product lifecycle such as construction and decommissioning of production plants, transportation and application to farm land. As an example, in the UK, a 100-hectare stockless arable farm consumes on average 17,000 litres of fossil fuel annually through fertilizer inputs, which is many times the amount of fuel directly used on the farm to power tractors and other machinery [9].

Synthetic nitrogen fertilisers are therefore doubly bad for climate change, as both their production and use directly contribute a significant proportion of global warming. Furthermore the range of other damaging environmental and social effects from synthetic nitrogen use are substantial [35][36].

In organic agriculture biological nitrogen fixation is the alternative to synthetic nitrogen. This is achieved chiefly through the use of plants from the plant family Fabaceae (legumes) which have a symbiotic/mutualistic relationship with the rhizobia bacteria that fix atmospheric nitrogen into ammonia, in a chemical parallel to the Haber-Bosch process, but achieving it using only energy from sunlight and hydrogen from water at everyday temperatures and atmospheric pressure. With biological nitrogen fixation the ammonia produced is retained within the plant and used to make proteins and other nitrogen containing compounds. These are not water soluble, unlike nitrogen fertilisers, so there are none of the nitrous oxide losses caused by synthetic nitrogen fertiliser use. When the remains of the legumes are returned to the soil to make the nitrogen available to following crops the nitrogen mostly remains in the insoluble organic, rather than soluble inorganic, forms so is at much lower risk of loss as nitrous oxide, methane, and nitrates and nitrites.

The contrast between the organic approach, using biology to supply nitrogen, and the brute force, energy hungry, Haber-Bosch process, could not be more stark. The multiple ills that 'cheap' reactive nitrogen have created are such that the Haber-Bosch process may be humankind's most successful folly.

Not only does biological nitrogen fixation provide a biologically, and with increasing oil/energy prices, economically efficient supply of nitrogen for agriculture, but also the primary constituent of the organic matter in which the nitrogen is bound is carbon.

To help mitigate and adapt to climate change we need to move carbon from the atmosphere to the soil. Biological nitrogen fixation therefore gives us a double climate dividend in comparison to the negative 'double whammy' of synthetic nitrogen; not only does it supply nitrogen, it is also part of the natural process that pulls CO_2 out of the atmosphere and into the soil, a process which is carried out by those sky-soil bridges, the plants.

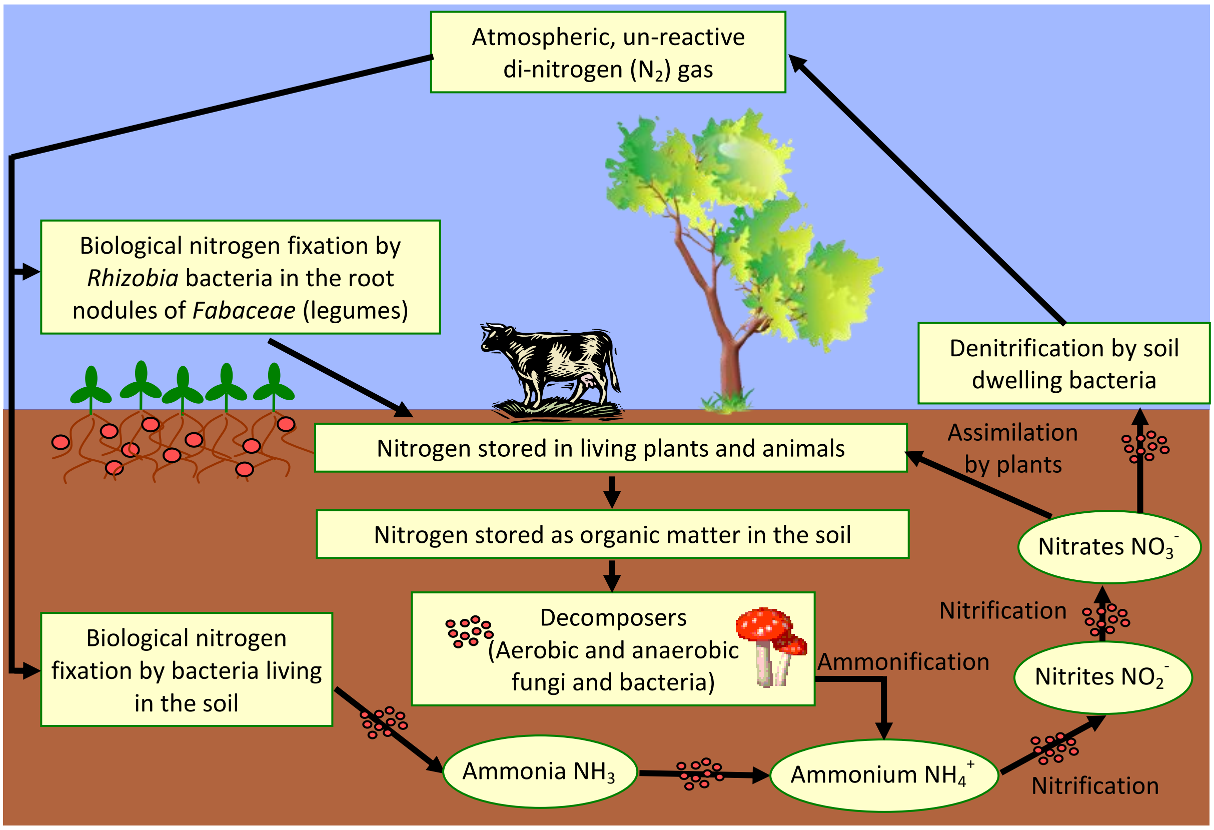

Figure 3. Highly simplified diagram of the nitrogen cycle as utilised by organic agriculture. Unreactive, atmospheric dinitrogen gas (N_2) is converted into reactive nitrogen (Nr) principally by growing leguminous plants, but also by free-living soil bacteria. Nitrogen is assimilated by animals from eating plants. Non-legume plants assimilate nitrate nitrogen released by the decomposition of organic matter in the soil. Nitrogen constantly cycles between living plants, animals and the soil. Nitrogen is lost from the soil due to denitrifying bacteria.

SOIL 'CARBON' / ORGANIC MATTER

The second main climate mitigation factor organic agriculture offers is building 'soil carbon'. The term soil carbon is somewhat misleading, in that carbon, with a few exceptions, does not exist in soil in its elemental form, i.e. as pure carbon such as charcoal. Practically all soil carbon is in the form of organic matter (OM), both living and dead, the latter being the remains of plants and animals (mostly microbes) in various stages of decomposition. Organic matter is what makes a soil a soil - without it, it is just rock dust.

The care, protection and good husbandry of soil, particularly ensuring the soil is high in organic matter, is the core issue upon which the organic movement was founded, see [16]. This is reflected in the names of the founding associations such as the Soil Association in the United Kingdom and Soil & Health in New Zealand all of which pre-date the term organic. This fundamental concern with soil health continues today as reflected in the first Principle of Organic Agriculture (see above).

That organic farming achieves higher levels of organic matter than industrial agriculture is beyond doubt, with many examples, particularly those from long term trials being unequivocal [13][18][22][23][29]. That the comparative level of soil organic matter that organic agriculture achieves is significant is also unambiguous. For example, the Rodale Institute compared organic and conventional cropping systems in the United States and found that organic farming increased soil carbon by 15–28 percent. If the 65 million hectares of corn and soybean grown in the United States were switched to organic farming, a quarter of a billion tons of carbon dioxide could be sequestered [21].

However, the benefits of building soil organic matter do not simply end with carbon sequestration. Higher soil organic matter has a wide range of other beneficial effects, many of which help address global warming. For example, higher humus levels help soils resist compaction and drain better [10] so they are less likely to become anaerobic, and when soils are compacted and/or anaerobic they produce methane [7]. Improved drainage will be important in coping with the increasing intensity of rain due to climate change yet, almost paradoxically, higher organic matter soils also hold more water, so they need less irrigation [6][7][8]. Higher infiltration rates and soil structure also reduce soil erosion which can directly impact climate change [19] as well as the indirect effects resulting from reducing productivity of the eroded soil. Higher organic matter increases the workability of soil so less fuel and smaller machines are required for tillage (cultivation) and less tillage is needed which in turn reduces compaction [7].

These are but a few of the many benefits for climate change as well as wider environmental and agronomic benefits that come from the higher levels of organic matter that organic farming achieves.

LIVESTOCK AND MANURE

Organic agriculture also has a valuable contribution to make to reducing the global warming impacts from livestock and the manure they produce. Organic farming insists on stock, especially ruminants (i.e. cows, goats, sheep etc.), being grazed on pasture.

Industrial agriculture feedlots are the dominant means of cattle and pig production in many developed countries, e.g. the USA. Feedlots involve large numbers, sometimes hundreds of thousands of animals kept in pens and fed a predominantly grain based diet. Feedlot and high grain diet systems for ruminants are particularly damaging from the perspective of climate change for many reasons. Growing the grain crops contributes to global warming due to the fossil energy used during mechanical crop establishment, harvest and transport as well as energy embodied in the nitrogen fertilisers and biocides used [27]. Livestock and grain production regions are often distant from each other, so the climate costs of grain transport can be considerable and disposal of the animal's manure is also difficult as there is no nearby farmland on which to dispose of the manure.

Pastoral systems (stock grazing pasture) are far more energy efficient as the animals walk to the food and harvest it themselves. Further, organic pastures contain clovers and other nitrogen fixing species so no synthetic nitrogen is required and pasture suffers from few pests and diseases compared with grain crops so biocides are not required. As the animals are manuring the fields as they graze the large quantities of slurry manure produced by feedlot systems simply do not exist. What is a problem (and a cost) for the feedlot system is a benefit for the organic one, i.e. the nutrients in the animals dung is recycled back to the soil, helping soil biological activity and building soil organic matter.

Where organic stock are kept indoors for part of the year (e.g. in high latitudes due to cold and/or wet winters) they are required to be bedded on straw or similar material. This provides an energy and carbon source for microbes, allowing them to capture the reactive nitrogen compounds in the animals dung and urine, minimising their loss as the GHGs methane and nitrous oxide. This farm yard manure is treated as a valuable resource in organic systems as it contains plant nutrients in the form of organic matter which helps maintain soil health and soil organic matter (carbon).

The manure produced by feedlots has no high-carbon component and can lose considerable amounts of reactive nitrogen, which is responsible for the bad smell such manures produce. Feedlot manures are therefore mostly considered a waste product to be disposed of in the cheapest means possible, rather than as a valuable resource.

In mixed farming, where stock and crops are rotated (alternated) around the fields (which is strongly encouraged in organic agriculture) the benefits that accrue are even greater. For example a diverse rotation is very effective at mitigating pests, diseases and weeds compared with the monocultures of industrial agriculture, which require biocides to prop them up, and consume significant amounts of fossil fuel throughout their product lifecycle [25]. The pasture phase is very effective at building soil organic matter and nitrogen with all the benefits that entails (as discussed above) as well as creating optimal soil conditions for the following crops, all with minimal fossil fuel use, thereby reducing the farm's global warming impact.

Biological nitrogen fixation, soil organic matter/carbon and livestock production are not however the only means by which organic agriculture achieves a superior climate change profile than industrial agriculture.

THE MULTIFACETED BENEFITS OF ORGANIC AGRICULTURE

The list of advantages that organic agriculture has over industrial agriculture in terms of mitigating and adapting to climate change are many and continuing to expand as scientific frontiers expand. For example, both direct and indirect energy use in organic agriculture is lower than industrial agriculture [31]. Organic approaches such as intercropping, polycultures and agroforestry have been shown to have lower climate change impacts and positive benefits compared with non-organic systems [15][25][27]. In developing nations' agricultural systems, organic production often considerably out-yields industrial agricultural systems while requiring fewer external inputs and achieving superior outcomes for people and the environment [24][25].

Organic agriculture has always encouraged the use of renewable energy and the minimisation of fossil fuel consumption [1]. One example of this is organic farmers using biogas digesters which turn manure and other biological materials, e.g. food processing 'waste' into organic fertiliser and biogas for heating and producing electricity, which simultaneously reduces the production of GHGs from the manure. Organic agriculture prohibits the clearing of land for agricultural production, which is a major source of GHGs, preferring to optimise production on the current agricultural land base and protect the soil already under agricultural management. Organic techniques are also able to restore degraded agricultural land, thus increasing its productivity.

Organic agriculture is more demanding of skills and management on the part of farmers, due to the greater diversity of crops and stock on individual organic farms and the more detailed ecological and biological knowledge required to manage such systems. In industrial agriculture the equivalent knowledge resides with the biochemists in their distant laboratories. Having a much deeper understanding of farm systems means organic farmers are more likely to be able to adapt their farm systems to climate change - something much harder for a monoculture industrial farmer to do.

The increased biodiversity promoted by organic farming [2] also provides a buffer against the changing pest and disease patterns expected as climate change progresses, i.e. organic farming has enhanced resilience against new pests and diseases [27]. In the developed world agriculture often represents only a small component of the total climate change impact of the food system, with packaging, distribution, retailing, waste etc. accounting for the majority [28][29].

Climate change is an ecological and societal problem. The foundations of organic agriculture are focused on ensuring genuine and meaningful sustainability. Organic agriculture offers many and diverse ways of mitigating and adapting to climate change; from the physics and chemistry of sequestering nitrogen and carbon from the sky to the soil, through holistic ecosystem management. Organic agriculture is not 'business as usual' and is the global farmland management system best designed to succeed in the face of the immense challenges, demands and opportunities of a climate change impacted world.

INVESTMENT IMPLICATIONS/CONCLUSIONS

- Ecological agriculture is pre-programmed to generate superior climate change performance as measured by soil organic matter, biodiversity, carbon sequestration, and materially reduced GHG emissions. This also generates significant opportunities for creating additional and attractive income streams from environmental markets.

- Through its avoidance of synthetic nitrogen fertiliser, ecological production dramatically reduces GHG emissions, reduces its exposure to on-going (rising) input costs and enhances the movement of carbon from atmosphere to soil.

- The lack of reliance on cereal based feeding systems for protein production (lamb, beef, dairy etc.) further strengthens the financial robustness and performance of organic production systems in the face of rising commodity/input prices.

- Ecological food production is enormously advantaged over the industrial version as a result of its superior soil management and consequent higher levels of organic matter. This generates not only higher levels of carbon sequestration but far greater levels of resilience in the production system as a whole. This in turn translates into more consistent yield (i.e. the amount of food produced) over time and superior yield in the face of drought and flood, both of which are forecast to be more frequent and severe under a climate change impacted world.

- From an asset management perspective the advantages are clear cut, the performance implications transparent and the knowledge scarce. Of such environments are investment opportunities made.

SUGGESTED FURTHER READING

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