supernatural

Natural Biofertiliser

New AD Ltd, The Re:Centre, University Campus, Richmond Road, Bradford, BD7 1DP, Reg No: 09952309, UNGM No: 450371

Who are supernatural?

Supernatural is the fertiliser brand for the New AD Group of companies, a group focused on the development and support of organic products and their adoption around the world.

Our Company

Supernatural's primary responsibilities are the marketing of organic products such as fertilisers and biomass along with the education surrounding the applications of these products.

The New AD group of companies is a pioneering enterprise based in the UK whose prime directive is to provide innovative and effective global solutions for the anaerobic digestion, waste management and organic agriculture industries.

With the knowledge that comes from our many years of experience in the renewable energy, waste management and agricultural industries, we are able to offer our clients solutions that are both cost efficient and highly effective.

Our Mission

Our mission is simple, to reduce waste being sent to landfill whilst generating renewable energy.

To achieve this mission, we are developing cost effective solutions to support and proliferate what we believe is a highly important technology; anaerobic digestion. Through the use of anaerobic digestion, we can convert organic waste into a number of products including organic fertiliser and biomass with clean renewable energy being generated as a by-product of this process.

Our target is to develop upwards of 25 anaerobic digestion facilities in partnership with global market leaders with a combined fertiliser production capacity in excess of 2,000,000 tonnes per year.

We are utilising our extensive database of contacts for the purpose of procuring sustainable input materials, managing networks for digestate distribution and developing projects.

We operate principally in the UK and throughout the EU. However, to assist the goals of nations around the world to reduce the effects of climate change we are developing business in Southern Asia, the Middle East and Africa.

We travel to the ends of the earth and employ a constantly innovative attitude to ensure our objectives are achieved to the highest standards.

The New AD group of companies was founded, to provide a new business model for a constantly developing industry.

We can create a more sustainable, cleaner and safer world by making wiser energy choices.

Our Values

Our vision, working in tandem with our values, underpins everything we do.

As a business, our vision is to:

- Quickly become the UK's leading broker of feedstock for AD plants and digestate from AD plants.
- Deliver a positive return to our investors based on a sound business model and a clear commercial focus.
- Employ staff of the highest calibre who are committed to the pursuit of the highest possible standards.
- Meet todays environmental challenges with drive and determination and contribute towards a sustainable planet and to the UK's commitments to Europe in the fields of waste management and renewable energy.

Our values are:

Enterprising

We have a unique opportunity to be pioneers in the UK's anaerobic digestion market and to set the standard for converting agricultural crops into clean, renewable energy. We are not scared to defy convention and to push the boundaries of what is possible. We take our responsibilities seriously yet we work with imagination, innovation and accountability at the heart of everything we set out to achieve.

Relentless

Our single-minded focus is the establishment of relationships with our international contacts and domestic customers that will deliver lasting value for our investors, partners, employees and the communities we operate in.

The energy industry has traditionally postponed or abandoned making difficult decisions about the future. New AD however, will energetically pursue high payoff options while remaining mindful of our commitments to delivery, to employing the brightest and the best people and to our stakeholders.

Collaborative

The whole is greater than the sum of its parts. To achieve our immediate and long-term vision, we will form solid partnerships both with external organisations and within the New AD framework. This gives us a comprehensive skill-set to optimise how much we can achieve.

We have the courage of our convictions, but we accept valid opinions, tangential thought processes and active debates because collaborating together with a shared focus is how we will achieve excellence.

Principled

We believe in doing the right thing to benefit the business, our staff and our stakeholders. The Principles are by their very nature subjective, but with honesty, integrity, respect and trustworthiness as our key drivers, we will firmly stand by what we believe in.

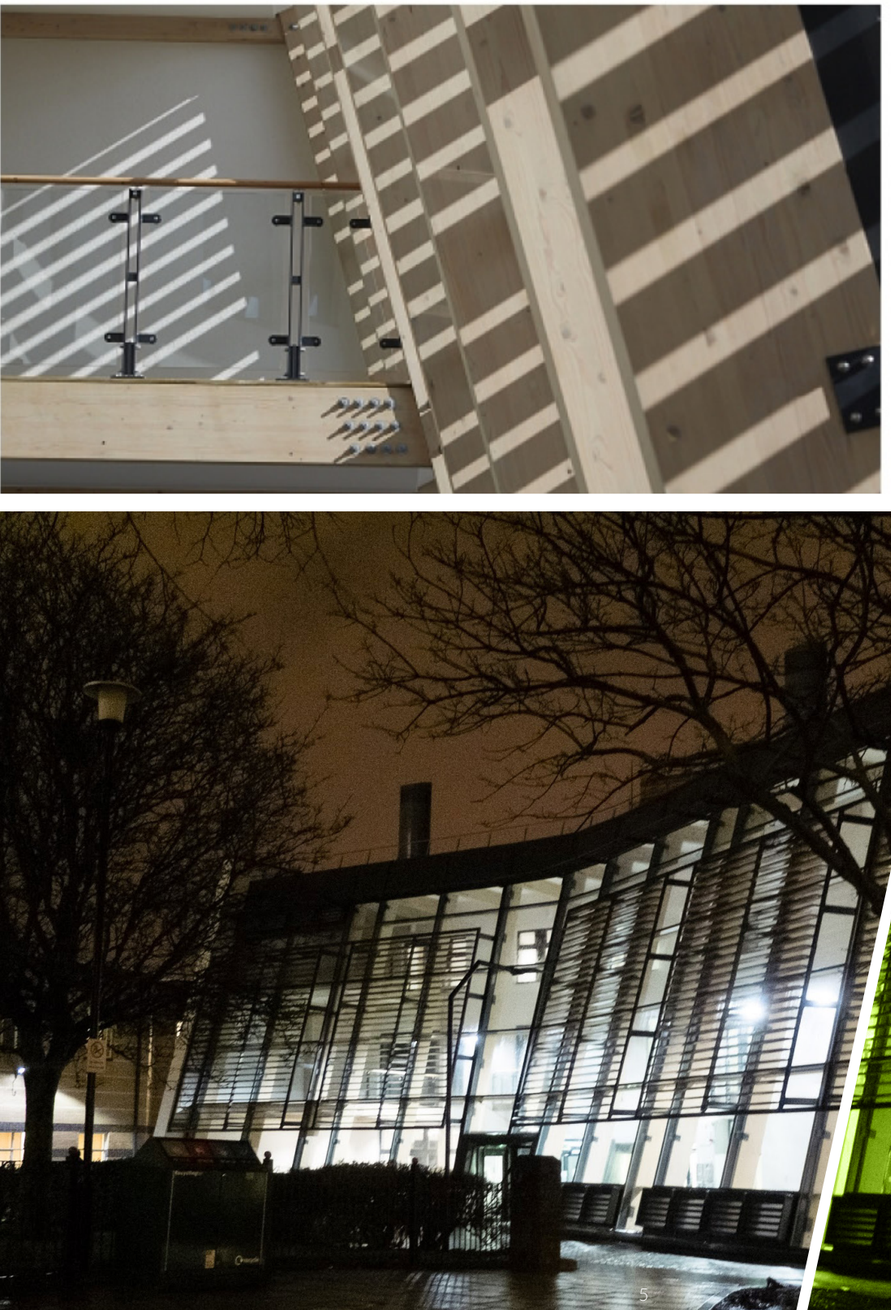
In an industry governed by regulation and reputation, it is imperative to operate within the letter and the spirit of the law, to be inclusive and to deliver on our commitments.

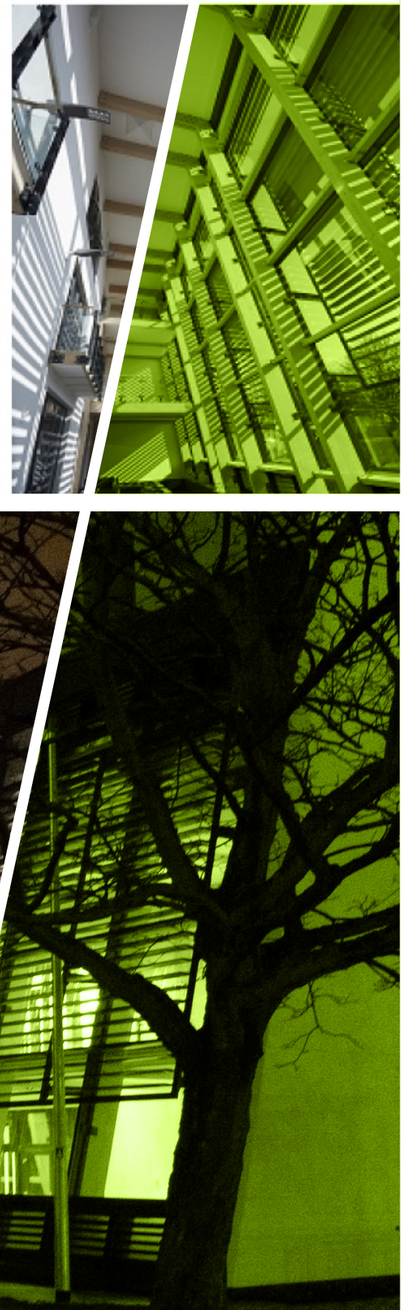
Passionate

From the Directors down, everyone who works at New AD has an innate passion for what we do as well as a passion for making a difference to future generations and for the sustainability of the planet.

We come to work because that passion drives us to succeed. We will put the hours in, take personal responsibility and satisfy clients and stakeholders with work of the highest quality. Whether that is travelling to the Middle East to inspect a potential feedstock or answering a speculative email, every aspect of what we do is done with pride, professionalism and enthusiasm.

Securing The Future For The Next Generation





Our Head Office; The Re:Centre

At New AD we need an office that reflects our ideals of complete sustainability, responsibility, clarity and excellence, this is the Re:Centre located on the campus for the University of Bradford. The building is rated as being in the top 1% in terms of sustainability from all buildings surveyed in world.

The Re:Centre is a coming together, a confluence, of entrepreneurs, academics, environmentalists, students, national businesses, local businesses and stakeholders. Its function is to be a hub, where knowledge and experience – both practical and theoretical – are shared between all users of the centre and their associates. With this alignment of minds and ideas New AD is able to fully utilise the full capabilities of the university to advance in its aim of diverting waste from landfill and producing sustainable products.

Environmental Features

The Re:Centre is an exciting and dynamic space with a unique design which has achieved the highest BREEAM rating - Outstanding. BREEAM is the world's leading design and assessment method for sustainable buildings. This means that the building is in the top 1% in the world for its levels of sutainability and enviromental effectiveness. Environmental features in the Re:Centre include:

Natural ventilation

In the summer, cool air is drawn through the building into the sunspace and up through the chimneystacks. In the winter, naturally warmed air in the core and sunspace will flow throughout the building.

High levels of insulation

State of the art forms of insulation are employed extensively throught the building. This ensures that heat is retained within the building rather than lost to the outside world. In winter this ensures that a comfortable working environment is sustained.

Photovoltaics & air source heat pump

Renewable sources of electricity and heat are captured from the surrounding environment utilising photovalic and geothermal technology.

Build with sustainable materials

With wood sourced from sustainably grown areas, and recycled plastics and metal products found throughout, the construction of this building started sustainable and its operation is still sustainable.

Securing The Future For The Next Generation

New AD Executives

Faisal Rahman
Managing Director

Faisal sees opportunities. This combined with his keen sense of business acumen has led to the development of many different businesses and a wealth of experience from a plethora of industries. Primarily he has operated within the technology sectors, from telecommunications with the likes of BT to most recently in renewable energies with a number of significant companies.

Faisal worked with BT Global on its development and rollout of the £40bn 21st Century Network. As a result he developed not only a variety of contacts in the UK, but also around the world with a particular emphasis on the Middle East. This network generates numerous opportunities and as a consequence he is often approached to consult on a variety of projects.

Bill Elliott
Development Director

Bill has been Chairman or a senior director of companies in the field of waste disposal and renewable energy for over 25 years, including SITA, Envar and Tamar Energy.

He was Development Director of SITA (UK) until 1999 while it grew to be the largest waste management company in the UK and since then has led a number of companies through recovery on their shareholders, mostly Private Equity. He became Executive Chairman of Envar Ltd in 2008 and he led a small development team that concentrated on Anaerobic Digestion, In-Vessel Composting and renewable energy projects. Following a review of its position he moved those projects as well as some new ones into a new company; Tamar Energy Ltd.

David Border
Technical Director

David Border is a microbiologist with 28 years of research, operational and business experience in the UK and USA. He has committed himself to the commercial development of organic waste recycling using composting and anaerobic digestion. David has published many technical articles and reports and is currently preparing a series of eBooks on anaerobic digestion, composting and microalgae.

He set up David Border Consultancy in 1994 as a vehicle to carry out organic waste related consultancies. He has been a frequent lecturer and writer on matters relating to commercial organic waste composting. He regularly attends international conferences on various technologies used to process organic wastes.

Charlie Trousdell
Compliance Director

Charlie's early career was in botanical horticulture firstly as a student at RHS Wisley in the mid 1970s, then at Royal Botanic Gardens Kew, where he took part in plant collecting expeditions. He continued a career in amenity horticulture into the late 1980s then studied for a degree in Environmental Science at the University of Brighton in early 1990s.

He then worked as a consultant setting up composting schemes just before landfill tax came into force so was very much a pioneer in the field. He helped establish TJ Composting in 2000 for which he was MD. Has been an active member of the then Composting Association since 1997 and a director and Chairman of AFOR and is now on Steering Group of the ORG within REA.

Amjad Pervez
Strategy Director

Amjad is a prolific businessman with a vast experience in both domestic and international markets. He is currently the International Strategist for New AD, a Non-Executive Director for the Bradford Teaching Hospitals NHS Trust, a Board Member of Producer city prosperity board, a Founding Partner of Seafresh, a Chair of the Rainbow Trust, a Board Member of Bradford Breakthrough and Chairman of the Jinnah Awards UK.

He has worked with a number of highly successful companies over the past 20 years and has received numerous awards for his work in the business world including Businessman Of The Year 2013 and Business Personality Of The Year 2014.

Gregg Munton
Informatics Director

As a founding member of New AD, Gregg worked with Faisal in the development of the strategy from a technical and analytical point of view. Gregg studied Electrical Engineering at university and has a relentless interest in Alternative and Renewable Energy Technologies, Statistical Analysis, Nanomaterials and Cutting Edge Sciences.

He has worked with Faisal for a number of years on a variety of projects providing an objective scientific and engineering perspective. His incessant desire for precision in everything he does with his keen sense of business strategy has had a significant influence on the progress of New AD.

Eric Timmins
Finance Director

Eric is a qualified accountant with many years of senior management experience within a number of major organisations.

These include as a senior business analyst at ASDA plc where he spent 12 years at their meat, dairy and retail operations. He served as a group commercial accountant for 3 years at William Hill plc. He also operated at Northern Foods plc more than 15 years in a variety of accounting roles including Financial Controller at Fox's Biscuits and Financial Director at Batchelors Foods based in Dublin.

Over the Last 5 years Eric has been engaged in energy management control and reporting on a contultancy basis for a variety of companies.

John Richardson
Investments Director

John is an astute entrepreneur who has the ability to focus, understand and communicate at the highest levels of business. He has been involved in numerous government level projects including design and build contracts for The Mid Yorkshire Hospital Trust and the development of a job centre in Wakefield.

His expertise lies within appraising any project, no matter the scale, with an acute awareness for time sensitive delivery. Undoubted is his ability to drive any project to a successful conclusion. Additionally, he has also operated within a sporting environment, being chairman of a rugby club for more than 20 years. With over 40 years experience in the world of business, John is invaluable in today's rapidly evolving world.

Dr Shahid Ali
Medical Director

Dr Shahid Ali is a medical leader with strategic vision and a passion to improve health services and achieve better health outcomes for patients and populations. He works as a general practitioner and specialist, and has held senior NHS management roles locally, regionally, and as a national clinical leader.

He is co-founder and a Director of Dynamic Health Systems. Currently he is working on several work streams including empowering and enabling patient centred care using technology, integration of services across pathways and intelligence for commissioning. He is Professor of Digital Health in the University of Salford.

Ian Simpson
Sales Director

Ian has more then 45 years experience in the agriculture industry and has been involved in the sales deaprtment of all aspects of the industry. This significant level of experience in his field means there is no aspect of the industry that he is at the very least exceedingly proficient.

For 35 years Ian has worked in the animal feeds industry with a focus on sales and procurement. For 20 years Ian has been with one of the leading suppliers of animal feeds and supplemnents in the UK, NWF Agriculture where he is now the National Sales Director, he has been instrumental in developing sales from 50,000 tonnes a year to more than 550,000 tonnes per year. Prior to becoming involved in the animal feeds industry he worked in the animal slaughter industry as a stock buyer for more than 10 years.

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Company Board Of Directors

Organic Agriculture

Organic agriculture can increase agricultural productivity and can raise incomes with low-cost, locally available and appropriate technologies, without causing environmental damage. Furthermore, evidence shows that organic agriculture can build up natural resources, strengthen communities and improve human capacity, thus improving food security by addressing many different casual factors simultaneously.

Organic and near-organic agricultural methods and technologies are ideally suited for many smallholder farmers globally, as they require minimal or no external inputs, use locally and naturally available materials to produce high-quality products, and encourage a whole systemic approach to farming that is more diverse and resistant to stress.

Improving agricultural sustainability through adoption of organic agriculture may not be a solution to all the food problems, but considerable progress has been made in recent years. Whether organic farming will result in enough food to meet current and future needs can never be totally certain, but it is a step in the right direction. The results observed in the transition to organic agriculture are highly promising for food security globally.

Evidence indicates that productivity in organic agriculture can grow over time. With further support, the benefits to food security and related improvements to natural, social and human capital, could spread to much larger numbers of farmers and rural people in the coming decades.

Environmental Effects

Use of organic fertilisers instead of synthetic fertilisers ensures that the food items produced are free of harmful chemicals. As a result, the end consumers who eat these organic products are less prone to diseases such as cancer, strokes, and skin disorders, as compared to those who consume food items produced using chemical fertilisers.

Organic fertilisers are easily biodegradable and don't cause environmental pollution. On the other hand, chemical fertilizers contaminate both the land & water, which is a major cause of diseases for human beings and is the force behind the extinction of a number of plant, animal, and insect species.

Value For Money

Ironically, many customers think they get more for their money with synthetic fertilisers. It's easy to understand: compare the nitrogen, phosphorus and potassium content of synthetic fertilisers with organic ones and you see huge differences: 19-19-19 vs. 4-4-4, for example.

However, organic fertilisers are significantly less wasteful at delivering nutrients to plants because they exploit the fabulous efficiency of the natural microbial system. Soil has been performing this biological sleight of hand for eons, honing it to perfection.

Visit our website to learn more

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Organic Agriculture

Fertility of Soil

Organic fertilisers ensure that the farms remain fertile for hundreds of years. Land located at the site of ancient civilizations, such as Egypt and China, are still fertile, even though agriculture has been practiced there for thousands of years.

Added Value

A significant number of people around the world now are deciding that the organic lifestyle is how they want to lead their lives. This can be attributed to the reported health and environmental benefits that organic produce brings. This makes produce which is grown according to organic standards a premium product, which commands a significantly higher price than its non-organic counterpart. This ensures farmers and exporters enjoy a competitive advantage, thus resulting in a positive impact on the balance of trade.

Developing Nation Benefits

Organic agriculture can increase agricultural productivity and can raise incomes with low-cost, locally available and appropriate technologies, without causing environmental damage. Furthermore, evidence shows that organic agriculture can build up natural resources, strengthen communities and improve human capacity, thus improving food security by addressing many different casual factors simultaneously.

Organic and near-organic agricultural methods and technologies are ideally suited for many poor, marginalized smallholder farmers in Africa and the Middle East, as they require minimal or no external inputs, use locally and naturally available materials to produce high-quality products, and encourage a whole systemic approach to farming that is more diverse and resistant to stress.

Improving agricultural sustainability through adoption of organic agriculture in Africa and the Middle East may not be a solution to all the food problems, but considerable progress has been made in recent years. Whether organic farming will result in enough food to meet current and future needs can never be totally certain, but it is a step in the right direction. The results observed in the transition to organic agriculture are highly promising for food security in Africa and the Middle East. Evidence indicates that productivity in organic agriculture can grow over time. With further support, the benefits to food security and related improvements to natural, social and human capital, could spread to much larger numbers of farmers and rural people in the coming decades.

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Fertiliser Use: Organic vs Chemical

Nutrient Release:

Chemical: Nutrients are in ready-to-use form and when mixed into the soil, can be immediately absorbed by the roots. Excessive nutrients than necessary caused the roots and plants to burn up.

Organic: Slow and consistent at a sustained natural rate that plants are able to use. No danger of over concentration or over-dosage of nutrients.

Corrects Imbalances:

Chemical: Turns soil into acidic. Direct application of high dosage can burn the roots of the plants due to high salt concentration.

Organic: They help to correct imbalances in the soil pH to make it suitable for plant growth. It does not disturb the balance of the soil as it does not leave behind artificial compound.

Environmental Footprint:

Chemical: Tend to release many chemicals into the soil that contain nutrients helpful to soil but it may also contain elements that are not easily biodegradable. These may go on to contaminate our land and bodies of water.

Organic: Does not build up harmful residues or cause pollution due to run-off from irrigation or rain.

Minerals Content:

Chemical: Lacks organic matter and lessens the activity of microbes in the soil.

Organic: Minerals are typically present in broad range that compliments with the soil, providing more balanced nutrition to plants.

Nutrient Contents:

Chemical: Rich in NPK but long-term application can cause soil dehydration and destruction of plant tissue. Excessive nutrients can bind up other nutrients in the soil, making them unavailable to the plants. The longer chemical fertilisers are applied, the higher the quantity you will require for the succeeding application.

Organic: Rich in organic matter & it can adapt to any application by changing the ingredients blend. Pre-blended formulas or individual nutrient for blending allow flexibility for plant preferences and needs. The longer that organic fertilisers are used, the easier it will be to maintain the level of organic fertilisers for the succeeding application.

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Typical Biofertiliser Analysis

SuperNatural

SuperNatural from New AD offers the most natural source of essential nutrients to promote vigorous plant growth, bountiful yields and brilliant flowering. Completely natural and contains no synthetic ingredients. Used as directed, this all-purpose plant food will not impact or harm ground waters or other sensitive ecosystems. In fact, it will not only build up and enrich the soil but also benefit the plant and soil biosphere.

Derived from agricultural crops, these fertiliser granules are formulated with a broad spectrum of nutrients that slowly release as a plant needs them. The result is a longer lasting green, a stronger and robust shoot and root system, and flowering and fruiting beyond compare.

SuperNatural Ultra - Liquid

pH	Dry Matter	Total Nitrogen	Ammoniacal Nitrogen	Total Phosphorus	Total Potassium	Total Magnesium	Total Sulphur
-	% m/m	% m/m	mg / kg	mg / kg	mg / kg	mg / kg	mg / kg
8.6	4.31	0.46	4212	561	2098	97	291

SuperNatural Sprint - Granular

pH	Dry Matter	Total Nitrogen	Ammoniacal Nitrogen	Total Phosphorus	Total Potassium	Total Magnesium	Total Sulphur
-	% m/m	% m/m	mg / kg	% m/m	% m/m	% m/m	% m/m
10.1	94.7	3.44	43.3	1.27	6.69	0.73	0.53

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Case Study: DC-Agri field experiments for quality digestate and compost in agriculture

Introduction

The Digestate & Compost in Agriculture (DC-Agri) field experiments provide a robust evidence base to support the confident use of digestates & composts by farmers and growers as renewable fertilisers.

The research demonstrates that digestates and composts can increase yields with no negative impacts on crop quality or safety, and that compost can increase soil organic matter more quickly than other organic materials.

Importantly, the results show how farmers can make the most of the nitrogen fertiliser value in food-based digestate, but underline the high economic and environmental cost of applying it when crops do not require nitrogen.

The DC-Agri project was commissioned in 2010 and the core experiments ran across three growing seasons, with supplementary research completed in 2015. The experiments were underpinned by robust scientific methodologies.

There were 22 experimental sites throughout Wales, Scotland and England across the various work packages, with cross-site protocols and standard operating procedures providing quality control and consistency between sites. All treatments were in triplicate, increasing the strength of the data generated.

In 2010, food-based digestate was a little understood, little used, 'novel' material. Now farmers have a range of fertiliser planning tools and guidance at their fingertips. Built on DC-Agri data, these resources enable them to maximise the fertiliser value of more than 1.5 million tonnes of food waste that is processed by the UK's anaerobic digesters every year.

Whilst compost is not new, we now have the scientific evidence base required to enable the materials to be used reliably and with an understanding of the contribution that both green/food and green compost (compost made from feedstocks containing green waste only or a mixture of green and food waste) can make to improving key soil properties; one of our most precious natural resources.

Materials used

The DC-Agri field experiments were undertaken using the following organic materials:

Whole food-based digestate		Livestock slurry		Green compost		Green/food compost		Farmyard manure	
pH	Dry Matter (%)	pH	Dry Matter (%)	pH	Dry Matter (%)	pH	Dry Matter (%)	pH	Dry Matter (%)
8.50	2.16	7.37	4.60	8.26	70	8.50	66	8.16	27

Case Study: DC-Agri field experiments for quality digestate and compost in agriculture

Fertiliser value

Many organic materials contain nitrogen that can be used to grow healthy crops, but how this becomes available to plants is generally less well understood in comparison with bagged fertilisers. Digestate contains more available nitrogen than most organic materials, and this section describes one of the principal focusses of the DC-Agri project, which was to quantify how much of this will become available for crops so that farmers can use it reliably.

This section also describes the results showing how organic materials, including digestate and compost, can increase crop yields as a result of the range of nutrients that they provide.

a) Digestate as a nitrogen fertiliser

Food-based digestate is an effective renewable fertiliser supplying readily available nitrogen. Nitrogen is the single most important nutrient influencing crop yields. It is important to provide farmers with the information necessary to quantify how much crop available nitrogen will be provided by digestate.

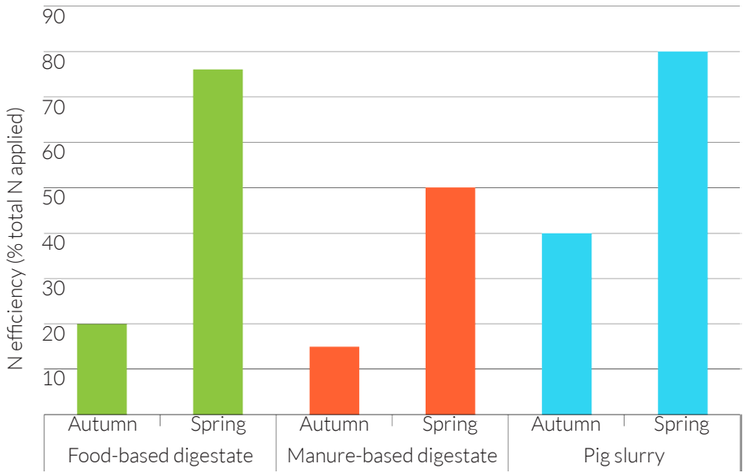
Indicative nutrient contents for food-based digestate

Dry matter content	Nitrogen (N)	Readily available N	Phosphate (as P_2O_5)	Potash (as K_2O)	Magnesium (as MgO)
4%	5 kg/t	4 kg/t	0.5 kg/t	2 kg/t	0.1 kg/t

Just like livestock slurries and manures, when digestate is applied to a field not all of the nitrogen will be taken up by the crop. Some of it may be lost, for example as ammonia gas or as water soluble nitrate. For farmers to be able to use digestate reliably, it is therefore necessary to calculate the nitrogen use efficiency (NUE), i.e. the efficiency with which the nitrogen applied is taken up by the crop after losses are taken into account. It is also necessary to understand how higher NUEs can be achieved.

The average NUE of food-based digestate, applied in spring using a bandspreader, was c. 55% of total nitrogen applied, as measured in replicated field experiments. This was reduced to c. 15% of total nitrogen applied when food-based digestate was bandspread in the autumn, highlighting the effect of nitrogen losses via overwinter nitrate leaching. Livestock slurry-based digestate applied in spring had a mean NUE of c. 50% which decreased to c. 15% of total nitrogen applied for autumn applications.

For both materials, there was considerable variation between the NUE results obtained from the individual experimental sites; this was understandable given the complexity and interactions of the processes involved and is also the case for other organic material applications (e.g. livestock slurries).



Nitrogen use efficiency at the Wensum site growing winter wheat. This is an example of the low nitrogen use efficiency of autumn bandspread applications in comparison with spring applications. This result was seen consistently across the other sites.

There was good agreement between NUE estimates made using MANNER-NPK, the freely available fertiliser planning tool, and the field measurements. This indicates that MANNER-NPK can provide good estimates for farmers and advisors who want to account for the nitrogen content of digestates when developing fertiliser strategies. However, there is scope for the MANNER-NPK estimates to be further improved by incorporating information on environmental nitrogen losses from digestate into the algorithms for MANNER-NPK. The experiments also showed that repeat compost applications significantly increased the levels of soil nitrogen that can be supplied to crops.

Case Study: DC-Agri field experiments for quality digestate and compost in agriculture

b) Nutrient boost from organic materials

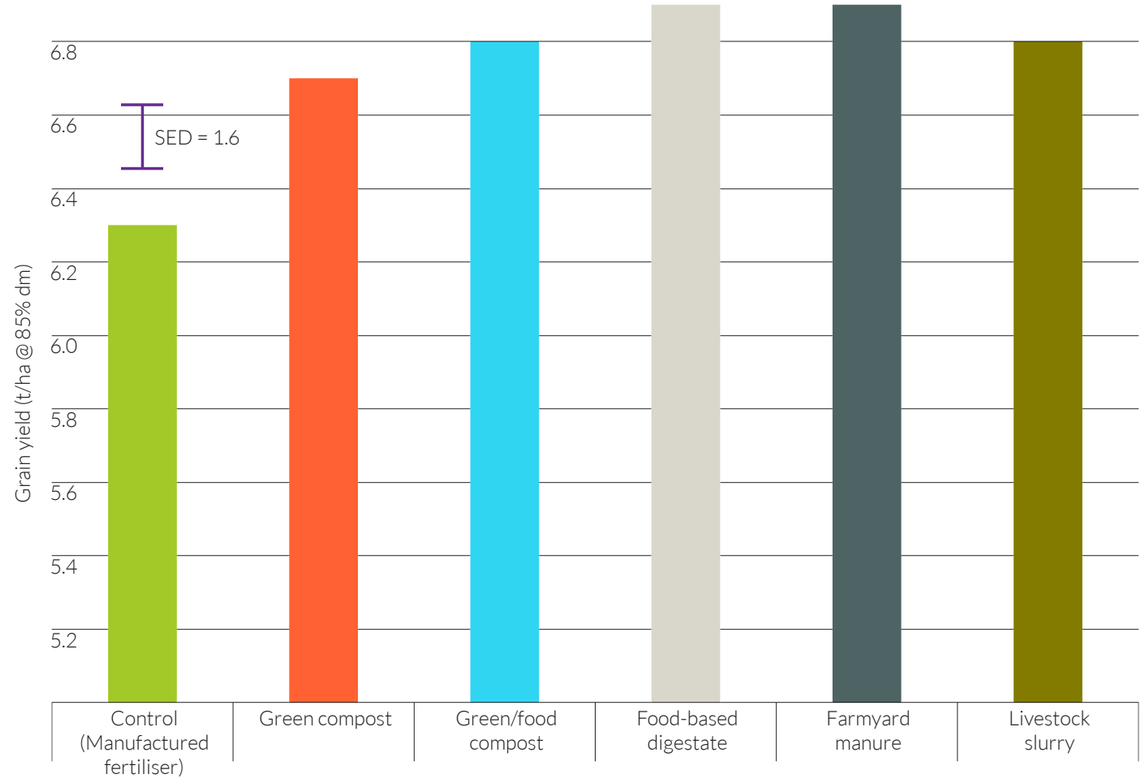
Composts and digestates provided an additional source of phosphate, potash and sulphur, providing a 'nutrient boost' early in the season which resulted in higher crop yields in comparison with crops grown only with bagged fertilisers This is particularly important on shallow soils over chalk and limestone where it can be difficult to reach and maintain target phosphorus levels, soils with a low nutrient status or soils susceptible to sulphur deficiency.

This benefit was valued at £55-£160/ha, taking into account the value of bagged fertiliser saved and the cost of spreading (but not sourcing) the organic materials. It also demonstrated the value of an integrated nutrient management plan, using compost or digestate and manufactured fertiliser together. Benefits were also measured for crops grown using other organic materials.

Crop quality

The impact of using green/food compost, green compost and foodbased digestate on crop quality and safety was measured. The quality of crops grown with compost and digestate was measured against specific grain weight, grain protein content and the oil content of rape seed and found to be just as good as crops grown using bagged fertilisers.

Similarly, crops grown using compost and digestate were found to be safe following assessments of crop metal concentrations, mycotoxins in cereal grains & organic material contamination of cut grass.



Average winter cereal yields from 2011-2013 at the soil quality experimental sites (results are an average across eight site/seasons), comparing organic materials applied in combination with manufactured fertilisers, against the fertiliser-only control. The standard error of the difference between mean values (SED) was 0.16. Bars labelled with different letters indicate significant differences between treatments (P<0.05).

Case Study: DC-Agri field experiments for quality digestate and compost in agriculture

Soil quality

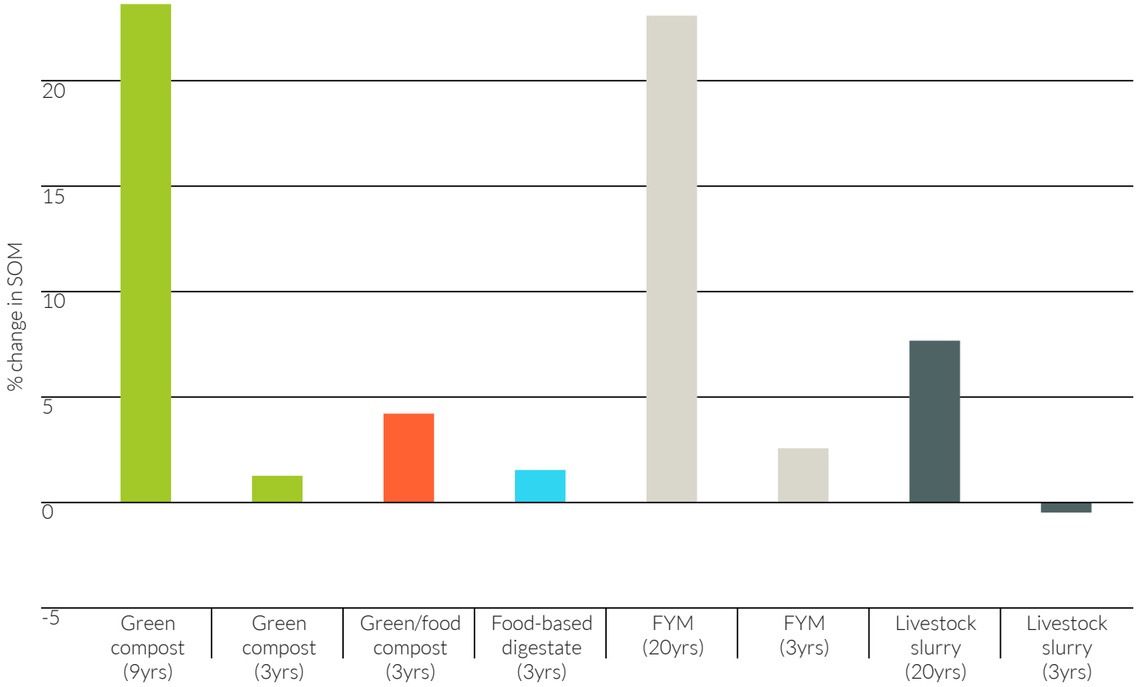
a) Soil organic matter

Two of the experimental sites were used in previous experiments and had a known history of organic material applications prior to DC-Agri. Here there was clear evidence that repeat applications of bulky organic materials for nine years or more increased topsoil organic matter contents, with both green compost and farmyard manure resulting in a c. 20-25% increase in soil organic matter relative to the control treatment, which only received bagged fertilisers. At the other sites, where materials were applied for only three years, there were small, non-significant increases in soil organic matter.

None of the whole food-based digestates used had a significant impact on soil organic matter levels. This was consistent with the results for the livestock slurries used and understandable given the low dry matter content of these materials.

Although the nine years of green compost applications supplied only half the organic matter that had been supplied by the almost 20 years of farmyard manure applications, it resulted in a comparable increase in total soil organic matter levels and shows that compost can build soil organic matter levels more quickly than other materials. Retention of the organic matter supplied by the green compost was almost double that of farmyard manure, which suggested that green compost was more resistant to decomposition.

This was supported by the lignin composition of the applied materials, with the organic matter content of the green compost containing c. 70% lignin compared to c. 55% in the farmyard manure. Soil organic matter content is a key indicator of soil health, and increasing soil organic matter is generally associated with stronger, more resilient crops. This is as a result of the combined improvement in soil physical and biological properties, which are described in the following sections.



Change in soil organic matter following the repeated addition of organic materials for three and over nine years. Results are expressed as a percentage difference from the control treatment (bagged fertiliser only). Annual applications of organic materials were made for longer at some sites than others: on two sites green compost was applied for nine years and FYM and livestock slurry applications were made for 20 years; on at least five sites, all other materials were applied for three years.

Case Study: DC-Agri field experiments for quality digestate and compost in agriculture

b) Soil biology

Measurements of the size of the soil microbial pool, as determined by its carbon and nitrogen content, indicates a soil's ability to store and recycle nutrients, and is also important in the development of soil structure, with higher content linked to better soil quality.

Statistically significant increases in soil microbial biomass were found where green compost had been applied for nine years. The increases were greater where farmyard manure had been applied for 20 years, despite similar increases in soil organic matter on the green compost treatment. This is most likely because the farmyard manure applications comprised a more readily decomposable source of organic matter that was able to support a bigger microbial population than that produced by the green compost additions.

Earthworms have a major influence on soil quality, and higher additions of fresh organic matter to soil are usually associated with greater earthworm populations. Earthworm populations were greater following the application of farmyard manure and to a lesser extent green and green/food compost to both arable and grassland soils, most likely due to the additional food supply provided by the organic materials.

However, earthworm populations were sometimes lower following the application of higher levels of ammonium in the food-based digestate, compared to the other treatments. At one grassland site, there was also a statistically significant difference between the food-based digestate and the fertiliser only control, and the effects at this site were still apparent approximately two years after the final digestate application (largely due to a reduction in the population of juvenile earthworms).

It is known that livestock slurries that contain a high proportion of ammonium may sometimes have a negative impact on earthworms, and additional laboratory research confirmed that this effect may also be seen sometimes following applications of food-based digestate.

Based on this research, WRAP's guides to good practice include recommendations that ammonium-N loading rates are controlled by following normal good practice (as described in the guides), and that users adjust application rates using up-to-date digestate nutrient analysis data in order to reduce the possibility of any negative impacts. Rapid on-farm nitrogen meters (e.g. Agros and Quantofix) can be used to provide on-site measurements of digestate ammonium-N contents.

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Case Study: DC-Agri field experiments for quality digestate and compost in agriculture

c) Soil physical properties

Soil density, particularly topsoil bulk density, has a direct impact on a number of essential soil physical and biological processes. These include root penetration, water infiltration rates, gas exchange and soil biological activity. Soil density is usually a key measure in the assessment of soil compaction and tends to be inversely related to soil organic matter content.

Published research has shown that decreases in soil density will reduce the amount of force required for ploughing and other tillage operations. This can generate financial savings for farmers as a result of the related reductions in machinery wear and fuel costs.

At the arable sites, improvements in soil organic matter and soil biological functioning on the long-term green compost treatment (and farmyard manure treatment) were associated with a decrease in bulk density. These decreases were greater on the farmyard manure treatment, which had similar soil organic matter contents, although the time-frame over which this was achieved and the total organic matter load required to achieve it was almost double that of the green compost treatment.

At the grassland sites, compost and farmyard manure additions also decreased bulk density. Where digestate and livestock slurry had been applied for three years, there was some evidence of soil compaction (i.e. increased bulk density), although these changes were not statistically significant.

d) Soil heavy metals and organic contaminants

There was no effect of the compost and digestate additions on topsoil total metal contents, and all measurements remained well below maximum permissible limits set in relation to applications of sewage sludge.

Measurements of organic contaminants (PAHs, dioxins, furans and phthalates) were generally low and considered to be acceptable. Whilst there are no specified 'safe' limits for these contaminants in agricultural soils (or soil amendments such as sewage sludge, compost or digestate), a set of preliminary, human health related limits have been suggested for land application of wastewater and sewage sludge. For PCBs, the proposed maximum soil concentration of 0.89 mg/kg was greater than the concentrations measured at the DC-Agri experimental sites (at <0.002 mg/kg). These results are in line with research in Finland, where observed annual loadings from digestates of dioxins, furans, phthalates and PCBs were similar to or lower than those from atmospheric deposition in Scandinavia, and were therefore of low-risk to food safety.

This is an important finding for the sustainable use of compost and digestate on agricultural land, providing confidence that they can be used safely on agricultural soils.

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Emissions to the environment

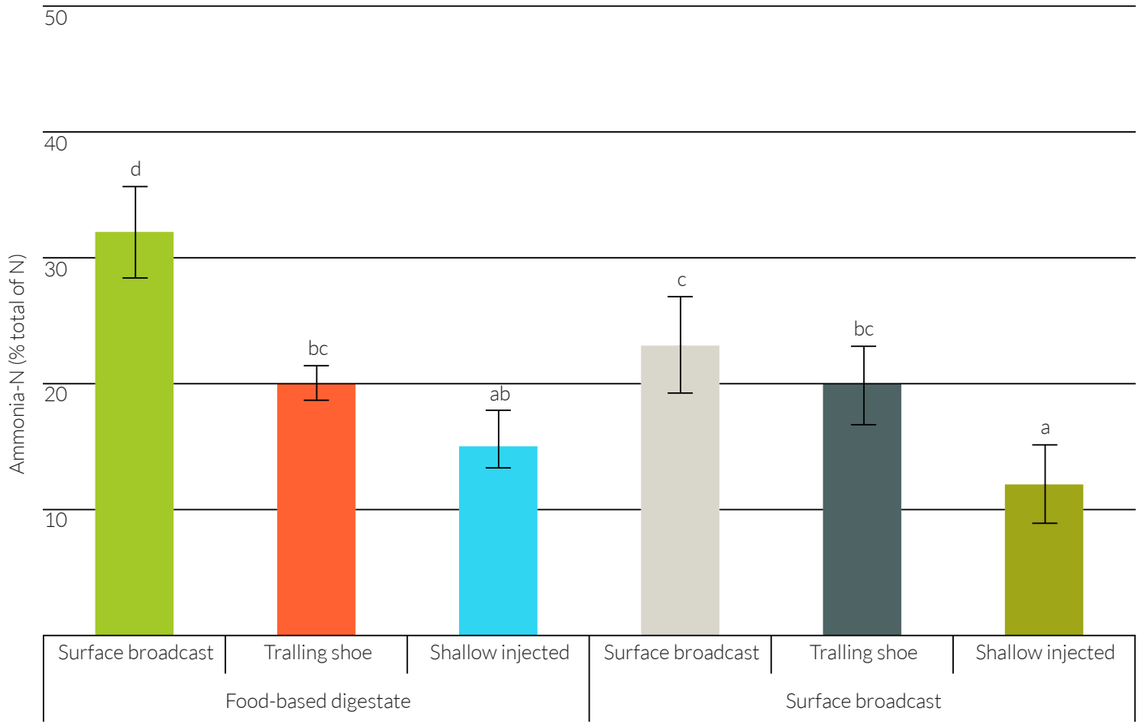
As noted above, digestate is an effective renewable fertiliser supplying readily available nitrogen, mostly in the form of ammonium. This is a significant benefit, but the unstable nature of ammonium emphasises the need to follow good practice in order to avoid environmental harm.

In summary, it is recommended that digestate is only applied when there is a crop nitrogen requirement and using precision application methods such as bandspreading or shallow injection.

a) Ammonia

Greater ammonia emissions were found from applications of food-based digestates (c. 40% of total nitrogen applied) compared to livestock slurry (c. 30% of total nitrogen applied). This was partly due to the greater ammonium content of the food-based digestate and partly to its elevated pH (mean pH 8.3).

Ammonia emissions were reduced on grassland where the food-based digestate (and cattle slurry) was applied via trailing hose and particularly when it was applied via shallow injection. However, appropriate soil conditions are required for shallow injection to operate to its full potential (i.e. soils should not be too wet or stoney).



Cross-site ammonia emissions from both autumn and spring applications to grassland at three sites. Bars labelled with different letters indicate statistically significant differences between treatments (P<0.001) and show that both shallow injection and trailing shoe application methods reduce ammonia emissions by 40-50% in comparison with surface broadcasting.

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b) Greenhouse gases

Nitrous oxide losses from the foodbased digestates were low, with measured emission factors all less than the current default value of 1% set by the Intergovernmental Panel on Climate Change. This is consistent with data from on-going research into livestock manures and slurries undertaken as part of the Agricultural GHG Research Platform.

Methane emissions from digestates were lower than from livestock slurry. Small increases in cumulative (12 month) carbon dioxide emissions were observed on the slurry and digestate treatments compared with the untreated control, and to a lesser extent the farmyard manure treatment. The reason for the small increase in carbon dioxide emissions was unclear; one possible explanation is that microbial respiration was stimulated by the supply of both readily available nitrogen and readily decomposable carbon.

c) Leaching losses

Overwinter nitrate leaching losses from food-based digestate were significant and similar in magnitude to those from pig slurry (at c. 15-20% of the total N applied), but much greater than those from farmyard manure or compost (at <5% of the total N applied). Nitrate leaching losses can be reduced and nitrogen use efficiency increased by applying digestate only when there is a crop nitrogen requirement.

Phosphorus leaching losses were low for all organic materials and similar to those measured on the untreated control treatment. No viable E.coli were found in the drainage waters even where organic materials were applied.

d) Compost

Atmospheric emissions (i.e. ammonia, nitrous oxide, methane) and leaching losses (nitrate, soluble phosphate and E.coli) from both green and green/food compost were found to be low. Due to its valuable total nitrogen content, but low readily available nitrogen content, compost applications should be seen as a means to build up long-term (organic) soil nitrogen reserves rather than as a short-term replacement for bagged nitrogen fertiliser.

Tools and training

An integrated dissemination programme has been central to the DC-Agri project, translating research results into practical advice for industry. This has focussed on farmers, farmer advisers and agriculture students across GB, and provided them with the training and tools necessary to make informed decisions about the use of digestate and compost.

Conclusions

The DC-Agri results have clearly demonstrated that the repeated application of compost is a valuable means by which farmers can improve soil organic matter status, with associated increases in soil biological and physical functioning. This will ultimately lead to increases in crop yields and resilience, as well as reduced fuel costs.

The increased nutrient supply from organic materials, including digestate and compost, can produce higher crop yields of equal quality to crops grown with bagged fertilisers. This, combined with a reduced reliance on manufactured fertiliser inputs, can also lead to improved financial returns.

Digestate is a good source of crop available nitrogen, and the DC-Agri results highlight the importance of following good practice to maximise its potential as a renewable fertiliser. The results also highlight the economic and environmental cost of mismanaging the high ammonium content. One of the most valuable outputs of the DC-Agri project is the robust scientific evidence that is now available to inform good practice.

Governing Bodies & Industry Institutions

Detailed below is a brief of the bodies that oversee and regulate the organic agriculture industry along with institutions that help to develop the industry as a whole.

Department for Environments, Food & Rural Affairs

The Department for Environments, Food & Rural Affairs are the UK government department responsible for safeguarding the UK's natural environment, supporting our world-leading food and farming industry, and sustaining a thriving rural economy. Their remit means they play a major role in people's day-to-day life, from the food we eat, and the air we breathe, to the water we drink.

Their purpose is unleashing the potential of food and farming, nature and the countryside, championing the environment and protecting us all from natural threats and hazards.

DEFRA's responsibilities are:

- a cleaner, healthier environment which benefits people and the economy
- a world-leading food and farming industry
- a thriving rural economy, contributing to national prosperity and wellbeing
- a nation protected against natural threats and hazards, with strong response and recovery capabilities
- excellent delivery, on time and to budget and with outstanding value for money
- an organisation continually striving to be the best, focused on outcomes and constantly challenging itself

Food and Agriculture Organisation

Achieving food security for all is at the heart of FAO's efforts – to make sure people have regular access to enough high-quality food to lead active, healthy lives.

Their three main goals are: the eradication of hunger, food insecurity and malnutrition; the elimination of poverty and the driving forward of economic and social progress for all; and, the sustainable management and utilization of natural resources, including land, water, air, climate and genetic resources for the benefit of present and future generations.

An intergovernmental organization, FAO has 194 Member Nations, two associate members and one member organization, the European Union. Its employees come from various cultural backgrounds and are experts in the multiple fields of activity FAO engages in. FAO's staff capacity allows it to support improved governance inter alia, generate, develop and adapt existing tools and guidelines and provide targeted governance support as a resource to country and regional level FAO offices.

FAO's activities comprise five main areas:

- Putting information within reach and supporting the transition to sustainable agriculture
- Strengthening political will and sharing policy expertise
- Bolstering public and private collaboration to improve smallholder agriculture

Soil Association

The Soil Association was founded in 1946 by a group of farmers, scientists and nutritionists who observed a direct connection between farming practice and plant, animal, human and environmental health.

Today, they are the UK's leading membership charity campaigning for healthy, humane and sustainable food, farming and land use. They have over 150 staff based in Bristol and Edinburgh and working as certification inspectors across the country.

The Soil Association is a charity, reliant on donations and on the support of its members and the public to carry out its work.

Their work is divided into three areas:

Facing the future - In the face of climate change and a growing world population, business as usual in our food and farming system is not an option. They want to ensure that organic systems can secure a durable and humane solution to the challenges facing us.

Good food for all - Good food, the best food, is organically grown, minimally processed, fairly traded, fresh and seasonal. And this food should be a right, not a privilege: they want to make sure everyone has access to food that is healthy for them and the planet.

Enabling change - They represent and work with pioneering farmers, growers and businesses who deliver practical change – the extraordinary people who make change happen on the ground.

National Farmers Union

Formed in 1908, the NFU champions British farming and provides professional representation and services to its Farmer and Grower members.

Farmers and growers need someone to give British farming a voice, so what they're most passionate about can be continuously protected and shaped. They need someone who can offer them advice and services that are actually of real value to them.

The NFU is that someone. They are the farmers and growers trade association, providing professional representation on the issues that affect them most.

Their objectives are to champion farming in England and Wales and to provide professional representation and service to Farmer & Grower members.

The NFU has 55,000 members across England and Wales. There are around 83,000 farm holdings which are greater than 50 acres of land. These belong to full time farmers. Many farmers have more than one holding. The NFU estimates that more than 70 per cent of full time farmers are NFU members.

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New AD Ltd, The Re:Centre, University Campus, Richmond Road, Bradford, BD7 1DP
www.newadltd.com | +44 (0)1274 238 020 | info@newadltd.com | Reg No: 09952309 | UNGM No: 450371