

IRD MATTERS

FEBRUARY 2019

CONTENTS



SOIL

farming without **soil** 12

will the **agriculture bill** save our soil? 26

the **living** soil 21

FOOD

pathways to **soil** and **food** security 17

how **green** is my coal mine? 08

questions and **answers** 23

Publisher

Royal Agricultural University Cirencester

Coordinator
Jonibek Rakhmonov
Msc. Sustainable Agriculture and Food Security
Uzbekistan

Editor
Sophia Lingham
Msc. Sustainable Agriculture and Food Security
United Kingdom

Design and Layout
Alan Peter
mdsdc17@gmail.com

Amanda Moshi
Msc. Agri-Technology and Innovation
Tanzania

Article Contributors
Adewale Ogunmodede
Msc. Sustainable Agriculture and Food Security
Nigeria

Ahmed Maden
Msc. Food Safety and Quality Management
Algeria

Ferdinand Spieth
Msc. Agri-technology and Innovation
Germany

Janis Faltman
Msc. Agri-technology and Innovation
Germany

Johan Casper Van Hammerstein
Msc. Agri-technology and Innovation
Germany

Kellie Hummel
Msc. Sustainable Agriculture and Food Security
The United States of America

Rebecca Barlett
Msc. Sustainable Agriculture and Food Security
The United Kingdom

Royal Agricultural University
Cirencester
Gloucestershire
GL7 6JS
UK
Tel: **+44 (0) 1285 652531**

DISCLAIMER
The views expressed in this magazine are those of the authors and not necessarily those of the Royal Agricultural University

FORWARD



Image source: Future Learn

Today marks the 16th annual publication of 'IRD Matters' the virtual magazine developed and published by Masters Students studying Sustainable Agriculture and Food Security, Food Safety & Quality Management and Agricultural Technology & Innovation. This year we would like to take you on a journey through the dimensions of food security and the links to a critical global resource - soils.

We are living in a world of over 7 billion people and still rising; a world that currently produces enough food but where 1 in 9 people go to bed hungry every day. We also live in a world where 3 in 9 people are obese, where so much food is thrown away in developed countries and where so little gets to safe storage post-harvest in developing countries. The world is also experiencing unprecedented challenges of maintaining stable food supply from diminishing resources and climate uncertainty. These are just some of the headline issues often quoted around debates on food security; but how critical are our soils to this debate?

Through a combination of expert and student articles, we aim to address two critical issues:

1. How important are our soils globally in underpinning food security and how can we protect such valuable resources? and,
2. To what extent can the technologies of growing food without the use of soil contribute to food security?

I am sure the magazine team will increase your appetite to learn more about sustainable soil utilisation and technology in the context of food security that will stimulate further discussions and debate.



Dr Richard Baines

SAFS, FSQ & Agri-Tech Tutor and Magazine Commissioning Agent

AGRICULTURE
FOR THE UNBORN GENERATION
The Case of Soilless Farming

Agriculture is more than just the production of food, it is the foundation for shelter, health, and economic empowerment. Despite advancement in technology in the 21st century, the reality remains there is an increase in hunger and poverty – any development that does not ensure food production is but a haste towards modern day slavery as those with food will rule over the hungry. Hunger and poverty are synonymous as a hungry man lives at the fundamental level of animal instincts where there thought process is dominated by survival and thus productivity is low.

The scenery isn't an easy fix considering the effect of **natural phenomenon** based on human influence such as deforestation, over cutting vegetation, lands having inadequate fallow period, improper crop rotation, over grazing and fertilizer abuse; **demographics** as we witness huge population growth, urban migration as citizens seek for greener pasture, the advanced age of the local farmers with the average age of Nigerian farmers at 60 years and youths being unwilling to pick up agriculture; **climate change** reality with changing precipitation, unpredictable weather, crop instability and increased greenhouse emission; and **food waste** which today is at an all-time high. As at today, between 33%-50% of foods produced is never eaten, in Lagos state where parties are a norm on Saturday, the amount of food wasted in such occasions hasn't been quantified. Food waste equals waste of resources used in production, waste of man hours, not counting the effect to the environment yet well over 700 million people go to bed hungry!

To ensure food security, everyone has a part to play, I will however narrow this discussion to soilless farming. In simple terms – soilless farming is growing without soil. It is important to understand how we grow with no soil, but first we need to understand the function of soil in growing. Soil is meant to give support, allow for aeration and retain water moderately. For a Nigerian and most Africans, the question



usually is – don't we have enough land? Why go soilless?

The fact is – Africa has enough land, but the truth is we do not have enough arable land, and less fertile land. To explain further, land for a farmer is a land that can support plants growing, in Nigeria, there is well over 70% of arable land, however the fertility of the land Is paramount to the farmer as this will guaranty yield and thus profit, however the fertile land for growing is less than 50%. Add to this the reality of coastal encroachment in the South, desertification in the North, oil spillage, deforestation, sooths mixing with rain water to form acidic rain and thus destroy the integrity of the soil – thus reducing the number of fertile land for growing. In addition, with the urban migration, insufficient good road networks, storage facilities, there is the issue of increased food waste as most of the foods are lost in transit, so there is a need to bring the farms to the cities or to peri-urban areas.

Soilless farming isn't a way to replace soil, but rather to compliment soil. Soilless farming will ensure food production is not seasonal, ensures reduced use of fertilizer, no use of insecticides and herbicides, healthier growing, etc. Farming becomes predictable and enticing for the youths to pick up. There is better land use, as we can grow vertically, maximize space and more!

There is the case for most governments wanting more people especially in Africa to pick up agriculture as a way to create more jobs, but this in itself doesn't ensure food security. USA for example has less than 15% of its population involved in agriculture while more than double of that is involved in Agriculture in developing and underdeveloped countries, this is so because humans are doing what machines can do, and as such more hands are needed yet yield less effective result hence the issue of food insecurity is on the rise. Agriculture especially in developing countries needs to adopt technology to ensure technology does what man does more efficiently and man can focus on what machines cannot do – think. Who amongst our readers would love to have an account in a bank where they still use ledger, no computers, everything is manually imputed and you can only carry out your bank activities in the branch you opened your account, where they have to send letters rather than use telephones as a means of communication, no internet, - and they say it is because they want to ensure job creation! Well my guess is no one, so if you won't accept that in banking sector, why should agriculture be left behind dedicated to use of hoes and cutlasses just to create job? The first job of the farmer is food production and not job creation.

Soilless farming includes hydroponics and aquaponics, but alone they won't solve human food requirement issues but with soilless farming we are taking a step in the right direction. It can be done anywhere, indoor or outdoor, subsistence or commercial, and anyone can manage it, you just need to be willing to seek for the knowledge to learn how to grow without soil. There are many soilless farmers who are experts in Nigeria and are willing to teach others – Mrs Adelaja (CEO Fresh Direct), Mr P.J Okocha (Managing partner PS Nutraceuticals), Mr Yomi Williams (CEO Gartner Callaway), Mr Onofowora (CEO BIC Farms), Mr Moritz (Seedforthe farm), Mrs Chioma (Saladville) etc.

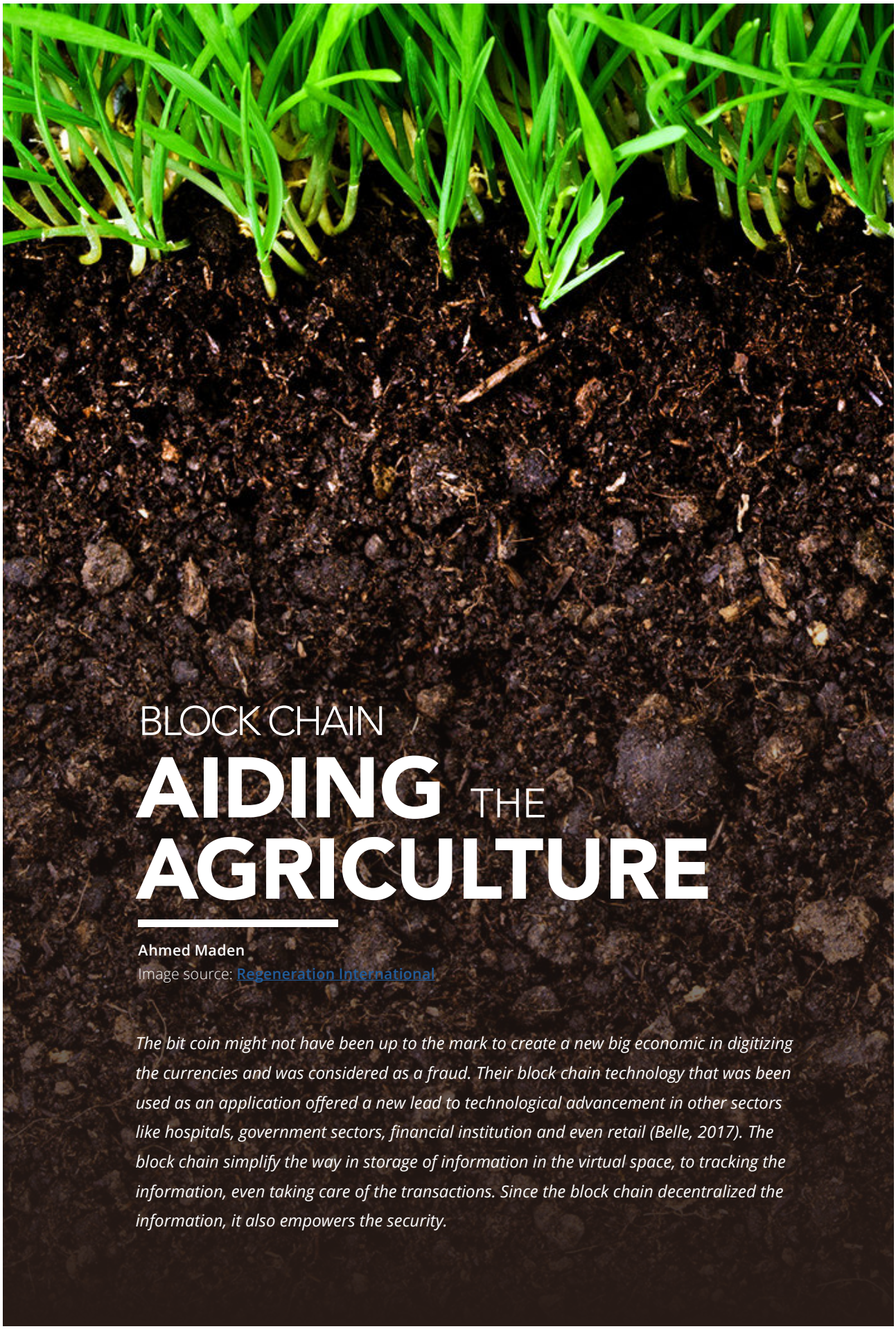


Agriculture for today must be one which is healthy for the farmer, the consumer and the environment – this is foundation for soilless farming.

Samson Ogbole
Farmer & Biochemist
Co-founder,
PS Nutraceutical, Nigeria.

Image source: Shutterstock

***Soilless farming** is growing without soil. It isn't a way to replace soil, but rather to compliment it.*



BLOCK CHAIN AIDING THE AGRICULTURE

Ahmed Maden

Image source: Regeneration International

The bit coin might not have been up to the mark to create a new big economic in digitizing the currencies and was considered as a fraud. Their block chain technology that was been used as an application offered a new lead to technological advancement in other sectors like hospitals, government sectors, financial institution and even retail (Belle, 2017). The block chain simplify the way in storage of information in the virtual space, to tracking the information, even taking care of the transactions. Since the block chain decentralized the information, it also empowers the security.

Food Security

The block chain security provide more transparency at a very new level. It provides better response in empowering or strengthening the security of the entire supply chain of the food. The massive organisation like Nestle and Unilever are considering block chain technologies (Yli-Huumo, Park, & Smolander, 2016). The block chain technology aid the food security by giving following benefits. The main function that the block chain provides is traceability.

- **Checking the quality of the soil:** soil is the fundamental need of maintaining the food growth. Regarding the quality of the grains and vegetable and the demand of the organic vegetables, it is quite important to maintain the soil quality, its fertility to increase more crops as per the requirement of the market (Graham-Rowe, Jessop, & Sparks, 2014). Identifying motivations and barriers to. The traceability enables the farmers to check the quality of the soil before planting the seeds.
- **They empower the track back test:** the trackback test helps in getting the exact time to know at what time the food was supplied to the retail.
- **QR code commodities:** Through this technology it was much easier for the retailer to know the details of the supplies they order and who are the suppliers who have sent the product. The quality of the food is also maintained by knowing the date it has been supplied.
- **Food testing:** the quality of the food commodities is quite important in order to maintain a better business among the customer. Since the food is a necessity, healthy food are trace based on the harvest date, health of the plant or animal, fisheries. The testing of the food are done by trace back test that was first done over mango slices to check the quality of the product.
- **Reduction of the food waste:** the quality check of the products are done to make sure that there is no waste of food before or after supply. The approximate delivery duration before the contamination of the products can also be checked through the database of the block chain, so the good quality food are in the shelves of the retail stores while the waste are reduced to landfills.
- **Preventing fraud:** the food fraud mainly involves the regarding the interest of the distributed ledger is hard to track the prime data, because of the multiple storage
- **Faster Payment:** the faster and hassle payment are done because there are no third party involved during the payments. There are no third party fees deducted to proceed the transaction (Garrone, Melacini, & Perego, 2014).



Image source: Future Learn

References

Belle, I. (2017). The architecture, engineering and construction industry and blockchain technology. Digital Culture, 279-284.

Garrone, P., Melacini, M., & Perego, A. (2014). Opening the black box of food waste reduction. Food policy, 46, 129-139.

Graham-Rowe, E., Jessop, D. C., & Sparks, P. (2014). Identifying motivations and barriers to minimising household food waste. Resources, conservation and recycling, 84, 15-23.

Kamilaris, A., Prenafeta-Boldú, F. X., & Fonts, A. (2018). The rise of blockchain technology in agriculture.

Tian, F. (2016, June). An agri-food supply chain traceability system for China based on RFID & blockchain technology. In Service Systems and Service Management (ICSSSM), 2016 13th International Conference on (pp. 1-6). IEEE.

Yli-Huumo, J., Ko, D., Choi, S., Park, S., & Smolander, K. (2016). Where is current research on blockchain technology?—a systematic review. PloS one, 11(10), e0163477.



DEEP FARM: 'HOW GREEN IS MY COAL MINE NOW?'

Professor Saffa Riffat

Image source: **Elizabeth Waugh - Getty Images**

Most of the food we eat is transported by road, sea and air contributing to large CO2 emissions. For each one calorie of food we eat10 calories of crude oil are used. Projections show that feeding a world population of about 9 billion people in 2050 would require overall food production to be increased by some 70% between now and 2050. The demand of additional food will require an increased yield using intensive farming without conversion of forests, savannahs and peatlands to agricultural land.

The Intergovernmental Panel on Climate Change (IPCC) says the world is headed for painful problems sooner than expected, as greenhouse (GHG) gas emissions keep rising. Current crop production will need to be changed to ensure food security for human and animal against the impacts climate change.

In order to use less land, farms could be spread vertically rather than horizontally. This 'Vertical Farms' approach, uses multi-layer greenhouses or skyscraper towers to meet the challenges of food intensification. With a controlled climate, LED light and water/nutrient supply, these farms can produce multiple crops and high yields. However, vertical farms are expensive to manufacture, install and maintain. Urban land values are high and to maintain their perfect environment vertical farms use a large amount of energy to heat and cool crops to desired temperatures. They are also vulnerable to extreme weather conditions, wars and terrorism. Due to these challenges, they are not widely adopted and tellingly Mirai, Panasonic and Google have all abandoned vertical farming projects.

Utilising existing underground spaces with lower commercial value and fewer competing uses is more practical and cost effective. A new breakthrough has been made by University of Nottingham academics Professors Saffa Riffat (President of the World Society of Sustainable Technologies) and Yijun Yuan (EU Marie Curie Fellow Fellow), who filed four patent applications in November 2018 claiming novel cultivation technology using based on the recommissioning of redundant mine shafts and tunnels, generically termed "Deep Farm".

In principle, any existing coal mine shafts and tunnels might be considered but it is especially advantageous to use those close to cities and towns to minimise "food miles". A further advantage is that old tunnels liable to cause subsidence might be made safe by adapting them for Deep Farm cultivation.

In the UK, there are over 150,000 abandoned mine shafts and 25 square km of tunnels. Even discounting those that are



DEEP FARM TECH

Up to 10 crop cycles per year can be achieved compared to 1-2 cycles for conventional agriculture. One small Deep Farm can produce around 80 tonnes of food per annum and crops can be ready for harvesting within 3-4 weeks of propagation.

no longer accessible through collapse or flooding, ample opportunities exist to use these abandoned structures for intensive food production.

A vast number of coal mines and tunnels with the potential to be used for food production exist in countries including China, the USA, Australia, South Africa, Germany and Poland. In addition, salt, gold mines as well as defence and railway tunnels could be adopted for planting.

The dis-used tunnels could be modified if necessary to create shafts using drilling machines or controlled explosive devices.

A variety of crops can be grown using hydroponic planters (plant roots fed with nutrient-rich water) or aeroponics (growing plants in an air or mist environment). LED units providing illumination at appropriate wavelengths to maximise photosynthesis with minimum power input to replace sunlight. A major benefit is that crop production is largely unaffected by climatic or seasonal factors - one of the greatest limitations of conventional farming methods.

Furthermore, enclosed units isolated from each other allow plant diseases and pests to be readily controlled with little or no application of chemical biocides.

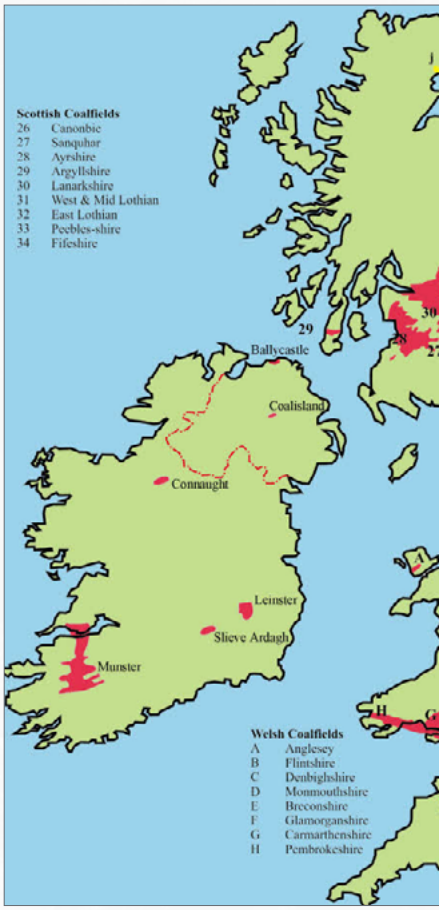
Deep Farm technology will allow crop production all year-round. Up to 10 crop cycles per year can be achieved compared to 1-2 cycles for conventional agriculture. One small Deep Farm can produce around 80 tonnes of food per annum and crops can be ready for harvesting within 3-4 weeks of propagation. Deep Farms will have a lower energy requirement than traditional vertical farms. A single shaft will have about the same consumption as three UK homes using innovative LED illumination and controls combined with natural lighting using light rods or optical fibres. The carbon dioxide demand of photosynthesising plants can be captured from ambient air using materials such as activated carbon. Within the closed cycle of a Deep Farm, water is readily recovered and recycled with "make-up" water sourced from ground around the shaft.

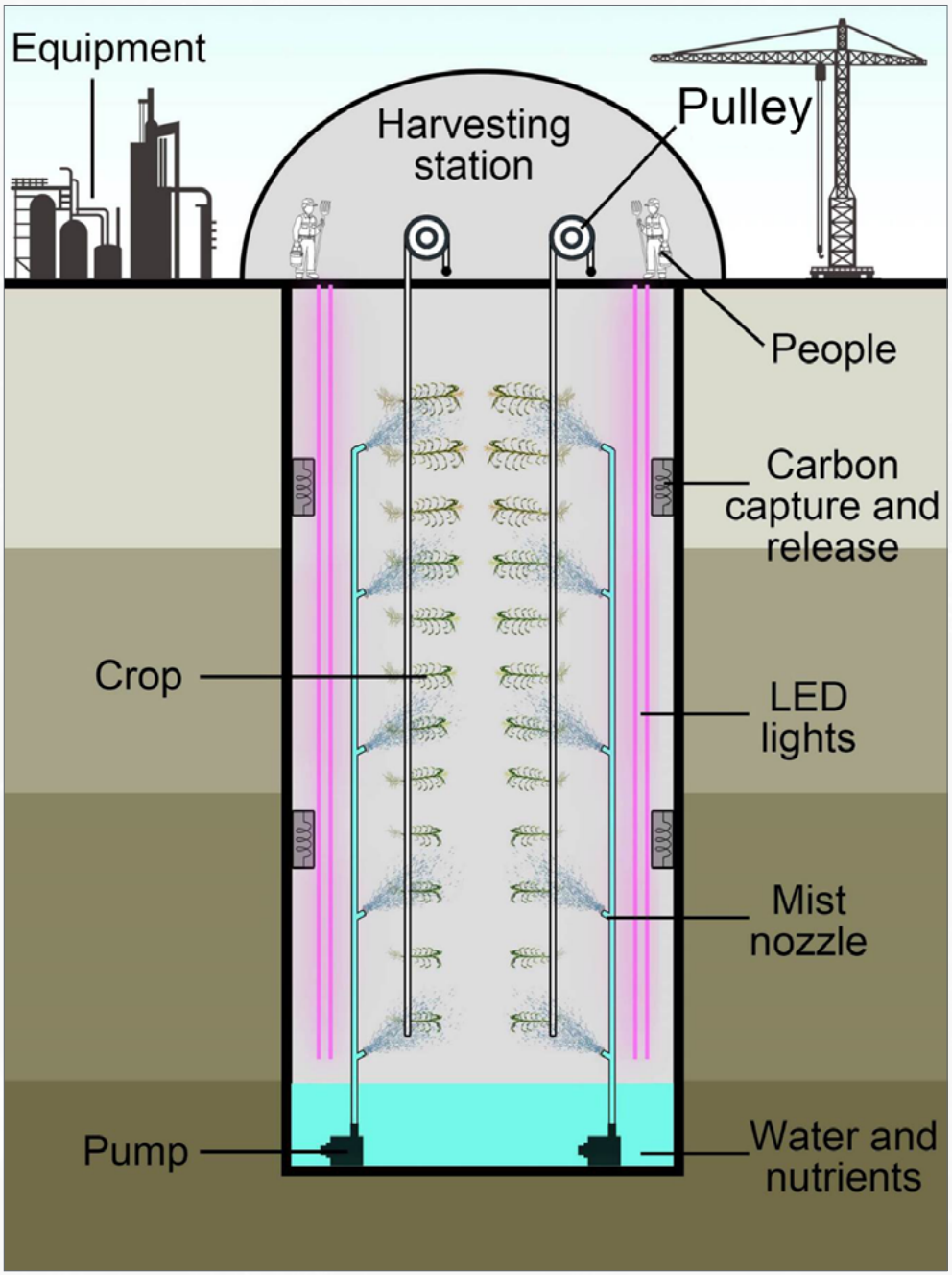
Deep Farm can be used to grow a range of vegetable and herb crops including lettuce, kale, spinach, basil, carrots, onions, cucumbers, and different types of mushrooms. The crop planting and harvesting could be carried at the top of the mine shafts using simple belts (or baskets) and pulley arrangements but robots may also be employed. To harvest the crops the belt with plants would be pulled up, minimising to work within the mine shafts. So, in terms of the rationality of the biological chain and the biological space, some crops are best located underground, leaving the ground surface for human and animal activities.

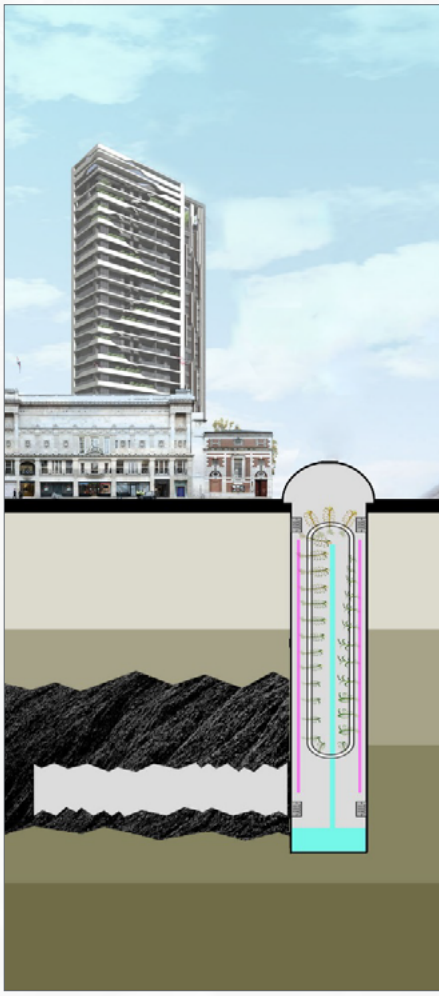
RIGHT:
UK's Mines (Reference Google)

SECOND RIGHT:
Converting coal tunnels into shafts/deep farms

BELOW:
Food planting/harvesting in Deep Farm using pulleys

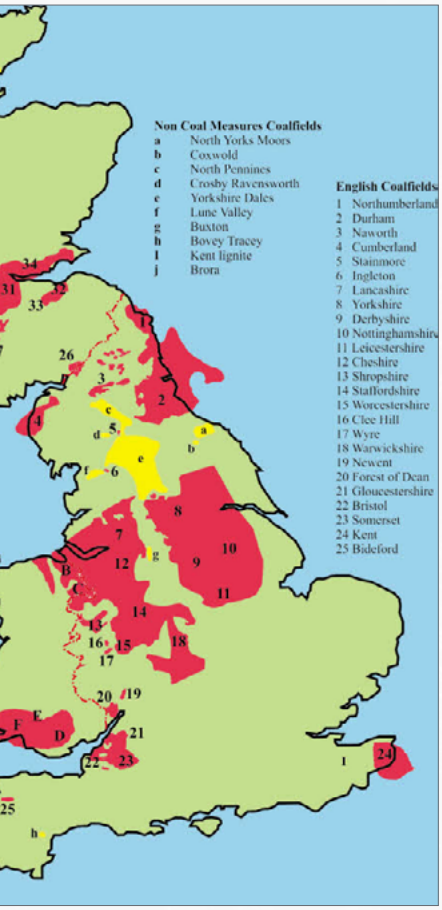


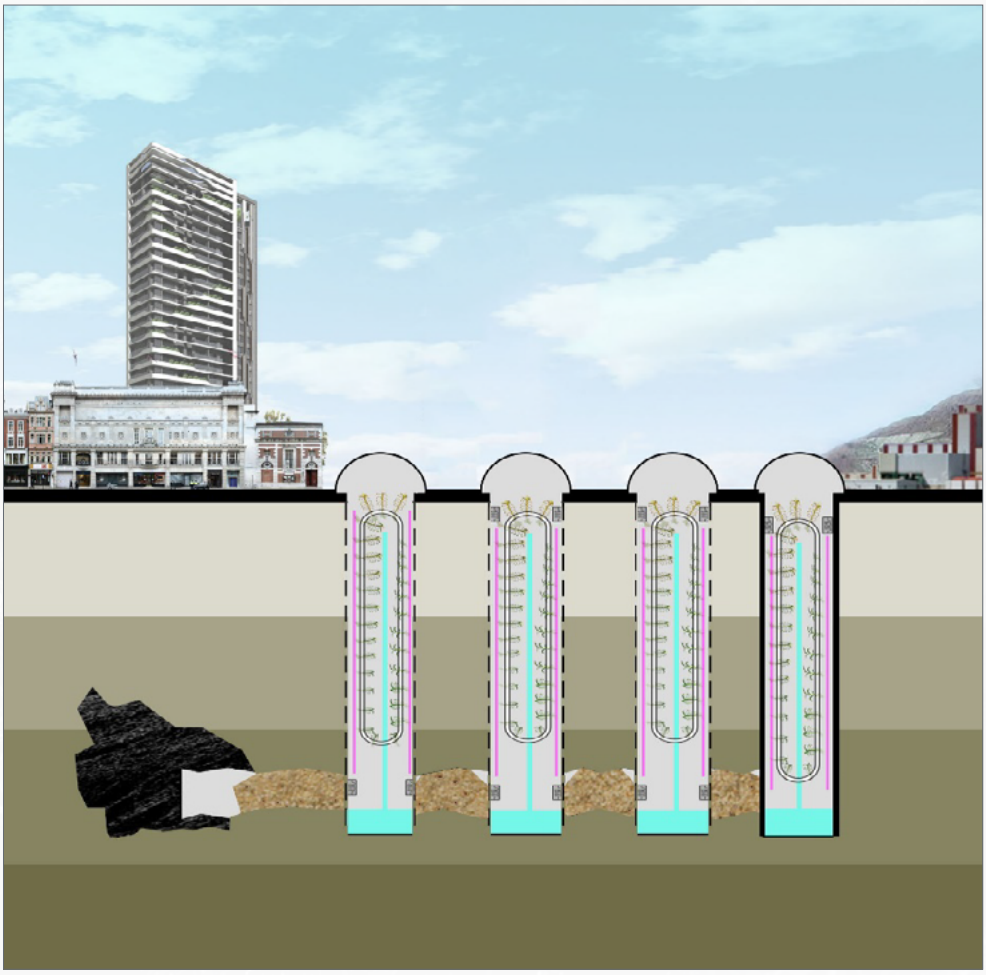


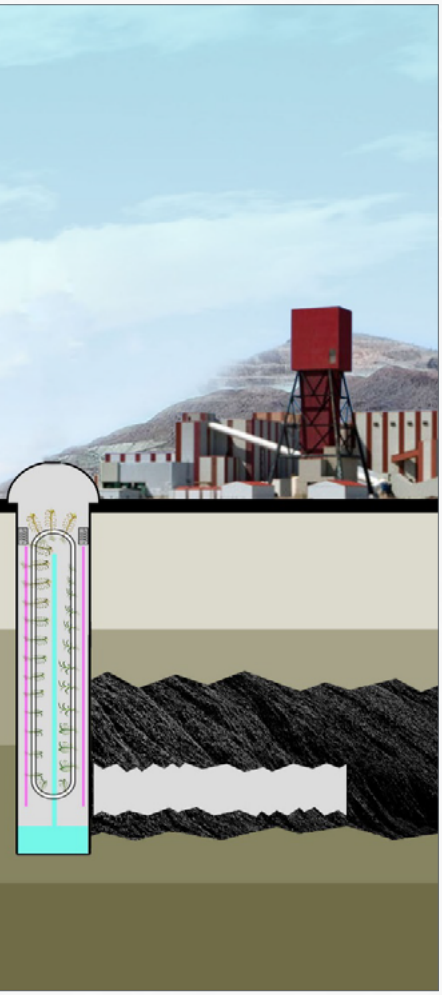


RIGHT:
Mine shafts for intensive food production

SECOND RIGHT:
UK's last deep coal mine Kellingley Colliery, North Yorkshire closed on 18 December 2015 (Credit: Press Association)









For more information please contact Prof Saffa Riffat:

Professor Saffa Riffat
Fellow of the European Academy of Sciences
President of the World Society of Sustainable Energy Technologies
University of Nottingham
Nottingham, NG7 2RD
UK

Email: saffa.riffat@nottingham.ac.uk
Telephone: +44-115-748 4479

Kellie Hummel
Image source: Shutterstock

farming without soil

When you look up the word "farm" or "farming" it talks about the cultivation of crops or livestock on an area of land but does not often include the word soil. Some may question how soilless farming could be possible, but it is actually something that has been around for many years. One example is the Mexican Chinampas, or floating gardens, which are manmade floating islands used specifically for agriculture. They are built on freshwater lakes using things like vegetation and mud to create the growing substrate for their crops. There is evidence to show they date back to the time of the Aztecs (Possibly even prior to their arrival) and they are still being used in some areas today. The following are just a few more examples of what people are doing in today's world to grow food without the help of soil.

used in at least 150 locations in Japan	95% less water than conventional farming in a field	much more resilient to the changing climate	it could lower greenhouse gas emissions by 96%	can be used on long distance space flights to feed the astronauts

Polymer Film

Yuichi Mori of the Mebiol Research and Development Center created a polymer film made of hydrogel to growing plants. The film can sit on almost any flat surface and absorbs water and nutrients through pores that are one millionth of a millimeter in diameter. The plants grow on top of the film and spread their roots along its surface rather than digging deeper into the earth. The microscopic pores of the polymer film also act as a blockade to bacteria and viruses, so pesticides and herbicides are not needed. The polymer holds onto water molecules very well, which results in both a 90% decrease in water use compared to conventional farming, but also the development of higher levels of sugars, amino acids, and phytochemicals in the plant due to the stress levels of having to work harder to absorb the water and nutrients from the film. The polymer film can be used almost anywhere and is currently being used in at least 150 locations in Japan including Drop Farm.

Aeroponics

AeroFarms is the commercial leader in this style of indoor farming where plants are grown in an air environment and then misted with nutrients and water. Their closed loop system uses 95% less water than conventional farming in a field and 40% less than a typical hydroponic system. They use a reusable cloth medium that is made out of BPA free post-consumer recycled plastics and each cloth takes about 350 water bottles out of the waste system. After harvesting the plants, the cloth can be sanitized and reused for the next group of seedlings, which eliminates the risk of contaminating the next crop as soils may do. The rigorously controlled indoor environment does not allow for the growth or proliferations of pests and diseases, so herbicides and pesticides are not needed and it uses LED lights to create the specific spectrum, intensity, and frequency of light that is optimal for each plant. Because of this specialized environment, they are able to grow plants in half the time needed to grow it in the field, resulting in 390 times more productivity per square foot than commercial fields.

Hydroponics

Hydroponics Kenya is the pioneering company of hydroponic farming technology for East and Central Africa. Their high quality and cost-effective systems involve using mineral nutrient solutions in water to grow crops both for animal fodder and for human consumption. These systems are much more resilient to the changing climate and less affected by the changing seasons and poor weather conditions throughout the year, which has historically been a large factor in causing severe food insecurity in Africa. Peter Chege, the founder and CEO of the company, says they are able to provide faster growth of plants and a higher nutritional value while using less water, space and labor and having less incidence of disease. They aim to enable small and medium holder farms to have predictable, nutritious, and low-cost yields of crops both for themselves and the animals on their farm. The company provides both products such as its hydroponic greenhouses as well as trainings and demonstrations on the various hydroponic systems at their office in Zambezi, Kikuyu, Kiambu County, Nairobi.

Lab Grown Meat

Mosa Meat, Memphis Meat, Super Meat, and Finless Foods are all working towards creating affordable and delicious lab grown meat. Clean meat as it is sometimes referred to as, could considerably reduce the environmental impacts of the meat production industry as resources would only be needed to generate and sustain cultured cells rather than grow and sustain a whole organism from birth. One study suggested that it could lower greenhouse gas emissions by 96%. To grow the meat, a muscle sample is taken from an animal and then stem cells are collected from the sample. These multiply quickly, differentiate into primitive fibers, and then bulk up and form muscle tissue. According to Mosa Meat, one tissue sample can generate enough muscle tissue for 80,000 quarter pounders. Unfortunately, the cost to make it is still fairly high and Memphis Meats reported that a quarter pound of the lab grown ground beef costs about $600. One test of a hamburger also found that the meat was overly dry due to a lack of fat. Because it is relatively new to the market, the FDA is only starting to consider how to regulate it. Traditional meat producers are also arguing that it should not be labeled as meat because of it being grown in a lab, not on an animal.

Polymer Film



Image source: Make a Smart City

Aeroponics

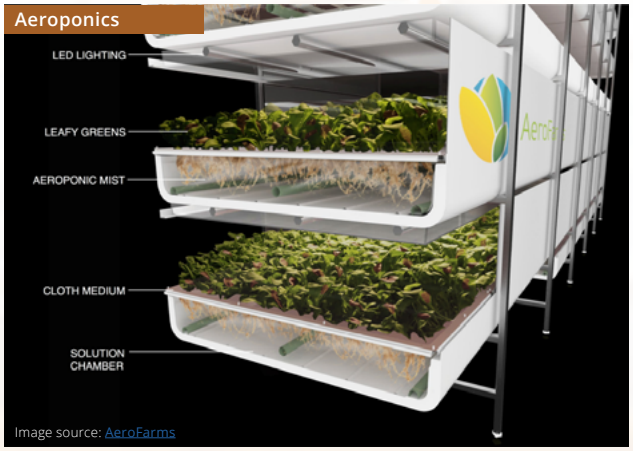


Image source: AeroFarms

Synthetic Soil

Scientists from the Centre for Interdisciplinary Research in Space (CIRIS) have teamed up with researchers from France and Italy to create an artificial soil for plant growth. They are looking into creating an environment in which plants can be grown in the difficult conditions of space including investigating how plants respond to low levels of gravity. Because there is no there is no soil in space, nor is there soil as we know it on Mars or the moon, they had to develop something to grow the plants. They came up with a high-tech planter filled with an artificial soil composed of lava rock. They have successfully used this technology to grow food and hope that it can be used on long distance space flights to feed the astronauts, as a step towards food security if another planet is colonized, and/or to help raise crop productivity in areas with poor soil here on Earth.

Hydroponics



Image source: Facebook

Lab Grown Meat

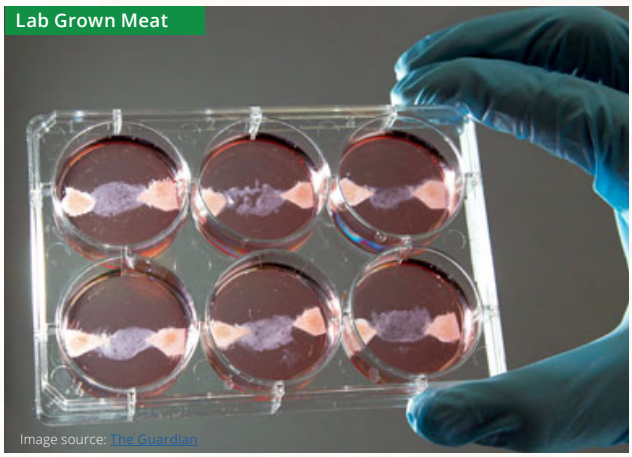


Image source: The Guardian

Synthetic Soil



Image source: Nick Arrillaga

FLOATING DEEP FARMS THAT CAN SOLVE **FOOD PRODUCTION** AGAINST **SEA LEVEL RISE**

Professor Saffa Riffat

University of Nottingham academics Professors Saffa Riffat (President of the World Society of Sustainable Technologies and Fellow of the European Academy of Sciences) and Yijun Yuan (EU Marie Curie Fellow have come up with breakthrough/ patented technologies to allow intensive food production in seas, coastal areas and rivers.



Feeding the projected 2050 world population of about 9 billion people in will require global food production to be increased by some 70% between now and then. But current land-based systems for food production cannot meet this extra demand. The problem is exacerbated by rising sea levels caused by climate change. Land area reduction due to inundation and coastal erosion will have a major impact on the availability of agriculture land for food production with small islands being especially vulnerable.

To use less land, farms could be spread vertically rather than horizontally. This 'Vertical Farms' approach, uses multi-layer greenhouses or skyscraper towers to intensify food production. With a controlled climate involving LED lighting and a closely monitored water/nutrient supply, these farms can produce multiple crops and high yields.

But there is an option.

Marine agriculture has already been explored to ensure future food security. Ocean Reef Group, USA proposed growing plants in pods (biospheres – each of which can hold around 22 plant pots) on the seabed. The project is interesting but is not viable for a large scale food production.

A fisherman, Bren Smith has developed a vertical ocean farm which uses a water column to grow a variety of species such as sugar kelp, oysters, mussels and scallops. Indeed, some countries (e.g. China and Thailand) have been practicing aquaculture for many years. In the UK salmon from fish farms is already a staple of our diet. In fact, recently aquaculture surpassed wild fishing as the primary source of protein from the ocean. However, the type of farms are not suitable for crop production. Farmers in Bangladesh survive the monsoon using an ancient technique of building floating farms that rise and fall with swelling waters.

Turning to the seas could be one solution for crop production to ensuring the human population is adequately fed in the coming decades. A breakthrough has been made by University of Nottingham academics Professors Saffa Riffat (President of the World Society of Sustainable Technologies) and Yijun Yuan (EU Marie Curie Fellow), who filed 5 patent applications in November/December 2018 claiming novel cultivation technology based on using Deep Farms in land, seawater and rivers.

Professor Riffat said 'We really have new breakthrough technologies in food production in land and sea'.

Floating Deep Farms use large vertical shafts submerged in sea water near coastal areas. The shaft is sealed at the bottom end and is covered by a dome. A variety of crops can be grown using hydroponic planters (plant roots fed with nutrient-rich water) or aeroponics (growing plants in an air or mist environment). LED units providing illumination at appropriate wavelengths to maximise photosynthesis with minimum power input replacing sunlight. A major benefit is that crop production is largely unaffected by climatic or seasonal factors - one of the greatest limitations of conventional farming methods. Furthermore, enclosed Floating Deep Farms allow plant diseases and pests to be readily controlled with little or no application of chemical biocides.

The engineering knowhow to build marine vertical shafts is already available from the off-shore oil/gas and wind energy industries. Indeed, Floating Deep Farms could be integrated with wind turbines to power the LED lighting and other systems necessary for crop production. Such installations could would not be subject to seasonal light variation, continuing in production throughout the year. Unlike present off-shore "wind farms" supplying renewable energy, Floating Deep Farms could be sited in deep water far from the coast since their locations would not be limited by power cables. Crops could be delivered to land by electrically powered ships charged by wind energy. It is also tempting to suggest that Floating Deep Farm installations might also have a secondary function of capturing discarded plastic.

Tide and wave energy could also be used for powering Floating Deep Farms. Obviously, these would inshore. Tidal power might be preferable to PV, especially because they can be available day and night. Would integrated Deep Farms change the economics of barrages such as those proposed for the Severn Estuary?

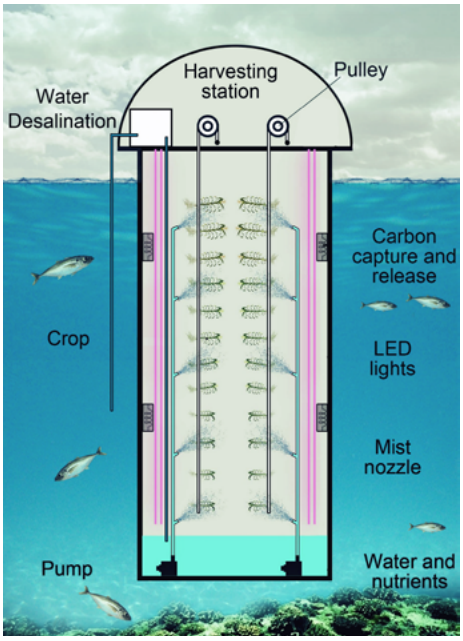
Floating Deep Farm could be combined with towers which could be used for housing or offices. Such integration could be used in coastal areas.

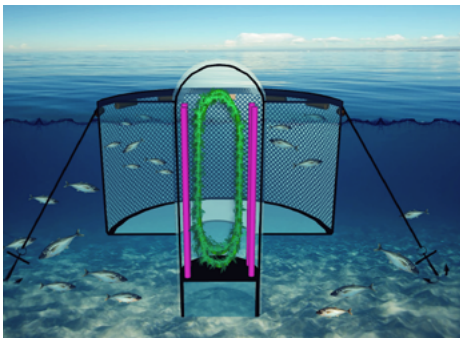
About 70% of the earth is covered with seawater. The fresh water required by the Floating Deep Farm can be created through a simple seawater evaporation desalination unit driven by a combination of solar energy and waste heat from LED lights. It is anticipated that much of the fresh water will be recycled, so, after initial charging, only a limited quantity of "make-up" water will be required. The quantity of water required will be reduced by 80% compared to conventional land-based agriculture.



ABOVE:
Floating Deep Farms at the coastal area of a megacity

BELOW:
Floating Deep Farm concept





ABOVE:
Floating Deep Farm combined with aquaculture

Unlike conventional greenhouses and vertical farms, which rely heavily on heating and cooling systems to regulate the temperature, the submersion of the Deep Farm into seawater offers a stable temperature throughout the year. The diurnal fluctuations in solar radiation and temperature that limits the productivity of many plants will be eliminated by the closed environment of Floating Deep Farms.

For coastal installations, various aesthetic design approaches could be used to make Floating Deep Farms blend with the surrounding environment and also to avoid any impact on communities which are often rely on fish for food and as a source of income. The Floating Deep Farm can also be designed to incorporate an aquaculture for fish and other species (e.g., scallops and mussels). This will allow oxygen generated by the plants to be fed directly into the fish section of Floating Deep Farm. Obviously structures would need to withstand extreme weather, but offshore wind turbine technology has already addressed these problems.

Eighteen of the word's megacities (population of about 350 million) which are located along the coastal areas could use Floating Deep Farms to supply fresh crops instead of using frozen food transported by refrigerated trailers. This will help to reduce expensive carbon miles caused by mass food importation and therefore minimise the world's overall carbon footprint.

Professor Riffat says 'Floating Deep Farms would address food shortage in developing and third world countries with coastal areas '.

Floating Deep Farms will allow crop production all year-round. Up to 10 crop cycles per year can be achieved compared to 1-2 cycles for conventional agriculture. One small Deep Farm can produce around 80 tonnes of food per annum and crops can be ready for harvesting within 3-4 weeks of propagation. Floating Deep Farms will have lower energy requirements than traditional vertical farms. A single Deep Farm will have about the same consumption as three UK homes using innovative LED illumination and controls combined with natural lighting using light rods or optical fibres. The carbon dioxide demand of photosynthesising plants can be captured from ambient air using materials such as activated carbon.

Floating Deep Farms can be used to grow a range of vegetable and herb crops including lettuce, kale, spinach, basil, carrots, onions, cucumbers, and different types of mushrooms. The crop planting and harvesting could be carried at the top of the Floating Deep Farm using simple belts (or baskets) and pulley arrangements but robots may also be employed. To harvest the crops the belt with plants would be pulled up, avoiding the manual work required in the shaft.

Professor Riffat said 'We have come up with solutions to address food production in countries which are vulnerable to sea level rise caused by climate change'.

For more information please contact Prof Saffa Riffat:

Professor Saffa Riffat
Fellow of the European Academy of Sciences
President of the World Society of Sustainable Energy Technologies
University of Nottingham
Nottingham, NG7 2RD
UK

Email: saffa.riffat@nottingham.ac.uk
Telephone: +44-115-748 4479



PATHWAYS TO SOIL & FOOD SECURITY

FROM THE SOIL TO STOMACH TO THE SOUL

Christopher Cooke
Image source: All Things Connect

A new form of human thinking is shining fresh light on the means by which we produce food and fibre, whilst stimulating the recovery and regeneration of soil. This article highlights that a more holistic perspective can release certain hope in an uncertain world.

Why this Article?

Regenerative soil and quality food are fundamental to human wellness and wellbeing.

To achieve security, I suggest that we have a third fundamental dynamic to consider, that of meaningful human engagement.

The opportunity exists to upgrade our decision making and practices, to coexist in alignment with the complex adaptive processes of nature that extend from the soil to the stomach to the soul. To do so requires the utilisation of a latent way of thinking that inspires holistically informed engagement.

This article is for those who wish to learn how to shine a light on a new way forward, as an essential and inspiring next step, towards a fulfilling life, a viable human species, and viable planet.

Set your state, now, into a celebration of human creative-evolution, and our species' ability to wake-up, and grow-up, as challenging life-conditions demand.

Can we cope?

"The Earth is in a death spiral. It will take radical action to save us". George Monbiot's headline captured my attention. His article *(14th November 2018)* included reference to a recent challenge from a young woman. George and a colleague had questioned the realism of the assembled audiences' desire to reduce UK carbon emissions to net zero by 2025. *"What is it that you are asking me as a 20-year-old to face and to accept about my future and my life?... this is an emergency. We are facing extinction. When you ask questions like that, what is it you want me to feel?"* To this challenge George reports that he and his fellow journalist had no response.

It seems that the silent voice of our fragile Earth is finally becoming expressed in human voice. It seems appropriate for George to seek realism. It seems appropriate for the young woman is to seek survival. There is space for new thinking with no response.

The hard truth is that we are in the late stages of our conventional paradigm's inability to cope! It is a time of instability, and apparently conflicting truths, and if we are honest, a time of *we just don't know.*

A new, more complexity aware truth, has arisen through voices such as Einstein's. He warned us long ago that we cannot solve the problems of the present paradigm, with the same thinking that created the problems in the first place.

A new way forward requires fresh thinking!

Humanity has already demonstrated its ability to creatively evolve to survive and thrive over the long run of time. This is despite radical changes in climate, soil degradation, overhunting, overfishing, energy crises, deforestation and habitat destruction, conflict and war, revolutions, and civil wars.

Additionally, history is littered with civilisation's that have disappeared because they dogmatically clung to what they believed to be true. Paradoxically they were all, by today's standards, organic!

By some means enough people survived on the edges. There were always other lands, or unadulterated space, still available. They survived because they were able to think and act differently. Earth's ecosystem processes could sustain their new lifestyle until they, in many cases, created their own next survival problem!

The so-called Anthropocene, with its mechanistic and technological certainty in dominating nature, is an expression of a way of thinking, or worldview, that has led the way since the late 19th century. Despite its many achievements, it is the worldview that has discounted and dominated nature in the headlong, growth based quest, for the good life. This time there are no other lands or unadulterated spaces on Earth.

Perhaps the new space we are seeking is a bigger thinking space. Given the historic patterns of the emergence of new thinking, what larger psychological space lies beyond the thinking that led to the Anthropocene?

A new worldview is waiting to be born.

Authors such as William Morris (1869), Rachel Carson (1960), Arthur Young (1976), Buckminster Fuller (1978), Ken Wilber (1974), M Scott Peck (1993), James Lovelock (2014), and Jordan Peterson (2018), amongst many others, have been sending us insights about new ways and means for over a hundred and fifty years.

They have been offering fresh perspectives of how we can relate to self and each other, in new ways, enjoy an abundance of natural resources, and define a new 'unifying' quality of life. They offer stuff that works!

What this tells us is that, if we know where to look and for what, new thinking has quietly been emerging on the edges.

New thinking that may actually engage us in new more meaningful ways and equip us to handle the present situation.

Now this is big news!

The change in thinking has already happened!

Integral Psychology provides impeccable insight into the waves of development of human nature that have emerged over the past 120,000 years.

It provides an integral or whole-view perspective through which we can differentiate between pre-conventional, conventional, and later, worldviews.

One of the earliest signs of holistic thinking emerged in 1926, when Jan Smuts published his foundational text 'Holism and Evolution'. In it was a section on Einstein's *Theory of Relativity*. When reviewed by Einstein, he commented that Smuts was one of only a handful of people in the world who truly understood.

The immense respect Jan Smuts carried internationally seemed to prevent any heretical challenges. Indeed, he was sought by students and academics alike to become the rector of The University of St Andrews (1931-1934), and the President of the British Association for the Advancement of Science (1930 -1931). His writings have supported many individuals as they struggled to utilize, their innate yet latent 'holistic' appreciation of science, society, ecology, spirituality, and self. Simply put, from a holistic perspective, the science of Holism appreciates that nature functions in wholes.

From the late 1970's, 'holistically oriented' mappings, of the previously invisible megatrend of the worldviews of humanity, emerged. It took time, and a radical shift in thinking by the primary researcher Clare W Graves (The Graves Technology - 1978)[4], for these emergent patterns to be observed, mapped, validated, and practical applications tested.

The following table is derived from this original mapping of the attributes of each worldview. Given our interest in soil and food security, the table summarises how each worldview organises socially to obtain food and fibre. The right-hand column offers an emotional and values-based signature of an 'inability to cope.' This inability to cope has been shown to trigger a ratcheting to a new coping means, the next *Wave* or *Stage*, that handles the new needs. Each transition, or emergence offers a new expression of individual personality, and collective culture. Research has shown that the transition from wave 6 to 7 is a major leap, with a new capacity to handle complexity that is greater than the total capacity of the 1st six waves.



Image source: Australian Raw Milk Movement

Table 1 - The Wave Table - A Flow of Emergent Worldview Attributes: The common name; motivational theme; mode of decision making; time of 1st signs; the social means to obtain food and fibre; the emotional and values signature that signals an inability, of that worldview, to cope.

Worldview Common Name / 'Motivational Theme' / 'Mode of Decision Making'	1st Signs	The social means to obtain food and fibre	Signature of an inability to cope
Wave 1: SurvivalSENSE / Physiological & Instinct Driven / An instinctual way	Ξ 120,000 years	Foraging Clans	"Fear" Safety needed.
Wave 2: TribalBOND / Assurance & Safety Driven / Our ancestors' way	Ξ 40,000 years	Foraging Tribe / Hunter	"Anger" Individual power exerted.
Wave 3: Impulse POWER / Survival & Power Driven / My way or the highway	Ξ 10,000 years	Organised Hunt / Horticultural Village	"Guilt" Salvation needed.
Wave 4: TruthFORCE / Security & Order Driven / The one Right way	Ξ 5,000 years	Agriculture	"Frustration" Independence exerted.
Wave 5: StriveDRIVE / Independence & Success Driven / The best way	Ξ 800 years	Industrial Agriculture	"Loneliness" Community needed.
Wave 6: HumanEQUITY Affiliation & Equality Driven / Our consensual way	Ξ 150 years	Preservation of Nature / Conservational / Organic	"Stuckness" Acceptance integrates.
Wave 7: SystemicFLOW / Magnificence of Existence & Life's Continuation on Earth Oriented / Holistically informed, tests and monitors all decisions against ecosystem process function.	Ξ 120 years	Enhanced Effectiveness of Ecosystem Processes / Regenerative	"Confusion" The continuation of life on earth requires other like minds.
Wave 8: HolisticBEING / Synthesis & Communion Oriented / Holistically informed, tests and monitors all decisions against ecosystem process function.	Ξ 100 years	Global Restorational / Global Regenerative / Holistic	"?" Not yet mapped.

We can use the 'Wave Table' of worldview attributes to have a shorthand conversation about the root cause of our situation.

- Wave 5 thinking is now in its lifecycle peak which dominates nature through its primary means 'scientism';
- Wave 6 thinking with its dominant 'egalitarian' means, carries an innate rejection of any suggestion of hierarchy, and has been trying to fix:
  - the apparent servitude of Wave 2 thinking;
  - the apparent aggressiveness of Wave 3 thinking;
  - the apparent depersonalisation of Wave 4 thinking;
  - the apparent 'Rat Race' of Wave 5 thinking.

Note: *Wave 6 thinking is captured most eloquently by Daniel Quinn in his short story Sinking Ship*[5].

- The thinking that can handle the present complexity and nurture all life including the continued development of Waves 1 through 6, is an innate capacity of Wave 8.
- It is postulated (Clare W Graves – 1978) that as a species we have the innate capacity to develop between 18-24 waves / stages of development.

In a few short sentences we have a triggered a more comprehensive awareness of the present situation. It becomes abundantly clear that holistically oriented decision making is essential.

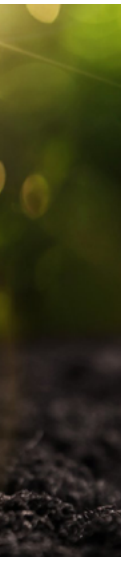
So how does this help us grow corn?

As we grow to understand that the mode and manner in which we provide food and fibre stems from our perspective or worldview, and that each worldview has a different drive or orientation, and that until the 7th wave there is little consideration of the ecological processes that sustain all life on Earth.

The postulates that naturally arise for soil and food security are profound:

- **Soil:** to achieve fully regenerative soil it is best appreciated, and worked with, from a holistic stance.
- **Food security:** is only truly possible when our ecosystem process functions are effective and our social policies encourage the adoption of holistic principles and practices.
- **Human Engagement:** is a state achieved when our particular worldview generated values are being exercised.
- **Human Engagement:** is a complex dynamic flow of states and transitions where an inability to cope may well be the pathway to a new way of thinking.

Simply put, a holistically informed approach to soil and food security, AND human engagement, is an imperative.



So where is a holistic practice we can follow?

In his book, Holistic Management[6], Allan Savory writes that he initially discarded the work of Jan Smuts as being too dated. Yet in the late1960's he found it essential to help him grow a deep appreciation of the holistic worldview: *"Finally, I read Smuts [Jan Smuts 1926] and realized wherein the holistic worldview differed from everything prior. It became obvious to me that not only are there no parts in nature, there are no boundaries either. "*

Today, many agricultural and conservation practitioners, horticulturalists, authors, and soil scientists have been influenced by Allan Savory. Individuals such as Gabe Brown, Judy Schwartz, Walter Jehne, Dr Christine Jones, Joel Salatin, and others, are demonstrating the significant social, economic and ecological benefits through the adoption of holistically informed practices in agriculture. They offer, and deliver, stuff that works and outperforms the present paradigm.

Allan Savory's contribution is often perceived by many to be solely focused on holistic planned grazing, and the reversal of desertification in arid lands.

In fact, at the core of his work lies the Holistic Decision-Making Framework which is applicable to all social contexts and the management of all habitats from tropical rain forest to desert.

In all my searching for holistically informed practice, I believe that it is the first reliable and valid decision-making framework that equips us all to test decisions holistically; it does so by continually raising our awareness, in design, decision making and practice, of how to enhance ecosystem processes that sustain all life.

The overall Holistic Management practice advocated by Allan Savory, actually stimulates the release of latent holistic thinking in the user. "Thank God, I'm not going crazy" was a recent comment from a Welsh farmer who at last found his different way of thinking legitimised, and a new outlet for his passion for farming.

Holistically informed decision making, science, and policy making has vast potential across all aspects of society.

What's next?

To be truly serious about soil and food security, the premise of this article is that a holistically informed practice is essential.

To the aspiring, holistically informed practitioner, I then offer these suggestions:

1. Take some time to explore the emergence of the holistic worldview. The book Holistic Management[7] is a good place to start. A Theory of Everything[8] by Ken Wilber is also a worthy read.
2. Use 'The Wave Table' in this article to consider the 'worldview' behind any theory, practice, tool or methods that you come across or consider using.
3. Surround yourself with Wave 7 and 8 thinking to stimulate your appreciation of the essential processes and principles of nature.
4. Use Wave 7 and 8 thinking to choose the appropriate the tools of Wave 1,2,3,4,5,6 thinkers, and witness the emergence of new, elegantly simple practices, that are the hallmark of Waves 7 and 8 thinking.

Finally, should you wish to learn more please contact me by visiting our website www.3lm.network

Christopher Cooke heads up the strategic advisory services for 3LM, the Savory Network hub (2016 to date) for the British Isles. www.3lm.network

Christopher is an accomplished thought leader, senior manager, and engineer. He was involved in the privatisation of the UK and International Water Industry (1983-1997). In addition to advanced technical and engineering roles he became curious about how complexity-aware thinking could lead to radical improvement in biological, business, and social processes.

Since 1997 he has led an international 'bio-psycho-cultural-social systems' informed practice known as 5 Deep. 5 Deep has contributed to the novel handling of wicked problems in agriculture, health-caring, business, and social development issues, such as were found in the 30-year drought in Australia (1986-2010) when conventional farming failed, and a more biological agriculture thrived.

(Endnotes)

1. George Monbiot: https://www.theguardian.com/commentisfree/2018/nov/14/earth-death-spiral-radical-action-climate-breakdown?CMP=share_btn_fb&fbclid=IwAR1IiFzlZryCeqhQ2hmMetmxxD1DdbrYRSi1xwwr5PqNdeUu-AipHJMkvRc
2. A body of knowledge that has arisen since the early primary research of Clare W Graves. The Book - Spiral Dynamics (Beck and Cowan) 1996, emerged from the work of Clare W Graves. The book Integral Psychology was published by Ken Wilber in 2000.
3. http://www.stellenboschwriters.com/smutsjan.html
4. https://www.goodreads.com/book/show/6780869-the-never-ending-quest
5. http://ishmael.org/Education/Parables/SinkingShip.cfm
6. https://www.amazon.co.uk/Holistic-Management-Commonsense-Revolution-Environment/dp/161091743X
7. https://www.amazon.co.uk/Holistic-Management-Commonsense-Revolution-Environment/dp/161091743X
8. https://www.amazon.co.uk/Theory-Everything-Integral-Business-Spirituality/dp/1570628556



the living soil

Prince Adewale Ogunmodede
Image source: **Shutterstock**

Some facts to help understand why soil is important:

1 Soil is a network of interacting living organisms within the Earth's surface layer which support life above ground.

2 The nutritional value of the food we eat is directly related to the health of the soil in which it grows.

3 Management of agricultural soils should consider the structural, biological and mineral health of the soil (not just N, P, K) to produce nutritionally-dense food.

4 Soil has varying amounts of organic matter (living and dead organisms), minerals, and nutrients.

5 An average soil sample is 45% minerals, 25% air, and 5% organic matter (less in degraded soils).

6 Carbon is a master variable within the soil that controls many processes, such as development of soil structure, water storage and nutrient cycling.

7 Soil high in organic carbon content enables better rainfall infiltration & retention, providing greater resilience to drought.

8 Every gram of soil organic carbon can hold up to 8 grams of water.

9 Soils are vulnerable to carbon loss through degradation, but regenerative land management practices can build soil and restore soil health.

10 Soil erosion within conventional agricultural practices can occur at rates up to 100 times greater than the rate of natural soil formation.

11 Natural processes can take more than 500 years to form 2cm of topsoil.

12 Soil carbon takes three distinct forms: living carbon, labile carbon and fixed carbon.

- Living carbon takes the form of microbes, fungi, plant roots, nematodes, earth worms etc.
- Labile carbon in the soil is comprised of decomposing (dead) plant and animal material that is in a state of transition.
- Fixed carbon in the soil consists of stable compounds as humates and glomalins.

13 Sequestered carbon comprises the fixed carbon plus the total living biomass.

14 Soil stores 10% of the world's carbon dioxide emissions.

15 Around 95% of our food is directly or indirectly produced in our soils.

16 Microbial activity controls and manipulates the chemistry of the soil, not the other way around.

17 Soil microbes have a symbiotic relationship with plants: plants provide sugars to microbes and microbes make nutrients bio-available for plants.

18 Living organisms in soil ultimately control water infiltration, mineral density and nutrient cycling.

19 Fungi and bacteria help break down organic matter in the soil and earthworms digest organic matter, recycle nutrients, and make the surface soil richer.

20 In a handful of fertile soil, there are more individual organisms than the total number of human beings that have ever existed.

21 Soil is one of the most complex biological materials on our planet.

22 Soil is home to a quarter of all known species on Earth.

23 In just one tablespoon of soil, you'll find more than seven billon organisms – that's more than the amount of people on the planet!

FEED THE SOIL, not the plant

https://www.soilassociation.org/blogs/2018/june/14/14-things-you-might-not-know-about-soil/





Philip Hudson, *Lecturer at RAU*

Q ***What is the most important aspect of food security?***

That it's complicated! And by that I mean that we should be careful of looking at food security as though it is just a simple issue of just having enough to eat. That's important of course but it's also what we eat, how we eat, the impact of what we eat and where we eat that needs to be taken into consideration in deciding the policy measures that we put in place. So I'd say that the most important aspect of food security is that there isn't a one-size fits all answer.

Q ***What is the first thing you would do to help the soil?***

I'm no expert on soils but it seems to me that soil is the 'workhorse' of the global food system and yet it seems to go unrecognised; certainly from an international institution perspective. Take, for example, the United Nations 17 sustainable development goals which cover a huge range of very important issues including ending poverty, eliminating hunger, protecting the planet and ensuring peace and prosperity. The management and preservation of soils is inherent to achieving those goals and yet the word "soils" is never used. So, my first thing to help the soil would be to get it the international recognition it deserves in ensuring that we as humans are able to secure the goals we are aiming for.

Q ***Will GMO feed the world?***

I don't accept the premise of this question because it implies a one size fits all solution to the problem of ensuring that we have enough food to feed our growing population. I'm clear that the use of GMO technology does have a part to play in helping us (humans) to feed ourselves but it's only a piece of a complicated jigsaw puzzle of solutions that we need to adopt if we're going to achieve that goal.

The risk I think of taking the GMO's is the only answer to feeding the world approach is that we ignore other aspects of food production that also contribute solutions to growing more food sustainably and that I think would be a mistake.

John Conway, *Lecturer at RAU*

Q ***Your best suggestion to help the reader to contribute for soil for food security?***

My best advice would be to remember that line from the Bible.

All go to one place: All come from dust, and all return to dust.

"By the sweat of your brow you will eat your bread, until you return to the ground--because out of it were you taken. For dust you are, and to dust you shall return."

And ensure that everything that comes from "dust" [i.e. soil] is returned to the soil; recycle all organic matter to feed the soil microbes so that they may feed us.

Image source: Shutterstock





SOIL SECURITY IS FOOD SECURITY

Oladokun Samson Abiodun
Image source: European Commission

The United Nations predicts the need to double world food production in order to meet with an increasing human population, expected to be about 9.8 billion in 2050. There has never been a better time for Africa's most populous nation, and indeed the world, to manage wisely the home of its food: the soil.



McBratney (2015), affirms that approximately 95% of the world's food comes from soils. Soils have often been viewed as a static homogenous medium that supports crop production; they are actually finite non-renewable resources that provide immense ecosystem services-provision of food and raw materials, regulation of air, water and nutrients, support and cultural use (Brady and Weil, 2008). The ability of the soil to meet the global goal of food security is determined by how well it is sustainably managed.

There exist visible signs of food insecurity in Nigeria, despite a huge population size and arable landmass. Soils in most parts of Nigeria have inherently low fertility and do not receive adequate nutrient replenishment (FAO, 2015). This is attributable to the interacting effects of the indicators of soil quality, which have been visibly stretched to limits by poor management systems. The problem of soil degradation has become endemic, as farmers often over-plough the soil, denying the soil fallow periods needed to regenerate. The over-exploitation of primary agriculture-focused lands in Nigeria have currently caused challenges in soil compaction, nutrient loss, decline in organic matter, erosion, and loss of biological diversity. Nigeria's soil quality challenge seems to exhibit some geographical peculiarities, as soil erosion is often experienced in the Coastal and marine states of Ogun, Ondo, Delta, Rivers, Bayelsa, Akwa Ibom and Cross River States, while the northern states experience salinization. Salinity surveys of irrigated schemes in the northern Nigeria have shown that certain soils in Borno, Gongola, Kano and Sokoto states vary from non- saline to moderately saline (FAO 2015). A solution to this would be the application of fresh water to such soils to get rid of the saline deposits. The soils of south-western states are frequently exposed by the activities of uncontrolled logging, tree-felling and rampant bush burning. This increases the leaching susceptibility of these soils. The acidification and contamination of the soils in the oil rich Niger-delta region by oil spills have been a subject of national concern. Indeed, the poor management of the soil across the different Nigerian states has led to soil crises and, as you expect, a soil crisis means a food crisis (Miles, 1990). Indicators like soil texture, structure, hydraulic properties, drainage properties, soil organic carbon and biological diversity are crucial to accessing how well the soils can meet the food needs of humans. While many view soil quality in terms of fertility (N, P and K supply), the efficiency of the soil function depends largely on the interacting effects of these indicators.

The solutions to ensuring soils security are not far-fetched, they lie in the cultural approaches of farrowing, crop rotation, mulching, reduced or zero tillage, alongside sophisticated interventions like fertilizer application, crop breeding, nutrient recycling and fixation. This is a clarion call to all and sundry to take conscious effort in preserving the sanctity of our soils, as Lal (2009) suggests that properly managed West African soils have the capacity to grow adequate and nutritious food for present and future populations. Soils proffer more than food security; they ensure "life security" by continuously serving as sinks that sequestrate the carbon emissions that industrialization and lifestyle choices have put on the environment. I join Nigeria's former president, Olusegun Obasanjo, in pleading that "Our only quest should be to nourish Africa's soils and feed the continent".

Oladokun Samson Abiodun is a Chevening Scholar studying Sustainable Agriculture and Food Security at Newcastle University.

REFERENCES

Food and Agricultural Organization (FAO, 2015). Status and Challenges of Soil Management in Nigeria -Global soil partnership.

https://www.nature.com/news/2006/060331/full/news060327-15.html. Accessed on- 30th October, 2018.

Lal, R. (2009) Ten tenets of sustainable soil management. Journal of Soil Water Conservation. 64(1):20A- 21A

McBratney, A. (2015). Soil and Food Security. IUSS Deputy Secretary General 2010-2014 The University of Sydney. Biomedical Building,1 Central Avenue, Australian Technology Park, Eveleigh, NSW 2015.

Miles, L. (1990). For people and planet. The earthscan action handbook. London. Earthscan publication p12.

Weil, R.R and Brady, N.C. (2016). The Nature and Properties of Soil: Essex Pearson Education, 15th edition, 20.

will the agriculture bill save our soil?

Vicki Hird, Sustain

Image source: **Shutterstock**

There are so many good reasons to protect, nurture and enhance all our soils across the UK – from ensuring food security, to helping climate mitigation. But is that recognised in new legislation and new policy in Defra and if not why not? How can we make sure there is a solid policy and support going forward?

Why save our soils?

It has been encouraging to see far more focus on soils in the past few years. Farmers are far more engaged in soil discussions than ever before and even at a political level there is strong support for more action on soils. It comes from the recognition that we are facing a crisis but also that soils are a huge asset. They are valuable and increasingly that value is being recognised.

It is worth looking at a few worrying facts about UK soils[1]

- English farmers are losing valuable resources through diffuse pollution. 235,000 tonnes of nitrogen and 8,391 tonnes of phosphorus are lost every year that would otherwise help sustain farming.
- The annual costs of soil degradation in England and Wales are between £0.9 and £1.4 billion, with a central estimate of £1.2 bn. These costs are mainly linked to loss of organic content of soils (47% of total cost), compaction (39%) and erosion (12%).
- The contribution of damaged soils to flooding events is estimated to be £233m per year.
- The UK has lost 84% of its fertile topsoil since 1850, with the erosion continuing at a rate of 1cm to 3cm a year.
- Around 300,000 hectares of UK soil are thought to be contaminated with toxic elements, such as cadmium, arsenic and lead.

It is about everything

There are many good quotes about why we need to protect soils for the future of humanity but Franklin D Roosevelt's is a favourite: "A nation that destroys its soil, destroys itself". We need to protect the soil, not only to ensure we can continue to secure the majority of our food supply, but also to ensure other life on Earth can too. We need these other life forms rather badly in order to regulate water, climate, nutrients, nurture wellbeing and so on. Add to that the carbon sequestration capacity of many soils and the flood control and it is easy to see it is 'about everything'.

It may be possible to carry on as we are and use artificial inputs to maintain functional soils or even develop artificial soil-free growing schemes for some years. But unless we tackle the huge systemic issues in land use, from the dysfunctional nutrient cycles including nitrogen and phosphorous, to vast loss and waste of food, and the inefficiency of feeding grain to industrial scale livestock systems instead of directly to humans, climate impacts and so on, we will find ourselves very soon with a food availability crisis as the limits of soil and land are reached.

Globally this requires intergovernmental action with incentives and penalties for inaction to protect soils globally and where countries or companies have been responsible historically there need to be compensation or reparation agreements so that countries least able to protect their soils (due to previous resource extraction or colonial actions) are given a fair level of support. Action on unsustainable consumption of products that derive directly or indirectly from soil is also key and also very hard. But we need to start now.

In the UK, the Soil Association has worked for many years to protect soils via better practices which are now being adopted by many conventional farmers. Sustainable Soils alliance is asking for 8 key things to protect soils including a long terms strategy,



incentives, measurement and monitoring. It also quite rightly sees education and training for land managers and collaboration as key. But does policy development follow suit?

What's in the agriculture Bill?

Sustain welcomed the arrival of the new Agriculture Bill. It has been more than half a century since we had one and it contains valuable new approaches to integrating support for farmers with 'public good' outcomes. But it needs strengthening. In a 10 point article we explore how the Bill delivers or fails currently on areas such as protecting livelihoods, the environment, health and nature.

After years of neglect (as our agriculture policy was led by Europe) it was encouraging to see the level of parliamentary interventions around the issue of public health and agriculture. MPs including Kerry McCarthy MP and Helen Whately MP suggested that this should be a core purpose of the Bill (we agree) and specific measures, for instance to support fruit and vegetable production and livestock systems which reduce antibiotic use (and banning imports of products where excessive use has been made), are needed. There was strong support for a new emphasis on protecting biodiversity and ecosystems like soil and water and to tackle climate change and enhance animal welfare. But the Bill itself does not mention soil...

Sustain believes that the role of future agriculture policy should be to ensure a prosperous, resilient and sustainable farming system that provides healthy, safe food grown to high standards of animal welfare, environment and nature protection. Farming must also be able to provide the diverse foods we need, as well as good livelihoods and decent safe employment, supported by fair market prices and trading practices. That all depends on a high level of soil protection and enhancement.

Achieving this requires legal duties to deliver an integrated policy, a sufficient budget and a strong regulatory baseline, with incentives for farmers and land managers to make the transition to better practices where the market will not pay and new training, advice and research provision. It also requires government to identify and support better food and farming as a priority and to redefine productivity to deliver on wider objectives. Enhancing soil as an input could be included. We have previously circulated our agreed and endorsed paper 'Beyond 2020 New Farm Policy'. This outlined a new set of principles and a policy framework to deliver a new sustainable and viable future for UK farming.

But what we have now is a new Agriculture Bill that says much but in terms of definite action is all about transferring existing EU frameworks. Soil is not one of them. Other useful purposes exist merely as 'enabling powers' rather than duties, at the whim of a Secretary of State and the Treasury. It has no targets and no long term budget. It is clear this will only change if there is huge opposition pressure. When one MP proposed an amendment on soils the response from the Minister was that was covered by a reference to land. Is that good enough for something so fundamental?

Sustain supports much of the Bill as it focusses far better on delivering public benefits than the old system. But it is a missed opportunity to set out, in legislation, a new vision for farming policy in the UK alongside national strategies which can be understood in terms of real outcomes. The purpose should be amended to include explicit reference to farmers being supported to deliver environment, animal welfare and public health goals up front and duties rather than powers should ensure the financial support. Regulation of the market – the fair dealing - needs to be a duty, not a power and needs to take all sectors under the protection of new statutory codes.



ABOUT EVERYTHING

We need these other life forms rather badly in order to regulate water, climate, nutrients, nurture wellbeing and so on. Add to that the carbon sequestration capacity of many soils and the flood control and it is easy to see it is 'about everything'.

LEFT:
Soil sampling- dung being drawn down



Gaining climate goals via the soil

UK soils store over 10 billion tonnes of carbon in the form of organic matter. Over half of the UK's soil carbon store is contained in peat soils.

Of Wales' peat-lands, only 30% of the area is thought to be in good condition. Around 80% of Northern Ireland's peat-lands have been degraded and need to be restored. Much more carbon storage could be delivered if farmers and land managers were given the support, guidance and training to build soil health, biology and organic matter. Each square metre is different, let alone each farm, so there needs to be a tailored, flexible but firm approach based on outcomes or prescriptions depending on the farm type. And alongside there needs to be good funding for measurement and assessment, as another US president said "that which is not inspected deteriorates."

The Climate Change Committee which provides the government with independent advice on building a low-carbon economy and preparing for climate change released two key reports recently which will have major implications for food and farming, on land use and on biofuels. *'Land use: Reducing emissions and preparing for climate change'* finds that fundamental reform is required to ensure land becomes a more effective carbon store. Baroness Brown, Chair @theCCCuk Adaptation Sub-committee said "We are very concerned that soil health and carbon sequestration is not included as a public good in the Agriculture Bill."



LEFT:
Dry soil

GAINING CLIMATE GOALS

Much more carbon storage could be delivered if farmers and land managers were given the support, guidance and training to build soil health, biology and organic matter. Each square metre is different, let alone each farm, so there needs to be a tailored, flexible but firm approach based on outcomes or prescriptions depending on the farm type. And alongside there needs to be good funding for measurement and assessment, as another US president said "that which is not inspected deteriorates."

THE BILL

It has been more than half a century since we had one and it contains valuable new approaches to integrating support for farmers with 'public good' outcomes. But it needs strengthening.

LEFT:
Clover-rich grass

Sustain is keen to ensure that sustainability issues as a whole are integrated into land use, farming and food policy, to ensure that the new public and policy attention on carbon does not result in inadvertent damage to the environment or health, by other means, or in adoption of unethical practices. So there is a huge own goal in terms of climate mitigation if we fail to deliver better soil health and carbon sequestration through this Bill but it needs to be part of a holistic approach to food, farming and land.

This is one of the most important pieces of legislation before the House and as such the public should be aware and involved via their representatives. Farming not only produces the bulk of our food and provides a core material for one of our largest employers, the food industry, but it also manages 70 per cent of the land and cares for livestock and our crucial natural systems such as water, soil and landscapes. We should all be watching to make sure both roles are well managed.

References

[1] from the Sustainable Soils Alliance website https://sustainablesoils.org/facts-figures/



Sustainable Use and Management of Soil and Water

Environmental Sustainability of Soil and Water usage in Agriculture

Rebecca Barlett
Image source: Ego Pharmaceuticals

Introduction

'The Nation that destroys its soil destroys itself' (Franklin D. Roosevelt).

Arguably soil and water management within agriculture needs to be sustainable to ensure the future resource. Without continued use of soil and water there would be struggle for all living beings to survive. Therefore applying environmentally sustainable management techniques of soil and water within agriculture is essential. However, there needs to be evaluation of sustainable systems to ensure that they are truly sustainable and work towards the benefit of soil and water health whilst still using the mediums to grow and secure food resources. By assessing the current accusations against modern agricultural systems, the analysis of systems claiming to be sustainable can occur, and if they meet their label of environmentally sustainable.

Accusations

Modern day agriculture has made differences to the way soils and water resources are used. These methods of use can give rise to negative results of which only a few are considered.

1. Erosion

Accelerated by human activities such as soil disturbance e.g. ploughing, removal of vegetative soil cover/hedgerows, increased field size, overstocking, poor crop management and inappropriate use of heavy machinery in agricultural practises (European Commission, 2006). Natural soil formation is very slow, so it is viewed that soil is practically a non-renewable resource due the time scale.(European Commission, 2006). The degradation can sometimes occur rapidly when poor soil management leads to gully erosion (Kibblewhite, Ritz and Swift, 2007). The consequences of soil erosion can be: loss of soil and fertility, restrictions on land use hindering food production, reduced water retention capacity increasing flood risk and negative impacts on aquatic ecosystems and biodiversity (European Commission, 2006).

Figure 1 – Gully erosion (USDA, 2008).



2. Soil organic matter (SOM) loss

SOM is an important source of nutrients and can help increase biodiversity which provides vital ecological services such as increasing crop protection and recycling nutrients (Primentel and Burgess, 2014). Land use and management can affect the levels of SOM at different sites, in grasslands and forestry SOM will tend to accumulate, however this can be lost quickly if the soil was cultivated, disturbed or vegetation removed (Rees et al, 2011). Therefore, land management practices that cause soil disturbance such as tillage, planting, and leaving soils bare after harvest will reduce SOM.

Figure 2. Ploughing practices which reduce SOM (Gibson, 2015).



3. Eutrophication

Nitrate and phosphorus fertilisers which drain from fields and nutrients from animal wastes contribute towards the anthropogenic pollution of water systems in the form of eutrophication (European Environment Agency, 2018). With the increased load of nutrients the quality of the water decreases, and damage is done to the ecosystem and surrounding environment.

The build-up of nutrients leads to an explosion in growth of phytoplankton as well as outbreaks of cyanobacteria (Davis and Shaw, 2016). These outbreaks of cyanobacteria can cause death of livestock and wildlife and liver damage (Davis and Shaw, 2016).

By assessing the current accusations against modern agricultural systems, the analysis of systems claiming to be sustainable can occur, and if they meet their label of environmentally sustainable.

Figure 3. Eutrophication in the River Gipping, Ipswich (Chadwick, 2011).



Good Agricultural Practices

Good Agricultural Practices (GAP) are used around the world, therefore, suggestions and requirements can be unique to countries. The UK Government have their own GAP's for protecting water, soil and air and these are discussed.

The UK government suggest good practice for maintaining soil fertility is to apply fertilisers, organic manures and lime to help maximise the profitability of the farming system (DEFRA, 2009). Taking regular soil analyses as well as crop and grass analysis to confirm sulphur and trace element deficiencies will help to identify any that may be affecting crops or livestock (DEFRA, 2009).

Maintaining soil organic matter (SOM) guidance is to reduce losses, minimising cultivations and adding organic carbon by roots and other crop residues and recycling organic manures (DEFRA, 2009).

Nutrient management is highlighted as important with the recommended soil analyses occurring every 3 to 5 years to set and maintain a correct fertilizer policy (DEFRA, 2009). Ensuring the crops are getting a blanched supply of the major nutrients and if needed the trace elements, which are generally supplied by the soil but supplements with fertilizers or organic matter can be used (DEFRA, 2009).

A recognised fertiliser recommendation system along with a FACTS Qualified Adviser (Fertiliser Advisers Certification and Training Scheme) should be engaged to ensure the correct fertiliser policy is being used in the correct manner (DEFRA , 2009).

The last section on good practice for soil fertility is too take care not to harm natural and semi natural habitats, including surface waters with fertiliser by either accidentally spreading directly onto them or from surface run-off (DEFRA, 2009).

Soil management plans are recommended by DEFRA to improve the way land managers treat soils. It can include a risk map for run-off and erosion with a field by field assessment of the condition of the soil and how to manage it (DEFRA, 2009). Archaeological sites need to be protected and areas where erosion maybe occurring should be identified and the intended use of each field should match the capability of the land so to minimise the risks of harming the environment (DEFRA, 2009).

In regard to water management it is recommended an audit of water use should be carried out and changes in technology uses should be made to make water delivery systems more efficient with less leakages (DEFRA, 2009). For crop irrigation good practice should include efficient use of water e.g. considering using boom irrigation to reduce water consumption, avoiding irrigation in windy conditions, irrigating at night, early morning or late evening to reduce evaporation (DEFRA, 2009). Storage of winter water is also recommended (DEFRA, 2009).

The recycling of water is encouraged, with water used for some activities such as vegetable washing being recycled as irrigation water if deemed of good enough quality (DEFRA, 2009).

Sustainable Farming Systems

There are many farming systems claiming to be sustainable with different philosophy's towards growing, table 1 outlines only a few of these systems.

Table 1 – Sustainable systems philosophies.

System	Philosophy
Herbal Ley	Growing of grass in rotation with grain or tilled crops as a soil conservation measure (Merriam-Webster, 2018). Herbal leys involve more species of grass, legumes and herbs in a sward (Soil Association, 2016). The added species diversity could bring benefits to soil structure, drought resistance, nitrogen fixation, season round yield, and mineral and protein content, with many of the herbs and legumes having larger root systems to provide additional carbon capture and help break up soil compaction (Soil Association, 2016).
Agro-forestry	Woody perennials are deliberately used on the same land management unit as crops and/or animals in some form of spatial arrangement or temporal sequence (FAO, 2015). Is a form of multiple cropping under which three fundamental conditions are met: 1) there exist at least two plant species that interact biologically; 2) at least one of the plant species is a woody perennial, 3) at least one of the plant species is managed for forage, annual or perennial crop production (Somarriba, 1992).
Organic	Is a holistic system designed to optimize the productivity and fitness of diverse communities within the agro-ecosystem, including soil organisms, plants, livestock and people. The principal goal of organic production is to develop enterprises that are sustainable and harmonious with the environment (Martin, 2009).
Biodynamic	Views the farm as an integrated, whole, living organism. Work to nurture and harmonize all the elements of the farm, with plants and animals working together to fill complementary roles in the web of life (Biodynamic Association, 2018). The farm must be managed holistically and have both crops and animals, even if this proves not to be most efficient.
Regenerative	Farming and grazing practices that aim to reverse climate change by rebuilding soil organic matter and restoring degraded soil biodiversity resulting in both carbon drawdown and improving the water cycle (Regeneration International, 2018). It is a holistic land management practice that leverages the power of photosynthesis in plants to close the carbon cycle, and build soil health, crop resilience and nutrient density (Regenerative Agriculture Initiative and The Carbon Underground, 2017)
Conservation agriculture	Promotes maintenance of a permanent soil cover, minimum soil disturbance using no tillage and direct seed and/or fertiliser placement and diversification of plant species. Permanent soil organic cover (at least 30%) with either crop residues or cover crops. Species diversification is also needed through varied crop sequences and involving at least 3 different crops (FAO, 2018).

Pontbren Project using Agroforestry

A group of 10 neighbouring farms in Powys covering 1,000ha led an innovative approach to using woodland management and tree planting to improve the efficiency of upland livestock farming (Woodland Trust et al, 2013).

This planting of trees has helped combat the increase of flood runoff which had been noted over the last decades. Results showed that careful placement of these trees helped reduce magnitudes of flood peaks by 40% at the field scale (Jackson et al, 2008).

Another investigation showed that in a traditionally sheep grazed field the infiltration rates of rainwater were not as good as those with trees, the woodland infiltration rates were 60 times those of the pasture (Woodland Trust et al, 2013).

By using trees the Pontbren farmers could lower flood runoff levels which in turn reduces soil loss and erosion and also limits the amount of pollutant run off into water courses. Research at Pontbren suggests that using integrated tree planting and agricultural management could play an important role in creating a more sustainable land drainage system in the upland catchment area (Woodland Trust et al, 2013).

By changing the land management in Pontbren to planting more trees and woody perennials meant more protection of soils with less resource being lost compared to modern agriculture practices. Agroforestry also works with the UK's GAP's as it fits in with the guidance with minimising run off of fertilisers into water courses and reduces the risk of soil erosion. Planting trees will also help deliver the 'good chemical status' of water courses that is required by the Water Framework Directive (Woodland Trust et al, 2013). Separate research carried out away from Pontbren, on the uptake of fertilisers by trees shows that tree roots in an agroforestry system are able to reduce nitrogen and phosphorus residues in soil from between 20-100% and also reduce pesticide transport by 100% (Pavlidis and Tsihrintzis, 2017).

Soil Organic Matter (SOM) loss is an important factor to evaluate against the agroforestry model. Although little was mentioned in the Pontbren project about SOM the leaf fall and root turnover of trees can contribute towards the amount of SOM in the soil (Whitefield, 2004).

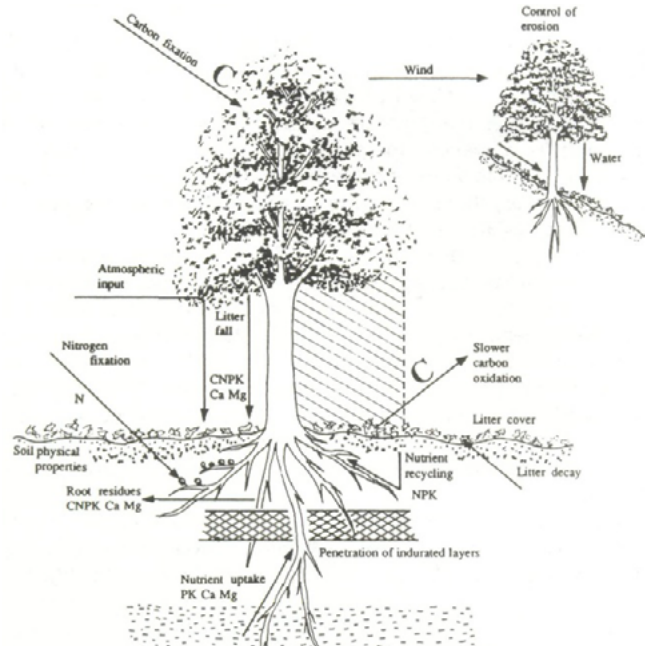
Other research in Canada on Soil Organic Carbon (SOC) showed that in the upper layer of mineral soil investigations the broad leaf deciduous trees had 56-70% more SOC than those test areas with just a shelterbelt or hedgerow (Lim, et al 2018).

Agroforestry again works with the GAP's by ensuring good practice in reducing soil organic matter loss through adding organic carbon by root turnover of trees and recycling organic matter in the form of leaf litter. Leading to agroforestry being a positive system for

taking up the GAP's good practice recommendations.

Figure 4 illustrates how trees can improve the soil by nitrogen fixing, leaf litter cover encouraging nutrient recycling and nutrient uptake. The process of nutrient uptake could be seen as vital as the roots can take up the excess fertiliser used in modern agriculture and make use of it instead of it being lost in run off which can pollute the surrounding environment and water courses. The recycling of nutrients is also beneficial by requiring less fertiliser or nutrient input in the first place. Figure 4 also highlights the way trees can help with erosion from both water and wind factors.

Figure 4 – Process by which trees improve soil (Young, 1990).



When matching these positive inputs with agricultural practice such as growing crops within an agroforestry system, the diversity of the structure can lead to reduce pest problems. Aphid populations have been found to be consistently lower in arable agroforestry compared to the same crops grown out in open fields (Whitefield, 2004). This could be due to the increased habitat for predatory species of aphids living within the non-crop vegetation at the base of the trees (Whitefield, 2004).

Agroforestry can also help with greenhouse gas targets as the trees and shrubs planted can increase carbon stores both above and below ground (Woodland Trust et al, 2013). In terms of the Pontbren project if every farmer in Wales planted 4.5% of their land with broadleaf woodland it would achieve more than the three quarters of the Welsh Governments 100,00 ha target as part of the Climate Change Strategy for Wales (Woodland Trust et al, 2013).

Agroforestry works with the GAPs by naturally being able to store water and minimise its loss. By planting trees with crops or grazing land the trees are able to supply the herbaceous plants with water via hydraulic lift (Whitefield, 2004), thus ensuring the topsoil has enough water for the crops and grass, minimising the need for excessive irrigation. The microclimate that trees also lend to crops and grazing can prevent too much evaporation in the summer months and protection from rain and wind in the winter months.

Conclusion

Sustainable land use/agriculture requires a combination of production with conservation. Agroforestry can contribute to this through control of erosion, maintenance or improvement of soil fertility and checking forest clearance, a key role is played by multipurpose trees (Young, 1990).

In terms of soil and water management, agroforestry can be argued as a sustainable system. Not only does it prevent negative impacts on soil from agriculture such as erosion, SOM loss and over fertilisation it also helps work towards protecting water sources by the take up of excess fertilisers preventing eutrophication. Agroforestry can provide a system that follows the UK's GAP's policies for soil and water management and it could be argued to be positive in other areas outside of this such as biodiversity, economic diversity and animal welfare.

However, there can be disadvantages to this system such as initial economic output in buying and planting trees, along with the time frame needed for the trees to reach maturity and become productive and profitable. Agroforestry can also be argued as being a more complex system to manage, as farmers would need to know more about forestry and the health status of their trees and be aware of diseases and other factors that can influence production outputs. The inability to use large farm machinery due to the trees for harvesting could also cause more economic issues for farmers.

Greater research into how to make agroforestry work more effectively for all types of farming situations across the UK would be a mass benefit, as agroforestry has proved to be sustainable from a soil and water management agenda. Other factors that influence farming and food production would need to be addressed holistically to ensure this type of farming system can be labelled as a truly sustainable approach for all aspects of agriculture.

Aphid populations have been found to be consistently lower in arable agroforestry compared to the same crops grown out in open fields (Whitefield, 2004). This could be due to the increased habitat for predatory species of aphids living within the non-crop vegetation at the base of the trees (Whitefield, 2004).

References

Biodynamic Association (2018). Biodynamic Principles and Practices. Retrieved from https://www.biodynamics.com/biodynamic-principles-and-practices

Chadwick. N (2011). TM1544: An Algal River Gipping. Retrieved from: https://www.geograph.org.uk/photo/2818028

Davis. J.L and Shaw. G, (2016). Impacts on eutrophication of the safety of drinking and recreational water. Retrieved from: https://www.eolss.net/Sample-Chapters/C03/E2-20A-04-02.pdf

DEFRA (2009). Protecting our Water, Soil and Air; a Code of Good Agricultural Practice for farmers, growers and land managers. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/268691/pb13558-cogap-131223.pdf

European Commission (2006). Thematic Strategy for Soil Protection; Impact Assessment of the thematic strategy on soil protection. Retrieved from: http://ec.europa.eu/environment/archives/soil/pdf/SEC_2006_620.pdf

European Environment Agency (2018). Eutrophication. Retrieved from: https://www.eea.europa.eu/archived/archived-content-water-topic/wise-help-centre/glossary-definitions/eutrophication

FAO (2015), Agroforestry; Definition. Retrieved from: http://www.fao.org/forestry/agroforestry/80338/en/

FAO (2018). Conservation Agriculture. Retrieved from http://www.fao.org/conservation-agriculture/en/

Franklin D. Roosevelt Quotes. (n.d.). BrainyQuote.com. Retrieved from site: https://www.brainyquote.com/quotes/franklin_d_roosevelt_396994

Gibson. R (2015). Report questions competitiveness of UK farming. Retrieved from: http://www.thejournal.co.uk/business/business-news/report-questions-competitiveness-uk-farming-8414641

Jackson, B.M et al (2008). The impact of upland land management on flooding: insights from a multiscale experimental and modelling programme. Journal of Flood Risk Management. 1 (2) 71-80. https://doi.org/10.1111/j.1753-318X.2008.00009.x

Kibblewhite, M. G., Ritz, K., & Swift, M. J. (2007). Soil health in agricultural systems. Philosophical transactions of the Royal Society of London. Biological sciences, 363(1492), 685-701. https://dx.doi.org/10.1098%2Frstb.2007.2178

Lim, S.S et al (2018). Soil organic carbon stocks in three Canadian agroforestry systems: From surface organic to deeper mineral soils, Forest Ecology and Management, Volume 417, 2018, Pages 103-109. https://doi.org/10.1016/j.foreco.2018.02.050.

Martin. H (2009). Introduction to Organic Farming. Retrieved from: http://www.omafra.gov.on.ca/english/crops/facts/09-077.htm

Merriam – Webster (2018). Ley farming. Retrieved from: https://www.merriam-webster.com/dictionary/ley%20farminghttps://www.soilassociation.org/blogs/2016/april/27/growing-herbal-leys/?_cldee=YW51LmpvaGFuaUBnbWFpbC5jb20%3D&urlid=8

Pavlidis, G. and Tsihrintzis, V.A (2017). Pollution control by agroforestry systems; A short review. European Water. 59. 297-301. Retrieved from: https://www.ewra.net/ew/pdf/EW_2017_59_40.pdf

Pimentel. D and Burgess. M (2014). Maintaining sustainable and environmentally friendly fresh produce production in the context of climate change. Global Safety of Fresh Produce, 133-139. https://doi.org/10.1533/9781782420279.2.133

Rees. B et al (2011). Soil Organic Matter Loss. Retrieved from: https://www.researchgate.net/publication/232808369_Soil_organic_matter_loss

Regeneration International (2018). What is regenerative agriculture? Retrieved from: https://regenerationinternational.org/why-regenerative-agriculture/

Regenerative Agriculture Initiative and The Carbon Underground (2017). What is Regenerative Agriculture? Retrieved from https://2igmzc48tf4q88z3o24qjfl8-wpengine.netdna-ssl.com/wp-content/uploads/2017/02/Regen-Ag-Definition-2.23.17-1.pdf

Soil Association (2016). Growing Herbal Leys. Retrieved from: https://www.soilassociation.org/blogs/2016/april/27/growing-herbal-leys/?_cldee=YW51LmpvaGFuaUBnbWFpbC5jb20%3D&urlid=8

Somarriba, E. (1992). Revisiting the past: an essay on agroforestry definition. Agroforestry Systems.19 (3), 233.Retrieved from: https://link.springer.com/article/10.1007/BF00118781

The Woodland Trust et al (2013). The Pontbren Project; a farmer led approach to sustainable land management in the uplands. Retrieved from: http://www.woodlandtrust.org.uk/mediafile/100263187/rr-wt-71014-pontbren-project-2014.pdf

USDA/Agricultural Research Service. (2008). Modelling Erosion Damage from Ephemeral Gullies. ScienceDaily. Retrieved from www.sciencedaily.com/releases/2008/07/080712142820.htm

Whitefield, P. (2004). The Earth Care Manual (2nd edition) Hampshire: Permanent Publications .

Young, A. (1990). Agroforestry, Environment and Sustainability. Outlook on Agriculture, 19(3), 155-160. https://doi.org/10.1177/003072709001900305

Young, A (1989). Agroforestry for soil conservation. Oxon: CAB International. Page 99 retrieved from: http://www.worldagroforestry.org/downloads/Publications/PDFS/03_Agroforestry_for_soil_conservation.pdf


FROM FARM TO TABLE
www.rau.ac.uk