Geo Factsheet

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GLOBAL WARMING MITIGATION

Part 2: Removing Carbon from the Atmosphere

Introduction

The anthropogenic (human caused) increase in greenhouse gas concentrations over the past 150 years is primarily connected with the increase in CO_2 emissions from fossil fuels. However, around one-third of the total human-induced warming effect is due to greenhouse gases released from agricultural and land-use changes.

Intensively managed agricultural systems interfere with ecosystems and their role in the Earth's natural biogeochemical cycling systems causing increased production of the three major greenhouse gases (carbon dioxide, methane, nitrous oxide). The major practices blamed for this increase in gases are deforestation, rice cultivation, and pastoral agriculture.

However, ecosystem processes also act to reduce these Greenhouse Gas increases, through the uptake and storage of CO_2 in plants and soil. These uptake and storage processes (referred to as "carbon sinks") play a significant role in the global carbon cycle, so that only around a half of the CO_2 emitted from fossil fuels accumulates in the atmosphere. The other half is absorbed by the oceans and terrestrial ecosystems. Without these sinks, the rate of increase in atmospheric CO_2 concentrations would be roughly twice the present rate.

Taking a cue from these natural carbon sinks a number of geophysical engineering (geo-engineering) projects have been suggested to artificially increase the rate of carbon capture and offset the current gas level to buy some time for the other mitigation strategies to take effect.

This second *Geo Factsheet* on Global Warming Mitigation looks at techniques to preserve and enhance the sink capacity of the planet through both agricultural practices and 'geo-engineering'. The aim is to reduce agricultural emissions, and offset emissions from other sectors by removing CO_2 and other global warming gasses from the atmosphere and storing them naturally or artificially.

Agricultural Mitigation

Table 1 shows a range of agricultural measures which might be implemented to mitigate the effect of major global warming gases, as well as their potential impact on sustainable development and other global issues.

(a) Rice Cultivation

Rice is the second most consumed cereal on the planet and is a staple food for a large part of the world's population, providing one fifth of the calories consumed worldwide. The expected growth in global population will mean the production of an extra 350 million tons of rice per year by 2020 to feed an extra 3 billion people. Most varieties of rice need a significant water supply and are grown in flooded fields or paddies. This water cuts off soil bacteria from their usual oxygen supply, creating an anaerobic fermentation of soils organic matter. This produces methane which escapes into the atmosphere up the plant stalk in respiration or through diffusion in the water. Rice paddies currently represent 15% of annual anthropogenic methane emissions and contributing significantly to global warming *(Fig. 1)*. This may increase to 23% if population pressure continues as expected.

Fig. 1 Global Warming Gas Potential

While the mechanics of the greenhouse effect are similar for all gases, each gas differs in its overall impact on the Earth's radiation balance, depending on the concentration of the gas, its residence time in the atmosphere, and its physical properties with respect to absorbing and emitting radiant energy.

Global Warming Potential is the measure used to compare the effect of different greenhouse gases on a global basis. It works by assigning each molecule of carbon dioxide a value of one in its warming effect and the warming potential of other gases are given values relative to the CO_2 standard.

Values for the other major greenhouse gasses are: 310 for nitrous oxide and 21 for methane which means that one tonne of nitrous oxide is thought to have the same warming effect as 310 tonnes of CO_2, and one tonne of methane to have the warming effect of 21 tonnes of CO_2.

Despite CO_2's lower potential relative to the other gases, the total contribution of CO_2 to greenhouse warming is much greater owing to the much higher concentration of CO_2 at 60% compared to 20% for Methane and 6% for Nitrous Oxides.

Table 1 A selection of agricultural mitigation practices and their potential impacts.

Measure	Examples	Mitigation Effects			Sustainable Development *Key:* *Sc: Social* *Ec: Economic* *En: Environmental*			Food Security	Energy Conservation	Biodiversity	Aesthetic/ Amenity
		CO_2	CH_4	N_2O	Sc	Ec	En				
Cropland Management	Rice Management	+/-	+	+/-	+	+	+	+	-		
	Crop Rotation	+		+	+/-	+	+	_	+	+	+/-
	Agroforestry	+		+	+		+	+/-		+	+
Livestock Management	Feeding Practices	+	+	+/-	+		+				
	Manure Management	+	+/-	+		+/-	+	+			
Bioenergy	Energy Crops	+	+/-	+/-	+	+/-	+/-	-	+	-	

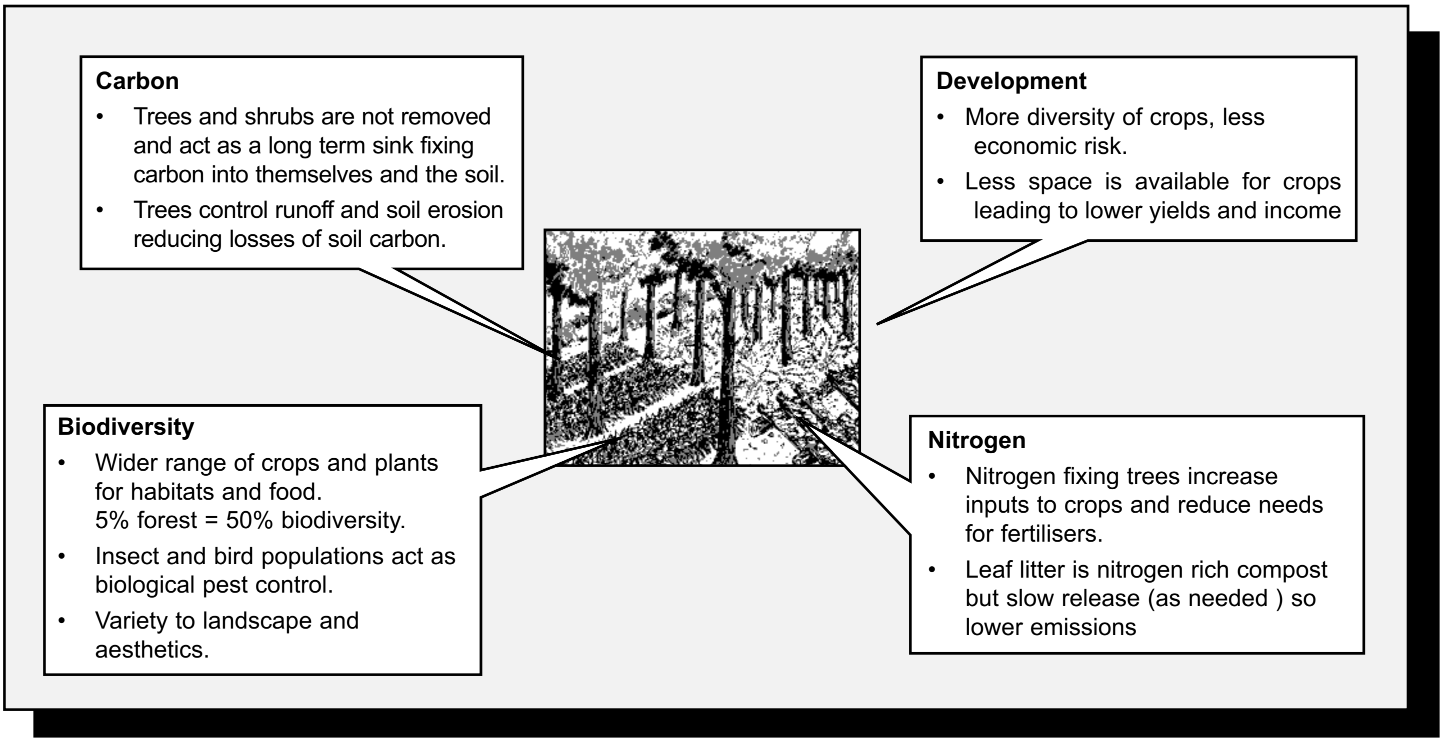
Key: + Positive impact - Increase impact +/- Mixed results

There is no one solution to this issue so different approaches are being used. The most advanced and expensive solution with a wide spread adoption of a different rice cultivar which is less able to transport the methane to the atmosphere. A more realistic option is a change in the practice of rice growing to reduce the amount of water used and thus the anaerobic conditions. Changing to the more drought tolerant Ghaiya rice would allow for less field flooding. Draining the fields in the off-season and on two or more occasions during cultivation will allow the soil bacteria a chance to recover. However, as *Table 1* shows this may cause increases in CO_2 production or nitrous oxide emissions which may offset the benefits depending upon the management approach.

(b) Agroforestry

According to the IPCC, tropical deforestation accounts for one third of the anthropogenic carbon dioxide emissions both through direct release from ‘slash and burn’ processes and indirectly though soil carbon loss in associated soil erosion. Agroforestry is the name given to a range of approaches to balance agricultural use with the forest cover to the benefit of both the farmers and the environment. Recent studies have shown that these environmental benefits might also include global warming mitigation as shown in *Fig. 2*.

Fig. 2 Agroforestry Benefits.



Carbon
- Trees and shrubs are not removed and act as a long term sink fixing carbon into themselves and the soil.
- Trees control runoff and soil erosion reducing losses of soil carbon.

Development
- More diversity of crops, less economic risk.
- Less space is available for crops leading to lower yields and income

Biodiversity
- Wider range of crops and plants for habitats and food.
  5% forest = 50% biodiversity.
- Insect and bird populations act as biological pest control.
- Variety to landscape and aesthetics.

Nitrogen
- Nitrogen fixing trees increase inputs to crops and reduce needs for fertilisers.
- Leaf litter is nitrogen rich compost but slow release (as needed) so lower emissions

Case Study 1: Carbon Mitigation through Community Forestry, Betalghat, Uttarakhand, India

Fig. 3

This area of Northern India is a mixture of lowland river valleys around the river Kosi and mountains up to 1800 m. Rainfall is 1000 mm/pa, 80% of which is received in the July-September monsoon.

The productivity of the land is higher along riverbeds and drops on steeper slopes subject to soil erosion.

The Betalghat Community Forest makes up 1589ha of the high ground and is managed by the local communities. Human pressures have degraded formerly dense forests to current vegetation cover of less than 10%, now used for grazing cattle, goats and buffalo and for fuel wood.

The low ground is the Bazpur Farm Forest, 2667ha of privately owned agricultural lands on river flood plains. Used for subsistence agriculture of wheat and rice,

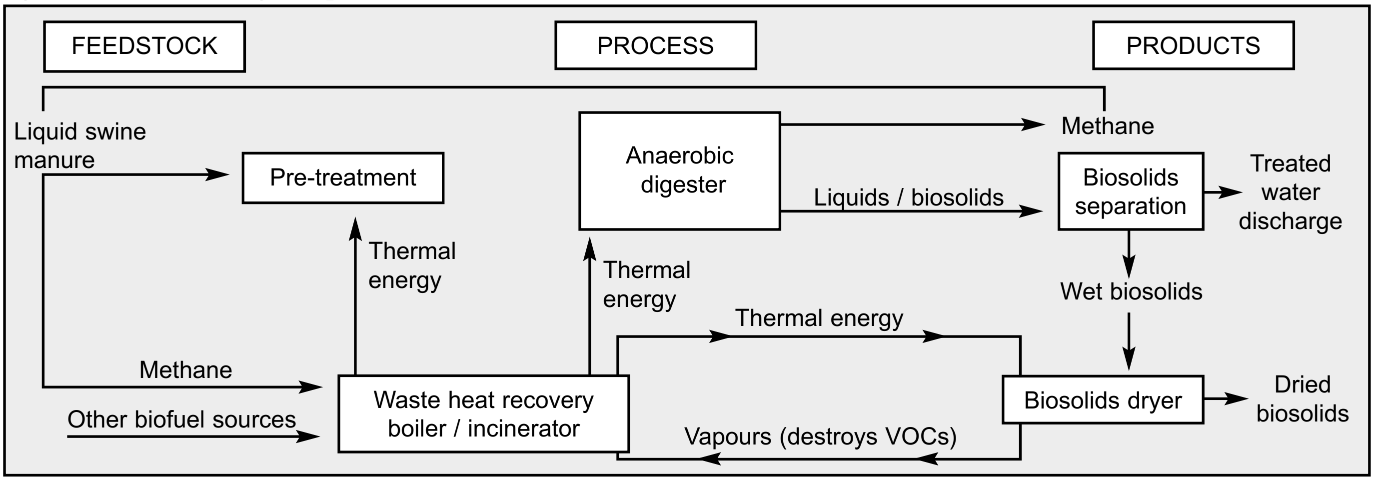
Almost 50% of the Community and 25% of the agricultural land in the area were reforested or afforested. The community forest was restocked with a mixture of fast growing species such as Pine and Khair chosen to allow for fuel wood and fodder requirements while maintaining a forest cover and soil retention. Farm forestry areas were planted with fruit species such as Mango and Kinoo to fix carbon and provide an additional income.

The monitored carbon sink potential on this project is expected to be an additional 200000 tons of CO_2 over a 30 year period.

Case Study 2: Anaerobic Digester at Scenic View Dairy, Fennville, Michigan

Scenic View is a dairy farm with 2200 cattle. They fitted an anaerobic digester in 2006. Animal waste is corralled into sealed holding pools and then pumped directly into the digester. The flow diagram below shows the process:

Fig. 4 The anaerobic digester process.



Benefits

- ***Methane Reduction:*** *The system captures 80% of the methane produced from cattle waste and burns this biogas for energy generation, releasing only water vapour and CO_2 as waste. The CO_2 has less global warming potential than the methane and is relatively carbon neutral as it came from recently growing biomass.*
- ***Reduction in Carbon Emissions:*** *Scenic View was the first in digester the world to combine electricity generation with biogas. Electricity is sold to the national grid and excess biogas has been piped to local homes. The sustainable power generated from Scenic View creates energy (gas and electric) for the farm plus 600 homes, reducing their costs and dependency on fossil fuels and associated carbon footprints.*
- ***Nitrogen Emissions:*** *The quick collection and storage of the animal waste minimises not only the escaping methane but also Nitrogen (in various forms). Post digester nitrogen levels in wet and dry solids are available for fertiliser, reducing the dependency on chemical imports. In addition the nitrogen compounds are in a slower release from and reduce the risk of over fertilising and excess N_20 release and associated global warming impacts.*

Other Benefits

Prior to the installation of the digester, Scenic View used sand for animal bedding which has now been replaced by the separated digested biofibres which is sanitised and odour free.

Projected return on investment is 3-4 years.

(c) Livestock Management

Livestock cultivation makes up 70% of all agricultural land use and occupies 30% of the Earth's land surface. It also uses a third of the global arable land in producing feed such as corn and alfalfa. Most of the livestock are ruminants, their stomachs using bacteria to break down vegetation and producing 40% of global methane emissions as a by-product. Around 70% of this methane comes direct from the digestive tract of the livestock and is hard to deal with. Studies have shown that more digestible feed such as grain, silage, clover and alfalfa can go some way towards reducing these emissions and that genetic breeding over time could lead to livestock with lower emissions.

However, the remaining 30% of livestock emissions come from fermenting animal waste. Small scale biogas plants in parts of India and Africa have shown that the collection and fermentation of the dried waste can be used to produce renewable energy, an income and lower CO_2 emissions (due to the reduction in firewood collection). Yet the dried animal waste has already lost much of its methane to the atmosphere. Wet waste collection therefore could have much greater benefits in terms of methane reduction. Many MEDCs such as the USA have started to implement this simple technology *(Case Study 2)*.

(d) Bioenergy

Agricultural crops are increasingly being seen as sources of energy to replace fossil fuels. A wide range of crops have been suggested for use, including grain, crop residues, cellulosic crops such as sugarcane and even various tree species. These products can be burnt directly, but would normally be processed further to generate liquid fuels such as ethanol or bio-diesel. These fuels release CO_2 when burnt, but this CO_2 was recently taken from the atmosphere via photosynthesis and is therefore considered carbon neutral. It actively displaces CO_2 which otherwise would have come from fossil fuels.

However, competition for other land uses and environmental impacts need to be considered carefully before using energy crops. The expanding bioenergy sector impacts on agri-ecosystem services such as food production and have been partly blamed for recent rises in food costs across the globe. Biodiversity of plantations have also been called into question as a threat to both soil and nature conservation. Furthermore carbon sequestration potential has not yet been adequately studied and may provide a false quick fix to the fossil fuel issue *(see Geo Factsheet 235 on biofuels)*.

Converting the potential biomass production into mitigation potential is not straightforward. The mitigation potential of crops is determined by supply and demand based on the cost of production and transport. These are based on availability of land in suitable locations and the growth rate of the crops which are themselves affected by climate change, though changes in temperature, soil moisture, and atmospheric CO_2 concentration, which will vary regionally. All of these factors will alter the mitigation potential; some positively and some negatively.

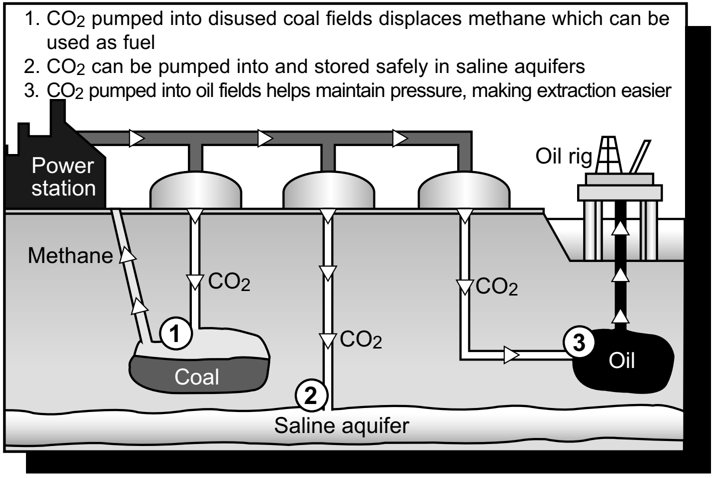
Geo-engineering: Removing greenhouse gases from the atmosphere

This approach to reducing greenhouse gases is divided into two groups; carbon capture and storage and carbon sequestration.

(a) Carbon Capture & Storage (CCS)

Carbon capture is the process of collecting CO_2 as it emerges from large point sources such as the chimneys of power stations. This carbon dioxide is then stored, either in deep geological formations such as depleted oil, gas or coal fields, or in deep ocean basins or in the form of mineral carbonates *(Fig. 5)*. The concept is relatively new and being piloted in various countries during 2008-9 to test its feasibility and efficiency.

Fig. 5 Options for carbon capture and storage.



The belief is that the application of CCS to power stations would reduce CO_2 emissions by between 80-90% and that geological storage alone has the capacity to hold at least 70 years worth of emissions at current rates. However, the idea is not without its potential pitfalls with an estimated additional energy cost of between 20 and 90%, the unsure nature geological capacities, the unknown risk of carbon leakage as well as the issue of ocean acidification if sea water is used as a storage media. Despite this, the IPCC estimates that the economic potential of CCS could be between 10% and 55% of the total carbon mitigation effort until year 2100 and that the CO_2 could be trapped for millions of years, with sites retaining over 99% of the injected CO_2 over 1000 years.

(b) Carbon Sequestration

This is the process of removing CO_2 from the atmosphere directly, as opposed to a point source of input. This idea is very much in the early stages of development but for some it is believed to be the most important area of development if we are to stave off the worst impacts of climate change. Suggested methods of sequestration revolve around two central ideas; the enhanced use of natural sequestration from green plants or ocean basins and artificial approaches. Either way these new geo-engineering techniques are still in the developmental stages.

Conclusion

Global Warming Mitigation is a complex process and a massive undertaking requiring not only continued research to the range of approaches illustrated by these geofactsheets but also massive financial investment on a global scale together with a collective will of the global population. Individuals, organisations, countries and even regions such as the EU are starting to adopt mitigation strategies as part of their climate change commitment. However, to be more than tokenism and to have a real impact on the future of the planets climate will require a globally integrated strategy across different sectors and levels of development.

The question is how long it will take to get mitigation strategies to a point where they can make a real difference, and how long the world has before global warming gas concentrations reach the critical tipping point.

Case Study 3: Natural Ocean sequestration

Phytoplankton in the world's oceans naturally sequester CO_2 during photosynthesis. Studies across the different ocean basins have investigated the feasibility of increasing the rate of this natural process by seeding the water with iron sulphate, an important nutrient which can limit the rate of the process in certain iron poor ocean basins.

Results have been varied with about 30% of the oceans suffering from low iron levels and benefiting from the additional iron sulphate. In addition it is believed that only about 10% of the sequestered CO_2 is fixed into plant biomass and transported to the ocean depths on death or consumption of the phytoplankton by higher trophic levels, the majority being recycled back into CO_2 through respiration and decay in the upper water column. This low success rate is further compounded by the potential financial and environmental costs of adding iron sulphate to the oceans which have not yet been investigated.

An alternative approach is through the use of simple technology. Atmocean, a US company are currently working on 200m long ocean tubes which use kinetic wave energy to pump nutrient rich deep water to the surface. In the presence of sunlight the enhanced and regular supply of nutrients generate larger blooms of phytoplankton without the need to regularly seed the water with iron. The engineering involved is quite straight forward and self sustaining however, the ecological impacts are unknown and one estimate suggests that as many as 100 million such tubes might be needed to achieve large scale mitigation results.

Case Study 4: Artificial carbon sequestration

In 2007 Richard Branson and former U.S. Vice President Al Gore offered the Virgin Earth Challenge, a $25 million reward to anyone who can develop an effective, economical way to sequester at least 1 billion tons of CO_2 from the atmosphere per year.

A range of approaches have been suggested and some lab based trials look promising but the trick is to capture the CO_2 and do something with it without emitting more CO_2 than captured through electricity consumption.

One approach involves 120m high towers which suck in air and pass it through a cloud of sodium hydroxide in which the carbon dioxide dissolves and falls to the base. The resulting CO_2 is then buried in geological formations, similar to the CCS approach.

Another idea is to have artificial trees with "leaves" that absorb the gas. Workers at Global Research Technologies have developed a plastic that grabs CO_2 from the air which then can we washed off the plastic using steam and the collected CO_2 is then buried in the same way.

While some critics have pointed to the vast engineering task needed to utilise such technology and that the ideas are still in the early stages, the atmosphere-scrubbing technology has already been touted by environmentalists as an energy-efficient and cost-effective way to complement approaches such as CCS to target transportation emissions which are not so easily captured at source.

Further Research

- www.ncdc.noaa.gov/oa/climate
- www.ipcc.ch1 – IPCC site
- www.hm-treasuring.gov.uk – for Stern Review
- www.stabilisation2005.com – avoiding dangerous climate change
- March 2009, *Geo-engineering against climate change update,* Focus. BBC

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This Factsheet was researched by Rob Burn who is Head of Geography at Newstead Wood School. ***Curriculum Press, Bank House, 105 King Street, Wellington, TF1 1NU. Tel. 01952 271318.*** *Geopress Factsheets may be copied free of charge by teaching staff or students, provided that their school is a registered subscriber. No part of these Factsheets may be reproduced, stored in a retrieval system, or transmitted, in any other form or by any other means, without the prior permission of the publisher.* ***ISSN 1351-5136***