Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

Agriculture and climate change

science & technology in action 10th edition
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Context

Climate change is a natural *phenomenon*. Human history has recorded hot episodes, mini ice ages and temporary changes caused by volcanic eruptions. A *catastrophic* climate change, resulting from a meteorite impact, wiped out the dinosaurs.

On Earth, life as we know it is maintained by ***greenhouse gases*** in the atmosphere (mainly water and carbon dioxide) – they retain some of the energy radiated from the Earth's surface towards space. Without them the average temperature on Earth would be −18°C and there would be extreme temperature differences between day and night, as happens on the Moon.

In the past 200 years the increased industrialisation, mechanised transport and agriculture, urbanisation and increasing human population have raised the level of atmospheric carbon dioxide from about 280 ***ppm*** to about 390 ppm, ***enhancing*** the greenhouse effect and raising global temperatures. Over the same period atmospheric ***methane*** (CH_4) has risen from 720 ppb to 1800 ppb; its ***global warming potential*** is 25 times that of CO_2 over a period of 100 years. ***Anthropogenic*** global warming has led to warmer weather, reduced ice cover, ***desertification*** and more frequent extreme weather events.

Agriculture

Climate change has consequences for agriculture. In many places ***glacial*** melting causes flooding and, later, drought. Global production of ***maize***, wheat, rice and meat has been affected by storm damage, drought and flooding. Poultry have suffered from heat stress. Moreover, farm organism-***parasite*** relationships can change in unpredictable ways.

Agriculture can respond in a number of ways. Better water storage facilities reduce the risk of drought. Hardy seed varieties or animal species — less used because of lower productivity — can be used again. Climate change has shortened growing seasons in the tropics but extended them in places like Ireland and New Zealand. Formerly frozen Arctic land may now become productive.

The regions most severely affected by climate change are often the poorest. It is clear that global cooperation is required to ensure sharing of economic resources, technology, knowledge and training.

The urgent need to limit the growth in greenhouse gas emissions poses a major challenge for agriculture. Worldwide, there is substantial ***malnutrition*** and a growing population. The demand for meat and dairy products is on the rise. At the same time, this agriculture sector is expected to reduce emissions, particularly of methane (CH_4) and ***nitrous oxide*** (N_2O) – two powerful greenhouse gases.

EU Targets

The EU has committed itself overall to 20% power from ***renewable*** sources, 20% reduction (from 1990 levels) in GHG emissions and a 20% improvement in energy efficiency by 2020. It has promised a 30% cut in emissions by 2030 if serious action is taken by other major world economies. Careful action is required. For instance, a reduction in Ireland's national herd would reduce emissions here — but might transfer production to places where agriculture is less well developed and so increase GHG emissions or 'carbon leakage'. Is it possible to match increased production with reduced GHG emissions?

Methane

Enteric fermentation is the process by which microorganisms ***anaerobically*** break down ***cellulose*** in the stomach of ***ruminant*** animals (cattle, sheep, goats, buffalo). In the process considerable quantities of methane (CH_4) are released but can be reduced by grazing the animals on high quality grasses. Incorporating oils in an animal diet has some positive effect but probably not as much as improving the digestibility of feed. Some steps that reduce ***methanogenic*** bacterial action have limited effectiveness or undesirable side-effects, and in some cases have been banned. Methanogen vaccines are not yet commercially available.

Feeding a better quality diet such as better grass or selected ***concentrates*** can decrease CH_4 emissions per kilogram of meat produced. It can also allow earlier slaughter. (***Growth promoters*** can achieve a similar outcome but are not permitted in the EU). Improved animal health means less loss through illness and death and so production can be maintained with smaller herds. Traditionally, higher herd numbers were needed to cover these losses.

It should be noted that cows on pure beef farms may be unproductive for long periods, while still contributing to GHG emissions. Genetic selection of animals for health, growth rate, meat quality, milk production and reduced methane output will be more important in the future. There may be problems when an advantageous trait will sometimes be associated with a less desirable one.

Manure

Manure emits methane, particularly when stored. One response is to cover the storage facility and capture the gas for use as a fuel. This effectively replaces a powerful GHG with a weaker one, CO_2. Ireland is assessing options for the development of ***biogas*** facilities that will anaerobically digest animal manures and other biodegradable wastes such as food waste to help capture methane and displace the use of fossil fuel. Flooded ***rice paddies*** also generate methane. It may be possible to develop rice adapted to drier conditions.

Nitrous oxide

As animal manure and crop residues decompose they fertilise soil but they also produce some nitrous oxide (N_2O). In the past, excessive fertiliser application resulted in the production of unnecessary amounts of N_2O, as well as polluting waterways and even compromising animal health.

The ***EU Nitrate Directive*** addresses this issue. Careful management aims to tailor fertiliser application to secure ***optimal*** grass or crop growth. Too low an application rate will result in a loss of productivity and ultimately a greater amount of GHG per kilogram of food.

Longer growing seasons will necessitate increased fertiliser use but planting of legumes can reduce the need for fertiliser. ***Controlled release fertilisers*** are ***nitrification inhibitors*** or ***urease inhibitors***. Overall they improve nitrogen use efficiency by minimising losses to the air and waterways.

Animal manure deposition is by nature erratic (causing hot-spots of N_2O production). Nitrous oxide may also be generated in the production of animal feed.

Greenhouse gases (GHGs)

The change in the natural (relatively stable) levels of greenhouse gases has been brought about by human activity. Most of this ***enhanced*** greenhouse effect (about 70% of it) is due to carbon dioxide resulting from combustion of fossil fuels (for transport, electricity, heat etc.). The table below shows the estimated contribution of agriculture and land use change to this enhanced (or anthropogenic) greenhouse effect.

Greenhouse gas	Agriculture	Land use change	Total effect (all sources)
Carbon dioxide	1.4%	12.2%	77%
Methane	8.6%	0%	15%
Nitrous oxide	5.5%	0%	7%
Others (CFCs etc.)	0%	0%	1%

The output of CO_2 from agriculture is typically balanced by the uptake of CO_2 in the growth of crops — apart from fuel and energy use (1.4%). However the contribution of land use change is significant (12.2%) due to the destruction of forests through burning and decay. Today this mainly occurs in Brazil, South East Asia and tropical parts of Africa.

Agriculture's most significant contributions to GHGs are due to methane (8.6%) and nitrous oxide (5.5%). In fact agriculture is the most significant source of these GHGs.

Sustainability

Our current level of use of the Earth's resources, whether biological or mineral, is increasing and unsustainable. Many changes will be required in order to move towards a sustainable future. We need to displace fossil fuels or develop technologies to capture and store the carbon dioxide emitted — or both.

We need to promote sustainable land use practices that retain and enhance the soil's carbon stores (avoid soil degradation such as desertification, ***salinisation*** etc.) and minimise deforestation of natural forests. To be sustainable reforestation must at least balance deforestation rates. This will bring additional benefits in terms of biodiversity and water management.

Proper use of grassland, through good management and optimal grazing, results in ***carbon sequestration*** in the soil. Healthy pastures also promote ***biodiversity***. ***Set-aside*** definitely reduces GHG emissions but, globally, the demand for food ***militates*** against it.

The growing of crops involves ***tillage***, which disrupts the soil and releases CO_2. Reduced or ***zero-till*** planting minimises this effect while promoting biodiversity but it involves a major change in agricultural practice.

Perennial crop plants develop deep roots, improving carbon storage. ***Catch crops*** can protect the soil after the main crop has been harvested. Good ***crop rotation*** improves soil health and reduces losses due to parasites. In Brazil, the ryegrass hay /maize /soybean system has increased soil carbon levels but economic/social factors affect its implementation.

Conclusion

Mitigation of GHG emissions while increasing agricultural output is a challenge. Reducing one GHG may result in increased emissions of another. Any programs have to be adaptable as climate change is ongoing and new problems or opportunities can emerge. Measures need to be effective and

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The Department of Agriculture, Food and the Marine (DAFM) strives to lead the sustainable development of a competitive innovative, consumer-focussed agriculture food, fishery and forestry sector in Ireland through its various activities DAFM promotes the protection of the agricultural environment, through the following activities:

Over €1.2bn is administered by the Department of Agriculture, Food and the Marine in annual payments to farmers under the Single Farm Payment. In order to receive payment farmers must maintain their land in good agricultural and environmental condition (GAEC) and comply with nineteen Statutory Management Requirements. The GAECs contribute to retaining and enhancing soil carbon levels as well as protecting landscape features such as hedgerow which sequester carbon.

The importance of Single Farm Payment has been enhanced under the recent review of CAP for the period 2014-2020 to further support climate action by protecting permanent pasture from cultivation and encouraging the development of ecological focus areas.

The Rural Environmental Protection Scheme (REPS) and the Agri-Environment Options Scheme (AEOS) promote sustainable agriculture and encourage climate actions in various ways, such as:

- Arable grass margins and riparian margins.
- Use of trailing shoe technology to improve nutrient recover from slurry
- Green cover establishment from a sown crop

DAFM administers the Nitrates Derogation system under the Regulation which provides intensive farmers with a higher limit of livestock manure application, subject to certain conditions which again improves nutrient efficiency and reduces emissions.

Ireland is just 10% forested while the average for EU countries is 35%. By planting 20,000 hectares of forest every year it is expected that Ireland will meet or exceed the EU average by 2030, with a corresponding increase in the timber output from Irish forests.

Further information on climate action in agriculture can be found at **www.teagasc.ie** and **http://www.agriculture.gov.ie/ruralenvironment/climatechangebioenergybiodiversity/agricultureclimatechange/**

Further information is available at www.agriculture.gov.ie

Find this and other lessons on www.sta.ie

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Syllabus references

The main syllabus references for the lesson are:

Leaving Certificate Agricultural Science

- Principles of soil cultivation with reference to tillage crops and grassland.
- Chemical properties of soils. Living organisms and their effects.
- Decomposition of organic matter. Carbon and nitrogen cycles.
- Improving soil fertility. Conservation of grassland products.
- Digestion: Study of the digestive systems of the ruminant, horse, pig and fowl, the digestive juices; the digestive enzymes.

Leaving Certificate Biology

Ecology. Nutrient recycling. Human impact on an ecosystem.

Leaving Certificate Chemistry

- Sources of hydrocarbons.
- Atmospheric chemistry (Option)

Learning Outcomes

On completion of this lesson, students should be able to:

- Distinguish between the greenhouse effect and the enhanced greenhouse effect
- Outline how GHG (greenhouse gases cause) climate change
- State undesirable effects of climate change
- Outline the competing demands of meeting human food requirements and reducing GHG emissions
- Describe some of the ways in which agriculture can reduce GHG emissions

General Learning Points

These are additional relevant points which are used to extend knowledge and facilitate discussion.

Anthropogenic (human-caused) emissions of GHGs are causing global warming. Although this makes some areas of the planet more productive agriculturally, the consensus is that the overall effect is negative, at a time of rising population. Agriculture contributes substantially to CH_4 and N_2O emissions. Therefore emissions must be reduced while attempting to increase food output.

Global warming potential (GWP) is the estimated contribution to global warming compared to that produced by the same mass of CO_2.

Gas	Lifetime in atmosphere	100 year GWP
Carbon dioxide (CO_2)	30 − 100 years	1
Methane (CH_4)	12 years	25
Nitrous oxide (N_2O)	114 years	300

Student Activities

1. Make a poster to show the physical and chemical properties of CO_2, CH_4 and N_2O, and any interesting stories about them
2. Make a list of present and possible means of reducing CH_4 output from ruminant animals.
3. How does food wastage occur? How does it contribute to greenhouse gas emissions?
4. Draw one pie chart to show worldwide emissions of the major greenhouse gases. Draw another one to show the emissions in the agricultural sector. (Other pie charts could show emissions from different sectors in individual countries.)
5. What are the advantages and disadvantages associated with using bioenergy?
6. Non-food products from plants and animals, or products derived from them (wool, bioplastics, etc.) can be used for long-term carbon sequestration. Investigate why this option is under-utilised at present.
7. Discussion topic: As trees grow they absorb CO_2. When they die and decay the same amount of CO_2 is released. Stable forests therefore do not affect the level of atmospheric CO_2 (or of O_2). So why is deforestation so damaging?
8. Group task: There has been much research in Ireland into the feasibility of growing crops for energy (fuel), e.g. willow and *Miscanthus*. Such fuels are regarded as nearly 'carbon neutral'. Make a poster to summarise the likely energy inputs and outputs of growing such crops.

True/False Questions

a) Farmers can reduce GHG emissions by keeping machinery in good working order and carefully planning field operations. **T F**
b) Production of fertilisers, feed and animal medicine involves GHG emissions. **T F**
c) A slight increase of 2 degrees in average global temperatures is no cause for concern. **T F**
d) Planting trees with deeper roots in order to reduce storm losses has an adverse effect on carbon sequestration. **T F**
e) 'Radiative forcing' is a phenomenon of no significance to climate change. **T F**
f) Elevated CO_2 levels are affecting ocean ecology. **T F**
g) The effects of GHGs have reached saturation level. Further emissions will not affect Earth's climate. **T F**
h) Although burning increases GHG emissions, it can have beneficial effects on soil and ecosystems. **T F**

Check your answers to these questions on www.sta.ie.

Examination Questions

Leaving Certificate Agricultural Science (OL) 2013, Q. 11 (b)

There is now widespread evidence that the emission of greenhouse gases into the earth's atmosphere is causing global climate change. Major changes are expected in terms of temperature and rainfall. One of the main greenhouse gases is carbon dioxide, released when fossil fuels are burned. Another is methane gas released by cattle. These gases cause pollution of the air. They are called greenhouse gases as they have an effect similar to that of a greenhouse - they prevent some of the sun's heat escaping back into space.

(i) Name one greenhouse gas.

(ii) Why are greenhouse gases so called?

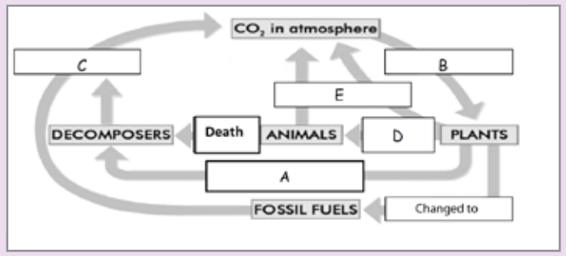
(iii) What is meant by the term pollution?

(iv) Suggest one way to reduce the levels of greenhouse gases.

(v) The diagram below shows the carbon cycle.

In your answer book match the terms from the list below to the letters A, B, C, D and E in the diagram.

List: Photosynthesis; Respiration; Eaten by; Combustion; Decay.



Leaving Certificate Agricultural Science (HL) 2009, Q. 8

- With the aid of a labelled diagram briefly describe the carbon cycle.
- Suggest one practice farmers could adopt to reduce the carbon footprint of Irish agriculture.
- Compare and contrast slurry and farm yard manure.
- Suggest two disadvantages of spreading slurry.

Leaving Certificate Agricultural Science (HL) 2011, Q. 8 (b)

- Explain the meaning of the term B.O.D.
- Name one agricultural pollutant with a high B.O.D.
- Explain how the named pollutant affects water quality.
- Suggest two key elements of a waste management strategy for the named pollutant.

Leaving Certificate Agricultural Science (OL) 2012, Q. 9 (b)

Crop rotation is an important feature of potato cultivation. Give two reasons why crop rotation is important.

Did You Know?

Greenhouse gases are fairly transparent to incoming solar light radiation. They absorb and re-emit some of it when it is re-radiated from the Earth at a different wavelength – hence global warming.

Stratospheric ozone (O_3) is degraded by N_2O. However, as well as being our guardian against UV, ozone is also a greenhouse gas. Burning of biomass and fossil fuels releases ozone into the troposphere (lower atmosphere). In turn, it can be dissociated by sunlight. This leads to the formation of hydroxyl radicals which can mop up CH_4. Greenhouse gas interactions are complex.

Primitive farming, still practised in many places, involves clearing forest and burning it to provide space for farming ('slash and burn)'. It was sustainable while populations were small. Communities moved on and the land had time to recover. A modified process, slash and char, involves charring wood and returning the biochar, mixed with manure and crop residues, to the ground. This process increases the carbon sequestration capability of the soil. Controlled burning creates firebreaks, preventing larger fires becoming catastrophic – reducing net GHG emissions.

Biographical Notes

John Tyndall (1820 – 1893)

Tyndall was born in Leighlinbridge, County Carlow where his father was a local policeman. Of the subjects he learned at school technical drawing, mathematics and surveying were particularly useful in his later work with the Ordnance Survey. He was transferred to Preston (UK) in 1842 and worked on the planning of the railway network. In 1847 he became a teacher -- of mathematics and surveying. He went to study in Germany in 1848 where he studied under Bunsen in Marburg. His early publications on magnetism brought him international recognition and he was elected to the Royal Society in 1852.

Among his many investigations, he measured the extent to which various atmospheric gases absorb radiant heat (i.e. infrared radiation) and suggested that increases in the concentration of some of these gases could cause climate change. He concluded (correctly) that water vapour was the greatest atmospheric absorber of infrared radiation.

Tyndall became a brilliant lecturer and demonstrator. His published works include 17 books and over 140 research papers on a variety of scientific topics including light, heat, sound, electricity, diamagnetism, radiation , clouds, rivers and glaciers.

Revise The Terms

Can you recall the meaning of the following terms?
Revising terminology is a powerful aid to recall and retention.

anaerobically, anthropogenic, biodiversity, biogas, carbon sequestration, catastrophic, catch crop, cellulose, concentrates, controlled release fertiliser, crop rotation, desertification, enhance, enteric fermentation, EU Nitrate Directive, glacial, global warming potential, greenhouse gas, growth promoter, maize, malnutrition, methane, methanogen, methanogenic, militate, mitigation, nitrification inhibitor, nitrous oxide, optimal, parasite, perennial, phenomenon, ppm, renewable, rice paddies, ruminant, salinisation, set-aside, tillage, urease, zero-till.

Check the Glossary of terms for this lesson on www.sta.ie