Carbon and Climate Change – An Overview

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Published in:
Farming Connect

Publication date:
2020

Citation for published version (APA):
Cutress, D. (2020). Carbon and Climate Change – An Overview. *Farming Connect*, 1-9.

Carbon And Climate Change – An Overview

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- Current trends show climate change due to human influences such as major industrialisation are having a significant effect on global climate patterns
- The biggest single factor driving climate change is the emission of carbon compounds particularly carbon dioxide (CO_2)
- Agriculture and the land use sector is one of the biggest influences on climate change globally through greenhouse gas (GHG) emissions and reductions of natural carbon sinks, however, this sector also offers significant potential for removing atmospheric GHGs

What is climate change?

Climate change refers to a meaningful statistical change in the state or variability of the climate (loosely defined as the average weather) over a period of time. The main climactic pattern change associated with the term climate change is the increase of global average temperatures. Whilst many view climate change as an inherently human-associated process, due to its consistent representation in the media, climate change does also inherently occur naturally over time. However, research has noted an acceleration in climate change towards increased temperatures which correlates with human activity, particularly following historical industrialisation. As such, 'climate change' is often specified to be related to direct and indirect human activity (As noted by the united nations framework convention on climate change UNFCCC) and the term 'climate variability' is used to discuss natural causes of change. Climate variability has demonstrated natural cycling of cold 'glacial' and warmer 'interglacial' periods which occur over 1,000's or 10,000's of years. This, normally gradual, changing of temperature which can fluctuate in range over 11°C can be linked to shifts in the earth orbit along with volcanic eruptions and changes in the sun's solar activity.

One of the key ways science allows us to ascertain climate change is through monitoring polar ice sheets. Ice sheets have developed over hundreds of thousands of years, and within them contain trapped air bubbles which act as a snapshot of that period's atmospheric gas levels. The trend observed over the last 1,000 years demonstrates a significant increase, in gasses associated with climate change, becoming present in higher concentrations as human industrial activity became more common (1760's onwards) (Figure 1). Another term which has direct links to climate

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change, and tends to focus on the effects of human activity, is 'global warming', as it implies this focuses on the noted trend of the surface warming effects of climate change.

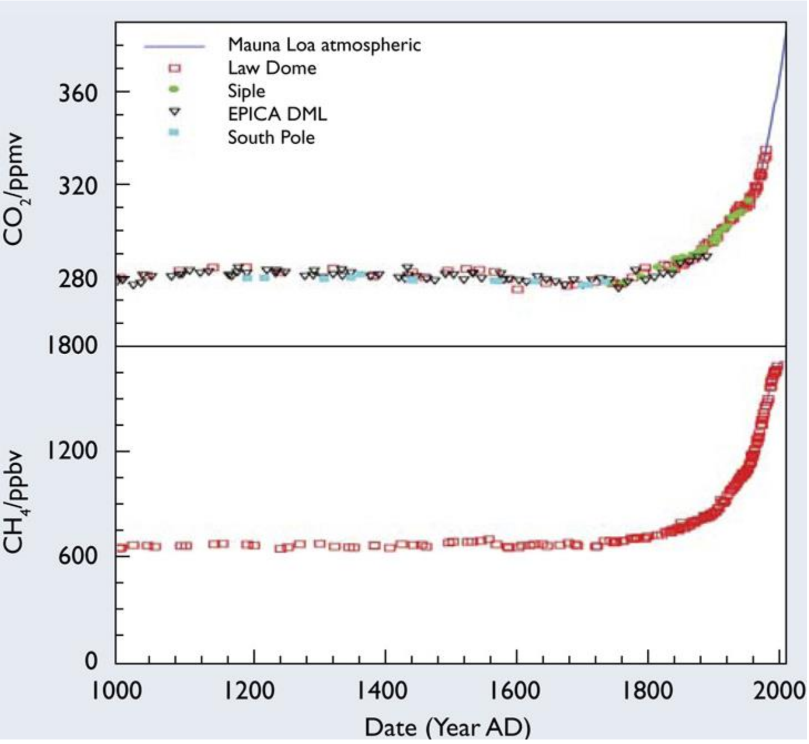

Figure 1Taken from British Antarctic Survey - CO_2 and CH_4 level over the last 1,000 years

What are greenhouse gasses?

The process which causes the increase of temperatures related to current climate change patterns is referred to as the greenhouse effect. This process involves the observation that certain atmospheric gasses act similarly to glass in a greenhouse, in that they allow shorter wavelength radiation from the sun through, but absorb and reradiate (in all directions) the longer infrared radiation 'reflected' back from the earth (figure 2). The gases in the atmosphere which act to absorb and reradiate heat have commonly become referred to as greenhouse gases (GHGs) and it is high quantities of these which can cause global temperatures to increase. GHGs include water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydroflurocarbons (HFCs) and perfluorocarbons (PFCs). As can be seen 4 of these GHG groups contain carbon molecules, and within these, CO_2 makes up the largest proportion. The most recent figures suggest CO_2 to be present at 407.8 parts per million in the atmosphere, this further demonstrates a continuing annual trend of increases. As such 'carbon' often becomes a proxy term for discussing GHGs or climate change in general. Current concentrations of CO_2 are more than 200 x higher than all other human activity related GHGs combined, as such, CO_2 is considered the single biggest contributor to climate change.

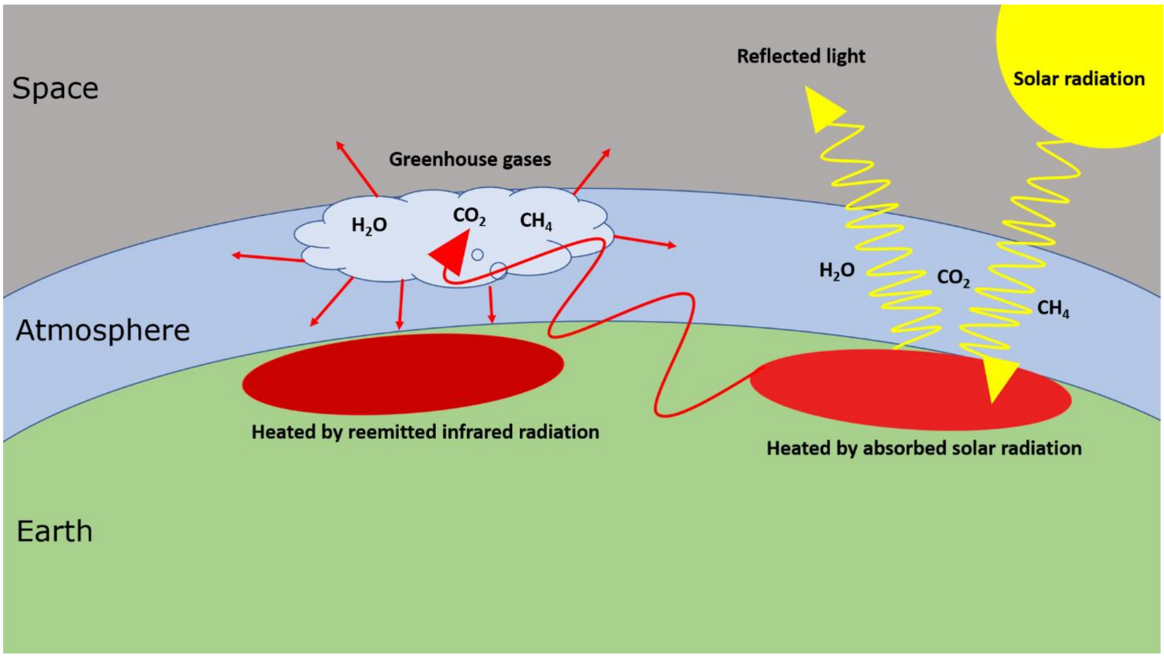

Figure 2 The Greenhouse effect and the Gases involved

Changes to the net amount of energy which reaches the earth's surface are discussed in regards to radiative forcing (RF), with positive radiative forcing increasing earth's surface temperatures and negative radiative forcing having the opposite effect,t both are measured in watts per square meter (W/m^2). A common measurement which is based on RF is global warming potential (GWP), this looks at the total RF effect over time per unit of a gas in relation to CO_2 as a set standard (CO_2's GWP = 1). One of the most significant impacts which lead to the increased presence of GHGs in the atmosphere was the initial discovery that burning fossil fuels produces energy. Fossil fuels had previously acted as a long-term store of carbon. Between 1750 and 2011 fossil fuels combustion has accounted for >70% of all the human-related CO_2 present in the atmosphere, demonstrating its significant impact. CH_4 and N_2O emissions are the second and third largest emissions respectively (16% and 6%). More than half of all the CH_4 produced originates from microbial sources, whether these are within ruminant stomachs, rice paddies or soils. Recent research suggests a compounding effect of rising temperatures as climate change effects cause increasingly ideal environments, in which microbes will thrive. Increase microbial activity and stability will, therefore, lead to increased CH_4 and N_2O production. The largest contributor of N_2O is suggested to be fertilisers used in agricultural practices as these are cycled through nitrification and denitrification via microbes in soils.

Carbon and carbon equivalents

Carbon is a crucial element for all life on earth, it is present in animals, plants, rocks, oceans, the soils and it cycles between these allowing its continued re-distribution into various sources, or 'carbon sinks'. Whilst there are complex considerations involved in carbon cycling concerning naturally produced 'organic' carbon sources, as well as artificial 'inorganic' sources, the key consideration for climate change involves the balance of emissions of 'inorganic' CO_2 and its storage or sequestration into the land and the oceans.

Land sequestration

Sequestration of CO_2 in land systems occurs almost entirely through photosynthesis, where CO_2 is converted to sugars within plants and released back as oxygen (O_2). Therefore, vegetation, particularly forestry, acts as a vital carbon sink. However, increasing temperatures, associated with climate change patterns, may limit photosynthesis through various mechanisms, leading to saturation points eventually being reached. Sequestration (essentially storage) of carbon into vegetation, leads to its conversion to soil organic carbon (SOC), this cycling is linked both directly to plant growth, plant-soil microbiome interactions and plant death through decomposition. There are direct routes for sequestration of carbon, independent of plants into soils, however, the sequestration values are comparatively low and carbon is far less effectively sequestered longer-term.

Ocean sequestration

Our oceans are said to have absorbed 41% of the human activity related CO_2 being emitted into the atmosphere to date and as such are considered significantly beneficial as a carbon sink. One main route of sequestration within oceans involves the biological incorporation of carbon, through marine photosynthesis (via phytoplankton etc), into marine organisms through consumption. Following consumption, there is vertical cycling of carbon, as dead organisms sink to the ocean's depths. This vertical gradient of carbon is often referred to as the carbon biological pump, equally a physical pump system also exists whereby atmospheric CO_2 dissolves at the surface of oceans and is circulated into deep oceans through convection currents. Whilst oceans act as a carbon sink, many other aquatic systems (lakes and rivers) are considered to be opposingly involved in the net emission of CO_2. However, one other set of aquatic systems which has been demonstrated to act as a significant sink of carbon are glacier-fed rivers and lakes these contain high levels of minerals particularly carbonate and silicate which can actively remove CO_2 via weathering process'.

An important concept when considering the impact of CO_2 on climate change is that its presence in the atmosphere is cumulative, therefore, any emissions which are not sequestered long term by the land, or our oceans, remain in the atmosphere and are additive on top of all future emissions. This principle influenced the formation of a social cost of carbon (SCC) concept, which influences the implementation of climate change policies, climate change caps and costing of carbon outputs.

Global climate change

Globally the trends of climate change over the last several hundred years have led to a 1 – 1.2°C increase in average land temperatures. Alongside this, a significant proportion of work suggests increases in climate extremes globally. The extremes include higher levels of rainfall leading to more intensive flooding, whilst other regions are experiencing more intense and longer droughts. A high level of agreement has been reached on models of climate patterns which predict substantive warming by the end of the 21st century at our current rates of emissions, with 'extreme maximum temperatures' set to rise by up to 5°C and become more frequent. Increasing temperatures appear linked to increasing sea ice presence and glacial melting which are thought to be the main drivers for increasing sea levels.

Globally emissions per sector suggest that electricity and heat production along with agricultural and land use-based sectors are biggest contributors of GHGs (**Figure 3**).

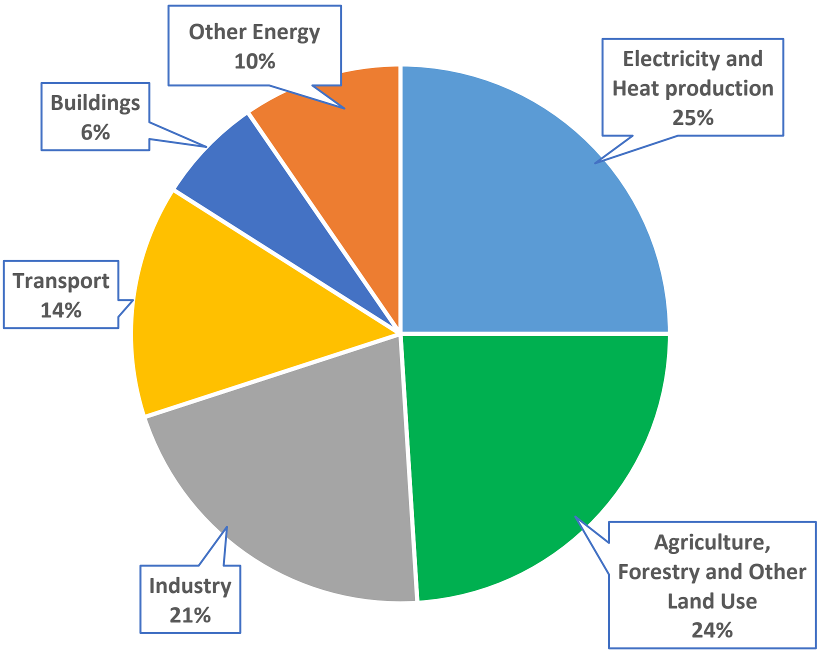

Figure 3 Human-activity related GHG emissions per economic sector based on IPCC (2014)

UK Climate change

In the UK the most recent comprehensive report of our weather patterns, from 2018, has demonstrated increasing heating trends. On average a 0.3°C increase in land temperatures has been documented since 2009 and an average increase of 0.9°C compared to the period from 1961-1990. This matches with the occurrence of our seventh warmest year, in 2018, in the UK since 1884, with all of the top 10 warmest years since 1884 occurring between 2002 and 2018. Alongside these figures, the UK has also experienced some extreme weather patterns including;

- The highest UK December temperature on record 18.7°C - (2019)
- A new UK record temperature of 38.7°C - (2019)
- The warmest driest summer in over 100 years - (2018)
- Most extreme rainfall in south wales in 50 years - (2018)

The UK is currently considered to be the country with the 8th highest emissions of CO_2 when scaled per head of population and the 15th highest country when direct emissions are analysed. The UK has, however, seen a gradual decrease in its emissions levels within the last 30 years with 44% reductions in total GHGs produced and 39% reductions in CO_2 specifically. This trend correlates significantly with our change in reliance on coal as a fuel source.

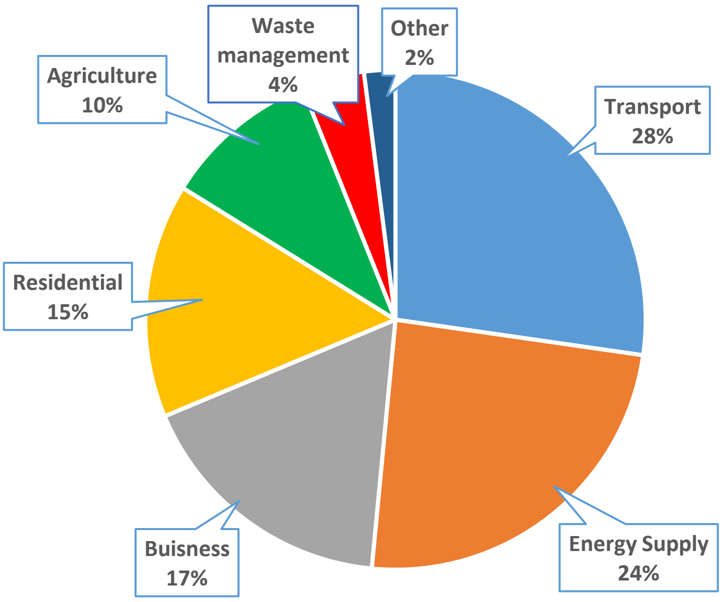

Figure 4 GHG emissions per sector in the UK - Data from the Department of Business, Energy and Industrial Strategy (DBEIS) (2016)

Agriculture and climate change

Agriculture can be seen to be having significant effects on both regional and global GHG emissions (figure 3 and 4). In the most recent figures from the Department for Environment Food and Rural Affairs (DEFRA), the UK ranked the 12th highest country for our CO_2 emissions per $ of agricultural production. Agricultural and land-based emissions which are contributing to this can come from many sources including;

- Livestock – through direct emissions, feed production and processing
- Manure and slurry – through their storage and spreading procedures
- Management of grasslands and crops – through fertilisers and other chemical applications which can influence GHG productions directly or indirectly
- Soil management – through the processing of fertilisers, the drainage of peat and compaction and physical factors
- Farm infrastructure and transport – through fuel use, heating, electricity, machinery production and food processing.

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However, natural and agricultural land-based systems also offer opportunities for some of the most substantive approaches through which we can increase our sequestration or mitigation of global climate change. This is particularly possible through maintenance or creation of carbon sinks such as soil. Key carbon sinks to be considered in agriculture include;

- Vegetation – including riparian strips, mixed species grasslands, protected scrubland
- Forestry – Agroforestry practices, hedgerow plantations
- Soils – through appropriate management of soil health, reduced or no-till farming and many others

Research suggests that the warming environment, related to climate change, will have a mixture of beneficial and detrimental effects on farmers. Warmer temperatures and increased CO_2 may well increase life cycle speeds of grain crop production, though other crops which are more temperate adapted or sensitive to changes may suffer. Equally the likelihood of more extreme flood and drought scenarios may have significant stresses on farmers crops and outdoor livestock productivity. Alongside this, longer summers and warmer winters will likely increase disease pressure on crops and animals (cold winter periods often act to halt/kill disease vectors).

Summary

Over the last several hundred years (following industrialisation) there has been increasing evidence of a statistically meaningful increase in global temperatures. This suggests human activity is having an increased climate change effect. The main human factors affecting this global warming are the increased production of GHGs produced through a variety of process across multiple sectors. Whilst GHG figures globally are still increasing overall, the UK has seen some decline in its emissions, however, there are still further gains to be made in combating GHG production and accumulation in the earth's atmosphere. Agricultural/forestry land is a substantial emitter of GHGs but conversely has a huge potential to be utilised as a mitigating sector through the role of trees/vegetation and soils as active carbon sinks.

Date (March 2020)

Note to editors:
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Background information:
This project has received funding through the Welsh Government Rural Communities - Rural Development Programme 2014-2020, which is funded by the European Agricultural Fund for Rural Development and the Welsh Government.
The Farming Connect Knowledge Transfer Programme and Advisory Service is delivered by Menter a Busnes on behalf of Welsh Government. Lantra Wales leads on the delivery of the Farming Connect Lifelong Learning and Development Programme.

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