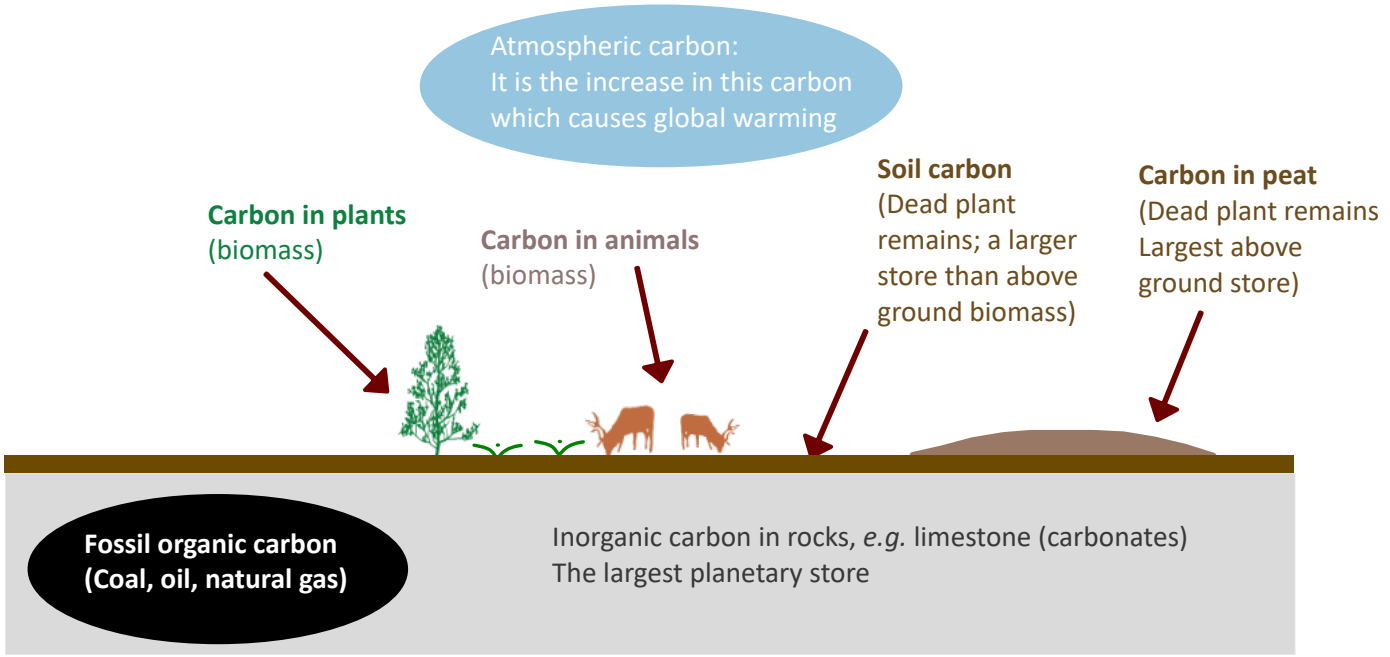
Global warming, carbon emissions and land use in Scotland: a simplified guide

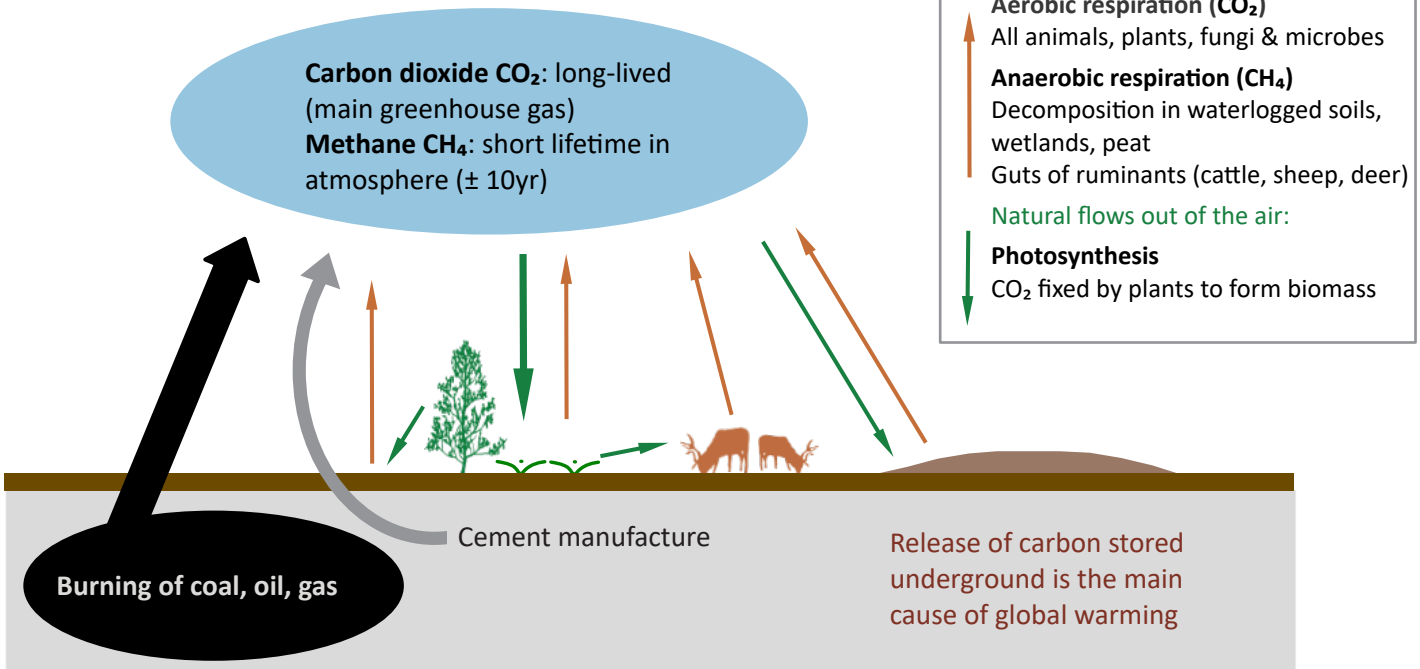
Dr James Fenton 7 March 2020
ecology@fenton.scot, www.fenton.scot

1. TERRESTRIAL CARBON STORES IN SCOTLAND



---

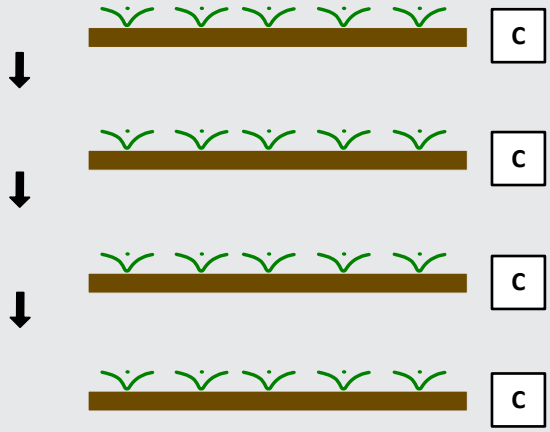
2. CARBON FLOWS



Note: The impact of the sea is not considered here, but the marine environment has been absorbing much of the carbon released from fossil fuels (more so than the land), i.e. *acting as a carbon sink*

3. DIFFERENCE BETWEEN A CARBON STORE & A CARBON SINK

a. Most ecosystems (including forests)

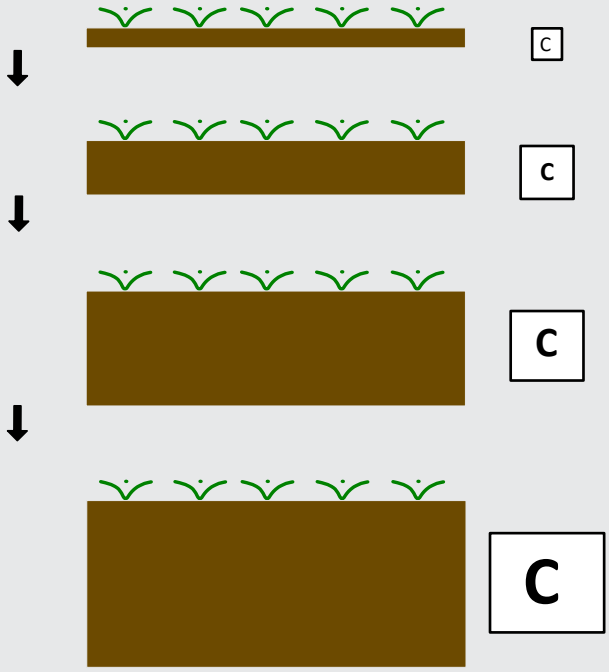


A carbon store but not a carbon sink

In most ecosystems the amount of carbon stored in plants, animals and soil is constant over time.

These ecosystems do not result in a reduction in atmospheric carbon

b. Peat-forming ecosystems



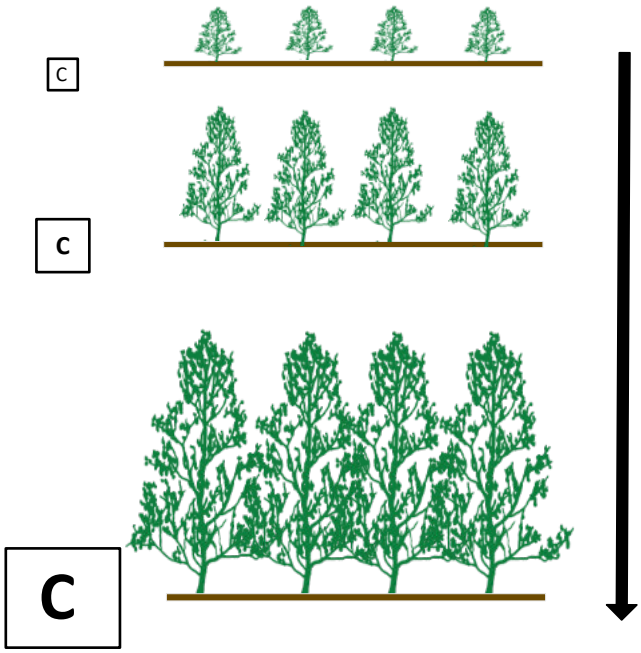
A carbon store and a carbon sink

In peat-forming ecosystems the amount of carbon stored (carbon sequestration) increases over time, hence leading to a reduction in atmospheric carbon

Unlike forests, peat bogs can remain as carbon sinks for 1000s of years

c. New forests

A new forest on mineral soils is a temporary carbon sink

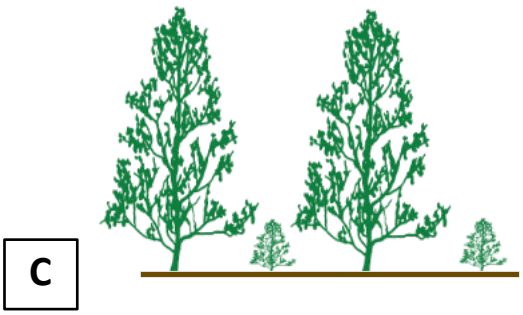


Carbon sink phase

If the forest is felled, then the stored carbon will be released if the wood is burnt. Hence burning wood (biomass) is carbon neutral over time

If the trees are used as structural timber, then the forest is in effect a carbon sink, because over time the amount of structural timber increases

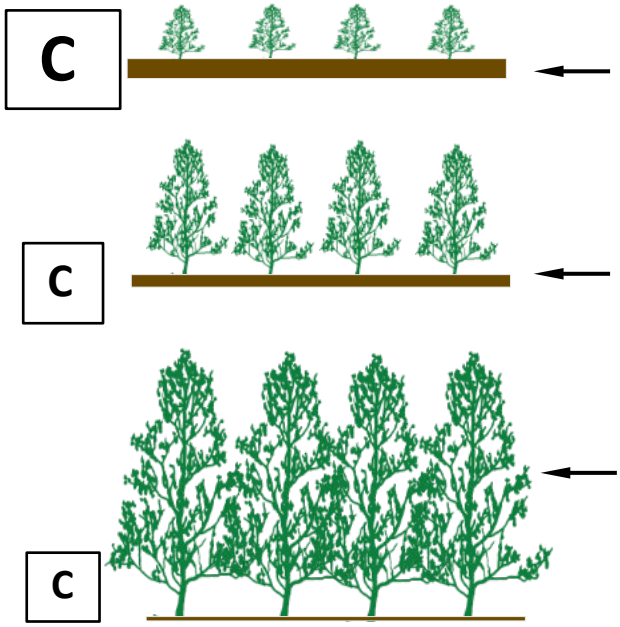
In a managed forest with planting/felling cycles, the average amount of carbon stored over sequential rotations will equal half the maximum standing crop



Once a forest matures and trees dying are matched by trees regenerating then the forest remains a store, but is no longer a sink: *i.e.* it can no longer cause a reduction in atmospheric carbon (will no longer mitigate climate change, or be 'offsetting' carbon)

4. TREES & CARBON FLOWS

a. Trees planted on organic-rich upland soils



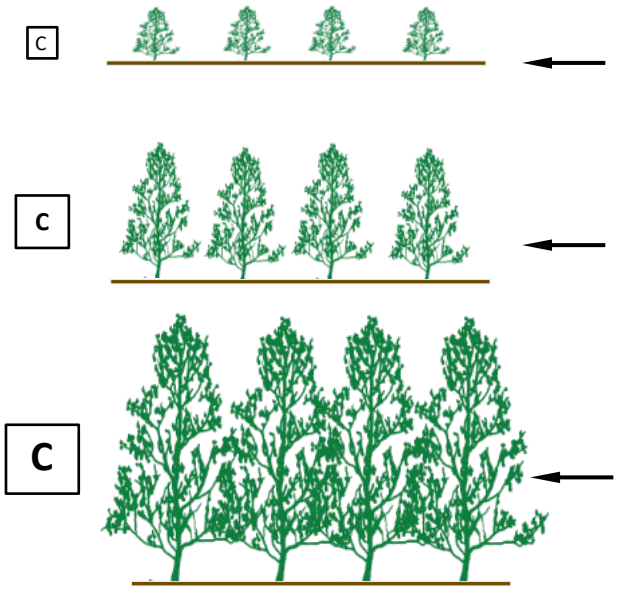
In Scotland most carbon is stored in the soil
Upland soils are particularly carbon-rich (podsols, peaty gleys, peat, under bracken)
A dense humus (organic) layer 10cm deep will hold as much carbon as a mature forest

As trees grow, the organic layer dries out and oxidises, releasing its stored carbon

Although trees have become a carbon store, the overall carbon store has declined

Hence in this instance tree planting will not mitigate global warming

b. Trees planted on organic-deficient mineral soils

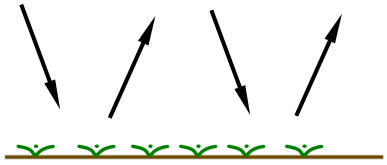


Little carbon stored in soil

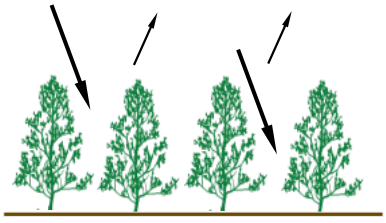
As trees grow, total amount of carbon stored increases (as biomass, not soil carbon)

A new forest on such soils can potentially mitigate global warming

c. Albedo: a complicating factor



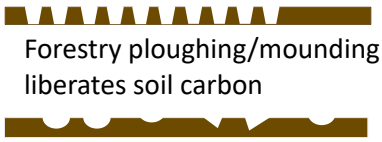
Open ground: two-dimensional, much radiation reflected; more so if pale in winter (dead grass) or winter snow



Forests: three-dimensional, more radiation absorbed (especially dark conifers), warming-up the local climate

In higher latitudes, the reduction in albedo from forest expansion can be a driver of global warming: the warming impact of reduced albedo overriding the cooling impact of the carbon stored

d. Other impacts: establishment & felling



Forestry ploughing/mounding liberates soil carbon

Felling machinery churns up the soil, releasing carbon

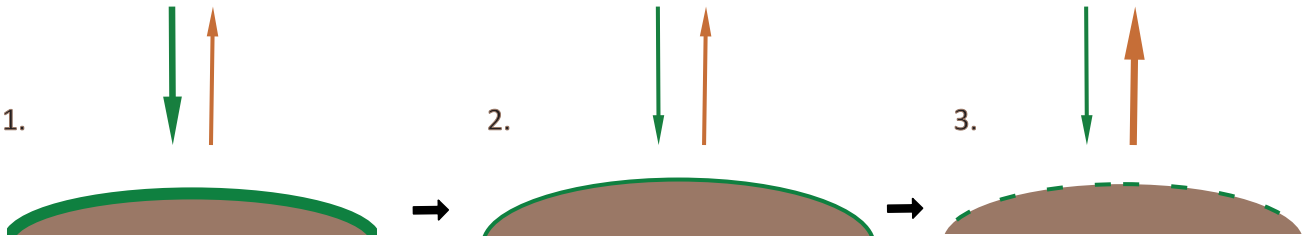
To determine whether a given tree planting scheme will mitigate climate change, the following variables need to be determined:

1. **Rate of tree growth**
2. **Current albedo**
3. **Future albedo**
4. **Current soil carbon content**
5. **Site's long-term peat-forming potential (best left to grow peat)**
6. **Establishment method**
7. **Probability of trees blowing down in later years**

5. PEATLAND AND CARBON FLOWS

a. Carbon balance of peat

Note: In practice it can be difficult to determine the overall carbon balance of a given peat bog



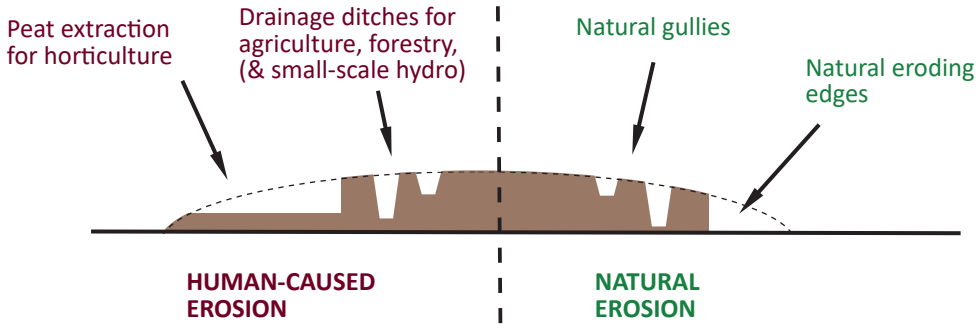
– Active peat-forming bog
– Carbon input (CO_2) > carbon output (CO_2, CH_4)
– Complete vegetation cover
– Crustose lichens rare
– **A carbon sink**

– Mature bog
– Carbon input (CO_2) = carbon output (CO_2, CH_4)
– Vegetation cover variable
– Crustose lichens common
– **A carbon store but not a sink**

– Eroding bog
– Carbon input (CO_2) < carbon output (CO_2, CH_4)
– Exposed peat present
– Crustose lichens common
– **A carbon source**

---

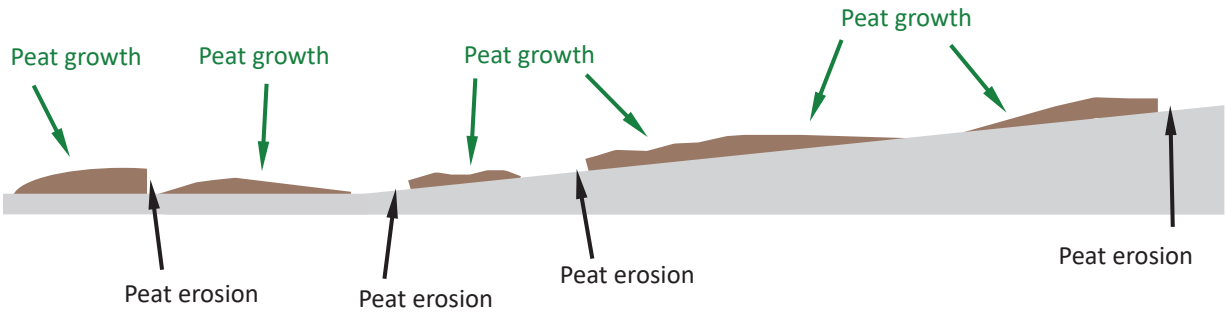
b. Peat erosion



In drought conditions fierce fires, whether natural or human-caused, can result in exposure of peat at the surface

---

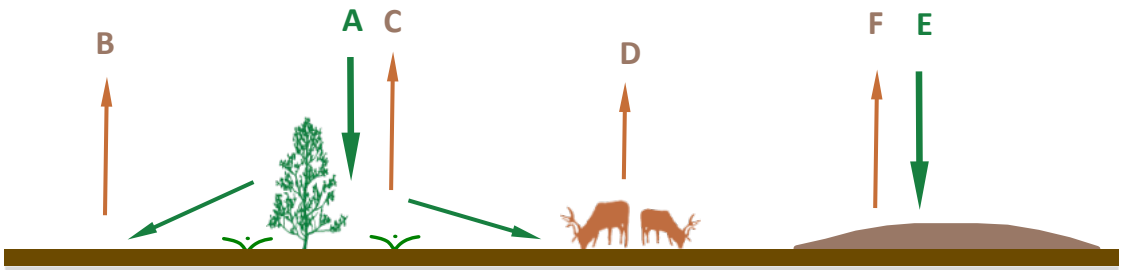
c. Peatlands at the landscape scale



Much of upland Scotland is a naturally complex landscape of both growing & eroding peat. The growing peat is absorbing carbon, the eroding areas emitting carbon. It can be hard to determine the overall carbon budget of such areas

Revegetating the eroding areas will reduce carbon release, but can go against nature conservation principles (allowing natural processes to be in charge) – see Fig. 8b below. Whatever action is taken, long-term natural processes will continue to result in new eroding areas and new recovering areas

6. CARBON CYCLING IN NATURAL ECOSYSTEMS



Note: In winter when there is little or any photosynthesis plants will be a net carbon source, releasing CO_2 to the air through respiration. In summer, while respiration continues, uptake of carbon by photosynthesis will exceed that from respiration. Hence in winter plants are a carbon source, in summer a carbon sink

In **most ecosystems** the overall carbon balance is neutral, *i.e.* in the picture above

A = B + C + D

Carbon is merely cycling between biomass and the air (see also Fig. 3a)

Hence carbon emissions in most natural ecosystems are not relevant to global warming

In **peatlands**, in an actively growing bog (Fig.5a1) **E > F**

In a mature bog (Fig.5a2) **E = F**

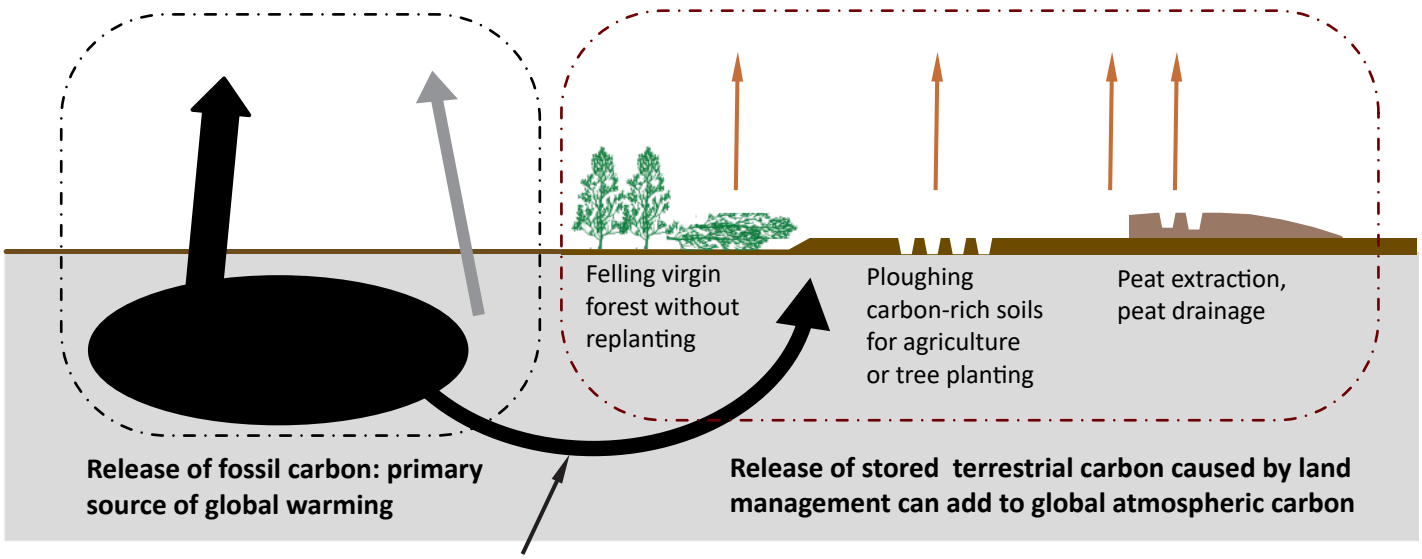
In an eroding bog (Fig. 5a3) **E < F**

Natural peat bogs can be in any of these three states and hence are relevant to global warming

---

7. LAND USE AND GLOBAL WARMING

The management practices below contribute to global warming

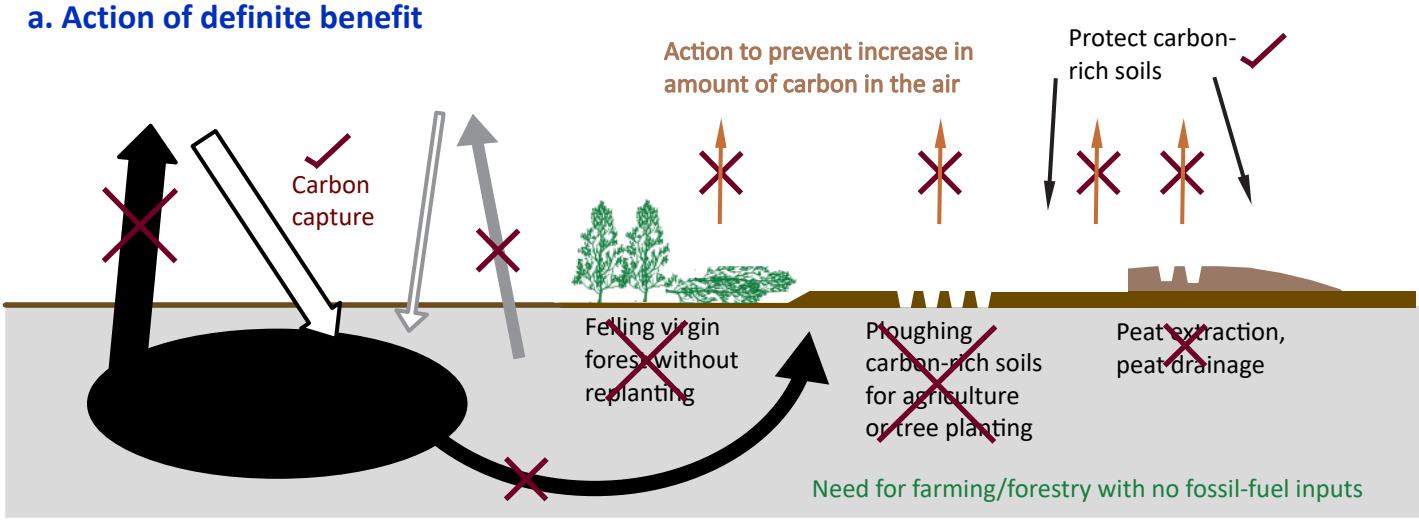


The following use of fossil fuels in land use needs to be eliminated to ensure net-zero carbon:

– Farm/forestry machinery, including wood processing
– Fertiliser, herbicide & pesticide manufacture & transport
– Processing & transport of animal feed

8. ACTION TO MITIGATE GLOBAL WARMING (to achieve net-zero emissions)

a. Action of definite benefit



1. Stopping release of organic and inorganic fossil carbon (coal, oil, gas, cement)

– Through replacement with non-fossil alternatives &/or carbon capture (still unproven at a large scale)

– Including stopping use of fossil carbon in any land management activities (machinery, fertiliser manufacture, animal feed, *etc*.)

2. Stopping felling of virgin forest and replacement with pasture (does not apply to Scotland)

3. No ploughing of carbon-rich soils, whether for agriculture or forestry

4. Cessation of peat extraction for horticulture

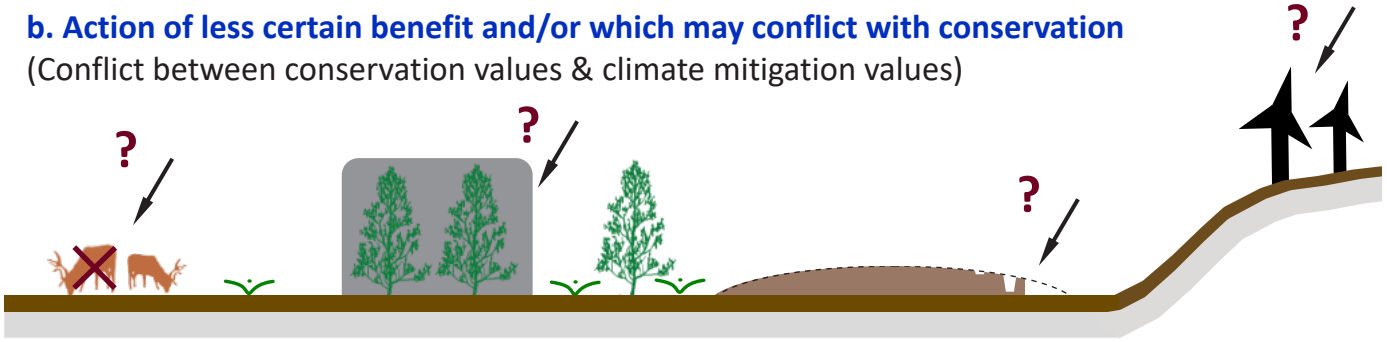
5. Filling-in drainage ditches in peat

6. Leave carbon-rich soils intact (& unplanted) to allow soil carbon stores to build up, leading eventually to new peat bogs

---

b. Action of less certain benefit and/or which may conflict with conservation

(Conflict between conservation values & climate mitigation values)



– Removing grazing results in unnatural ecosystems with loss of grazing-dependent species (loss of biodiversity), and reduction on overall ecosystem fertility (loss of dunging/manuring effect)

– Methane from the guts of ruminants is recycled atmospheric carbon, not the adding of fossil carbon to the air

– Sheep have a future for producing a non-fossil (non plastic) textile (wool) in an extensive, low carbon system

– Planting trees on organic soils

– Planting trees on natural habitats (which have a high biodiversity value, such as ancient grasslands or heath)

– The whole issue of how effective tree planting is in Scotland for climate change mitigation needs greater scrutiny of all the variables listed in Fig. 4

– Reprofiling & revegetating naturally eroding peatlands: Scotland is the world centre of temperate blanket peat and interfering with natural peatland cycles goes against the conservation principle of rewilding: "let natural processes dominate"

– Addition of renewable energy infrastructure **in cherished and wild landscapes**; could result eventually in no wild places left in Scotland (Dams, pipes, draw-down zones, tracks, turbine houses,wind turbines, powerlines, masts)

Carbon offsetting: a questionable concept in Scotland

'Carbon offsetting' is an accounting system where use of a given amount of fossil fuels is balanced by creating a new store of the same size on land. The whole approach to using terrestrial ecosystems in Scotland for carbon offsetting is questionable, although it may work with tree planting on organic-poor soils and reprofiling of eroding bogs: however such action can be in conflict with nature conservation

It sometimes is also used to mean creation of the same amount of renewable energy as the amount of fossil carbon used, but this perhaps not true offsetting because it does not lead to lowering of carbon in the air (the cause of global warming). The only real solution to global warming is to stop outputting fossil carbon to the air