CARBON ACCOUNTING IN AGRICULTURE: Why and how

Climate change and agriculture

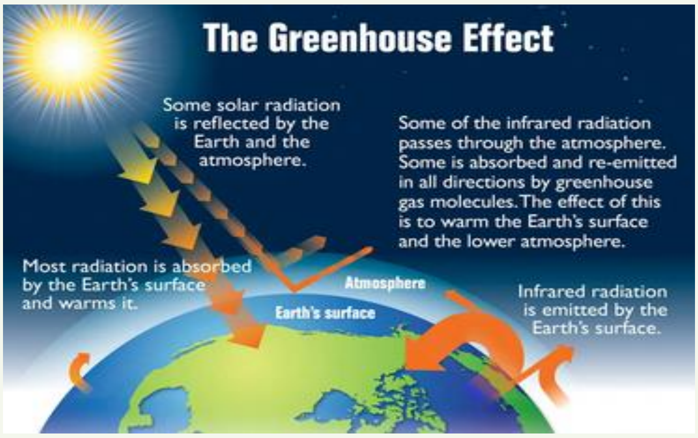
Agriculture is in a unique position: both impacted by climate change due to its dependency on environmental conditions and its contribution to climate change through the release of greenhouse gases (GHGs). According to the Intergovernmental Panel on Climate Change (IPCC) AR6 report, the Agriculture, Forestry, and Other Land Use (AFOLU) sector contributed to 22% of GHG emissions globally in 2019[1].

Climate change impacts in the region

Singapore's Third National Climate Change study (V3) projected an average increase of 1.0°C – 2.2°C in daily maximum temperature for Southeast Asia by mid-century[2]. The IPCC AR6 WGII report projects with medium confidence that climate change will result in increased pest occurrence and distribution, further amplified by climate change induced extreme events (e.g., droughts, floods, heatwaves and wildfires)[3]. These extreme weather events may also destroy crops, farm infrastructure, and disrupt agri-input supply chains.

Agricultural GHG emissions

Agriculture releases GHGs into the environment through activities such as fertiliser application, use of energy, and waste management.



Source: US EPA

GHGs absorb infrared radiation (heat energy) emitted from Earth's surface and reradiate it back. An increase in GHGs in the Earth's atmosphere hence leads to global warming – the long-term increase in Earth's air and sea surface temperatures.

Commonly released GHGs in agriculture are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Benefits of carbon accounting in agriculture

1. **Provide quantitative evidence for sustainability of produce.**

While agriculture has garnered a negative reputation globally as being a major contributor to GHG emissions, many urban farms implement practices that are more sustainable compared to traditional agriculture e.g. more efficient use of water, shorter transport distances from farm to consumers. These benefits can be quantified in terms of GHG emissions reductions. With growing recognition from consumers and investors globally on the importance of sustainability, carbon accounting can be one tool to provide evidence for sustainability claims.

2. **Fulfil reporting requirements.**

All listed companies in Singapore will be required to report their Scope 1 and 2 emissions from FY25 onwards and Scope 3 emissions by FY26 onwards*. Large non-listed companies have an additional two years. Farms who supply to companies (and hence contribute to the companies' Scope 3 emissions) which are required to do such reporting may be asked by these companies to report their emissions.

*Definition of Scope 1, 2, and 3 emissions can be found on page 2.

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Life cycle assessment: a method of carbon accounting

Life cycle assessment (LCA) for a product refers to the "compilation and evaluation of inputs, outputs and potential environmental impacts of a product system throughout its lifecycle" (ISO 14044:2006)[4].

LCA is a carbon accounting method that determines the GHG emissions of a product throughout its lifecycle. Carbon accounting may also be conducted at the organizational, national, project, or policy levels.

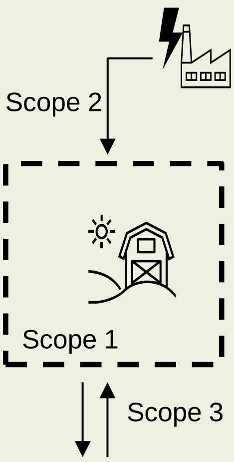
Emissions accounted for include both GHGs directly released by the farm's processes, e.g. release of GHG when fertiliser is applied to the soil, as well as indirect emissions. Indirect emissions refer to the GHGs directly released from activities which are not carried out by the farm but occur to produce the inputs used by the farm and process the outputs from the farm.

LCA concepts and terminologies

Emission scopes[5]

GHG emissions can be classified into scope 1, 2 and 3 emissions:

- **Scope 1** – Direct emissions from sources owned or controlled by the farm, e.g. emissions from fertiliser application
- **Scope 2** – Indirect emissions from energy purchased by the farm, e.g. emissions that result from the generation of grid electricity used by the farm
- **Scope 3** - Indirect emissions from other inputs or outputs in the farm's value chain involved in the production of the food, e.g. emissions released from the production of the fertiliser used by the farm



Functional unit

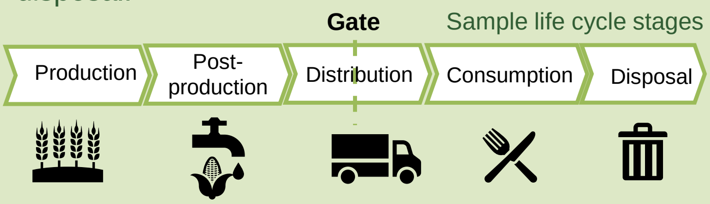
The functional unit is a unit of reference around which inputs and outputs of the product system are quantified, e.g. 1 kg of food produced.

Assessment boundary

The assessment boundary of an LCA typically includes all processes starting from the acquisition of raw materials all the way to the end of life of the product (cradle-to-grave). A partial cradle-to-gate inventory may also be conducted instead where the analysis stops when the product leaves the farm gate.

Life cycle stages

For a cradle-to-gate inventory, farms may consider using three life cycle stages: (1) production, (2) post-production, and (3) distribution. A cradle-to-grave inventory would also include stages such as the use of the produce (e.g. cooking and eating) and disposal.



Terminology

Global warming potential (GWP). The potential of each GHG to trap heat in the atmosphere relative to one kilogram of carbon dioxide, usually calculated based on a 100-year time horizon.

GHG	GWP for 100-year time horizon	
	IPCC AR5*	IPCC AR6*
CO_2	1	1
CH_4 (non-fossil)	28	27
N_2O	265	273

*While AR6 values are the most recent, AR5 values are still sometimes used.

CO_2-equivalents (CO_2-eq). Unit metric that allows for the summation of different GHGs through multiplying them by their GWP.

Emission factors. "Coefficients which quantify the emissions or removals per unit activity" - *IPCC 2006 Guidelines for National Greenhouse Gas Inventories*[6]

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Common agricultural GHG emission sources in Singapore

Note: List is not exhaustive and varies depending on farm type.

Production/application of inputs/consumables

- Seed
- Water
- Fertiliser*
- Refrigerant*
- Substrate*
- Pesticide
- Packaging for produce*

Generation of energy

- Grid electricity*
- Diesel/petrol*
- Renewable energy

Treatment of waste

- Vegetable trimming
- Packaging from inputs
- Wastewater

* indicates typical major emission sources for farms in Singapore.

These activities release various GHGs, most commonly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in agriculture. The specific GHG released depends on the activity, e.g. application of nitrogen (N) fertilisers releases N_2O, while generation of electricity releases CO_2.

GHG emissions calculations (general)

GHG emissions for a particular activity can be calculated using the following formula.

Emissions = Activity data (AD) x Emission Factor (EF)

Emission factors can be obtained from various sources including:

- IPCC Guidelines for National Greenhouse Gas Inventories
- Commercial databases
- Published literature
- Direct emission measurement studies

A sample reference for calculated carbon footprint of food items could be the 2019 Environmental Impact of Key Food Items in Singapore study which can be found at https://www.ecosperity.sg/en/ideas/environmental-impact-of-food-in-singapore.html.

Case study

Farm X produces only lettuce and would like to find out the carbon footprint of their lettuce. A suitable functional unit would be 1 kg of lettuce.

The farm decides to conduct a cradle-to-gate inventory. They use the following inputs and generates the following outputs at the different life cycle stages to produce 1 kg of lettuce

Production (growing the lettuce)
- Nutrient solution: 200 g
- Polyurethane sponge: 10 g
- Wastewater (used nutrient solution): 10 L
- Grid electricity: 10 kWh
- PUB water: 20 L
- Seeds: 5 g

Post-production (processing the lettuce and washing)
- PUB water: 30 L
- Vegetable trimmings: 100 g
- Wastewater: 30 L

Distribution (sending the lettuce to the market)
- Petrol: 50 L

Activity	Emission factor
Use of petrol in lorry	A $kgCO_2$-eq/L petrol
Production of grid electricity	B $kgCO_2$-eq/kWh electricity
Production of nutrient solution	C $kgCO_2$-eq/g solution
Production of polyurethane sponge	D $kgCO_2$-eq/g sponge
Third party treatment of wastewater	E $kgCO_2$-eq/L wastewater
Production of PUB water	F $kgCO_2$-eq/L water
Production of seeds	G $kgCO_2$-eq/g seeds
Incineration of waste	H $kgCO_2$e-eq/g waste

Note: Each activity may release more than one GHG but consolidated EFs where the emissions have been converted into CO_2-equivalents have been provided here.

Scope 1 emissions = 50A $kgCO_2$-eq/kg lettuce produced

Scope 2 emissions = 10B $kgCO_2$-eq/kg lettuce produced

Scope 3 emissions = 200C + 10D + 40E + 50F + 5G +100H $kgCO_2$-eq/kg lettuce produced

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Potential strategies/technologies to consider for emissions reduction

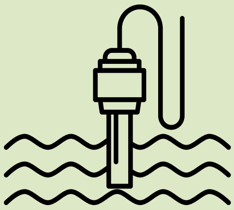
Renewable energy

Utilisation of renewable energy can reduce GHG emissions from energy generation.

- If the farm is using petrol/diesel and generating their own energy on-site, this would reduce scope 1 emissions.
- If the farm is using grid electricity, this would reduce scope 2 emissions.

Farms may choose to:

- Install their own renewable energy technologies, e.g. solar panels.
- Purchase renewable energy certificates (RECs).
- Enter into Power Purchase Agreements (PPA) - energy company pays for, installs, and maintains the solar panels on the farm's property, and sells the generated electricity at a lower price to the farms.



Precision agriculture

Precision agriculture involves applying the exact amount of inputs and environmental conditions required by the crops. Technologies involved include:

- Sensors for real-time measurement of growing and environmental parameters
- Climate control systems to adjust the environmental conditions
- Automated dosing systems to apply fertiliser/nutrients as required
- Adjustable grow lights to provide the optimal light recipe.

This would reduce emissions associated with the production of the inputs (scope 2 if electricity, and likely scope 3 emissions if the inputs are purchased) and treatment of any waste produced from the use of excess inputs.

Optimising productivity could also reduce emissions on a per kg produce basis if production increase outpaces any increase in inputs used.

Find out more!

Local farms can tap on the Agri-Cluster Transformation (ACT) Fund with the enhanced Energy Efficiency Programme (EEP) to build capabilities and capacities that drive higher productivity in a sustainable and resource-efficient manner. Farms can tap on co-funding under the EEP to undergo an energy efficiency audit which would establish their baseline energy consumption and identify potential areas for improvements. Farms can also leverage the enhanced Capability Upgrading component to adopt resource and energy-efficient equipment and technologies from SFA's prequalified list. All licensed farms can apply for co-funding under the EEP.

Let us know your thoughts

About the Author

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