

Operational Carbon Footprint of an Organic Agroforestry System in Denmark

Operation-level Life Cycle Assessment (LCA) of a combined food and energy agroforestry system

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Image source: REFOREST Living Lab Denmark webpage

2,720.95

kg CO₂e/ha over the four-year operational cycle

62-63%

of total operational emissions originated from tree belts

~87%

of both crop-alley and tree-belt footprints came from direct diesel combustion

System context



Combined Food and Energy (CFE) system

Organic alley-cropping system at Taastrup Campus, University of Copenhagen.

Arable alleys: winter wheat, spring oat, spring barley undersown with clover-ryegrass, and clover-ryegrass ley.

Short-rotation coppice tree belts are harvested every fourth year.

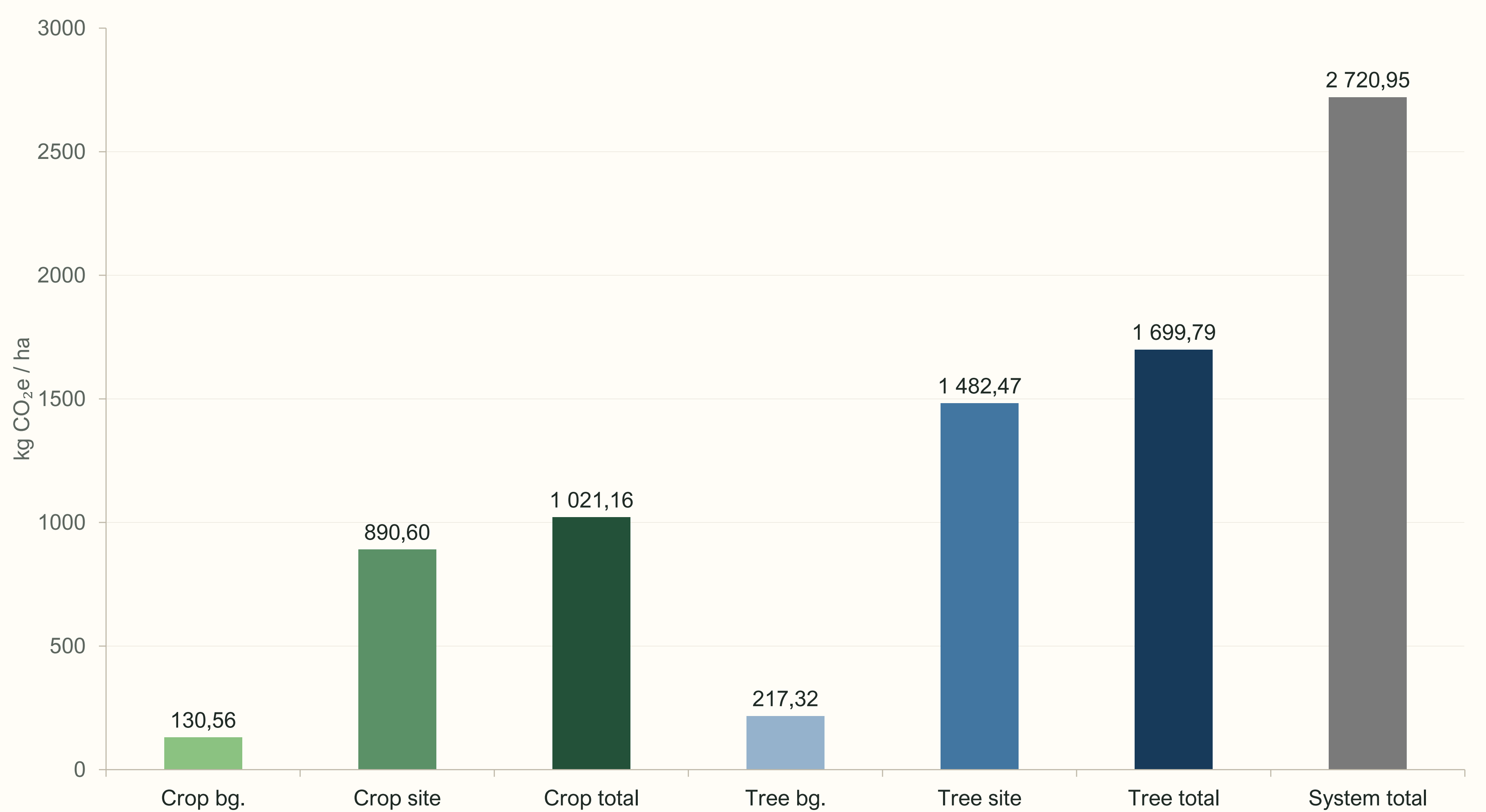
Crop component occupies 94.83% of the total area; tree belts are smaller but structurally and ecologically important.

Study aim & Objectives

Identify how the operational carbon footprint is distributed across space, time and management operations, and which activities contribute most to Greenhouse Gas (GHG) emissions.

Cumulative operational carbon footprint

Field-operation emissions in crop alleys and tree belts over the four-year cycle [kg CO₂e/ha].



bg. = upstream diesel production and supply; site = direct on-site mobile fuel combustion. Values are Global Warming Potential (GWP 100 years), CML2001 - Aug. 2016.

Assessment approach

Functional unit	1 ha managed land
Emission scope	Field operations and diesel use
Components	Direct on-site combustion + upstream diesel production/supply
Impact metric	Global Warming Potential (GWP), 100 years; CML2001 - Aug. 2016

Two operational patterns were compared:

- steady annual crop-alley operations
- cyclic woody biomass harvest in tree belts

Interpretation focus

Which land-use component carries the largest operational burden?
How much of the footprint is driven by direct diesel combustion?
Which operations offer the most realistic decarbonisation leverage?

What drives the footprint?

Crop alleys

1,021.16 kg CO₂e/ha

Years 1-3: moderate and balanced emissions.

Year 4 clover-ryegrass ley: only 100.69 kg CO₂e/ha due to mowing-only management.

Ploughing and harvesting dominate cereal phases.

Tree belts

1,699.79 kg CO₂e/ha

Establishment: 212.09 kg CO₂e/ha.

Three growth years required no direct machine intervention.

Coppice harvest peak: 1,487.70 kg CO₂e/ha in year 4.

System lesson

Management design matters

Land-use category alone does not explain emissions.

The timing and intensity of operations create the carbon profile.

Diesel use is the central operational driver.

Decarbonisation opportunities

The main optimisation potential is concentrated in machine operations that shape diesel demand.

Harvest logistics

optimise routing, timing and machinery coordination

Diesel efficiency

reduce fuel use per operation and per harvested biomass unit

Lower tillage intensity

reduce disturbance and combine field passes where possible

Low-emission harvest systems

prioritise technologies that cut the coppice harvest peak

Conclusion

The arable component creates a steady annual emission load, while the woody component creates a pronounced harvest-related peak. Future whole-system assessments should integrate soil-carbon dynamics and long-term agroforestry benefits alongside operational emissions.

Key message

Tree-belt coppice harvest is the dominant operational emission peak, while the crop alleys create a steadier annual diesel-related load