Assessing Eco-Efficiency of Agri-Food Enterprises

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1

Introduction: Background & Motivation

- Agri-food sector as a major GHG emitter (fertilizers, livestock, energy use)
- Increasing pressure to improve environmental and resource efficiency (Green Deal, CSRD, ESRS)
- Existing carbon calculators face methodological fragmentation, high Scope 3 uncertainty and limited adaptation to Slovak agri-food conditions
- Existing calculators provide absolute, or relative - mainly environmental indicators
- Need to link carbon footprint results with production and economic performance

2

Data Sources and Integration

- **Carbon Footprint Calculator for agricultura and food processing companies: Certificate - Total emissions (t CO2e) and breakdown by Scope 1–3.**
- **Enterprise Data: e.g. Utilised agricultural area (ha), Number of employees, Production volumes, Input use, energy, livestock data, product data.**
- **Economic Data (e.g. FINSTAT): Revenue, operating revenue in Euros (€)**
- **Integration: Combining environmental, production, and economic data for holistic assessment.**

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3

Methods: Indicators and Benchmarks

- **Total Carbon Footprint (CF):**

Sum of emissions from all identified sources.

- **Normalised Emission Intensity Metrics:**

  Per land unit

  Per labor unit

  Per revenue and operating revenue

  Product-level indicators

- **Product level emission intensity analysis**

economic allocation to estimate emission intensity of specific outputs (e.g., wheat).

Total carbon footprint

$$CF = \sum_{i=1}^{n} E_i$$

Emission intensity per hectare

$$EI_{ha} = \frac{CF}{A}$$

Emission intensity per employee

$$EI_{lab} = \frac{CF}{L}$$

Emission intensity per revenue and income

$$EI_{rev} = \frac{CF}{R}, EI_{inc} = \frac{CF}{I}$$

Product-level emission intensity (economic allocation)

$$E_j = CF \cdot \frac{R_j}{R}, EI_{prod} = \frac{E_j}{Q_j}$$

Notation:
CF – total emissions; Ei – emissions by source; A – land area; L – labour;
R – revenue; I – operating revenue; Qj – product output

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4

Benchmark Sources for Evaluation

- **Land-based indicators (t CO_2e / ha)**
  Farm Carbon Toolkit (2022) → farm-level benchmarks (**UK farms**, practical tool)
  Hillier et al. (2011) → model-based (Cool Farm Tool, **EU conditions**)
  Weiss & Leip (2012) → EU average (CAPRI model, **sector-level**)
- **Economic and labour indicators**
  Kovanda et al. (2025) → farm benchmarks (Czech Republic, **mixed farm** sample)
- **Product-level indicators (kg CO_2e / unit)**
  Agri-footprint (Blonk, 2022) → LCA database (**EU averages**, product systems)
  Desjardins et al. (2012) → specific production system (**beef cattle**, case-based)
- **Emission structure interpretation**
  IPCC (2006) → **global** methodology (default emission factors)
  EEA (2023) → EU inventory (**aggregated sector** data)
  Leip et al. (2010) → EU nitrogen-related emissions (**model-based**)

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5

Hotspot and Scenario Analysis

Hotspot analysis
Emission share by source
$S_i = E_i / CF$

S_i – share of emission source *i*
E_i – emissions of source *i*
CF – total carbon footprint

Main emission categories
– fertilizers and manure management
– livestock (enteric fermentation)
– fuel and energy use
– other processes

Identification of dominant emission sources

Scenario analysis
Change in emissions
$CF_S = CF \pm \Delta E$

Carbon cost
Cost = CF × Pc

CF_s – emissions in scenario
ΔE – change in emissions
P – carbon price (€/t CO_2e)

Scenarios
– change in key emission sources (±10%)
– illustrative carbon price scenarios (50–150 €/t CO_2e)

Assessment of economic sensitivity and carbon risk

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6

Case study farm

- Slovak agricultural farm - Cfarm, 2024
  Utilised agricultural area: 569 ha
  Number of employees: 8

  micro enterprise; double-entry accounting, FSDN/ISPU participant

- Production orientation

  mixed crop-livestock system
  Arable crops: wheat, other cereals (incl. spelt)
  Livestock: cattle - calf production

- Total emissions
  215.83 t CO_2e

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7

Eco-efficiency indicators and benchmarking

Indicator	Our farm	Benchmark	Source
Emissions per hectare (t CO_2e/ha)	0.379	0.3 – 1.5	Farm Carbon Toolkit; Weiss & Leip
Emissions per employee (t CO_2e/employee)	27.0	34 – 346	Kovanda et al.
Emissions per revenue (t CO_2e / mil. €)	2,719	427 – 4,557	Kovanda et al.
Emissions per operating revenue (t CO_2e / mil. €)	1,894	427 – 4,557	Kovanda et al.
Wheat (kg CO_2e/t)	462	350 – 600	Agri-footprint
Other cereals (kgCO_2e/t)	630	400 – 700	Agri-footprint
Calves (kg CO_2e/kg live weight)	3.02	3.5 – 6.7	Desjardins et al. (2012)

8

Hotspot analysis – results

Emission share by source

$S_i = E_i / CF$

Emissions are highly concentrated in few sources

Two main categories account for ~75% of total emissions

Emission source	Share (%)
Fertilizers and manure management	49.5
Enteric fermentation	27.0
Fuel use (machinery)	7.3
Other sources	16.2

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9

Scenario analysis – results

Change in emissions

$CF_s = CF \pm \Delta E$

Carbon cost

$Cost = CF \times P$

Key results:

- Relatively small emission changes → noticeable economic impact

- Carbon price → strong effect on cost and economic performance

Illustrative carbon pricing scenarios

Scenario	Emissions (t CO_2e)	Carbon cost (€)	Share of operating revenue (%)
Baseline	215.83	21,583	18.9
−10% emissions	197.73	19,773	17.4
+10% emissions	233.93	23,393	20.5
50 €/t CO_2e	215.83	10,792	9.5
100 €/t CO_2e	215.83	21,583	18.9
150 €/t CO_2e	215.83	32,375	28.4

10

Recommendations for farm management

Fertilizers and manure (≈ 50% of total emissions)

- highest mitigation potential
- improve nitrogen efficiency and precision application, manure storage and appl. Improvement

Livestock (≈ 27% of total emissions)

- improve feed conversion efficiency, herd health, weight gain and increase productivity per animal

Fuel use (≈ 7% of total emissions)

- improve machinery and field operation efficiency, lower diesel consumption, …

Economic performance

- improve input-use efficiency
- increase production value per emission unit

Carbon risk

- carbon cost ≈ 19–28% of operating revenue
- emission reduction lowers future carbon cost exposure

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11

Conclusions, limitations and future development

Conclusions

- Extends carbon footprint results using normalized emission intensity metrics
- Links emissions with production and economic performance
- Integrates benchmarking, hotspot and scenario analysis

Limitations

- Single-year data
- Dependence on calculator assumptions
- Simplified product-level allocation
- Differences in benchmark methodologies

Future development

- Extension to multi-year analysis
- Application to multiple farms and food-processing companies
- Development of sector-specific benchmarks
- Use for management and policy assessment

12

Thank you for your attention

https://decarb.uniag.sk/ako-to-funguje/

https://uhlikovastopa.eu/ako-to-funguje-uhlikova-stopa-firmy/

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13

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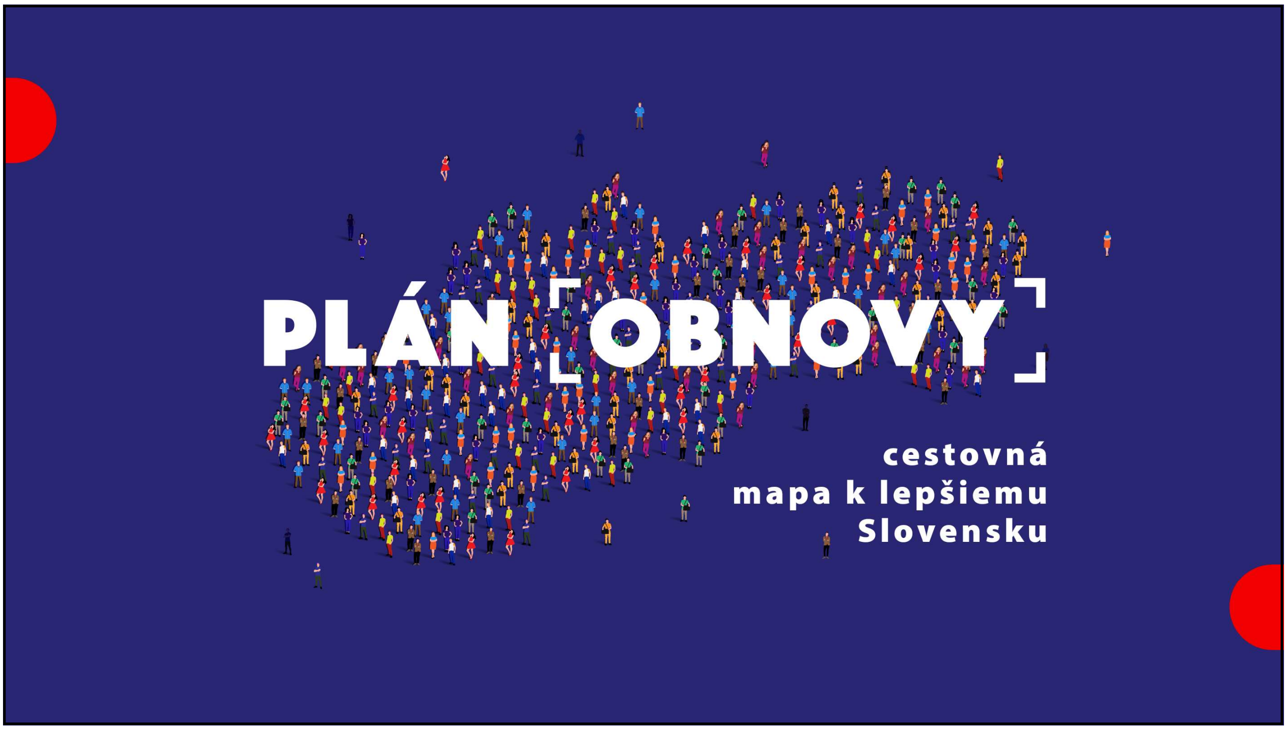
14



15