Sustainability of complex insect production chains: from food waste to feed and food

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Institute of Food Quality and Food Safety,
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75th EAAP Annual Meeting
Florence – Italy

OVERVIEW

FOUNDED **1983**

MEMBERS **175**

EMPLOYEES **200**

LOCATIONS
- QUAKENBRÜCK (GER)
- BERLIN (GER)
- KARLSRUHE (GER)
- BRUSSELS (BEL)

LEGAL STATUS
REGISTERED ASSOCIATION

DIRECTOR
DR. VOLKER HEINZ

MISSION
KNOWLEDGE FOR SUPERIOR FOODS

DIL MEMBERS

Core competences

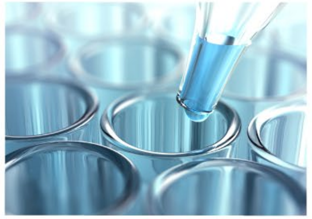
SAFETY
+
AUTHENTICITY

STRUCTURE
+
PROCESSING

SUSTAINABILITY

BIOMASS PRODUCTION

Food Fraud Checkpoint

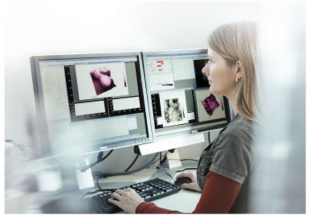


Food Biotechnology

LCA Analytics

FOOD PROCESSING

Process Control & Challenge Testing



Food Physics & Process Engineering

Automation & Digitalization

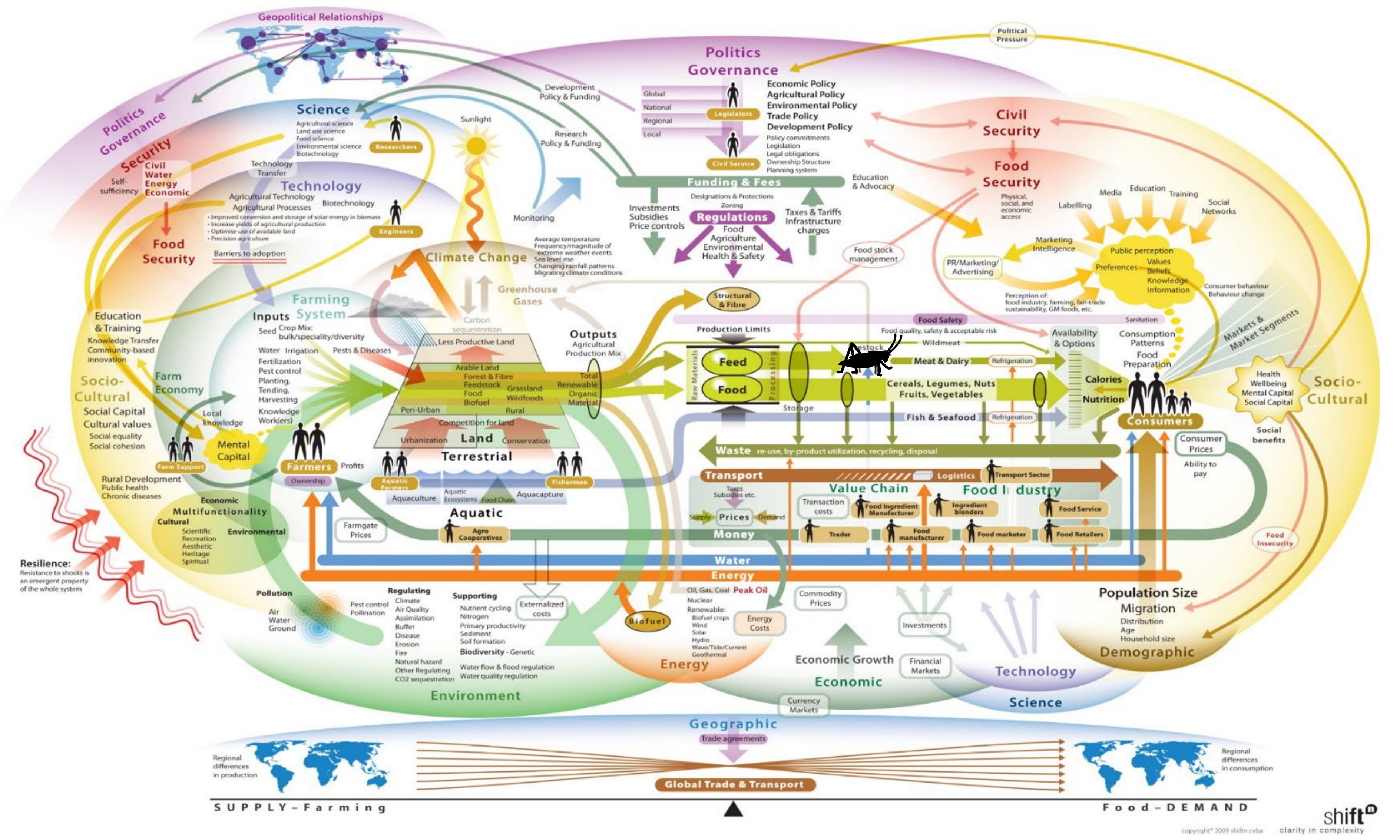
HEALTH & WELLBEING

Food Safety Labs (S3**)
(Microbiol./Chemical)

DNA Sequencing

Food Data Group

Complex system



courtesy of ShiftN

Urgent Need to Define End-of-Waste Criteria for Efficient Utilization of Organic Waste

"Waste Not"
by
Song Dong

ACS Sustainable Resource Management
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Viewpoint

Urgent Need to Define End-of-Waste Criteria for Efficient Utilization of Organic Waste

Daniel Pleissner,* Loreena Stephan, and Sergiy Smetana

Cite This: https://doi.org/10.1021/acssusresmgt.4c00265
Read Online

Can we assure the safe transformation of food waste by insects?

DIL

- Quality of feed matters
- Bioaccumulation of some heavy metals
- Safety assurance is needed
- Not always reduction of environmental impacts

BRILL WAGENINGEN ACADEMIC

JOURNAL OF INSECTS AS FOOD AND FEED (2024) DOI:10.1163/23524588-00001122

Journal of Insects as Food and Feed
brill.com/jiff

REVIEW ARTICLE

A decade of advances in black soldier fly research: from genetics to sustainability

C.G. Athanassiou[1], C.L. Coudron[2], D. Deruytter[2], C.I. Rumbos[1], L. Gasco[3], F. Gai[4], C. Sandrock[5], J. De Smet[6], G. Tettamanti[7,8], A. Francis[9], J.-I. Petrusan[9] and S. Smetana[9,10]*

- Circularity with insects – consequential LCA
- Determination of the indirect effects (market effects)
- Initial consequential approach - first insight into the potential positive and negative rebound effects
- The circularity potential should aim effects on the market, and thus, support consequential modelling with insights into the rebound effects.

Journal of Insects as Food and Feed, 2023; 9(9): 1111-1114

Wageningen Academic Publishers

Circularity and environmental impact of edible insects

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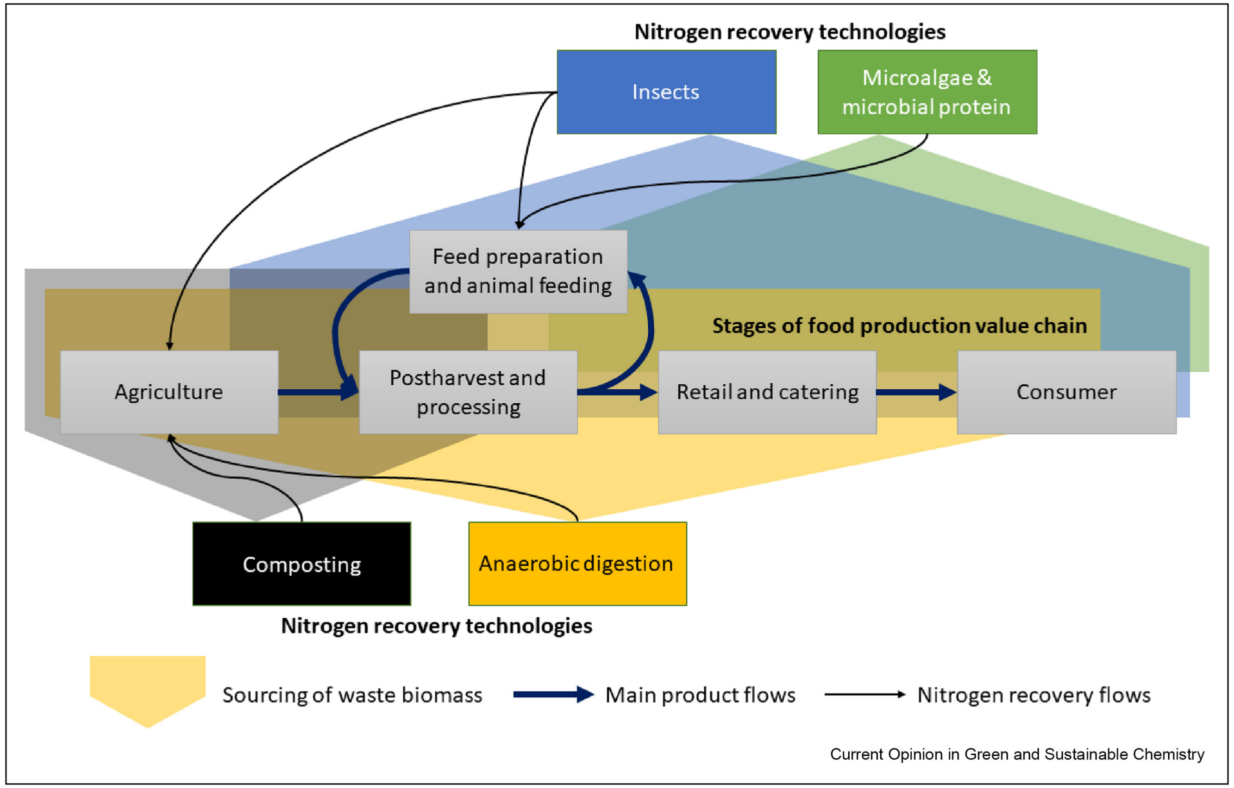
Can we assure the safe transformation of food waste by insects?



Insects (*Hermetia illucens*) on residuals can recover 5.4–53% of nitrogen from residuals (stored in insect biomass) and additionally up to 50% of nitrogen in frass.

Intensification of some direct emissions (around 70% increase for CO_2 emissions and 60% increase of ammonia-nitrogen emissions)

1 kg protein (0,16 kg N) produced by insect and similar amount in frass:
GWP: −6.42 to 7.0 kg CO2eq.
NRE: 102.7–138.7 MJ
LU: 1.6–1.7 m2a
AC: −0.1 to 0.1 kg SO2eq

Current Opinion in Green and Sustainable Chemistry
Volume 43, October 2023, 100853

Review article

Life cycle assessment of bio-based nitrogen upcycling approaches

Sergiy Smetana

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https://doi.org/10.1016/j.cogsc.2023.100853

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Methodological insights: LCA

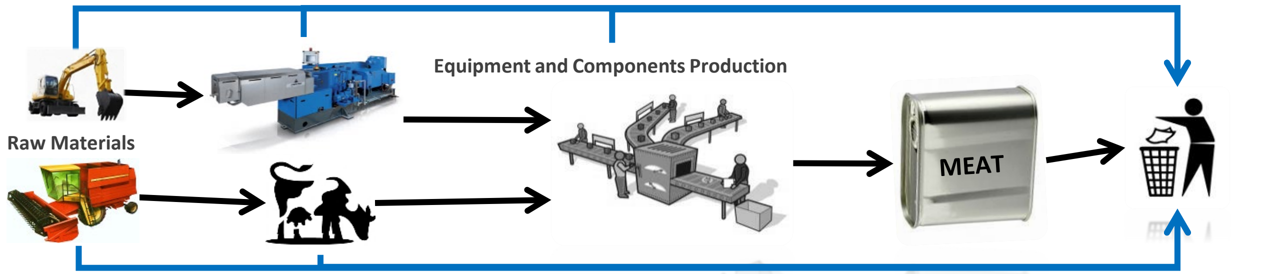
Main Objective

Estimate environmental impact of technologies and products

Basis

Life Cycle Thinking

ISO DN 14040-14044



Results

Inventory and Analysis

1 annual

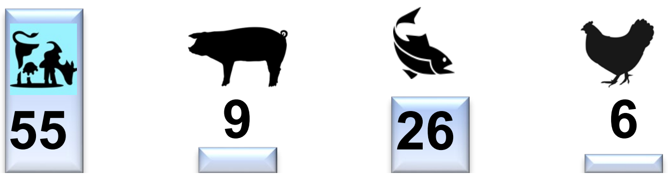
=

1 kPt

Technologies and Products Comparative Possibilities

Sustainable Degree of Product, Pt

1 t of Meat/Fish



Impact Categories

- Climate Change
- Human Health
- Resource Depletion
- Ecosystem Quality
- Land Use
- Water Use
- Acidification
- Eutrophication
- Minerals Use
- Fossil Fuel Use
- Carcinogens …

Outcomes

Quantified Data

More Sustainable Equipment Selection
Product Sustainability Determination
Environmental Labeling
Technologies Improvement
Food Innovation

More efficient, less harmful and less resource consuming products

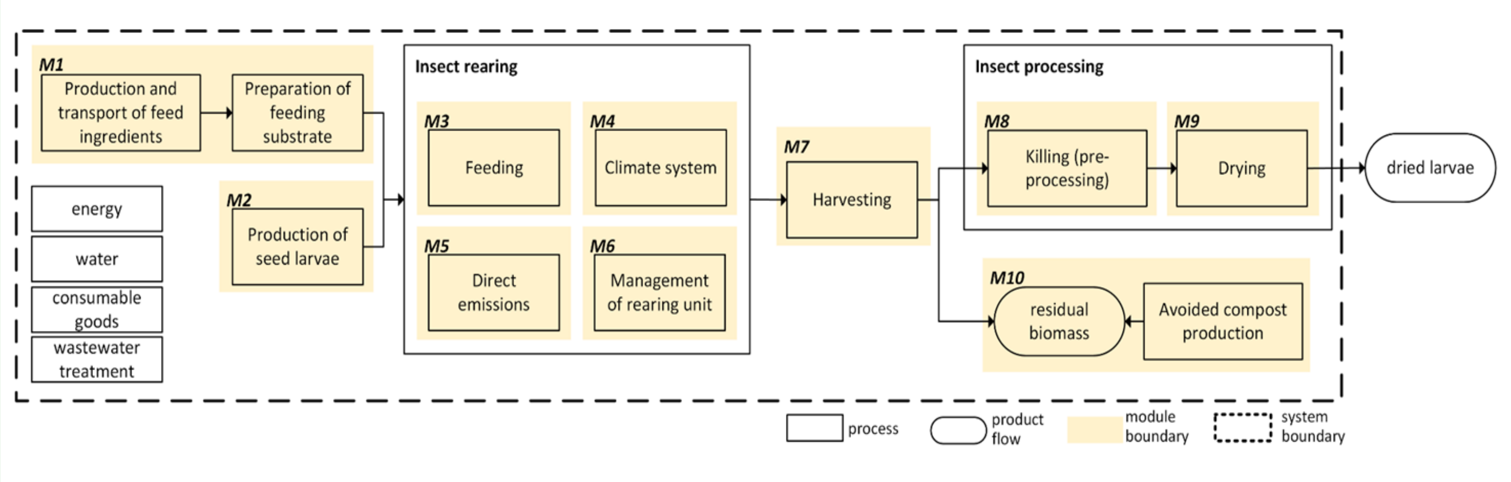
PEF

European Commission

- Hotspots
- Best options
- Cradle-to-grave
- FU
- Comprehensive methods
- Potential impacts

Modularity to deal with complexity

Scheme of modules for the insect production chain (Spykman et al., 2021)



S. Smetana, A. Bhatia, A. Tonda, N. Mouhrim, A. Green, D. Paguero, A. Francis, V. Heinz (2024). **Application of modular Life Cycle Assessment approaches enhanced with Decision Support System for the design of sustainable insect chains.** JIFF. **Under Revision.**

Exemplary LC inventory for the different modules of insect production chains

Module	*H. Illucens*	*T. molitor*	*A. domesticus*	*M. domestica*
M1	M1.1. = 0.333 kg Water = 1.336 kg El = 0.099 kWh Det = 0.000838 kg	M1.1. = 0.95 kg Water = 0.386 kg El = 0.07 kWh Det = 0.0007 kg	M1.1. = 0.63 kg Water = 0.37 kg El = 0.07 kWh Det = 0.0007 kg	M1.1. = 0.55 kg Water = 0.836 kg El = 0.099 kWh Det = 0.000838 kg
M2	Feed = 0.012 kg Water = 1.848 kg Det = 0.002 kg El = 0.06 kWh Gas = 0.063 MJ	Feed = 0.012 kg Water = 1.848 kg Det = 0.002 kg El = 0.06 kWh Gas = 0.063 MJ	Feed = 0.012 kg Water = 0.06 kg Det = 0.002 kg El = 0.036 kWh	Feed = 0.012 kg Water = 1.848 kg Det = 0.002 kg El = 0.06 kWh Gas = 0.063 MJ
M3	El = 0.054 kWh Water = 0.335 kg Det = 0.00042 kg	El = 0.054 kWh Water = 0.335 kg Det = 0.00042 kg	El = 0.1 kWh	El = 0.036 kWh Water = 0.335 kg Det = 0.00042 kg
M4	El = 0.032 kWh Gas = 0.109 MJ	El = 0.176 kWh Gas = 0.59 MJ	El = 0.083 kWh	El = 0.03 kWh Gas = 0.1 MJ
M6	Water = 16.12 kg Det = 0.02 kg El = 0.112 kWh	Water = 16.12 kg Det = 0.02 kg El = 0.112 kWh	Water = 5.0 kg Det = 0.02 kg El = 0.06 kWh	Water = 16.12 kg Det = 0.02 kg El = 0.112 kWh
M7	Water = 1.65 kg Det = 0.01 kg El = 0.016 kWh	Water = 1.65 kg Det = 0.01 kg El = 0.014 kWh	Water = 1.65 kg Det = 0.01 kg El = 0.008 kWh	Water = 1.65 kg Det = 0.01 kg El = 0.05 kWh
M8	Water = 0.584 kg Det = 0.0002 kg El = 0.004 kWh Gas = 2.2 MJ	Water = 0.584 kg Det = 0.0002 kg El = 0.22 kWh	Water = 0.584 kg Det = 0.0002 kg El = 0.14 kWh	Water = 0.584 kg Det = 0.0002 kg El = 0.004 kWh Gas = 2.2 MJ
M9	Water = 0.061 kg Det = 0.000076 kg El = 0.0059 kWh Gas = 6.16 MJ	Water = 0.061 kg Det = 0.000076 kg El = 0.0059 kWh Gas = 6.16 MJ	Water = 0.061 kg Det = 0.000076 kg El = 0.28 kWh	Water = 0.061 kg Det = 0.000076 kg El = 0.0059 kWh Gas = 6.16 MJ
M10	100% residuals = waste for compost	100% residuals = waste for compost	100% residuals = waste for compost	100% residuals = waste for compost

Note: Values are indicated per unit of output from each module (M1 - production of 1 kg fm feeding substrate, M2 - production of 1000 of 5-DOL larvae, M3 - feeding of 1 kg fm substrate to larvae, M4 - running of climate system for 1 day with approximately 1 kg fm insect output, M5 - direct emissions (is excluded from inventory as no inputs are indicated), M6 - management activities allocated to 1 kg fm insects, M7 - harvesting activities allocated to 1 kg fm insects, M8 - killing of 1 kg fm insects, M9 - removal of 1 kg water from insect larvae, M10 - substitution or allocation of 1 kg fm residuals , El - electricity; Det - detergent, Gas - natural gas.

Modularity to deal with complexity

Module variations and changes of scaling factors (*H. illucens*)

Module	Scaling factor value change	Module	Scaling factor value change
M1. Insect feeds		M9. Secondary processing	
M1.1 Compound chicken feed	100%	M9.1 Convection drying	100%
M1.2 Gainesville fly diet	Weight 3% increase (wheat bran, alfalfa, cornmeal)	M9.2 Freeze-drying	200%
M1.3 Distiller's grains	100%	M9.3 Microwave drying	130%
M1.4 Wheat middlings	Weight 3% increase		
M1.5 Fruit and vegetable waste	Weight 10x increase		
M1.6 Poultry manure	Weight 4x increase		
M8. Pre-processing		M10. System expansion	
M8.1 Blanching	100%	M10.1 Avoided compost production	100%
M8.2 Freezing	2500%	M10.2 Avoided fertilizer production	20%
M8.3 High pressure processing	235%	M10.3 Mass allocation	50%
M8.4 Microwave sterilization	200%	M10.4 Economic allocation	22%

Main environmental impacts of four insect species under the study based on modular variations (where available)

Type of feed	Impact categories	H. illucens	T. molitor	A. domesticus	M. domestica
Compound feeds	GHG ALO WD	1.4-15 0.01-94.7 1.26	9-10.3 12 1.8-8.7	7.7-8.7 27-180 1.4-2.7	20 16.7 1.3
By-products	GHG ALO WD	0.3-5 0-4.9 0.8-2	3-10.3 5.3-17 0.1-0.2	5-27 12-79 0.1-0.2	0.8-12 0.03-61 8.5-11
Wastes	GHG ALO WD	-6.42÷3.5 -16.8÷4.9 0.8-1.1	0.6-1.2 0.1-0.3 0.4-1.7	1.3-2 0.5-1 0.4-0.7	5.9-9.7 4.4-7.7 114-188

Note: Life Cycle Impact Assessment method - IMPACT 2002+, Functional unit - 1 kg of dry matter of insects produced (dried whole insects), GHG - greenhouse gas emissions in $kgCO_2eq.$, ALO - agricultural land occupation in m^2a, WD - water demand in m^3 (assessed with IMPACT World+).

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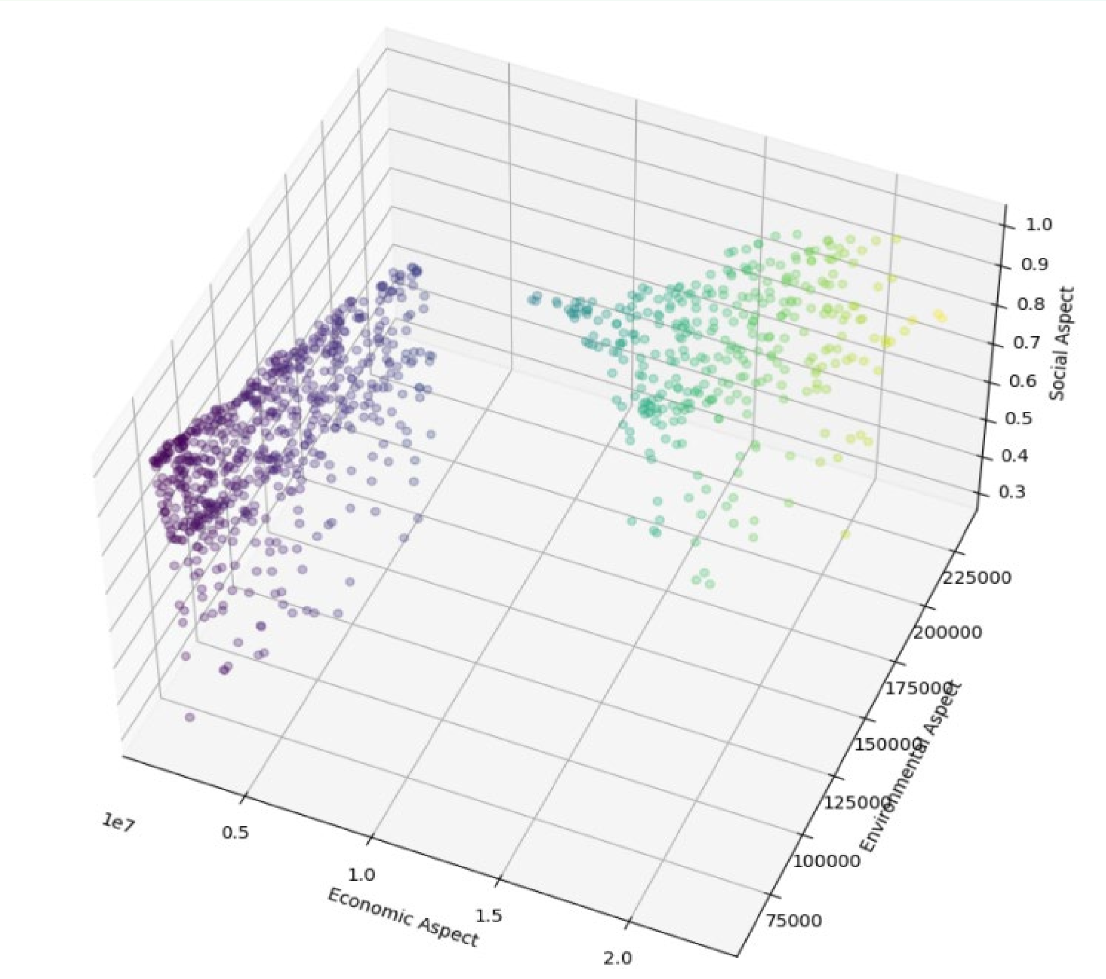
Modularity to deal with complexity



Pareto front resulting from the multi-objective optimization, showing all three objectives. The visible discontinuity is related to the absence of candidate solutions describing facilities of intermediate scale (SC=2 or SC=3), hinting those solutions including small and very large-scale facilities dominate all others.

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Take away messages

1. Insect production systems are complex
2. And include a few other complex problems
3. There are however, possibilities for the easy solutions (industrial synergism)
4. Modelling of insect production chains with multiple unknowns is complicated
5. Validation of scenarios are needed

Acknowledgments

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Thank you for for your attention!

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