

Assessing sustainability of agricultural systems by multi-criteria approach: an overview

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Where are we from?



Nancy



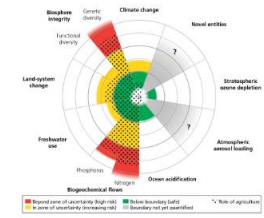
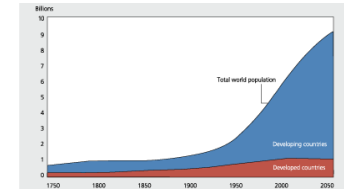
INRAE

Colmar



Introduction (1/2)

- Sustainability challenges of world agriculture
 - To feed a growing population (Godfray et al., 2010)
 - within planetary boundaries (Campbell et al. 2017)
- An explosion of assessment methods & tools (Eichler Inwood et al., 2018; Lampridi et al. 2019)
- The need to provide reviews
 - on conceptual and methodological aspects
 - To help end-users in their choice
- Here a focus on multicriteria aspects
 - Part of a review from PhD work of E. Soulé



Introduction (2/2)

- Multicriteria assessment vs. multicriteria decision aid

Sustainability science

Dimension/themes (criteria)/sub-themes...

Indicators

List of indicators
Composite indicators
...?

Operational research

Attribute

Criteria

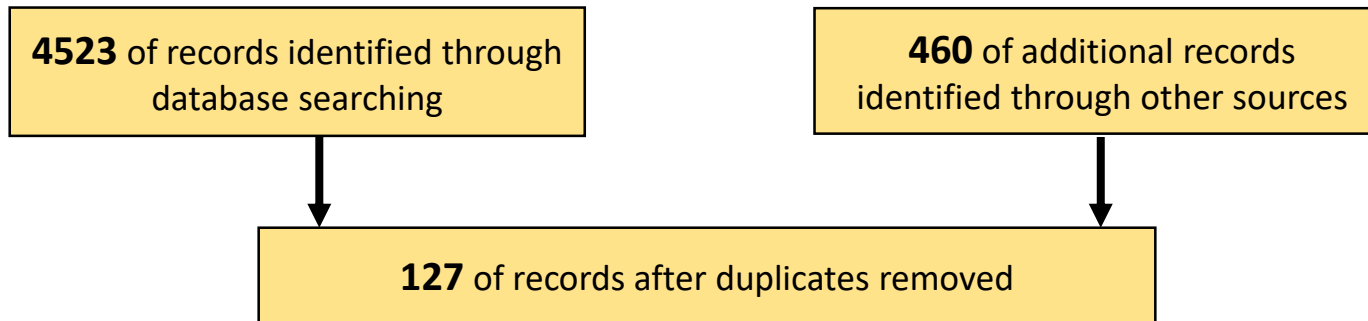
MCDA methods
(MAUT, AHP, outranking ...)



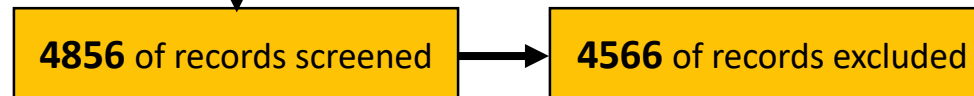
Methods (1/4)

- A systematic review (Moher et al. 2010)

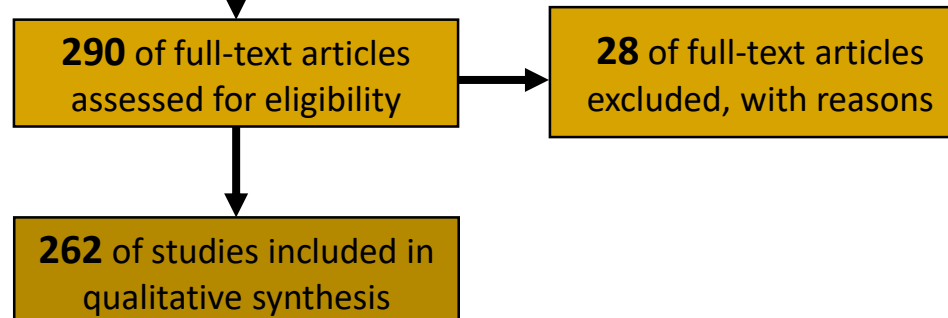
Identification



Screening

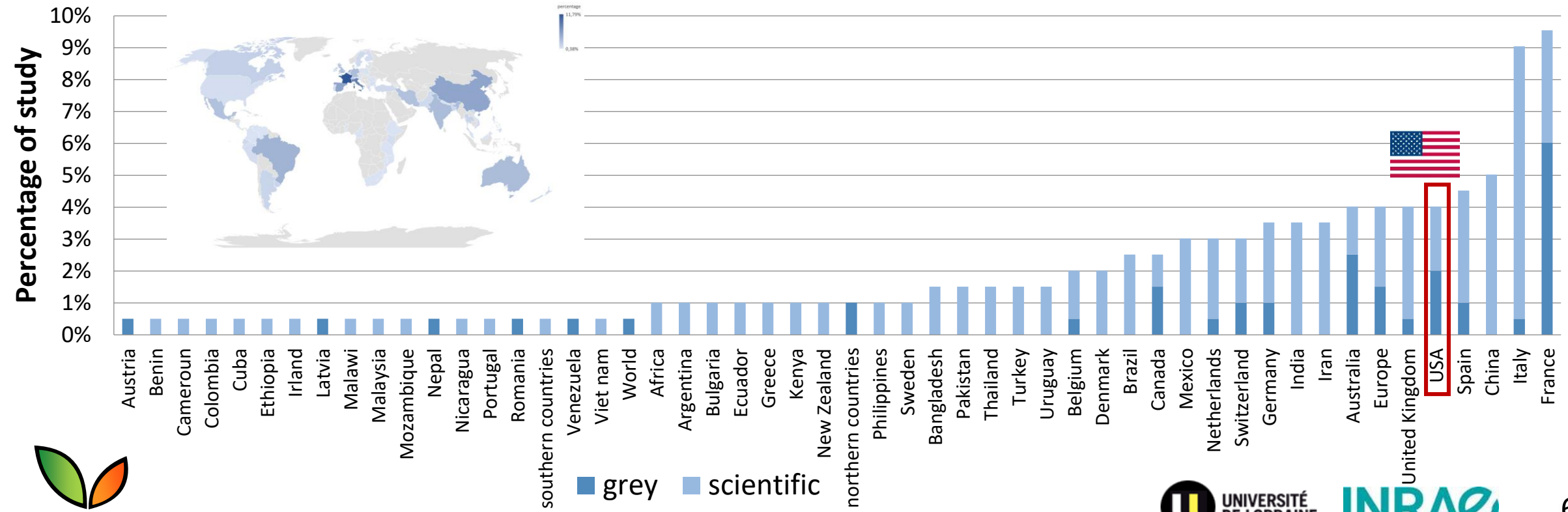


Eligibility

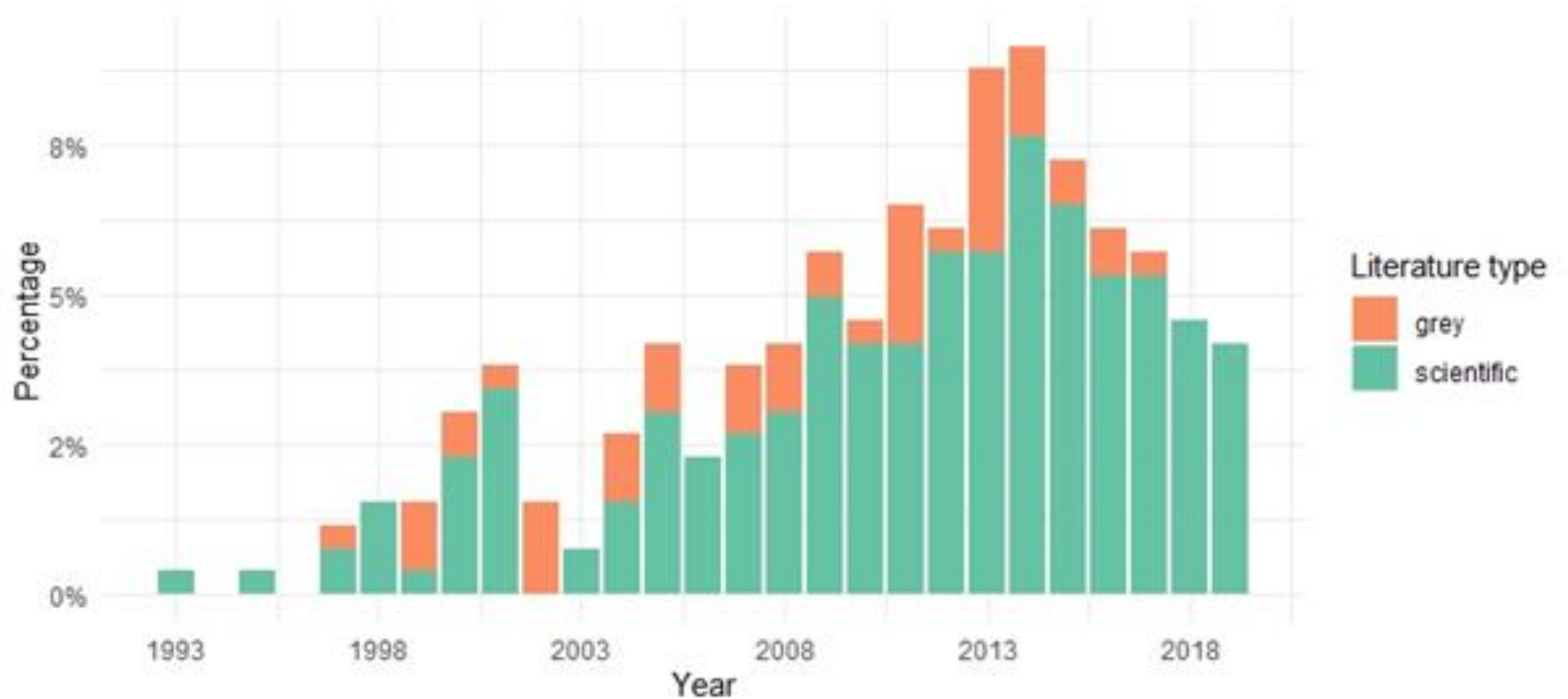


Methods (2/4) methods: from where?

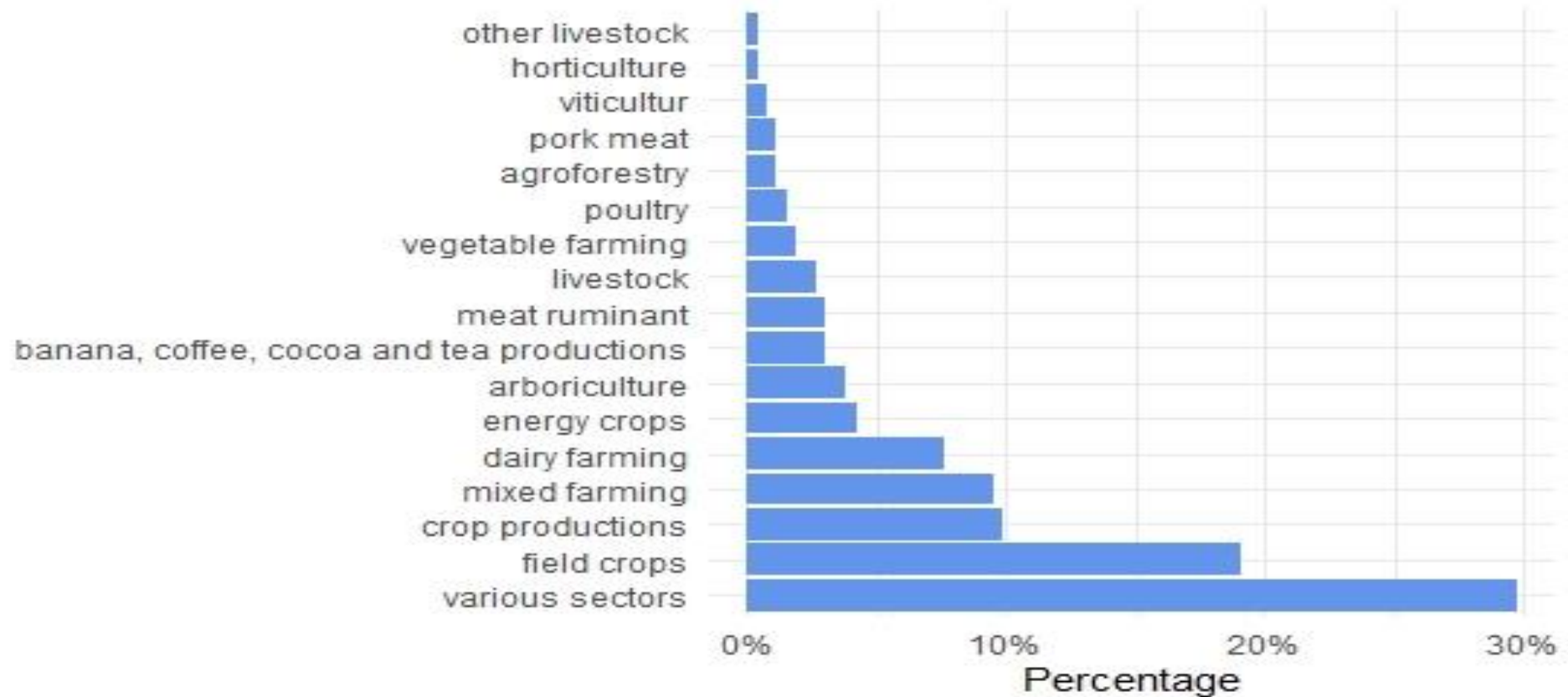
Publications by country (52)



Methods (3/4): development of methodswhen?

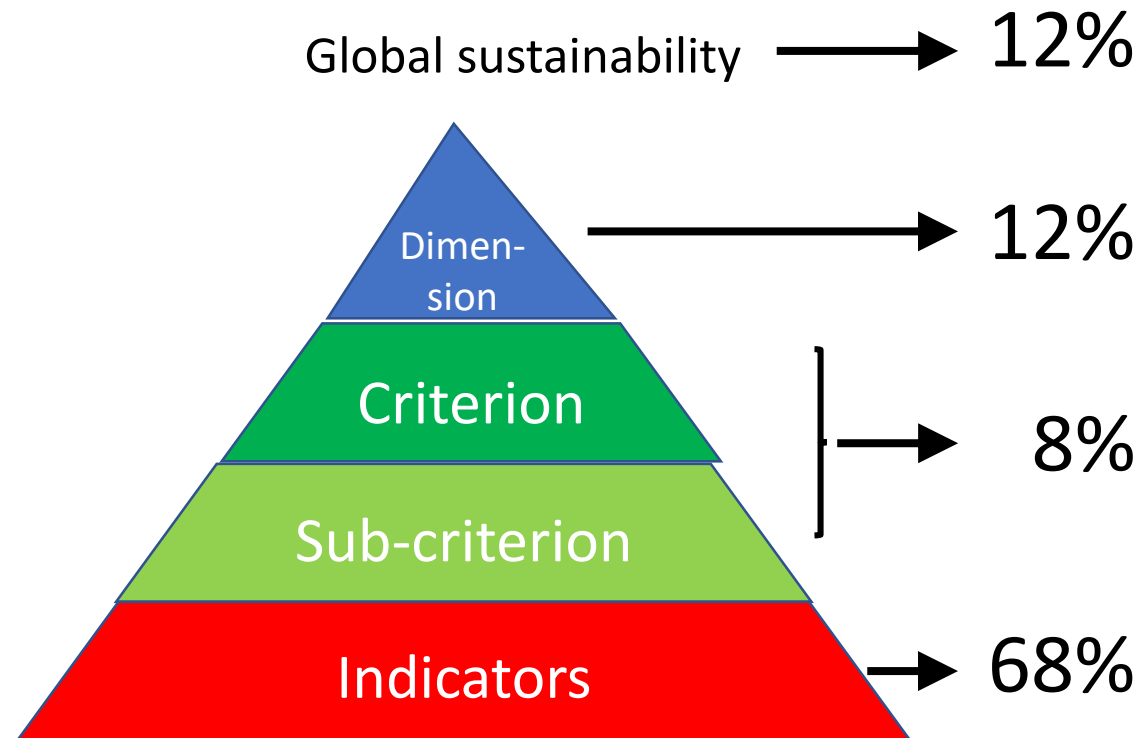


Methods (4/4): which production?



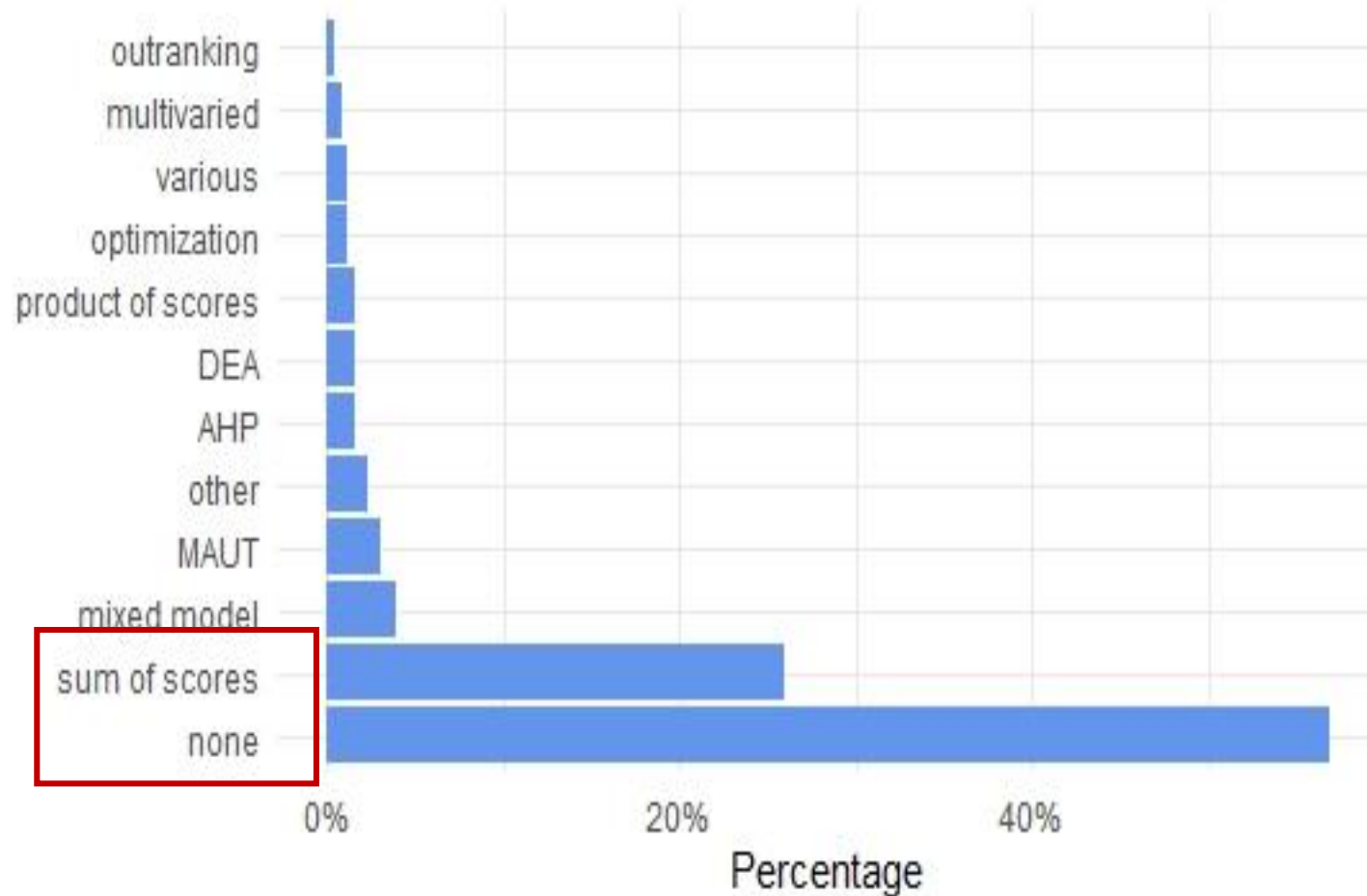
Results (1/3)

- Level of aggregation (% methods)



Results (2/3)

- Number of methods used



Results (3/3)

- Weighting methods

60% with an explicit weighting procedure

9% not totally transparent



31% no weights.



Example 1

INSPIA method
(Trivino-Tarradaset al. 2019)

- Typical approach of sum of scores

Hierarchical structure

Aggregation:

- Normalization “min-max”
- Weighting (by experts panel)
- Weighted sum of scores



25% Net income per ha
25% Net income per annual work unit (AWU)
25% Production cost per ha
25% Yield

60% N Productivity
40% P Productivity

50% Irrigation water application
50% Water productivity * Irrigated crops

33% Energy balance
33% Energy efficiency
33% Energy productivity

25% Soil tillage index
25% Soil cover rate
25% Soil erosion risk
25% Organic matter

40% Crop diversity
60% Crop rotations

33% Natural area
33% Biodiversity structures
33% Buffers and security areas

100% PPP management

50% GHGs Balance
50% GHGs per kg

30% N Balance
30% N Efficiency
20% P Balance
20% P Efficiency

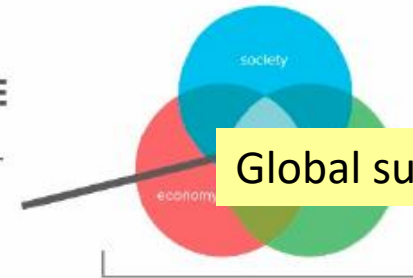
50% Working hours per ha
50% Satisfaction index

40% Farmers' training levels
60% Risk of abandonment of agricultural activity

Basic indicator

INSPIA
COMPOSITE
INDEX

Addressing
balance



Global sustainability indicator

100% PROFITABILITY



60 % PROFITABILITY



40% INPUT PRODUCTIVITY

33% FERTILIZER
33% WATER *
33% ENERGY



40 % FARM MANAGEMENT

50% SOIL MANAGEMENT
50% CROP MANAGEMENT



30 % ENVIRONMENTAL PROTECTION

50% ENHANCING BIODIVERSITY
50% PPPs (resources)



20% CLIMATE CHANGE

100% GHGs
100% FERTILIZATION



10% FERTILIZATION

50% LABOUR PRACTICES AND DECENT WORK
50% INTERACTION WITH SOCIETY



100% WELFARE and WELL-BEING

Economic 33%

Environment 33%

Social 33%

Aggregated indicators

Aggregated indicator per s. dimension

Example 2

- Use of DEXi tool (Bohanec et al. 2008) used by 4 methods (e.g. MASC)

Design of decision tree

Definition of attribute

Example of output of MASC (Craheix et al. 2012)

The screenshot shows the DEXi tool interface. On the left, a tree structure represents the decision model, with categories like 'Durabilité Economique', 'Acceptabilité Sociale', and 'Durabilité Environnementale'. The main window displays the 'Attribute' definition for 'Durabilité Totale', including its description, scale, and utility function. Below this, the 'Decision rules' window shows a table of rules for 'Durabilité Totale' based on the three main dimensions.

Attribute Definition:

- Name: Durabilité Totale
- Description: Appréciation qualitative de la durabilité agro-environnementale
- Scale: + tres faible(-); faible(-); moyenne; elevee(+); tres elevee(+)
- Utility function: Rules: 64/64 (100.00%), determined: 100.00%

Decision rules Durabilité Totale:

Durabilité Economique	Acceptabilité Sociale	Durabilité Environnementale	Durabilité Totale
1 tres faible	1 tres faible	1 tres faible	1 tres faible
2 tres faible	2 tres faible	2 faible a moyenne	2 tres faible
3 tres faible	3 tres faible	3 moyenne a elevee	3 tres faible
4 tres faible	4 tres faible	4 tres elevee	4 tres faible
5 tres faible	5 faible a moyenne	5 tres faible	5 tres faible
6 tres faible	6 faible a moyenne	6 faible a moyenne	6 faible
7 tres faible	7 faible a moyenne	7 moyenne a elevee	7 faible
8 tres faible	8 faible a moyenne	8 tres elevee	8 faible
9 tres faible	9 moyenne a elevee	9 tres faible	9 tres faible
10 tres faible	10 moyenne a elevee	10 faible a moyenne	10 faible
11 tres faible	11 moyenne a elevee	11 moyenne a elevee	11 faible
12 tres faible	12 moyenne a elevee	12 tres elevee	12 moyenne
13 tres faible	13 tres elevee	13 tres faible	13 tres faible
14 tres faible	14 tres elevee	14 tres elevee	14 tres faible
15 tres faible	15 tres elevee	15 tres elevee	15 tres faible
16 tres faible	16 tres elevee	16 tres elevee	16 tres faible
17 faible	17 tres elevee	17 tres elevee	17 tres faible

Definition of decision rules (if then)
-automatic with weighting or manual

The screenshot shows the output of the MASC tool, a detailed table of sustainability indicators grouped into four dimensions: Economical, Social, Environmental, and Overall sustainability. Each indicator is rated on a scale from 1 to 4, and the overall sustainability is calculated as 4/7.

Indicator	Rating	Dimension
Profitability	3/4	Economical Dimension
Subsidies independency	2/4	Economical Dimension
Economic efficiency	2/4	Economical Dimension
Specific Equipment Needs	1/3	Economical Dimension
Soil Acid-base Status	3/4	Economical Dimension
Soil compaction	4/4	Economical Dimension
Phosphorus & Potassium Fertility	4/4	Economical Dimension
Pest control	3/4	Economical Dimension
Weed control	4/4	Economical Dimension
Sanitary Quality	3/3	Economical Dimension
Technological Quality	3/3	Economical Dimension
Emergence of new supply chain	2/3	Economical Dimension
Employment contribution	3/4	Economical Dimension
Supply of Raw material	4/4	Economical Dimension
System complexity	3/4	Economical Dimension
Technical monitoring	2/3	Economical Dimension
Workload distribution	1/3	Economical Dimension
Pesticides use risks	1/4	Economical Dimension
Physical Difficulties	3/3	Economical Dimension
Surface Water	2/4	Economical Dimension
Ground Water	3/4	Economical Dimension
NO ₃ Losses	3/4	Economical Dimension
Phosphorus losses	2/4	Economical Dimension
NH ₄ Emissions	3/4	Economical Dimension
N ₂ O Emissions	3/4	Economical Dimension
Pesticides Emission	3/4	Economical Dimension
Accumulation of Toxic Elements	4/4	Economical Dimension
Organic Matter Content	2/4	Economical Dimension
Soil erosion	4/4	Economical Dimension
Dry Period Irrigation Needs	3/4	Economical Dimension
Dependency on Water	3/4	Economical Dimension
Energy consumption	1/3	Economical Dimension
Energy efficiency	2/3	Economical Dimension
Phosphorus Conservation	2/4	Economical Dimension
Flying Insects	3/4	Economical Dimension
Soil macrofauna	2/4	Economical Dimension
Floristic abundance	1/4	Economical Dimension
Floristic diversity	2/4	Economical Dimension
Soil micro-organisms	3/4	Economical Dimension
Autonomy	2/4	Social Dimension
Economic incomes for the farm	2/4	Social Dimension
long-term productive capacity	4/5	Social Dimension
Contribution to economic development	3/4	Social Dimension
Expectations of society	4/4	Social Dimension
Expectation of farmers	4/5	Social Dimension
Water quality	3/4	Environmental Quality
Air Quality	3/4	Environmental Quality
Soil Quality	3/4	Environmental Quality
Abiotic Ressource Conservation	2/5	Environmental Dimension
biodiversity Conservation	3/4	Environmental Dimension
Overall sustainability	4/7	Overall sustainability

- To mitigate threshold effect and lack of transparency: CONTRA method (Bockstaller et al. 2017) : fuzzy decision tree

Conclusions

- An unprecedented review by the sample size and the scope
- Providing insights in methods implemented in sustainability science
- Few methods use approaches developed in
- How to support better use of methods from operational research?
- Multicriteria methods and dynamic aspects of sustainability (e.g. resilience)





Thank you for your attention!

