



## **Weighting in multi-criteria sustainability assessments: quantifying the uncertainty of expert judgements in the SMART Farm Tool**

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# Content

1. Sustainability framework: SAFA
2. SMART MCA structure
3. Indicator weights consensus method
4. Uncertainty assessment
5. Effects on farm comparisons
6. Conclusions



**smart**  
sustainability monitoring  
and assessment routine

# Sustainability framework



Food and Agriculture Organization  
of the United Nations



**SAFA**

SUSTAINABILITY ASSESSMENT OF  
FOOD AND AGRICULTURE SYSTEMS



Food and Agriculture  
Organization of the  
United Nations

**SAFA**

SUSTAINABILITY ASSESSMENT OF FOOD AND AGRICULTURE SYSTEMS

**GUIDELINES**

VERSION 3.0

# FAO SAFA guidelines

## 4 Dimensions, 21 Themes, 58 Subthemes

For each theme and subtheme:

- Objective
- Descriptions
- Suggested indicators (quantitative, qualitative; policy, practice, performance)

Aspiration to be:

- Universal (globally applicable)
- Holistic (combat partial truths/reporting)
- Legitimate (developed by major multilateral organization)

GOOD GOVERNANCE				
CORPORATE ETHICS	Mission Statement		Due Diligence	
ACCOUNTABILITY	Holistic Audits	Responsibility		Transparency
PARTICIPATION	Stakeholder Dialogue		Grievance Procedures	Conflict Resolution
RULE OF LAW	Legitimacy	Remedy, Restoration & Prevention	Civic Responsibility	Resource Appropriation
HOLISTIC MANAGEMENT	Sustainability Management Plan		Full-Cost Accounting	

ENVIRONMENTAL INTEGRITY			
ATMOSPHERE	Greenhouse Gases		Air Quality
WATER	Water Withdrawal		Water Quality
LAND	Soil Quality		Land Degradation
BIODIVERSITY	Ecosystem Diversity	Species Diversity	Genetic Diversity
MATERIALS & ENERGY	Material Use	Energy Use	Waste Reduction & Disposal
ANIMAL WELFARE	Animal Health		Freedom from Stress

ECONOMIC RESILIENCE				
INVESTMENT	Internal Investment	Community Investment	Long-Ranging Investment	Profitability
VULNERABILITY	Stability of Production	Stability of Supply	Stability of Market	Liquidity Risk Management
PRODUCT QUALITY & INFORMATION	Food Safety		Food Quality	Product Information
LOCAL ECONOMY	Value Creation		Local Procurement	

SOCIAL WELL-BEING			
DECENT LIVELIHOOD	Quality of Life	Capacity Development	Fair Access to Means of Production
FAIR TRADING PRACTICES	Responsible Buyers		Rights of Suppliers
LABOUR RIGHTS	Employment Relations	Forced Labour	Child Labour Freedom of Association & Right to Bargaining
EQUITY	Non Discrimination	Gender Equality	Support to Vulnerable People
HUMAN SAFETY & HEALTH	Workplace Safety and Health Provisions		Public Health
CULTURAL DIVERSITY	Indigenous Knowledge		Food Sovereignty



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# smart

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SAFA: Theory

SMART: Praxis

GOOD GOVERNANCE			
ACCOUNTABILITY	Active Dialogue	Transparency	Due Diligence
INTEGRITY	Trust & Fairness	Reliability	Full Disclosure
EFFICIENCY	Proportionate Dialogue	Openness & Honesty	Confidence Building
EFFICACY	Stakeholder Engagement	Collaboration	Responsible Approaches
EFFICIENCY	Stakeholder Engagement	Collaboration	Responsible Approaches

ENVIRONMENTAL INTEGRITY			
ACCOUNTABILITY	Active Dialogue	Transparency	Due Diligence
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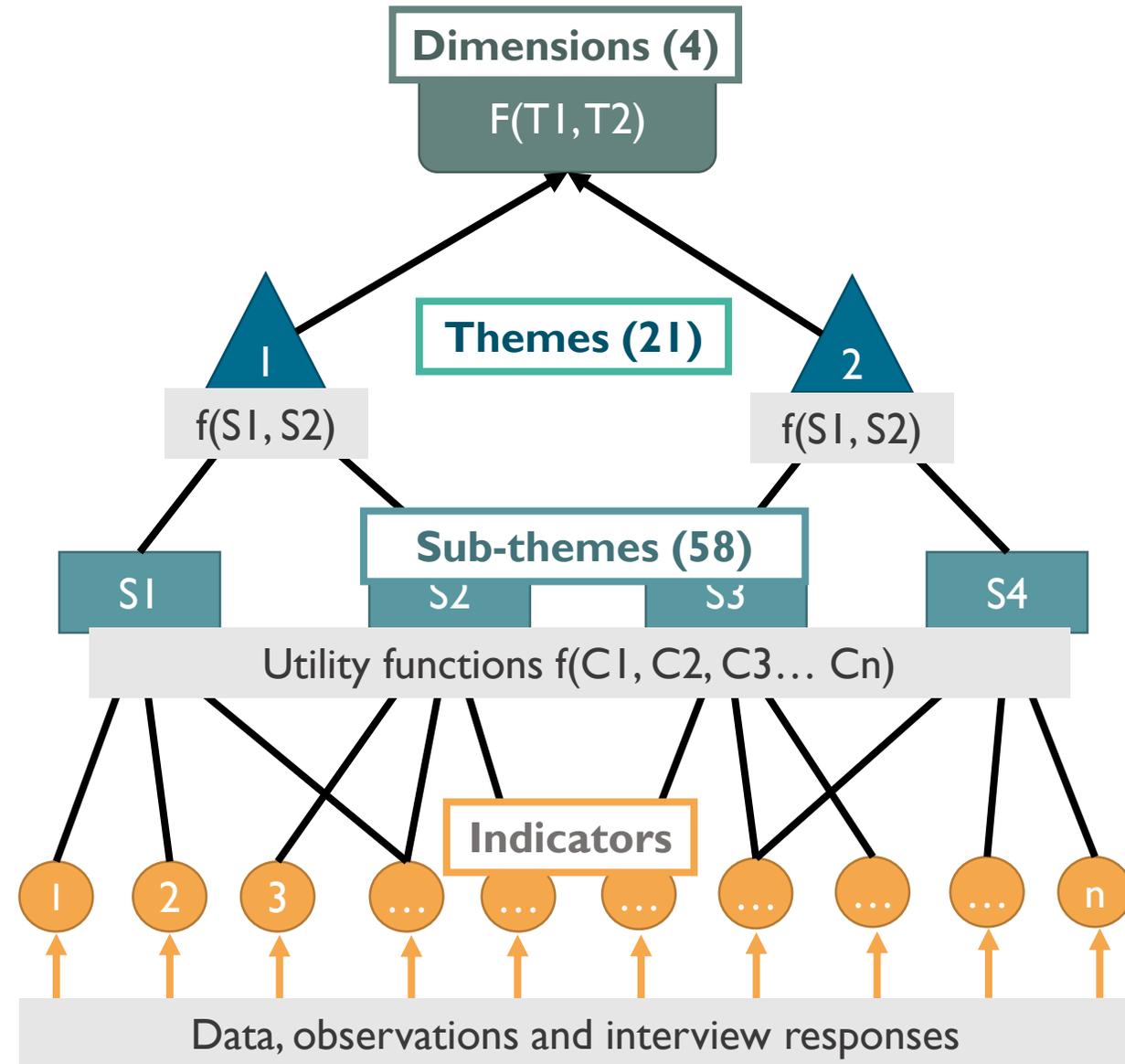
SOCIAL WELL-BEING			
ACCOUNTABILITY	Active Dialogue	Transparency	Due Diligence
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# Multi-Criteria Assessment structure

- 327 simple indicators, multiple interactions
- Simple aggregation method: **weighted average** (compensation, commensurability)
- Indicators standardized (0-100% range)
- **Distance-to-target** MCDA method
- No aggregation beyond **SAFA theme**

Governance	Environmental	Social	Economic
Work permits, audits, sourcing policies	Extensive/semi-natural areas	Wage level, work overload, equal pay	Adequate liquidity, access to credit
Cases of environmental or social impacts	Pesticide use (active substances, toxicity)	Collective bargaining, unionisation	Diversification of income, collective marketing
Conflict prevention mechanisms	Fertilization and soil management	Inputs from social hotspot countries	Secure land tenure, succession



# Indicator weights consensus method

## Delphi and Nominal Group Technique (NGT)

### Consensus Methods: Characteristics and Guidelines for Use

ARLENE FINK, PhD, JACQUELINE KOSECOFF, PhD, MARK CHASSIN, MD, MPP, MPH, AND  
ROBERT H. BROOK, MD, ScD

### Is There a Consensus on Consensus Methodology? Descriptions and Recommendations for Future Consensus Research

Jane Waggoner, MS, Jan D. Carline, PhD, and Steven J. Durning, MD, PhD

#### Abstract

The authors of this article reviewed the methodology of three common consensus methods and conclude with a set of guidelines and suggestions designed to aid researchers in selecting a consensus method. All consensus methods described. Lastly, the authors agreed that the statistical

### Methods in Ecology and Evolution



*Methods in Ecology and Evolution* 2015, 6, 1097–1109

doi:10.1111/2041-210X.12387

### The Delphi technique in ecology and biological conservation: applications and guidelines

Nibedita Mukherjee<sup>1,2,3\*</sup>, Jean Hugé<sup>3,4</sup>, William J. Sutherland<sup>1</sup>, Jeffrey McNeill<sup>5</sup>,  
Maarten Van Opstal<sup>3,6,7</sup>, Farid Dahdouh-Guebas<sup>2,3,†</sup> and Nico Koedam<sup>2,†</sup>

<sup>1</sup>Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, UK; <sup>2</sup>Plant Biology & Nature Management, Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium; <sup>3</sup>Laboratory of Systems Ecology and Resource Management, Université Libre de Bruxelles, CP 264/1, Avenue F.D. Roosevelt 50, 1050 Brussels, Belgium; <sup>4</sup>Centre for Sustainable Development, Ghent University, Poel 16, 9000 Gent, Belgium; <sup>5</sup>School of People, Environment and Planning, Massey University, Private Bag 11222, Palmerston North, New Zealand; <sup>6</sup>Center of Cultural Anthropology, Université Libre de Bruxelles, CP 124, Avenue F.D. Roosevelt 50, 1050 Brussels, Belgium; and <sup>7</sup>Public Health Department, Vrije Universiteit Brussel, Laarbeeklaan 103, 1090 Brussels, Belgium

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# Indicator weights consensus method

## Delphi and Nominal Group Technique (NGT)

- Crabbe et al. (2009)

### Consensus Methods: Characteristics and Guidelines for Use

ARLENE FINK, PHD, JACQUELINE KOSECOFF, PHD, MARK CHASSIN, MD, MPP, MPH, AND ROBERT H. BROOK, MD, ScD

### Is There a Consensus on Consensus Methodology? Descriptions and Recommendations for Future

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**Table 2.** Comparison of the Delphi technique to other commonly used techniques in group decision-making. Anon, Anonymous. + means that the method is effective for achieving the set objective, – means that the method is not suited for achieving the set objectives. The Delphi technique combines the benefits of group discussion, iterations and anonymity without the added constraint of geographic proximity.

	Method	Possibility of iterations	Impacted by social pressure	Suitable for conflict issues	Possibility of anon. discussion	Possibility of voting	Possibility of anon. voting	Requirement of geographic proximity	Requirement of skilled facilitator	Requirement of expert judgment	References
No discussion possible	Questionnaire	–	–	–	–	+	–	+	–	–	White <i>et al.</i> (2005)
	Statistical Aggregation	–	–	–	–	–	–	–	–	–	Kerr & Tindale (2011)
	Confidential voting	–	–	+	–	+	+	–	–	–	Redpath <i>et al.</i> (2004)
	Public Voting	–	+	–	–	+	–	–	–	–	Burgman <i>et al.</i> (2014)
	Prediction markets	+	–	+	–	–	–	–	–	–	Kerr & Tindale (2011)
Discussion possible	Focus group discussion	–	+	–	–	+	–	+	+	+	Fischer & Young (2007)
	Nominal Group technique	+	+	–	–	+	–	+	+	+	Sutherland (2006)
	Delphi technique	+	–	+	+	+	+	–	+	+	Hasson, Keeney & McKenna (2000)

# Indicator weights consensus method

## Delphi

- Anonymous rating of indicators
- Summary results of ratings
- Exchange of justifications

## NGT

- Physical discussion and voting (non-anonymous)
- Summary results of voting

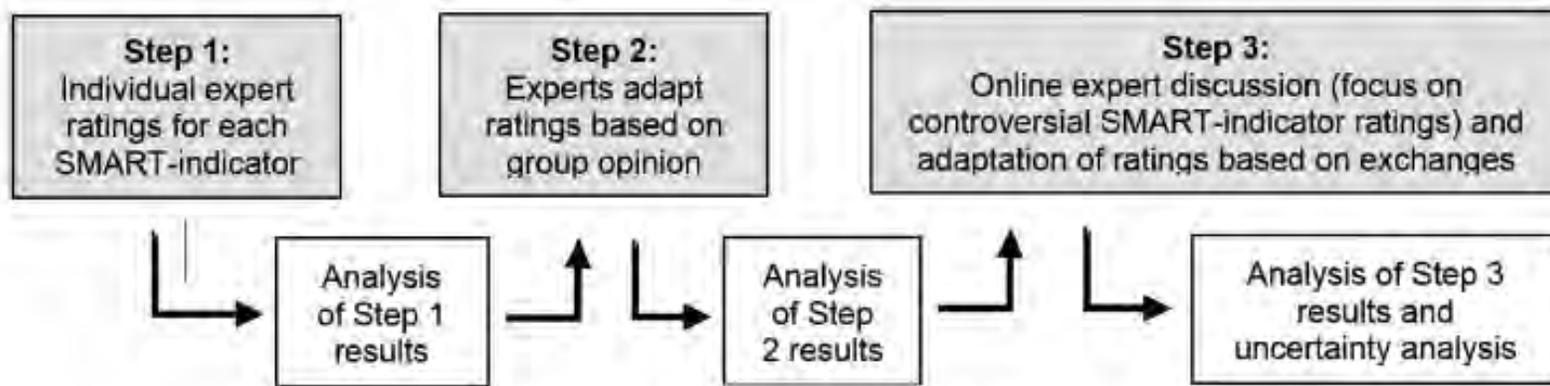
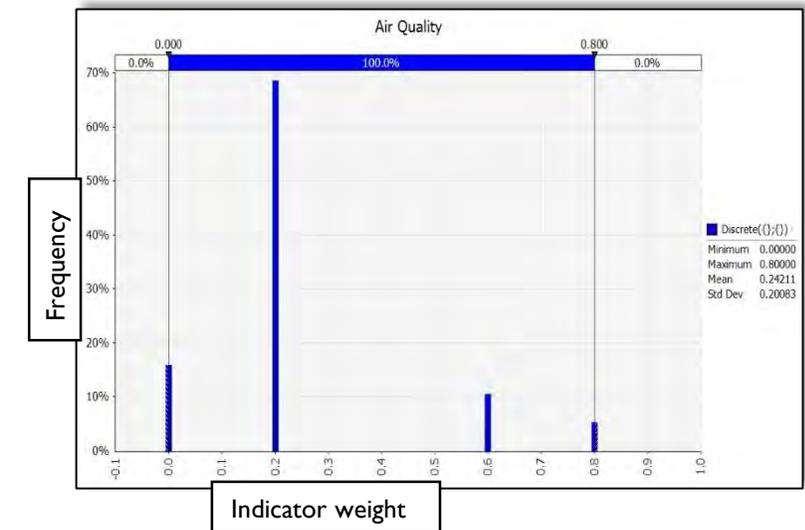


Fig. 1. Overview of steps of the hybrid Delphi/NGT process implemented in this study.



# Indicator weights consensus method

“ClickMeetings” as NGT element

Information about the discussed indicator

Graphical overview of all expert ratings to one theme

Turn on full screen

Theme: Freedom from Stress  
Goal: Animals are kept under species-appropriate conditions and free from discomfort, pain, injury and disease, fear and distress.  
Indicator name: Animal-friendly housing system (368,1)  
Indicator description: Does the farm comply with requirements for particularly animal-friendly housing systems and/or are the conditions beyond the legal minimum in the country?

CHAT  
SMART Expert Discussion: Ok, let's discuss the next indicator (no. 368.1). Expert 4, with 20%, you've rated indicator 368.1 lower than the average of the ratings. Could you explain your rating?

Chat window

Adjust the font size of your chat window

Theme: Freedom from Stress

SMART Expert Discussion

List of participants

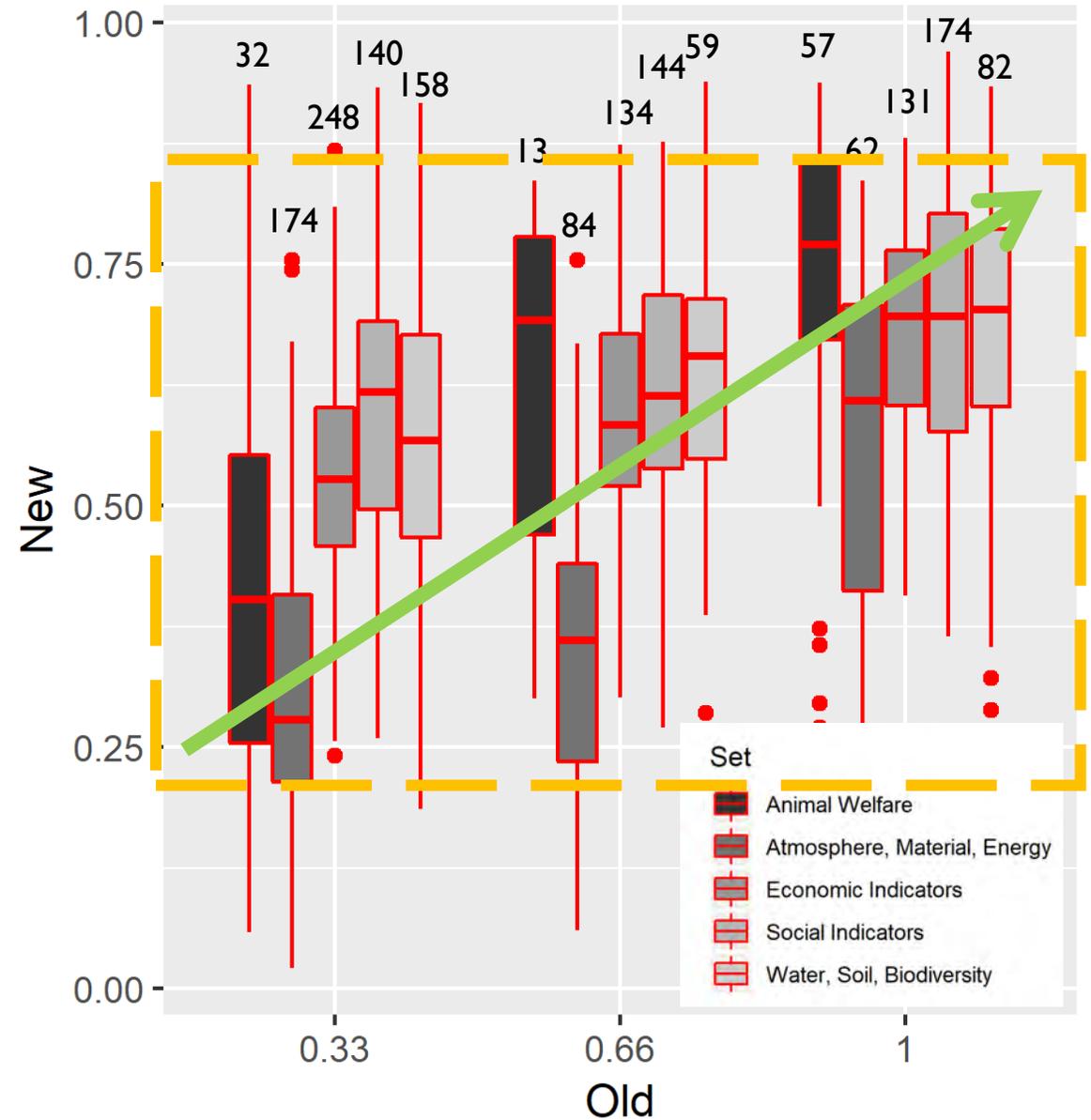
Uncheck to zoom into graph

Enter the discussion by adding a comment here.

# Indicator weights consensus method

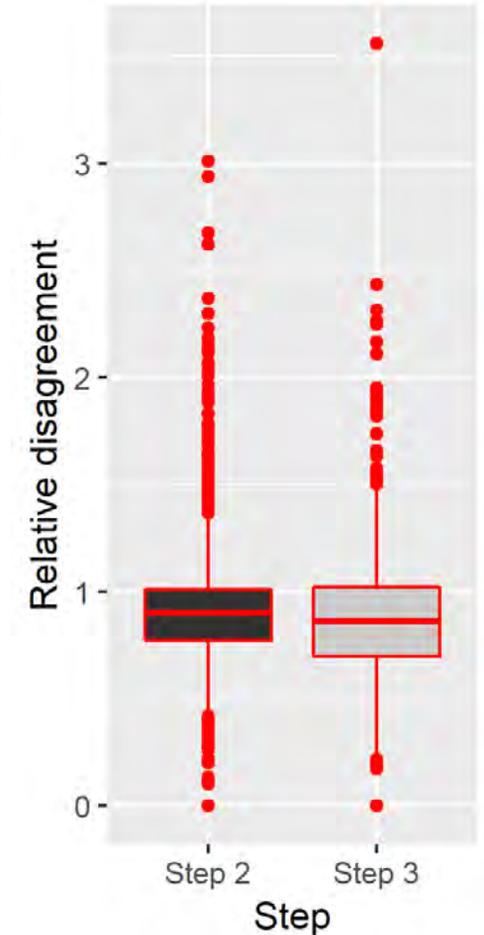
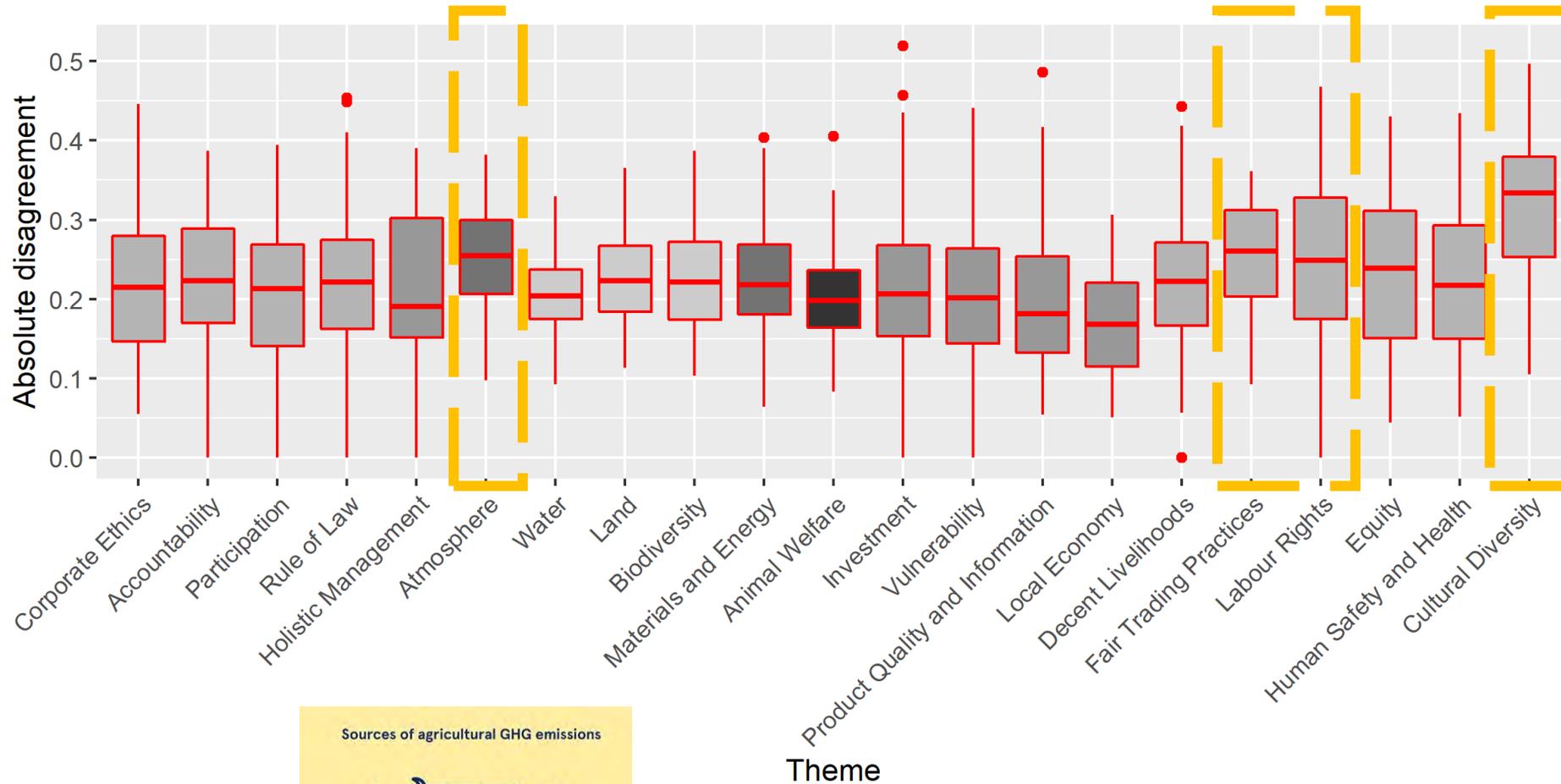
## Validation

- Dataset of preliminary indicator weights (“Old”) taken from an independent set of FiBL experts (ranging -3 to +3)
- Correlation with the final values (“New”) provided by the Delphi/NGT process (ranging -10 to +10)
- “Flattening” of values when provided with a larger (10-point) scale - sign of fatigue? (Saisana 2015)



# Uncertainty assessment

Patterns in uncertainty (s.d. of expert weights)



-11%\*    -14%



**Consensus building**

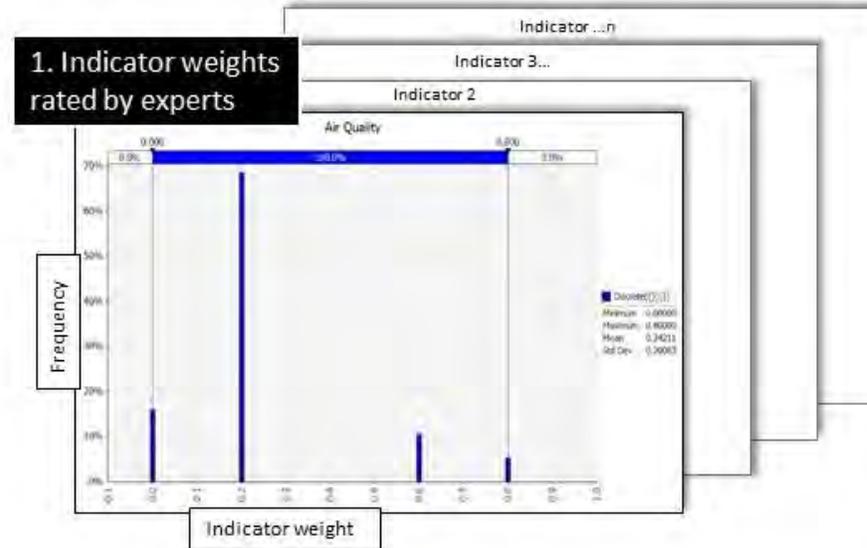


# Uncertainty assessment

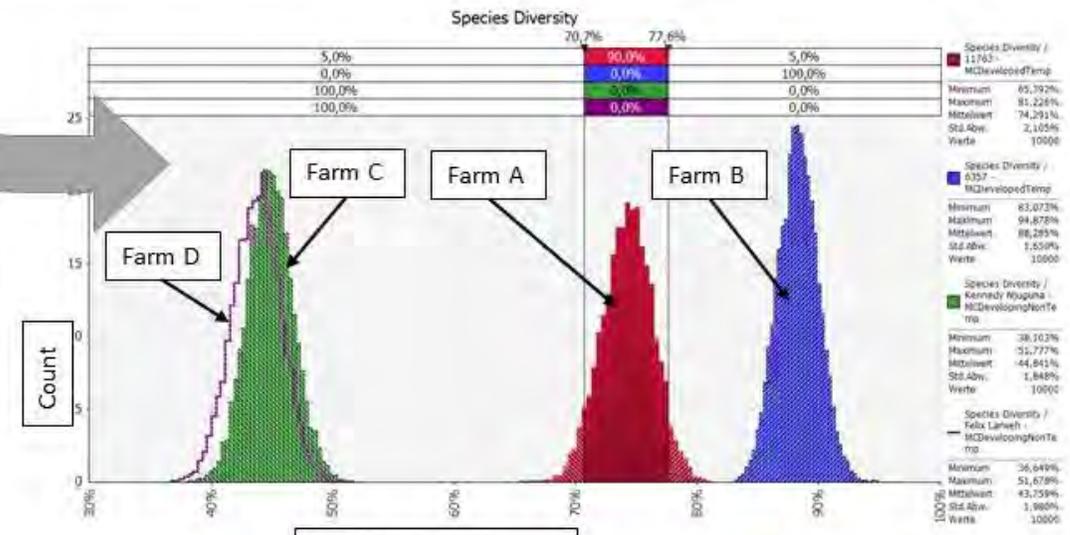


Group consensus method: **Delphi + Nominal Group Technique**

- 64 experts
- Global representation
- Separate assessment for each SAFA subtheme



2. Uncertainty assessment



4. Interpretation and statistical analysis

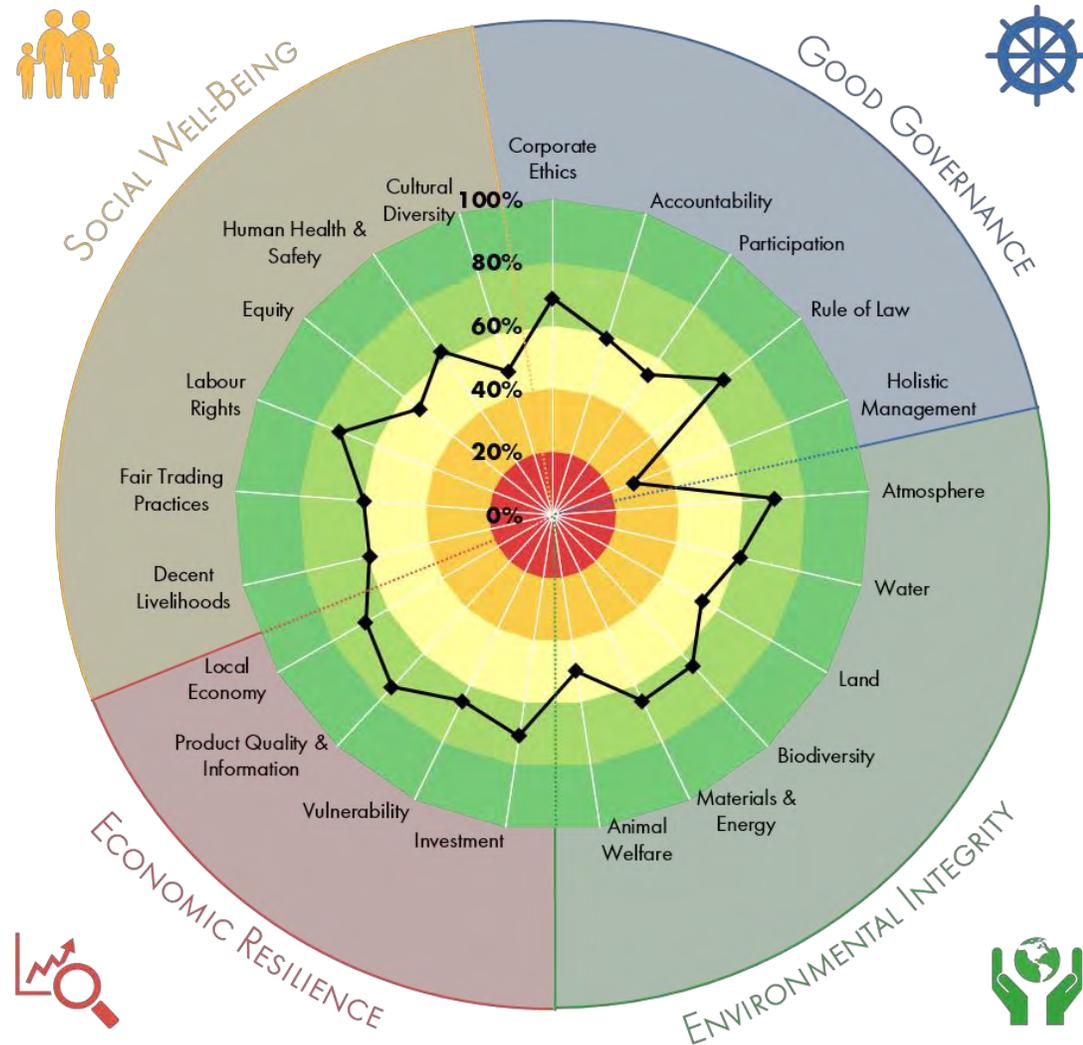
Subthemes	Farm A		Farm B		Difference (B-A)
	Mean	Mean	Mean	Mean	
Mission Statement	45.07	38.53	38.53	45.07	-6.54
Due Diligence	87.19	92.72	92.72	87.19	5.54
Holistic Audits	58.35	59.17	59.17	58.35	0.83
Responsibility	66.31	45.81	45.81	66.31	-20.49*
Transpare					1.15
Stakehold					1.93

3. Farm-level comparisons per sub-theme

# Uncertainty assessment

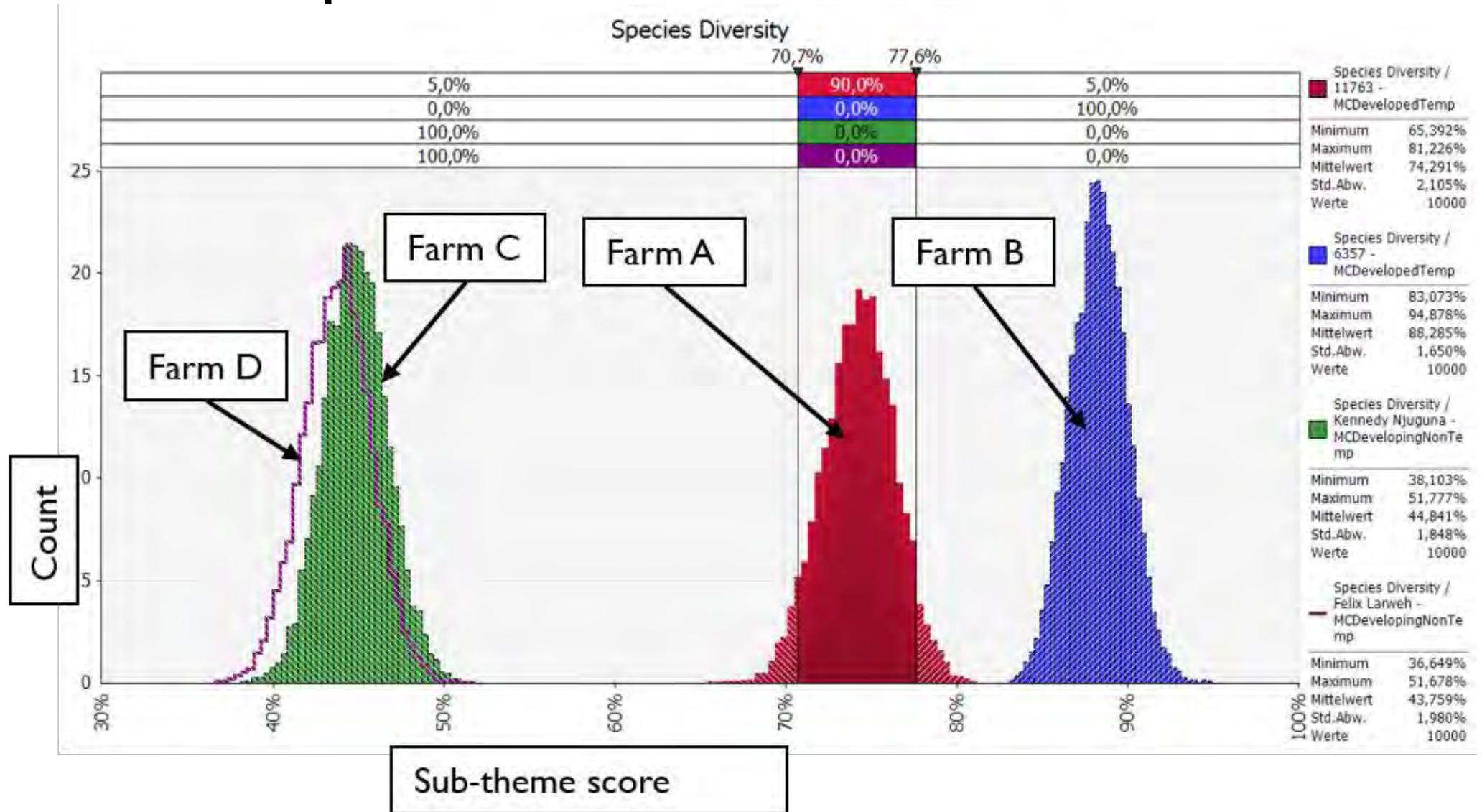
## Monte Carlo Simulation

- Refsgaard et al. (2007)
- @ Risk Software
- Error propagation to simulate uncertainty distribution in model output
- Outputs of SMART are SAFA subtheme performance scores ranging 0-100%



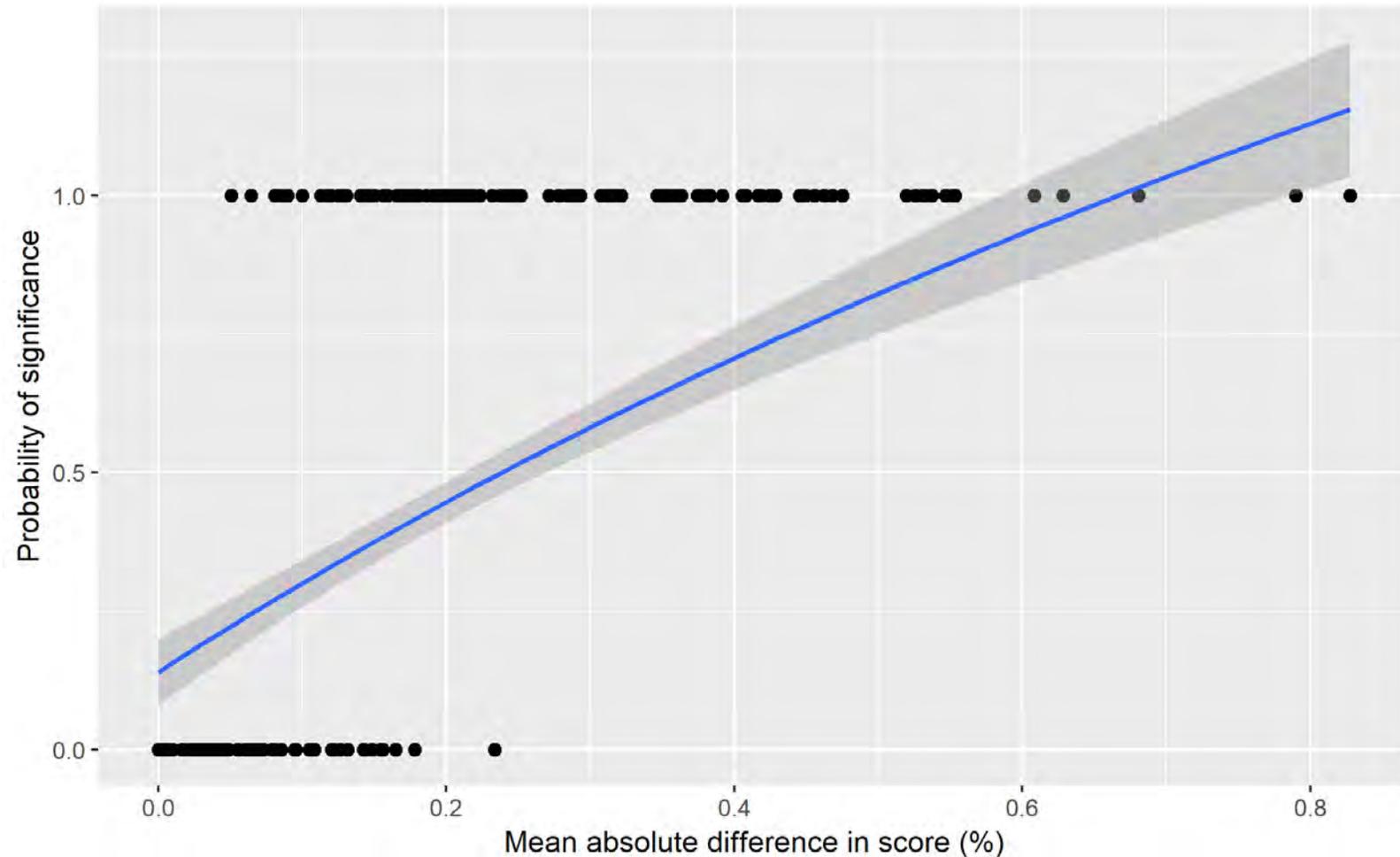
Palisade Corporation. 2009. Guide to using@ RISK.: Risk analysis and simulation add-in for Microsoft Excel. <https://www.palisade.com>. USA, Newfield NY.

# Effects on farm comparisons



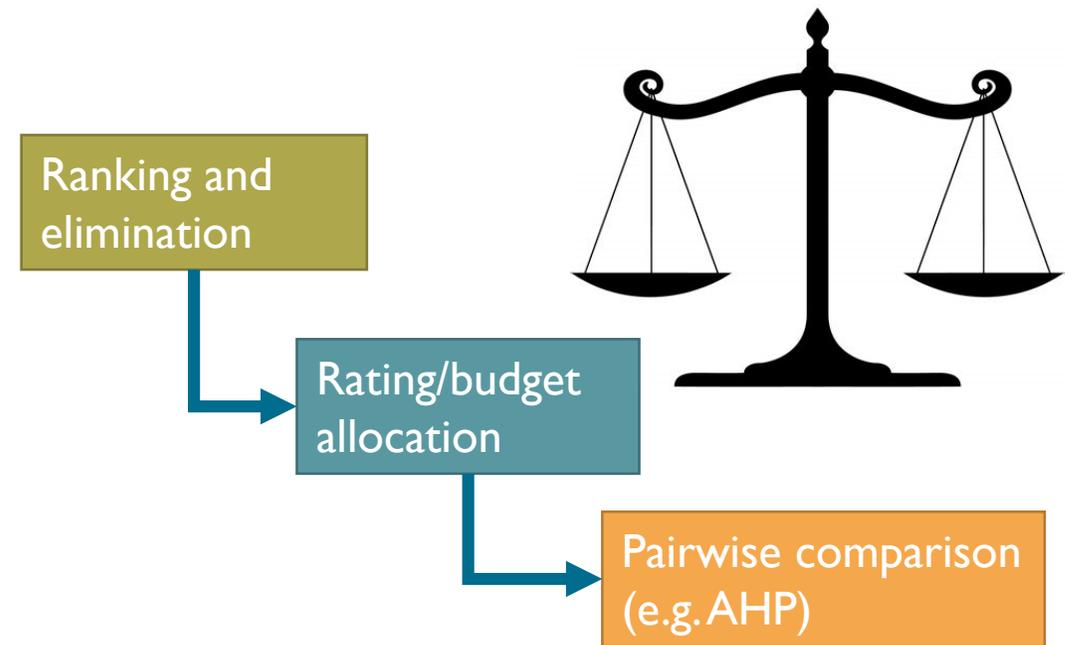
# Effects on farm comparisons

- Four example farms (Schader et al. 2016)
  - 2 farms in Europe (Livestock and Arable)
  - 2 farms in Sub-Saharan Africa (Livestock and Agroforestry)
- Non-significant differences between farms ranging up to 20%
- High uncertainty in the governance dimension
- **Mean of ca. 6%**



# Conclusions

- Weights could be validated with separate dataset
- Adding NGT element to Delphi process improved consensus (by ca. 3%)
- Additional time & effort probably not worth it
- As expected, high levels of uncertainty in social/cultural themes, but also in air quality/GHG (!)
- Consistency and quality of consensus process could have been improved
  - Balanced and manageable indicator sets
  - Quantify consistency of expert ratings



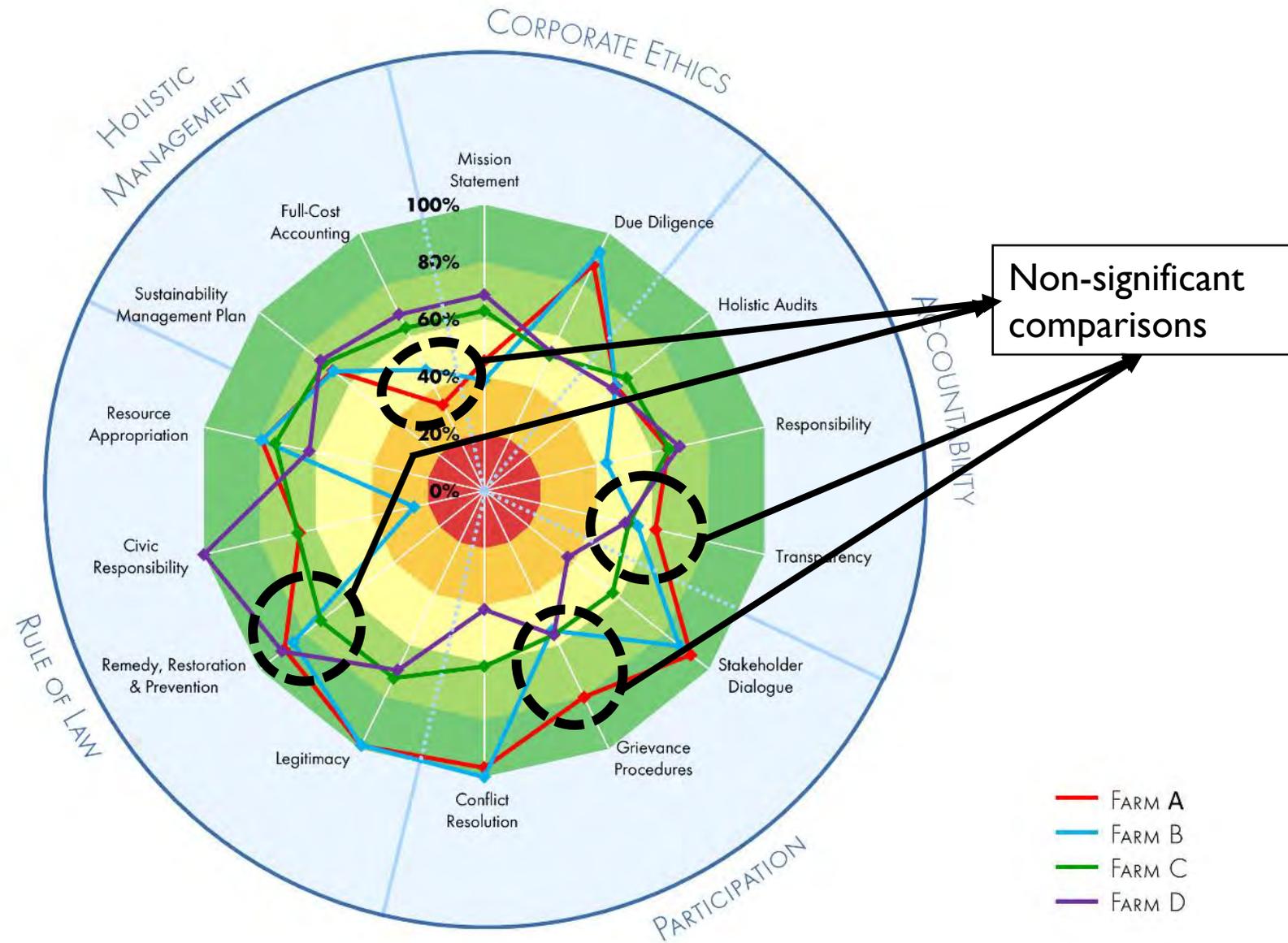
Indicator A	Criterion C2.1																	Indicator B
12.1.1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	12.1.2
12.1.1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	12.1.3
12.1.1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	12.1.4
12.1.2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	12.1.3
11.1.2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	12.1.4
11.1.3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	12.1.4

The shaded squares are the ones chosen by the expert to represent the relationship between the 2 indicators being compared.

Saaty's 9 point scale

# Conclusions

- Sustainability assessment tools rarely calculate uncertainty
- Clear need, although not always straightforward with expert judgement
- Present method estimates and integrates parameter uncertainty
- Users of such tools should be informed of uncertainty



# Thank you for your attention!

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**Video**  
FiBL Switzerland - The Research Institute of Organic Agriculture: Video, duration 4:35 minutes, available in 10 languages:  
English, Deutsch, Français, Español, Italiano, no-pwocet, Português, 日本語, 汉语, العربية

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> [Kaolin, lime and rock dusts to control Drosophila suzukii](#)  
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Activity Report 2016

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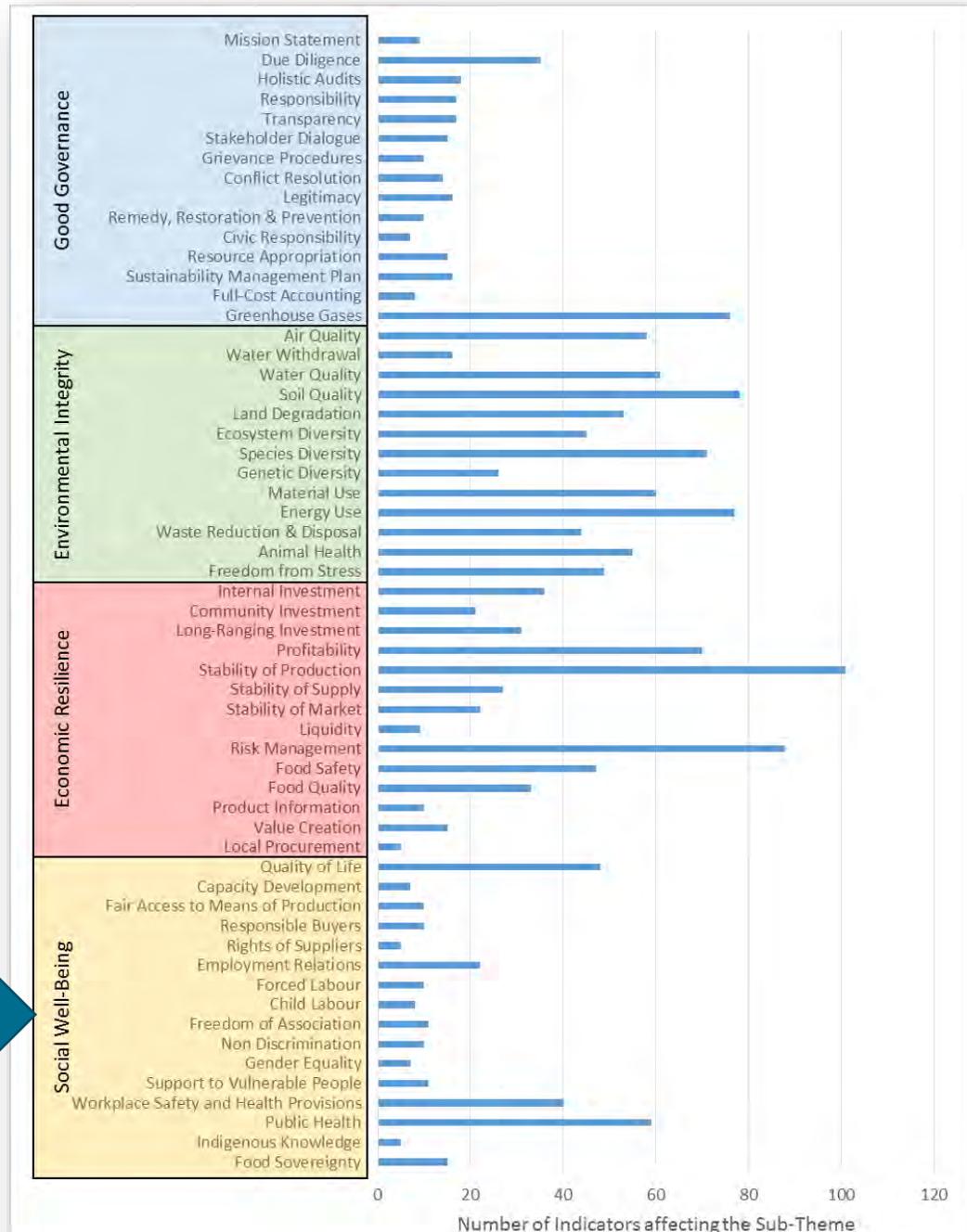
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# Extra slides

# Indicator selection

- Indicators influence multiple subthemes (+ve/-ve)
- > 1700 indicator weights (influences) between indicators and SAFA sub-themes
- Ca. 30 indicators per SAFA sub-theme
- Emphasis on simple, easy to measure indicators

- Work overload
- Relationship with suppliers
- Local procurement of inputs
- Self-sufficiency, local/direct sales
- Equipment and safety protocols
- Level of mechanization
- Working hours, overtime compensation
- Formal contracts, collective bargaining
- Child labour, forced labour



# SMART methodology – aggregation

Sub-theme for which a SAFA objective is defined <b>Capacity Development</b>	Impacts of each indicator in the sub-theme			Sustainability Score at the Sub-theme level
	Impact Weight	Indicator Rating	Impact weight * score	
Further training for farm staff	0.93	100%	0.93	<b>44.36%</b>
Apprenticeships	0.71	100%	0.71	
Training on sustainability	0.73	0%	0.00	
Employees: Access to external training	0.85	25%	0.21	
Access to advisory services	0.91	25%	0.23	
Education and training at master level (master crafts men places)	0.56	0%	0.00	
	<b>4.69</b>		<b>2.08</b>	
<b>Relevant indicators impacting on degree of goal achievement</b>	<b>Sum of impacts = maximum achievable points</b>		<b>Sum of impacts * actual performance = achieved points</b>	

# Data collection on farm

- Similar to a compliance check
- Familiarity and acceptance by farmers
- Semi-structured interview
  - 2-3 hours for a small to medium sized farm (<100 ha)
  - Up to several days for large farms (>1000 ha)

