Uncertainty analysis

Lecture

Mark Huijbregts
Department of Environmental science
Radboud University

Contents

Difficulties in LCA (I)

- Not every factory has the same emissions
- Emissions will differ from year to year
- Parameters may include measurement errors or may not be measured at all

☞ Which value should you choose?

Difficulties in LCA (II)

- Allocation in multi-output systems can be done in many ways
- Midpoint or endpoint impact assessment?
- Choice for time horizon?

☞ Which method should you select?

Difficulties in LCA (III)

How to deal with lack of spatial detail?

How to assess sum emissions?

How to deal with unrepresentative data?

☞ How to handle ignorance?

Uncertainty versus variability

Uncertainty: The value of a parameter is not exactly known. Uncertainty can be reduced by additional research.

Variability: The value of a parameter differs between individuals (interindividual), places (spatial) or in time (temporal). Variability is inherent in the system and cannot be reduced by additional research.

Types of uncertainty

- Statistical uncertainty
- Uncertainty due to choices
- Model uncertainty

Other terminology used:
systematic errors, random errors, data uncertainty, completeness uncertainty, subjective judgement, contextual uncertainty, preferential uncertainty, …

Qualitative assessment: life cycle impact assessment

LCIA framework and requirements
http://lct.jrc.ec.europa.eu/pdf-directory/ILCD-Handbook-LCIA-Framework-requirements-online-12March2010.pdf

Defining (and applying) evaluation criteria to life cycle impact assessment methods commissioned by the JRC-Ispra

Qualitative assessment: LCIA (I)

Evaluation criteria categories
Introduction
Completeness of scope
Environmental relevance
Scientific robustness & Certainty
Documentation & Transparency & Reproducibility
Applicability
Stakeholder acceptance criteria

Qualitative assessment: LCIA (II)

Evaluation:
A : full compliance
B: compliance in all essential aspects
C: compliance in some aspects (``so-so``)
D: little compliance
E: no compliance

Results EU-LCIA best practice project

Recommendations of methods and factors

- … at midpoint and at endpoint
- … in a consistent framework, where possible

Classification of recommendations

- I: Recommended and satisfactory
- II: Recommended, some improvements needed
- III: Interim, i.e. the most appropriate among the existing approaches but immature for recommendation

Identification of future research needs

- Classification according to importance
- Estimation of work load

Impact category	Recommended model Midpoint	Class.	Recommended model Mid to Endpoint	Class.
Climate change	IPCC (GWP) (100 years)	I	ReCiPe	III
Ozone depletion	WMO (ODP) (infinite)	I	ReCiPe	III
Human toxicity, carcinogenics	USEtox	II/III	DALY calculation applied to USEtox midpoint	II/III
Human toxicity, non- carcinogenics	USEtox	II/III	DALY calculation applied to USEtox midpoint	III
Particulate matter/Respiratory inorganics	Not settled yet: Greco et al., 2007 or RiskPoll or ReCiPe	I/II	Adapted DALY calculation applied to midpoint	II
Ionising radiation, human health	Frischknecht et al., 2000	II	Frischknecht et al., 2000	III
Ionising radiation, ecosystems	Garnier-Laplace et al., 2008	III	PDF calculation applied to midpoint	III

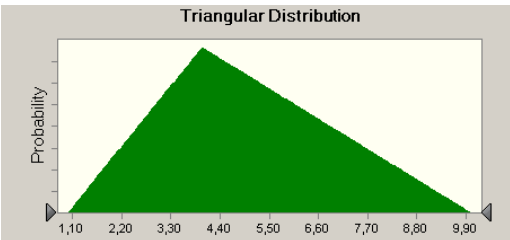
Impact category	Recommended model Midpoint	Class.	Recommended model (Mid to) Endpoint	Class.
Photochemical ozone formation	LOTOS-EUROS as applied in ReCiPe	II	ReCiPe for human health, nothing for vegetation	II
Acidification	Accumul. Exceedance	II	ReCiPe	III
Eutroph. terrestrial	Accumul.Exceedance	II	None	-
Eutroph. aquatic	ReCiPe	II	ReCiPe for freshwater, none for marine waters	III
Ecotoxicity	USEtox	II/III	PDF calculation applied to USEtox midpoint	III
Land use	Milà i Canals	III	ReCiPe	III
Resource depletion, water	Swiss Ecoscarcity	III	None	-
Resource depletion, mineral . fossil (and renewable)	Category 1: None Category 2: EDIP97 update 2004	- II	Category 4: ReCiPe	III

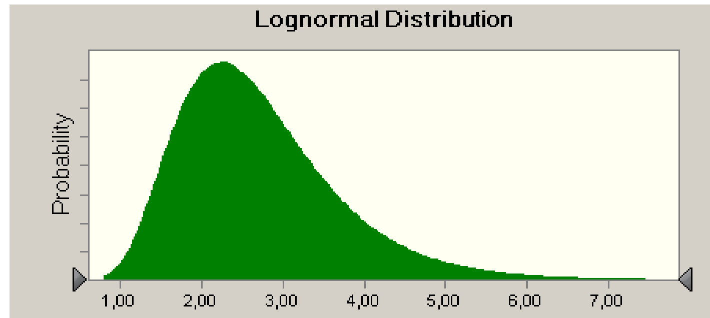
Statistical uncertainties

Monte Carlo simulation

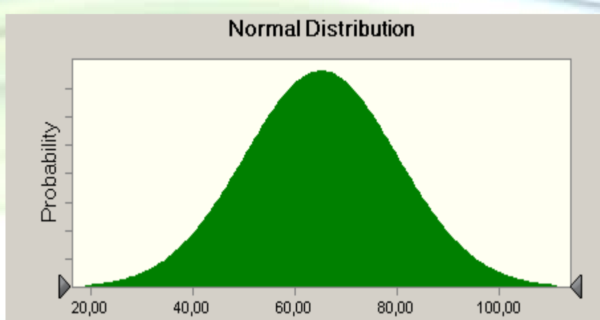
1. define uncertainty distributions for input parameters: lognormal, triangular, normal, uniform, etc…
2. translate input uncertainties in output uncertainties by probabilistic sampling: 1,000-10,000 runs
3. visualize and communicate uncertainty in LCA outcomes

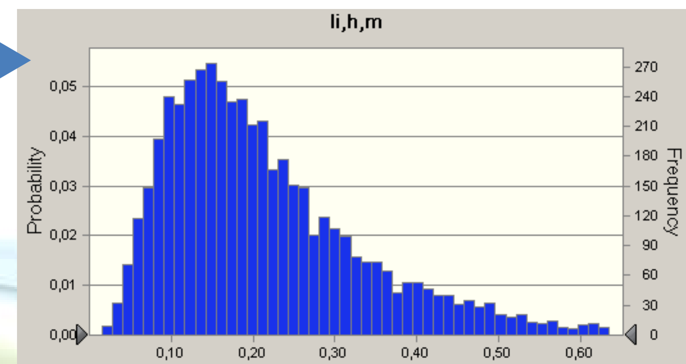
Monte Carlo simulation





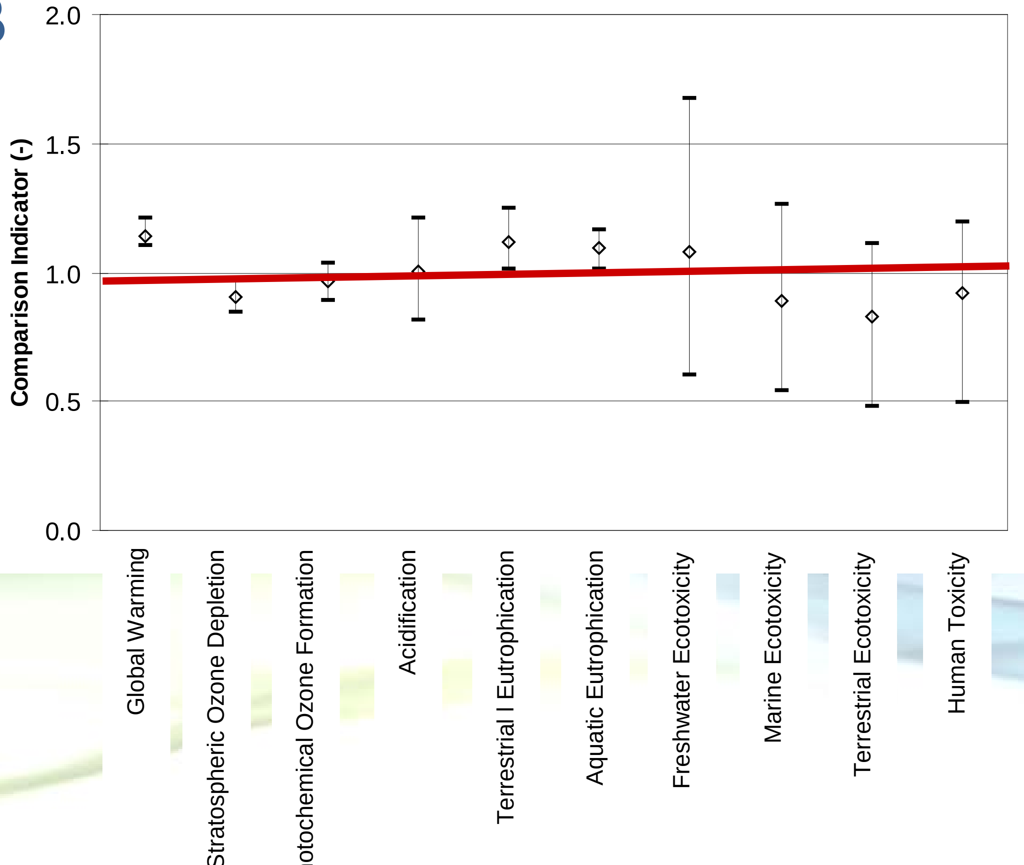
$$\frac{M_x \cdot CF_{e,x}}{NF_e} = NS_{e,x}$$



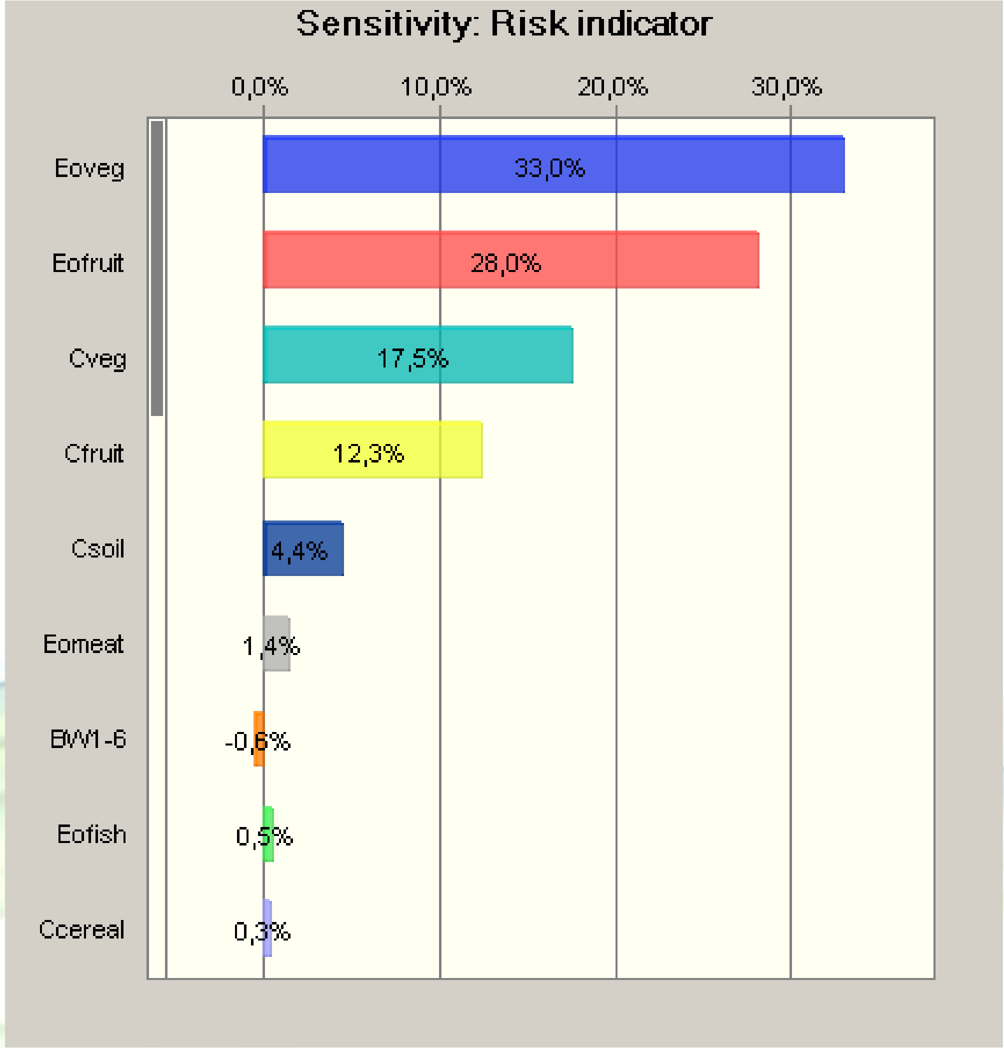


Comparison Indicator

- Account for correlations between two product systems in MC
- How? -> CI = ISA/ISB



Uncertainty Importance



To obtain a high score in the sensitivity chart a parameter must have:

- ☞ considerable influence on the comparison indicator
- ☞ large variance (broad range of input values)

Model and choice uncertainty

Choice analysis

1. Identify number of options
2. Calculate outcomes per option

Cultural Theory….

Cultural Theory

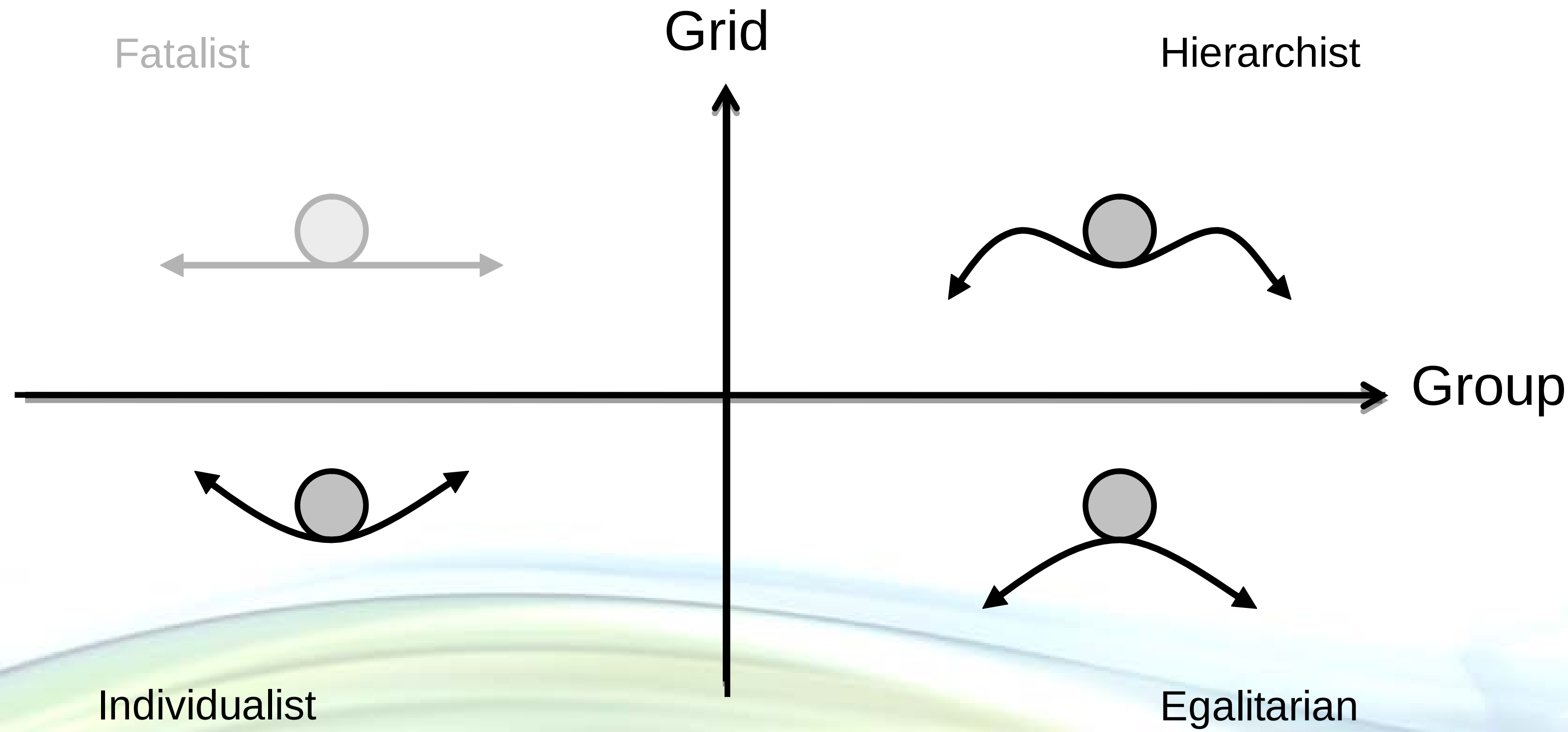
- Individualists: act on their own; external rules and institutions less important. Natural systems as being inherently stable and inexhaustible

- Hierarchists: aim at maintaining the system; natural systems as being stable and manageable within certain limits.

- Egalitarians: members of their group are equal. Rules imposed from outside the group will be rejected. Regard natural systems as being vulnerable

- Fatalists: Act on their own. Victims of exogenous rules. Experience the world as being governed by chance.

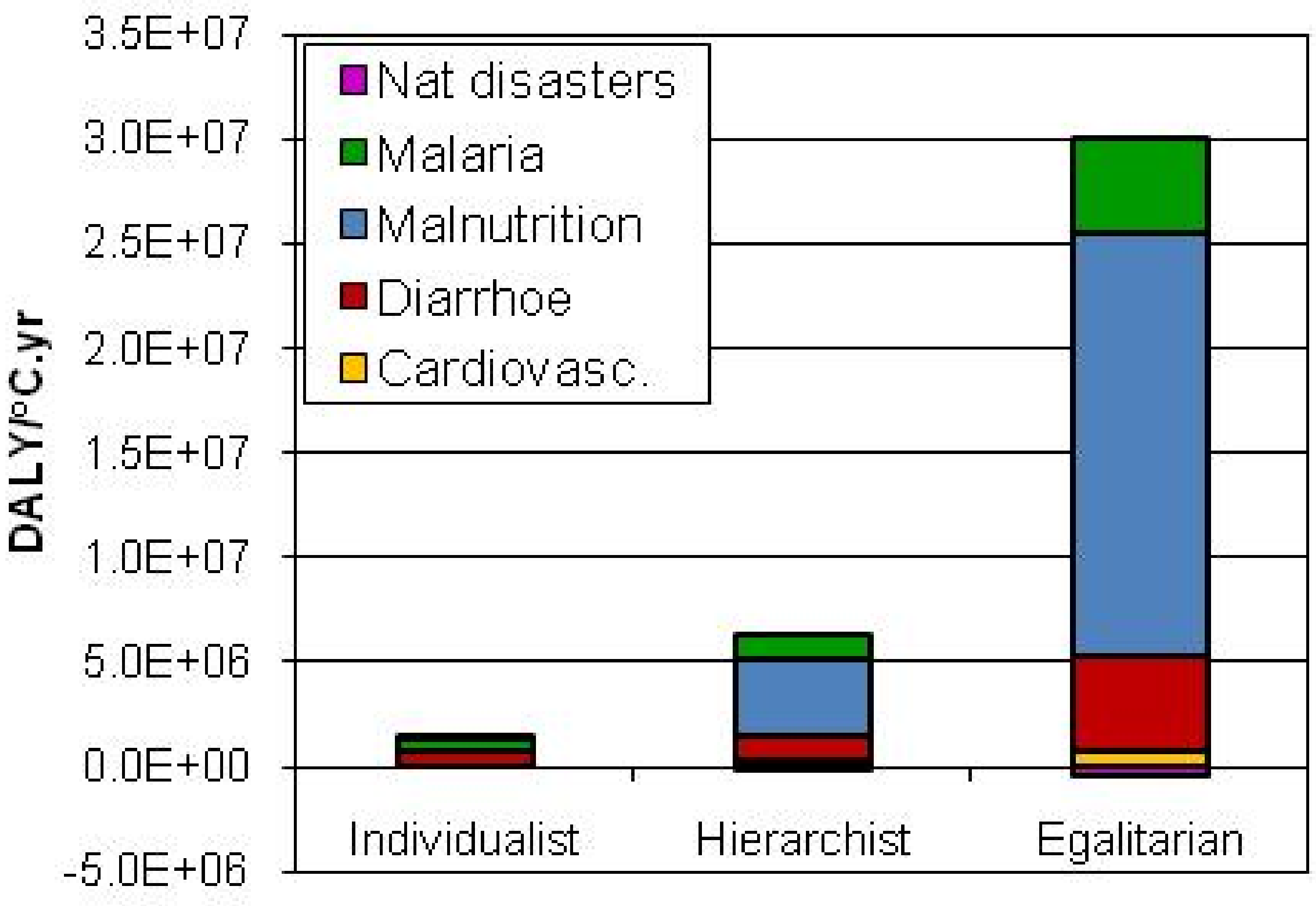
Cultural Theory



Cultural Theory

Impact category	Value choice	Individualist	Hierarchist	Egalitarian
All impact categories	Time horizon	20 years	100 years	Infinite
	Discount rate	5%	3%	0%
	Age weighting	Yes	No	No
	Positive effects	Yes	No	No
Climate change	Future development	Optimistic	Baseline	Pessimistic
Ozone depletion	Cataract	No	Yes	yes
Ionizing radiaition	Effects included	Definite	Definite/probable/possible	All effects
Human toxicity	Carcinogenity	IARC 1	IARC 1, 2A,2B	All substances
Respiratory inorganics	Secondary PM	No	From SO_2	From SO_2, NH_3, NO_x
Ozone formation	Ozone scenario	24h ozone	8h ozone	8h ozone

Cultural Theory - Example



Reducing model uncertainty

- Expand number of stressors
- Implement spatial detail
- …

LCA software

Uncertainty analysis

1. CMLCA (www.leidenuniv.nl/cml/ssp/software/)
2. Simapro (www.pre.nl/simapro)

Summary

- Uncertainties not always assessed in LCA
- Statistical uncertainty: Monte Carlo simulation, ….
- Choice and model uncertainty: Cultural theory, ….
- Ignorance: further research!!