# International developments in Life Cycle Impact Assessment of Land Use

Dr. Miguel Brandão

Massey University

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

# International Activities

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **European Commission**
  - ILCD Handbook
  - PEF and OEF

- **UNEP/SETAC Life Cycle Initiative**
  - Guideline on Global Land Use Impacts on Biodiversity and Ecosystem Services in LCA
  - Biotic Production Potential
  - Carbon Sequestration Potential
  - Case Study

# The ILCD Handbook

Superseded by PEF/OEF

NEW ZEALAND
LIFECYCLE
MANAGEMENT CENTRE

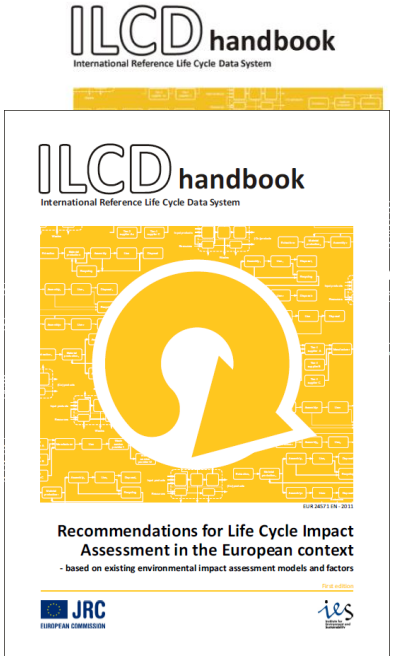
# European Commission recommendations

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

**Methods evaluated against:**

- Scientific criteria
  - Completeness of scope
  - Environmental relevance
  - Scientific robustness and certainty
  - Documentation, transparency and reproducibility
  - Applicability

- Stakeholder acceptance criterion
  - Degree of stakeholder acceptance and suitability for communication in a business and policy context



# Scoring procedure

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

**A: Full compliance**

**B: Compliance in all essential aspects**

**C: Compliance in some aspects**

**D: Little compliance**

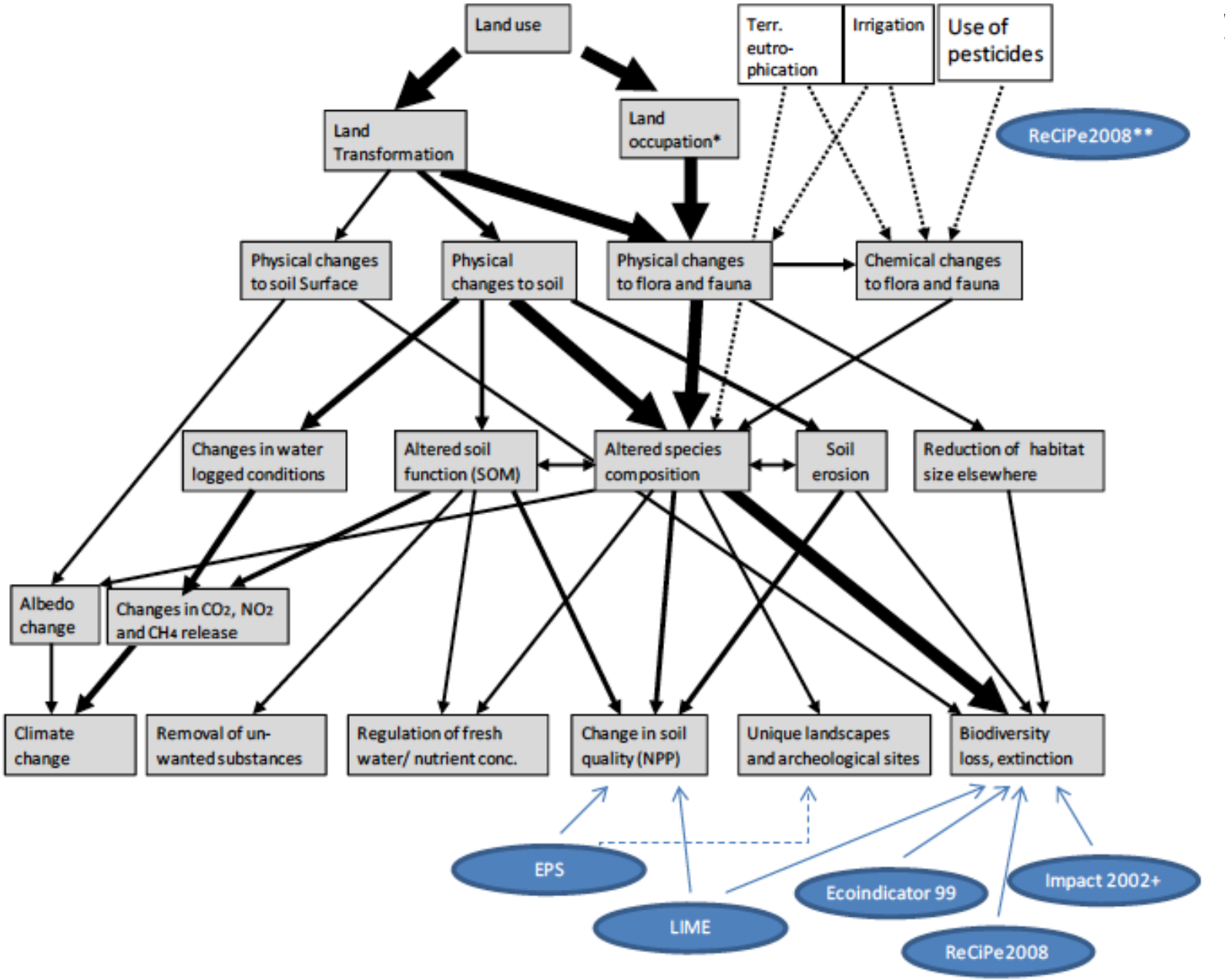
**E: No compliance**

# ILCD LCIA method recommendation levels

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **Level I: Recommended and satisfactory**
- **Level II: Recommended, some improvements needed**
- **Level III: Recommended, but to be applied with caution**
- **Interim: Immature for recommendation but the most appropriate among existing approaches**

# Land Use cause-effect chain



# ILCD selected methods and underlying models

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

| Midpoint method | Underlying model | Reference |
|---|---|---|
| ReCiPe | Not based on a specific model | De Schryver and Goedkoop (2009b) |
| Milà i Canals | Based on Soil Organic Matter (SOM) | Mila i Canals *et al.* (2007b) |
| Baitz | Based on seven quality indicators | Baitz (2002) further developed by Bos and Wittstock (2008) |
| **Endpoint method** | **Underlying model** | **Reference** |
| EPS 2000 | Based on species diversity loss and production of wood | Järvinen and Miettinen (1987) |
| Eco-Indicator 99 (EI99) | Based on species diversity loss | Köllner (2000) in Goedkoop and Spriensma (2000) |
| ReCiPe | Based on species diversity loss | De Schryver and Goedkoop (2009b) |
| LIME | Based on species diversity loss and production of wood | Itsubo *et al.* (2008b) |
| Swiss Ecoscarcity | Based on species diversity loss | Köllner (2001), Köllner and Scholz (2008) |

# Sub-criteria for Land Use

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- Specific underlying model
- Land transformation
- Land occupation
- Duration of physical changes
- Quantitative changes to fauna and flora
- Physical changes to soil
- Effects on climate change
- Effects on Net Primary Production
- Biodiversity loss

# Analysis of midpoint methods (ILCD, 2011)

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

| | ReCiPe Midpoint | | Baitz (2002), further developed by Bos and Wittstock (2008) | | Milà i Canals *et al.* (2007b) | |
|---|---|---|---|---|---|---|
| **Completeness of scope** | E | No impact mechanism included. | B | Seven different indicators describing soil quality. Most data must be collected by the practitioner. When no site-specific data are available, country-average data are used. | C | Limited impact indicator, based on soil organic matter (SOM). Case-specific characterisation factors (CF) should be developed by the user. Site-specific data are needed. CFs available for elementary flows based on the land-use classification system CORINE+. |
| **Environmental relevance** | E | Characterisation model does not distinguish different species composition between land use types. | C | Characterisation model includes seven different land use effects. Only local effects are considered. | C | The charactersation model includes one indicator. Only local effects are considered.. |
| **Scientific robustness & Certainty** | 0 | Not further evaluated due to lack of environmental characterisation model. | B | The main scientific value is in the comprehensive selection of indicators, and the pragmatic guidance to users for calculating characterisation factors. | A | Characterisation model is reviewed and is recent (2007). |
| **Documentation, Transparency & Reproducibility** | 0 | Not further evaluated. | D | A general bakground database is available. Documentation is available in both German and English, although the latter is not publicly available yet. | A | The model documentation and characterisation factors are published and available free of charge. |
| **Applicability** | 0 | Not further evaluated. | E | Characterisation factors should be determined by the user. The method provides guidance. Already implemented and tested in some databases. | E | Default factors are available for background processes. Case-specific characterisation factors should be produced by the practitioner. Considerable information is needed. |
| **Overall evaluation of science-based criteria** | E | No compliance with science-based criteria for the evaluation of land use impacts. | D | Seven quality indicators describing different soil-quality aspects; there is no way to aggregate these at midpoint level. Characterisation factors are not available; normalisation is not available. | C | Only one indicator describing soil quality. Case-specific characterisation factors should be produced by the practitioner. Model is reviewed and good for agro- and forestry-systems. |
| **Overall evaluation of stakeholders' acceptance** | E | No compliance with science-based criteria for the evaluation of land use impacts. | D | Complex method that produces different indicators. Not endorsed by an authoritative body. | C | Principles of the model are relatively easy to understand, but not endorsed by an authoritative body. Exclusion of biodiversity is a limitation for several relevant stakeholders. |

# Midpoint method evaluation (ILCD, 2011)

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

| Overall evaluation | ReCiPe Midpoint | Baitz (2002), further developed by Bos and Wittstock (2008) | Milà i Canals *et al.* (2007) |
|---|---|---|---|
| - Completeness of scope | E | B | C |
| - Environmental relevance | E | C | C |
| - Scientific robustness & Certainty | 0 | B | A |
| - Documentation, Transparency & Reproducibility | 0 | D | A |
| - Applicability | 0 | E | E |
| Stakeholders' acceptance | 0 | D | C |

**Level III**

# Analysis of endpoint methods (ILCD, 2011)

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

| | ReCiPe | | Eco-Indicator 99 | | EPS2000 | | LIME | | Swiss Ecoscarcitiy | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Completeness of scope** | C | Valid for Northwest Europe. Indicator based on biodiversity. Possible double-counting not considered. | C | Valid for mid-Europe. Indicator based on biodiversity. Double-counting with pesticides and fertilisers considered. | D | Indicator based on biodiversity (red list species) and wood productivity. Biodiversity only based on Swedish data. Possible double-counting not considered. | D | Valid for Japan. Indicator based on biodiversity and NPP. | C | Valid for mid-Europe. Indicator based on biodiversity and adopts the CORINE classification. |
| **Environmental relevance: Overall evaluation** | C | Characterisation model reflects loss of species based on species-area relationship. Considers land use intensiveness. Exclusion of effects on primary production. | D | Characterisation model reflects loss of species based on species-area relationship. Exclusion of effects on primary production. | D | No characterisation model used. Inclusion of biodiversity and primary production effects based on empirical data. | C | Characterisation models include effects on primary production and biodiversity loss. | D | Characterisation model reflects biodiversity loss. Transformation not available in Ecoscarcity implementation. |
| **Scientific robustness & Certainty: Overall evaluation:** | C | Only input data reviewed. No uncertainty figures available. Most recent data used. | C | Only input data reviewed. Uncertainty figures available. Relatively old data employed. | C | Only input data reviewed. Uncertainty figures available. Relatively old data employed. | E | Indicators cannot be confirmed due to lack of documentation. No model uncertainties considered. | B | Characterisation model is reviewed. Uncertainty figures available. |
| **Documentation,Transparency & Reproducibility: Overall evaluation** | A | The model documentation and results are published and available free of charge. | A | The model documentation and results are published and available free of charge | A | The model documentation and results are published and available free of charge. | E | English documentation does not exist. | A | The model documentation and results are published and available free of charge. |
| **Applicability: Overall evaluation** | B | Characterisation factors are available, can be easily applied and updated | B | Characterisation factors are available and can be easily applied and updated. | B | Characterisation factors are available and can be easily applied and updated. | D | Characterisation factors are not available in English . | B | Characterisation factors are available and can be easily applied and updated. |
| **Overall evaluation of science based criteria** | C | Based on most recent data and knowledge, considers land-use intensiveness, but does not take into account double-counting effects | D | Based on old data, does not consider land-use intensity, but takes into account effects of double-counting and uncertainty data. | D | No characterisation model used, considers NPP and biodiversity effects. Based on old data, uncertainty data included. | D | The characterisation model produced only applies to Japan. Lacks English documentation. | C | Based on recent data and knowledge, considers several land-use types (only for occupation). It does not take into account double-counting effects. The model is reviewed. |
| **Overall evaluation of stakeholders acceptance** | C | The principles of the model are relatively easy to understand, but the model is not endorsed by an authoritative body. | C | The principles of the model are relatively easy to understand, but the model is not endorsed by an authoritative body. | C | The principles of the model are relatively easy to understand, but the model is not endorsed by an authoritative body. | C | The principles of the model are relatively easy to understand, but the model is not endorsed by an authoritative body. | C | The principles of the model are relatively easy to understand, but the model is not endorsed by an authoritative body. |

# Endpoint method evaluation (ILCD, 2011)

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

| Overall evaluation | ReCiPe Endpoint | Eco-Indicator 99 | EPS | LIME | Swiss Ecoscarcitiy |
|---|---|---|---|---|---|
| - Completeness of scope | C | C | D | D | C |
| - Environmental relevance | C | D | D | C | D |
| - Scientific robustness & Certainty | C | C | C | E | B |
| -Documentation, Transparency & Reproducibility | A | A | A | E | A |
| - Applicability | B | B | B | D | B |
| Stakeholders' acceptance | C | C | C | C | C |

Interim

# Midpoint method evaluation (ILCD, 2011)

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

| Recommendation | Recommended default LCIA method | Indicator | Classification |
|---|---|---|---|
| **at midpoint** | Model based on Soil Organic Matter (SOM) (Milà i Canals *et al.*, 2007) | Soil Organic Matter | Level III |
| **from midpoint to endpoint** | No methods recommended | | Interim |

# UNEP-SETAC Guideline on Global Land Use Impacts on Biodiversity and Ecosystem Services in LCA


Thomas Koellner[1], Rosie Saad[2], Laura de Baan[3], Tabea Beck[4], Ulrike Bos[4], Miguel Brandão[5], Barbara Civit[6], Jan Paul Lindner[4], Manuele Margni[1], Llorenç Milà i Canals[7], Danielle Maia de Souza[2,5] and Ruedi Müller-Wenk[8]

[1]U Bayreuth (Germany), [2]CIRAIG (Montréal, Canada), [3] ETH Zurich (Switzerland), [4] U Stuttgart (Germany), [5] JRC (Italy), [6] Universidad Tecnológica Nacional (Argentina), [7] Unilever - Safety & Environmental Assurance Centre (UK), [8] U St. Gallen (Switzerland)

# PROJECT DESCRIPTION AND PARTNERSHIP

# Land use LCIA: aims of the project

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

Working group UNEP/SETAC LC Initiative (phase 2):

- Harmonize practices and provide principles for Life Cycle Inventories on a global scale
- Provide guidelines for LCIA methods based on the recommendations established in phase 1
- Provide operational sets of characterization factors for impacts on :
  1) biodiversity
  2) services provided by terrestrial ecosystems
- Illustrate those findings in study cases

# Characterisation factors for land use impacts on biodiversity and ecosystem services

**A) Biodiversity Damage Potential**

Local species diversity and functional diversity

**B) Ecosystem Services Damage Potential**

B1) Biotic Production

Capacity of ecosystems to produce biomass

B2) Carbon Sequestration

Capacity of ecosystems to uptake carbon from air

B3) Freshwater Regulation

a) Capacity of ecosystems to regulate peak flow and base flow of surface water b) Capacity of ecosystems to recharge ground water

B4) Erosion Regulation

Capacity of ecosystems to stabilize soil and to prevent sedimentation

B5) Water Purification

Chemical, physical and mechanical capacity of ecosystems to clean a polluted suspension of water

# Land Use LCIA: an international collaboration

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

## Core group: complementary parts and case studies

- PES – U Bayreuth
- NSSI – ETH Zürich (Switzerland)
- CIRAIG – École Polytechnique de Montréal (Canada)
- LBP – U Stuttgart (Germany)
- CES – University of Surrey (UK)
- JRC – European Commission (Italy)
- IWOE – University of St. Gallen (Switzerland)
- Unilever – Safety & Environmental Assurance Centre (UK)
- U Tecnológica Nacional (Argentina)

UNIVERSITÄT BAYREUTH

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

CIRAIG™ Interuniversity Research Centre for the Life Cycle of Products, Processes and Services

Unilever

U.T.N.

University of Stuttgart Chair of Building Physics (LBP) Life Cycle Engineering (GaBi)

UNIVERSITY OF SURREY

JRC EUROPEAN COMMISSION

Universität St.Gallen

# Overview I

**Part A: Foundations**

- UNEP-SETAC Guideline on Global Land Use Impacts on Biodiversity and Ecosystem Services in LCA by Koellner et al.

**Part B: Modelling Characterization Factors for Biodiversity**

- Land use impacts on biodiversity in LCA: a global approach by Laura de Baan et al.
- Land use impacts on functional species diversity: proposal of characterization factors to assess effects on ecosystem processes by Maia de Souza et al.

# Overview II

**Part C: Modelling Characterization Factors for Ecosystem Services**

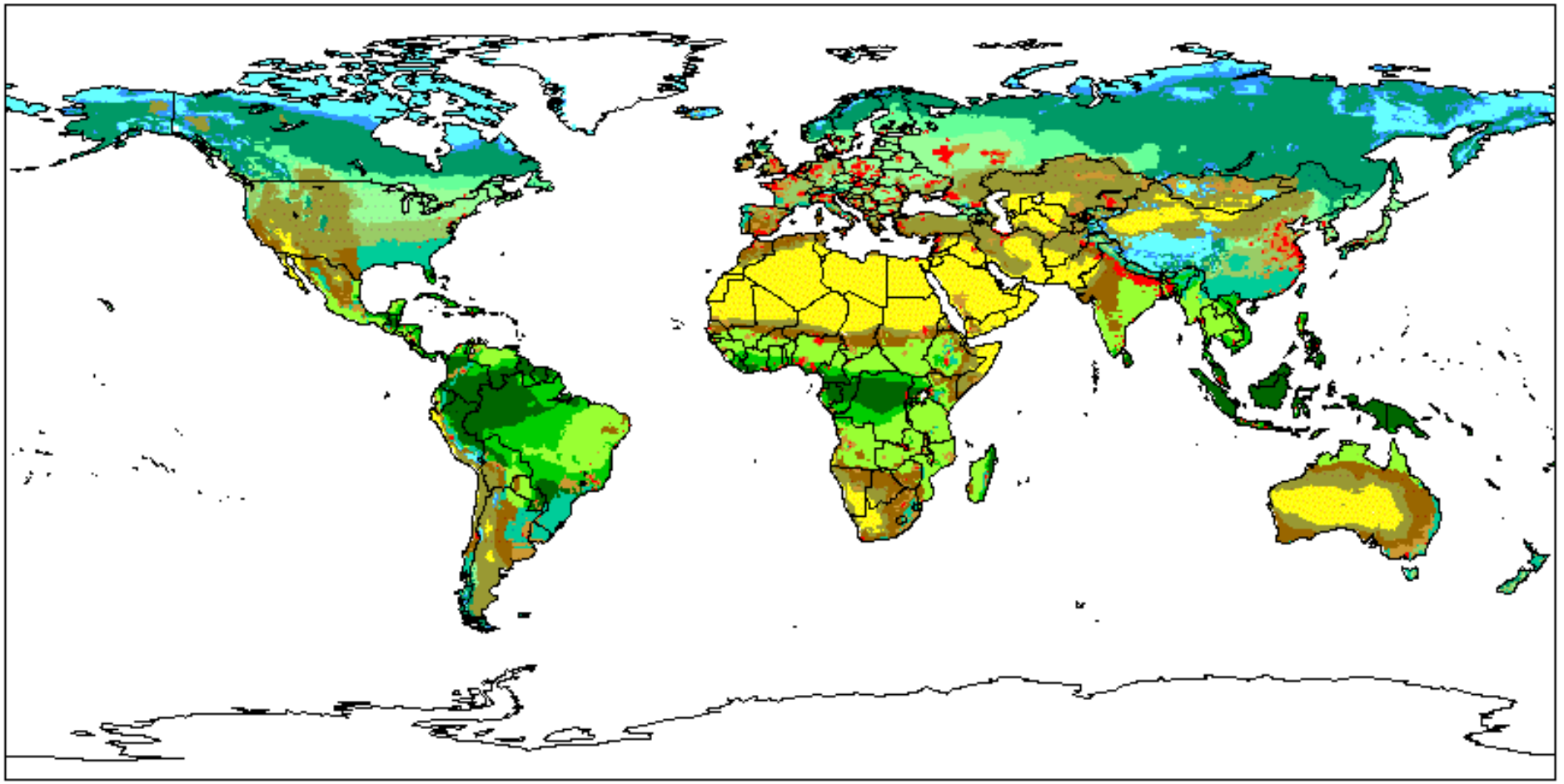
- Global characterisation factors to assess land use impacts on biotic production *by Brandão and Milà i Canals*
- Impact of land use on climate for use in LCA - carbon cycling between ecosystems and the atmosphere *by Müller-Wenk and Brandão*
- Land use impacts on freshwater regulation, erosion regulation and water purification: a spatial approach for a global scale *by Rosie Saad et al.*

**Part D: Application to Case Studies**

- Land use impact assessment of Margarine *by Milà i Canals et al.*

# CONTEXT AND GENERAL KEY-ELEMENTS

year **1700**

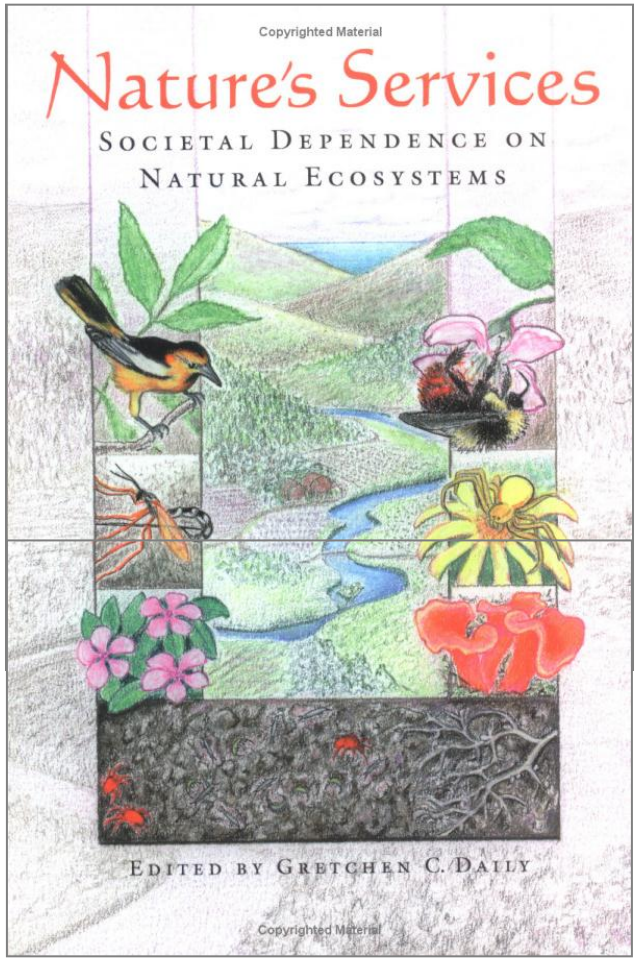


Cropland land
Grazing land
Ice
Tundra
Wooded tundra
Boreal forest
Cool conifer forest
Temp. mixed forest
Temp. deciduous forest
Warm mixed forest
Grassland/Steppe
Hot desert
Scrubland
Savanna
Tropical woodland
Tropical forest

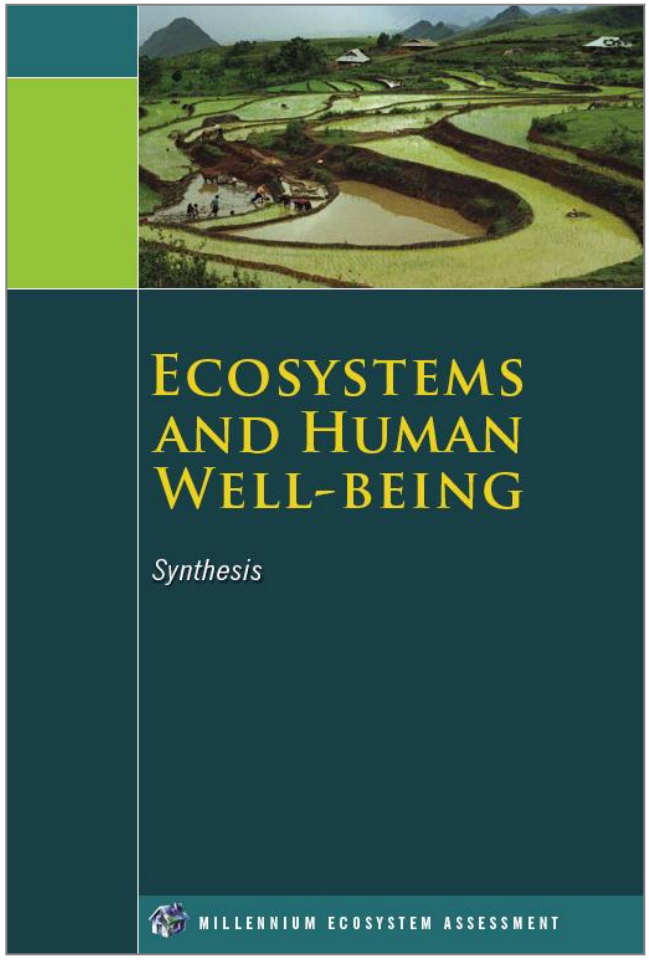
Source: Joint gateway of the Historic Land Use Estimation Efforts by the National Institute of Public Health and the Environment (RIVM, Netherlands) and the Center for Sustainability and the Global Environment (SAGE, USA).
http://www.ncdc.noaa.gov/paleo/ctl/landuse.html

# *Ecosystem services* are functional properties of ecosystems that contribute to human well-being

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE



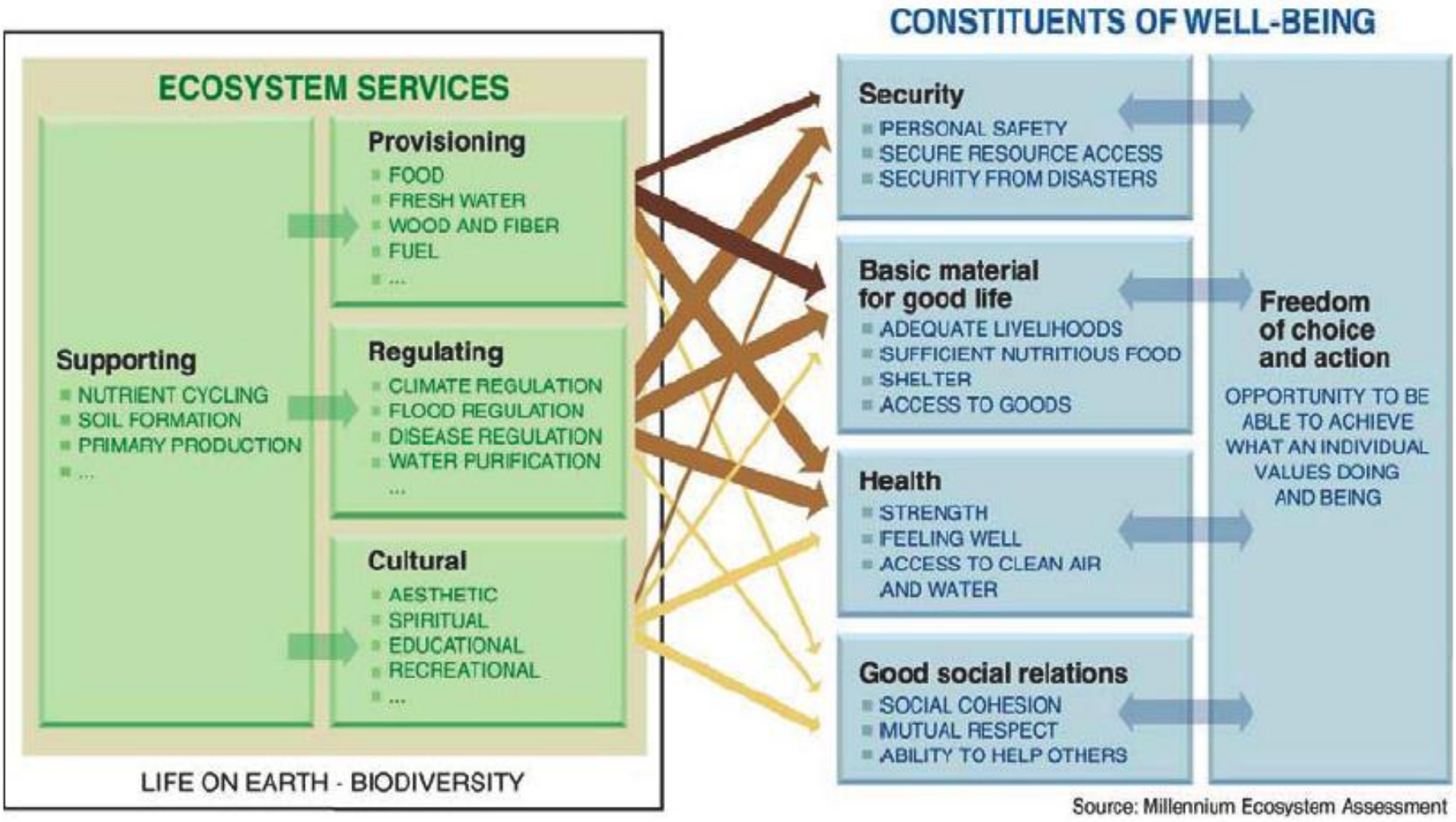

1997




2004

# The Millennium Ecosystem Assessment

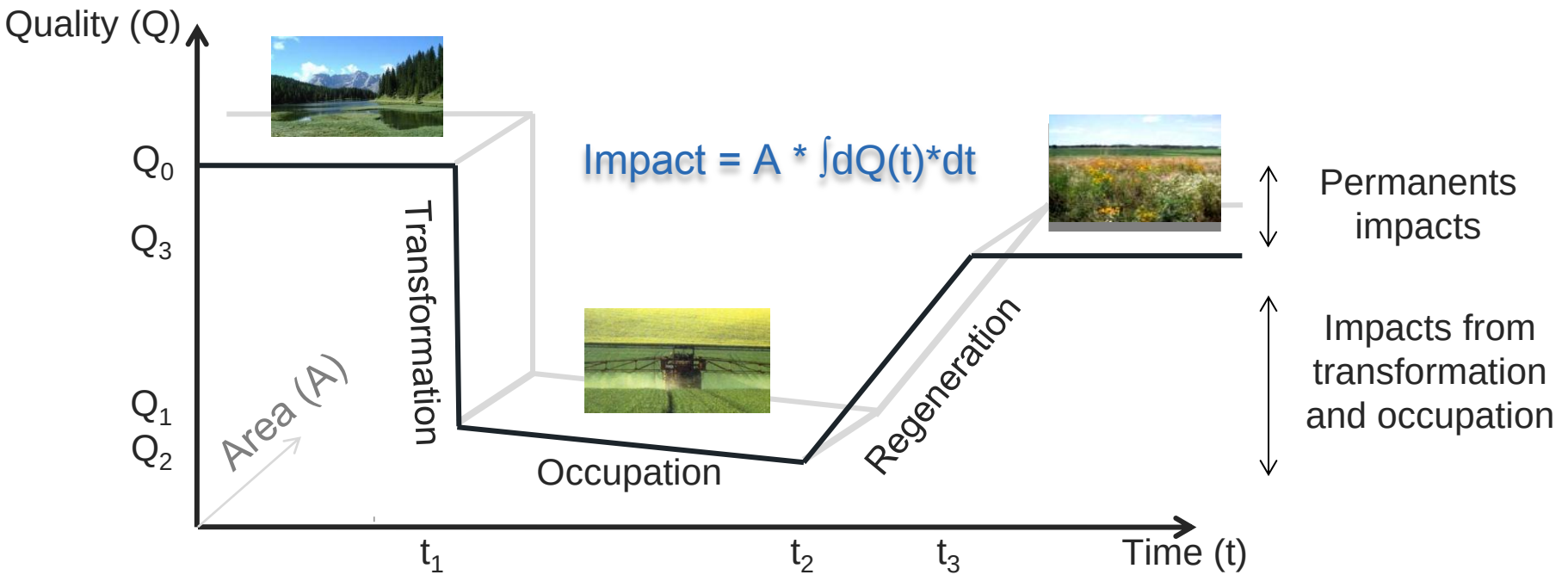
NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE




Source: Millennium Ecosystem Assessment

# Key-elements: assessment based on a quality curve

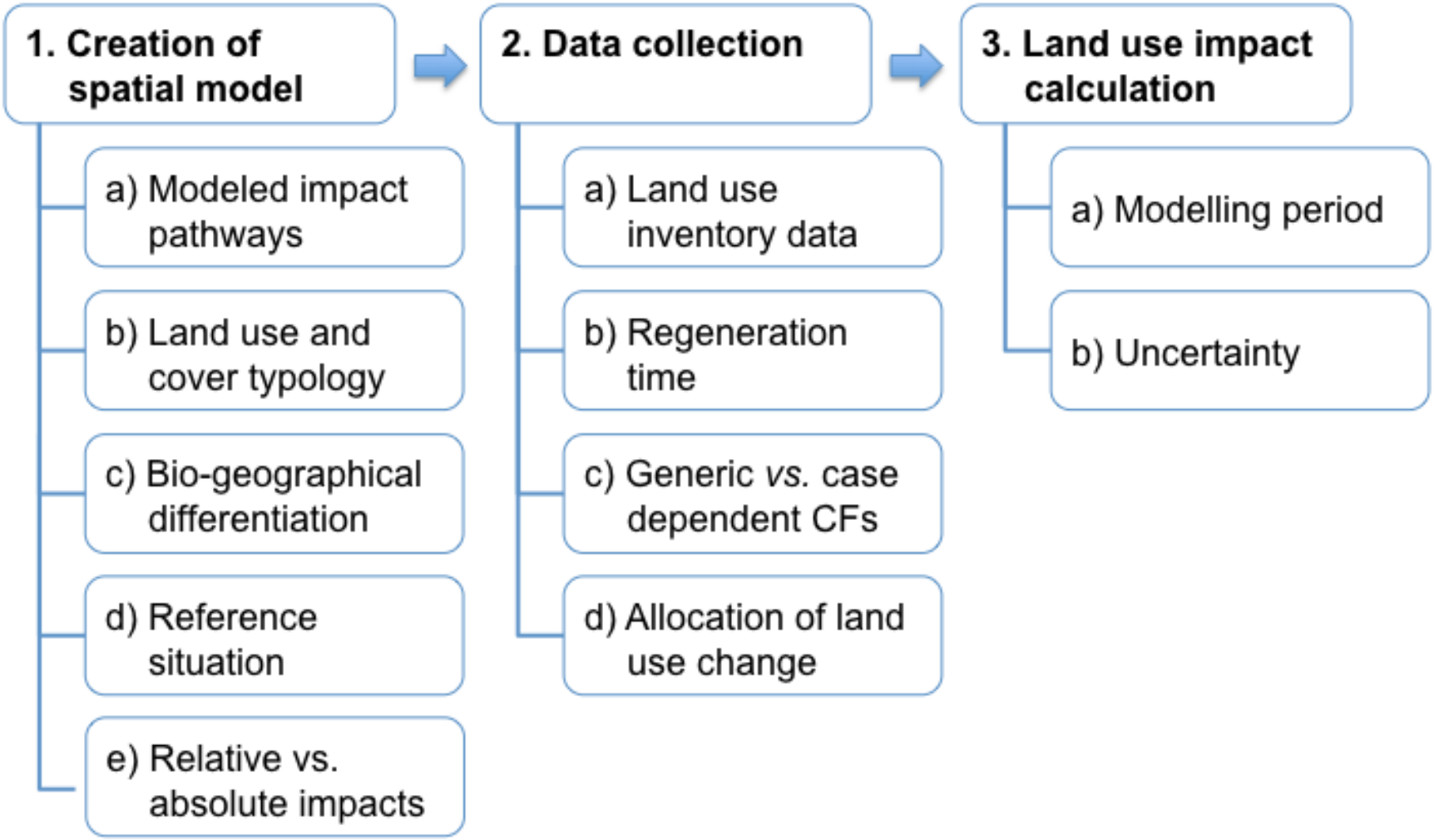
- Transformation: change of a land area to meet the requirement of a new type of occupation
- Occupation: use of a land for anthropogenic purpose



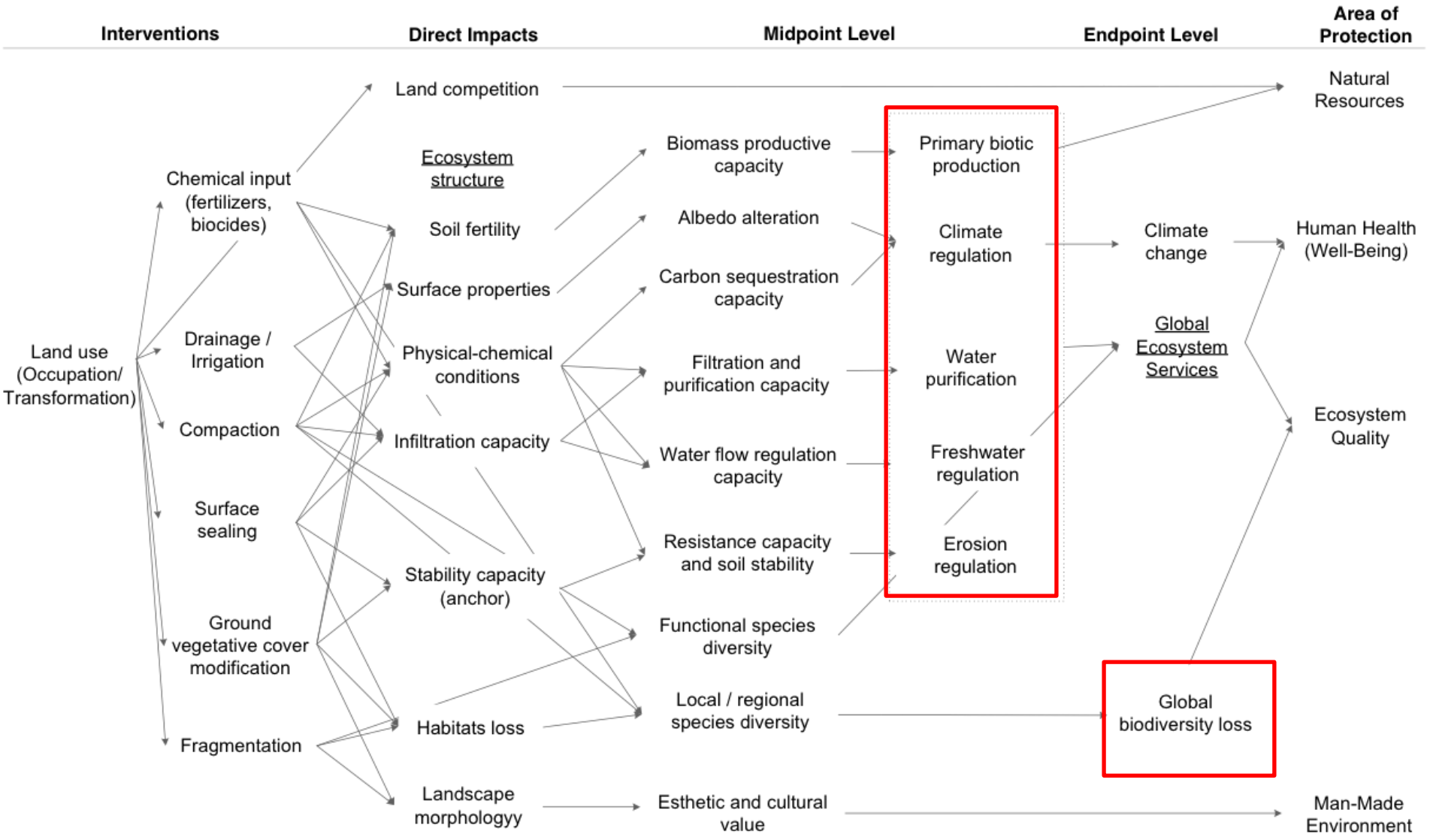

*Curve adapted from Milà i Canals et al. (2007)*

# OUTCOME AND RESULTS

# Recommendation for several key-elements (LCA practitioner / developer)



# Impact assessment: Cause - effect chain




*Cause – effect chain adapted from Saad (2010) and Lindeijer et al. (2002)*

# Indicators adopted

| Life Cycle Impact Category | Description | Early methodologies | Consolidated CFs on a global scale | Indicators |
|---|---|---|---|---|
| Biodiversity Damage Potential (BDP)[a] | Impacts on biodiversity | | | |
| 1) Species diversity (SD) | Capacity of ecosystems to support global species diversity | (Goedkoop et al. 2009) | (de Baan et al. 2013) | Species diversity lost per area for a specific land cover relative to reference land cover [%] |
| 2) Functional diversity (FD) | Capacity of ecosystems to support functional diversity | – | (Souza et al. 2013) | Functional diversity lost per area for a specific land cover relative to reference land cover [%] |
| Ecosystem Services Damage Potential (ESDP)[b] | Impacts on global ecosystem services | | | |
| 1) Biotic Production Potential (BPP) | Capacity of ecosystems to produce biomass | (Baitz et al. 2000; Milà i Canals et al. Milà i Canals 2007b) | (Brandão and Milà i Canals L 2013) | Deficit of Soil Organic Matter (SOM) due to land use [Mg SOM year] |
| 2) Climate Regulation Potential (CRP) | Capacity of ecosystems to uptake carbon from air | – | (Müller-Wenk and Brandão 2010) | Carbon flows [$t$ C/m$^2$ year] change due to land use |
| 3) Freshwater Regulation Potential (FWRP) | a) Capacity of ecosystems to regulate peak flow and base flow of surface water | a) – | a) – | a) Water regulation capacity [dimensionless] |
| | b) Capacity of ecosystems to recharge ground water | b) (Baitz et al. 2000; Milà i Canals et al. 2009) | b) (Saad et al. 2013) | b) Ground water recharge rate [mm/ year] |
| 4) Erosion Regulation Potential (ERP) | Capacity of ecosystems to stabilise soil and to prevent sediment accumulation downstream | (Baitz et al. 2000) | (Saad et al. 2013) | Erosion resistance [ton/ha year] |
| 5) Water Purification Potential (WPP) | Chemical, physical and mechanical capacity of ecosystems to clean a polluted suspension of water | (Baitz et al. 2000) | (Saad et al. 2013) | Cation exchange capacity [$cmol_c/kg_{soil}$] |

Source: Koellner et al. (2013)

# Elementary flow and land-use typology in LC inventories

- Elementary flows:
  - Land occupation : [$m^2$*years], land use type $_i$ and region $_k$
  - Land transformation : [$m^2$], initial land use type $_{i \rightarrow j}$ , region $_k$

- Hierarchical land use classification on global scale:
  - **Level 1** : very general land use and land cover classes (from GLC 2000)
  - **Level 2** : refines level 1 (mainly from ecoinvent v2.0 and GLOBIO3 classification)
  - **Level 3** and **level 4** : mostly specify land management and the intensity of land uses

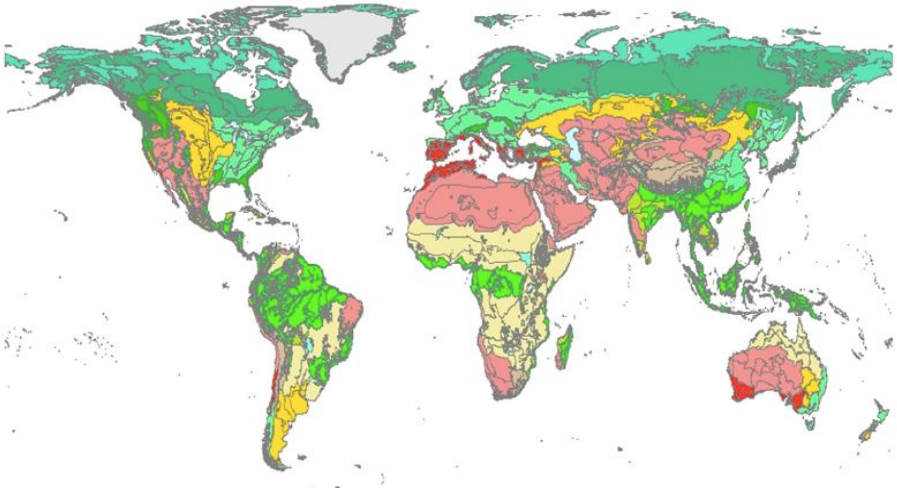
The (*) marks land cover types, which serve as a natural reference.

NEW ZEALAND LIFECYCLE

| ID_use | Land use class | Description |
|---|---|---|
| **0.** | **Unspecfied** | Land use and cover not known. |
| 0.1 | Unspecified, used | Human land use and resulting land cover not known. |
| 0.2 | Unspecified, natural (*) | Natural land cover not known. |
| **1.** | **Forest** [a)] | Areas with tree cover >15%. |
| 1.1 | Forest, natural (*) | Forest not used by humans |
| 1.1.1 | Forest, primary (*) | Forests minimally disturbed by human impact, where flora and fauna species abundance are near pristine. |
| 1.1.2 | Forest, secondary (*) | Areas originally covered with forest or woodlands, where vegetation has been removed, forest is re-growing and is no longer in use. |
| 1.2 | Forest, used | Forests used by humans |
| 1.2.1 | Forest, extensive | Forests with extractive use and associated disturbance like hunting, and selective logging, where timber extraction is followed by re-growth including at least three naturally occurring tree species. |
| 1.2.2 | Forest, intensive | Forests with extractive use, with either even-aged stands and clear-cut patches, or less than three naturally occurring species at planting/seeding. |

| ID_use | Land use class | Description |
|---|---|---|
| **5.** | **Agriculture** [f)] | Areas used for crop production. |
| 5.1 | Arable | Cultivated areas regularly ploughed and generally under a rotation system. Cereals, legumes, fodder crops, and root crops. Includes flower and tree (nurseries) cultivation and vegetables as well as aromatic, medicinal and culinary plants. Excludes permanent pastures. |
| 5.1.1 | Arable, fallow | Cropland temporarily not used (< 2 years). |
| 5.1.2 | Arable, non-irrigated | Annual crop production based on natural precipitation (rainfed agriculture). |
| 5.1.2.1 | Arable, non-irrigated, extensive | + Use of chemical-synthetic and organic fertilizer as well as pesticides is reduced. |
| 5.1.2.2 | Arable, non-irrigated, intensive | + Chemical-synthetic and organic fertilizer as well as pesticides are applied. |

# Regionalization in LC inventories




- Hierarchical regionalization on global scale :
  - **Level 1**: Differentiation between terrestrial biomes, freshwater biomes, coastal water and shelf/deep sea biomes
  - **Level 2**: Climatic regions ((sub)tropical, temperate, boreal, polar)
  - **Level 3**: Terrestrial and freshwater biomes (n=16), marine biomes (n=3)
  - **Level 4**: Olson terrestrial and freshwater ecoregions (n=867 and n=238 priority regions)
  - **Level 5**: Exact geo-referenced information of land use

# Cross tabulation: land use types and regions

- To account for a spatial differentiated impact analysis :
  - Zoning by ecological units using level 1 to 5 of hierarchical regionalization
  - Land use types classification (Level 1 to 4) used in Ecoinvent

| | Polar | Subpolar | Boreal | Cool temperate | Warm temperate | Subtropical dry | Subtropical wet | Tropical dry | Tropical wet |
|---|---|---|---|---|---|---|---|---|---|
| **1 Forest** | | | | | | | | | |
| 1.1 Forest, natural | . | | | | | | | . | . |
| 1.2.1 Forest, extensive | | . | . | . | | . | | | |
| 1.2.2 Forest, intensive | . | | | | | . | | | . |
| **2 Wetlands** | | | . | | . | . | | . | |
| **3 Shrub land** | | . | | | | | | | |
| **4 Grassland** | | | | | | | | | |
| 4.1 Grassland | | | . | | | | | | . |
| 4.2 Pasture/meadow | . | | | | . | . | . | . | |
| **5 Agriculture** | | . | | | | | | | |
| 5.1.1 Arable, fallow | | | . | | . | | | | . |
| 5.1.2 Arable, non-irrigated | | | . | | | . | | | . |
| … | | | | | | | | | |
| 5.2.2.2 Permanent crops, irrigated, intensive | . | . | | | . | | | | |
| 7 Artificial areas | | . | . | | | . | . | | . |
| 7.1.2 Urban, continuously built | . | | | . | | | | | |
| 7.6 Traffic area | | . | | | | | | | |

# Cross tabulation: land use types and regions

- To account for a spatial differentiated impact analysis :
  - Zoning by ecological units using level 1 to 5 of hierarchical regionalization
  - Land use types classification (Level 1 to 4) used in Ecoinvent

- Advantages :
  - Specific inventory versus cost
  - Management of input data and coping with spatial variability
  - Processing significant amounts of data (GIS software)
  - Defining an appropriate spatial resolution scale for background and foreground systems in LC inventories

# Assessment of actual land use against reference in the region

Land use in the product system

Natural situation as reference

# CONCLUDING REMARKS

# Concluding remarks

- Comprehensive framework suggesting relevant land use impact pathways
- Operational characterization factors for a worldwide application
- Guidance for the developers of regionalized impact assessment method:
  - To choose the appropriate level of sophistication and resolution
  - To adapt the method to a specific national / regional context
- Influence of value choices made explicit (reference situation, regeneration time, modeling period, etc.)
- Further aggregation to archetypical situation of land use types x region,
  - e.g., land transformation from forest to cropland in mountainous regions
- The challenge of details v/s practicality and the effort in data collection:
  - For foreground systems land use/location might be known in detail
  - For the background system land use/location might be partly known or unknown
- Application in industry needed

# Special issue in the International Journal of LCA

Global Land Use Impacts on Biodiversity and Ecosystem Services in LCA within the framework of the UNEP/SETAC Life Cycle Initiative

- Editors: Koellner, T. and Geyer, R.

- Part A: Foundations in land use impact assessment and inventories
- Part B: Modelling Characterization Factors for Biodiversity
- Part C: Modelling Characterization Factors for Ecosystem Services
- Part D: Application to Case Studies

# Papers of the special issue

**Part A: Foundations**

1. Koellner T, L de Baan, T Beck, M Brandão, B Civit, M Margni, L Milà i Canals, R Saad, D Maia de Souza and R Müller-Wenk (2013): UNEP-SETAC Guideline on Global Land Use Impact Assessment on Biodiversity and Ecosystem Services in LCA. Int J LCA.
2. Koellner T, L de Baan, T Beck, M Brandão, B Civit, M Goedkoop, M Margni, L Milà i Canals, R Müller-Wenk, B Weidema and B Wittstock (2013): Principles for Life Cycle Inventories of land use on a global scale. Int J LCA.

**Part B: Modelling Characterization Factors for Biodiversity**

3. de Baan L, R Alkemade and T Koellner (2013): Land use impacts on biodiversity in LCA: a global approach. Int J LCA.
4. Maia de Souza D, D Flynn, R Rosenbaum and T Koellner (2013): Land use impacts on functional species diversity: proposal of characterization factors to assess effects on ecosystem processes. Int J LCA.

**Part C: Modelling Characterization Factors for Ecosystem Services**

5. Brandão M, L Milà i Canals (2013) Global characterisation factors to assess land use impacts on biotic production. Int J LCA DOI:10.1007/s11367-012-0381-3
6. * Müller-Wenk R and M Brandão (2011): Climatic impact of land use in LCA—carbon transfers between vegetation/soil and air. Int J LCA 15: 172-182.
7. Bos U, T Beck, J P Lindner and B Wittstock (2013): Land use impact assessment of ecosystem services according to LANCA. Int J LCA.
8. Saad R, T Koellner and M Margni (2013): Land use impacts on freshwater regulation, erosion regulation and water purification: a spatial approach for a global scale level. Int J LCA.

**Part D: Application to Case Studies**

9. Milà i Canals L, G Rigarlsford G, S Sim (2013) Land use impact assessment of Margarine. Int J LCA DOI:10.1007/s11367-012-0380-4

# Global Characterisation Factors to Assess Land Use Impacts on Biotic Production

Miguel Brandão, Llorenç Milà i Canals

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

Life Cycle Initiative

# Contents

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **Context: modelled impact pathway**
- **Indicators for Biotic Production Potential**
- **Data sources for land uses and bio-geographical coverage**
  - Reference situation
- **LCI data**
- **Needs for further research**

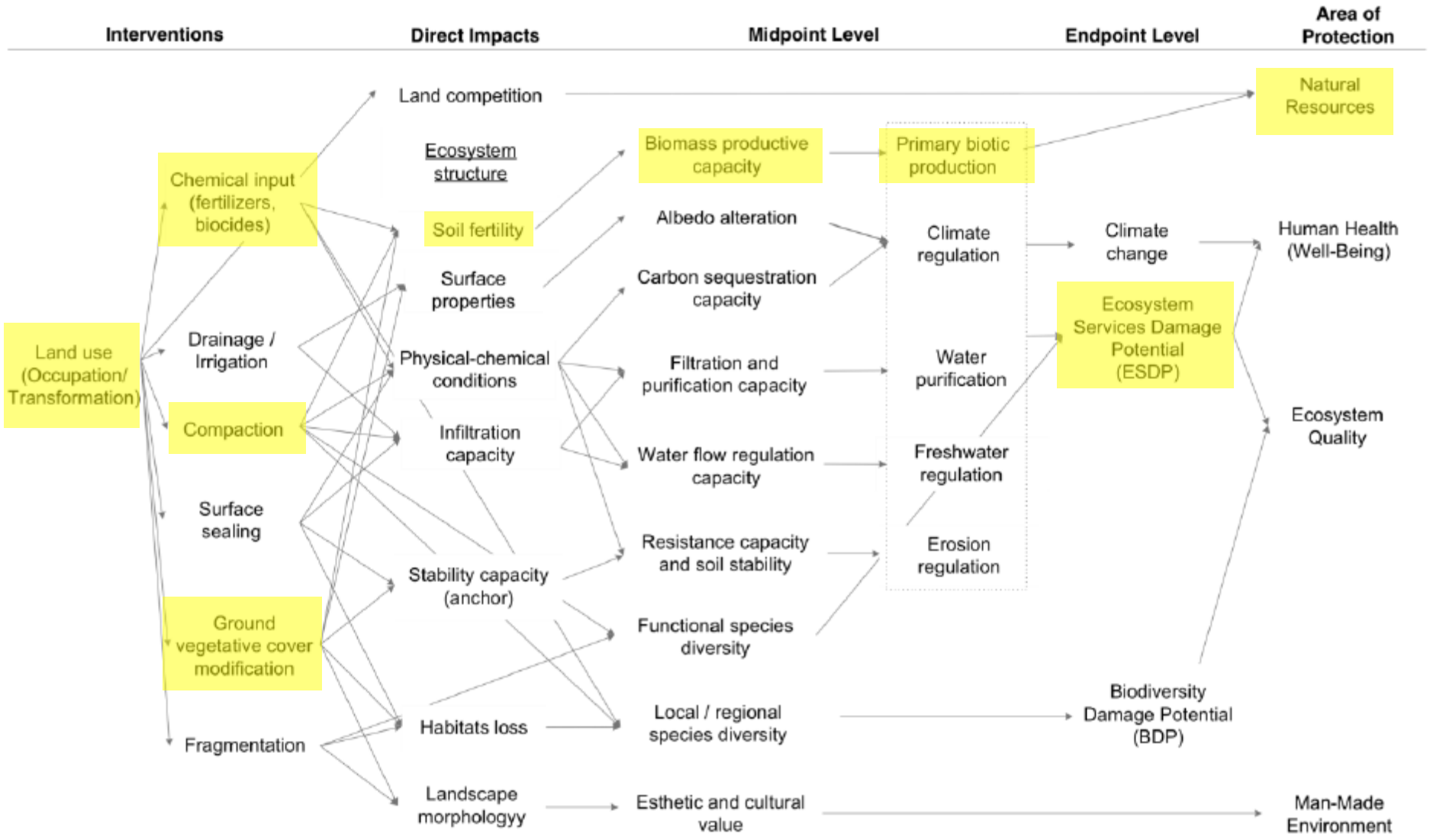
# Objective

- **To provide operational characterisation factors (CF) to assess impacts on Biotic Production Potential (BPP) in LCA:**

- **Global Coverage**
- **Spatial differentiation (biomes; climate zones)**
- **Relevant for different land use types / life cycle stages**
  - i.e. including bio-productive (agriculture, forestry…) and non-bio-productive (road, mine…) uses

# Biotic Production Potential, BPP

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE



# Indicators for BPP

- **BPP refers to the conditions of land that determine its short, medium and long-term inherent ability to produce and sustain biomass**
- **Review of indicators for BPP**

| Indicator | Reference |
|---|---|
| Back-up technology (endpoint) | Stewart and Weidema (2005) |
| Net Primary Production, NPP | Weidema and Lindeijer (2001) |
| Human Appropriation of Ecosystem Carbon Stock, HAPECS | Brandão *et al*. (2010) |
| Erosion | Cowell and Clift (2000) |
| Salinisation | Feitz and Lundie (2002) |
| Energy/exergy | Wagendorp *et al*. (2006) |
| Microbial biomass and diversity | Peixoto *et al*. (2006) |
| Soil organic carbon, SOC | Milà i Canals *et al*. (2007) |

# SOC as indicator for BPP

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **Soil Organic Carbon (SOC) is a robust, stand-alone indicator for BPP**
  - Also recommended in ILCD (European Commission 2010)
- **Data are increasingly available, e.g. through IPCC (2006)**
  - SOC in different soil types and land uses in world climate zones
  - Effects from land management on SOC
- **Reference situation: SOC present in (quasi-)natural land cover predominant in global biomes and ecoregions**
- **Impact measured as "Carbon deficit" (or credit) [kg C year]**

# Some SOC values (tonnes C $ha^{-1}$ in 0-30 cm depth)

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

| CLIMATE REGION | AREA ($km^2$) | Relative (%) | Permanent Grassland | Long-term Cultivated | Native Ecosystem | Set-Aside | Paddy Rice |
|---|---|---|---|---|---|---|---|
| Tropical Dry | 30,553,142 | 22.8 | 36.4 | 37.1 | 37.2 | 36.4 | 38.7 |
| Tropical Montane | 7,351,295 | 5.5 | 65.0 | 76.3 | 70.9 | 72.7 | 74.8 |
| Warm Temperate Moist | 5,528,026 | 4.1 | 79.2 | 81.4 | 78.0 | 77.4 | 80.9 |
| Warm Temperate Dry | 12,631,558 | 9.4 | 36.9 | 38.1 | 37.2 | 37.5 | 37.7 |
| Cool Temperate Moist | 11,808,612 | 8.8 | 91.3 | 94.3 | 95.0 | 96.0 | 96.6 |
| Cool Temperate Dry | 12,221,975 | 9.1 | 49.1 | 51.4 | 49.2 | 50.3 | 50.3 |
| Boreal Moist | 13,770,293 | 10.3 | 84.1 | 70.9 | 85.1 | 73.8 | 66.1 |
| Boreal Dry | 3,808,837 | 2.8 | 74.9 | 72.7 | 81.8 | 74.1 | 71.8 |
| Polar Moist | 7,565,826 | 5.6 | 42.7 | 36.4 | 46.4 | 36.6 | 25.5 |
| Polar Dry | 1,975,716 | 1.5 | 47.5 | 45.8 | 53.5 | 46.6 | 45.2 |
| **Total (without Antarctica)** | **134,075,489** | **100.0** | | | | | |

Source: extrapolated from IPCC 2006

# Calculating CF for BPP

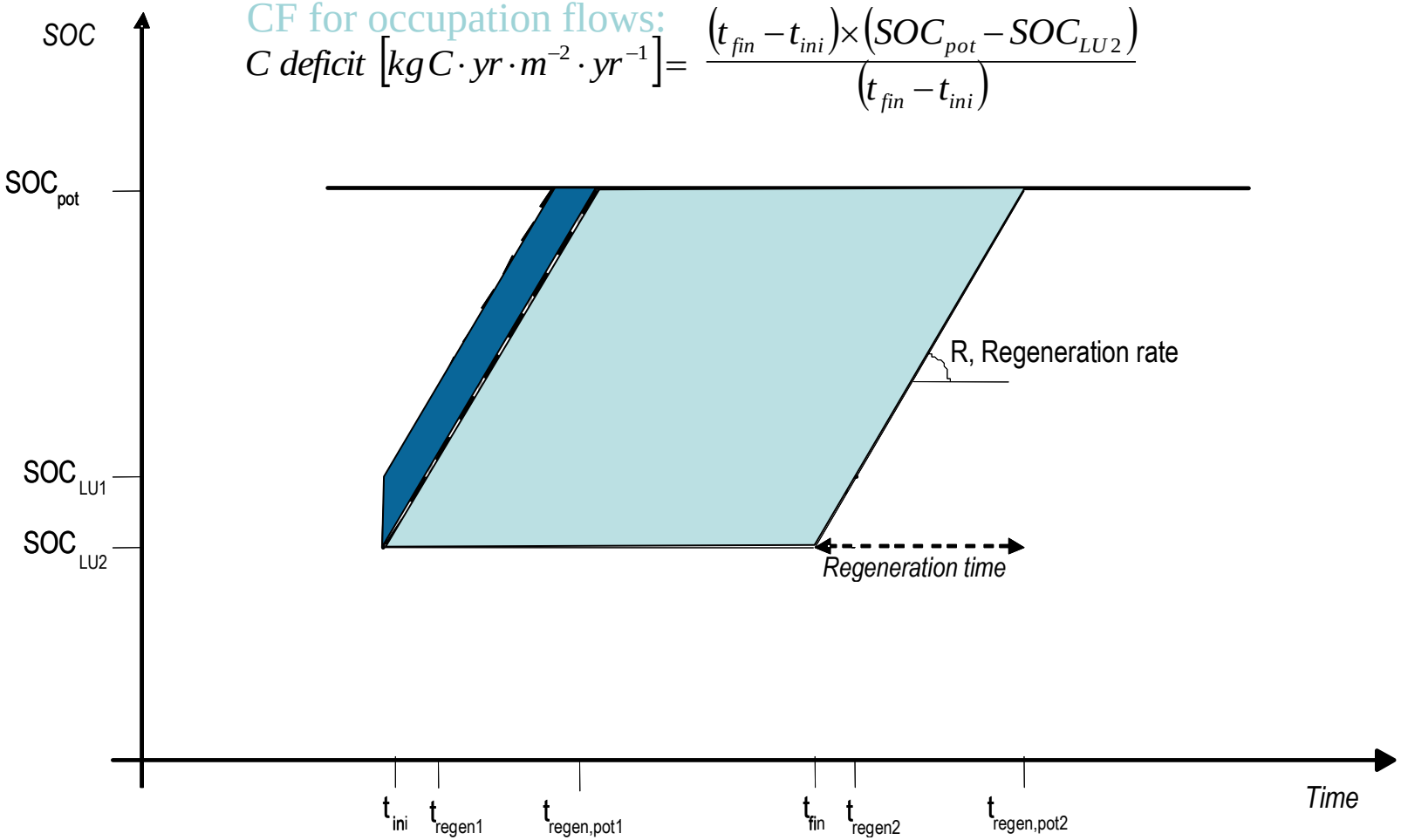
NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

CF for transformation flows:

$$C\ deficit\ \left[kg\,C\cdot yr\cdot m^{-2}\right]=\left(SOC_{pot}-SOC_{LU1}\right)\times\left(t_{regen1}-t_{ini}\right)+\frac{1}{2}\left(t_{regen1}-t_{ini}\right)\times\left(SOC_{LU1}-SOC_{LU2}\right)$$

CF for occupation flows:

$$C\ deficit\ \left[kg\,C\cdot yr\cdot m^{-2}\cdot yr^{-1}\right]=\frac{\left(t_{fin}-t_{ini}\right)\times\left(SOC_{pot}-SOC_{LU2}\right)}{\left(t_{fin}-t_{ini}\right)}$$



# LCI data to make this work

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **Amount of occupation / transformation (i.e. including duration of use for occupation)**
- **Type of land use (agriculture, arable; grassland…)**
- **Location: climatic region / biome**
- **For study-specific CF:**
  - SOC change due to occupation or transformation
  - Regeneration times for transformation

# Assumptions, uncertainty

- **Regeneration time assumed to be always shorter than modelling time (500 years)**
  - IPCC suggests new steady state reached in 20 years (agricultural / forestry land uses)
  - For artificial land uses, regeneration times based on Lindeijer *et al*. (1998)
  - For certain LUC (e.g. removal of topsoil) regeneration time > 500 years might have to be considered

- **Uncertainty: provided by IPCC 2006 on their land use and management factors (± 10-90%)**

# Applications

- **SOC has been used as indicator for BPP / soil quality in several case studies to date (local vs. air-freight vegetables; biofuels; margarine)**
  - Useful in distinguishing very differentiated systems
  - Results strongly influenced by SOC data sources and assumptions such as regeneration time

# Discussion, needs for further research

- **Increasingly abundant data sources for SOC**
  - IPCC: global coverage, consistency
- **Factors for permanent crops not provided yet**
  - Needs for further differentiation?
- **Allocation of transformation is an inventory issue**
  - 20 years vs. consequential vs. average in a country…
- **Regeneration times are very uncertain: cautious interpretation of CF for transformation**
- **Link SOC-BPP needs further testing**

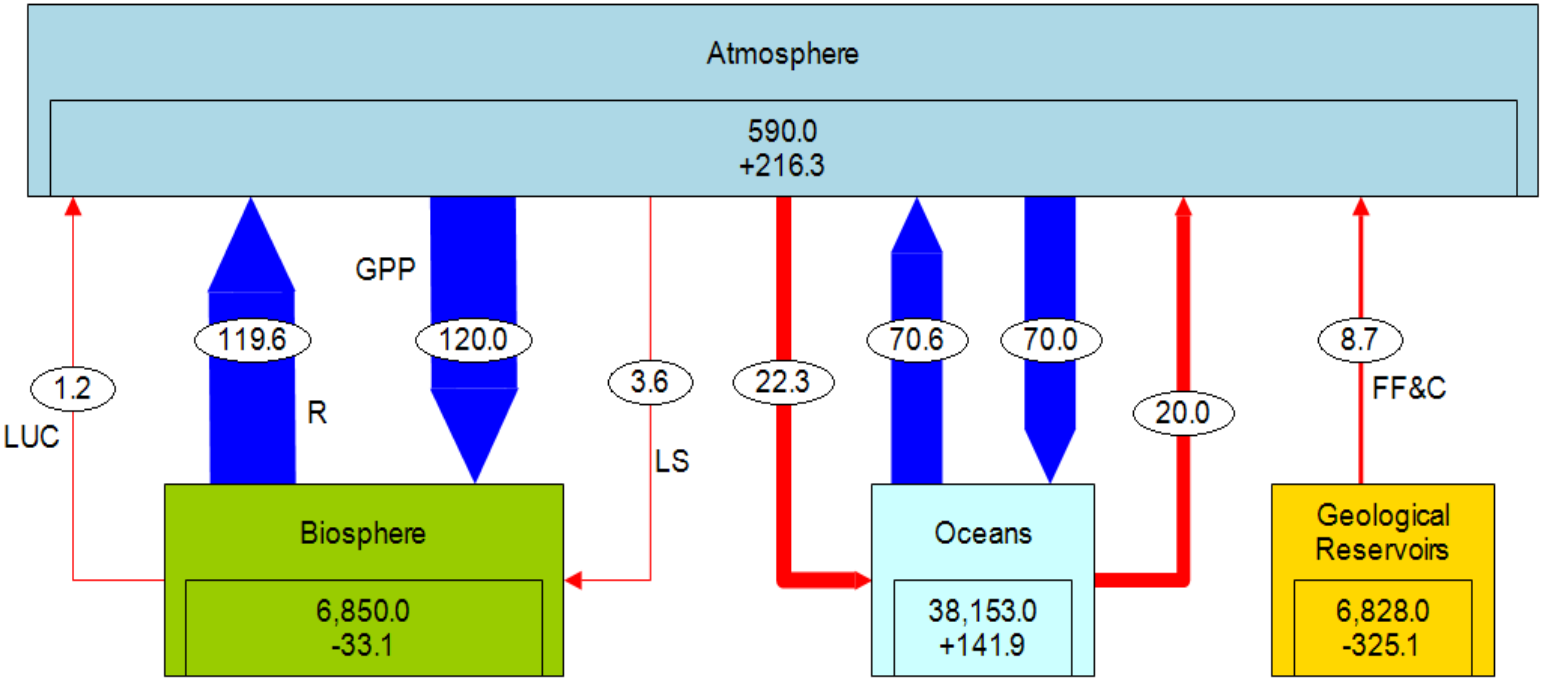
# Impact of land use on climate for use in LCA - carbon cycling between ecosystems and the atmosphere

Miguel Brandão and Ruedi Müller-Wenk

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

# Importance of Land Use in the Global Carbon Cycle

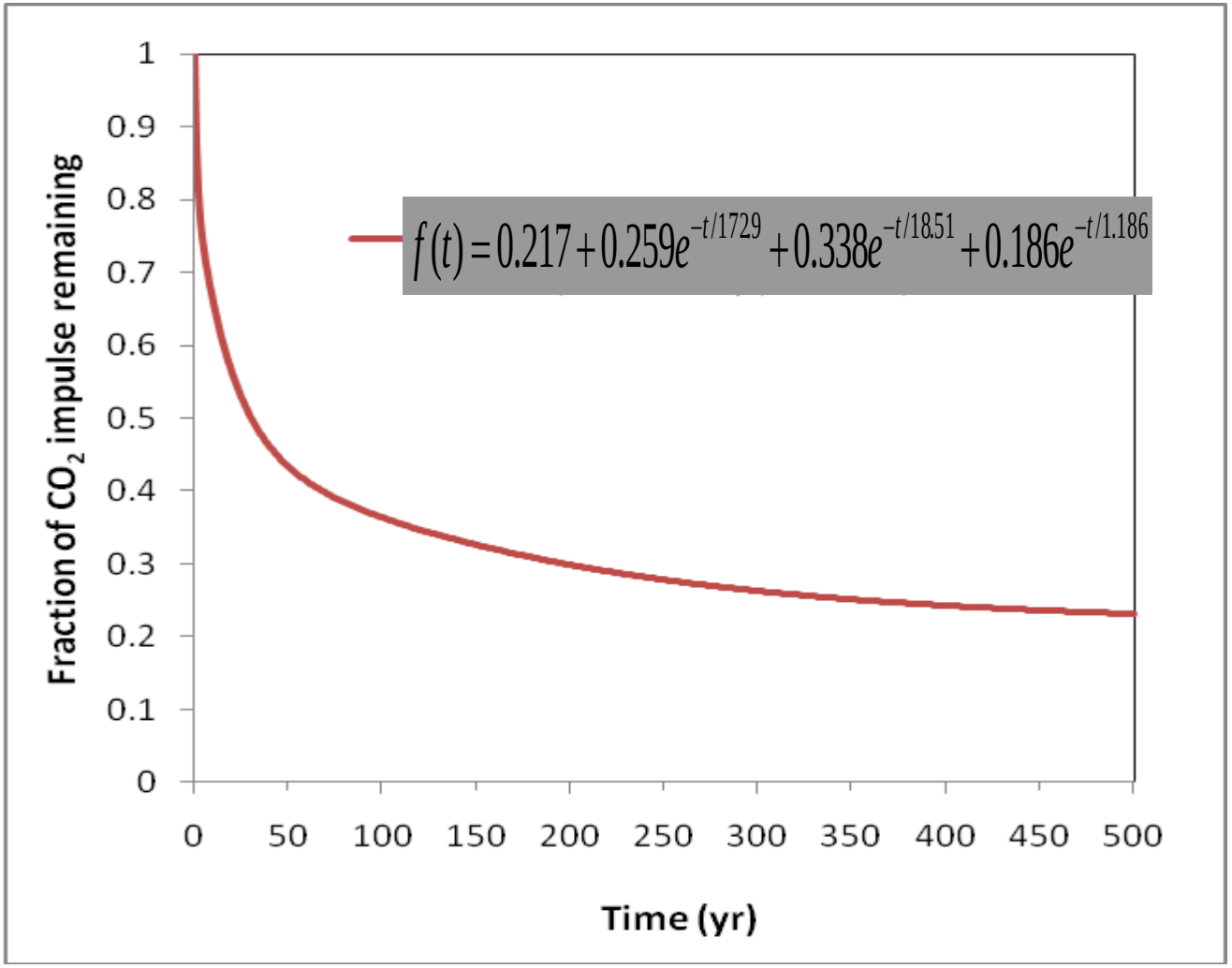
NEW ZEALAND LIFECYCLE CENTRE




Reservoir Stocks in GtC:
Biosphere = Vegetation, Soil & Detritus
Oceans = Surface, Intermediate & Deep Ocean; Marine Biota; and Surface Sediment

Fluxes and Rate Flows in GtC per annum
(pre-industrial 'natural' fluxes in blue and 'anthropogenic' fluxes in red):
LUC = Land Use Change
LS = Land Sink
GPP = Gross Primary Production
R = Respiration and Fires
FF&C = Fossil Fuel & Cement Emissions

# Decay of atmospheric $CO_2$




$$f(t) = a_0 + \sum_{i=1}^{3} a_i \cdot e^{-t/\tau_i}$$

$a_0 = 0.217$

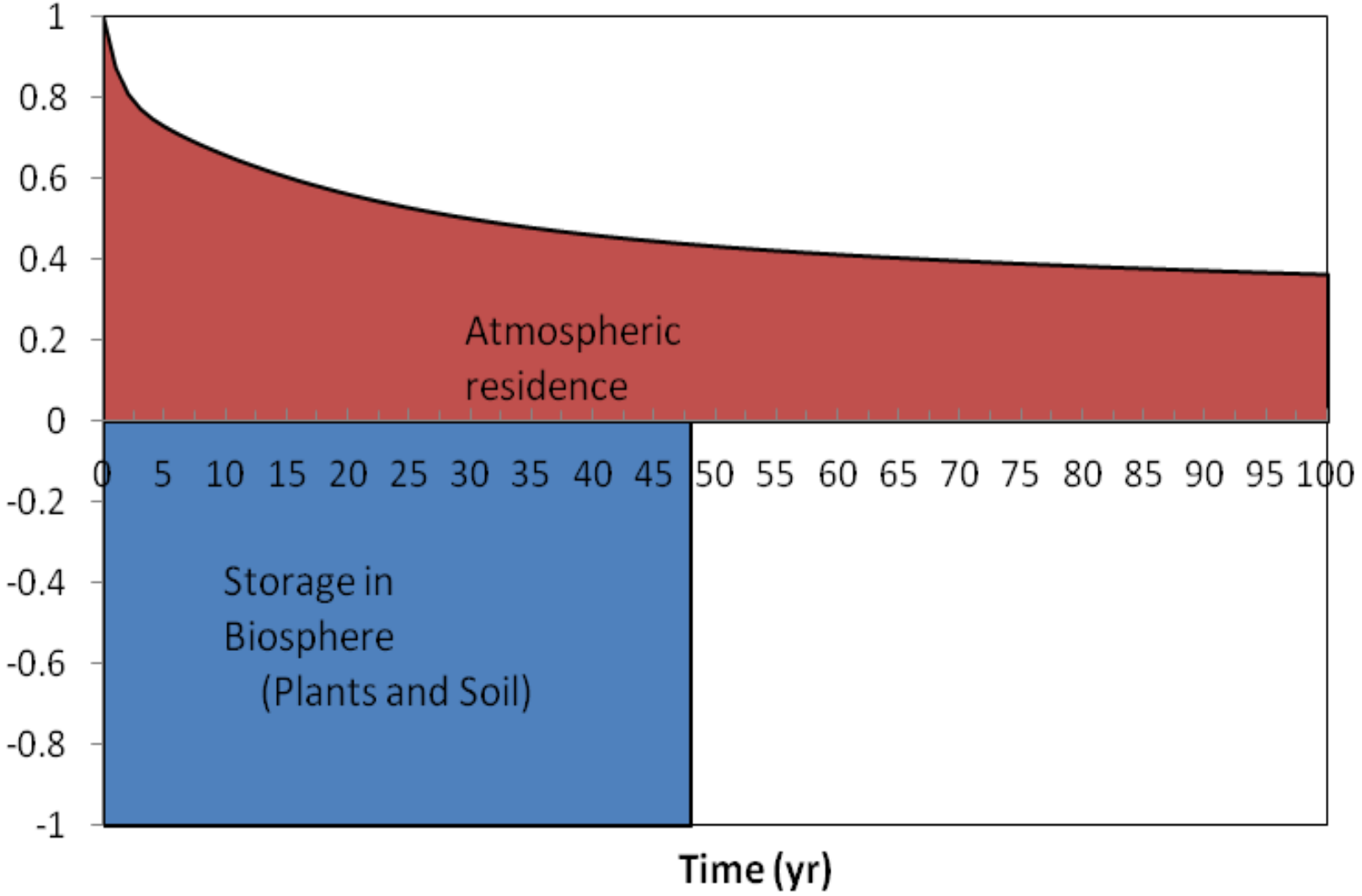
$a_1 = 0.259$ $\quad \tau_1 = 172.9$

$a_2 = 0.338$ $\quad \tau_2 = 18.51$

$a_3 = 0.186$ $\quad \tau_3 = 1.186$

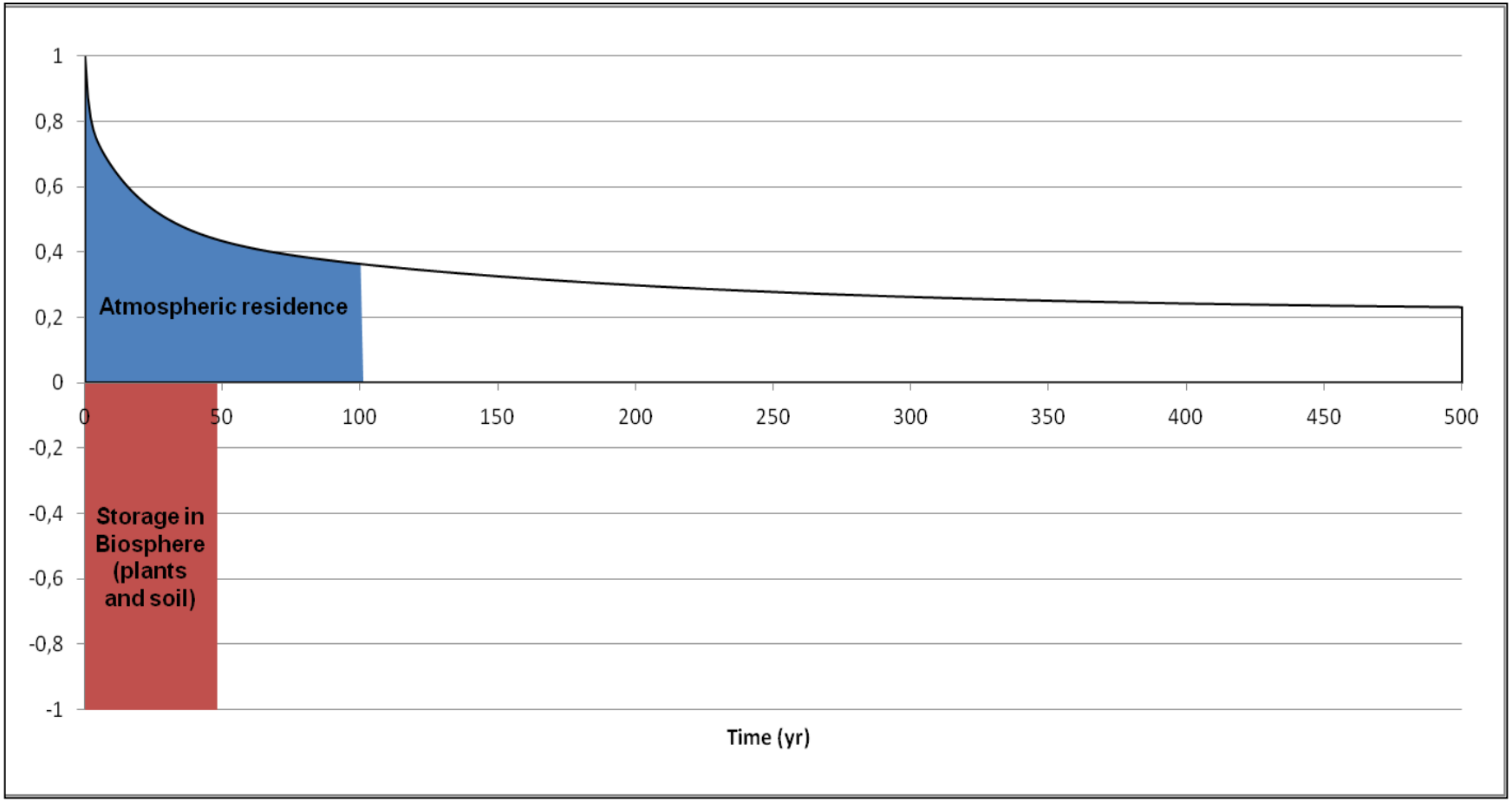
Source: equation from IPCC (2007, p.212)

# Radiative forcing ($W/m^2$), t $CO_2$-eq. and t C*yr



# Radiative forcing ($W/m^2$), t $CO_2$-eq. and t C*yr

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE



# Global Warming Potential: the extended Moura-Costa approach

| | **Global Warming Potential ($CO_2$-eq)** | | |
|---|---|---|---|
| | 20 years | **100 years** | 500 years |
| Carbon Dioxide | 1 | 1 | 1 |
| Methane | 72 | 25 | 7.6 |
| Nitrous Oxide | 289 | 298 | 153 |
| | | | |
| Carbon Dioxide Sequestration (tonne-years) | 1/14.6 = 0.074 | 1/47.8 = 0.021 | 1/157.3 = 0.006 |
| **Carbon tonne-years** | 0.074*44/12= =0.27 | **0.021*44/12= =0.08** | 0.006*44/12= =0.022 |

# Characterisation Factors (tC/ha)

| Biome | Transformation | Occupation (1 year) |
|---|---|---|
| Tropical Forests | 25-55 | 0.77-0.96 |
| Temperate Forests | 24-75 | 0.64-0.86 |
| Boreal Forests | 27-150 | 0.41-0.96 |
| Tropical Grassland | 0-27 | 0-0.37 |
| Temperate Grassland | 0-45 | 0-0.42 |
| Wet Tropical Forests | 39-84 | 1.19-1.48 |
| Dry Tropical Forests | 10-24 | 0.32-0.43 |

# Land Use Impact Assessment of Margarine

Llorenç Milà i Canals, Giles Rigarlsford and Sarah Sim

Special forum on Global Land Use Impacts on Biodiversity and Ecosystem Services in LCA

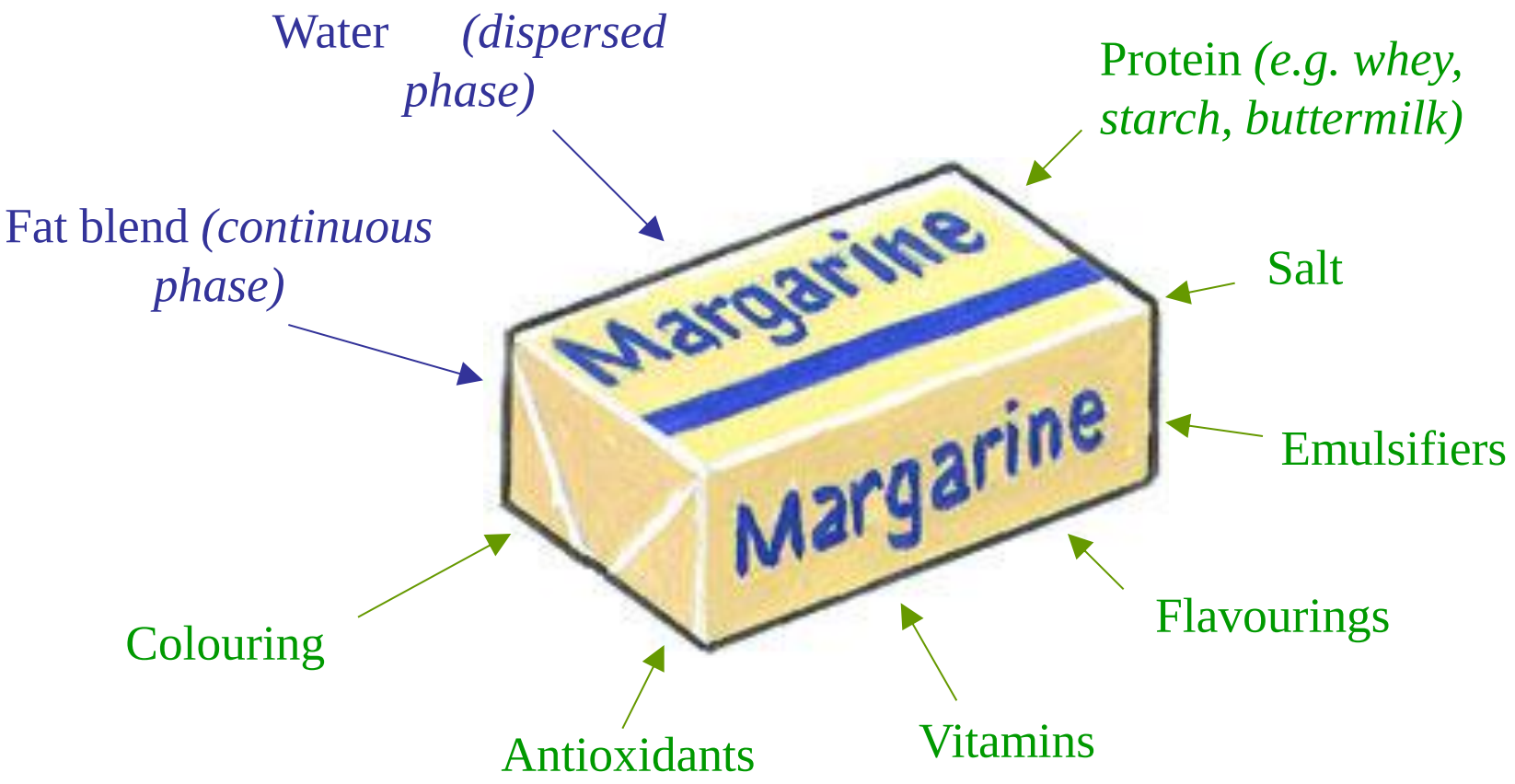
NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

# Contents

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **Context and Goals**
- **The studied margarines**
- **Methods**
  - Linking LCI to LCIA: quantifying LU and LUC; sourcing countries / biomes
- **Results**
- **Discussion**
- **Conclusions**

# What is Margarine?



# Goals

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **Assessment of applicability and relevance of newly developed characterisation factors (CF)**
  - Bio-geographical differentiation
  - Land use classification
- **Margarine is a land-based product (through sourcing of vegetable oils)**
  - Previous studies have addressed common LCA impact categories (Nilsson *et al*. 2010) and also the water footprint of margarine (Jefferies *et al*. 2012)
  - Key hotspots for land use impacts?

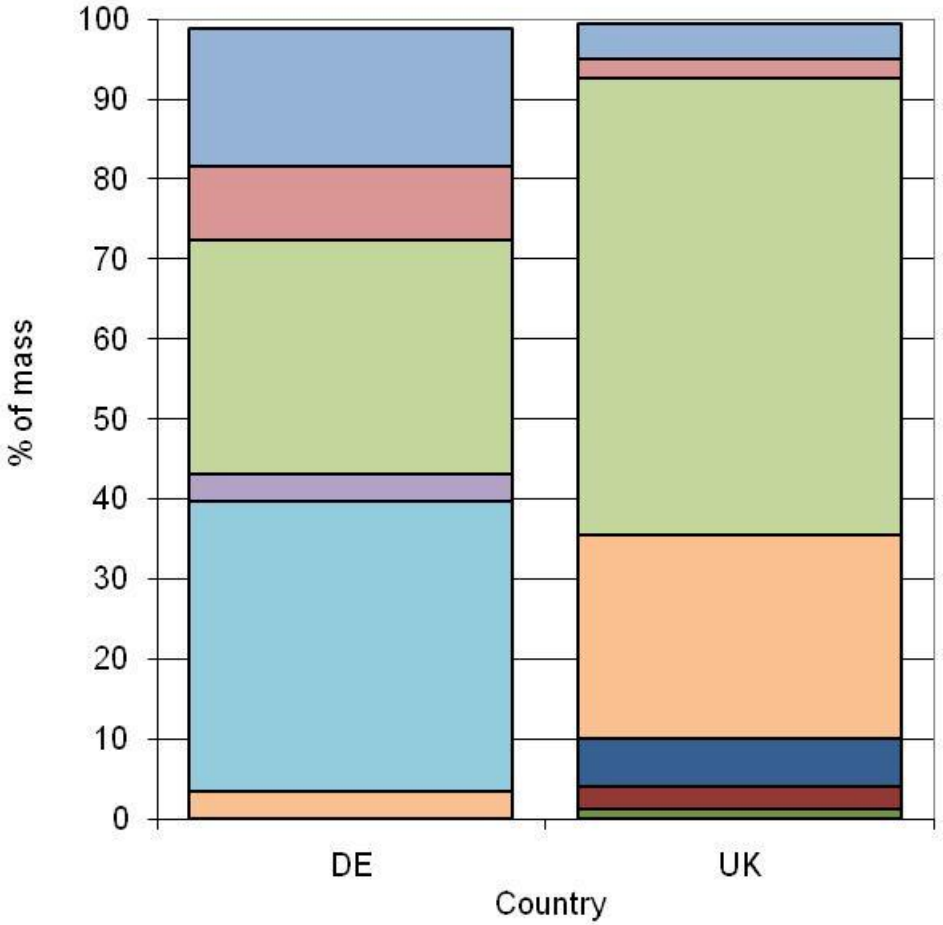
# Margarine products considered
# Functional unit = 500g tub

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE


70% fat


38% fat

- Palm Oil
- Palm Kernel Oil
- Water
- Maize oil
- Rapeseed oil
- Sunflower oil
- Linseed oil
- Tapioca starch
- Salt



# Methods – LCI: sourcing countries

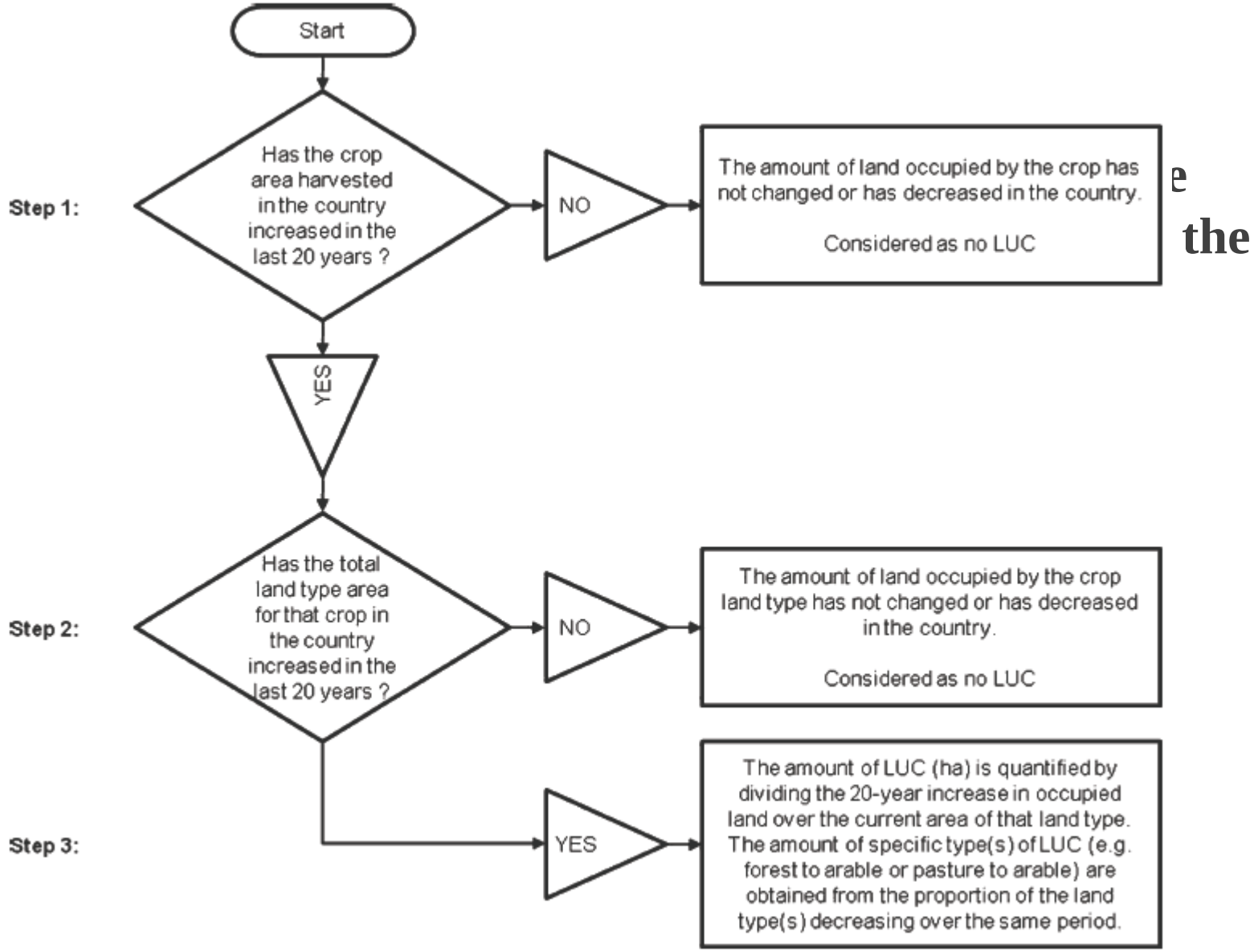
- **Sourcing country is variable and not always known (commodity markets)**
- **Yield is highly variable: this determines occupation (land use, LU)**

| Crop | Source country | Biome |
|---|---|---|
| Sunflower seed | Argentina | Temperate grasslands, savannas and shrublands |
| Sunflower seed | Russian Federation | Boreal forests/taiga and Temperate broadleaf and mixed forest |
| Sunflower seed | Ukraine | Temperate broadleaf and mixed forest |
| Rapeseed | Germany | Temperate broadleaf and mixed forest |
| Oil Palm Fruit | Malaysia | Tropical and subtropical moist broad-leafed forest |
| Linseed | Canada | Boreal forests/taiga |
| Maize (seed) | Germany | Temperate broadleaf and mixed forest |
| Cassava (tapioca, tuber) | Thailand | Tropical and subtropical moist broad-leafed forest |

# Methods – LCI: land transformation (LUC)

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **L**
  **q** **e**
  **s** **the**
  **l**



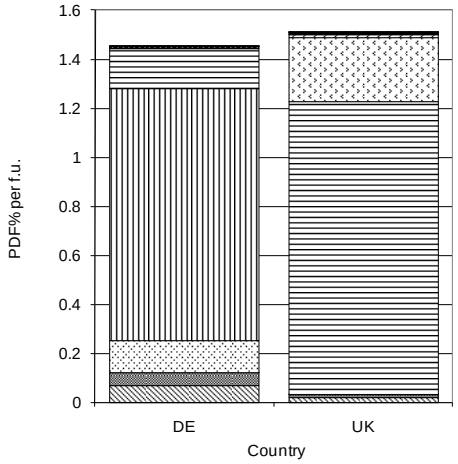
# Methods – LCIA

- **Biodiversity Damage Potential, BDP: de Baan *et al*. (2012)**
- **Climate Regulation Potential, CRP: Müller-Wenk and Brandão (2010)**
- **Biotic Production Potential, BPP: Brandão and Milà i Canals (2012)**
- **Freshwater Regulation Potential (FWRP), Erosion Regulation Potential (ERP), Water Purification Potential-physicochemical filtration (WPP-PCF) and -mechanical filtration (WPP-MF): Saad and Margni (2012)**

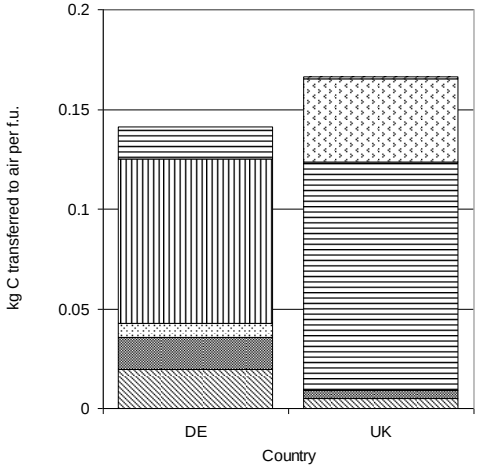
# Results– LCIA

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

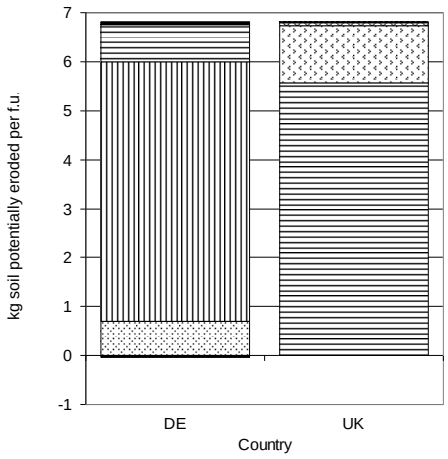
a) BDP (Biodiversity)



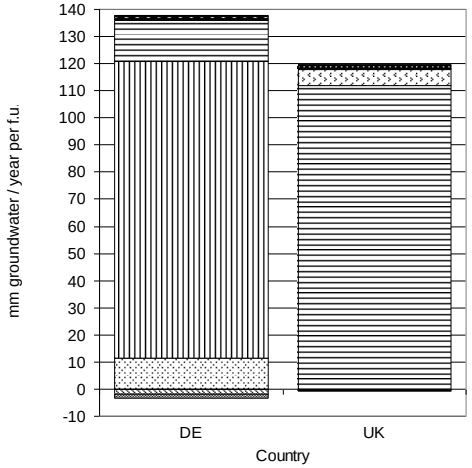

b) CRP (Climate)




c) ERP (Erosion)




d) FWRP (Freshwater)



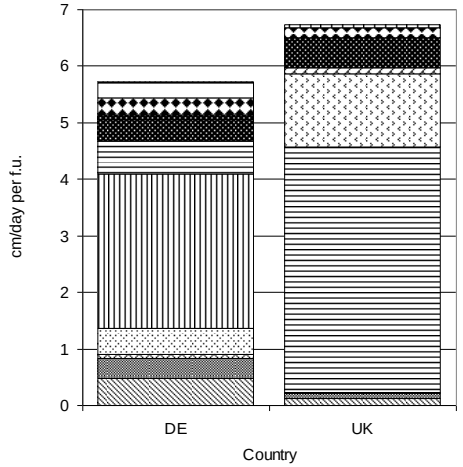

**Legend**

- Palm Oil
- Palm Kernel Oil
- Processing of PO & PKO
- Maize oil
- Rapeseed oil
- Sunflower oil
- Linseed oil
- Tapioca starch
- Salt
- Packaging
- Production
- Distribution
- Disposal

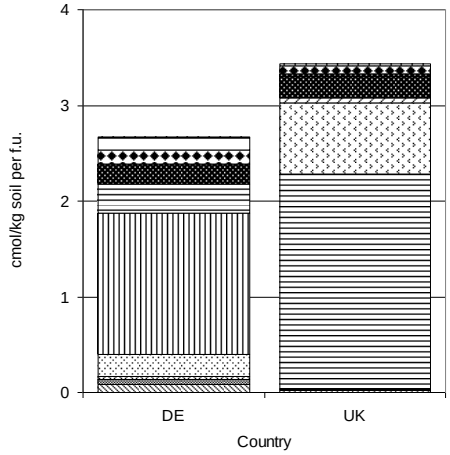
# Results– LCIA

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

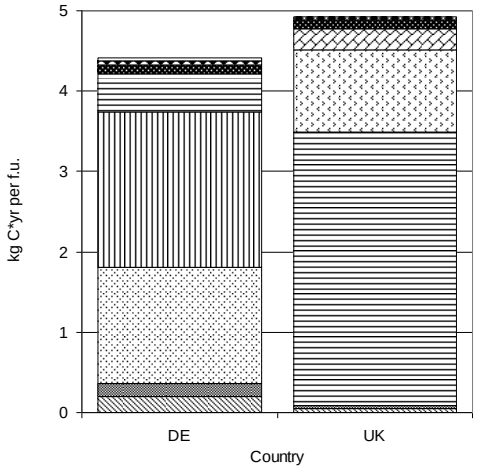
e) WPP-MF



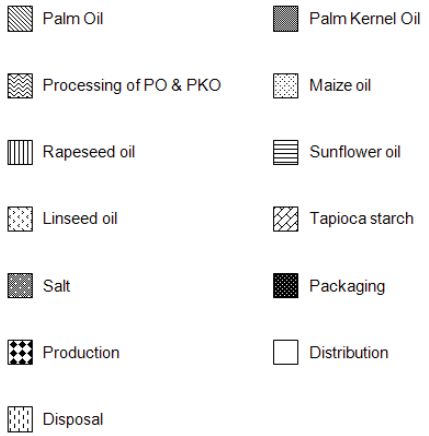

f) WPP-PCF




g) BPP




**Legend**



# Discussion

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **Results**
  - Occupation dominating the impacts
- **Applicability**
  - Sourcing locations for commodities
  - Adaptation of background LCI databases
- **Methodological choices**
  - Significance of reference situation: potential vegetation vs. current land use mix (GLC 2000)

# Conclusions

- **Spatially differentiated, land-use comprehensive, impact assessment is now possible on a life cycle perspective**
  - To be added to other impacts: common LCA; water…
- **Significant work still needed:**
  - LCI databases: to report land occupation (at least) on a regional (biome?) level
  - Land classification proposed is adequate; arable vs. permanent crops need to be distinguished
- **Agreement needed on how to quantify and allocate LUC**
- **Land use impacts in LCA are in its INFANCY:**
  **More case studies required!**
  - Overlap between impact categories?
  - Value of spatial differentiation?
  - Reference: theoretical vs. actual habitat?

# Thank you!
# Questions?

Llorenc.Mila-i-Canals@Unilever.com
www.unilever.com/sustainability
www.sustainable-living.unilever.com

Special forum on Global Land Use Impacts on Biodiversity and Ecosystem Services in LCA
Brussels, 17th February 2012

# Overview

NEW ZEALAND LIFECYCLE MANAGEMENT CENTRE

- **Use of soil indicators by the international LCA community**
- **Update on how impact assessment methods capture soil-related inventory**
- **Update of international frameworks with reference to soil indicators**
- **Steps for ensuring new approaches are consistent with these**

# Questions?

m.brandao@massey.ac.nz

NEW ZEALAND
LIFECYCLE
MANAGEMENT CENTRE