# Soil quality indictors in Life Cycle Assessment

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8 and 9 April 2014

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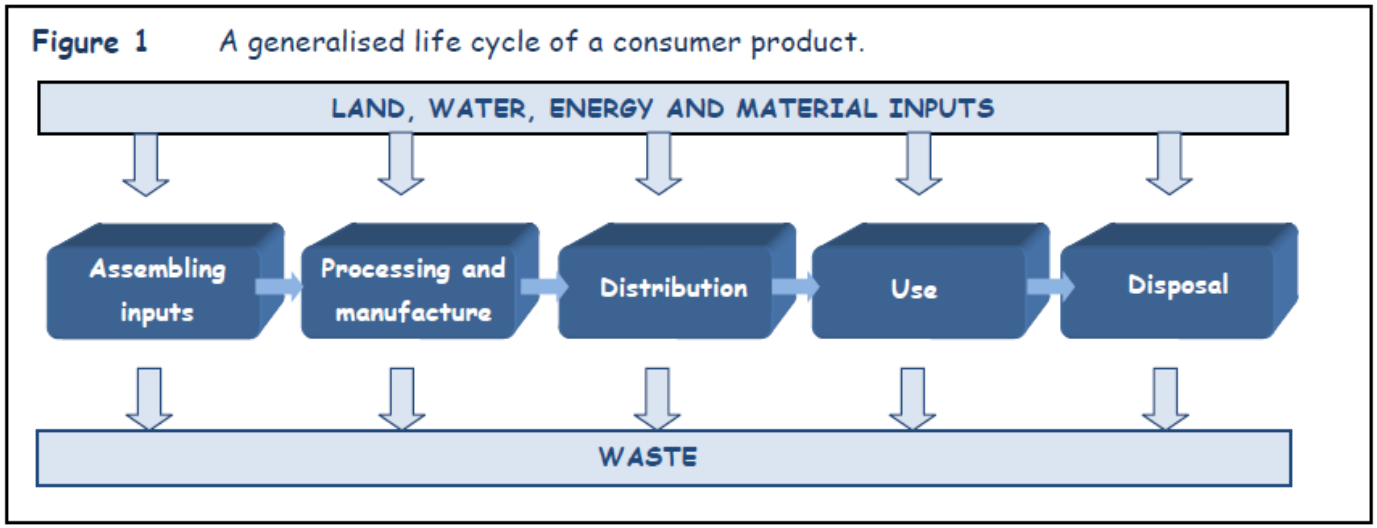
# Setting the scene

- What is an LCA
- Why undertake LCAs
- Life cycle inventory activities to date in Australia

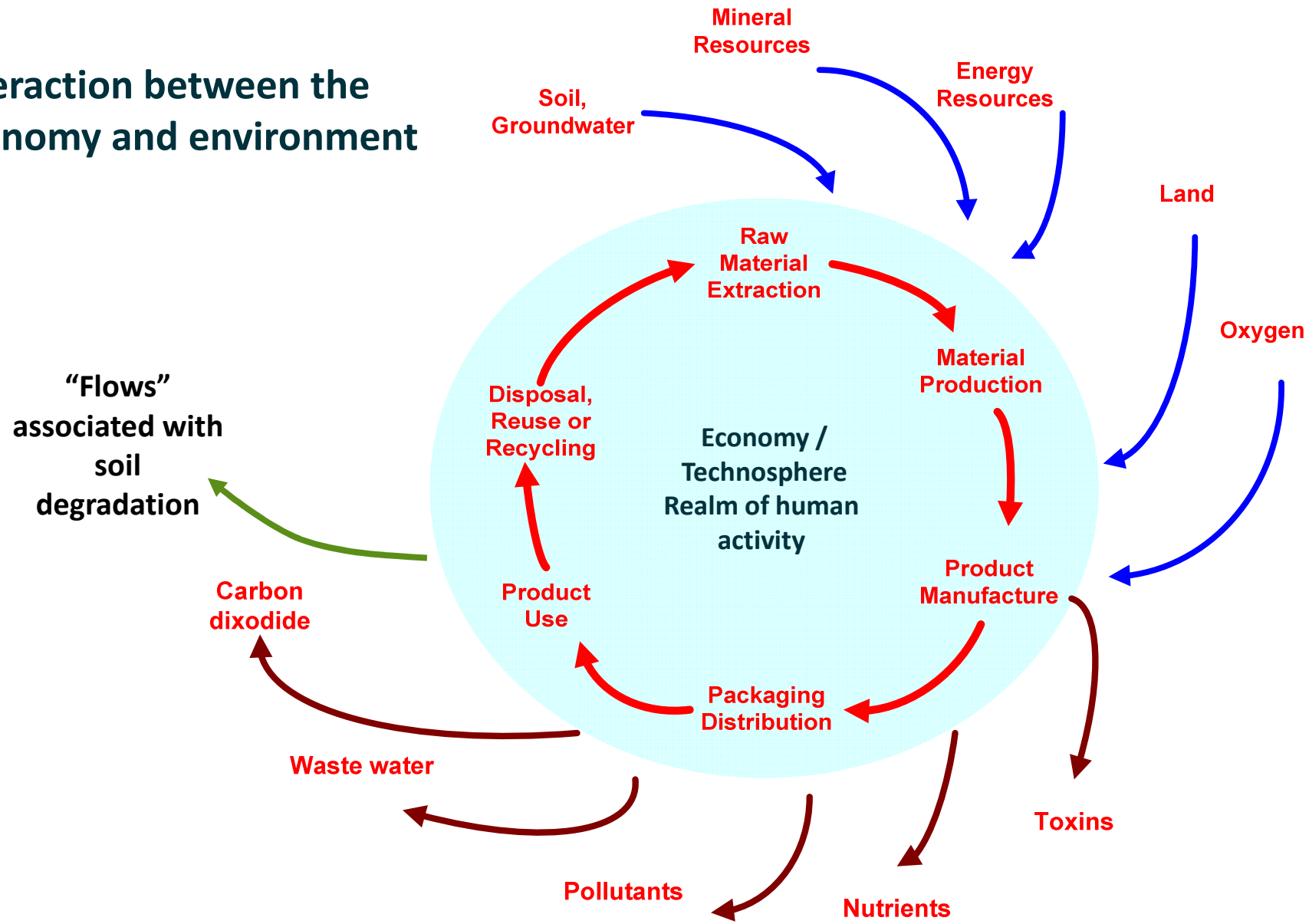
# What is a Life Cycle Assessment?

- LCA is the most commonly used tool to determine the environmental impact that a product or service has, by taking into account all of the impacts from resource extraction, production, use, through to end of life disposal.

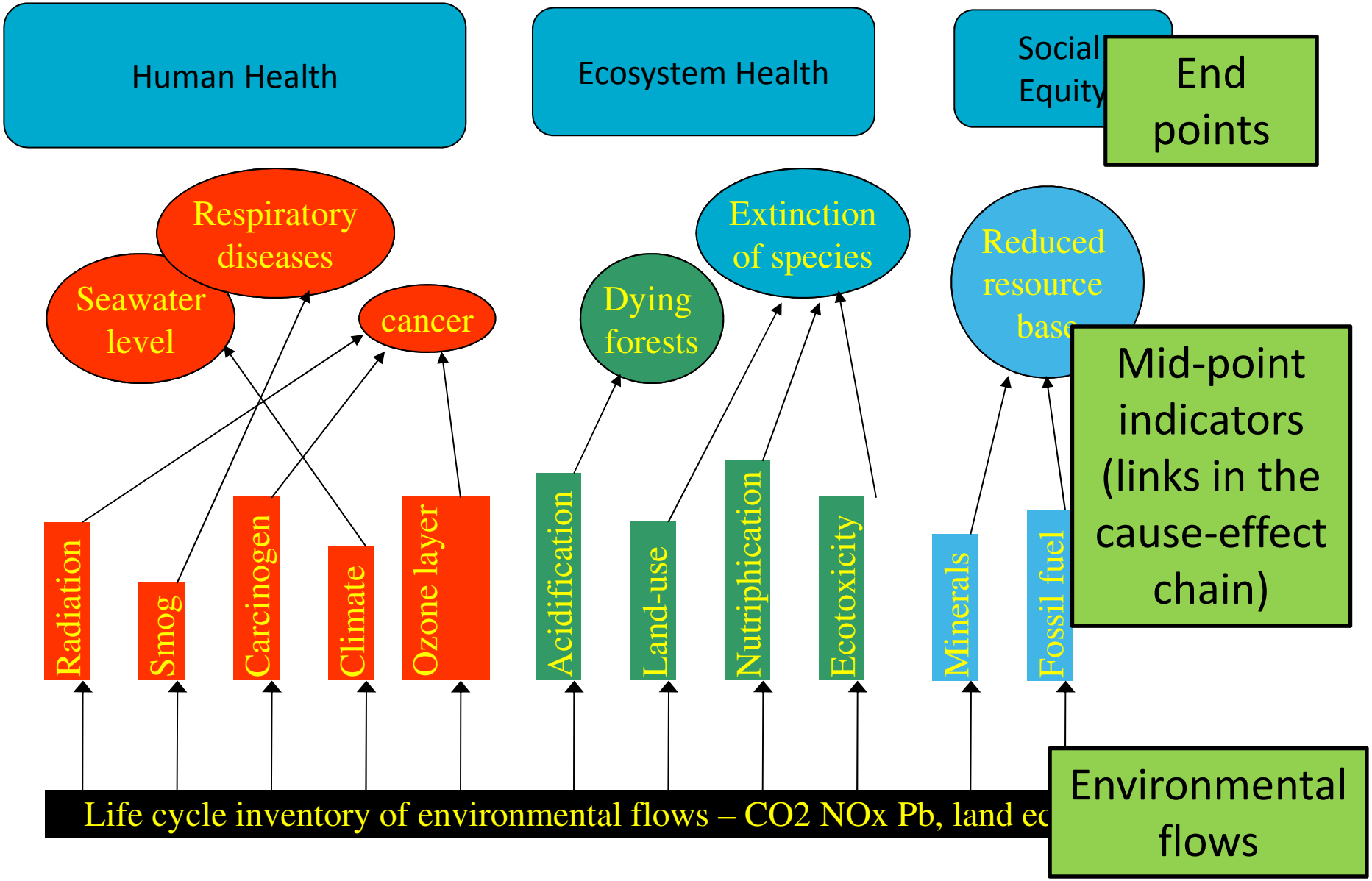



Source: Ryan, S 2012. Buying Choices for a More Sustainable Canberra, Report for the ACT Commissioner for Sustainability and the Environment

# Interaction between the economy and environment




Source: RMIT LCA Course Notes

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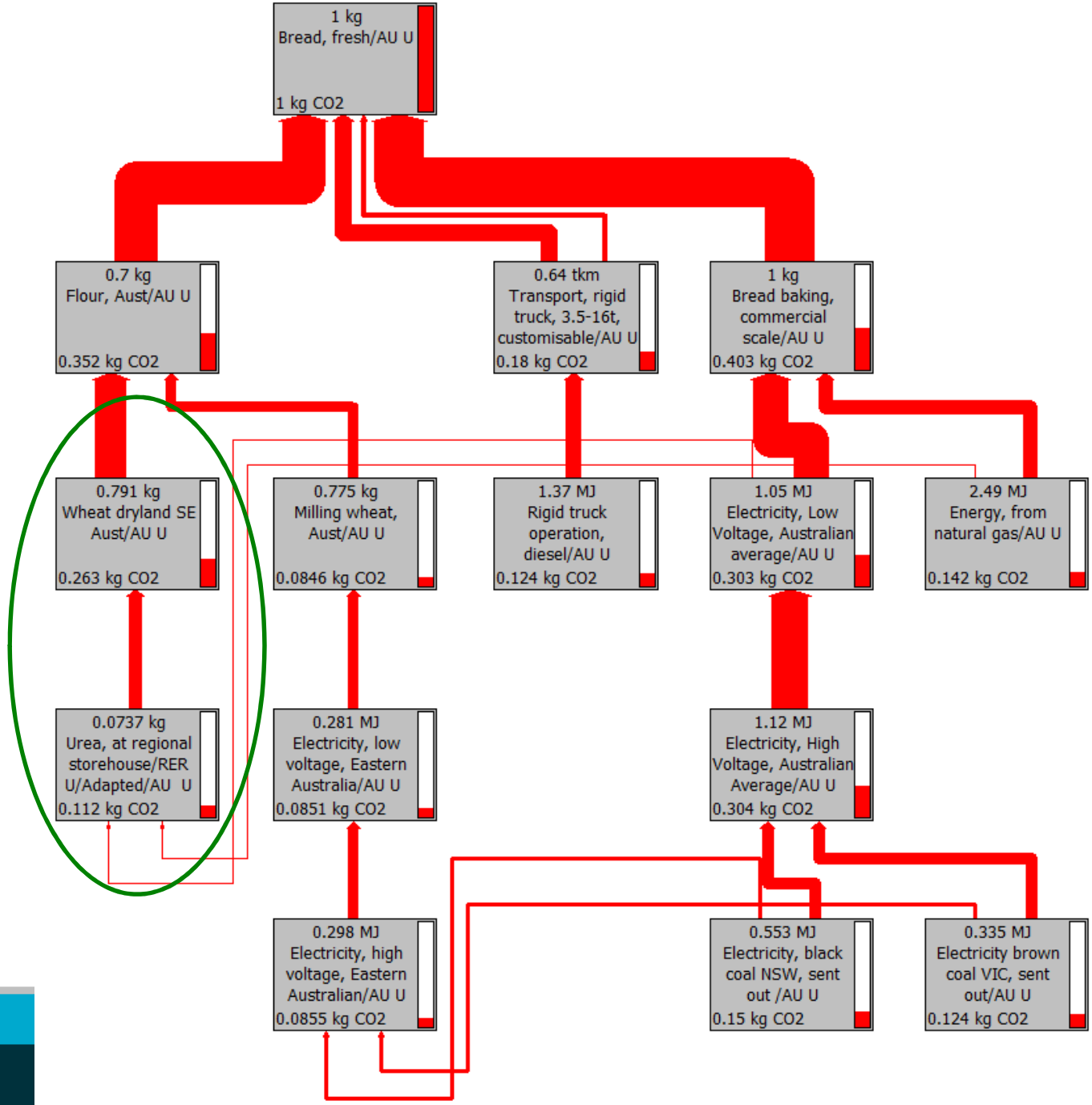

1 kg
Bread, fresh/AU U
1 kg CO2
0.7 kg
Flour, Aust/AU U
0.352 kg CO2
0.64 tkm
Transport, rigid truck, 3.5-16t, customisable/AU U
0.18 kg CO2
1 kg
Bread baking, commercial scale/AU U
0.403 kg CO2
0.791 kg
Wheat dryland SE Aust/AU U
0.263 kg CO2
0.775 kg
Milling wheat, Aust/AU U
0.0846 kg CO2
1.37 MJ
Rigid truck operation, diesel/AU U
0.124 kg CO2
1.05 MJ
Electricity, Low Voltage, Australian average/AU U
0.303 kg CO2
2.49 MJ
Energy, from natural gas/AU U
0.142 kg CO2
0.0737 kg
Urea, at regional storehouse/RER U/Adapted/AU U
0.112 kg CO2
0.281 MJ
Electricity, low voltage, Eastern Australia/AU U
0.0851 kg CO2
1.12 MJ
Electricity, High Voltage, Australian Average/AU U
0.304 kg CO2
0.298 MJ
Electricity, high voltage, Eastern Australian/AU U
0.0855 kg CO2
0.553 MJ
Electricity, black coal NSW, sent out /AU U
0.15 kg CO2
0.335 MJ
Electricity brown coal VIC, sent out/AU U
0.124 kg CO2

# Reasons for environmental assessment (Life Cycle Assessment)

- Environmental product declarations to inform consumer choice
  - ❖European Commission to adopt LCA as the approach to be used for environmental assessment of products for the 'Single Market for Green Products' (see http://ec.europa.eu/environment/eussd/smgp/product_footprint.htm).
- Delivery agreements where the supplier is required to demonstrate an on-going improvement program of environmental sustainability
  - ❖EU, Japanese, Australian markets – especially supermarkets
- The likely advent of trade agreements premised on climate change mitigation efforts
  - ❖Covered economies versus uncovered economies for carbon pricing

# Reasons for environmental assessment (Life Cycle Assessment)

- Unilateral need to respond to global warming – triggered by realignment of insurance risk and costs to the economy
  - ❖Covered economies versus uncovered economies for carbon pricing
- Negotiations for international agreements on greenhouse gas emissions reduction targets
  - ❖Especially China and India for export production (carbon footprint of exports)
- Need to produce more food globally with a lower environmental impact
  - ❖ Global significance but more so for countries that produce large amounts of staple foods – e.g. Australia, China, India, Africa, south America, north America, Russia……
- Need to have a consistent framework for assessing the environmental impact of different industry sectors and combined impact in different regions
  - ❖ Regional and national significance for evaluation of NRM investments, industry investment in sustainable production, .....

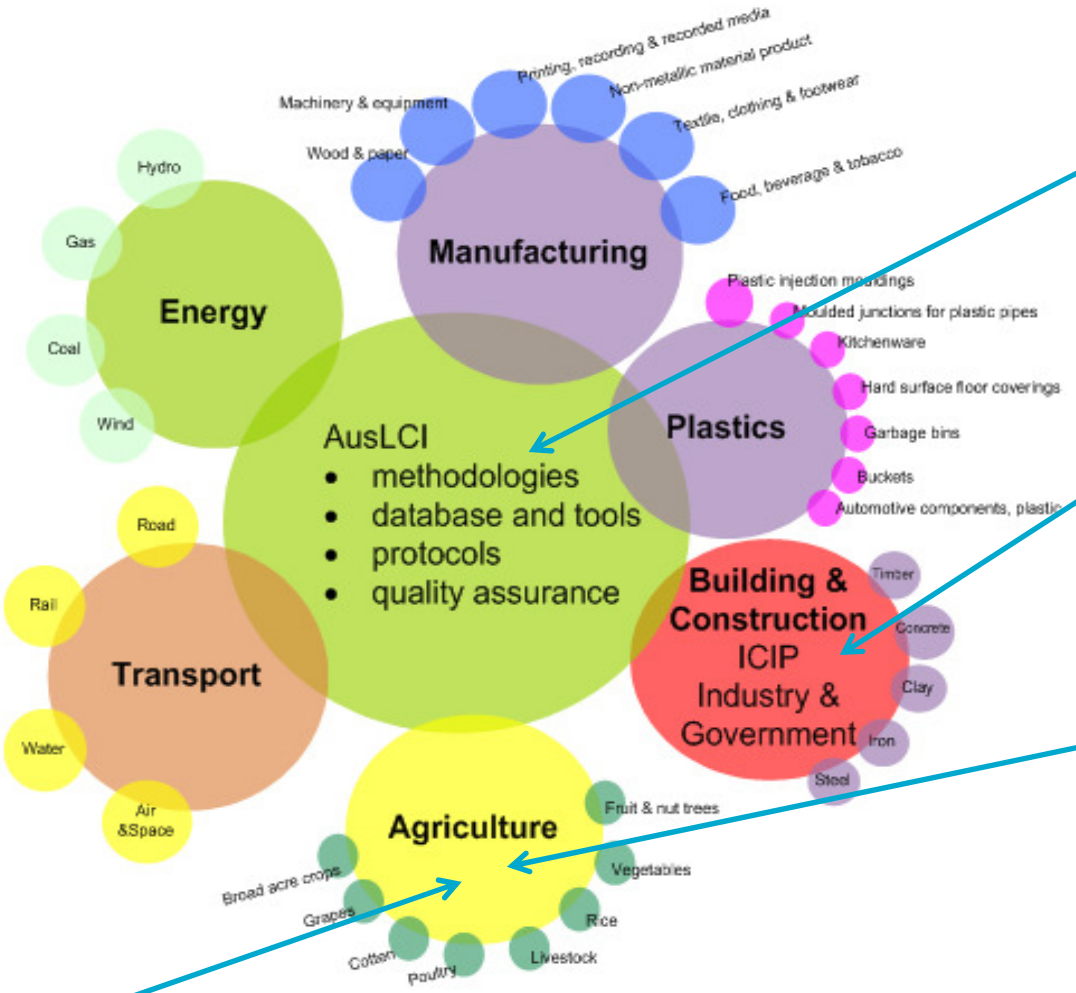
# Role of Life Cycle Inventory

- Life Cycle Assessment is only as good as the underlying data or Life Cycle Inventory (LCI) that is used for the analysis.
- Country specific LCI for agricultural products is essential for Australian agriculture to undertake environmental impact studies.
- In the absence of country specific data, LCA practioners will use the next best data available and this is often from Europe and the USA (with ecoinvent® being the most used LCI).

# Advantages of a Public Inventory

- Act as a repository for LCI from the many LCA studies being undertaken, to reduce duplication of common inventory e.g. wheat
- Consistent approach applied to inventory across sectors e.g. consistent modelling of pesticide flows
- Guidelines and standards can be set for:
  - Transparency
  - Data quality
  - Review
  - Standard formats
- Inventory can be structured so that it can be efficiently updated e.g. change in $N_2O$ emissions factor for N fertiliser use, improved flows model as GIS data is updated nationally.

# LCI Activities in Australia




Series of guideline documents on data collection, reviewing, best practice guide now available on AusLCI website

Major project by BPIC now completed with gate-to-gate data published, needs further development to be integrated into full life cycle unit process LCI.

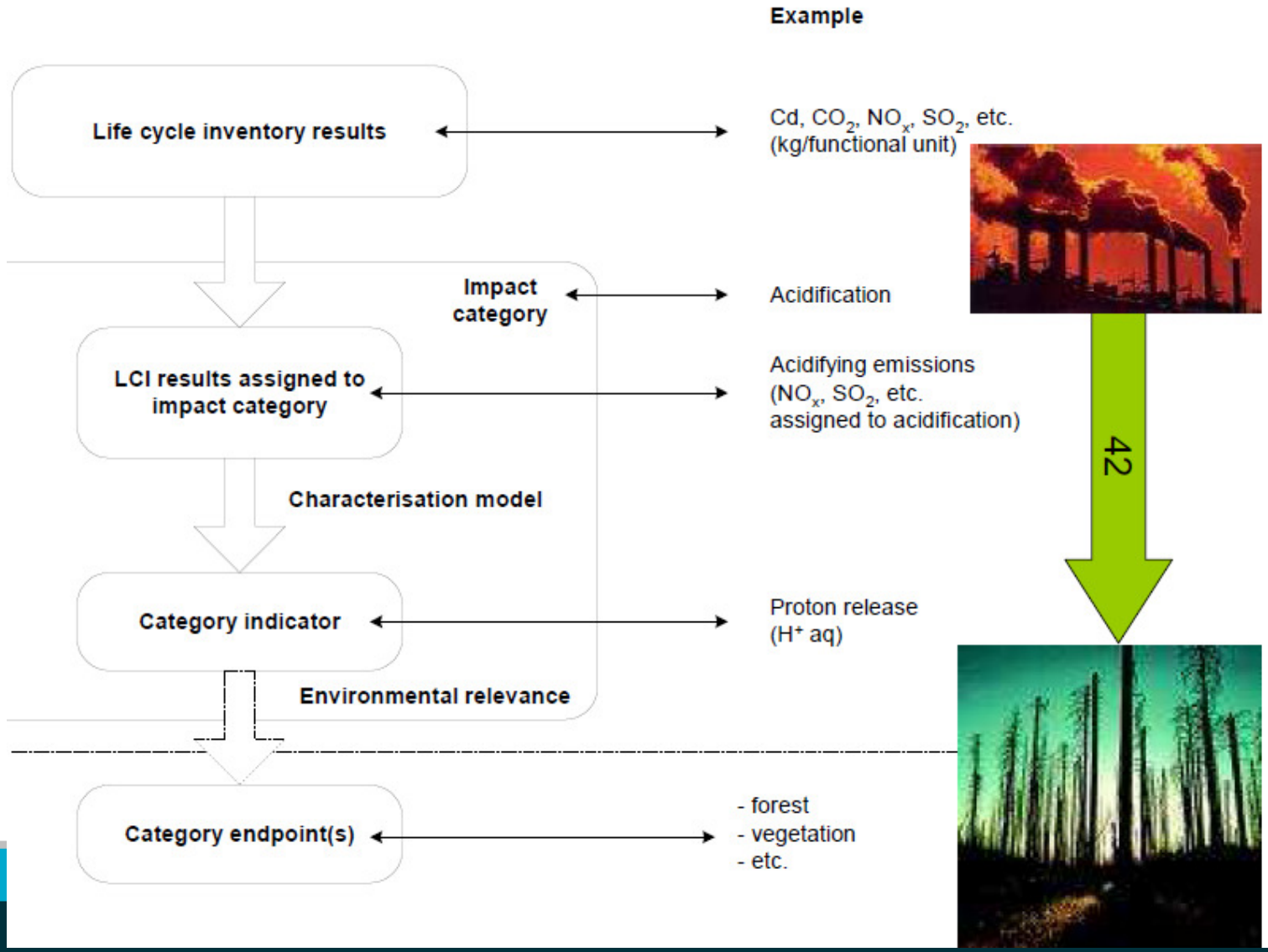
AusAgLCI – commenced in Dec 2011, will cover major products, public research agency providing data, funding support from industry, goal is unit processes from cradle-to-farm gate.

Extensions to AusAgLCI – Department of Agriculture Innovation Fund project for grazing and general cropping inventory (CSIRO and LCS; March 2014) and GRDC project for detailed cropping systems including rotations (NSW DPI, CSIRO and LCS; July 2014)

# Over to Tim.....

- Elementary flow, cause and effect pathways, impact assessment in general
- Approaches taken for different land-based impact categories
- How should we think about soil indicators in the context of LCA

# The principle of characterisation



# Elementary flow

- material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation

- Source ISO 14044

# Examples of elementary flows

- Mineral ores
  - Lead ore, in ground
  - Lead, 5.0% in sulfide, Pb 3.0%, Zn, Ag, Cd, In, in ground
  - Lead, Pb 0.014%, Au 9.7E-4%, Ag 9.7E-4%, Zn 0.63%, Cu 0.38%, in ore, in ground

- Fuels
  - Coal, brown in kg
  - Coal, brown, 10.0 MJ per kg, in ground in kg
  - Coal, brown, 14.1 MJ per kg, in ground in kg
  - Energy from brown coal in MJ

- Land occupation and transformation
  - Occupation, arable, conventional tillage in m2.years
  - Transformation, from arable, non-irrigated, extensive in m2

# Examples of elementary flows

- Soil –Raw material input
  - Carbon, in organic matter, in soil
  - Clay and soil, extracted for use
  - Clay and soil, related unused extraction
  - Soil, unspecified, in ground

- Emission to air
  - Particulates
  - Particulates Matter >10um
  - Particulate Matter 10.0 um
  - Particulate Matter 2.5 um

# Examples of elementary flows

- Water emissions
  - Soil loss by erosion into water
  - Organic substances, unspecified
  - Solved substances
  - Solved substances, inorganic
  - Suspended substances, unspecified
  - Salts, unspecified
  - Acidity, unspecified
- Soil emissions
  - Salts, unspecified
  - Acidity, unspecified

# Examples of elementary flows

- Biomass

Documentation | Input/output | Parameters | System description

| | | | |
|---|---|---|---|
| Transformation, from forest, extensive | land | 28.3 | m2 |
| Transformation, to forest, intensive | land | 28.3 | m2 |
| Occupation, forest, intensive | land | 4240 | m2a |
| Wood, hard, standing | biotic | 1.12000 | m3 |
| Energy, gross calorific value, in biomass | biotic | 14300 | MJ |
| Carbon dioxide, in air | in air | 1320 | kg |

(Insert line here)

# How many elementary flows are there

- In SimaPro
  - Raw materials 1800
  - Air emissions 4700
  - Water emissions 3700
  - Soil emissions 3400

  - Also emission sub-compartments for air water and soil emissions

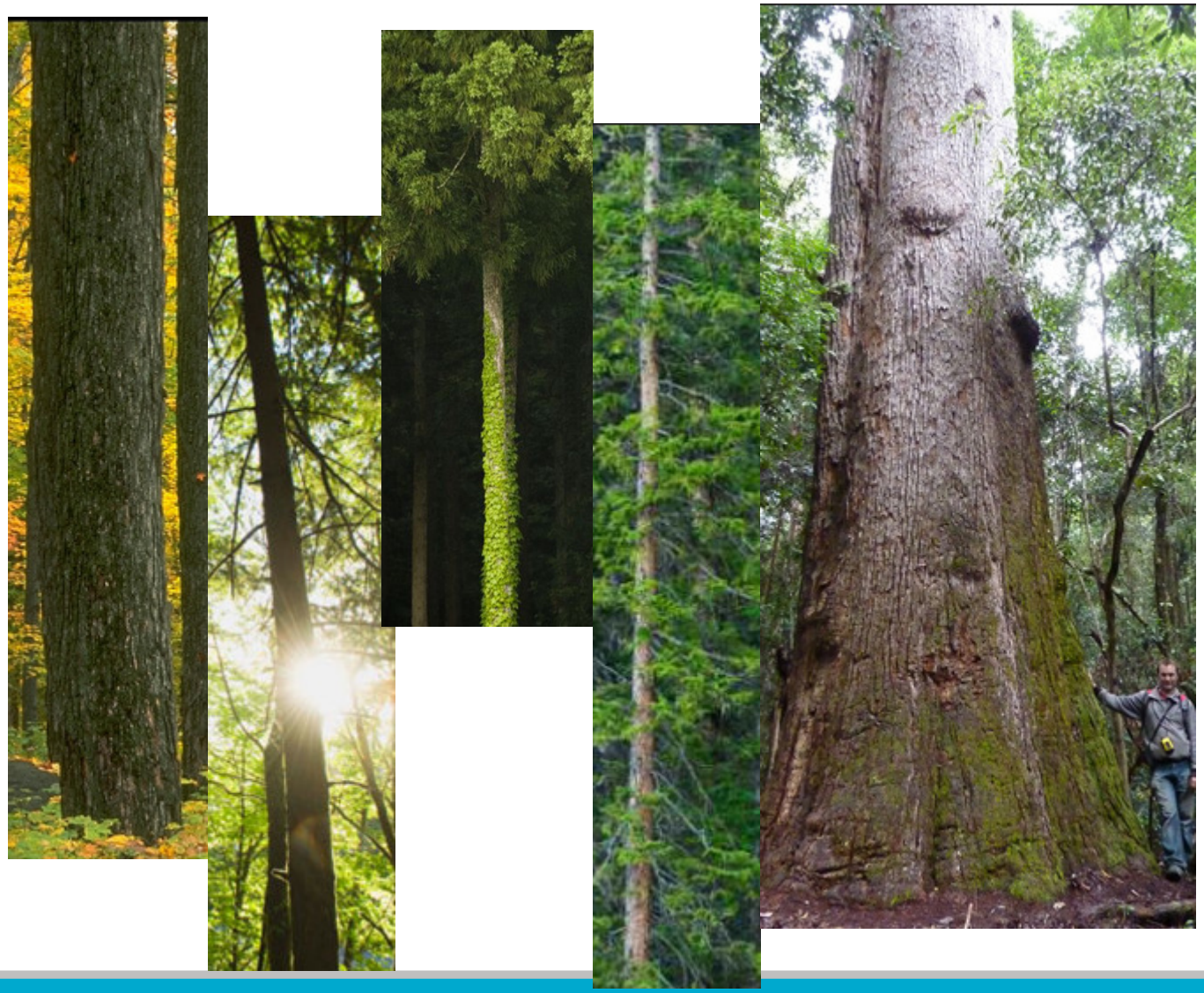
| Air | Water | Soil |
|---|---|---|
| non-urban air or from high stacks | ground- | agricultural |
| low population density, long-term | ground-, long-term | forestry |
| lower stratosphere + upper troposphere | ocean | industrial |
| urban air close to ground | surface water | unspecified |
| indoor | unspecified | |
| unspecified | | |

# How to position the elementary flow.

- Elementary flow definitions should enable meaningful aggregation in the impact assessment model.
- Timber production
  - Flow of standing hardwood, in mass units, - or
  - Land occupation in area time and land transformation in area?

  - Which is better to aggregate and predict effects on biodiversity?

# Adding up the trees



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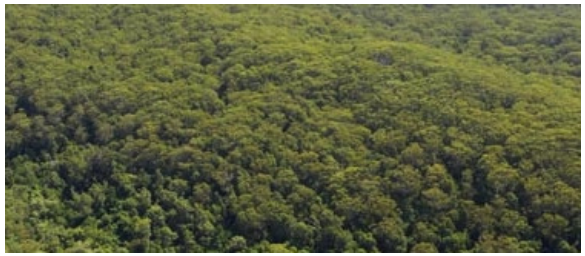
# Area of land use change



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# New types of elementary flows

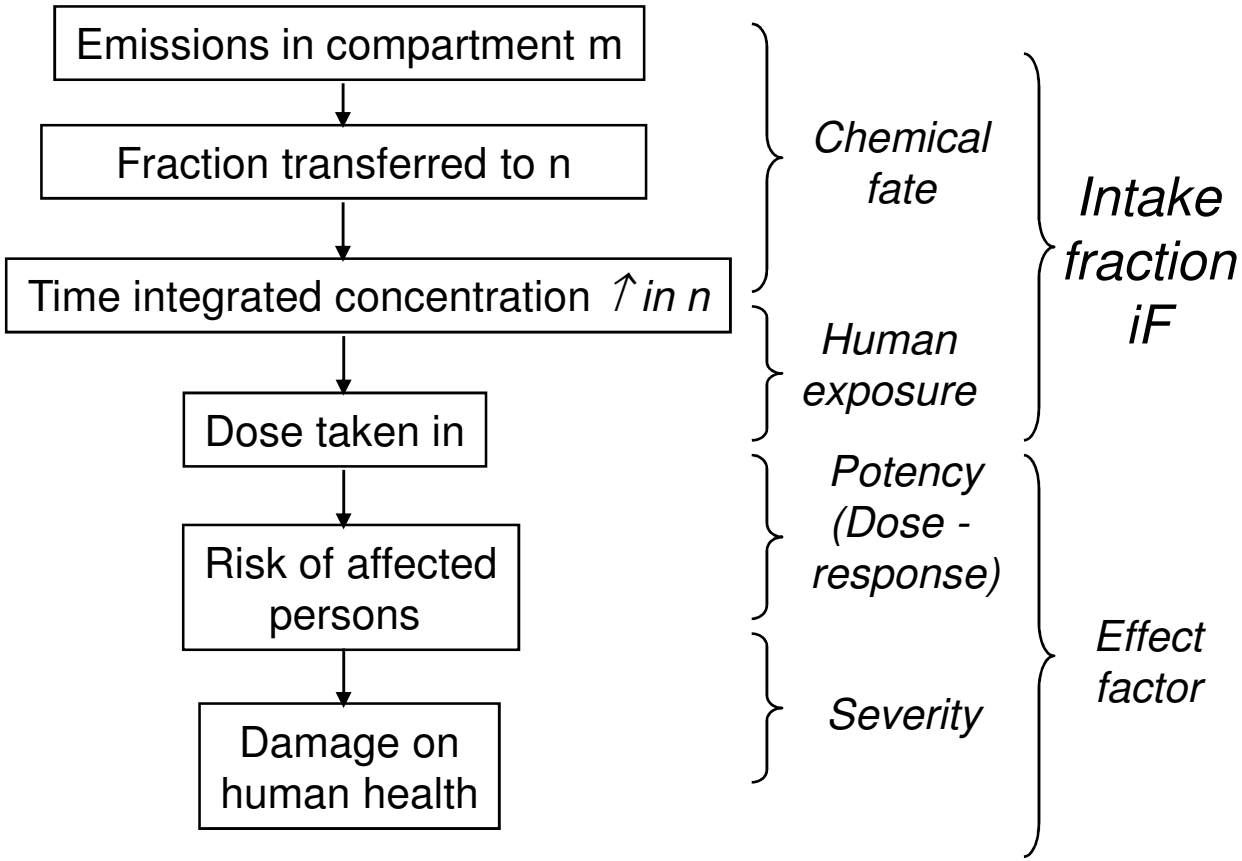
- Social Hot Spot database – risk levels used for attributes
- Risk of Child Labor in sector, Female , VHR
- Risk of Child Labor in sector, Female , HR
- Risk of Child Labor in sector, Female , MR
- Risk of Child Labor in sector, Female , LR
- Risk of Child Labor in sector, Female , URL
- Risk of Child Labor in sector, Female = ne

| Compartment | Subcompar | Substance | CAS number | Factor | Unit |
|---|---|---|---|---|---|
| Social | | Risk of Child Labor in sector, Total , HR | | 5 | CL mrh eq / work hours |
| Social | | Risk of Child Labor in sector, Total , LR | | 0.01 | CL mrh eq / work hours |
| Social | | Risk of Child Labor in sector, Total , MR | | 1 | CL mrh eq / work hours |
| Social | | Risk of Child Labor in sector, Total , VHR | | 10 | CL mrh eq / work hours |

# New types of elementary flows

- Water footprint flows – adding geography to elementary flows
- Water, lake, AE
- Water, lake, AF
- Water, lake, AL
- Water, lake, AM
- Water, lake, AO
- Water, lake, AR
- Water, lake, AT
- Water, lake, AU
- Water, lake, AZ
- Water, lake, BA
- Water, lake, BD
- Water, lake, BE
- Water, lake, BF

# The environmental mechanism – example of human toxicity



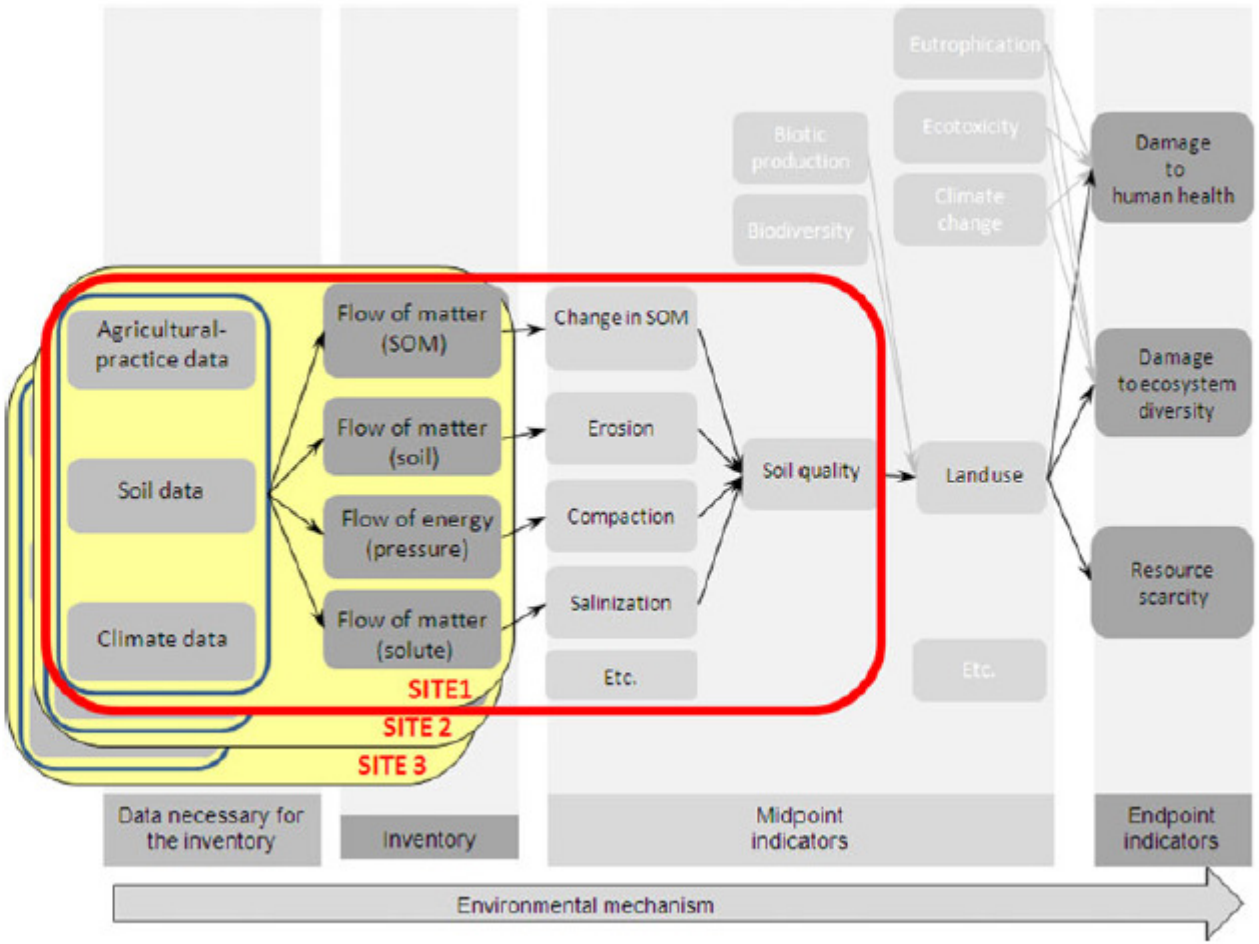

(ES&T 2002, 36, 207-212 A)

# Current approaches to land use

- Biodiversity  metrics based:
  - Direct occupation of land – displacing biodiversity and stopping it re-establishing on that land
  - Increased segregation of remaining natural land.
- Japanese LIME model included NPP as an endpoint in LCA.
- Ecological footprint- based on exclusive use of land based on NPP.
- ILCD – carbon deficit from land use change.
- World impact+ method – focus on regionalisation of impact assessment – included soil ecological functions – erosion resistance, water supply, water filtration.

# The scope of our work for the next two days

**Fig. 1** Conceptual steps for assessing impacts on soil quality (*outlined*) (adapted from Garrigues et al. 2012). Not all potential links between midpoint indicators are shown




Source: Garrigues et al. 2013. Development of a soil compaction indicator in life cycle assessment. International J Life Cycle Assessment 18:1316.

# Back to Sandra

- Current flows in AusAgLCI to cover impact categories
- Inventory produced to date
- Some LCI results
- Expectations from the workshop

# Impact categories

- ***Global warming:***
  - Flows are based on IPCC (2006) and National Inventory Report (DCCEE 2011) methodologies.
  - Emissions directly associated with production (e.g. direct and indirect GHG emissions from fertiliser use, burning of stubble, crop residues) are included as inventory flows but not potential carbon sinks and sources (soil, litter and vegetation carbon changes); it will be the domain of the LCA practioner to add these where appropriate.
- ***Water use:***
  - Elemental flows required to support a range of impact assessment approaches are included. Green water is included if there is a land transformation that changes the availability of water downstream for other users.
- ***Land use:***
  - The land cover classifications used by ecoinvent® are used as the basic flow in the inventory.
  - To inform the discussion on land use and the competing demands for land, an approach that classifies both area and the capacity of land to produce food is required.

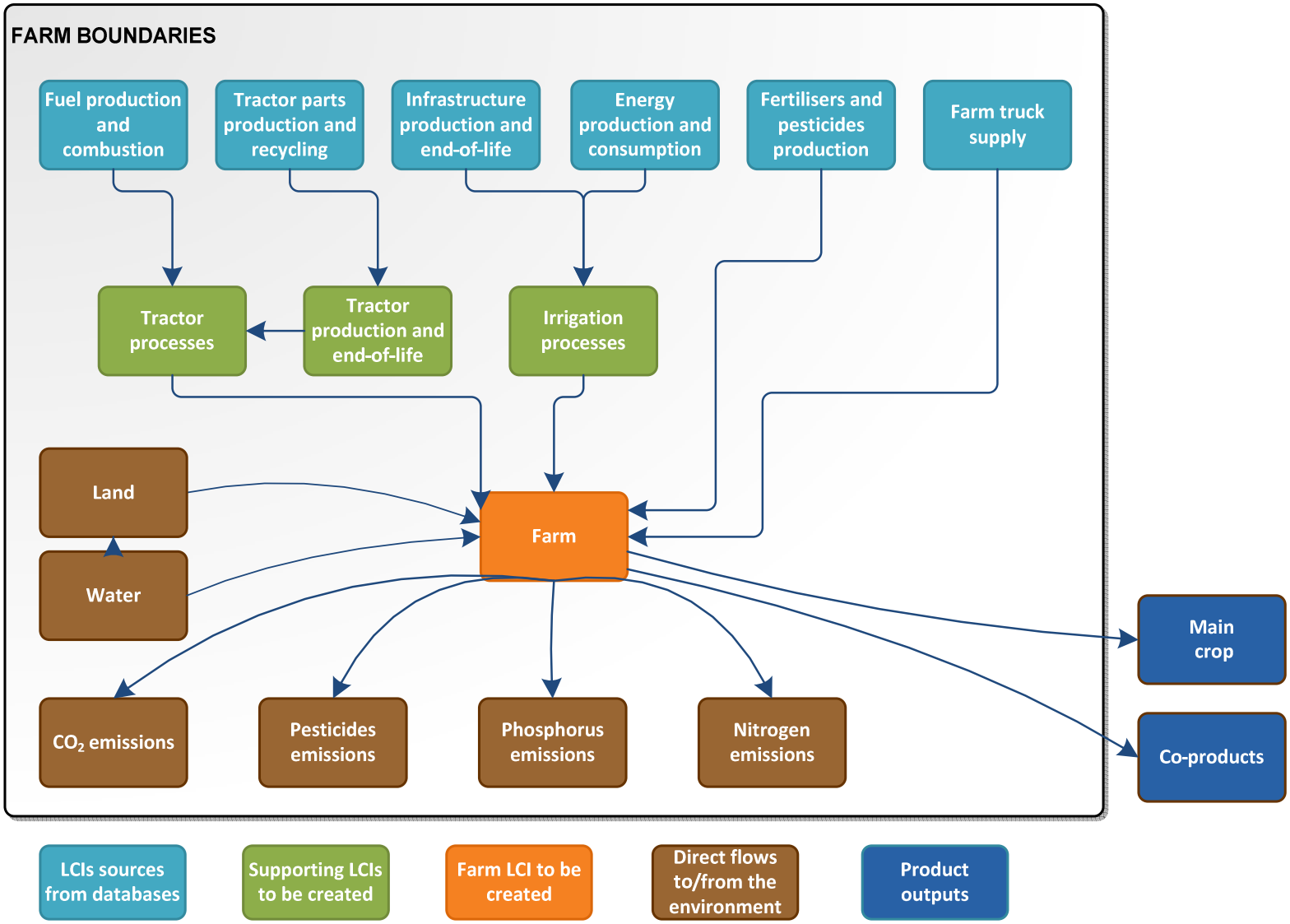
# Impact categories - continued

- ***Eutrophication:***
  - Nitrogen flows are estimated using Australian NIR methodology and phosphorus flows are estimated by the method used by ecoinvent®.
  - Both methods are responsive to fertiliser inputs, and use regional data (at the intersection of GIS layers for agro ecological region and land use) to determine if leaching and run-off is occurring, and to estimate net export of soil (relevant for P transport to waterways).
- ***Ecotoxicity:***
  - Flows of specific active ingredients to soil, water and air are estimated from PestLCI, adapted to Australian conditions.
  - Parameters modified for Australian conditions are climate related (temperature, precipitation, evaporation, solar radiation), soil characteristics (depth, proportion sand, silt and clay, pH, organic content, bulk density), and field data (slope).
  - Profiles for use in PestLCI have been constructed from GIS layers at the intersection of agricultural land use and agro ecological region.
  - A number of pesticides used in Australia have been added to the model, using readily available data on key parameters (molecular weight, solubility, vapour pressure, half life in soil).

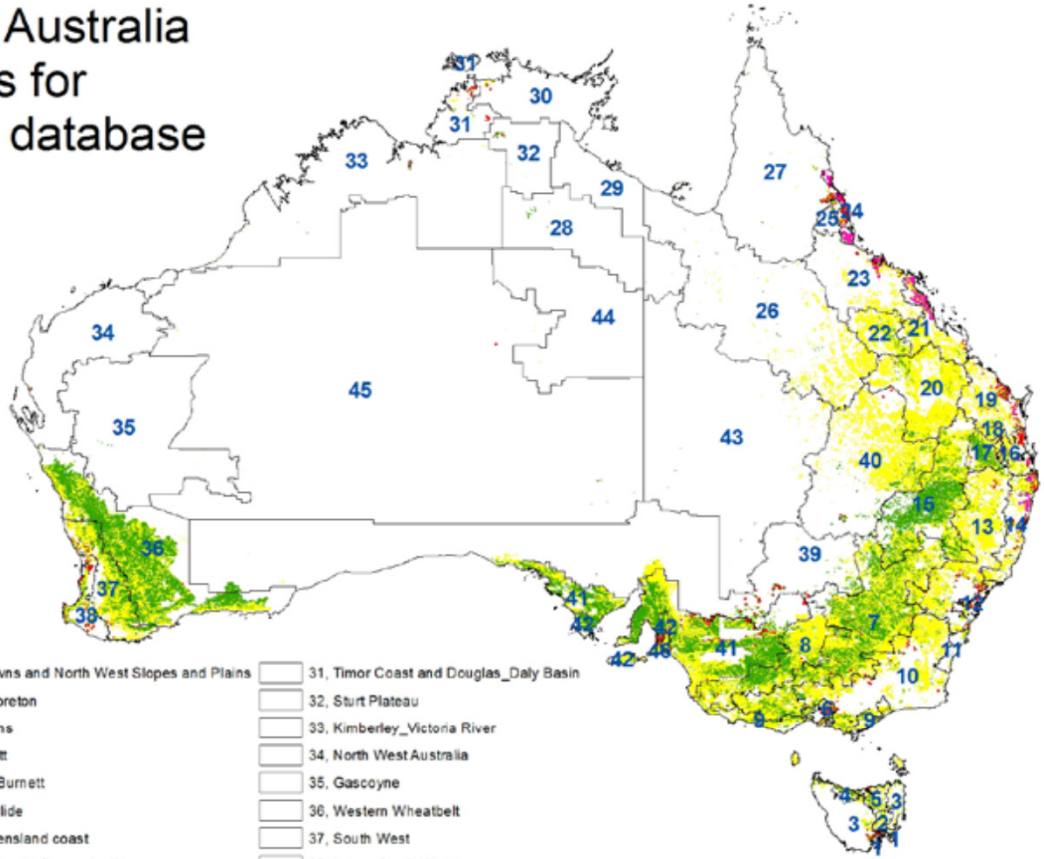
# What has been produced to date

| Sector | Processing | Material | Total |
|---|---|---|---|
| Cotton | 14 | 4 | 18 |
| Horticulture | 17 | 16 | 33 |
| Livestock* | 2 | 12 | 14 |
| Grains | 19 | 16 | 35 |
| Sugar | 13 | 7 | 20 |
| Irrigation | | | 23 |
| Other | | | 4 |
| Total | | | 147 |

* Supporting inventory


FARM BOUNDARIES
Fuel production and combustion
Tractor parts production and recycling
Infrastructure production and end-of-life
Energy production and consumption
Fertilisers and pesticides production
Farm truck supply
Tractor processes
Tractor production and end-of-life
Irrigation processes
Land
Water
Farm
Main crop
Co-products
$CO_2$ emissions
Pesticides emissions
Phosphorus emissions
Nitrogen emissions
LCIs sources from databases
Supporting LCIs to be created
Farm LCI to be created
Direct flows to/from the environment
Product outputs

# Agroecological regions of Australia and the Land Use Classes for products in the AusAgLCI database



**Legend**

**Agroecol_regions**

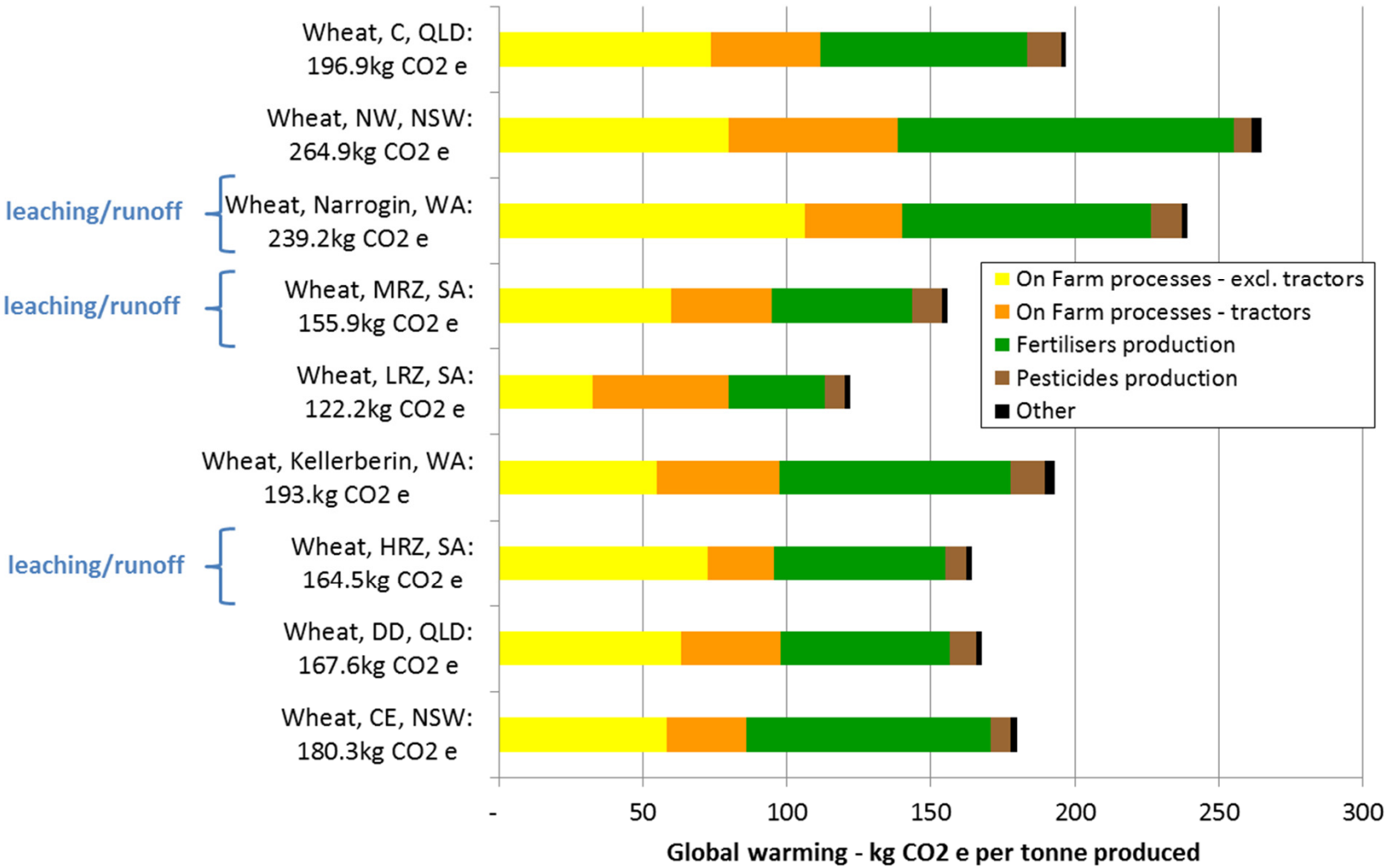
**region_no, Region_nam**

- 1, Hobart
- 2, Jordan_Coal_Tasman
- 3, Tasmanian_Forests
- 4, Burnie
- 5, North Central
- 6, Melbourne Region
- 7, Central and South West Slopes and Plains
- 8, South Riverina and Wimmera
- 9, Far South and East Victorian Coast
- 10, Southern Highlands - Tablelands and Gippsland
- 11, South Coast and Illawarra
- 12, Sydney Basin
- 13, Central - North Tablelands and Granite belt
- 14, Northern Rivers and Mid-north Coast
- 15, Western Downs and North West Slopes and Plains
- 16, Brisbane_Moreton
- 17, Darling Downs
- 18, South Burnett
- 19, Wide Bay _ Burnett
- 20, Dawson_Callide
- 21, Central Queensland coast
- 22, Central Highlands Queensland
- 23, Burdekin
- 24, Wet Tropic Coast
- 25, Northern Queensland Tablelands
- 26, Central West and Gulf
- 27, Cape York
- 28, Barkly Tablelands
- 29, Marrakai_Arnhem Land
- 30, Esley_Gulf Land
- 31, Timor Coast and Douglas_Daly Basin
- 32, Sturt Plateau
- 33, Kimberley_Victoria River
- 34, North West Australia
- 35, Gascoyne
- 36, Western Wheatbelt
- 37, South West
- 38, Lower South West
- 39, Goldfields_Nullabor_Flinders and Darling
- 40, Maranoa_Warrego
- 41, Mallee_Murray and central North South Australia
- 42, Southern Coastal South Australia
- 43, Channel Country
- 44, Central Australian Ranges
- 45, Tanami - Petermann - Simpson and Western Deserts
- 46, Adelaide Region

**Land Use Classes**

- Pastures
- Cropping
- Seasonal Hort
- Perennial Hort
- Sugar
- Cotton

# Preliminary Wheat GHG Results



# The scope of our work for the next two days

Day 2 Day 1

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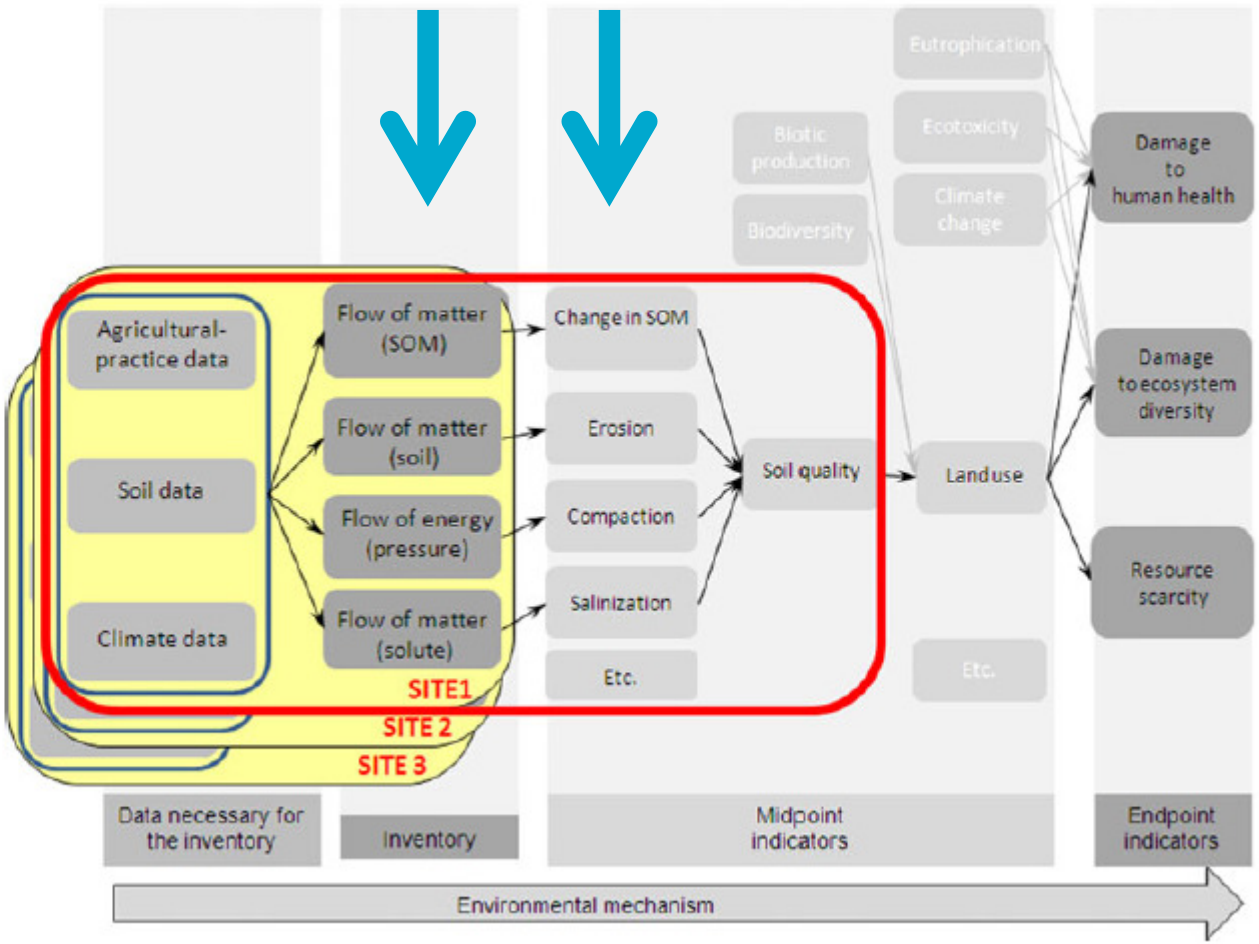


Source: Garrigues et al. 2013. Development of a soil compaction indicator in life cycle assessment. International J Life Cycle Assessment 18:1316.

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