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Food or fuel: how to best use land?

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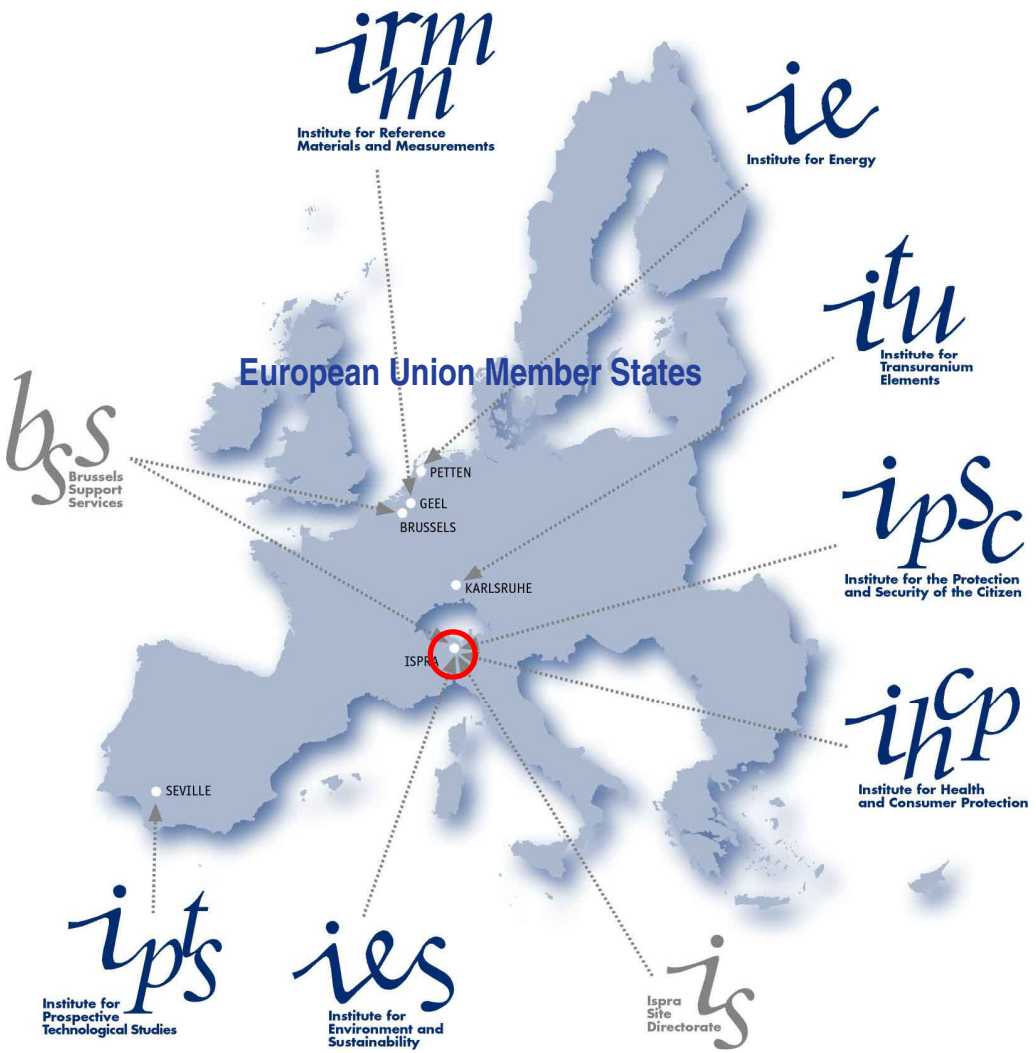


Outline

- Goal and scope
- Inventory Analysis
- Impact Assessment
- Interpretation
- Concluding remarks

- Competition for land between ecosystem goods and services (e.g. food, fuel, carbon sink)
- "What are the global environmental *consequences* of diverting wheat from food to fuel purposes in UK?"
  - Indirect Land Use Change (iLUC)
  - Climate Change (GWP100), including biogenic C flows and temporary storage
  - Ecosystem Services (Net Ecosystem Carbon Balance)
- Consequential approach
- Functional unit: 1 ha
- Modelled system includes affected parts within its boundaries
- System subdivision
  - foreground system (UK wheat cropland)
  - background system (marginal production, thereby avoiding allocation)

- Includes subsequent displacements from product and co-products
  - Food wheat
  - Animal feed from the co-production of DDGS
  - Vehicle fuel (gasoline)
- … and replacements (if consumption is held constant)
  - Food wheat
  - A combination of palm oil, soymeal and feedwheat
    - ILUC!
- Dynamic, linear, marginal
- Substitution effects
- Marginal producers
  - Wheat for food and feed (Canada)
  - Argentina (soymeal)
  - Indonesia (vegetable oil)

Accounting for feed displacement by DDGS

	Dry Matter (DM) (%)	Digestible Energy (MJ / kg DM)	Metabolizable Protein (g / kg DM)	Vegetable oil (kg/kg DM)
Soybean meal	89	15.48	363	0.233
Feed wheat	87	16.23	75	
DDGS	93	16.12	244	
Palm kernel meal	90	13.72	115	5.236

A = t soybean meal
B = t feed wheat
C = t palm oil

x = energy
y = protein
z = vegetable oil

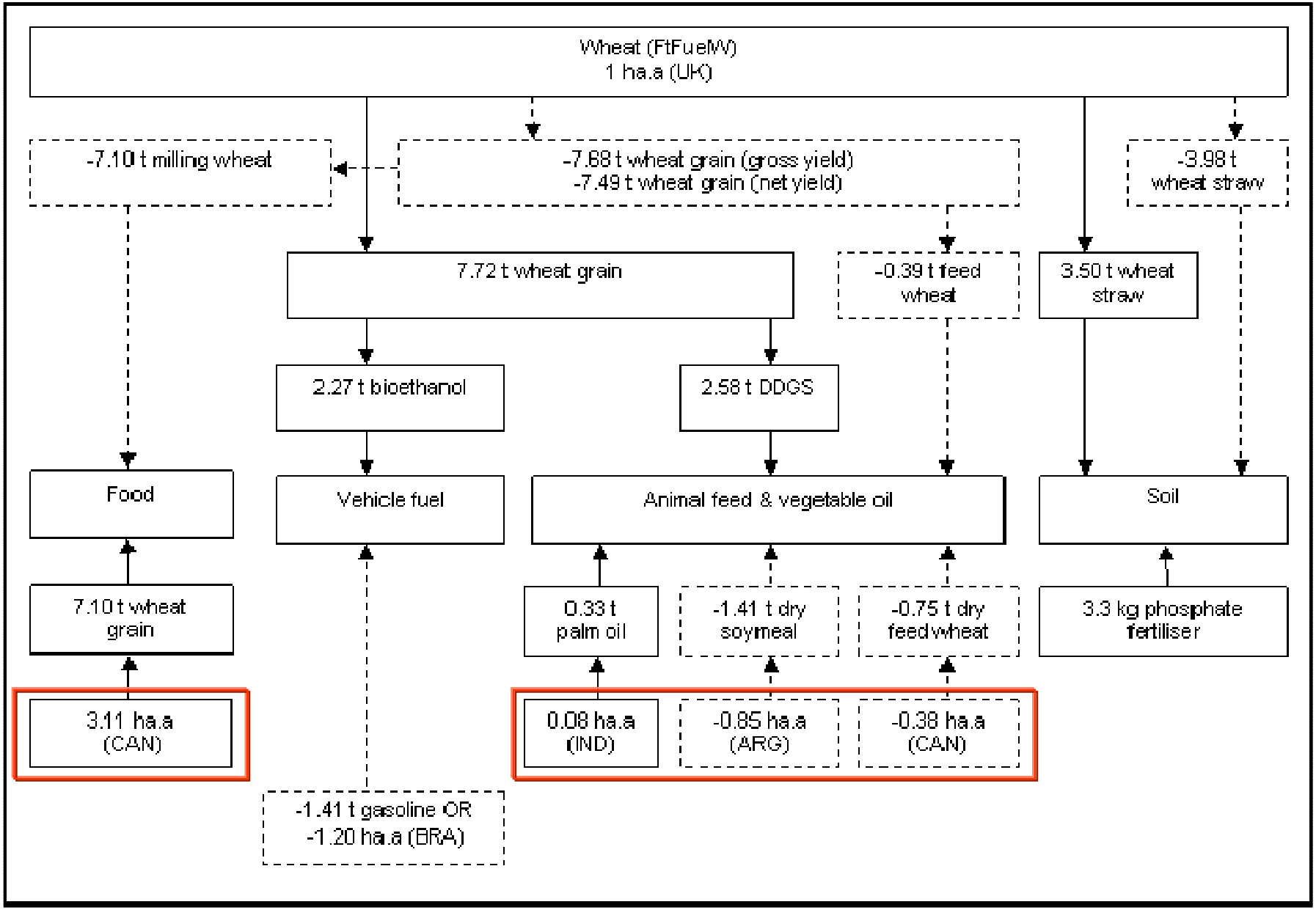
$$\begin{cases} A = 15.48x + 363y + 0.233z \\ B = 16.23x + 75y \\ C = 2.29x + 19y + z \end{cases}$$

$$\begin{aligned} 15.48A + 16.23B + 2.29C &= -39x \\ 363A + 75B + 19C &= -586y \\ 0.233A + C &= 0 \end{aligned}$$

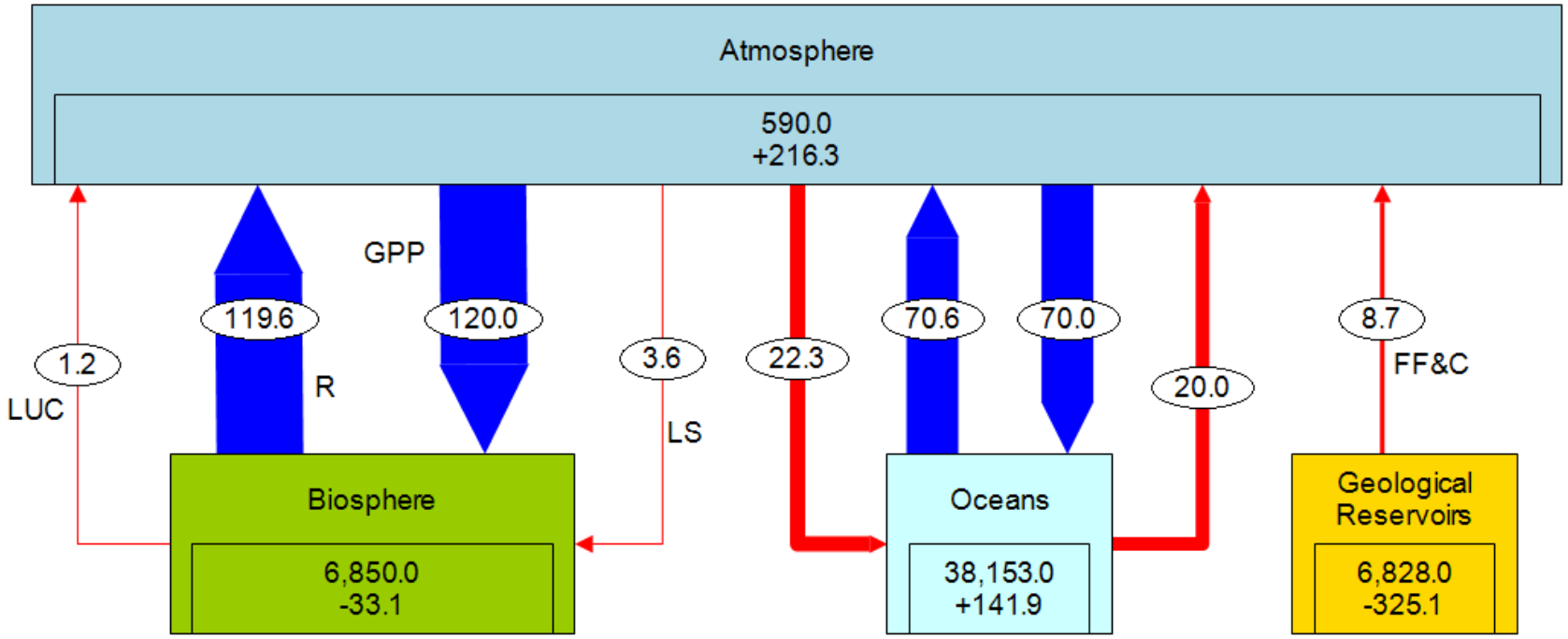
$$\begin{bmatrix} 15.48 & 16.23 & 2.29 \\ 363 & 75 & 19 \\ 0.233 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} A \\ B \\ C \end{bmatrix} = - \begin{bmatrix} 39 \\ 586 \\ 0 \end{bmatrix}$$

A = -1.41
B = -1.09
C = 0.33

Marginal inventory, incl. ILUC

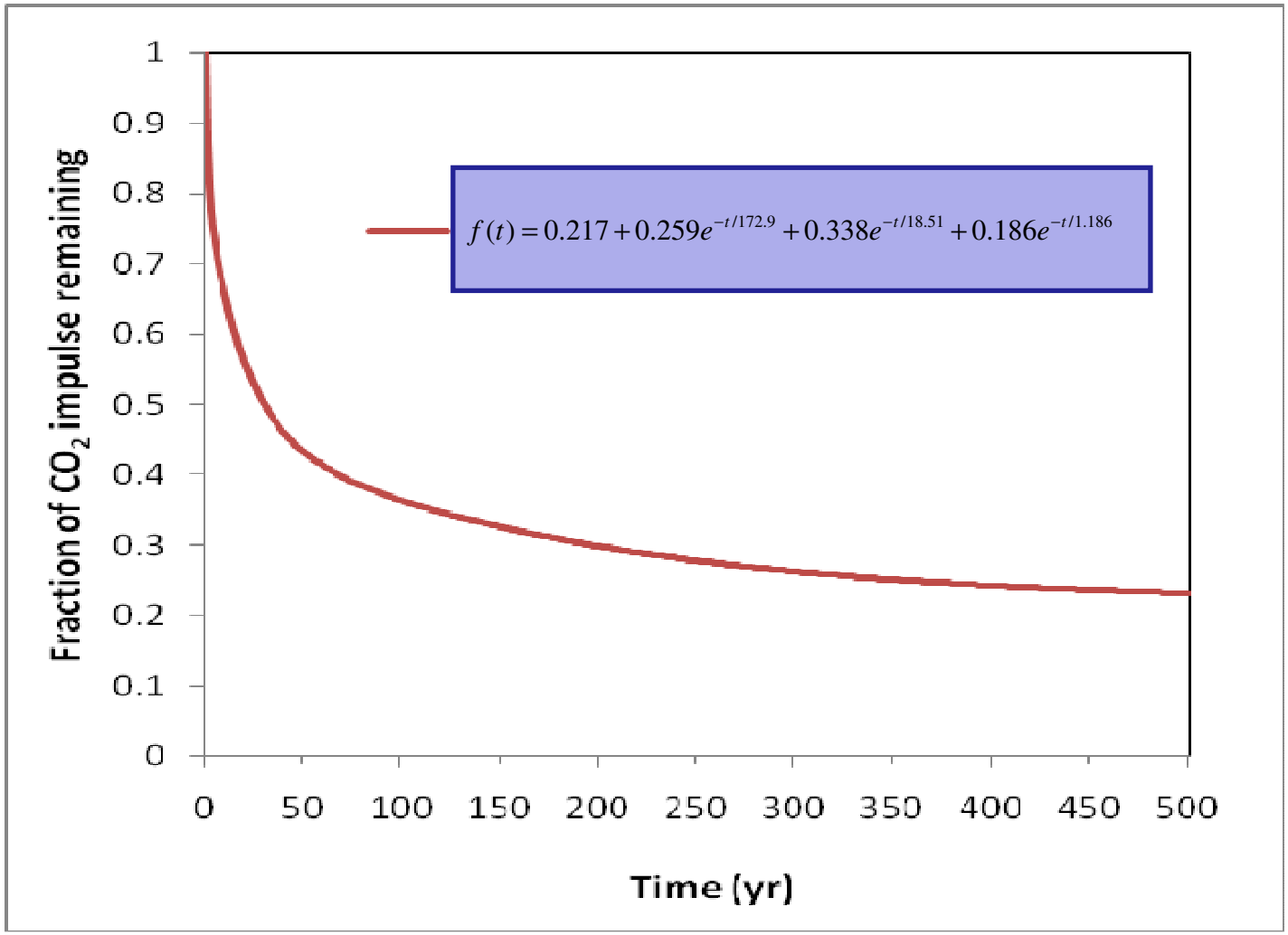


Importance of Land Use in the Global Carbon Cycle



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



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

$a_0 = 0.217$

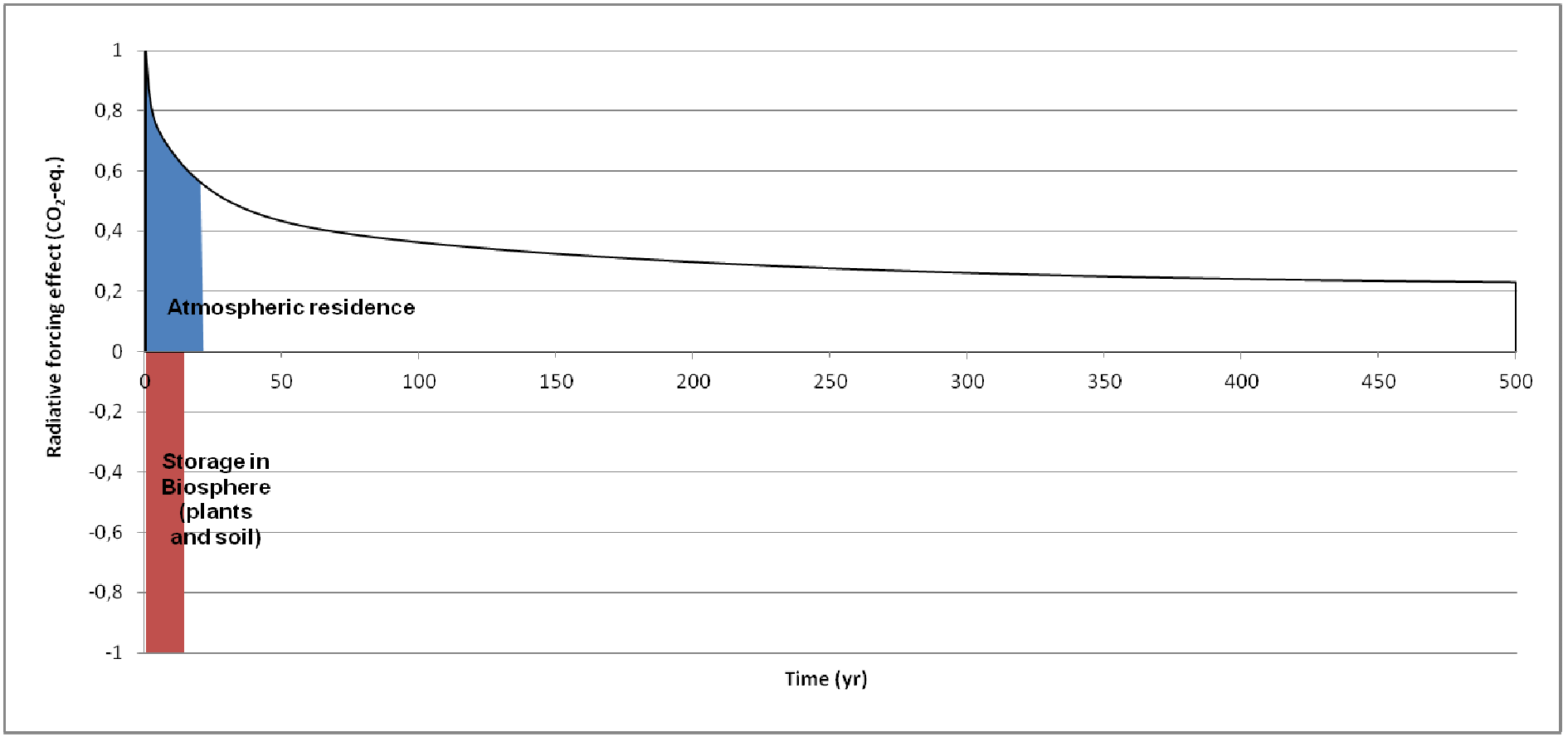
$a_1 = 0.259$ $\quad \tau_1 = 172.9$

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

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

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

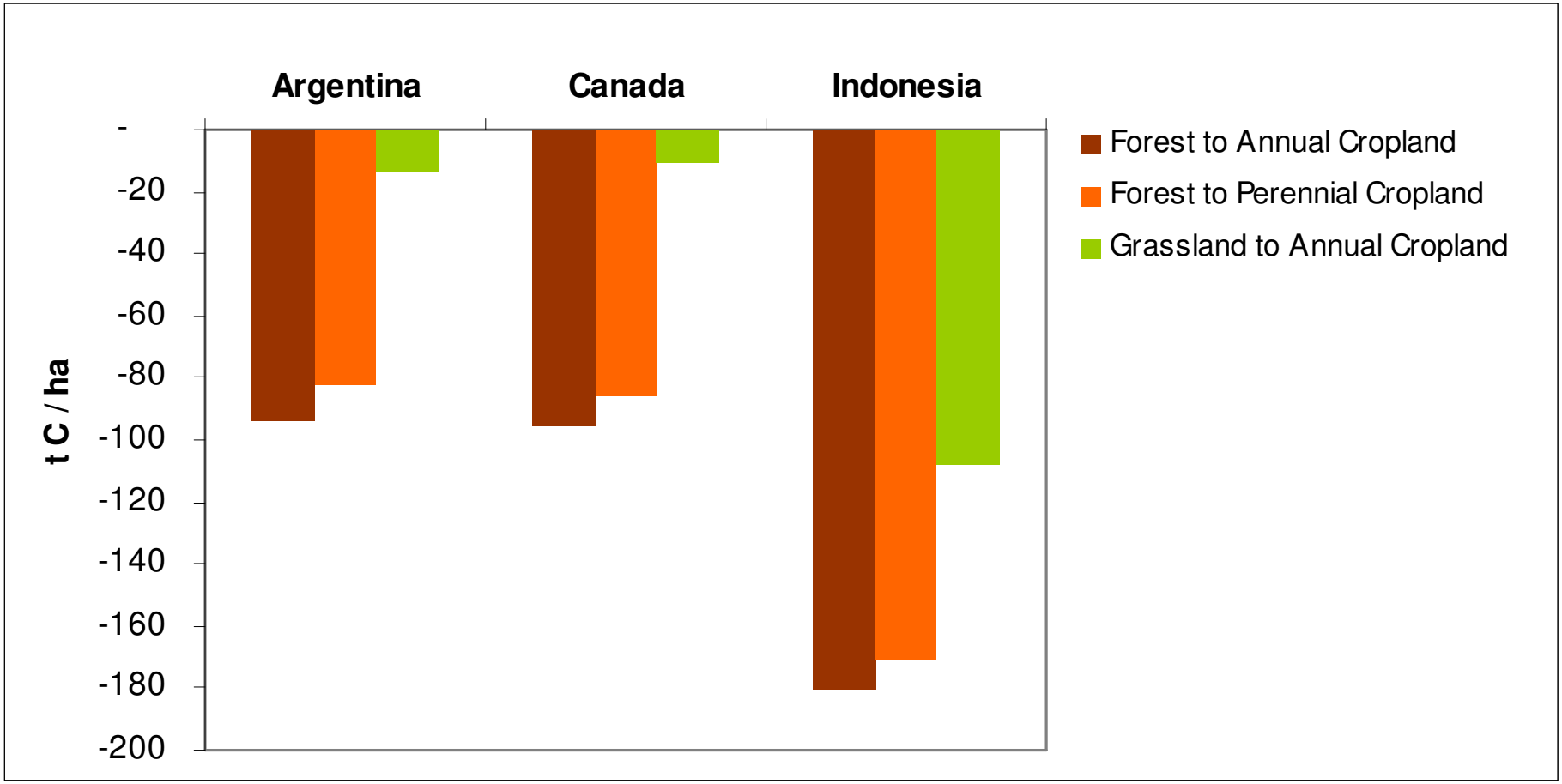
Radiative forcing (W/m^2), t CO_2e and t C*yr



Global Warming Potential: the Moura-Costa approach

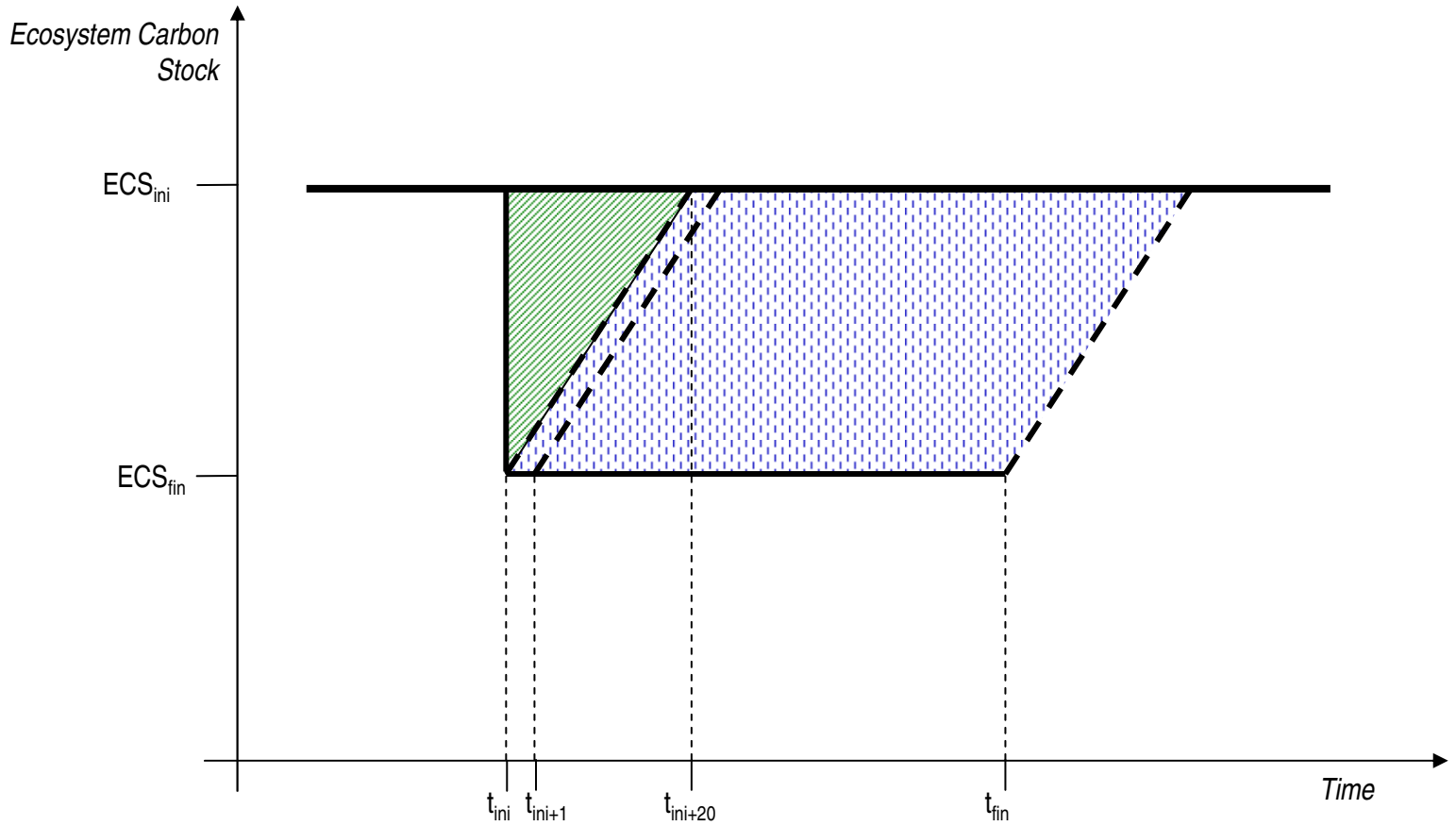
	Global Warming Potential (CO_2-eq)		
	20 years	**100 years**	500 years
Carbon Dioxide	1	1	1
Methane	72	25	7.6
Nitrous Oxide	289	298	153
Carbon Dioxide tonne-years	1/14.6 = 0.074	**1/47.8 = 0.021**	1/157.3 = 0.006
Carbon tonne-years	0.074*44/12= =0.27	0.021*44/12= =0.08	0.006*44/12= =0.022

Changes in carbon stocks



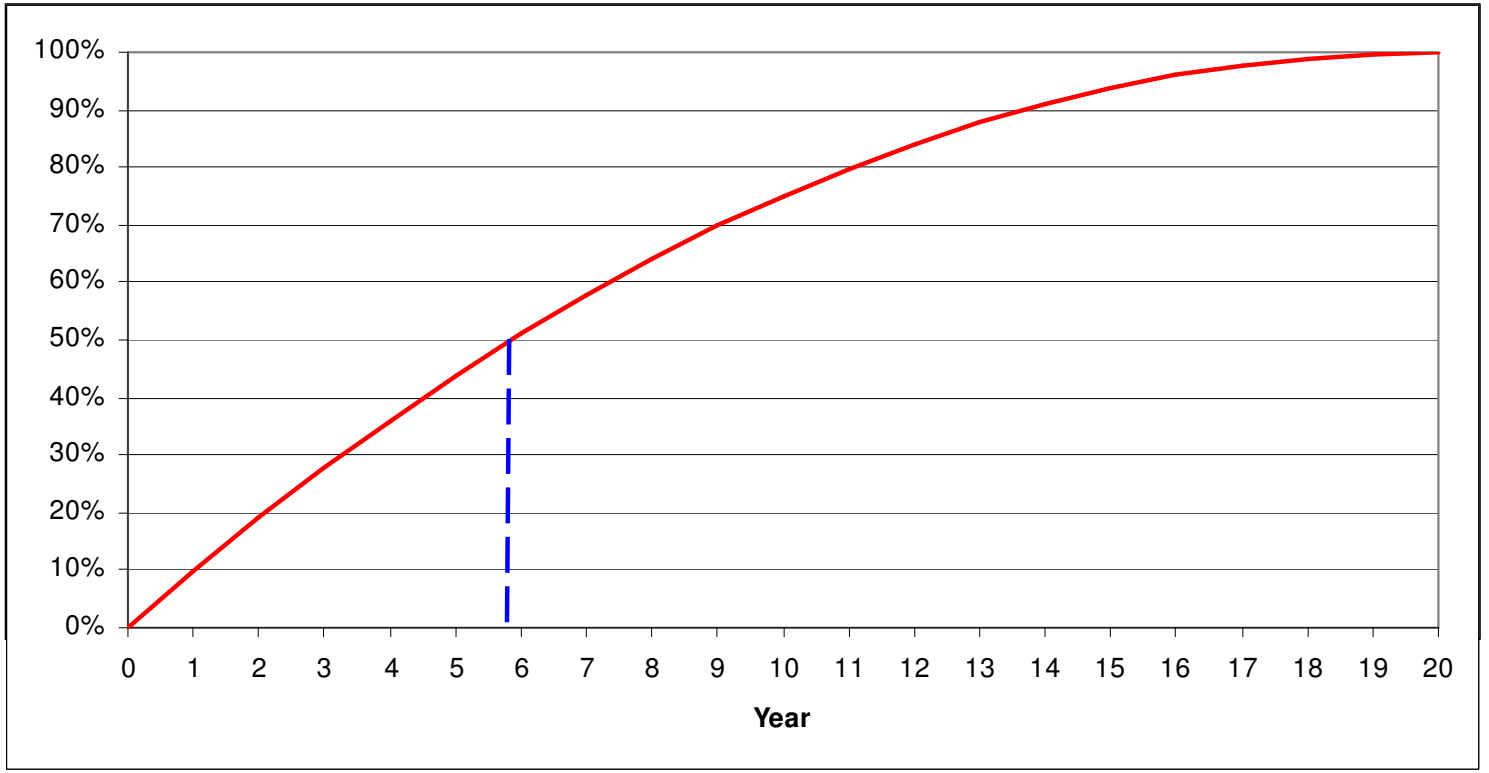
Source: IPCC (2006)

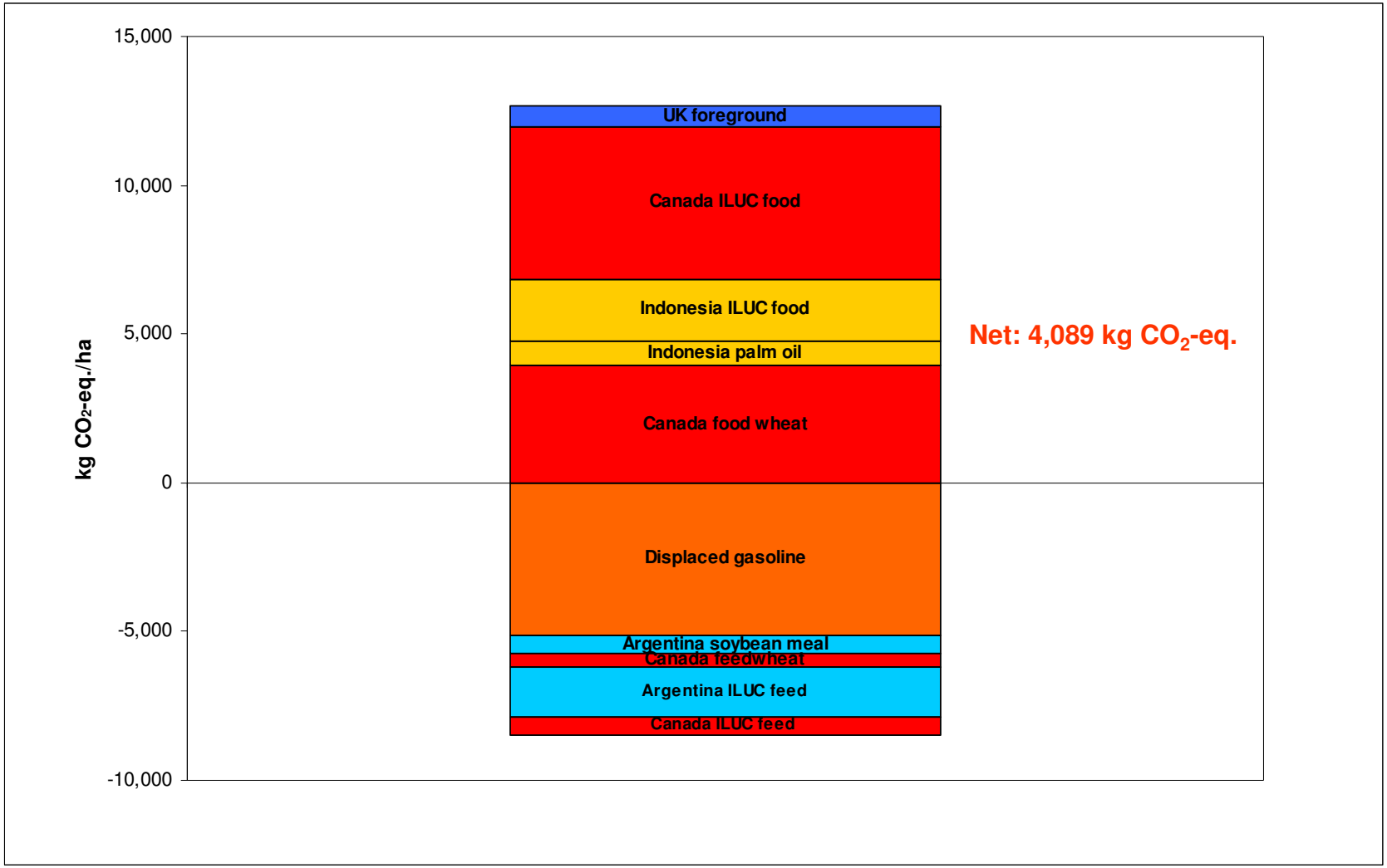
$$ECS\ \ deficit\ \ [\Delta ECS\ ] = \ (ECS_{ini} - ECS_{fin}) * 20/2 \ \ + (ECS_{ini} - ECS_{fin}) \times (t_{fin} - t_{ini})$$



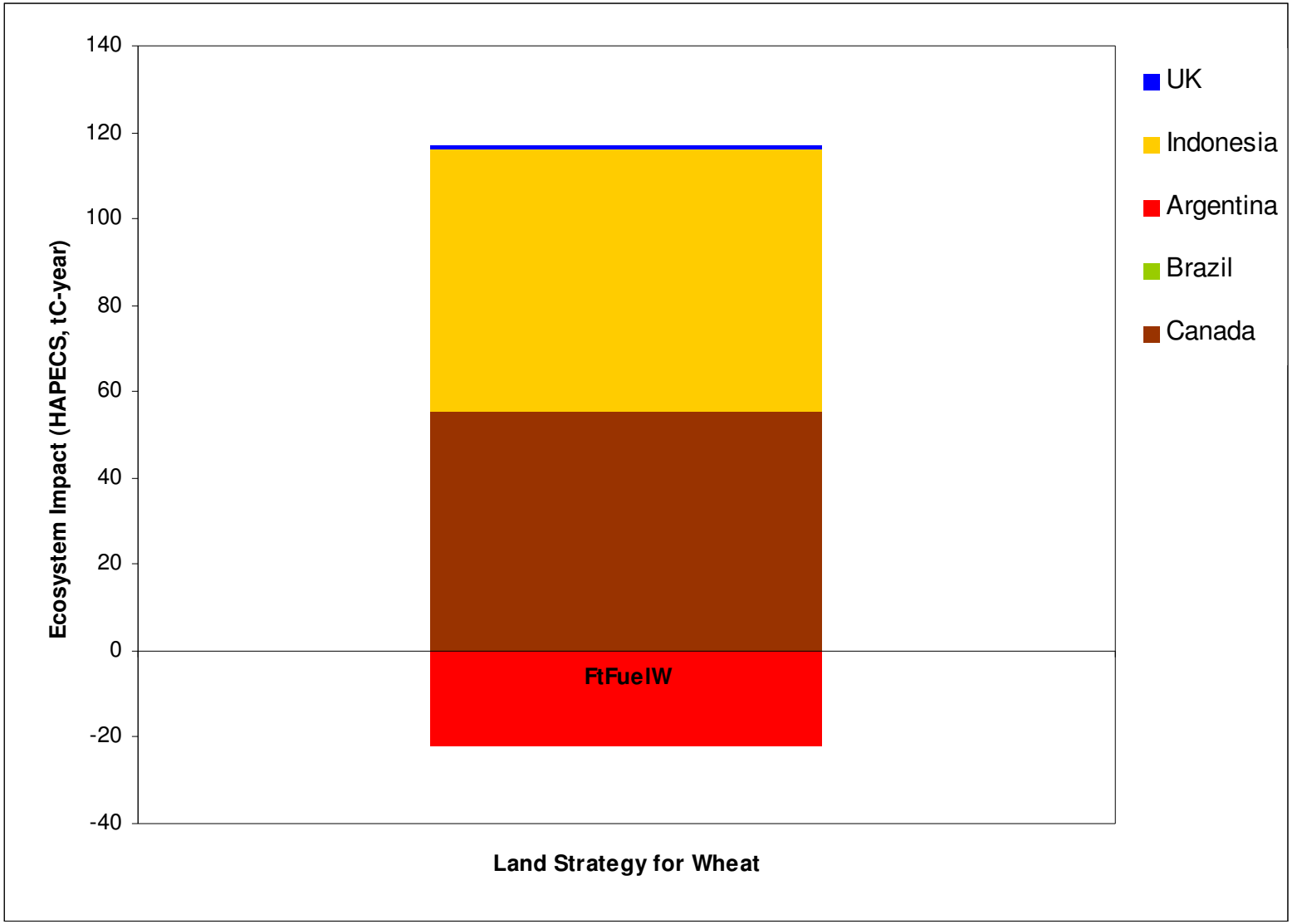
Allocating ILUC

YEAR	Yearly burden	Cumulative burden
1	9.75%	9.75%
2	9.25%	19.00%
3	8.75%	27.75%
4	8.25%	36.00%
5	7.75%	43.75%
6	7.25%	51.00%
7	6.75%	57.75%
8	6.25%	64.00%
9	5.75%	69.75%
10	5.25%	75.00%
11	4.75%	79.75%
12	4.25%	84.00%
13	3.75%	87.75%
14	3.25%	91.00%
15	2.75%	93.75%
16	2.25%	96.00%
17	1.75%	97.75%
18	1.25%	99.00%
19	0.75%	99.75%
20	0.25%	100.00%




15,000
10,000
5,000
0
-5,000
-10,000
kg CO2-eq./ha
UK foreground
Canada ILUC food
Indonesia ILUC food
Indonesia palm oil
Canada food wheat
Displaced gasoline
Argentina soybean meal
Canada feedwheat
Argentina ILUC feed
Canada ILUC feed
Net: 4,089 kg CO2-eq.

Land use impacts on Ecosystems



Interpretation & Concluding Remarks

- Changing wheat from food to fuel purposes
  - does not result in GHG savings!
  - reduces global ECS → biodiversity and ecosystem services
- Methods, methodological choices and uncertainties
  - Goal & scope and Inventory
    - Functional unit
    - System boundaries
    - Physical displacement
    - Land occupation impacts always > allocated land transformation impacts
    - Time-period
    - **Yields!!!**
  - Impact Assessment (Ecosystems and Climate)
    - Disruptions to carbon cycle
    - Time-period
    - All tonne-years are equal
- Better alternative to
  - CGE models?
  - attributional LCAs?

Brandão (2010) Food, Feed, Fuel, Forest or Carbon Sink: Can LCA Provide Guidance on How to Best Use Land for Climate-Change Mitigation? EcoBalance 2010, Tokyo, Japan.

Thank you!

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Radiative forcing (W/m^2), t CO_2e and t C*yr