Eco-systems of agricultural landscapes
and sustainable land use: Livestock systems

05 - Livestock Environment Interaction - 3
The Carbon Footprint

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Definition of the term “Carbon Footprint”

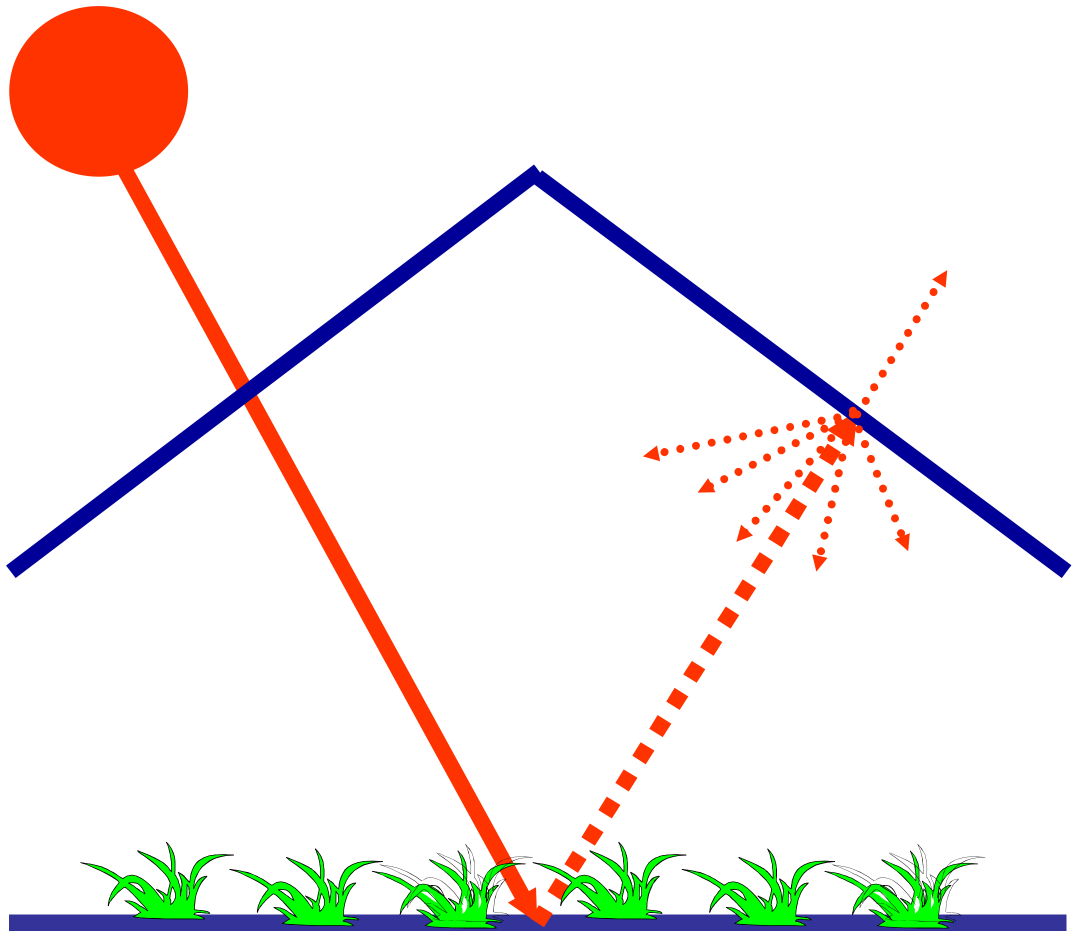
Carbon footprint has historically been defined as:

“The total set of greenhouse gas (GHG) emissions caused by an organization, event, product, process or person.”

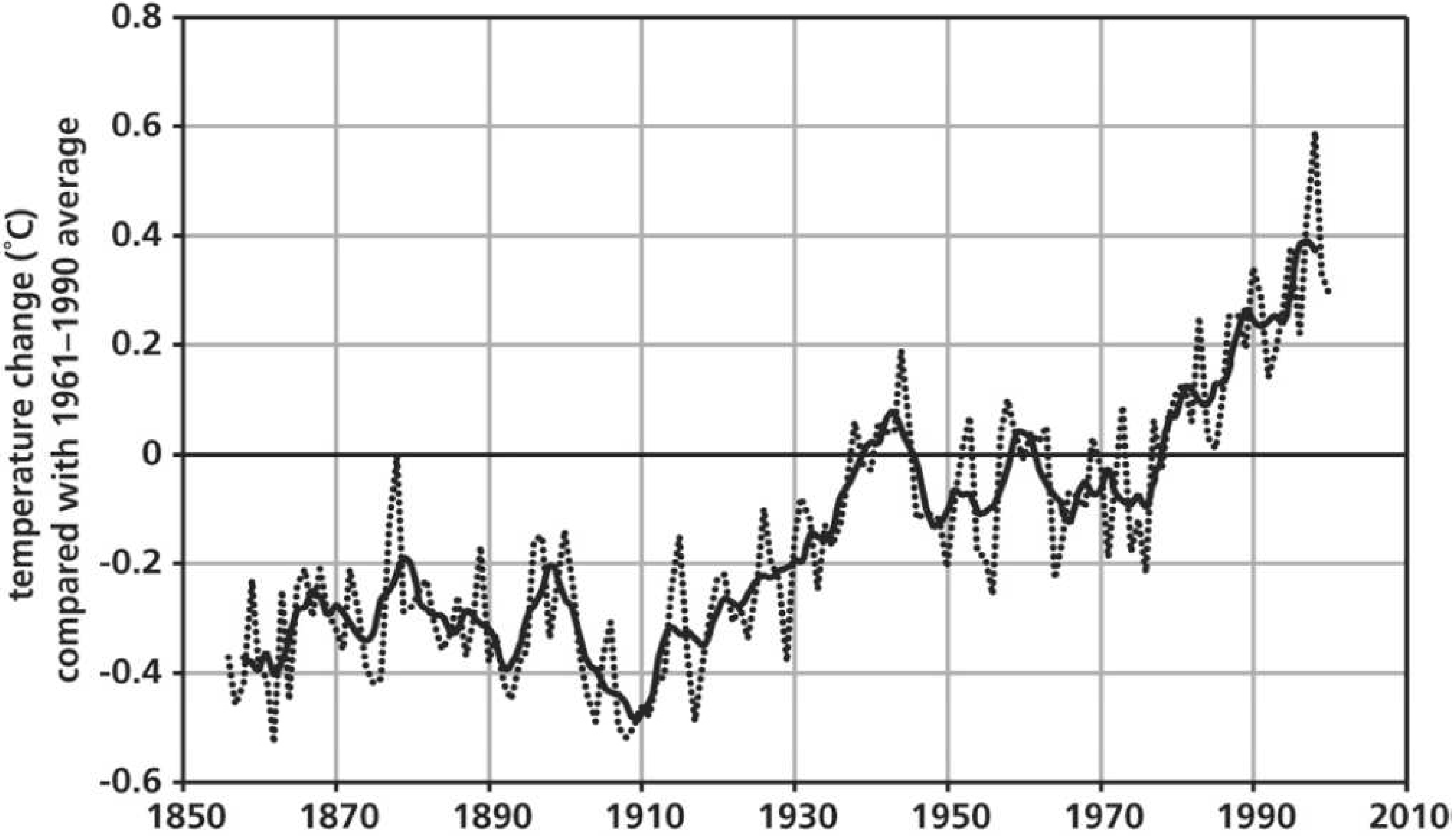
A more practicable definition has been suggested, which is gaining acceptance within the field:

"A measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as carbon dioxide equivalent (CO_2e) using the relevant 100-year global warming potential (GWP100).”

The Greenhouse Effect



Annual Global Warming since 1850



Mt Kilimanjaro, view from Mombasa Road, 1979

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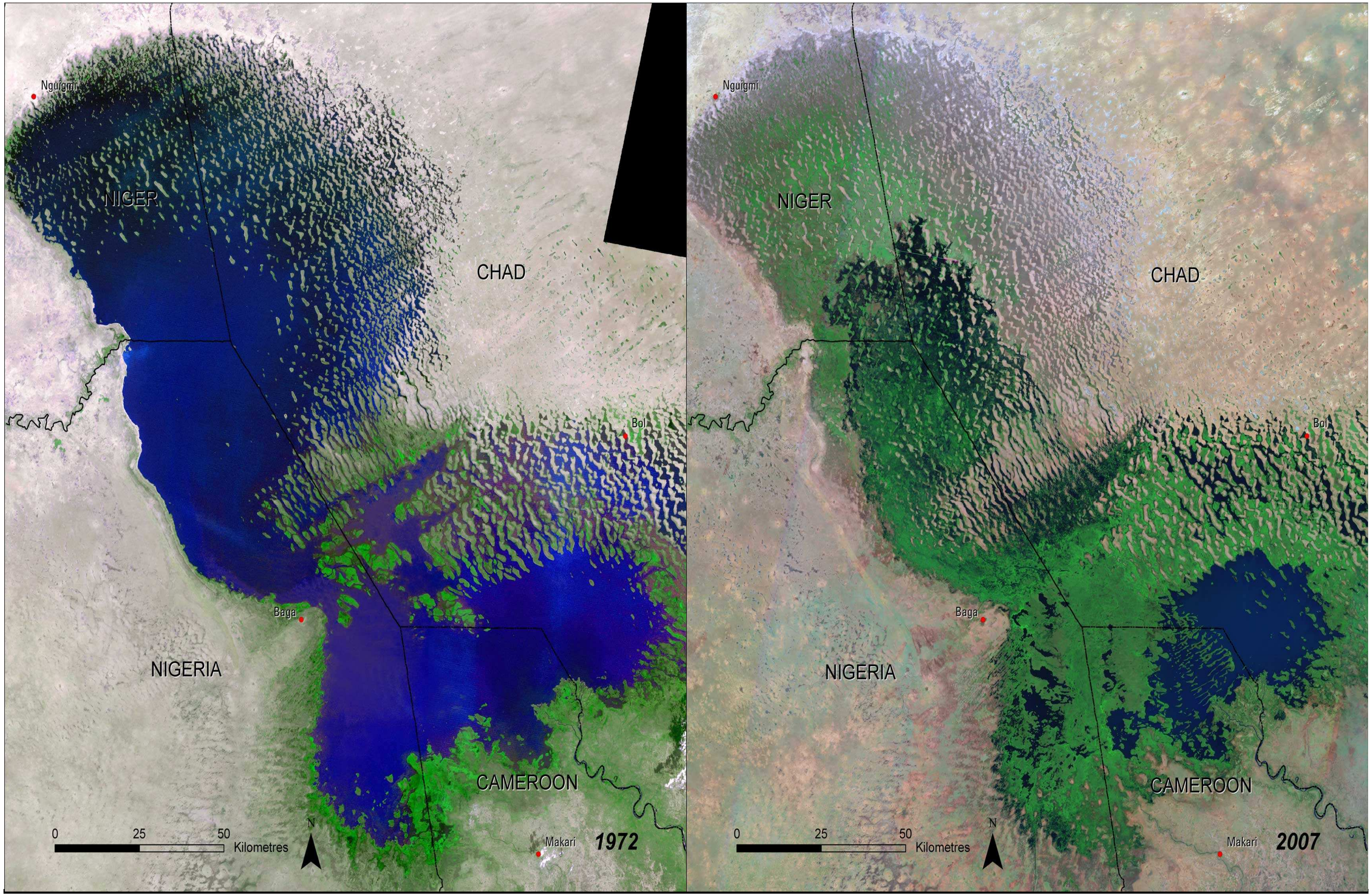
Mt Kilimanjaro, view from Mombasa Road, 2014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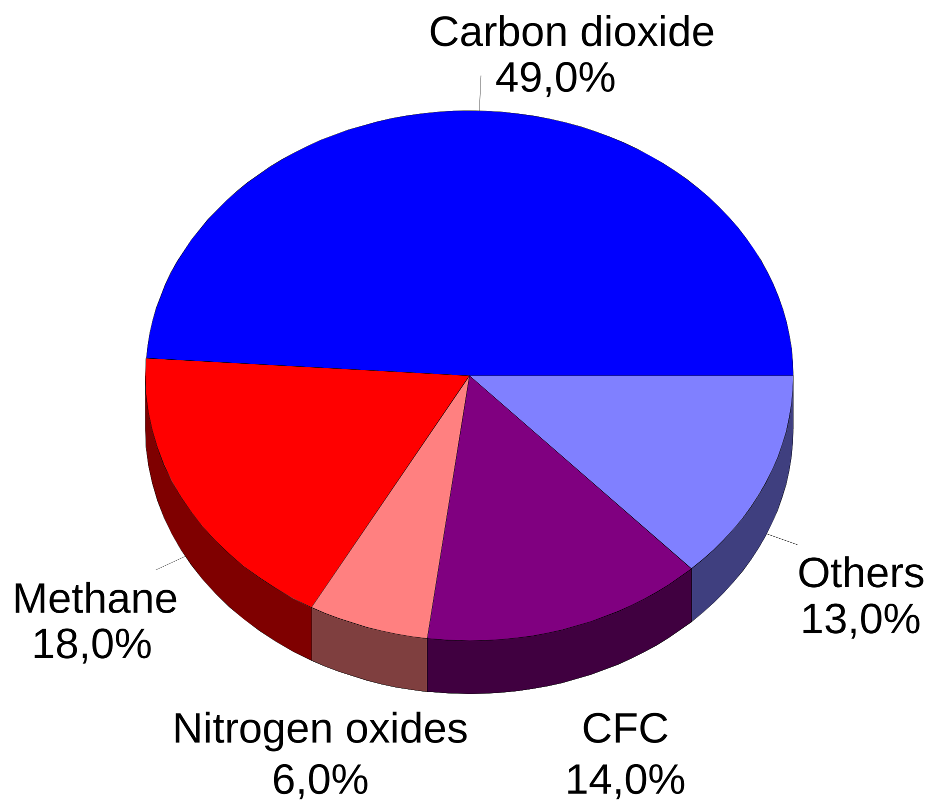
Proportional contribution of various „Greenhouse Gases“ to global warming



Source: Preston & World Resources Institute, 1996

Sources of direct and indirect agricultural greenhouse gases

Sources of agriculture	Million tonnes GHG CO_2-eq
Nitrous oxide from soils	2128
Methane from cattle enteric fermentation	1792
Biomass burning	672
Rice production	616
Manure	413
Fertiliser production	410
Irrigation	369
Farm machinery (seeding, tilling, spraying, harvest)	158
Pesticide production	72
Land conversion to agriculture	5900

Source: Cool Farming. 2008. www.greenpeace.org

Global warming potential of various greenhouses gases in carbon dioxide equivalents

Greenhouse Gas	100 year global warming potential
Carbon dioxide	1
Carbon dioxide as carbon	3.67
Methane	21
Nitrous oxide	310
Sulphur compounds	up to 23 900
Hydro fluorocarbons (HFC)	140 to 6300

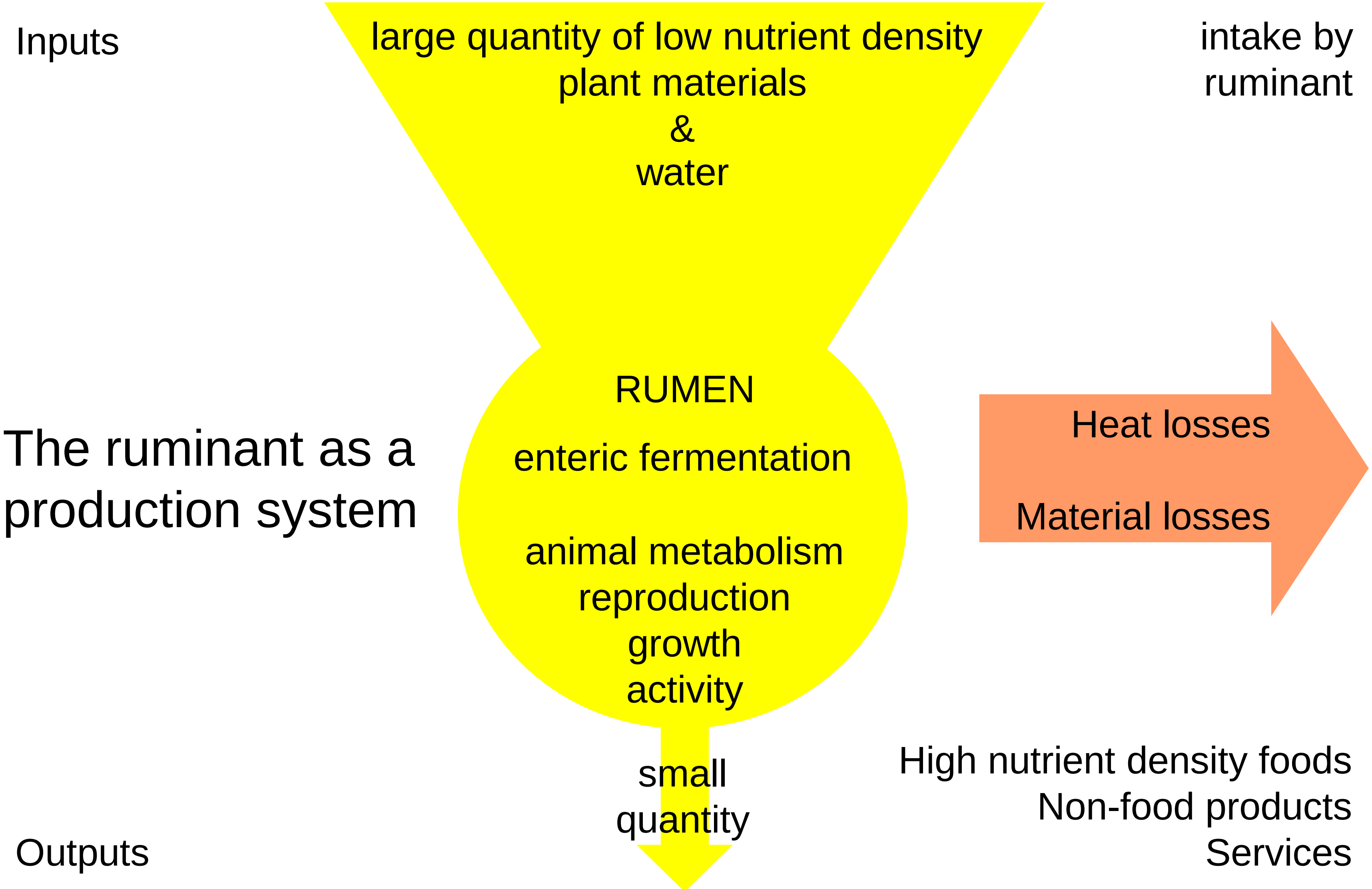
Source: http://www.defra.gov.uk/

Global warming potential of the main meat categories, milk, and selected plant products

Product	Global warming potential kg CO_2 eq. / kg product
Mutton	17.40
Beef	12.98
Pork	6.35
Poultry	4.57
Milk	1.32
Wheat (Bread)	0.80
Potato	0.21

Source: Cool Farming. www.greenpeace.org

The ruminant as a production system



Heat losses

Material losses

(Radiation)
(Convection)
(Conduction)

Evaporation (H_2O)

Faeces
Urine
Gases (CO_2, CH_4, NH_3)
(Products)

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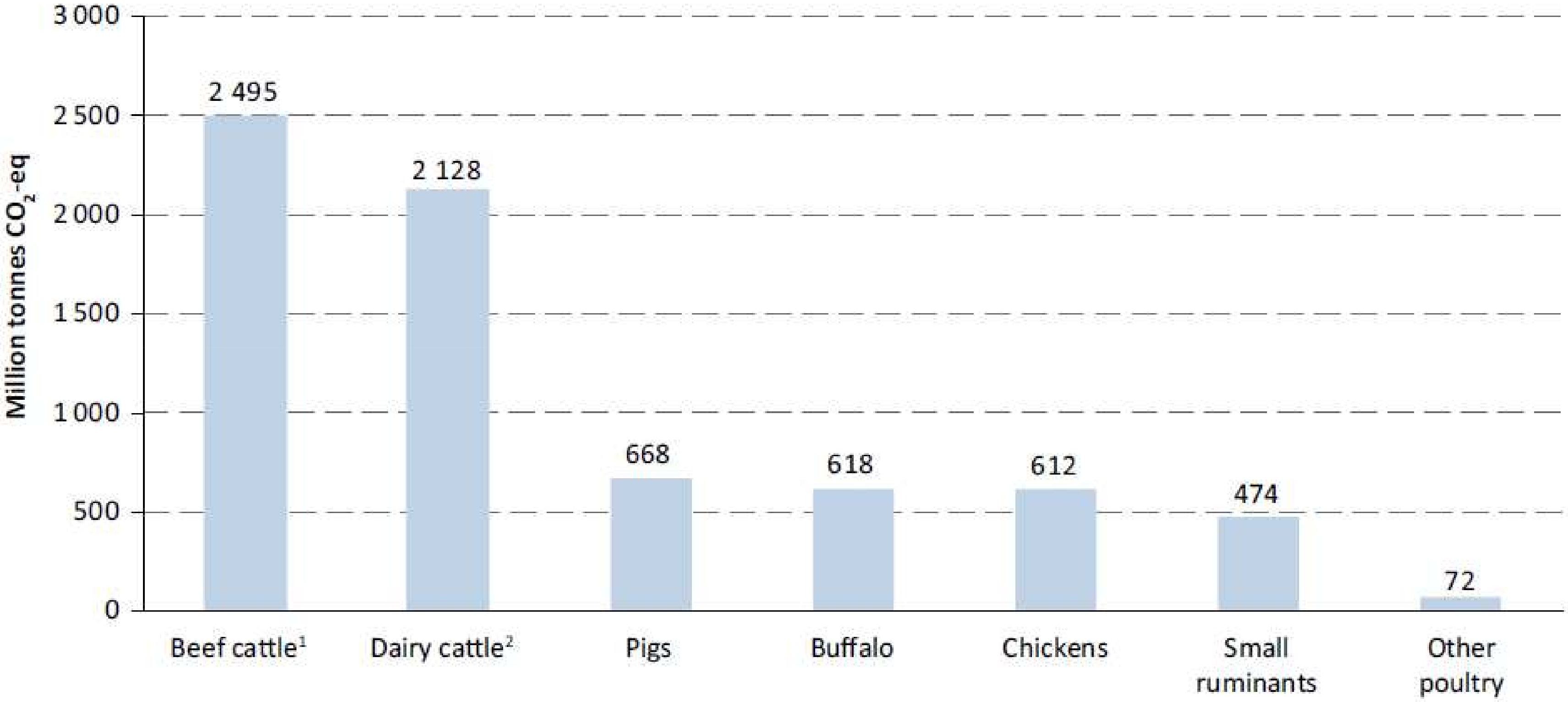
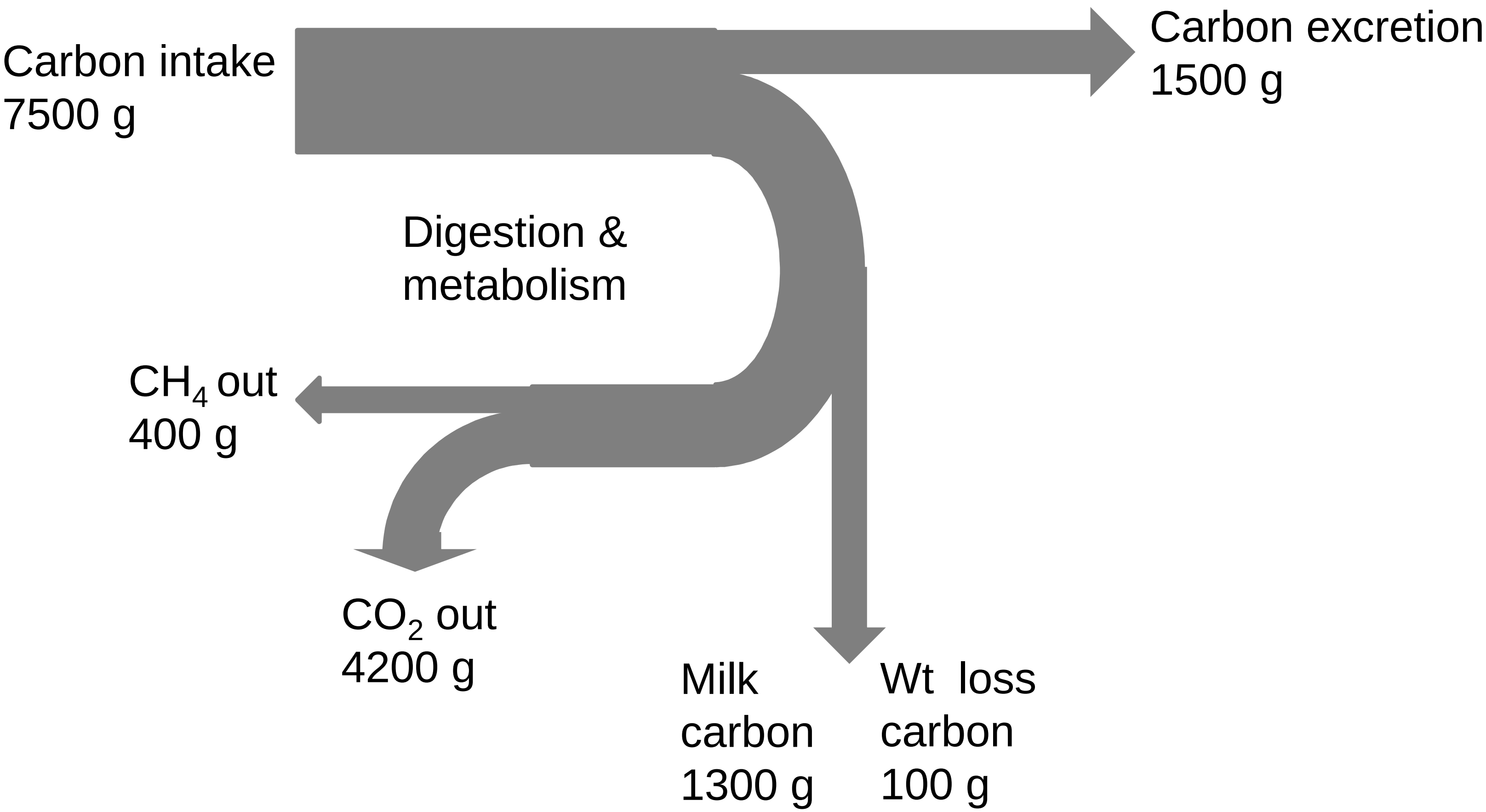
Global GHG emissions as CO_2-eqs from different livestock species [million tonnes/year by source]



Source: FAO GLEAM 2013

Daily carbon balance: Example of a dairy cow

feed intake 18 kg DM/day; 20 kg milk/day; 500 g weight loss/day



Dairy cow performance and CO_2 and CH_4 production

Cow live wt [kg]	Wt gain [g/day]	Milk production [l/day]	CO_2 production [l/day]	CH_4 production [l/day]
400	150	20	4156	249-416
400	100	30	5023	304-507
600	300	0	2897	199-331
600	300	20	4905	303-504
600	150	30	5978	363-605
600	0	40	6795	408-680

J. Madsen et al. / Livestock Science 129 (2010) 223–227
http://www.livepro-dc.life.ku.dk/~/media/LiveProDC/docs/pdf/Article%20by%20Madsen%20%20Methode.ashx

Climate affecting emissions from livestock production originate out of

- primary production
- secondary production
- cultivation of virgin land
- burning of agricultural biomass
- machine times
- agricultural transports
- international agricultural trade

Primary production: Carbon-dioxide, Methane, Nitrous Oxide

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Secondary Production: Carbon-dioxide,
Methane, Ammonia, Sulphur
Compounds, Dust

Annual methane losses from a model livestock production system: dairy farming in S.W. England

(102 cows, 110 others, stall feeding of silage and concentrate)

type of loss	total emission kg CH_4 - C $year^{-1}$
losses from ruminants	6775
losses from stored wastes	2285
losses from silage effluent	2596
losses from dirty water	332
total losses	11988

Source: after Jarvis & Pain, 1994

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Cultivation of Virgin Land: Carbon Dioxide, Methane, Nitrous Oxides, Ozone, Ash, Black Soot

M.Sc. Integrated Natural Resource Management
Ecology and Sustainable Livestock Systems
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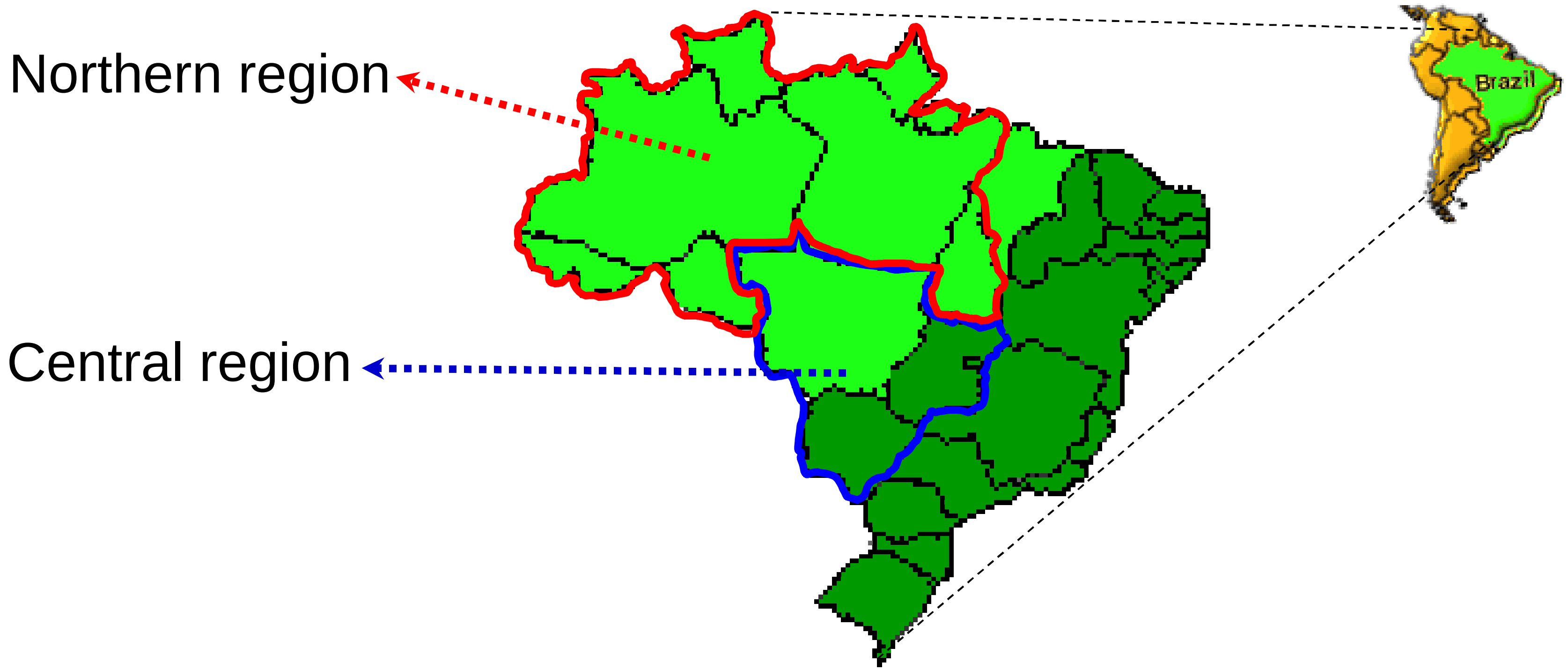
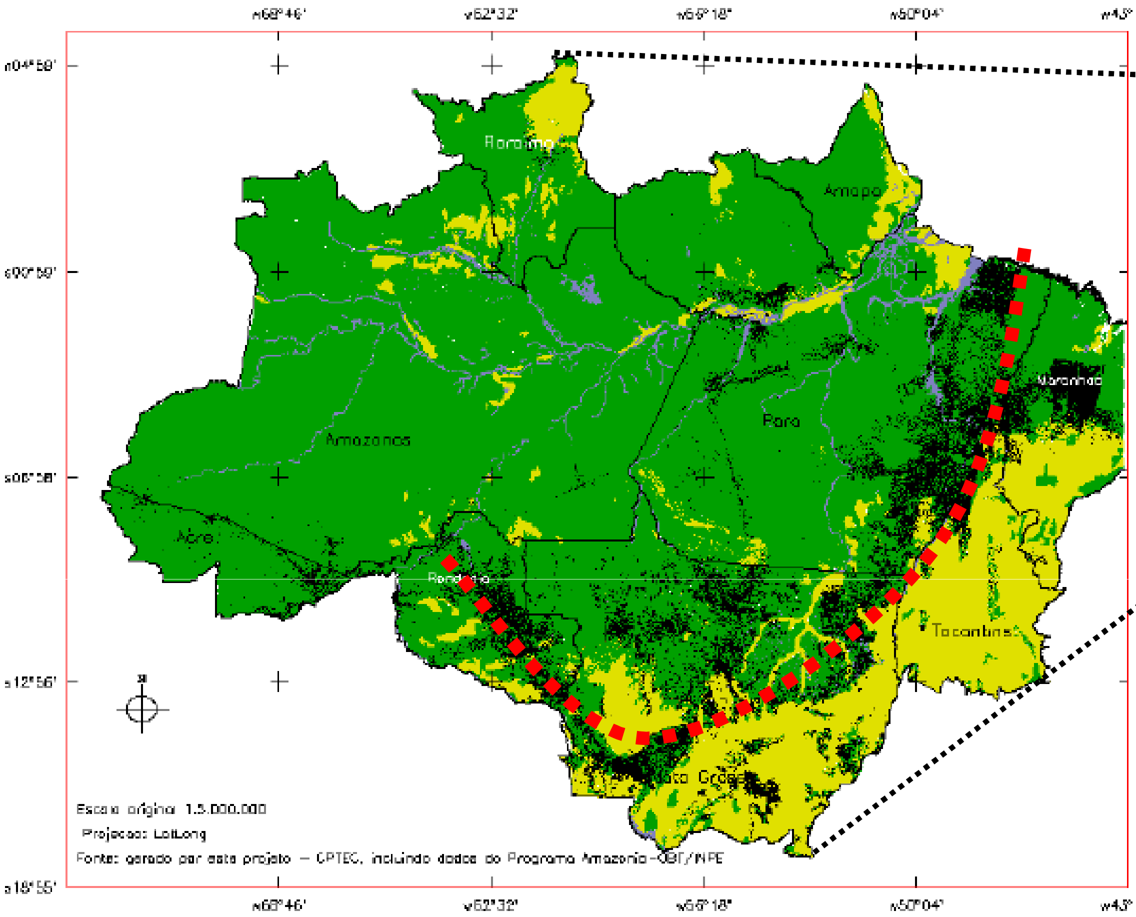
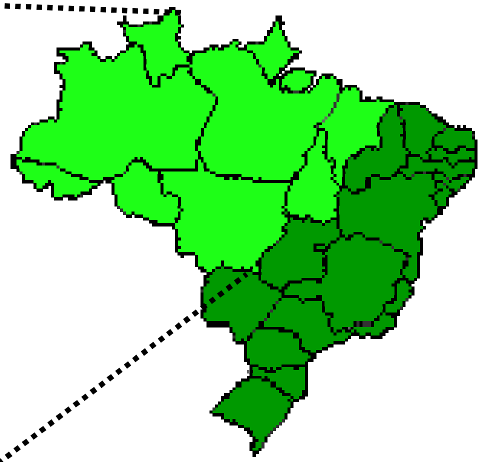
Agricultural expansion in Brazil



Dependence on agricultural exports
Beef exports are fastest growing commodity
Herd growth concentrated in Central and Northern Brazil

Source: D. Bungenstab, 2004



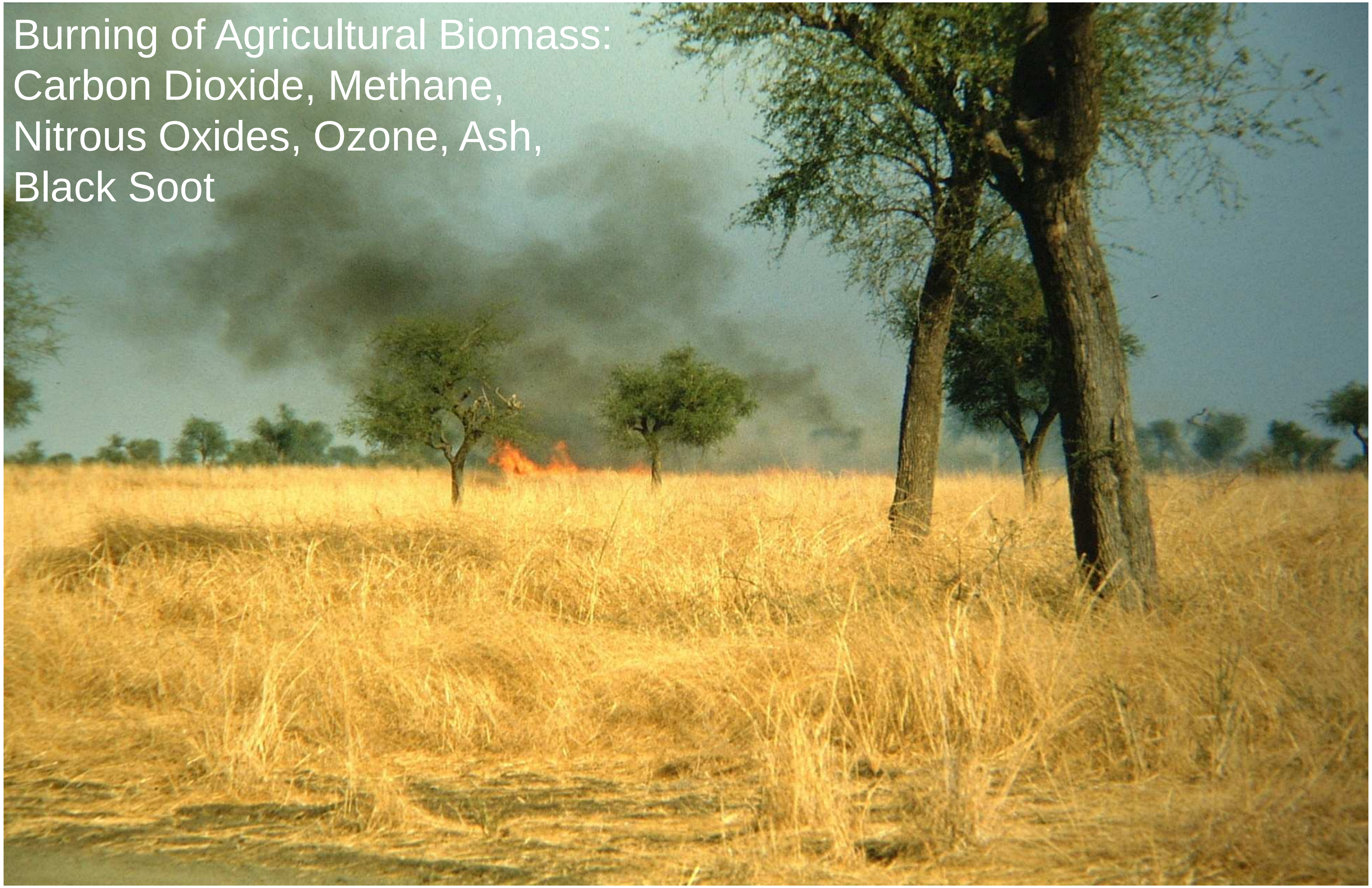


Deforestation:
20000 km² • yr^{-1}
50 to 60% for
cattle ranching

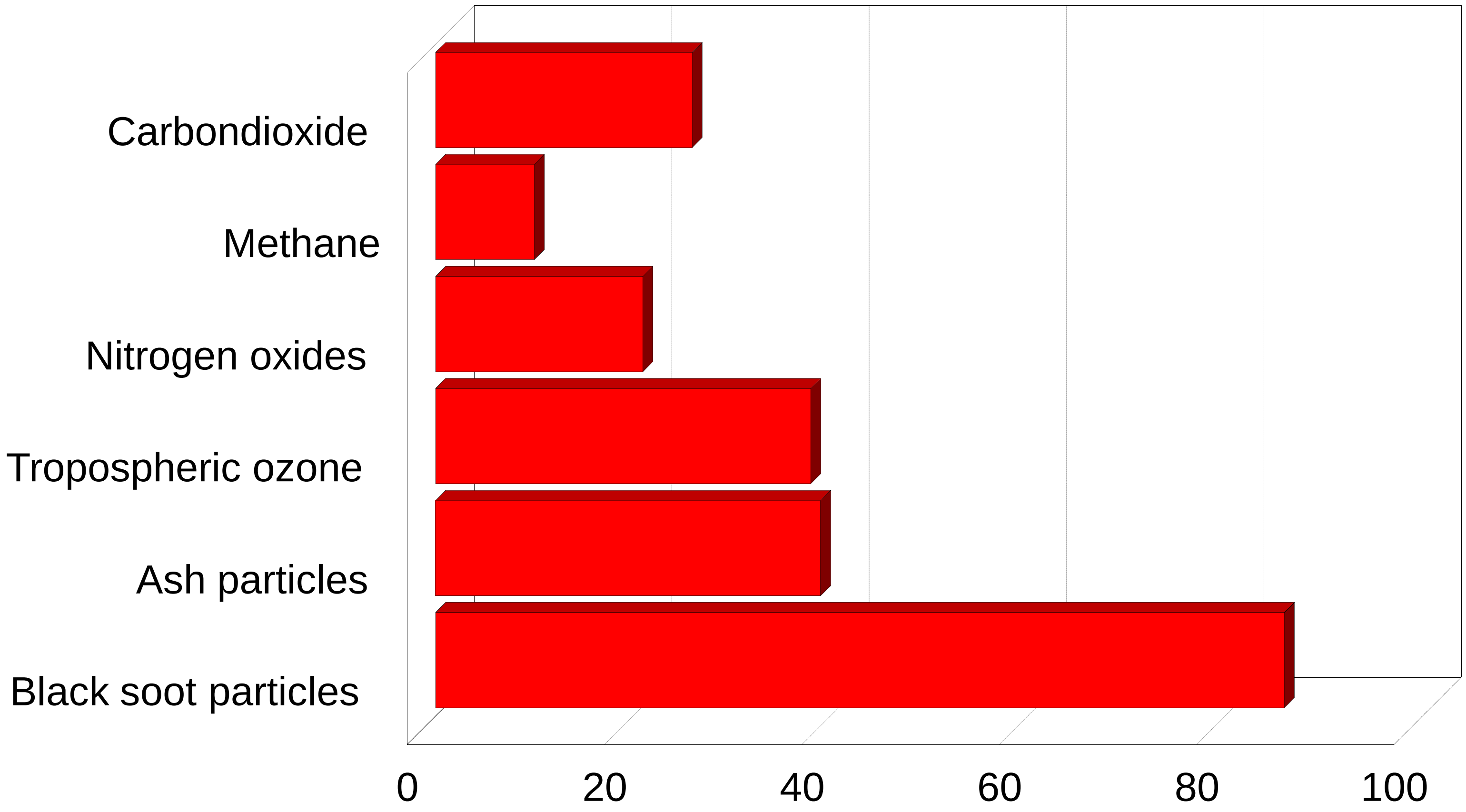
Rainforest   Cerrado   Deforestation

Source: D. Bungenstab, 2004

Burning of Agricultural Biomass: Carbon Dioxide, Methane, Nitrous Oxides, Ozone, Ash, Black Soot

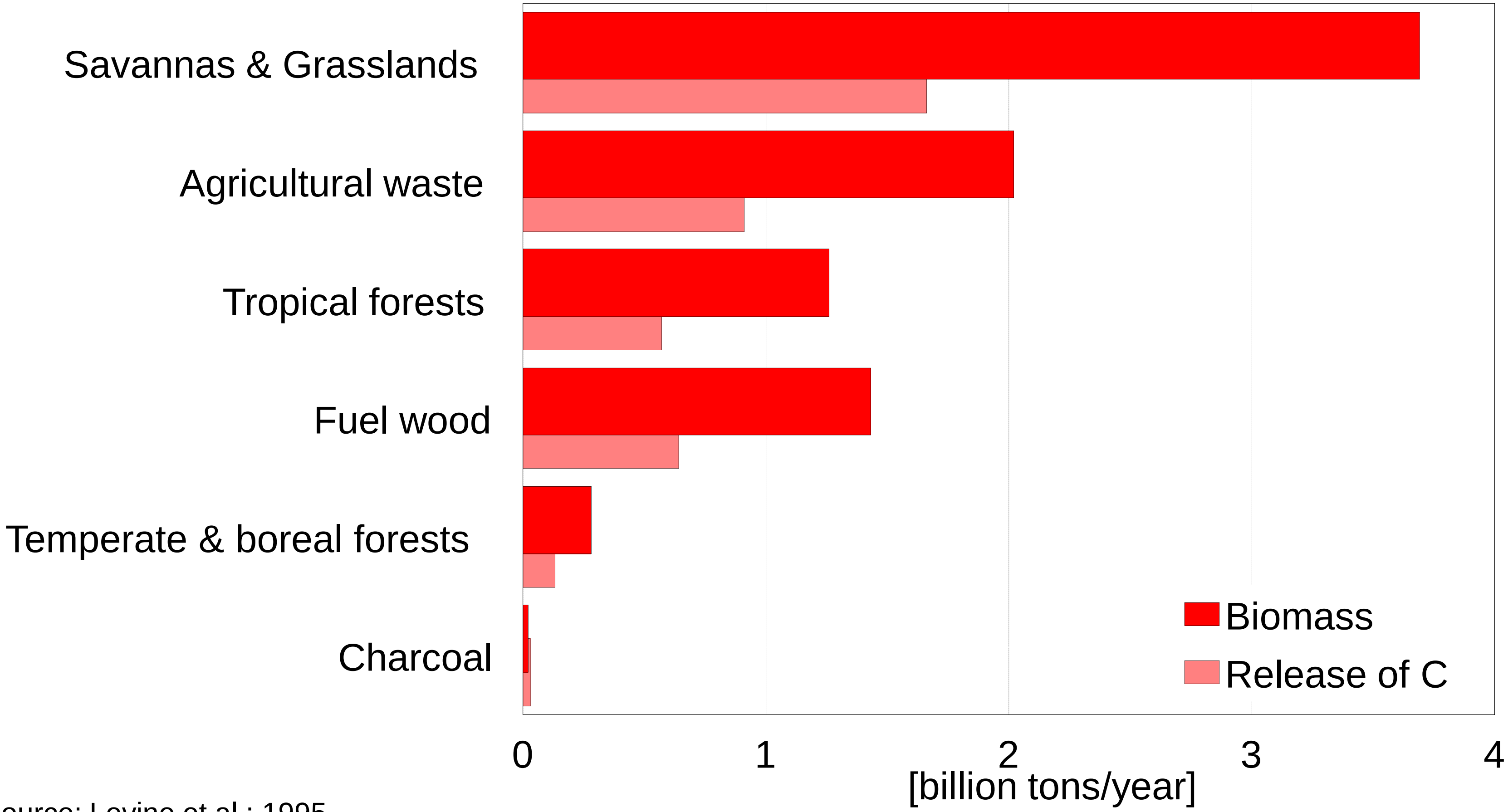


Relative contribution of biomass burning to various climate affecting emissions [% of all emissions]



Source: Levine et al.; 1995

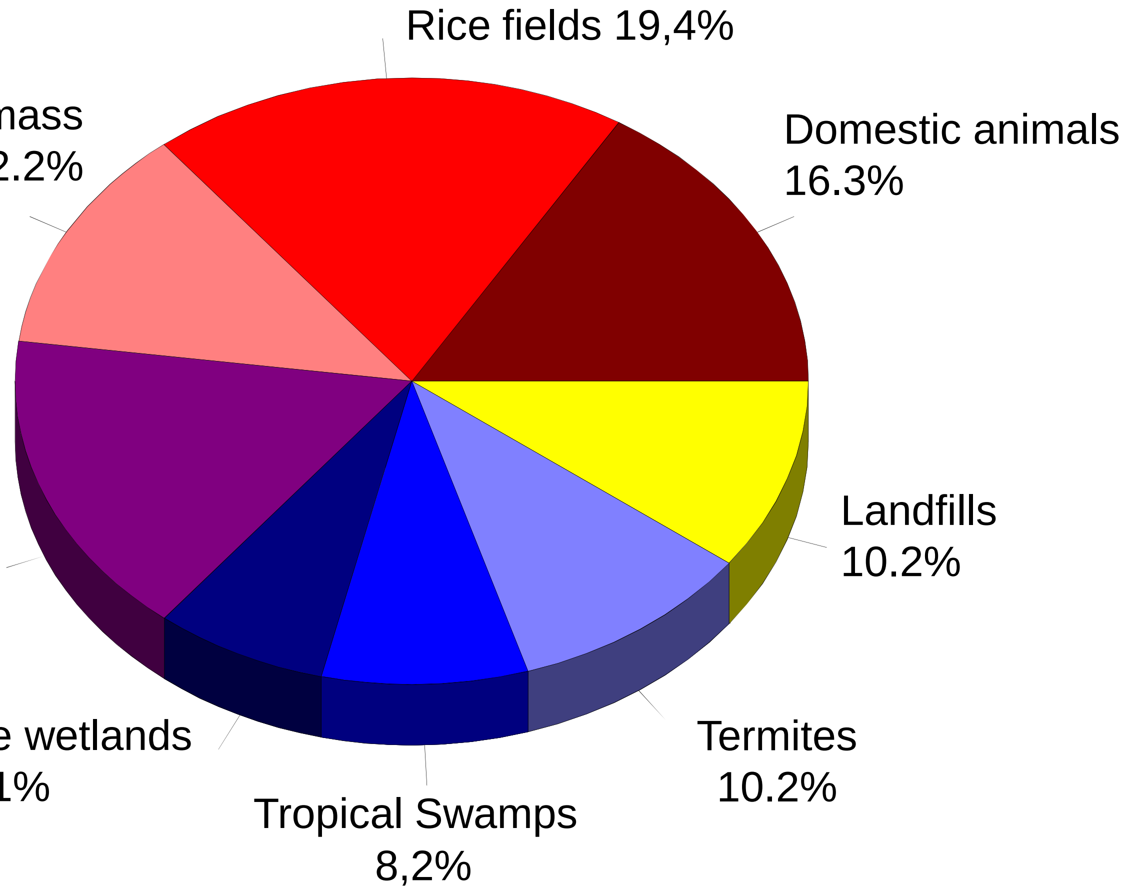
Contribution of burning various types biomass and the resulting release of carbon into the atmosphere



Source: Levine et al.; 1995


Local machine times and agricultural transports:
Carbon Dioxide, Sulphur Compounds, Black Soot

Proportion of various sources in the global methane emission



Enteric fermentation CH_4 emission levels of ruminants are affected by:

- animal species and genotype
- animal age and nutritional status
- animal performance level

- feed availability and intake level

- feed quality
  - nutrient density, digestibility, protein-energy ratio
  - seasonal variation
  - botanical composition
  - pasture and range management

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Enteric fermentation CH_4 emission from dairy cattle in relation to average milk yield per cow

Region	Kg CH_4/head/year	Kg Milk/head/year	Kg Milk/Kg CH_4
North America	118	6700	57
Western Europe	100	4200	42
Eastern Europe	81	2550	32
Oceania	68	1700	25
Latin America	57	800	14
Asia	56	1650	29
Indian Subcontinent	46	900	20
Africa and Middle East	36	475	13

Source: IPCC Guidelines for National Greenhouse Gas Inventories and Authors' Calculations

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Manure management systems affecting loss of CH_4, N_2O, trace gases

Liquid systems

- with storage lagoons
- with storage pits or silos
- with forced drying and grinding
- with biogas production

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Manure management systems affecting loss of CH_4, N_2O, trace gases

Solid systems

- with or without bedding, dry stockpiling
- with or without bedding, composting
- with fuel use

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Manure management systems affecting loss of CH_4, N_2O, trace gases

Pastoral systems

- with partial collection for fuel use
- with complete spreading by grazing stock

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Manure management CH_4 emission factors [kg CH_4/head/year] for dairy cattle in relation to region and climate type

Climate type Region	Cool	Temperate	Warm
North America	36	54	76
Western Europe	14	44	81
Eastern Europe	6	19	33
Oceania	31	32	33
Latin America	0	1	2
Asia	7	16	27
Africa and Middle East	1	1	2
Indian Subcontinent	5	5	6

Source: IPCC Guidelines for National Greenhouse Gas Inventories

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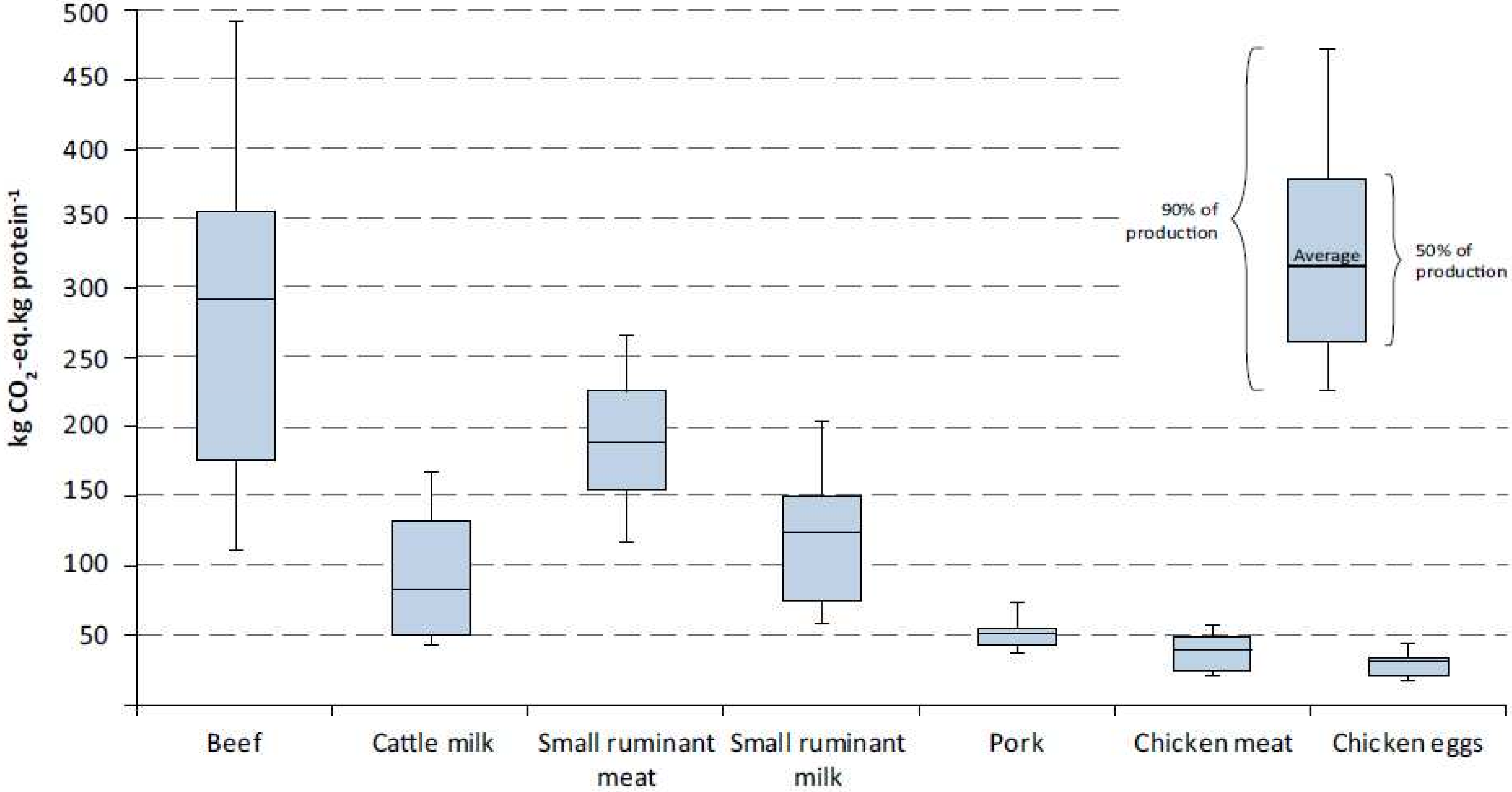
Global GHG emission intensity [kg CO_2-eqs/kg product] for different commodities



Source: FAO GLEAM 2013

Mitigation options for livestock related GHG emissions

Biological emission controls

- dietary manipulation
- feed utilisation efficiency
- grazing management
- biological treatment of feed
- health programmes
- selection and breeding
- control of ruminal microbes

Land use changes

- reducing land clearances
- ICLF Systems
- carbon sequestration

Technical emission controls

- livestock housing
- ventilation control
- storing and handling of manure
- manure application to land
- biogas production
- reduction of N-leaching
- mechanical treatment of manure

Economic emission controls

- emission taxes
- consumption taxes
- product taxes
- subsidies for clean production
- emission quotas
- transferable emission quotas

Legal emission controls

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Three strategies to cope with the consequences of projected global warming

I Avert further global warming

II Slow down global warming to give time to develop strategies to cope with the consequences

III Accept whatever warming occurs and concentrate on development of adaptive strategies

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Projected consequences of global warming for agriculture

(doubling atmospheric CO_2-content, temperature increase 1.5 to 5^0C)

Shift of eco-climatic zones several 100 km towards the poles;

- considerable widening of the tropical/subtropical dry belts;
- substantial loss of agricultural land;
- widespread permanent flooding of coastal areas due to rise in sea levels;
- slow but inevitable breakdown of temperate and boreal forest ecosystems with additional release of CO_2;
- uncertain effects of increased CO_2 on abundance and vitality of pests and weeds;
- resultant catastrophic decrease of agricultural production.

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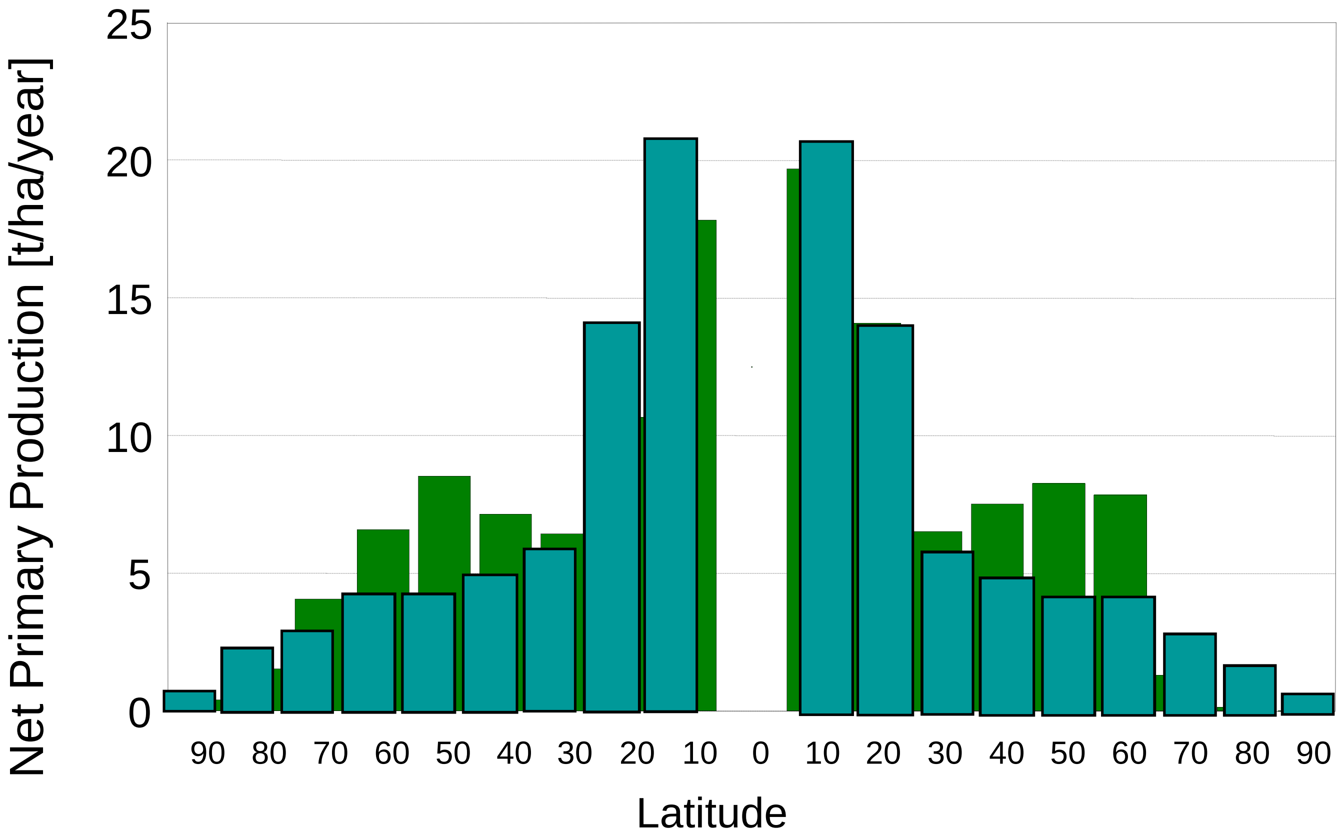
Estimated Net Primary Production (NPP) of all natural vegetation in latitudinal belts of 10° before and after global warming



Source: Pearson, C.J. & Ison, R.L. 1987, modified

Necessary adaptations of agricultural production systems to projected climate change

(doubling of CO_2 – concentration)

Irrigation agriculture (tropics)	none
Rainfed crop production (humid tropics)	none
Rainfed crop production (dry tropics)	flexible planting times, different cultivars, different cultivation techniques, water harvesting
Perennial crops, plantations (dry tropics)	water harvesting, change of crops, different cultivation techniques
Pasture based livestock production (dry tropics)	possibly change of herbivore species and/or breed, flexible stocking densities, increased mobility
Rainfed crop production (temperate zones)	irrigation, different cultivars, different planting times, different cultivation techniques
Crops under glass	none
Pasture based livestock production (temperate zones)	decreased and highly flexible stocking densities
Intensive livestock production indoors	none

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Three strategies in the adaptation of agriculture to climate change

- to determine whether new cultivars, crops, and management practices can be developed that can thrive under the new conditions,
- to see whether farmers will adopt the new cultivars, crops or management practices,
- To experience the response of the market to changes in supply

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Three types of uncertainty delaying management and policy decisions

(1) Uncertainty due to lack of information

(2) Uncertainty due to lack of understanding

(3) Uncertainty due to lack of determination

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