Energy budget, Carbon Footprint of Agricultural Products - A Measure of the Impact of Agricultural Production on Climate Change

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Energy Resources

(a) Renewable energy is the energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.

(β) Non-renewable energy resource (also called a finite resource) is a resource with economic value, that cannot be readily replaced by natural means, at a quick enough pace to keep up with consumption. An example is carbon-based fossil fuels (coal, petroleum, natural gas).

Energy Resources

(a) Until the middle of the 19th century

Exclusively renewables

- Plant materials (Phytomass)
- River flow
- Wind
- Animal force
- Rare non-renewable sources (e.g. coal)

Energy Resources

(b) From the mid 19th century and after

Mostly non-renewables

- ✓Fossil fuels
- ✓Nuclear

Problems

- ✓Fossil fuels (green-house gas emissions, air pollution, acid rain, water pollution, soil pollution)
- ✓Nuclear energy (radioactive waste risks, e.g. Chernobyl – Fucushima)

Renewable Energy Resources

Advantages

- Renewable energy won't run out
- Maintenance requirements are lower
- Renewables save money
- Renewable energy has numerous health and environmental benefits (without pollutants)
- Renewables lower reliance on foreign energy sources

Disadvantages

- Higher upfront cost (the technologies until now are typically more expensive).
- Intermittency (Though renewable energy resources are available around the world, many of these resources aren't available year-round).
- Storage capabilities (is expensive).
- Geographic limitations (for example Greece has a diverse geography varying micro-climates, topographies, vegetation, and more).

Non-renewable Energy Resources

➢ Advantages

- Easy to transport and store
- Easily accessible
- Can be efficiently converted to the type of energy required
- Available throughout the year unlike solar energy or water energy

➢ Disadvantages

- Produces greenhouse gases
- Its by products cause damage to the environment
- Once exhausted they are not easily replenished
- Its residual products are generally non-biodegradable
- Its products pose potential threat to human health
- Responsible for acid rain

Renewable energy resources today

- Hydroelectric
- Solar
- Wind
- Phytomass
- Sea waves - Tidal (difficulties in use)

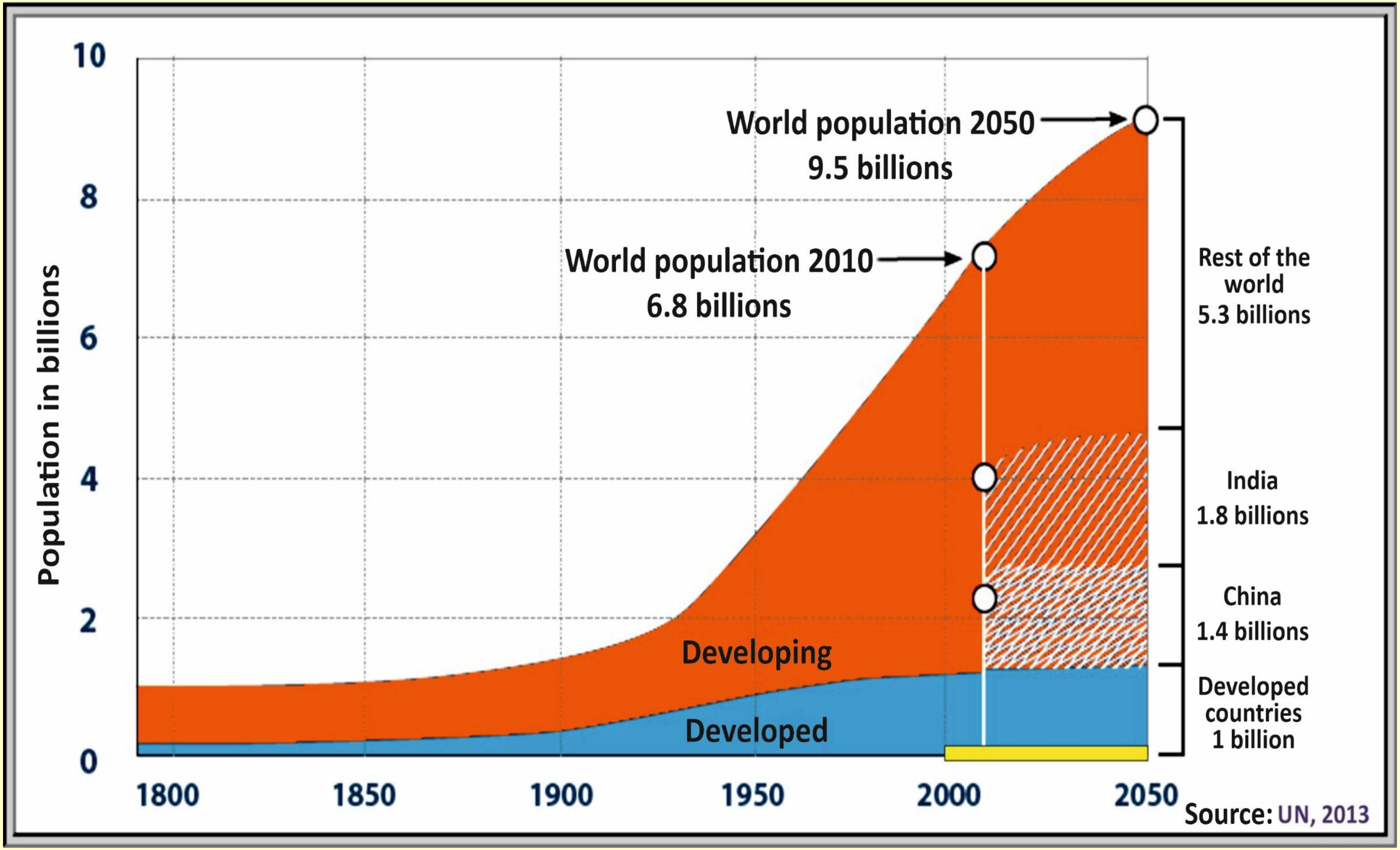
Conclusions

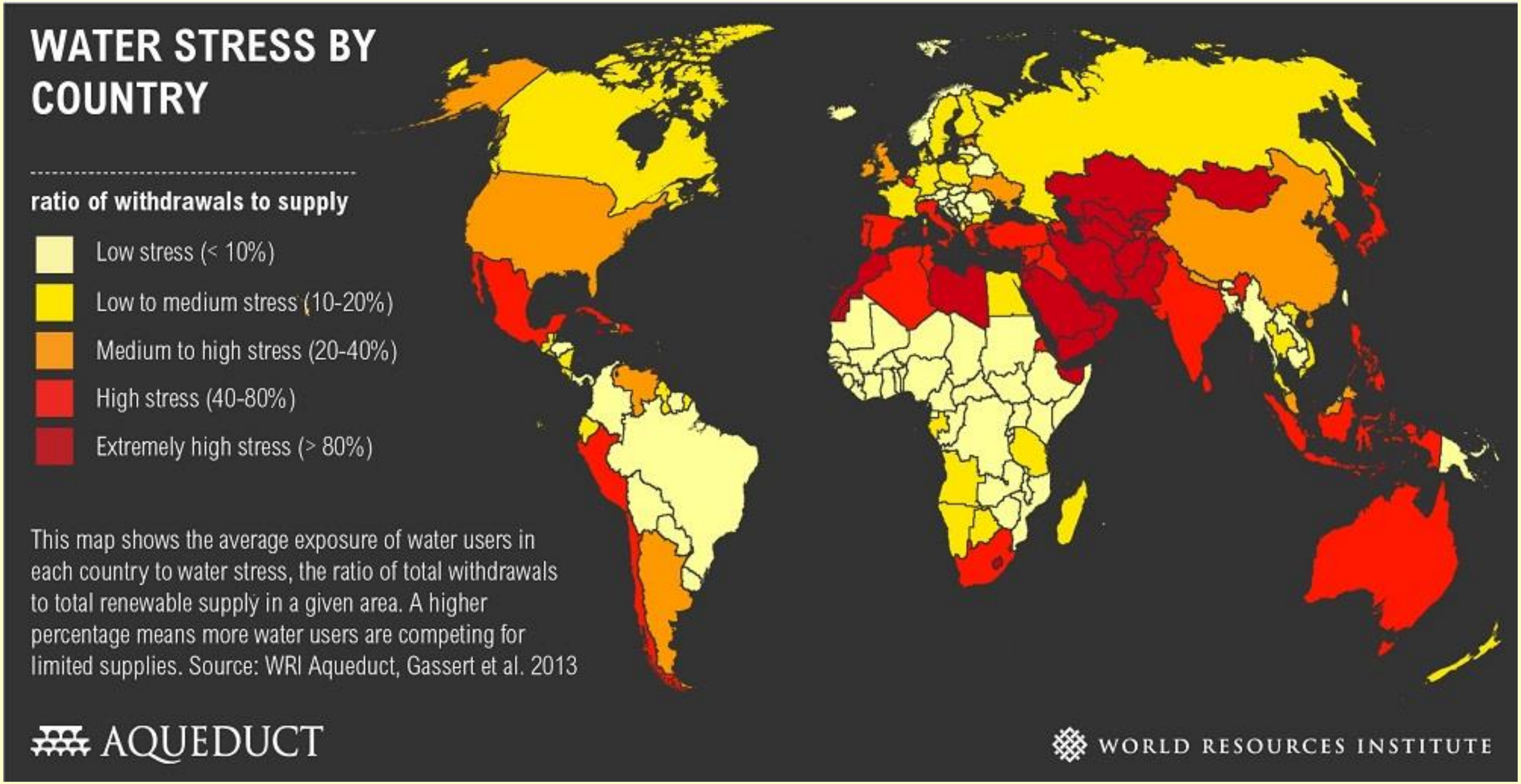
- High dependence on fossil fuels
- Prudent use: two approaches

a. reduction of energy use

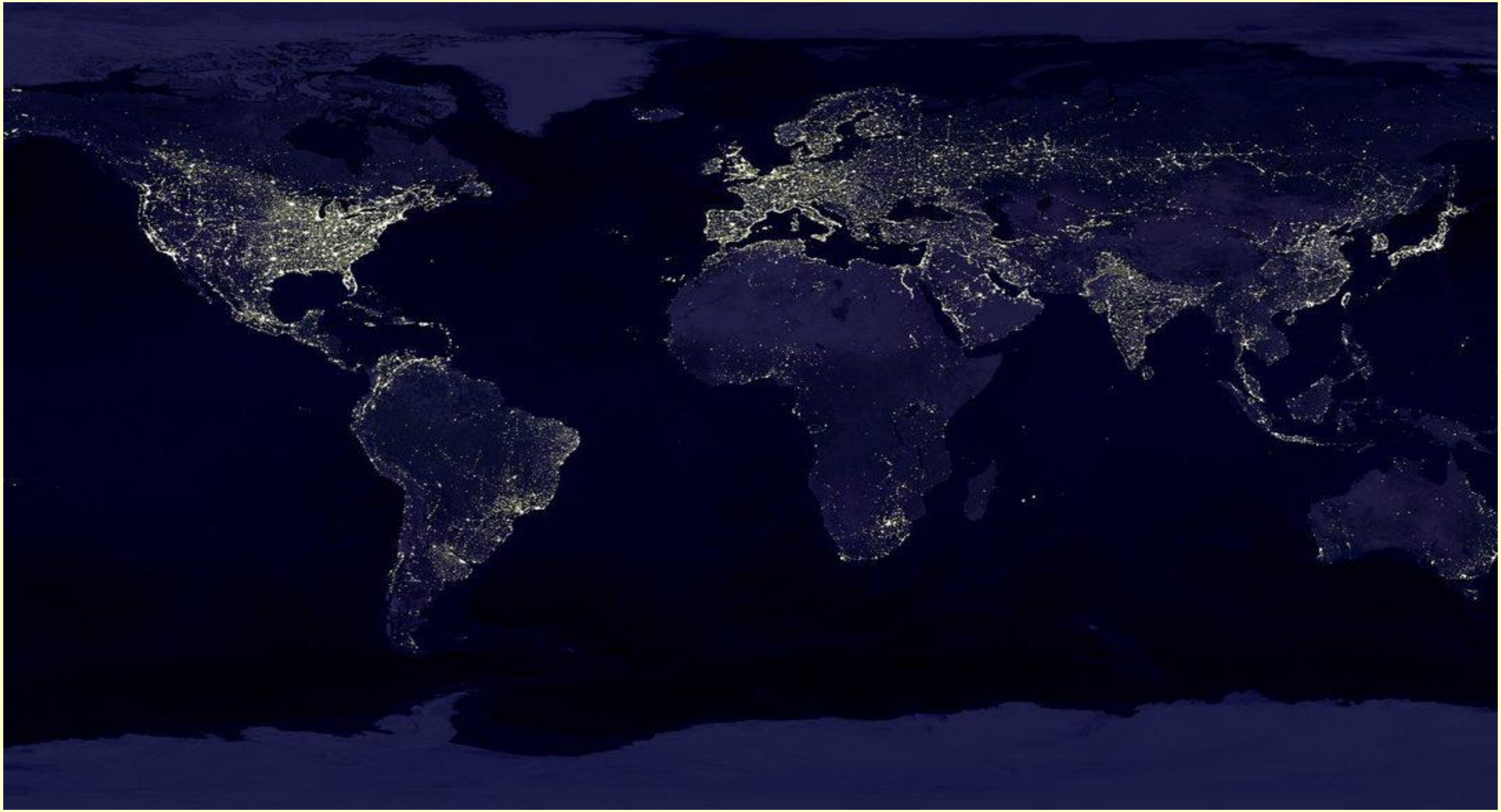
b. more efficient use of energy

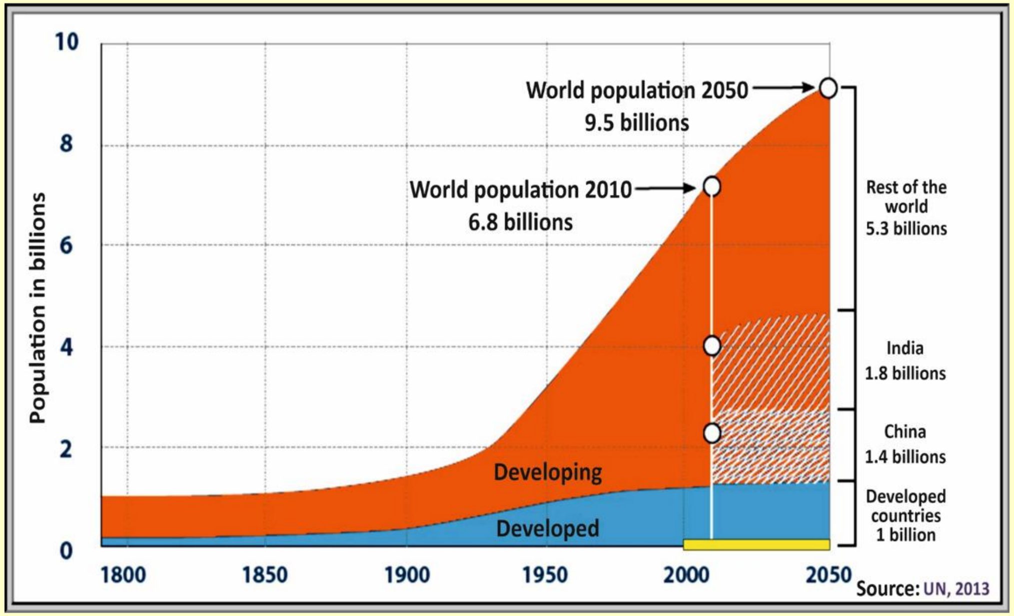
Main message is saving energy: the big resource


World population 2050
9.5 billions
World population 2010
6.8 billions
Population in billions
10
8
6
4
2
0
1800
1850
1900
1950
2000
2050
Developing
Developed
Rest of the world
5.3 billions
India
1.8 billions
China
1.4 billions
Developed countries
1 billion
Source: UN, 2013

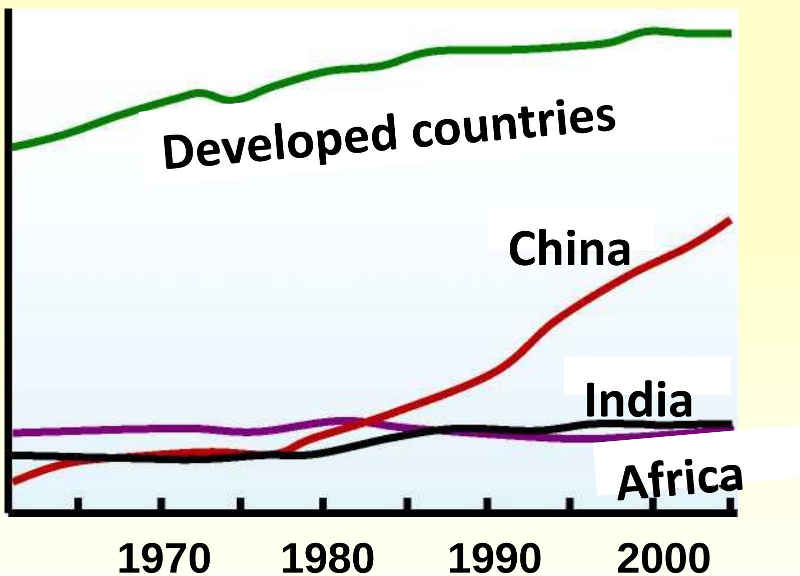

WATER STRESS BY COUNTRY
ratio of withdrawals to supply
Low stress (< 10%)
Low to medium stress (10-20%)
Medium to high stress (20-40%)
High stress (40-80%)
Extremely high stress (> 80%)
This map shows the average exposure of water users in each country to water stress, the ratio of total withdrawals to total renewable supply in a given area. A higher percentage means more water users are competing for limited supplies. Source: WRI Aqueduct, Gassert et al. 2013
AQUEDUCT
WORLD RESOURCES INSTITUTE

The Earth at night (Nasa, 2018)





Consumption of animal products (FAO)



Global Nutrition System 1970-2050

- Restrictions on growth and the population "bomb"
- Overproduction in the developed people
- Reduce or eliminate malnutrition in the developing world
- "Green revolution"
- Washington consensus

Conclusions

- ✓ The food production system enters unexplored waters: the past is a guide for the future
- ✓ Action is required on many fronts
- ✓ Sustainable intensification (even if we call it something else)
- ✓ Increase investment in agricultural sciences and converting low technology to high
- ✓ Change in thinking about consumption
- ✓ Integrated Assurance System in Primary Agricultural Production GLOBAL GAP

If we fail to produce food we will fail in all

Everything flows, nothing is left behind (Heraclitus)

Τα πάντα ρει και ουδέν μένει

Agriculture is affected by Changing climate

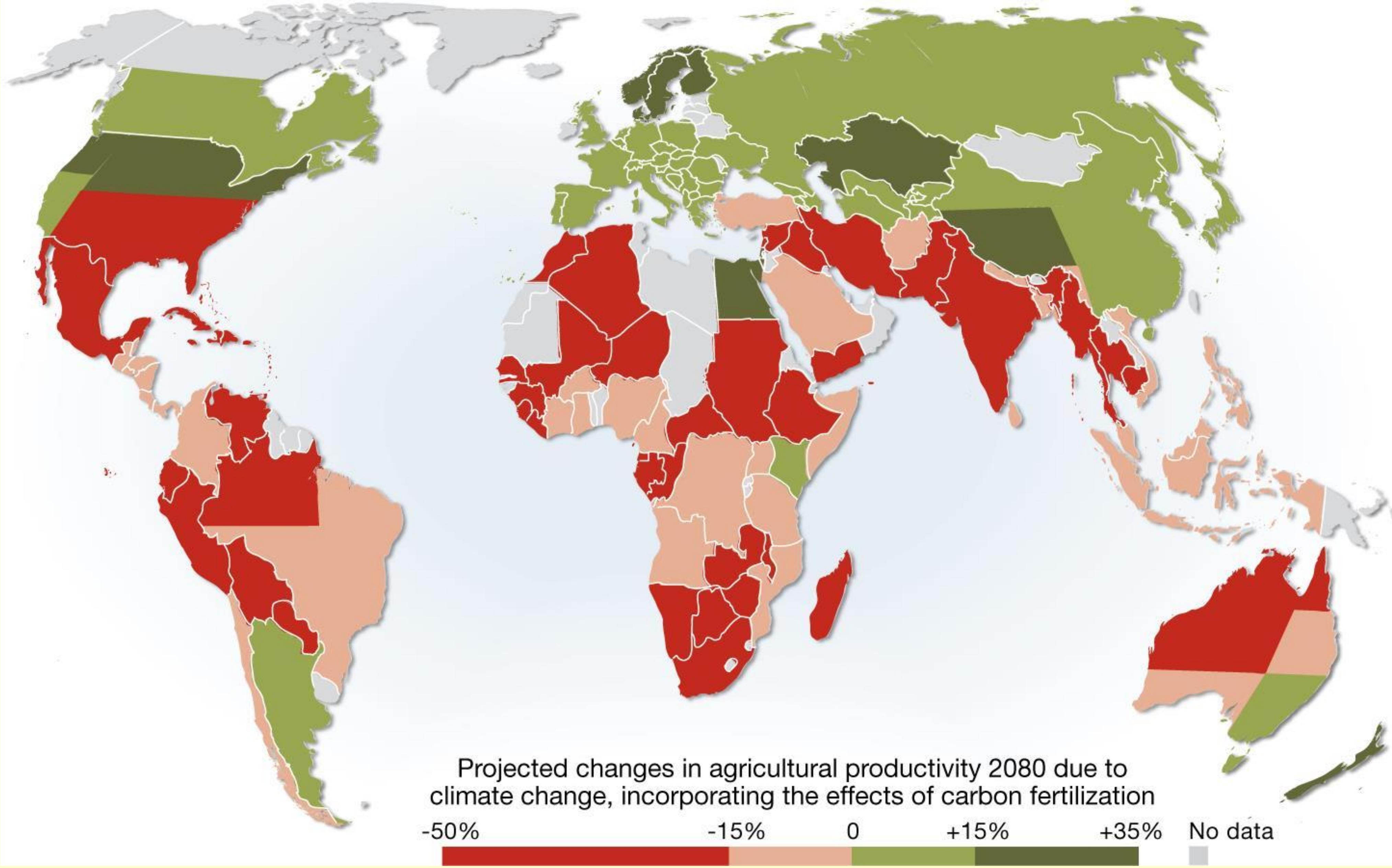
- ✓ Increase of drought periods
- ✓ More heat waves
- ✓ Heavy rain
- ✓ Dissemination of enemies, diseases, etc.

Decrease in yields (up to 75%), quality and safety

Agriculture is affected by climate change

↓

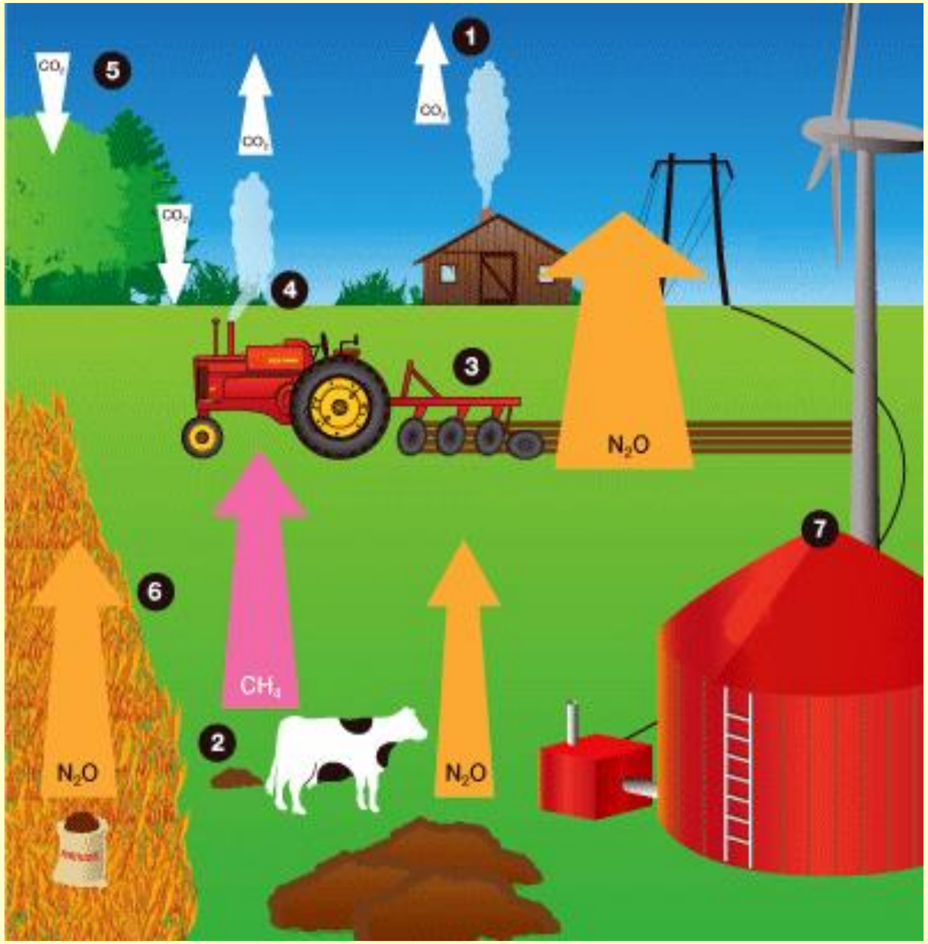
Decreases in yields (up to 75%), quality and safety



Source: UNEP 2019

Emissions of greenhouse gases by activity in the EU (Eurostat, 2016)

25.0 % Electricity production
11.0 % Transportation
20.0 % Manufacturing
20.0 % Households and small businesses
10.0 % Agriculture
14.0 % Other



1. Farmhouses
2. Animals
   α. Intestinal fermentation 31% CH_4
   β. Manure management 7% N_2O

3 | 6. Soil treatment and crops 51% N_2O

4. Farm machines
5. Agro-forest vegetation
7. Renewable energy production from manure 11% CH_4

Source: IPCC, 2018

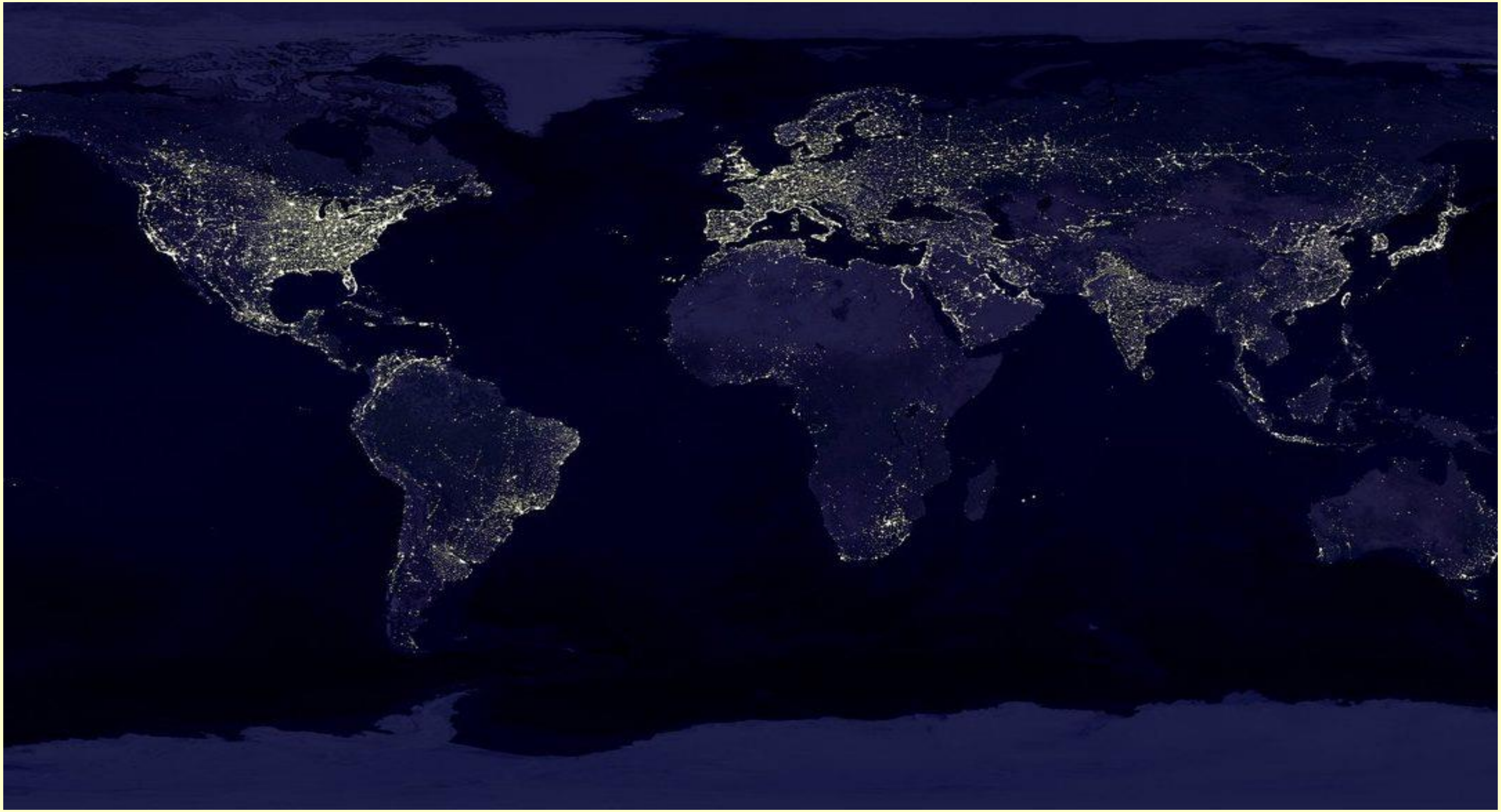
Agriculture

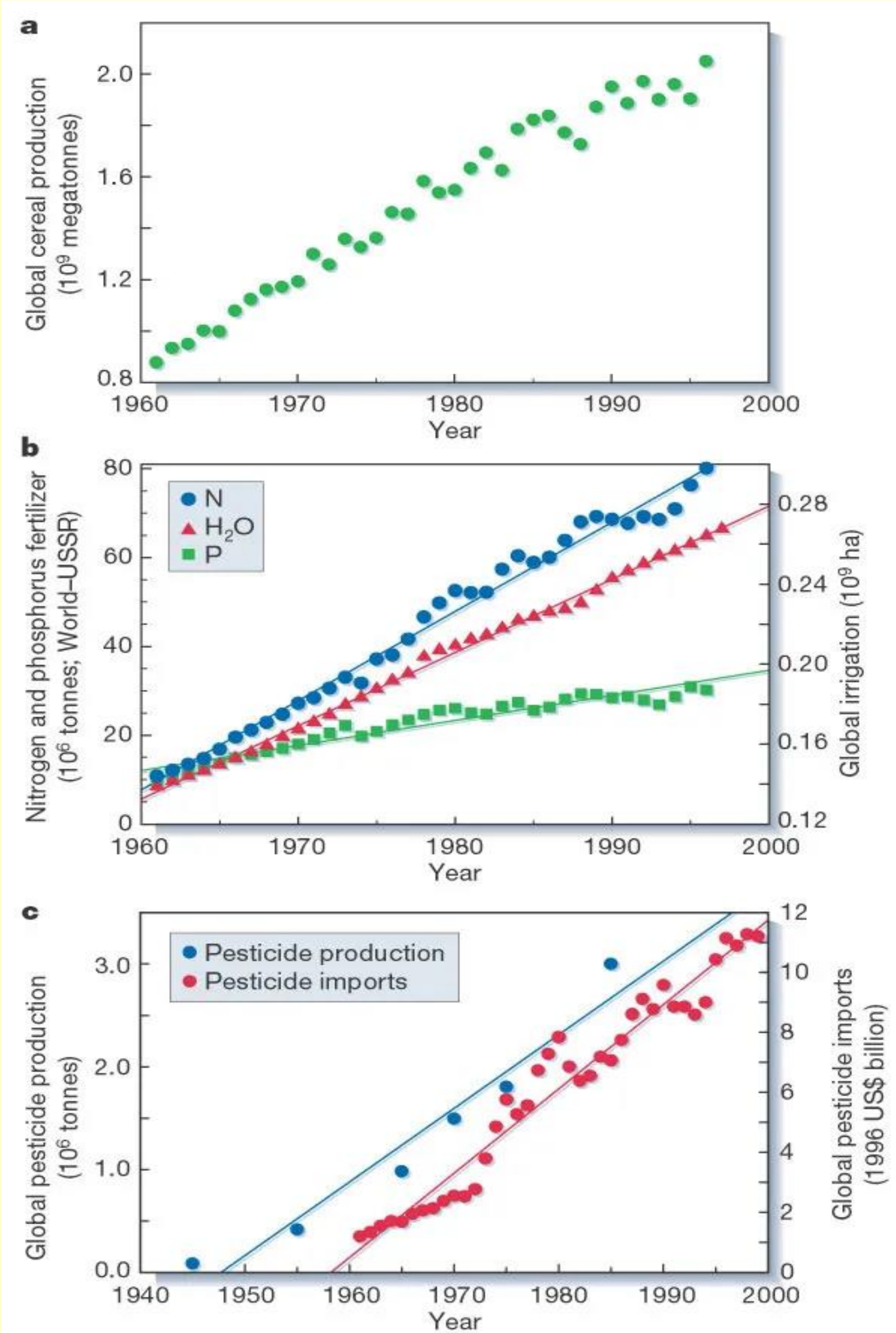
5-10% of the total energy consumed

The man of the Tropical and Subtropical areas consumes as much energy as the Temperate and Polar man consumes to produce only his proteins

(31 kg/year/person = 250 kg of fossil fuel)

The Earth at night (Nasa, 2018)



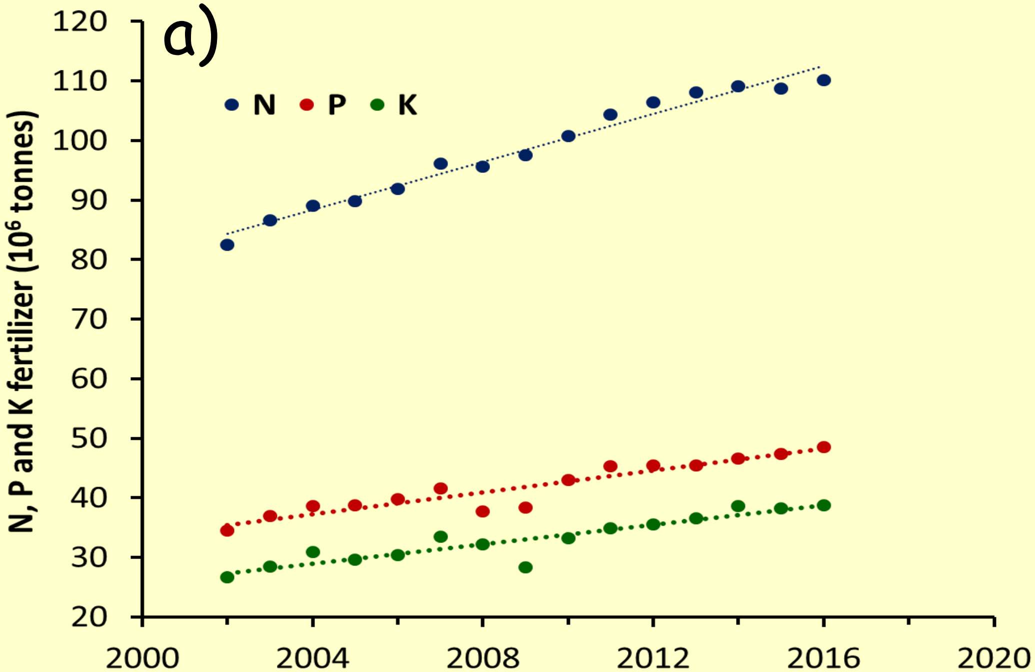


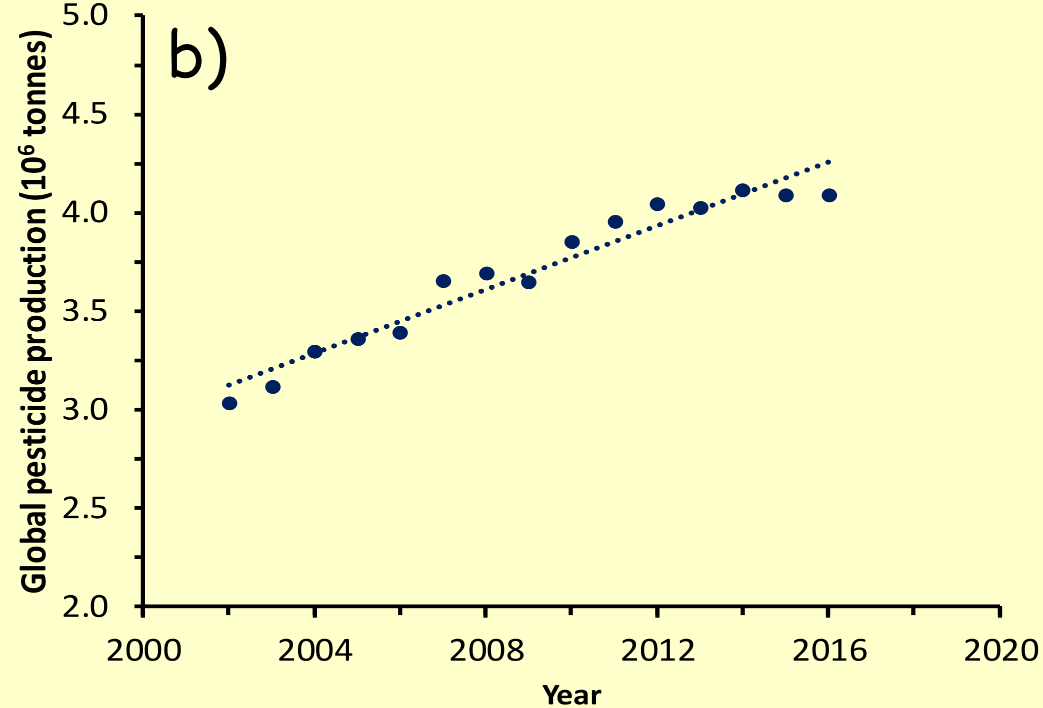
Agricultural sustainability and intensive production practices

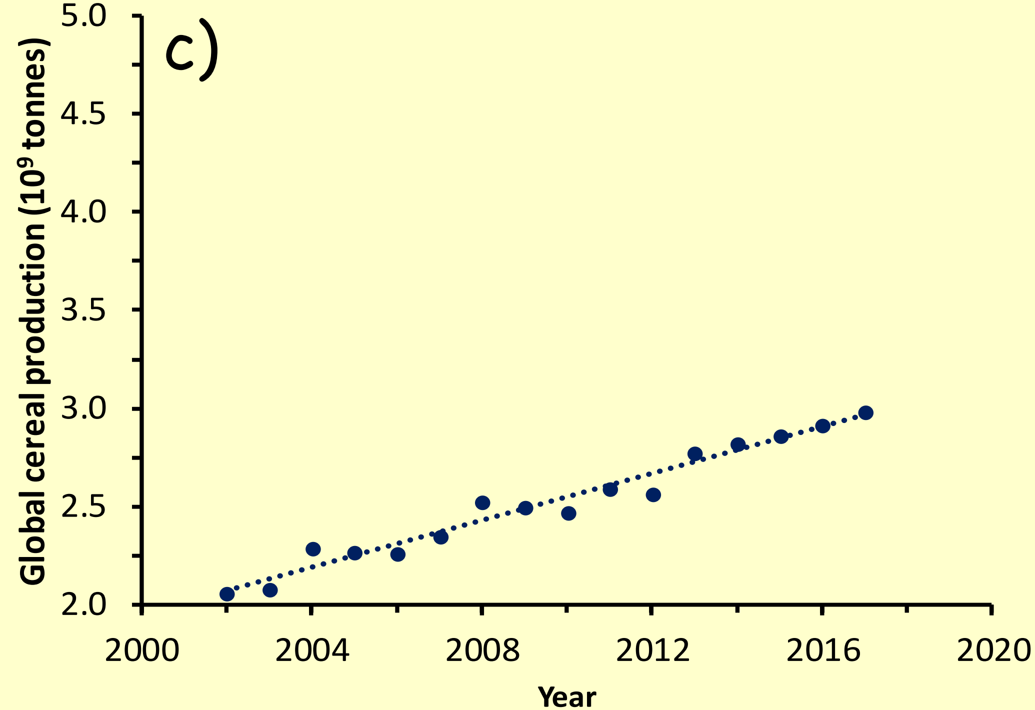
(Tilman et al. 2002, *Nature* 418:671–677).

Agricultural trends from 1960 until 2000.

a) Total global cereal production
b) Total global use of N and P fertilizer (except former USSR not included) and area of global irrigated land
c) Total global pesticide production and global pesticide imports (summed across all countries)

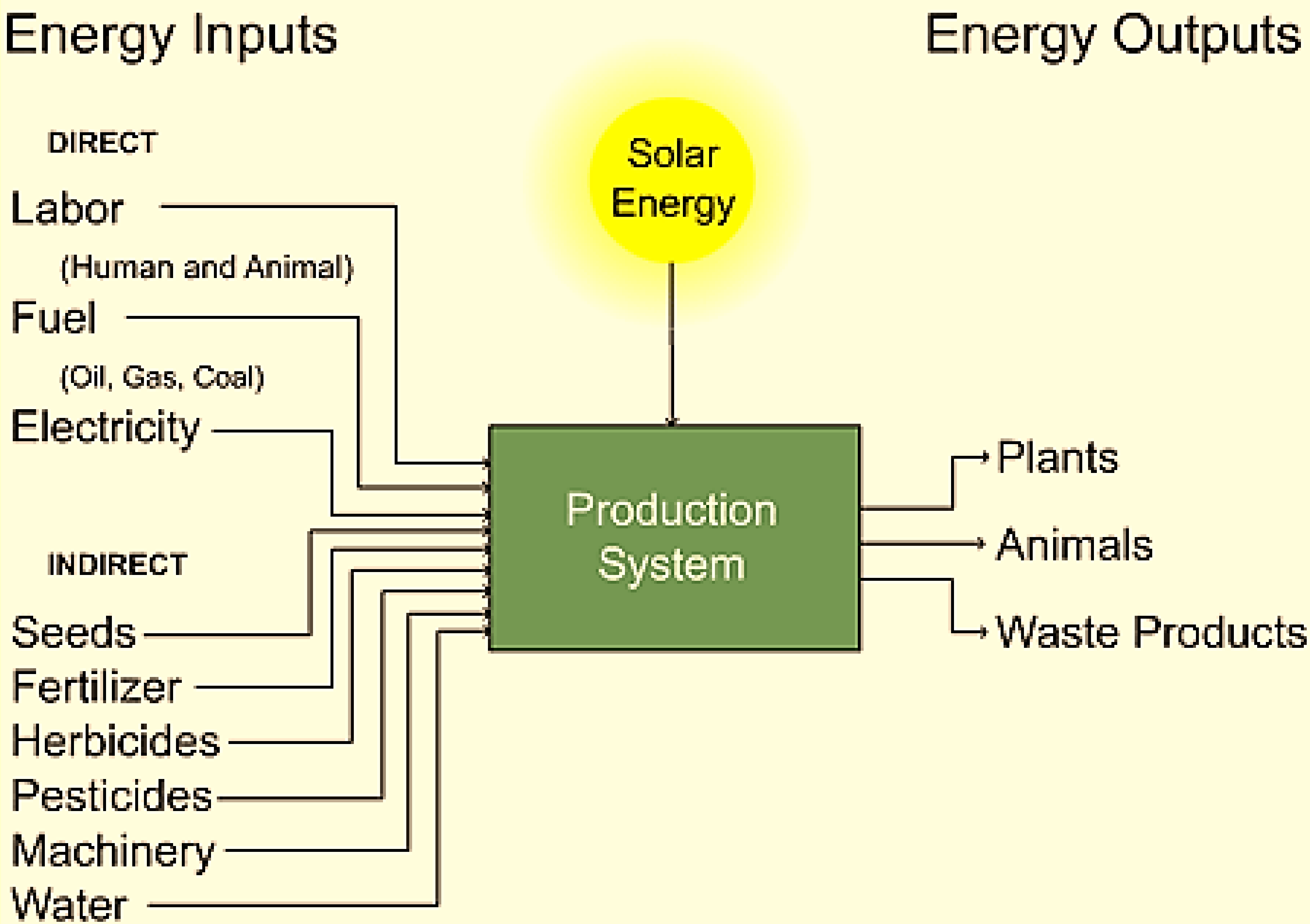




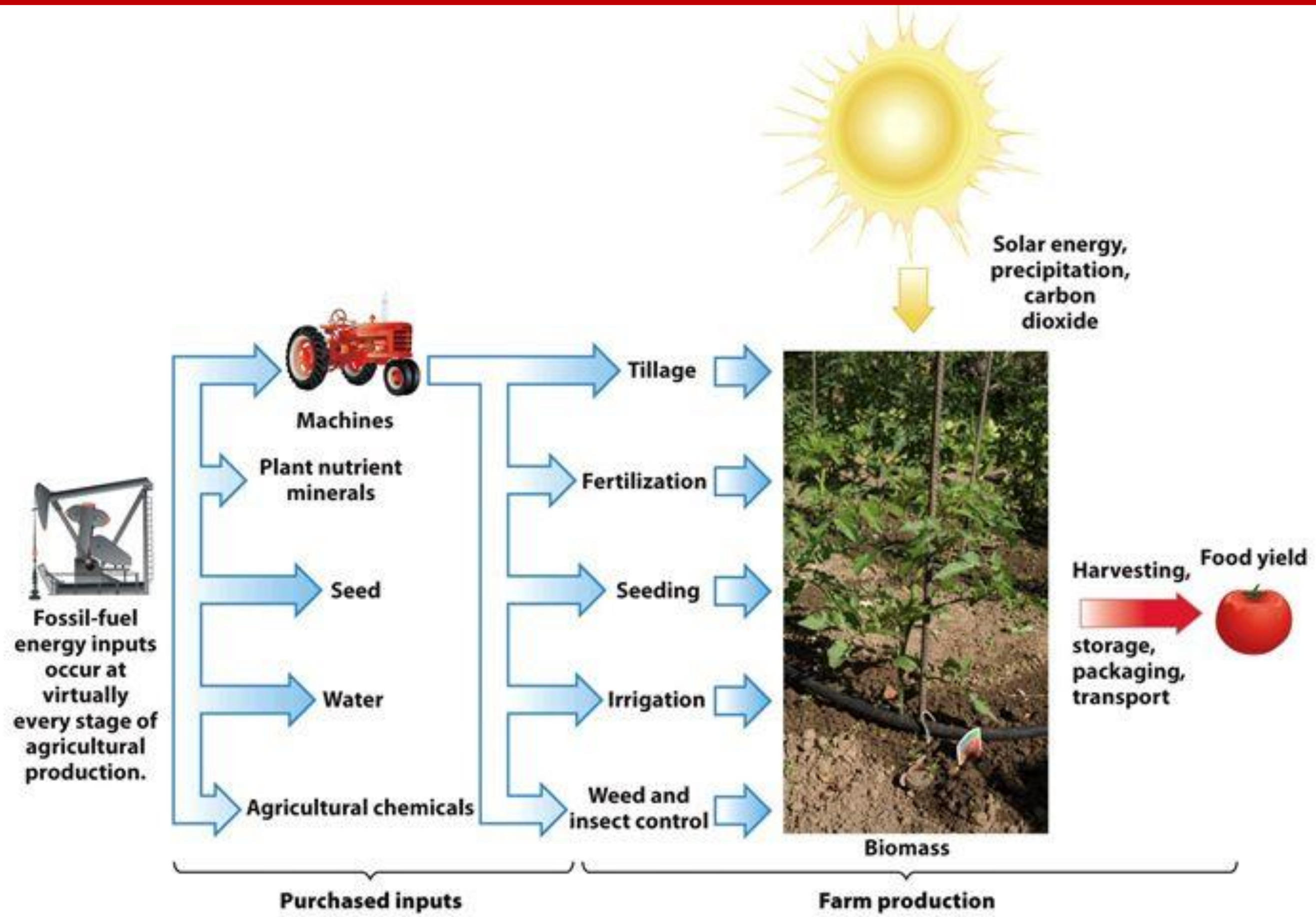


Agricultural trends over the last 20 years

a) Total global use of N, P and K fertilizer b) global pesticide production and c) Total global cereal production (FAO, 2019)


Energy Inputs
Energy Outputs
DIRECT
Labor
(Human and Animal)
Fuel
(Oil, Gas, Coal)
Electricity
INDIRECT
Seeds
Fertilizer
Herbicides
Pesticides
Machinery
Water
Solar Energy
Production System
Plants
Animals
Waste Products

Energy Inputs in Industrialized Agriculture



- Energy analysis of agroecosystems
- Economic analysis of agroecosystems

Both requires drawing up energy or economic balances

There are advantages – disadvantages for both analyses

Generally, is possible for human to start trading in energy units rather than monetary ones?

Energy units

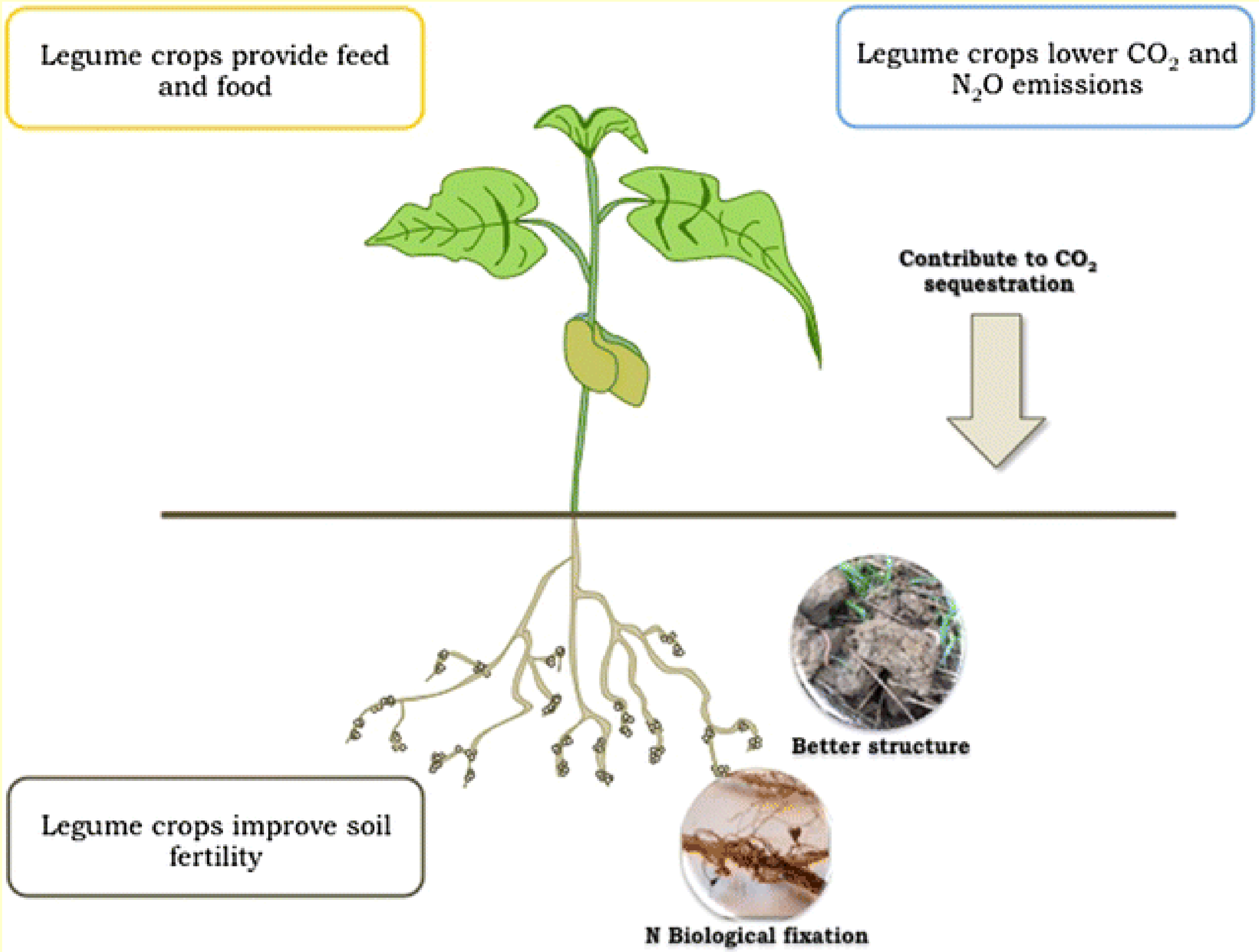
kWh=860 kcal

MJ=238.8 kcal

Energy inputs in agroecosystems

- ✓Machines (depreciation)
- ✓Fertilizers
- ✓Electricity
- ✓Fuel
- ✓Seed
- ✓Pesticides
- ✓Human work

Inputs	Average Corn Production Quantity	kcalx × 1000	Reduced Energy Inputs Quantity	kcal × 1000
Labor	11.4 hrs	462	15 hrs	608
Machinery	18.0 kg	333	10 kg	185
Diesel	88.0 L	1,003	60 L	684
Gasoline	40.0 L	405	0	
Nitrogen	155.0 kg	2,480	Legumes	1,000
Phosphorus	79.0 kg	328	45 kg	187
Potassium	84.0 kg	274	40 kg	130
Lime	1,120.0 kg	315	600 kg	169
Seeds	21.0 kg	520	21 kg	520
Irrigation	8.1 cm	320	0	0
Herbicides	6.2 kg	620	0	0
Insecticides	2.8 kg	280	0	0
Electricity	13.2 kWh	34	34 kWh	34
Transport	146.0 kg	48	75 kg	25
Total		7,470		3,542
Corn yield 9,000 kg/ha		31,612		

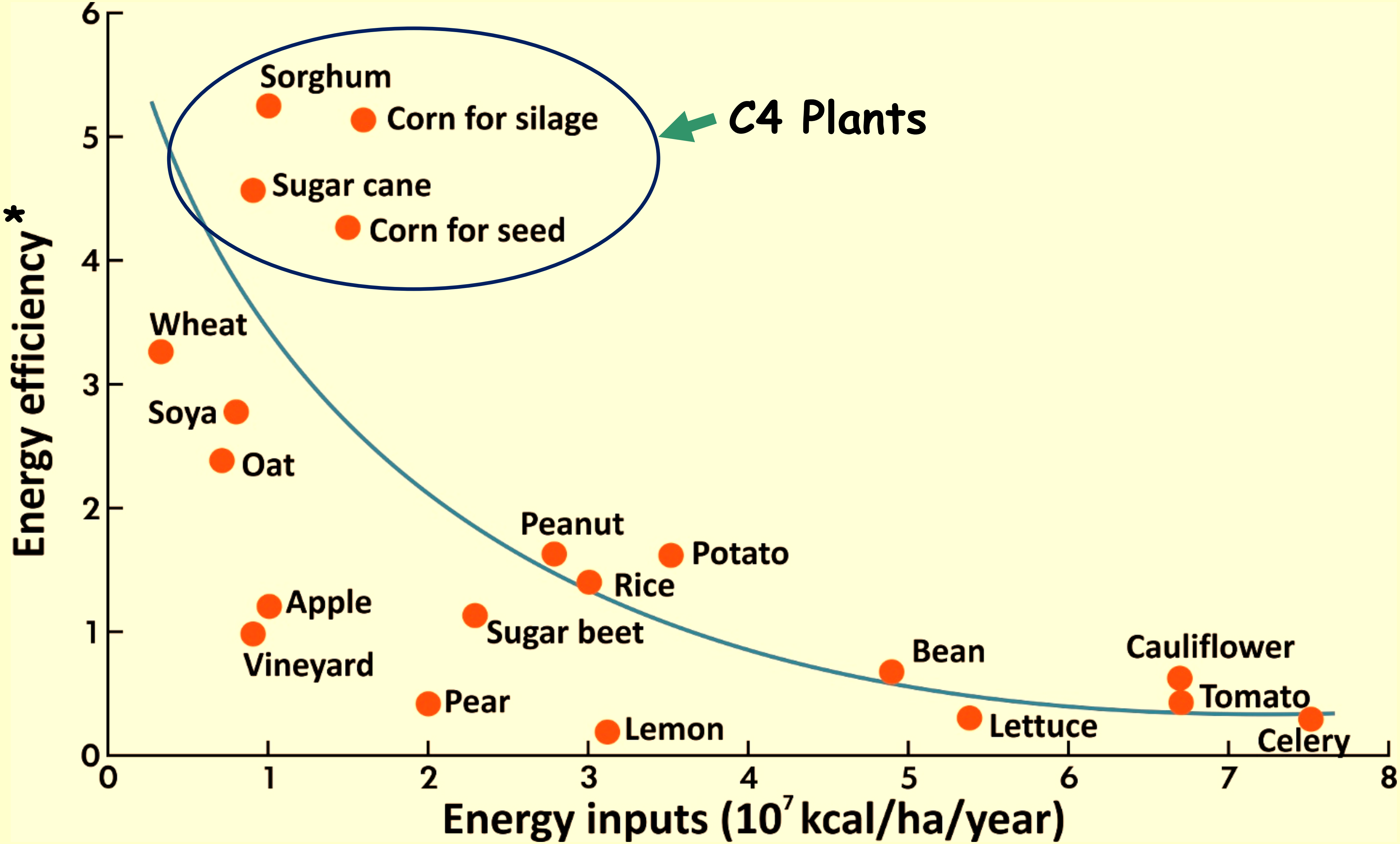


FROM Stagnari F., A. Maggio, A. Galieni, M. Pisante. (2017) Multiple benefits of legumes for agriculture sustainability: an overview. Chem. Biol. Technol. Agric., 4:2, DOI 10.1186/s40538-016-0085-1

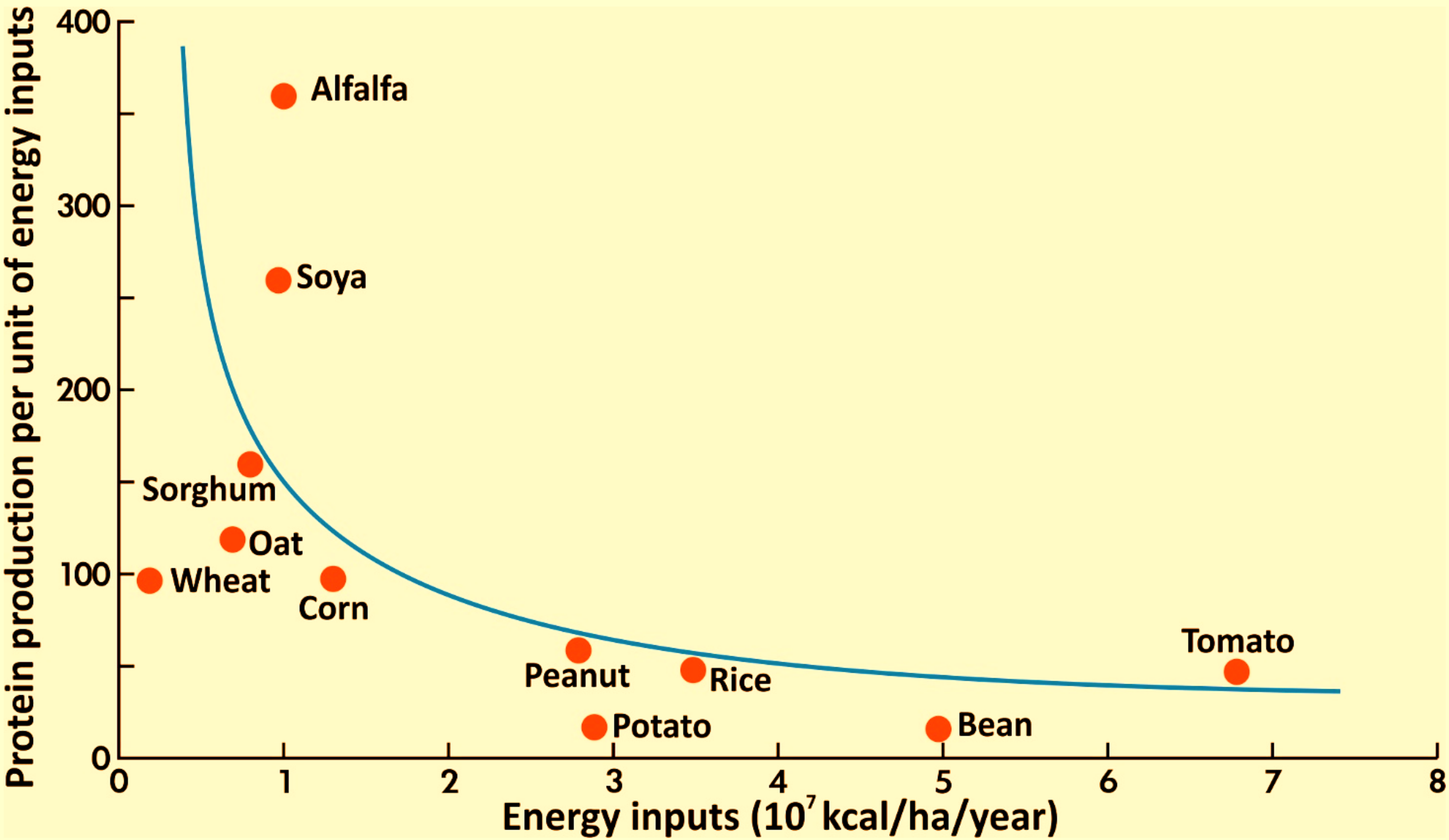
Efficient use of energy in agriculture

Questions

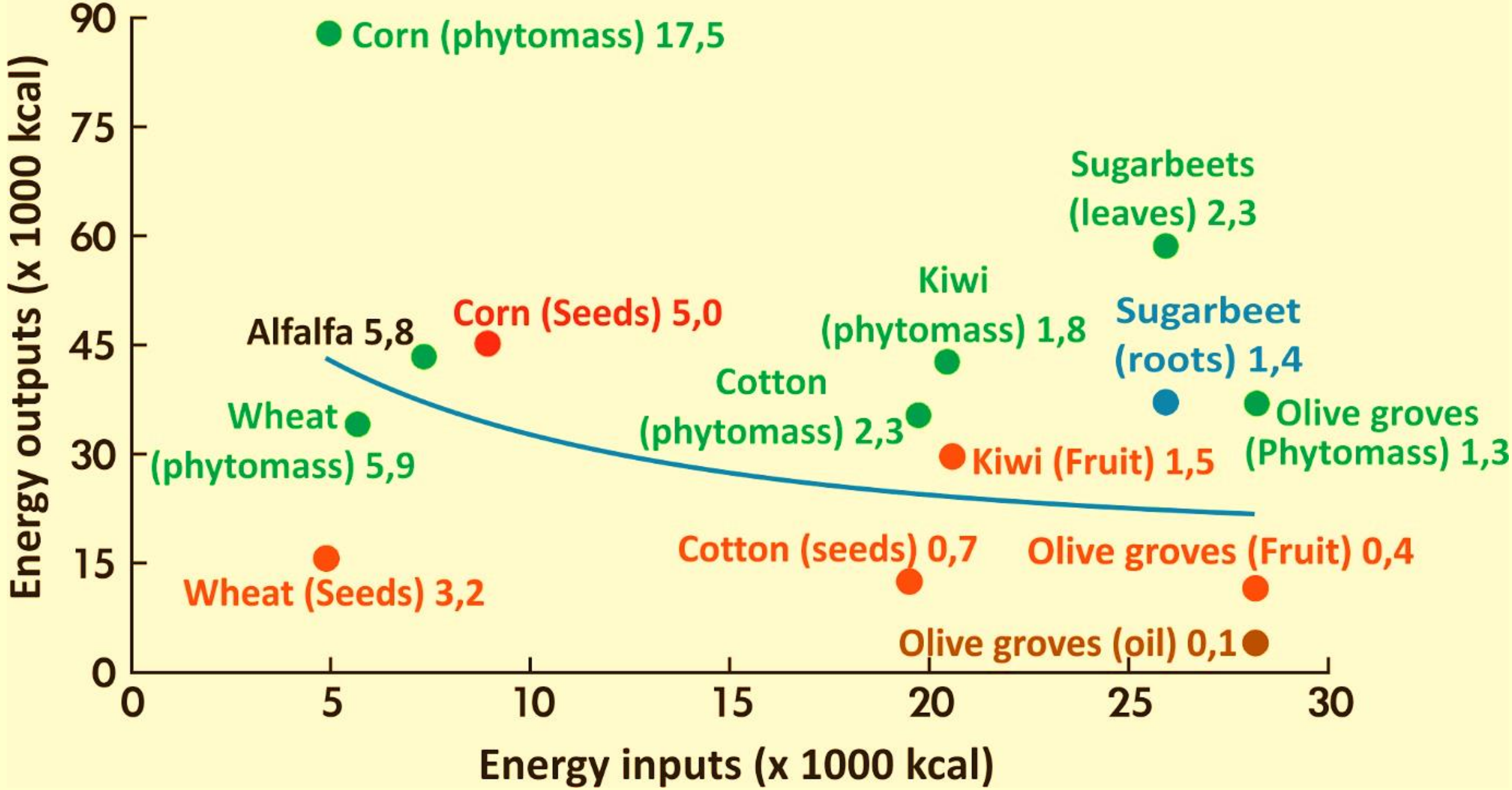
- Which agro-systems are energy-intensive ecosystems and what extent do they occupy in the country?
- What is their economic and social significance?
- What are the biggest energy inputs?



*Energy efficiency = energy outputs / energy inputs

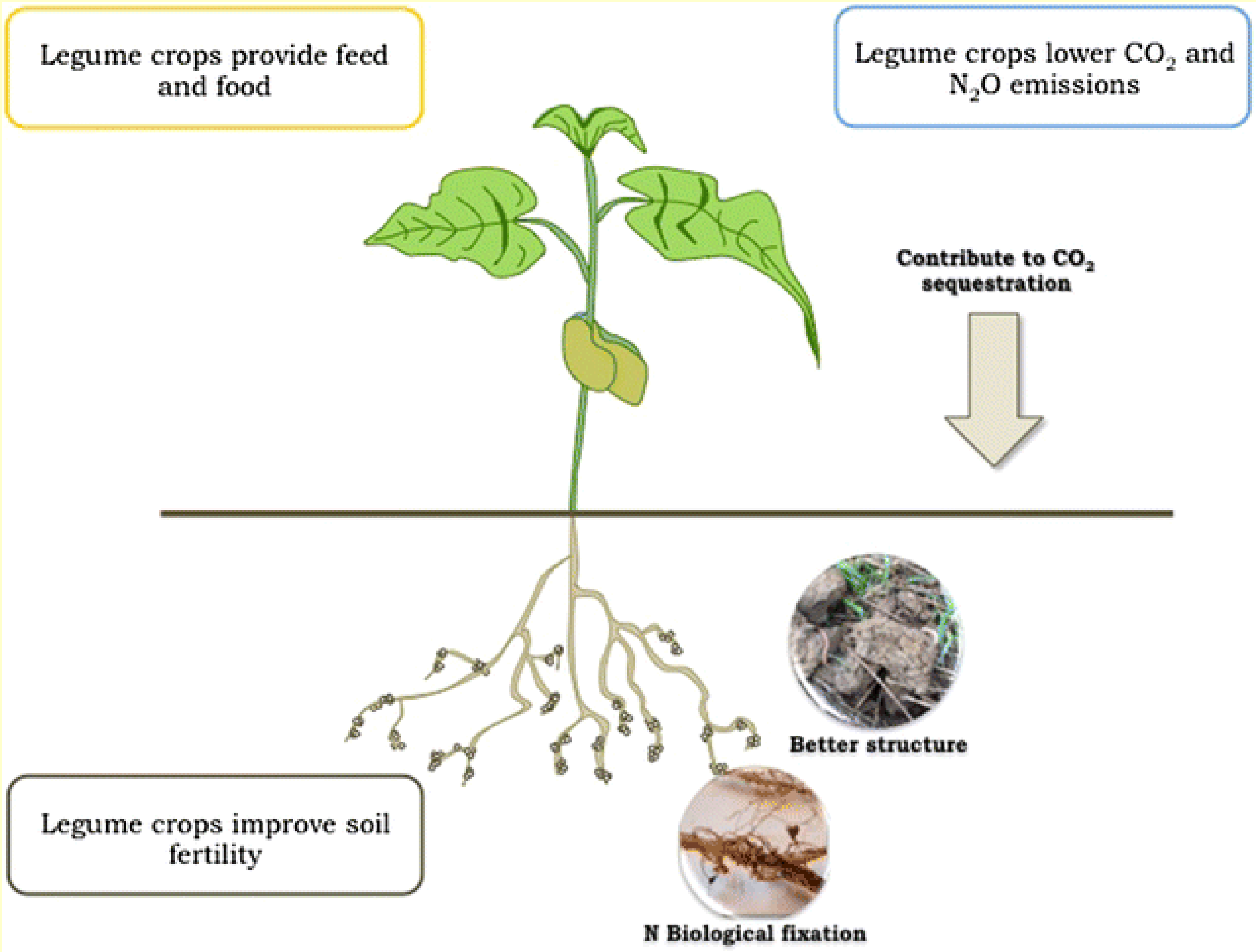

Protein production per unit of energy inputs
400
300
200
100
0
Alfalfa
Soya
Sorghum
Oat
Wheat
Corn
Peanut
Rice
Potato
Bean
Tomato
0
1
2
3
4
5
6
7
8
Energy inputs (10^7 kcal/ha/year)

Energy inputs, outputs in crops: Case studies from Greece



Energy inputs for corn production system

Inputs	%
Nitrogen	39.1
Electric energy for irrigation	24.8
Fuel	17.1
Potassium	3.9
Seed	3.5
Other sources	6.6



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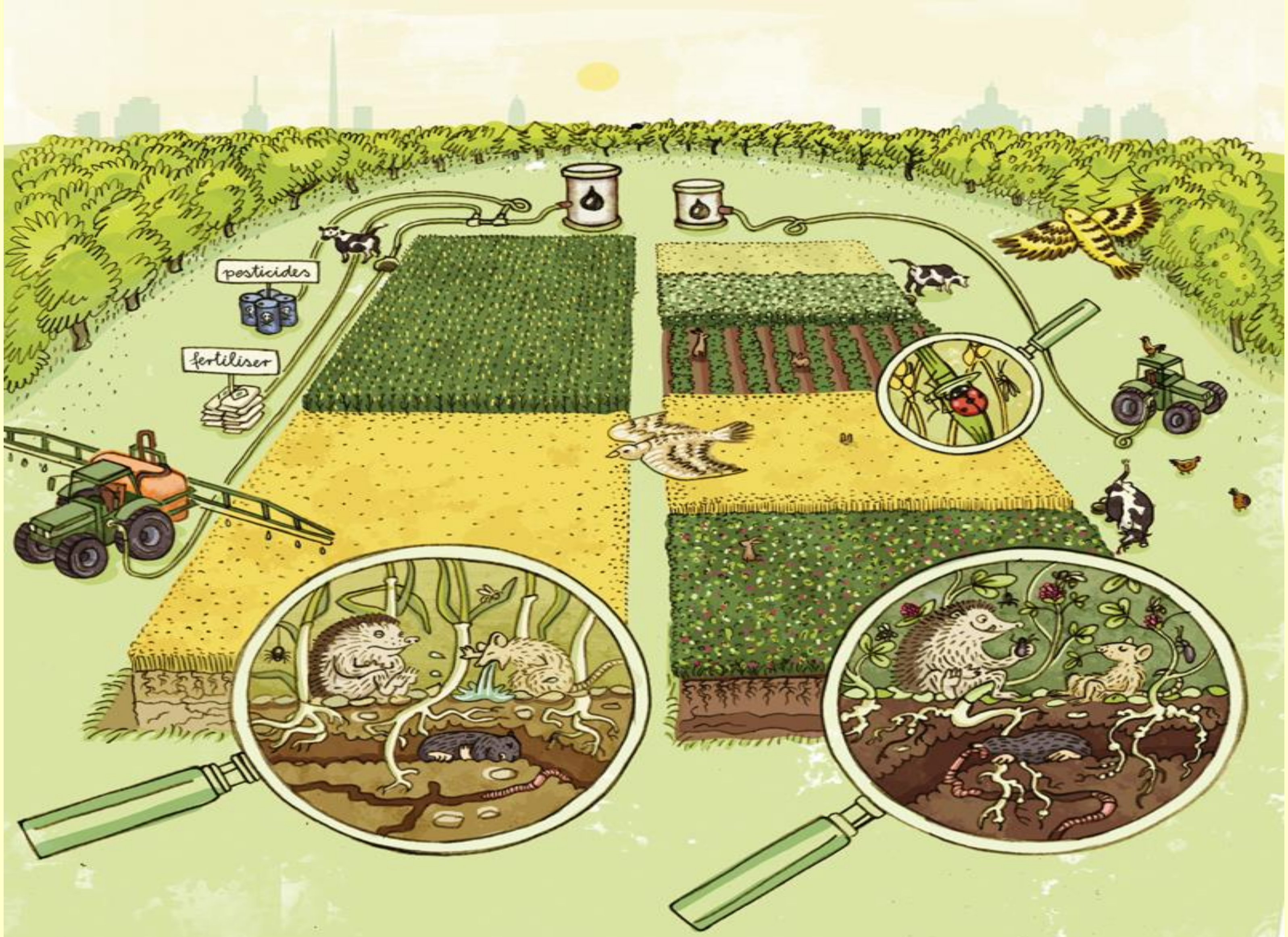
- Does the size of each large inflow from place to place vary greatly for the same type of agro-system?

- How has the energy flow evolved?

- What is the relationship between each energy input class and performance and what interactions are there between inputs in terms of performance?

Changes in inputs and outputs of corn in the US from 1700 to 1985

Energy inputs	1700	1910	1945	1970	1985
Human work	65	7	3	1.2	0.6
Machinery	2	28	41	91	102
Animal work	?	89	0	0	0
Fuels	0	0	143	211	128
Nitrogen fertilization	0	0	17	248	319
Seed	4	4	16	52	52
Insecticides	0	0	0	4	6
Herbicides	0	0	0	20	35
Irrigation	0	0	13	113	225
Electric energy	0	0	1	8	10
TOTAL INPUTS	72	127	233	747	877
TOTAL OUTPUTS	752	752	853	2032	2960
OUTPUTS:INPUTS	10.5	5.9	3.7	2.7	3.4



Environmental dimension

The new food production model

Ways to Achieve:

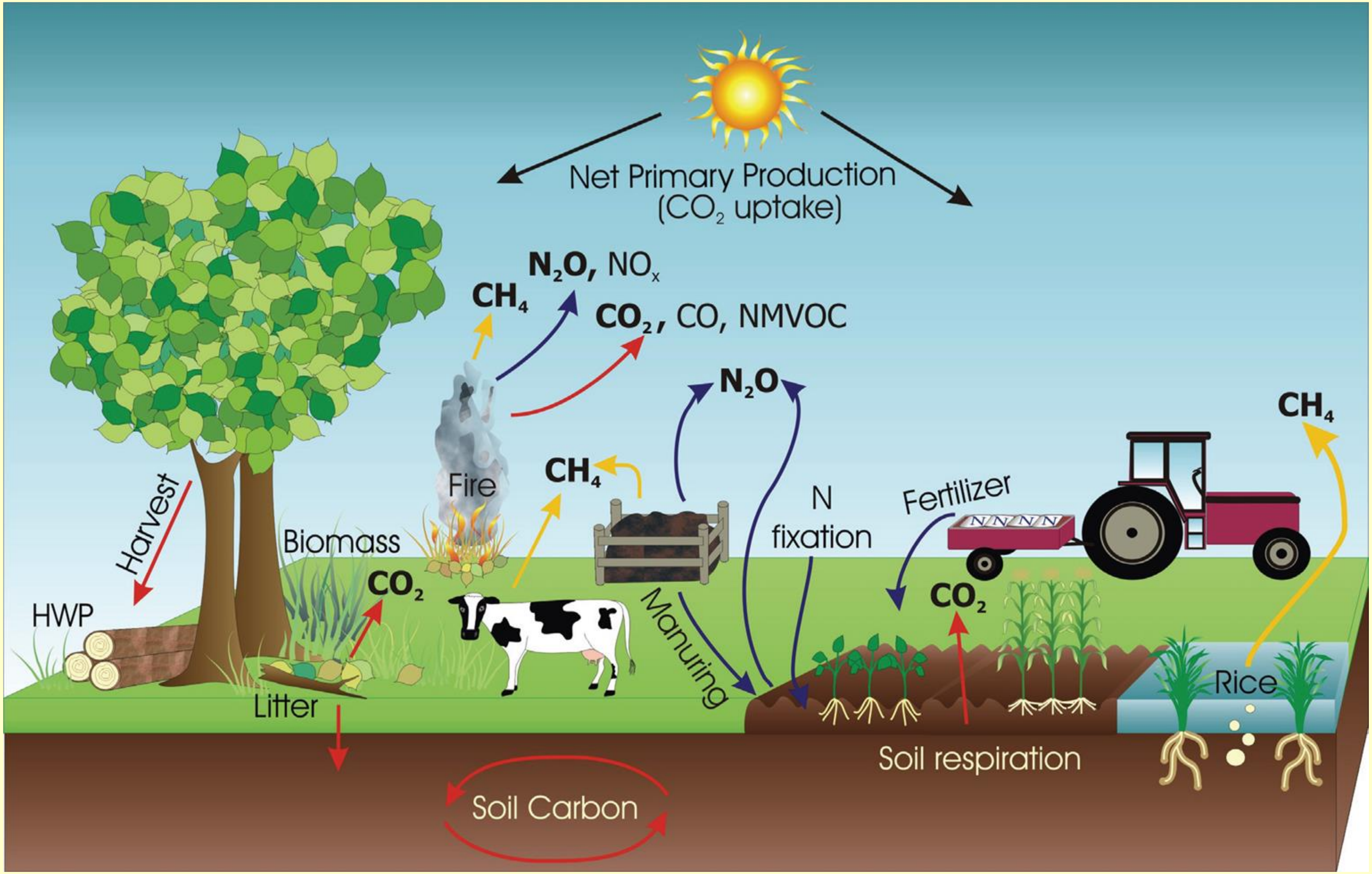
(a) by transforming existing equipment,
(b) re-evaluating product prescriptions,
(c) assessing new biodegradable packaging materials,
(d) staff training in energy management

Reduction of energy consumption and of the gas emissions (carbon footprint)

The Paris Climate Change Agreement is the first ever universal, legally binding global climate deal.

It was signed on 22 April 2016 and ratified by the European Union on 5 October 2016.

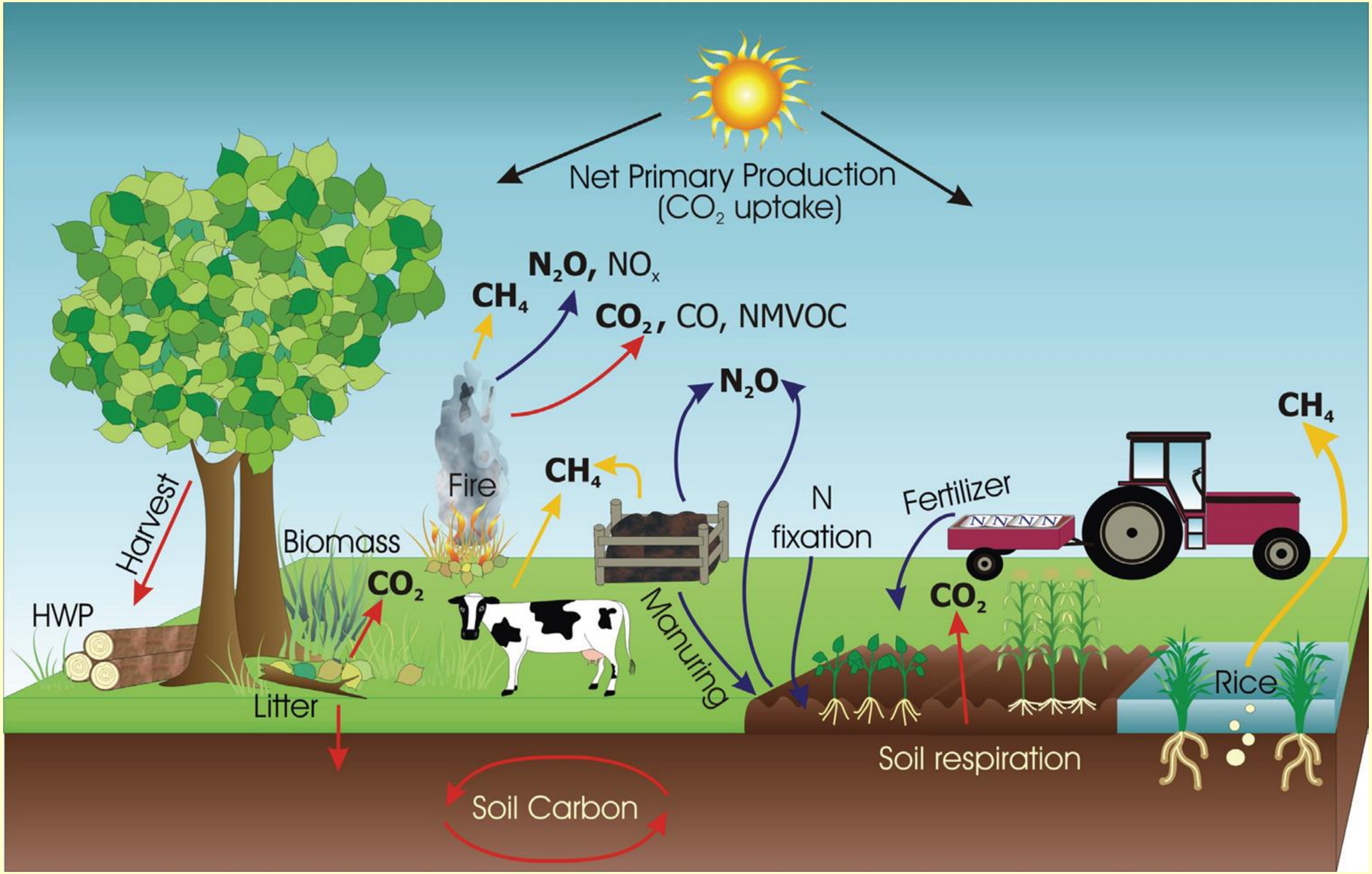
http://www.consilium.europa.eu/el/policies/climate-change/timeline/



Environmental dimension

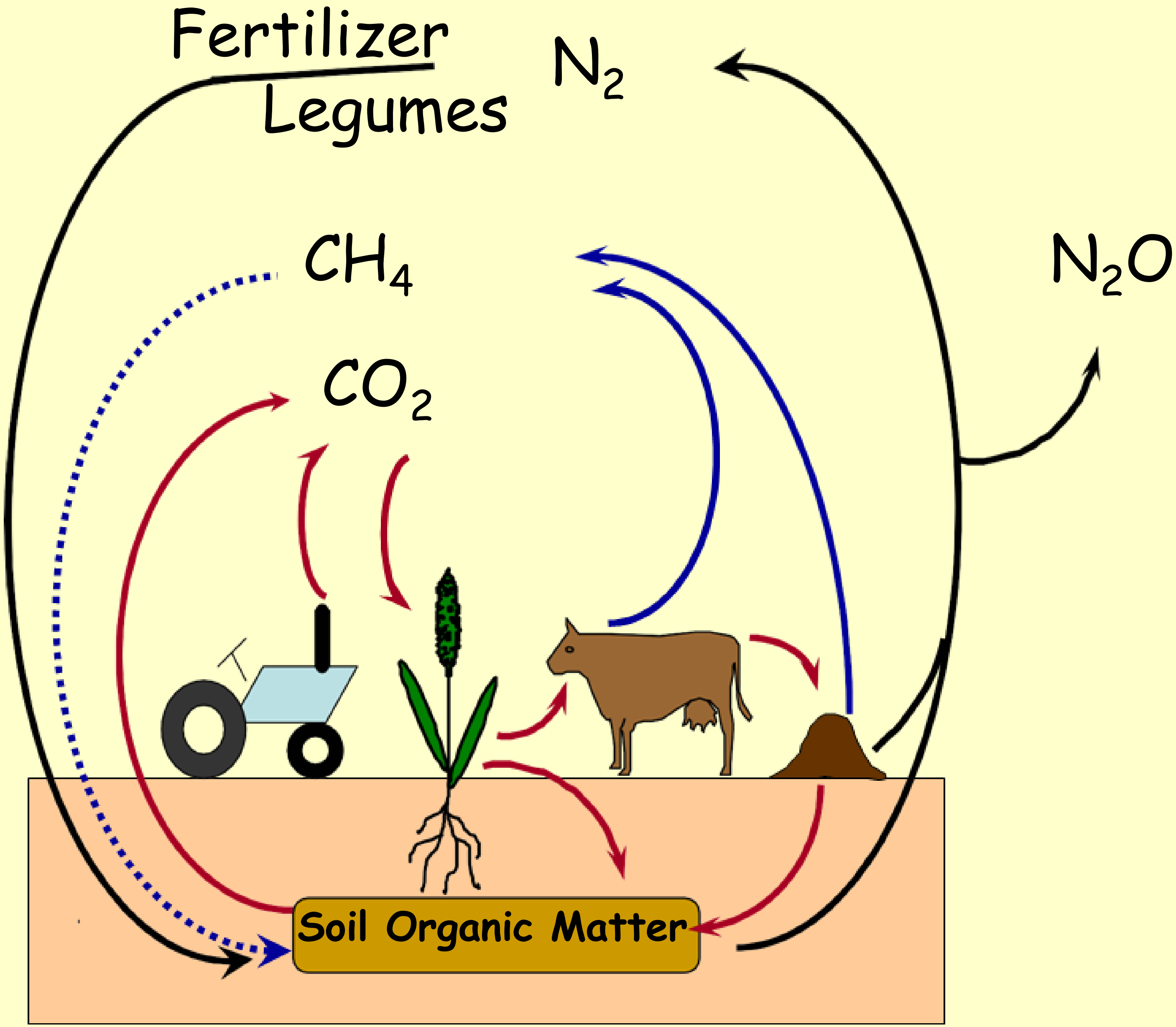
Questions for carbon footprint

- What contributes to the carbon footprint of an agricultural product?
- Why is it important to know?
- How is it calculated?



Environmental dimension

C and N Cycling in Agroecosystems



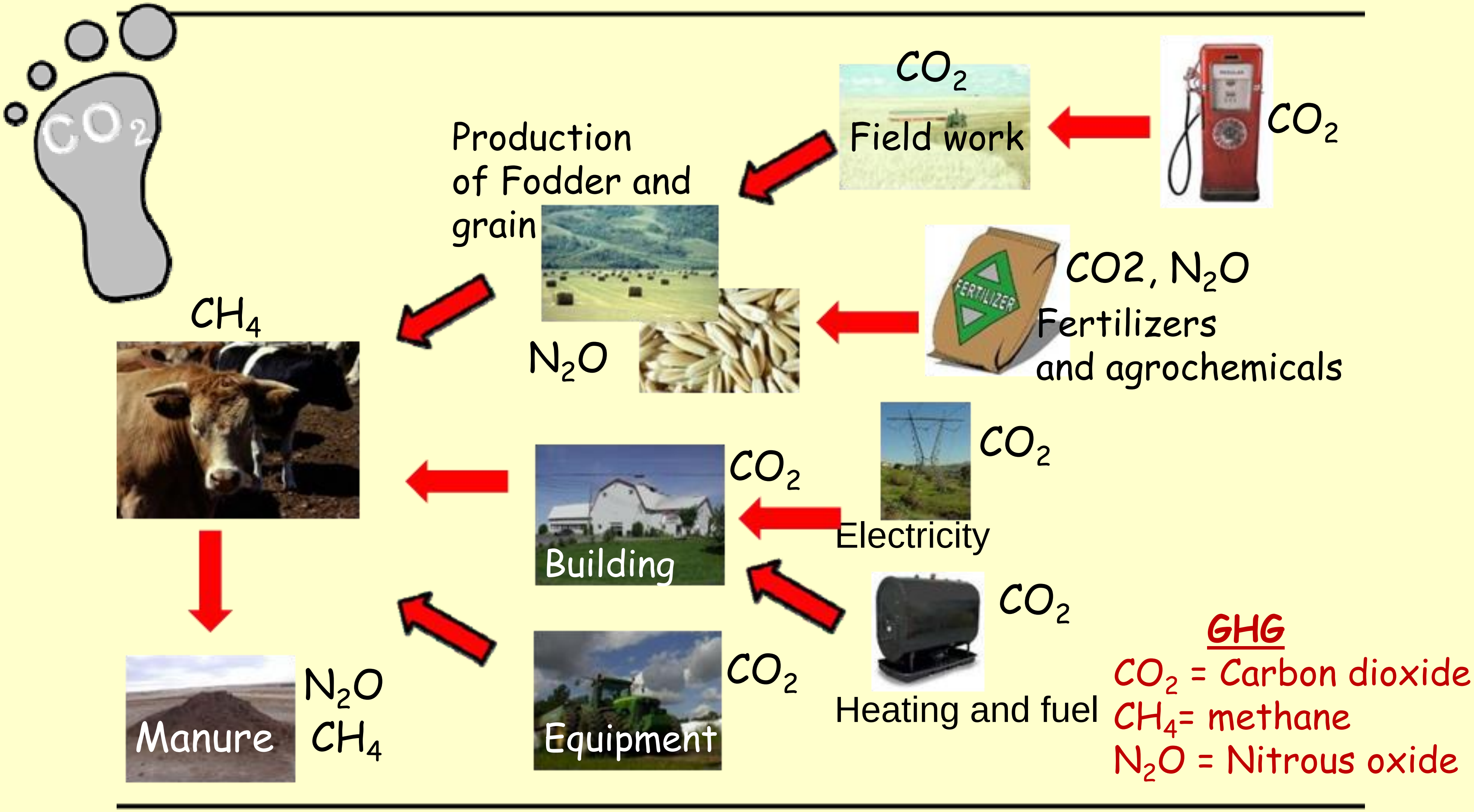
Carbon Footprint of Crops

Includes the following sources of GHGs:

- Direct soil N_2O emissions (animals, manure)
- Indirect soil N_2O emissions (fertilizers)
- Soil carbon change
- CO_2 fertilizer and machinery manufacturing
- CO_2 field operations
- CO_2 on-farm transport

Carbon footprint' of beef cattle

Source of GHG emissions



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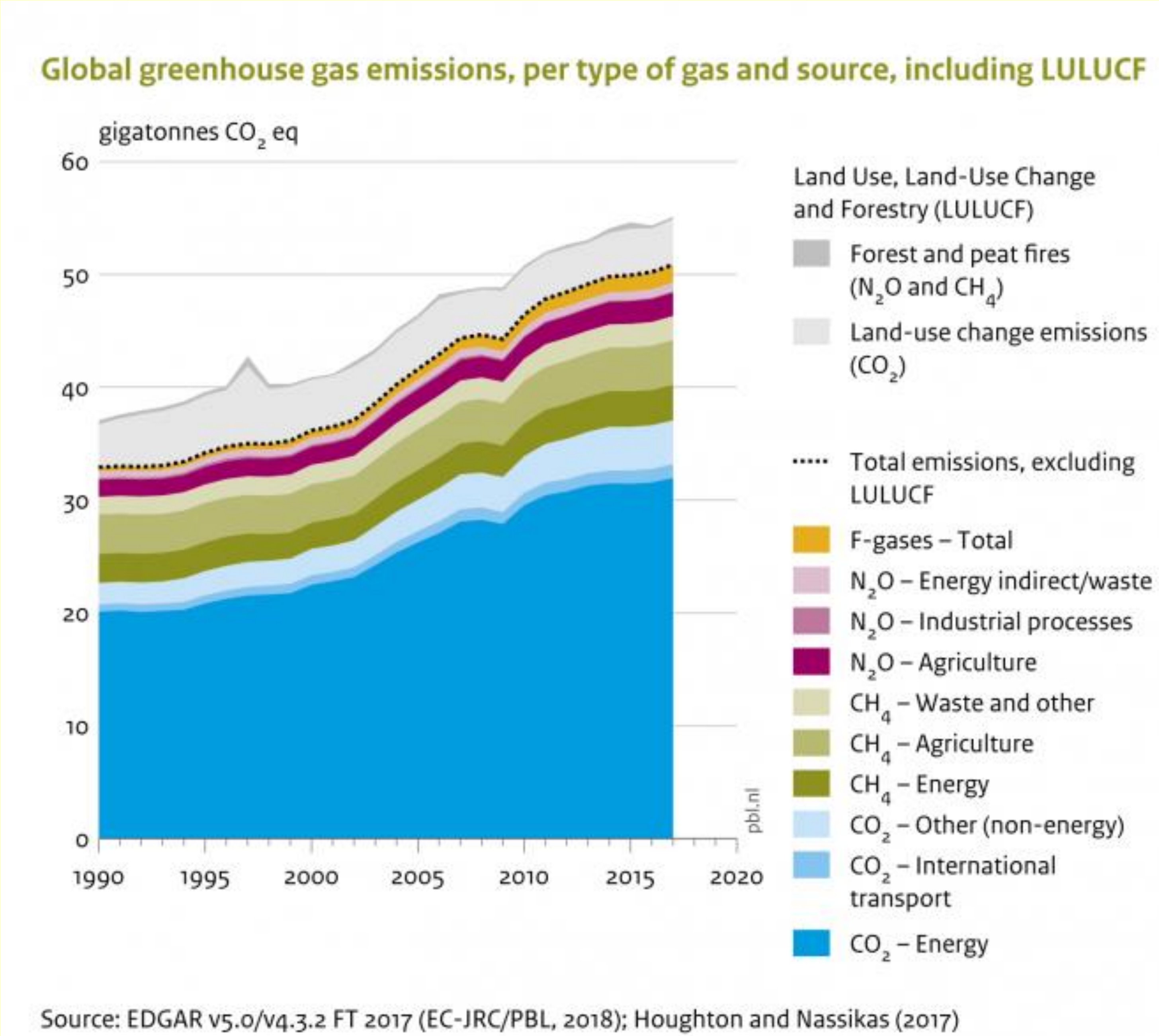
Atmospheric GHG concentrations are increasing



Global mean temperature change relative to 1951-1980

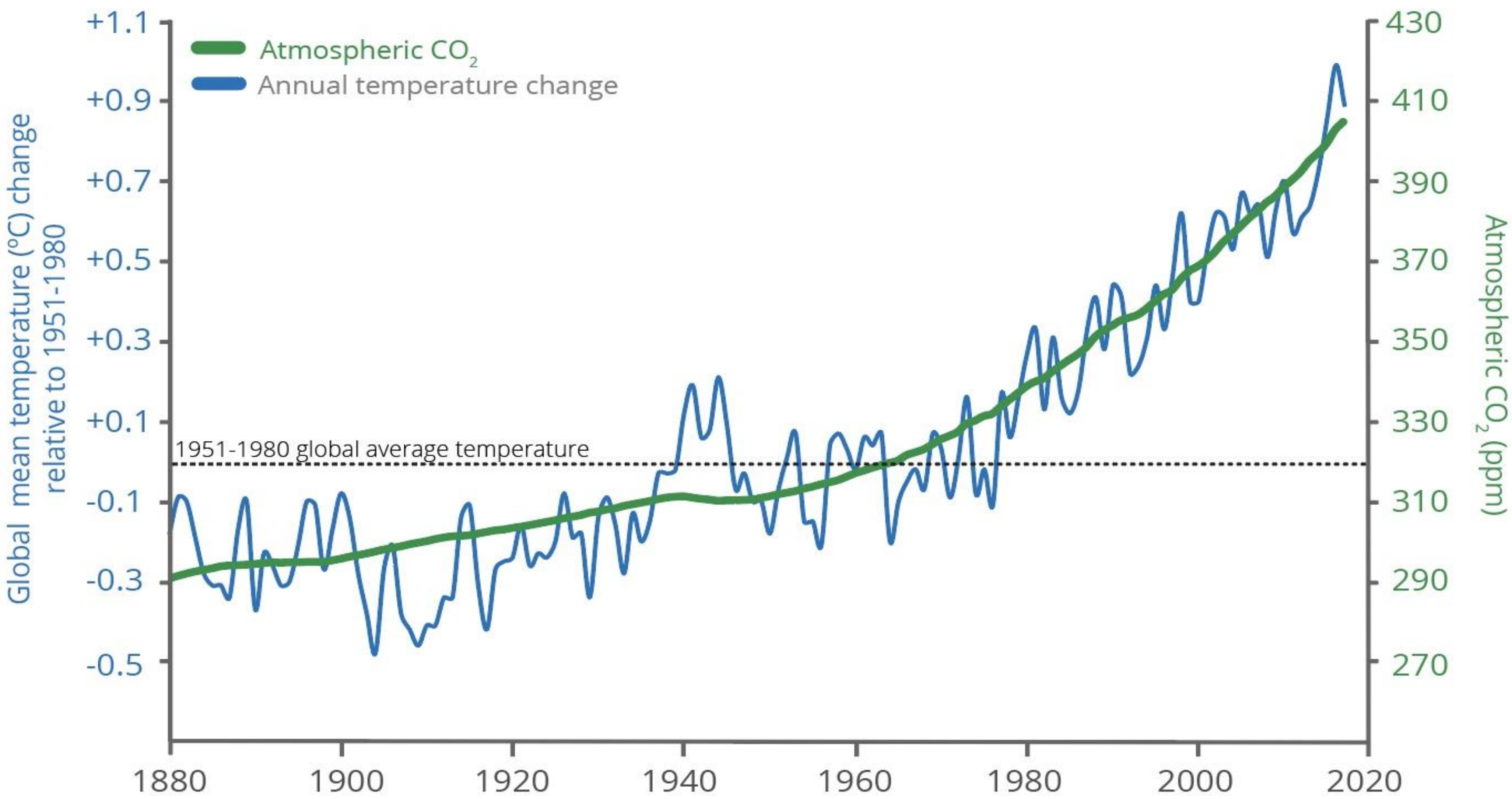


Figure from UW Climate Impacts Group
(data: NASA GISS; NOAA NCEI/ESRL)

Questions for carbon footprint

- What contributes to the carbon footprint of an agricultural product?
- Why is it important to know?
- How is it calculated?

Carbon Dioxide Equivalents

Always, estimates of carbon footprint are expressed in terms of a mass of 'carbon dioxide equivalents' or kg CO_2-e per unit of Product:

$$CO_2\text{-e} = CO_2 \times 1 + CH_4 \times 25 + N_2O \times 298$$

CO_2-equivalents allows different GHGs to be compared relative to CO_2, using their 'Global Warming Potential' (GWP), which accounts for their capacity to absorb radiation and their residence time in the atmosphere.

Indicator= CO_2-e/Product

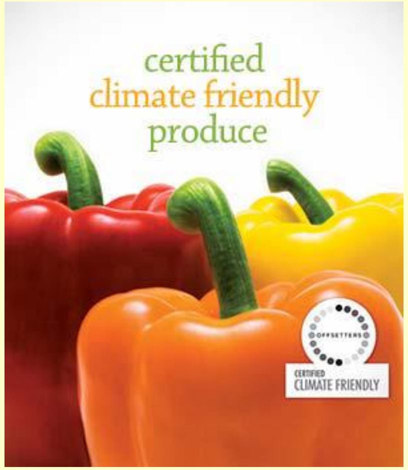
Concerns about the use of the term carbon footprint:

- as carbon labeling for agricultural products
- for allocation of environmental burdens
- as a tool for decision making

Carbon labeling for agricultural products is gaining importance

Will consumers be affected consumers
by the carbon labels?
YES!!
"Generally, consumers which are received appropriate guidance about embodied carbon emissions, they may purchasing green-labelled goods"

As scientists, we have an obligation to provide the best information possible to ensure that product statements are credible and defensible


certified
climate friendly
produce
OFFSETTERS
CERTIFIED
CLIMATE FRIENDLY


Nutrition
MILK FROM FARMS SELECTED
FOR THEIR HIGH STANDARDS
OF QUALITY AND WELFARE
working with
the Carbon Trust
800g
CO2
per pint
The carbon footprint of a pint of this milk is 800g and we have committed to reduce it.
TESCO
Semi-
Skimmed
milk
1
568 ml 1pint e


島根県飯南町
高原の里
飯南町
CO2排出量
16.0g
（100g当り）
生産から輸送における
CO₂の排出量
包装
0.75
輸送
0.78
g
生産
14.47


picked &
processed
within
24 hours
TESCO
Orange
working with
the Carbon Trust
360g
CO2
240g
per 250ml serving
The carbon footprint of this juice is 360g per 250ml serving and we have committed to reduce it


Casino
COOKIES
PÉCAN
Pépites Choco
Casino
COOKIES
PECAN
Casino
COOKIES
PÉCAN
Pépites Choco
Casino
COOKIES
PECAN
12 biscuits

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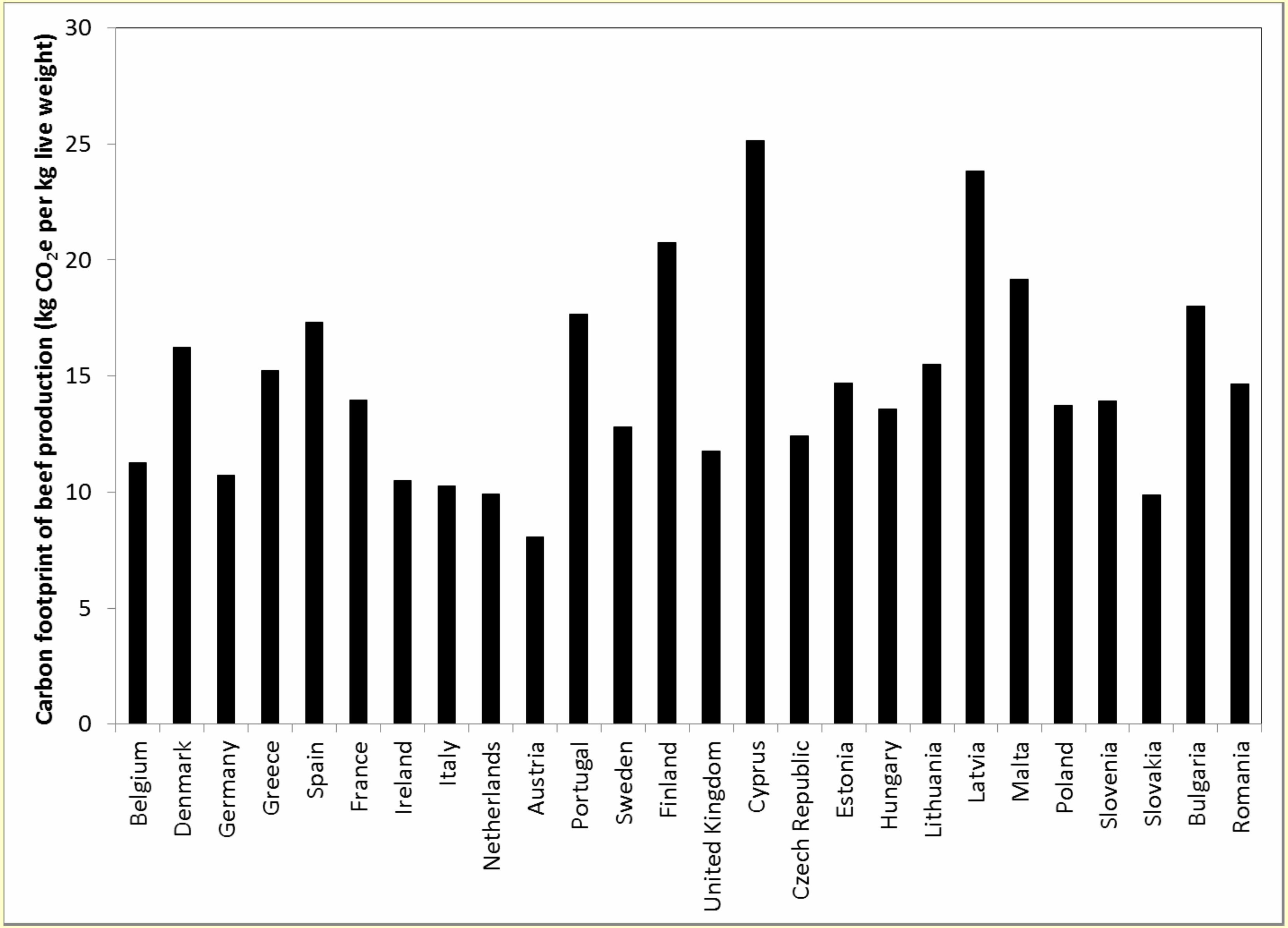
Carbon footprint of beef cattle in the EU



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Literature from our team in the laboratory

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2. Kavargiris SE, **AP Mamolos**, CA Tsatsarelis, AE Nikolaidou, KL Kalburtji 2009 Energy resources' utilization in organic and conventional vine yards: energy flow, global warming potential and biofuel production. *Biomass and Bioenergy* 33:1239-1250.
3. Litskas VD, **AP Mamolos**, KL Kalburtji, CA Tsatsarelis, E Kiose-Kampasakali 2011. Energy flow and greenhouse gas emissions in organic and conventional sweet cherry orchards located in or close to Natura 2000 sites. *Biomass and Bioenergy* 35:1302-1310.
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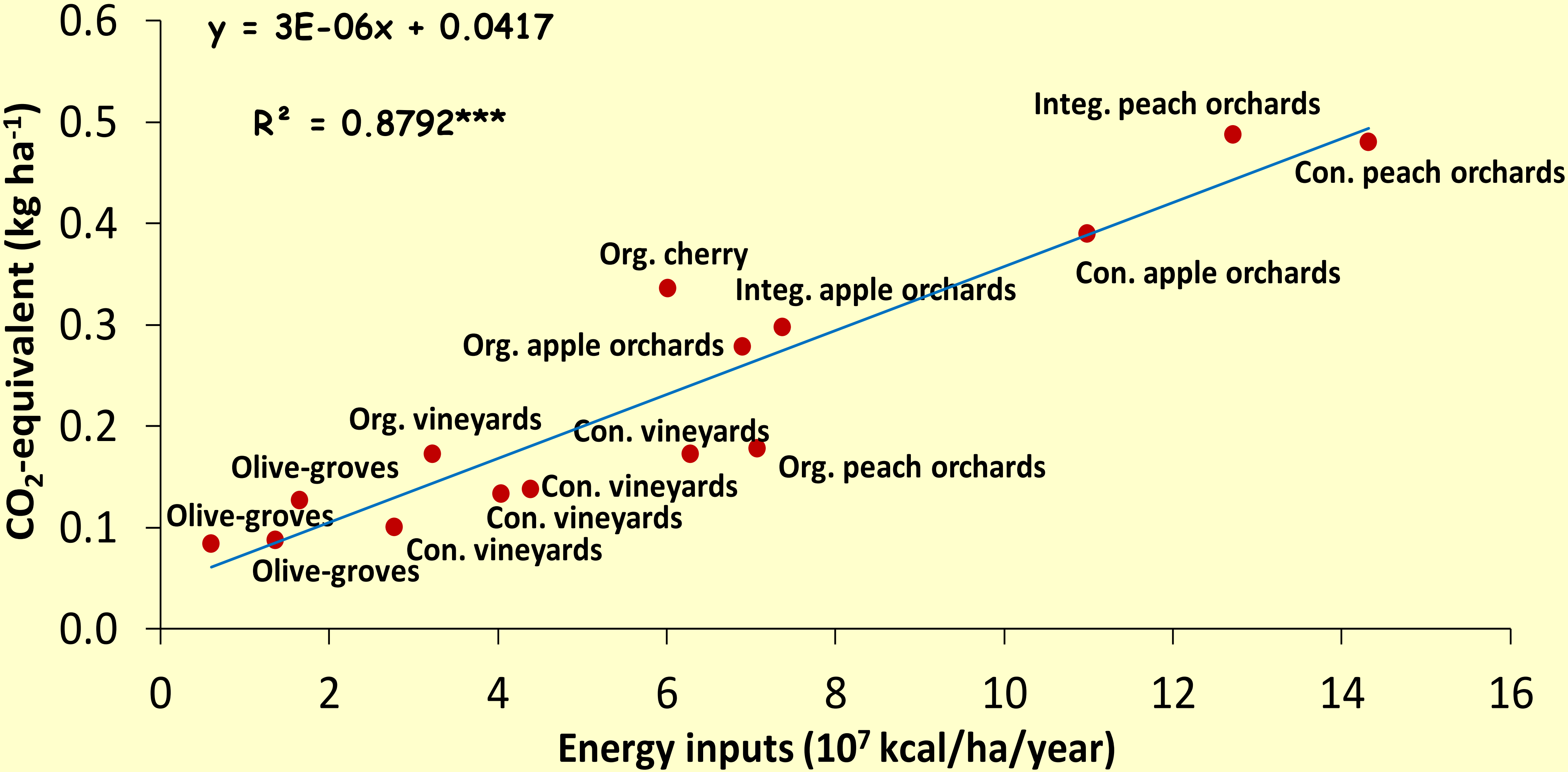


y = 3E-06x + 0.0417
R² = 0.8792***
CO2-equivalent (kg ha-1)
Energy inputs (107 kcal/ha/year)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
2
4
6
8
10
12
14
16
Integ. peach orchards
Con. peach orchards
Con. apple orchards
Org. cherry
Integ. apple orchards
Org. apple orchards
Org. vineyards
Con. vineyards
Org. peach orchards
Olive-groves
Con. vineyards
Con. vineyards
Olive-groves
Con. vineyards
Olive-groves

Generally, the human need to produce more food with less GHG

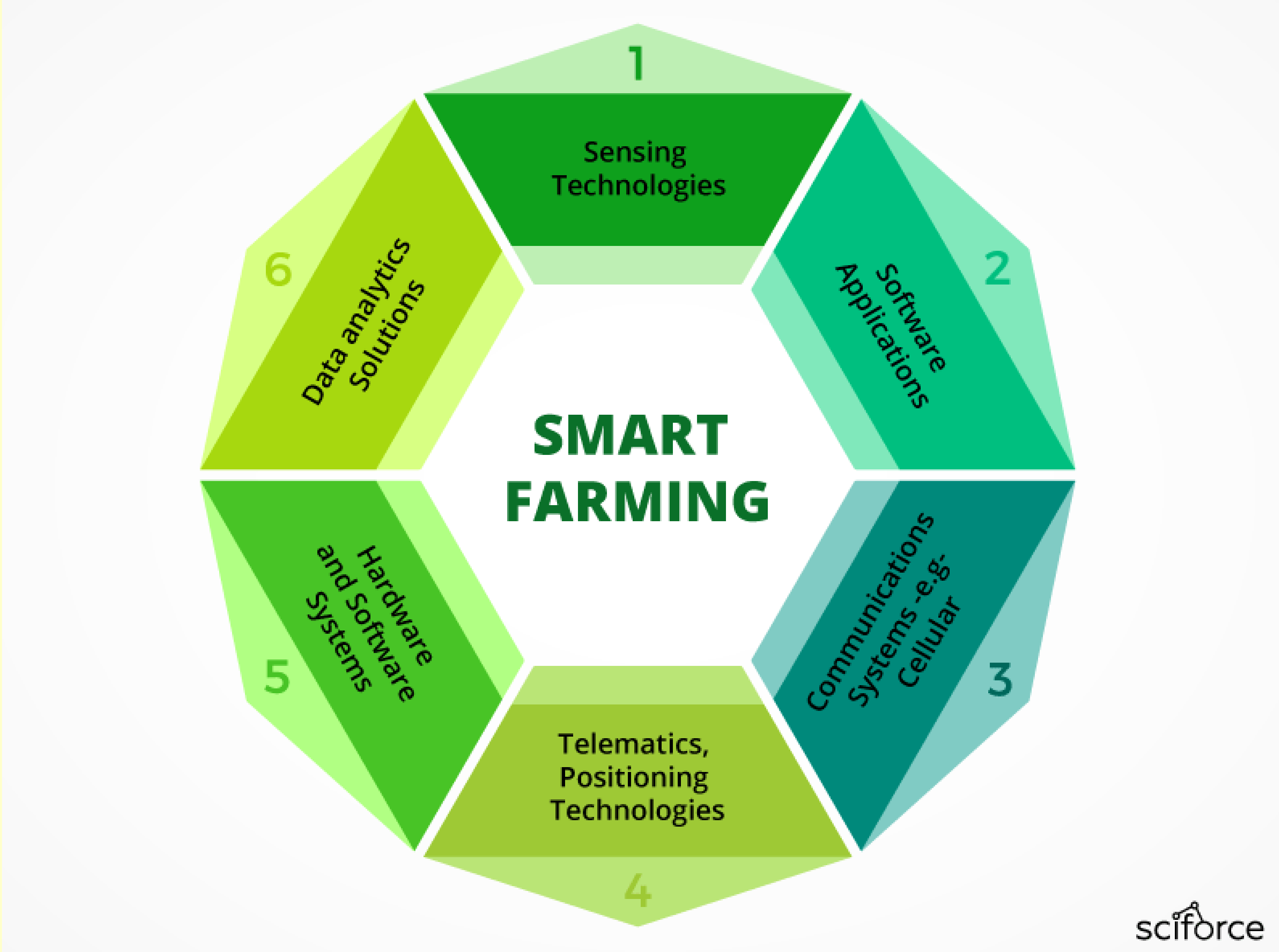
This decrease in emissions intensity has been possible through: a) the breeding of higher yielding, b) more productive animals, c) improved crop production, d) feeding of leguminous crops, e) the adoption of improved land management practices.

Many of these gains in productivity have not yet been achieved in the developing countries, where significant increases in productivity and decreases in emissions intensity can be achieved.

Practices especially for the plant production, that contribute to reducing GHG are:

a) Rotation programs
b) Use of varieties adapted to new climatic conditions
c) Conversion of intensive agriculture into alternative forms
d) Reduction of taxes on certified producers following alternative forms of agriculture

Why climate-smart agriculture?



Conclusions

Agriculture as a productive and developmental sector

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It should not be at the expense of natural resources and environmental quality characteristics

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In this direction

the use of indigenous plant genetic material and the proper use of energy resources could help to contribute to reducing greenhouse gas emissions

Dr. Barry Commoner' in his book The Closing Circle: Nature, Man and Technology

Five basic aspects of Agroecology

1. Everything is connected to everything else
2. Everything must go somewhere
3. Everything is always changing
4. There is no such thing as a free lunch
5. Everything has limits (i.e., resources are finite)

Nature does nothing neither incomplete nor unfair (Aristotle, 340 BC)

Η φύσις μηδέν μήτε ατελές ποιεί μήτε μάτην

Thank you