Contribution of agricultural soils to GHG emissions and carbon storage

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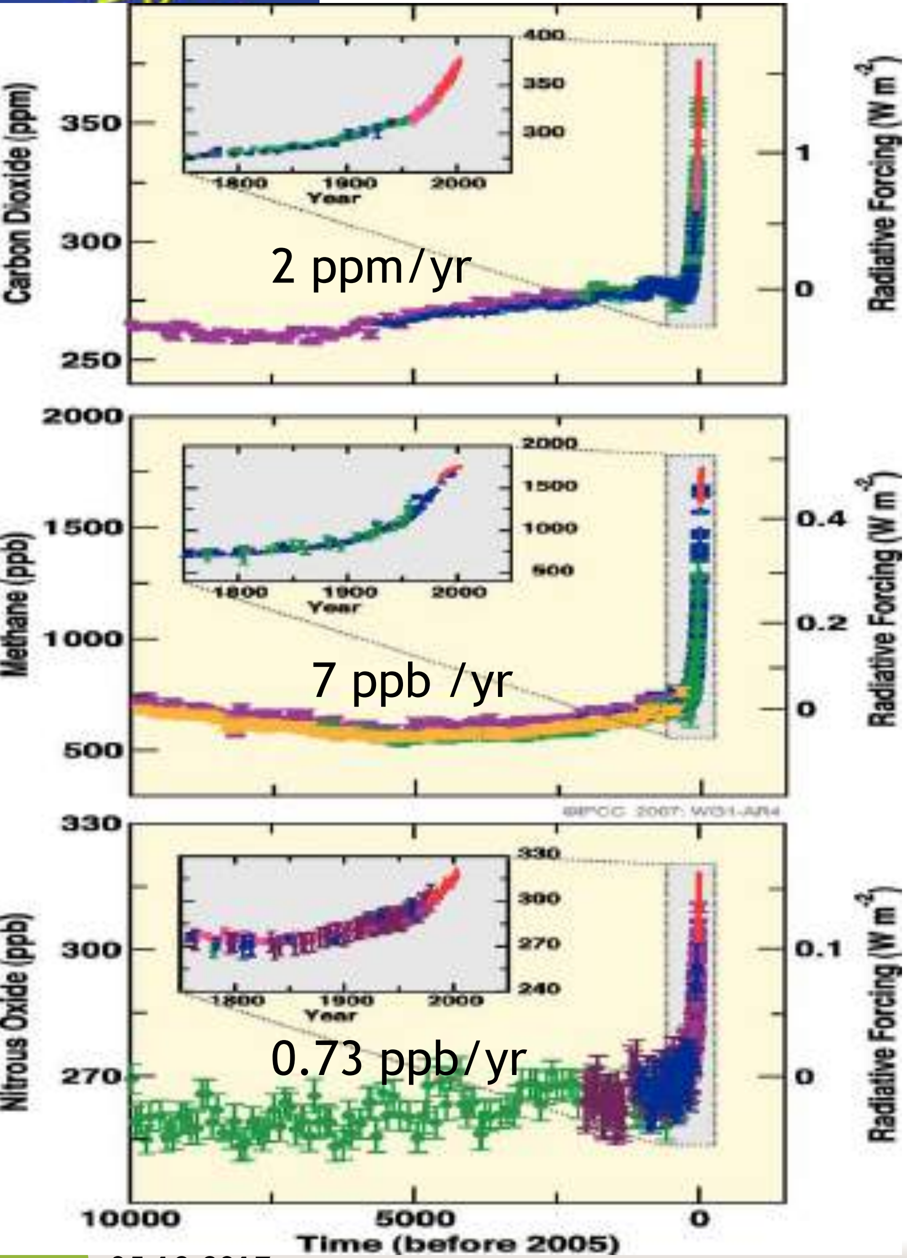
INRA SCIENCE & IMPACT

LIFE15 ENV/IT/000392

Some elementary concepts to understand the anthropic activity effects on climate change



Several gases contribute to greenhouse effect: CO2, CH4, N2O, HFC's, PFC's, SF6, Some gases are better at trapping heat than others

… need to be able to compare the warming capacity of one gas to another.

GWP (Global Warming Potential)

Allows to compare the amount of heat trapped by the mass of a GHG to the amount of heat trapped by a similar mass of carbon dioxide (unit g CO2eq)

GWP_{CO2}=1 GWP_{CH4}=21 GWP_{N2O}=310

Evaluation for time interval 100 years

1g CH4 = 21 g CO2eq **and** 1g N2O= 310 gCO2eq

Effect of GHG Concentration increase on earth Climate

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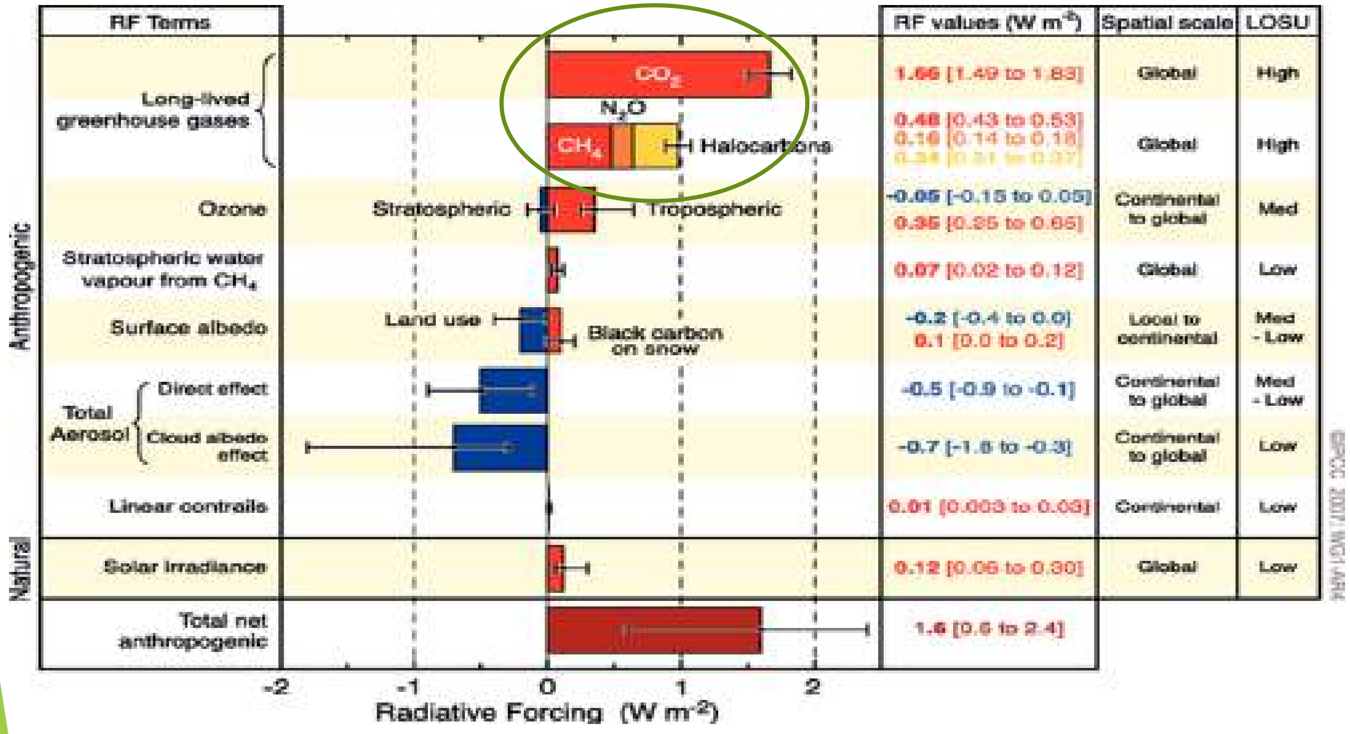
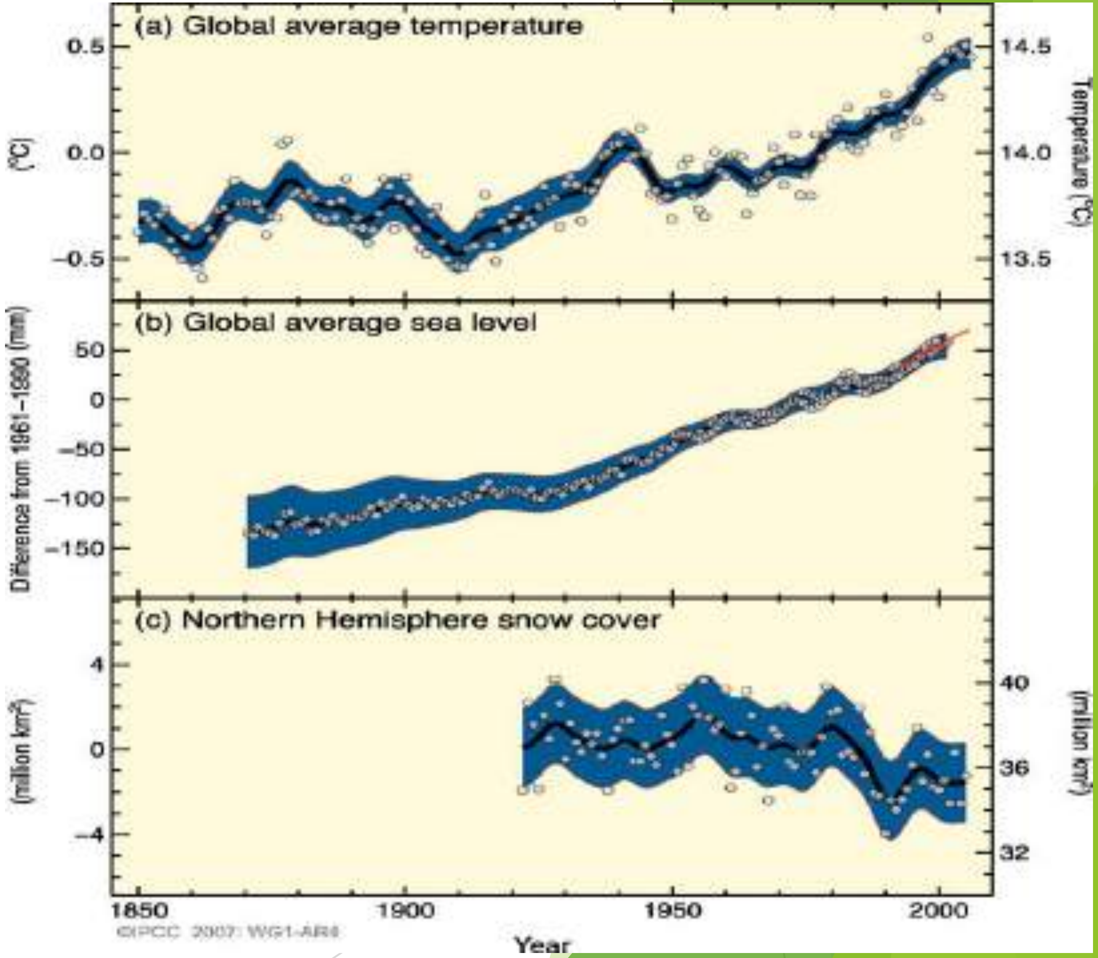
Additional radiatif forcing~ 2.5 W m^{-2}





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National GHG inventories

Importance of Agricultural activities

National GHG Inventories is a **framed exercise** : based from the IPCC methodology guidance.

The format is derived from UNFCCC (United Nations Framework Convention on Climate Change)

<u>GHG emissions are divided between 6 sectors :</u>

-Energy use

-Industrial processes

-Solvent and other product use

-**Agriculture**

-Land use, Land-use change and Forestry (LULUCF)

-Waste and treatment

IPCC methodology : The basis

Mainly based on the notion of emission factor :

$$E = \Sigma_{ij}\ EF_i \times Inputs(i,j)$$

i = activity
j = place
k = …

3 stages :

1. Identify sources

Sources by socio-economic categories
- *energy*
- *transport*
- *agriculture*
- *forest*
- *…*

2. Estimate emission factors

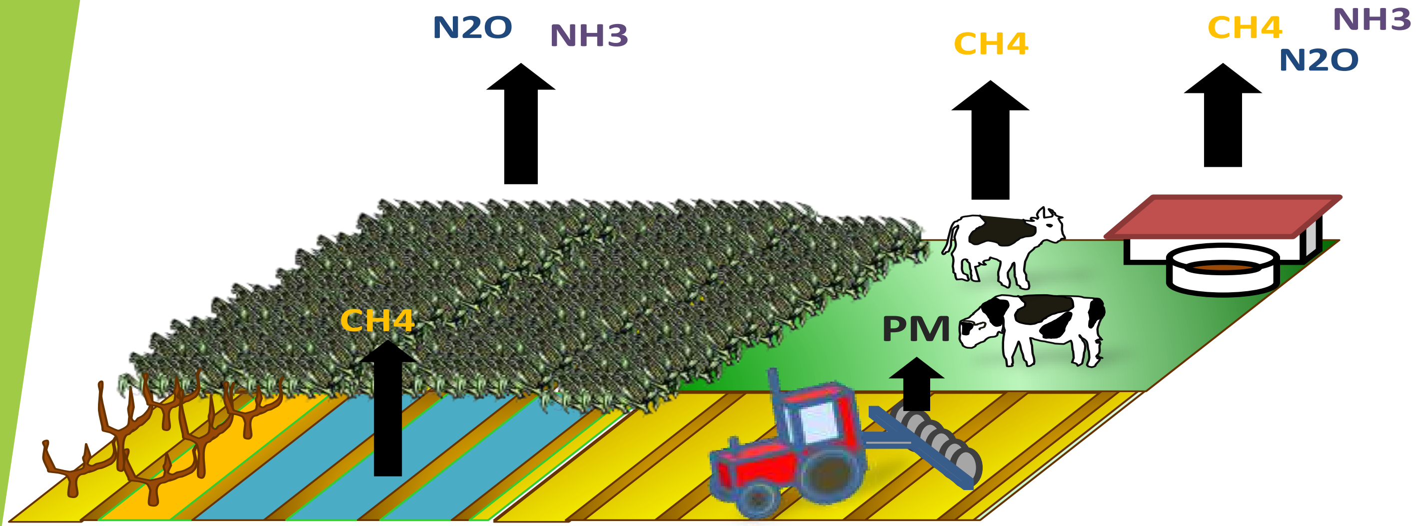
Emission Factor derived from Meta-analysis of Research studies

3. Estimate the inputs

National Statistics from Economic databases (agriculture industrie, transport …)

Focus on agricultural sector

The agriculture sector of the inventory (UNFCCC format) includes emissions from livestock and cultivated soils.



Livestock

- Enteric fermentation
- Manure management

Cultivated soils

- Rice cultivation
- Agricultural soils (crops and pastures)
- Burning crop residues
- Liming (CO_2)
- Urea spreading (CO_2)

Emissions related to energy consumption and farm inputs are recorded in the energy and manufacturing sectors respectively

GHGs concerned by agricultural activity in ***Italia***, some values … Ref. Italian National Institute for Environmental Protection and Research (ISPRA, 2014)

Agriculture account 7.8% (12% at Global scale) of total emissions (excluding energy consumption for tractors and fertilizer production)

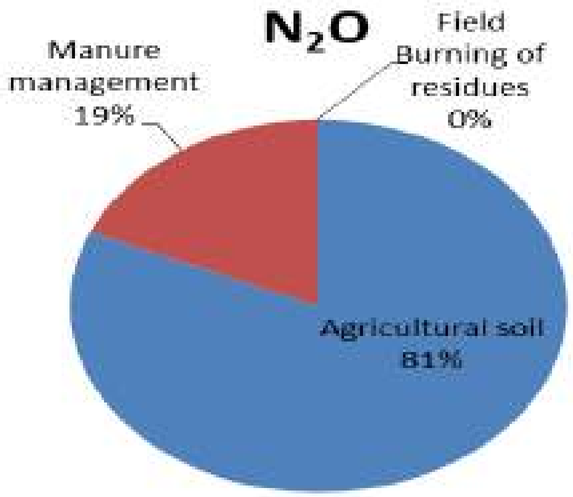
Agricultural Sources are mainly controlled by biological processes

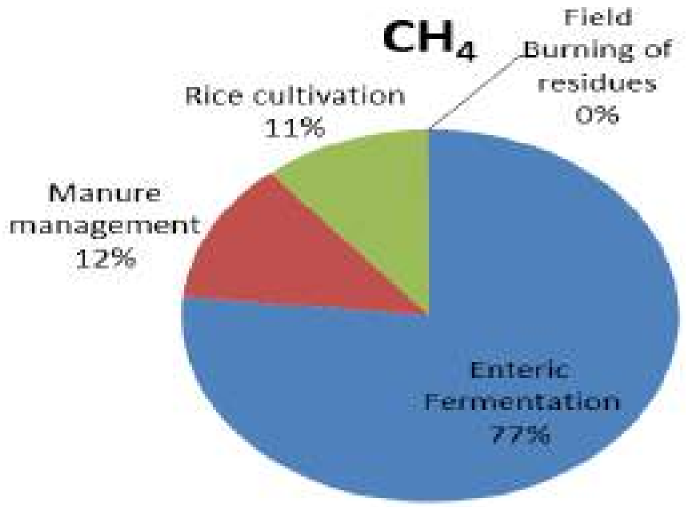
59% related to the nitrous oxide (N2O) of cultivated soil during nitrification and denitrification processes.

41% related to methane (CH4) during fermentation under anaerobic conditions (enteric fermentation, rice fields, manure managements)

CO2 generally not taken into account, because agriculture is more a sink for atmospheric CO2 with *Net Ecosystem Production (NEP)* ~ > 0

Source distribution within agricultural activities in Italia (2012)





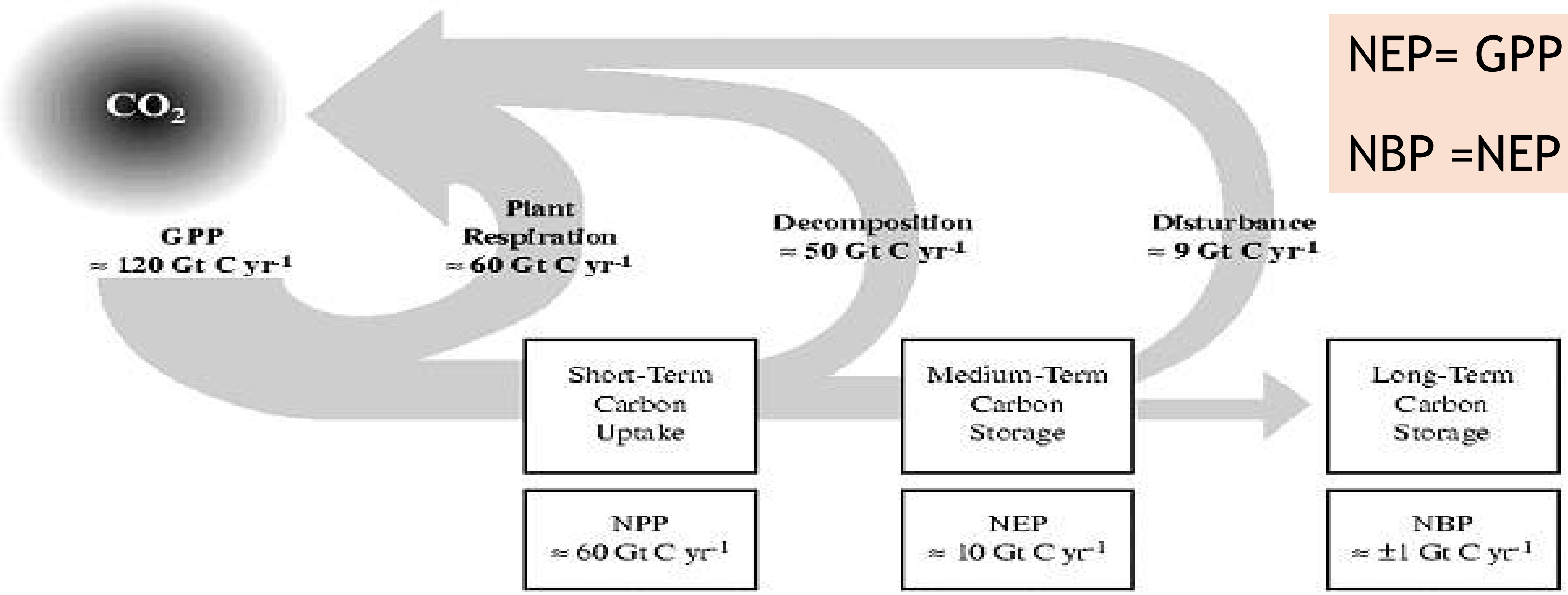
20.371 Mt CO2eq in 2012

13.918 Mt CO2eq in 2012

Despite large annual exchanges, CO2 fluxes are almost balanced (storage-emission)

NEP= GPP – Respiration =10 Gt C yr^{-1}

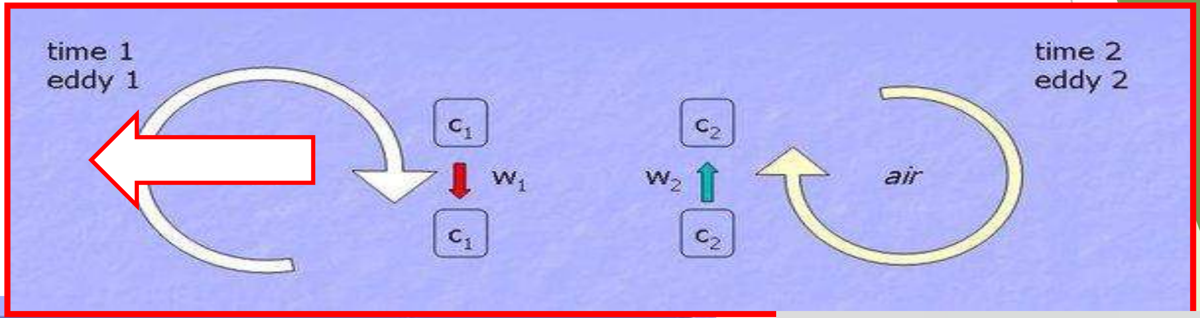
NBP =NEP – harvest, fire..~ 1 Gt C yr^{-1}



- ***Gross Primary Production (GPP)*** = total carbon fixed in the process of photosynthesis by plants
- ***Net Primary Production (NPP)*** = GPP reduced by losses resulting from the respiration of the plants (autotrophic).
- ***Net Ecosystem Production (NEP***) = Net accumulation of organic matter or carbon by an ecosystem (photosynthesis minus plant and soil respirations
- ***Net Biome Production (NBP) =*** net production of organic matter in a region containing a range of ecosystems (a biome) and includes, other processes leading to loss of living and dead organic matter (harvest, forestclearance, and fire, etc.)

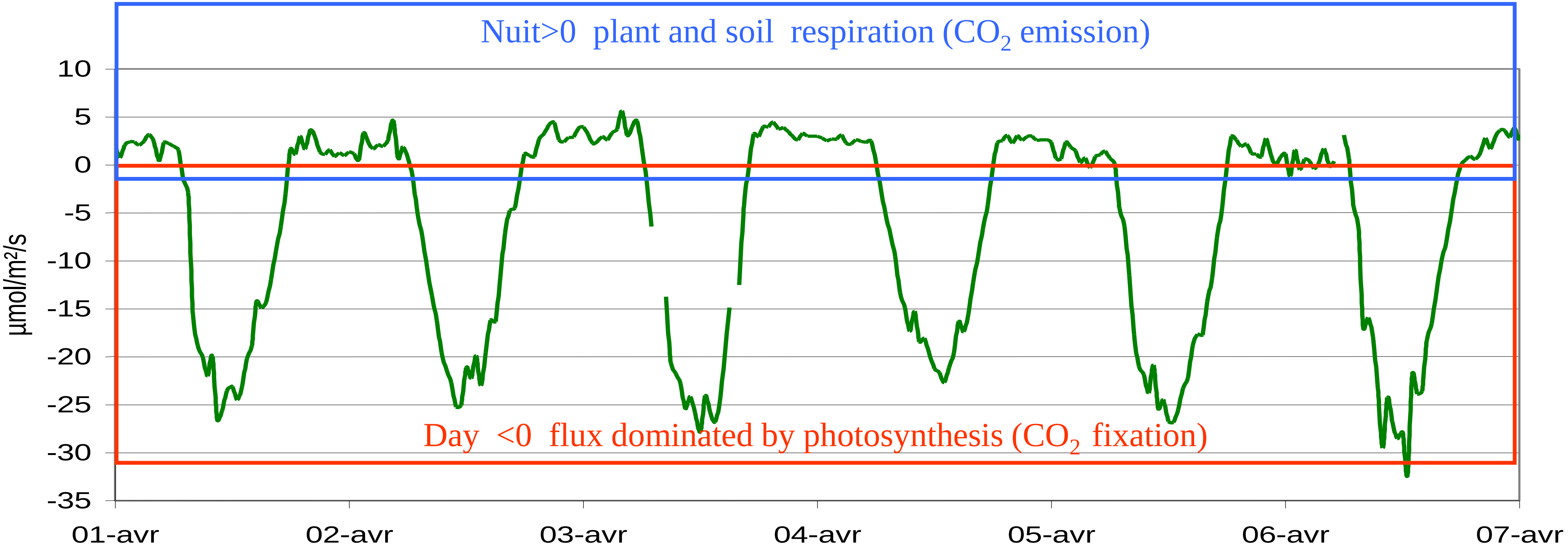
Example of method to evaluate NEP (Net CO2 flux) "Eddy Covariance"

Cov(W,CO2)



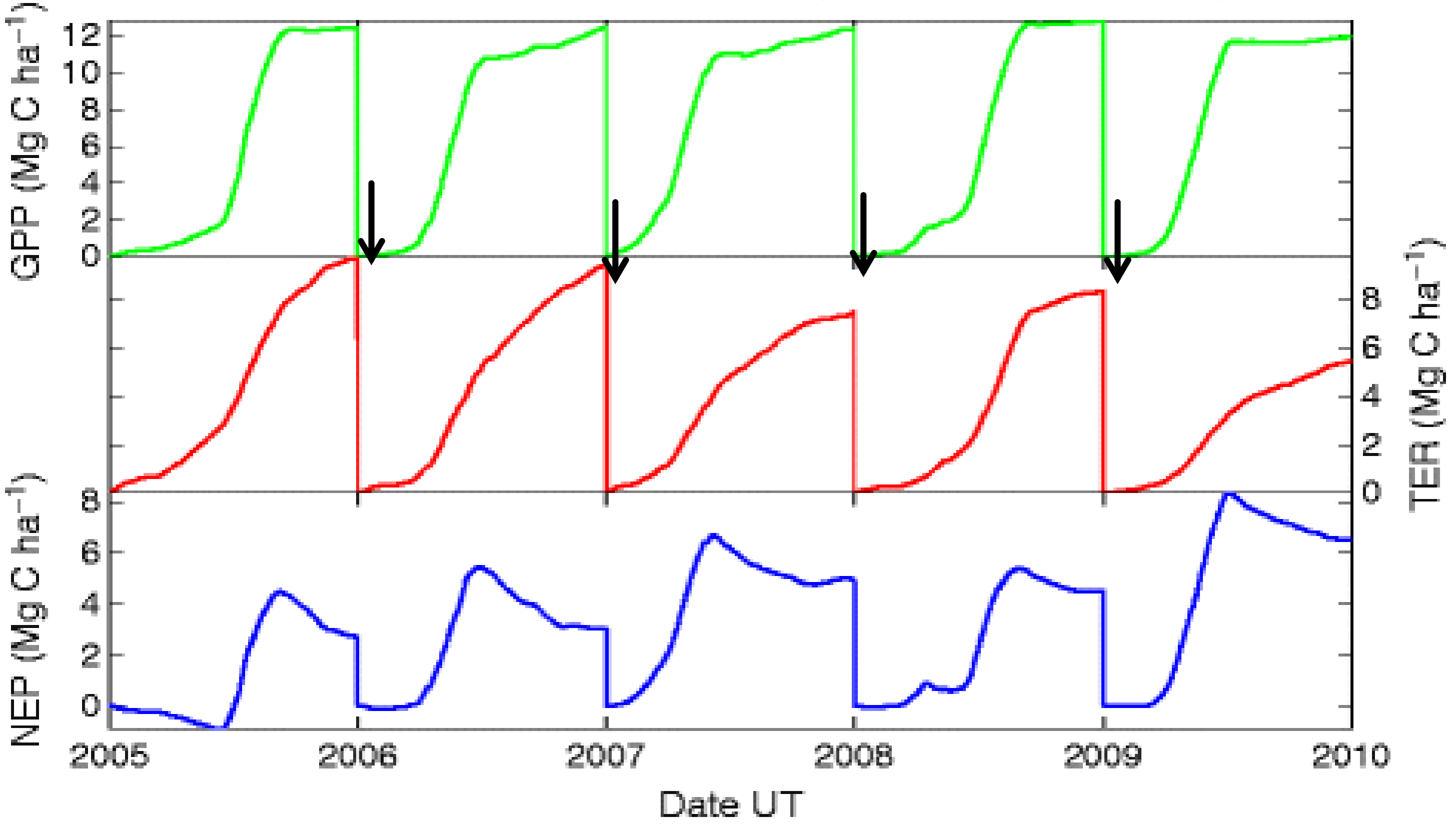
The Principle : The flux is proportional to the covariance between the vertical wind and the concentration

CO2 fluxes on a wheat crop, at Grignon 1-6 April 2007



Integration of CO2 fluxes => Carbon balance of crop rotation: Barley -Maize-Wheat

Gross Primary Productivity (GPP),
Total Ecosystem Respiration (TER)
Net Ecosystem Productivity (NEP)

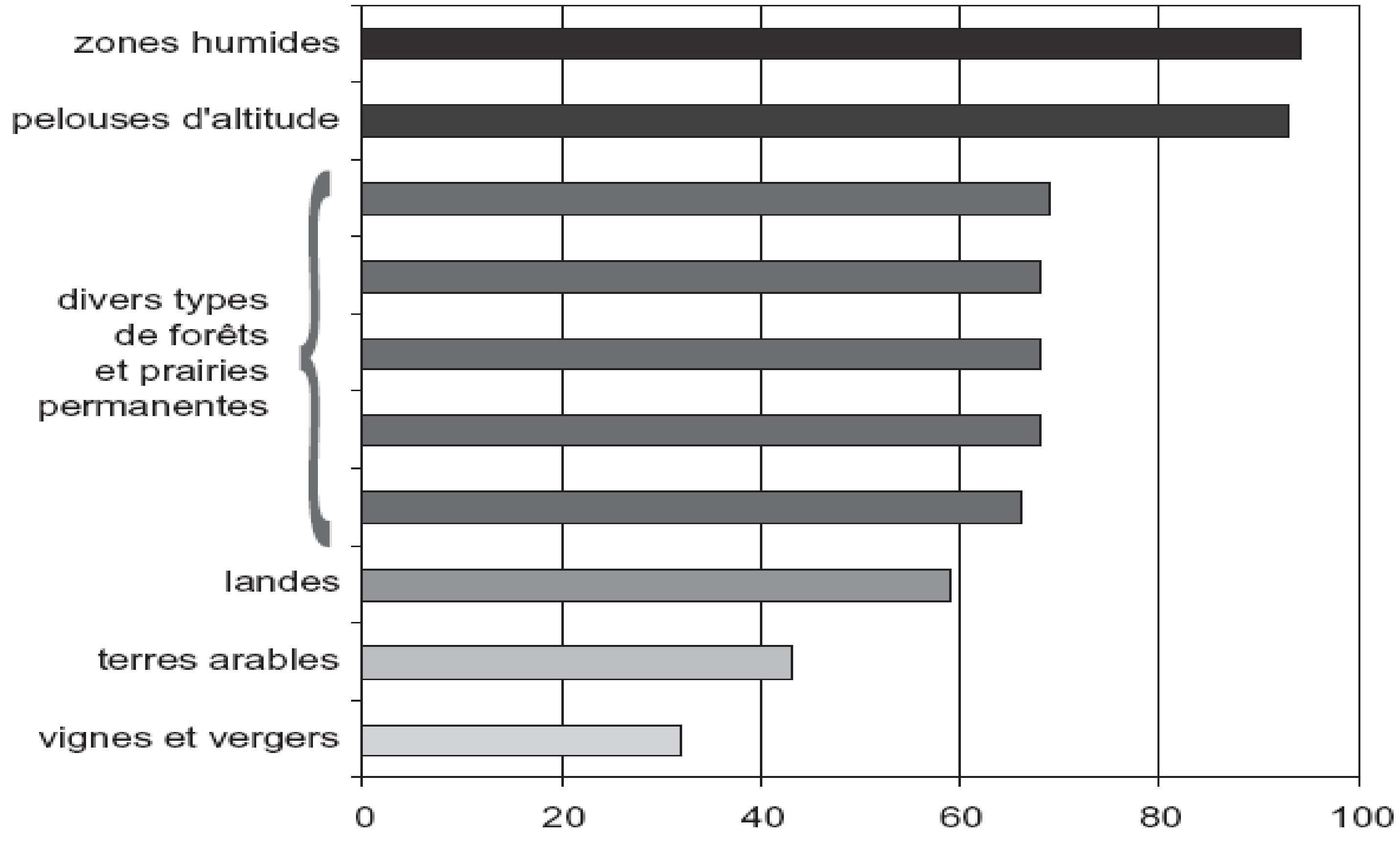


$$\Delta SOC=(NEP+F_{Charvest}+F_{Corg.fert}+F_{Cleaching}+F_{CCH4})\cdot\Delta t$$

To Improve C-balance assessments of various ecosystems => ICOS Research Infrastructure project was launched in 2008.
It provides long-term, continuous observations of concentrations and fluxes of the greenhouse gases (GHGs)

Soil Carbon stocks depend on land use

Les stocks de carbone organique (en t.ha^{-1}) des trente premiers centimètres des sols de France en fonction du type d'occupation du sol



Wetland and altitude lawns

Various Forest types

permanent Grassland

Moors

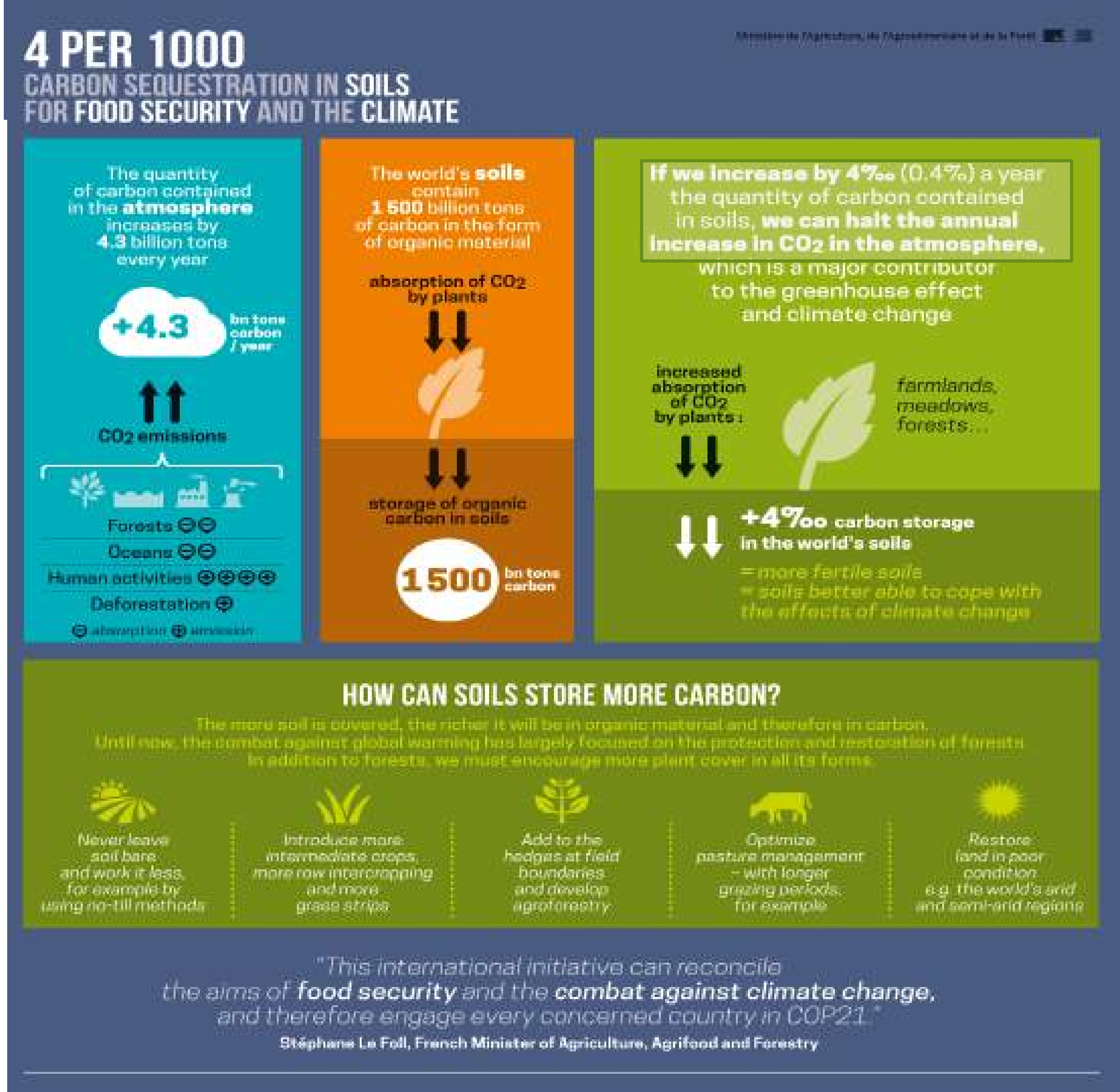
Harvested Land
Arable crop
Vineyard and Orchard

Source : Inra, expertise scientifique collective, 2002.

Mitigation option for removal atm. CO_2: <u>Initiative 0.4%</u> introducing during COP21

<u>Main Challenge</u>

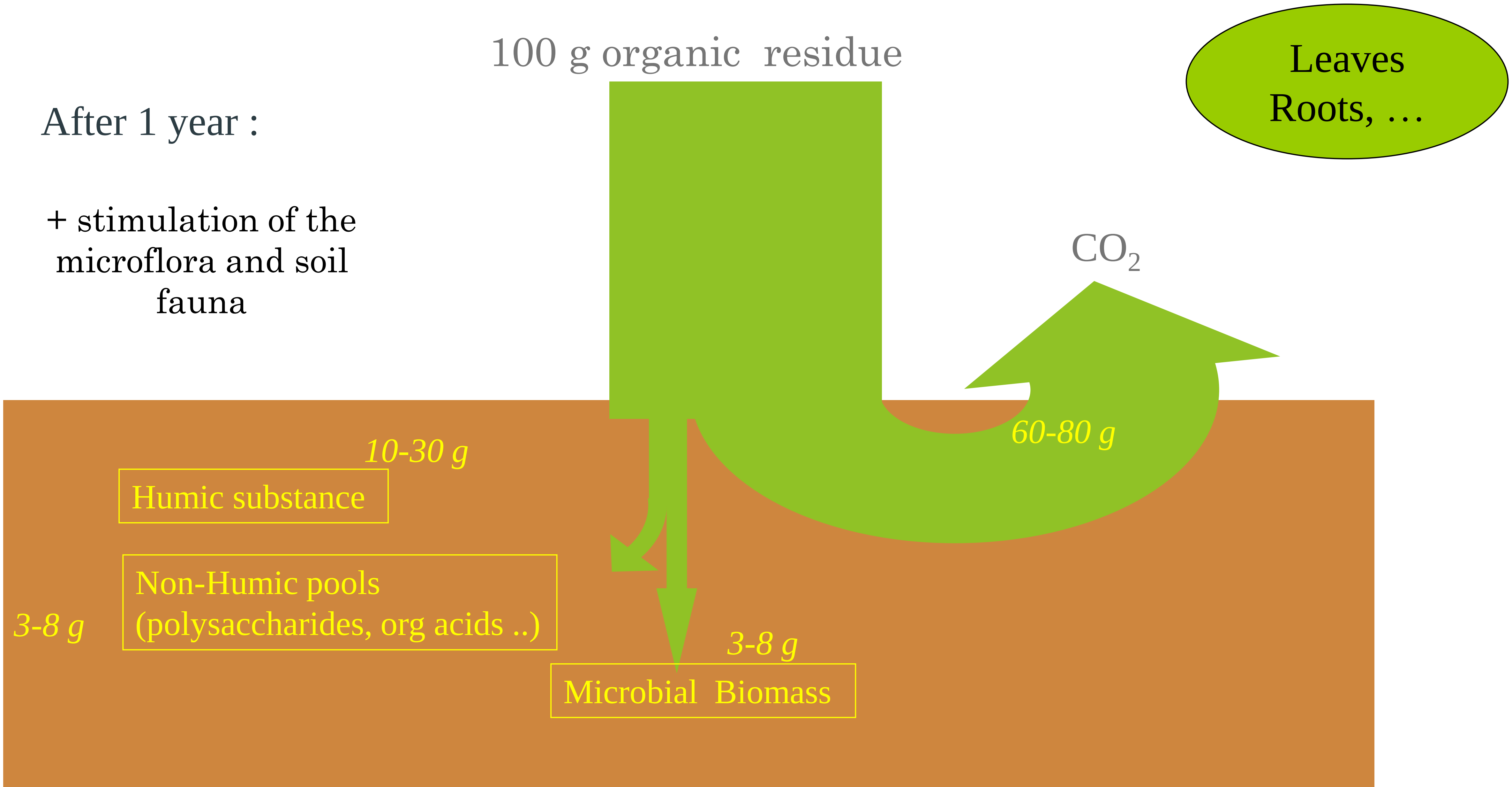
- Developing techniques with reduced tillage (never leave soil bare)
- Introducing more associated and intermediate cultures, more grass strips
- Developing agroforestry and hedges
- Optimizing pasture management: longer grazing period.
- Improving the management of organic inputs (livestock manure)
- Increasing productivity generate higher c-residue
- Restoring degraded lands



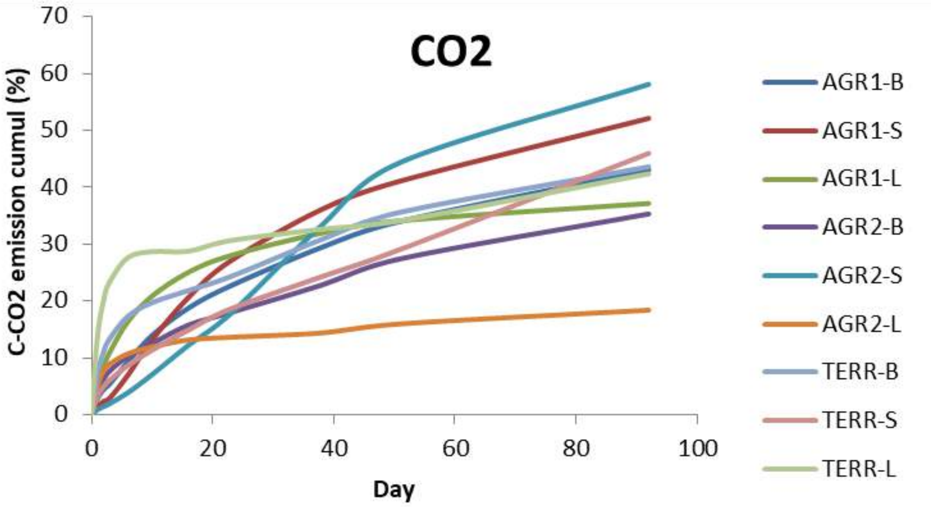
The Becoming of the organic carbon after residues addition into the soil

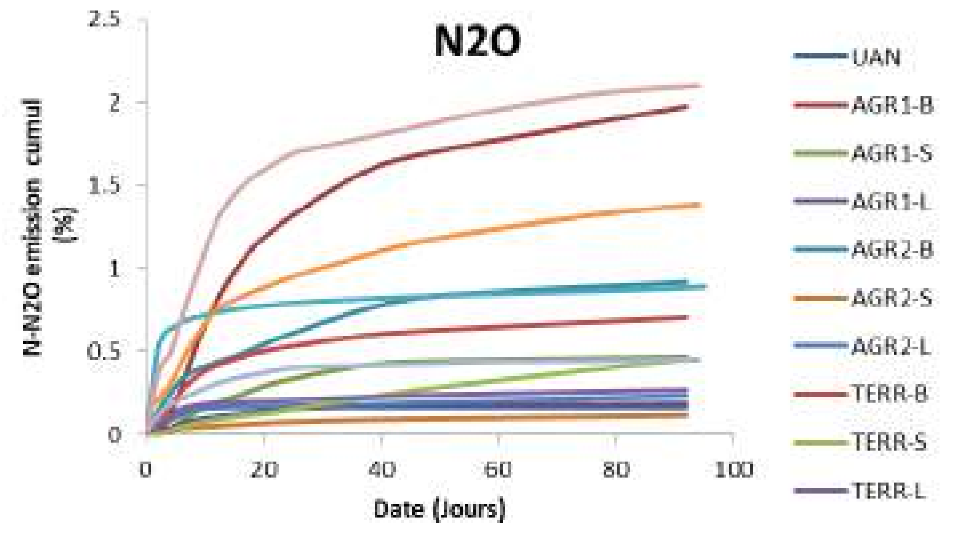
After 1 year :

+ stimulation of the microflora and soil fauna

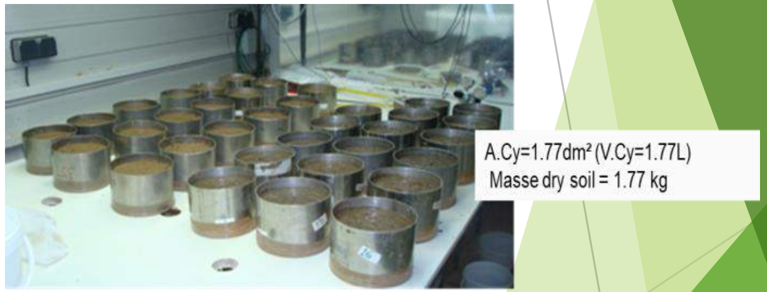


But… depend mainly to the quality (biochemical composition) of the organic amendments

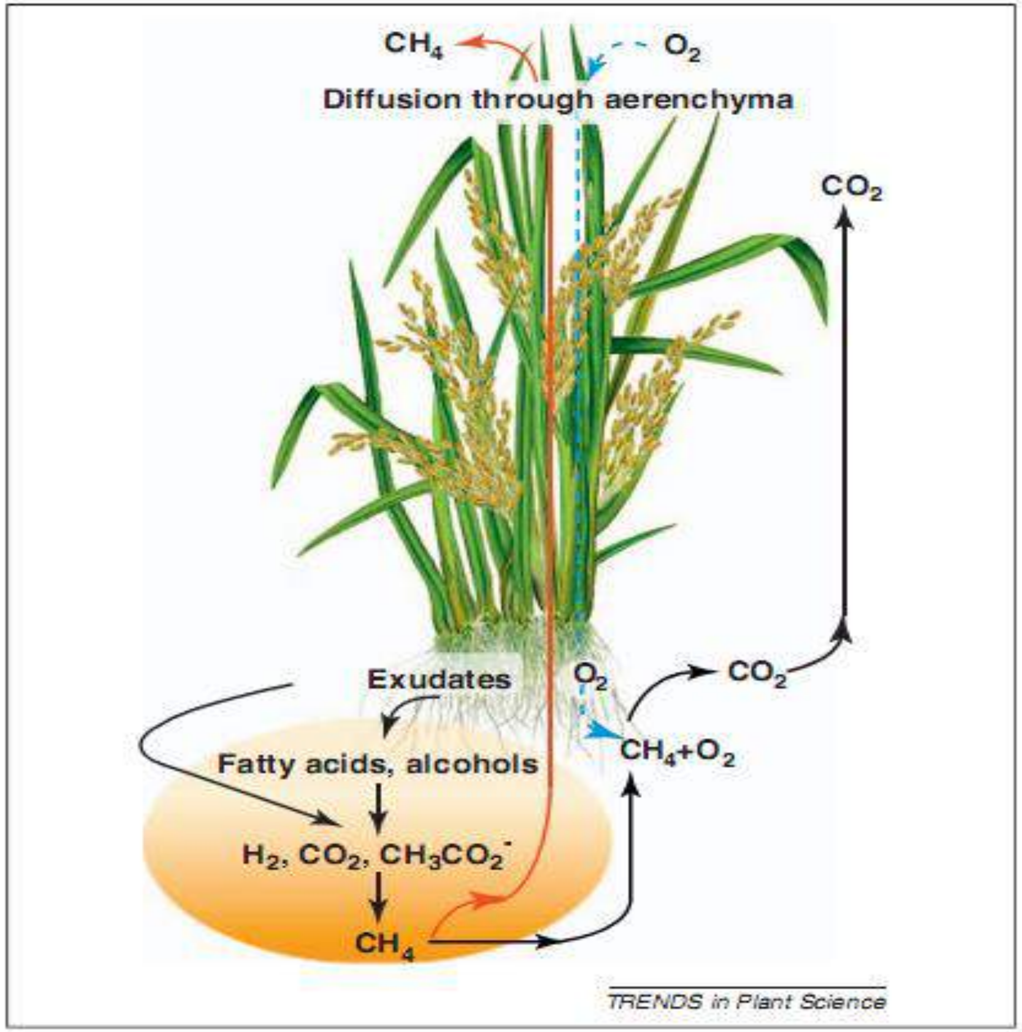


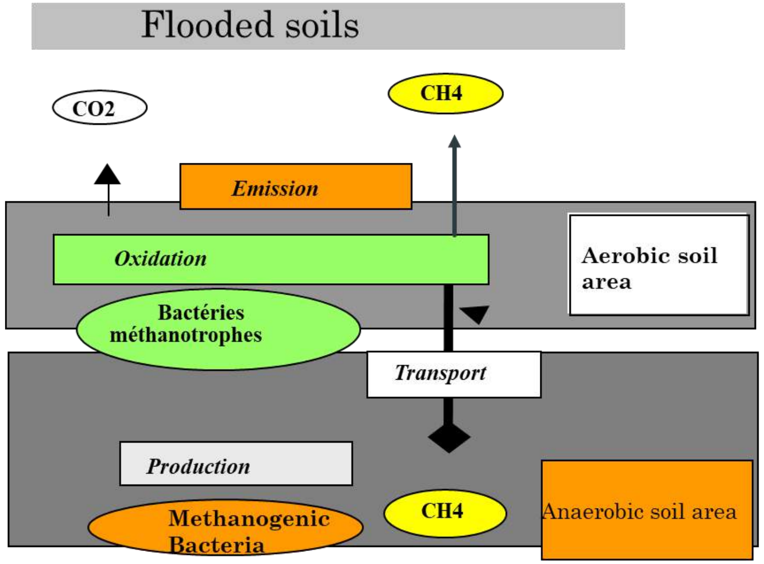


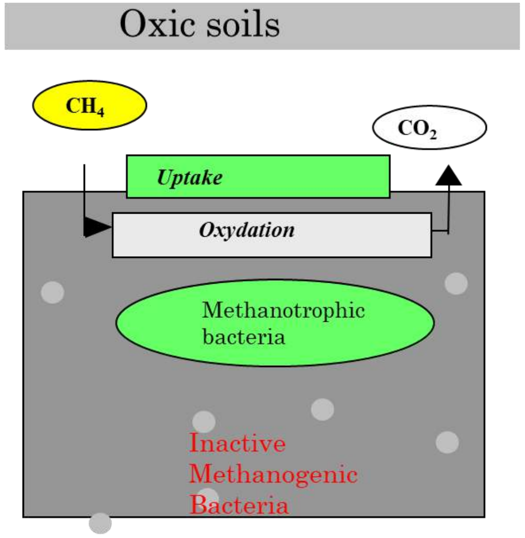
Cumulated Emissions in CO2 and N2O after application of anaerobic digestates from various feedstock (Cattle manure or slurry, bio-waste, industrial waste)



C release as C-CH4 : Rice Cultivation







$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

For rice cultivation the transport of CH4 is achieved through the aerenchyma of the plant

Options for mitigation :

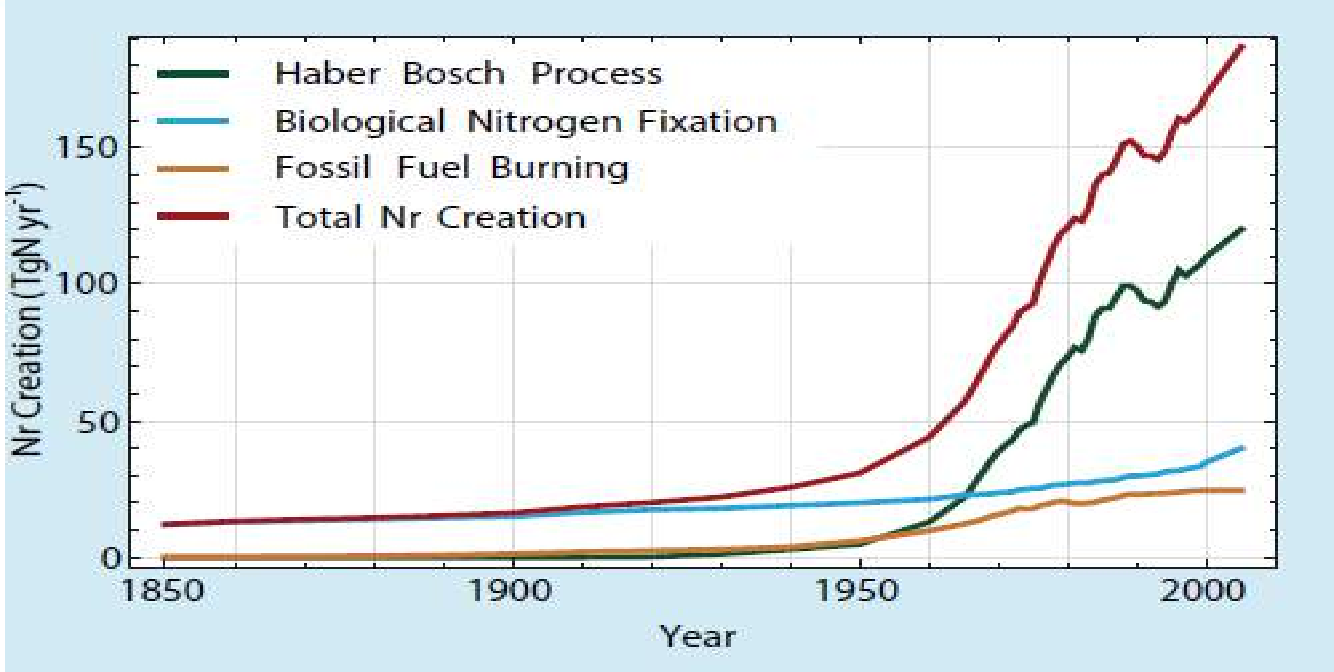
Rice cultivar with low exudation

Adjusting rice residue incorporation during dry period

Keeping soil as dry as possible

Nitrogen Management in Agriculture and Impact on GHG Emissions

The production of reactive nitrogen (Nr) since the beginning of 20th century has greatly increased



Nitrogen is one of the main limiting factors for plant production and soil microbial processes even if it is very abundant in our environment: N2 = 78% of the air.

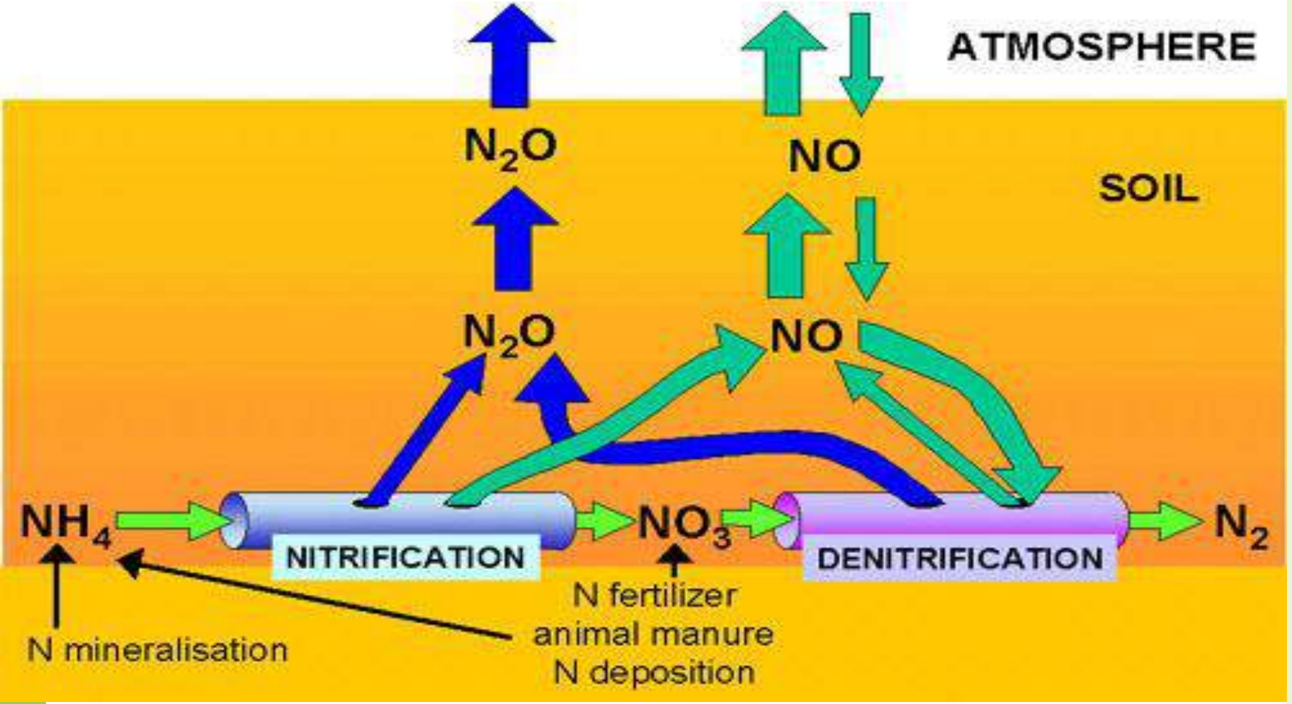
But 99% of living beings are not able to use this "inert" nitrogen and can only use "reactive" nitrogen

Only the Legumes, by symbiosis with nitrogen-fixing bacteria (eg Rhizobium), are able to convert N2 into reactive nitrogen (NH4 + Organic N).

Reactive nitrogen (Nr) compounds are present in various mineral forms (NH3 and NH4 +, NOx, HNO3, N2O, NO3- ...) and organic forms (urea , amines, proteins and nucleic acids)

Use of N-fertilizer promotes N_2O emission

Process mainly Biological



Aerobic, Autotroph

Anaerobia, Heterotroph

Emission are dependent on:

- Amount of Nitrogen applications and formulation of nitrogen (mineral v.s. organic form)
- Agricultural practices (tillage or not, method and timing of nitrogen application)
- Soil humidity (anoxia condition)
- Soil availability of carbon
- Soil temperature
- Soil texture
- Soil PH
- …..

N2O emission assessments are difficult because fluxes are very sporadic

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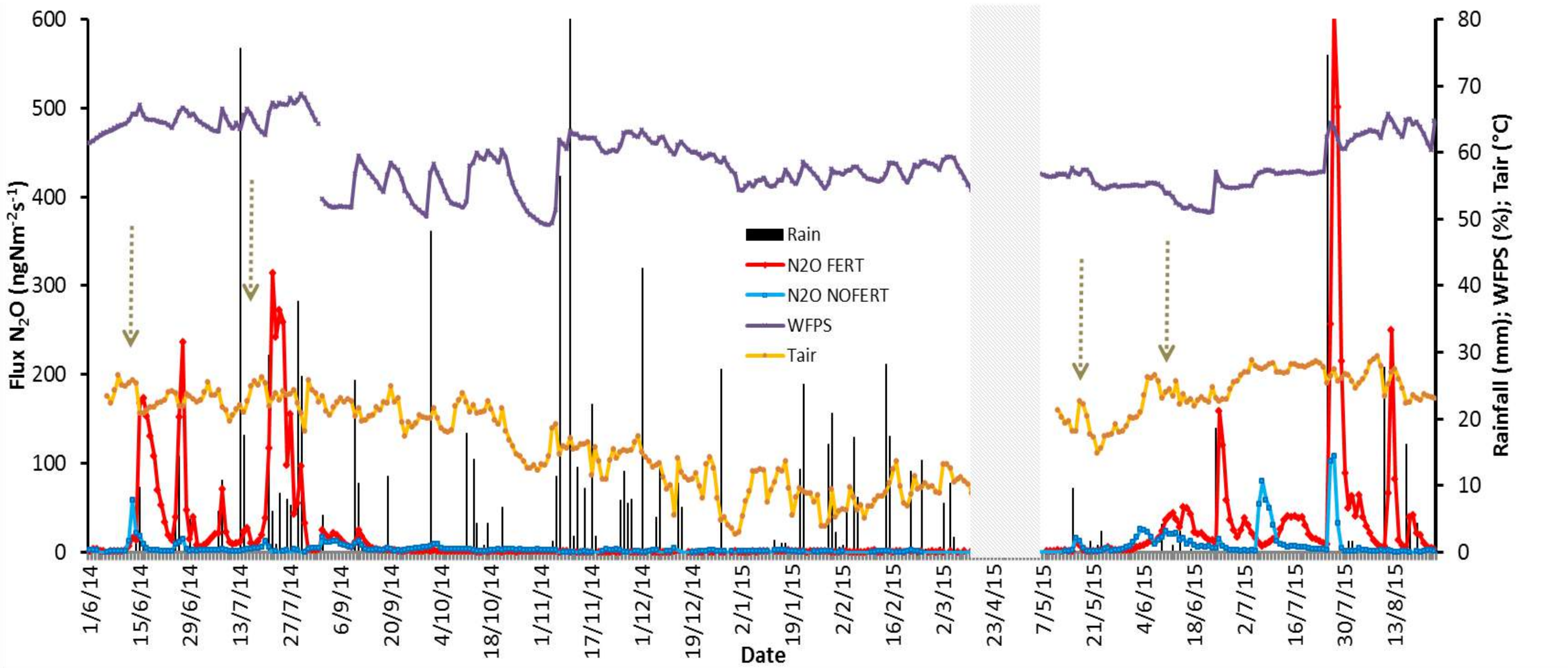

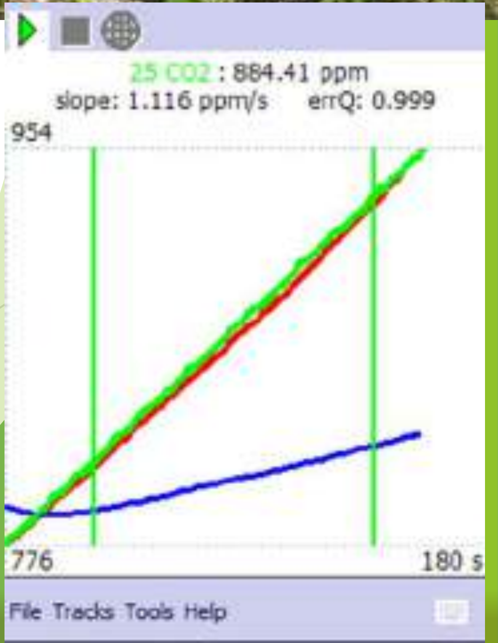

N2O flux measurements using auto-chamber prototype developed during IPNOA (Life+)

$$flux = \frac{V}{A}\frac{dC}{dt}$$

Mitigation options to limit N2O emissions

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Improve the nitrogen use more efficiency :

- Adjusting the application dose to the needs of plants (precision farming)
- Improving timing of application according to the plant needs
- Using slow or controlled release forms like nitrification inhibitors
- Placing the nitrogen into the soil, more accessible to crop roots
- Introducing in crop rotation more legumes or promoting fertilization by livestock effluents or other organic wastes

  => Allow to reduce use of manufactured fertilisers and sources of GHG during the production of the fertilisers

In concluding

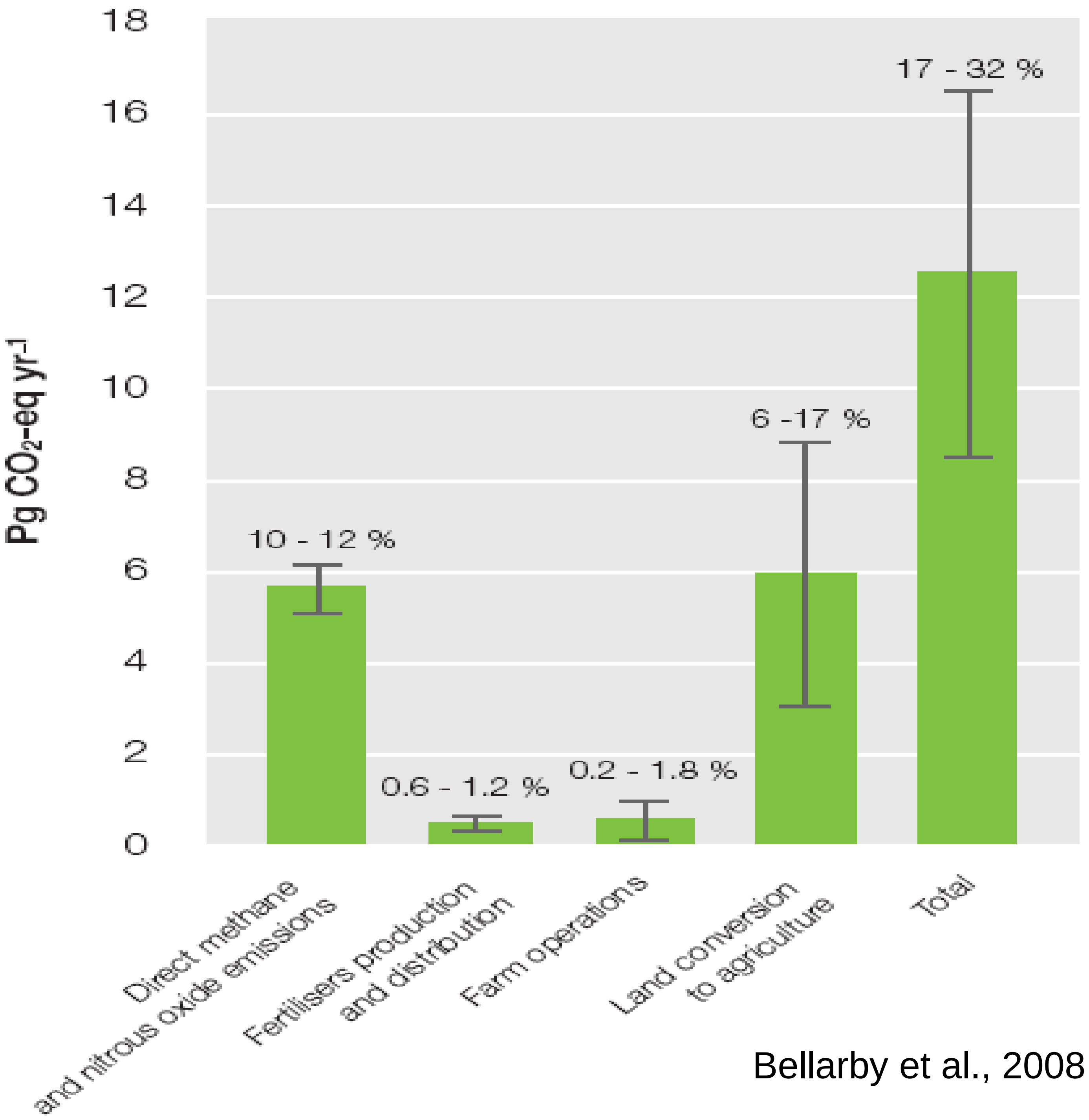
Agriculture contributes significantly to climate change

This includes

*<u>- Direct or Indirect </u>*emissions of N2O and CH4 but also

<u>“Upstream“ or “Downstream”</u> emissions from fossil fuel use

<u>Land Conversion to Cropland.</u>



Bellarby et al., 2008

Conclusions

Even if the agricultural activity contributes significantly to the additional greenhouse effect, *alternatives* exist to reduce agricultural emissions

-Main mitigation options are related to the increasing of carbon storage in the ecosystems (no bare soil, development of agro-forestry or bioenergy crops, increasing the production yields, using of specific cultivars, increasing grazing intensity, or permanent grassland) but also practices that tailor the nitrogen additions with plant needs

-**Note that** some of these practices are favourable to other ecological services: for example the storage of soil carbon favours the stabilities of the soils, avoiding erosion and improving soil structure and biodiversity.

-**However** as mitigation practices can affect more that on GHG it important to consider their impacts on all GHGs, and more globally on all activities sectors, the co-benefits of a practice may vary from place to place because of difference in climates, soils, water resources.

Conclusions

More …

-Efficiency of mitigation actions may vary with the economic context
-Mitigation actions induces a economic cost (positive or negative) that is important to evaluate

-Actions selected under an expected mitigation of GHG emissions could induce modifications of the "used inputs" or of "the output production", and could modify emissions *"upstream"* and *"downstream"* of an agricultural exploitation.

=> The question arises then of the delimitation of the system on which mitigation calculations will be carried out ?

=> Use of "life cycle analysis" approach (LCA), which assesses environmental impacts of a system that produces a good or a service, since the extraction of the necessary raw materials to its manufacture until its treatment at the end of life is then necessary

Thank to your attention