

## The potential of improving the estimation of national biogenic greenhouse gas emissions via the integration of crop identity

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# Greenhouse gas emissions by gas, World, 1850 to 2023



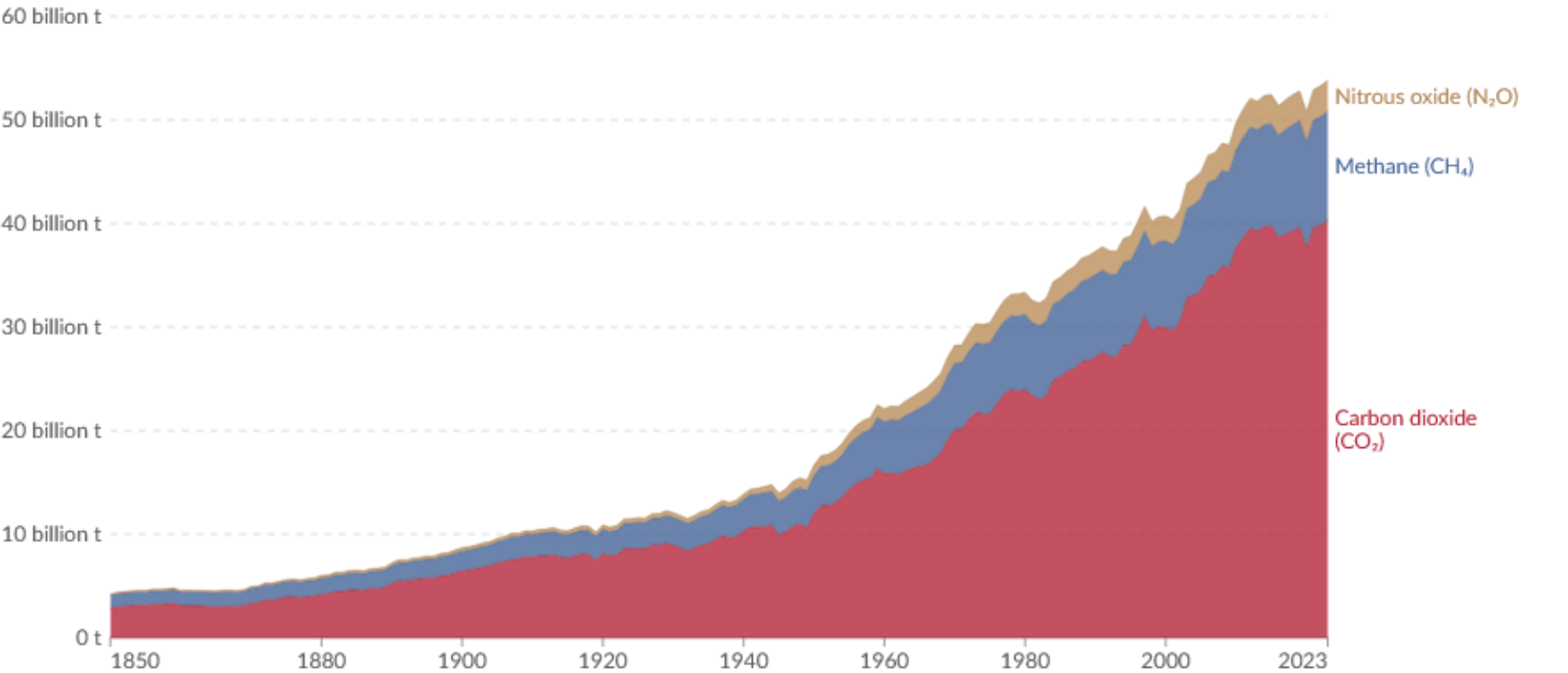
Greenhouse gas emissions from all sources, including agriculture and land-use change. They are measured in tonnes of carbon dioxide-equivalents over a 100-year timescale.

Table

Chart

Edit countries and regions

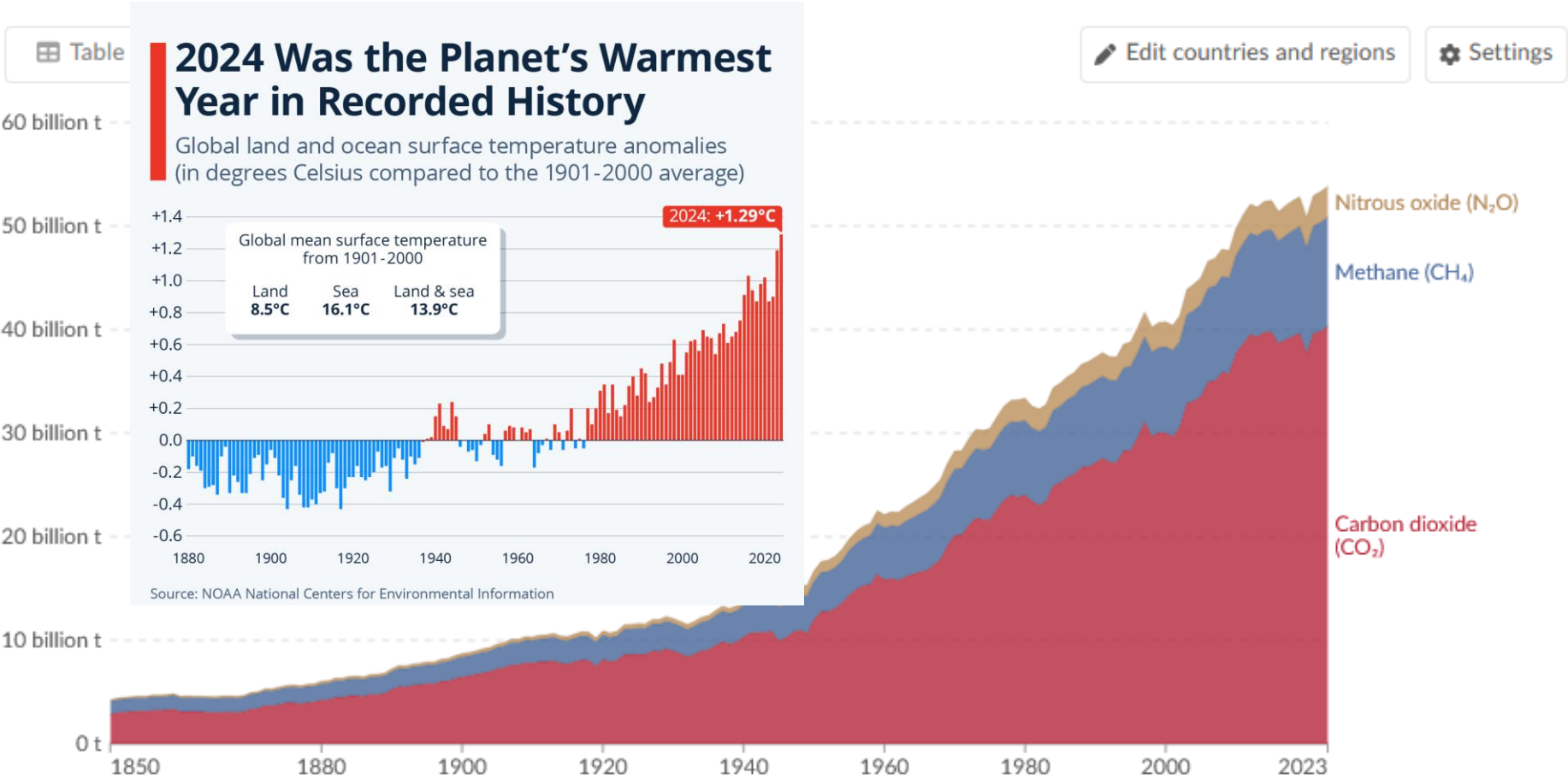
Settings



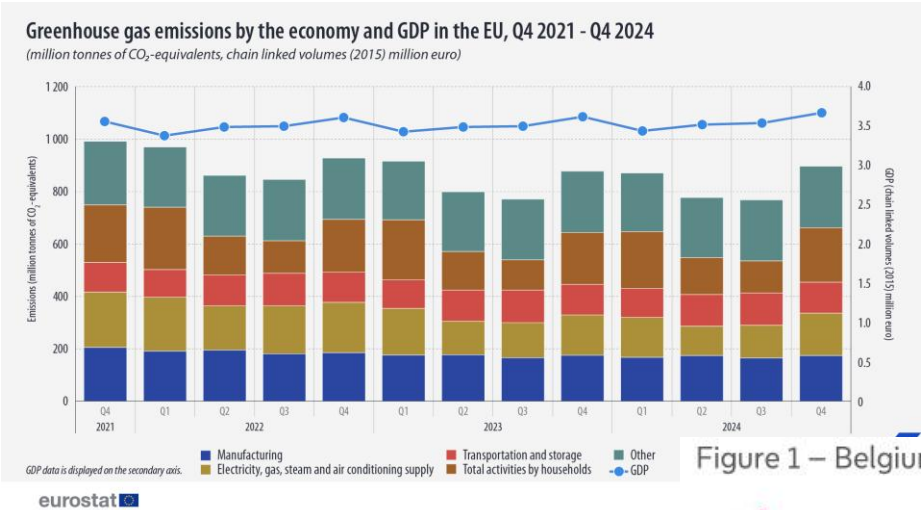
# Greenhouse gas emissions by gas, World, 1850 to 2023



Greenhouse gas emissions from all sources, including agriculture and land-use change. They are measured in tonnes of carbon dioxide-equivalents over a 100-year timescale.



Global warming trends and GHG emissions



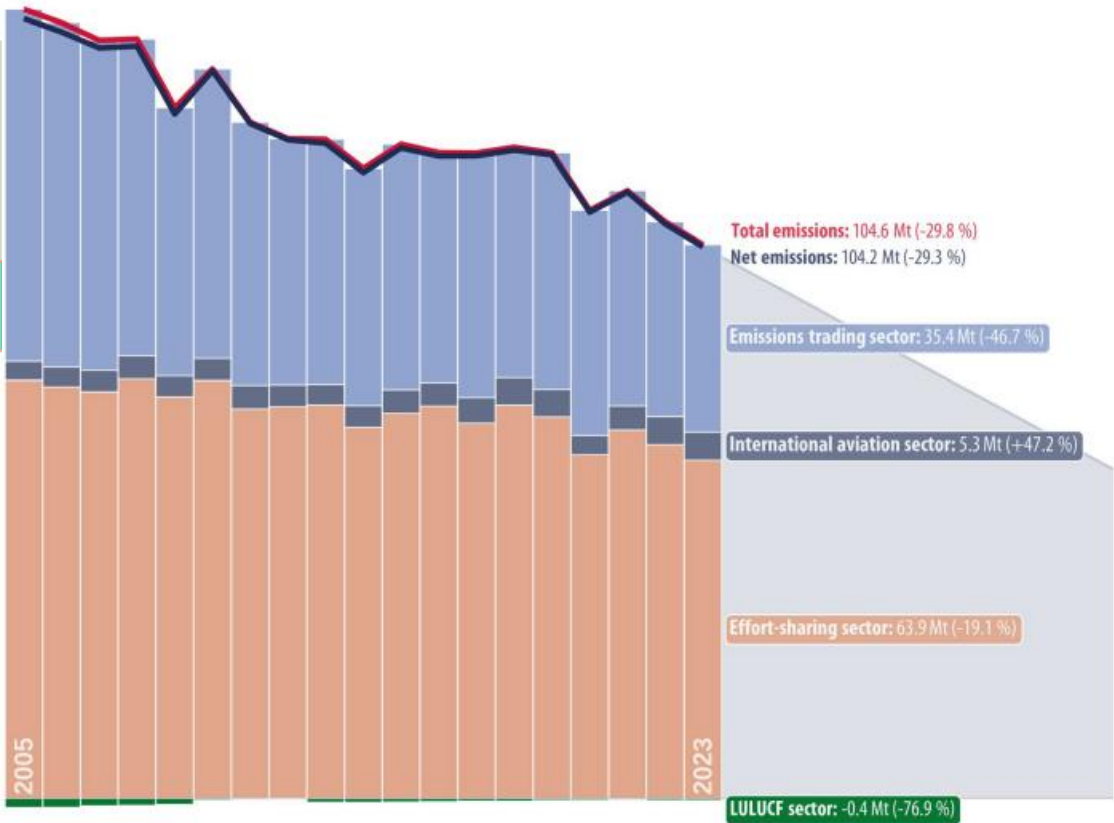
EU targets compared to emission levels of 1990:

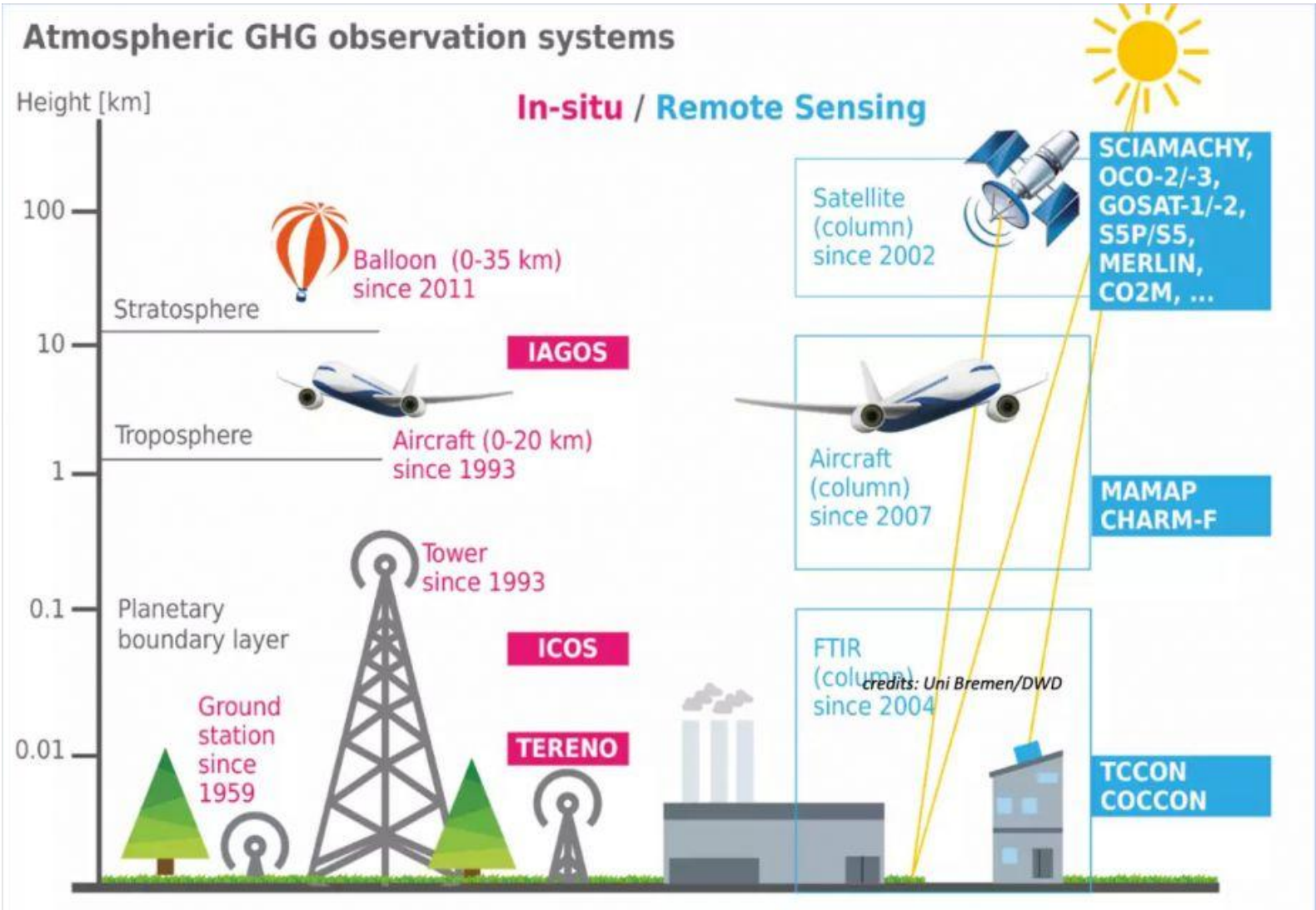
- 2030: 55% (**new target 66.25 – 72.5%**)
- 2040: 90% (**now with 5% carbon credit**)
- net neutrality by 2050

Figure 1 – Belgium's greenhouse gas emissions in million tonnes (Mt), 2005–2023

|         |                                              |  |  |                                              |  |  |                                           |  |  |                                                         |  |  |                                                         |  |  |
|---------|----------------------------------------------|--|--|----------------------------------------------|--|--|-------------------------------------------|--|--|---------------------------------------------------------|--|--|---------------------------------------------------------|--|--|
| Belgium | Total net GHG emissions 2022-1990 (% change) |  |  | Total net GHG emissions 2022-2015 (% change) |  |  | GHG intensity of GDP 2022-2015 (% change) |  |  | Projected net GHG emissions by 2030 (tonnes per capita) |  |  | Projected net GHG emissions by 2050 (tonnes per capita) |  |  |
|         | -26%                                         |  |  | -10%                                         |  |  | -19%                                      |  |  | 7.0                                                     |  |  | 5.2                                                     |  |  |
|         | -32%                                         |  |  | -10%                                         |  |  | -20%                                      |  |  | 5.1                                                     |  |  | 3.6                                                     |  |  |

|      |                                                               |  |                                                                    |  |                                                                                                                 |  |                                                                               |  |
|------|---------------------------------------------------------------|--|--------------------------------------------------------------------|--|-----------------------------------------------------------------------------------------------------------------|--|-------------------------------------------------------------------------------|--|
| EU27 | Overshoot vs. linear trajectory (net GHG emissions 2022-2050) |  | Overshoot vs. non-linear benchmark (total GHG emissions 2022-2050) |  | Target year for climate neutrality (NECP progress reports, national long-term strategies or "xx" other sources) |  | Legal status of the climate-neutrality target (based on the Net-Zero Tracker) |  |
|      | 49%                                                           |  | 21%                                                                |  | 2050*                                                                                                           |  | In policy document                                                            |  |
|      | 34%                                                           |  | 40%                                                                |  | 2050                                                                                                            |  | In law                                                                        |  |



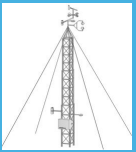


- “Expensive”
- Point measurements (but with footprint)
- Exact fluxes but no concentration

- “Cheap”
- Flaws in temporal/spatial resolution
- Column prevents origin/transport attribution

Atmospheric inversion

Fluxtower  
EC data



UPSCALE

“Prior”-fluxes  
Across region of  
interest

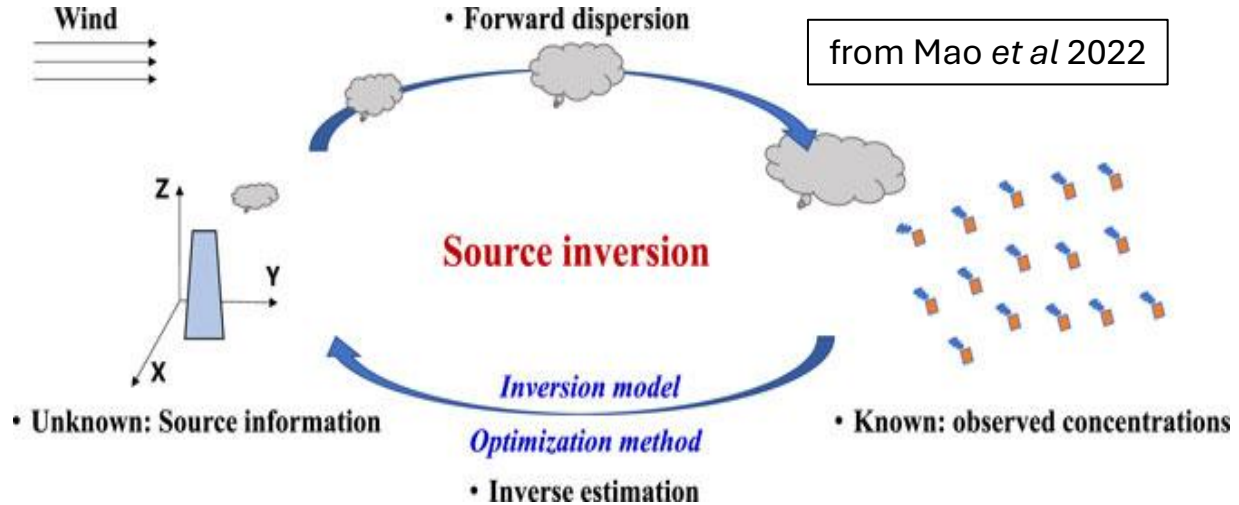


Atmospheric  
Transport Model  
(e.g. WRF-Chem)



Atmospheric  
GHG  
concentrations

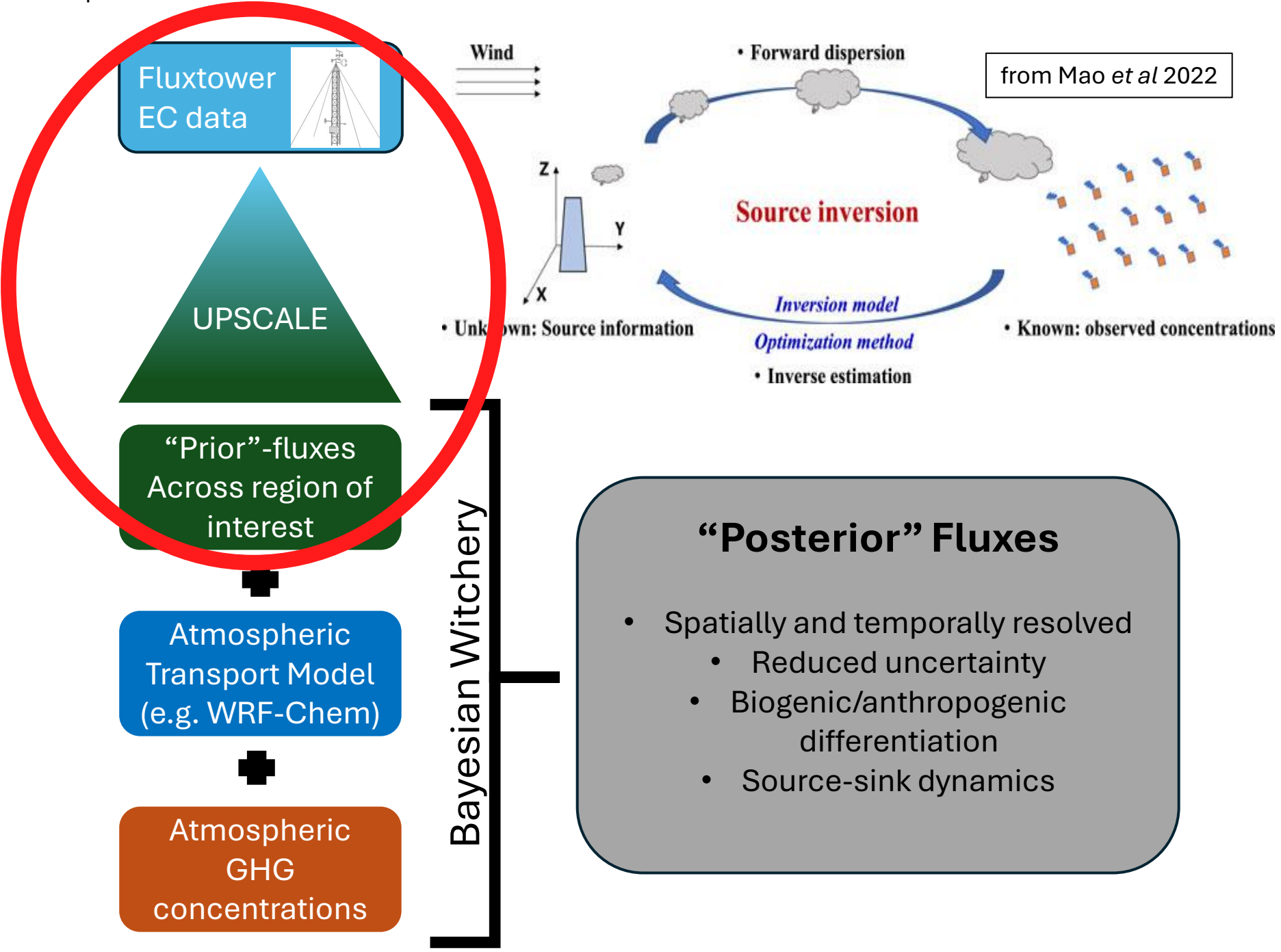
Bayesian Witchery



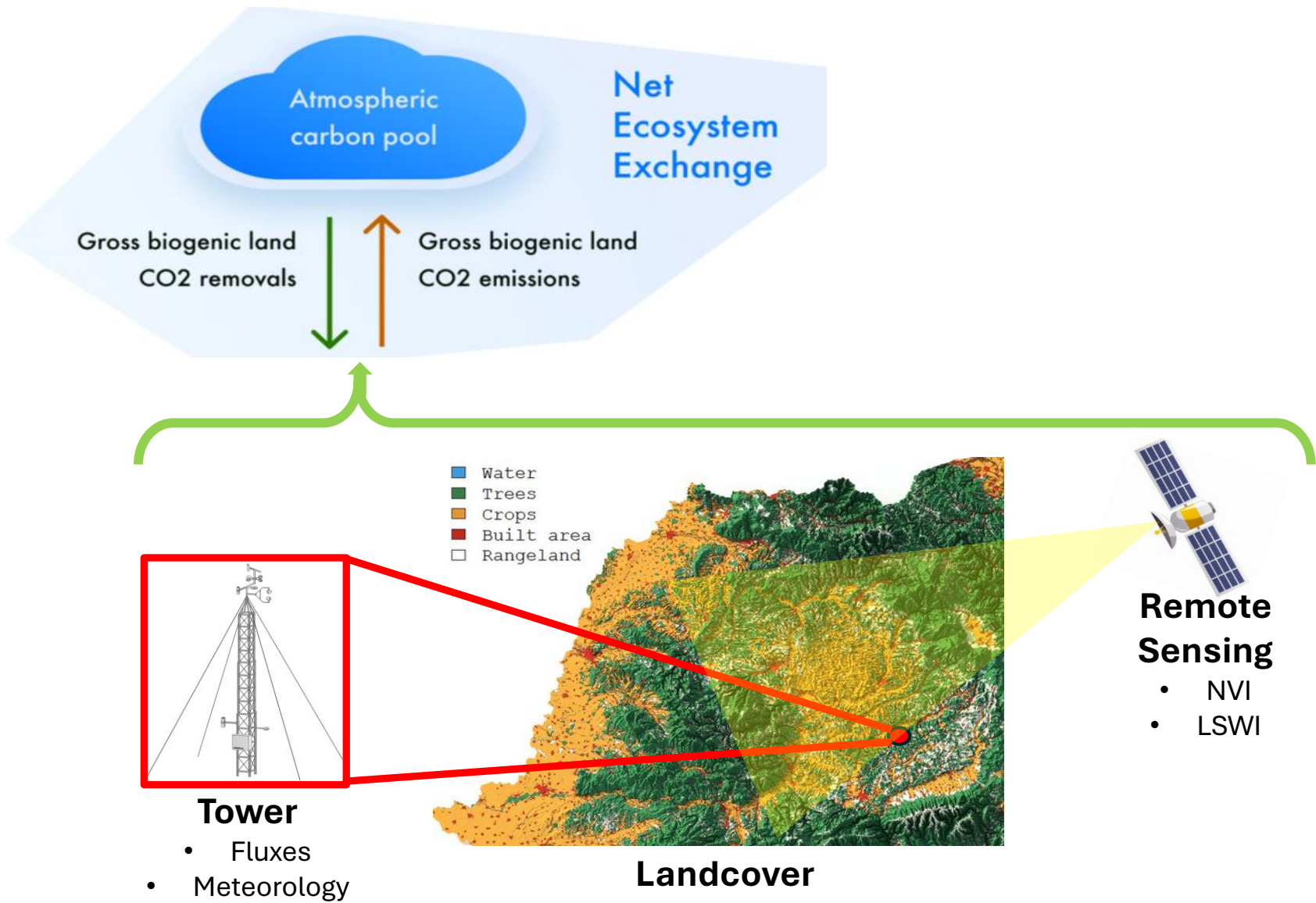
“Posterior” Fluxes

- Spatially and temporally resolved
  - Reduced uncertainty
  - Biogenic/anthropogenic differentiation
  - Source-sink dynamics

# Atmospheric inversion



Upscaling

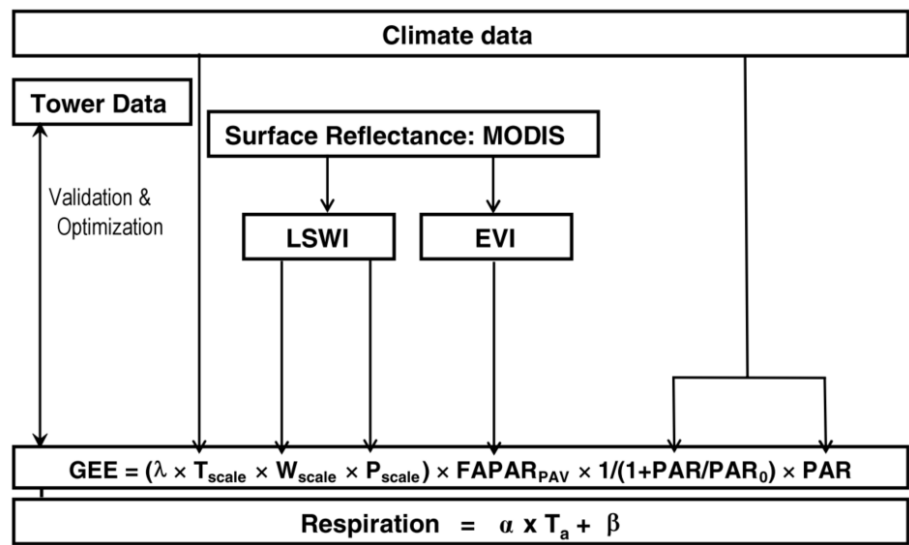


Simulating CO<sub>2</sub> fluxes bottom-up via flux-tower, satellite and meteorology data:

**Vegetation Photosynthesis  
Respiration Model (VPRM)**

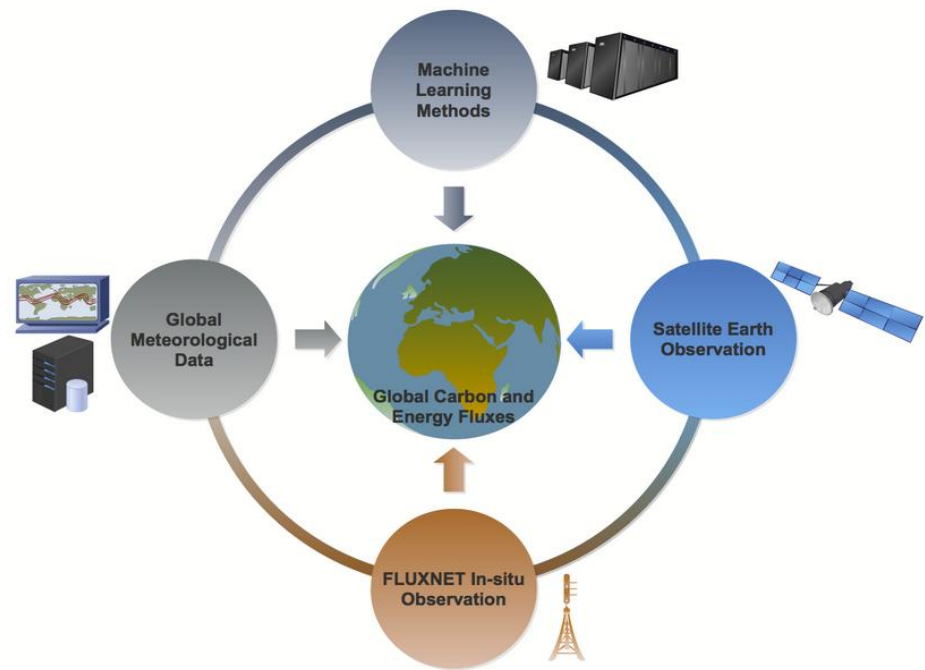
- Well established and widely used (Mahadevan *et al* 2008)
- Equation based
- Landcover based on SYNMAP (Jung *et al* 2006) in 1 km resolution
- Available in hourly average 2012-2023 (2019 missing) in 0.125° x 0.083° resolution for Belgium

MAHADEVAN ET AL.: NET ECOSYSTEM EXCHANGE MODEL

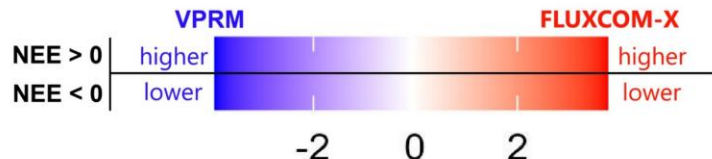
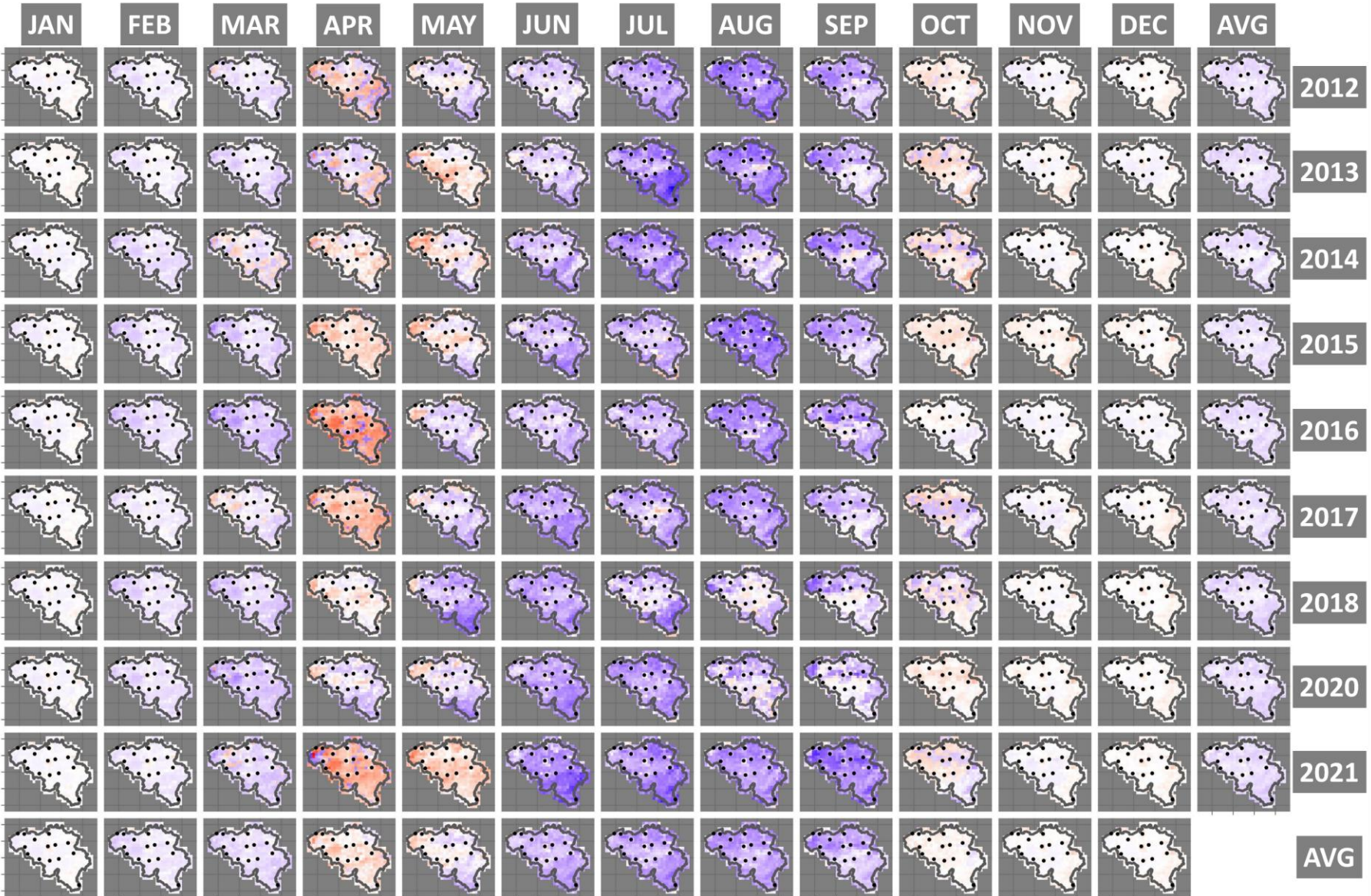


**FLUXCOM-X**

- new and hot
- Machine learning based (boosted regression trees)
- Landcover based on MODIS MCD12Q1 (Friedl *et al* 2019) in 500m resolution
- Available in monthly average 2012-2021 in 0.05° x 0.05° resolution for Belgium

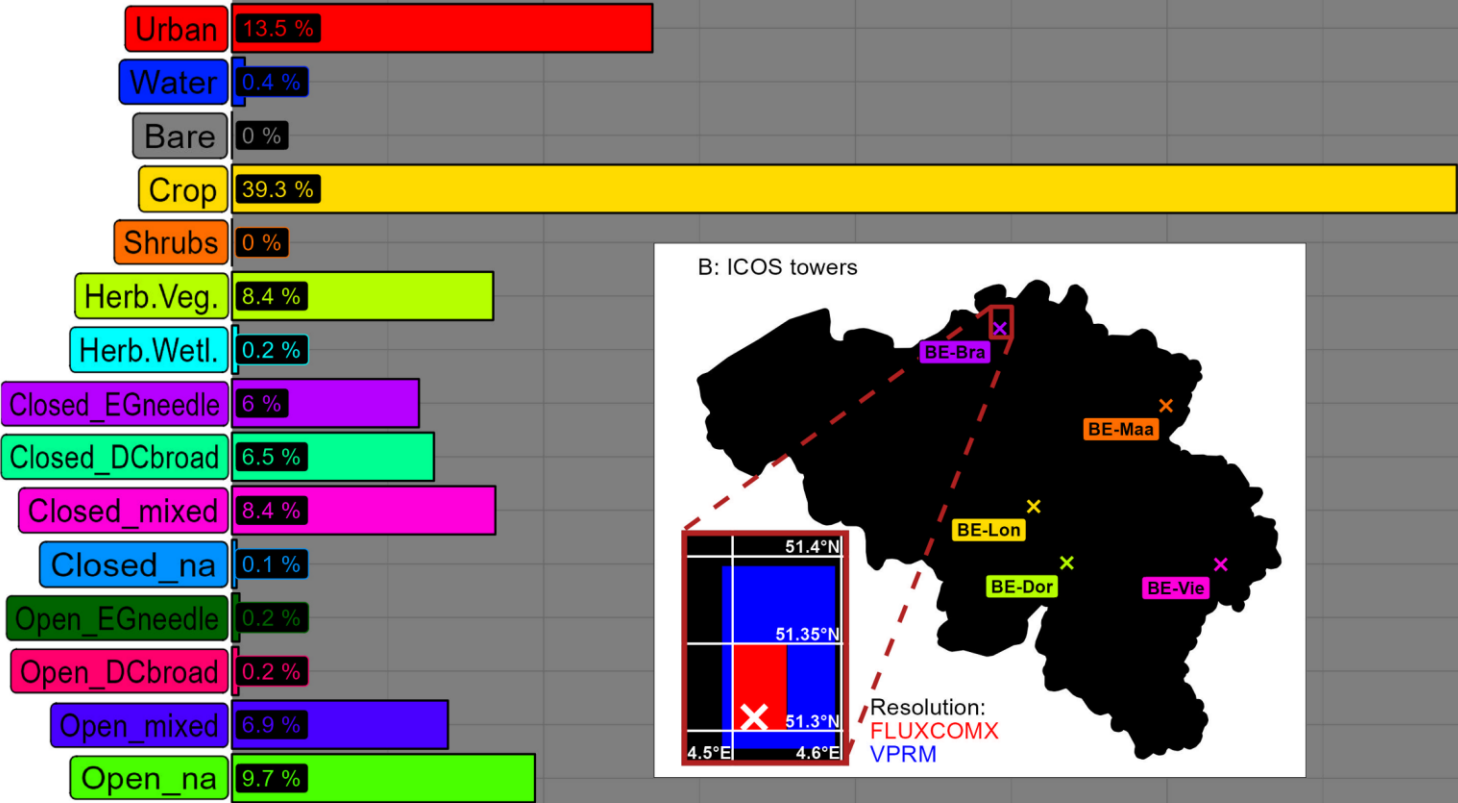


A general overview of the FLUXCOM initiative.



VPRM vs. FLUXCOM-X

A: Landcover composition Belgium 2019



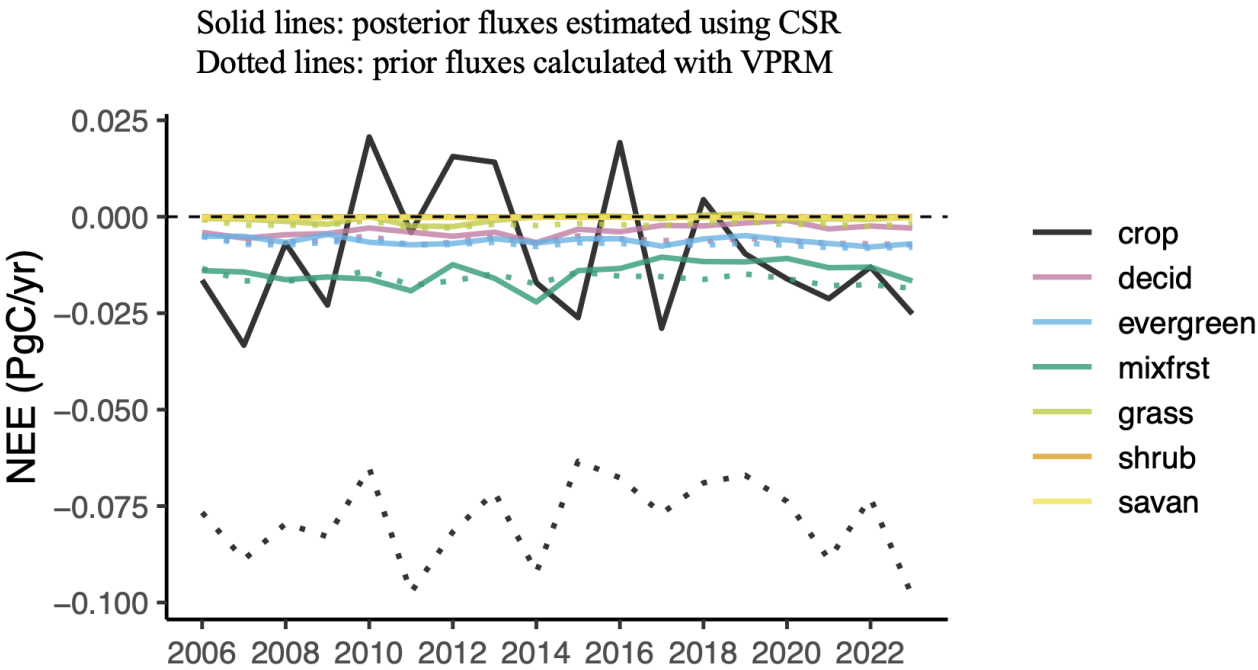
| Landcover                        | BEL LC (%) | Dif. VPRM (gC/m <sup>2</sup> /d) | Dif. FC-X (gC/m <sup>2</sup> /d) |
|----------------------------------|------------|----------------------------------|----------------------------------|
| Cropland (BE-Lon)                | 39.3       | 1 ±2.7                           | 0.9 ±2.8                         |
| Closed mixed forest (BE-Vie)     | 8.4        | -0.3 ±0.9                        | 0.2 ±0.8                         |
| Herbal Vegetation (BE-Dor)       | 8.4        | 0.1 ±2.1                         | 0.2 ±1.4                         |
| Evergreen needle forest (BE-Bra) | 6          | -0.3 ±1.1                        | 0.1 ±1.3                         |
| Shrubs (BE-Maa)                  | 0.1        | -0.3 ±1                          | 0.1 ±0.5                         |



# Estimated CO<sub>2</sub> fluxes for different vegetation classes over Germany

**Vegetation types:**

- Cropland (crop)
- Deciduous forest (decid)
- Evergreen forest (evergreen)
- Mixed forest (mixfst)
- Grassland (grass)
- Shrubland (shrub)
- Savanna (savan)

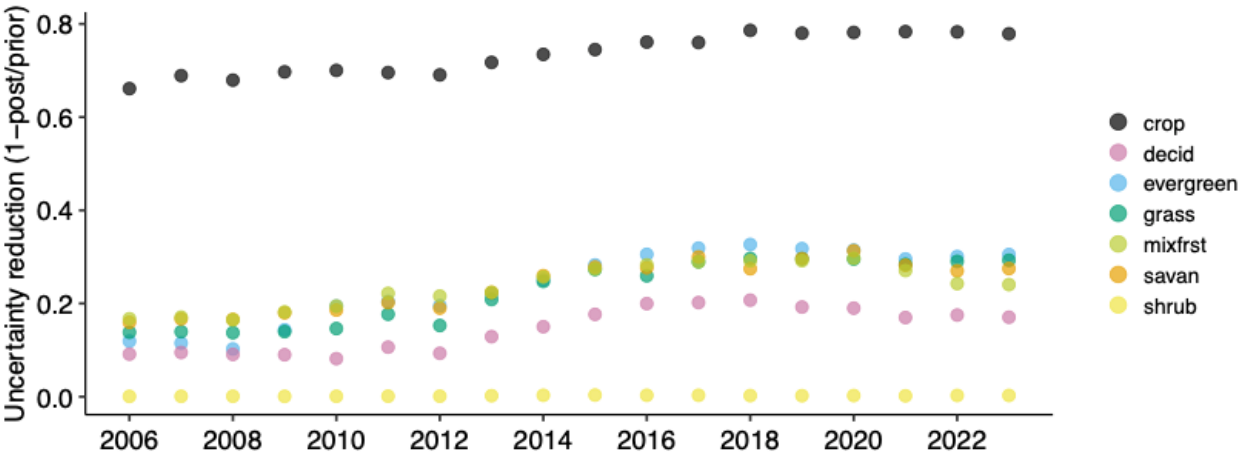


Thanks to Dr. Saqr Munassar  
(Max-Planck Institute for Biogeochemistry,  
Jena GER)



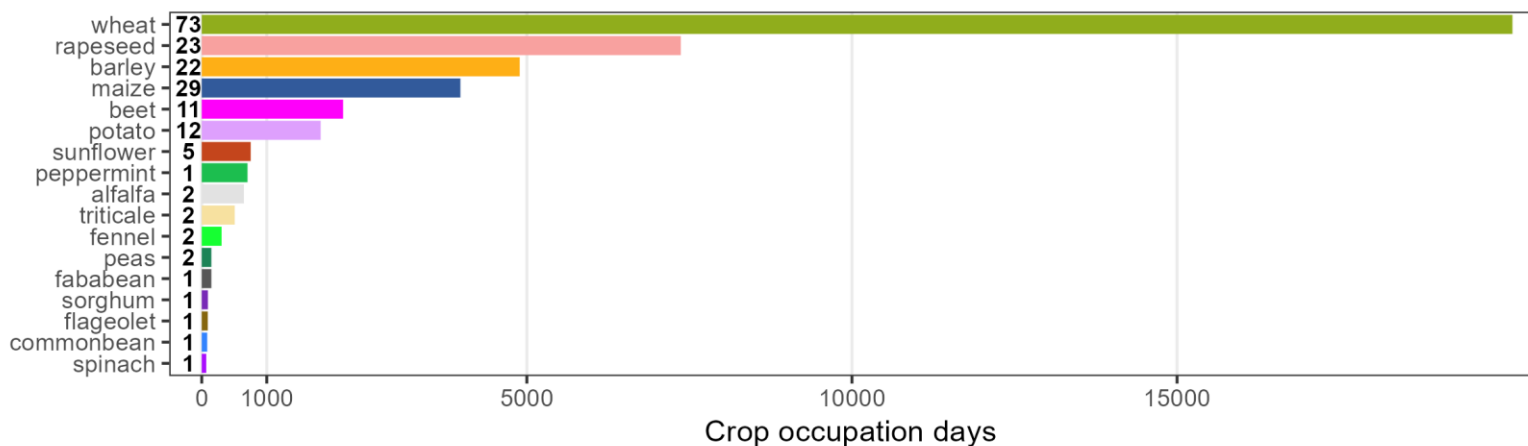
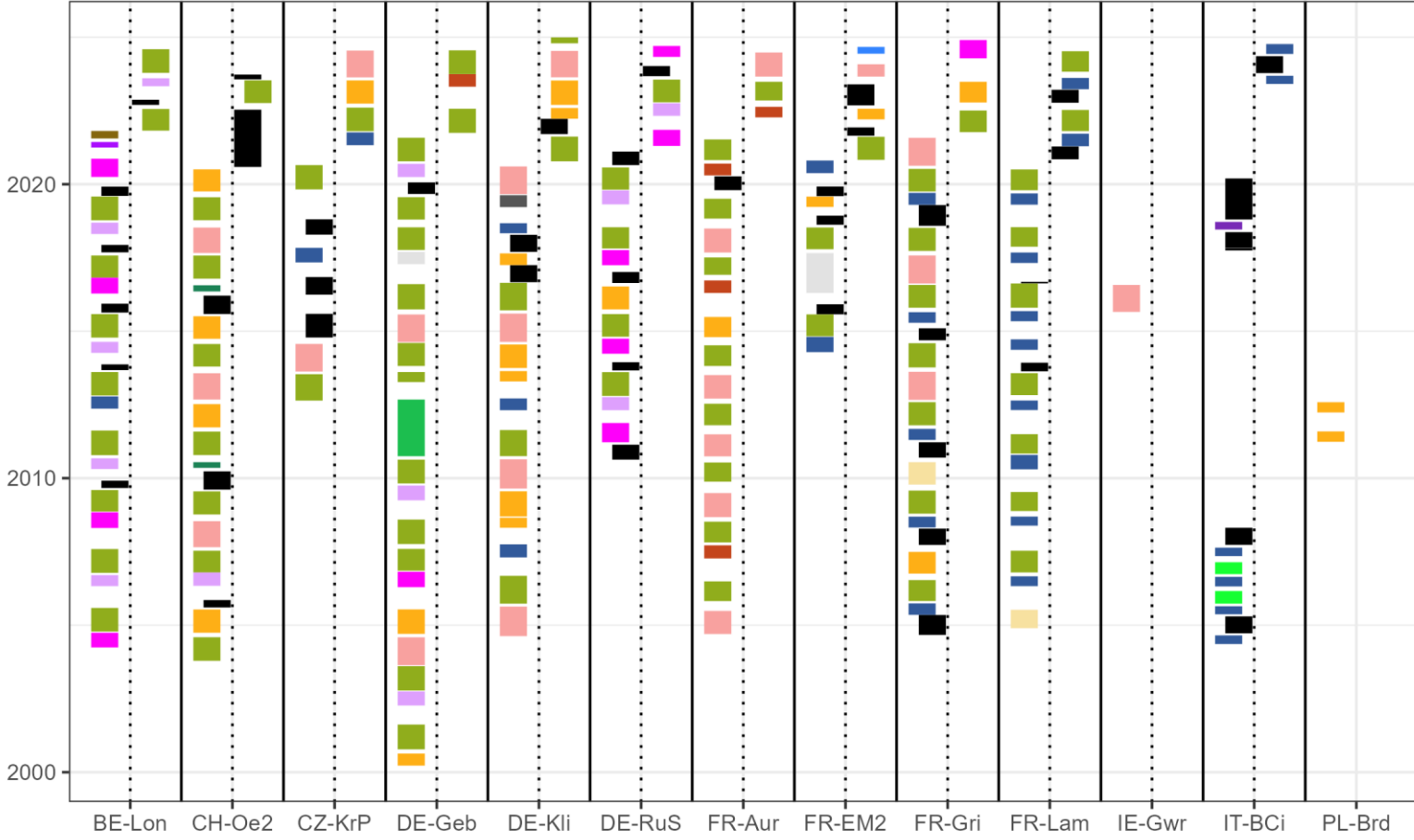
# Posterior uncertainty reduction

- ☐ Prior uncertainty assigned to each class according to the fractional contribution to total fluxes
- ☐ Crop flux estimates show largest posterior uncertainty reduction.
- ☐ Recent years exhibit larger uncertainty reduction of flux estimates than in early years, due to improvements in spatial coverage of observations.

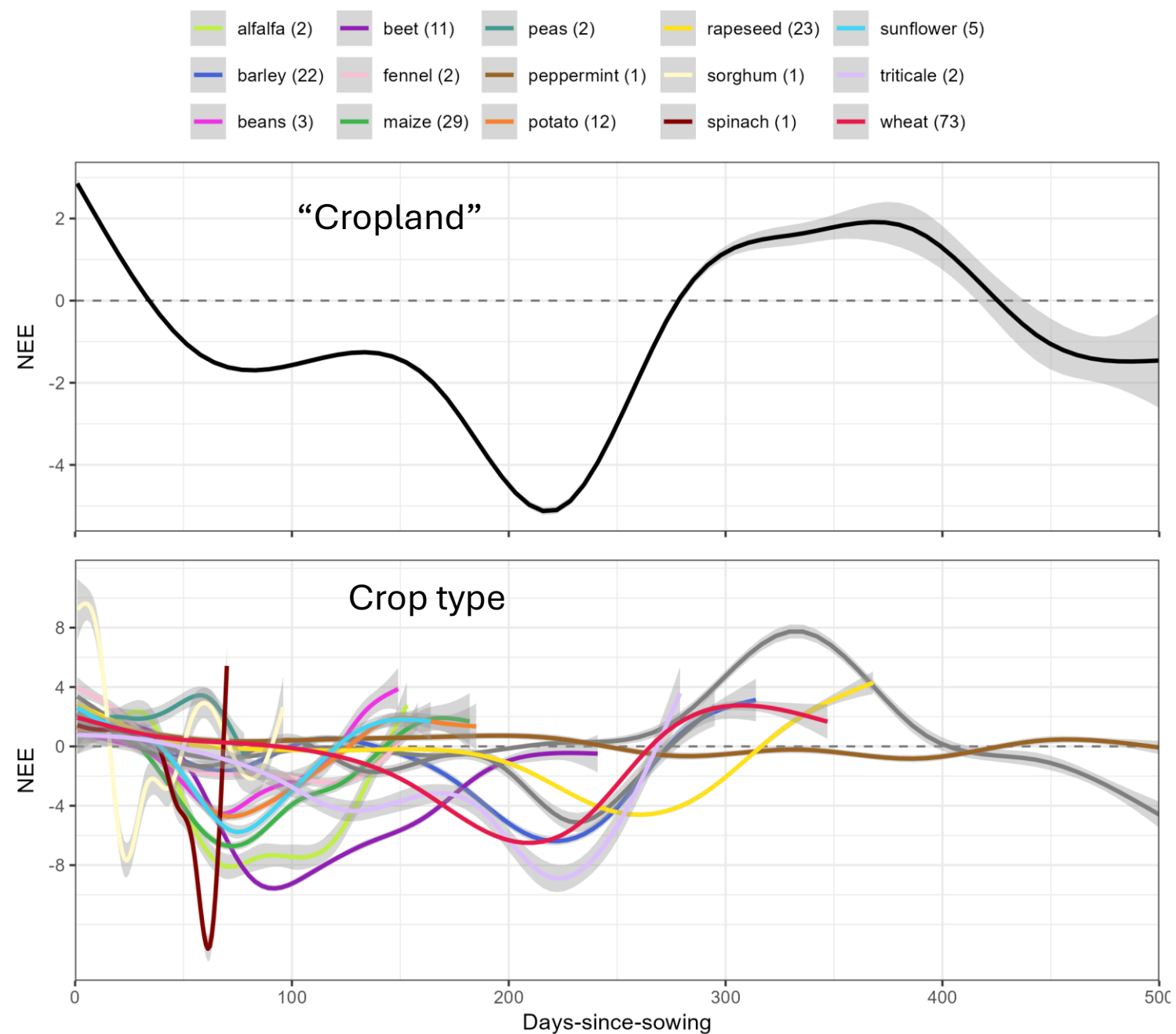


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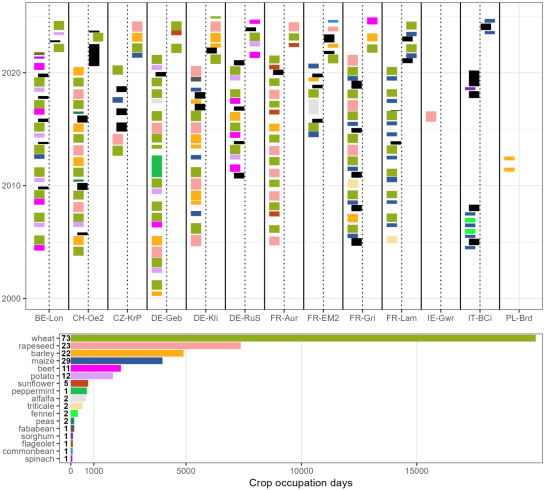
Crop type integration



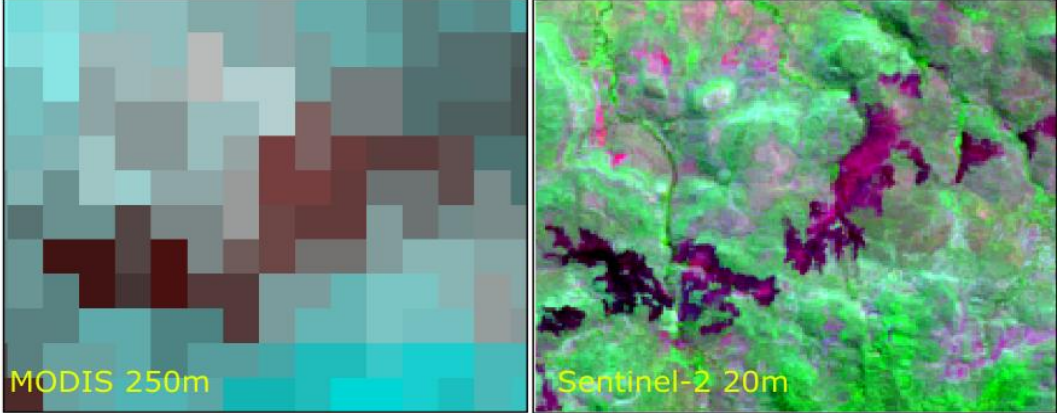
Crop type integration



Crop type EC fluxdata



Sentinel-2 high resolution images since 2017



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**Classical VPRM**

**Reconfigured  
VPRMcrop**

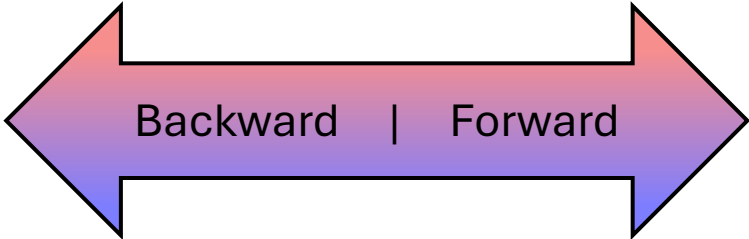
**Classical  
FLUXCOM-X (like)**

**Crop resolved  
FXcrop**

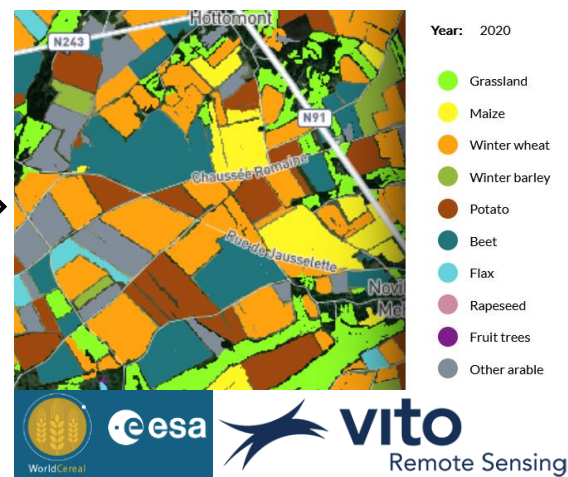
Crop type integration



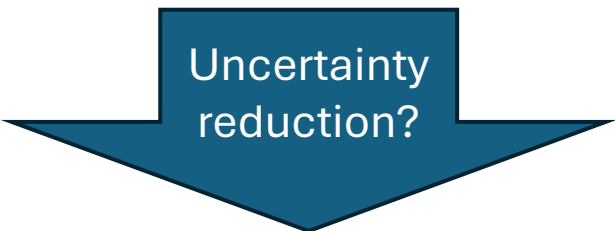
Farmer Crop reporting



Remote sensing Crop ID

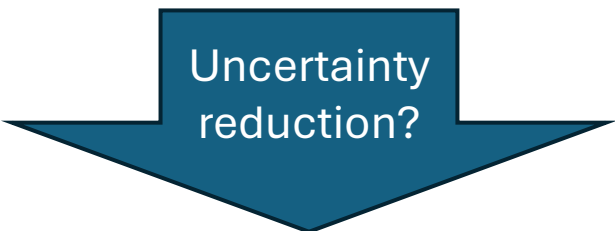


**Classical VPRM**



**Reconfigured VPRMcrop**

**Classical  
FLUXCOM-X (like)**

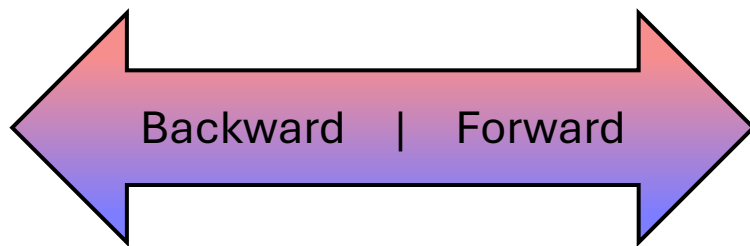


**Crop resolved  
FXcrop**

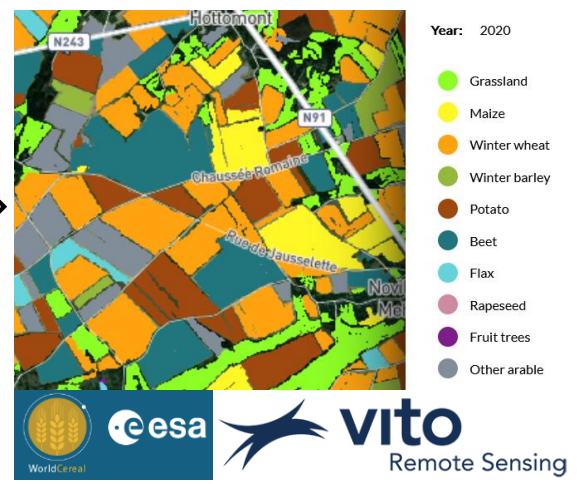
Crop type integration



Farmer Crop reporting

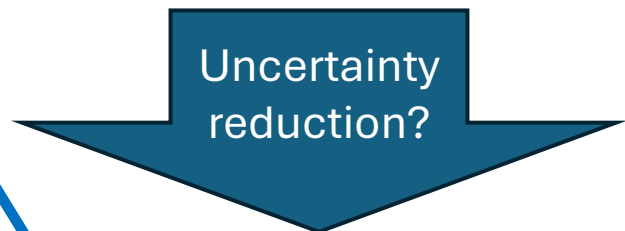
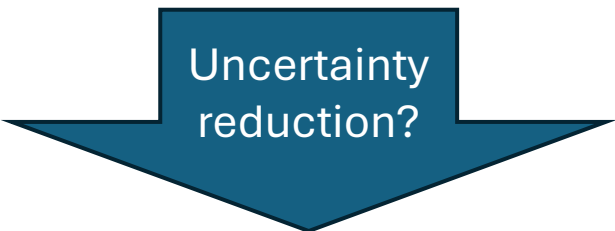


Remote sensing Crop ID



**Classical VPRM**

**Classical  
FLUXCOM-X (like)**



Fluxtower  
EC data

Accuracy  
improvement?

**Reconfigured  
VPRMcrop**

**Crop resolved  
FXcrop**

**Thank you for your attention!**

**Questions?**