EXPLOITING JRC'S GLOBAL NITROGEN OXIDE CALCULATOR FOR BIOFUELS LCA

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She did most of the work

JRC Ispra

What is JRC?

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

“Robust science for policy making”

JRC calculates GHG savings from biofuels in the Renewable Energy Directive

It also has a strong soils-emissions group...

GNOC Global Nitrous Oxide Calculator

European Commission

- Results are consistent with IPCC (2006) tier 1 when averaged over a large region

- But it allows you to put in local management, soil and climate properties

- Details in online manual http://gnoc.jrc.ec.europa.eu/

- Calculations for a specific site can be done by spreadsheet calculation

OR…

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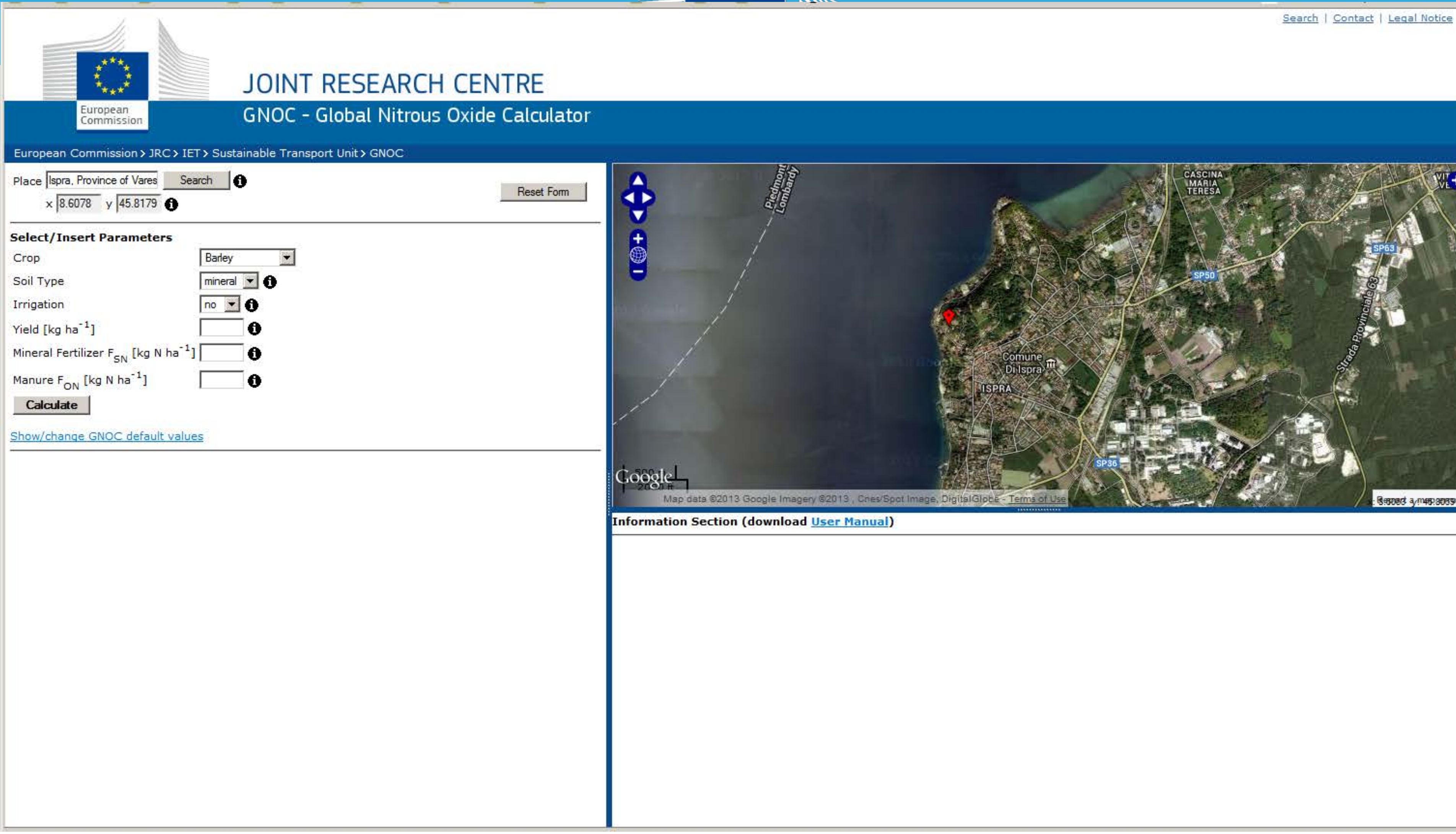
The GNOC online tool

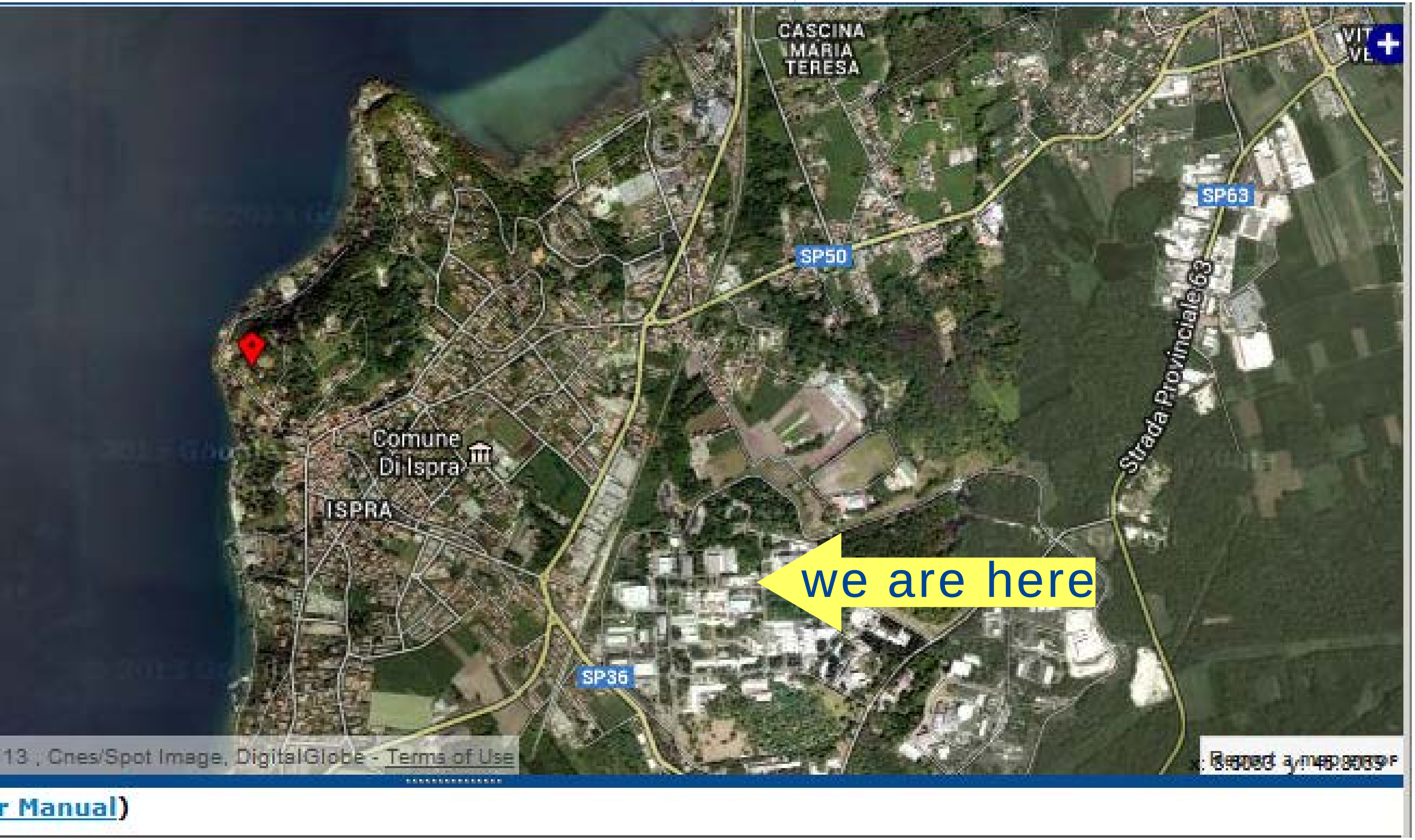
http://gnoc.jrc.ec.europa.eu/

or Google "global nitrous oxide"

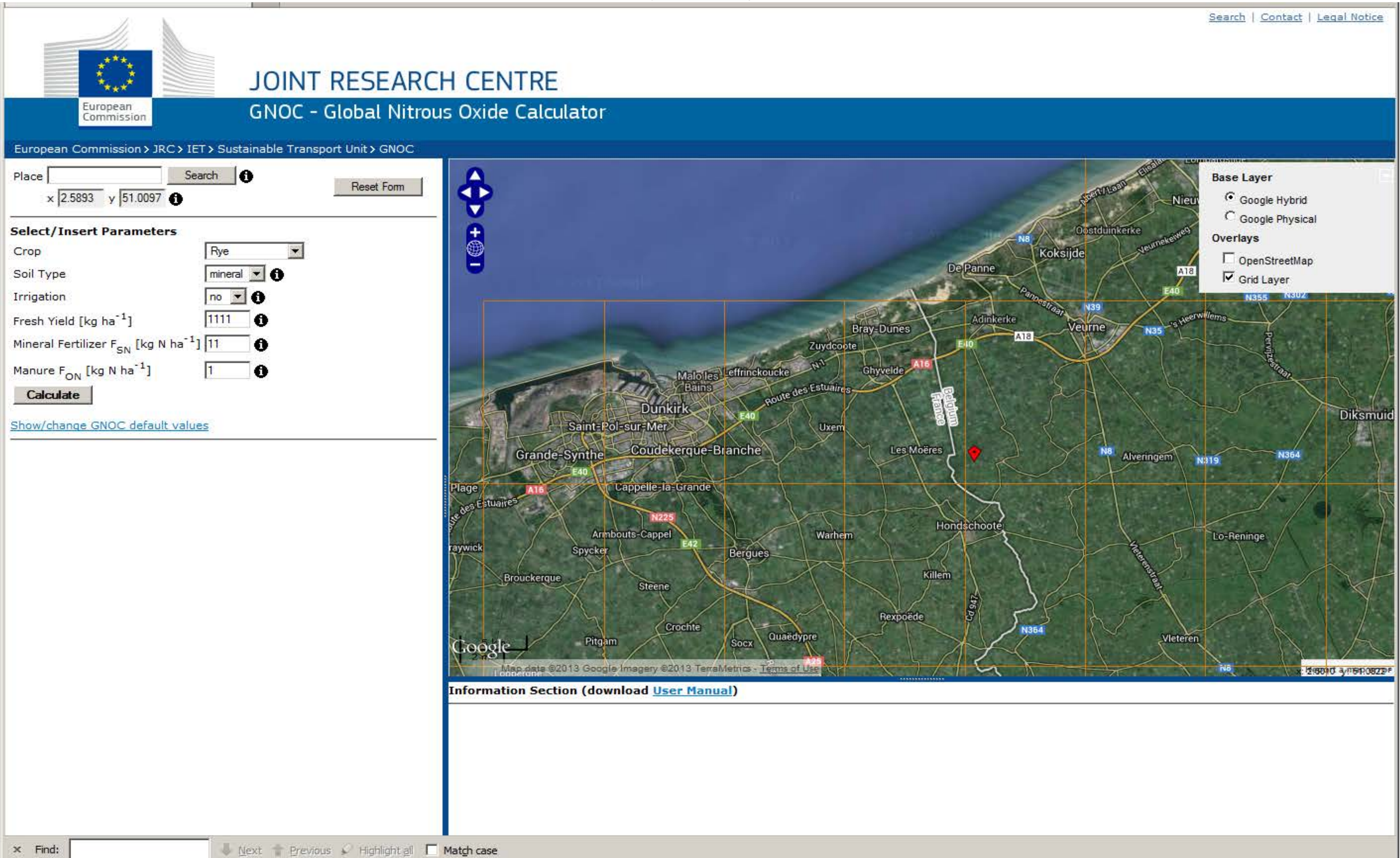
GNOC screenshot: main menu



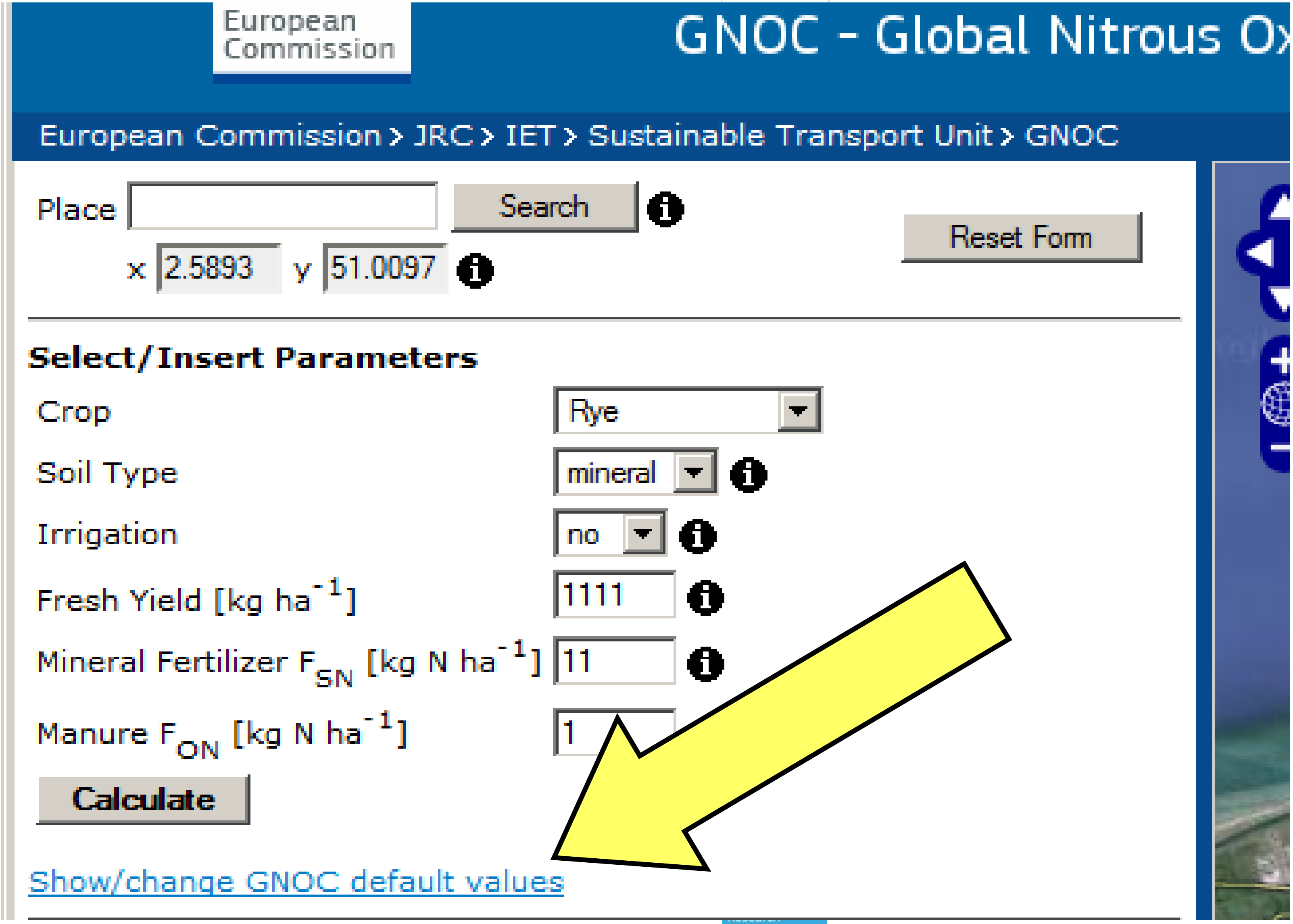
You can change window sizes and zoom in...



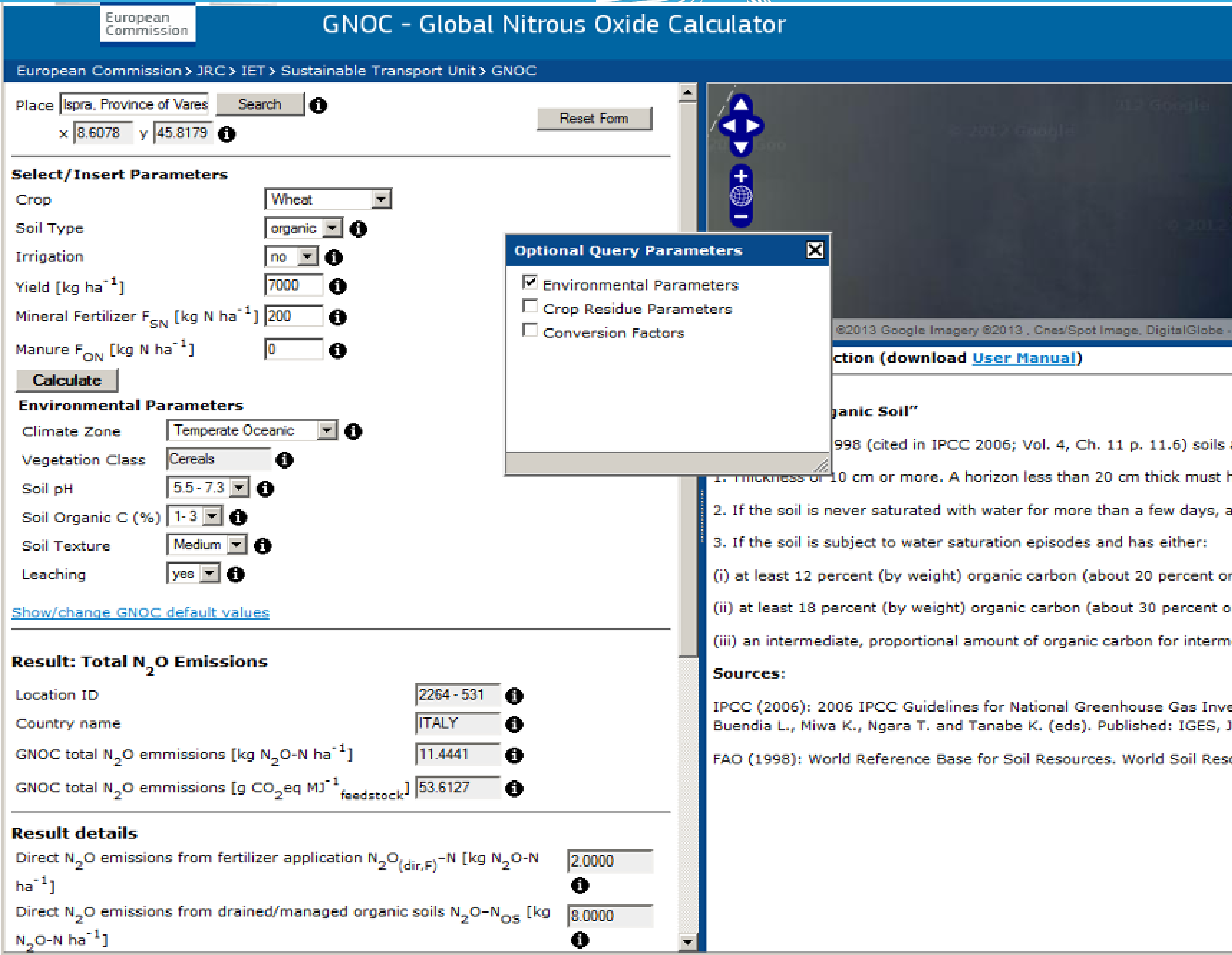
GNOC on-line screen shot: ~10km grid size



Use default settings or change them…



Changing environmental parameters...



Changing crop residue parameters

Place | Ispra, Province of Vares | Search

x 8.6078 y 45.8179

Reset Form

Select/Insert Parameters	
Crop	Wheat
Soil Type	organic
Irrigation	no
Yield [kg ha^{-1}]	7000
Mineral Fertilizer F_{SN} [kg N ha^{-1}]	200
Manure F_{ON} [kg N ha^{-1}]	0

Calculate

Crop Residue Parameters	
Calculation method (click info button for details)	IPCC EQ 11.7A
Dry matter fraction of harvested product DRY [kg d.m. (kg fresh weight)$^{-1}$]	0.1
Slope factor - a - to estimate above-ground residue dry matter AG_{DM} [dimensionless]	1.51
Intercept - b - to estimate above-ground residue dry matter AG_{DM} [dimensionless]	0.52
Fraction of above-ground residues removed from field $Frac_{Remove}$ [kg N (kg crop N)$^{-1}$]	0.2
Fraction of residues burned in field $Frac_{Burnt}$ [kg d.m. (kg d.m)$^{-1}$]	0.01
Combustion factor C_f [dimensionless]	0.9
Ratio of belowground residues to above-ground biomass R_{BG-BIO} [kg d.m. (kg d.m.)$^{-1}$]	0.24
Ratio of above-ground residues dry matter to harvested yield for crop R_{AG} [kg d.m. (kg d.m.)$^{-1}$]	-9999
N content of above-ground residues N_{AG} [kg N (kg d.m.)$^{-1}$]	0.006
N content of below-ground residues N_{BG} [kg N (kg d.m.)$^{-1}$]	0.009
Fixed amount of crop residues [kg N ha^{-1}]	-9999

Show/change GNOC default values

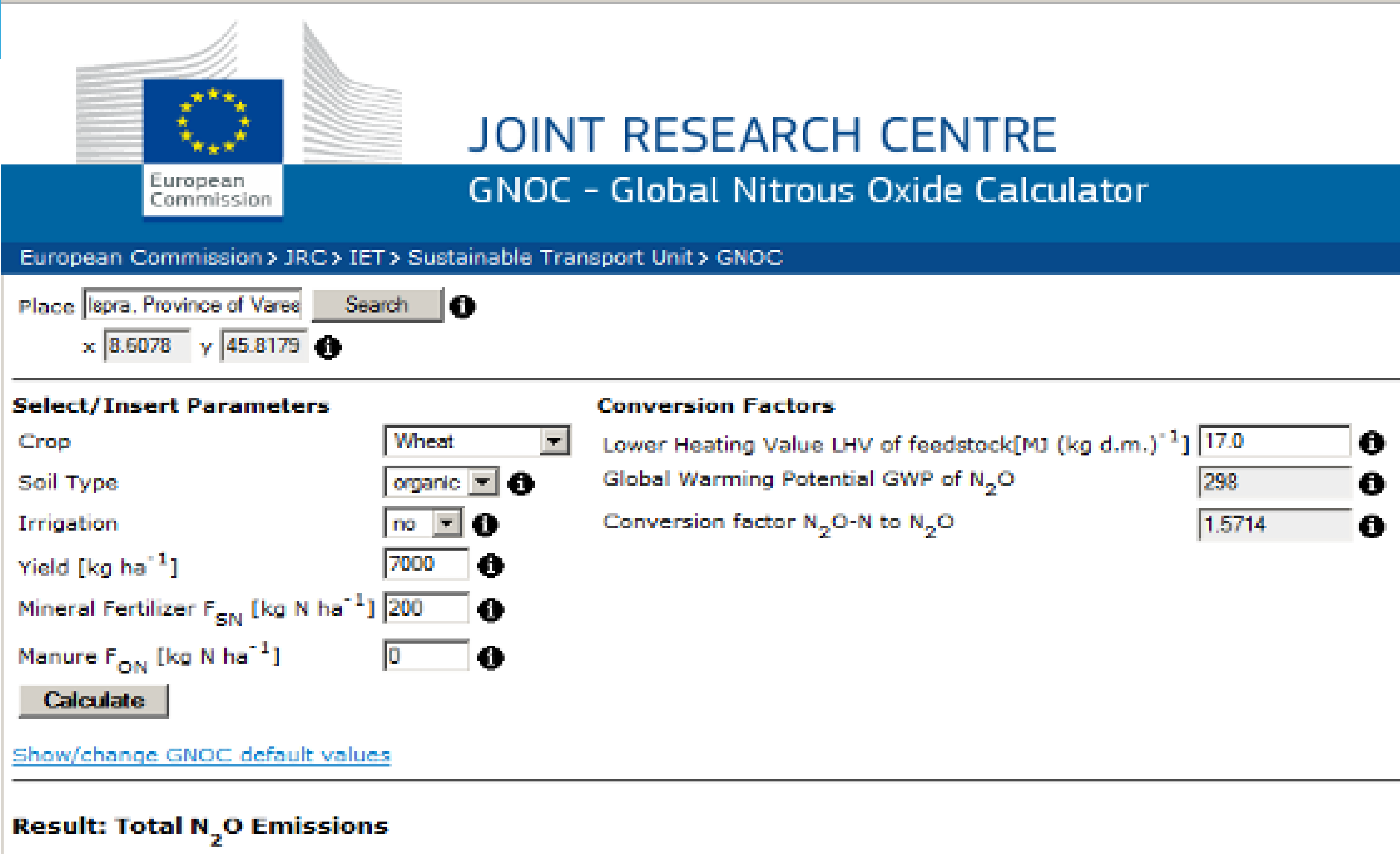
Result: Total N_2O Emissions

Location ID	2264 - 531
Country name	ITALY
GNOC total N_2O emmissions [kg N_2O-N ha^{-1}]	11.4441
GNOC total N_2O emmissions [g CO_2eq MJ^{-1}$_{feedstock}$]	53.6127

Result details

Direct N_2O emissions from fertilizer application N_2O_{direct}-N [kg N_2O-N ha^{-1}]	2.0000

changing conversion factors...



results with breakdown and calculated input data to the N2O formula:

European Commission

Result: Total N_2O Emissions

Location ID	2264 - 531
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Result details

Direct N_2O emissions from fertilizer application $N_2O_{(dir,F)}$–N [kg N_2O-N ha^{-1}]	2.0000
Direct N_2O emissions from drained/managed organic soils N_2O–N_{OS} [kg N_2O-N ha^{-1}]	8.0000
Indirect N_2O emissions produced from leaching and runoff from fertilizer application $N_2O_{(L,F)}$–N [kg N_2O-N ha^{-1}]	0.4500
Indirect N_2O emissions produced from atmospheric deposition of N volatilised $N_2O_{(ATD)}$–N [kg N_2O-N ha^{-1}]	0.2000
Above-ground residue dry matter AG_{DM} [kg d.m. ha^{-1}]	9398.8000
Annual amount of N in crop residues F_{CR} [kg N ha^{-1}]	64.8269
N input from sugarcane vignasse and filtercake [kg N ha^{-1}]	0.0000
Direct N_2O emissions from N in crop residues $N_2O_{(dir,CR)}$–N [kg N_2O-N ha^{-1}]	0.6483
Indirect N_2O emissions produced from leaching and runoff from N in crop residues $N_2O_{(L,CR)}$–N [kg N_2O-N ha^{-1}]	0.1459

HOW GNOC WORKS

How GNOC works…
GNOC combines Stehfest & Bouwman and IPCC (2006)

European Commission

N from crop residues
are taken from IPCC 2006/7

↓

Nitrogen fertilizer and N in
manure is added

↓

direct N2O emissions on mineral soils
calculated from Stehfest and
Bouwman formula

or, for organic soil: IPCC 2006/7

↓

Indirect N2O emissions estimated
following IPCC 2006/7

Stehfest and Bouwman formula for direct N_2O emissions from mineral soils.

- empirical fit to measured N2O data
- uses the same database as they used for IPCC tier 1
- (that’s why it agrees with IPCC tier1 at large scale)
- IPCC tier regresses the N2O emission measurements ONLY against only N input, so ignores more-important variables, like soil
- But Stehfest and Bouwman regressed against more variables …

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Parameters considered in Stehfest and Bouwman

Parameter	Parameter class or unit	Effect value (ev)
Fertilizer Input		0.0038 * N application rate in kg N ha-1 yr-1
Soil organic C content	<1 %	0
	1-3 %	0.0526
	>3 %	0.6334
pH	<5.5	0
	5.5-7.3	-0.0693
	>7.3	-0.4836
Soil texture	Coarse	0
	Medium	-0.1583
	Fine	0.4312
Climate	Subtropical climate	0.6117
	Temperate continental climate	0
	Temperate oceanic climate	0.0226
	Tropical climate	-0.3022
Vegetation	Cereals	0
	Grass	-0.3502
	Legume	0.3783
	None	0.5870
	Other	0.4420
	Wetland rice	-0.8850
Length of Experiment	1 yr	1.9910

PUTTING IN GNOC-DEFAULT INPUT DATA

Global calculations of N_2O emissions – general conditions -

European Commission

- **Spatial resolution ~10 by 10km**
  most global data sets required for the calculations are available at this resolution

- **Reference year 2000**
  ...because M3 database of crop distribution and yield the required resolution is for this year

BUT DEFAULT EMISSIONS FOR BIOFUEL DIRECTIVE ARE CORRECTED TO LATEST YIELD DATA

- **The default Input data only uses datasets global coverage**
  Ensure as far as possible equal detail for all parts of the world

- **Crops include a wide range of potential biofuel feedstock.....**

Biofuel Crop	S&B Vegetation class
Barley	Cereals
Rye	Cereals
Sorghum	Cereals
Triticale	Cereals
Wheat	Cereals
Rapeseed	Cereals[2]
Maize	Other[1]
Sugarbeet	Other
Sugarcane	Other
Cassava	Other
Coconut	Other
Oilpalm	Other
Safflower	Other
Sunflower	Other
Soybean	Legumes

1 following the classification of crop types in Stehfest and Bouwman (2006), row crops are summerized in the vegetation class “other”
2 screening the measurement data we concluded that emissions from rapeseed are more similar to the cereals class than to the crops in the "other" class

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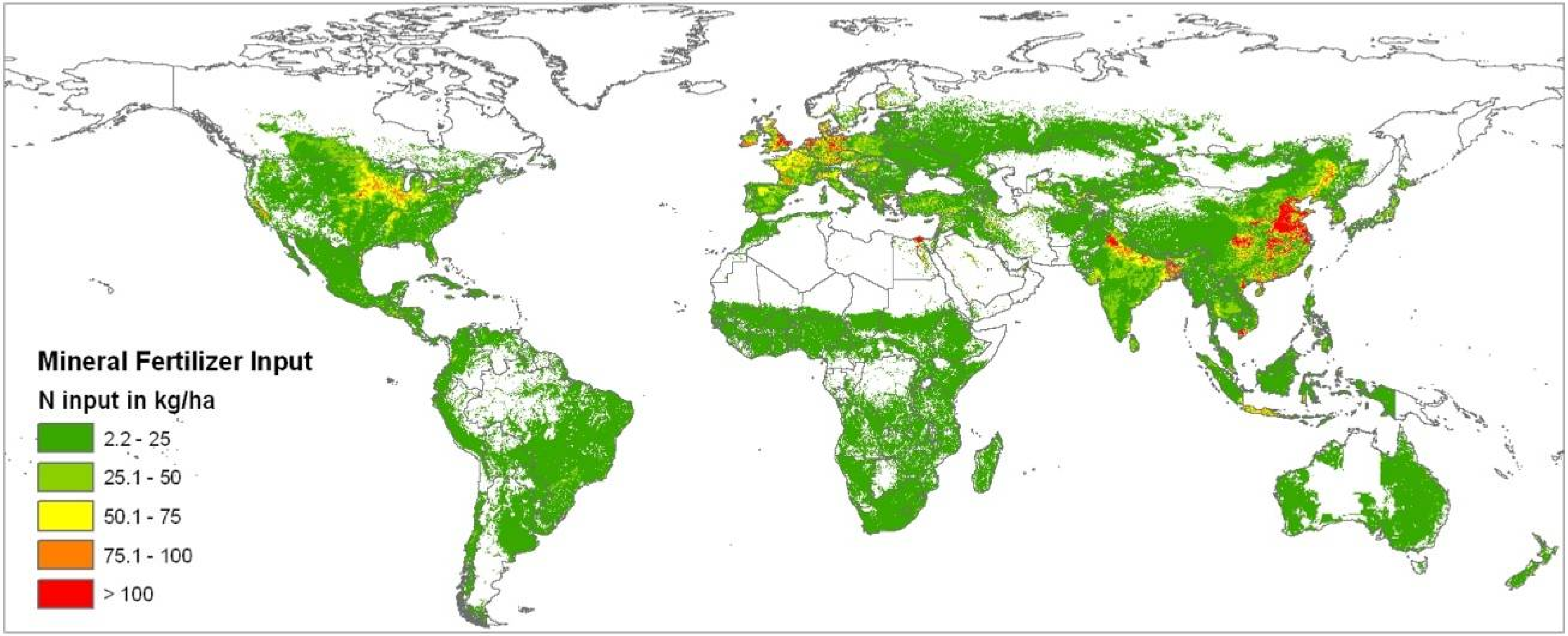
Data based on IFA **mineral fertilizer** data on a country level

disaggregated using FAO statistics on fertilizer use by crop for the different countries

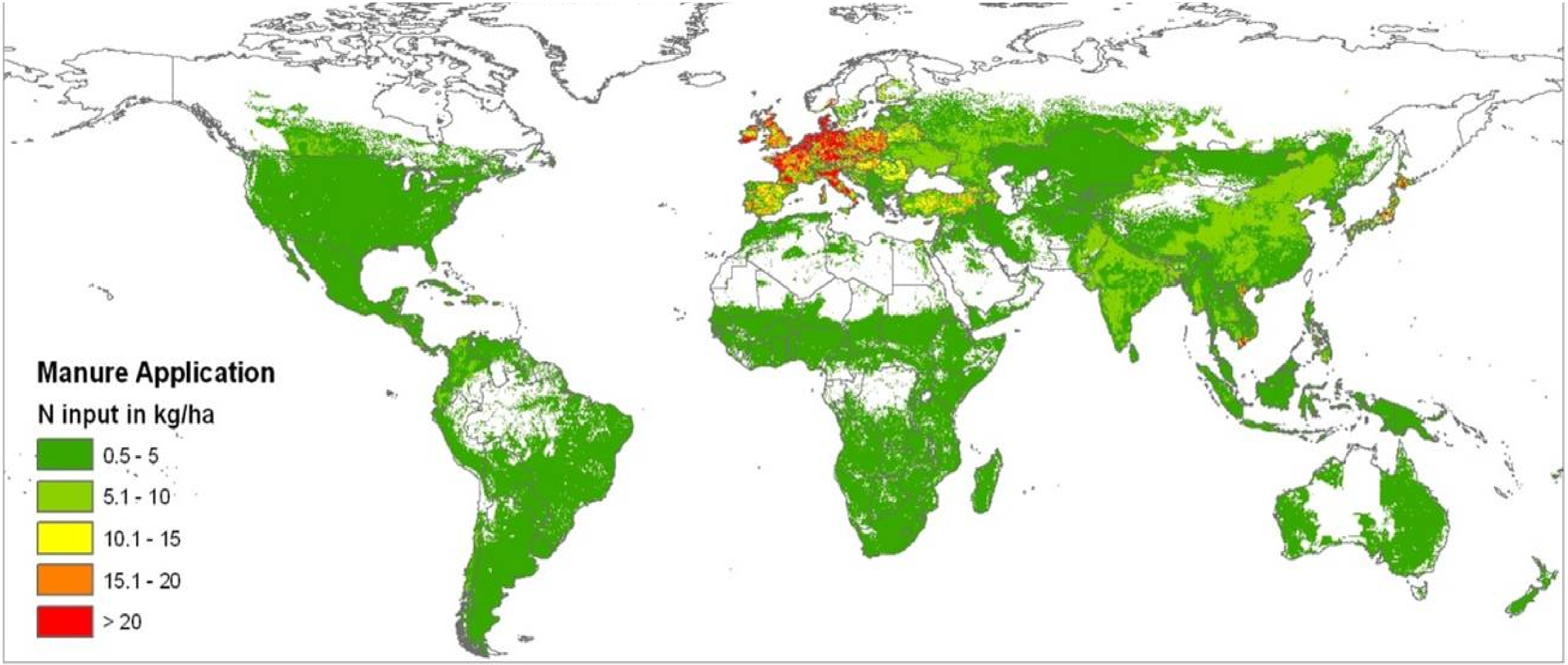
For each crop mineral N input calculated for a ~10by10km grid

Results are corrected to match 2010/11 fertilizer from IFA/Fertilizers Europe



Default input data: Manure N

- **manure** based on FAO animal feedstock and IPCC default method to derive manure N input.
- First allocated between cropland and pasture by area.
- Then manure on crops is distributed proportional to each crop's mineral N requirement.
- Only half of manure-N is counted (rest is attributed to waste disposal).



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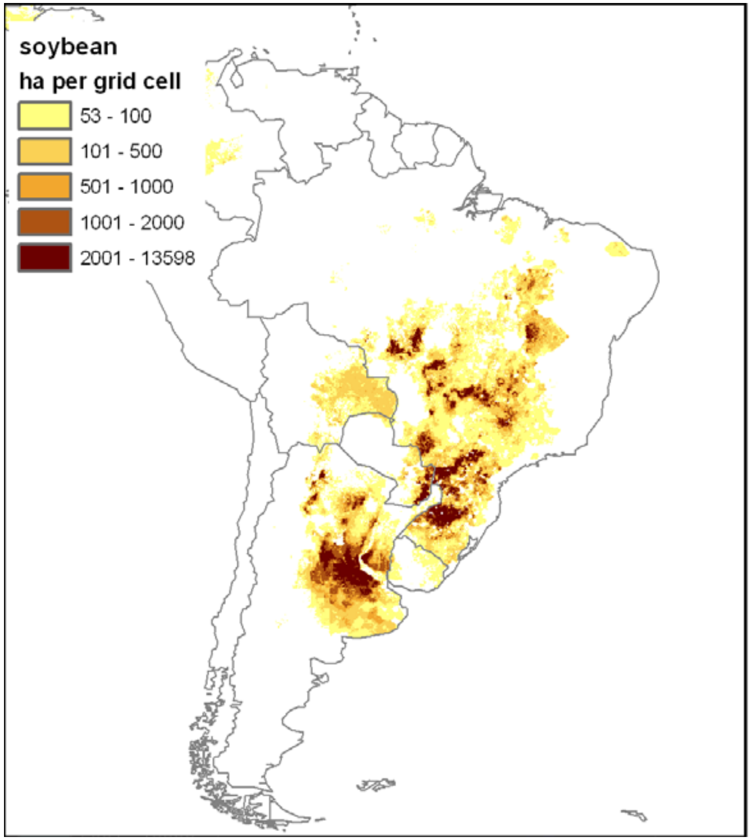
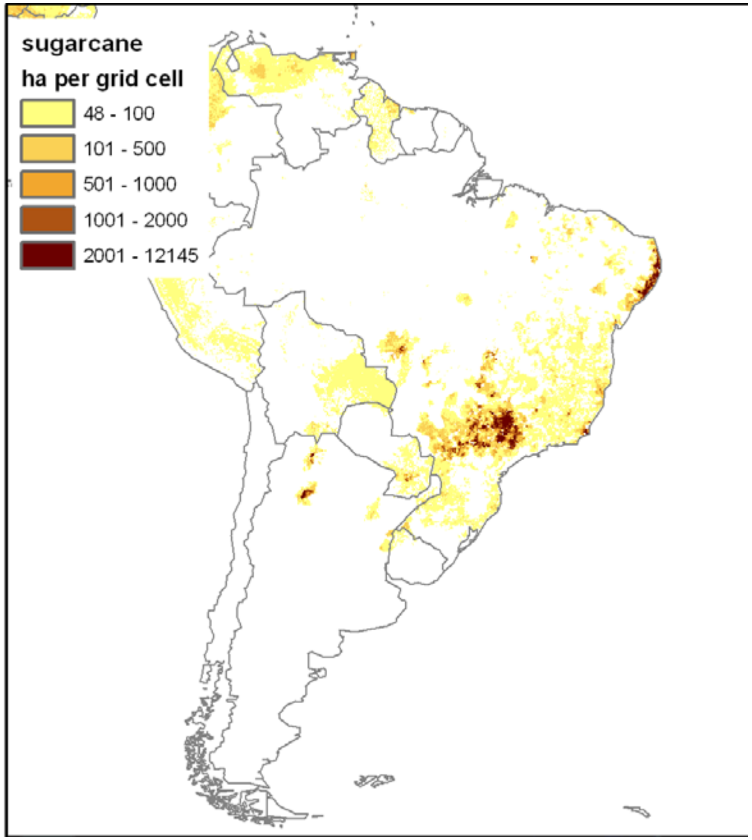
Default Input data: crop distribution and yield

From M3 database ~10 by 10km grid for >100 single crops for the years ~2000 from Monfreda et al. (2008)*

- N2O results are corrected to take into account latest-available yield data (2010-11)





*Monfreda, Ch.; Ramankutty, N. and Jonathan A. Foley, J.A. (2008), "Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000", Global Biogeochemical Cycles, Vol.22, 1-19.

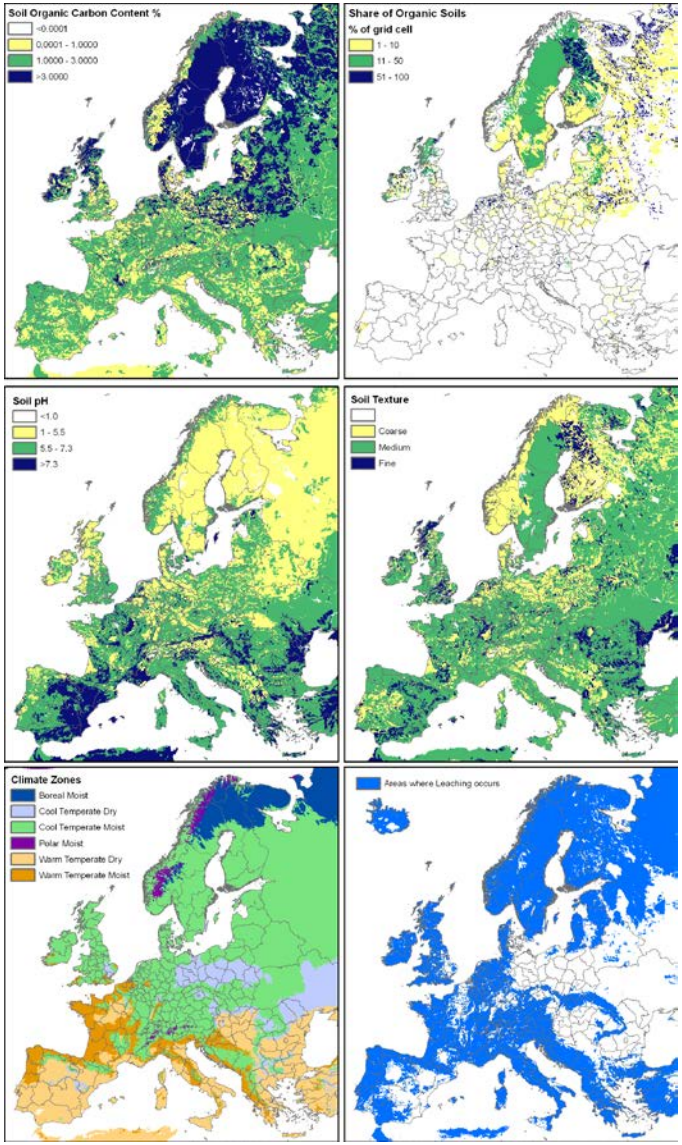
Default Input Data (cont.)

Environmental parameters

- Soil properties were calculated based on the JRC's Harmonized World Soil Database by Hiederer* (2009).

- Climate zones as defined in IPCC (2006) are based on Carre** et al. (2010)

- Areas where leaching occurs calculated based on soil and climate data according to IPCC (2006)



*Hiederer, R. (2009), Joint Research Centre, Institute for Environment and Sustainability, Land management and Natural Hazards Unit, pers. communication.
** Carre, F.; Hiederer, R.; Blujdea, V. and Koeble, R. (2009): Guide for the Calculation of Land Carbon Stocks Drawing on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

USING GNOC IN JRC's CALCULATION OF DRAFT DEFAULT EMISSIONS FOR BIOFUELS

UNCERTAINTY IN N2O EMISSIONS DOMINATES UNCERTAINTY IN DIRECT EMISSIONS ESTIMATES

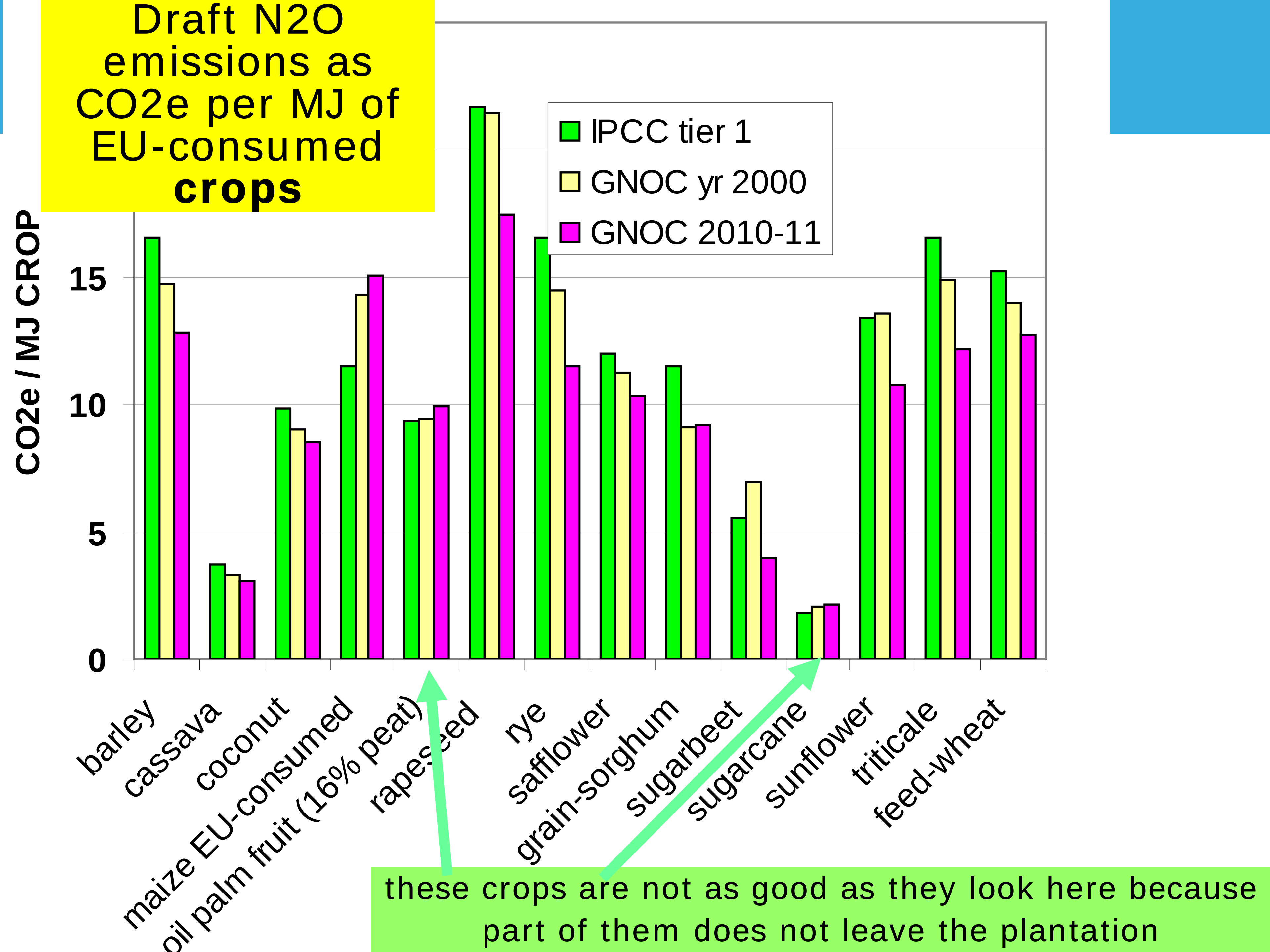
- The biggest source of farm-emissions variation is soil-N2O emissions. They vary by factors >1000
- The strongest variable affecting N2O emissions is soil properties and drainage (not fertilizer!).
- Therefore declared cultivation emissions are meaningless unless local soil-properties are considered (at the least)
- “IPCC tier1” method is popular in LCA, but it assumes soil properties average out at national level, and ignores all variables except N input: IPCC IS NOT INTENDED FOR USE AT SUB-NATIONAL LEVEL
- Using IPCC tier1, even the *national averages* are very uncertain: range of uncertainty is “-70% to +300%”
- (many LCAs use IPCC tier1, but keep quiet about the range!)
- Therefore it is worth a lot of effort to reduce uncertainty with less rough approaches

Soil N_2O emissions estimate for biofuel cultivation pathways

- Existing default values in EU's Renewable Energy Directive used DNDC soils model
- But lots of input data needed: could only by applied by GIS to EU15
- But there were systematic differences with IPCC tier1, which had to be used for non-EU crops.

So for new draft defaults,

- N_2O from JRC's new **GNOC online tool** = **G**lobal **N**itrous **O**xide **C**alculator
- GIS country-averages using GIS input data
- weightings for countries supplying crops *consumed* in EU from FAO trade matrix.
- AVERAGE results close to those from IPCC tier 1


Draft N2O emissions as CO2e per MJ of EU-consumed **crops**
CO2e / MJ CROP
0
5
10
15
IPCC tier 1
GNOC yr 2000
GNOC 2010-11
barley
cassava
coconut
maize EU-consumed
oil palm fruit (16% peat)
rapeseed
rye
safflower
grain-sorghum
sugarbeet
sugarcane
sunflower
triticale
feed-wheat
these crops are not as good as they look here because part of them does not leave the plantation

CORRECTION OF IPCC SOYBEAN BELOW-GROUND N

Soybean N_2O: correction of IPCC below-ground N

GNOC uses IPCC recommendations on N contribution from below-ground residues (BGR)

But IPCC data on this for **soy** are much too low (1923 reference on BGR, and N content assumed = above-ground residues)

...and, if used in GNOC or IPCC N_2O-method, it gives far lower N_2O than measured data

[Chudziak 2013] proposes method of updating the N in **B**elow-**G**round **R**esidues so it agrees with known measurements.

Confirmed by recent Argentine BGN and N_2O measurements

The GNOC emissions with the revised BGN are still generally below measured N_2O data

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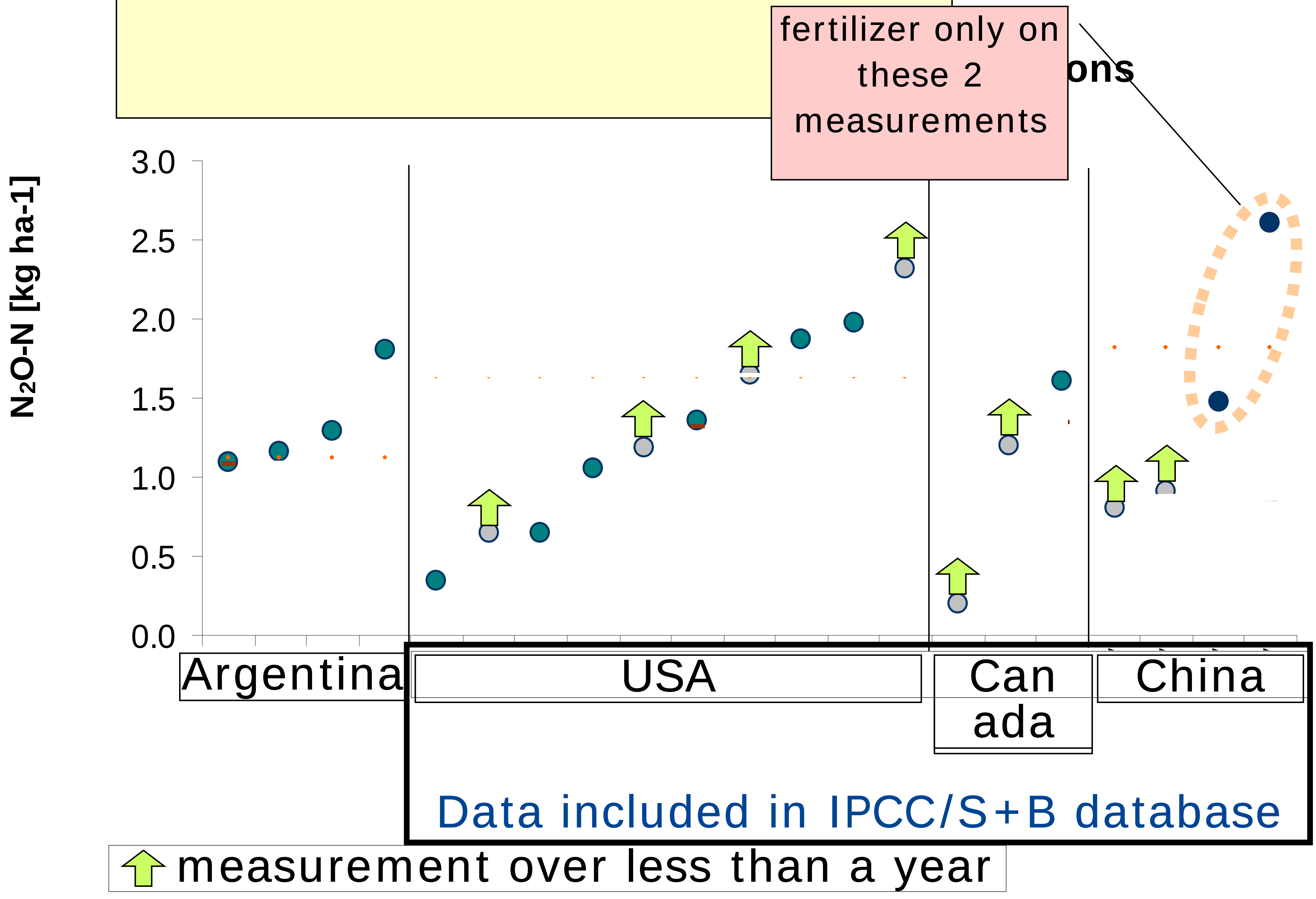
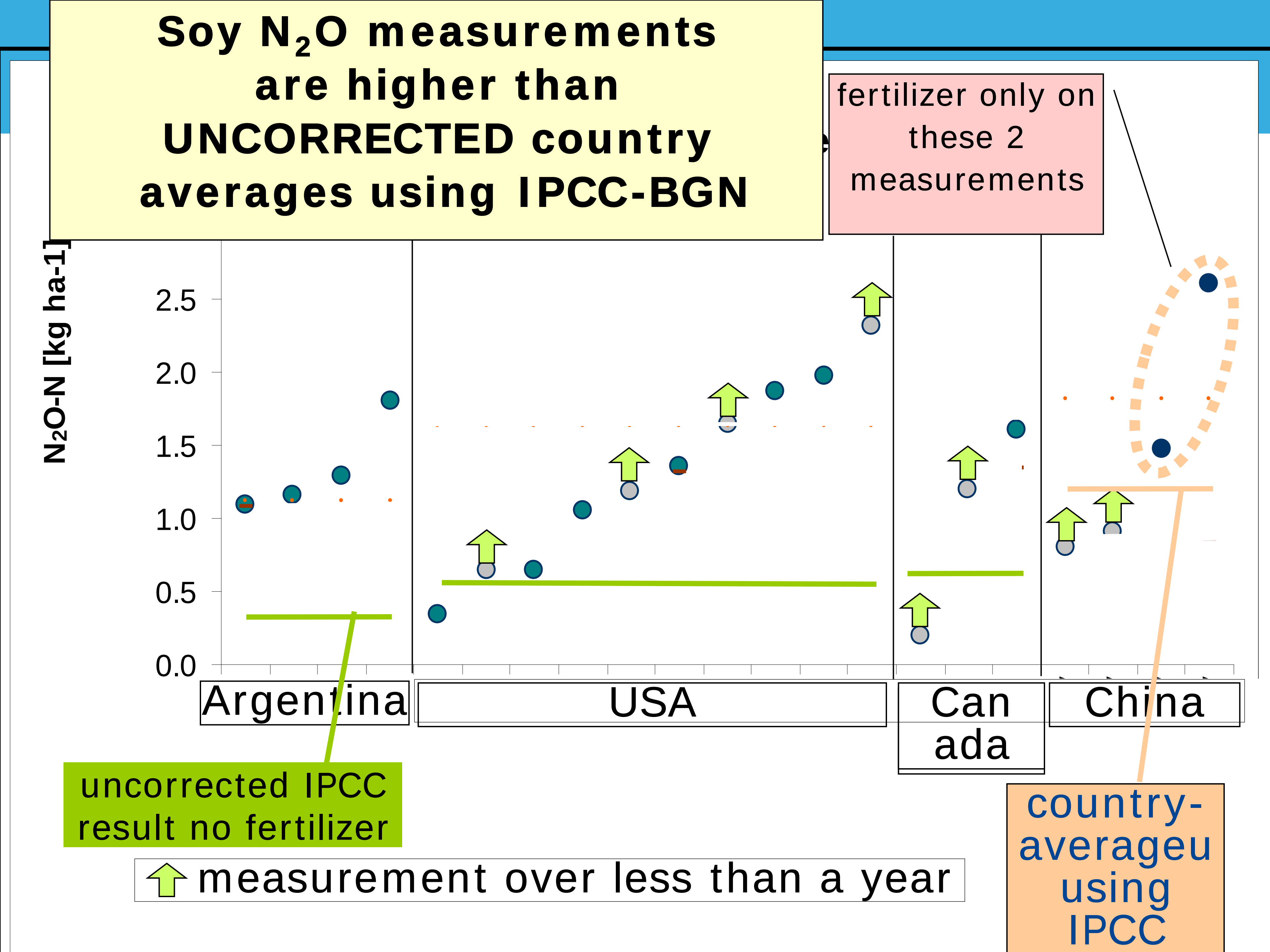
Soy N_2O measurements

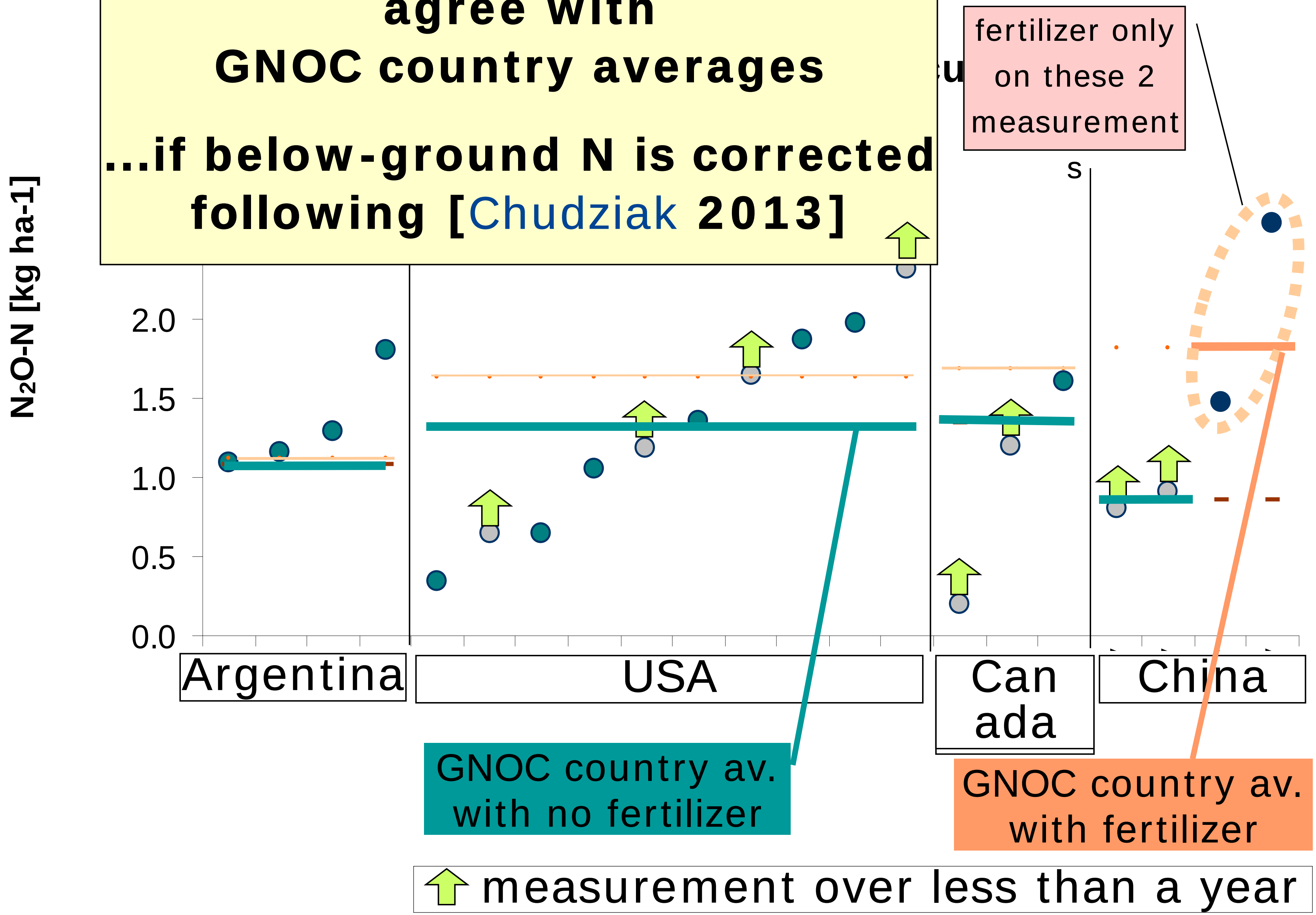




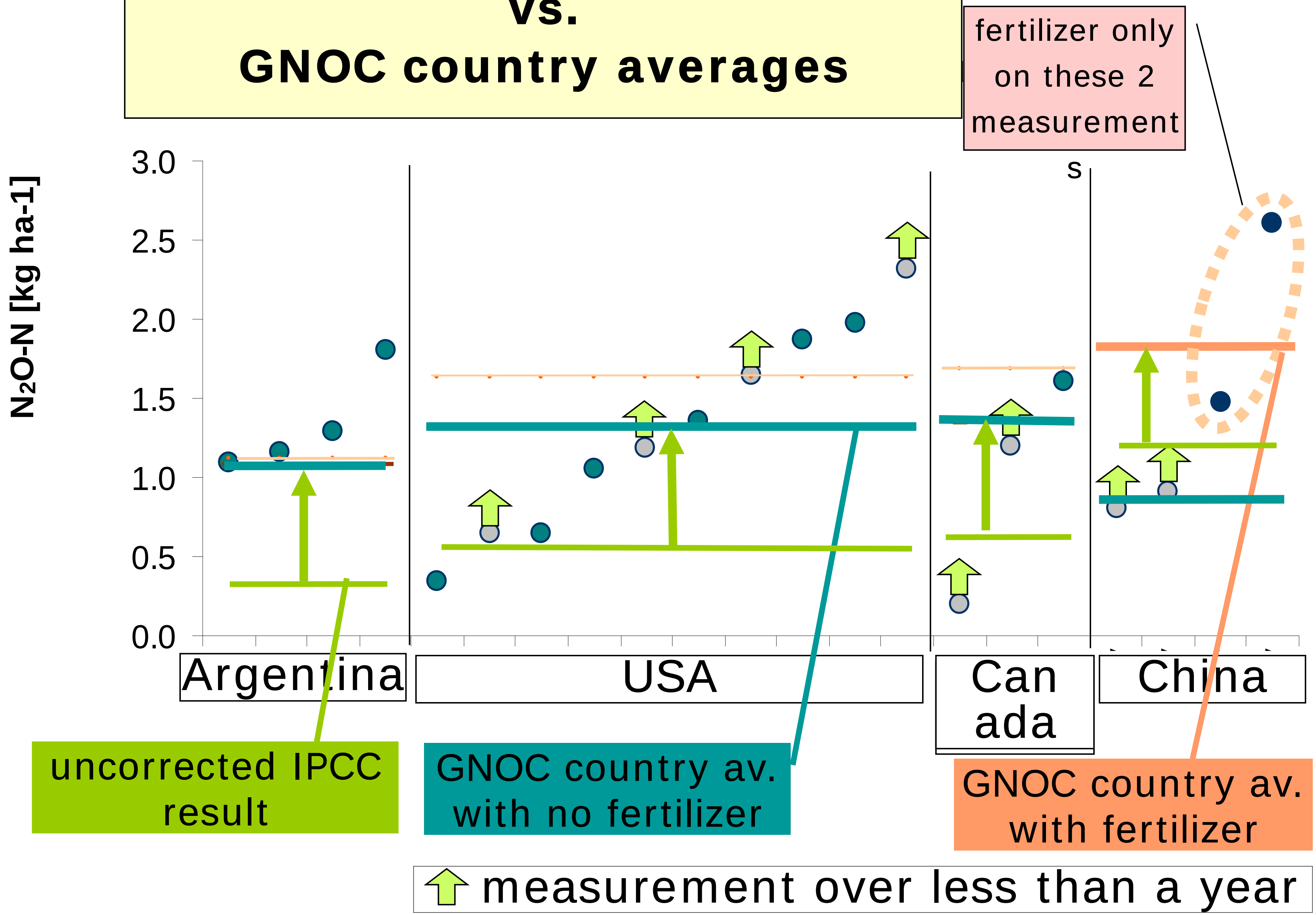
Soy N_2O measurements are higher than UNCORRECTED country averages using IPCC-BGN
fertilizer only on these 2 measurements
N_2O-N [kg ha-1]
2.5
2.0
1.5
1.0
0.5
0.0
Argentina
USA
Canada
China
uncorrected IPCC result no fertilizer
country-averageu using IPCC
measurement over less than a year

Soy N_2O measurements agree with GNOC country averages

...if below-ground N is corrected following [Chudziak 2013]



Soy N_2O measurements vs. GNOC country averages



THIS IS THE END

http://gnoc.jrc.ec.europa.eu/

detailed questions to:

renate.koeble@ext.jrc.ec.europa.eu

spare slides to answer questions

Source of N fertilizer input data in default calculations

Principle:
defaults are for weighted average of EU *consumption*

Crops (practically) all produced in EU
- **feed-wheat, barley, rye**
- **rapeseed, sunflower**
- **sugar beet**

Produced partly in EU:
- **Maize**

Practically all imported:
- **soy**
- **palm**
- **coconut**
- **sugar cane**

N fertilizer input data from Fertilizers Europe 2010/2011

FAO or Eurostat yields for 2010-11

N fertilizer input data from International Fertilizer Association,

FAO yields for 2010-2011

Countries weighted by export to EU (FAO trade matrix) (..and EU production)

JRC's GNOC can be applied to fields all over the world, and the average results are compatible with IPCC, but different from Annex V

S+B's Database of all published soils-N2O measurements up to 2006

fit reaction constants

soils chemistry model (DNDC)

GIS dataEU15: crop locations, soils properties, inputs, farm timetable, weather etc

fit against N inputs, soil properties, crop and climate type

fit against N input only, assuming soil properties average out on large areas

"S+B formula", used in **JRC's GNOC Global Nitrous Oxide Calculator**

N2O per crop in annex V defaults, for EU15

higher or lower

GIS data on the variables

IPCC tier1 method for N_2O in NATIONAL Kyoto declarations

world average same within 1%
(for same input data)
EU-averages slightly lower

N2O per crop for new default values, average of all producers

S+B = Stehfest and Bouwman, of PBL-NL

16% of the RED-eligible oil-palm area in Indonesia and Malaysia is on peat

European Commission

RED says that no palm oil for EU biofuel may come from land converted from wetland *after 2008*.

In 2013, by extrapolation of historical data in [Miettinen 2012], we estimate that 9575kha of oil-palm are NOT on peat, and therefore eligible to supply palm oil for biofuel under the sustainability criteria.

Interpolating the historical data gives 1810 kha of oil palm on peat in 2008. This peat area is also eligible to supply palm oil under RED sustainability criteria.

So the fraction of eligible palm oil area which is on peat is 1810/(1810+9575) = 16%

This increases average N2O emissions from oil palm, but the huge loss of soil carbon due to draining peat for oil palm is still not counted.

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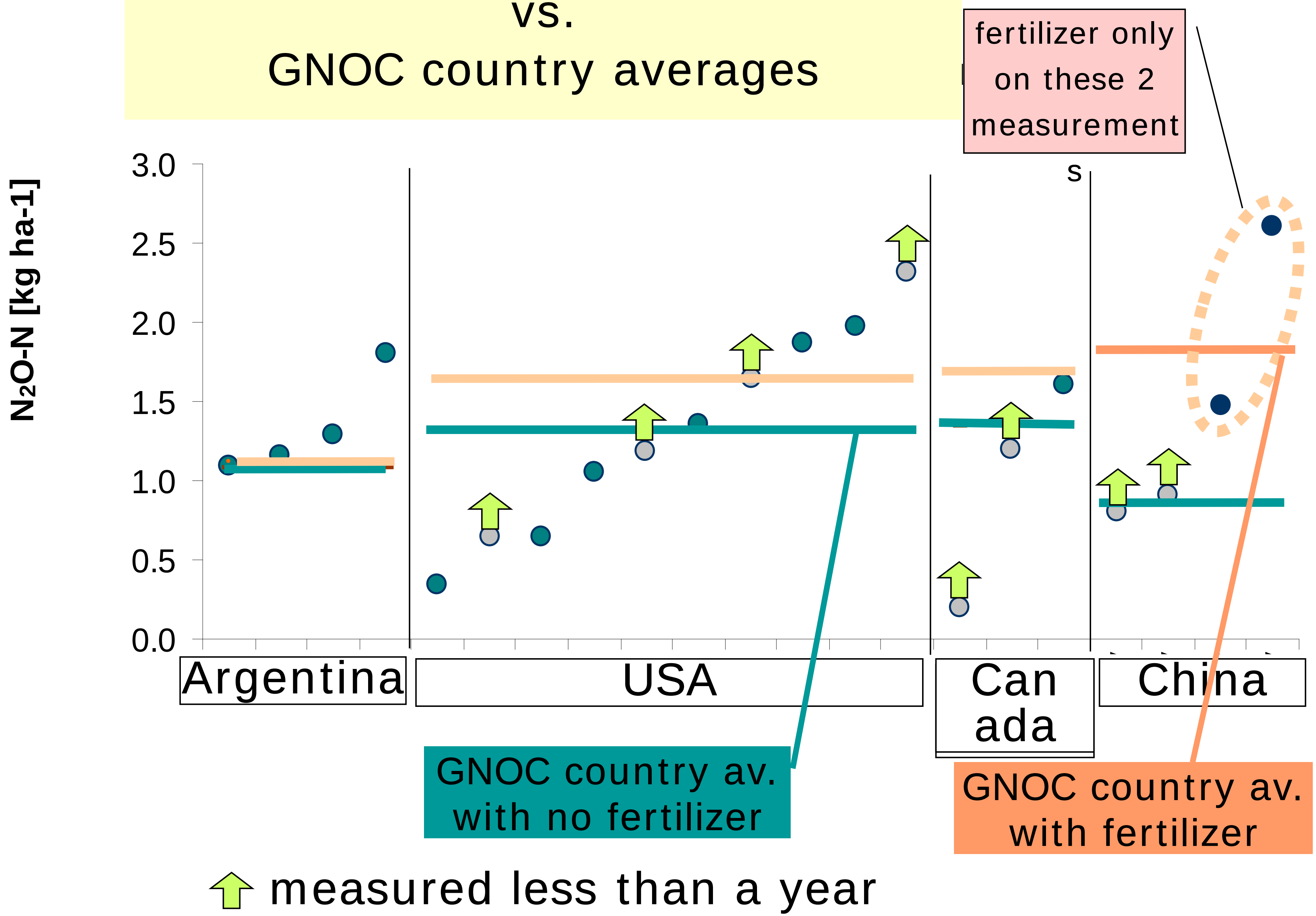
Soy N_2O measurements vs. GNOC country averages



UPDATE OF DEFAULT EMISSIONS – ANNEX V

Big scope for reducing declared emissions, compared to default values

- declare only low-emission steps; use defaults for the high-emission ones

Processors can…

*A*void the 40% "conservatism factor" on process emissions, just by declaring.

Use renewable inputs (plant oils or biomass for heat, bio-ethanol/methanol)

Choose most favourable plant split for by-product allocation

Buy crops from regions with low soil emissions

Farmers can greatly reduce emissions by

buying low-emission fertilizer

using manure, etc.