

EMISSION INVENTORIES AND USE OF EO IN DENMARK

EO FOR MONITORING, REPORTING, AND VERIFICATION OF CARBON REMOVALS
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MAIN ISSUES

What is the purpose ? – Estimation of:

- Area
- C stock
- C stock change

What resolution do we need ?

What is the uncertainty ?

Important to distinguish between C in aboveground (living biomass) and C stock in soils

Experiences learned

Some examples

CURRENT DANISH GHG INVENTORY

Wall to Wall – 25*25 m² pixel resolution (625 m²)

LandSat: 1990, 2005, 2011

Categorial maps: SE, FL, CL, GL, WE.

- Settlement, forest maps
 - Cropland and Grassland: IACS (Integrated Administration and Control System)
 - Free access from annual maps uploaded by DAA or direct access via WFS
- Wetlands/moors

Hierarchical definition: If not this then this

Minimal Mapping Unit (MMU): 0.5 hectares – eight pixels

Land Use Change: **Only if eight pixels are connected** – to avoid undocumented LUC and noise

AN INVENTORY IS SIMPLE

—
Activity * Emission factor

Or

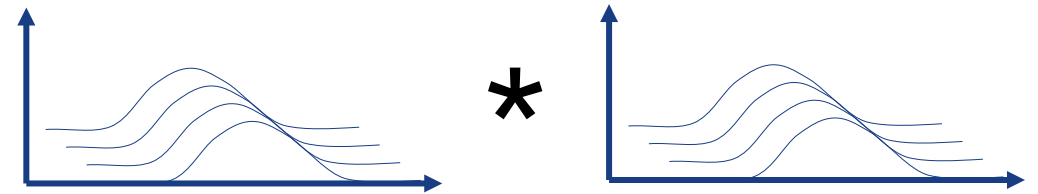
Emission

$$= C \text{ stock}_t - C \text{ stock}_{t-1}$$

$$= \sum_1^n (\text{Area}_t * C \text{ stock per area}_t) - \sum_1^n (\text{Area}_{t-1} * C \text{ stock per area}_{t-1})$$

$$= \text{Area}_t * C \text{ stock change per area}_t$$

Uncertainty * Uncertainty



Mean values and known distribution functions are important – remember the purpose

EXAMPLE 1 – ORGANIC SOILS

KOLINDSUND, JUTLAND

Organic soils are often wet,
cold and dark

Kolindsund: 2800 hectare
fertile land

Lake drained in 1880, 25
km long, max depth 2 m
below sea level.

Western end with up to 40
% clay and very low OC
content.

Eastern end up to 5 % OC.



Photo: <https://dataforsyningen.dk/data/981>



Photo: <https://www.kolindsundnatur.dk/fakta/landbrug/>

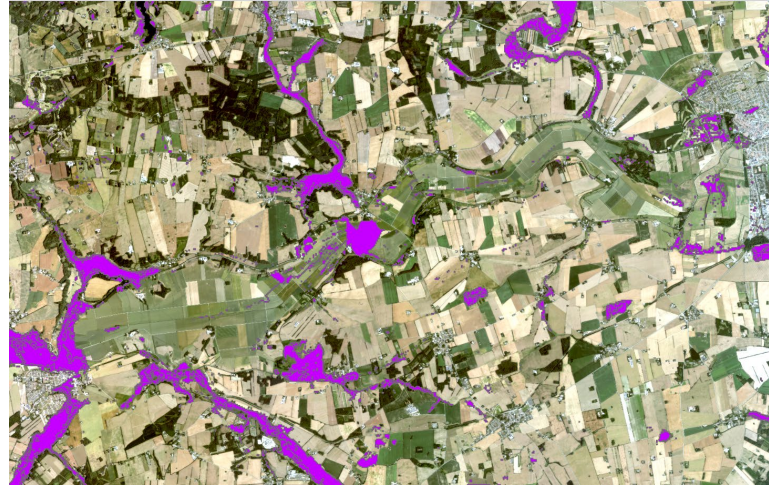
EXAMPLE 1 – ORGANIC SOILS KOLINDSUND, JUTLAND

—
New data and updated methodology

One important new parameter:
EO with soil color

Use of EO may increase the accuracy
but may also do the opposite

(OBS: Many of the new pixels OC
level are just above 6 % OC)



2010 mapping



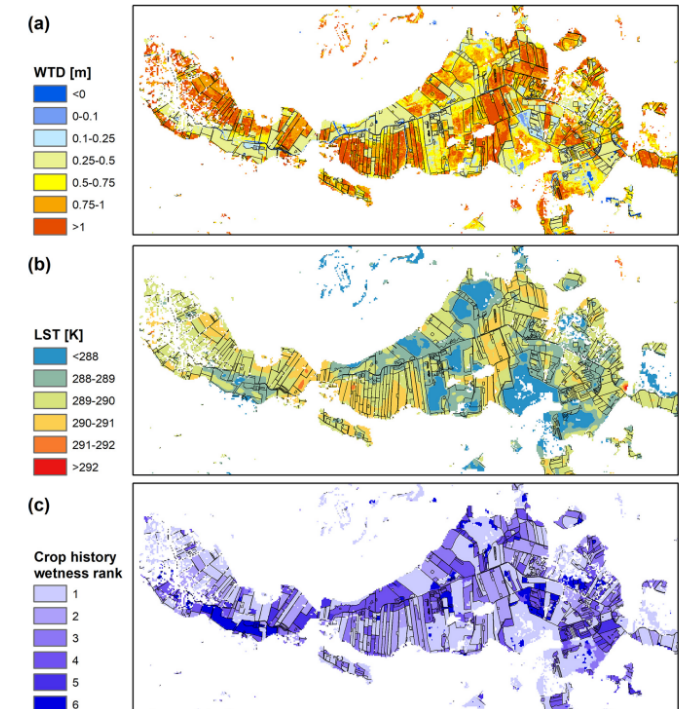
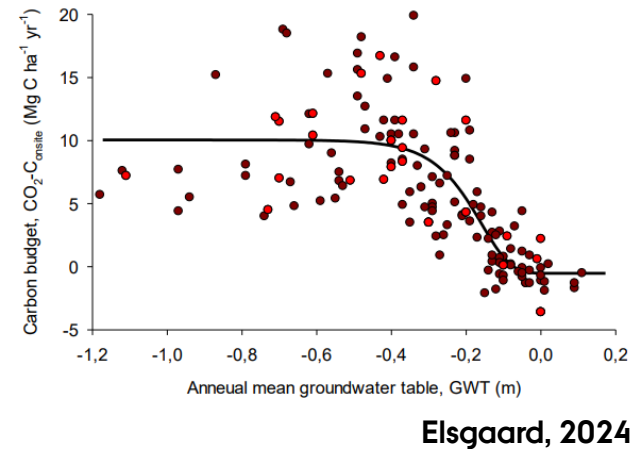
2022 mapping

EXAMPLE 2 – ORGANIC SOIL GROUND WATER TABLE (GWT)

CO₂ emission depends
on GWT

Landsat 1998-2018:
Annual mean surface
temperature

Crop rotation from IACS
2016-2020 to make a
wetness ranking (1-6
where 1 is dry)



Åmosen, Zealand (Koch et al., 2023)

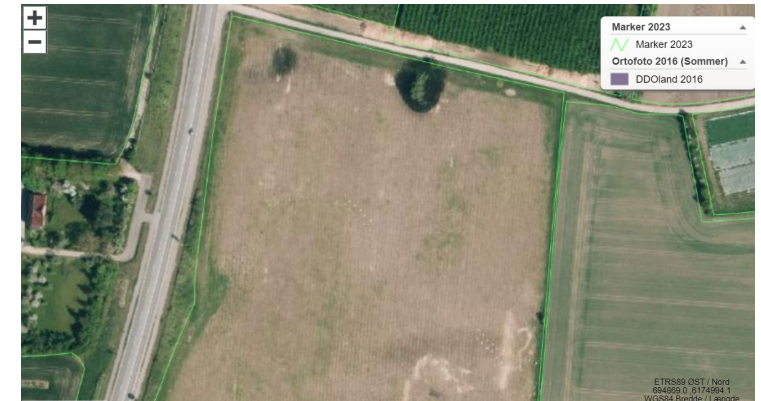
EXAMPLE 3 – LIVING BIOMASS

- Apple orchard
 - C-stock: Area from IACS * C-stock in full grown apple orchard
 - Area has a low uncertainty,
 - C-stock is stable due to a long crop rotation – no need for a growth model
- Coppice from Willow
 - C-stock: Area from IACS * average C-stock for a willow plantation
 - Area has a low uncertainty,
 - Average C-stock. C-stock varies because harvest is taking place every 2-3 years.
 - Use of max C-Stock would only have a little influence on the national inventory, but large on farm level.

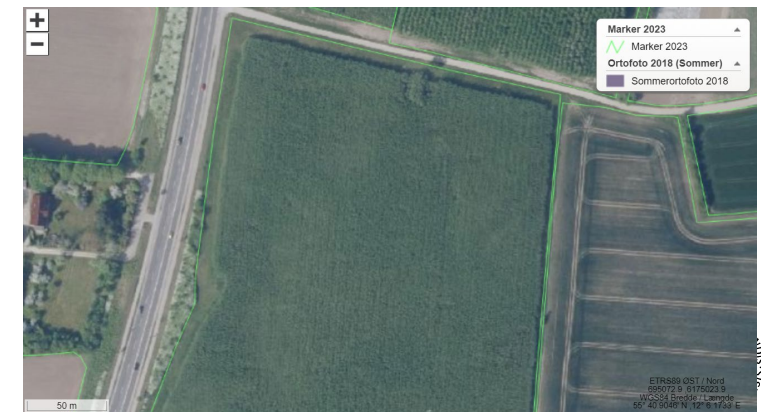
2014



2016



2018



EXAMPLE 4 – LIVING BIOMASS HEDGES



2014



LiDAR 2014

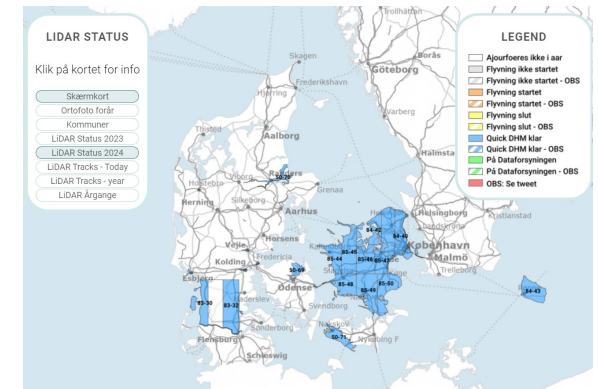
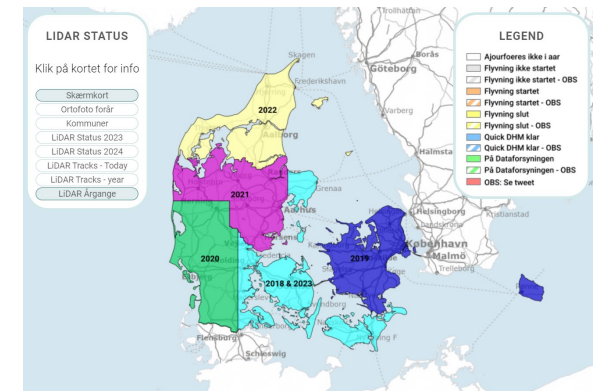


2022



EXAMPLE 4 – LIVING BIOMASS HEDGES

- **Hedges: Non-forest areas and areas not included in IACS ≈ Uncertain area**
- **Differences in C-stock between species and/or windy and calm conditions (density and/or height)**
- **Approach:**
 - **LiDAR volume in 2006 and 2014/2015**
 - **DSM minus DEM, minimum height 2 meter**
 - **C-stock = Volume, $m^3 * kg C m^{-3}$**
 - **m^3 chips m^{-3} hedge = 0,0137**
 - **Std: $\pm 0,0025$, n=14, 9.8 hectare chipped**
- **We are currently updating our LiDAR estimates**
- **Cloud data may increase the density function**



EXAMPLE 5 – LIVING BIOMASS FOREST

- Forest area:
 - NFI: 642,979 ha (2022)
 - Land Use Matrix: 647,346 ha (2022)
 - Difference = 6.347 ha or 0.7 %
- C-stock changes = NFI data
- Use of EO data would have
 - Increased the area with Afforestation
 - Increased the area with Deforestation
 - Temporarily affected the C stock storage and the emission estimates

2018



2022



2024



LESSONS – CONCERNS – WISH LIST

- Denmark is using IACS data and EO to a large extent in the national GHG inventory with a conservative approach in the Land Use Matrix to avoid large and undocumented changes in areas
- When feasible we are using raw Sentinel data but only on project basis
- We have issues with:
 - Settlement where cloud data/hard returns can improve the accuracy of the area hard/soft surfaces
 - According to LULUCF regulation 839/2023 shall all land be included in the inventory from 2030
 - We have major concerns about the reporting demand for very detailed Land Use categories and C stock changes - Sentinel data may create a lot of noise
 - We do not have the C stock data for the detailed resolution
 - Forest
 - Area with organic soils and emission factors from these
 - Wetlands
 - Ground water table and emission factors