# Estimation and Evaluation of ecosystem carbon accounts for the EU countries

Emil Ivanov

London group session of Experimental Ecosystem Accounting

16 Oct 2014, New Delhi

# 1. Outline

Development, evaluation and consolidation of European carbon accounts. Work done at EEA and UNOTT

- Working definition, scope and parameters

- Data foundation, methodology and estimation carbon accounts

- Accounting framework, inputs and outputs and their evaluation

- Possibilities for assessing assets and services derived from carbon accounting data

- Lessons, challenges and further work

# 2. Working definition and scope

- A quantitative, annual and spatially explicit estimate of carbon stored in main pools and transfers between them and within them
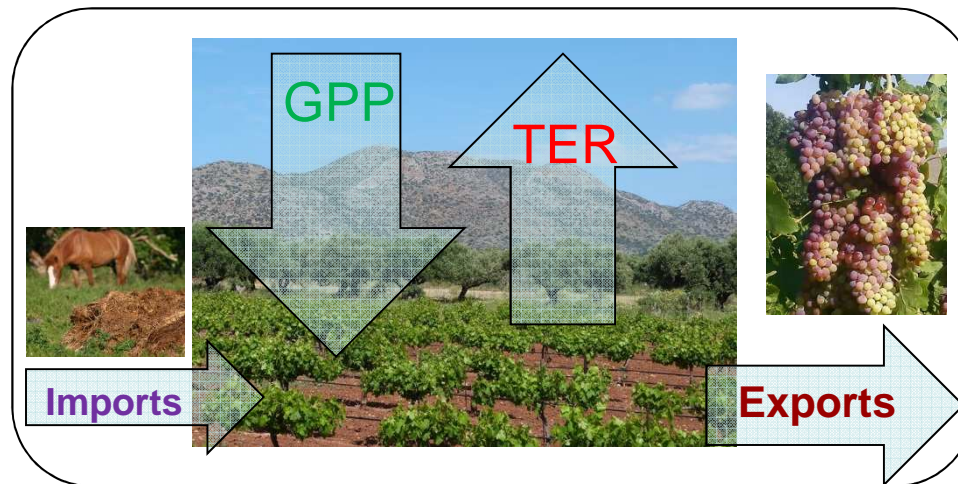


- Biomass, forest assets, regulatory and provisioning services

# 3. Data foundation and methodology

Properties of the carbon data foundation compatible and comparable with assets and services from other ecosystem accounting components

- Use of common European land cover (CORINE), administrative (NUTS2-3) and other spatial information (DLT, river catchments)

- Harmonizing inputs at 1km x 1km grid by downscaling (regional/national statistics) and up-scaling (scientific estimates)

- Common ecosystem reporting units

# 4.1 Working approach and framework

- Overall structure

- Relations between the carbon accounting components

- Estimation of NECB

| SEEA-EEA & ENCA-QSP land cover ecosystem units | | LCEU 1 | LCEU 2, 3, 4 | LCEU 5 | LCEU 6 | LCEU 7, 8, 9, 10, 11, 12 | LCEU 12 | LCEU 13, 14 | Total inland & coastal eco-systems | Open sea, oceans | Atmosphere | TOTAL | Supply & use system |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IPCC land use classification | SL – Settlements | CL – Cropland | GL – Grassland | FL – Forest Land | OL – Other Land | WL – Wetlands | Water bodies, rivers | | | | | |
| **I. Ecosystem Carbon Basic Balance** | | | | | | | | | | | | | |
| C1 | Opening Stocks | | | | | | | | | | | | |
| C2.3 | NPP (Net Primary Production) | | | | | | | | | | | | |
| C2.4 | Secondary ecosystem repiration (heterotrophic) | | | | | | | | | | | | |
| C2.a | NEP (Net Ecosystem Production) – C2.3-C2.4 | | | | | | | | | | | | |
| C2.b | s/Total secondary biocarbon resource | | | | | | | | | | | | |
| C2 | **Total inflow of biocarbon (gains) = C2.a+C2.b** | | | | | | | | | | | | |
| C3.a | Harvest of agriculture crops, wood & other vegetation | | | | | | | | | | | | |
| C3.b | Withdrawals of secondary biocarbon | | | | | | | | | | | | |
| C3 | Total withdrawals of biocarbon – C3.a+C3.b | | | | | | | | | | | | |
| C4 | Net indirect anthropogenic losses of biocarbon & biofuel combustion | | | | | | | | | | | | |
| C5 | Total use of ecosystem biocarbon – C3+C4 | | | | | | | | | | | | |
| C6 | Natural processes and disturbances | | | | | | | | | | | | |
| C7 | **Total outflow of biocarbon (losses)** | | | | | | | | | | | | |
| C8.1 | NECB 1 [Flows] = Inflows - Outflows = C2-C7 | | | | | | | | | | | | |
| C8.2 | Adjustment and reappraisals | | | | | | | | | | | | |
| C8.3 | NECB 2 [Stocks] = Change of biocarbon stocks | | | | | | | | | | | | |
| C9 | Closing Stocks = C1+C8.1+C8.2 or = C1+C8.3 | | | | | | | | | | | | |

Source: CBD Technical Series No. 77 , p. 105

# 4.2 Criteria for selecting accounting data inputs

27 EU countries, data inputs at 1km x 1km grid (for opening stocks) and decade time-series (for annual carbon fluxes and transfers)

# 4.3 Criteria for validation data



Compilation of independent measurements **representative for spatial and temporal variability** across Europe

FLUXNET with data on GPP, TER and NEP (2000 – 2006)

Published studies on carbon balances of forests, croplands and grasslands in Europe (2000 – 2011)

# 5.1 Accounting parameters

| Carbon Accounting items | | Ecosystem components/ functions |
|---|---|---|
| **Opening Stocks** | 1. Soil organic carbon (SOC) | Labile and stable fractions, dead material and litter |
| | 2. Biomass (TCB) | In woody and herbal vegetation |
| **Fluxes and transfers** | 3. Primary production  (GPP) | Carbon fixing through photosynthesis |
| | 4. Carbon release (TER) | Heterotrophic and autotrophic respiration |
| | 5. Human use of primary production (TPPU) | Harvests of crops, timber, fibre etc. |
| | 6. Carbon imports (TCR) | Manure and sludge deposition |
| **Balances** | 7. Net ecosystem production (NEP), Ecosystem carbon balance (NECB) | Source or sink function, amount of accumulation or depletion |

# 5.2 Accounting parameters and data sources

| Carbon Accounting items | | Data sources |
|---|---|---|
| **Opening Stocks** | 1. Soil organic carbon (SOC) | **JRC map of SOC** (Hiederer and Köchy, 2012), global at 1km, 30 cm and 1m depth; EEA estimate of SOC, 30cm |
| | 2. Biomass (TCB) | **Downscaled forest biomass by EEA** <br> **Upscaled biomass for non-forest biomass** by EEA |
| **Fluxes and transfers** | 3. Primary production (GPP) | **Downscaled NASA-CASA NPP** (from 8km to 1km), converted to GPP by adding autotrophic respiration from MODIS (Running et al.) |
| | 4. Carbon release / respiration (TER) | **Downscaled NASA-CASA Soil respiration** (from 8km to 1km), converted to TER by adding autotrophic respiration from MODIS (Running et al.) |
| | 5. Human use of primary production (TPPU) | **Downscaled regional statistics on crops** (EUROSTAT), **timber** (EFISCEN, National FI and EFIMED) and grazing livestock, using land-cover and vegetation indices |
| | 6. Carbon imports (TCR) | **Downscaled deposition** of dry sludge and manure (from livestock distribution) |
| **Balances** | 7. NEP, Ecosystem carbon balance (NECB) | **NEP** estimated from GPP and TER, **NECB** estimated by aggregating all flows |

# 5.3 Accounting parameters and evaluation data

| Carbon Accounting items | | Data sources |
|---|---|---|
| **Opening Stocks** | 1. Soil organic carbon (SOC) | Published data; EIONET soil org. carbon data (Panagos et al., 2013) |
| | 2. Biomass (TCB) | Published data |
| **Fluxes and transfers** | 3. Primary production (GPP) | FLUXNET and published data |
| | 4. Carbon release (TER) | FLUXNET and published data |
| | 5. Human use of primary production (TPPU) | Published data |
| | 6. Carbon imports (TCR) | Published data |
| **Balances** | 7. Net ecosystem production (NEP), Ecosystem carbon balance (NECB) | FLUXNET and published data (NEP); published data on ECB |

# 6. Working process

- Review of input data

- Evaluation (step 1) of the inputs, if alternatives exist

- Estimation of harmonized and consistent accounts

- Evaluation (step 2) of the outputs

# 7. Carbon stocks in soil

- Inputs



JRC map of SOC (Hiederer and Köchy, 2012)    EEA map of SOC
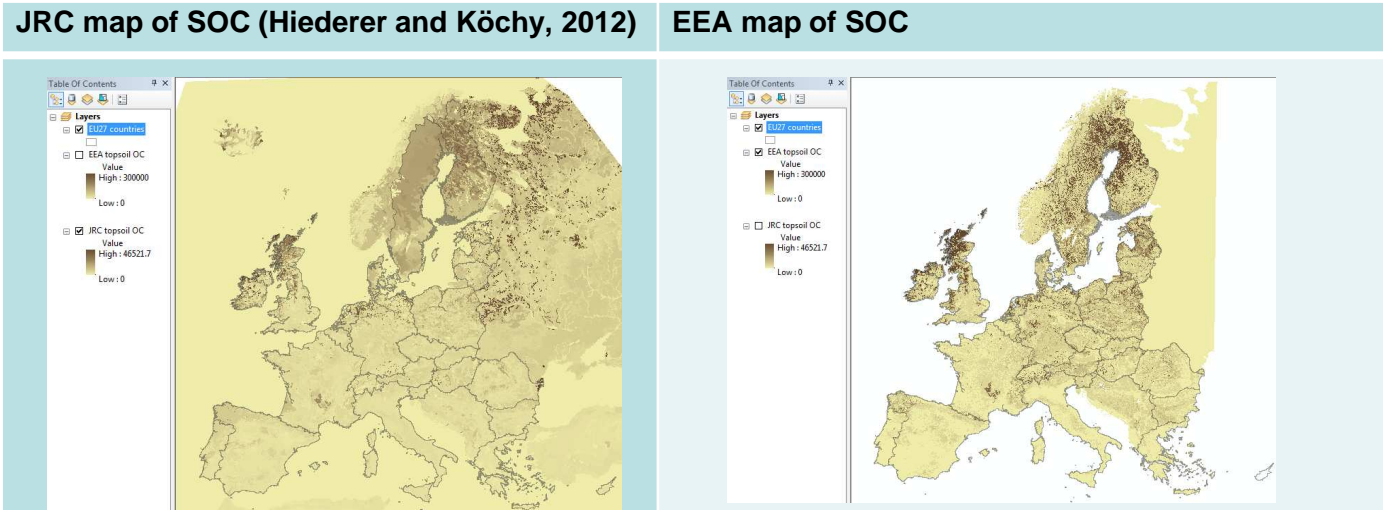
- Evaluation and selection

| Country | Average SOC (t C /km2) Reference from Panagos et al. | EEA SOC(t C /km2), R² = 0.5 | JRC SOC(t C /km2), R² = 0.69 |
|---|---|---|---|
| Bulgaria | 2800 | 7342 | 4744 |
| Denmark | 8640 | 10136 | 6173 |
| Italy | 5630 | 3182 | 4003 |
| Netherlands | 10010 | 21696 | 8938 |
| Poland | 7960 | 18695 | 7027 |
| Slovakia | 4530 | 10429 | 5062 |

# 8. Carbon stocks in biomass

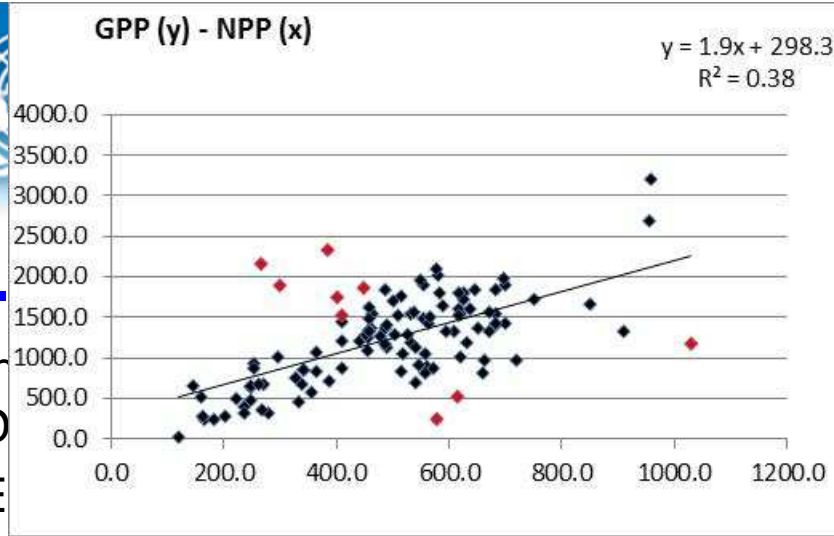| N | Unique name | Mapping approach |
|---|---|---|
| 1 | Forest biomass | Downscaling for forest statistics using land-cover and vegetation indices |
| 2 | Agroforestry biomass | Upscaling of 'known values' using land cover |
| 3 | Arable crops biomass | Upscaling of 'known values' using land cover |
| 4 | Complex crops biomass | Upscaling of 'known values' using land cover |
| 5 | Pastures stocks biomass | Upscaling of 'known values' using land cover |
| 6 | Permanent crops biomass | Upscaling of 'known values' using land cover |
| 7 | Natural vegetation biomass | Upscaling of 'known values' using land cover |

## Input data quality:

Forest biomass is expected to have higher accuracy compared to the non-forest due to the ensured consistency with regional statistics.

## 9. [...] services

GPP (y) - NPP (x)

$y = 1.9x + 298.3$
$R^2 = 0.38$



- I[...] NASA-CASA NPP (8km, Potter et al.), D[...]
- E[...] $R^2 = 0.38$ / $R^2 = 0.61$
- Evaluation of annual change, 2005 - 2006

MODIS NPP
$R^2 = 0.2378$

NASA-CASA NPP
$R^2 = 0.3628$

Downscaled NASA NPP
$R^2 = 0.4175$
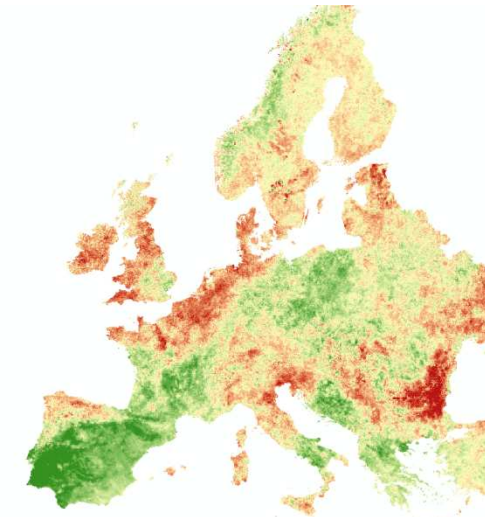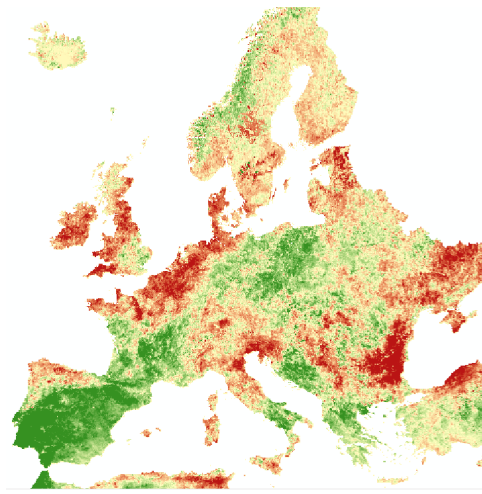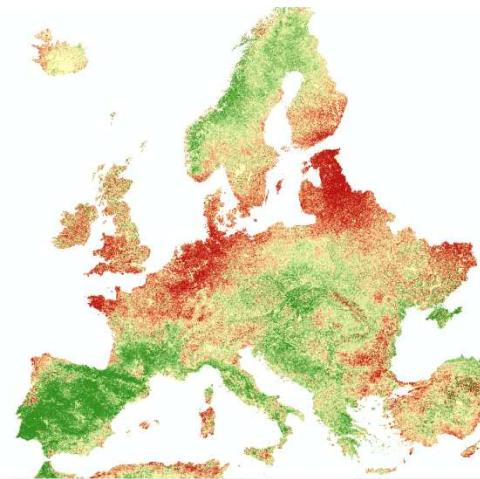


- Selection: Downscaled NPP
- Converted to GPP by adding Autotrophic respiration from MODIS (by Running et al.)

# 10. Soil respiration, TER

- Inputs: NASA-CASA soil respiration (the only available)

- Converted to TER by adding up 50% of the autotrophic respiration (by Running et al.), following an assumption that the below-ground plant respiration may be already included in the in the Soil respiration estimate

- Evaluation of mean values of time-series: $R^2 = 0.28$ / $R^2 = 0.48$



TER (y) - Rsoil (x)

$y = 1.4x + 295.6$
$R^2 = 0.28$
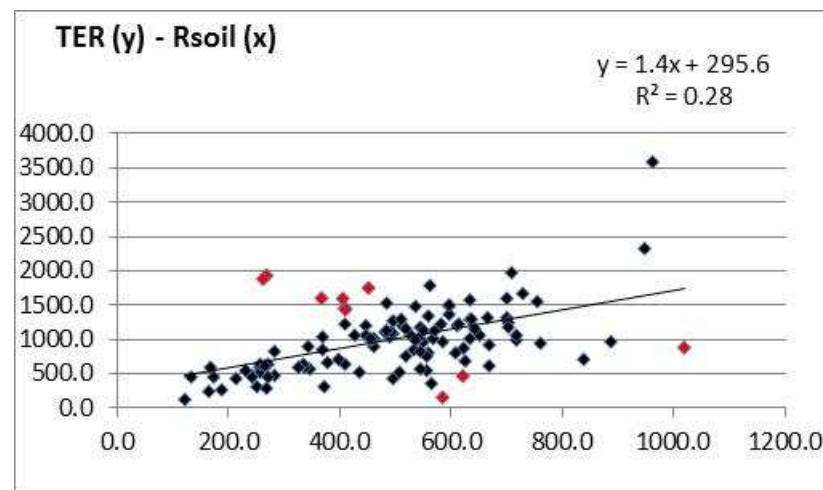
# 11.1 Carbon use and returns

- Inputs:

**Statistical data**

| | |
|---|---|
| FD31-1 | Harvested crops - cereals |
| FD32-1 | Harvested crops - citrus |
| FD33-1 | Harvested crops - fruits |
| FD34-1 | Harvested crops – industrial crops |
| FD35-1 | Harvested crops - oilseeds |
| FD36-1 | Harvested crops - olives |
| FD37-1 | Harvested crops - rice |
| FD38-1 | Harvested crops - roots |
| FD39-1 | Harvested crops - vineyards |

**Spatial disaggregation data**
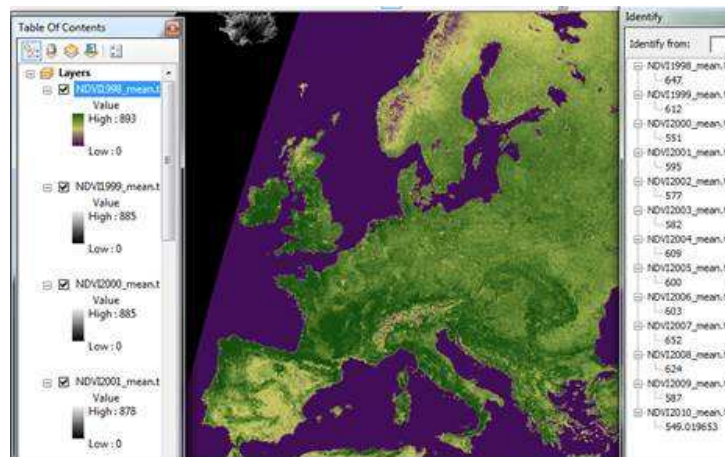


**Administrative data**
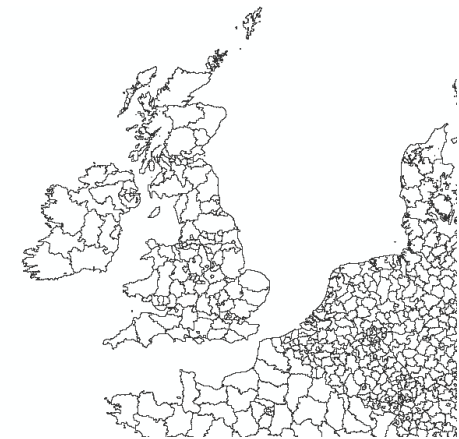


- Processing

Downscaling techniques for crops, timber and livestock

- Outputs (next)

# 11.2 Carbon 'uses' / provisioning services
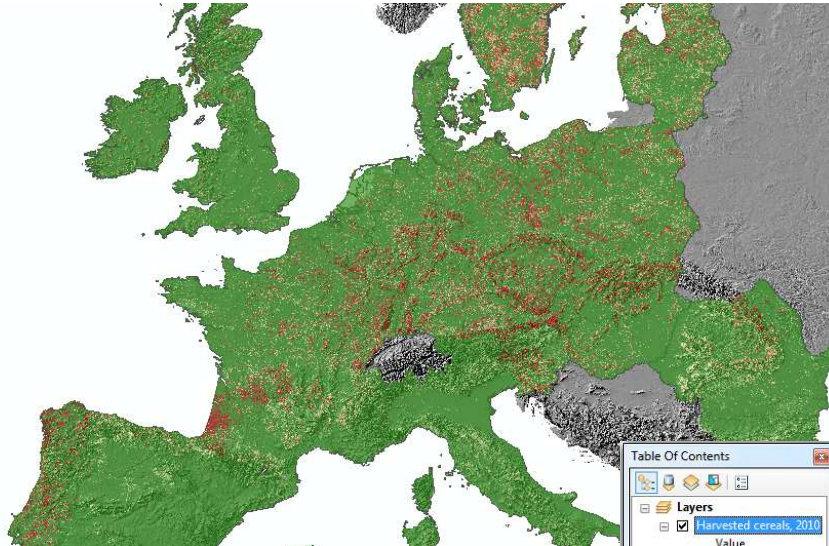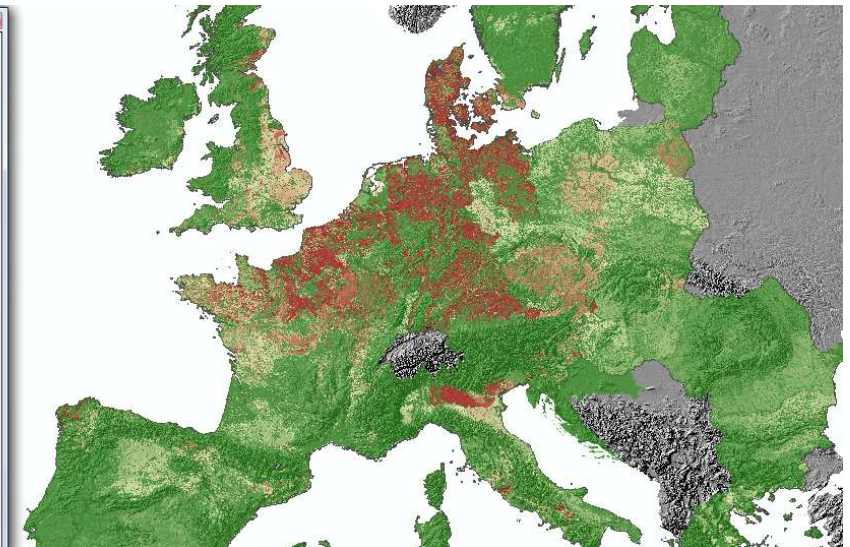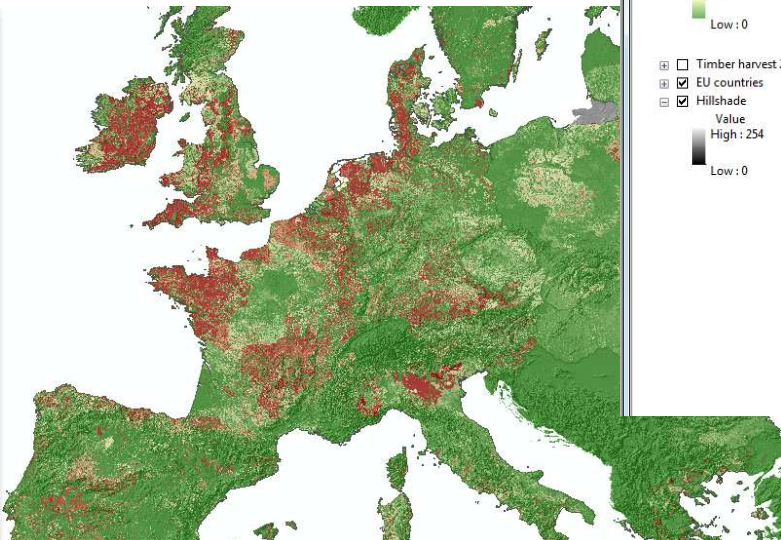
# 12. Balancing estimates

The two basic balancing items are designed to summarize 'vertical' and 'horizontal' carbon transfers

Net ecosystem production = Gross Primary Production – Terrestrial Ecosystem Respiration
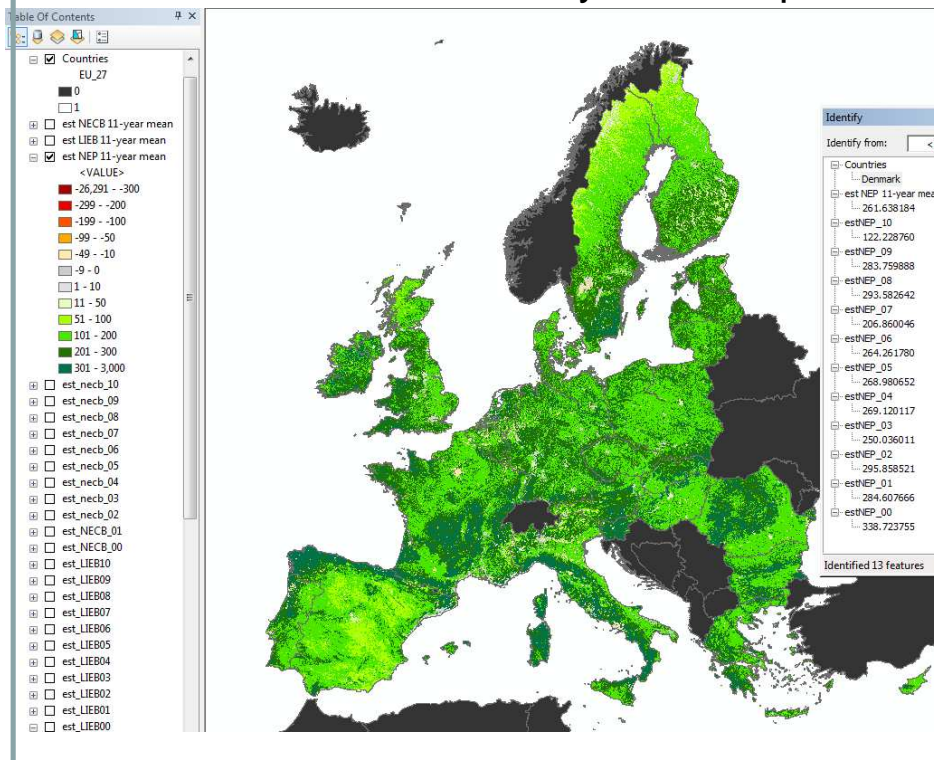
Balance of lateral imports and exports = Carbon returns – carbon 'uses'
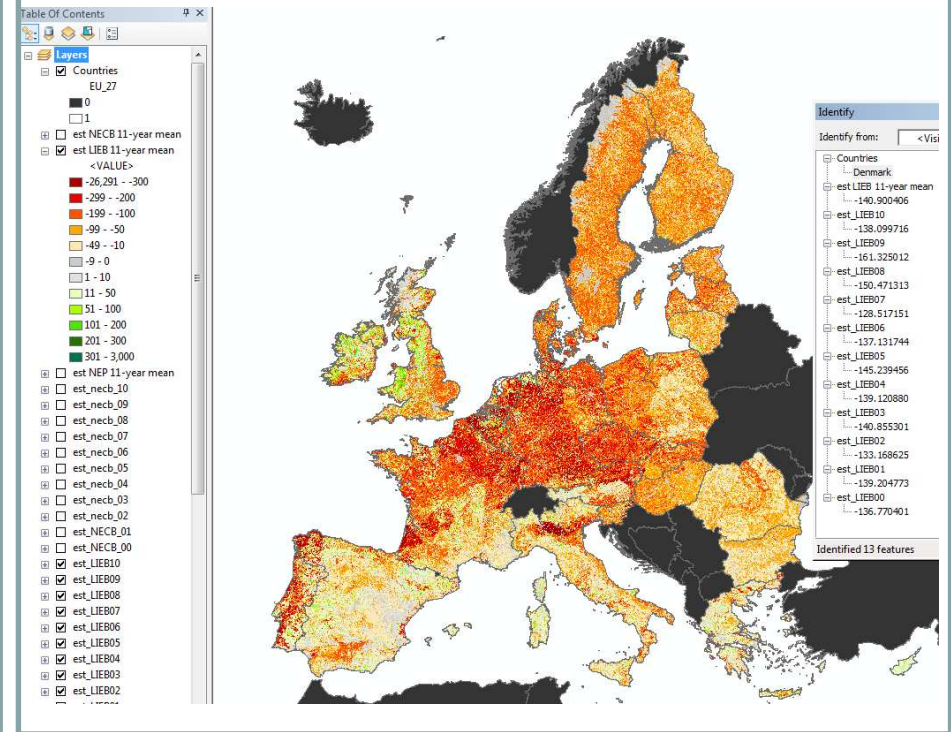
# 13. Estimation of NECB
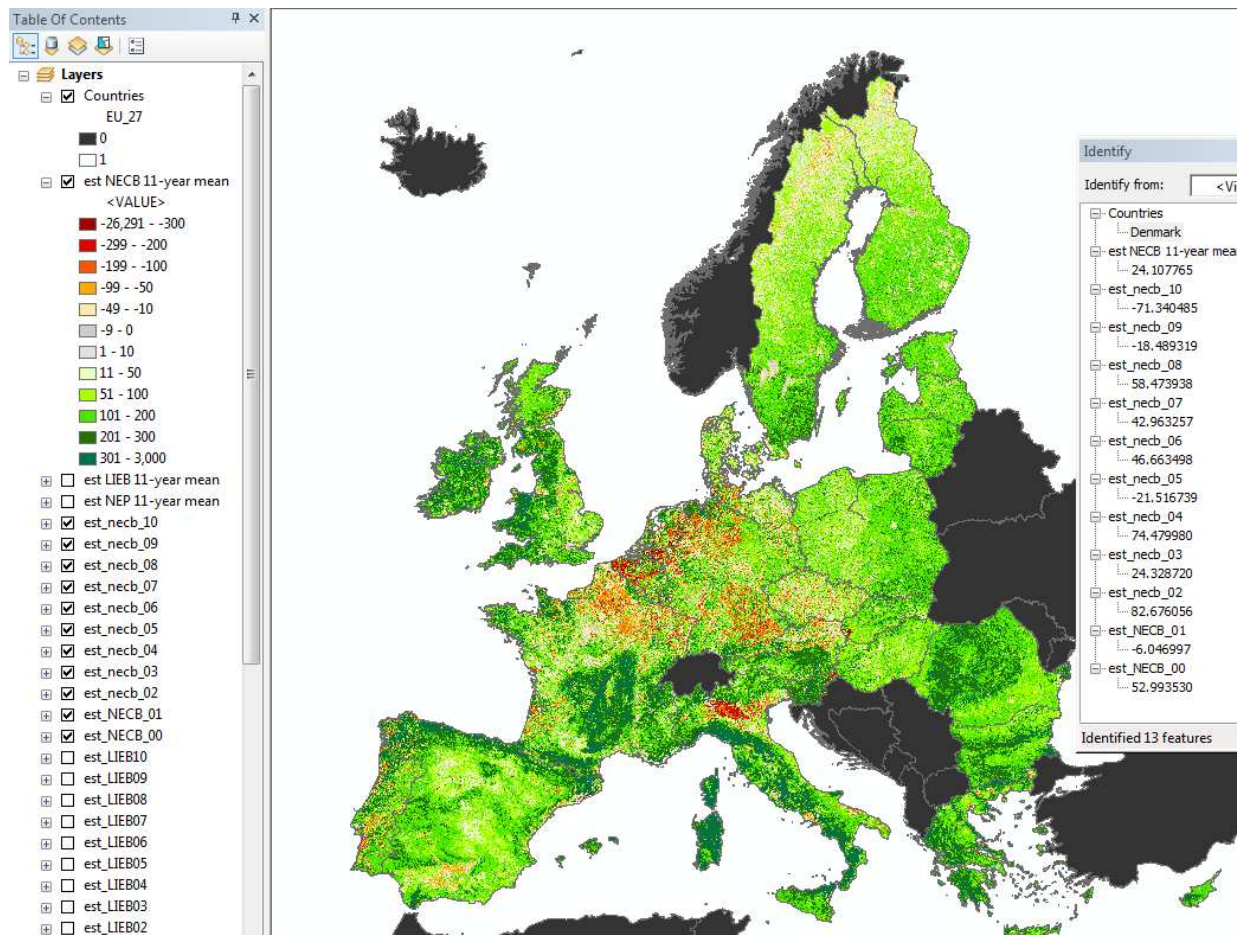


On country level the ecosystem carbon accounts should be consistent with IPCC's in assessing whether ecosystems acted as net source or sink of $CO_2$ for a given period of time.

The maps shows a decade average, with areas in green indicating prevailing sink (most of Europe) and in red – prevailing source functions (e.g. parts of North West Europe, Po valley in Italy, and spots of forest-burned areas of Portugal).

# 14.1 Evaluation of estimated outputs

- The validation datasets contains records for:
  - European forests: **217 records on GPP, 216 on TER** (ecosystem respiration), **25 on carbon exports** (timber harvest), **216 on NEP** and **60 on Ecosystem carbon balance.**
  - European croplands: **80 records on GPP; 79 on TER; 81 on carbon imports (manure, seeds)**; **104 on carbon exports (harvested crops); 116 on NEP and 99 on Ecosystem Carbon balance**.
  - European grasslands: **58 on GPP; 56 on TER**; **6 on carbon imports** (manure); **15 on carbon exports (fodder)**; **65 on NEP and 15 on carbon balance** (ecoregions are not well represented)
  - European wetlands (very few): **GPP 12; TER 11; NEP 11**. Most of the studies are from Boreal sites.

- Mean values disaggregated per accounting category, ecosystem type and ecoregion

# 14.2 Evaluation of estimated outputs

Three tests were applied:

1. Assess whether the accounting estimates are of the same order of magnitude as the validation data;

2. Assess whether the means of the accounts fall within the statistical variation range of the control

3. Assess whether the equality of means is also statistically significant at either 90 or 95% confidence level.

# 14.3 Evaluation of estimated outputs

| | | | N (site-years) | Control (sc. + fluxnet) | Mean | | St. D. | Accounts 1km - sECA Mean | Test 1 | Test 2 | Test 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | low | | high | | | | | |
| Forest | GPP | all | 217 | 1029 | **1466** | 1904 | 438 | **1001** | 1.5 | no | no |
| Croplands | GPP | all | 80 | 1004 | **1293** | 1583 | 290 | **909** | 1.4 | no | no |
| Grasslands | GPP | all | 58 | 876 | **1395** | 1914 | 519 | **977** | 1.4 | yes | no |
| Forest | TER | all | 216 | -1395 | **-1054** | -714 | 340 | **-751** | 1.4 | yes | no |
| Croplands | TER | all | 79 | -1260 | **-981** | -702 | 279 | **-726** | 1.4 | yes | no |
| Grasslands | TER | all | 56 | -1698 | **-1240** | -782 | 458 | **-753** | 1.6 | no | no |
| Forest | TPPU | all | 25 | -253 | **-194** | -135 | 59 | **-175** | 1.1 | yes | yes |
| Croplands | TPPU | all | 104 | -723 | **-475** | -227 | 248 | **-160** | 3.0 | no | no |
| Grasslands | TPPU | all | 15 | -379 | **-280** | -181 | 99 | **-70** | 4.0 | no | no |
| Croplands | TCR | all | 81 | -27 | **50** | 127 | 77 | **38** | 1.3 | yes | yes |
| Grasslands | TCR | all | 6 | 55 | **100** | 145 | 45 | **35** | 2.9 | no | yes |
| Forest | NEP | all | 216 | 139 | **417** | 696 | 278 | **249** | 1.7 | yes | no |
| Croplands | NEP | all | 116 | 98 | **319** | 540 | 221 | **183** | 1.7 | yes | no |
| Grasslands | NEP | all | 65 | -24 | **191** | 406 | 215 | **224** | 0.9 | yes | yes |
| Forest | NECB | all | 60 | 54 | **322** | 590 | 268 | **105** | 3.1 | yes | no |
| Croplands | NECB | all | 99 | -323 | **-105** | 112 | 217 | **61** | -1.7 | yes | no |
| Grasslands | NECB | all | 15 | -125 | **73** | 203 | 207 | **188** | 0.4 | yes | yes |
| Forest | NECB | Atlantic | 7 | | **-135** | | 0 | **66** | -2.0 | no | no |
| Forest | NECB | Continental | 44 | 170 | **407** | 644 | 237 | **48** | 8.5 | no | no |
| Forest | NECB | Mediterranean | 9 | | **260** | | | **270** | 1.0 | yes | yes |
| Croplands | NECB | Atlantic | 45 | -304 | **-110** | 83 | 193 | **43** | -2.6 | yes | no |
| Croplands | NECB | Continental | 31 | -273 | **-115** | 42 | 158 | **74** | -1.6 | no | no |
| Croplands | NECB | Mediterranean | 23 | -400 | **-82** | 236 | 318 | **86** | -1.0 | yes | yes |
| Grasslands | NECB | Continental | 15 | -125 | **39** | 203 | 164 | **195** | 0.2 | yes | yes |

22

# Overall conclusions on accounting data quality

- All estimates (totally 56, considering each carbon flow, ecosystem and ecoregion) have the same order of magnitude

- Many (31 from 56) also fall within the variation range of the control

- Fewer (25 from 56) show also statistically significant equality of means.

- some validation parameters (harvest of carbon in forests and grasslands) need additional data to be fully representative and reliable for assessing carbon variation in the EU

- Scale-effects may be contributing to the 'disagreement' between crops harvest from field studies and downscaled statistics

# 14.4 Evaluation of estimated outputs

- GPP and TER are around 25% underestimated
- Crops' harvest appear much underestimated
- The balances show better agreement between 'control' and accounts

| | | | Control (sc. + fluxnet) | | | | | Accounts 1km - sECA | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N (site-years) | low | Mean | high | St. D. | Mean | Test 1 | Test 2 | Test 3 |
| Forest | GPP | Boreal | 31 | 465 | 794 | 1123 | 329 | 684 | 1.2 | yes | yes |
| Forest | GPP | Atlantic | 21 | 907 | 1520 | 2132 | 612 | 1141 | 1.3 | no | no |
| Forest | GPP | Continental | 99 | 1424 | 1672 | 1920 | 248 | 1072 | 1.6 | no | no |
| Forest | GPP | Mediterranean | 51 | 1196 | 1489 | 1782 | 293 | 1165 | 1.3 | no | no |
| Forest | GPP | Alpine | 15 | 978 | 1360 | 1743 | 382 | 875 | 1.6 | no | no |
| Croplands | GPP | Atlantic | 32 | 816 | 1171 | 1526 | 355 | 930 | 1.3 | yes | no |
| Croplands | GPP | Continental | 30 | 1161 | 1344 | 1527 | 183 | 919 | 1.5 | no | no |
| Croplands | GPP | Mediterranean | 18 | 1200 | 1426 | 1652 | 226 | 835 | 1.7 | no | no |
| Grasslands | GPP | Pannonian | 7 | 707 | 941 | 1175 | 234 | 1069 | 0.9 | yes | yes |
| Grasslands | GPP | Atlantic | 7 | 1100 | 1461 | 1821 | 360 | 1142 | 1.3 | yes | yes |
| Grasslands | GPP | Continental | 24 | 1293 | 1674 | 2055 | 381 | 1010 | 1.7 | no | no |
| Grasslands | GPP | Mediterranean | 12 | 679 | 928 | 1177 | 249 | 962 | 1.0 | yes | yes |
| Grasslands | GPP | Alpine | 8 | 963 | 1370 | 1777 | 407 | 820 | 1.7 | no | no |
| Forest | TER | Boreal | 30 | -989 | -736 | -484 | 252 | -485 | 1.5 | yes | no |
| Forest | TER | Atlantic | 21 | -1605 | -1165 | -725 | 440 | -880 | 1.3 | yes | no |
| Forest | TER | Continental | 99 | -1459 | -1199 | -939 | 260 | -820 | 1.5 | no | no |
| Forest | TER | Mediterranean | 51 | -1290 | -1071 | -852 | 219 | -828 | 1.3 | no | no |
| Forest | TER | Alpine | 15 | -708 | -520 | -332 | 188 | -671 | 0.8 | yes | yes |
| Croplands | TER | Atlantic | 31 | -1157 | -857 | -558 | 300 | -762 | 1.1 | yes | yes |
| Croplands | TER | Continental | 30 | -1278 | -1090 | -902 | 188 | -723 | 1.5 | no | no |
| Croplands | TER | Mediterranean | 18 | -1308 | -1011 | -715 | 297 | -632 | 1.6 | no | no |
| Grasslands | TER | Pannonian | 7 | -970 | -838 | -706 | 132 | -842 | 1.0 | yes | yes |
| Grasslands | TER | Atlantic | 7 | -1599 | -1294 | -989 | 305 | -909 | 1.4 | no | yes |
| Grasslands | TER | Continental | 24 | -1802 | -1454 | -1105 | 349 | -778 | 1.9 | no | no |
| Grasslands | TER | Mediterranean | 10 | -1147 | -895 | -642 | 253 | -745 | 1.2 | yes | yes |
| Grasslands | TER | Alpine | 8 | -1801 | -1179 | -557 | 622 | -607 | 1.9 | yes | yes |
| Forest | TPPU | Atlantic | 7 | | -229 | | 0 | -236 | 1.0 | yes | yes |
| Forest | TPPU | Continental | 18 | -245 | -180 | -115 | 65 | -253 | 0.7 | yes | no |
| Croplands | TPPU | Atlantic | 50 | -789 | -499 | -209 | 290 | -177 | 2.8 | no | no |
| Croplands | TPPU | Continental | 31 | -566 | -428 | -290 | 138 | -157 | 2.7 | no | no |
| Croplands | TPPU | Mediterranean | 23 | -746 | -485 | -225 | 261 | -125 | 3.9 | no | no |
| Grasslands | TPPU | Continental | 15 | -383 | -288 | -194 | 94 | -70 | 4.1 | no | no |
| Croplands | TCR | Atlantic | 34 | -19 | 54 | 127 | 73 | 52 | 1.0 | yes | yes |
| Croplands | TCR | Continental | 32 | -37 | 57 | 151 | 94 | 35 | 1.6 | yes | yes |
| Croplands | TCR | Mediterranean | 15 | -9 | 28 | 64 | 37 | 9 | 3.1 | yes | yes |
| Grasslands | TCR | Continental | 6 | 55 | 100 | 145 | 45 | 34 | 2.9 | no | yes |
| Forest | NEP | Boreal | 30 | -83 | 67 | 216 | 149 | 198 | 0.3 | yes | no |
| Forest | NEP | Atlantic | 21 | 86 | 354 | 622 | 268 | 260 | 1.4 | yes | yes |
| Forest | NEP | Continental | 99 | 284 | 473 | 662 | 189 | 251 | 1.9 | no | no |
| Forest | NEP | Mediterranean | 51 | 196 | 418 | 641 | 223 | 337 | 1.2 | yes | yes |
| Forest | NEP | Alpine | 15 | 477 | 840 | 1202 | 363 | 203 | 4.1 | no | no |
| Croplands | NEP | Atlantic | 51 | 125 | 351 | 576 | 226 | 167 | 2.1 | yes | no |
| Croplands | NEP | Continental | 38 | 52 | 215 | 379 | 164 | 196 | 1.1 | yes | yes |
| Croplands | NEP | Mediterranean | 27 | 169 | 404 | 639 | 235 | 203 | 2.0 | yes | no |
| Grasslands | NEP | Pannonian | 7 | -9 | 103 | 215 | 112 | 226 | 0.5 | no | yes |
| Grasslands | NEP | Atlantic | 7 | -93 | 166 | 426 | 260 | 232 | 0.7 | yes | yes |
| Grasslands | NEP | Continental | 24 | 74 | 254 | 434 | 180 | 231 | 1.1 | yes | yes |
| Grasslands | NEP | Mediterranean | 11 | -122 | 33 | 188 | 155 | 216 | 0.2 | no | no |
| Grasslands | NEP | Alpine | 8 | -88 | 191 | 471 | 279 | 212 | 0.9 | yes | yes |
| Forest | NECB | Atlantic | 7 | | -135 | | 0 | 66 | -2.0 | no | no |
| Forest | NECB | Continental | 44 | 170 | 407 | 644 | 237 | 48 | 8.5 | no | no |
| Forest | NECB | Mediterranean | 9 | | 260 | | | 270 | 1.0 | yes | yes |
| Croplands | NECB | Atlantic | 45 | -304 | -110 | 83 | 193 | 43 | -2.6 | yes | no |
| Croplands | NECB | Continental | 31 | -273 | -115 | 42 | 158 | 74 | -1.6 | no | no |
| Croplands | NECB | Mediterranean | 23 | -400 | -82 | 236 | 318 | 86 | -1.0 | yes | yes |
| Grasslands | NECB | Continental | 15 | -125 | 39 | 203 | 164 | 195 | 0.2 | yes | yes |

# 15. Conclusions

- Improvement and consolidation of wide-area ecosystem carbon accounting data is now possible

- Current data is not for local decision-support (not enough spatially explicit/accurate)

- Uncertainties inherent in both input and validation data need to be addressed and studied further

- Consistency with IPCC and other ecosystem accounting components

- Need to address 'minor' transfers and further issues too

# Thank You!

Emil Ivanov

[ivanove@un.org](mailto:ivanove@un.org)