Carbon fluxes in land-use-change areas across Europe derived from CASA model

You-Ren Wang; Guido van der Werf; A. J. Han Dolman
Department of Earth Sciences, VU University Amsterdam

Introduction to CASA Model

Most biogeochemical models work on 1, 0.5, or 0.25 degree resolution (roughly 100 x 100, 50 x 50, or 25 x 25 km). With CASA, 1-km resolution modeling is possible.

NEE, which represents carbon fluxes, can be calculated by this simplified CASA model by simulating NPP and Respiration, NEE being the difference between them.

High resolution environmental and meteorological data are integrated and fed into this CASA model, including:

A. Several MODIS products:
- fPAR : from MODIS products MOD15A2 and MCD15A2, having a resolution of 1 km.
- PET : Potential Evapotranspiration, from MODIS products MOD16, having a resolution of 1 km.
- Tree cover : Percentage of tree cover, from MODIS products MOD44B, having a resolution of 250 m.
- Land cover : Type of land use according to IGBP vegetation classification, from MODIS product MCD12Q, resolution 500 m.

Coordinate conversion between MODIS tile system and conventional Lat/Lon system was performed.

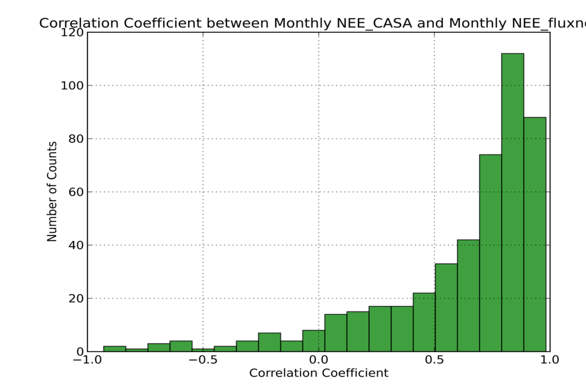
B. Harmonized WATCH ERA Interim data made by Max Planck Institute for Biogeochemistry (having a resolution of 0.25º) were also employed, including:
- Solar radiation
- Precipitation
- Air temperature

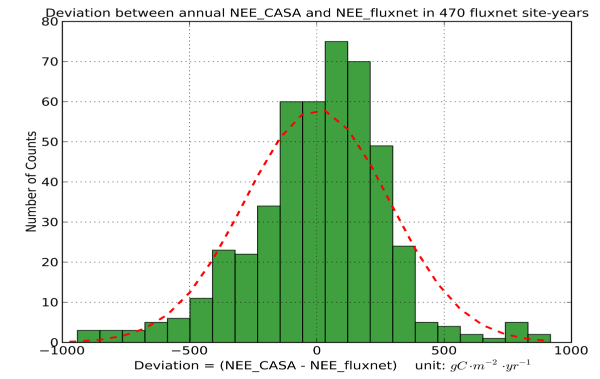
CASA Parameter Optimization with Fluxnet

From Fluxnet database, nearly one thousand site-year data in the three datasets “LaThuile”, “Opened”, and “Free Fair-Use” were downloaded and quality screened. Including 151 sites and 11 vegetation types, 470 site-years passed all the selection criteria and were selected for parameter optimization for the calculation of NEE_CASA.

Several CASA model parameters were optimized such that the correlation coefficients between CASA and Fluxnet is maximized, the distribution of NEE difference between CASA and Fluxnet is centered at zero, and the sigma (standard deviation) of the distribution is minimized.

CASA Seasonal Variation and NEE deviation



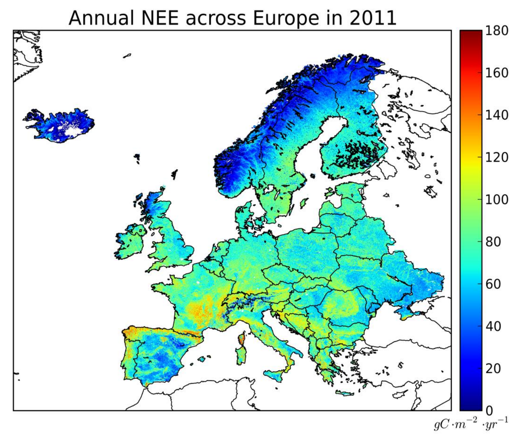


With optimized parameters, the mean correlation coefficients between monthly NEE_CASA and monthly NEE_Fluxnet for the 470 site-years reaches 0.61. The distribution of the deviation between annual NEE_CASA and annual NEE_Fluxnet shows a sigma equal to 286.66 ($gC \cdot m^{-2} \cdot yr^{-1}$).

Thus, it can be assumed that any random NEE calculated by this CASA model will have 68% of chance that the actual NEE value is within the range NEE_CASA $\pm$ 286.66 ($gC \cdot m^{-2} \cdot yr^{-1}$), or $\pm$ 573.32 for 95% of chance.

NEE_CASA map and Upscaling Uncertainty Estimates

NEE_CASA can now be simulated. The total NEE across European countries, which has an area of 6.33 million km^2, is simulated to be 458.32 TgC in 2011:



Let NEE_i be NEE ($gC \cdot m^{-2}$) of the i^{th} 1 km x 1 km pixel in 2011, we get:

$$NEE_{total} = NEE_1 \times 10^6 + NEE_2 \times 10^6 + \ldots + NEE_{6.33\ million} \times 10^6 \ (gC \cdot km^{-2}).$$

By the rule of error propagation, the uncertainty relation of the equation above is:

$$(\delta NEE_{total})^2 = (\delta NEE_1)^2 \times (10^6)^2 + (\delta NEE_2)^2 \times (10^6)^2 + \ldots + (\delta NEE_{6.33\ million})^2 \times (10^6)^2$$

As described previously, the uncertainty δNEE_i (with respect to Fluxnet sites) is equal to 286.66 ($gC \cdot m^{-2}$). Therefore:

$$(\delta NEE_{total})^2 = (286.66)^2 \times (10^6)^2 + (286.66)^2 \times (10^6)^2 + \ldots + (286.66)^2 \times (10^6)^2 \ (gC) = (6.33 \times 10^6) \times (286.66)^2 \times (10^6)^2 \ (gC)$$

Thus, uncertainty of one sigma for total NEE is:

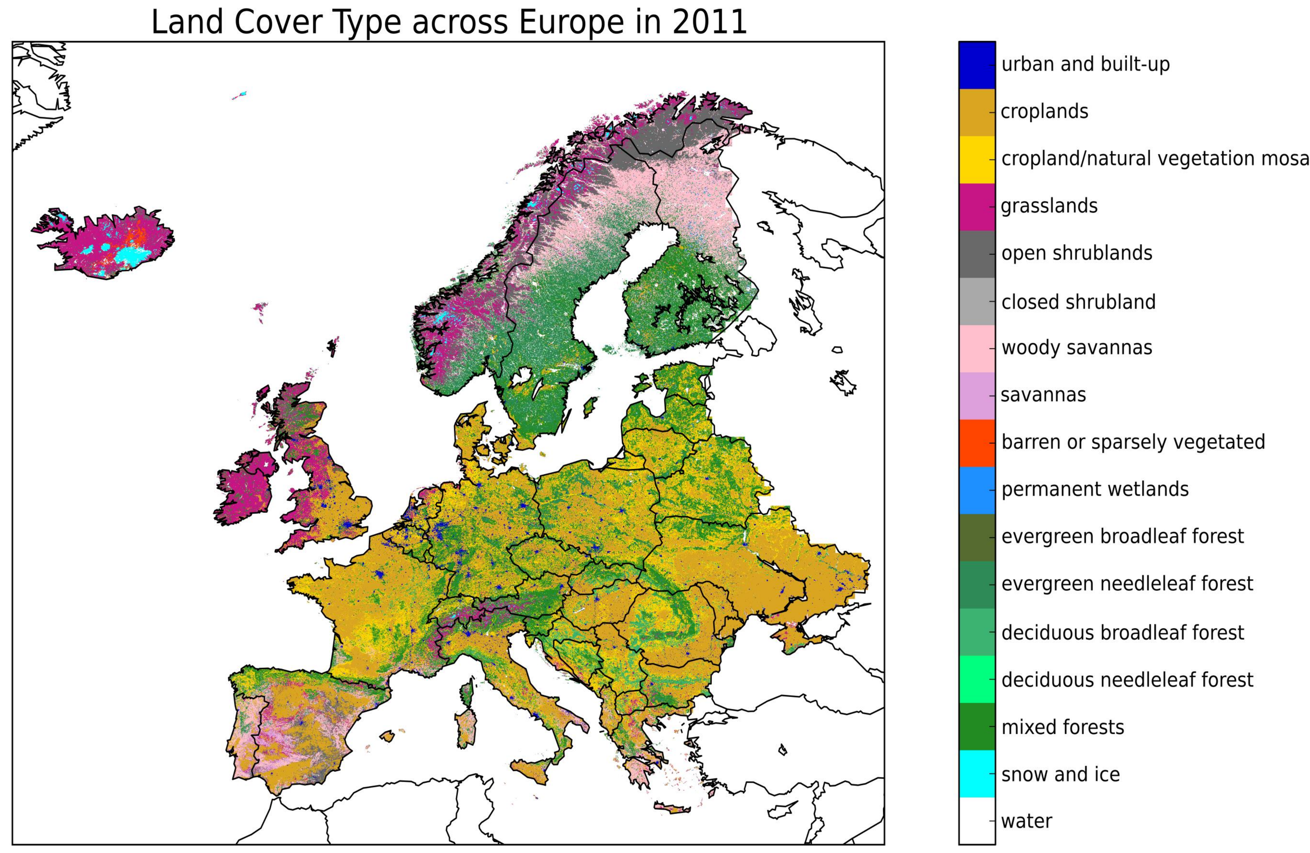
$$\delta NEE_{total} = (\sqrt{6.33} \times 10^3) \times 286.66 \times 10^6 = 721.2 \times 10^9 \ (gC) = 0.72 \ (TgC)$$

For 95% confidence level, two sigma is needed: 2 x 0.72 = 1.44 (TgC)

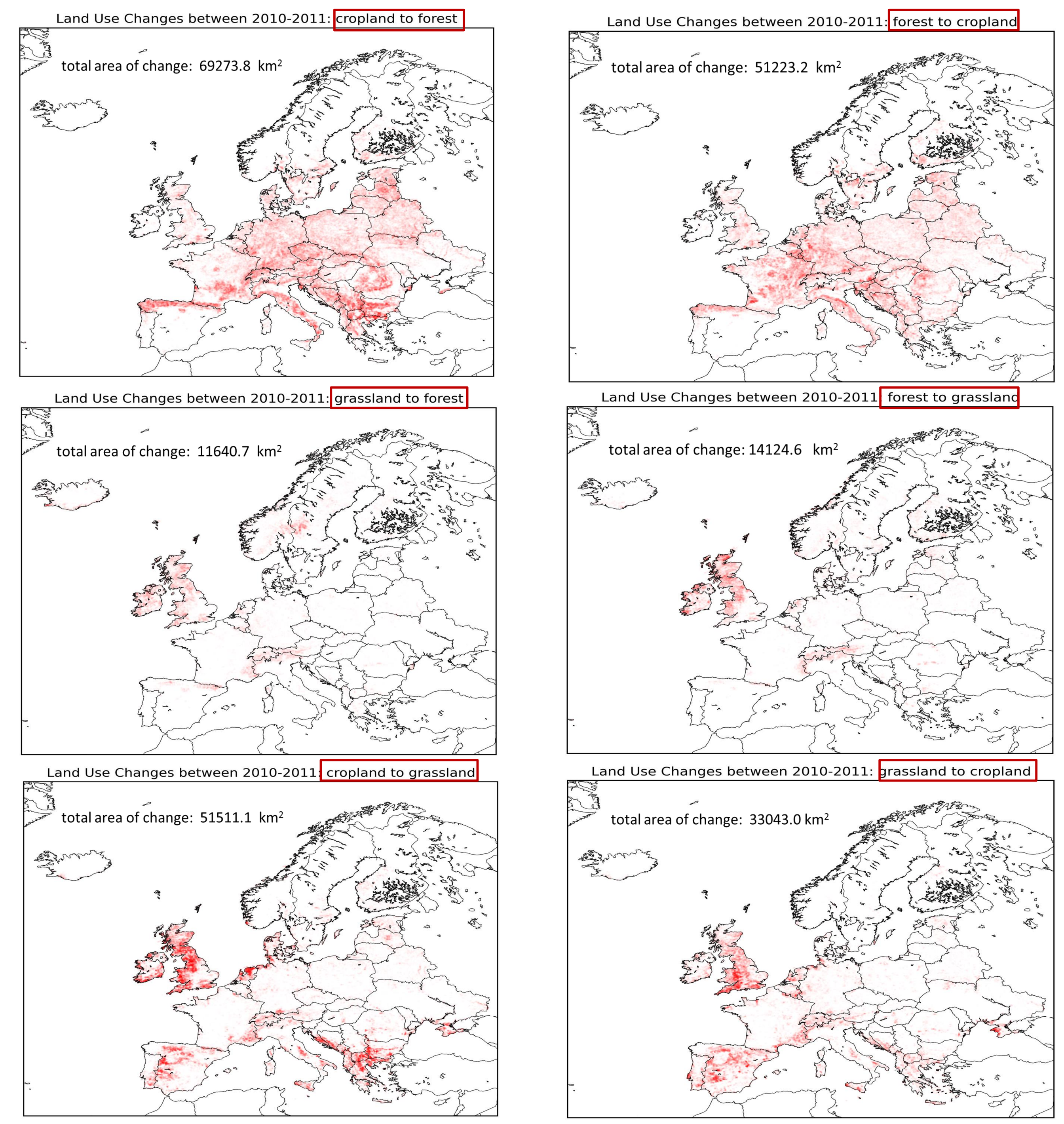
Therefore, in 2011, the total NEE across European countries is:

NEE_{total} = (458.32 $\pm$ 1.44) TgC at 95% confidence level.

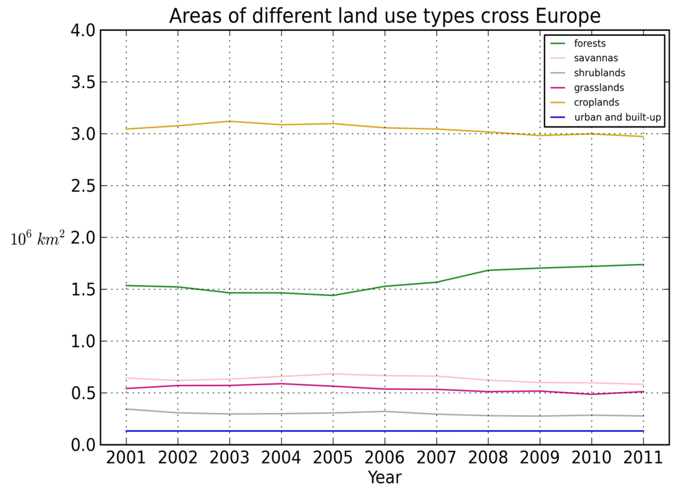
Map of Land Cover in 2011



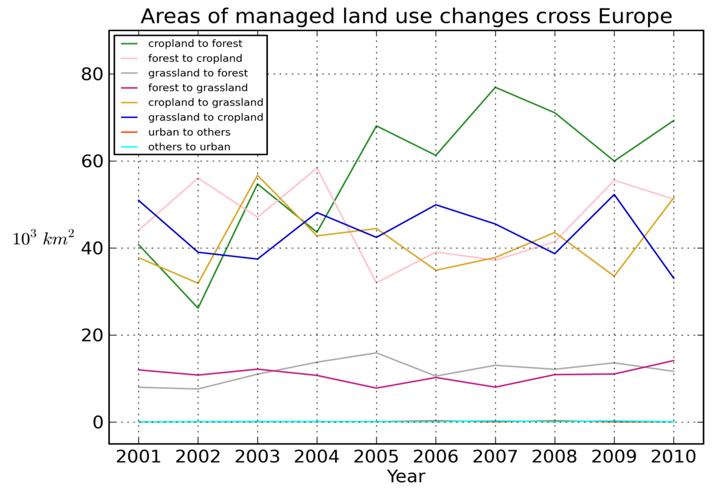
Locations (not actual sizes) of Land Use Changes between 2010 and 2011



Trends of Land Use Changes

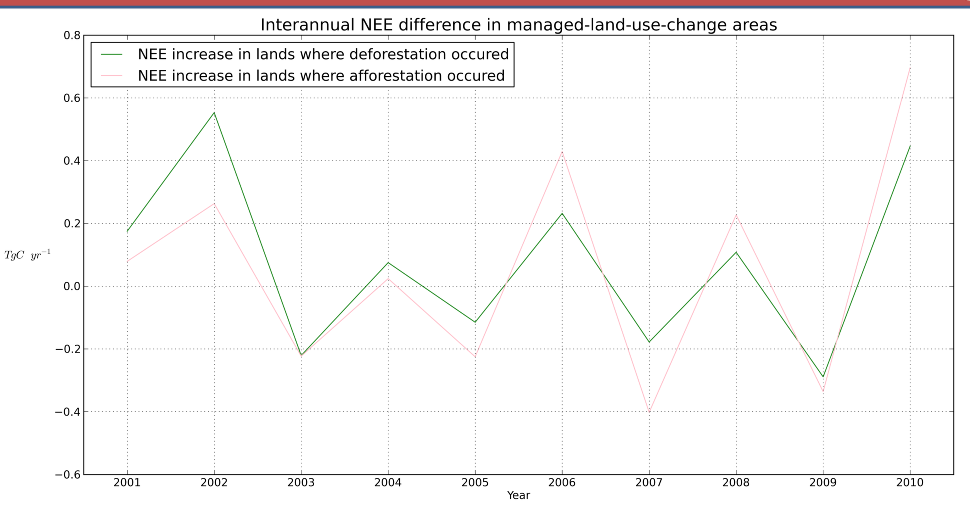


Land areas of six land use types including forests, grasslands, croplands, savannas, shrublands, and urban and build-up from 2001 to 2011.



Managed land use changes from 2001 to 2011 among forests, croplands, grasslands, as well as between urban and others.

Interannual NEE Difference in Land-Use-Change Areas



By combining MODIS land cover type data and NEE_CASA simulation, carbon fluxes from one year to the next year in areas of deforestation and afforestation are calculated.

The plot shows that deforestation (”forests to croplands” and “forests to grasslands”) and afforestation (“croplands to forests” and “grasslands to forests”) areas have very similar trends in carbon fluxes throughout 2001 to 2010. Moreover, the two curves both can have either positive or negative carbon fluxes between a year and the next, which contradicts the general concept that a deforestation should decrease the carbon budgets and an afforestation should increase them.

Conclusion

Based on the observation and discussion above, it can be concluded that the type of land-use-change may not be the key factor that determines the direction of carbon fluxes of a land.

The direction of carbon fluxes, however, seems to be predominantly determined by the change of meteorological conditions (solar radiation, precipitation, etc.), which overpowers the effects of land-use-change.

CC BY

Contact

Dr. You-Ren Wang
Email: y.r.wang@vu.nl
Phone: +31 647 644 066

Data sources for this CASA modeling

MODIS Land Production
ERA
FLUXNET