



Estimating national forest carbon stocks and dynamics: combining models and remotely sensed information

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Forests are a critical component of the global carbon cycle, storing significant amounts of carbon, split between living biomass and dead organic matter. The carbon budget of forests is the most uncertain component of the global carbon cycle – it is currently impossible to quantify accurately the carbon source/sink strength of forest biomes due to their heterogeneity and complex dynamics.

It has been a major challenge to generate robust carbon budgets across landscapes due to data scarcity. Models have been used for estimating carbon budgets, but outputs have lacked an assessment of uncertainty, making a robust assessment of their reliability and accuracy challenging.

Here a Metropolis Hastings - Markov Chain Monte Carlo (MH-MCMC) data assimilation framework has been used to combine remotely sensed leaf area index (MODIS), biomass (where available) and deforestation estimates, in addition to forest planting information from the UK's national forest inventory, an estimate of soil carbon from the Harmonized World Database (HWSD) and plant trait information with a process model (DALEC) to produce a constrained analysis with a robust estimate of uncertainty of the UK forestry carbon budget between 2000 and 2010.

Our analysis estimates the mean annual UK forest carbon sink at $-3.9 \text{ MgC ha}^{-1} \text{ yr}^{-1}$ with a 95 % confidence interval between -4.0 and $-3.1 \text{ MgC ha}^{-1} \text{ yr}^{-1}$. The UK national forest inventory (NFI) estimates the mean UK forest carbon sink to be between -1.4 and $-5.5 \text{ MgC ha}^{-1} \text{ yr}^{-1}$. The analysis estimate for total forest biomass stock in 2010 is estimated at 229 (177/232) TgC, while the NFI an estimated total forest biomass carbon stock of 216 TgC. Leaf carbon area (LCA) is a key plant trait which we are able to estimate using our analysis. Comparison of median estimates for (LCA) retrieved from the analysis and a UK land cover map show higher and lower values for LCA are estimated areas dominated by needle leaf and broad leaf forests forest respectively, consistent with ecological expectations. Moreover, LCA is positively and negatively correlated with leaf-life span and allocation of photosynthate to foliage respectively, supported by field observations.

This emergence of key plant traits and correlations between traits increases our confidence in the robustness of this analysis. Furthermore, this framework also allows us to search for additional emergent properties from the analysis such as spatial variation of retrieved drought tolerance. Finally our analysis is able to identify components of the carbon cycle with the largest uncertainty e.g. allocation of photosynthate to wood and wood residence times, providing targets for future observations (e.g. ESA's BIOMASS mission). Our Bayesian analysis system is ideally suited for assimilation of multiple biomass estimates and their associated uncertainties to reduce both the overall analysis uncertainty and bias in estimates biomass stocks.