WILD EUROPE

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Carbon carrying capacity in primary and old-growth forests as the reference level to assess mitigation potential: demonstrated for European forest

Science Informing Policy Briefing Note 1/24

Authors

Dr Heather Keith[1], Zoltan Kun[2], Sonia Hugh[1], Prof Brendan Mackey[1]

1 Climate Action Beacon, Griffith University, Australia

2 Wild Europe, Hungary

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Karol Kalisky

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Contact: H.Keith @griffith.edu.au

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MITIGATION ACTIVITIES NEED TO BE EVALUATED AND PRIORITISED TO MEET THE CLIMATE CHALLENGE

The international community have committed to pursuing efforts to stabilise atmospheric CO_2 concentration and temperature increase to 1.5 °C[1,2]. However, operationalising this commitment to achieve a true reduction in the carbon stock in the atmosphere requires revising some components of the carbon accounting methods, particularly in the land sector and for forests, so that activities can be evaluated for their true mitigation potential.

REVISED APPROACH TO REFERENCE LEVELS USED IN CARBON ACCOUNTING

The reference level is used to calculate past changes and to predict future changes in carbon emissions. Current methods are based on projected future net annual emissions based on the current carbon stock in ecosystems, together with forecasted dynamics resulting from management as either previous practices or future approved policies. This method shows changes in net emissions due to human activities. However, it does not show the accumulated carbon stock loss due to human activities, nor importantly, the potential carbon stock gain that forests could store if management changed to allow restoration of maximum stocks for the site conditions.
To answer this question of potential stock gain, we propose an ecologically-based local reference level derived from a primary forest ecosystem's carbon carrying capacity. This approach ensures consistent information regarding:

(i) assessing the carbon stock loss that has occurred in the past due to human activities,

(ii) predicting the potential gains in stocks by changing forest management,

(iii) determining the foregone mitigation benefits due to managing forests at carbon stocks below their maximum.

This context using a carbon stock-based target provides an alternative accounting solution which can be implemented under the Paris Agreement. Changes in the condition of forests can be tracked resulting from in/decreases in their carbon stocks due to human activities and management strategies.

CARBON CARRYING CAPACITY

Defined as the mass of carbon stored in an ecosystem at landscape scales given the life history traits of the tree species (e.g. longevity), prevailing environmental conditions (noting these are varying due to climate change), and the impacts of natural disturbance regimes, but excluding direct anthropogenic disturbance[3]. The stock at carbon carrying capacity is the potential stock that can be maintained by natural processes within an ecosystem in a resilient and self-sustaining manner. Carbon stocks remain relatively stable when averaged over long spatial and temporal scales inclusive of the regenerative capacity of ecosystems.

PRIMARY AND OLD-GROWTH FOREST

Defined as naturally regenerated forest of native tree species, with no clearly visible indications of direct human activities, and whose composition, structure and dynamics are dominated by ecological and evolutionary processes, including natural disturbance regimes[4]. Resulting forests include old-growth as well as a range of tree ages and seral stages at stand and landscape scales. In Europe, the long history of land use means that the term is more appropriately interpreted as referring to forests that are long unlogged and have reached a level of maturity including many with old-growth characteristics and a high degree of naturalness and ecological functioning, without implying that there was never human disturbance. Primary forests have the highest levels of ecosystem integrity.

MITIGATION POTENTIAL OF FORESTS

Management of forests is critical for climate mitigation:

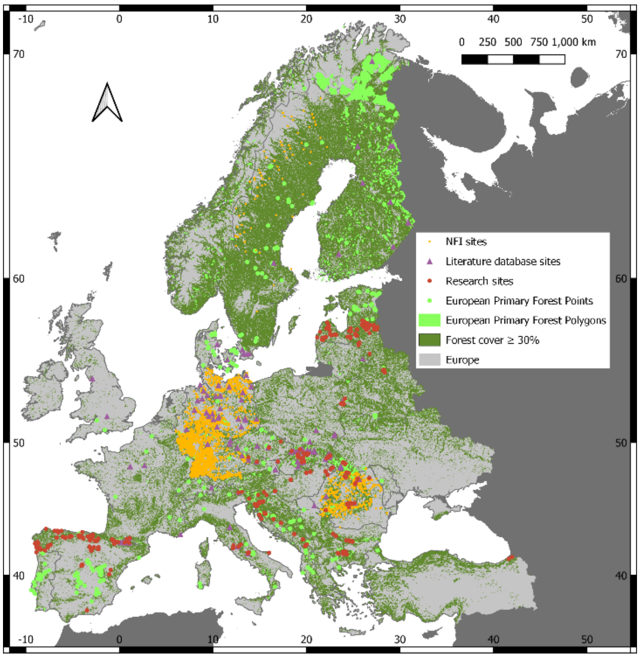
(i) storing large stocks of carbon in the biosphere,

(ii) avoiding emissions to the atmosphere from human activities,

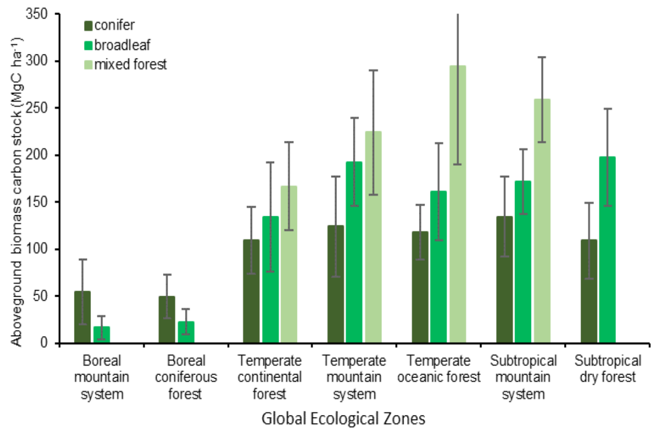
(iii) increasing removals from the atmosphere as terrestrial sinks.

CARBON CARRYING CAPACITY OF EUROPE'S PRIMARY FORESTS

The map shows the extant forest cover in Europe together with the areas identified as remaining primary forest (1.07% of forest area) (shown as point or polygon locations)[5] (ongoing work is revising this estimation for different forest categories). Field sites located in areas of primary forest included research sites, site data reported in the literature, and national forest inventory sites. Total data included 288,262 trees from 7,982 sites in 27 countries.

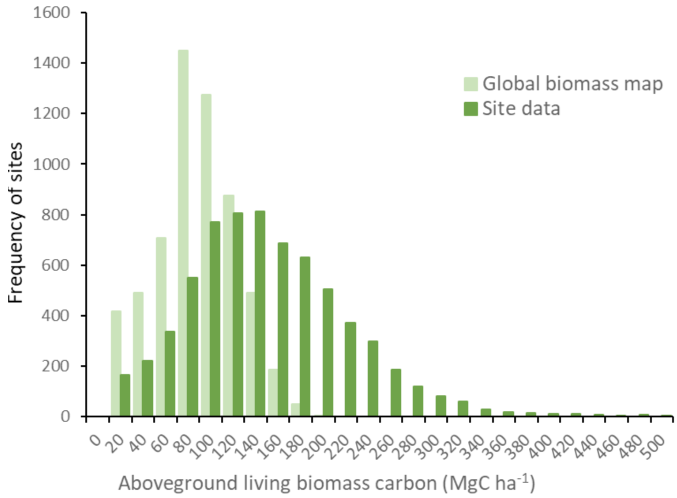


Above-and below-ground biomass and dead biomass were calculated for each site. Biomass carbon stock varied across forest types, with the lowest in alpine birch forest in Sweden (21 MgC ha^{-1}) to the highest in mixed spruce-fir-beech forest in Bosnia-Herzegovina (346 MgC ha^{-1}), including an average of 16% in dead biomass. Site data for biomass carbon stocks have been aggregated by forest type within Global Ecological Zones across Europe, showing the mean and standard deviation.



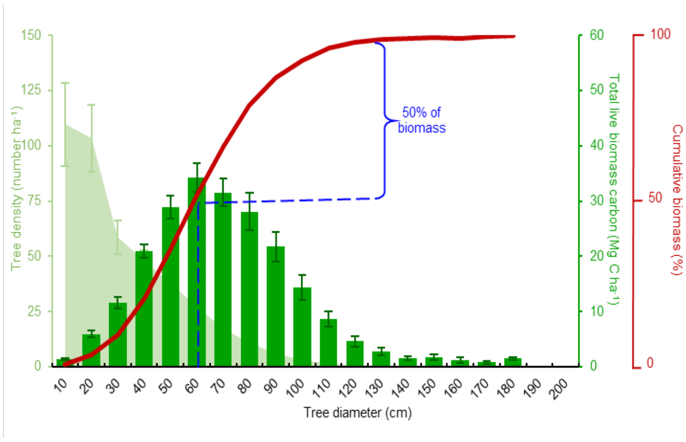
GLOBAL MODELLED AND DEFAULT VALUES UNDERESTIMATE FOREST BIOMASS CARBON STOCKS

Global maps of biomass carbon stocks show a consistently lower distribution of stock densities across all forest types. The site data have many more sites with high carbon stock densities (greater than 140 MgC ha^{-1}). The modelled values from the map are approximately 60% of the stocks measured at the sites, with the greatest difference occurring in mixed and broadleaf forests.



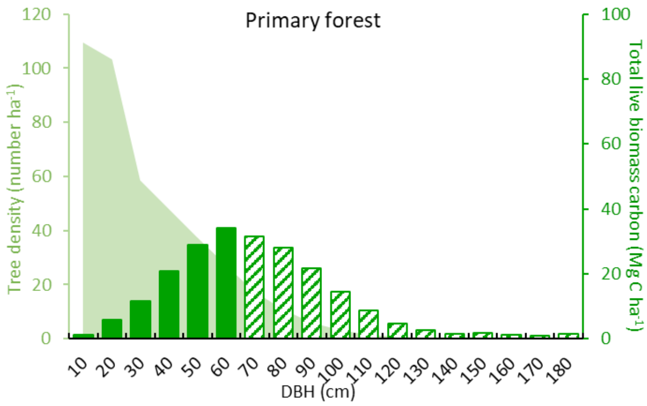
LARGE, OLD TREES IN PRIMARY FORESTS CONTRIBUTE THE LARGEST CARBON STOCKS

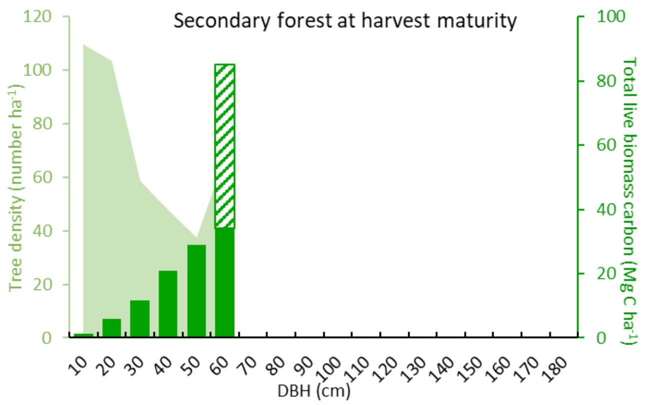
The contribution of each tree size class to the total carbon stock of the forest is shown by the distribution of stock densities. High density of tree numbers occurs in small tree diameter sizes (pale green shaded area). In contrast, carbon stock density (dark green columns mean and standard errors) shows a small number of large trees contributing the largest stocks. Across all primary forest sites, 50% of the cumulative carbon stock in living biomass (red curve) was contained in trees greater than 60 cm diameter (blue dashed line).



FOREGONE LOSSES DUE TO MAINTAINING FORESTS AT BELOW MAXIMUM CARBON STOCKS

Carbon stock is foregone by harvesting secondary forests used for commodity production at a tree size threshold of harvest maturity. This foregone stock was simulated in the analysis of tree size distribution by restricting trees at or below the harvest diameter threshold but maintaining the same tree density. The graphs show the results for site data aggregated across all forest types. Primary forests exhibit an approximately normal distribution of carbon stock density by tree diameter size class. Using a harvest threshold of 60 cm, the larger trees in the primary forest (hatched columns) would not occur in the secondary forest, but the same number of trees would be at the 60 cm threshold. The difference in total carbon stock is a loss of 31% in the secondary forest.





The foregone stock varied across forest types (conifer, broadleaf, mixed forest) and with harvest diameter thresholds from 50 to 80 cm, ranging from 12-21% at the high tree diameter to 46-52% at the low tree diameter.

This analysis represents stands at harvest maturity, and thus does not include younger stands within the harvesting rotation. Therefore, at a landscape scale with the full age distribution of stands in secondary forests, this foregone stock is an underestimate.

MITIGATION POTENTIAL FROM CARBON STOCK GAINS BY CONTINUING FOREST GROWTH

Gains in carbon stocks can be achieved by allowing secondary forests at their current carbon stock to continue growing beyond the age of harvest maturity to reach their carbon carrying capacity. Applying the ecologically-based reference level of the carbon carrying capacity as estimated from primary forests provides the target for restoration.

Area of secondary forest (Mha)	Current carbon stock (MtC)	Predicted carbon carrying capacity (MtC)	Potential gain in carbon stock (MtC)
172.3	9,790	22,449	12,659

The potential gain in carbon stock (12,659 Mt C = 46,415 Mt CO_2) by regrowing secondary forests equates to an annual rate of removals of 309 Mt CO_2 (assuming maximum stocks would be achieved after 150 years). These estimated removals by protecting, restoring and ongoing growth of existing forests are additional to, and higher than, the current forest sink in the EU (2021: 289 Mt CO_2-e), and comparable to the Green Deal 2030 target for removals of 310 Mt CO_2.

These results demonstrate the considerable opportunities for increasing carbon storage in the existing forest area, although cognisant of the requirements of other uses for forest resources.

Increasing carbon storage in ecologically-stable, long-lived ecosystems is a superior mitigation benefit compared with fast-growing trees on a rotation basis where the landscape carbon stock is maintained at a lower level. Primary and old-growth forests, with their full complement of biodiversity and ecological processes, provide high ecosystem integrity allowing safe retention in carbon reservoirs[6,7].

PROTECTION AND RESTORATION OF PRIMARY AND OLD-GROWTH FORESTS IS A CRITICAL ACTION FOR CLIMATE MITIGATION

(i) Retaining an accumulated stock of carbon in living and dead biomass and soil organic matter in safe storage and avoiding emissions.

(ii) Maintaining the terrestrial carbon sink through ongoing forest growth and carbon sequestration.

(iii) Removing CO_2 from the atmosphere through ecological restoration of secondary and degraded forests.

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