

Eliasch Report

Carbon absorption and storage¹

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Of all vegetation types, forests are the main sink of carbon (Dixon *et al.* 1994, Fig. 1). By accumulating carbon in stems, roots and branches over many years (their standing crop), trees withhold the products of photosynthesis for longer periods of time than herbs, which decompose, and thus recycle carbon, more rapidly. Quantification of the capacity that trees have for absorbing CO₂ over a given time interval (their net primary production, NPP) and storing C in the form of organic molecules is, however, difficult. This is because both direct and indirect methods of estimating standing crop and NPP suffer from measurement and sampling difficulties and/or require model assumptions that are difficult to calibrate in practice (Clark *et al.* 2001a & b, Gower *et al.* 2001, Turner *et al.* 2006). Because of the difficulty to estimate certain components of total NPP (e.g., below-ground NPP and transfer of gross NPP to heterotrophs), current estimates are likely underestimates (Clark *et al.* 2001a). Depending on the particular component of NPP and the method to estimate it, this underestimation may be as high as 30%. Less frequently, overestimation of up to 11% can also occur (Table 1 of Clarke *et al.* 2001a).

In general, forest NPP tends to be directly proportional to total annual precipitation, most likely as a consequence of higher evapotranspiration (Knapp & Smith 2001), on which photosynthesis depends. NPP varies between different forests types, being higher in warmer tropical regions and decreasing with the duration of the growing season and temperature towards higher latitudes (Figure 1). Forests' NPP is also directly proportional to nitrogen availability, which in turn is proportional to their leaf area index (LAI, the ratio of leaf area to the area of ground over which it grows) or, more specifically, to leaf area duration (LAD, the integration of LAI over the growth season) (McCarthy *et al.* 2006).

It is important to bear in mind that the bulk of the standing crop in mature forests is dead because, being dependent on resources, which are limiting, the live component remains relatively constant after canopy closure (Franco 1985, Franco & Kelly 1998). In contrast to the living component, wood, which is mostly dead tissues, accumulates in stems and branches throughout the life of each tree. This means that long-term sequestration of carbon by forests is dependent on the ability of trees to keep their lignified tissues from degrading and decomposing. Lignification slows down the rate of decomposition of trees compared to other plant types. As a consequence, the average residence time of carbon in trees (forests) is

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higher than in other plants (biomes) and, within forests biomes, carbon residence time increases with decreasing temperature, as decomposition rates decrease, from tropical to temperate to boreal forests (Fig. 2). The average residence time of C in trees varies from 13.6 years in less productive temperate forests to 25 years in boreal forests. On the other hand, the residence time of C in the soil of the moister, warmer tropical forests is only 12 years, compared to almost 140 years in boreal forests. Taking into account the fact that trees can reach ages of hundreds of years, the relatively short residence times of carbon in the plants indicate that the majority of the biomass drops to the floor and is incorporated to the soil soon after being produced. With the exception of tropical forests, where the majority of C is in the trees, the majority of carbon in other biomes is – slowly decomposing – in the soil. In practical terms, this means that efficient policies for long-term carbon sequestration must take into account the different dynamics of accumulation and loss of separate living/dead/organic components that make up the different plant tissues, litter, deadwood and soil carbon. These policies must take into account the relevance of harvested wood products, too. Diminishing the wasteful degradation of forest trees, extending the lifetime of forest products, and substituting fossil fuels by wood products and wood biofuels would help delay the return of carbon to the atmosphere and make a more efficient use of otherwise imminently decomposing matter (Böttcher *et al.* 2008). In addition to this, monitoring the nutrient and soil status (e.g., erosion) of managed forests would help foresee and thus prevent their impoverishment and slow degradation. Carbon sequestration and sustainable forestry ought to be made compatible through efficient management of the carbon budget of forests worldwide.

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Figure 1. (a) The amount of carbon^a stored in plants (green bars) and soils (black bars) in different biomes worldwide. (b) Annual net primary production (NPP) of world biomes. Biomes are: TrF = tropical forests, TeF = temperate forests, BoF = boreal forests, TrSa&G = tropical savannas and grasslands, TeG&Sh = temperate grasslands and shrublands, D&sD = deserts and semideserts, Tu = tundra, Cr = croplands, We = wetlands.

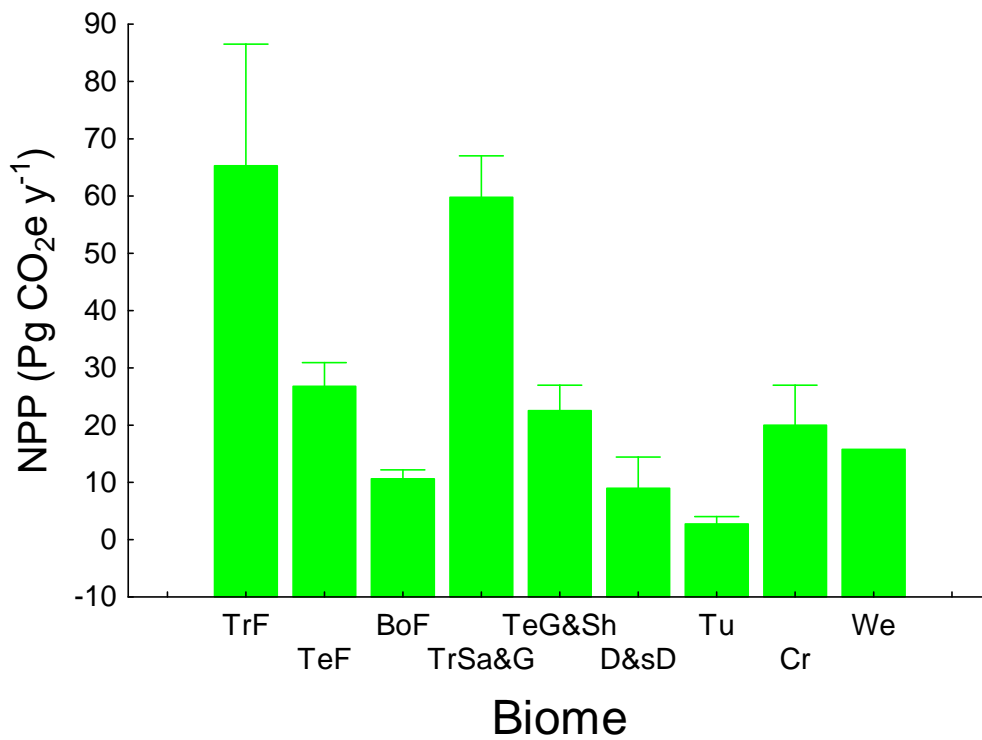
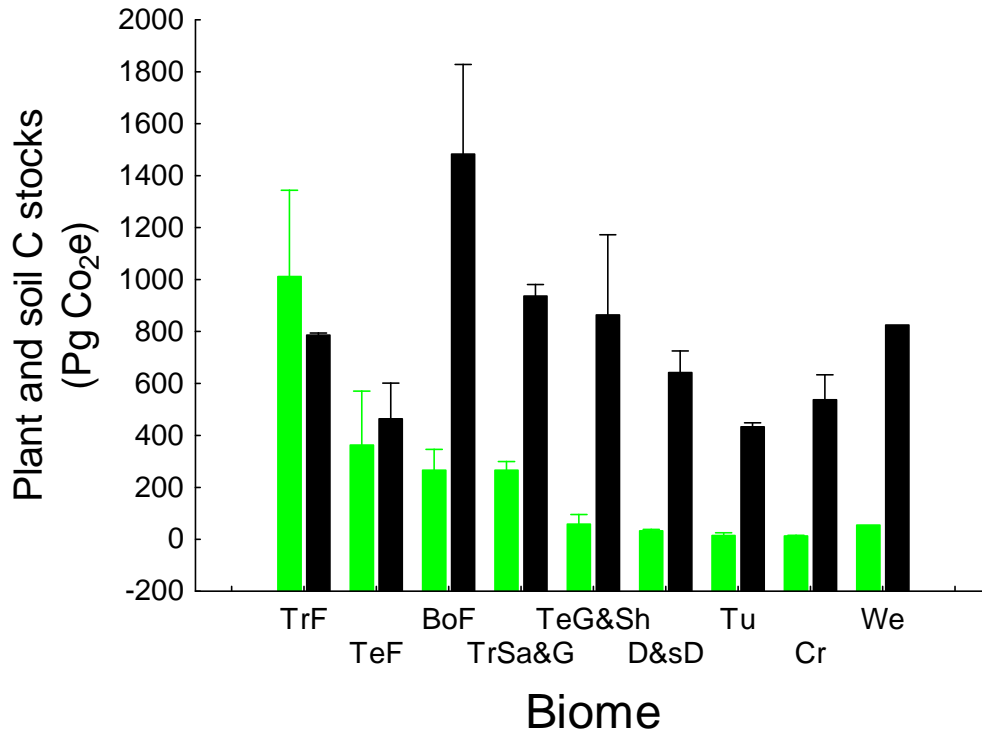
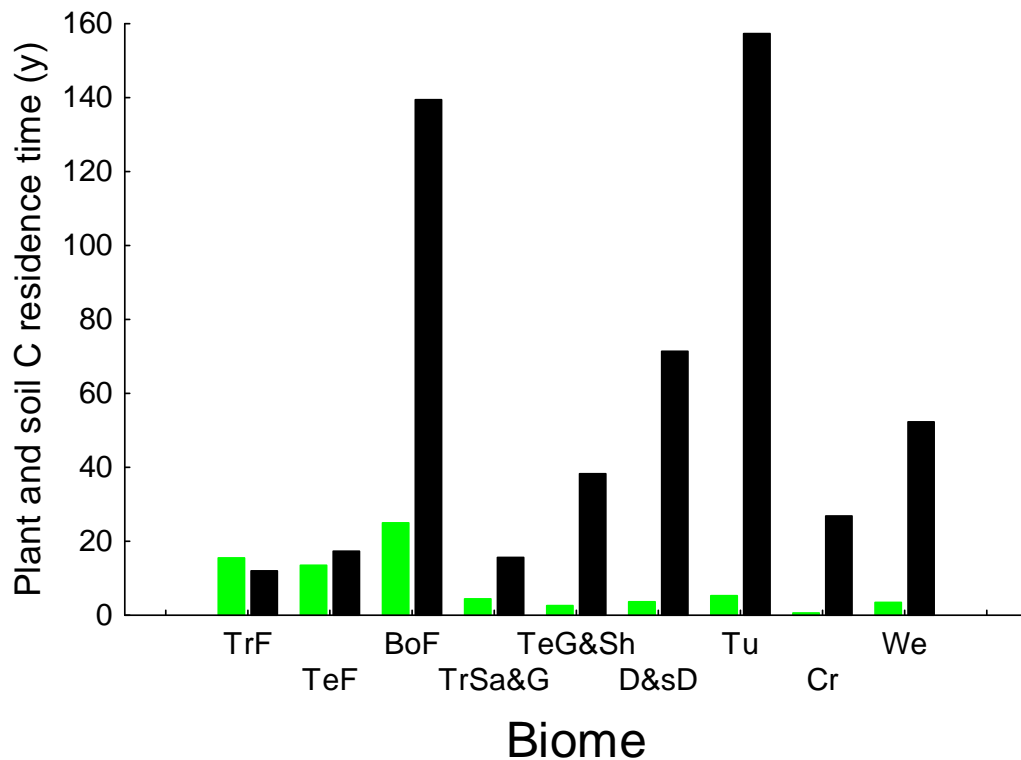


Figure 2. The mean residence time of carbon^b stored in plants (green bars) and in soils (black bars) in different world biomes.



Footnotes:

^aFrom data in Table 3.2 of IPCC (2001). The values reported by IPCC have been converted to CO₂ equivalents (CO₂e) by multiplying them by 3.667, the mole conversion factor of carbon to CO₂. This assumes all biomass is made up of carbon. The proportion of C in lignin (a polymer of coniferyl alcohol, C₁₀H₁₂O₃), however, is 66.65%. With the exception of wetlands, for which there was only one estimate, each variable had two different estimates reported and these were used to calculate standard deviation. Thus, this standard deviation measures the error in the estimation of the global C budget; it is not a measure of variation of the C budget in different samples or throughout time.

^bMean residence time (the time that carbon remains in each biome before it is released back to the atmosphere in the form of CO₂) has been calculated as the ratio of C stocks to NPP of each biome (after Franco 1985). This assumes an equilibrium carbon flux between components NPP → plant stock → soil stock where C released to the atmosphere is equal to that captured as NPP. For abbreviations of world biomes see footnote *a*.