

Appendix 1. The relationship between the *NNCI* and *NPP*

In order to validate the estimates of *NNCI* we need to compare them with published estimates. However, studies mostly report an estimate of *NPP* instead of *NNCI*. *NNCI* and *NPP* are related by the following equation:

$$NNCI = NPP - \sum_i F_i \cdot GPP$$

In some studies only a subset (*j*) of the fluxes (*F*) are estimated. We subsequently refer to these reported estimates of *NPP* as *NPP**. *NPP** would generally be less than *NPP* as some fluxes (e.g. the carbon exuded in the liquid phase from roots, and the flux to fine root production) are not usually measured or estimated (Clark *et al.* 2001; Scurlock *et al.* 2002; Roxburgh *et al.* 2005), thus

$$NPP^* = NNCI + \sum_j F_j \cdot GPP, (A1)$$

where $0 \leq j \leq i$.

When none of the non-respiratory fluxes (*F_i*) is estimated, the reported *NPP** (or above-ground *NPP**) is actually the *NNCI* (or commonly, the above-ground *NNCI*). To estimate *NNCI* for a given area of the ground we need first to estimate the proportional expenditure of *GPP* that it represents. Dividing Equation 1 by the *GPP* gives the following:

$$\frac{NNCI}{GPP} = 1 - (R_a + \sum_i F_i) .$$

For *NPP** (Equation A1)

$$\frac{NPP^*}{GPP} = \frac{NNCI}{GPP} + \sum_j F_j = 1 - R_a - \sum_k F_k ,$$

where

$$\sum_k F_k = \sum_i F_i - \sum_j F_j .$$

As plants must utilise some of the *GPP* to meet their metabolic requirements, and some of the *GPP* must be used to build new tissues, this ratio is further constrained. Thus, it is not surprising that for many forest species *NPP** is an approximately constant fraction (about half) of *GPP* during periods of vegetative growth (Gifford 1994, Dewar *et al.* 1998). Law *et al.* (1999), citing Ryan *et al.* (1997), Amthor and Baldocchi (2001) and Waring *et al.* (1998), noted that the ratio of *NPP*:GPP* ranges between 0.30 and 0.70 for temperate forests, with widely varying annual mean temperatures and above-ground drymass.

Chen *et al.* (2003) estimated *NPP* for a tropical savanna in Northern Australia of $11 \text{ t C ha}^{-1} \text{ year}^{-1}$. In this rare case, the totality of the fluxes, ΣF_i , appears to have been accounted for. Although the flux of carbon to net fine-root production in this study was $7.0 \text{ t C ha}^{-1} \text{ year}^{-1}$, the mean estimated fine-root stock was 0.5 t C ha^{-1} . In this example, the *NNCI* would comprise the annual net tree-biomass increment (1.6 t C ha^{-1}), the annual (tree-leaf) litterfall (0.9 t C ha^{-1} , assuming that the mass of new foliage is equal to the mass of shed foliage), the annual net understorey-biomass increment (0.5 t C ha^{-1}), the annual net coarse-root biomass increment (1.0 t C ha^{-1}) and the fine-root stock (0.5 t C ha^{-1} , assuming that fine roots have a longevity of no more than 1 year so that the fine-root stock is the net mass of new carbon retained as fine roots over a year). The total *NNCI* would be $4.5 \text{ t C ha}^{-1} \text{ year}^{-1}$, only 41% of the *NPP*, and 22% of the *GPP* estimated by Chen *et al.* (2003).

The high turnover of fine-root tissues observed by Chen *et al.* (2003), and the low ratio of *NNCI*:*GPP* is to be expected in environments where water and nutrients are not readily available throughout the year. Haberlandt (1915) noted that in very wet soils where water and nutrients are abundantly available, plants do not require a large absorbing surface to obtain these resources. Consequently, both the number and average length of root hairs are reduced under these conditions. Thus, in environments that are most favourable for plant growth ($\overline{F_v} \cong 0.95$ and high *GPP*), a relatively large proportion of the *GPP* could be utilised for construction of new plant tissues (e.g. $\text{NNCI}/\text{GPP} \cong 0.7$). By contrast, in drier environments where soil moisture and nutrients do not move freely in solution but are 'bound' onto soil particles, absorption is more difficult and there is a need for increased root-hair production. Thus, plants growing in environments where conditions for growth are less favourable (drier or colder, or nutrient impoverished because of the soil type) would need to expend a larger proportion of *GPP* on tissues to access water and nutrients (Haberlandt 1915), and on maintenance of long-lived tissues (Geiger and Servaites 1991), leaving a smaller proportion available for growth. In the most extreme environments where *GPP* is very low and $\overline{F_v} \rightarrow 0$, a small fraction of the *GPP* may be expended on growth ($\text{NNCI}/\text{GPP} \rightarrow 0$), whereas the remainder is utilised for maintenance and/or other fluxes ($R_a + \sum_i F_i \rightarrow 1$). That rationale is consistent with measurements by Ryan *et al.* (1997)

for forest sites in the BOREAS study in Canada. At these sites there was strong seasonal variation in solar radiation and the average site temperatures ranged from 0 to -4°C . Ryan *et al.* (1997) reported annual *NPP**/*GPP* for black spruce (*Picea mariana*) and jack pine (*Pinus banksiana*) at 0.26 and 0.29, respectively, whereas the ratio for aspen (*Populus tremuloides*) was 0.35. The ratios of *NPP**/*GPP* for stands of black spruce and jack pine having a northern aspect were 0.17 and 0.19. In that study the dormant-season autotrophic respiration fluxes accounted for >25% of the annual *GPP*. In the wet-dry tropical savanna study in Northern Australia cited earlier, Chen *et al.* (2003) reported that *NPP*:*GPP* was 0.53. However, as noted above, the ratio of *NNCI*:*GPP* for this savanna was only 0.22.