A topdown and bottomup approach to estimate global carbon cycle

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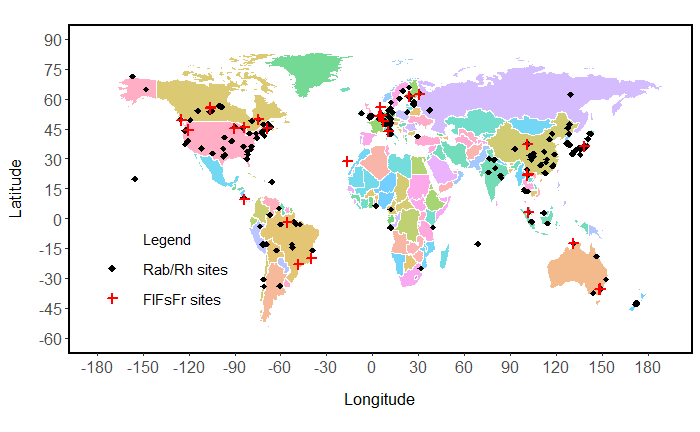


Fig.1 Spatial distribution of Rab/Rh sites from SRDB\_v4 and FlFsFr sites across globe.

**3.3.** **Global carbon cycle and soil respiration**

|  |  |
| --- | --- |
| E:\VT\MyResearch\17.SRDB\GlobalRsProject1\R\GPPHist.jpg | E:\VT\MyResearch\17.SRDB\GlobalRsProject1\R\GPPTimeTrend.jpg |
| Fig.3 Histogram of the 33 estimates (the highest and lowest GPP estimation were excluded) of gross primary production (a) and temporal change of gross primary production (b). | |

Table 1. Summary of published values on global carbon consumed by fire, herbivores animals and carbon sink by terrestrial ecosystem. Mean (± 95% confidence interval, if available) for each item was obtained or calculated based on data from the paper. N/A means data not available. Rab stands for belowground autotrophic respiration, Rh stands for heterotrophic respiration.

|  |  |  |  |
| --- | --- | --- | --- |
| **Item** | **Period** | **Amount (Pg)** | **Reference** |
| NPP (56.20) | 1862-2011 | 56.20 (± 1.78) | (Ito, 2011) |
| Herbivores consumed  (2.20) | N/A | 1.40 (± 0.20) | (Doughty & Field, 2010) |
| N/A | 3.00 | (Whittaker & Likens, 1973) |
| Fire consumed carbon  (3.53) | 1997-2009 | 2.00 | (van der Werf et al., 2010) |
| 1960s | 3.50 (± 1.50) | (Crutzen & Andreae, 1990) |
| N/A | 7.30 | (Gerber et al., 2004) |
| 1901-2002 | 4.00 | (Piao et al., 2009) |
| 1980-2000 | 5.10 | (Zaehle et al., 2005) |
| 1920-1970 | 2.02 | (Mieville et al., 2010) |
| 1970-2010 | 2.71 | (Mieville et al., 2010) |
| 1900-2000 | 3.02 (± 0.30) | (Mouillot, Narasimha, Balkanski, Lamarque, & Field, 2006) |
| 1960-2000 | 2.08 | (Schultz et al., 2008) |
| Land sink carbon (2.10) | 1959-2014 | (2.10± 0.28) | (Le Quéré et al., 2015) |
| Carbon washed away by fresh water (1.90) | N/A | 1.90 | (Cole et al., 2007) |
| N/A | 1.70 | (Bastviken et al., 2011) |
| N/A | 2.10 | (Deemer et al., 2016) |
| Rab / Rh | 1983-2004 | 0.75 (± 0.16) | (Bond-Lamberty et al., 2004) |

Table 4. Summary of global GPP (units: Pg) estimates

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Period** | **GPP (Pg)** | **Trend**  **(Pg yr-1)** | **Reference** | **Notes** |
| 1975 | 71.73 |  | (Box, 1978) | Converted from dry matter |
| 1990-1999 | 120.00 |  | (Ciais et al., 1997) |  |
| 1991 | 133.10 |  | (Ruimy, Dedieu, & Saugier, 1996) | Temperature data was 1991 |
| 1995 | 113.00 |  | (Thompson & Randerson, 1999) |  |
| 1965-1994 | 114.7 |  | (Kucharik, Foley, & Delire, 2000) |  |
| 2000 | 183.39 |  | (Knorr & Heimann, 2001) |  |
| 1953-1999 | 121.5 |  | (AKIHIKO Ito, 2003) |  |
| 1993 | 153.48 |  | (Still, Berry, Collatz, & DeFries, 2003) |  |
| 1961-1998 | 124.70 |  | (Akihiko Ito & OIKAWA, 2004) |  |
| 1990-1999 | 118.00 |  | (Woodward & Lomas, 2004) |  |
| 1971-2000 | 124.60 | 0.44 | (Akihiko Ito, 2005) |  |
| 1997-1999 | 137.40 |  | (Krinner et al., 2005) |  |
| 1980-2000 | 135.70 |  | (Rayner et al., 2005) |  |
| 1992-1999 | 160.95 |  | (Takahiro Sasai, Ichii, Yamaguchi, & Nemani, 2005) | Estimated from figure 3 |
| 1965-2000 | 122.00 |  | (Zeng, Mariotti, & Wetzel, 2005) |  |
| 2001-2003 | 109.29 |  | (Zhao, Heinsch, Nemani, & Running, 2005) |  |
| 1982-2001 | 112.13 | 0.28 | (A Ito & Sasai, 2006) | Average of six estimations |
| 1900-2000 | 125.00 | 0.14 | (R. M. Law, Kowalczyk, & WANGs, 2006) |  |
| 2001-2003 | 113.67 |  | (Zhao, Running, & Nemani, 2006) | Average of ten estimations |
| 2000-2001 | 132.25 |  | (Demarty et al., 2007) | Average of two estimations |
| 2001-2004 | 131.50 |  | (T. Sasai, Okamoto, Hiyama, & Yamaguchi, 2007) |  |
| 2001 | 97.00 |  | (Thornton & Zimmermann, 2007) | Average of D0, D1and P1 |
| 1981-2004 | 124.00 |  | (Qian, Joseph, & Zeng, 2008) |  |
| 2000 | 118.00 |  | (Jacobson & Streets, 2009) |  |
| 2000-2003 | 110.00 |  | (Yangjian Zhang, Xu, Chen, & Adams, 2009) |  |
| 1980-2000 | 139.7 | 0.27 | (Arora et al., 2009) | Exclude data of 1850s |
| 1986-2002 | 129.00 |  | (Alton, 2011) | P-fixed |
| 2001 | 120.00 |  | (Prentice et al., 2007) | IPCC |
| 2000-2011 | 107.00 |  | (Yebra, Van Dijk, Leuning, & Guerschman, 2015) |  |
| 2001-2003 | 118.00 |  | (Ryu et al., 2011) |  |
| 1982-2004 | 117.00 |  | (Bonan et al., 2011) |  |
| 1998-2005 | 123.00 |  | (Beer et al., 2010) |  |
| 1992-2008 | 119.00 |  | (Jung et al., 2011) |  |
| 2000-2003 | 110.50 |  | (Yuan et al., 2010) |  |
| 1970-2000 | 134.00 |  | (Gerber et al., 2004) |  |
| 2000 | 141 |  | (Raddatz et al., 2007) | Figure 7 |
| 2010 | 147.5 |  | (Raddatz et al., 2007) | Figure 7 |
| 1997-2010 | 119 | 0.0181 | (Anav et al., 2015) | Table 3 |
| 1997-2010 | 112 | 0.005 | (Anav et al., 2015) | Table 3 |
| 1997-2010 | 148 | 0.078 | (Anav et al., 2015) | Table 3 |
| 1997-2010 | 147 | 0.417 | (Anav et al., 2015) | Table 3 |
| 1997-2010 | 130 | 0.353 | (Anav et al., 2015) | Table 3 |
| 1997-2010 | 131 | 0.262 | (Anav et al., 2015) | Table 3 |
| 1997-2010 | 149 | 0.621 | (Anav et al., 2015) | Table 3 |
| 1997-2010 | 140 | 0.598 | (Anav et al., 2015) | Table 3 |
| 1997-2010 | 153 | 0.508 | (Anav et al., 2015) | Table 3 |
| 1997-2010 | 169 | 0.454 | (Anav et al., 2015) | Table 3 |
| 2000-2010 | 117 | 0.41 | (M. Chen et al., 2017) | ENSEMBLE |
| 2000-2010 | 112 | 0.28 | (M. Chen et al., 2017) | MODIS |
| 1980-2009 | 162.5 |  | (Welp et al., 2011) | The global damping time constant method |
| **1950-2010** | **128.05** | **0.32** |  | **Average** |

Fig. 1 Terrestrial carbon cycling pathway. Solid filled boxes denote the values are mean (± 95% confidence interval) of data collected from the literature. The dashed boxes denote calculated values. All units are Pg C yr-1. Abbreviations used are as follows: Gross Primary Production (GPP) was from (Prentice et al., 2007), Net Primary Production (NPP), autotrophic respiration (Ra), belowground autotrophic respiration (Rab), root respiration (Rroot), stem respiration (Rstem), leaf respiration (Rleaf), belowground heterotrophic respiration (Rh), and Soil respiration (Rs). Calculation in panel (a): Rh =NPP - Herbivores - Land Sink - Fire - Freshwater. Calculation in panel (b): Ra = GPP - NPP, Rroot = Ra × proportion of Rroot to Ra (0.37), Rstem = Ra × proportion of Rstem to Ra (0.25), Rleaf = Ra × proportion of Rleaf to Ra (0.38). For details and references about each carbon component, please see supplemental material Table S1 and Table S2.

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| N/A | 1.70 | (Bastviken et al., 2011) |
| N/A | 2.10 | (Deemer et al., 2016) |
| Rab / Rh | 1983-2004 | 0.75 (± 0.16) | (Bond-Lamberty et al., 2004) |

Table 2 Summary of papers separate leaf respiration fraction (Fl), stem respiration fraction (Fs) and root respiration fraction (Fr). N/A means data not available.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fl** **(**%) | **Fs (**%) | **Fr (**%) | **Vegetation type** | **Reference** |
| 50.00 |  |  | Tropical forest | (Allen & Lemon, 1976) |
| 53.00 | 35.00 | 12.00 | Tropical forest | (Yoda, 1983) |
| 55.00 |  |  | Warm-temperate forest | (Yoda, 1978) |
| 28.00 | 26.00 | 46.00 | Temperate deciduous forest | (Edwards, Shugart, McLaughlin, Harris, & Reichle, 1981) |
| 33.50 | 39.40 | 29.00 | Pinus radiata trees | (Michael G Ryan, Hubbard, Pongracic, Raison, & Murtrie, 1996) |
| 31.60 | 39.40 | 29.00 | Forest in northern Manitob, Canada | (M. G. Ryan, Lavigne, & Gower, 1997) |
| 43.17 | 34.53 | 22.30 | Forest in Central Saskatchewa, Canada | (M. G. Ryan et al., 1997) |
| 32.92 | 13.60 | 53.48† | Pine forest | (B. E. Law, Ryan, & Anthoni, 1999) |
|  | | 24.92 | Crop | (Suleau et al., 2011) |
|  | | 46.70 | Young Beech forest | (Granier et al., 2000) |
| 23.30 | 6.70 | 70.00 | Tropical savanna | (X. Chen, Hutley, & Eamus, 2003) |
| 24.40 | 18.28 | 57.32† | Deciduous forest | (Bolstad, Davis, Martin, Cook, & Wang, 2004) |
| 31.27 | 26.01 | 42.72 | Hardwood forest | (Curtis et al., 2005) |
|  | | 29.01 | Spruce-dominated forest | (Davidson, Richardson, Savage, & Hollinger, 2006) |
|  | | 34.78 | Temperate forest | (Nagy, Janssens, Curiel Yuste, Carrara, & Ceulemans, 2006) |
|  | | 49.04 | Rain forest | (Yiping Zhang et al., 2006) |
|  | | 36.43† | Douglas Fir | (Jassal et al., 2007) |
| 46.22 | 17.07 | 36.71† | Scots Pine | (Zha, Xing, Wang, Kellomaki, & Barr, 2007) |
| 38.10 | 26.33 | 35.57 | Eucalyptus forest | (Keith et al., 2009) |
| 41.49 | 12.04 | 46.47† | Scots pine forest | (Kolari et al., 2009) |
| 50.51 | 21.21 | 28.28 | Amazonian forests | (Malhi et al., 2009) |
| 24.86 | 25.15 | 49.99 | Pine forest | (Wieser et al., 2009) |
|  | | 36.21 | Alpine meadow | (P. Zhang, Tang, Hirota, Yamamoto, & Mariko, 2009) |
| 50.00 | 15.45 | 34.55 | Black spruce forest | (Hermle, Lavigne, Bernier, Bergeron, & Paré, 2010) |
| 22.96 | 34.31 | 42.73† | Brazil Eucalyptus | (Michael G. Ryan et al., 2010) |
| 55.52 | 19.42 | 25.06 | Rain forest | (Tan et al., 2010) |
|  | | 23.55 | Maize | (Jans et al., 2010) |
| 30.70 | 43.15 | 26.15† | Eucalyptus plantation | (Campoe, Stape, Laclau, Marsden, & Nouvellon, 2012) |
|  | | 24.00† | Mediterranean pine forest | (Matteucci et al., 2015) |
| **38.27****(±2.54)** | **25.10(****±2.49)** | **36.63(±2.48)** | **Average** |  |

Label † means that root respiration was estimated from model: RA0.5 = -7.97 + 0.93Rs0.5 (units: g c m-2 yr-1). (Bond-Lamberty et al., 2004).

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