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Review

Uncertainty in below-ground carbon biomass for major land covers in Southeast Asia

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ABSTRACT

Owing to difficulties associated with measuring root biomass accurately in space and time, below-ground root biomass is often calculated indirectly from above-ground biomass measurements via general allometric equations. Of concern is that general equations may not provide accurate site-specific calculations for accurate carbon stock assessments. This review comparing more than 100 root-related studies conducted in SE Asia shows highly variable and uncertain below-ground woody carbon (BGC) biomass estimates for many vegetation types associated with on-going land-use changes throughout the region. Most BGC data exist for Indonesia, Malaysia, and Thailand; only a few studies have been conducted for Brunei, Cambodia, Lao PDR, Myanmar, Papua New Guinea, Philippines, Singapore, Timor Leste and Vietnam. While substantial data exist for a variety of forests and timber-plantations, little work has focused on key transition land-covers including rubber, oil palm, swidden fallows, agroforests, grasslands, and croplands. Mangroves (12–219 Mg C ha^{-1}), peat forests (11–71 Mg C ha^{-1}) and other forest types (11–74 Mg C ha^{-1}) have the highest BGC values. The limited data for rubber plantations (5–32 Mg C ha^{-1}), oil palm plantations (4–22 Mg C ha^{-1}), swidden fallows (3–16 Mg C ha^{-1}), and non-swidden agroforestry (3–16 Mg C ha^{-1}) indicate modest differences in the amount of BGC for several land covers that are at the heart of ongoing debates regarding the human and environmental impacts of agricultural intensification. The paucity of data currently in existence for the region highlights the need for additional field investigations—following accepted protocols—of root biomass to facilitate efforts to improve carbon stock estimates. Government agencies, private enterprises, and development agencies could help lead the way in developing a better forest carbon database by teaming with researchers to assess total ecosystem carbon stocks prior to vegetation being removed for construction, mining, or stand rotations.

Contents

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1. Introduction

Roots contribute up to half of the carbon cycled annually in forests; and they may account for approximately one-third of global annual net primary production (Vogt et al., 1996; Jackson et al., 1997). Coarse roots provide structural support and access to deep water (e.g., tap roots), while fine roots absorb water and nutrients from the surrounding soils (Jackson et al., 1997; Körner, 1994; Schulze, 1983; Shi et al., 2008). Although the two root sizes are functionally different and turnover at different rates, they are both important stores of biomass carbon (Clark et al., 2001; Rasse et al., 2005). Carbon sequestered in roots during root growth and maintenance is eventually transferred to the soil when they turnover or die (Albrecht et al., 2004; Chalermchatwilai et al., 2011; Srivastava et al., 1986). As root-derived carbon has a long residence time (cf. Abiven et al., 2005; Rasse et al., 2005; Sanaullah et al., 2011), below-ground woody carbon biomass (BGC) is an important component of the terrestrial carbon budget. When soils are tilled, organic matter previously protected from microbial action is decomposed rapidly because of changes in water, air, and temperature conditions; and the breakdown of soil aggregates accelerates erosion (Sundermeier et al., 2012). Erosion, tillage, and other activities that overturn and expose the soil can lead to important losses of below ground carbon. In addition, biomass burning is a major source of terrestrial carbon transfer to the atmosphere in gas form (Le Quéré et al., 2009). Much attention is currently focused on reducing the loss of terrestrial carbon in both above- and below-ground stores following land-cover conversion, particularly in tropical regions (Ziegler et al., 2012).

Forest carbon conservation in developing countries is suggested as an effective means of reducing greenhouse gas emissions (Stern, 2007). For example, the United Nations Framework Convention on Climate Change (UNFCCC) program for Reducing Emissions from Deforestation and forest Degradation (REDD+) is designed to preserve/increase the storage of terrestrial carbon, meanwhile fostering beneficial ecosystem services and promoting human livelihoods (UNFCCC, 2010, 2011). Under REDD+, developing countries would receive payments from industrialized nations for achieving long-term reductions in deforestation and/or replacing some land-use activities with others that sequester more carbon (UNFCCC, 2010, 2011). Approximately US$4 billion was pledged for REDD+ programs between 2010 and 2012 (Ballesteros et al., 2011). As of September 2013, Southeast Asia hosted a number of early REDD+ type projects (Table 1): Indonesia (44 projects), Cambodia (four projects), Malaysia (one project), Vietnam (seven projects), Thailand (one project), Papua New Guinea (four projects), the Philippines (four projects), and Lao PDR (one project). Several countries in the region have also started national-level preparations to engage with a future REDD+ mechanism (CIFOR, 2011; FCPF, 2011); for example, of the 17 countries globally that have established UN-REDD national programs, seven of those are located in the Asia-Pacific region (Cambodia, Indonesia, Papua New Guinea, the Philippines, Solomon Islands, Sri Lanka, Vietnam, UN-REDD Programme, 2009).

Ideally, eligibility for financial remuneration by REDD+ requires participating countries to have accurate estimates of carbon stocks and emissions associated with all important land cover transitions (Brown, 2002; UNFCCC, 2009). While above-ground carbon of various land covers is frequently measured, and new techniques are emerging to make AGC calculations more reliable (cf. Gibbs et al., 2007; Tollefson, 2009), much less work has addressed estimating below-ground woody carbon biomass (cf. Mokany et al., 2006; Vogt et al., 1996; Ziegler et al., 2012). In a recent meta-analysis based on more than 250 studies, we found great uncertainty in total ecosystem carbon for several major land covers that are related to important land-use transitions in SE Asia (Ziegler et al., 2012). Some of this uncertainty stemmed from our calculation of BGC from a limited number of root:shoot ratio (RSR) data readily available in the literature. Herein, we improve upon these carbon stock estimates by reviewing relevant studies/papers of below ground root biomass from the SE Asia region. In addition to providing a summary of BGC estimates and root:shoot ratios for vegetation types that are commonly associated with on-going and projected land-cover change, we also assess data availability and quality, as

Table 1
Comparison of number of root biomass estimates for eleven land-covers with the number of REDD+ projects in each Southeast Asian country and southern China.

Country/class	MAN	FOR	PEAT	OTP	LOF	RP	OP	SF	AGF	GPS	PC	REDD+
Brunei		1										
Cambodia		10			3	1						4
China	2	12			9	4						12
Indonesia	23	5	8	30	13		6	8	10	3		44
Lao PDR		1										1
Malaysia	4	18	1	5	3		9	2				1
Myanmar		1										
Papua New Guinea		1		3								4
Philippines	4	1		2	1							4
Singapore		1			1							
Thailand	27	9		5	1	1				4	7	1
Timor Leste												
Vietnam	55	1		6							1	7

The eleven land covers considered are: mangrove (MAN); forest (FOR), peat forest (PEAT), orchard and tree-plantation (OTP), logged over forest (LOF), rubber plantation (RP), oil palm plantation (OP), swidden fallows of any length (SF), non-swidden agroforest (AGF), grassland, pasture or shrub land (GPS) and permanent cropland (PC). Data are listed in Table S1; reported values refer to the number of data entries for each class, not to number of case studies or sites. REDD+ refers to planned or implemented REDD+ type projects (as of September 2013)