Carbon stocks in Indonesian homegarden systems: Can smallholder systems be targeted for increased carbon storage?

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Abstract. *Homegardens are a common smallholder agroforestry system in Indonesia and throughout the tropics. These species-rich, tree-based systems produce non-wood and wood products for both home use and market sale. Due to their high biomass, these systems simultaneously offer potential for carbon (C) storage. While small size limits the amount of C stored by individual smallholder agroforestry systems, on a per area basis these systems can store as much C as some secondary forests. In aggregate, smallholder homegarden agroforestry systems can contribute significantly to a region's carbon budget while simultaneously enhancing smallholder livelihoods. A field study in Lampung, Indonesia indicates that homegardens with an average age of 13 years store 35.3 Mg C ha^{-1} in their above-ground biomass, which is on par with the C stocks reported for similar-aged secondary forests in the same area. However, to compare accurately the C stocks of different land-use systems a scale is required that adjusts C stocks of the systems' ages and rotation lengths to a common base. The time-averaged C stock, which is half the C stock at the maximum rotation length, serves this purpose. Our projections reveal that, depending on management options, the time-averaged above-ground C stocks of homegarden systems could vary from 30 to 123 Mg C ha^{-1}. These projected time-averaged above-ground C stocks of homegardens are substantially higher than those of* Imperata*-cassava systems (2.2 Mg C ha^{-1}), which is an extensive vegetation type in the study area. If homegarden systems and other smallholder tree-based systems were to expand in currently degraded and underutilized lands, such as* Imperata *grasslands, the C sequestration potential would be about 80 Mg C ha^{-1}, with considerable variation depending on species composition and management practices. Clear opportunity exists to induce management that leads to higher C stocks at the systems level. However, incentive mechanisms are needed that assure smallholders will benefit from selecting management practices that favor higher C stocks.*

Key words: agroforestry, agroforestation, carbon sequestration, certified emissions reductions (CERs), clean development mechanism (CDM), climate change, greenhouse gas, *Imperata* grasslands, land rehabilitation, tree farming

Introduction

Increasing levels of atmospheric 'greenhouse gases' are generally accepted to be a main contribution to global warming, which, studies indicate, is changing the Earth's weather patterns and could raise ocean levels substantially in the next 100 years (Schimel et al., 1995; Watson et al., 1996). These climatic changes can impact environmental norms and human populations, causing serious negative disturbance to the global economy. As international agreements over greenhouse gas emissions and global warming are negotiated, there is growing interest in the possibility of reducing the increase in the amount of carbon dioxide (CO_2) in the atmosphere through forest-based carbon (C) sequestration projects.

Forest-based land-use systems—natural forests, forest plantations, and agroforestry systems—sequester CO_2, through the C stored in their biomass. By promoting land-use systems which have a higher C content than the existing plant community, net gains in C stocks (hence sequestration) can be realized. The most significant increases in C storage can be achieved by moving from lower-biomass land-use systems (e.g., grasslands, agricultural fallows and permanent shrublands) to tree-based systems. Forest-based C storage projects have been implemented by electric utilities and other industries as a means to offset the C released by their use of fossil fuels. These projects are still in their preliminary phases. As many efforts to achieve increased forest C storage may have negative implications for the rural poor, options that support human livelihoods deserve special attention. Projects implemented under the Clean Development Mechanism (CDM) of the Kyoto Protocol will offer opportunities for investors seeking 'certified emissions reductions' (CERs) to invest in developing countries for the dual objective of reducing greenhouse gas emissions and contributing to sustainable development. Forest-based C storage projects will likely be part of the CDM.

Indonesia provides an attractive environment for C investment. There are over 8.5 million ha of *Imperata* grasslands in Indonesia (Garrity et al., 1997). Originally forests, these lands

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