



## **Estimating substitution and climatic effects of forest biomass production and utilization for the entire logistic chain: life cycle perspective**

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Forests sequester carbon from atmosphere and store it in biomass and ecosystem. However, our understanding is still poor on how the harvesting of biomass would affect the ecosystem carbon stocks as well as the carbon stocks at technosystem, for which forest biomass has the potential to substitute fossil intensive materials that emit higher emission. Furthermore, implication for the large-scale harvesting of forest biomass for energy (mainly logging residues) is questioned recently whether to leave them in forest or harvest them to substitute fossil energy, due to environmental sustainability and net climatic impacts in the context of carbon balance of the forest ecosystems. In the utilization phase as well, the use of energy biomass and timber products (pulpwood and sawlogs) has raised questions of the calculation methodology in order to identify the entire carbon flows and the need for understanding most climate beneficial ways to produce simultaneous timber and energy biomass from forests. This study adopted an innovative approach to develop a tool for identifying the carbon balance for the whole ecosystem-technosystem-atmosphere continuum, which includes the carbon sink and source considerations for all the assortments of harvested biomass with respective to their logistic chain. The analysis is done by utilizing life cycle assessment and ecosystem modelling as integrated enabling to track of carbon in forest biomass by extending their varying logistics chain depending on biomass utilization, for example for energy and wood based materials after harvest. That means that whenever forest biomass is moving from ecosystem and builds up the carbon stock in various technosystem (e.g., energy system or wood product system), the tool would assess the climatic effect of the combined and entire production and utilization chain. This approach sets ground for development of carbon accounting procedures and evaluating the overall role and commitments for utilization of forest bioenergy and wood products in climate change mitigation.