ENERGIAFA VAGY ÉPÜLETFA? SZIMULÁCIÓ A CO2FIX MODELLEL

Wood For Energy Or Construction? A CO2FIX Model Simulation

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Kivonat

Az erdő fontos szerepet játszik az építési és a bioenergia célú faanyag termelésében. A fa építőipari felhasználása kedvező a karbontárolás szempontjából, ugyanakkor a képet tovább árnyalhatja a fatermesztés hatása a karbonmérlegre. A kutatás célja a Gliricidia (mint energiafa) és a teakfa (építőipari és bútorfa) ültetvények szénmegkötésének szimulálása volt a CO2FIX modell segítségével. A CO2FIX modell biomasszára, talajra, termékre és bioenergiára vonatkozó adatokat igényelt az erdei széndinamika egy adott időszakra vonatkozó szimulációjához. 60 éves erdőgazdálkodási ciklust figyelembe véve a kutatási eredmény azt mutatta, hogy a Gliricidia 3 éves vágásfordulójú sarjaztatott ültetvényében, a Gliricidia 5 éves rotációs ciklusú ültetvényében és a 15 éves teakfa klónerdőnél nőtt az összes széntartalom, míg a 60 éves teakfa klónerdőben csökkent. A legkedvezőbb forgatókönyv, amely a futamidő alatt összességében a legnagyobb szénkészletet eredményezte, az 5 éves ciklusú Gliricidia sarjaztatott ültetvény volt.

Abstract

Forest plays important role in providing wood, either wood construction or bioenergy. The use of wood in the construction industry is favorable from the point of view of carbon storage, but the picture can be further colored by the effect of wood cultivation on the carbon balance. This research objective was to simulate the total carbon in gliricidia (wood for energy) and teak (wood for construction and furniture) plantation using the CO2FIX model. CO2FIX model required data for cohorts biomass, soil, product, and bioenergy to develop the simulation of forest carbon dynamic in certain period. Taking a 60 years long forest management scenario the research finding showed that the total carbon in Gliricidia 3 –year-rotation coppice, in Gliricidia 5-year-rotation coppice, and in the 15 years old Teak clonal forest increased, while decreased in the 60 years old Teak clonal forest. The best forest management scenario that resulted the highest total carbon stock during 60 years was Gliricidia 5-year-rotation coppice.

Introduction

The trade-off between wood for construction and for energy is an exciting issue in forest management. The utilization of wood for construction is vital to increase the stored carbon in building materials (KERKVLIET-HERMANS 2020). For instance, concrete replacement with timber has shown a significant CO_2 removal because the conversion of roundwood for construction has produced less emission and the wood stored the carbon (PATRIZIO et al. 2021). However, the demand for biomass to substitute fossil fuels has increased (XINGANG - PINGKUO 2013). The increasing of wood demand will affect more intensive forest utilization, either bioenergy plantation development or residual harvesting optimization (LAURI et al. 2014).

In Indonesia, the government has paid attention to sustainable forest management and energy transition to reduce greenhouse gasses (GHG) emissions. Indonesia's government has set a target of utilizing new and renewable energy (NRE) for energy transition by at least

31% by 2050 (PRESIDENT REPUBLIC INDONESIA 2017). Similar to Indonesia, strengthening the role of domestic and renewable energy sources is essential to guarantee competitiveness and security of supply in the EU. Within the energy supply based on renewable energy sources, biomass has had a decisive role up to now (with a share of approx. 60%), and - given the growing demand for firewood, various industrial sectors for wood and the need to assign renewable energy sources to the local energy infrastructure - its role in the energy mix is likely remains decisive. (PAPP et al. 2020, EUROPEAN COMMISSION 2022).

As in the European Union, biomass represents the largest proportion of renewable energy supply in Hungary. By 2050, gas, which dominates 70% of district heating, is planned to be replaced by locally available or produced energy sources, including biomass, utilized with environmentally friendly technologies. (MTI 2022)

Since the overall demand for biomass is estimated to grow in the future while supply growth is limited, recent European studies demonstrates the urgent need to prioritise biomass, the importance of balancing demand and supply, and call for finding the optimal future use of biomass, corresponding to the EU’s biodiversity strategy in the next decades. (MATERIAL ECONOMICS 2021; EUROPEAN COMMISSION 2021).

Both in Indonesia and the EU, one of the sources of is biomass produced from sustainable bioenergy plantations. For instance, wood chips and pellets are the potential energy sources to substitute coal in power plants, therefore, the Indonesia Forestry Enterprise (Perhutani) has established a bioenergy plantation using gliricidia (*Gliricidia sepium*) (MULYANA et al. 2020a; MULYANA et al. 2020b).

Similar to the EU, wood consumption, especially wood for construction and furniture, also increases over time in Indonesia. The appropriate forest management scheme that uses dynamic carbon simulation from a dynamic carbon perspective is important. The projection of the carbon dynamic is important for scientists and policymakers to mitigate the effect of silvicultural practices on carbon sequestration (NABUURS – SCHELHAAS 2002; PEREZ-CRUZADO et al. 2012). Scholars worldwide have elaborated simulation methods to estimate the carbon dynamic in some forest management types. Integrating decision-support software and scenario modelling was important to recognize the role of forests in climate change mitigation and adaptation (SOLOVIY et al. 2020). CO2FIX model has been tested to assess carbon dynamics in 16 forest types in European countries (NABUURS – SCHELHAAS 2002), agroforestry systems (NEGASH – KANNINEN 2015; PANWAR et al 2017), dry forest (ALMULQU 2017) and rehabilitation program (AKMALLUDIN et al 2019). Furthermore, this research aimed to simulate the total carbon in gliricidia (wood for energy) and teak (wood for construction and furniture) plantation using the CO2FIX model.

Material and methods

Forest management scenario

In this study has simulated 1 hectare of forest area to be planted with *Gliricidia sepium* (wood for bioenergy) or *Tectona grandis* (wood for construction and furniture). The assumption of site quality for all the forest management scenarios was similar (site index 3). It means that the soil properties and climatic conditions were identical for these forest management scenarios. The different conditions of the forest management scenarios were cutting cycle and stand density (Table 1).

Table 1: Forest management scenarios

Scenario	Species	Cutting cycle (year)	Initial Spacing	Remarks
	Gliricidia sepium	3	1 x 1 m	Bioenergy plantation

Forest plantation for bioenergy		5	1 x 1 m	
Forest plantation for wood construction	*Tectona grandis*	15	3 x 4 m	Superior clonal teak plantation
		60		Conventional teak plantation

The length of the simulation on CO2FIX simulation was varied. This study used the length of simulation of 60 years that follows the theory of least common multiples for 3, 5, 15, and 60 years. PANWAR et al. (2017) also used the least common multiple on CO2FIX simulation that used the length of simulation 54 years for two rotation schemes (6 and 9 years). However, in some CO2FIX simulation studies, the scholars have used the length of simulation 20 years (AKMALLUDIN et al 2019), 30 years (RIZVI et al. 2016), 50 years (NEGASH – KANNINEN 2015), and 200 years (ALMULQU 2017).

CO2FIX Modelling

CO2FIX model has been used widely as a tool to estimate carbon dynamics in many forest management scenarios, such as forest (ALMULQU 2017), agroforestry (NEGASH – KANNINEN 2015; RIZVI et al. 2016; PANWAR et al. 2017), reclamation (AKMALLUDIN et al 2019), and afforestation projects (MASERA et al. 2013). CO2FIX also has been applied in 16 types of European forest areas countries (NABUURS – SCHELHAAS 2002), three types of land use systems in Chilean Patagonian (STOLPE et al. 2010), agroforestry system and woodlot in Africa (KAONGA – BAYLISS – SMITH 2012; NEGASH – KANNINEN 2015), and some land use system in Asia (ALMULQU 2017; PANWAR et al. 2017; AKMALLUDIN et al 2019).

In this study, we have operated the CO2FIX model version 3.1 (SCHELHAAS et al. 2004) to simulate the carbon dynamic among the forest management scenarios. The CO2FIX model is multi-cohort based on carbon accounting of forest stand in biomass, soil, bioenergy, and products (Table 2).

Table 2: Input data to estimate the carbon dynamic using CO2FIX

Cohort	Data	References
Biomass	Current annual increment of *Gliricidia sepium* and *Tectona grandis*	MULYANA et al. (2020a), PERUM PERHUTANI (2011)
	Carbon content of *Gliricidia sepium* and *Tectona grandis*	MULYANA et al. (2020b)
	Wood density of *Gliricidia sepium* and *Tectona grandis*	WORLD AGROFORESTRY (2021)
	The turnover rate for foliage, branches, and roots	NABUURS – MOHREN (1993)
	Mortality, competition, and management mortality	Default
	Thinning-harvesting	PERUM PERHUTANI (2011)
Soil	Temperature and evapotranspiration	WORLD CLIMATE (2021)
	Cohort parameters	PURWANTO – TOKUCHI (2004); SCHELHAAS et al. (2004)
Products	Production line, end products, recycling life span, and default parameter	Default
Bioen-ergy	General parameters, technology for industrial resi-dues fuelwood, technology for slash fuelwood	Default

Note: default means following the CO2FIX initial data in SCHELHAAS et al. (2004).

Results

Carbon from atmosphere

Regarding climate change mitigation, the amount of carbon that can be removed from the atmosphere is important as one of the considerations for choosing the forest management scenario. In this study, the forest management scenario for wood construction with superior clonal teak (T15) has produced a higher amount of carbon removal from the atmosphere, followed by gliricidia with cycle cutting five years (G5), conventional teak plantation (T60), and short rotation gliricidia plantation (G3) (Figure 1).

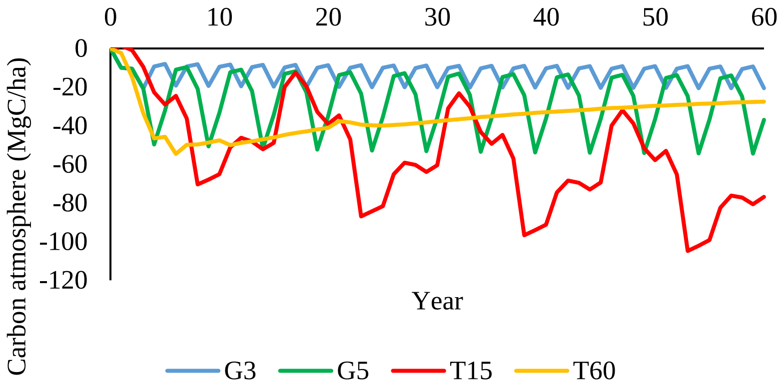
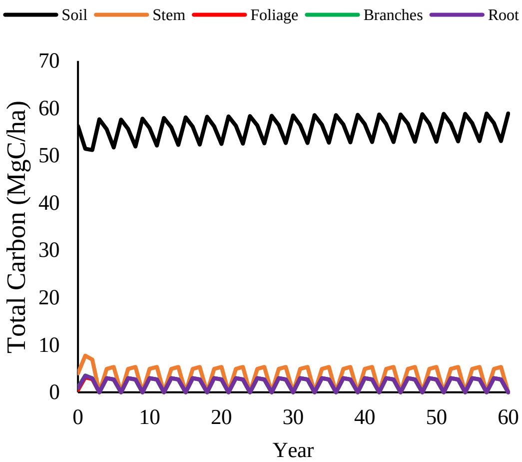


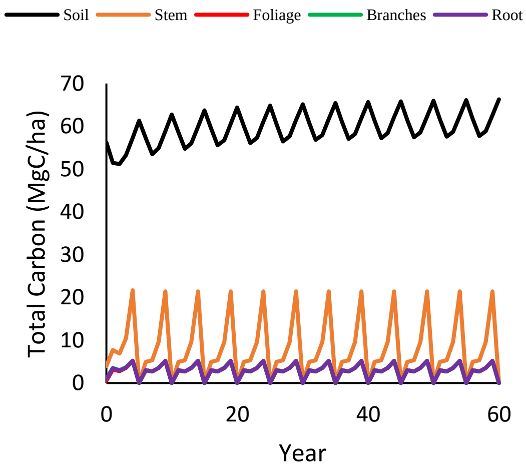
Figure 1: Carbon from the atmosphere (Note: G3 is Gliricidia for 3 years, G5 is Gliricidia for 5 years, T15 is Teak for 15 years, and T60 is Teak for 60 years)

Carbon dynamic in soil and biomass module

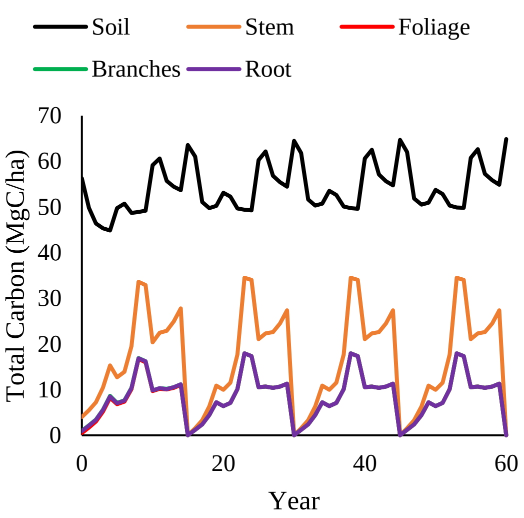
According to STOLPE et al. (2010), the parameter on soil simulation in CO2FIX model for KO_{sol} (decomposition rate of soluble compounds) has been set at a value of 0.0001, and the bias between the observed and projected value was 1% in pasture area and 11% in pine plantation. The CO2FIX result on soil carbon estimation was considerable for soil carbon dynamic simulation.



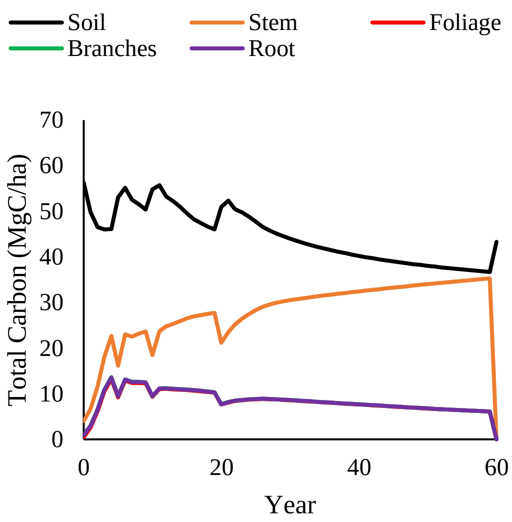
(a)



(b)



(c)



(d)

Figure 2: Soil and biomass carbon in each forest management scenario; a). Gliricidia 3 years; b). Gliricida 5 years; c). Teak 15 years; d). Teak 60 years

Referring to figure 2, the forest management scenarios (Gliricidia 3, Gliricidia 5, and Teak 15 years) have shown a similar pattern that the carbon stock in the soil was relatively stable. It happened in the soil carbon at Leyte Island, the Philippines, which was not significantly different among the land use of secondary forest, grassland, and forest plantation (BOBON – CARNICE – LINA 2021). However, the forest management of Teak 60 years showed that soil carbon stock decreased during the simulation period. The lowering of soil carbon also happened in Sitka spruce on drained peatland in Europe forest (NABUURS – SCHELHAAS 2002).

The carbon stock in the soil compartment in figure 2 showed that the forest management of superior clonal teak for 15 years had resulted in the highest value. It was similar to the forest management scenario for sawn wood production in Southern Europe, which has higher soil carbon stock than the chipped wood production scheme (PEREZ-CRUZADO et al. 2012). However, the forest management scenarios for wood construction in conventional teak have resulted in the lowest value on carbon stock in the soil compartment.

Carbon dynamics in many soil types have shown different responses. Carbon content in volcanic soil (typic hapludands and umbric andosols) in the Chilean Patagonian forest ranged from 200 to 250 MgC/ha and 250-300 MgC/ha for pasture areas (STOLPE et al. 2010). Furthermore, (STOLPE et al. 2010) revealed that the carbon content in pine forest plantations (branches, leave, and roots) was less than 50 MgC/ha.

Total carbon during the simulation

Carbon in the bioenergy cohort has contributed significantly to total carbon for wood for energy and clonal teak forest management scenarios. This finding is similar to AL-MULQU'S (2017) finding in a dryland forest in East Nusa Tenggara, Indonesia. However, according to figure 3, the carbon in the bioenergy cohort was less contribution to the total carbon. In Southern Europe, chip wood for bioenergy has produced higher carbon stock in biomass, product, and bioenergy compared to sawn wood production (PEREZ-CRUZADO et al. 2012).

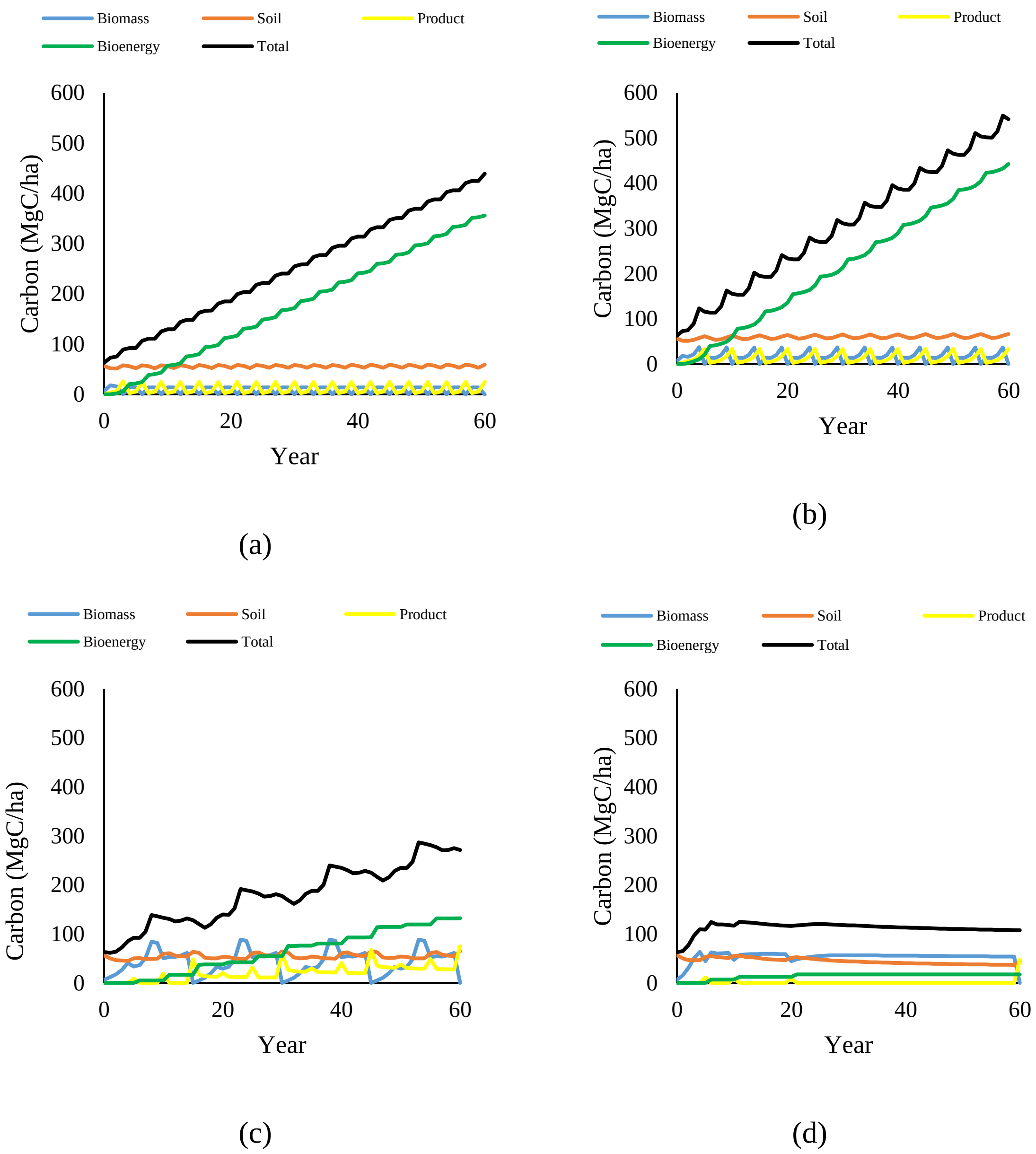


Figure 3: Total carbon in each forest management scenarios; a). Gliricidia 3 years; b). Gliricida 5 years; c). Teak 15 years; d). Teak 60 years

Conclusions

Input data sources limited this study; future research on cohort products and bioenergy will be useful to make the simulation more precise. However, the finding showed that planting gliricidia with a cutting cycle of five years has resulted in the highest value of total carbon. Policymakers should also consider the socio-economic and ecological aspects of choosing the appropriate forest management option. Furthermore, the research on the economic feasibility study and environmental point of view for these forest management scenarios is important.

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