NET CARBON BALANCE IN TWO SILVOPASTORAL SYSTEMS FOR DAIRY HEIFERS

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ABSTRACT
The objective of this study was to estimate the carbon balance in two silvopastoral systems (SPS) for rearing dairy heifers: Eucalyptus and african-mahogany based. Emissions of GHG were calculate based on IPCC protocols. Carbon stocks in trees were estimated through allometric equations and local references and the estimation of carbon storage in the forest component considered only the wood for solid products and the root system, while the biomass of the root system of the pasture was considered as a carbon pool as well. The net carbon balances of the silvopastoral systems were -137.18 Mg CO_2e ha^{-1} and -47.54 Mg CO_2e ha^{-1} for eucalyptus-based SPS and african-mahogany based SPS, respectively, showing the potential of both systems for mitigating climate change.
Key words: ICLF; GHG; Climate Change

INTRODUCTION

Concerns about global warming and its relation to livestock have increased worldwide in recent years. Consequently, as a major agricultural player and holder of the second largest herd of cattle in the world, the Brazilian livestock sector is under increasing pressure for upholding an environmental friendly, sustainable production.

As signatory party to the Paris Agreement, Brazil has committed to reduce its emissions by 37% in 2025, based on 2005 levels, according to the Intended Nationally Determined Contributions (INDC). To accomplish this target, the government established the “low-carbon agriculture plan” that finances the adoption of sustainable practices such as silvopastoral systems.

Silvopastoral systems have been reported to be an efficient strategy for restoring degraded lands by increasing biomass, improving soil chemical and physical properties, reducing water and soil losses and increasing the stocks of carbon on both biomass and soil pools (DE STEFANO; JACOBSON, 2018).

Albrecht and Kandji (2003) suggested that carbon stocking in integrated crop-livestock-forestry systems depends upon the systems’ structure (arrangement, species), function and management. These authors also consider that in silvopastoral systems intended for wood production, C storage is temporary as biomass is eventually removed and part of the C is released to the atmosphere. On the other hand, if the logs are processed in any form of long-lasting products, a great part of the stored C may last fixed for much longer (ROY, 1999).

The aim of this study was to estimate the carbon balance in two silvopastoral systems for rearing dairy heifers: (i) with eucalyptus and (ii) african-mahogany trees.

MATERIAL AND METHODS

The experiments were conducted between January 2010 and December 2020 at Embrapa Dairy Cattle Research Station in Coronel Pacheco, state of Minas Gerais, south-eastern Brazil (21°33' S, 43°15' W, 470 m a.s.l.) where, according to Köppen's classification, the climate is Cwa (mesothermal).

Both systems were set up on *Urochloa. decumbens* cv. Basilisk pastures already established. System 1 (SPSEUC) was composed by a clone of *Eucalyptus urophylla* x *Eucalyptus grandis* hybrid planted in single rows spaced 20 m and 2 m between trees in the row (250 trees/ha) and System 2 (SPSAFM) is composed by african mahogany trees established in single rows spaced 22 m and 2 m between trees in the row (227 trees/ha). Seedlings were planted in January, 2010. The grazing system and the average performance of crossbreed dairy heifers during the production cycle in this study was assumed to be similar to those reported by Paciullo et al. (2021).

IPCC protocols (2006, 2007) were used to calculate the net carbon balance as per hectare basis, following Torres et al (2017). The carbon pools considered were: the wood for timber, the biomasses of the trees and pastures root systems (FIGUEIREDO, 2017) and the soil organic carbon – SOC (CARVALHO et al., 2010). Carbon stocks of the trees were estimated using SisILPF-Eucalipto and SisILPF-Mogno software (OLIVEIRA et al., 2018).

The study covered a 20 years' production circle for both eucalyptus and african mahogany trees established into two different silvopastoral systems managed with periodic thinnings. For dairy heifers enteric emissions a default enteric fermentation CH_4 emission factor of 39 kg CH4 animal^{-1} yr^{-1}, as proposed by Torres et al. (2017) was used. For converting GHG emissions into CO_2e, the following 100-yr global warming potential were used: 1 for CO_2, 25 for CH_4 and 298 for N_2O, as proposed by IPCC (2006).

Technical thinning age was defined based on maximum productivity in terms of wood volume per unit area (VILLANOVA et al., 2018). As suggested by Resende et al. (2019), GHG removal from the atmosphere through C sequestration were expressed by negative values, while positive values indicate emissions.

RESULTS AND DISCUSSIONS

Over the 20 years study period, the total GHG emission were 30.53 Mg CO_2e ha^{-1} and 30.27 Mg CO_2e ha^{-1} for SPSEUC and SPSAFM, respectively. This result was already expected for both systems were managed almost similarly, differing basically by the specie used.

The most important difference was observed in the wooden pool, that corresponded to 69.3% of the total C stored in SPSEUC and 60.1% in SPSAFM (Table 1). For SPSEUC, the C stored in wood was -116.21 Mg CO_2e ha^{-1} while in SPSAFM was -47.43 Mg CO_2e ha^{-1} and the tree root systems stored -30.70 and -9.58 Mg CO_2e ha^{-1} for SPSEUC and SPSAFM, respectively. This difference between the systems is due to different growing rates of the species. While eucalyptus grew 12.5 m^3 ha^{-1} yr^{-1}, African mahogany showed a growing pace as slow as 3.5 m^3 ha^{-1} yr^{-1}. The estimated carbon sequestration by the pasture and soil pools were -12 Mg CO_2e ha^{-1} and -8.8 Mg CO_2e ha^{-1} irrespective of the system.

Table 1. Systems description and net carbon balance (Mg CO_2e ha^{-1}) of two silvopastoral systems, in Coronel Pacheco, MG.

System	SSPEUC		SSPAFM	
Year	Stocking rate (AU ha^{-1})	Solid wood m^3 ha^{-1} (thinnings)	Stocking rate (AU ha^{-1})	Solid wood m^3 ha^{-1} (thinnings)
1	1.5		1.5	
2	1.5		1.5	
3	1.4		1.4	
4	1.4		1.4	
5	1.3		1.3	
6	1.2	41.3	1.2	3.5
7	1.5		1.5	
8	1.5		1.5	
9	1.4		1.4	
10	1.4		1.4	
11	1.3		1.3	
12	1.2	63.2	1.2	12.1
13	1.5		1.5	
14	1.5		1.5	
15	1.5		1.5	
16	1.5		1.5	
17	1.4		1.4	
18	1.3		1.3	
19	1.2		1.2	
20	1.2	149	1.2	63.5
Emission (Mg CO_2e ha^{-1})	30.53		30.27	
Carbon Stock (Mg CO_2e ha^{-1})	-167.71		-77.81	
Balance (Mg CO_2e ha^{-1})	-137.18		-47.54	

Torres et al. (2017) observed GHG emissions ranging from 2.81 to 7.98 Mg CO_2e ha^{-1}, and a net carbon balance ranging from -18.97 to -192.16 Mg CO_2e ha^{-1} on four agrosilvopastoral systems composed by eucalypt trees associated with *U. decumbens* cv. Basilisk, ageing 3 to 5 years and established in Viçosa, MG, 140 km distant from the experimental site. These values are higher than the ones found in this study for SSPEUC, probably because those authors considered the entire tree volume, whereas only the timber volume was taken into account in this study.

Another study carried out by Resende et al. (2020) in Coronel Pacheco, MG, showed that in 8 years old silvopastoral systems with eucalypt trees and *U. decumbens* for beef cattle reached 26.27 Mg CO_2e ha^{-1} stored on tree biomass (crown+roots, after tree harvest), while GHG emissions were 23.54 Mg CO_2e e ha^{-1} on average, with a net balance of -2.73 Mg CO_2e ha^{-1}.

Unfortunately, the literature about carbon stocks in silvopastoral systems with african mahogany trees are scarce. Warnasooriya & Sivananthawerl (2016) reported about 80 Mg CO_2e ha^{-1} stored by 20 years old african mahogany stand with 400 trees ha^{-1} in Sri Lanka. This result is 30% higher than the one observed in the present study (61.5 Mg CO_2e ha^{-1} if the entire tree volume is considered).

The mean annual carbon balance was -19.39 Mg CO_2e ha^{-1} and -2.88 Mg CO_2e ha^{-1} for SPSEUC and SPSAFM, respectively. It is noteworthy that for both systems, the most important impact comes at clearcutting (at 20 years), when all trees are removed from the site and transformed into solid products (Figure 1). As at this age, tree size allows for a better use of timber for solid products (it was estimated that at least 60% of the volume of the trees was used for this purpose) and the amounts of carbon removed from the atmosphere increased rapidly.

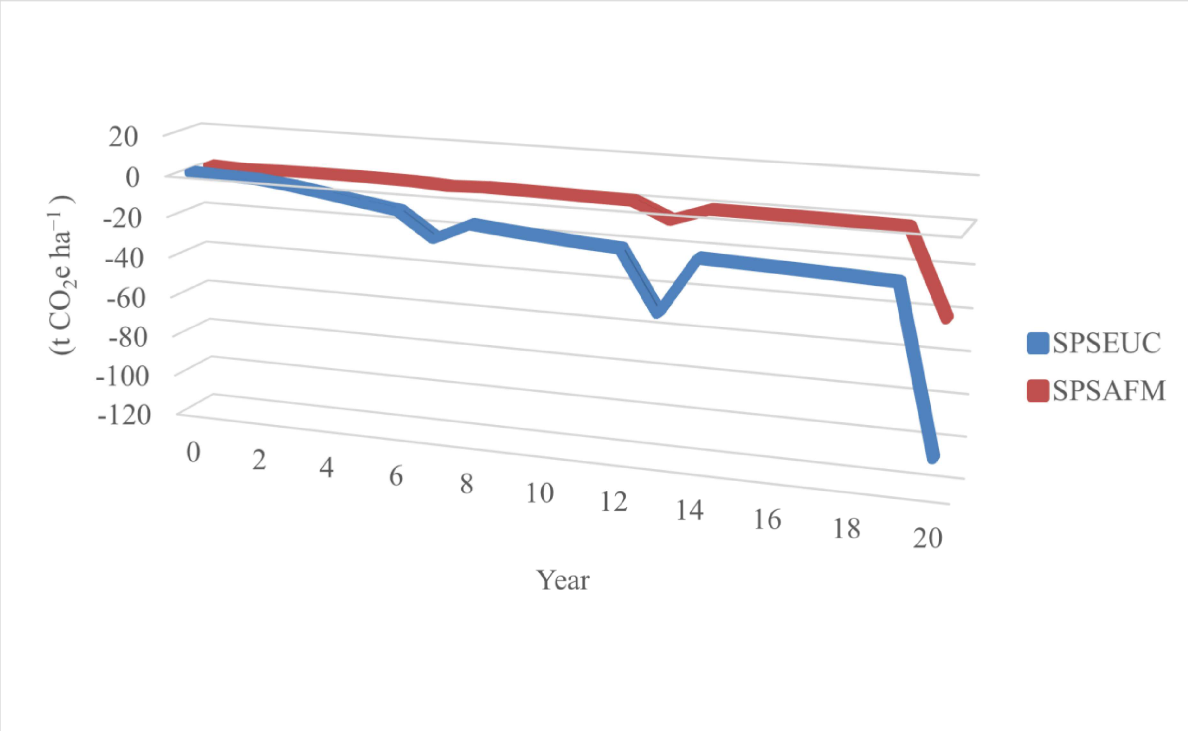

Figure 1. Net carbon balance of two different silvopastoral systems in Coronel Pacheco, MG.

CONCLUSIONS

Silvopastoral system with eucalyptus removes more carbon from the atmosphere than with african mahogany. In spite of significant differences, both systems are negative on net GHG emissions. The clearcutting at the age of 20 years represents 75% and 90% of the total carbon sequestered by the eucalyptus and the african mahogany-based silvopastoral system, respectively.

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