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Carbon footprint of rubber/sugarcane intercropping system in Sri Lanka: a case study

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Abstract

The global climate has been changing with the elevated CO_2 in the atmosphere; hence identification of effective measures to mitigate or combat the adverse effects of climate change is at uttermost importance. The goal of Government of Sri Lanka (GoSL) for planting 40,000 ha of rubber (*Hevea brasiliensis* Muell. Arg.) in the Uva province may partly address this issue sequestering the key greenhouse gas (GHG), CO2. Farmers in the area usually practice intercropping sugarcane (*Saccharum officinarum*) under immature rubber plants for extra income during the initial period of rubber cultivation. In the process of valuing rubber cultivation in mitigating the climate change effect, information on net greenhouse gas (GHG) emission from rubber/sugarcane intercropping system is required. Being scanty of such knowledge, this study was aimed to estimate the carbon footprint in the cultivation of rubber/sugarcane intercropping system in Sri Lanka.GHG emissions from the cultivation of rubber and sugarcane were calculated using the information available in the smallholdings having rubber/sugarcane intercropping in Monaragala district (IL2). GHG emission resulting from raw rubber processing, i.e. Ribbed Smoked Sheets (RSS) and Crepe Rubber (CR), was assessed using the data available in Kumarawatta Estate, Monaragala and Dartonfield Estate, Agalawatta, respectively. Also, GHG emission resulting from processing refined sugar was gathered from Palwatta Sugar Industries (Ltd), Monaragala. Carbon sequestration capacities of both crops were adopted from previous studies. Guidelines of Intergovernmental Panel on Climate Change (IPCC) were used in the estimation of carbon footprint. GHG emission in the process of cultivating rubber for its lifespan (30 years) was 65.15 CO2-eq ton/ha. When sugarcane was cultivated in rubber lands for four year period as a rubber/sugarcane intercropping system, GHG emission increased only by 9.72 CO2-eq ton/ha. Processing of RSS throughout the lifespan was responsible for additional 93.49 CO2-eq ton/ha emission whilst that for processing CR was limited to 50.14 CO2-eq ton/ha. Processing of refined sugar during four year intercropping period was accountable only for 0.62 CO2-eq ton/ha emission. In conclusion, carbon footprint (Net GHG emission) of cultivating rubber/sugarcane intercrop to produce CR and refined sugar was -1537.02 CO2-eq ton/ha/30yr whilst that for RSS and refined sugar was -1493.73 CO2-eq ton/ha/30yr. Increase in carbon footprint by intercropping sugarcane was only ca. 0.5% over mono cropping rubber. Potential application of this information in developing carbon trading projects is discussed.

Keywords: Carbon footprint; rubber; sugarcane; intercropping

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1. Introduction

Changing global climate due to enhanced greenhouse effect has been identified as one of the critical issues. To address this detrimental issue, Intergovernmental Panel on Climate Change (IPCC) has introduced key mechanisms which have been internationally recognized. First one is to mitigate climate change through reduction of emission of greenhouse gasses (GHG) and increasing the greenhouse gas absorption sinks to reduce their accumulation in the atmosphere. The second is adaptation for building capacity to adjust ecological, social and economical changes resulted due to climatic impacts[1,2]. Aligning with the global community, Government of Sri Lanka (GoSL) has developed a strategic climate plan based on different thrust areas. Industrial sector has been identified as one of the most important sectors influencing climate change.

Tree plantations such as rubber (*Hevea brasiliensis* Muell. Arg.) helps mitigate the climate change by sequestering atmospheric CO_2, thus considered to be carbon negative. As one of the major plantation crops in Sri Lanka, rubber plantation covers 131,000 ha and provides 152,000 MT of rubber[3]. Previous studies show that rubber plantations are capable of sequestering 1,660 MT of CO_2 per hectare[4] with ultimate fixing of 290 MT of CO_2 per hectare[5] during its 30-year economic life cycle.

Under the development goals of GoSL, 40,000 ha of new planting programme of rubber in the Uva province has been launched which would complement to combat the adverse effects of climate change providing GHG absorption sink. Sugarcane (*Saccharum officinarum*) is a common crop in this area, hence farmers prefer to cultivate sugarcane with rubber under intercropping system in order to obtain an extra income during the initial period of rubber cultivation[6,7]. Furthermore, intercropping ameliorates crop microclimate for improved growth of rubber[8,9]. Harvests of both crops are to be processed into different forms for marketing, thus several activities are involved in these processes of emitting CO2. Despite the knowledge on carbon fixing in crops, no information is available on the emission in the whole process. Any attempt for developing carbon trading projects on mitigation option of climate change requires information on net emission of GHG (carbon footprint). In this backdrop, the present study was aimed to estimate the carbon footprint of rubber/sugarcane intercropping system through activity base analyses.

2. Methodology

The data were mainly collected in Monaragala district which is located in the Intermediate Zone 2 (IL2) of Sri Lanka where rubber/sugarcane intercropping holdings are mostly available. Collection of agronomic data was carried out in four sites situated in Kumbukkana Gramasewa division of Monaragala district. Information on processing of sugarcane was collected from the processing unit of Palwatta Sugar Industries (Ltd) in Monaragala district. The information on rubber was collected from rubber processing units at Kumarawatta Estate, Moneragala and Dartonfield Estate, Agalawatta.

GHGs (CO_2 and CH_4 and N_2O) emissions from agronomic practices of rubber and sugarcane cultivation and processing into raw rubber and refined sugar were assessed and then used with data on carbon sequestration, for rubber[4] and for sugarcane[10] for the calculation of carbon footprint. Under the agronomic practices of rubber and sugarcane cultivation, land preparation, transportation of planting materials, transportation and application of fertilizers were considered. Transportation of field latex to the factory, machinery usage in rubber processing and drying were the key activities occupied in raw rubber processing, i.e. crepe rubber (CR) and Ribbed Smoked Sheets (RSS). Similarly, transportation of cane yield to the factory, machinery usage for milling, boiling and drying were the main steps practiced in processing of refined sugar. Emission of GHGs due to fuel combustion involved in above activities was taken into account. In addition, process related emissions at refinery stage of fuel were taken into account. Emission through the electricity usage in factories was counted on the basis of emission values available for electricity generation. The application of nitrogen fertilizer for both crops was quantified and emissions due to mineralization, leaching and volatilization were counted. Furthermore, GHG emissions at fertilizer production at factory level were taken into account.Net GHG emission (carbon footprint) of rubber sugarcane intercropping system was calculated according to the IPCC guidelines[11].

3. Results

3.1 Carbon footprint for rubber industry

Cultivation of one hectare of rubber over 30 year period emits 65.15 CO2-eq ton of GHG with the average annual value of 2.17 CO2-eq ton. Immature six year period of rubber cultivation contributes to 15% of that amount (9.84 CO2-eq ton/ha). The rest 55.31 CO_2-eq ton is emitted during twenty four year harvesting phase, with the average annual of 2.30 CO2-eq ton/ha. The major GHG emission activity involved in rubber cultivation is the application of nitrogen fertilizers. This contributes to 96.53% to the total by emitting 62.89 CO2-eq ton/ha. Transportation and land preparation accounts only for 1.78% and 1.62%, respectively.

GHG emission associated with the preparation of CR over 24 year period is 50.14 ton CO2-eq/ha. Of this process, emission related to machinery is limited to 7.5% and the rest is arising from drying process. The average annual emission of processing CR is 2.08 CO2-eq ton/ha. In contrast, production of RSS is confined only to drying process which emits 93.49 ton CO2-eq/ha with the average annual of 3.89 ton CO2-eq/ha.

Therefore, cultivation of rubber to produce CR contributes to emission of 115.29 CO2-eq ton/ha whilst that for production of RSS contributes 158.64 CO2-eq ton/ha. Total CO2 sequestration capability of rubber during the 30 year period is estimated as 1660 ton/ha.

Cultivation of rubber as a mono crop for 30 year period to produce CR accounts for -1544.71 CO2-eq ton of net GHG emission (total emission– total sequestration) per hectare with an average annual value of -51.49 CO2-eq ton per hectare. If rubber is cultivated for RSS production, net GHG emission would change to -1501.36 CO2-eq ton per hectare for 30 years with the average value of -50.04 CO2-eq ton per hectare. Further, carbon footprint of production of one ton of CR is -61.29 CO2-eq ton whist that for RSS is -59.57 CO2-eq ton.

3.2 Carbon foot print for sugar industry

Emission of GHGs by cultivating hectare of sugarcane in rubber lands for four year period is 9.71 CO2-eq ton with average annual value of 2.42 CO2-eq ton/ha. Application of nitrogen fertilizers is the highest contributor for emission (95.57%) in sugarcane cultivation releasing 9.28 CO2-eq ton/ha for four year period. Land preparation and transportation are accountable for 0.18 CO2-eq ton/ha (1.85%) and 0.23 CO2-eq ton/ha (2.36%), respectively.

During the manufacturing of refined sugar from sugarcane (harvested during the lifespan of four year period), 0.62 CO2-eq ton of GHG is released. In processing, electricity was the main contributor (98.08%) for emission.

Accordingly, cultivation of sugarcane as a rubber based intercrop to produce refined sugar is responsible for 10.33 CO2-eq ton of GHG emission from one hectare.

Total CO2 sequestration capability of sugarcane during four year period is estimated as 2.64 ton/ha.

As a result, carbon footprint of sugar industry, i.e. net emission of GHG by cultivating sugarcane as an intercrop to produce refined sugar for four year period is calculated as 7.69 CO2-eq ton/ha. Annual net GHG emission is 1.92 CO2-eq ton/ha. Further, carbon footprint of production of one ton of refined sugar is 0.34 CO2-eq ton.

3.3 Carbon foot print for rubber sugarcane intercropping system

Total emission of GHGs by cultivating one hectare of rubber/sugarcane intercropping system to produce CR and refined sugar is 125.62 CO2-eq ton/ha whilst that for RSS and refined sugar is 168.91 CO2-eq ton/ha. Total amount of sequestration by the system is 1662.64 CO2-eq ton/ha.

Therefore, carbon footprint of rubber/sugarcane intercropping system for production of CR and refined sugar, is -1537.02 CO2-eq ton/ha for 30 year lifespan with an annual net GHG emission of -51.23 CO2-eq ton/ha. Production

of each ton of CR and refined sugar is responsible for net emission of -61CO2-eq ton and -68 CO2-eq ton, respectively.
Alternatively, when intercropping is practised to produce RSS and refined sugar, carbon footprint is maintained at -1493.73CO2-eq ton/ha for 30 year lifespan. The annual net emission is -49.79 CO2-eq ton/ha/yr. The values for production of each ton of RSS and refined sugar contributes to net emission of-59 CO2-eq ton and -66 CO2-eq ton, respectively.

4. Discussion

Importance of rubber as an environment friendly crop has further been proven by the results of the study showing negative value for carbon footprint. This information could effectively be used in carbon trading projects under the option of climate change mitigation. However, GHG emission due to volatilization, mineralization and leaching of nitrogen fertilizers was identified as one of the major components contributing to the emission. Therefore, by adopting necessary technologies to reduce this amount would lead to much greener rubber cultivation by increasing more negative values. One option available would be the use of site specific fertilizer doses for reduced amounts. Cultivation of cover crops, shade crops and intercrops in rubber lands which has an ability to fix atmospheric nitrogen would be another practicable solution to cut down quantities of synthetic fertilizers. In addition to acting as a source of organic manure, cultivation of crops like *Gliricidea* under rubber could be used as an alternative energy source.
Processing of RSS has recorded high emission values over CR. Processing of CR is mainly based on electric power based machineries whilst the main production procedure (drying) of RSS is achieved by burning of firewood. Under Sri Lankan conditions, inefficient firewood furnaces are still in use and this would be the cause for recording higher emission values for RSS production. Usage of renewable energy based electricity and solar power for such energy operations could address this inefficiency.
Being a C4 plant with highly efficient photosynthesis system, cultivation of sugarcane was expected to have negative carbon footprint. This means cultivation and processing processes emit more carbon than what sequestered by the crop. Therefore, sugarcane cannot be grown for mitigation option for climate change. As a solution, sugarcane could be cultivated with a perennial crop like rubber to have a carbon negative system.
In this analyses, carbon emission from firewood burning (in furnace) was counted as the source of produce was not clear. In the case of obtaining firewood from renewable sources, net emission could be further reduced making higher negative value for carbon footprint.

5. Conclusions

Rubber cultivation was found to be a carbon negative process with a negative value for carbon footprint. Nevertheless, it was not the case for sugarcane as processing of refined sugar emits more carbon than net carbon balance in cultivation. Therefore, rubber/sugarcane intercropping provides more sustainable system proving both economic benefits at farmer level and environmental friendliness with a negative carbon footprint.

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