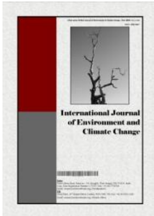

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Net Carbon Flux of a Higher Education Institute: Faculty of Agriculture, Rajarata University of Sri Lanka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To account the synthesis of carbon sequestration, carbon emissions, and net carbon flux with respect to an agricultural higher education institute in a tropical region.

Place and Duration of Study: Faculty of Agriculture, Rajarata University of Sri Lanka, between May 2019 and August 2019.

Methodology: The onsite carbon flux estimated for emissions and fixations by considering the Faculty of Agriculture (FoA) and the farm premises as a closed system. Net carbon flux is the difference between CO_2 sequestered and the total CO_2 emissions. The carbon flux was calculated as $\Delta CO_2 = E_T + R_H + E_F - S_T$. Where; E_T is CO_2 emission from vehicles, R_H is CO_2 emission from human respiration, E_F is CO_2 emission from farm operations and S_T is sequestered carbon in trees and turfs. As the carbon sinks; all palm trees, turf and large trees were used. The tillage methods, land-use practices, crop management practices in the farm were considered as carbon sources. And also, the respiration of faculty staff and students and transportation within the faculty were considered as sources of carbon. All the measurements in data collection, estimations of carbon storage and emissions were estimated as per the available methods and equations used in similar studies.

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Results: The total CO_2 equivalent was 771.82 Mg. The total CO_2 emission was 164.9 Mg. Therefore, the Net carbon flux was found as 606.92 Mg for the faculty in 2019.
Conclusion: The faculty is a green one which has a positive net carbon flux. The methodology used in the study can be applied for assessment of carbon stock in other educational institutes in Sri Lankan context with special reference to agricultural education.

Keywords: Net Carbon Flux; Greener faculty; Farm emissions; Greenhouse gas.

1. INTRODUCTION

Faculty of Agriculture (FoA), Rajarata University of Sri Lanka is located in *Anuradhapura* in the dry zone of Sri Lanka. The average temperature of the area is 28.5°C and varies between 20.5°C to 34.3°C. The uncomfortable temperature is one of the major challenges faced by students and staff in this faculty. Therefore, it is worthwhile to account on the CO_2 emission level of the faculty to see its own contribution to the issue. Because, higher temperature due to Green House Gas (GHG) emission has short-term and long-term impacts on the performance of education [1]. For instance, reduction in grammatical reasoning and the poor performance of multiplication have been exhibited when classroom temperature increased from 23°C to 28°C. Further, it has been found that the performance of memory tasks generally reaches its maximum at 26°C and decreases at higher temperatures [2]. Moreover, it has shown that the average score in mathematics has been improved by 0.5% for each reduction in classroom temperature by 1°C in the range of temperatures between 25°C and 20°C [3]. The indoor thermal conditions influence the productivity of the general tasks such as writing, typing, communication, etc., For instance, those performances are decreased by 2% per 1°C increase of temperature in the range of 25-32 °C [4]. Students generally preferred “cooler-than-neutral’ temperatures where the temperature is below 2–3 K to the neutrality level which is predicted for adults under the same thermal environmental conditions [5-6]. However, the optimal thermal conditions for the students in tropical regions have shown a few degrees higher than the moderate regions [7-8].

Human-induced warming has reached approximately 1°C above pre-industrial levels in 2017, while temperature is increasing at 0.2°C per decade [9]. Considering the past and present climate trends in South Asia, it is expected to have high temperatures than the 20th century and temperatures higher than the global mean rate [10]. Similarly, Sri Lanka will be heavily impacted by these rising temperatures in the future [11]. This may not be a nightmare because, Sri Lanka experienced a 0.016°C increase per year between 1961 and 1990 in all over the island and 2°C increase per year in the central highlands in the recent decades [12]. Many processes contribute to GHG emissions. For instance, transportation is a major reason [13]. In addition, other industries or service providers also contribute to GHG emissions. Such sector is higher education (HE). For instance, the emissions due to air travel of international students to and from UK universities were around 652,000 tons of carbon in 2003/2004 [14]. However, the cost of emissions has not much considered over the social value of education when enrolling students. Therefore, HE has provided through real-time in-class teaching with student-teacher interaction as before [14-16]. But, HE sectorial contribution to GHG emission has been identified as significant [14]. Therefore, some countries have taken measures to reduce GHG emissions by gradually decreasing energy consumption and waste generation within HE institutes [17-18]. Some of those measures are greening the curriculum by reducing paper works and introducing e- learning and distance learning [14] [19].

The exact GHG emission has been accounted in most of the HE institutes for different purposes such as to certify as a green university under international standards or to map the energy requirements [20-21]. However, in order to plan effective GHG emission reduction strategies, the quantification of current contribution to GHG emissions from the HE institute and path identification is essential. A viable option is maintaining of an account on institutional contributions to GHG emissions. That supports the institution for better structural designs and buildings in the future which reduce energy use and GHG emissions [22]. in this regard, as highlighted by the United Nations Framework Convention on Climate Change (UNFCCC), accounting for net carbon flux with special reference to “emissions by sources and removals by sinks” can be used in HE institutes to quantify their current contribution to GHG (UNFCCC).

Simply, the net carbon flux is the amount of carbon exchanged between earth's carbon pools such as atmosphere and ocean and living things. Negative fluxes indicate the places where uptake of CO_2 occurs. Positive fluxes indicate places where emission of CO_2 occurs. Thus, the study was conducted to account the net carbon flux of FoA, Rajarata University of Sri Lanka by taking it as an example higher educational institute. This study depicts the methodology to perform such study in Sri Lankan context which has not carried out yet.

2. MATERIALS AND METHODS

The onsite carbon flux estimated for emissions and fixations by considering the FoA, Rajarata University of Sri Lanka and the farm premises as a closed system. The coordinate of the study location was $8.3707N^0$; $80.4205E^0$. Net carbon flux is the difference between CO_2 sequestered in and the total CO_2 emissions. The carbon flux was calculated as $\Delta\ CO_2 = E_T + R_H + E_F - S_T$. Where; E_T is CO_2 emission from vehicles, R_H is CO_2 emission from human respiration, E_F is CO_2 emission from farm operations and S_T is sequestrated carbon in trees and turfs [23]. The CO_2 emission from energy use was excluded since, FoA depends on offsite generated hydroelectric power [24-28]. The CO_2 emission due to disposal of food wastes was excluded in the study due to two reasons. The CO_2 emissions due to food wastes should be considered at the point of combustion as the method of calculating CO_2. The fixation of CO_2 in food has happened at the point of biomass growth [29]. When consider the food utilization of faculty staff and students at present, most of the cooking products, foods and beverages are grown outside the faculty and carried as final goods to the faculty. The food waste disposals of faculty were mainly dumped in offsite locations.

The total considered land area was 32 acres (12.95ha). This includes both the faculty premises and farmland. Turf cover (less than 1m tall grass cover) of the playground, paddy fields and open shrubby patches in the farm were measured. When calculating, open shrubby patches, the open area remaining in the farm land was considered after reducing the area of buildings, roads, playground and paddy fields located in the farmland area. These open shrubby patches are the area where no intentionally grown vegetation or ornamental green covers. In the study, all the palm trees, turf and large trees were used as carbon sinks. The land use pattern, agricultural practices such as tillage methods, crop management practices such as irrigation, agrochemical input uses and applications were considered as carbon sources within the faculty farm. And also, the human respiration and transportation within the faculty were considered as sources of carbon. All the estimations of carbon storage, measurements, and emissions were estimated as per the available methods and equations used in similar studies. Net carbon flux is defined here as the difference between sequestered-carbon and the total carbon emissions [30].

2.1 Estimation of Sinks by Plant Matter

Estimation of biomass is basically done by using destructive or non-destructive methods [31-32]. The destructive methods remove the full tree or parts to estimate fresh or dry biomass. Even though the method is simple, it is time consuming, costly and destructive [33][30]. In contrast, non-destructive biomass estimation methods do not fell the trees [34-36]. The non–destructive measurements on stem and branches are taken along with limited sampling of branches by climbing trees or measuring at the breast height [30]. The trees within the faculty were measured with a tape to obtain the tree girth at breast height (DBH) as non–destructive measurements. The total carbon content of the biomass was calculated using the allometric equations and assumptions as suggested by the previous studies with special reference to tropical regions. DBH was used to calculate the Above Ground Biomass (AGB) and Below Ground Biomass (BGB) [37-38]. The Total Biomass Carbon (TBC) content was estimated using AGB [39].

Total Above Ground Biomass (TAGB) of live trees was estimated using the equations for the areas receiving an average annual rainfall between 1,500-4,000 mm [35]. All these equations use DBH values except in equation 2, where it uses the height (H) of the palm trees. Accordingly, equations (1,2,3 and 4) were used to estimate TAGB of live trees, palm trees, liana and saplings. TAGB of dead trees and bamboo trees were calculated using equations (5) [39][30], and (6) [40].

$$TAGB = \exp(-1.996 + 2.32 * LN(DBH) \qquad (eq.1)$$

$$TAGB = 4.5 + 7.7 * H \ \ldots\ldots\ldots\ldots \qquad (eq.2)$$

$$TAGB = DBH^{\wedge} 2.657 * \exp(0.968) \ \ldots \qquad (eq.3)$$

TAGB = exp (-2.134 + 2.53 ln (DBH) …. (eq.4)

TAGB = exp (-2.134 + 2.53 ln (DBH) * 0.975 (eq.5)

TAGB = 5.1162 +0.6599 DBH …... (eq.6)

The below ground mass (BGB) was estimated as a function of AGB [35]. Thus, equation (7) was used to estimate BGB except for litter and downed wood [30]. The carbon sequestered by grass turf was calculated by using a fixed sequestration rate of 128.8-ton km^{-2} yr^{-1} [23] [27], and separately added to the total carbon content of plant mater.

BGB = exp (-1.0587+0.8836 x ln (ABG) (eq.7)

The total biomass for the vegetation was calculated by using the summation of the total biomass (Total Above Ground mass plus Below Ground Mass) of all plant matter. The conversion of biomass to carbon was done by using the conversion factor 0.47. Total amount of CO_2 (Mg) was calculated by multiplying the carbon stock by the factor 3.67, which is the ratio of molecular weights between carbon dioxide and carbon [41].

2.2 Estimation of Emissions by Humans and Vehicles

The students, academic staff and non-academic staff population in the year 2019 were considered. The assumption was made that students stay at the university within 24 hours, since the students are provided full time residential facilities by the faculty. The stay period of academic and non-academic staff in the faculty was considered as 8 hours per day. Total count of academic staff members was 73, including all the permanent lecturers, temporary lecturers and the demonstrators. Total count of academic support staff members was 107. The total student population was considered as 500. The number of working days of the faculty was considered as 209 days per year considering the vacations and all the other holidays in 2019. The CO_2 content released by respiration was considered as 1386g $Person^{-1}Day^{-1}$ [27]. The average weight of a person was assumed as 70kg and the metabolic rate per day is about two times as resting. Carbohydrate was considered as the metabolic fuel [27].

Privately owned vehicles by the staff, students as well as the faculty owned vehicles were considered. The average travelling distance of a motorbike and total number of motorbike travels per day were identified as 400m and 35 times by observing within a random day. The number of petroleum powered motor cars of staff members was considered as 20 with 200 m average running distance per turn within the faculty and two turns per each member. The travelling distance of faculty owned diesel powered van and the petroleum powered three –wheelers was considered. The average 400m travel distance per turn and 10 turns per day were used for each faculty-owned vehicle by considering the reported vehicle uses from the gate pass records in 2018. The fuel efficiencies were considered as 7.6 km/l for a petroleum powered car, 4.1 km/l for a diesel powered van, 21.6 km/l for a motorbike and 17 km/l for a petroleum powered three-wheeler as per the national motor survey details in 2008 [42]. The hybrid cars were not considered due to the low emission rate with respect to small travel distance (400m) within the faculty premises. The emitted CO_2 content by combustion of one liter of diesel was considered as 2.68kg and one liter of petroleum (Octane 92) as 2.31kg [43].

2.3 The Farm Operations and the Emissions

Agricultural activities emit CO_2 by three ways: (1). machinery uses, (2). production and application of fertilizers and pesticides, (3). Soil Organic Carbon (SOC) due to oxidization by soil disturbances. The decomposition and oxidation of SOC are affected by the amount of disturbed soil and the used tillage practices [44]. Energy and CO_2 emissions associated with different tillage practices as a combination of fuel type of farm machines such as energy consumed in manufacturing, transportation, and repairing of the machines [45]. The tillage practice was considered as mild in the study correspondence to the limited types of machineries, small scale operations and low fuel use at the faculty farm. The manufacturing and repairs were not considered, since those are not done within the faculty premises or due to negligible counts. The farm land area (5.26 ha) is assumed to be cultivated for two seasons per year. The CO_2 emission rates for disc ploughing under conventional tillage, planting and all the disturbances within a single cultivation were assumed respectively as 17.44 kg $ha^{-1,}$ 6.79 kg ha^{-1} yr^{-1} and 4.57 kg ha^{-1} yr^{-1}, assuming the current paddy cultivation in the farm [44].

3. RESULTS AND DISCUSSION

The percentages of major categories of vegetation have shown in Fig. 1. The results revealed that, 58% of the total vegetation was consisted of trees of different plant species.

Fig. 2 and Table 1 give the details of biomass of different vegetation. Live trees contain the highest amount of biomass as 15.24 Mg/ha, whereas dead trees have the lowest biomass of 0.03 Mg/ha. Thus, the highest contribution for the CO_2 absorption is made by the live trees in the faculty. The total CO_2 sequestered from all the vegetation was 771.82 Mg for the faculty.

The total carbon emission of the faculty was 164.9 Mg. The highest CO_2 emission was reported as 162.22 Mg from human respiration. The minimum CO_2 emission was reported as 0.15 Mg by tillage practices. Thus, the net carbon flux in the faculty farm was 606.92 Mg (771.82Mg- 164.9 Mg).

This net carbon flux was calculated by considering few assumptions and approximations as per the available literature. The CO_2 emissions due to fuel transportation and production were not considered when calculating the total emissions by fuel use due to their presence in off-sites. The post-production CO_2 emissions of fertilizer are resulted due to packaging, transportation, and field applications [46]. Therefore, such CO_2 emissions were not calculated in the study due to minimum transportation distance within the faculty and almost zero levels of repacking or processing. Faculty farm contains small plots especially for experimental purposes, mainly under reduced fertilizer uses at present. Moreover, lime is not applied in the field plots as a practice which releases more CO_2. Thus, the emissions from fertilizer application were ignored due to negligible amounts. The energy use and CO_2 emissions from pumping water are needed to be applied to both on-farm wells and off-farm surface reservoirs [47]. However, such emissions were not considered due to the use of offsite generated hydroelectric energy. Moreover, irrigation on–farm surface water has been powered by the gravitational forces and topography. As the limitations of the study, the livestock component of the faculty farm has not been added as a component due unavailability of data and limited number of animals or frequent count changes. The seedlings and some small plants also have not been added to the carbon quantification due to practical difficulty of counting and identifying. However, there is no universally accepted methodology in estimating biomass/carbon stock either in forests or in other vegetation or place. Various methods are available and used as per the customized requirements of the studies. Nonetheless, the estimation of total emissions and carbon sequester requires a complete quantification of all the components for a long period of time to have fine results which is difficult and expensive [30].

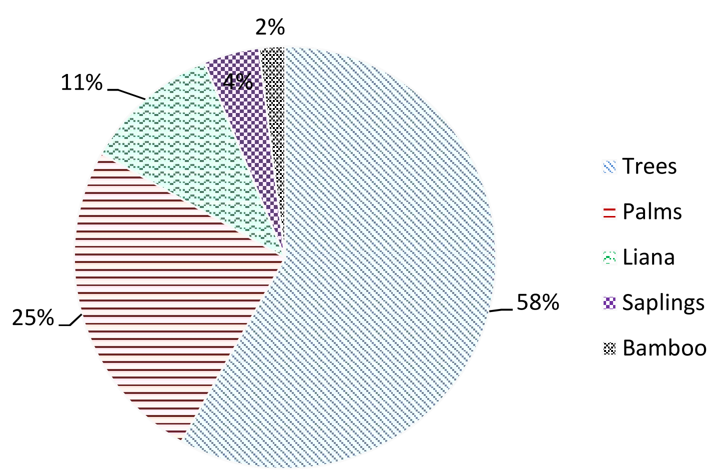

Fig. 1. Composition of the vegetation in the faculty

Table 1. Biomass partitioning among different components

Biomass component	Trees	Palms	Liana	Dead trees	Saplings	Bamboo	Grass
Total ABG (Mg/ha)	12.11	1.92	0.07	0.02	0.24	0.83	-
Total BBG (Mg/ha)	3.14	0.63	0.04	-	0.09	0.29	-
Total Bio Mass (Mg/ha)	15.25	2.55	0.11	0.02	0.33	1.12	15.18
Grand total biomass density (Mg/ha)	34.56						
Total Carbon density (Mg/ha)	34.56 * 0.47 = 16.24						
Total CO_2 equivalent (Mg/ha)	16.24*3.67= 59.60						
The CO_2 sequestered within the faculty (Mg)	59.60 *12.95 = 771.82						

Table 2. CO_2 emission from the faculty as estimated from 2019

Component of CO_2 emission	CO_2 Emission (Mg)	Total CO_2 emission (Mg)	%
Farm Land Preparation		0.15	0.09
Disc Plough	0.09		
Planting	0.04		
Single Cultivation	0.02		
Vehicles		2.53	1.53
Diesel Van	0.55		
Three-wheeler	0.11		
Motorbikes	1.36		
Cars	0.51		
Human Respiration		162.22	98.37
Academic staff (8 hrs)	7.04		
Nonacademic staff (8hrs)	10.34		
Students (24hrs)	144.84		
Grand total CO_2 emission (Mg)		164.9	100%

4. CONCLUSION

The recorded total carbon density (16.24 Mg/ha) is a lower value when compared with studies conducted in Sri Lanka. For instance, total carbon density was reported as 157 Mg ha^{-1} for the crop monoculture and mixed plantation forests in *Nuwara Eliya* district, Sri Lanka in 2008 [48]. Another study conducted in *Kandy*, Sri Lanka reported that total carbon density of natural forest as 36.55 Mg ha^{-1} and for plantations as 45.06 Mg ha^{-1} [30]. Small tree cover of the faculty is the main reason for a lower total carbon density. However, it is clear that faculty holds a carbon stock than its emissions. This carbon stock neutralizes the contribution of the faculty to climate change impacts due to its emissions by making it as a greener one. The faculty can maintain this net positive carbon flux by keeping the existing tree and grass cover as it is or by increasing biomass/carbon stock through tree planting. For instance, usually a live tree can sequester 22kg of CO_2 per year [49]. Therefore, the accounting of available carbon stock is an important task to manage the future tree planting and land use activities.

In Sri Lankan HE institutional context, most of the emissions like emissions due to hydro power use, on site emissions due to food waste disposal and waste accumulation can be neglected due to small scale or due to the mode of disposals at present. But the farm operations should be considered with respect to the relevant degrees of interventions i.e. livestock keeping, fertilizer making, crop cultivation, mechanical works. All the other factors related to number of people and their retention times, horticulture and landscape patterns can be considered generally in a normal year to represent the context of the institutes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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