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Estimation of carbon footprint in Tamil Nadu Agricultural University, Coimbatore

C.G. Karishma^{1*}, S.V.Kottiswaran², A. Balasubramanian³ and B. Kannan¹¹Soil & Water Conservation Engineering, Agricultural Engineering Collage & Research Institute, TNAU, Coimbatore-641 003, India²Agricultural Engineering Collage & Research Institute, TNAU, Coimbatore-641 003, India³Department of Silviculture, Forest College and Research Institute (FC&RI), Mettupalayam-641 301, India*Corresponding Author Email : karishmaswce@gmail.com

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Abstract

Aim: A study was conducted in the Eastern block of Tamil Nadu Agricultural University, Coimbatore to estimate the carbon footprint from various sources comprising of transport, human population, diesel generator and electricity use.

Methodology: The data were collected based on the questionnaire developed. Empirical equations were used for computation and data were statistically analysed.

Results: Carbon footprint analysis in the selected buildings revealed that, the equivalent carbon emission from power, diesel generators, human population and transport were 291, 14.17, 78.72 and 36.43 tonnes per year, respectively. It was inferred that emission from power use was greater in comparison with emission from transport, human population and diesel generators.

Interpretation: For a diversified source of emission in a university, reduction in anthropogenic emissions can be achieved by increasing the capacity of carbon sinks, i.e., through carbon sequestration and switching to low-carbon energy sources.

Key words: Climate change, Carbon footprint, Carbon sink, Low-carbon energy sources

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Introduction

Most of the observed increase in global average temperature is due to steady increase of CO₂ in the atmosphere. Greenhouse gas emissions cause heat to be trapped by the earth's atmosphere, and this has been the main driving force behind global warming. The main sources of such emissions are natural systems and human activities. Yue and Gao, statistically analysed global greenhouse gas emissions from natural systems and anthropogenic activities and concluded that the earth's natural system can be considered as self balancing and that anthropogenic emissions add extra pressure to the earth system (Yue and Gao, 2018). Poverty, population pressure, agricultural expansion and intensification and development of infrastructure have been suggested as major threats to biodiversity in the tropics (Davidar *et al.*, 2010) which increases the pressure on the remaining forests (Bargali *et al.*, 1992a, b; 1993; Kittur *et al.*, 2014; Baboo *et al.*, 2017; Bargali *et al.*, 2018).

Continuous increase in the human population together with livestock populations, the pressure on these forests in terms of intensive livestock grazing, fuel wood and timber harvesting for their energy and income generation are mounting and consequently resulting in the reduced carrying capacity of these forests (Davidar *et al.*, 2010; Sagar and Singh 2004) which increased the change in local atmosphere (Arora *et al.*, 2011; Bargali *et al.*, 2019; Manral *et al.*, 2020). Even CH₄ and chlorofluorocarbons have significant importance but their concentration is significantly less than CO₂. Anthropogenic activity has been increasing the concentration of greenhouse gases in the atmosphere. Following the rule that only measurable is manageable, minimisation of greenhouse gas intensiveness of different products, bodies, and processes is going on worldwide (Pandey, 2011). The Carbon footprint is made up of the sum of two parts, the direct and indirect or secondary footprint (Tukker and Jansen, 2006).

Electricity production generates the largest share of greenhouse gas emissions. Approximately, 67% of our electricity comes from burning fossil fuels, mostly coal and natural gas (USEIA, 2016). Transportation contributes 26% of greenhouse gas emission. Emissions from transportation primarily come from the exhaust of cars, trucks, ships, trains and planes. Over 90 % of the fuel used for transportation is petroleum based, which includes gasoline and diesel (Kahn Ribeiro, *et al.*, 2007). Letete, *et al.* (2011) had estimated carbon footprint for the year 2007 at University of Cape Town's to be about 83400 tons CO₂ equivalent, with campus energy consumption, Transportation and Goods Services contributes about 81%, 18% and one% footprint. Electricity consumption alone contributes about 80% of all the emissions associated with university activities. Carbon Dioxide from various emission inventories in Institute of Science and Technology, Arakkunnam was carried out by Mary Lissy (2012) and suggested remedial measures for the reduction of emissions as a part of social commitment. Utaraskul, (2015) had studied the Carbon footprint of 35 students in Environmental

Science Program, Faculty of Science and Technology, Suan Sunandha Rajabhat University based on three criteria transportation, food consumption and energy consumption by using electric appliances. Considering all these factors a study was conducted in the Eastern side of Tamil Nadu Agricultural University, Coimbatore to estimate the carbon footprint from various sources comprising of transport, human population, diesel generator and electricity use.

Materials and Methods

The study was carried out in the eastern block of Tamil Nadu Agricultural University, Coimbatore. The study area is 77606 sqm comprising of 29 buildings.

Data collection: The data were collected from 29 buildings based on the semi-structured questionnaire developed and interaction with the individuals (respondents).

Estimation of carbon footprint

Estimation of CO₂ dioxide emission from electrical appliances:

Total units consumed by electrical appliances (x) = $b \cdot c \cdot d / 1000$ (kWh)..... (1)

Type of fitting (lights, fans etc.), (a) Wattage of the fitting. (b), Installed fixtures in numbers. (c), Average working hours in a year. (d), CO₂ emission factor. (e)

Total CO₂ emission from electrical appliances = $x \cdot e$ (2)

Estimation of CO₂ emission from diesel generators:

Total CO₂ emission from generators = $b \cdot c$ (3)

Diesel consumed litres per year (b) CO₂ emission factor ©

Estimation of CO₂ emission from human population:

Total CO₂ emission from human beings = $a \cdot b \cdot c \cdot d$ (4)

Total number of individuals in the building. (a) Average working hours in a week; (b) Average working days in a year. (c) Per capita CO₂ emission

(0.9 kilograms of CO₂ for each day per person).

Estimation of vehicular CO₂ emission

Total CO₂ emission from vehicles = $c \cdot e$ (5)

Distance travelled. ©, CO₂ emission factor. (e)

[To be taken into consideration: type of vehicle (two wheeler, four wheeler etc.), type of fuel (diesel or petrol) and mileage of vehicle].

Note: The emission factors for vehicles were assumed from the report given by “Automotive Research Association of India”, 2007. When the emission factors were unavailable in the database, the constant emission factors for petrol and diesel were assumed. Total CO₂ emission = Electrical appliances carbon dioxide emission + CO₂ emission from diesel generators + Human CO₂ emission + CO₂ emission from vehicles (6)

Statistical analysis: The data obtained were statistically analysed to evaluate possible significance of independent variables to dependant variable.

Multiple linear regression model: A model which depicts the influence of two or more independent variables on the dependent variable. In this model, the dependent variable will be a continuous variable and independent variables can be continuous, discrete and categorical.

Multiple linear regression model is represented by:

$$Y = a + b_1x_1 + b_2x_2 + \dots + b_px_p$$

Where, a is the constant and b_1, b_2 etc. are the partial regression coefficients, x_1, x_2, x_p are the p independent variables. Partial regression coefficients show the influence of independent variable to dependent variable. This can be tested for its significance by applying Student's t -test, the coefficient of multiple determination R^2 is the contribution of all independent variables considered in the model to dependent variable.

Results and Discussion

The power use in buildings and the equivalent carbon emitted was computed using Eq.1 and 2, respectively. Fig. 1. Shows that the Carbon emission was highest in the department of Agricultural Engineering College and Research Institute (24.82 tonnes per year), followed by the crop physiology department (19.57 tonnes per year) and technology parks. Total power consumed 341865 kWh/year and the equivalent Carbon emission was 291 tonnes per year in the study area.

One of the options to reduce carbon emission is to replace the existing fluorescent tube lights in the buildings with LED which can bring about a considerable reduction in CO₂ emission as well as cost. Table 1 reveals that the carbon emission from FTL and LED was 46.342 and 20.966 tonnes per year respectively. It is evident that there is a difference in emission reduction of 25.376 tonnes of CO₂ per year. The unit saved by replacing FTL to LED is 29853.750 kWh per year. It is interpreted that out of 29 buildings only 10 buildings used diesel generator and the overall diesel consumption per year was 5340 l, with equivalent CO₂ emission of 14.17 tonnes per year. Fig.2 reveals that the maximum emission was found in Physical Sciences and Information Technology Department. The total population in the study area was 1428 and the CO₂ emitted from the population in different buildings was 78.72 tonnes per year. Fig. 3 represents the CO₂ emission plotted against population in the buildings. It is

Fig.1: Equivalent carbon dioxide emission from power use.

Fig. 2: Equivalent carbon dioxide emission from diesel generators.

Fig. 3: Equivalent carbon dioxide emission from human population.

inferred that as the population increased the CO₂ emission also increased drastically and vice-versa.

Vehicles were categorized according to their type and the average values of petrol and diesel consumed, mileage, distance travelled and CO₂ emitted is presented in Fig. 4. The maximum CO₂ emission was observed in bus (1.671 tonne per year) and the minimum for two wheelers between 110 to 200 CC (0.080 tonnes per year). The total Carbon emission from transport was estimated to be 36.43 tonnes per year. The total contribution from different sectors to carbon emission is given in Fig. 5. It can be inferred that emission from power use was higher in comparison with emission from transport, human population and diesel generators. This is in accordance with the study carried out by Letete *et al.* (2011). Letete *et al.* (2011) who had estimated carbon footprint for the year 2007 at University of Cape Town's and inferred that Electricity consumption alone contributed about 80%

of all the emissions associated with university activities. A multiple linear regression equation was fitted by considering CO₂ emitted as the dependant variable and electrical units consumed, human population, transport (mileage and distanced travelled) and diesel as independent variables and the results are presented in Table 2.

The mean units consumed, human population, mileage, distanced travelled, and diesel consumed was found to be 1180.000 (kWh per year), 47.600, 41.000 (km i⁻¹), 2625.980 (km per year), 534.000 (L per year) with the standard deviation values of 7361.908, 95.772, 16.279, 1725.069, 244.049 units respectively. Four regression equations were fitted by taking units, consumed, human population, transport (mileage and distanced travelled) and diesel as independent variables and CO₂ emitted as dependent variable. The results showed that for a unit increase in units consumed, CO₂ increased to 0.001 units and the following equation is CO₂ emitted tonnes per year = -0.002 +

Fig. 4: Equivalent carbon dioxide emission from vehicular transport.

Fig. 5: Overall carbon dioxide emission from different sources.

0.001 units consumed per year For a unit increase in human population, CO₂ emission increased to 0.055 units CO₂ emitted tonnes per year = $-8.210E-16 + 0.055$ number of persons.

The results of regression analysis with mileage and distance travelled as independent variables showed that for a unit increase in the distance travelled the CO₂ emission increased to $8.562E-5$ and for a unit increase in the mileage the CO₂ emission decreased to 0.011 units. CO₂ emitted tonnes per year = $0.402 - 0.011$ mileage km l⁻¹ + $8.562E-5$ distance travelled per year For a unit increase in the diesel consumed by diesel generator, the CO₂ emission increased to 0.3 units CO₂ emitted tonnes per year =

$8.882E-16 + 0.003$ diesel consumed.

It was inferred that emission from power use (69%) was greater in comparison with emission from transport (9%), human population (19%) and diesel generators (3%). Potential actions to mitigate emissions include increased energy conservation and efficiency, employment of renewable energy systems and use of alternative fuels. Other greenhouse gas mitigation options include sequestration of CO₂ in biologic sinks such as plant biomass. The problem of anthropogenic CO₂ accumulation in the atmosphere can be addressed either by reducing CO₂ emission or by developing carbon sinks.

Table 1: Comparison of fluorescent tube light and LED

Buildings	Electrical units used (kWh per year)		CO ₂ emitted (tonnes per year)		Units saved (kWh per year)	CO ₂ emission reduction (tonnes per year)
	FTL	LED	FTL	LED		
Mushroom Research Training Centre	1360.800	612.360	1.157	0.521	748.440	0.636
Agro Climate Research Center (ACRC) & Press	4859.400	2186.730	4.130	1.859	2672.670	2.272
Community Radio Station	1050.000	472.500	0.893	0.402	577.500	0.491
Directorate of Open and Distance Learning (ODL)	1890.000	850.500	1.607	0.723	1039.500	0.884
Agricultural Technology Information Center (ATIC)	1008.000	453.600	0.857	0.386	554.400	0.471
Sustainable Laboratory	252.000	113.400	0.214	0.096	138.600	0.118
Department of Sustainable Organic Agriculture	1965.600	982.800	1.671	0.835	982.800	0.835
Technology Park 2	134.400	60.480	0.114	0.051	73.920	0.063
Technology Park 3	134.400	60.490	0.114	0.051	73.910	0.063
Technology Park 4	134.400	60.500	0.114	0.051	73.900	0.063
Technology Park 6	134.400	60.510	0.114	0.051	73.890	0.063
Physical Sciences and Information Technology	6678.000	3005.100	5.676	2.554	3672.900	3.122
Agricultural Engineering College & Research Institute	9777.600	4399.920	8.311	3.740	5377.680	4.571
Water Technology Center (WTC)	1512.000	680.400	1.285	0.578	831.600	0.707
Nematology	1722.000	774.900	1.464	0.659	947.100	0.805
Pathology	6115.200	2751.840	5.198	2.339	3363.360	2.859
Directorate of Agri Business Development	3024.000	1360.800	2.570	1.157	1663.200	1.414
Technology Business Incubator	2419.200	1088.640	2.056	0.925	1330.560	1.131
Bioenergy Workshop	1932.000	869.400	1.642	0.739	1062.600	0.903
Food and Agricultural Pprocess Engineering Laboratory	1386.000	623.700	1.178	0.530	762.300	0.648
Farm Machinery Workshop	1764.000	793.800	1.499	0.675	970.200	0.825
Soil and Water Conservation Workshop	2469.600	1111.320	2.099	0.945	1358.280	1.155
Radio Isotope Laboratory	1201.200	540.540	1.021	0.459	660.660	0.562
Pesticide Toxicology Laboratory I	714.000	321.300	0.607	0.273	392.700	0.334
Pesticide toxicology laboratory II	201.600	90.720	0.171	0.077	110.880	0.094
Crop Physiology	680.400	340.200	0.578	0.289	340.200	0.289
Total	54520.200	24666.450	46.342	20.966	29853.750	25.376

Table 2: Regression analysis for overall carbon emission

Model	Electricity consumed kWh per year	Human Population/ day	Transport		Diesel generator
			Mileage km l ⁻¹	Distance travelled (km per year)	
Mean	1180.000	47.600	41.000	2625.98	534.000
Standard deviation	7361.908	95.772	16.279	1725.069	244.049
Constant	0.002	8.210E-16	0.402		8.88E-16
Regression co-efficient values	0.001	0.055	0.011	8.56E-05	0.003

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Add-on Information

Authors' contribution: C.G. Karishma: Conceived and designed

the analysis data collection, performed the analysis and wrote the paper; **S.V. Kottiswaran:** Technical guidance, supervised the research and contributed to final manuscript; **A. Balasubramanian:** Technical guidance, supervised the research and contributed to the final manuscript; **B. Kannan:** Technical guidance, supervised the research and contributed to the final manuscript.

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