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Carbon Footprint of crops in Haryana

AJAY SINGH[1], NARESH KUMAR*, KIRTI SHARMA[2], GURNAM SINGH AND VIPIN ARYA[3]

KVK, CCS Haryana Agricultural University, Kaithal-136 027 (Haryana), India
**(e-mail: nareshsagar07@hau.ac.in; Mobile: 95181 82995)*

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ABSTRACT

CFA and CFN_2O contents in the wheat were estimated to be 1976.08 and 1544.54 kg CO_2/ha[1]. The maximum carbon footprint emissions were resulted from nitrogen (58%) followed by phosphorus (20.53%) and energy (22.45%). CFA and CFN_2O contents in the cotton were estimated to be 1968.20 and 1481.39 kg CO_2/ha. The maximum carbon footprint emissions were from nitrogen (53.84%) followed by phosphorus (20.76%) and energy (18.34%). CFA and CFN_2O content in the bajra were estimated to be 1436.79 and 1047.37 kg CO_2/ha. The maximum carbon footprint emissions were resulted from nitrogen (51.83%) followed by phosphorus (27.52%) and energy (19.76%). CFA and CFN_2O contents in the mustard were estimated to be 1405.55 and 1048.53 kg CO_2/ha. The maximum carbon footprint emissions were resulted from nitrogen (49.69%) followed by phosphorus (26.53%) and energy (22.45%). CFA and CFN_2O contents in the sugarcane were estimated to be 8692.98 and 3400.42

Key words: Carbon footprint, emissions, CFA, CFN_2O

INTRODUCTION

Carbon footprint refers to the cumulative effect of all the greenhouse gases (carbon dioxide, nitrous oxide and methane) as a consequence of all activities. The total Global Carbon emissions stand at 54 billion tonnes of carbon dioxide equivalent, wherein 17 billion tonnes (31%) come from the agro-food system, and 37 billion tonnes (69%) contribute from the non agriculture sector (Jaiswal and Agrawal, 2020). For the agricultural sector, crop and animal production leads to emission of 7.2 billion tonnes. Pre-and post-production emissions contribute 5.8 billion tonnes, whereas deforestation, crop residue burning and agricultural drainage activities lead to emission of 4 billion tonnes carbon dioxide equivalent. The main impact caused by food production in the world affects both global warming as well as freshwater consumption. A food production giant and agrarian economy in the world, and the third-largest emitter of global greenhouse gas emission, is "India" after China and USA. Recent estimates report that global food production must increase by 70% to meet the projected food demand of the estimated 9 billion global populations by 2050. With a population of <"1.3 billion, it is evident that the food system in India will be central to the global challenge of providing sufficient nutritious food while minimizing GHG emissions. However, given the increasing population and shifting dietary patterns, GHG emissions from agricultural production in India are expected to change (Vetter *et al*., 2017). With the steadily increasing population in India, the country is faced with the twin challenges of increasing food production as well as reducing the associated GHG emissions. The carbon footprint (CF), which is used as an indicator of the effect of activities of the human species on the environment, is an essential tool in the evaluation of natural resource usage and subsequent anthropogenic emissions (Sah and Devakumar, 2018). CF could be used as an indicator in formulating strategies in the quest to mitigate the associated dangers.

METHODOLOGY

The purpose of the study was to analyze the differences in the carbon footprint of different agro climates in the state of Haryana. Therefore, the data collected were of the

[1]Maharishi Markandeshwar (Deemed to be university) Mullana, Ambala-133 203 (Haryana), India.
[2]School of Allied Health Sciences, CGC University, Mohali-140 307 (Punjab), India.
[3]School of Agricultural Sciences, Nagaland University, Nagaland-797 106, India.

primary nature and focused upon identification of district under each agro climate. This required the use of purposive sampling techniques involving interactions with the farmers. Data were also obtained through the use of questionnaires and were taken through personal interviews in the month of August 2023. Five crops, namely, wheat and cotton from Sirsa, mustard from Bhiwani, bajra from Mahendergarh and sugarcane from the district of Yamunanagar were taken considering the largest area under these crops in the respective districts. After choosing the districts, 10 farmers were chosen randomly. Thus, a total of 50 farmers were chosen for a thorough analysis in order to form a conclusion.

The necessary primary data in relation to the specific objectives of the study were collected in August 2023. The details collected from a sample of farmers included chemical fertilizers, plant protection chemicals, diesel, electricity, seeds, as well as produce. To understand the differences in carbon footprints in different agro climatic regions, the necessary primary data were collected for a representative district in a particular agro climatic region (Table 1).

Table 1. Emission factors for various parameters

S. No	Inputs	Unit	Emission factor
1.	N	Kg	7.41
2.	P	-do-	6.76
3.	K	-do-	0.31
4.	Zn	-do-	3
5.	Sulphur	-do-	0.21
6.	Weedicide	-do-	9.95
7.	Insecticide	-do-	15.2
8.	Fungicide	-do-	10.2
9.	Diesel	Liter	2.75
10.	Electricity	Kwh	0.97
11.	Seed	kg	0.19

The calculation of the carbon footprint included individual inputs used from seeding to harvesting stages in crop production. CO_2, CH_4 and N_2O emissions were measured by converting them into CO_2 eq, using the latest GWP coefficients from the IPCC for a 100-year time frame: 1 for CO_2, 28 for CH_4 and 265 for N_2O. Carbon footprint was considered with two functional units such as carbon footprint per unit area, expressed as tons CO_2-equivalents per hectare (t CO_2 eq/ha), and carbon footprint per unit weight, expressed as tonnes CO_2-equivalents per tonne of grain (t CO_2eq/t). The first step was to calculate the greenhouse gas emissions related to seeds, agrochemicals, electricity and farm machinery.

$$CFA = \Sigma\,(Ai_{*}EFi)$$

Where, CFA was the total GHG emission per hectare caused by activity/input i in t CO_2-eq, Ai–activity data/quantity of input, i of agricultural activity/input [fertilizer (kg N/ha; kg P_2O_5/ha), pesticide (kg/ha), diesel (l/ha), energy (kW.h/ha)], and EF was the emission factor of process, i in t CO_2-eq per unit mass. The energy consumption for irrigation by each farmer (Ec) - in kW.h - was computed using the following expression:

$$Ec = hp * n * d * Fc$$

The value of hp was energy rating of pump (in horsepower), n was the number of pumps, d value was approximate time of operation of pump in whole growing season in hours, Fc was the conversion factor of horsepower-hour (hp.h) to kW.h which was 0.75. The values of hp, n and d were taken from survey.

The direct and indirect values of N_2O emissions were calculated using the following equations:

$$N_2O \text{ total} = N_2O\text{direct} + N2O \text{ indirect}$$

$$N_2O \text{ direct} = (FSN + FCR + FON) * EF1 * {}^{\gamma}N_2O$$

$$N_2O \text{ indirect} = N_2O_{(ATD)} + N_2O_{(L)}$$

$$N_2O_{(ATD)} = (FSN * EF4 * Fras_{GASF} + FON * EF4 * Fras_{GASM}) * {}^{\gamma}N_2O$$

$$N_2O_{(L)} = (FSN + FON + FCR)_{*}EF5_{*}Fras_{LEACHING*}{}^{\gamma}N_2O$$

Where, FSN, FON and FCR were the quantity of nitrogen from synthetic fertilizers, animal manure and both above-ground and below-ground crop residues, added to the soil, respectively (kg N/crop season). N_2O(ATD) and N_2O(L) were N_2O release of nitrogen through atmospheric deposition, as well as nitrogen leaching and runoff resulting from managed soil additions, respectively. EF1 was the emission factor for N_2O emissions from N inputs (kg N/input), EF4 and EF5 were the emission factors for N_2O release from volatilization, as well as leaching and runoff of nitrogen from both fertilizer and manure, respectively. FrasGASF, FrasGASM and FrasLEACHING were the proportionate elements of atmospheric deposition of nitrogen volatilized from mineral fertilizer, organic matter and leaching from managed soil, respectively; cN_2O (44/28) was the mass conversion factor for N_2 to N_2O.

$$CFN_2O = N_2Ototal*265$$

Where, CF = GHG emission due to N_2O and 265= GWP of N_2O.

The computation of methane emissions directly resulting from submerged paddy cultivation was obtained using the following equation.

$$CF_{CH4} = EF_{d*}t_*A_*28$$

Where, EFd was the Adjusted daily emission factor for specific harvested areas, t was time in days for crop growth, A was area harvested in hectares (Ha) and 28 was GWP of CH4

$$EFd = EFc*SFw*SFp*SFo$$

Where, EFc was the standard emission factor for fields that were constantly flooded without organic fertilizer, SFw and SFp were the adjustment factors to take into account the differences in water management regimes in the growing season and preceding growing season, respectively. SFo was the adjustment factor to take into account the difference in the kind or amount of applied organic fertilizer. EFc as well as other scaling factors are given in Supplementary Table 1. SFo was established individually for each farmer using the formula:

$$SFo = (1 + \Sigma_i ROAi*CFOAi)^{0.59}$$

Where, ROAi = Rate of application of organic amendment in t/ha, CFOAi = Conversion factor of organic amendment I, CFOAi was assumed to be 0.29 for straw incorporation for straw incorporated for more than 30 days, and 0.14 for farm yard manure incorporation (Kong *et al.*, 2022).

The GHG emission due to crop burning was estimated by using the following equation:

$$CFB = Y*Rf*DMf*Bf*Of*Bf$$

Where, Y = Crop yield obtained from survey, Rf = Residue to crop ratio, DMf = Dry matter fraction, Bf = Fraction burnt and Of = Fraction oxidized. EF = Emission factors for CO_2, CH_4 and N_2O released during burning.

Lastly, the carbon footprint per unit area (in kg CO_2 eq./ha) for each farmer was calculated using the formula:

$$CF_{per\ unit\ area} = CFA + CFN_2O + CFCH_4 + CFB$$

The carbon footprint per unit weight (inkgCO_2eq/kg) for each famer was calculated as:

$$CF_{per\ unit\ weight} = \frac{CFPerunitarea}{Yield}$$

RESULTS AND DISCUSSION

The highest resource consuming crop was sugarcane as sugarcane required a huge amount of chemical fertilizers, plant protection chemicals and electricity (Table 3). Compared to other crops, sugarcane required more seeds than other four crops. Among other crops, wheat used more chemical fertilizers and energy than other crops. Among plant protection chemicals cotton used more than bajra and mustard. The requirement of seeds was more in sugarcane than other four crops wheat, bajra, cotton, and mustard (Table 2).

From the Table 3, it was found that per hectare carbon emissions were highest in sugarcane (12093.31 kgCO_2) followed by wheat (3520.62 kgCO_2), cotton (3461.18 kgCO_2), bajra (2484.17 kgCO_2) and mustard (2454.08 kgCO_2). Carbon emissions per unit weight were highest in cotton (194.99 kgCO_2), followed by bajra (114.39 kgCO_2).

Fig. 1 shows that per hectare total percentage contribution of different sources to the carbon footprint of wheat was highest due to consumption of chemical fertilizers, which was 79.57%. Similarly, in second position, diesel contributed 13.64% carbon emissions (Kashyap and Agarwal, 2021). All other remaining inputs contributed less than 10% carbon emissions. Electricity contributed 4.05%, followed by plant protection chemicals at 1.43% and then seed at 1.32%.

The bar chart (Fig. 2) indicated that per hectare total percentage contribution of various sources to carbon footprint in cotton was highest for the use of chemical fertilizers (76.59%). Secondly, the diesel contributed (15.19%) to carbon emissions. All other inputs contributed less than 10% to carbon emissions. This was followed by plant protection chemicals (5.05%), electricity (3.15%) and seed (0.02%).

Fig. 3 reveals that per hectare total percentage contribution of different sources to the carbon footprint of mustard was found maximum due to consumption of chemical fertilizers, which was about 76.32%. Similarly, diesel occupied the second position with a contribution of about 22.45% in carbon emissions. All other remaining inputs contributed less than 10% carbon emissions. This included plant

Table 2. Data collected on various parameters in different crops in Haryana (per ha)

S. No.	Inputs	Units	Districts				
			Sirsa	Sirsa	Bhiwani	Mahendergarh	Yamunanagar
			Wheat	Cotton	Mustard	Bajra	Sugarcane
1.	N	Kg	155	143.75	94.25	100.50	265
2.	P	-do-	60	60.75	55.37	58.50	103.25
3.	K	-do-	10	30	0	0	52.50
4.	Zn	-do-	5	10	0	0	9
5.	Sulphur	-do-	0	0	0	0	0
6.	Weedicide	-do-	0.40	2.13	0	1.25	4
7.	Insecticide	-do-	0.90	4.01	1	0.25	26
8.	Fungicide	-do-	1	1	2.50	0	6.25
9.	Diesel	Liter	98	109.25	114.75	65.50	100.75
10.	Electricity	Kwh	82.50	64.25	0	107	3654
11.	Seed	kg	137.50	2.25	2	4.37	8000
12.	Yield	Qtl.	50.50	17.75	21.50	21.75	840

Table 3. Carbon footprint emissions in different crops in Haryana ($KgCO_2$/ha)

S. No.	Inputs/crops	Districts				
		Sirsa	Sirsa	Bhiwani	Mahendergarh	Yamunanagar
		Wheat	Cotton	Mustard	Bajra	Sugarcane
1.	N	1148.55	1065.18	698.39	744.70	1963.65
2.	P	405.60	410.67	374.33	395.46	697.97
3.	K	3.10	9.30	0	0	16.27
4.	Zn	15.00	30.00	0	0	27.00
5.	Sulphur	0	0	0	0	0
6.	Weedicide	16.16	21.26	0	10.74	39.80
7.	Insecticide	4.37	61.56	11.02	1.14	395.20
8.	Fungicide	7.65	17.20	5.86	0	211.65
9.	Diesel	269.50	300.43	315.56	180.12	277.06
10.	Electricity	80.02	62.32	0	103.79	3544.38
11.	Seed	26.12	0.42	0.38	0.83	1520.00
CFA		1976.08	1978.38	1405.55	1436.79	8692.98
CFN_2O		1544.54	1482.79	1048.53	1047.37	3400.32
CE/ha		3520.62	3461.18	2454.08	2484.17	12093.31
CE/q		69.71	194.99	114.14	114.21	14.39

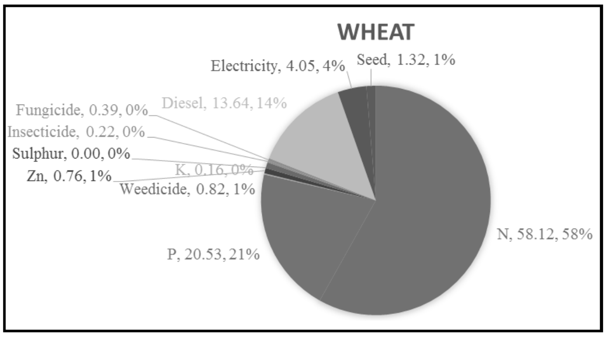

Fig. 1. Percentage contribution of different sources to the CF of wheat.

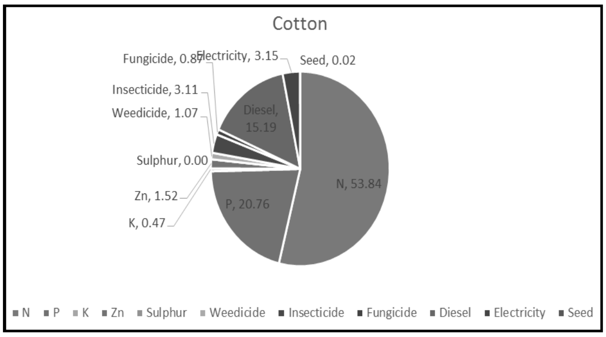

Fig. 2. Proportional contribution of various sources to the carbon footprint (CF) of cotton.

protection chemicals contributing about 1.20% and then seed about 0.03%.

The graph displayed that per hectare total percentage share of various sources to carbon footprint of bajra was maximum due to use of chemical fertilizers (79.35%). After that at second position, carbon emissions were due to use of diesel (12.54%). All other remaining sources were giving lower carbon emissions below 10% (Fig. 4). The sources in this respect were electricity (7.22%), plant protection chemicals (0.83%) and seed (0.06%).

The per hectare total contribution percentage of different sources to the carbon footprint of wheat was found maximum due to the consumption of electricity (40.77%). Similarly,

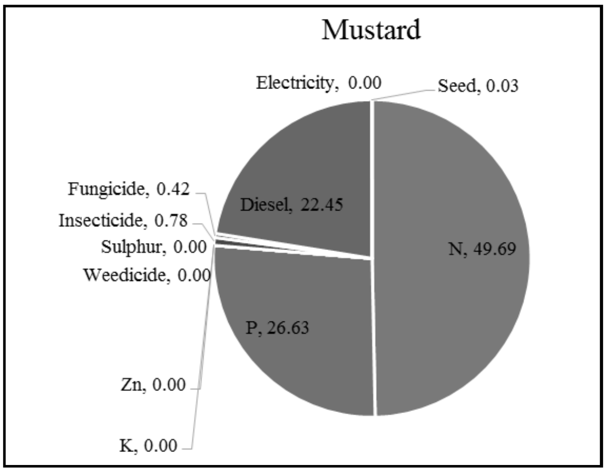

Fig. 3. Percentage distribution of various sources contributing to the carbon footprint (CF) of mustard.

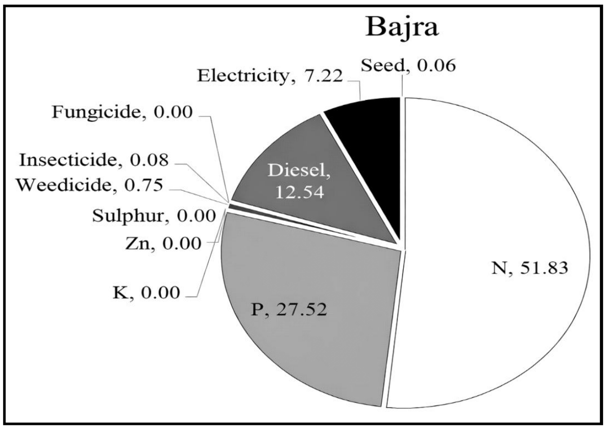

Fig. 4. Percentage breakdown of different sources contributing to the carbon footprint (CF) of bajra.

in the second position, chemical fertilizers contributed to carbon emissions (31.12%). All other remaining inputs contributed less than 10% carbon emissions except for seed, which contributed to 17.49% (Fig. 5). Plant protection chemicals contributed to 7.44% and followed by diesel to 3.19%.

CONCLUSION

The results of studying the carbon footprint of wheat, cotton, mustard, bajra and sugarcane in Haryana based on three agro climatic regions using questionnaires revealed variations in the carbon footprint of various crops at significant levels, where nitrogen fertilizer and diesel use were considered key factors responsible for such variations. The variation in the carbon footprint among various crops was found to be high in sugarcane as opposed to other crops. The results showed

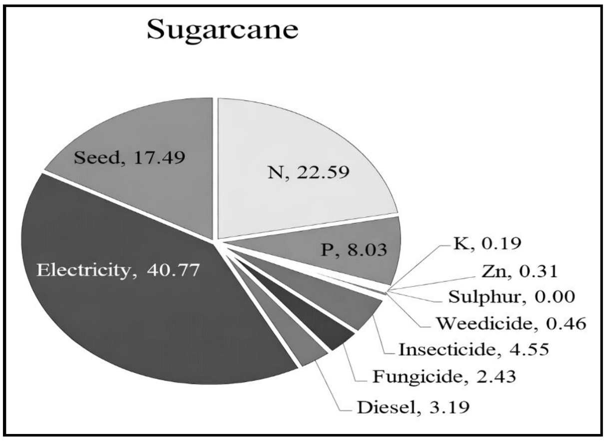

Fig. 5. Percentage distribution of various sources contributing to the carbon footprint (CF) of sugarcane.

high emissions in sugarcane, followed by wheat, cotton, mustard and bajra. On the basis of emissions in terms of weight, cotton showed high emissions, followed by bajra, mustard, wheat and sugarcane, respectively. The variations in the carbon footprint of various crops were based on variations in resource use.

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