Progressive Agriculture 27 (2): 162-167, 2016 ISSN: 1017 - 8139

Progressive Agriculture
Journal homepage:http://www.banglajol.info/index.php/PA

Carbon footprint of lentil in old Brahmaputra floodplain soil

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Abstract

Crop production has contributed significantly to global carbon footprint (CF). Characterizing the carbon footprint of agricultural production offers key information for achieving low carbon agriculture. Bangladesh has struggled for long and worked hard for increasing food production capacity for its large growing population. It is necessary to choose the crops and management practices which have low CF to maintain a win-win situation between food production and greenhouse gas (GHG) emissions. However, the CF of Bangladesh's crop production has not yet been assessed. Therefore, this study was conducted to estimate the CF of lentil as one of the major legumes cultivated in Bangladesh. The crop was cultivated at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU) Farm, Mymensingh i.e. Agro-ecological zone (AEZ 9) during November, 2013 to April, 2014 by following standard management practices. The Carbon footprint was calculated by using the collected emission factors from literature as default values for each input and operation used for the production of crops as per guideline of ISO (2006) and IPCC (2006). The GHG emissions in the crop fields are taken from the studies of Pathak and Aggarwal (2012). The yield of lentil was 0.90 t ha^{-1} with a CF of 406 kg CO_2-equivalentst^{-1} of lentil. Direct and indirect GHG emissions singly contributed the half of CF accounting 52.54% of total CF. The contribution of fertilizer, irrigation, machinery and labor inputs to the overall carbon footprint were 23.16%, 15.97%, 1.26% and 7.06%, respectively. Among the fertilizers, nitrogenous fertilizer was dominant and singly contributed to 70% of fertilizer CF. However, for developing best management practices for climate change mitigation in crop production of Bangladesh, further studies of soil and regional specific CFs of lentil are needed.

Key words: Carbon footprint, jentil, greenhouse gas, indo gangetic plain

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Introduction

Carbon footprint is one of the most modern terms for estimating global warming potential (GWP) and refers to the total greenhouse gas (GHG) emissions associated with a product or service. Emissions of different individual greenhouses gases are converted into GWP and articulated in the common unit of CO_2-equivalents. Recently, CF assessment of products especially in agricultural products has gained much attention and popularity in international society in the fight with climate change. Furthermore, because of its ease of assigning information about the GHG intensity of variety of products and activities among the general public, CF also offers a simple mode of communication about climate accountability of different entities between people, policy makers and scientists. Scientific analyses of CF are being performed, mainly for consumer. Industrialization, rising population and consequently energy use have led to a 10-fold increase in the worlds energy budget since the beginning of the twentieth century (Boyle, 2004). Atmospheric CO_2 levels have increased from a pre-industrial value of around 280 ppm to 407.42 ppm as of April 2016 and rose by 2.36 ppm/year during 2010-2016 and faster since then (NOAA, 2016). Concerns about GHG emissions and their effect on global warming have inspired the quantification of the carbon footprint. For identifying and developing low carbon options and measures for reducing GHG emissions in production, CF assessment has been widely accepted and applied in bioenergy production (Rowe et al., 2009), industry enterprises (Wiedema et al., 2008), as well as household activities (Kenny and Gray, 2009). World agriculture has been considered as one of the biggest emitters of GHGs globally. Also with the development of modern agriculture and agricultural industrialization it had moved towards higher-energy and higher carbon-input systems (diesel, chemical fertilizers, pesticides etc.). Covering about 35% of the land area, agriculture accounts for nearly 13.5% of the total global anthropogenic GHG emissions, contributing to 25, 50, and 70 % of CO_2, CH_4, and N_2O, respectively (Montzka et al., 2011).

Lentil (*Lens culinaris*) is one of the most important pulse crops in south Asia. Pulses are the richest sources of plant proteins and provide around 10% of the total dietary requirements of the proteins globally. Globally, it is cultivated as a rainfed crop on 3.85 million hectares (mha) area with 3.59 million tonnes (mt) production (Erskine et al., 2011).The major geographical regions of lentil production are South Asia and China (44.3%), North America (41%), Central and West Asia and North Africa i.e. CWANA (6.7%), Sub-Saharan Africa (3.5%) and Australia (2.5%) (Kumar et al., 2013). Although in South Asia especially at Indo Gangetic plains (part of Bangladesh, India, Pakistan and Nepal) rice-wheat cropping pattern covers about 13.5 Mha of land (Gupta and Seth, 2007), however, pulses are vital components in diversification of predominant rice-based cropping system in this region. Lentil is the second most important pulse crop in terms of area (205,000 acres) and production (80,000 t), but still ranks the highest in consumer preference and total consumption (BBS, 2011). Characterizing the carbon footprint (CF) of agricultural production offers key information for pursuing low carbon agriculture and food consumption. In an effort to quantify the carbon costs from material and management inputs using survey data from Scottish farms, Hillier et al., (2009) reported values of CF for major crops from UK. They found that over 75% of the total emissions in crop production resulted from nitrogen fertilizer use while no significant differences in carbon input between different farming management practices. Legume-based cropping systems will not only reduce nitrogen losses, but they may also increase the proportion of crop residue carbon that is sequestered in stable soil organic matter (Drinkwater et al. 1998). Gan et al. (, 2011) stated that durum preceded by a biological N-fixing crop lentil, the previous year lowered its carbon footprint by 17% compared with durum preceded by a cereal crop. However, only very limited research has been done to quantify the CF of leguminous crops. Therefore, the aim of this study was to quantify CF of lentil.

Methodology

The experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU) Farm, Mymensingh (24^0 43.407/ N, 90^0 26.22/ E) during November, 2013 to April, 2014 on a medium high land. Characteristically, the experimental soil is a Non-calcareous Dark Grey Floodplain soil and is under Sonatala' soil series having silt loam (12% sand, 75% silt and 13% clay) texture with a bulk density of 1.45 Mg m^{-3}. Agro-ecologically, the soil belongs to AEZ 9 i.e Old Brahmaputra Floodplain. The experimental area has sub-tropical humid climate and is characterized by hot and humid summers and cold winters with an annual mean temperature of 25.8°C and rainfall of 2427 mm (BMD, 2015). BARI Masur-6 was the test crop which is one of the modern varieties of lentil developed by Bangladesh Agricultural Research Institute (BARI), Gazipur which was released by National Seed Board (NSB) in 2006. Seeding rate was 30 kg ha^{-1} which is sown in three replicated plots. Seeds were sown on 24 November, 2013 whereas harvested on 25 April, 2014. The rate of fertilizers were 34, 100, 66 $kgha^{-1}$ for Urea, TSP and MOP respectively (15kg N, 33 kg K and 20 kg P).

Carbon cost counting

Carbon cost counting was performed using emission factors from the literature as default values basically following Hillier et al., (2009). In this counting, the total carbon cost was assumed as the sum of emissions due to the energy consumption associated with mechanical operations and with chemical inputs as well as direct nitrous oxide emissions due to N fertilizer application.

Carbon cost for chemical inputs (Ef)

This is the sum of C cost of manure and fertilizers, pesticides and herbicides, counted by the following equation:

$$Ef = \Sigma_i U_{fi\ -\ CO2} \times W_{fi}$$

Where, $U_{fi\ -\ CO2}$ is the quantity in ton of carbon dioxide emissions when producing 1 ton of chemical material input. i. W_{fi} was the quantity of chemical material in unit area in kg/ha. The Uf figures used were 1.74 t C t^{-1}, 165.09 and 120.28 kgCMg^{-1}foraddition of N, P and K fertilizer, respectively (Hillier et al., 2009).

Carbon cost for irrigation (Eir)

This was estimated by the following equation:

$$E_{ir} = V_{ir\text{-}CO2} \times w \times h \times n$$

where, $V_{ir\text{-}CO2}$ is the conversion factor of carbon emission intensity of electricity used in motor; W is motor power used for pumping water (kw); h is the working hours of the motor for each irrigation event; n is the times of irrigation event in a whole production cycle.

Carbon cost for machinery use (Em)

The calculation was done by the following equation:

$$E_m = V_{m\text{-}CO2} \times L$$

Where, $V_{m\ -\ CO2}$ is the conversion factor of carbon emission intensity of diesel oil per liter; L is the oil consumption rate in L that the machinery used in each performance.

Carbon cost for labor input (Cl)

This was estimated by using the equation given below:

$$Cl = V_{CO2} \times Nl$$

Where, V_{CO2} is the carbon dioxide respired by an adult per day (0.51kg/12 hour); Nl is the total numbers of labor input in the whole cycle of crop production. For soil preparation operations all figures were taken directly from the estimates per hectare on average.

Carbon cost from GHG emissions

GHG emissions are a major contributor to the carbon footprint. The basic equation to estimate GHG emissions from crop cultivation was based on IPCC (2006). The GHG emission values are taken from the studies of Pathak (2012) due to absence of resourceful data in the context of Bangladesh. N_2O emission for lentil was 0.628kgha^{-1}. Following equations are being used to calculate C cost of GHG emissions. C cost for NO_2 emission (kg ha^{-1}) =N_2O-N emission (kg ha^{-1})*1.57*298.

Data processing

The carbon footprint was calculated by the sum of the all above items expressed in unit of area for the production (kg CO_2 equivalent (E)ha ^{1}) and unit of yield of the production (kg CO_2E t ^{1}), respectively.

Results and Discussions

Estimated total carbon footprint was 406 kg CO_2 E t ^{1} of lentil (Table 1). This data were bit different from the reported value of 270 kg CO_2 E t ^{1} of grain by Gan et al., 2011 in a pulse–pulse–durum system. The difference might be due to variation in crop selection and inputs. Greenhouse gas emissions were the highest sources of carbon footprint in lentil. GHG emissions singly contributed 187.14 kg ha^{-1} CO_2 equivalent carbon accounting 52.5% of the total carbon footprint (Table 1 and Figure 1).

Total C cost for fertilizers was found 82.5 kg ha^{-1} accounting 23% of the total footprint (Figure 1). This is in line with Moraditochaee et al., 2014 who stated that fertilizers alone contributed 24.29% of the total emission. Among the other field operations, irrigation contributed 56.9 kg ha^{-1} CO_2 E accounting 16% of the total carbon footprint. Sloggett et al. (1992) estimated that 23% of the on-farm energy use for crop production in the US was for on-farm pumping. Dvoskin et al. (1976) assessed fuel consumption for lifting irrigation water in several regions of the western US. They also reported that carbon emission ranged from 7.2 to 425.1 kg CO_2E ha^{-1} for 25 cm of irrigation and from 53.0 to 850.2 kg

CO_2E ha^{-1} for 50 cm of irrigation. Follett (2001) estimated C emission by pump irrigation at 150–200 kg CO_2E $ha^{-1}yr^{-1}$ depending on the source of energy. West and Marland (2002) estimated emission by irrigation at 125– 285 kg CO_2E ha-1yr-1. In comparison, irrigation of winter wheat in Punjab, India, by tube well was estimated to emit 3–25 kg CO_2E ha-1 (Singh et al., 1999).

Table 1. Carbon cost for different inputs and yield

Inputs	Amount
Total C cost for fertilizers(kg ha^{-1})	82.5
C cost for irrigation (kg ha^{-1})	56.9
C cost for machinery(kg ha^{-1})	4.49
C cost for labour inputs (kg ha^{-1})	25.16
C cost for total GHG emission (kg ha^{-1})	187.14
Total carbon footprint (kg/ha)	356.18
Yield (t ha^{-1})	0.90
Total C cost (kg t^{-1})	406.28

The contribution of machinery in carbon footprint of lentil is very low compare to other field operations (4.49 kg ha-1 CO_2) and 25.16 accounting 1.3% of total carbon footprint of lentil. This is in line with Farag et al. (2013) who stated that farm machineries contributing about 1% of the total carbon footprint. Similar data was found by Ologun et al. (2014) who reported that farm machineries contributing about 2% of the total carbon footprint.

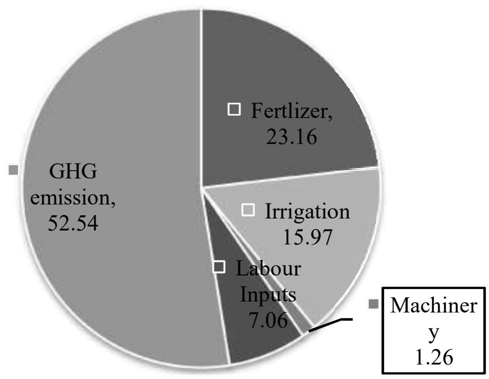

Figure 1. Contributions of different field operations to carbon footprint of lentil.

Among the three fertilizers, N fertilizer was the highest source of carbon footprint (Figure 2). N fertilizer individually contributed 58 kg ha^{-1} CO_2 equivalent carbon accounting 70% of the carbon footprint caused by fertilizer application in lentil (Figure 2).

Table 2. Different inputs for lentil

Irrigation inputs			Machinery Inputs	Total labor inputs	Fertilizer inputs		
Motor power, W(kw)	Working hour (h)	No. of irrigation	Oil Consumption rate (L)		Urea ($Kgha^{-1}$)	TSP ($Kgha^{-1}$)	MoP ($Kgha^{-1}$)
22.05	3	2	6.3	72	34	100	66

This result was similar to Yan and Yang (2010) who found that on average to the total emission from fertilizers, 76% was contributed by N fertilizer use. Application of N fertilizer induced N_2Oemission under dry land condition resulting higher GHG emission. In addition, N_2O has a GWP of 298 times higher than that of CO_2 (time scale 100 y) (IPCC, 2007). In addition, N fertilizers increase the decomposition rate of organic matter (Abro et al. 2011, Potthoff et al. 2005, Chen et al. 2007) which ultimately boost up CO_2 emission (Abro et al. 2011).

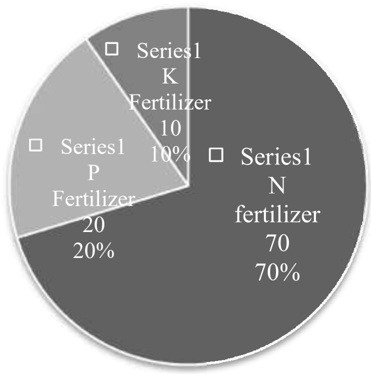

Figure 2. Contribution of different fertilizers to fertilizer carbon footprint of lentil.

This result may suggest that mitigation of greenhouse gases emission from fertilizer use may be focused on reducing N fertilizer use though N fertilization in much excess had been already in debt (Zhang et al., 2000). Contribution of other fertilizers in carbon footprint of lentil was lower than N fertilizer. P fertilizer and K fertilizer only contributed 20% and 10% of fertilizer carbon footprint, respectively. Application of Rhizobium biofertilizer could be a possible option to reduce N fertilizer application of lentil as well as GHG emission.

Potential Compounding factors of CF estimation

Changes in soil organic carbon stock was not included in this study considering it was negligible and immeasurable. Lentil was cultivated only for three month and this time period is not sufficient to study the changes in soil organic carbon stock as it requires long period to study measurable change. Other limitation was the use of N_2O emission data from Indian agriculture as there is no available N_2O emission data for lentil on Bangladesh context.

Conclusion

N fertilizer was the major contributor of CF in Lentil through GHG emission. Therefore altering the use N fertilizer may reduce the CF as well as GHG emission. Experimental measured N_2O emission could further improve the reliability of CF in Lentil. Furthermore, studies of soil and region specific CFs of lentil including Rhizobium inoculation are needed to make a robust conclusion.

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