Chapter 7
Greenhouse Gas Emissions from Selected Cropping Patterns in Bangladesh

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Abstract There are many cropping systems followed in Bangladesh for enhancing cropping intensity and increasing crop production, but greenhouse gas (GHG) emission from agricultural fields are mostly reported on country basis. In order to estimate of GHG emission from agriculture fields, Cool Farm Tool Beta-3 was used to determine total GHG from selected cropping systems. It was found that non-rice based cropping system had lower global warming potential (GWP) than rice based cropping systems. Among the rice based cropping systems, Onion-Jute-Fallow, Jute-Rice-Fallow, Wheat-Mungbean-Rice and Maize-Fallow-Rice systems are relatively more suitable for reducing GHG emission and subsequent GWP. There are spatial variations in CH_4 emissions and the higher amounts were found in Mymensingh and Dinajpur districts in Bangladesh. In 2013–14, about 1.56 Tg year^{-1} CH_4 emissions took place from paddy field in Bangladesh. Further study is required for validation and suggesting suitable mitigation strategies to check the GHG emission in Bangladesh.

7.1 Introduction

The demand for food is increasing in Bangladesh due to rapid population growth. Farmers are growing different crops in a year to increase food production by following different cultural management options including use of variable amounts of fertilizers. Most of the farmers use excessive urea fertilizer (Biswas et al. 2004) and try to keep paddy field continuously flooded. These practices, not only increase cost of production, but also enhance additional GHG emission from crop fields. Annual total GHG emissions from agriculture are estimated to be 1.4–1.6 Gt CO_2-C equivalent (CO_2-Ce) yr^{-1}, corresponding to the attributed 10–12% of the human-induced

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warming effect (IPCC 2014). Major GHGs in general are emitted from agriculture field (Rice, barley, wheat and cereal crop) are CH_4, CO_2 and N_2O (Haque et al. 2015a, b). Rice crop covers about 85% of agricultural land in Bangladesh and contribute to global warming potential (GWP) (Solomon et al. 2007; Lee 2010). Globally 81% of agricultural emissions come from nitrogenous fertilizer production and its use (Iserman 1994). These imply that climate smart agricultural practices need to be followed for reducing GHG emission from crop fields; but pattern based emission data are lacking in Bangladesh. So, GWP for selected major cropping patterns and CH_4 emission from paddy fields were computed for subsequent ecosystem modification and adaptation in crop production.

7.2 Materials and Methods

Field experimental data were collected from Hand Book of Agricultural Technology, Proceedings Research Review and Planning Workshop of Soils Program of NARS institutes (2015) and different research organization in Bangladesh. Crop area data of 2013–14 were collected from Year Book of Agricultural Statistics-2014. Cool Farm Tool Beta-3 (CFT) was used to determine total GHG gas emission under different cropping systems and expressed as GWP. Many major cropping systems are followed in different districts. Among them Jute-T. Aman (rainfed lowland)-Fallow, Onion-Jute-Fallow, Boro (dry season irrigated rice)-Fallow-T. Aman, Mustard-Boro-T. Aman, Mustard-Boro-Fallow, Wheat-T. Aus (pre-monsoon)-T. Aman, Potato-Boro-T. Aman, Maize-Fallow-T. Aman, Potato-Maize-T. Aman, Wheat-Mungbean-T. Aman and Grass pea-T. Aus-T. Aman cropping systems were undertaken for estimation of total GHG and GWP. Emission factors, input variables and outputs of CFT are as follows.

Emission factor	Input variables	CFC output
Fertilizer induced N_2O	Fertilizer types/application rate ha^{-1}/ management practices ha^{-1}	kg CO_2eq/ha, kg CO_2eq/ kg product
Fertilizer production	Fertilizer type/ application rate, production technology	kg CO_2eq/ha, Kg CO_2eq/ kg product
Pesticide production	Number of applications	kg CO_2eq/ha, Kg CO_2eq/ kg product
Diesel use	Liters used	kg CO_2eq/ha, Kg CO_2eq/ kg product
Electricity use	Kwh	Kg CO_2eq/ha, Kg CO_2eq/ kg product
Crop residue management	kg/management practice	kg CO_2eq/ha, Kg CO_2eq/ kg product
Water management	Liters/management practice	kg CO_2eq/ha, Kg CO_2eq/ kg product

7.2.1 Correction Factor Determine of GHG

Using static close chamber method (Haque et al. 2013, 2015a and Haque et al. 2016a, b, c) and CFT (Hiller et al. Hillier et al. 2011), correction factor was determined for actual GHG and GWP estimate under major cropping systems in Bangladesh.

7.2.2 Statistical Analysis

Statistical analyses were carried out using SAS software (SAS Institute 1995). Fisher's protected Least Significant Difference (LSD) was computed at 0.05 probability level for making treatment means comparison.

7.3 Results

7.3.1 Cropping System Based GHG

Total CH_4 emission was about 48 kg ha^{-1} under Jute-T. Aman-Fallow, Maize-Fallow-T. Aman, Potato-Maize-T. Aman and Wheat-Mungbean-T. Aman. However, rice based cropping system like Jute-T. Aman-Fallow showed significantly lower amounts of GHG than others systems (Table 7.1). Rice-Rice based cropping systems showed significantly higher amounts of CH_4 emission (97–295 kg ha^{-1}), but CO_2 and N_2O emissions were not significant. Rice-Rice-Fallow cropping systems

Table 7.1 Greenhouse gas emission from major cropping systems in Bangladesh

Cropping system	CO_2 (kg ha^{-1})	CH_4 (kg ha^{-1})	CH_4 (CrF) (kg ha^{-1})	N_2O (kg ha^{-1})
Jute-Fallow-Onion	836.6i	0f	0f	4.3bcd
Jute-T. Aman-Fallow	668.4 k	48.4e	40.17e	4.2 cd
Boro (IF)-T. Aman-Fallow[a]	1114.2ef	196.6b	163.17b	3.9d
Boro (CF)-T. Aman-Fallow[a]	1141de	295.4a	245.18a	3.9d
Mustard-Boro-T. Aman	1516.1c	196.6b	163.17b	4.8abc
Mustard-Boro-Fallow	1082.6gh	148.2c	123.0c	3.8d
Wheat-T. Aus-T. Aman	1109.1 fg	96.8d	80.34d	2.5f
Potato-Boro-T. Aman	1871.3b	196.6b	163.17b	3.5de
Maize-Fallow-T. Aman	1167.5d	48.4e	40.17e	5.5a
Potato-Maize-T. Aman	1924.9a	48.4e	40.17e	5.1ab
Wheat-Mungbean-T. Aman	1080.9 h	48.4e	40.17e	3.5de
Grass pea-T. Aus-T. Aman	799.2j	96.8d	80.34d	2.8ef

Small letters in a column compare means at 5% level of probability by LSD

[a] IF = Intermittent flooding, CF = Continuous flooding, CrF = After imposing correction factor

Table 7.2 Global warming potential from selected cropping pattern under standard chemical fertilization

Cropping system	GWP (CO_2eq kg ha^{-1})	GWP (CO_2eq kg ha^{-1}) (CrF)[a]
Onion-Jute-Fallow	2125 k	2125 k
Jute-T. Aman-Fallow	3129j	2923j
Boro (IF)-T. Aman-Fallow[a]	7191d	6355d
Boro (CF)-T. Aman-Fallow[a]	9688a	8432a
Mustard-Boro-T. Aman	7854b	7018b
Mustard-Boro-Fallow	6376e	5746e
Wheat-T. Aus-T. Aman	4592f	4180f
Potato-Boro-T. Aman	7811c	6975c
Maize-Fallow-T. Aman	3988 h	3782 h
Potato-Maize-T. Aman	4618f	4412f
Wheat-Mungbean-T. Aman	3315i	3109i
Grass pea-T. Aus-T. Aman	4055 g	3643 g

Small letters in a column compare means at 5% level of probability by LSD

[a] *IF* = Intermittent flooding, *CF* = Continuous flooding, *CrF* = Correcting factor

increased about 102–515% CH_4 and reduced 8–41% N_2O than Jute-T. Aman-Fallow, Maize-Fallow-T. Aman, Potato-Maize-T. Aman and Wheat-Mungbean-T. Aman based systems in Bangladesh (Table 7.1). Carbon dioxide emission significantly increased under Potato-Maize-T. Aman cropping system but it was significantly the lowest under Jute-T. Aman-Fallow system. Non rice cropping systems showed the lowest GHG emission.

7.3.2 *Cropping System Based GWP*

The GWP among different cropping systems varied significantly. Computed GWP was significantly the lowest (2125 CO_2eq kg ha^{-1}) in Jute-Fallow-Onion and the highest (9688 and 7854 CO2eq kg ha^{-1}) in Boro (CF)-T. Aman-Fallow and Mustard-Boro-T. Aman cropping systems (Table 7.2). Major cereal cropping systems viz. Jute-T. Aman-Fallow (3129 CO_2eq kg ha^{-1}), Maize-Fallow-T. Aman (3988 CO_2eq kg ha^{-1}), Potato-Maize-T. Aman (4618 CO_2eq kg ha^{-1}), Grass pea-T. Aus-T. Aman (4055 CO_2eq kg ha^{-1}), Wheat-Mungbean-T. Aman (3315 CO_2eq kg ha^{-1}) systems showed significantly the lowest GWP than other cropping systems.

7.3.3 *Management and GHG Emission*

Water management significantly influenced CH_4 emission but not $CO_2$and N_2O emissions (Table 7.3). About 40% CH_4 emission was reduced because of intermittent drainage. The choice of variety also influences GHG emissions. For example,

Table 7.3 GHG and GWP as influenced by water management

	GHG (kg ha^{-1})			
Water management	CH_4	CO_2	N_2O	GWP
Intermittent drainage	148b	543a	1.1a	4585b
Continuous flooding	247a	570a	1.1a	70821a

Small letters in a column compare means at 5% level of probability by LSD

Table 7.4 GHG and GWP as influenced by varietal differences

	Greenhouse gas emission (kg ha^{-1})			
Variety (wet season)	CH_4	CO_2	N_2O	GWP
HYV Rice	48.4b	406a	0.9a	1875b
Local Rice	195a	199b	0.6b	5255a

Small letters in a column compare means at 5% level of probability by LSD

high yielding rice varieties (HYV) showed significantly higher emission of CO_2 and N_2O than local rice varieties but significantly lower amounts of CH_4 emission than local rice varieties (Table 7.4).

7.3.4 Methane Production Area in Bangladesh

Our result indicated that Mymensingh and Dinajpur had significantly higher amounts of CH_4 emission than other districts of Bangladesh (Fig. 7.1). Among the 64 district, the lowest CH_4 was found in Ramgati and Bandarban. In terms of CH4 emission rate, it varied from 89 to 148 kg ha^{-1} $year^{-1}$ depending on locations of the country and types of rice culture and variety used (Fig. 7.2). In total, computed CH_4 emission was about 1.56 Tg $year^{-1}$ in Bangladesh (Fig. 7.3).

7.4 Discussion

In Bangladesh, very suitable (VS), suitable (S) and moderately suitable (MS) areas for T. Aus (Pre-monsoon), T. Aman (Monsoon) and Boro (Dry season irrigated rice) rice covers about 2.01, 2.01 and 2.43 million ha (Mha) of cultivable land, respectively (Hossain et al. 2012). In future, such suitable areas will be affected because of increase in temperature. Boro rice based cropping system gave higher GWP than T. Aus and T. Aman rice based cropping systems because of variations in growth duration, fertilizer and water requirements than other rice varieties. Haque et al. (2016a, c) found that fertilizer and irrigated water increases total GHG emission and subsequent GWP. Efficient water and efficient fertilizer management practices need to be followed for reducing GWP from rice based cropping systems.

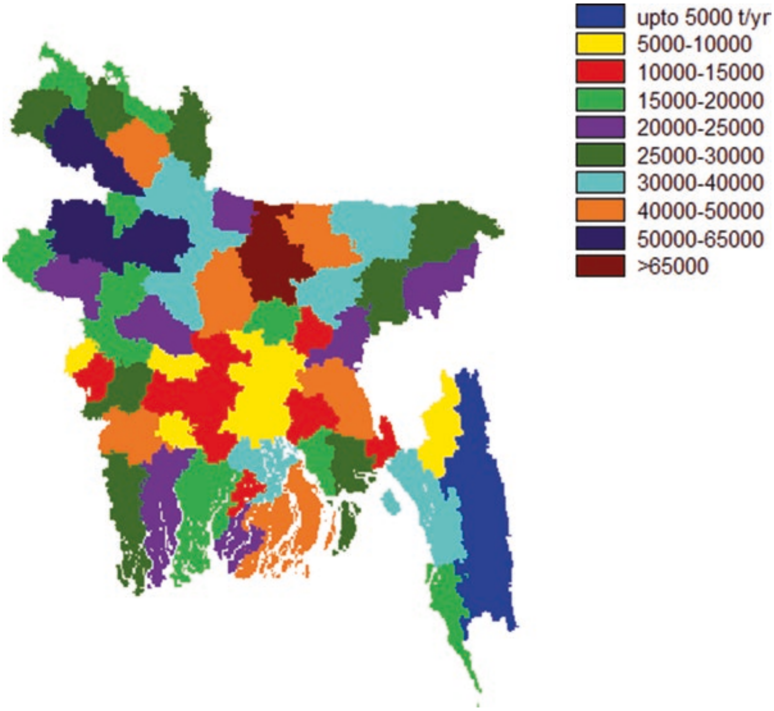


Fig. 7.1 Annual methane emission from paddy fields in different regions of Bangladesh

Jute-Rice-Fallow (3129 CO_2eq kg ha^{-1}), Wheat-Mungbean-Rice (3315 CO_2eq kg ha^{-1}) and Maize-Fallow-Rice (3988 CO_2eq kg ha^{-1}) systems could also be alternate options for mitigation of GHG emission in Bangladesh. However, Wheat-Rice-Rice (4592 CO_2eq kg ha^{-1}) and Potato-Maize-Rice (4618 CO_2eq kg ha^{-1}) systems need to be practised considering food security of the country (Table 7.2). Earlier findings also mentioned that rice based cropping system gave higher CH_4 and GWP than other cropping systems (Haque et al. 2015a). However, it is clear that adopting more effective and efficient cropping systems play a key role in increasing crop yields while mitigating emission of GHG in agriculture. Integrated soil-crop management practices are advocated to address the key constraints to yield improvement and alleviate environmental impacts, specifically reducing GHG emission (Fan et al. 2011; Zhang et al. 2012).

Amongst different cereal crops grown worldwide, rice emits the highest GHG, especially when grown under irrigated conditions (Table 7.1). This is because CH_4 emission is partly mediated by rice plants. Methane emission varies across different regions of the country because of rice culture types, varieties and water management conditions. In low lying areas of Bangladesh, local rice cultivars are gown in flooded lands and remain water stagnant almost up to maturity of the crop. This flooding condition favors greater CH_4 emission from paddy fields. Similar findings were also reported by Gupta et al. 2009 and Alberto et al. 2014. Intermittent drainage at critical stages of

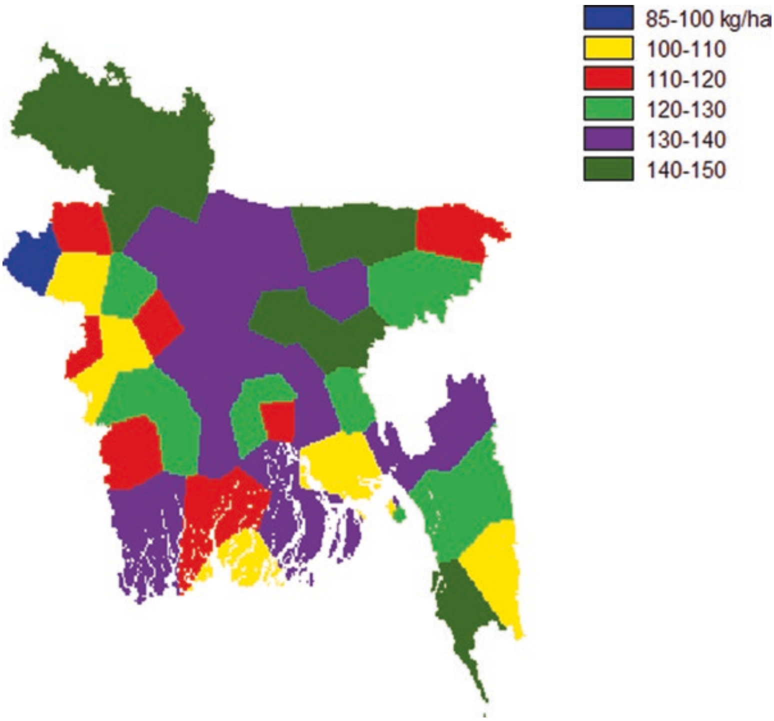
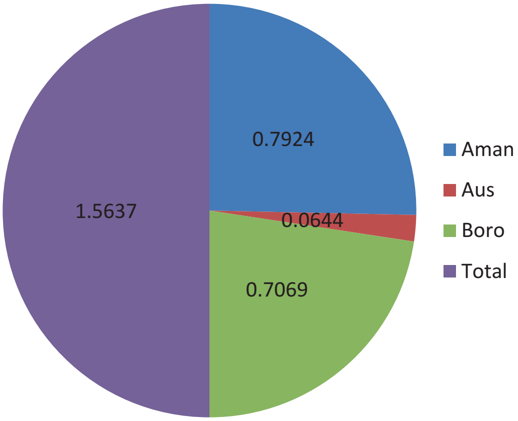


Fig. 7.2 Methane emission rates from paddy field in different regions of Bangladesh

Fig. 7.3 Total methane emission (Tg $year^{-1}$) from paddy fields in Bangladesh



crop growth is one of the significant options to reduce carbon footprint of paddy cultivation. Livestock also plays a key role in CH_4 emission and also needs to be accounted. There is a need to validate the model results with specific test studies. However, the results as obtained from model run in the present investigation are in agreement with the reports for other similar production environments in South Asia.

7.5 Conclusion

There are spatial variations in the GHG emissions over Bangladesh, primarily because of cropping systems differences and inputs and/or management practices followed. Jute-Rice-Fallow and Wheat-Mungbean-Rice cropping systems are suitable to reduce GHG emission and subsequent GWP than other cropping systems. There is a need to validate models results with location specific studies. The options needed to mitigate GHG emission for various productions environments of Bangladesh are to be delineated.

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