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Greenhouse gas emissions from agricultural food production to supply Indian diets: Implications for climate change mitigation

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ABSTRACT

Agriculture is a major source of greenhouse gas (GHG) emissions globally. The growing global population is putting pressure on agricultural production systems that aim to secure food production while minimising GHG emissions. In this study, the GHG emissions associated with the production of major food commodities in India are calculated using the Cool Farm Tool. GHG emissions, based on farm management for major crops (including cereals like wheat and rice, pulses, potatoes, fruits and vegetables) and livestock-based products (milk, eggs, chicken and mutton meat), are quantified and compared. Livestock and rice production were found to be the main sources of GHG emissions in Indian agriculture with a country average of 5.65 kg CO_2eq kg^{-1} rice, 45.54 kg CO_2eq kg^{-1} mutton meat and 2.4 kg CO_2eq kg^{-1} milk. Production of cereals (except rice), fruits and vegetables in India emits comparatively less GHGs with <1 kg CO_2eq kg^{-1} product. These findings suggest that a shift towards dietary patterns with greater consumption of animal source foods could greatly increase GHG emissions from Indian agriculture. A range of mitigation options are available that could reduce emissions from current levels and may be compatible with increased future food production and consumption demands in India.

1. Introduction

Agriculture is an important sector of the economy in India, contributing about 20% of national gross domestic product, and providing a livelihood for nearly two-thirds of the population (ICAR, 2015). Equally important is the contribution of agriculture to national food security. India achieved self-sufficiency in food production after the Green Revolution (GR), but retaining this success has been challenging due to the increasing scarcity of resources, including labour, water, energy, and rising costs of production (Saharawat et al., 2010). Increased use of production inputs, such as mineral fertiliser, has made Indian agriculture more greenhouse gas (GHG)-intensive. Agricultural production is a major emitter of GHGs, currently accounting for 18% of total GHG emissions in India (INCCA, 2010). Recent estimates report that global food production must increase by 70% to meet the projected food demand of the estimated 9 billion global population by 2050 (CTA-CCAFS, 2011). 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 minimising GHG emissions. However, given the increasing population and shifting dietary patterns, GHG emissions from agricultural production in India are expected to change.

Quantifying GHG emissions associated with the production of food items in India is an important stage in quantifying GHG emissions associated with diets. It allows us to (i) identify variation in GHG emissions between typical dietary patterns within India; (ii) forecast the effect of changes in diets on GHG emissions; and

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(iii) identify options to minimise GHG emissions from food production, either through production-side changes or through dietary changes. For example, a number of countries have experienced a 'nutrition transition' associated with greater disposable incomes, urbanisation and globalisation. The transition is typified by increasing consumption of animal products, edible oils and sweetened beverages and decreasing consumption of cereals and pulses (Drewnowski and Popkin, 1997; Popkin et al., 2012). There is evidence that a similar trend is emerging among some population groups in India, although cultural preferences for lacto-ovo-vegetarian diets suggest that India's experience will differ from other countries including China (Baker and Friel, 2014; Misra et al., 2011). The implications of dietary changes in India for GHG emissions have not been quantified.

In India, the majority of agricultural GHG emissions occur at the primary production stage (Pathak et al., 2010), and are generated through the production and use of agricultural inputs, farm machinery, soil disturbance, residue management and irrigation. These practices are used to increase yields and improve harvests. Due to its direct contribution to global GHG emissions, agriculture can also serve as an important climate change mitigation strategy (Smith et al., 2013, 2008), both by reducing GHG emissions to the atmosphere, and by sequestering atmospheric carbon into plant biomass and soil, though the role of some soil carbon sequestration practices for climate mitigation has been questioned (Powlson et al., 2014). India's Intended Nationally Determined Contributions (INDCs) to the United Nations Framework Convention on Climate Change (UNFCCC, http://unfccc.int/2860.php [accessed 19.05.2016]) place emphasis on mitigation from agriculture, and various mitigation strategies (particularly concerning methane, CH_4, and nitrous oxide, N_2O) have been proposed (Smith et al., 2014, 2008). Quantification of GHG emissions from the production of different food commodities helps farmers, researchers and policymakers to understand and manage these emissions, and identify mitigation responses that are consistent with the food security and economic development priorities of countries (Hillier et al., 2011; Whittaker et al., 2013).

Various methods exist to estimate GHGs from agriculture, ranging from simple Tier 1 methods (IPCC 2006) to complex process-based models, which simulate the soil carbon and nitrogen cycles in some detail (Ogle et al., 2013). Several tools and calculators have been developed for estimating GHG fluxes from farm activities and to support decision making in terms of identifying informed interventions. Here, we used a modified version of The Cool Farm Tool (Hillier et al., 2011), which integrates several empirical models into one tool for GHG estimation from farm activities. The tool recognises context-specific factors that influence GHG emissions such as pedo-climatic characteristics, production inputs, and other management practices at farm level. GHG emissions from livestock products are calculated using the comprehensive data from the 19th Livestock Census of the Government of India (GOI, 2012) following the approach of Herrero et al. (2013).

The objective of the study is to analyse and compare farm-level GHG emissions of major food commodities at a national scale in India. The study gives an overview of emission-related hotspots,

Table 1
Major crops and livestock products by % of total intake in India, number of data points available with management information, averaged data and standard deviation for each product, nitrogen input and GHG emissions for different scales.

crop/livestock prod.	group	subgroup	% of consumption from total food in Indian diets	nr. of data points	yield [tonnes/ha]	std dev	N [kg/ha]	std dev	GHG [kg ha^{-1}]	std dev	GHG [kg kg^{-1} product]	std dev	GHG [kg 1000 $kcal^{-1}$]	std dev
Milk	Livestock product	Dairy-lo-fat	18.17	105							2.42	0.90	3.97	1.48
Wheat	Cereals	Cereals	9.42	6017	3.26	1.14	139.41	51.47	977.15	439.70	0.34	0.21	0.12	0.07
Paddy Rice	Rice	Cereals	8.97	11993	3.61	1.51	114.37	54.21	8447.59	4754.41	5.65	4.59	1.21	0.96
Mango[a]	Fruit	Fruit	4.60	/	10.4	/	11.7	/	750.00		0.07		0.16	
Onion	Other	Spices	3.72	48	19.55	8.59	192.57	98.24	1599.65	969.44	0.10	0.07	0.39	0.29
Tomato[a]	Other	Vegetable	3.67	/	130	/	360	/	3000.00		0.15		0.88	
Potato	Potato	Tuber	2.69	394	23.83	9.27	236.01	181.24	3406.46	2727.19	0.22	0.23	0.33	0.35
Orange[a]	Fruit	Fruit	2.57	/	10.3	/	113	/	1300.00		0.13		0.37	
Sugarcane	Other	Other	1.90	1312	79.35	33.49	258.84	122.67	3954.34	3975.21	0.09	0.22	0.73	2.07
Lentil	Pulses	Pulses	1.89	425	0.90	0.39	16.03	14.96	292.17	303.45	0.38	0.38	0.13	0.13
Spinach	Other	Vegetable	1.29	/	21	/	33.5	/	1100.00		0.05		0.30	
Peas	Pulses	Pulses	1.17	128	1.39	0.75	41.41	38.11	540.09	250.37	0.42	0.21	0.81	0.84
Poultry	Livestock product	Chicken	0.74	69							2.59	0.08	1.40	0.04
Egg	Livestock product	Egg	0.45	69							2.59	0.08	1.87	0.06
Groundnut	Pulses	Nuts and oils	0.39	629	1.36	0.73	50.66	44.71	383.58	295.60	0.38	0.47	0.10	0.13
Mutton	Ruminant meat	Meat	0.38	280							45.54	11.89	17.32	4.52
Spices (Cumin Seed)	Other	Nuts and oils	0.08	/	2	/	100	/	1500.00		0.75		0.25	
Other Cereals[b]	Cereals	Cereals	2.76	3520	1.94	1.41	64.43	53.65	707.32	377.03	0.43	0.50	0.06	0.13
Other Pulses[c]	Pulses	Pulses	3.8	3720	0.82	0.57	25.14	36.50	490.32	359.31	0.75	1.59	0.14	0.38
Crops for vegetable oils[d]	Other	Nuts and oils	2.84	2569	1.30	0.62	40.66	36.20	532.12	632.39	0.54	0.93	0.12	0.18

[a] No plot/farm data were available; typical management and statistical information were used to generate management information.
[b] Includes bajra, barley, maize, ragi and jowar.
[c] Includes black, red and green gram.
[d] Includes coconut, rapeseed, soybean, safflower, sesamum, sunflower.