

Green House Gas Emission of Major Agriculture Crops of Southern India

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Abstract. Agriculture is one of the major sectors that contribute towards increasing GHG concentration in the atmosphere. To develop strategies to mitigate climate change, primarily it is essential to identify the sources of emissions from various agriculture practices at regional levels. State of Karnataka with 21.90 Million hectares of cultivated land has a production of 17.29 Million tones of grain yield with a carbon footprint of 7.25tCE/ha/year and 5.98 TgCE/year for bulk production respectively. This accounts for 1.75% of the country's emission from agriculture sector. Among the crops grown, cereals recorded 5.04TgCE annually and rice among the cereals, grown under flooded conditions contributed the maximum of 4.1 tCE/ha/year. Among two cropping systems, crops grown with irrigation emitted 4.21 TgCE/year from an area of 1.74 Mha, while rainfed crops emitted 1.76 TgCE/year from 20.15 Mha. Carbon efficiency was more under rainfed conditions with low carbon intensity which was otherwise under rainfed conditions. However yields were low under rainfed conditions. Among the various carbon inputs, use of inorganic nitrogen fertilizer contributed 72% of total emission. Hence, nitrogen source of plant nutrient need amendments from current practices to reduce emission levels. Current cultivation practices which are labor intensive than carbon intensive and hence showed very high sustainability.

Key words: Climate Change, Agriculture Carbon Footprint, Sustainability.

1. Introduction

Global climate change which is threatening the food security of developing countries is the biggest challenge to be addressed by the agriculture sector. Because globally about one third of GHG emission is attributed to agriculture and land use change [1]. At current rates of climate change average yields of major cereals of the world such as; rice, wheat and maize are expected to decrease by 50, 17 and 6 percent respectively by middle of this century [2]. The burgeoning populations on the other hand impose further pressure on food production under changing environments. Therefore agriculture is both cause and victim of climate change. To reduce emission levels from agriculture sector, the fundamental requirement is to quantify the carbon emission from various operations performed in a single whole cycle of crop production. As most agriculture practices are climate driven and therefore region and crop specific, it is necessary to quantify carbon emission at regional levels to address the global issue.

Apart from CO₂ other major GHGs emitted from agriculture sector are N₂O and CH₄. The source of N₂O is nitrogenous fertilizer use [3] and methane is paddy cultivation under flooded conditions [4]. India is estimated to emit 17.6 % of its emission from agriculture sector [5], while it is 8 % in United States [6]. Emission from agriculture depends on inputs used [7] Cultivation practices adopted [8] and soil fertility status [9], [10]. However there are hardly any studies in developing countries to quantify the emission from cultivation process of agriculture of various crops and cropping systems. Mitigation practices need to be developed for individual agricultural systems in view of climate, edaphic, social setting, and historical patterns of land use and management [1]. To do so, most fundamental requirement is to ascertain the carbon

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footprint of different crops and cropping systems [11]-[13] and thereby bring in amendments to reduce the carbon footprint. Most tropical countries being highly diverse in climate, crops and therefore the cultivation practices, it is important to assess the carbon emission at regional levels to evolve appropriate strategies. However there are not many studies in this direction, especially in India. In the light of the above, this study is an attempt to assess the carbon footprint of major agriculture crops that are most prevalent in southern states of India.

2. Materials and Methods

The state of Karnataka in India is spread over 11°56" to 17°55" N and 74°11" to 78°11" E, occupying an area of 1,91,791km², representing 5.83 % of the country's arable land. State is very diverse in climatic conditions, physiographic features and rainfall patterns. To provide effective recommendations for specific crops grown across the state, it is divided into ten agriculture zones. The data on which this study is based upon is collated from specific regions where the crops are cultivated over large areas. However the systematic set of data on major crops grown in the state was available from 1998 to 2010. Crops grown are categorized into four major groups as cereals, pulses, oil seeds and commercial crops. Crops included under cereals are Paddy (*Oriza sativa*), Wheat (*Triticum aestivum*), Maize (*Zea mays*), Jawar (*Sorgum bicolor*), Ragi (*Eleusine coracana*), and Bajra (*Pennisetum glaucum*), pulse crops are Red gram (*Cajanus cajan*), Black gram (*Vigna mungo*), Green gram (*Vigna radiata*), Bengal gram (*Cicer arietinum*) and Soybean (*Glycine max*) and oil seed crops are Sunflower (*Helianthus annuus*) and Groundnut (*Arachis hypogaea*) while Cotton (*Gossypium hirsutum*) and Tobacco (*Nicotiana tobaccum*) are categorized as commercial crop. These crops represent the major agriculture crops cultivated in southern India.

Carbon footprint of crop production is assessed by considering the total GHGs emission in terms of carbon equivalent (CE) through materials added, and from mechanical operations performed in a single whole cycle of crop production [7]. Carbon footprint of crop production is estimated as ;

$$\text{Carbon Footprint (tCE)} = \text{Inputs used in agriculture? Emission Factor} \quad (1)$$

Where, "Input used in agriculture" is the total amount of carbon inputs used such as, fertilizers, pesticides, diesel, electricity, etc. and "Emission Factor" is the quantum of carbon invested on individual components when manufactured and/or applied as input. In case of rice methane is the additional GHG released. To account this, the national averages of 17.48 g m⁻²year⁻¹ and 6.95 g m⁻²year⁻¹ under irrigated and rainfed conditions respectively is used [10] with a global warming potential of 21 [1]. Similarly carbon equivalent from direct N₂O emission due to chemical nitrogen fertilizer application was used [7]. Thus, estimation of total carbon footprint (CFt) in crop production was calculated by summarizing all the individual carbon costs from above-mentioned inputs:

$$CF_t = CFF + CFN + CF_p + CFIR + CFD + CFM \text{ (paddy only)} \quad (2)$$

Where, CFF, CFN, CFP, CFIR, CFPF, CFD and CFM represents the individual carbon costs from fertilizers input, direct N₂O from N fertilizer applied, pesticides, fossil fuel used for various mechanical operations during crop production and methane emission from paddy fields respectively. Sustainability of cultivation practices in terms of GHG emission, which is expressed as sustainability index [8] was derived from total carbon accumulated in the biomass to a given amount of carbon input. The total biomass produced was derived from grain, stem and root biomass [8]. Stem and root biomass was derived from the published literature. Carbon efficiency and carbon intensity are calculated as per [9].

3. Results

Thirteen years average (1998-2010) data indicate that, out of 21.9 Million hectares of agriculture land in Karnataka, 5.10, 13.50, 2.71 and 0.6 Million hectares are used for cultivating cereals, pulses, oil seed and commercial crops respectively and was found to be significantly different (Table 1). Total production from these crops is 17291 mt having carbon footprint of 7.25 tCE/ha which accounts to a total emission of 5.98TgCE/year. Among the crops grown, cereals recorded the maximum (6.31 tCE/ha) per hectare and oil seeds recorded the least (0.17 tCE/ha), while total carbon emission in a year remained highest in cereals (5.04 TgCE/year) but least was seen in case of oil seeds and commercial crops (0.081 TgCE/year). The

sustainability index was found to be highest in pulse crops (27.26), while rest of the crops remained low and almost same. This was also evident from carbon use efficiency as well as from carbon intensity of these four groups (Table 1). Among the individual crops, rice (grown under flooded conditions) recorded the highest carbon footprint of 4.09tCE/ha, followed by rice under rainfed condition, while all other crops did not emitted more than 0.2 tCE/ha (Fig. 1). Among the two major cropping systems prevailing, crops grown under irrigated conditions recorded 4.21 TgCE/year for the total cultivated area of 1.74Mha while 20.15 Mha of rainfed (unirrigated) area emitted only 0.17 TgCE/year (Fig. 2). Among the various sources of input carbon, nitrogen fertilizer accounted for 72% (Fig. 3) including 1% from N₂O.

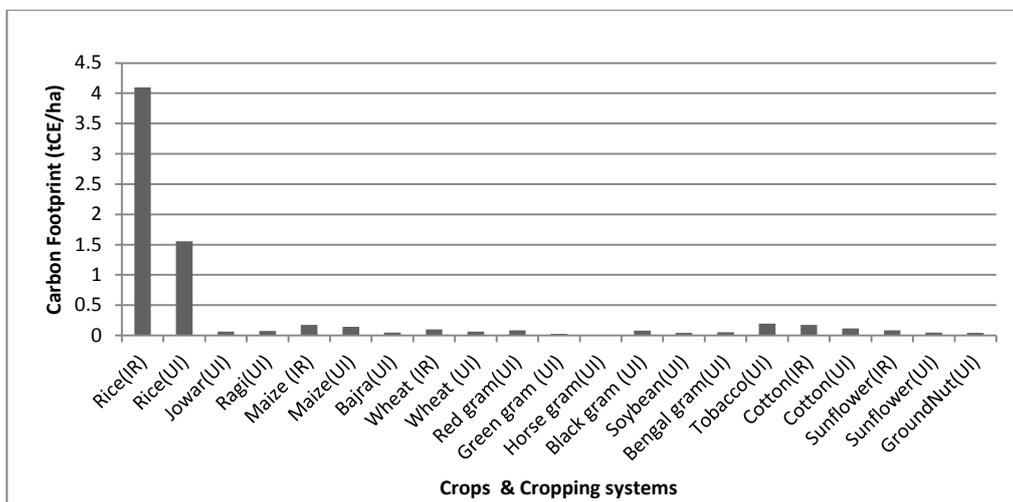


Fig. 1. Carbon footprint of all crops grown under irrigated (IR) and rainfed (RF) conditions

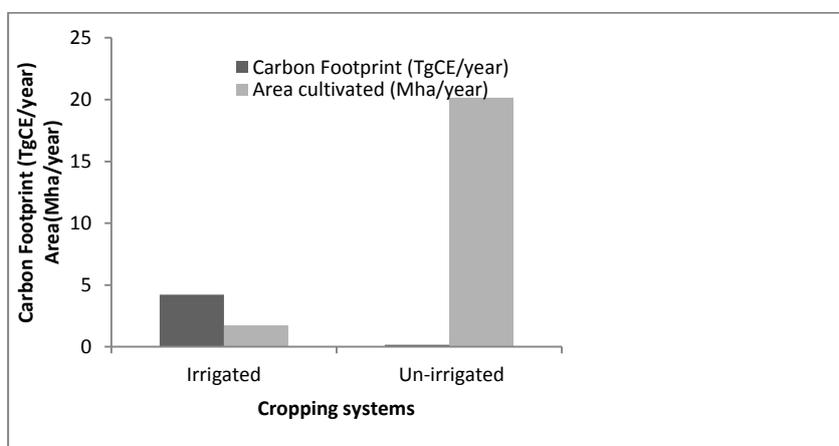


Fig. 2: Carbon footprint of crops grown under irrigated and rainfed cropping systems.

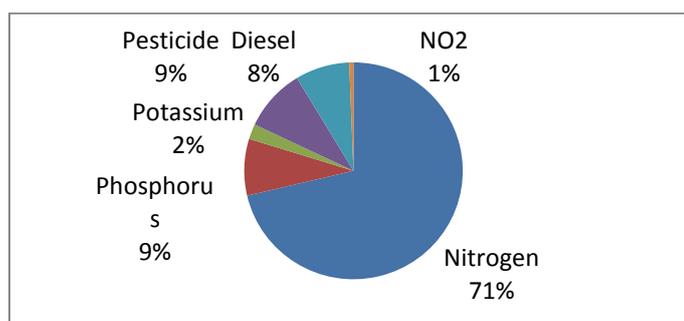


Fig. 3: Emission from different inputs used in cultivation of major agriculture crops.

Table 1: Crop production of four major groups of agriculture crops and resultant carbon emission.

Major Crops	Area (ha)	Production (mt)	Carbon footprint		Sustainability index	Carbon Efficiency	Carbon Intensity
			(tCE/ha)	Total (Tg/year)			
Cereals	5145	8859	6.31	5.04	3.98	25.38	0.13
Pulses	13469	5583	0.28	0.72	27.26	128.57	0.06
Oil seeds	2710	1590	0.17	0.0003	4.39	26.72	0.04
Commercial crops	576	760	0.48	0.081	3.05	18.34	0.07
Total/mean	21900	16792	7.25	5.98	38.68	49.75	0.075
C.D.@ 5%	59.79	NS	NS	NS	NS	NS	NS

Note: 1Tg=10¹²g. Values in the parenthesis indicate the percentage of total area under rainfed agriculture.

4. Discussion

State of Karnataka is having close to 6% of the cultivated area of the country. It has very diverse climatic conditions, agricultural crops as well as two major cropping systems (Irrigated and un-irrigated). These variabilities needs to be accounted comprehensively as they contribute differently towards the carbon footprint. The emission of this region accounts for 1.75 % of the total emission of agriculture sector of India [5]. Among the different crops grown world's most important cereal crop, rice emitted the highest GHG, especially when grown under irrigated conditions (Fig. 1). This is because of methane emission, which is an additional GHG emitted only by rice. It is the major contributor among all the crops cultivated. Methane emission has been clearly demonstrated to increase under flooded conditions across the major paddy growing regions of the world [10], [14]. Hence intermittent irrigation at critical stages of crop growth is one of the measures to reduce the carbon footprint of paddy. However, methane emission in India is considerably less compared to other parts of the world [14], [15]. This is attributed to low soil organic carbon content in Indian soils [10].

Carbon footprint seen in rest of the crops grown was very less when compared to paddy and can be attributed to lower inputs used in crop production. The major reduction in the input seen in India compared to advanced countries is the reduction in mechanical energy. Because, most of plowing, weeding, harvesting and post harvest operations were done manually instead of using mechanical energy which significantly reduces the carbon input. This is possible because of manpower availability within the family, small holdings that can be handled by the man power within the family and none affordability to invest in farm machinery due to lower income are some of the factors that contribute substantially towards reducing the carbon footprint. Further, 80% of the crops grown are under rainfed conditions and the recommended fertilizer inputs for rainfed crops are considerably less compared to crops grown under irrigated conditions (Fig. 2). Therefore low inputs are another contributing factor for lower carbon footprint of this region. No use of plastic is another contributing factor [7]. Among the inputs used in the cultivation, most significant contributing factor seems to be the use of chemical fertilizers specially the inorganic nitrogen fertilizer, which accounted for 72% (which includes 1% of NO₂ which is emitted from nitrogen fertilizer) of the total emission (Fig. 3). Similar results have been reported from China [7]. Therefore, in order to reduce emission from agriculture sector amendments are needed for the current practices of nitrogen use in the form of frequency, composition, time, etc. Another important consideration is to replace inorganic source with organic forms. The current practice of low carbon inputs has resulted in higher sustainability of the agriculture practices of this region. The sustainability of current cultivation practices is found to be close to zero tillage practice followed elsewhere [9]. Such a high sustainability can also be attributed to crop combination of this region, apart from the reasons explained earlier. Because 61% of the cultivated area is under pulse crops and are leguminous in nature. Since they have ability to fix atmospheric nitrogen, the requirement of inorganic nitrogen inputs are less. This was clearly evident from the low emissions of 0.28 tCE/ha from pulses. The efficiency of converting added carbon inputs into biomass seems to be less for all crops except for pulses. This is also responsible for poor yields and even crop loss, which is a real cause of concern. This is invariably due to dependency of agriculture on rainfall (80% of the cultivated area is under rainfed conditions), which is true in most of the semiarid tropical regions of the world. Since most of rural population is agriculture dependant, there is enough manpower available in the agriculture sector of most

developing countries. This illiterate population has very little options of alternate source for lively hood that unknowingly contributing for environment friendly agriculture.

5. References

- [1] IPCC, Climate change, *Fourth assessment report*. Geneva,Switzerlan, IPCC. 2007.
- [2] Anonymous, 2009, Asian Development Bank, Addressing Climate Change in the Asia and Pacific Region.www.ifpri.org/sites/default/impact-climate-change-agriculture-factsheet-asia? Print. Accessed on10-4-2013.
- [3] IPCC. In, Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T.,Tanabe, K. (eds.), *2006 IPCC Guidelines for national greenhouse gas inventories, prepared by the National Greenhouse Gas Inventories Programme*. IGES, Tokyo, Japan.
- [4] J. Zou, Y. Huang, J. Jiang, X. Zheng, and R.L. Sass. A 3 - year field measurement of methane and nitrous oxide emissions from rice paddies in China: Effects of water regime, crop residue, and fertilizer application.2005.*GlobalBiogeochemicalCycles***19**: doi: 10.1029/2004GB002401. issn: 0886-6236.
- [5] NCCA. Green house gas emission; Executive summary. Indian Network for Climate change Assessment-2007. Ministry of Environment & Forest, Government of India. 2010. p. 4-5.
- [6] K. Paustin, J.M. Antle, J. Sheehan, E.A. Paul, Agriculture’s role in green house gas mitigation. Arlington, VA: *Pew Centre on global climate change*. 2006.
- [7] K. Cheng, G. Pan, P. Smith, T. Luo, L. Li, J. Zheng, X. Zhang. Carbon footprint to China’s crop production- An estimation using agro-statistics data over 1993-2007 *Agri. Ecosyst. Environ.* 2011, **142**:231-237.
- [8] R.Lal. Carbon emissions from farm operations. *Environ. Int.* 2004, **30**: 30–990.
- [9] A. Duby, R. Lal. Carbon footprint and sustainability of agricultural production systems in Punjab, India, and Ohio, USA. *J. Crop Improvement*, 2009, **23**: 332-350.
- [10] P.K. Gupta, V. Gupta, C. Sharma, S.N. Das, N. Purkait, T.K. Adhya, H. Pathak, R. Ramesh, K.K. Baruah, L. Venkataraman, G. Singh. C.S.P. Iyer. Development of methane emission factors for Indian paddy fields and estimation of national methane budget. *Chemophore*. 2009, **74**: 590-598.
- [11] S. Perry, J. Klemes, I. Bulatov, Integrating waste and renewable energy to reduce the carbon footprint of locally integrated energy sectors. 2008.*Energy*, **33**,1489–1497.
- [12] I.J.Hiller. C, Hawes. G, Squire. A, Hilton. S, Wale. P, Smith. The carbon footprints of food crop production. *Int. J Agric. Sus.* 2009,**7(2)**: 107-118.
- [13] A. Druckman, and T. Jackson. The carbon footprint of UK households 1990–2004. A socio-economically disaggregated, quasi-multi-regional input–output model, 2009, *Ecol, Econ.*, **68**: 2066–2077.
- [14] M.C.R. Alberto, R. Wassmann, R.J. Buresh, J.R. Quality, T.Q. Correa Jr, J.M. Sandor, C.A.R. Centeno. Measuring methane flux from irrigated rice fields by Eddy covariance methodusing open-path gas analyzer. *Field crop. res.* 2014, **160**:12-21.
- [15] X, Xu. B, Zhang. Y, Liu. Y, Yanni Xue. B, Di. Carbon footprints of rice production in five typical rice districts in China. *Acta Ecol. Sin.* 2013, **33**:227-232.