Carbon Footprint for Paddy Rice Production in Egypt

Farag, A. A.[1]; H. A. Radwan[2];M. A. A. Abdrabbo[1]; M. A. M. Heggi[1]; B. A. McCarl[3]

[1]Central Laboratory for Agricultural Climate, Agricultural Research Center, Dokki 12411, Giza-Egypt
[2]Agricultural Engineering Research Institute, Agricultural Research Center, Dokki, Giza-Egypt
[3] Department of Agricultural Economics Texas A&M University, Texas-USA
awny_a@yahoo.com

Abstract: Emissions resulting from rice cultivation are estimated in this paper including emissions from mechanical operations, field burning and N fertilization. The estimates are constructed using data and procedures from the IPCC guidelines for emissions estimation Coupled with Life Cycle Analysis procedures. The results show that the larger amounts of emissions come from Lower Egypt (Nile Delta). The regions with higher emissions are located as a rice belt in the Northern of the Nile Delta, Methane emission from the flooded rice fields are the main source of GHG emissions, contributing about 53.25 % of the total emissions. Rice straw burning after harvesting is the second largest source contributing 35.82 %. Nitrogen fertilization contributes out 9.92% and mechanical activities contribute about 1%. Finally, the carbon footprint for paddy rice is 1.90 Kg CO_{2eq} / Kg paddy rice.

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Abbreviation:

Carbon footprint (CFP) – also named Carbon profile - is the overall amount of carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions (e.g. methane, nitrous oxide, etc.) associated with a product. The carbon footprint is a sub-set of the data covered by a more complete Life Cycle Assessment (LCA) (**ISO, 14040**)

1.Introduction

With the accumulating evidence on climate change, there has been interest in examining the greenhouse gas (GHG) contribution of production practices and products as a mean of identifying intensive emitting options that could be target of GHG mitigation actions. Such a GHG emission level estimation is often called a carbon footprint[1]. Agriculture is one target of such activity as emission levels are about13% of the annual GHG emissions that are related to all human activities (**Olivier *et al.*, 2005 and Harada *et al.*, 2007**).

Rice cultivation is one activity that has received attention as a GHG emitter (IPCC, 2007). Rice is important in Egyptian agriculture, with Egypt being the largest rice producer in the Near East region (**Abdulla, 2007**). Total area used for rice cultivation is approximately 600 thousand ha or about 22% of all cultivated area in Egypt during summer (**Tantawi and Sabaa, 2001**). The average yield is 8.2 tons/ha with an approximate straw production of 5-7 tons/ha (**Sabaa and Sharaf, 2000; Badawi, 2004**).

Rice is an important emitter of methane (CH_4), one of the major greenhouse gases (GHG). According to the Intergovernmental Panel on Climate Change (IPCC), the warming contribution of CH_4 is 19–25times higher than that of CO_2 per unit of weight based on 100-yr global warming potentials **(IPCC, 2007**).

Agricultural activities are responsible for approximately 50% of the anthropogenic emissions of CH_4, with rice paddies contributing over 10% (**Scheehle and Kruger, 2006; USEPA, 2006**).

The Intergovernmental Panel on Climate Change (IPCC, 2007) estimated the annual global emission rate from paddy fields averages 60 Tg/yr, with a range of 20 to 100 Tg/yr. This is about 5-20 per cent of the total CH4 emissions from anthropogenic sources. This figure is mainly based on field measurements from paddy fields in the United States, Spain, Italy, China, India, Australia, Japan and Thailand (**IPCC,1997**).This carbon foot print is mostly composed of the methane production from flooded rice (67%) and the deforestation effect (29%) due to the persistence of 149 000 ha of hill side slash-and-burn land use change for rice production (**Bockel *et al.*, 2010**).

Observed seasonal rice methane emissions from around the world show large ranges, reflecting the effects of local as well as regional differences in agricultural, biological, and climatic factors. (**Wassmann *et al.*, 2000)** compute an average median emission value of 27.23 g m^2, with a range from less than 1 g m^2 to 155 g m^2.

The burning of rice residue is a another emission source yielding carbon dioxide (CO_2),

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methane (CH_4), and nitrous oxide (N_2O), plus pollutants such as carbon monoxide (CO), particulate matter (PM), and toxic polycyclic aromatic hydrocarbons (PAHs)(**Lemieux *et al.*, 2004 and Duan *et al.*, 2004**).

Emissions of N2O may also occur. Direct sources include emissions from cultivated and fertilized soils. Indirect emissions result from transport of N from agricultural systems into ground and surface waters with subsequent emission as ammonia or nitrogen oxides **(Xu*et al.*, 1997; Mosier *et al.*, 1998)**. Methodologies for calculating both direct and indirect emissions of N_2O related to agricultural production take into account anthropogenic N inputs including synthetic fertilizers, animal wastes and other organic fertilizers, biological nitrogen fixation by crops, cultivation of organic soils, and mineralization of crop residues returned to the field (**IPCC, 1997**).

With reference to CO_2 emissions, agricultural practices may be grouped into primary, secondary and tertiary sources (**Gifford, 1984**). The main sources of farm level CO_2 emissions are either due to cropping operations (e.g., tillage, sowing, harvesting and transport) or stationary operations (e.g., pumping water, grain drying). Therefore, reducing emissions implies enhancing use efficiency of these operations by conserving inputs used in the operations, and using other CO_2-efficient alternatives (**Lal, 2004**).

The aim of this study was to estimate the GHG emissions from Egyptian rice fields in terms of the emission from rice cultivation, mechanical operations(irrigation pumping, tillage, harvesting), nitrogen fertilization and burning rice straw. Finally we calculate the carbon footprint taking into account all GHGs associated with paddy rice (kg-CO_{2eq} / Kg paddy rice)

2. Material and Methods

2.1 Study area

This study focus on the major rice cultivation areas in Egypt especially that along the Northern Coast. This study considers emissions in four major regions Lower, Middle, and Upper Egypt plus lands out of the Nile Valley. The cultivated area of each governorate was collected from the statistics of the Ministry of Agriculture and Land Reclamation forth years 2008 to 2011. Rice in Egypt is planted as a summer season crop generally under flooded conditions. Urea and synthetic fertilizers are predominantly applied with significant organic matter application (about 15 -20 cubic meters of cattle manure per hectare). Rice straw is normally left in the fields after harvest in September and October, and most of it is burned. Greenhouse gas emissions from rice occur during the growing season and upon burning rice straw.

2.2 Methane emissions from rice cultivation

The annual amount of CH_4 emitted from rice is a function of the number and duration of crops grown, water regimes before and during the cultivation period, and organic and inorganic soil amendments **(Neue and Sass, 1994; Minami, 1995; Harada *et al.*, 2007)**. Soil type, temperature, and rice cultivar also affect CH4 emissions. Therefore, the basic equation to estimate CH_4 emissions from rice cultivation is shown in Equation (1) Based on **IPCC (2006)**. CH4 emissions are estimated by multiplying daily emission factors by cultivation period of rice and annual harvested areas.

$$CH_{4\,Rice} = \sum_{i,j,k} \left(EF_{i,j,k} * t_{i,j,k} * A_{i,j,k} * 10^{-6} \right) \qquad (1)$$

Where:

$CH_{4\ Rice}$= annual methane emissions from rice cultivation, in Gg CH4 yr^{-1}

EF_{ijk}= a daily emission factor for *i, j,* and *k* conditions, in kg CH4 ha^{-1} day^{-1}

t_{ijk} = cultivation period of rice for *i, j,* and *k* conditions, in days

A_{ijk}= annual harvested area of rice for *i, j,* and *k* conditions, in ha yr^{-1}

i, j, and *k* = represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary

Emissions for each different region considered are adjusted by multiplying a baseline default emission factor by various scaling factors as shown in Equation (2). The calculations are carried out for each water regime and organic amendment separately as shown in Equation 1.

$$EF_{ij} = EF_c * SF_w * SF_{pj} * SF_o * SF_{s,r} \qquad (2)$$

Where:

EF_{ij} = adjusted daily emission factor for a particular harvested area

EF_c = baseline emission factor for continuously flooded fields without organic amendments

SF_w = scaling factor to account for the differences in water regime during the cultivation period (Continuously flooded = 1, error range= 0.79-1.26 based on??)

SF_{pj} = scaling factor to account for the differences in water regime in the pre-season before the cultivation period (less than 30 days= 1.90, error range=1.65-2.18 source)

SF_o = scaling factor that accounts for differences in both type and amount of organic amendment applied (from Equation3) source

$SF_{s,r}$ = scaling factor for soil type, rice cultivar, etc.,

On an equal mass basis, more CH4 is emitted from organic amendments containing higher amounts of easily decomposable carbon and emissions also increase as more of each organic amendment is applied. Equation (3) and the default conversion factor for farm yard manure present an approach to vary the scaling factor according to the amount of farm yard manure applied. (IPCC,2007).

$$SF_o = (1 + \sum_i ROA_i * CFOA_i)^{0.59} \qquad (3)$$

Where:

SF_o = scaling factor for both type and amount of organic amendment applied

ROA_i= application rate of organic amendment *i*, in dry weight for straw and fresh weight for others in tonne ha^{-1}

$CFOA_i$= conversion factor for organic amendment *i*(in terms of its relative effect with respect to straw applied shortly before cultivation)

According to IPCC 2006, Guidelines for National Greenhouse Gas Inventories, the default conversion factor for farm yard manure is equal 0.14 with an error range of 0.07-0.20.

2.3 Greenhouse gases emission from field burning

Based on 2006, IPCC Guidelines, the emission factors for burning of rice residue can be estimated using equation 4.

$$L_{fire} = RB * EF * 10^{-3} \qquad (4)$$

Where: L_{fire} the burning emissions in Mg ha^{-1} is the amount of emission from burning of rice residue; RB (Mg) is the amount of rice residue on a dry matter basis that is burned in the field in kg ha-1; EF (g kg-1 dm) is emission factor. The default emission values for rice straw burning of different greenhouse gases are tabulated in Table 1.

Table(1): Default value for emission factors for rice residues open burning.

	Gef (g kg^{-1}dm)
CO_2	1185
CO	113.2
CH_4	2.7
N_2O	0.07
NO_x	3.1
$PM_{2.5}$	27.63
PM_{10}	13
Black Carbon	0.69

According to 2006 IPCC Guidelines

2.4 Greenhouse gases emissions from Fertilizer application

The average nitrogen fertilizer application for cultivated rice is about 285 kg. N / ha. The emission of N2O from rice field was estimated following **Bouwman (1996)**, using the following equation for N_2O emissions from agricultural soils:

$$E = 1 + 0.0125 X F \quad (5)$$

Where E is the emission rate (kg N2O-N ha-1), the 1 gives the background emission rater and F is the fertilizer application rate (kg N ha-1 y-1).

There is also one ton CO_2 per ton of N applied that is generated in manufacturing.

2.5 Greenhouse gases emission from fuel consumption

Egyptian agricultural engineers have compiled average values for power requirements and fuel used per hectare for specific farming tasks in those regions as shown in Table 2 (**Grisso *et al.*, 2004**) these figures assume typical conditions and average working depths and may be used to make fuel estimates for the indicated operations.

Predicting fuel consumption for a specific operation can be estimated using the following calculation according to **ASAE (1998)**:

$$Q_i = Q_s \text{ x } P_{db} \quad (6)$$

Where:

Q_i = estimated fuel consumption for a particular operationin $L.h^{-1}$

Q_s = specific fuel consumption for the given Tractor L/Kw.h

While, a specific fuel consumption (Q_s) estimate may be calculated from the equation as follows(**Grisso *et al.*, 2004**):-

$$Q_s = 2.64 \text{ x} + 3.91 - 0.203 (738 \text{ x} + 173)^{0.5} (7)$$

Where; (x) is the ratio of equivalent PTO power required by an operation to that maximum available from the PTO, this ratio depending on draft and speed of implement.

Power requirements for thresher and mower:

To estimate the engine power during threshing and mowing operation, the fuel use was measured immediately after each treatment. The following formula was used to estimate ending used engine power (EP) according to **Hunt Donnell (1983).**

$$EP = [f.c\ (1/3600) PE \text{ x L.C.V x } 427 \text{ x } \eta thb \text{ x } \eta m \text{ x } 1/75 \text{ x } 1/1.36] \qquad (8)$$

Where :

f.c = The fuel consumption, (L/h)

PE = The density of fuel, (kg/L) (0.823 kg/L)

L.C.V = The lower calorific value of fuel, (11000 k.cal/kg)

ηthb = Thermal efficiency of the engine, (35 % for Diesel)

427 = Thermo-mechanical equivalent, (Kg.m/k.cal)

ηm = Mechanical efficiency of the engine, (80 % for Diesel)

Table(2): Average energy-use rates and fuel requirements for farming tasks

Operation	Energy-use rate, PTO hp-hrs/acre	Diesel fuel, gal/acre	Diesel fuel Liter/ha
Chisel plow	16	1.1	13.4
Combine, small grains	11	1	12.2
Mower	25	1.8	21.6
Thresher	20	1.4	16.8
Water pump (8 hp)	24	1.7	20.4

3. Results and Discussion

3.1 Distribution of rice cultivation in Egypt:

Total rice cultivated and burned from 2008—2011 is tabulated in Table 2. Note the burned rice residue is smaller with composting, manufacturing and other uses being employed on about 40% of the land (according to **EEAA, 2009**). We assumed that the amount burned is stable during the studied period (Table 3).

The largest rice cultivation area a occurs in the Behira, Kafr_El Sheikh, Dakahlia, and Sharkia governorates and these area Northern Coastal zone Governorates in the Egyptian “rice belt”.. After that region, the Lower Egypt region (Nile Delta) has the next largest rice cultivation area.

The highest total rice cultivation was recorded at 2008 at about 739 thousand hectares, these area was decreased by about 170 thousand hectares in 2009 years (after a new policy regarding flood irrigation). The rice cultivation area decreased again at 2010 to be about 456 thousand hectares, but this area increased again at 2011 to be about 588 thousand hectare, but then the rice cultivation area increased in 2011 perhaps due to the 25 January revolution and a lack of government enforcement.

3.2 Annual CO_2 Emission from Machinery activities:

Table 3 shows the calculation results for annual CO_2 emission from machinery activities from 2008 till 2011. Most (76%) of the CO_2 emission production result from irrigation water pumping using diesel pumps.GHG emissions from mower activities contributes about 7.7 % of the total machinery emissions while thresher and combine together contribute about 10 %. The highest annual machinery emission was recorded in 2008 due to the high amount of rice cultivation area. Lower Egypt has the highest GHG emissions because has the largest rice cultivated area (Table 4).

In Egypt flood irrigation predominates for rice production, water is poured into a paddy field until reaches a certain height relevant to plant stage of development. Periodically the irrigation is repeated until the crops are mature and ready for the dry harvest. The roots are kept under water for most of the crop life. The energy required to pump water depends on numerous factors including the water flow rate and the pumping system efficiency (**IPCC, 2006**). The energy use depends on the water table depth or the lift height. The diesel pump system could be as close as possible to the water source or be made floatable to be moved along the irrigation canal. The overall irrigation efficiency is higher as less percolation and drainage losses occur along the open ditch conveying systems. This system need slots of pumping energy and thus pumping uses the most fuel (**Abdulla, 2007**; **Tantawi and Sabaa, 2001**).

3.3 Annual CH_4 and CO_2 Emissions from rice cultivation:

Data in Table 5 illustrate the annual emissions of methane and carbon dioxide from flooded rice field from 2008 till 2011 for different regions (Lower Egypt, Middle Egypt, Upper Egypt and Out the valley). Regarding to CH_4 emissions, the flooded rice fields are a significant source of atmospheric CH_4. The emission is the net result of opposing bacterial processes, production in anaerobic micro environments, and consumption and oxidation in aerobic micro environments, both of which can be found side by side in flooded rice soils. The annual CH_4emissions from the cultivated area was estimated at 285323 Tonnes for 2008, withCH_4decreasingduring 2009, 2010 and 2011 due to smaller cultivated area. Normally, the decomposition of organic matter in soil is caused by microbiological activity with wetlands soils showing rapid decrease in oxygen due to heavy microbiological activity during growth (**Cabangon *et al.*, 2002**). Hence, the soil in wetlands is identified as anaerobic, a condition affecting the chemical and biochemical processes when compared to aerobic soils (**Lemieux *et al.*, 2004 ; Duan *et al.*, 2004**). The minus value results from the anaerobic condition of soils that have been long used for rice cultivation and results in conditions of oxygen deficiency, greatly reducing the oxidation reduction potential (**Wassmann *et al.*, 2000 ; Badawi, 2004**; **Bockel *et al.*, 2010**).

3.4 Annual N_2O from applied nitrogen fertilizers:

Estimates of N_2Oemissions from nitrogen fertilization are presented in Table 6. We again find the highest N_2O emissions during 2008 again due to highest cultivated area of rice. Table 5 also shows the total nitrogen used under the assumption of a constant application rate of 285 kg N per hectare. In turn the highest N_2O emission was also in Lower Egypt. Direct emission of N_2O produced naturally in soils through the microbial processes of nitrification and denitrification, has been shown to be influenced by agricultural management, such as water regime, organic amendments and cropping type (Jiang *et al*., 2003).

3.5 Annual CO_2 Emission from burning rice straw:

Annual output of rice straw per hectare in recent years is almost stable with a value of about 7-8 Tons per hectare, while the total national output differs due to changes the total rice cultivated area (Table2). The estimated annual emissions from rice straw burning are presented in Table 7.

The highest GHG emissions again occur in the 2008 season and in Lower Egypt, These findings are in line with estimates in **Gupta *et al.* (2004).** The major constraint in reducing these emissions is the short time available between rice harvesting and sowing of next crop.

3.6 Total Annual CO_2 Emission and carbon footprint:

The estimated levels of CO_{2eq}across all sources (Machinery, Cultivation, Nitrogen fertilization and rice straw burning) are tabulated in Table 8. Again here the highest total $CO_{2eq}$was occurred in 2008 season and in the Lower Egypt region. The carbon footprint was also estimated at 1.90 Kg CO_{2eq} / Kg is the same in all regions and years because of the assumptions of equal quantity of water and nitrogen fertilizer application in all regions as well as the assumption of constant yields (8.0 tonnes rice grain per hectare and 6.6 tonnes rice straw per hectare).

The carbon footprint of a product is the quantity of greenhouse gases (GHG), expressed in carbon dioxide equivalent (CO_{2eq}) units, emitted across the supply chain for a single unit of that product. Indeed, CFP is a mean for the government to sensitize citizens and industrials to climate change and to reach its GHG reduction target. Moreover, it has a significant advantage for private companies to label their product with the government support since they increase their credibility (**Gerber *et al.*, 2010**). Measuring the carbon footprint of a product across the supply chain is a recent trend that has several benefits. By giving consumers the choice to turn consumption toward more carbon effective products and by advising them on their own reduction opportunities, CFP labels sensitize the population in order to switch to a low carbon economy. Thus, standards systems such as carbon foot printing, potentially can contribute to a low carbon economy through (i) market differentiation, (ii) driving performance and (iii) platforms for discussion and synergies (**Brenton *et al.*, 2010**).

3.7 The contribution of GHG emission sources for rice production

Figure1 shows the percentage contributions from the different aspects and field practices. Methane emissions are the main source of emissions contributing about 53.25 % of the total. Rice straw burning is second contributing 35.82 %, while the machinery activities contribute about 1%. Moreover, nitrogen fertilization contributes about 10% of total GHGs.

Mitigation may be possible and perhaps could generate tradable, income enhancing carbon credits (**Tsuruta *et al.*, 1997**). To reduce emissions one could replace burning of rice straw with some other use, decrease ploughing and take steps to slow organic decomposition and increase photosynthesis. For methane reduction, agriculturists could reduce fertilization, improve soil quality by increasing aeration and drain water from the paddies prior to the panicle formation stage. For N_2O reduction, farmers can add organic fertilizer instead of chemical fertilizer (**Chun *et al.*, 2003, Scheehle and Kruger, 2006; USEPA, 2006**).

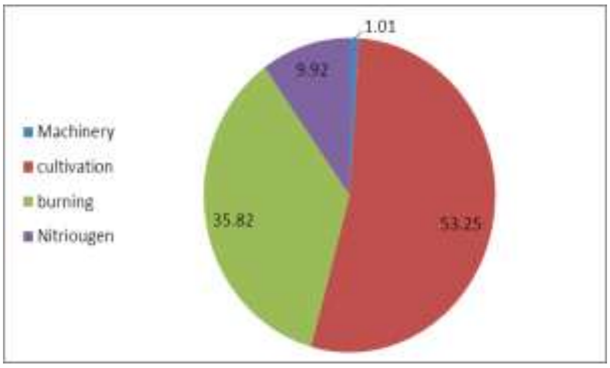

Fig 1: The average percentage of different sources of the GHG resulted from different field practices of rice production in Egypt during the studied period from 2008to 2011.

Uncertainty in emission estimations

Several factors may affect the accuracy of the estimation of emission estimates above. The calculations rely heavily on inferences from limited statistical information and extrapolations of emission factors from limited literature.

Conclusions

This paper presents a detailed calculation of GHG emission from Egyptian rice production. The main sources are methane releases, field burning and nitrogen fertilization. Lower Egypt is the region with the largest emissions. Additionally the carbon footprint per kg paddy rice was computed and some possible mitigation strategies discussed.

Table (3): Distribution of the rice cultivation in Egypt from 2008 – 2011.

Governorates	**Total Cultivated area /ha**				**Total Burnt area/ ha**			
	2008	**2009**	**2010**	**2011**	**2008**	**2009**	**2010**	**2011**
Alexandria	1870	850	955	1059	1122	510	573	635
Behera	97056	83432	64513	87869	58234	50059	38708	52721
Gharbia	74378	52840	43705	51377	44627	31704	26223	30826
Kafr_El Sheikh	149293	135262	115183	123549	89576	81157	69110	74129
Dakahlia	203940	149875	119732	175675	122364	89925	71839	105405
Damietta	30831	26968	23522	28830	18499	16181	14113	17298
Sharkia	140995	106807	77874	98522	84597	64084	46724	59113
Ismailia	1968	1648	1346	2269	1181	989	808	1361
Port Said	8924	8408	6481	9337	5354	5045	3889	5602
Suez	0	0	0	0	0	0	0	0
Qalyoubia	11300	4142	2200	6903	6780	2485	1320	4142
Cairo	14	4	3	0	8	2	2	0
Lower Egypt	720568	570235	455514	585390	432341	342141	273308	351234
BeniSuef	700	209	60	148	420	125	36	89
Fayoum	12605	0	0	0	7563	0	0	0
Middle Egypt	13305	209	60	148	7983	125	36	89
Assuit	81	5	0	0	49	3	0	0
Upper Egypt	81	5	0	0	49	3	0	0
Within the valley	733954	570450	455574	585538	440372	342270	273344	351323
New Valley	4498	378	1135	2830	2699	227	681	1698
Noubaria	726	55	53	108	436	33	32	65
Out the valley	5225	432	1188	2938	3135	259	713	1763
Total	**739178**	**570882**	**456762**	**588477**	**443507**	**342529**	**274057**	**353086**

Table (4): Emissions of carbon dioxide from different mechanical operations during 2008 – 2011.

Region	**Area**	**Irrigation**	**Chisel plow**	**Mower**	**Thresher**	**Combine**	**Total**
	ha	**Tonnes CO$_2$**					
			2008				
Lower Egypt	720568	84775	8298	8641	7272	2263	111249
Middle Egypt	13305	1565	153	159.6	134	42	2054
Upper Egypt	81	10	1	1.0	1	0.25	13
Out the valley	5225	615	60	0.6	53	16	745
Total	**739179**	**86964**	**8513**	**8802**	**7460**	**2322**	**114060**
%		76.24	7.46	7.72	6.54	2.04	100
			2009				
Lower Egypt	570235	67088	6567	6838	5755	1791	88039
Middle Egypt	209	25	2	2.11	0.38	0.66	30
Upper Egypt	5	0.6	0.06	0.05	0.01	0.02	1
Out the valley	432	51	5	4.36	0.79	1.36	62
Total	**570881**	**67164**	**6574**	**6845**	**5756**	**1793**	**88132**
%		76.21	7.46	7.77	6.53	2.03	100
			2010				
Lower Egypt	455514	53591	5246	5463	4596	1431	70327
Middle Egypt	60	7	1	0.1	0.1	0.2	8
Upper Egypt	0	0	0	0	0	0	0
Out the valley	1188	140	14	2.2	1.3	4	161
Total	**456762**	**53738**	**5260**	**5465**	**4597**	**1435**	**70495**
%		76.23	7.46	7.75	6.52	2.04	100
			2011				
Lower Egypt	585390	68871	6741	7020	5907	1839	90378
Middle Egypt	148	17	1.7	0.2	0.5	0.5	20
Upper Egypt	0	0	0	0	0	0	0
Out the valley	2938	346	34	3.2	10	9	402
Total	**588476**	**69234**	**6777**	**7023**	**5917**	**1848**	**90800**
%		76.25	7.46	7.74	6.52	2.04	100

Table (5): Emissions of Methane and carbon dioxide from rice fields during 2008 – 2011.

	Area	CH_4	CO_2eq *
Region	ha	Tonnes	Tonnes
	2008		
Lower Egypt	720568	278139	5840924
Middle Egypt	13305	5135	107850
Upper Egypt	81	31	657
Out the valley	5225	2016	42354
Total	**739179**	**285323**	**5991785**
	2009		
Lower Egypt	570235	220110	4622325
Middle Egypt	209	80.674	1694
Upper Egypt	5	2	41
Out the valley	432	166	3502
Total	570881	220360	4627561
	2010		
Lower Egypt	455514	175828	3692396
Middle Egypt	60	23	486
Upper Egypt	0	0	0
Out the valley	1188	458	9630
Total	**456762**	**176310**	**3702513**
	2011		
Lower Egypt	585390	225960	4745171
Middle Egypt	148	57	1200
Upper Egypt	0	0	0
Out the valley	2938	1134	23815
Total	**588476**	**227152**	**4770186**

- CO_2eq: the value of CH_4 multiplied by 21

Table (6): Emissions of nitrous oxide and carbon dioxide from rice field during 2008 – 2011.

	Area	**Total applied N**	**N_2O**	**CO_2**
Region	**ha**	**kg**	**kg**	**Tonnes**
		2008		
Lower Egypt	720568	205361880	2567025	1087842
Middle Egypt	13305	3791925	47400	20087
Upper Egypt	81.0	23085	290	122.3
Out the valley	5225	1489125	18615	7888
Total	**739179**	**210666015**	**2633329**	**1115939**
		2009		
Lower Egypt	570235	162516975	2031463	860884
Middle Egypt	209	59565	746	316
Upper Egypt	5.0	1425	18.8	7.5
Out the valley	432	123120	1540	652
Total	**570882**	**162701085**	**2033768**	**861859**
		2010		
Lower Egypt	455514	129821490	1622770	687689
Middle Egypt	60	17100	215	91
Upper Egypt	0.0	0.0	0.0	0.0
Out the valley	1188	338580	4233	1794
Total	**456762**	**130177170**	**1627218**	**689574**
		2011		
Lower Egypt	585390	166836150	2085453	883763
Middle Egypt	148	42180	528	223
Upper Egypt	0	0	0	0
Out the valley	2938	837330	10468	4435
Total	**588476**	**167715660**	**2096449**	**888422**

Table (7): Emission of CO_2, CO, CH_4, N_2O, NO_x, PM2.5, PM10 and black carbon from rice straw during 2008 – 2011.

Region	**Area**	**Tonnes**								
	ha	**CO_{2eq}**	**CO**	**CH_4**	**N_2O**	**NOx**	**PM2.5**	**PM10**	**Black carbon**	**Total CO2**
		2008								
Lower Egypt	432341	3381337	380079	7704	19.97	8846	79697	37095	197	3929399
Middle Egypt	7983	62435	7018	142	0.37	163	1472	685	3.64	72555
Upper Egypt	48.6	380	42.7	0.87	0.00	0.99	8.96	4.17	0.02	441.7
Out the valley	3135	24519	2756	55.9	0.14	64.14	577.90	268.98	1.43	28493.0
Total	**443507**	**3468671**	**389896**	**7903**	**20**	**9074**	**81755**	**38053**	**202**	**4030889**
2009										
Lower Egypt	342141	2675885	300783	6097	15.81	7000	63070	29356	156	3109604
Middle Egypt	125	981	110	2	0.01	2.57	23.12	10.76	0.06	1139.7
Upper Egypt	3.00	23	2.64	0.05	0.00	0.06	0.55	0.26	0.00	27.3
Out the valley	259	2027	228	4.6	0.01	5.30	47.78	22.24	0.12	2355.8
Total	**342529**	**2678916**	**301124**	**6104**	**16**	**7008**	**63141**	**29389**	**156**	**3113127**
2010										
Lower Egypt	273308	2137545	240271	4870	12.63	5592	50381	23450	124	2484007
Middle Egypt	36.0	282	31.6	1	0.00	0.74	6.64	3.09	0.02	327.2
Upper Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Out the valley	713	5575	627	12.7	0.03	14.58	131.40	61.16	0.32	6478.4
Total	**274057**	**2143401**	**240929**	**4884**	**13**	**5607**	**50519**	**23514**	**125**	**2490813**
2011										
Lower Egypt	351234	2747001	308777	6259	16.23	7186	64746	30136	160	3192247
Middle Egypt	88.8	695	78.1	2	0.00	1.82	16.37	7.62	0.04	807
Upper Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Out the valley	1763	13787	1550	31.4	0.08	36.07	325	151	0.80	16022
Total	**353086**	**2761482**	**310405**	**6292**	**16**	**7224**	**65087**	**30295**	**161**	**3209076**

Table (8): Carbon footprint for paddy rice based on the estimation of the total emission of CO_2 from different rice production activities during 2008 to 2011.

Region	**Area**	**CO_2**	**CO_2**
	ha	**tonnes**	**Gg**
2008			
Lower Egypt	720568	10969414	10969
Middle Egypt	13305	202546	203
Upper Egypt	81	1233	1.23
Out the valley	5225	79480	79.48
Total	**739178**	**11252673**	**11253**
Carbon footprint Kg Co_2eq / Kg paddy rice			1.90
2009			
Lower Egypt	570235	8680852	8681
Middle Egypt	209	3180	3.18
Upper Egypt	5	76	0.08
Out the valley	432	6572	6.57
Total	**570882**	**8690679**	**8691**
Carbon footprint Kg Co_2eq / Kg paddy rice			1.90
2010			
Lower Egypt	455514	6934420	6934
Middle Egypt	60	912	1
Upper Egypt	0	0	0.00
Out the valley	1188	18063	18.06
Total	**456762**	**6953395**	**6953**
Carbon footprint Kg Co2eq / Kg paddy rice			1.90
2011			
Lower Egypt	585390	8911560	8912
Middle Egypt	148	2250	2
Upper Egypt	0	0	0.00
Out the valley	2938	44674	44.67
Total	**588477**	**8958484**	**8958**
Carbon foot print Kg Co_2eq / Kg paddy rice			1.90

Corresponding author
Farag, A. A
Central Laboratory for Agricultural Climate, Agricultural Research Center, Dokki 12411, Giza-Egypt
awny_a@yahoo.com

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