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## **The Development-Conservation Trade-off Facing Indian Agriculture: Carbon Costs of Punjab Agriculture**

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### **Abstract**

Developing nations pursuing the dual goals of development and conservation face high social and political costs in adopting pro-conservation policies. Such costs often hinder in embodying environmental valuation of natural resources into the market prices. This study has dealt with this macro issue by understanding the case-specific implications of intensive agricultural practices on the environment in the state of Punjab. The study is based on the primary data from 80 farmers of Punjab following the paddy-wheat rotation. The input use data of the crops have been used to compute the monetary cost of cultivation and the corresponding environmental cost has been expressed as carbon equivalents (CE). The analysis of variance has been carried out to address the issue of differing efficiencies of production across different landholding categories. The study has revealed that paddy crop is more expensive than wheat crop in both monetary and environmental terms and small farmers demonstrate larger inefficiencies in production as compared to medium and large farmers. Electricity has been found to be the major component for environmental cost for paddy while diesel and fertilizer occupied significant shares for both crops. Moreover, electricity for agricultural purposes being completely subsidized in Punjab, has not been reflected in the monetary cost, thus destroying an important incentive for rational use of resources.

**Key words:** environment, paddy, wheat, carbon equivalents, intensive agriculture

**JEL Classification:** Q01, Q10, Q15, Q51

### **Introduction**

The Brundtland Commission (World Commission on Environment and Development, 1987) had laid down the task of reconciling short-term goals of increasing food production and agricultural productivity for the present generation with the long-term needs for conserving natural resources in order to meet the requirements of our future generations. With this goal in mind, the nations across the world have been modifying their production technologies to accommodate environmental issues, with developed nations pioneering ahead. However, in the context of developing nations, such considerations come at

considerable social and economic costs, thereby necessitating the need to strike a balance between agricultural development on one hand and conservation of resources on the other to achieve the much desired goal of ensuring food security and sustainability.

The policy solutions to the problem of trade off between development and conservation for developing nations need to be manoeuvred carefully in the light of such constraints. The Food and Agriculture Organization of United Nations has suggested many suitable policy initiatives, such as well-defined property rights for the private and public resources and embodiment of environmental costs in the market prices of scarce natural resources (Alexandrios and Bruinsma, 2012). However, these seemingly simple

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initiatives may actually become Herculean tasks given the socio-political mesh of developing nations.

This development-conservation trade off is mirrored in the Indian scenario, wherein the Green Revolution has been termed both as a boon and a bane for the agricultural sector. The environmental costs of the intensive practices embedded in the warp and woof of Green Revolution have often been discussed, but rarely quantified. Further, far from embodying these costs, the market prices themselves are highly distorted due to heavy input subsidies in India. This study is an effort towards quantifying the environmental costs of agricultural production system in the state of Punjab. The choice of the study location is based on the fact that among different states of India, Punjab has recorded the highest foodgrain yield (3890 kg/ha) during the year of study, viz. 2012-13. Further, Punjab tops in fertilizer-usage per hectare, area under irrigation and cropping intensity for the same year, thus putting it in a suitable position for a preliminary study on carbon cost of agriculture in the state.

This study primarily deals with a macro issue of environmental degradation, by understanding the case-specific implications of highly intensive agricultural practices being followed in the state of Punjab. It tries to capture the gravity of this problem by computing environmental costs of the paddy-wheat rotation, which occupies 80 per cent of the gross cropped area of Punjab. An effort has also been made to synthesize the environmental costs with the monetary costs associated with paddy-wheat rotation. It carries implications for

the broader linkages between state and central power subsidies and the agricultural sector.

## Data and Methodology

The primary data for study were collected through personal interview method using a pre-tested interview schedule, the time frame of the study being the agricultural year 2012-13. Four-stage sampling technique was adopted for selection of sample. In the first stage, two top-ranking districts (Ludhiana and Sangrur) with respect to rice and wheat acreages were selected based on the state level data (*Statistical Abstract of Punjab*, 2012). From each selected district, two blocks, from each block two villages and finally from each village, ten farmers were selected randomly, making the sample size of 80 farmers. The criteria followed for selection was that the farmer must be practicing paddy and wheat rotation on not less than 70 per cent of the net sown area. The farmers from different landholding categories were clubbed into the following three groups: small (up to 5 acres), medium (5-10 acres) and large (>10 acres) farmers. The analysis of data was done in light of the debate on differing efficiencies of production across these different landholding categories.

From data, the variable cost and return over variable cost were computed for paddy and wheat on per acre basis. To calculate the environmental costs of production of these crops all agricultural inputs were converted into their carbon equivalents (kg CE) using conversion factors culled from literature (Table 1).

**Table 1. Carbon equivalents of various inputs of crop production**

Particulars	Carbon equivalent (kg CE per unit of component)	Source
Seed, kg	0.4	Dubey (2008)
Fertilizers, kg		
Farm Yard Manure	0.0075	Lal (2004)
Nitrogen	1.3	Dubey (2008)
Phosphorus	0.2	
<b>Plant protection chemicals, kg active ingredient</b>		
Insecticides	5.1	Lal (2004)
Weedicides	6.3	
Fungicides	3.9	
Stationary combustion of diesel <sup>2</sup> (Pumps, Diesel Engines), litres	4.20	Endnote
Mobile combustion of diesel <sup>3</sup> (Tractors), litres	4.67	Endnote
Irrigation through electrically powered pumpset <sup>4</sup> , kWh	0.2049	Endnote

**Table 2. Agronomic and economic productivity of paddy crop in Punjab, 2012-13**

Particulars	Small farmers (n <sub>1</sub> =21)	Medium farmers (n <sub>2</sub> =27)	Large farmers (n <sub>3</sub> =32)	All farmers (N=80)
Agronomic productivity, q/ acre	27.6 <sup>a</sup>	28.4 <sup>a</sup>	29.3 <sup>a</sup>	28.6
Total variable cost, ₹/acre	11963 <sup>a</sup>	10104 <sup>b</sup>	10289 <sup>b</sup>	10666
Total returns, ₹/acre (@ ₹ 1280/t)	35352 <sup>a</sup>	36408 <sup>a</sup>	37523 <sup>a</sup>	36577
Returns over variable cost, ₹/acre	23389 <sup>a</sup>	26305 <sup>a</sup>	27234 <sup>a</sup>	25911

Note: <sup>ab</sup>Figures with different superscripts in a row differ significantly (p<0.05)

“Carbon equivalent” is described by Green and Byrne (2004) as a “measure to express the emissions of different greenhouse gases based on their global warming potential (GWP<sup>1</sup>)”. These carbon equivalents are expressed as carbon costs of each agricultural input in kg CE per acre. The carbon cost for production of paddy and wheat was the aggregate of the cost of each input.

One way analysis of variance was carried out to test the significance of difference among the different landholding categories with respect to various agronomic, economic and environmental indicators.

## Results and Discussion

### Agronomic and Economic Productivity of Paddy Crop in Punjab

The agronomic productivity of paddy has been expressed in form of grain yield, while the economic productivity has been measured using the returns over variable costs. A perusal of Table 2 reveals that the agronomic productivity of paddy crop in Punjab was 28.6 q/acre and did not vary significantly across the landholding categories. As enunciated by the ANOVA, the variable cost for small farmers was significantly higher (₹ 11963/acre) as compared to medium (₹ 10104/acre) and large farmers (₹ 10289/acre). The overall variable cost was computed as ₹ 10666/acre, whereas the total returns per acre were found to be ₹ 36577/acre, leading to a profit of ₹ 25911/acre. The returns over variable cost did not differ across the three landholding categories. The paddy cultivation was thus a remunerative business, although the variable costs were higher for the smaller farmers.

### Monetary and Environmental Costs of Paddy Production in Punjab

The break-up of monetary cost of paddy production, presented in Table 3, reveals that the cost was highest on machine labour (33.2%), followed by human labour (27.9%), fertilizer application (18.6%), plant protection (11.7%) and transport and marketing (4.6%) in the total variable cost.

All cost components were subjected to the analysis of variance and it was found that significant differences in cost per unit of land for the three landholding categories existed for total machine labour, total fertilizer, plant protection and interest over the variable costs. The per unit cost of fertilizer and manure, was highest for the small farmers, followed by medium and large farmers. These differences could be due to the fact that small and medium farmers do not have sufficient amount of home-produced manure and thus have to resort to buying manure at high rates. The cost of total machine labour and interest over the working capital was significantly higher for the small farmers than the other two categories. The cost of applying plant protection chemicals was lower for the small farmers as compared to the other two categories. The total per unit cost of paddy cultivation was higher for the small farmers than to the other farmer categories.

The environmental cost for paddy cultivation was measured using the carbon equivalents of all inputs used in the production process as shown in Table 4. A perusal of Table 4 indicates that the overall carbon cost of paddy production was 627 kg CE/acre. The values for small, medium and large farmers were 835 kg CE/acre, 575 kg CE/acre and 533 kg CE/acre, respectively. The cost was significantly higher for the small farmer as compared to other two farmer categories. The carbon inputs were found to differ significantly among the

**Table 3. Break-up of cost of cultivation of paddy crop in Punjab, 2012-13**

(₹ /acre)

Particulars	Small farmers (n <sub>1</sub> =21)	Medium farmers (n <sub>2</sub> =27)	Large farmers (n <sub>3</sub> =32)	All farmers (N=80)
Human labour	3064 <sup>a</sup> (25.6)	2898 <sup>a</sup> (28.7)	2991 <sup>a</sup> (29.1)	2979 (27.9)
Seed	263 <sup>a</sup> (2.2)	192 <sup>a</sup> (1.9)	229 <sup>a</sup> (2.2)	226 (2.1)
Machine labour	4179 <sup>a</sup> (34.9)	3122 <sup>b</sup> (30.9)	3483 <sup>b</sup> (33.8)	3544 (33.2)
Fertilizer and manure	2645 <sup>a</sup> (22.1)	1952 <sup>b</sup> (19.3)	1574 <sup>c</sup> (15.3)	1983 (18.6)
Plant protection chemicals	1084 <sup>b</sup> (9.1)	1266 <sup>a</sup> (12.5)	1335 <sup>a</sup> (13.0)	1246 (11.7)
Marketing and transportation	508 <sup>a</sup> (4.2)	488 <sup>a</sup> (4.8)	489 <sup>a</sup> (4.8)	494 (4.6)
Interest on working capital	220 <sup>a</sup> (1.8)	186 <sup>b</sup> (1.8)	189 <sup>b</sup> (1.8)	196 (1.8)
Total variable cost	11963 <sup>a</sup>	10104 <sup>b</sup>	10290 <sup>b</sup>	10666

Note: Figures within the parentheses denote percentage of total

<sup>abc</sup>Figures with different superscripts in a row differ significantly (p<0.05)

**Table 4. Input-wise carbon equivalents for paddy production in Punjab, 2012-13**

(in kg CE/acre)

Particulars	Small farmers (n <sub>1</sub> =21)	Medium farmers (n <sub>2</sub> =27)	Large farmers (n <sub>3</sub> =32)	All farmers (N=80)
Seed	3 <sup>a</sup> (0.3)	3 <sup>a</sup> (0.5)	3 <sup>a</sup> (0.5)	3 (0.4)
Fertilizers	102 <sup>a</sup> (12.2)	98 <sup>a</sup> (17.0)	94 <sup>a</sup> (17.7)	97 (15.5)
Pesticides	5 <sup>a</sup> (0.5)	4 <sup>a</sup> (0.7)	5 <sup>a</sup> (0.9)	5 (0.7)
Diesel	267 <sup>a</sup> (32.0)	202 <sup>b</sup> (30.5)	224 <sup>ab</sup> (42.1)	228 (36.4)
Electricity	459 <sup>a</sup> (54.9)	269 <sup>b</sup> (46.8)	207 <sup>b</sup> (38.8)	294 (46.9)
Total	835 <sup>a</sup>	575 <sup>b</sup>	533 <sup>b</sup>	627

Note: Figures within the brackets depict percentages of total

<sup>ab</sup>Figures with different superscripts in a row differ significantly (p<0.05)

landholding categories only for diesel and electricity consumption. In the case of diesel, the small farmers showed higher consumption of diesel per acre, at 267 kg CE/acre as compared to medium farmers who consumed 202 kg CE/acre. However, the carbon cost

of diesel for large farmers was in between of those for both small and medium farmers. The cost of electricity used for operating tube-wells was significantly higher for the small farmers, at 459 kg CE/acre, as compared to medium and large farmers who consumed 269 kg

**Table 5. Agronomic and economic productivity of wheat crop in Punjab, 2012-13**

Particulars	Small farmers (n <sub>1</sub> =21)	Medium farmers (n <sub>2</sub> =27)	Large farmers (n <sub>3</sub> =32)	All farmers (N=80)
Agronomic productivity, q/acre	20.6	20.4	20.3	20.4
Total Variable Cost, ₹ /acre	7851	7841	8134	796
Total Returns, ₹ /acre	31629	31327	30635	31130
Returns over variable cost, ₹ /acre	23778	23486	22501	23169

*Note:* Figures in bracket depict percentage to the total

CE/acre and 207 kg CE/acre, respectively. These differences may be attributed to the fixed cost of operating a tube-well or diesel engine which inflates the per unit cost of a small farmer in comparison to a large farmer. Since most farmers prefer ownership of assets in Punjab, the small farmers often have to operate the tube-wells and other machinery at a less than optimal scale.

It is further observed that the largest contribution to carbon inputs was from electricity consumption by tube-wells which made up 46.9 per cent of the total. It was followed by the carbon input due to diesel consumption (36.4 %). Fertilizer-usage was next with a contribution of 15.5 per cent. Input of pesticides and seed made small contributions of only 0.7 per cent and 0.4 per cent, respectively, to the carbon input cost. It could be inferred that small farmers of paddy have to incur higher costs in both monetary and environmental terms due to lower economies of scale and underutilization of fixed assets such as tube-wells.

### **Agronomic and Economic Productivity of Wheat Crop**

The agronomic and economic productivities of wheat were also measured using grain yield and returns over the variable cost, respectively. Table 5 reveals that the mean agronomic productivity of wheat crop in Punjab was 20.4 q/acre and it did not vary significantly across the landholding categories. In fact, the wheat crop did not show any significant variation across the landholding categories for the total variable costs and returns.

The total variable cost of wheat cultivation was computed to be ₹ 7961/acre and the total returns were obtained equal to ₹ 31129/acre. Thus, the returns over variable costs obtained were ₹ 23168/acre. As opposed to the paddy crop, no significant differences were

observed across the values for the different landholding categories. The wheat crop is however, slightly less remunerative than the paddy crop, as shown by the returns over variable cost.

### **Monetary and Environmental Cost of Wheat Production in Punjab**

In cost of wheat production (Table 6), there was a significant share of machine labour (39 %) and fertilizers (30%). Although the overall cost of cultivation was not significantly different across the landholding categories, some individual components, not mentioned in the table, did show differences. Firstly, the cost of permanent labour for large farmers and owned machinery for medium and large farmers was significantly higher as compared to that for small farmers. In contrast, the cost of hired machinery was higher for small farmers.

The information on environmental cost of wheat production, in the form of carbon inputs is presented in Table 7. The total carbon input for wheat was 276 kg CE/acre, which is lower than that for paddy primarily due to less electricity consumption for irrigation purposes. There was no significant difference among the three landholding categories for the total carbon input as well as for any input component. It can be seen that diesel consumption made up the largest portion of carbon input with 52.7 per cent of share in the total amount. Fertilizer application followed with a contribution of 40.1 per cent. Other inputs such as seed, pesticides and electricity constituted only 5.8, 0.7 and 0.7 per cent of the total carbon input.

### **A Comparison of Monetary and Environmental Costs**

The comparison of monetary and environmental costs for paddy and wheat crops has depicted wide



**Table 6. Break-up of cost of cultivation for wheat crop in Punjab, 2012-13**

Particulars	(₹/acre)			
	Small farmers (n <sub>1</sub> =21)	Medium farmers (n <sub>2</sub> =27)	Large farmers (n <sub>3</sub> =32)	All farmers (N=80)
Human labour	545 (6.9)	601 (7.7)	866 (10.6)	692 (8.7)
Seed	802 (10.2)	752 (9.6)	754 (9.3)	766 (9.6)
Machine labour	3364 (42.8)	3003 (38.3)	3031 (37.3)	3109 (39.0)
Fertilizer and manure	2297 (29.3)	2430 (31.0)	2435 (29.9)	2397 (30.1)
Plant protection	521 (6.6)	620 (7.9)	582 (7.1)	579 (7.3)
Marketing and transport	177 (2.3)	290 (3.7)	318 (3.9)	272 (3.4)
Interest on working capital	145 (1.8)	144 (1.8)	150 (1.8)	147 (1.8)
Total variable cost	7851	7841	8134	7961

*Note:* Figures within the parentheses depict percentage to the total

**Table 7. Input-wise carbon equivalents for wheat production in Punjab, 2012-13**

Particulars	(kg CE/acre)			
	Small farmers (n <sub>1</sub> =21)	Medium farmers (n <sub>2</sub> =27)	Large farmers (n <sub>3</sub> =32)	All farmers (N=80)
Seed	16 (6.0)	16 (5.8)	16 (5.8)	16 (5.8)
Fertilizers	110 (40.6)	114 (41.0)	108 (39.0)	111 (40.1)
Pesticides	2 (0.7)	2 (0.7)	2 (0.7)	2 (0.7)
Diesel	142 (52.0)	145 (51.7)	149 (53.9)	146 (52.7)
Electricity	2 (0.8)	2 (0.7)	2 (0.7)	2 (0.7)
Total	272	279	276	276

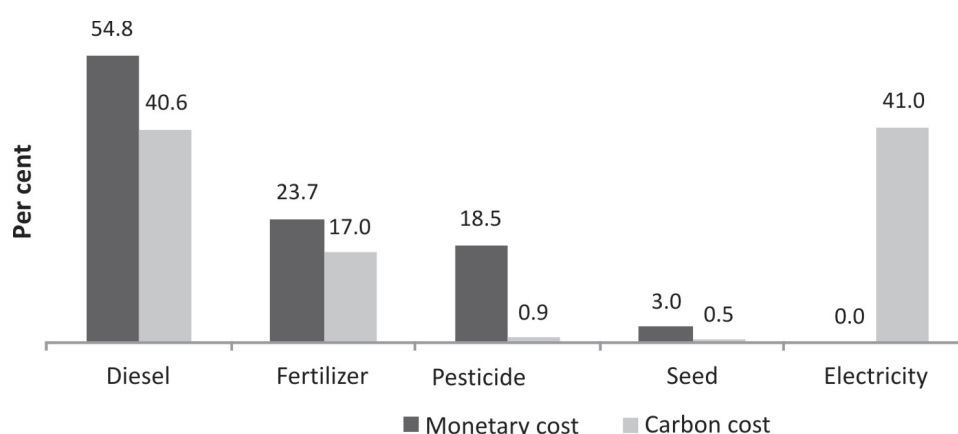
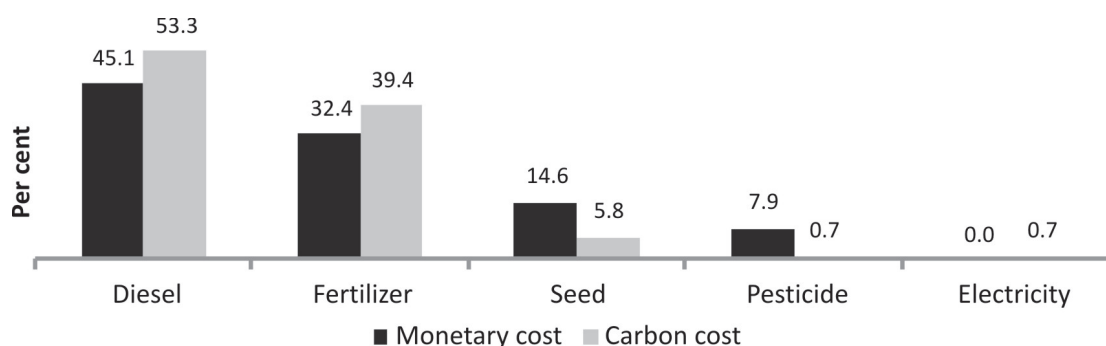
*Note:* Figures within the parentheses depict percentages of total

disparity which exists between the valuation of resources and their actual cost on the environment. For making these costs comparable, we eliminated the labour cost and interest over the working capital, for which there is no counterpart in the environmental cost, from the monetary cost. Further, the costs on machine labour and marketing and transportation were clubbed

with the larger group of diesel cost. We thus had the cost components as elucidated in the Table 8, which comprised 70 per cent and 80 per cent of the total variable costs of paddy and wheat cultivation, respectively. The difference in the percentage cost component of paddy and wheat is primarily due to a larger share of labour cost in total variable cost of

**Table 8. A comparison of monetary and carbon costs of paddy and wheat**

Particulars	Monetary cost (₹/acre)		Carbon cost (kg CE/acre)	
	Paddy	Wheat	Paddy	Wheat
Seed	226	766	2.7	16.1
Fertilizer	1983	2397	97.4	110.6
Pesticides	1246	579	4.6	1.9
Diesel	3984	3380	227.9	145.5
Electricity	0	0	293.9	2.1

**Figure 1. Share of different inputs in monetary and carbon costs for paddy crop****Figure 2. Share of different inputs in monetary and carbon costs for wheat crop**

paddy. It can be observed that the monetary and carbon cost of seed and fertilizer was comparatively higher for the wheat crop while that of pesticides, diesel and electricity was higher for the paddy crop.

Figures 1 and 2 depict a comparison of the shares of monetary and environmental costs of each component for paddy and wheat, respectively. The Figure 1 shows that the cost of diesel comprised the largest share (54.8%) in rupee cost and the cost of electricity occupied the topmost share (41%) in environmental cost of paddy production. Carbon cost of diesel followed closely with 40.6 percentage share.

Fertilizers occupied 23.7 per cent and 17.0 per cent share of rupee and carbon cost, respectively. The pesticides cost to a farmer was 18.5 per cent of his total spending, while they accounted for only 0.9 per cent share in carbon cost. The large share of electricity in environmental cost seems to have distorted the cost structure and reduced the share of other components.

Figure 2 depicts the monetary and environmental costs of wheat production. It shows that diesel consumption contributed highest share in both the costs, viz. 45.1 per cent in the cultivation cost and 53.3 per cent in the carbon cost. Similarly, fertilizers



occupied the second position in both the costs, 32.4 per cent in monetary cost and 39.4 per cent in environmental cost. The higher requirement of seed in wheat was evident as 14.6 per cent of the rupee cost was spent on seeds, while 5.8 per cent carbon cost was also contributed by wheat seed. Pesticides made up 7.9 per cent of monetary cost but occupied only 0.7 per cent of carbon cost. The environmental cost of electricity was very small at 0.7 per cent. This was due to less need of electricity for wheat cultivation since irrigation requirements of wheat are considerably low. While there was no distortion of cost due to excessive electricity usage as in paddy, it is evident that environmental costs of diesel and fertilizer were larger than the monetary cost, again indicating a mismatch in monetary and environmental valuation of resources.

## Conclusions

The study has revealed that paddy crop is more expensive than wheat crop in both monetary and environmental terms. The expense is heavier for the smaller farmers due to the inefficiencies associated with using fixed assets like tube-wells and owned heavy machinery on small plots of land. The need to hire machinery and buy manure at high cost further inflates the cost of cultivation for small farmers of Punjab.

The environmental burden of electricity used to operate tube-wells for irrigation of paddy crop has been found to be the highest among all other components. Diesel and fertilizers were also the major components of the environmental costs of both paddy and wheat. However, unlike diesel and fertilizers, the environmental cost of electricity was not reflected in its monetary cost due to complete subsidization of electricity in the agricultural sector of Punjab. Subsidization of electricity, which was coined as a necessity for development of paddy based agricultural system in Punjab, has thus become a threat to its long-term sustainability by destroying the economic incentives to conserve electricity. Therefore, concerted efforts are urgently needed to modify policy to reach at some synergy between development and conservation motives.

## Endnotes

1. **Global Warming Potential (GWP)** – It has been described by IPCC (2007) as “an index, describing

the radiative characteristics of different greenhouse gases, that represent the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing infrared radiation”. In other words, it represents the warming effect of one unit of gas relative to that of carbon dioxide. Global Warming Potential of major green-house gases is as follows:

Carbon dioxide (CO<sub>2</sub>) – 1

Methane (CH<sub>4</sub>) – 1

Nitrous oxide (N<sub>2</sub>O) – 310.

2. **Stationary Combustion of Diesel** — It relates to the fossil fuel combustion from stationary sources. For the agricultural sector these include emissions from fuels combusted in pumps, grain drying, horticultural greenhouses and any other stationary combustion (IPCC, 2006c).

The conversion factors for stationary combustion of diesel are given below:

CE of CO <sub>2</sub> , kg CE/TJ	74100	} IPCC (2006a)
CE of CH <sub>4</sub> , kg CE/TJ	10	
CE of N <sub>2</sub> O, kg CE/TJ	0.6	
Diesel, MJ/litres	56.31	Singh and Mittal (1992)

Note: TJ is Tera Joules

CE from emissions of (CO<sub>2</sub> + CH<sub>4</sub> + N<sub>2</sub>O) due to stationary diesel consumption

$$=[\text{CE of CO}_2 \times \text{GWP of CO}_2] + [\text{CE of CH}_4 \times \text{GWP of CH}_4] + [\text{CE of N}_2\text{O} \times \text{GWP of N}_2\text{O}]$$

$$=[74100 \times 1] + [10 \times 21] + [0.6 \times 310] \text{ kg CE/ TJ of diesel}$$

$$=74496 \text{ kg CE/ TJ of diesel}$$

$$=4.2 \text{ kg CE/ litre of diesel}$$

3. **Mobile Combustion of Diesel** — The combustion of fossil fuels for all on-road and off-road vehicles comprises mobile combustion. Volume 1, Chapter 2 of IPCC guidelines describe emission from mobile combustion from the agriculture sector as the emission from fuels combusted in traction vehicles on farm and in forests.

The conversion factors for mobile combustion of diesel are given below:

CE of CO <sub>2</sub> , kg CE/TJ	74100	} IPCC (2006b)
CE of CH <sub>4</sub> , kg CE/TJ	4.15	
CE of N <sub>2</sub> O, kg CE/TJ	28.6	
Diesel, MJ/litres	56.31	Singh and Mittal (1992)

Note: TJ is Tera Joules

CE from emissions of (CO<sub>2</sub> + CH<sub>4</sub> + N<sub>2</sub>O) due to stationary diesel consumption

$$\begin{aligned}
 &= \text{CE from emissions of (CO}_2 + \text{CH}_4 + \text{N}_2\text{O)} \\
 &= [\text{CE of CO}_2 \times \text{GWP of CO}_2] + [\text{CE of CH}_4 \times \text{GWP of CH}_4] + [\text{CE of N}_2\text{O} \times \text{GWP of N}_2\text{O}] \\
 &= [74100 \times 1] + [4.15 \times 21] + [28.3 \times 310] \text{ kg CE/TJ of diesel} \\
 &= 83053.15 \text{ kg CE/TJ of diesel} \\
 &= 4.67 \text{ kg CE/ litre of diesel}
 \end{aligned}$$

#### 4. Carbon Emissions from Electricity Consumption for Irrigation

Step 1: Calculation of electricity consumed from operation hours of machinery (Singh and Mittal, 1992)

Electricity consumed (kWh) = Rated Horse Power  $\times$  Conversion Factor  $\times$  hours of operation

Step 2: Calculation of carbon equivalents for per unit electricity produced

These are calculated as per source of electricity as given below:

Source of electricity	Weightage in total electricity production <sup>#</sup>	kg CE per unit consumption of source <sup>†</sup>	kg CE/kWh
Coal/Peat	0.6794	0.274	0.1862
Gas	0.1031	0.156	0.0026
Oil	0.0116	0.225	0.0161
Others*	0.2058	0.00	0.0000
Total	1.00		0.2049

Source: <sup>#</sup> International Energy Agency (2011)

<sup>†</sup> West and Marland (2002)

\*Hydro, Nuclear, Wind, Biofuels

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