Int.J.Curr.Microbiol.App.Sci **(2018) Special Issue-7: 4436-4445**

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Special Issue-7 pp. 4436-4445**
Journal homepage: http://www.ijcmas.com

Original Research Article

Resource Use Pattern, Efficiency and Environmental Pollution in Cereal Crops of Vindhyan Agriculture in India

Kusumakar Gautam* and Kerobim Lakra

Department of Agricultural Economics, Birsa Agricultural University, India
**Corresponding author*

Keywords

Agriculture, Input use, Natural resource, Efficiency, Crops, Cobb-Douglas production function

A B S T R A C T

Agriculture is the backbone of the India faces occasional upheavals in the production and productivity due to climatic aberrations resulting widespread floods, droughts and other natural calamities. Given the finite supply of natural resources, agriculture that is inefficient may eventually exhaust the available resources or the ability to afford and acquire them. It may also generate negative externality, such as pollution as well as financial and production costs, which has cascading effect on the human life. Agriculture that relies mainly on inputs that are extracted from the earth's crust or produced by society, contributes to the depletion and degradation of the environment. Despite this continuing practice, unsustainable agriculture continues because it is financially more cost-effective than sustainable agriculture in the short term. In the present study, I have tried to show the natural and human resource use pattern in agriculture using different crops grown in the region and resource use efficiency of the inputs used in different crops. Efficiency of the input use has been worked out with the help of Cobb Douglas production function in which the existing input use, recommended input use in the different crops and the optimal input use have been worked out to compare the trade-offs between the level of input use. Further the carbon emission on the farms has been studied by fertilizer and diesel use.

Introduction

In term of economy the extent to which farm revenue can be generated depends on market orientation and government subsidy. The sold value of crops must be accounted in the sustainability equation. Fresh agricultural produce sold from a farm requires little additional energy, in addition to energy required for cultivation, harvest, and transportation (including consumers). Food sold at a remote location, whether at a farmers' market or the supermarket, incurs a different set of energy cost for materials, labour, and transport. To be sold at a remote location requires a complex economic system in which the farm producers form the first link in a chain of processors and handlers to the consumers. Such practice provide greater revenue due to efficient transport of a large number of items, but it involves externalities and relies on the use of non-renewable resources, shipping, processing, and handling, making it least sustainable. Moreover, such a system is considered vulnerable to fluctuations, such as strikes, oil prices, and global economic conditions including labour, interest rates, futures markets, and farm product prices.

In Third World agriculture anthropologist Robert Netting's work play significant role in as social components of sustainability. In Smallholders, Householders: Farm Families and the Ecology of Intensive, Sustainable Agriculture, he defines an important cross-cultural pattern of high-labor, high-production cultivation exemplified East Asian paddy rice cultivators, African cultivators such as the Kofyar, alpine peasants, and Mesoamerican farmers of raised fields. One key to socio-economic sustainability in such systems is that these farmers systems provide for much of their own subsistence and also participate in the market. From a system's view, the gain and loss factors for sustainability can be listed. The most important factors for an individual site are sun, air, soil and water as rainfall. These are naturally present in the system as part of the larger planetary processes and incur no costs. Of the four, soil quality and quantity are most amenable to human intervention through time and labour. (The economic input depends solely on the price of labour and cost of machinery used). Natural growth and outputs are also subject to human intervention. What grows and how and where it is grown is a matter of choice. Two of the many possible practices of sustainable agriculture are crop rotation and soil amendment, both designed to ensure that crops is cultivated can obtain the necessary nutrients for healthy growth.

Keeping in view, the population of India, where more than 55 per cent of the populations are employed in agriculture and allied sectors, agriculture is the back bone of this country, the scenario of agriculture in Uttar Pradesh, which is the most populous state of the country, is not very different than in other regions in the country. There are variations in the availability of natural resources and socioeconomic conditions in the rural areas. According to Pretty and Ball, 2001, Agriculture as an economic sector contributes to carbon emissions through the consumption of direct and indirect fossil fuel. With the increased use of nitrogen fertilizers, pumped irrigation and mechanical power, industrialized agriculture has become progressively less energy efficient. These three sources account for more than 90% of the total energy inputs to farming. Under the Framework Convention on Climate Change, a source is any “process or activity which releases a greenhouse gas, or aerosol or a precursor of a greenhouse gas into the atmosphere”.

Materials and Methods

Sampling Design

The study has been conducted in Eastern part of the state of Uttar Pradesh which is purposively selected, with the reason that there are hardly few studies of this kind have taken place. Study has been conducted in the districts of Sonbhadra and Mirzapur purposively with the reason that the district is having the maximum farming land used for cultivation of different crops in the state.

The district Sonbhadra comprises of 8 community development blocks out of which 1 block has been selected randomly, further 6 villages from selected block has been selected arbitrarily making total 6 selected village. District Mirzapur comprises of 12 community development blocks out of which 2 blocks has been selected, further 6 villages from each selected block has been selected making a total of 12 selected village, making a total of 18 villages in the study.

Analytical Tool

The Cobb-Douglas production function in logarithmic form is linear in the parameters and this brings use of it into the general framework of linear statistical analysis, as is quite familiar (Afriat, 1972). The land use pattern, cropping pattern, input use pattern and productivities of the crops were examined. The concept of the technical efficiency of firms has been of fundamental importance for the development and application of econometric models of production functions.

The definition of the technical efficiency of a given firm (at a given time period) as the ratio of its mean production (conditional on its levels of factor inputs and firm effects) to the corresponding mean production if the firm utilized its levels of inputs most efficiently (Battese and Coelli, 1991). The resource use efficiency in crop production was estimated with the help of Cobb-douglas production function. The Cobb-Douglas production function as also used by Afriat; 1972; Battese, 1991; Campus, 2014, for efficiency of production function is described as below:

$Y = a\, X_1^{b1}\, X_2^{b2}\, X_3^{b3}\, X_4^{b4}\, X_5^{b5} X_6^{b6}$

Where,

Y= Output (Quintals)

a = Intercept; X_1= Labour (Mandays); X_2= Capital (Rs): X_3= Seed (Q/Kg): X_4= Pesticide (Rs.)

X_5= Diesel (Lit.): X_6= Fertilizer (Kg/Ha)

b_1, b_2, b_3, b_4, b_5 and b_6 are regression coefficients.

For estimation of the above mentioned model, it is converted into linear form by taking log on both the sides. The double log linear form of the model may be written as:

$\text{Log } Y = a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log 1\, X_4 + b_5 \log X_5 + b_6 \log X_6$

The efficiency of various inputs were estimated by working out their marginal productivities as mentioned below:

$$\frac{d\bar{Y}}{d\bar{X}_i} = \frac{b\bar{Y}}{\bar{X}_i}$$

And then $\frac{b\bar{Y}}{\bar{X}_i}$ was compared with $\frac{P_x}{P_{yi}}$. With following conclusions:

If, $\frac{b\bar{Y}}{\bar{X}_i} > \frac{P_{xi}}{P_y}$, there is under use of the i^{th} input in the production process,

If, $\frac{b\bar{Y}}{\bar{X}_i} < \frac{P_{xi}}{P_y}$, there is over use of the i^{th} input in the production process and

If, $\frac{b\bar{Y}}{\bar{X}_i} = \frac{P_{xi}}{P_y}$, there is optimal use of the i^{th} input in the production process.

The optimal level of the input use can be calculated by following equation:

$$X_i = \frac{b\bar{Y}.P_y}{P_{xi}}$$

The recommendations for increasing or decreasing the input use were made (Meeusen, and Broeck, 1977).

Results and Discussion

According to the Table1, as far as the cereal crops are concerned, Barley, wheat, Paddy and Bajara are important crops of the region.

In the case of Barley, the R^2 value which is also called coefficient of determination which ranges between 0 and 1 comes to be 0.78 and diesel and fertilizer were found to be significant at 10 per cent level of significance with t values 2.40 and 2.51 respectively. According to the above table, as far as the cereal crops are concerned, Barley, wheat, Paddy and Bajara are important crops of the region. In the case of Barley, the R^2 value which is also called coefficient of determination which ranges between 0 and 1 comes to be 0.78 and diesel and fertilizer were found to be significant at 10 per cent level of significance with t values 2.40 and 2.51 respectively.

In the case of wheat, capital and seed were found to be significant at 10 per cent level of significance and Labour, Diesel and Fertilizer were found to be significant at 5 per cent level of significance with t values 2.10 and 2.20 and labour, diesel and fertilizer were found to be significant at 5 per cent level of significance with t values 2.60, 2.60 and 2.70 respectively and R^2 value comes to be 0.82 signifies that 82 per cent variation in the yield of wheat were due to the independent variables which were found to be significant.

In the case of Paddy, labour, Capital, Seed and fertilizer were found to be significant at 10 per cent level of significance and diesel was found to be significant at 5 per cent level of significance where t-value for labour, capital, seed, diesel and fertilizer were 2.60, 2.10, 2.20, 2.60 and 2.70 respectively and R^2 value comes to be 0.79 signifies that 79 per cent of variation in the yield of paddy were explained by the variables labour, capital, seed, diesel, and fertilizer.

In the case of bajara, only seed is significant at 10 percent level of significance with t value 2.41 and R^2 0.68.

It signifies that only 68 percent of variation is explained by the independent variables.

The rest of the variables like labour, capital, pesticide, diesel and fertilizer were found to be insignificant.

Input use efficiency of Cereal crops

According to the above table, the existing use of the inputs like labour, capital, seed, pesticide use, diesel use and fertilizer has the following scheme. As for the Labor input, it varies from 75-99 man days, average use is 87 man days, recommended use is unknown/uncertain while the level of optimal use is 95 and it's a case of underuse as the average use is lower than the level of optimal use. As for capital input it varies from Rs 8750-14500, average input is Rs.122268, recommended input is uncertain and the level of optimal input is Rs13451, the case again is that of underuse. As for the seed used it varies from 66-133 kg, average use is 98 kg, recommended use is 75-80 kg and level of optimal use is 101 kg and the case again is that of under use. As for the pesticides use it varies from 0.75-1.85 kg, average use is 1.13 kg, recommended use is 1-1.5 kg and the level of optimal use is 1.21 kg the case again is that of underuse. As for diesel use, it varies from 148-453 liters, average use is 294 liters, recommended use is uncertain and the level of optimal use is 301 liters and the case again is that of under use. Finally, in the case of fertilizer used, it varies from 60-320 kg, average use is 190 kg, recommended use is 120 kg, and the level of optimal use is 221kg and the case again is that of underuse.

According to the above table, the existing use of the inputs like labour, capital, seed, pesticide use, diesel use and fertilizer has the following scheme. As for the Labor input, it varies from 115-137 man days, average use is 126 man days, recommended use is unknown/uncertain while the level of optimal use is 131 and it's a case of underuse as the average use is lower than the level of optimal use. As for capital input it varies from Rs 12000-16400, average input is Rs.14200, recommended input is uncertain and the level of optimal input is Rs14896, the case again is that of underuse. As for the seed used it varies from 98-109 kg, average use is 103 kg, recommended use is 100 kg and level of optimal use is 104 kg and the case again is that of slightly under use. As for the pesticides used it varies from 24-32.27 kg, average use is 28.12 kg, recommended use is 25 kg and the level of optimal use is 29.21 kg and the case again is that of underuse.

As for diesel used, it varies from 377-410 liters, average use is 393.5 liters, recommended use is uncertain and the level of optimal use is 402 liters and the case again is that of under use. Finally,, in the case of about fertilizer used, it varies from 265-419 kg, average use is 342 kg, recommended use is 250 kg, and the level of optimal use is 395kg and the case again is that of underuse.

According to the above table, the existing use of the inputs like labour, capital, seed, pesticide use, diesel use and fertilizer has the following scheme. As for the Labor input, it varies from 74-114 man days, average use is 94 man days, recommended use is unknown/uncertain while the level of optimal use is 98 and it’s a case of underuse as the average use is lower than the level of optimal use.

As for capital input it varies from Rs 10750-16250, average input is Rs.13500, recommended input is uncertain and the level of optimal input is Rs14521, the case again is that of underuse. As for the seed used it varies from 9.6-24.6 kg, average use is 17.1 kg, recommended use is 20 kg and level of optimal use is 17.86 kg and the case again is that of under use. As for the pesticides used it varies from 1.2-3.2 kg, average use is 2.2 kg, recommended use is 1.5 kg and the level of optimal use is 2.4 kg the case again is that of underuse. As for diesel used, it varies from 112-562 liters, average use is 337 liters, recommended use is uncertain and the level of optimal use is 412 liters and the case again is that of under use. Finally, in the case of fertilizer use, it varies from 80-130 kg, average use is 105 kg, recommended use is 190 kg, and the level of optimal use is 115kg and the case again is that of underuse.

According to the above table, the existing use of the inputs like labour, capital, seed, pesticide use, diesel use and fertilizer has the following scheme. As for the Labor input, it varies from 35-55 man days, average use is 47 man days, recommended use is unknown/uncertain while the level of optimal use is 51 and it’s a case of underuse as the average use is lower than the level of optimal use. As for capital input it varies from Rs 2138-14138, average input is Rs.8138, recommended input is uncertain and the level of optimal input is Rs9856, the case again is that of underuse.

As for the seed used it varies from 4-16 kg, average use is 10 kg, recommended use is 5 kg and level of optimal use is 11 kg and the case again is that of under use. As for the pesticides used it varies from 0-36 kg, average use is 18 kg, recommended use is 12 kg and the level of optimal use is 19 kg the case again is that of underuse.

As for diesel used, it varies from 40-280 liters, average use is 152 liters, recommended use is uncertain and the level of optimal use is 189 liters and the case again that of under use.

Finally, in the case of fertilizer use, it varies from 60-300 kg, average use is 180 kg, recommended use has come to be 100-105 kg, and the level of optimal use is 202kg and the case is that of underuse.

Table.1 Regression Coefficients for the crops using Cobb Douglas Production Function

S. No.	Crops	Constant	X_1 (Labour)	X_2 (Capital)	X_3 (Seed)	X_4 (Pesticide)	X_5 (Diesel)	X_6 (Fertilizer)	R^2
1.	Barley	0.74	0.23	0.01	0.03	0.02	0.25* (2.40)	0.14* (2.51)	0.78
2.	Wheat	0.001	0.42** (2.60)	0.42* (2.10)	0.04* (2.20)	0.03	0.41** (2.60)	0.32** (2.70)	0.82
3.	Paddy	0.14	0.36* (1.92)	0.02* (2.10)	0.007* (2.30)	0.046	0.41** (2.41)	0.11* (3.5)	0.79
4.	Bajara	0.064	0.24	0.20	0.64* (2.41)	0.10	0.25	0.26	0.68

Note: Figures in Parenthesis are 't' - values
** Significant at 10 per cent Probability level*
*** Significant at 5 per cent Probability level*
**** Significant at 1per cent Probability level*

Table.2 Level of optimal input use in Barley

Particulars	Variability (Min to Max)	Average use	Recommended use	Level of Optimal use
Labour (Mandays)	75--99	87	---	95
Capital (Rs)	8750-14500	12268	---	13451
Seed (kg)	66-133	98	75-80	101
Pesticide (kg)	.75-1.85	1.13	1-1.5	1.21
Diesel (Liters)	148--453	294	---	301
Fertilizer (kg)	60--320	190	120	221

Table.3 Level of optimal input use in Wheat

Particulars	Variability (Min to Max)	Average use	Recommended use	Level of Optimal use
Labour (Mandays)	115-137	126	---	131
Capital (Rs)	12000-16400	14200	---	14896
Seed (kg)	98-109	103	100	104
Pesticide (kg)	24-32.25	28.12	25	29.21
Diesel (liters)	377-410	393.5	---	402
Fertilizer (kg)	265-419	342	250	395

Table.4 Level of optimal input use in Paddy

Particulars	Variability (Min to Max)	Average use	Recommended use	Level of Optimal use
Labour (Mandays)	74-114	94	---	98
Capital (Rs)	10750-16250	13500	---	14521
Seed (kg)	9.6-24.6	17.1	20	17.86
Pesticide (liters)	1.2---3.2	2.2	1.5	2.4
Diesel (liters)	112-562	337	---	412
Fertilizer (kg)	80-130	105	190	115

Table.5 Level of optimal input use in Bajara

Particulars	Variability (Min to Max)	Average use	Recommended use	Level of Optimal use
Labour (Mandays)	35--55	47	---	51
Capital (Rs)	2138-14138	8138	---	9856
Seed (kg)	4--16	10	5	11
Pesticide (kg)	0--36	18	12	19
Diesel (liter)	40-280	152	---	189
Fertilizer (kg)	60-300	180	100-105	202

Table.6 Carbon Emission coefficients for different fuel sources and the energy conversion units (Boustead and Hancock, 1979; Fluck 1992; Lal, 2003)

S. No	Fuel Source/ Energy Units	Equivalent Carbon emission
A.	**One kg of fuel**	
	Diesel	0.94
	Coal	0.59
	Gasoline	0.85
	Oil	1.01
	LPG	0.63
	Natural Gas	0.85
B.	**Units**	
	Million Calories (mcal)	93.5×10^{-3}
	Gigajoule (GJ)	20.15
	BTU	23.6×10^{-6}
	Kilowatt hour (kW h)	7.25×10^{-2}
	Horsepower	5.41×10^{-2}

Table.7 Environmental Pollution and CO_2 emissions on the Sample Farms

S. No.	Crops	Fertilizer use (Kg. / Ha)	CO_2 Emission (Kg CO_{2-e})	Diesel use (Litre)	CO_2 Emission (Kg CO_{2-e})	Total emission (Kg CO_{2-e}/Ha)
1.	Barley	190	304	294	276.36	580.36
2.	Wheat	105	168	337	316.78	484.78
3.	Paddy	342	547.2	393.5	369.89	917.09
4.	Bajara	180	288	152	142.88	430.88

Environmental Pollution

Agriculture contributes around 10-12 % of total global greenhouse gas (GHG) emissions but is the main source of non-carbon dioxide (CO_2) GHGs, emitting nearly 60 % of nitrous oxide (N_2O) and nearly 50 % of methane (CH_4) (Smith *et al.*, 2007). Given their significant contribution to rising atmospheric greenhouse gas concentrations, accounting for emissions of CO2, N2O and CH4 from agricultural practices has become increasingly important. Emissions of these gases may occur either directly during agricultural activities (eg. cultivation and harvesting), or indirectly during the production and transport of required inputs eg. herbicides, pesticides and fertilisers (Wood & Cowie, 2004). Addressing global climate change is a paramount challenge of the 21st Century. Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide (CO_2), the chief heat-trapping greenhouse gas, have risen 35 percent, from about 280 to 377 parts per million (ppm). This increase is primarily from the burning of fossil fuels and from deforestation. Atmospheric concentrations of methane (CH_4), the second leading GHG, have more than doubled over the past two centuries. These and other GHG increases have led to a 0.6^oC (1.1^oF) increase in the global average surface temperature since 1900. If current emissions trends are not altered, global temperatures are expected to rise a further 1.4 to 5.8^o C (2.5 to 10.4^o F) by 2100, according to the Intergovernmental Panel on Climate Change (Baumert *et al.*, 2005). Sources of non-CO2 green- house gases are responsible for virtually all the global warming we are going to see for the next half century (Mohr, 2005).

The production, processing, transport and storage of agricultural products, like most human activities, gives rise to emissions of greenhouse gases (GHGs). These GHG emissions include carbon dioxide (CO_2) emitted through the combustion of fossil energy at various stages in the life-cycle of a product: in the production of agri-chemicals and soil amendments; by farm machinery during field preparation, planting, cultivation and harvesting; by vehicles used to transport the intermediate and final products; by the factories that process the products; and in the production of electricity used to keep the products refrigerated, if necessary (Steenblik and Möïsé 2010).

According to the Table 7, on an average total NPK fertilizer use in Barley is 190 kg /Ha which emits 304 Kg CO_{2-e} by the use of fertilizer and on an average 294 liters of diesel use which adds 276.36 Kg CO_{2-e} making a total of 580.36 Kg CO_{2-e}/ Ha. In the case of Wheat, from fertilizer alone 168 Kg CO_{2-e} CO_2 emission and 316.78 Kg CO_{2-e} from diesel use making a total of 484.78 Kg CO_{2-e}/ Ha. Likewise from Paddy total 9170.9 Kg CO_{2-e}/ Ha was emitted. In the production of Bajara- 430.88 Kg CO_{2-e}/Ha emission has been found which adds to the annual greenhouse gas emission.

It has been found out that the inputs like labour, capital, seed, fertilizer, pesticide and diesel use in the agriculture is under use in the study which has been undertaken in the study of different cereals. Different crops have showed the level of input use with the average use is currently practiced, it's recommended and optimal use has been calculated. In almost all the crops viz. Barley, Wheat, Paddy and Bajara the input use is in underuse.

It has been confirmed by many studies that there is strong evidence that sustainable agricultural and land management can make an important contribution to climate change mitigation through both emissions reduction and carbon sequestration and suggested that the national and international markets for carbon grow, so the sequestered carbon could represent an important new source of income for farmers (Pretty and Ball; 2001).

As suggested by Smith *et al.*, 2007 trends in GHG emissions in the agricultural sector depend mainly on the level and rate of socio-economic development, human population growth, and diet, application of adequate technologies, climate and non-climate policies, and future climate change. In all the GHG mitigation in agriculture has a significant potential and maintaining a synergy in between climate chance policies, sustainable agricultural development and quality improvement of environment will lead a way forward for the mitigation GHG emissions.

According to a report of FAO on Soil Organic Carbon Accumulation and Greenhouse Gas Emission Reductions from Conservation Agriculture, the terrestrial sequestration of carbon can efficiently be achieved by changing the management of agricultural lands from high soil disturbance practices to low disturbance and by adopting effective nitrogen management practices so that the nitrogen balance remains positive.

References

Afriat, S. N., "Efficiency Estimation of Production Functions", *International Economic Review*, Vol. 13, No. 3 (Oct., 1972), pp. 568-598.

Battese, G. E., "Frontier Production Functions and Technical Efficiency: A Survey of Empirical Applications in Agricultural Economics" No. 50 - May 1991, ISSN: 0 157-0188, ISBN: 0 85834 936 1, Department of Econometrics, University of New England, Armidale, NSW 2351, Australia.

Battese, G.E. and Coelli, T.J.," Frontier Production Functions, Technical Efficiency and Panel Data: with application to paddy farmers in India", No: 56 November 1991, ISSN: 0 157-0188 and ISBN: 085834 9701, Department of Econometrics, University of New England, Armidale, NSW 2351, Australia.

Baumert, K. A., Herzog T. and Pershing J., "Navigating the Numbers: Greenhouse Gas Data and International Climate Policy", World Resources Institute, 2005.

Boustead I, Hancock GF. Handbook of industrial energy analysis. Chi-chester (UK): Horwood; 1979. 422 pp.

Campus, K. (2014). Resource Use Efficiency in Organic Vegetable Production : A Case Study of Manzini Region, *2*(2), 52–61. https://doi.org/10.5296/jas.v2i2.5958

Corsi, S., Friedrich, T., Kassam, A., Pisante, M. and MoraesSà, J., Report on "Soil Organic Carbon Accumulation and Greenhouse Gas Emission Reductions from Conservation Agriculture: *A literature review" Integrated Crop Management* Vol.16-2012 Plant Production and Protection Division, Food and Agriculture Organization of the United Nations, Rome, 2012

Fluck RC. Energy in farm production. In: Fluck RC, editor. Energy in world agriculture. 6th ed. New York: Elsevier; 1992. p. 218–67.

Flynn, H. C. and Smith, P., "Greenhouse gas budgets of crop production – current and likely future trends", First edition, IFA, Paris, France, January 2010, International Fertilizer Industry association.

Kindred D. Berry P., Burch O. and Bradley R. S., "Effects of nitrogen fertilizer use on greenhouse gas emissions and land use change", *Aspects of Applied Biology 88, 2008, Effects of Climate Change on Plants: Implications for Agriculture* pp-1-4.

Kumbhakar, S. C., Ghosh, S. and McGuckin, J.T. "A Gereralized production Frontier approach for estimating determinants of inefficiency in U.S. dairy farms", *Journal of Business & Economic Statistics*, Vol. 9, No. 3 (Jul., 1991), pp. 279-286.

Lal, R. (2004). Carbon emission from farm operations. *Environment International*, *30*(7), 981–90. https://doi.org/10.1016/j.envint.2004.03.005

Meeusen, W. and Broeck, J. D. “Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error” *International Economic Review*, Vol. 18, No. 2 (Jun., 1977), pp. 435-444.

Mohr, N., “A New Global Warming Strategy: How Environmentalists are Overlooking Vegetarianism as the Most Effective Tool against Climate Change in Our Lifetimes”, An EarthSave International Report, 2005.

Paustian, K., Six, J., Elliott, E.T. and Hunt, H.W., “Management options for reducing CO_2 emissions from agricultural soils” Biogeochemistry vol. 48: pp-147–163, 2000 Kluwer Academic Publishers.

Pretty, J. and Ball, A., *“*Agricultural Influences on Carbon Emissions and Sequestration: A Review of Evidence and the Emerging Trading Options*”,* Centre for Environment and Society Occasional Paper 2001-03, University of Essex.

Schulte, R. P. O., “Irish Agriculture, Greenhouse Gas Emissions and Climate Change: opportunities, obstacles and proposed solutions”, Report of the Teagasc Working Group on Greenhouse Gas Emissions, Teagasc, Agriculture and food development authority, Oak Park, Carlow.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O’Mara, F., Rice, C., Scholes, B., and Sirotenko, O., Agriculture. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.

Steenblik, R. and Möïsé, E., “Counting the Carbon Emissions from Agricultural Products: Technical Complexities and Trade Implications”, Policy brief, *background paper for the October 2010 seminar, “Carbon Standards in Agricultural Production and Trade,” organized by the International Food & Agricultural Trade Policy Council (IPC) with support from Sao Paulo’s Federation of Industries (FIESP)*, 2010.

Trumbore S. E, “Potential responses of soil organic carbon to global environmental change”, *Proc. National Academy of Science.USA* Vol. 94, pp. 8284–8291, August 1997Colloquium Paper.

Wood, S. and Cowie, A., “A Review of Greenhouse Gas Emission Factors for Fertilizer Production”, For IEA Bioenergy Task 3, Research and Development Division, State Forests of New South Wales. Cooperative Research Centre for Greenhouse Accounting. June 2004.