Environmental Impact and Economic Cost of Agricultural Inputs

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Abstract: This paper evaluated the effect of agricultural input (fertilizer) on carbon emission (methane and nitrous oxide) in South Africa and the likely environmental costs of such emissions. The paper applied a quantitative research design and data were from secondary sources, mainly from the archives of Index Mundi, the US EPA and the World Bank. The Pearson correlation results show that fertilizer input is related to agricultural nitrous oxide and methane emissions at a P-value of 0.027 and 0.05 respectively. This thus, confirms that fertilizer input causes an agricultural induced emission of greenhouse gases (nitrous oxide and methane). Furthermore, findings from the estimation of potential environmental costs of methane and nitrous oxide emissions showed that these have had rising and steady environmental costs to the society, which, unfortunately is born by the society. Consequently, the study recommends agricultural related emission policy to enable farmers internalise some of the environmental costs of agricultural inputs that are born by the society, which is the socioeconomic costs. Such further research should determine a fair model that may be used to internalise environmental costs of agricultural inputs but to avoid consumers of agricultural produce from paying for such costs.

Keywords: economic costs; environmental costs; agricultural inputs; agricultural emissions; environmental impact

JEL Classification: M40; Q01; Q2; Q4; Q25

1. Introduction

During the Paris 2015 climate accord, over 100 countries agreed to step up efforts toward the reduction of agricultural related global warming (Wollenberg et al., 2016). Agricultural related environmental pollution has recently been gaining policy and regulatory attention since agriculture is one of the apparently concealed but significant environmental polluter (FAO, 2017). However, agricultural related pollution literature control and policies is more evident in developed countries (FAO, 2017).

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Agriculture provides food for more than seven billion people in all nations of the world but it comes with its hazards to the environment (Clark & Tilman, 2017). Albeit this important function of agriculture, it is also exigent to evaluate how agricultural processes notably, the agricultural inputs constitute environmental hazard – as sources of carbon emission. This paper evaluated the environmental impact and costs of agricultural inputs and this is pertinent as agricultural inputs such as pesticides and fertilizers do not only affect the health of neighboring communities, flora and fauna, it also affects the environment including the inland waters (Borges et al., 2018). Research indicates that of all the pesticides that farmers apply only about 1% or less gets to the target, other percentage of the pesticides miss their target and pollutes the environment (Arias-Estévez et al., 2008). Recently, Borges et al. (2018) evaluated and found that agricultural operations has resulted in high level methane and nitrous oxide pollution in Belgium inland waters. Similarly, Das et al. (2014) studied the methane and nitrous oxide impact of inorganic fertilizer application in rice farms. Zhao et al. (2016) analysed methane and nitrous oxide implication from no-till farming in China. These current research corroborate the fear that agriculture is contributing to GHG emissions and to global warming.

Based on the foregoing introduction, the question, which this paper set out to answer was whether agricultural input (fertilizer) does have implications on methane and nitrous oxide emission and the environmental cost of such emissions. Hence, the objective of this research was to analyse the carbon emission related environmental impact of agricultural input (fertilizer), and to determine the environmental cost of the related carbon emissions.

The subsequent sections of this paper is organised as follows. Immediately after this introduction, the paper presents a review of related literature. Following the literature is the method, results and discussion of findings. The final section of the paper presents the conclusion.

2. Literature Review

Many researchers have evaluated and concur the overriding effect of agricultural pesticides on the environmental and that such effects have enormous environmental costs (Tosi, Costa, Vesco, Quaglia & Guido, 2018; Dudley, Attwood, Goulson, Jarvis, Bharucha & Pretty, 2017; Clark & Tilman, 2017). Such effects constitute both environmental and economic costs to the society, for instance, the honey bee assists in pollinating agricultural products and also produces honey for human nutrition, however a recent study by Tosi et al (2018) indicate that a three-year survey in Italy show a high contamination of honey bee resulting from agricultural pesticides, such contamination also has a massive effect on economic loss on pure honey sales incurred by bee farmers. Hence Dudley et al (2017) maintain that unbridled pesticide application constitutes heavily to biodiversity loss. Environmental economists, health economists and development economists are thus worried that most of economic costs generated by misapplication of agricultural pesticides are often born by the society and remain externalised to the agricultural companies that actually cause the costs (Becker, 2017). Whilst human incur high economics costs associated with uncontrolled application of pesticides, the environmental impact also negatively affects the wild flora and fauna (Van Dijk, Van Staalduinen & Van der Sluijs, 2013), this in turn affects humans in form of environmental and/or climate change that also come with huge economic costs.

Agricultural nitrous oxide (N_20) emissions are emissions produced through fertilizer use (The World Bank, 2014). Agricultural lands are the major contributors to the production of nitrous oxide due to the high usage of synthetic fertilizers. These nitrogen containing fertilizers are used in order to ensure a large crop production, therefore, large amounts of these gases are emitted into the atmosphere (GHG Online, 2014). Following the application of synthetic fertilizers, the nitrogen is often washed away by heavy rains into rivers, dams, which mean the pollution of these inland waters and subsequent emission of the gases into the atmosphere. Although agriculture is an essential industry given its food supply base, but the usage of nitrogen laden fertilizers is orchestrating high level emission of nitrous oxide, which is as having high potential contribution to global warming (Signor, Cerri & Conant, 2013).

According to the US Environmental Protection Agency (2014) the US Nitrous Emission by source, shows that the main contributor for Nitrous Oxide emissions is the agriculture sector. The Nitrous oxide emissions in agriculture has been found to be in greater amounts in tropical agriculture due to high level usage of nitrogen fertilizer under the warm and humid temperature in tropical climate (Wang et al., 2014). Similar research has found that Methane emission is high in rice cultivation, due to the high usage of the Nitrogen containing fertilizers (Kamaljit, Manqin & Chaoqun, 2012). The modern agricultural methods and technologies do not only bring an increase in food production but it also brings an increase in environmental costs. Agriculture is seen as one the main contributor to greenhouse gases (GHGs). For example, rice production contributes about 11% of global methane emissions (Nono, Deratista & Monica, 2012). Zhao et al. (2016) applied the meta-analysis method and evaluated the methane and nitrous oxide emission concentration in non-till farming in China; their results showed on the one hand tha nitrous oxide emission could be reduced by adopting non-till farming system, on the other hand, methane and nitrous oxide emissions could increase under high temperature and precipitation. Clark and Tilman (2017) studied environmental impact variations from both agricultural input and food choices and concluded that food choices would offer less environmental impact of agriculture than switching to alternative agricultural system. Safa et al. (2016) applied two methods – the "*Artificial Neural Networks and*

Linear Regression Models” (P.268) to forecast the likely impact of agricultural inputs on carbon emission. Their results indicate that fifty-two percent and 20 percent of carbon emission from wheat farming are from fertilizer and fuel usage respectively.

This current research contributes to existing literature by evaluating the environmental and economic costs of agricultural pesticides in South Africa.

3. Method

This paper applied a quantitative approach in analysing how agricultural inputs (using fertilizer as input proxy) relate to carbon emission (methane emission and nitrous oxide emission). Data on fertilizer usage and associated methane emission and nitrous oxide emissions for South Africa were collected from various archives namely the Indexmundi and the World Bank online collections on fertilizer usage and related methane and nitrous oxide emissions. In order to measure the socioeconomic cost of carbon emission, the USA EPA estimated monetary cost of carbon per tone was used.

The analytical tool employed in the data analysis is the Pearson correlation statistics and the OLS regression.

The Pearson correlation "r" model as in Puth *et al.* (2014) is represented by:

$$r = \frac{\sum_{i=1}^{N}\{(X_i - \bar{X})(Y_i - \bar{Y})\}}{\sqrt{\sum_{i=1}^{N}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{N}(Y_i - \bar{Y})^2}}$$

The regression model used is represented by:

$$Y = \beta o + \beta_1 \chi_1 + \varepsilon$$

3.1. Results

The following research questions were analysed:

1. Do agricultural inputs have environmental impacts?

2. Do the environmental impacts carry environmental economic costs?

***Analysis of Research Question 1*:** Do agricultural inputs have environmental impacts?

In answering this question, the agricultural fertilizer carbon emission impact was used as represented by agricultural nitrous oxide emission and agricultural methane emission for South Africa. The correlation and regression analysis and result appears in Table 1 and Table 2.

Analysis of Research Question 2: Do the environmental impacts carry environmental economic costs? analysis and result appears in Table 3.

Table 1. Correlation Analysis: Relationship between fertilizer input and Nitrous Oxide-Methane emissions

Fertilizer input and Agricultural Nitrous Oxide Emission

Correlations			
		AgricNitOxide	FertUsage
AgricNitOxide	Pearson Correlation	1	.810*
	Sig. (2-tailed)		.027
	N	7	7
FertUsage	Pearson Correlation	.810*	1
	Sig. (2-tailed)	.027	
	N	7	7
*. Correlation is significant at the 0.05 level (2-tailed).			

Fertilizer input and Agricultural Methane Emission

Correlations			
		FertUsage	Methane
FertUsage	Pearson Correlation	1	.753
	Sig. (2-tailed)		.051
	N	7	7
Methane	Pearson Correlation	.753	1
	Sig. (2-tailed)	.051	
	N	7	7

Table 2. Regression Analysis: Relationship between Fertilizer Input and Nitrous Oxide-Methane Emissions

Fertilizer input and Agricultural Nitrous Oxide Emission

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.822767045
R Square	0.676945611
Adjusted R Square	0.612334733
Standard Error	0.303811215
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.967065	0.967065	10.47727	0.0230294
Residual	5	0.461506	0.092301		
Total	6	1.428571			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	18.33205763	1.431234	12.80857	5.16E-05	14.652953	22.01116	14.65295	22.01116
FertUse	-0.083491072	0.025794	-3.23686	0.023029	-0.1497962	-0.01719	-0.1498	-0.01719

Fertilizer input and Agricultural Methane Emission

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.769792981
R Square	0.592581233
Adjusted R Square	0.51109748
Standard Error	0.550139929
Observations	7

ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.201016	2.201016	7.272385	0.04295129
Residual	5	1.51327	0.302654		
Total	6	3.714286			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	Ipper 95.0%
Intercept	26.53795374	2.591672	10.2397	0.000153	19.875848	33.20006	19.87585	33.20006
FertUse	-0.125957424	0.046707	-2.69674	0.042951	-0.2460225	-0.00589	-0.24602	-0.00589

Table 3. Environmental Costs of Methane and Glyphosate

Socioeconomic cost of Agricultural Nitrous Oxide and Agricultural Methane for South Africa

Year	NitO	Socio/economic Cost ($120perton)	Methane	Socioeconomic Cost ($120perton)
1990	13463	1615560	19108	2292960
2000	13710	1645200	18874	2264880
2005	14367	1724040	20015	2401800
2008	14369	1724280	20338	2440560
2010	14052	1686240	20084	2410080
2011	14052	1686240	20084	2410080
2012	14052	1686240	20084	2410080

Sources:

Estimated socioeconomic cost of carbon for South Africa: calculated by authors, with socioeconomic cost of carbon estimate of $120 per metric tons from the US Environmental Protection Agency (EPA) (2015), the socioeconomic cost of carbon. Available from: http://www3.epa.gov/climatechange/EPAactivities/economics/scc.html

Fertilizer NitO: IndexMundi (2015) South Africa - Nitrous oxide emissions: Agricultural nitrous oxide emissions (thousand metric tons of CO2 equivalent). Available from: http://www.indexmundi.com/facts/south-africa/nitrous-oxide-emissions

Fertilizer Methane: IndexMundi (2015) South Africa - Methane emissions Agricultural methane emissions (thousand metric tons of CO2 equivalent). Available from:http://www.indexmundi.com/facts/south-africa/methane-emissions

The environmental costs of Methane and Nitrous Oxide to the society is calculated Table 3 and it can be evident that the costs were rising between 1990 and 2008, but have remained the same between 2010 and 2012 given the associated emissions. This therefore means that the higher the emissions the higher the socioeconomic cost of emissions. In addition, Figure 1 illustrate the above environmental costs in a line graph

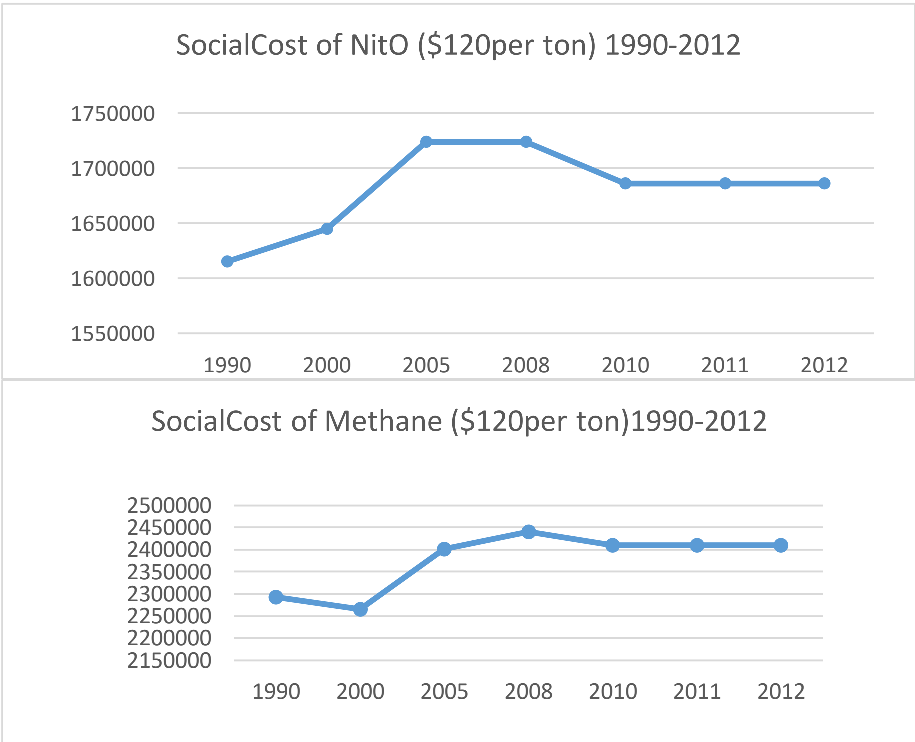

Figure 1. Line Graph of Socioeconomic cost of Agricultural Nitrous Oxide and Agricultural Methane for South Africa

Source: Authors' graph with data from Table 3

3.2. Discussion of Findings

Tables 1 and Table 2 presents the correlation analysis and regression between fertilizer input and agricultural related methane and nitrous oxide emissions.

In this analysis, agricultural input is represented by fertilizer usage data for South Africa from. Similarly, environmental impact of fertilizer usage is represented by agricultural nitrous oxide and methane emissions. Tested at 0.05 significant level, Findings from the correlation and regression analysis in Table 1 – 2 show that fertilizer usage in South Africa is positively related to agricultural nitrous oxide and methane emissions. This therefore indicate that the usage of fertilizer (an agricultural input) has a negative impact on society and the environment by increasing the amount of carbon emission (nitrous oxide and methane emissions) into the environment. This finding confirms previous literature findings in other countries such as by (Safa et al., 2016; Wollenberg et al., 2016) that agricultural inputs have negative effects on the environment.

Similarly, Table 3 presents the analysis of data on whether environmental impacts of agricultural inputs have environmental costs which affects the society. The socioeconomic cost of one ton of carbon as estimated by the US Environmental Protection Agency was used to calculate the socioeconomic cost of agricultural induced nitrous oxide emission and methane emission for South Africa for over seven years' period. Findings in Table 3 and Figure 1 show a rising socioeconomic cost of agricultural induced methane and nitrous emission since 1990. This finding on the environmental costs of agricultural inputs in South Africa provides confirmation to the US EPA on the potential environmental costs of carbon emission on the environment.

4. Conclusion

The purpose of the study was to discover if there are impacts on the environment resulting from the use of agricultural inputs and if there are costs attached to the agricultural induced environmental impacts namely methane emission and nitrous oxide emission. Hence, the objectives of this study were to determine the environmental impact of agricultural inputs, to know if the environmental impacts have environmental costs.

Agricultural input data was represented by fertilizer usage data in South Africa; environmental impact of agricultural inputs was represented by agricultural induced nitrous oxide emission and methane emissions data for South Africa. Findings from the study provided an answer to the two research questions on whether agricultural input (represented by fertilizer input) does impact carbon emission and whether it has environmental costs. Findings from the analysis of correlation and regression indicated that agricultural input (fertilizer as proxy) does affect the environment; it causes an agricultural induced emission of greenhouse gases (nitrous oxide and methane). Furthermore, findings from analysis of potential environmental costs of environmental impacts (methane and nitrous oxide) have socioeconomic costs for South Africa.

Drawing from the above findings, this study therefore makes the following recommendations. Given that the society bear the environmental costs of agricultural emssions, this study recommends that the government should devise farm input carbon emission policy to enable farmers, internalise some of the environmental costs of agricultural inputs that are currently born by the society. Such policy should be balanced in such a manner that the internalised socioeconomic cost of agricultural emission would not fall back on the consumers of agricultural produce to pay for such costs. This would certainly be intricate as farmers are likely to factor internalised socioeconomic cost of carbon emission into product prices. This intricacy is thus presents a new research problem for further researchers to engage. Therefore, further research is needed to determine the model that may be used to internalise environmental costs of agricultural emissions back to the farms without exposing the consumers to the receiving side of paying for agricultural emissions.

5. References

Arias-Estévez, M.; López-Periago, E.; Martínez-Carballo, E.; Simal-Gándara, J.; Mejuto, J.C. & García-Río, L. (2008). The mobility and degradation of pesticides in soils and the pollution of groundwater resources. *Agriculture, Ecosystems & Environ*ment, 123(4), pp. 247-260.

Becker, N. (2017). *External Costs of Food Production: Environmental and Human Health Costs of Pest Management*. Environmental Pest Management*:* Challenges for Agronomists, Ecologists, Economists and Policymakers. Oxford, John Wiley.

Borges, A.V.; Darchambeau, F.; Lambert, T.; Bouillon, S.; Morana, C.; Brouyère, S.; Hakoun, V.; Jurado, A.; Tseng, H.C.; Descy, J.P. & Roland, F.A. (2018). Effects of agricultural land use on fluvial carbon dioxide, methane and nitrous oxide concentrations in a large European river, the Meuse (Belgium). *Science of the Total Environment,* 611(018), pp. 342-355.

Clark, M. & Tilman, D. (2017). Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. *Environmental Research Letters*, 12(6), pp. 1 – 11.

Das, S. & Adhya, T.K. (2014). Effect of combine application of organic manure and inorganic fertilizer on methane and nitrous oxide emissions from a tropical flooded soil planted to rice. *Geoderma*, 1(213), pp. 185-192.

Dudley, N.; Attwood, S.J.; Goulson, D.; Jarvis, D.; Bharucha, Z.P. & Pretty, J. (2017). How should conservationists respond to pesticides as a driver of biodiversity loss in agroecosystems? *Biological Conservation*, 209, pp. 449-453.

Food and Agricultural Organisation (2017). Introduction to agricultural water pollution. Available at http://www.fao.org/docrep/w2598e/w2598e04.htm. Accessed 17 December 2017.

GHG-Online (2014). Nitrous Oxide Sources – Agricultural soils. Available at http://www.ghgonline.org/nitrousagri.htm. Accessed 9 December 2017.

Kamaljit, B.; Hanqin, T. & Chaoqun, L. (2012). Do nitrogen fertilizers stimulate or inhibit methane emissions from rice fields*? Global Change Biology*, 18(10), pp. 3259-3267.

Nono, L.; Daratista, I. & Monica, A. (2012). Effect of Methane Emission from Fertilizer Application. *Journal of Life Science and Biomedicine*, 2(4), pp. 167-177.

Puth, M.T.; Neuhäuser, M. & Ruxton, G.D. (2014). Effective use of Pearson's product–moment correlation coefficient. *Animal Behaviour*, 93, pp. 183-189.

Safa, M.; Nejat, M.; Nuthall, P.L. &Greig, B.J. (2016). Predicting CO_2 emissions from farm inputs in wheat production using artificial neural networks and linear regression models-Case study in Canterbury, New Zealand. *International Journal of Advanced Computer Science and Applications*, 7(9), pp. 268 – 274.

Signor, D.; Cerri, C.E.P. & Conant, R. (2013). N_2O emissions due to nitrogen fertilizer applications in two regions of sugarcane cultivation in Brazil, Environmental Research Letters, 8(1), pp. 1 – 9.

The World Bank (2014). Agricultural Nitrous Oxide Emissions. Available at http://data.worldbank.org/indicator/EN.ATM.NOXE.AG.ZS/countries/1W?display=graph (Accessed 09 December 2014).

Tosi, S.; Costa, C.; Vesco, U.; Quaglia, G. & Guido, G. (2018). A 3-year survey of Italian honey bee-collected pollen reveals widespread contamination by agricultural pesticides. *Science of the Total Environment*, 615, pp. 208-218.

US Environmental Protection Agency 2014. Overview of Greenhouse. Available at https://19january2017snapshot.epa.gov/ghgemissions/overview-greenhouse-gases_.html. Accessed 11 December 2016.

Van Dijk, T.C.; Van Staalduinen, M.A.; Van der Sluijs, J.P. (2013). Macro-invertebrate decline in surface water polluted with imidacloprid. PLoS One 8, e62374. Available at https://doi.org/10.1371/journal.pone.0062374. Accessed 11 December 2016.

Wang, W.J.; Halpin, N.; Di Bella, L.; Salter, B. & Reeves, S.H. (2014). Nitrous Oxide Emissions from Sugarcane Soils: Impacts of Fertilizer Formulation and Soybean Residue Management. available at http://www.soilscience2014.com/proceedings/Wang_2.pdf. Accessed 10 December 20116.

Wollenberg, E.; Richards, M.; Smith, P.; Havlík, P.; Obersteiner, M.; Tubiello, F.N.; Herold, M.; Gerber, P.; Carter, S.; Reisinger, A. & Vuuren, D.P. (2016). Reducing emissions from agriculture to meet the 2 C target. *Global change biology*, 22(12), pp. 3859-3864.

Zhao, X.; Liu, S.L.; Pu, C.; Zhang, X.Q.; Xue, J.F.; Zhang, R.; Wang, Y.Q.; Lal, R.; Zhang, H.L. & Chen, F. (2016). Methane and nitrous oxide emissions under no‐till farming in China: a meta‐analysis. *Global change biology*, 22(4), pp. 1372-1384.