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Research Article

Effect of Input Subsidy Reduction on Greenhouse Emission Reduction Potential in Paddy Production Systems in Karnataka State of India

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Abstract

Increasing concerns and call for reduction in Greenhouse gas (GHG) emission have necessitated the search for broader and all-inclusive policy initiatives, extending into agricultural production, where high carbon energy inputs are used. One classical policy strategy for GHG emission reduction, has been taxation. However, given the critical role of agriculture, especially in developing economies, policies that directly or indirectly increase agricultural inputs costs and reduce their demand require stronger theoretical, conceptual and empirical support to ensure that while agri-environmental quality is promoted, welfare of farming households, food security and overall economic growth are not compromised. Using paddy production in Karnataka state in India, the study assessed effects of agricultural input taxation (reduction in rice input subsidy) on future demand for such inputs and their effect on GHG emission reduction, vis-a-viz production and welfare losses. In microeconomic modelling framework, we applied quadratic almost ideal demand system and stochastic efficiency functions in the analysis of the data. Data for the study, a micro-level farm data, was obtained from Cost of Cultivation Scheme (CSS) for irrigated and non-irrigated production systems, covering the period 2009 -2018 production seasons. Specifically, the study used three future tax regime scenarios- 10%, 20% and 30% input subsidy reduction rates, to model an optimum greenhouse emission reduction potential. The results revealed that inputs evaluated were normal with inelastic demand functions; many input coefficients implied significant complementary relationships; irrigated paddy production system had higher estimates of GHG emissions. Input taxation (reduction in subsidy) under all the three scenarios effectively, resulted in declined inputs consumption patterns, and subsequently led to significant decrease in greenhouse emissions. The highest GHG emission reduction potential was observed in irrigated farming system. Greenhouse emission reduction potential was optimal at moderate subsidy reduction policy rate of 10%. It is recommended that, given the inelastic estimates derived, moderate tax (reduction in subsidy) policy option on inputs would yield effective greenhouse mitigation with appropriate compensation through effective integrative schemes.

Keywords

Input Demand Elasticities, Greenhouse Emission, Input Taxation, Quadratic Almost Ideal Demand System, Welfare Loss, Climate Action, Paddy Production

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1. Introduction

In recent past two decades, climate change has become a significant issue due to the significant accumulation of atmospheric gases. The effects of climate change are interlinked to all aspects of major economic endeavors of any economy with agrarian economies in developing countries being more vulnerable to the ramification of climate change with uncertain magnitudes [31]. It is argued that agricultural production is one of the most important economic sectors exacerbating pressures on the natural ecological quality and biodiversity [12, 23, 33, 38] contributing vehemently to the nitrogen problem to an extent of 40% in recent years with dichotomous effect on the environment and land productivity [11, 20, 35]. However, the continuous degradation in agroecological systems due to uncertainties in climate variables has led to the magnanimous use of highly carbon content input resources to enhance productivity in recent years [9]. This has perturbed the agro-environmental composition to the capacity that has exposed most farming systems to be environmentally unfriendly and unstainable to support future generation [3]. Agricultural inputs usage policy and effective measures to reduce its pressure through consumption optimization have so far not been successful especially in developing countries with huge government interventions in the form of subsidies [18, 20, 21, 24]. In order to lead agro-ecological systems transit into a sustainable system, it is essential to develop knowledge and instruments that decouple environmental negatives from production system. Over the last decade, much efforts have been geared towards policy options that mitigate the intensity of emission levels efficiently. The case for the use of economic instruments, depending on school of thought in the field of energy and environmental economics, has focused on efficiency in application of taxation and tradable quotas. However, the use of inputs taxation or reduction in subsidies based on high-carbon content agricultural inputs as an appropriate economic instrument to mitigate the intensity of emission levels in agriculture production has initiated a spectrum of controversial debates [4, 21, 22, 25, 27, 34] envisaged energy taxation based on polluters pay principle as an important driver for reaching climate objectives, and consistent with restraining greenhouse effect especially in agro-economies as it offers the opportunity to increase the incentive for sustainable energy use, shift to cleaner energy alternatives fuel mix and improves efficiency of energy use [6, 8, 24, 32]. In agricultural production systems, higher proportion of the emission usually occurs at the primary stage of production [17] and effective policy on inputs usage can cause significant reduction in emissions [26]. Inputs policy can be used to discourage production of undesirable outputs (environmental “bads”) at a relatively low deadweight loss as farmers would adapt and reorganize their input combination at the level of profit maximization in the long-run depending on their response to price elasticity [1, 24, 39] and risk-averseness of farmers. Thus, a careful analysis of input taxation (subsidy reduction) in terms of its impact on greenhouse emission is needed for informed policy development. In this regard, the paper utilized data on paddy production systems in Karnataka state, India, where inputs have been subsidized and their usage contributes significantly to agro-based carbon emission in India, to quantify and evaluate optimal effect of input taxation (reduction in subsidy benchmark) on input demand and its resultant possible effects on Greenhouse emission. Specifically, the study employed demand and stochastic efficiency functions within partial equilibrium framework to decouple and evaluate relative effect of changes in inputs demand and their respective effects on emission and producer welfare. Different taxation (reduction in subsidy) thresholds and regimes scenarios were explored to identify optimal future tax policy benchmarks for combating greenhouse emission of agricultural production. We aim to contribute to the ongoing conceptual and empirical policy debate on energy taxation and climate change. The remaining sections of the paper is organized as follows. Section 2 provides a brief description of data and the econometric model adopted while section 3 presents and discusses the empirical results produced from the econometric modeling. Section 4 contains the concluding remarks.

2. Materials and Methods

The study focused on paddy production under two farming systems, irrigation and non-irrigation technologies. A micro-level cross-sectional data obtained from the cost of cultivation scheme (CSS) conducted by the Government of India (CSO, 2021) for paddy production systems with significant contribution to agricultural emission in India for the period 2009 – 2018 production seasons in Karnataka state was used. These periods were used in order to delineate the effect of the covid-19 pandemic which caused sharp decline in input utilization pattern. The data sets were segregated into the farming systems (irrigated and non-irrigated) based on irrigated hours.

2.1. Greenhouse Gas Emission Estimation

The estimation of GHG emission in the present study considered emission level at farm gate (cardle-gate). The estimated emissions were converted into their CO_2 emission equivalent. Thus, greenhouse gas (GHG) will be used from here onwards to connote CO_2 emission. The greenhouse emission was estimated according to internationally accepted method of accounting for GHG emission [16] methodology.

2.2. Impact of Input Taxation on Input Demand

In assessing the effects tax (subsidy reduction) on demand for inputs, taking into account the behavioral responses of farmers, we estimated the demand of the different categories of inputs on which we sought to evaluate the tax (subsidy reduction). Systematic approach to evaluate demand patterns of microeconomic data, with different expenditure shares on the different categories of inputs under the axioms of choice and consumer behaviour theory, fits within the framework of the Almost Ideal Demand System (AIDS), proposed by [7]. However, the divergence in expenditure shares within the farming systems as a result of different risk bearing capacity of each farmer, limits the AIDS appropriateness to model the behaviour of the farmers, as it relies on strong assumption of linearity in Engel curves [10, 37]. To account for non-linearity resulting from risk levels of the farmers, the quadratic almost ideal demand system (QAIDS) that enables us to evaluate a farm input as necessities at different income and expenditure levels was adopted. Following a study [2], and based on indirect utility, the QAIDS is derived as:

$$InV(p,m) = \left[\left\{\frac{Inm - Ina(P)}{b(P)}\right\}^{-1} + \lambda(P)\right]^{-1} \quad (1)$$

Where $Ina(P)$ is the transcendental logarithm function that can be written as:

$$Ina(P) = \alpha_0 + \sum_{l=1}^{K} \alpha_i InP_i + \frac{1}{2}\sum_{l=1}^{k}\sum_{j=1}^{k} \gamma_{ij} InP_i InP_k \quad (2)$$

With P_i being the price of the bundle of good *i*. b(P) is a Cobb-Douglas price aggregator that takes the form,

$$b(P) = \prod_{l=1}^{k} P_i^{\beta_i} \text{ and } \lambda(P) = \sum_{l=1}^{k} \lambda InP_i \text{ where } \sum_{l=1}^{k} \lambda_i = 0.$$

Given that q_i *is* the quantity of input *i* consumed, $p_i q_i$ is the expenditure on input *i*, and the share of the total expenditure associated with the consumption of input *i* can be obtain as $w_i = {}^{p_i q_i}/_{m}$. By using Roy's identity, we can derive the expenditure share function as:

$$w_i = \alpha_i + \sum_{j=1}^{k} \gamma_{ij} InP_i + \beta_i In\left\{\frac{m}{a(P)}\right\} + \frac{\lambda_i}{b(P)}\left[In\left\{\frac{m}{a(P)}\right\}\right]^2, i = 1, \ldots, k. \quad (3)$$

Where *i,j* is the product group, *k* is the number of product group, *p* is the price index, $\alpha, \gamma, \lambda, \beta$ are parameters of the regression, *w* is the budget share, *m* is the total expenditure and *P* is the price of the inputs. To make the QAIDS conformable to consumer behaviour theory, we imposed restrictions of adding-up (to make sure that $\sum w_i = 1$), homogeneity, and the Slutsky symmetry on the parameters aforementioned in equation (3), as respectively given below.

$$\sum_{l=1}^{k} \alpha_i = 1, \sum_{l=1}^{k} \beta_i = 0, \sum_{j=1}^{k} \gamma_{ij} = 0 \text{ and } \gamma_{ij} = \gamma_{ji}$$

The estimates obtained for the parameters of the model enable us to evaluate the income and price elasticities with respect to each category of input. The equations were estimated following [28] procedure. By differentiating the share equation (Eqn 3) with respect to the log of expenditures, the expenditure elasticity was derived as $e_i = \frac{\partial q_i}{\partial m}\frac{m}{q_i} = 1 + \frac{\mu_i}{w_i}$. Similarly, by differentiating the share equation with respect to the price of the same good, the own price elasticity was evaluated as $e_{ii}^u = \frac{\mu_{ii}}{w_i} - 1$, whilst differential of w_i with respect to InP_i, yields the Marshallian uncompensated price elasticity of the goods: $e_{ij}^u = \frac{\mu_{ij}}{w_i} - \delta_{ij}$, with δ_{ij} as the Kronecker delta whose value is 1 if $i = j$ and 0 otherwise. Using the Slutsky equation, the compensated price elasticity was derived as, $e_{ij}^c = e_{ij}^u + e_i w_j$.

2.3. Impact of Input Taxation on Input Demand and Greenhouse Emission Reduction and Welfare Loss

The elasticities and parameters derived from QAIDS model were simulated to examine the effect of price changes (reducing the present subsidy-based scenario by 10 to 30%) on input demand. The estimated demand quantities were incorporated into a model to examine the impact on emission reduction potential due to the input subsidy removal. The emission reduction potential was evaluated through the model framework following [30] methodology as expressed in equation (4):

$$z = \sum_{ij} e_{ij}^z \, \delta Q_{ij} = \sum_{ij} e_{ij}^z \, Q_{ij} \, \epsilon_{ij}^u \, {}^{\delta p_{ij}}/_{p_{ij}} \quad (4)$$

Where z is the $kgCO_{2\,eq}$ reduction potential; *i* is the farming system and *j* is the input used; e_{ij}^z represents the specific input emission factor, Q_{ij} is the quantity of input demanded given the subsidy reduction scenario; ϵ_{ij}^u is the Marshallian own uncompensated price elasticity coefficient for the j^th^ input and ${}^{\delta p_{ij}}/_{p_{ij}}$ is the percentage change in price. Changes in price of inputs due to the reduction in subsidy may induce reduction in farmers' utility level (Welfare lost). Welfare lost was evaluated as changes in farm profit. However, the changes in farm expenditure due to price changes can be considered as allocative effect that can be redistributed to farmers through effective government policies [24]. Thus, the incremental expenditure was deducted from the gross returns to obtain the economic welfare lost due to the subsidy base reduction. The incremental expenditure was evaluated as:

$E' = E + dE$, *where* E= PQ with *P* being the price and *Q* is the quantity. By log-differentiation,

$$\frac{\partial E}{E} = \frac{\partial P}{P} + \frac{\partial P}{P}\frac{\partial Q}{\partial P}\frac{P}{Q} = \frac{\partial P}{P}(1 + e) \quad (5)$$

where *e* is the price elasticity of the i^{th} input. It therefore follows the incremental expenditure due to price increase as a result of reduction in subsidy base which can be evaluated as

$$E' = E\left(1 + (1+e)\frac{\Delta P}{P}\right) \quad (6)$$

However, if farmers are very elastic such that e = -1 then we obtain $E' = E$ implying that farmers adjust perfectly their consumption of energy such that there is no variation in their expenditures, which thus results improvement in energy use efficiency.

2.4. Cost of Carbon Reduction, Optimal Subsidy Rate and Economic Response

Optimal input subsidy removal was derived based on the profit generated from the farming system evaluated as $\pi = py - rq - C$ where π is the profit per ha, p is the price of output, y is the average crop yield per ha, r is the input price, q is the input quantity and C is the fixed cost of production. Change in profit (welfare loss) due to imposition of the subsidy reduction was evaluated as $\pi - E'$. In order to incorporate farmers risk aversion behaviour into the model, the stochastic efficiency with respect to function (SERF) according to [15], specified in the framework of negative exponential utility function was adopted to examine compensation variation. This was measured as the expected certainty equivalent, equals the utility obtained from the farming system, and derived as:

$$CE(x, r_a) = U^{-1}(x, r_a) \quad (7)$$

The negative exponential utility function which exhibits constant absolute risk aversion was chosen to estimate the coefficient of absolute risk aversion of the farmers in the SERF analysis. Using the negative exponential utility function, the expected utility and CE were computed as:

$$U(x, r_a) = \sum F_{t+1} - F_i\left[1 - \frac{\{\exp(-r_a x_i) - \exp(-r_a x_{i+1})\}}{r_a(x_{i+1} - x_i)}\right]$$

Where $r_L \le r_a \le r_U$

$$CE = \frac{-In\{1 - U(x, r_a)\}}{r_a} \quad (8)$$

The certainty equivalent (CE) interpreted as the certain money value equals the utility of expected profit from the farming system. Optimal utility-maximizing subsidy reduction rate was computed based on the maximum CE with the risk aversion bearing capacity coefficient of 0.01 (1%) and 0.05 (5%). The compensation variation due to the subsidy removal was computed as the risk premium associated with the reduction rate. The cost of carbon reduction was calculated as the ratio of welfare loss to carbon reduction potential.

3. Results and Discussions

Results of Greenhouse emission levels and carbon footprint in paddy production between 2008 and 2019 are presented graphically in Figure 1 below. The results show a significant increase in greenhouse emission at an increasing exponential reduction rate of 2.07 per cent during the study period. The average emission per hectare of cultivation of paddy was estimated at 12.34 thousand kg CO_2 eq ha^{-1} yr^{-1} with an increasing carbon footprint increasing at a rate of 2.32 per cent (Figure 1). The increase in emission can be attributed to retrogression in the environmental productivity and efficiency per hectare signifying technological rebound effect in paddy production despite advances in technology in Indian agricultural production systems.

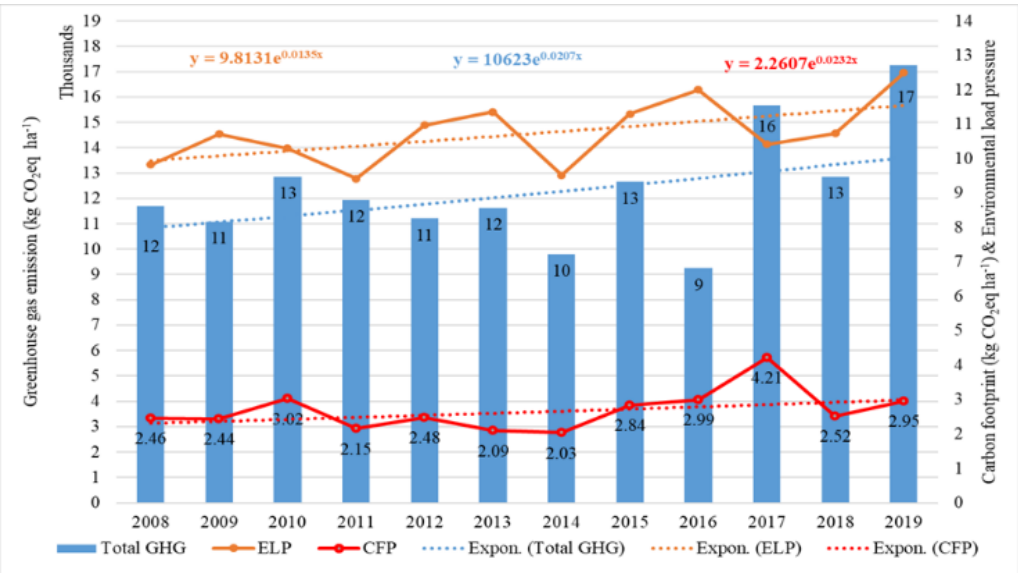

Figure 1. Greenhouse emission levels and carbon footprint in paddy production.

These results are consistent with those found in [40] who studied greenhouse gas emission from paddy fields in China. In [5], similar results were observed for cotton production systems, where greenhouse emission increased at an increasing exponential reduction rate of 2.28 per cent with average emission per hectare of cotton fields of 5.3 thousand kg CO_2 eq ha^{-1} yr^{-1}, in the same study area. Results of this study, are however, relatively higher as compared to a study conducted by [14, 19, 29].

3.1. Elasticities of Demand for Inputs in Paddy Production

Farmer's decisions on allocation of resources are guided by the relative changes in input and output prices. In measuring the effect of price policies at the farm level, the responsiveness of farmers to input price changes was estimated. The estimated results from the quadratic almost ideal demand system - QAIDS for inputs in paddy production are presented in Tables 1 and 2 for irrigated and non-irrigated production systems respectively.

Table 1*. Demand elasticity of inputs in Irrigated paddy farming (QAIDS results).*

Quantity demanded	**E_{i1}**	**E_{i2}**	**E_{i3}**	**E_{i4}**	**E_{i5}**	**E_{i6}**	**E_{i7}**
Seed	-0.621***	-0.237	-0.336**	-0.028	0.153	-0.019	-0.052
Human labour	-0.009	-0.603***	-0.055*	-0.083**	-0.120**	-0.025	-0.021
Animal labour	-0.192	-0.326**	-0.387	0.170*	0.113	0.131*	-0.169**
Machinery	-0.013	-0.466**	0.031	-0.750***	-0.084*	-0.009	0.009
Chemical fert.	0.046	-0.692**	0.018	-0.106*	-0.593***	0.047	-0.004
Insecticides	-0.068	-1.051	0.261	-0.165	0.152	-1.086***	0.043
Irrigation	-0.008	0.052	-0.214*	0.182	0.113	0.068	-0.603**

Note: *, **, *** indicate 10%, 5%, 1% level of significance, respectively

Table 2*. Demand elasticity of inputs in Non-irrigated farming (QAIDS results).*

Inputs	**E_{i1}**	**E_{i2}**	**E_{i3}**	**E_{i4}**	**E_{i5}**	**E_{i6}**
Seed	-0.523***	-0.460**	-0.023	0.054	0.013	0.015
Human labour	-0.037**	-0.696***	-0.004	-0.028**	-0.124***	0.039
Animal labour	0.010	0.052	-0.274***	-0.196***	-0.226***	-0.023
Machinery	0.002	-0.251***	-0.103***	-0.744****	-0.034	-0.084**
Fertilizer	-0.009	-0.592***	-0.127**	-0.049*	-0.764***	0.020
Insecticides	-0.016	0.068*	-0.097	-0.425**	0.012	-1.157***

Note: *, **, *** indicate 10%, 5%, 1% level of significance, respectively

As expected, from Table 1 and Table 2, the uncompensated Marshallian own price elasticities for all the inputs included in the model for both production systems, irrigated and non-irrigated, had negative signs indicating that an increase in price of an input, will lead to a decline in its demand. Again, with the exception of Animal labour under irrigation system, all the inputs own price elasticities appeared highly significant, falling under 1% significance level.

In irrigated farming systems, the estimates for irrigation water consumption indicate inelastic demand function, implying that increases in price of irrigation water will not cause proportionate significant reduction in the consumption pattern. In effect, changing the current existing conventional flooding irrigation system especially in paddy production to modern irrigation system will be relevant to save water and decrease the salinity of soils and emission from paddy fields. Results from Tables 1 and 2 also revealed elastic uncompensated demand elasticity for the consumption of insecticides. This signifies that aside insecticide chemicals being recommended as protective input for pest control; the farmer consumes the pesticides as productive input. Again, the results indicate existence of significant complementary relationship among many of the inputs demanded, evidenced by negative and significant coefficients, implying that an increase in the price of one input tends to decrease the demand for the other inputs. The cross-demand elasticity between insecticides usage and human labour in irrigated and non-irrigated paddy production systems revealed existence of substitutability relationship as indicated by the positive and significant coefficients. It suggests the usage of insecticides as productive input especially pests control mechanism which could have been done by the human labour. From Table 1, it is observed that irrigation demand and human labour had relatively strong complementary relationship, and thus follows that expansion in irrigation water consumption results in high demand for human labour for the management of the irrigation system.

Table 3. *Expenditure and Compensated Elasticities (QAIDS results).*

Input	Irrigation		Non-irrigation	
	Expenditure	**Compensated**	**Expenditure**	**Compensated**
Seed	1.141***	-0.594***	0.976***	-0.524***
Human labour	0.916***	-0.119**	0.850***	-0.275**
Animal labour	0.627**	-0.290**	0.648***	-0.232**
Machinery	1.255***	-0.541***	1.191***	-0.511***
Chemical fert.	1.264**	-0.428***	1.233***	-0.729***
Insecticides	1.929***	-1.033***	1.616***	-1.061***
Irrigation	0.436	-0.578**	-	-

Note: *, **, *** indicate 10%, 5%, 1% level of significance, respectively

In paddy production, the expenditure elasticities for seed, machinery and fertilizer and insecticides were greater than unity indicating that these inputs were elastic with respect to net farm expenditure (Table 3), meaning, proportionately larger response of demand for these inputs groups to changes in total expenditure ensue. These results are similar to findings reported by [5] in their study of cotton production and GHG in Karnataka State; and [13] who studied trend of input demand in Haryana State in India.

3.2. Implication of Input Subsidy Reduction on Inputs Demand

Agricultural price policies are often directed to influence either output or input prices, classically to favour producers and to sustain agricultural production. Higher output prices or lower input costs may result in different combination and utilization of resources and vice versa. Low energy prices weaken the capacity of the carbon market to reduce emissions, while higher energy prices lead to higher reduction in CO_2 emissions. Thus, high energy price is expected to affect CO_2 emissions by penalizing farmers who use more carbon-intense input combinations by increasing production expenditure in a form of raised input cost. In this section, we evaluated the impact of changing input prices on demand, welfare lost and optimum tax policy. The results, as presented in Table 4, indicate that under each of the three input tax scenarios, inputs committed for production of the paddy crop reduced significantly. For example, introducing 10 per cent reduction in the base subsidy on subsidized inputs reduced consumption of chemical fertilizer and insecticides by 12.44 kg ha^{-1} and 1.59 litres ha^{-1} respectively.

Table 4. *Simulation of input taxation (subsidy base reduction) on input demand.*

	Irrigated farming system (paddy)				**Non-irrigated farming system (paddy)**			
Inputs	**Demand (0% tax)**	**Demand (10% tax)**	**Demand (20% tax)**	**Demand (30% tax)**	**Demand (0%)**	**Demand (10% tax)**	**Demand (20% tax)**	**Demand (30% tax)**
Machinery	23.62	22.03	20.65	19.44	32.94	30.58	28.57	26.82
Fertilizer	216.54	204.10	193.12	183.34	453.44	428.42	406.24	386.43
Insecticides	14.60	13.17	11.97	10.95	36.14	31.56	27.83	24.76
Irrigation	101.28	110.26	116.44	120.66	-	-	-	-

In irrigated paddy system, increasing the price of irrigation water will not cause significant reduction in the consumption of water due price inelasticity of demand, implying the necessity of water in paddy production. However, irrigation being a principal contributor to emission in paddy production, changing the type of irrigation system will be relevant. In the paddy production process, reducing the subsidy resulted in reduction of inputs usage with considerable environmental benefit. These results are consistent with findings reported by [36] who concluded that removing fertilizer manufacturing subsidies has reduced greenhouse gas (GHG) emissions from agricultural activities with minimal impact on food production. Arguments for farm unemployment and food insecurity concerns that arise as a result of reduction in or removal of subsidy are addressed in respect of elasticity scores of human labour input in the demand framework. Given the results presented in Table 2, for inputs having less than unity own-price elasticity, increasing price of carbon intensive inputs will not cause significant reduction in employment within the farm sector. This is consistent with theory, and can be demonstrated (see [5]) that under the stated conditions, gradual removal of subsidy will not cause farm unemployment but will rather cause adjustments in input consumption structure to attain economic optimum in the production process. The reduction in consumption of chemical fertilizer, for instance, will reduce its emission significantly not necessarily due to its application to agricultural soils, but reduction in its demand will cause reduction in the energy intensive Haber-Bosch manufacturing process for producing fertilizers to meet the market demand.

3.3. Implication of Subsidy Reduction on Greenhouse Gas Emission Reduction Potential

The environmental benefit and economic implications of the input tax scenarios (reduction of the subsidy base support by 10%, 20%, 30%) and their corresponding reduction in greenhouse emission potentials are presented and discussed in this section. The subsidy reduction was evaluated on the critical carbon intensive inputs (fertilize, machinery, irrigation, and insecticides consumption). The reduction potentials of greenhouse emission were estimated via elasticities and emission factors of these inputs through the model framework, described in equation (4). The results showed that imposition of the tax (reducing the subsidy by 10, 20 or 30 percent) as depicted in Table 5, induced reduction of emission equivalent to 56.88, 117.62 and 182.45 kg CO_2 eq ha^{-1} respectively in irrigated paddy production system whilst the same tax margin scenarios induced emission reduction equivalents of 62.46, 123.90 and 185.54 kg CO_2 eq ha^{-1} in non-irrigated farming system respectively. Increasing the price of energy inputs will induce economic burden/loss to farmers due to increase in the cost of production.

Table 5. *Greenhouse gas reduction potential due to subsidy reduction.*

Factor	**Irrigated farming system**			**Non-irrigated farming system**		
Tax Regime scenario	**Z (10 %)**	**Z (20%)**	**Z (30%)**	**Z (10 %)**	**Z (20%)**	**Z (30%)**
Total changes in GHG (kg CO_2eq ha^{-1})	-56.88	-117.62	-182.45	-62.46	-123.90	-185.54
Economic welfare loss due to tax	1473.52	5178.70	5687.70	1070.34	6418.90	6978.67
Cost of carbon reduction (Rs kg^{-1})	25.91	44.02	31.17	17.14	51.81	37.61
Compensation premium	1334.11	3252.56	5174.89	4127.29	6497.32	8870.86

The results, further show that taxation under the three scenarios will induce welfare loss of Indian Rupee (INR) 1473.52, 5178.70 and 5687.70 respectively among irrigated paddy farmers and INR 1070.34, 6418.90 and 6978.67 for non-irrigated production system in same order, due to increase in cost of production as a result of the input taxation. For farmers to reach the initial level of utility, the economic cost to the farmers due to the tax burden through increased rate of inputs can be compensated at INR 1334.11, 3252.56 and 5174.89 respectively (Table 5) for the three scenarios among paddy irrigated farming system. Alternatively, higher output prices can be offered through effective institutional integration by using the tax revenue or the amount of monies paid as subsidies to manufacturing companies. These results and their implied economic conclusions are consistent with studies conducted by [16, 22, 24, 27] who observed that emissions tax rates can trigger adjustable investments in agriculture production systems with a significant reduction in GHG emissions and that moderate carbon tax can result in reduction in GHG effects at a lower cost of mitigation. The optimal tax policy was investigated based on the risk aversion of the farmers. The optimum tax policy (reduction in subsidy) is the reduction scenario that yields maximum utility at which the farmers remain indifferent between their present wealth (profit) generated from farming activities and the risk outcome due to the tax effect at relatively low economic cost and welfare loss. The results of the farmers' utility level based on the exponential utility function for the three taxation rates are presented in Table 6 below.

Table 6. *Utility function based on SERF model.*

Utility (Profit)	10% tax	20% tax	30% tax
Paddy (INR ha^{-1})	33,141.75	30,997.51	28,849.57

The results indicate that the optimum tax policy (reducing the base subsidy) was evaluated at 10 per cent implying that reducing the existing subsidy rate by 10 per cent will yield maximum returns to the farmers based on the risk assumed (1– 5%) at relatively low economic cost to the government and paddy producers. It follows that, imposing subsidy reduction rates beyond 10 per cent base subsidy component given by government on the high carbon intensive inputs will produce high environmental benefit but with relatively high economic cost to government and farmers. Thus, optimum greenhouse emission reduction potential rate is 10 per cent reduction of the existing subsidy.

4. Conclusions

This study was conducted to examine the effectiveness of input taxation policy (reduction in input subsidy) as a policy instrument for greenhouse emission reduction potential in paddy production in Karnataka state in India. The estimation of the greenhouse emission level in the production system was computed through internationally accepted accounting method for GHG emission. To investigate the demand of inputs, the QAIDS model was employed. The results revealed increased levels of greenhouse emission in paddy production systems. The results also revealed that the farmers were inelastic to inputs demand. Based on the income elasticities, the inputs were classified as normal commodities within the farming system. The simulation analysis illustrated that increase in the price of inputs will result in reduction of inputs utilization and greenhouse emission. The study further showed that greenhouse emission reduction potential was possible at moderate tax policy (10% taxation) given the risk aversion of the farmers and with the associated low mitigation cost and compensation cost. Considering the reduced rates in the inputs usage with reduction in greenhouse emission due to input taxation, gradual removal of subsidies policies with moderate tax policy, would be effective possible economic instrument for effective greenhouse mitigation strategy. The study suggests that reducing subsidy has significant benefit in reducing CO_2 emission from agriculture. The welfare effect associated with taxation can be mitigated through effective economic policies by payment of compensation through effective institutional integration where withheld subsidy can be paid to farmers.

Abbreviations

GHG	Greenhouse Gas
CSS	Cost of Cultivation Scheme
AIDS	Almost Ideal Demand System
INR	Indian Rupee
QAIDS	Quadratic Almost Ideal Demand System
CE	Certainty Equivalent

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Author Contributions

James Kofi Blay: Conceptualization, Design, Analysis, Writing original draft.

Huchaia Lokesha: Conceptualization; Design; Supervision.

Isaac Abunyuwah: Methodology & Modelling; Supervision; Writing- review & editing of the final draft

All the authors proofread the manuscript and approved the final version of the manuscript.

Data Availability Statement

Data used for this work is a public data that was downloaded from Cost of Cultivation Scheme conducted by Indian Government under the supervision of Department of Agricultural Economics at University of Agricultural Sciences, Bangalore, GKVK available at http://eands.dacnet.nic.in/Cost_of_Cultivation.htm

Conflicts of Interest

The authors declare no conflicts of interest.

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