

RETHINKING ABOUT DETERMINANTS OF INORGANIC FERTILIZER USE IN VIETNAM

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Abstract

The 'behavioural approach' in rural studies focusing on the motives, values and attitudes that determine the decision-making processes of individual farmers has become increasingly important in the investigation of farmer response to policy initiatives. Research on motives and factors affecting farmer's behaviors in using any types of fertilizers in terms of organic, inorganic or green technology in order to improve agricultural productivity has not been fully addressed yet. This paper particularly aims to address the adopting inorganic fertilizer among paddy farmers in two provinces in southern central areas in Viet Nam through the structured-questionnaires to 204 farm households. Findings indicated that farm size, motives of crop cultivation, adoption of "3 Decrease- 3 Increase" technology in rice production and gender of principal farm operator are 4 key components affecting the usage of inorganic fertilizers of farmers. Policy implications are recommended which highlighted the emphasis on model of "3 decreases 3 increases", land consolidation and plot exchange program. Critical discussions on agricultural productivity, the environmental concerns for the sustainable agricultural practices amongst paddy farmers were given as possible solutions for the Vietnamese green agriculture.

Key words: *inorganic fertilizer, rice cultivation, Vietnam*

1. BACKGROUND

Fertilizer use is a major determinant of grain yields to meet the food, fiber and feed demands of an increasing and gradually wealthier population, contributing 40% to 60% to yield increases (Ma, L., Feng et al, 2013). Meanwhile, the debates focuses on attaining sustainable agriculture entailing the pursuance of resilient agricultural practices that support synergies in increasing agricultural productivity and maintaining the ecosystem (Abdulai, A. N., & Abdulai, A, 2017). A plenty of research on factors affecting fertilizer (over)use and fertilizer use efficiency to address the overuse and inefficient use of fertilizer has generated negative the environmental consequences, such as The excessive use of fertilizer has resulted in serious environmental degradation and a high health cost (Ju, X., et al, 2016), water eutrophication and pollution (Uri, 1997), biodiversity loss (Asai et al., 2010), imbalance of soil nutrients and soil compaction and salinization (Feng, 2010), and climate change (Ma, L., Feng et al, 2013). Available research on factors affecting fertilizer (over)use and fertilizer use efficiency can be divided into two groups. One group examines determinants of fertilizer application in order to identify ways to reduce fertilizer input in agriculture (Zhou et al., 2010; Beshir et al., 2012) while other group examines fertilizer use efficiency and its influencing factors in order to increase fertilizer use efficiency in agriculture (Kebede, D., et al, 2017).

In particular, previous literature has addressed the analysis of the decisions on fertilizer use has mainly considered the factors lying within the public domain in term of prices and marketing, fertilizer provision and distribution, research and credit, agro-climatic conditions and characteristics of the farm or the farmer (Zhou et al., 2010) which gave assumptions that farmers make adoption decisions based on utility maximization. Since 1970s, Abbott (1979) indicated high fertilizer/crop price ratios, unavailability of fertilizer, lack of credit, lack of knowledge, land tenure, risk and uncertainty as major constraints to fertilizer use. Meantime, social scientists, especially anthropologists and sociologists, have criticized that farmers' subjective assessments of agricultural technologies are also important in influencing their adoption behavior (Feder et al., 1985; Adesina and Zinnah, 1993; Chianu and Tsujii, 2004; Abdoulaye and Sanders, 2005). For example, the works of Adesina, A.A., et al (1995) showed

that farmers' perceptions have been found important in adoption of modern crop varieties in several regions in Africa. (e.g. prices and marketing, fertilizer provision and distribution, research and credit, etc.), and on agro-climatic conditions and characteristics of the farm or the farmer (e.g. education, age, experience and farm resources). Most earlier works on fertilizer use by economists focus on fertilizer adoption and assume that farmers make adoption decisions based on utility maximization. The behavior of an individual with respect to a new adoption over a period of time can be determined by solving the temporal optimization problem of the individual at each point in time and using the equations of motion to generate the parameters for the optimization problem (Feder et al., 1985). Social scientists, especially anthropologists and sociologists, have argued that farmers' subjective assessments of agricultural technologies are also important in influencing their adoption behaviour. (Kivlin and Fliegel, 1967). For example, farmers' perceptions have been found important in adoption of modern crop varieties in several regions in Africa (Adesina and Zinnah, 1993; Adesina and Baiduforson, 1995; and Sall et al., 2000). In some what, the theory of reasoned action (TRA) by Ajzen and Fishbein (1980) and the theory of planned behaviour (TPB) by Ajzen (1985) were the two prominent theoretical approaches followed by most of the studies. Further specific research on the determinants of fertilizer use patterns in terms of synthetic fertilizer, organic or inorganic fertilizer in rice cultivation has not fully explored yet.

Vietnam has started to export rice in the late 1980s and also one of the largest rice exporters in the world (Berg, H., et al, 2017; Renaud and Kunezer 2012). Rice production plays an important role in food security, in protecting the environment and biodiversity in Vietnam. Despite the adverse climate, infertile soils, and adverse public policy, farmers in region have continued their utilization of inorganic fertilizers. With the impact of climate change becoming ever more serious, environmental protection has emerged as a common global concern. In fact, the traditional rice farming practices involving the use of inorganic fertilisers has caused serious land and air pollution, even harmed farmers' health. Therefore, measures need to be put in place to reduce the harm caused by inorganic fertilisers and achieve the goals of environmental protection and sustainable development.

A number of studies have examined factors that affect the volume of fertilizers used in countries worldwide. For example, Green and Ng'ong'ola (1993) via logit model studied factors affecting the use of fertilisers in developing countries in the Lilongwe Rural Development Project indicated that in descending order, crop, farming system, crop variety, credit access, income from off-farm employment and regular labour are the main factors influencing fertilizer adoption. Similar approach later accounted for research of Wanyama et al. (2009) that investigated the determinants of fertiliser use in maize production in the greater district of Trans-Nzoia, Kenya criticized that while adoption of fertilizer technology was significantly determined by age, nativity, farm size occupational status, access to credit, and distance to agricultural office, farm size was the most influential determinant of adoption of fertilizer technology in northern Ghana. The extent of fertilizer use was significantly determined by income of household head, membership of farmer association, distance to agricultural office, access to input shop, income earning household that do not participate in agricultural development project and income earning male headed household.

Research on adopting or not adopting inorganic fertilizer has been done since 1990s that indicated that some farmers cite lack of access, high costs, lack of credit facilities, removal of fertilizer subsidies, and government's withdrawal from fertilizer distribution as the main reasons for the non-adoption of IF at the recommended rates (Kwanashie et al. 1997; Enyong et al. 1999). Inorganic fertiliser is not a natural fertiliser and synthesised from mineral salts, such as ammonium sulphate or triple super phosphate (Cromell, 2012). The key aim of inorganic fertiliser application is to provide necessary nutrients to plants by improve the quality of soil. Inorganic fertilisers are popular with rice farmers because of their huge advantages. Firstly, the cost per pound of inorganic fertilisers is lower than that of organics that helps to boost farmers' profits. Secondly, inorganic fertilisers are available in many fertiliser providers, which makes farmers convenient to buy them if they need.

On the other hand, many agricultural experts advise that farmers should not use a large amount of inorganic fertilisers due to their shortcomings. One of their disadvantages is that they do not contain organic matter to enhance soil structure, aeration or moisture retention and do not support beneficial

soil organisms that improve soil over time. Another weakness of inorganic fertilisers is that nitrogen can be leached quickly through soil. Therefore, more frequent applications of fertiliser are required. Furthermore, the overuse of inorganic fertilisers can cause a buildup of salt in the soil and promote nitrogen or phosphorus run-off, which may contaminate water supplies. Finally, many inorganic fertilisers are volatilised (lost to the air) if not immediately watered. Hence, if inorganic fertilisers are not applied in accordance with the manufacturer's instructions, they will affect the quality of the soil and pollute the environment.

Using the logit model, Chianu, J. N., & Tsujii, H. (2005) looked at determinants of farmers' decision to adopt or not adopt inorganic fertilizer in the savannas of northern Nigeria and indicated that the likelihood of adoption of IF is higher among farmers who apply large quantities of organic manure than among farmers who apply small quantities. This behavior reveals that farmers understand the complementary relationship between organic manure and IF when applied together and must be encouraged by research and extension. Farmers who perceive an increase in the fertilizer needs of their crops are more likely to adopt IF than farmers who perceive a decrease or no change in the fertilizer needs of their crops (Chianu, J. N., & Tsujii, H., 2005)

However, research on adopting or not adopting inorganic fertilizer is likely to be modest in developing countries. There have been no studies of the determinants of inorganic fertiliser use in Vietnam. In Vietnam, common inorganic fertilisers used in rice farming are nitrogen, phosphate, potassium and NPK¹. The aim of the present research was to quantify the factors affecting the inorganic fertilisers used in rice cultivation in the south central provinces in Vietnam. The results can be used to identify ways to limit the use of inorganic fertilisers and minimise their harmful effects on the environment, in addition to spurring sustainable agricultural production.

2. METHODS

The conceptual framework for this research was based on research question, gaps from literature on fertilizer use and the determinants of inorganic fertilizer. In particular, in order to have a solid framework, the preliminary stage to explore the validity of variables from the interviews and pilot ones conducted with farmers was adopted in southern central Vietnam context. Factors affecting inorganic fertiliser use in rice farming in the two south central provinces in Vietnam were evaluated using multiple regression analysis. The model was explicitly expressed as:

$$\text{IFU (Inorganic fertilizer use)} = c_1 + c_2\text{Age} + c_3\text{Gender} + c_4\text{Education} + c_5\text{Policy} + c_6\text{Awareness} + c_7\text{ Purpose} + c_8\text{TDTI} + c_9\text{ Labour} + c_{10}\text{Size} + c_{11}\text{Soil} + c_{12}\text{Capital} + c_{13}\text{Livestock} + c_{14}\text{Price} + c_{15}\text{Location} + e$$

Where c_1 is constant, c_i is the estimated coefficients of the explanatory variables, and e is a disturbance term.

Data used in the analysis were collected from a two-stage survey of farm households in Quang Nam and Phu Yen. The preliminary stage is the exploratory one to explore/understand determinants of inorganic fertilizer use of farmers. Inorganic Fertilizer has been used in significant amounts in this region and tends to increase over time. Variables were captured and selected based on the gaps from literature review and from this exploratory before conducting the formal survey. The questionnaire of the survey was finally designed to solicit information on farmers' inorganic fertilizer use and its determinants in farming activities. It encompasses households' demographics, farmers' awareness about inorganic fertilizers, agricultural support policies, farmers' cultivation purposes, farm size, family labor, application of "3 Decrease-3 Increase" in Integrated Pest Management, soil quality, livestock source, fertilizer price, farm locations, capital accessibility. Respondents were asked to list the most influential factors in inorganic fertilizer use and farmers were asked to rate the decision variables according to their agreement and importance.

¹ is a kind of fertiliser which contains three main elements: Nitrogen (N), Phosphorus (P), and Potassium (K).

3. DATA ANALYSIS AND RESULTS

3.1. Data description

Table 2 shows the basic characteristics of the study sample. In the study, 204 farmers were interviewed: 101 in Phu Yen and 103 in Quang Nam. Therefore, the sample size was similar in the two provinces. Among the farmers interviewed, those aged 50 years and older accounted for the majority (66.5%) of the sample. This implies that the farms were mostly managed by older individuals, who may find it difficult to access and apply modern technologies in rice farming.

Regarding education levels, 104 farmers interviewed had a secondary education (accounted for 51.2%), and 47 farmers (23.2%) had a high-school education. Fewer numbers of farmers (n=38, 18.7%) had only a primary school education. A large proportion of farmers having high level of education means that farmers are likely to easily acquire knowledge and technology related to rice cultivation.

With regard to gender, 83.3% of the household heads were males. This finding was expected, as rice cultivation, as well as agricultural activities, requires physical stamina and strength. Therefore, men were the main decision makers.

Table 1. Characteristics of the sample

	Frequency	Percentage
<i>Location</i>		
Phu Yen	97	50
Quang Nam	97	50
<i>Age</i>		
30–40 years	16	7.9
40–50 years	43	21.2
50–60	73	36
60 years and older	62	30.5
<i>Education</i>		
Illiteracy	1	0.5
Primary school	38	18.7
Secondary school	104	51.2
High school	47	23.2
Above high school	4	2
<i>Gender</i>		
Male	169	83.3
Female	25	12.3

3.2. Factors affecting inorganic fertilizer use in rice cultivation in southern central Vietnam

The variance inflation factor (VIF) was used to determine whether multicollinearity existed among the variables in the model. The VIF coefficients of five independent variables were under 10, indicating that multicollinearity did not exist. As shown in Table 3, these five factors had a significant impact of

the amount of inorganic fertiliser used ($p < 0.01$). Of these factors, farm size had a major impact on inorganic fertiliser use in rice cultivation. Its regression coefficient was -0.408, indicating that farm size was negatively related to the amount of inorganic fertiliser used. When other factors remained constant and farm size increased 01 per-area, the amount of inorganic fertiliser used decreased 0.408 kg/per-area/crop. Thus, the results indicated that larger farms used less inorganic fertiliser in rice cultivation than smaller farms in the south central provinces. This suggests that the efficiency of the use of inorganic fertilisers increases if farm size increases. This conclusion is similar to the conclusions of Sunday et al. (2012) but opposite to the findings of other studies (Onyenweaku et al., 2007; Akinwumi, 1996; Wanyama et al. 2010).

The results of the Ordinary Least Squares (OLS) estimation are presented in Table 3. The results showed that the adjusted R square reached 0.457, which means that five independent factors explained 45.7% of the variation in the amount of inorganic fertiliser used: gender, farm size, joining the ‘Three Decrease Three Increases’ program, farming purpose and farm location/place

Table 2. Estimation result of the factors affecting inorganic fertiliser usage in rice farming in Southern central region of Vietnam

Model	Standardised estimation coefficient	t	SSig.	Collinearity statistics	
				Tolerance	(VIF)
Constant	10.312	14.577	.000		
GENDER	.143	2.635	.009	.955	1.046
SIZE	-.408	-7.065	.000	.844	1.185
TDTI	-.248	-4.616	.000	.971	1.003
PURPOSE	-.291	-5.269	.000	.924	1.083
PLACE	.171	2.997	.003	.863	1.159
Adj R2	0.457				

Table 3. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.687	.471	.457	2.55490

The Table 3 showed results that the adjusted R square reached 0.457, which means that five independent factors explained 45.7% of the variation in the amount of inorganic fertiliser used: gender, farm size, joining the ‘Three Decrease Three Increases’ program, farming purpose and place. As shown in Table 3, these factors had a significant impact of the amount of inorganic fertiliser used ($p < 0.01$). Of these factors, farm size had a major impact on inorganic fertiliser use in rice cultivation. Its regression coefficient was -0.408, indicating that farm size was negatively related to the amount of inorganic fertiliser used. When other factors remained constant and farm size increased 01 arr, the amount of inorganic fertiliser used decreased 0.408 kg/500 m2/crop. Thus, the results indicated that larger farms used less inorganic fertiliser in rice cultivation than smaller farms in the south central provinces. This suggests that the efficiency of the use of inorganic fertilisers increases if farm size increases. This conclusion is similar to the conclusions of Akpan et al. (2012) but opposite to the findings of other studies (Onyenweaku et al.2007; Akinwumi1996; Wanyama et al. 2010).

The results also demonstrated that being a member of the ‘Three Decreases - Three Increases’ program affected the amount of inorganic fertilisers used in rice cultivation. The ‘Three Decreases – Three

Increases' program is an integrated pest management practice. The regression coefficient of this factor was negative, which suggested that this factor had a significant negative impact on the amount of inorganic fertiliser used in rice cultivation in the south central provinces. Keeping all other factors constant, the amount of inorganic fertilisers used decreased 0.248 kg/per-area/crop on farms that were members of the program. It is well accepted that agricultural production must be increased considerably in the foreseeable future to meet the food and feed demands of a rising human population and increasing livestock production. The awareness generation about technology through formal crop-specific IPM training is essentially a knowledge-based technology, involves integration of different methods of disease and pest management. Farmers' adoption of integrated pest management (IPM) package depends on many factors, such as their technical skill and socioeconomic conditions as well as psychological and cultural factors, etc. (Singh, A., Vasisht, A. K., Kumar, R., & Das, D. K. 2008). Since farmers are the final decision-makers for adoption of any technology, it is important for the technology developers/providers to identify how farmers' react to the provided techniques and what about the adoption process of certain innovations. This technology has not only shown decreased applications of pesticides and low environmental risks but has also raised crop yields and net returns (Singh, A., Vasisht, A. K., Kumar, R., & Das, D. K. 2008).

The regression coefficient of the variable 'purpose of the farm' was 0.291. Thus, households farming for commercial purposes used more inorganic fertiliser (0.291 kg/per-area/crop) than households who grew crops for their own consumption. The purpose of cultivation affects the amount of inorganic fertilisers used in rice farming. We hypothesise that commercial farms (i.e. those that produce crops for sale on the market) demand higher outputs than farms where the crops are grown to satisfy the food needs of the farmer's family, with the latter tending to restrict their use of inorganic fertilisers. Zhou et al. (2010) pointed out that when farmers prioritised profitability goals, they used more inorganic chemicals than those who did not prioritise profitability.

Many studies have indicated that farm size was correlated with inorganic fertiliser use. In a study of factors affecting the use of fertilisers in rice cultivation in Abia State, Nigeria, Onyenweaku et al. (2007) concluded that farm size had positive impacts on fertiliser usage. Other studies on the use of inorganic fertilisers in rice cultivation in Côte d'Ivoire reached similar conclusions (Akinwumi, 1996; Wanyama et al., 2010). Akpan et al. (2012) also pointed that farm size was associated with fertiliser use, with greater amounts of fertilisers used on larger farms.

In common with the other two variables in terms of farm size and being a member of the 'Three Decreases Three Increase' systems, farming purpose had a significant negative impact on the amount of inorganic fertiliser used. A previous study of factors affecting farmers' decisions on fertiliser presented similar findings (Zhou et al., 2010). The purpose of cultivation affects the amount of inorganic fertilisers used in rice farming. We hypothesise that commercial farms (i.e. those that produce crops for sale on the market) demand higher outputs than farms where the crops are grown to satisfy the food needs of the farmer's family, with the latter tending to restrict their use of inorganic fertilisers. Zhou et al. (2010) pointed out that when farmers prioritised profitability goals, they used more inorganic chemicals than those who did not prioritise profitability.

Gender had a significantly positive impact on the amount of inorganic fertiliser used in rice farming in the south central provinces, with a coefficient was 0.143. When other factors remain unchanged, if the head of the household was female, the use of inorganic fertilisers increased by more than 0.143 kg/per-area/crop than when the head of the household was male. According to Kasule et al. (2008), gender affected the amount of fertilisers used in cultivation, with female farmers generally using less fertilisers than male farmers. Other studies provided evidence in support of the aforementioned finding (Akinwumi, 1996; Akpan et al., 2012). Onyenweaku et al. (2007) reported that female-headed households used more fertiliser in rice cultivation than male-headed ones. This finding is similar to that reported by Onyenweaku et al (2007), who studied factors affecting the use of fertilisers in rice cultivation in Abia state, Nigeria, but it is in contrast to the findings of other studies (Bayite-Kasule, S., 2009; Akpan et al. 2012).

The results revealed that the variable 'location/place' had a significant positive effect on the amount of inorganic fertiliser farmers used in rice farming. The regression coefficient of this factor was 0.171.

When other factors remained unchanged, the farmers in Quang Nam province used more inorganic fertiliser (0.171 kg) per per-area on each crop than the farmers in Phu Yen.

4. CONCLUSIONS AND IMPLICATIONS

The result of OLS indicated that five factors influenced the amount of inorganic fertiliser used in rice cultivation in the south central provinces: membership of the ‘Three Decreases - Three Increases’ program, farm size, farming purpose, gender and cultivation locations. Among of these, two factors had major impacts on the amount of inorganic fertilisers used: farm size and membership of the ‘Three Decreases - Three Increases’ program. Both factors were negatively related to the dependent variable, with a significance level of 1%. Thus, the results suggested that the ‘Three Decreases - Three Increases’ program was effective in reducing the amount of inorganic fertilisers used for rice farming in the south central provinces and that large farms used inorganic fertilisers more efficiently than small farms.

While there has been considerable research and policy analysis on fertilizer promotion and use around the world (Bayite-Kasule, S; 2009), in Vietnam this has not been the case. Promoting the use of inorganic fertilizer requires a critical analysis of the supply and demand constraints that keep usage rates low in Vietnam, especially among smallholder farmers. Results suggest some policy implications to reduce the amount of inorganic fertilisers used in rice farming in order to build a green and sustainable agriculture in the south central provinces in Vietnam. In particular, local authorities need to persuade more farmers to join the ‘Three Decreases Three Increases’ program to minimise the amount of inorganic fertilisers used in rice farming. For farmers joining the program, agricultural extension officers should support and monitor their compliance with the regulations set by the model. Second, large farms using fertilisers are more efficiently than small farms.

Therefore, policies on promoting land consolidation should be put in place. Currently, authorities in many localities provide financial support to accelerate land consolidation, but this support does not meet the total costs of consolidation. To encourage land consolidation, flexible and integrated rural development programs need to be put in place. Farmers need to change their mind-sets from small-scale production to large-scale farming. Local authorities, as well as agricultural extension officials, need to convince farmers to cooperate in production. Furthermore, they should create a favourable environment to promote links between farmers and enterprises to increase profits, while using fertiliser more efficiently over a wide area.

When running extension programs on how to use inorganic fertilisers efficiently, agricultural extension officers should focus on two groups of farmers: farms headed by women and farmers who cultivate rice for commercial purposes. Finally, in Quang Nam, where farmers use excessive amounts of inorganic fertilisers, the local authorities should promote extension programs and training courses, while recommending reductions in the use of inorganic fertilisers for rice farming. Further research could include studying more in-depth the overuse problem on a wider geographical scale. To the authors’ knowledge, there are limited education and training programs available particularly on fertilizer application in the study area. Although this study has focused on southern central Vietnam the research methodology and survey techniques are highly relevant for studying similar problems in other regions in order to come up with appropriate policies regarding prices, incentives, and future extension program priorities. As fertilizer consumption continues to grow, imbalanced and excessive use of fertilizers and their environmental impact will become a major concern. Policies aimed at improving fertilizer use efficiency may therefore focus on increasing knowledge on the environment and fertilizer management.

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