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Drivers in Adoption of Urea Deep Placement Technology in Paddy Cultivation: An Empirical Study in Kalahandi District of Odisha, India

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Abstract

Effectively managing the nutrient has been an important challenge among the farmers and a concern to the environmentalist. Not innovation, but rather a diffusion of technology among the farmers is a crucial challenge. Urea deep placement (UDP) in paddy cultivation is an innovation by international fertilizer development corporations to reduce nitrogen loss and increase the use efficiency of urea. The study adopted the treatment effect model at two-stage to answer the following two research questions: (a) what are the drivers in the adoption of UDP technology among farmers in paddy cultivation; and (b) what is the effect of adopted technology on the output of paddy? The important drivers, in this regard, include land ownership, gender, extension services, off-farm income, membership of farmer groups & training attended, assured risk coverage, and irrigation. Moreover, farm size and the adoption of urea deep placement technology significantly influenced the output of paddy. Added to the economic benefit of the technology adoption, it also creates employment opportunities in preparing urea briquettes and transplanting them. The placement of a urea briquette reduces chemical leakage and pollutes the water. Along with the adoption of deep placement technology, it has induced farmers on adopting mechanization and proper water distribution and channelization on the paddy field.

Keywords: Drivers; Urea deep placement; Adoption; Nitrogen; Paddy; Technology.

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1. Introduction

An agrarian economy, which led paddy cultivation prominently among all sets of farmerssubstantially covers two-thirds of the gross area cultivated. Paddy cultivation in India covers a43.19 million hectares area with 111.5 million hectares of annual production. Rice is the staple food across the nation is demanded at a huge rate to maintain food security and self-sufficiency. Even though the food grains production, particularly in paddy and wheat the economy is self-sufficient but the productivity is at a strain. The performance of the agriculture sector is crucial in ensuring a sound economic growth with a balance in the agro-ecological sphere; however the economy is a constraint with lower agricultural productivity and high cost of production [1] reflects that with challenges of the increase in global food demand along with the limited supply of quality inputs, sustainable intensification has gained importance.The excessive and inefficient use of inputs, disruptive technological advancement causes adversities in terms of soil leaching and carbon refluxions resulting in lower yield potential, high cultivation,and environmental degradation.

Resource conservation technology practices are such which enhance input use efficiency and reduce the negative consequences on crop production with safeguarding environmental stewardship. Mechanization in agriculture plays a pivotal role in bringing economies of scale. Fertilizer as a plant growth regulator is equally important as a plant nutrient *vice-versa* its inefficient use results makeitresponsible for socio-economic and ecological losses. The green revolution which led to an increase in food production has initiated the use of synthetic fertilizer to induce high food production compromisingagroecology. But it instigated huge usage which impacted quality loss in flora and fauna by volatilization, leaching,and runoff.

Annually as per [2] data, the economy consumes 188.63 lakhs tonnes of nitrogenous fertilizer which is around 15%of the global consumption. The necessity to increase food production sustainably demands nitrogen use efficiency. But, the nitrogen use efficiency in food production is only 15%, as 85%is underway in forms to the environment. Particularly in paddy, the nitrogen use efficiency decreases from 23% in the 1970s to 8% in 2005[3]. The report reveals that around 70% of all nitrous oxide emissions in India, of which 77% is from synthetic fertilizers. Being driven by food grain production, having 62% of the total cropped area consumed 69.3% of total nitrogenous fertilizer [4] Table 1.The nitrogen use ratio is more balanced and favorable in small and marginal farmers but most distorted among large farmers. It is 4.9:2.4:1 in the case of marginal and small farmers but 10.5:4.4:1 in the case of large farmers [4].

Table-1. Contribution of nitrogen fertilizer consumption in India at global level

Particular	Contribution at global level (in %)
Annual consumption	15
Nitrogen use efficiency in food production	15
Decrease in nitrogen use efficiency (1970- 2005)	From 23 to 08
Contribution of reactive nitrogen gas in total synthetic fertilizer	77
Contribution in consumption of nitrogen fertilizer out of total cropped area	69.3

Source: Fertilizer Association of India, 2020.

Technology being a key factor for economic progress, foremost techniques and good agricultural practices play a crucial role in maintaining cost and return with significant yield potential [5]. found that low adoption of improved technologies and quality inputs result to lower yield potentials. Ragasa, *et al.* [5], found that lack of adoption of improved technologies, practices,andquality inputs ensuing low potential yield. The substantial productivity could be obtained by adopting improved agriculturepracticesandneglectedtechnology*i.e.* urea deep placement technology for improving the nitrogen use efficiency in paddy cultivation and giving higher yield due to better management.

Reflecting the sets of problems of excessive and inefficient use of nitrogenous fertilizer and low yield potential, certainly good agricultural practices can improvethe economic and environmental efficiency in paddy production. This paper, therefore delves to answer the following research questions; (a) what are the drivers in the adoption of UDP (Urea Deep Placement) technology among farmers in paddy cultivation, (b) what is the effect of adopted technology on the output of paddy in the context.

2. Urea Deep Placement Technology of Agriculture

International Fertilizer Development Centre (IDFC)develop urea deep placementworking with the paddy producers in Bangladesh. It aimed atimprovingtheuse efficiency of nitrogen applicationand to improve paddy productivity. The prilled urea is compacted into briquette and converted into urea supper granules. Urea super granules are placedunderthesoil which will be positioned between four plants at a spacing of 20cm x 20cm. The application has to be taken place within 7 to 10 days of transplantation manually or mechanically. Under the process of UDP, the application is only once for the entire crop cycle. Studies show a significant result in the adoption of UDP in the different contexts of Bangladesh and Africa where yield increased to 20 to 30%, nitrogen use efficiency increased to 40%, cost of urea has been substituted with the cost of labor hired [6, 7]**.** Although some efforts have been made to investigate farmers' decisions on adopting such resource conservation technology and its impact on crop production in the African context and the western world. No adequate literature in India's rainfed context among marginal & small farmers decisions on technology adoption, its impact on crop production, and farmers perception of the environmental effect of technology adoption. The study tries to explore empirically what factors influence the farmer's decision to adopt the urea deep placement (UDP) of agriculture.Besides, the study also attempts to ascertain the impact of UDP on paddy production.

2.1. The Objective of the Study

Based on the above background, the following are the important two objectives of this article:

(1) To ascertain the important drivers in the adoption of UDP technology among farmers in paddy cultivation.

(2) To ascertain the effect of UDPonpaddy's output in study contexts.

3. Materials and Methods

3.1. Study Context

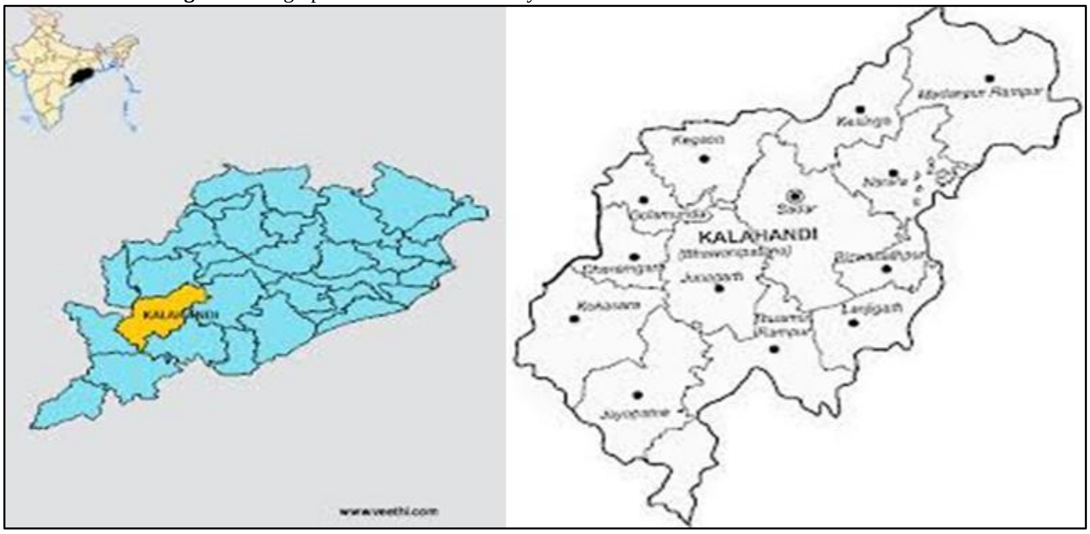
In the context of Odisha, paddy is the principal food crop in the state occupying about 44.55 lakhs ha annually. The Kharif paddy area consists of 10.43 lakhs ha of high land, 15.99 lakhs ha of medium land,and 14.82 lakhs ha of low land consuming551 thousand tons of nitrogenous fertilizer (2020-21). The per hectare consumption rate is 57kg. Kalahandi district, as the studied area has borne attributes of an agrarian economy with a cultivated area of 378000 ha which is located in the southwestern part of Odisha falls under the undulating zone with annually 1375mm of rainfall. The district with a rain-fed area of 371.3 ('000ha) is the major producer of paddy and pulses with a minor producer of maize around 11%and mango around 6% of Odisha's total production. The district holds a cropping intensity of 162% with the net irrigated area of 135.57 ('000ha) where canals ontheIndravati river give a fate to the farmers to cultivate two crops a year. Dominated by small & marginal farmers who constitute 86.8% operate 61.07%of the total land holding consuming 5688.48 metric tons of nitrogenous fertilizer [8].

Junagarh Block of KalahandiDistrictcontributes about 23% of the paddy production of Odisha.Recent development and reports speak it has become the rice bowl in India, which has brought its paddy production yield from 82,000 tonnes during Post Indravati to 7lacs tonnes presently. The Block has the highest net irrigated area to the Net sown area of 93.1% as compared to the other 13 blocks. The Gross Irrigated Area to Total Cereals Accounts (TCA)of Junagarh block is 63.9%. 32.8% of the surface water available in Junagarhhas been promptly used for cultivation purposes.Junagarh holds the highest around 66% of the Total Cereals Account in the Irrigated food crops and 32% in Rainfed food crops. Junagarh has around 1.85% of irrigation potential (1008 ha).

With an increase in the production of paddy, the agricultural practices set the agroecology into a distress situation due to improper and hazardous use of synthetic fertilizer [9]. Marginal and small farmers use almost 56% of the total nitrogenous fertilizer in the district against 71% of nitrogenous fertilizer by marginal and small farmers in the state of Odisha Odisha Agricultural Census [10].Reports show that fertilizer particularly nitrogenous fertilizer contributes 37% (N_2O) of the emission, whereas paddy contributes 11% (CH_4) and 13% from residue burning. The nitrogen use ratio is taking an unfavorable turn. The inefficientuse of fertilizer by farmers heave a loss of up to 60% of applied doses which strain environmental consequences by volatilization, leaching, and runoff.

The role of resource agencies and community institutions particularly as facilitating agencies plays an important role in providing promising innovative technology and cost-effective methods to marginal and small farmers. Studies by Shiferaw, *et al.* [11] reflect a significant role of institutions in ensuring and enhancing economic returns to the farmers by improving access to market and technology support. Resource agency in the context facilitates urea deep Placement technology in Junagarh Block of Kalahandi among marginal & small farmers one such favorable practice which aim at shifting from conventional techniques to resource conservation techniques & maintain economies of scale through cost-effective measures and improves input use efficiency.

Figure-1. Geographical context of the study in Kalahandi District of Odisha state in India



3.2. Sampling of the Study

Multistage sampling technique has been used in whichpurposive sampling techniques were used initially to select the villages connected with high catchment area under Indravati irrigation project right canal. It provides irrigation in both seasons for crop production. In the second stage, stratified sampling was applied for proportionate representation with two groups of farmers from all sample villages*i.e.* (adopters and non-adopters).A total of 162 farmers (85 adopters and 77 non-adopters) were selected using a simple random sampling technique [12]. Data was collected for 90 farmers from each category, i.e. adoptors and non-adopters. insufficient data was found among 5 adopter interview schedules and 8 non adopter interview schedules. Accordingly, 85 adopters and 77 non-adopters farmers' interview schedules were analysised.Through a structured interview scheduled primary data was collected from one-to-one interviewing with the farmers.

3.3. Analytical Framework and Variables for Model

The treatment effect model was employed to analyze the data at two stages. The first stage was to ascertain the important drivers in the adoption of urea deep placement technology among farmers in paddy cultivation. The second stage was to ascertain the effect of urea deep placement on paddy's output.The variables considered for the study are gender of the farmer, age, experience in cultivation, ownership title, off-farm Income, no of times receives extension service, amount of agricultural credit receives, member of farmers association/agricultural cooperatives, no of times training receives, farm size, no of laborforce,thequantity of synthetic chemicalused,thequantity of raw urea, the quantity of seeds used, UDP (adopted/non-adopted), the total output of paddy in quintal per acre.The entire above-mentioned variable is independent which may influence the farmer's decision in the adoption of UDP and results in the output of paddy production.

For modifying the selectivity bias, the Heckman two-stage approach is used from the treatment effect model [13, 14]. The implemented programs were mostly evaluated by extensively using the model. The study aims to ascertain the effect of urea deep placement on paddy's output. With inference, the study also measures the real effect of technology adoption along with correcting the selectivity bias. The model initially estimatestheselection equation to get predicted values of the variable (UDP technology adoption).Further, the predicted values are used to generate lambda value or IMR (Inverse Mills Ratio). In the second stage,to get the additional variable the lambda value and the predicted value of the selected variables were added.

$$Y = X_i'\beta + \delta A_i + u_{1i} \qquad \textbf{(I)}$$

In the above equation, Ydenotespaddy output,X_i'denotes exogenous variable influencing the paddy output, $A_i$isUDP technology adoption, where value 1 is denoted to farmer adopted and 0 if non-adopted. $u_i$denotesdouble-sided error with $N\ (0, \sigma_v^2)$. β and δ are parameters to be estimated. Maddala [15] proposed that, sinceA_i is endogenous this maynot provide adequate results. Therefore,theselection equation of A_i is estimated as

$$A_i^* = Z_i'\gamma + u_{2i} \qquad \textbf{(II)}$$

$Z_i'$are exogenous variables influence the selection variable A_i^*, γ is a parameter to be estimated and u_2 is a double-sided error term with $N\ (0, \sigma_v^2)$. The functional equation cannot be estimated without estimating the selection equation. The reason is as so which could be like, the decision to adopt a new technology could beinclined by unobservable variable like innovations in paddy production, which might influence the production. This infers the substantive equations and selection equations are correlated and lead to biased estimates of β and δ.

If u_{1i} and u_{2i} are assumed to have a joint normal distribution with the form of:

$$\begin{bmatrix} u_{1i} \\ u_{2i} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & \sigma^2 \end{bmatrix}\right) \qquad \textbf{(III)}$$

Urea deep placement adopted farmers expected output is given as:

$$\mathrm{E}[X_i, C_i = 1] = Z_i\beta + \delta + E[u_{2i}, C_i = 1] = Z_i\beta + \delta + \rho\sigma\lambda_i \qquad \textbf{(IV)}$$

Where

$$\lambda_i = \frac{\emptyset(-Z_i'\gamma)}{1-\phi(Z_i'\gamma)} \text{is the inverse mill ratio (IMR)} \qquad \textbf{(V)}$$

Equation (**IV**),infers that when selection equation (**II**) is estimated not taking IMR, then coefficient β and δ will be biased. For estimation, the output of both (adopted and non adopters) are considered. Equation (**I**) takes the following equation:

$$Y_i = \beta^i(\emptyset_i X_i) + \delta^i(\emptyset_i C_i) + \sigma\emptyset_i + e_{2i}$$

where

$$\emptyset_i \equiv \emptyset(Z_i'\gamma)$$

From the above-describredequations, the following empirical models were estimated to ascertain the results for stated objectives for the study:

$$Adaption = \delta_0 + \delta_1 Sex + \delta_2 Experience + \delta_3 Land\ ownership + \delta_4 Off\ farm + \delta_5 Extension + \delta_6 Farmer\ group + \delta_7 credit + \delta_8\ Training\ attended + \delta_9 Age + \delta_{10} Risk\ coverage + \delta_{11}\mathrm{Irrigation} + u_2$$

$$Output\ (rice) = \beta_0 + \beta_1 Farm\ size + \beta_2 Labour + \beta_3\ Weedicides + \beta_4 Prilled\ urea + \beta_5\ Seed + \beta_6 Adaption + u_1$$

Table-2. Definitions of the variables used

Variables	Defining the variables	Expected Sign
Gender of the farmer	1 for male and 0 for female	+
Age of the farmer	Farmer age (in years)	+
Farmer experience	How long years the farmer has experience in paddy cultivation	+
Ownership of land	Whether the land he/she cultivate is self-owned or leased-in	+
Off-farm income	Source of income other than agriculture 1 for farmers with other sources of income, 0 if no off-farm income	+
Extension services(with assured information and support)	1 for farmer receive extension service, 0 for not received extension service	+
Bank credit	agricultural credit received by the farmers (in Rs)	+
Farmergroup membership(specific and exclusive initiative taken by members)	Whether member of any farmer group adopted any specific and exclusive iniatiative taken to adopt the new technology. 1 for obtained membership, 0 if not	+

Training and exposure visit	Whether attended training on UDP technology 1 for obtained training, 0 if not	+
Farm size	Total farm size under irrigation (in acreage)	+
Labors	Total farm hand involved in cultivation	+
weedicides	Quantity of weedicides use (liter per acre)	+
Urea (Prilled)	Urea (prilled) used (kg)	+/-
Seeds	Seeds used (kg)	+/-
Ureadeep placement technology	Farmers adopted technology is denoted as 1 and non-adopters as 0	+
Output of paddy	Quantity of output in quintals for the cropping season	+
Risk coverage	Farmer with assured risk coverage 1; without any assured risk 0	+/-
Irrigation	Whether assured irrigation or rainfed	+/-

4. Result and Discussion

The model was estimated in two stages. In first stage, the response variable was paddy farmer's UDP technology adaptation. In Table 3, the likelihood ratiotest of 54.61 was highly significant at 0.01. This indicatesthat the study accepts the alternative hypothesis. The outcome error and treatment error arecorrelated.The significant covariates in driving the paddy farmer's behavior to adopt UDP technology were land ownership, off-farm income, gender of the farmer, extension services, farmer group membership, and training attended.

Table-3. Drivers in Adoption of Urea Deep Placement Technology

Variables	Coef.	Marginaleffect	Std.Err.	z	P>|z|	[95%Conf.	Interval.]
gender	0.6623	0.6320**	0.6462	1.02	0.017	1.9289	0.6042
experience	-0.0016	-0.0034	0.0236	0.07	0.944	-0.0480	0.0447
landowner	1.2525	0.4672***	0.2868	4.37	0.000	0.6903	1.8148
extension	-0.5671	-0.5421**	0.2855	1.99	0.047	-0.0074	1.1268
Off farm	0.2415	0.2138***	0.1604	1.48	0.001	-0.1586	0.4703
credit	0.1214	0.0021	0.0086	1.41	0.158	-0.0047	0.0290
farmer group	0.0211	0.0041	0.1322	1.31	0.512	0.5946	1.7643
training &e.v	0.8693	0.7513***	0.2891	3.01	0.003	0.30252	1.4361
age	-0.0120	-0.0044	0.0148	-0.81	0.416	-0.0411	0.0170
risk coverage	0.8818	0.0123	0.5698	1.55	0.122	-0.2350	1.9987
irrigation	0.7990	0.5712***	0.3744	2.13	0.033	0.0650	1.5330
cons	-2.6292***		0.9588	-2.74	0.006	-4.5086	-0.7498

Number of observation=162, LR chi2(9) =114.96, Prob> chi2=0.0000, Log likelihood = 54.61, Pseudo R2=0.5128
Source: Authors'estimation using STATA
Note: **=significant at 0.05, and *** significant at 0.01

4.1. Important Drivers in Adopting UDP Technology

Land ownership was significant at 0.01. The result indicates that farmers having their own land had a higher marginal effect (0.467) in adopting UDP technology than those who cultivate on leased land. Farmers with their own land could invest in improving the land quality,unlike leased farmers who have a fear of losing them to the landowner. But certain studies [16, 17] disagreed with the findings of this study and found the owner doesn't make significant participation in developing leased out the land. Similarly, [18] found that farmers with their own land had a greater possibility and probability of adopting new technology when investments are permanent.

Gender was significant at 0.05 which reflectsthosefemale farmers had a lesser chance of adopting the technology than male counterparts.The findings could be endorsed with the socio-cultural characteristics of India where ownership rights of land remain with the male. Even though female contributes more than half of the entire production and post-production process but the right to take decision had always been male-dominated. Studies by [19] comes in a similar line of the findings which can be corroborated.The study established that male farmers are advanced in adoptingwater and soil conservation technology. It is due to the need for physical strength and resources to adopt these techniques, which are typically owned by men.

Farmers with other sources of income were also found to be significant at 0.01. It is generous that farmers with extra income tend to invest in adopting new technologies. Hence, the availability of financial resources increased the tendency to invest more but with implications.

Extension services werefound to have a marginal effect of -0.54. Farmers receiving regular extension services had a higher probability of adopting new technology, whereby adopting any new technology the extension provider will provide his technical expertise to the farmers. Urea deep placement technology was reasonably new in the context implemented by the facilitating agency and maybe deficient towards the adopters. But studies [17, 18, 20] found that extension services to be positive and significant, make close contact with the extension officers providing them technical backstopping. Thus findings are credible only if the right information were communicated to the farmers on time.

Membership within farmer group had positivelyinfluencedthe adoption of urea deep placement technology which was found to be not significant. The likelihood of group influence had a greater probability of adopting new technology than those of the individual one. Adoption of new technology, inputs ,and material by a group of farmers always tends to be economical and risk is shared by every member.

Training attended and exposure visit by farmers was found to be highly significant at 0.01.Farmers who adopted technology had a higher marginal effect of (0.751) for attended training as compared to those who doesn't attenedtraining. As the technology was new, farmers were needed to be trained on its application for effective and efficient usage. Studies by [21, 22] found that the number of times the farmers participate in training increased their knowledge, skill, attitude and influenced them positively.

Risk coverage (farmer with assured coverage of risk) and avaialbaility of irrigation facility were found to be significantly drives the adaption of urea deep placement in agricultural practices (Table 3).

4.2. Effect of UDP Technology on Paddy Output

The second stage of the model has been discussed in the present section. In Table 3, the waldtest is highly significant at 0.01, which implies a significant correlation between outcome error and treatment error. The result of the rise in the observed output of paddy tends to occur lower than unobserved adoption of technology, which gives an estimated correlation of -0.0644 between the outcome error and treatment error.Thefindings revealed that only two covariates*i.e.*adoption of urea deep placement technology and farm size of the farmers significantly had a greater effect on the output of paddy.

The study revealed farm size to be positively significant (0.01) which reflects an increase intheoutput of paddy farmers about 57% with a 100% increase in farm size. Findings of the output could be true due to farmer's increase in knowledge from training attended, extension services, and economies of scale. Studies by Mohanty, *et al.* [23]; Nwaobiala [24]; Prakash, *et al.* [25] revealed when there is effective management of nutrients through adopted technology in the farm then it influences the output of paddy. Even though the use of seed is an important factor for the output to the context and findings revealed that it is insignificant. It is due to less access to improved seed variety on time and lack of germination of certified seeds provided by the government. Farmers use their saved seeds from the last few cropping seasons and farmers who could procureimproved seeds from private vendors also use them.

Table-4. Determinants of the output of Paddy

Variables	Coef.	Std..Err.	*P*>|z|
Farm size.	0.5712***	0.0521	0
Labour	0.0345	0.0475	0.572
Weedicides	0.0856	0.0926	0.245
Prilled urea	0.036	0.0833	0.672
Seed	0.0312	0.0285	0.153
Adaption	0.2236**	0.099	0.021
_cons	2.5122	0.1233	0
Hazard lambda	-0.0122	0.0826	0.874
Wald Chi2=285.76, Prob>Ch2=0.0000			
rho	-0.0644		
sigma	0.4038		

Source: Authors' estimation using STATA
Note: **=significant at 0.05, and *** significant at 0.01

The findings reveal that the adoption of urea deep placement positively influenced the output of paddy and was significant at 0.05. The adoption of technology among the farmers had a higher output of about 22.5% as compared to non-adopters, reflected in the coefficient value. The findings of the present study were found to be reliableto that ofthe findings of the studies conducted by Bandaogo, *et al.* [26].

Their findings revealed that deep placement technology had improved the use efficiency of the nitrogen fertilizer applied and output of paddy increases under the irrigated system. Studies conducted in Bangladesh revealed an increase in paddy yield by 15-25% and expenditure on commercial fertilizer was decreased by 24-32% after using urea briquettes (IFDC, 2007). Studies conducted by Hasan, *et al.* [27]; Mohanty, *et al.* [23]; Pani, *et al.* [28] revealed that UDP technology as a good agricultural practice not only increases the productivity and economies of scale but have environmental benefits because deep placement reduces chemical leakage andpolluting the water. Along with the adoption of deep placement technology, it has induced farmers on adopting mechanization and proper water distribution and channelization on the paddy field.

5. Conclusion

The study pursued to ascertain the important drivers that influenced farmer's decision in adopting urea deep placement technology and also to ascertain the effect on the output of paddy. It is concluded that land ownership, off-farm income, gender of the farmer, extension services, farmer group membership, training attended, assured risk coverage and irrigation were the important drivers that determined farmer's decisions in adopting the UDP technology. The study has tried to validate the linkage between the access to improved technologies and the right quantity of input use among the farmers. In the second stage, it is concluded that urea deep placement and farm size of the farmers had a significant effect on the output level of paddy in the studied context. As the use of technology has a triple effect on a socio-economic and environmental scales. The government of India could include the adoption of UDP under its national agricultural policy and provide direct benefit transfer under afew specific schemes. The agricultural facilitating agencies need to look at the above mentioned driving forces of better nitrogen use efficiency for not only reducing costs but also for environmental sustainability. Besides, the UDP technology creates potential employment opportunities in preparing urea briquettes and in transplanting. It also creates a research potential for the government, the research organization, and community organizations to work on environmental aspects for improving nitrogen use efficiency and dealing with nitrogen losses.

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