ASSESSMENT OF GAPS IN CURRENT FERTILIZER USE BY FARMERS AND SCIENTIFIC RECOMMENDATIONS IN SELECTED AREAS OF BANGLADESH

A Baseline Study

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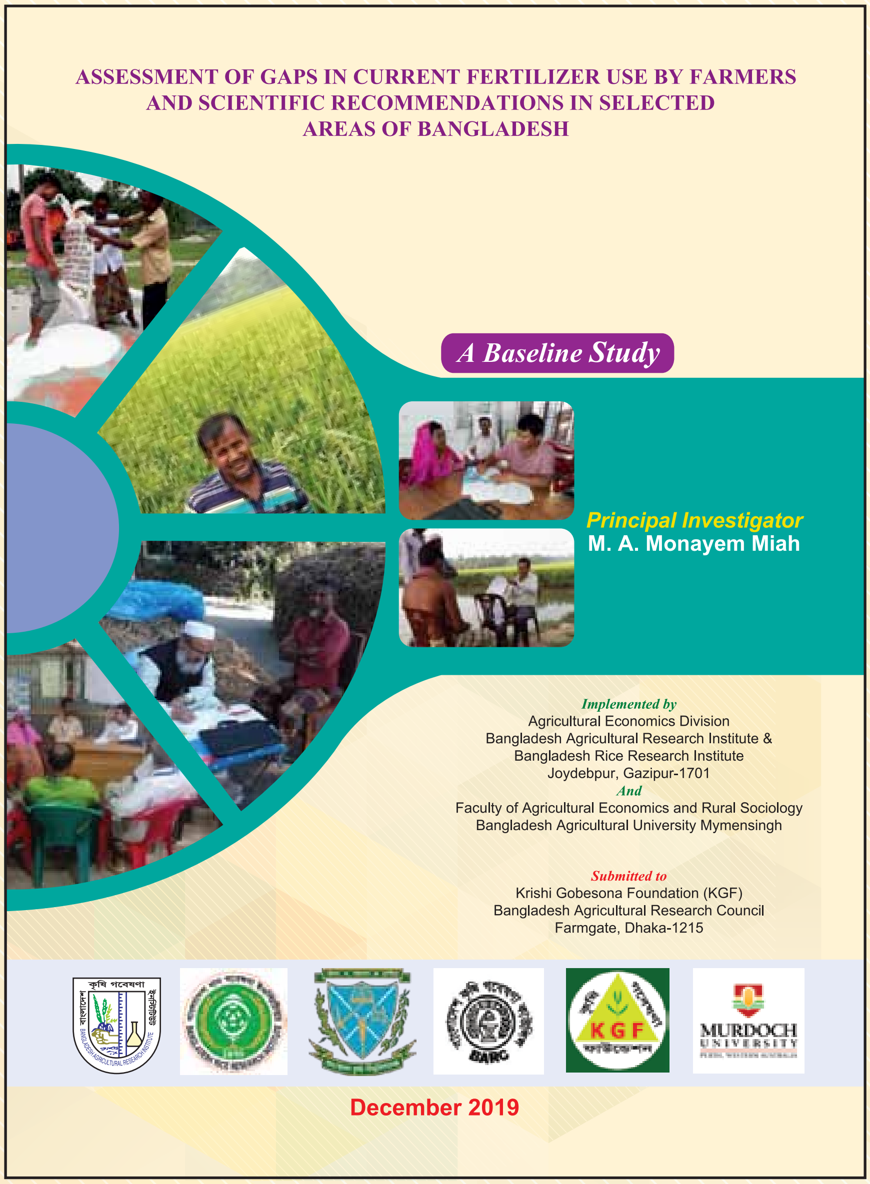

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We hope this document would be helpful to the agricultural scientists and policy makers of the country for future planning and undertaking research and development programs on soil fertility and fertilizer management for sustainable crop productivity and attaining food and nutritional security of the country.

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ABBREVIATIONS

AEZ	=	Agro Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Buraue of Statistics
BRRI	=	Bangladesh Rice Research Institute
DAE	=	Department of Agricultural Extension
DAP	=	Di Amonium Phosphate
FMZ	=	Fertilizer Management Zone
FRG	=	Fertilizer Recommendation Guide
FRS	=	Fertilizer Recommendation System
GoB	=	Government of Bangladesh
GDP	=	Gross Domestic Production
HH	=	Household
HYV	=	High Yielding Variety
INM	=	Integrated Nutrient Management
IPNS	=	Integrated Plant Nutrition System
HSC	=	Higher Scondary School Certificate
LCC	=	Leaf Colour Chart
MoP	=	Muriate of Potash
NGO	=	Non-Government Organization
NPK	=	Nitrogen, Phospate and Potash
SAAO	=	Sub-Assistant Agriculture Officer
SRDI	=	Soil Resource Development Institute
SSC	=	Secondary School Certificate
TSP	=	Triple Supper Phosphate
VMP	=	Versatile Multi-crop Planter
1 USD	=	83.2913 BDT (Bangladeshi Taka)
1 ASD	=	58.6576 BDT (Bangladeshi Taka)

Table of Contents

List of Tables

List of Figures

List of Appendix of Tables

Executive Summary

Crop production in Bangladesh has been increased by about 300% compared to that in 1970's through increasing cropping intensity coupled with the use of other modern crop production practices including nutrient management. High intensity of cropping, decreasing arable lands and diversified cropping raises issues about the profitability and sustainability of current nutrient management. The challenge for the future is to develop nutrient management packages that will ensure sustainable production maintaining soil fertility, avoiding nutrient deficiencies and imbalance or overuse of fertilizers. There are opportunities to develop sustainable improved crop production system through improved and profit-making nutrient management practices for the existing intensive and emerging cropping systems.

With the above context, a 4-year long international collaboration project on "Nutrient Management for Diversified Cropping in Bangladesh (NUMAN)" was launched in January 2018 involving Murdoch University, Australia and different National Agricultural Research System (NARS) institutes and Universities of Bangladesh. The project is co-financed by ACIAR and KGF. There was a need for baseline information regarding current fertilizer usages pattern, factors affecting the use, and barriers of applying recommended fertilizer doses at the farm level, which will later be used to evaluate the impact of the project. Therefore, the present study was conducted to: document current farm practices related to soil fertility and fertilizer management in the study areas; determine gaps between current farmers' practices and fertilizer recommendations; explore major barriers towards the adoption of recommended fertilizer dose; and identify the socioeconomic factors affecting gaps between current farmers' practices and scientific recommendations.

A good number of studies have been reviewed in the preparation of this report. It is observed that farmers apply different types of fertilizers without maintaining scientific recommendations (Miah et al., 2017; Siddique et al., 2018; Matin et al., 2014; Miah et al., 2017; Islam et al.' 2008; Islam et al., 2008). The magnitude of gaps between farmers' fertilizer use and scientific recommendations have not been widely reported in the past. Factors that influence farmer's decision to use manures and fertilizers have been discussed in many studies (Islam et al., 2009; Islam et al., 2009; Nasrin and Bauer, 2016; Majumder et al., 2016), but no studies identified factors affecting gasp of fertilizer use in Bangladesh. Barriers to using recommended fertilizer doses were discussed to some extent in some studies (Mujeri et al., 2012; Roy and Farid, 2011; Quamruzzaman, 2005; Gurstein, 2013) along with discussion of some strategies (Alam et al., 2005; Islam, 2014; Islam, 2015; Fishman et al., 2016; Gurstein, 2013; Pampolino et al., 2012) to encourage application of the recommended dose. However, specific strategies/guidelines are still needed for the extension agents and farmers to promote adoption of the recommended fertilizer dose. The information on contribution of women in household decision making regarding fertilizer use and nutrient management are largely absent in the literature of past studies Bangladeshi.

Both quantitative and qualitative research approaches were employed for the study. The quantitative approach included field survey to collect information from five purposively selected project hubs of Rajshahi, Thakurgaon, Mymensingh, Khulna, and Barguna districts. A total of 750 farmers of different categories were selected based on a stratified random sampling technique and interviewed. Quantitative data were also collected from different secondary sources. Beta regression model using 25 types of variables was employed to identify major factors affecting gaps between farmers' practice and scientific recommendation of fertilizers. Two types of data sets- over dose users and lower dose users and two major rice crops, *Boro* and *T. Aman* rice were used in Beta regression analysis. The qualitative approach included focus group discussion (FGD) with different groups of farmers. Key informant interviews (KII) were also conducted with experts, scientists, lead farmers, community leaders, etc. Descriptive statistics and functional analysis were done to analyze the collected data.

In the study area average family size was 5.2 persons/household (HH), age was 42.7 years and farming experience was 21 years. About 38% farmers had education up to primary level and 31% up to secondary level. About 44% of the women farmers managing farms had primary education and 39% had secondary education. About 80.4% farmers were Muslim and 19.6% were Hindu. Farming activities were the main occupation of 86.3% male farmers and 57% of female farmers managing farms. Average farm was 1.162 ha/HH, the largest farm size (4.972 ha) belonged to large category farmers followed by medium (1.343 ha), women managed HH (0.877 ha) and marginal (0.667 ha).

Only 6% farmers of the study areas received training related to soil fertility and fertilizer management, the highest percentage (7.5%) were from medium category followed by large (6%), women managed HH (5%) and marginal & small (4%) farm categories. Of the training recipient farmers about 54% received training on 'time and method of fertilizer application', 19.2% on 'soil quality enhancement', 11.5% on 'use of organic fertilizer', 7.7% on 'preparation and use of vermi-compost', 3.9% on 'use of urea super granules', and 3.9% on 'use of Versatile Multi-Crop Planter (VMP) machine'.

On the average, 5.5% of farmers had tested their soils, of which 10% were from Mymensingh, 6.7% from Khulna, 6 % from Barguna, 4% from Thakurgaon, and 0.7% were from Rajshahi district. Again, the highest percentage (8.2%) of farmers were from medium category. Only the women managed farms of Khulna and Mymensingh districts tested their soils. A total of 50 farmers received advice from soil testing; 48% of them received advice for using balanced fertilizer, 17% for Zn fertilizer, 15% for K fertilizer, 4.2% for lime application, and 2.1% for P fertilizer. About 94.5% farmers did not test their soil due to lack of awareness (37.0 %); not considering it important (33.4%); the testing service/facility is not readily available (18.6%); and the inconveniences and hassles in soil testing (7.2%).

About 16.7% farmers of the study areas practice conservation agriculture (CA) in *Kharif-2* season, 15.2% in *Rabi* season and 9.1% in *Kharif-1*season. Again, 24.1% of large farmers practiced CA followed by 14.5% of medium, 12.7% of small & marginal farmers, and 10.5% women farmers managing farms. About 22.2% farmers practiced crop rotation; and 40.0% farmers retain crop residues in the field in *Kharif-2* season, 35.1% farmers in *Rabi* season, and 15.6% farmers *Kharif-1*season.

About 23% farmers in the study areas know about optimum/recommended doses of fertilizer. Of them 30% farmers were from medium and 24% were from large, marginal & small farm categories, and 15% were from woman farmers managing farms. About 26% farmers had knowledge about adulteration of fertilizers and pesticides and 31% farmers reported the fertilizers and pesticides do not work as expected.

Nearly 78.2% of male farmers and 57.0% of female farmers managing farms identified nutrient deficiencies in crops by observing leaf color, 70.3% male farmers and 54.0% of female farmers by physical growth of crops, 10.7% farmers with the help of SAAO/peer farmers, and 8.1% farmers by observing tillering conditions. To correct deficiency symptoms, 40.1% farmers used more fertilizers, and 28.8% farmers consulted with SAAOs, 19.1% with fertilizer dealers and 13.7% farmers consulted with peer farmers, and a few farmers applied pesticides/plant growth regulators (PGR).

Different agro-socio-economic and environmental factors like type of crop, soil fertility, cropping season, land type, availability and use of cow dung, advice by extension/project staff, practice of peer farmers, recommendation made by fertilizer dealer, market value of the crop, sowing method, cost of fertilizer, availability of fertilizer, government fertilizer recommendations, and advice by service providers from soil test results etc. were reported to be considered for selecting the type and amount of fertilizers by the farmers. Of those factors type of crop, soil fertility, and cropping season were on the top irrespective of farm category. Fertilizer application in crop production was found highly profitable. The per kg cost of inorganic fertilizers for different crops ranged from Tk. 18.03 to Tk.21.43, whereas its return was estimated at Tk.20.51 to Tk.168.94 on total cost basis and the rate of return to fertilizer ranged from 0.98 to 7.88 on total cost basis and 4.88 to 10.11 on variable cost basis.

Six crops namely *Boro, T. Aus* and *T. Aman* rice, potato, *Kharif* maize, and watermelon were selected for assessing the nutrient application gaps at farm level between farmers' practice and scientific recommendation. Farmers in the study areas applied different types of fertilizers without caring scientific recommendations. Farmers used over dose of most of the fertilizers, especially in high value rabi crops like potato and watermelon; and under dose in *Kharif* crops like *T. Aus* and *T. Aman* rice, and *Kharif* maize. Among the farm categories, women managed farm households and small & marginal farmers used much lower doses of nutrients compared to medium and large category of farmers.

The major barriers reported by farmers in using balanced fertilizers were (1) Lack of knowledge, (2) Lack of sufficient capital, (3) High price of fertilizers, (4) Lack of training on soil fertility management, (5) Complexity of using recommended fertilizer doses, (6) Less availability of extension services, (7) Non-availability of soil testing facilities, (8) Giving less importance to recommendation and pre-determined attitudes about fertilizer use, (9) Giving less importance to less profitable crops, and (10) Less connectivity with progressive farmers.

Farmers of the study areas use high/over doses of fertilizers in most of the rabi crops, especially in high value crops. All the fertilizers (except urea) leave significant amount of residues in the field, which is used by the following crops grown in *Kharif* seasons. The farmers have knowledge about such residual effects. Again, the use of DAP is gradually increasing in the country including the study areas, which contains 18% N in addition to 20% P. Farmers of the study areas also have knowledge about this. For such knowledge and knowledge about negative impacts of overdoses of fertilizers farmers use a bit lower doses of all the fertilizers in *Kharif* crops compared to recommended doses using their own judgment. So, the apparent gaps in fertilizer use are not the real gap. In reality the crops get their nutrients from the external sources like direct application of fertilizers, residual effect of fertilizers applied in the previous crops and from inherent soil nutrient contents. So, in respect of crop requirement the nutrient use gaps are not the real gaps.

However, the estimated 12 models clearly revealed that the nutrient use gaps between current farmers' practice and scientific recommendation were influenced (positively or negatively) by a number of agro-socio-economic factors. The major significant factors were gender, category of farmers, crop residue retention, crop rotation, fertilizer use in previous crop, distance of input/output market, fertilizer price, level of extension contact, number of cattle owned, and study region.

Some of the problems associated with applying balanced or optimum fertilizer dose at farm level could be overcome if technical assistance and financial support are made available by the government. This support could be categorized into five areas: awareness creation, technology development, strengthening extension services, assurance of input quality and supply, and financial support.

Chapter I

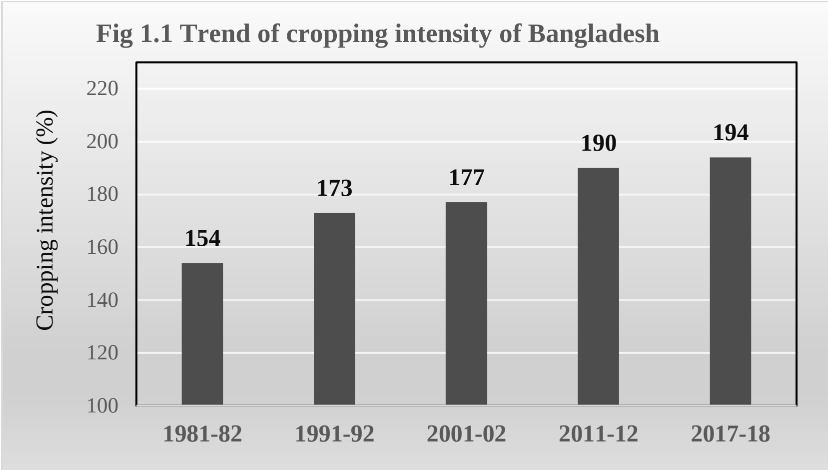
INTRODUCTION

1.1 Background

Bangladesh is a densely populated and agrarian country. Agriculture sector plays a significant role in its overall economic development. Two lakh (0.20 million) new heads are being added to the country's population every year, on the other hand its arable land is declining by 0.49% per year (FAO, 2013). As a result per capita land is declining at a rapid rate. The amount of per capita cultivable land was 0.17 ha in 1960, whereas it was only 0.048 ha or 11.86 decimal (0.195 ha/household) during the period from 2011 to 2015 (SRDI, 2013, Quasem, 2011, www.ceicdata.com/en/bangladesh). Despite this, the sector contributes 14.23% to GDP and provides employment for about 40.6% of the labour force of the country (BER, 2018; BBS, 2019). The Government of Bangladesh has given highest priority to this sector for attaining food and nutritional security of the country of 163.65 million population. It is, therefore, important to have a profitable agricultural production system and also to maintain soil health for future sustainable production to ensure long-term food security of the country. The government encourages farmers for crop intensification, especially in the less intensive coastal areas and also the farmers of the country as a whole to use high yielding crop varieties along with improved production technologies. The government is providing huge subsidies on major fertilizers to reduce cost of production and also to encourage farmers to use balance dose of fertilizers. The government has developed various policy documents like Seventh Five Year Plan, National Agriculture Policy, Agricultural Research Priority: Vision- 2030 and Beyond, and Sustainable Development Goals (SDGs) and assigned high priority to soil fertility and fertilizer management, salinity management crop intensification etc.

1.2 Trend in Cropping Intensity of Bangladesh

Sustainable crop production through increasing cropping intensity in rice based cropping systems is regarded as increasingly important in national issues such as food security, poverty alleviation and creation of job opportunities (Mondal et al., 2015). In order to produce more food within a limited land area the most important option is to increase the cropping intensity producing three or more crops on the same piece of land in a year. Hence, the cropping intensity of cultivable land in Bangladesh has been increasing over the years (Figure 1.1). The cropping intensity has increased to 194% in 2017-18 from 154% in 1981-82. The total production of major crops in Bangladesh has increased by 76% during the period from 2001-02 to 2016-17. Increasing trend production has been observed for the majority of crops such as rice, maize, jute, oilseeds, spices, fruits, vegetables, and tobacco. However, decreasing production trend have been observed for some crops like wheat, sugarcane, sweet potato etc. due to some valid reasons (Table 1.1).



Source: Various issues of BBS and Economic review, 2018

Table 1.1 Trend of major crop production in Bangladesh

Crop	Production ('000' MT)				% increase over 2001-02		
	2001-02	***2005-06***	***2010-11***	***2017-18***	***2005-06***	***2010-11***	***2017-18***
Rice	24300	26530	33542	36278	9	38	49
Wheat	1606	735	972	1099	-54	-39	-32
Maize	64	522	1018	3288	716	1491	5038
Jute*	859	838	1523	8895	-2	77	936
Sugarcane	6502	5511	4671	4182	-15	-28	-36
Pulses	344	279	232	474	-19	-33	38
Oilseeds	376	657	730	1026	75	94	173
Spices	418	1182	1649	2196	183	294	425
Fruits	1501	9322	4352	4512	521	190	201
Vegetables**	4561	5952	10516	13799	30	131	203
Sweet potato	346	308	298	247	-11	-14	-29
Tobacco	38	43	79	89	13	108	134
All crops	40915	51879	59582	76085	27	46	86

Source: Various issues of BBS; *Jute weight in bales; ** including potato

1.3 Trend of Fertilizer Use in Bangladesh

The expansion of modern farming practices like the use of high-yielding varieties (HYV) coupled with the other modern crop production practices is needed to ensure food for all. A consequence of these changes also impacted on increasing demand for fertilizers. The increased cropping intensity has been supported by the increased use of fertilizers from 225.15 kg/ha in 1999-00 to 321.51kg/ha in 2017-18 (BER, 2018). In 2017-18, the total quantity of fertilizer used in the country was 49.43 lakh MT which was 64% higher than that used in 1995-96 (Table 1.2). The use of urea fertilizer alone was the highest. . It clearly reveals that the uses of different types of chemical fertilizers increased to a great extent.

Table 1.2 Trend of using chemical fertilizers ('000' MT) in Bangladesh

Fertilizer	Using year					
	1995-96	*2000-01*	*2005-06*	*2010-11*	*2015-16*	*2017-18*
Urea	2046	2121	2451	2652	2291	2427
TSP	111	400	436	564	730	707
MoP	156	140	291	442	727	789
DAP	0	90	145	305	658	690
SSP	597	139	130	0	0	0
Zinc	1	3	8	7	53	80
Gypsum	104	102	105	105	229	250
Total	3015	2995	3566	4075	4688	4943
% increase over 1995-96	--	-0.7	18.3	35.2	55.5	63.9

Source: Various issues of Bangladesh Economic Review (BER)

1.4 Justification of the Study

The challenge for future nutrient management is to develop programs that help maintain adequate levels of a nutrient, with no deficiencies, imbalance or overuse of fertilizers. There are both economic and environmental benefits for better nutrient management strategies. The use of an optimum fertilizer dose increases both soil fertility and crop productivity, and decreases production cost. Ali et al., (2010) demonstrated the potential benefits of using a balanced fertilizer dose in a T.Aman rice-Boro rice rotation at Pabna. Over 4 consecutive rice cropping in 2 years, the yields and overall profit with the balanced dose and with farmer's practice were more or less similar. However, the balanced dose saved 36 kg of N (17.5 % saving), 22 kg of P (56% saving), 9 kg of K (14% saving), 1 kg of S per hectare. Khan et al., (2013) also found that use of balanced fertilizer dose increased 50% yield for mustard, 34-38% for potato, and 17-23% for rice compared to farmers' yield. Similarly, Mondal (2011) reported that yield gaps, estimated as the difference between national average yields and well managed demonstrations with current recommendations, were equivalent to 27% yield increase for wheat, 35% for mustard, 45% for potato, and 32% for lentil. Hence in the intensive cropping patterns there is scope for increasing crop yield through applying balanced fertilizer dose. The key questions are to identify what barriers exist to improving nutrient management and what interventions can lead farmers along pathways towards adoption of more profitable and sustainable nutrient management?

In the coastal zone, most fields grow a single rice crop (local variety) with low yield. Most farmers use limited fertilizers because of local variety and low yield. The potential to increase rice yield with more fertilizer needs to be explored with both traditional and improved varieties. Intensification of cropping systems in the coastal zone is being pursued in several projects through the introduction of an additional crop in the *Rabi* season. There is an opportunity to design sustainable and profit-making nutrient management practices for these emerging double cropping systems.

The shift of cropping practices from multiple tillage operations and crop residue removal to minimum soil disturbance, crop residue retention, and diversified crop rotations being known as conservation agriculture (CA) is likely to alter nutrient forms and availability in soils and fertilizer responses of crops (Majumdar et al., 2012). Under minimum soil disturbance there will be less mineralization of nutrients from organic matter during land preparation and crop establishment, but possibly more nutrient supply later in the season when availability is better matched with crop demand. In the case of P, K and Zn, minimum soil disturbance and increased residue retention above ground lead to concentrate nutrients closer to the soil surface (Chen et al., 2009). Hence, for emerging new cropping and soil management systems, based on minimum tillage and residue retention, new nutrient management practices need to be developed.

The increasing cropping intensity, the decreasing arable land (0.49% per year) and the crop diversification raise questions about profitability and sustainability of current nutrient management system. A good opportunity exists to create an impact in crop agriculture by implementing sustainable and profit-making nutrient management practices for both existing intensive and emerging cropping systems. Realizing the importance of sustainable nutrient management, a 4-year long project on "Nutrient Management for Diversified Cropping in Bangladesh (NUMAN)" has been launched in January 2018 involving Murdoch University of Australia and NARS institutes and agricultural universities of Bangladesh. There is a need for generation of baseline data and information regarding current fertilizer usages pattern, factors affecting the use, and barriers of using recommended fertilizer doses at farm level to help understand how best to support adoption of sustainable and profitable nutrient management practices. The baseline data will later be used to evaluate the impact of the project. Therefore, the present study was undertaken with the following objectives.

1.5 Objectives of the Study

i. To document current farm practices related to soil nutrient management in the study areas;
ii. To determine gaps between current farmers' practices and fertilizer recommendations;
iii. To explore major barriers towards the adoption of recommended fertilizer application; and
iv. To identify the socioeconomic factors affecting gaps between current farmers' practices and fertilizer recommendations.

1.6 Organization of the Report

The report contains a total of eight chapters, which have been organized in the following sequence. *Chapter I* introduces the contribution of the agriculture sector in the overall development of Bangladesh, and reports on trend of fertilizer use and cropping intensity of Bangladesh. The significance and purpose of the study are also outlined in this chapter. *Chapter II* includes the review of literature related to soil fertility and fertilizer management, gaps in fertilizer use between farmer's practice and scientific recommendations, and factors affecting fertilizer use. Methodological aspects of the study are discussed in *Chapter III* in accordance with objectives of the study. *Chapter IV* describes the socioeconomic profile of the respondent farmers. Current status of soil nutrient management at farm level are discussed in details in *Chapter V*. Factors influencing decision making in fertilizer use and fertilizer use gaps between current farmer's practice and scientific recommendation are described in *Chapter VI.* Major barriers to using the recommended dose of fertilizer are discussed in *Chapter VII.* Finally, *Chapter VIII* presents conclusions and recommendations regarding strategies for minimizing the fertilizer application gaps at farm level. Note, that a fertilizer application gap in the context of this report refers to the difference between the rate of application fertilizer by farmers and scientific recommendations.

Chapter II

REVIEW OF LITERATURE

2.1 Background

This chapter includes the review of literature and research that has been carried out in Bangladesh and around the world related to fertilizer use gaps and farmer fertilizer management practices to better understand the factors that influence their practice. The literature review also identifies the research gap in order to justify the present study.

2.2 Status of Fertilizer Use in Crop Production

Farmers in general can't think of crop production without use of fertilizers (organic or inorganic). Their rate of application of different fertilizers may or may not be at balanced rates for different crops. A baseline survey conducted in eight districts of Bangladesh revealed that 94% of farm households used at least some fertilizers for growing crops. Urea fertilizer was most commonly used (80%) fertilizer followed by TSP (68%), MoP (64%), organic manure (41%), Gypsum (30%), DAP (17%), Zinc sulphate (16%), Compost (8%), and NPKS mixed fertilizer (7%). In total, a farm household (HH) spends about Tk. 6556 ($82) on fertilizers/inputs per year. Most of the money is spent on chemical fertilizers such as urea, DAP, TSP and potash (DIME and GAFSP, 2013).

Miah et al. (2017) conducted a study with the financial assistance of ACIAR from a conservation agriculture project coordinated by Murdoch University, Australia. In this project input costs for production of crops including maize following CA practice were estimated to identify conservation benefits. The study revealed that on an average 6.43 ton manure, 297 kg urea, 196.7 kg TSP, 200.2 kg MoP, 41.7 kg gypsum, 5.5 kg DAP, 5.0 kg boric acid, and 4.4 kg zinc sulphate were used per hectare in producing maize. Except MoP, all these applied rates were lower than the recommendations [(e.g. urea 375-600 kg, TSP 180-350 kg, MoP 150-250 kg, Gypsum 130-220 kg, Zinc sulphate 6-12 kg, Boric acid 5-10 kg per ha depending on seasons. Winter season (*Rabi*) maize needs more fertilizer compared to summer season maize (*Kharif-1*).

Siddique et al. (2018) found that farmers' rate of nitrogen application as Urea and DAP was much higher than BRRI recommendation. Similarly, the application of phosphate fertilizer including TSP and DAP was considerably higher than BRRI recommendation in all seasons. On the other side, the application of MoP fertilizer was quite lower than the scientific recommendation.

A recent study (Matin et al., 2018) on 1050 sample farmers in seven wheat growing districts of Bangladesh revealed that about 12-31% of the respondent wheat farmers applied inorganic fertilizers, especially NPK fertilizers following scientific recommendation. A good percentage of farmers also used different inorganic fertilizers either at above or below the recommended levels (Table 2.1). However, all sample wheat farmers used manure bellow the recommended rate.

Table 2.1 Percent of wheat farmers applied recommended fertilizer doses

Manure & fertilizer	Recommended dose	Percent of farmers followed		
		Follow recommendation	Below recommendation	Above recommendation
Manure	7.0-10.0 t/ha	--	100	--
Urea	180-220 kg/ha	23.6	51.0	25.4
TSP	140-180 kg/ha	30.6	37.3	32.1
MoP	40-50 kg/ha	11.8	7.6	80.6

Source: Adapted from Matin and Rashid, 2018

Matin et al. (2014) conducted a household survey on 2700 pulse growing farmers in 15 pulse growing districts of Bangladesh. The major objective was to assess the socioeconomic impacts of pulses research and development in the country. They reports a complete scenario of using three inorganic fertilizers (e.g. urea, TSP & MoP) in different pulse crops at farm level (Table 2.2). The study clearly revealed that the adoptions of different recommended fertilizer doses were very low. However, higher percentage of lentil farmers used fertilizers at recommended level compared to other pulses farmers.

Table 2.2 Percent of pulse farmers applied recommended fertilizer doses

Level of adoption	Lentil *(n=540)*	Mungbean *(n=540)*	Black gram *(n=540)*	Chickpea *(n=540)*	Grass pea *(n=540)*
Urea/recommended dose	*40-50kg/ha*	*40-50kg/ha*	*40-50kg/ha*	*40-50kg/ha*	*40-50kg/ha*
Recommended level	29.2	10.7	2.5	3.3	2.8
Below recommendation	44.2	60.0	80.0	74.3	69.6
Above recommendation	26.6	29.3	17.5	22.4	27.6
TSP/recommended dose	*80-90kg/ha*	*80-85kg/ha*	*85-95kg/ha*	*80-90kg/ha*	*80-85kg/ha*
Recommended level	14.6	6.6	--	3.1	0.4
Below recommendation	50.4	83.6	100	90.2	99.6
Above recommendation	35.0	9.8	--	6.7	--
MoP/recommended dose	*30-40kg/ha*	*30-35kg/ha*	*30-40kg/ha*	*30-40kg/ha*	*30-40kg/ha*
Recommended level	29.0	5.0	9.0	9.8	0.7
Below recommendation	22.0	53.2	70.4	73.9	95.9
Above recommendation	49.2	41.8	20.6	16.3	3.3

Source: Calculated from Matin et al. 2014

Islam et al. (2013) reported that farmers used on an average 1.06 ton of manures per hectare in cultivation of BARI developed improved mungbean varieties. The study also reported that 47.3% farmers used an average rate 21kg urea, 37.3% farmers used 12kg MoP, and 55.3% used 26kg TSP per hectare in cultivation of improved variety of mungbean. The rate of application of these fertilizers were much below the recommended dose of urea (40-50kg/ha), MoP (30-35kg/ha), and TSP (80-85kg/ha).

Miah et al. (2014) conducted a survey with 217 mustard and 540 sesame farmers to find out the adoption status of recommended fertilizer at farm level. They found that only 6.9% mustard and 16.5% sesame farmers applied organic manure at the recommended rate (8-10 t/ha), whereas 44.7% mustard farmers and 83.5% sesame farmers did not use any organic manure. In mustard cultivation, 3.2, 91.8 and 5.0% farmers applied urea fertilizer at the recommended (250-300kg/ha), below recommended, and above recommended level, respectively. Similarly 16.1, 53.9, 5.7% farmers used urea fertilizer in sesame cultivation at recommended (100-150kg/ha), below recommended, and above recommended level, respectively. TSP fertilizer was found to be used by 1.8% farmer at recommended dose (170-180kg/ha), 50.2% at below recommended, and 19.4% at above recommended level in mustard cultivation. In sesame cultivation, 4.8% farmers applied TSP at recommended (130-150kg/ha), 49.6% below recommended, and 3.7% farmers above recommended level. In case of MoP, 11.5% mustard farmers and 6.9% sesame farmers applied MoP fertilizer at the recommended rate (85-100kg/ha for mustard & 40-50kg/ha for sesame) and rest of the respondent farmers either used lower or higher dose. The share of MoP non-users farmers ranged from 20-55%.

Due to various reasons, farmers cannot use recommended rate of nutrients/fertilizers. Many studies (e.g., Islam et al., 2009; Islam et al., 2008) have explored the gap of fertilizer application between farmers' practice and scientific recommendations and established that the gap exists at farm level, but the extent of gap varies widely among the farmers and type of fertilizers. For example, Islam et al., (2009) surveyed 250 farmers in Kurigram District regarding Boro rice cultivation practices and found that 11% of farmers had a wide gap, 72% medium gap and 17% farmers had low gap. Islam et al. (2009) found that there was an application gap for urea, TSP and MoP (extent of gap varied) in a survey of 100 farmers in Jashore district. Islam et al. (2008) conducted a survey with 250 farmers in Kurigram district and found gaps in the doses of urea, TSP, MoP, and gypsum between scientific recommendation and farmers' actual practices for Boro rice cultivation. . They reported 11% of farmers had a high gap, 72% medium gap, and 17% a low gap in fertilizer doses. Rahmam et al. (2011) also reported that farmers used more than four different types of chemical fertilizers, but in imbalanced proportion.

Soil organic matter is crucial for soil health and overall crop productivity and profitability. Farmers are now realizing that there is a problem with soil fertility related to soil organic matter depletion due to less use of crop residues and organic manure. Hossain (2001) reported that organic matter increases crop growth and yield, reduces the cost of production, increases water-holding capacity and improves the soil structure. Farmers can recognize soil having high organic matter content by its dark grayish to blackish in color. They use green manure, compost, quick compost, organic manure (cow dung), and azolla [aquatic fern] for improvement of soil organic matter. However, cow dung and crop residues have other uses such as fuel for cooking and fodder for livestock. Roy and Farid (2011) stated that farmers are often not aware of the benefits of organic matter and they have tendency to organic materials (cow dung crop residues) as fuel materials instead of using it as the source of organic manure. Rahmam et al. (2011) reported that farmers stated fertilizers as costly and scarce input. Farmers are reluctant to use crop residues/manures as the source of organic manure; instead use them as fuel for cooking, building of house, and as cattle feed.

2.3 Factors Influencing Fertilizer Use in Crop Production

The literature is inconclusive as to whether a factor positively or negatively influences input use, but different factors that have been identified as influencing Bangladeshi farmers' in decision making, which include access to credit, price of fertilizer, fertilizer distribution (availability, demand/supply, access), climate and season (uncertainty of rain), rainfed/ irrigated farming systems, farming experience, off-farm income, labor availability, fertilizer-paddy price ratio, age of farmer, family size, education level, contact with extension workers, training, and diversified income. Available literature discussed and identified factors influencing input use are briefly discussed below.

Islam et al. (2009) stated that there was an application gap between farmers' practice and scientific recommendation for urea, TSP, and MoP (extent of gap varied) fertilizers. They looked into seven characteristics in relation to fertilizer application gap, which are age, education, farm size, annual income, credit received, extension contact, and knowledge of using fertilizer. They identified two characteristics having significant relationship with fertilizer application gap like extension contact and knowledge of using fertilizer. According to farmers the main reasons for the application gap were scarcity of fertilizers, high price, lack of credit facilities, lack of adequate supply in time, and charging higher prices by government appointed dealers.

Islam et al. (2008) looked into the gap between the actual farmers' dose and recommended dose of urea, TSP, MoP and gypsum for Boro rice cultivation through analyzing the information from 250 farmers interviewed in Kurigram District. They identified some farmers' characteristics that showed significant negative relationship with the management gap, which were farming experience, knowledge, attitude towards modern *Boro* rice cultivation, use of information source, and decision making ability.

Nasrin and Bauer (2016) surveyed 299 HHs from Dinajpur, Mymensingh and Tangail district. The study revealed that farming experience and use of manure did not significantly impact on the use of fertilizer. Higher off-farm income, labour availability, and fertilizer-paddy price ratio (particularly for marginal farmers) had impacted on fertilizer use. Output price also played a significant role in addition to fertilizer prices in enhancing fertilizer usage. Fertilizer usage for marginal and small farms mostly depend on their financial conditions, access to various credit facilities, and services received from extension agents.

Majumder et al. (2016) identified different factors that influence the use of fertilizer. The factors were age, farming experience, level of education, diversification of income generating activities, access to credit, and access to particular types of education.

Chirwa (2005) studied the adoption of fertilizer and hybrid seed technologies for maize cultivation in Malawi. He found that fertilizer adoption was positively associated with higher levels of education, larger plot sizes, and higher non-farm incomes, but negatively associated with female headed HH and distance from input markets. However, Peterman et al., (2010) in their review found that Chirwa's finding differs from other studies in relation to the gender of the HH head.

Freeman and Omiti (2003) studied the fertilizer adoption behavior of the smallholder farmers in Kenya. They found that fertilizer adoption behavior was positively associated with the level of education of HH head, experience in fertilizer use, growing a cash crop (diversification into cash crops seen as a way to intensify fertilizer use), availability of fertilizer in rural retail outlets, availability in small packages, and land pressure (farm HH facing land pressure are more likely to adopt improved soil fertility management as a means to satisfy their subsistence needs). Again, the intensity of fertilizer use behavior was negatively associated with family labor and family size. HH with smaller family size are more likely to adopt and apply greater amounts of fertilizer which utilizes less labor per hectare compared to alternative practices such as the use of manure/compost. This might reflect rural HH's preference for labor saving technologies particularly when there are alternative income earning opportunities from off-farm sectors.

Mapila et al. (2012) looked into the determinants of fertilizer use by smallholder maize farmers in Malawi, Mozambique and Zambia. The study found that the use of fertilizer was influenced by different HH and farm characteristics, social and human capital, and farmers' perceptions of the effect of fertilizer on soil fertility. They also found that male headed HH were more likely to use fertilizer than female headed HH in Zambia, but this was not the case for Malawi and Mozambique. In Mozambique, land holding and access to inorganic fertilizers influenced fertilizer use. However, in Malawi and Zambia these were not significant. In Malawi, the fertilizer subsidy and what farmers expect the price to be also influence use as some farmers saved to pay the subsidized rate, but when it wasn't enough didn't have the resources to purchase additional fertilizer. Availability of food and crop performance in one season influence decisions to use fertilizer in the next season. HH with greater food reserves were more likely to use fertilizer than those with lower reserves. The study also revealed that HH participated in agricultural training/study tour are more likely to use fertilizer in Malawi, but not in the other countries. This was attributed to Malawi having a more intensive extension system. Membership of a farmer group positively influenced use only in Mozambique. In Zambia some farmers (30%) perceived it as bad for the soil and therefore were less likely to use it.

In Ethiopia, Fufa and Hassan (2006) looked into fertilizer use and considered some influencing factors such as age of head of HH, family size, literacy, land holding size, wealth status, weather, and price of fertilizer. It was revealed that older farmers used less fertilizer. If farmers expect the rainfall to be bad they are unwilling to use fertilizer and vice versa. Farmers' perception of the price of fertilizer also influenced its use. In Ethiopia input costs are high- one factor being the cost to transport it. If the farmers perceived the cost to be high fertilizer use reduced.

Bizimana et al. (2002) looked into the factors influencing technology adoption by the coffee farmers of Rwanda. The study found that there was a strong association between soil testing and fertilizer use- implying that a farmer who tests soils of his farm is also likely to use fertilizer. The study recommended some strategies to reduce the gap between nutrient management guidelines and farmers practice vary depending on the factors identified as impacting fertilizer use (e.g., improved credit facilities for credit constrained farmers, improved distribution systems for those hampered by supply issues, improved extension systems for farmers lacking training/knowledge/information and so on).

In China, 550 farmers were interviewed about their fertilizer application behaviors, decision making processes, attitudes towards adopting better fertilizer application technologies, and environmental consciousness (Yang and Fang, 2015). The study found different factors influencing the adoption of better fertilizer application technologies. The factors were demographic shift whereby younger HH members were leaving and older family members were remaining on the farms and were less able and/or willing to adopt new technologies; habitual practices modified by their individual judgment of the crop, weather and soil conditions. In this case the cost of inputs/outputs were seldom taken into account.

Reduction in the use of traditional practices that involved applying organic fertilizers. Farmers are instead applying more chemical fertilizers to respond to soil fertility decline. If the crops don't grow as well as expected they often blame the poor quality of the chemical fertilizers and translate that into the need for more fertilizers. Lack of extension training on fertilizer and perception that fertilizer dealers were a major source of knowledge on fertilizers as opposed to extension staff.

The study conducted by Hedlund et al. (2004) looked into the farmers' perceptions of soil fertility in Vietnam. Farmers' perceptions were more directly connected to the ability of the whole system to promote good yields than the scientific concept of soil fertility as the soil's ability to deliver sufficient nutrients and water to the plant. Farmers identified problems with soil fertility relating to three areas: acidity, market, and flooding. The most important problem was the market- unstable price of agricultural products leading to under investment in fertilizer.

Banerjee et al. (2014) investigated key factors limiting maize productivity in eastern India. The study revealed that the yield of maize was affected by multiple and interacting production constraints, differentiating the surveyed farms into six distinct resource groups. They suggested that a comprehensive technology package could address most of these constraints. The comprehensive technology package included increasing use of hybrid seed, appropriate seed rate, plant to plant spacing, capital and labor investment, organic manure, better nutrient management, and higher management intensity.

Asfaw and Admassie (2004) investigated the spill-over effect of intra-HH education on the adoption process and decisions relating to fertilizer use in Ethiopia. This study looked into the education of other HH members and found that the decision making process was a decentralized one in which educated adult members actively participated.

The use of inorganic fertilizer in the savannas of Nigeria falls below the recommendation, this paper looks into the factors influencing farmers' decision to adopt or not adopt inorganic fertilizer (Chianu and Tsujii, 2004). It revealed that 49% of the respondent farmers adopted inorganic fertilizer. The range of application was reported to be from 5.6 kg/ha to 64.4 kg/ha. Farmers cited high costs, lack of credit facilities, removal of fertilizer subsidies, and government withdrawal from fertilizer distribution as the main reasons for non-adoption. The paper found that adoption probability increases for farmers that were agro ecological zones, younger age, better education, food security of HH, and diversified cropping. Some farmers applied large quantities of organic manure might be due to better understand the complementary relationship between organic and inorganic fertilizer.

2.4 Strategies to Use Fertilizer Recommendation

Application of balanced or recommended fertilizer dose is very much important for improving soil fertility, attaining higher crop yield, reducing production cost, increasing profitability, and ensuring the overall sustainability in crop agriculture. Literature relevant to these issues are discussed in the following sections.

These articles (Alam et al., 2005; Islam, 2014; Islam, 2015) report on the use of leaf colour charts (LCC) to improve the timing of urea fertilizer application. Islam's study (2014, 2015) found that farmers who used the tool reduced their urea use and increased yields and returns. It was observed that farmers tended to apply urea too early in the season, but were able to correct this with the LCC. The tool was simple and cheap to produce. In the study the existing network of microfinance organizations distributed the LCC (i.e., people without considerable agricultural experience). Islam also looked into the trainer quality and observable characteristics- found there was no significant correlation between quality and characteristics such as age, gender and experience. There was some indications that experience played a role for some trainers- university graduates had lower adoption compared to individuals with diplomas in agriculture, and extension workers had lower rates compared to extension personnel with higher designations. Alam et al. (2005) also found that the LCC offers considerable opportunity to increase rice yields, N use efficiency, and added net returns for farmers in Bangladesh.

Fishman et al. (2016) asked the question- can information help to reduce imbalanced fertilizer application in India. They reported on the role out of individualized soil testing and site specific fertilizer recommendations. They found that there was no impact of soil testing/customized recommendation on actual fertilizer use and willingness to pay for lacking nutrients. They concluded that the lack of confidence or belief was the main factor inhibiting farmers' response. They recommend rigorously testing ways to inspire farmers' trust in soil test results and fertilizer recommendations.

Gurstein (2013) reports on creating an improved fertilizer recommendation system in Bangladesh, in particular an online soil test information service available via Banglalink and Grameenphone. It is needed to see if there is updated information about these services.

Pampolino et al. (2012) report on Nutrient Expert software as a tool for providing site specific nutrient management. This tool is for use by crop advisors, it requires basic computer skills and some understanding of agronomy and soil science terminology. This study evaluates its use by farmers in Indonesia and the Philippines and concluded that it was able to improve yields/income. One of the interesting aspects of the tool is that it provides a recommendation based on the goal of the farmer e.g., food security, income etc.

In terms of framing decisions about whether to adopt fertilizer recommendations or not, Prager and Posthumus (2010) present the following three relevant paradigms:

- Economic constraint: adoption defined by maximizing behavior of farm household. Decisive factors things like access to natural resources, access to capital, learning/investment costs and risk attitude.
- Innovation-diffusion-adoption: adoption defined by dissemination of information, decisive factor access to information.
- Adopter perception: adoption defined by personal factors in addition to information in utility maximization and the perception that there is a need to innovate, decisive factors human values, experience, education, perceived severity or urgency of soil fertility problems.

In Kenya, Misiko et al. (2011) conducted a study where 40 maize growing HHs participated in mineral fertilizer-response trials, focus group discussions, interviews and participant observation. The results of the collective trials inspired farmers to design and conduct experiments to compare crop performance with and without fertilizer and between different fertilizers or responses on different soils. The study describes in details the participating farmers' perceptions and understanding of soil fertility and management. Farmers' perceptions cannot be changed by promoting more fertilizer use alone, but may require a more basic approach that, for example, encourages farmer experimentation. The trials served as a basis for informed decision making among smallholders.

Studied used a participatory action research appropriate to improve capacity for site-specific nutrient management (Attanandana et al., 2007). Farmers participated in activities using a visual tool to identify soil series, a soil test kit, and decision aid to interpret the soil test information. The tools used were simplified and site specific and easily learned by farmers. The project worked with farmers to increase their knowledge and skill to manage the simplified technologies. Farmer leaders were recruited and trained in interpreting the soils information. These leaders were considered to play a central role in disseminating the technologies.

The study conducted by Saleque et al. (2007) with three objectives: 1) assess the ability of farmers to recognize spatial variability in soil-fertility in their rice fields; 2) compare the farmers' perception of soil-fertility with the lab results; and 3) identify farmer-defined fertilizer management zones (FMZ) in villages and develop fertilizer recommendations for rice on a FMZ basis. The study stated that farmers were able to delineate spatial variability in soil-fertility and soil-test results were in close agreement with farmers' defined soil-fertility category. For our research of interest is the approach to developing recommendations with farmers to achieve site specific recommendations- these were based on village-level soil-fertility maps as an aid to decide site-specific nutrient management in the village. The study concluded that farmers were vastly experienced in delineating fertility zones in their village. And, that preparations of soil FMZ map with the active cooperation of the villagers would yield a practical guide for their fertilizer recommendation for different parts of the village. Perhaps there would be some economies of scale and greater adoption of recommendations if a village could map the fertility zones and then apply relevant guides rather than requiring each 'field/farm' to be tested?

The study conducted by Mose (1998) in Kenya reveled that balanced fertilizer use could be improved through different ways. Improvement of the road infrastructure is one of the ways to reduce transaction costs associated with inputs such as fertilizer in remote/difficult to reach areas. Selling fertilizer in small quantities is another way of improving fertilizer use. The other ways are: having credit facilities available via fertilizer suppliers and/or other credit/savings facilities; increasing farm incomes in order to stimulate demand for fertilizers; ensuring that input suppliers have some basic training and or can provide information about fertilizer use; and fertilizer market development.

2.5 Barriers in Applying Balanced Dose of Fertilizer

Mujeri et al. (2012) reported a number of barriers for application of proper doses of fertilizers. The barriers are:

- Inadequacy of soil-testing facilities is a limiting factor for application of proper doses of fertilizers in all South Asian countries.
- Climate and season impact fertilizer use e.g., failures of rainfall increase the risk for farmers using fertilizers and they will be reluctant to use them.
- Farmers in irrigated areas as opposed to rain-fed ones are more likely to use fertilizers due to available funds and ability to time application. But managing the irrigation is essential for deriving profitable yields and protecting water quality.
- Delay in fertilizer supply can lead to untimely application – contributing factors include: inadequate warehousing capacity, delay in subsidy payment and poor infrastructure.
- Scarcity of extension workers- extension workers are lacking of professional capacity and are observed to spend most of their time in activities related to the distribution and administration of fertilizers.
- Inadequate availability of credit at an affordable cost- major constraints on fertilizer use for farmers. Credit also required by fertilizer distributors to enable them to hold sufficient stocks to meet seasonal demand.
- Problems with the fertilizer distribution system – farmers often have to travel long distances to purchase fertilizer, outlets often fail to deliver fertilizers on time and in the right quantity.
- Fertilizer quality – SRDI in Bangladesh analyzed 3780 samples in 2009 and found that 40% of those were adulterated. Katalyst (2009) reported similar results. Countries have enacted Fertilizer Quality Control Acts and posted fertilizer inspectors at sub-national levels, but there is a lack of logistical support and trained staff for effective monitoring. Also – no judicial power to implement the provisions of the Act.

Roy and Farid (2011) stated that organic matter is available in crop residues and animal dung, but tends to be used for fuel. In addition, farmers are not aware of the benefits of organic matter and they are not able to purchase organic fertilizer. IPNS has been accepted as a policy measure by the DoA. However, adoption at the field level is low. Standard specifications for fertilizer products exist, but field level monitoring is inadequate due to lack of infrastructure, funds and manpower. Technologies are not being transferred to farmers by extension staff who are preoccupied with fertilizer marketing, distribution and control. There is a wide gap between demand and supply… total demand is underestimated, peak season demand not estimated correctly either.

Bangladesh country paper (Quamruzzaman, 2005) reports that the major constraints to proper adoption and utilization of INM technology are: farmers often have inadequate knowledge and funds to appropriately apply/purchase fertilizer; the linkages and interactions among researchers, extension services and NGO personnel are weak; risks of water deficit in drought prone period are considered the most important deterrent to fertilizer use.

Gurstein (2013) reports on creating an improved fertilizer recommendation system (FRS) in Bangladesh. Steps included: establishing that access to inputs and information regarding usage were first level causes of farmer under-performance. Fertilizer recommendation information was only accessible to farmers with help from a technically proficient professional who were able to undertake the quite complicated and time-consuming calculations to compute individual requirements. Only a small number of farmers were able to access this service. The guide is complicated and requires farmers to input 15-16 pieces of information including things that the farmer is unlikely to be aware of – physiology of the soil, water level, type of soil, etc.

2.6 Role of Women in Agriculture and Nutrient Management

In Bangladesh, women are actively involved in postharvest operations at household level. The women belong to the tribal community and schedule cast of Hindu religion are usually involved in the field level agricultural activities to a great extent. However, they are increasingly engaged in different agricultural activities in and outside the home. Women's involvement in paid work outside the home is also positively and significantly associated with their economic agency, mobility in the public domain, respect from their family and sense of control over their lives (Kabeer et al., 2013).

Sultana (2011) looked into women in rural agricultural livelihoods using the livelihoods approach. She noted that the role of women in farming is often underestimated; it is often unrecognized because of the patriarchal society. Conventional assumptions about the role of women often hold despite research that finds women often have a significant role in HH decision making (including decisions relating to fertilizer use). Notions of gender segregation in farming are strongly linked with social norms and expectations.

Rahman (2010) looked into the contribution of women's labor input to productivity and efficiency in crop farming. He concluded that female labor accounts for 28% of total labor use (mostly supplied by the family rather than hired labor). In a previous paper Rahman (2000) noted that a commonly held view is that women are only involved in postharvest processing of crops and that their involvement in agricultural activities is contained around the household as opposed to the field. Although there is also evidence to the contrary. Source material is quite old, but notes: average working day for women is estimated to be 11.1 hours; time spent in agriculture 3.1 hours per day (4.4 hours during busy season).

Battacharjee (2015) conducted a study in Gazipur district to find out the participation behavior of men and women in agricultural activities. Traditionally women in Bangladesh are engaged in post-harvest agricultural activities solely or with their husbands or male relatives. This study finds that women had a major role in cleaning and winnowing (89%), sorting and grading of product (73%), processing of products (77%) and storage of products (66%). Men participated in these activities to a lesser degree, but were active in threshing of harvested crops (85%), carrying to market (84%) and sale of products (81%). In this study the women's participation in poultry production was 100% for collection, feeding and caring for the poultry. But the men played a vital role in selling of eggs (68%) and poultry (67%). In the case of cows, women were mostly involved in rearing (95%) and collection/purchase of cows (89%), but less involved in the sale of cows (36%). Women also heavily involved in the collection/purchase of goats (92%) and rearing/milking of goats (77%) and less involved in their sale (45%).

Most farm households have home gardens and these play an important role in household food security of Bangladesh. Again, they are operational farm units, which mainly engage women family labor and sustain high agricultural production (Ferdous et al., 2016).

Sraboni et al. (2014) stated in their report that empowerment gaps for women in rural Bangladesh were found to be greatest in terms of leadership in the community and control and access to resources. They also referred to the works of Rahman (2010) and Kabeer (2017) in this regard. Their common views are that women are not involved in agricultural production, especially outside the homestead, because of cultural norms that value female seclusion and undervalue female labor. Women in poor HH are more likely to be involved in the agricultural sector, because the women's earning are important to their families' subsistence.

WB et al. (2009) reports that women are particularly affected by declining soil fertility – men often control the best land with the best soil to produce commercial crops and women often farm marginal land. They have limited or no access to external inputs such as fertilizer. Land tenure has a major influence on maintenance of soil fertility and ability to intensify farming. Because women so infrequently lack secure access to land they may be more reluctant to invest in soil improvement. Secure access not only refers to ownership, but power within the HH to make decisions and influence decisions about how the land will be used. Because fertilizer recommendations are usually designed for monoculture systems they are difficult for women to apply in mixed cropping systems. Withdrawal of subsidies in some countries has reduced availability of inorganic fertilizers for resource-poor farmers including women. Recommend-need for gender disaggregated data on the user of fertilizer and other soil productivity technologies; fertility management methods that are suitable for cropping systems managed by women; extension to promote techniques in ways that include women; systematic effort to increase women's participation in soil improvement projects.

Kodamanchaly (2001) studied agricultural work responsibility of men and women in his PhD dissertation and reported that seed selection (41.38%), land preparation (30.17%), composting for organic fertilizer (25.29%), and guarding crops (28.16%) are some of the agricultural tasks carried out within the confines of the house, and as such women take an active role in them. As the agricultural activities move outside the house responsibility drops – less than 20% of respondents were responsible for activities such as transplanting, seed sowing, irrigation, fertilizer and pesticide application and repairing irrigation channels. He also looked into the agricultural production decisions in four areas: type of crop to be grown, agricultural inputs, adoption of new technology, and hiring of labor. As well as decision making generally.

Diiro et al. (2015) looked into different factors that influence men and women in using fertilizer use. They found some factors such as number of extension visits, age of household, and non-farm earning were significant for men, and education and distance to market are significant factors for women. They have concluded that different policies are needed to incentivize fertilizer use for men and women.

Women are now engaged in a broad range of economic activities and other sectors, and norms about limits on women are changing. Rural women's economic activities include: postharvest processing, livestock and poultry rearing, HH agriculture, horticulture, selecting and storing of seeds, food processing, garment making, coir (rope) production, and handicrafts. Many women are also found in the customarily male areas of earthwork, construction and agricultural field labor. Participation in these activities as formerly limited to landless or destitute women, but these patterns are changing. Norms about women's roles are not static-middle-class women have increased their involvement in agricultural field work (ADB, 2010).

Often not considered "farmers," in part because they do not own land, women miss out on agricultural extension and information about new technologies even when they relate to types of production they are involved in.

Rahman et al. (2016) looked into the contribution of women in rice production activities in Bangladesh. Women's participation in rice production is increasing day by day, the number of families that are becoming dependent on female wage labor for income is also increasing. It reveals that 42-43% of the work was done by rural women. They found some factors that affected participation of women in rice production activities. The factors are distance of the rice field from the home, number of available technologies used, and available adult male labor. However, no women reported working on fertilizer application.

Peterman et al. (2010) provides summary and analysis of 24 studies on gender differences in access to technological resources, specifically inorganic fertilizer, seed varieties, and machinery. In the literature on inorganic fertilizer an important theme is that, given equal access to fertilizer (controlling for other inputs and background factors), female farmers adopt fertilizer at the same rates as male farmers. Studies that look into the gender of the household head – some report that female heads are more likely to adopt inorganic fertilizer, others no significant effect on adoption and intensity of use.

Quisumbing and Pandolfelli (2010) reviews literature from 1998 to 2008 that described interventions or policy changes in the areas of land, water and soil fertility, new varieties and technologies, extension, human capital and technologies to enhance labor productivity, access to markets, credit and financial services, and social capital and infrastructure support services.

While securing access to land encourages investment in sustainable land management techniques, farmers need fertilizer and improved seeds to farm their land most productively. Although female heads of HH uniformly apply less fertilizer than males, when farmer characteristics are controlled for in regression analysis, the critical factors that significantly limit fertilizer application are lack of access to credit and cash, not the sex of the farmer.

2.7 Concluding Remarks

The following points have been observed in the aforesaid literature:

- Most farmers apply different types of fertilizers without maintaining scientific recommendations. The magnitude of fertilizer use gaps between farmers' practice and scientific recommendations are not widely reported in the literature.
- Factors that influence a farmer's decision to use manure and fertilizer have been discussed in a range of studies, but very few studies identify factors that are responsible for creating fertilizer use gaps (i.e., the gap between farmers' practice and scientific recommendations).
- Barriers and strategies of applying recommended fertilizer dose were discussed in different studies to some extent, but there is lack of information/research about the specific strategies/guidelines for the extension agents and farmers to promote adoption of the recommended fertilizer dose.
- The contribution of women in household decisions regarding fertilizer use and soil nutrient management are largely absent in the Bangladeshi literature.

Chapter III

APPROACH AND METHODOLOGY

3.1 Approach

The quantitative and qualitative research approaches were employed in accomplishing the project activities. A multi-disciplinary scientists group comprised Agricultural Economist, Sociologist, Soil Scientist, and Agronomist from home and abroad was involved in accomplishing the study. The quantitative approach included mainly field survey using semi-structured interview schedule and collecting data and information from different published and unpublished secondary sources. The qualitative approach mainly included focus group discussion (FGD) with different groups of farmers in the project hubs. However, the survey and FGD also collected some qualitative and quantitative data respectively. Apart from this, the key informant interviews (KII) was also conducted with the key informants such as extension agent, experts, scientists, community leaders, etc. In addition, an in-depth review of different published and unpublished documents relevant to soil nutrient management was done to document a state of fertilizer uses and recommendations.

3.2 Methodology

Different methodological procedures for collecting and analysing primary data are discussed in the following sections.

3.2.1 Sources and method of data collection

Data was collected from both primary and secondary sources. Primary data was collected from selected farmers with the aid of a pre-tested interview schedule. NUMAN project personnel in the respective project Hub and DAE personnel assisted researchers and enumerators in collecting primary data. Secondary data was collected from different published and unpublished sources, such as Fertilizer Recommendations Guide-2012, Bangladesh Bureau of Statistics, journal articles, SRDI, institutional websites, etc.

The face-to-face interview method was used to collect data from the selected farmers (Figures 3.1 to 3.3). Thus, the survey questionnaire was designed to collect primary data. The major socio-economic data collected from the farmers through face-face interview were current fertilizer use according to farm types, cropping patterns, land typology, gender, data on fertilizer application time for different crops, availability, types and price of fertilizers. Different factors that influence (positively or negatively) fertilizer usages pattern were also collected during field survey.

3.2.2 Sampling procedure and sample size

As mentioned, primary data were collected from farmers by using an interview schedule. The overall activities of NUMAN project are being launched in the five hubs namely Rajshahi, Thakurgaon, Mymensingh, Khulna, and Barguna districts (Figure 3.4). Baseline information of these areas are needed for the scientists of other disciplines (i.e. Agronomy, Soil Science, OFRD) for successful implementation of the project, and to evaluate the project output at the end of the project. Therefore, the socio-economic team selected the above mentioned districts purposively for this study. However, the study areas were five Upazilas from five selected districts. One Upazila from each district was purposively selected for this study. Thus, the total number of Upazilas was five. Again, two Agricultural Blocks (AB) from each selected Upazila were purposively selected through consultation with Agriculture Officer of the respective Upazila. Thus the total number of ABs was 10. The population of this study are those farm-households who engaged with crop farming.

It was hypothesised that the level of fertilizer use varies by farm sizes and gender. Therefore, these issues were taken into consideration during farm survey. However, before selecting sample respondents, a full list of farm-households by different farm sizes and gender managed was prepared with the help of Upazilla Agriculture Officers in respective Upazila. At first, the listed farm-households were categorized according to their farm sizes. The farm size categories was defined as follows: (i) marginal farmers (less than 0.49 acres of land) (ii) Small farmers (0.50-2.49 acres) and (iii) medium farmers (2.50 - 7.49 acres) and large farmers (above 7.5 acres). These categories are based on the Department of Agricultural Extension (DAE) for farm size. The project was interested to know whether the fertilizer application patterns varied in women managed farm compared with male managed households. Therefore, women managed farm-households were also selected purposively for interview. In the second stage of sampling, a total of 150 farmers (approx. 10% of each AB) from each of the selected Upazilas were propotionately selected for interview. The selection was done to select sample farmers from different farm categories and female managed farm-households. Thus, the total sample was 150 in each location (Table 1). In total, the total sample size was 750 (5 Upazila × 2 AB × 75 samples). In selecting the farms from different farm categories proportionate stratified random sampling was used. It is noted that two wives gave interviews in the absence of their husbands; they both claimed to work on different farm activities closely with their husbands.

Table 3.1 Distribution of sample farmers in the study areas

District	No. of Upazila	No. of block	Farm category				
			Marginal & Small	Medium	Large	Women managed	Total Sample
Thakurgaon	1	2	80	40	10	20	150
Rajshahi	1	2	80	40	10	20	150
Bogura	1	2	80	40	10	20	150
Mymensingh	1	2	80	40	10	20	150
Barguna	1	2	80	40	10	20	150
Total	5	10	400	200	50	100	750

Fig 3.1 Interviewing farmer at Dacope, Khulna

Fig 3.2 Interviewing farmer at Amtoli, Barguna

Fig 3.3 FGD with different categories of farmers at Porchim Chila, Barguna

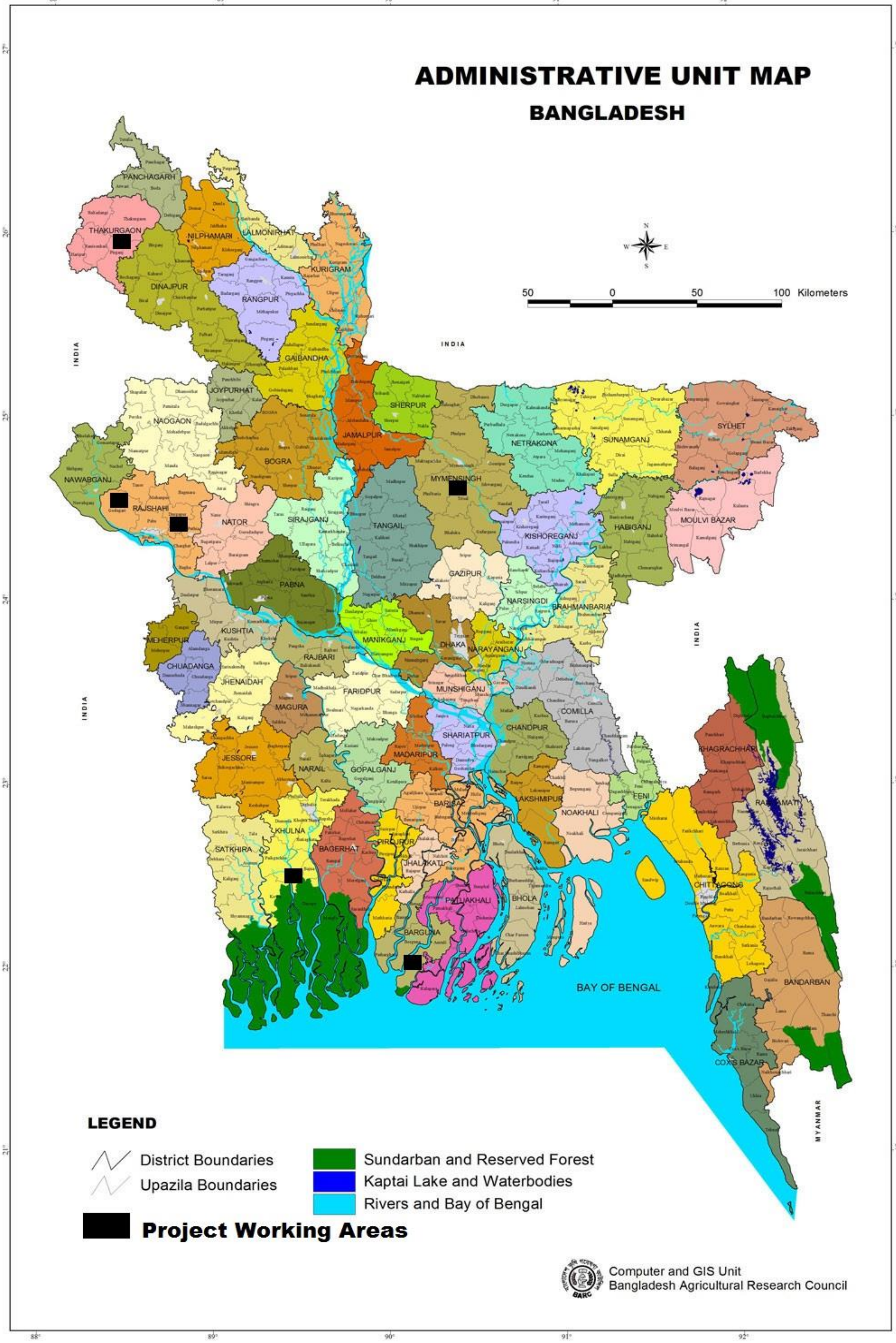


Fig 3.4 Map of Bangladesh showing study areas of the project

3.2.3 Focus group discussion (FGD)

In total 10 FGDs (one FGD at each AB) was conducted with different categories of farmers (i.e. large, medium, marginal & small, and female) of the surveyed blocks who took part in the previous household survey of this study. In each FGD, a total of 14 farmers, taking two farmers from large category, four farmers from each medium, marginal & small category, and women managed farm households were selected as participants. FGDs were done for collecting qualitative and quantitate data regarding main factors that farmers consider in deciding the type and quantity of fertilizer to use, access to fertilizer, cost of fertilizer, and soil nutrient related information and advice. The FGD checklist was developed, pre-tested and finalized before doing the FGDs. A discussion guide was prepared prior to the commencement of the FGDs. The guide comprises the general format of the discussions and the techniques that were used to elicit responses. It is noted that the discussion guide is merely a guide, which is flexible and subject to variation and alteration in the field. In addition to a moderator in FGD, there was a note keeper who recorded comments and observations of the FGDs. A voice recorder was also used to record whole discussion in order to recall necessary issues.

3.2.4 Key informant interview (KII)

Apart from FGDs, a number of KII were conducted for this study. The key informants were policy makers, experts, scientists, lead farmers, and community leaders. In addition, a number of published and unpublished secondary documents were reviewed to document a state of fertilizers use and scientific recommendations.

3.2.5 Measurement of plant nutrients

Farmers applied different types of fertilizers and cow dung manure in crop field. Therefore, different conversion factors were used to calculate the amounts of various plant nutrients such as N, P, K, S, and Zn used for crop production. The conversion factors were N (kg) = {Urea (kg) × 2.17 + DAP (kg) × 5.56 + 0.5×Cowdung (kg) × 0.005}; P (kg) = {TSP (kg) × 5.0 + DAP (kg) × 5.0 + 0.5 × Cowdung (kg) × 0.0015}; K (kg) = {MoP (kg) × 2.0 + 0.5 × Cowdung (kg) × 0.0023}; S (kg) = Gypsum (kg) × 5.56; and Zn (kg) = ZnSO4 (kg) × 4.35 (FRG, 2012).

3.2.6 Factors affecting gaps of fertilizer/nutrient use at farm level

The respondent farmers used different fertilizers in crop production either over dose or under dose compared to scientific recommendation. The value of gaps between farmer's practice and recommended dose was either positive or negative. The level of fertilizer use as well as fertilizer using gaps (response variable) is likely to influence by a number of socioeconomic variables. The response variable is converted to proportion (ratio of nutrient use gap and recommended dose) which is restricted to the interval ($0<y<1$). As the nutrient use gap index lies between 0 and 1 and the value close to 0 refers to use nutrients at more recommended level. This variable is continuous. Though this is a continuous variable we can use ordinary least square (OLS), Tobit, or fractional regression model. But before using these model we need to satisfy their properties.

The OLS regression is not appropriate for its bounded dependent variable and fail to satisfy normality assumption. The normality assumption is required in linear regression model for hypothesis testing, particularly if the sample size is small. Besides, its predictions could fall outside those intervals (0, 1). The variable nutrient gap is bounded (0, 1), but not censored. For this reason, Tobit regression is not perfect. To overcome these problems and limitations, we consider fractional or *beta regression model*, which is a generalized linear model, for proportions and percentage outcomes (Ferrari and Cribari-Neto, 2004). Beta regression fits the current data well and the regression parameters are well interpreted in terms of the mean of the response variable.

Beta Regression

In the statistical literature, beta regression has been established as a powerful technique to model percentages and proportions (Cribari-Neto and Zeileis, 2010). In beta regression, the response variable is assumed to follow a beta distribution on the interval (0, 1) and that its mean is related to a set of exploratory variables through a linear predictor with unknown coefficients and a link function. The model also includes a dispersion parameter. Beta regression is appropriate for analyzing both binomial and non-binomial data. It provides more accurate and efficient parameter estimates than OLS regression when the dependent variable follows a skewed distribution (Paolino, 2011) and when there is heteroskedasticity (Kieschnick and McCllough, 2003). Moreover, the results of a beta regression model have essentially the same interpretation as logistic regression. In this subsection, we outline the theoretical aspect of beta regression model.

Beta regression is very flexible for modeling proportions since the beta density of response variable (y) has different shapes depending on the values of the two parameters that index the distribution. The beta density can be expressed in the following equation (1).

$$\pi(y,\alpha,\beta) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\tau(\beta)} y^{\alpha-1}(1-y)^{\beta-1}, \quad 0 < y < 1 \text{ ------------------------------- [1]}$$

Where, $\Gamma(.)$ is the gamma function, $\alpha > 0,\ \beta > 0$.

The mean and variance of response variable (y) are defined as the following equations (2 & 3):

$$E(y) = \frac{\alpha}{(\alpha+\beta)} \text{ -- [2]}$$

$$Var(y) = \frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)} \text{ --- [3]}$$

As the beta regression is characterized by two shape parameters, a simple algebraic transformation of these parameters define the beta distribution in terms of its mean and a scaling, or precision parameter (Swearingen et al., 2011; Smithson and Verkuilen, 2006; Ospina et al., 2006). Therefore, the beta regression accommodates the mean and/or precision of dependent variable as a function of explanatory variables.

We will define a regression model for beta distributed random variables. In order to obtain a regression structure for the mean of the response along with a dispersion parameter, we considered a different parameterization by setting $\mu = \frac{\alpha}{(\alpha+\beta)}$ and dispersion parameter $\varphi = \alpha + \beta$ (Ferrari and Cribari-Neto, 2004).

The beta density of y can be written in the following new parameterization (equation 4),

$$f(y,\mu,\varphi) = \frac{\Gamma(\varphi)}{\Gamma(\mu\varphi)\Gamma(1-\mu)\varphi)} y^{\mu\varphi-1}(1-y)^{(1-\mu)\varphi-1}, \ 0 < y < 1 \text{ -------------------- [4]}$$

with $0<\mu<1$ and $\varphi >0$. It follows from equations (2) and (3) that $E(y) = \mu$ and setting $Var\ (y) = \frac{v(\mu)}{1+\varphi}$. where, $V(\mu) = \mu(1+\mu)$. For the precision parameter (φ) of a fixed (mean, μ), the higher the value of φ, the smaller the variance of the response variable (Ferrari and Zeileis, 2010).

Assuming the percentage or proportion response variables are beta distributed, a beta regression model is designed. Let $y_1, y_2, \ldots, y_n$ be independent random samples from beta density $\beta(\mu_{i,\varphi})[y - \beta(\mu_i \varphi)]$, and then the beta regression model can be written as the following equation (Cepeda-Cuervo, 2015).

$$g(\mu_{i)} = \beta_0 + x_{i1}\beta_1 + x_{i2}\beta_2 + \cdots + x_{ik}\beta_{k=\eta_i} \quad i=1,2,3 \ldots,n \text{ ------------------------------ [5]}$$

Where, $\beta = (\beta_{1,}\beta_{2,} \ldots \ldots \ldots, \beta_{k)})^T$ is a vector of unknown regression parameters, $x_{i1}, x_{i2}, \ldots \ldots x_{ik}$ are the fixed covariates; η_i is the linear predictor for the i^{th} observation, and n is the sample size. Here $g(.)$ is a monotonic and double differentiable link function over (0,1), which connects the linear predictor and the response variable. The logit link was used in this study for beta regression.

Beta coefficient is the degree of change in the outcome variable for every 1-unit of change in the predictor variables. If beta coefficient is not statistically significant, the variable does not significantly predict the outcome. In marginal analysis, if the marginal value of a beta coefficient for a variable is positive, the interpretation is that for 1% increase of the specific variable, keeping other factors constraints, the probability of overall fertilizer using gap (response variable) would be increased by beta coefficient value in percentage term. Again, if the marginal value of a beta coefficient is negative, the interpretation is that for 1% increase of the specific variable, keeping other factors constraints, the probability of overall fertilizer using gap (response variable) would be decreased by beta coefficient value in percentage term.

Empirical beta regression model

In order to identify the socioeconomic factors affecting fertilizer use gaps using econometric model, we have used two types of data sets based on fertilizer use that means over dose users and under dose users. Due to insufficient data, we considered two major rice crops namely *Boro* and *T. Aman* for this analysis. However, for one crop we have constructed three models for N, P, and K for over users and similarly constructed another three models of less users. Thus the total number of models constructed for two crops is twelve. The fertilizer using gaps is likely to influence by a number of socioeconomic factors. In this analysis we have used a total of 25 types of variables to identify important factors that affect fertilizer using gaps at farm levels. The typical empirical beta regression model is given below.

$$Y = \beta_0 + x_1\beta_1 + x_2\beta_2 + \cdots + x_{25}\beta_{25} \text{ -- [6]}$$

Where,

Y	=	Fertilizer use gap (restricted to the interval $0<y<1$)
X_1	=	Gender (if male =1, otherwise 0)
X_2	=	Age (in year)
X_3	=	Education (No. of schooling)
X_4	=	Occupation (if farming=1, otherwise 0)
X_5	=	Small & marginal farmer (if yes=1, otherwise 0)
X_6	=	Medium farmer (if yes=1, otherwise 0)
X_7	=	Medium high land (if yes=1, otherwise 0)
X_8	=	Triple crops cultivation (if yes=1, otherwise 0)
X_9	=	Awareness (1, 0)
X_{10}	=	Crop residue retention (if yes=1, otherwise 0)
X_{11}	=	Crop rotation followed (if yeas=1, otherwise 0)
X_{12}	=	Line sowing (if yes=1, otherwise 0)
X_{13}	=	Cultivate own land (if yes=1, otherwise 0)
X_{14}	=	Ln_fertilizer used in previous crop (kg/ha)
X_{15}	=	Distance (km)

X_{16} = Optimum dose use (if optimum use=1, otherwise 0)
X_{17} = Crop demand (if fertilizer use based on crop demand=1, otherwise 0)
X_{18} = Fertilizer price (Tk/kg)
X_{19} = Extension contact (if yes=1, otherwise 0)
X_{20} = Credit (if received credit=1, otherwise 0)
X_{21} = Cattle (No./household)
X_{22} = Societal membership (if yes=1, otherwise 0)
X_{23} = Mymensingh district (if yes=1, otherwise 0)
X_{24} = Rajshahi district (if yes=1, otherwise 0)
X_{25} = Thakurgaon district (if yes=1, otherwise 0)
$\beta_0, \beta_1, - - - - - \beta_{25}$ are coefficients to be estimated

3.2.7 Statistical Tests

A number of statistical tests were done to test the normality of dependent variable and to identify the best link function for beta regression.

Shapiro-Wilk W test: Shapiro-Wilk W test was done to test the normality of dependent variable. The normality tests are used to determine if a data set is well-modelled by a normal distribution and to compute how likely it is for a random variable underlying the data set to be normally distributed. The null-hypothesis of this test is that the population is normally distributed. Thus, if the *p* value is less than the chosen alpha level, then the null hypothesis is rejected and there is evidence that the data tested are not normally distributed. Again, if the *p* value is greater than the chosen alpha level, then the null hypothesis that the data came from a normally distributed population cannot be rejected (e.g., for an alpha level of 0.05, a data set with a *p* value of less than 0.05 rejects the null hypothesis that the data are from a normally distributed population). The test results in Table 3.2 reveal that data regarding dependent variables of different beta regression models are not normally distributed.

Table 3.2 Shapiro-Wilk W test for normal data

Model No.	Response variable	n	W	V	Z	Prob>z	Remarks
1	N_Overuse_Boro	114	0.94917	4.684	3.450	0.00028	Data are not normally distributed
2	P_Overuse_Boro	197	0.97290	3.990	3.182	0.00073	-do-
3	K_Overuse_Boro	57	0.85561	7.533	4.340	0.00001	-do-
4	N_Underuse_Boro	178	0.96465	4.766	3.571	0.00018	-do-
5	P_Underuse_Boro	84	0.92038	5.689	3.820	0.00007	-do-
6	K_Underuse_Boro	235	0.94748	9.021	5.102	0.00000	-do-
7	N_Overuse_Aman	238	0.92137	13.657	6.068	0.00000	-do-
8	P_Overuse_Aman	462	0.97622	7.452	4.811	0.00000	-do-
9	K_Overuse_Aman	354	0.84102	39.240	8.682	0.00000	-do-
10	N_Underuse_Aman	494	0.95581	14.704	6.458	0.00000	-do-
11	P_Underuse_Aman	270	0.87856	23.571	7.380	0.00000	-do-
12	K_Underuse_Aman	378	0.94107	15.424	6.493	0.00000	-do-

Ramsey RESET test: The Regression Equation Specification Error Test (RESET) proposed by Ramsey (1969) is a general misspecification test, which is designed to detect both omitted variables and inappropriate functional form. The RESET test is based on the Lagrange Multiplier principle and usually performed using the critical values of the F-distribution. Before choosing the model, Ramsey RESET test was done in order to detect omitted variables and inappropriate functional form (Table 3.3). We found model number 5, 9, 11 and 12 has omitted variable bias problem. Therefore, non-parametric regression model (beta regression) was used to overcome these omitted variables and inappropriate functional form of the model.

Table 3.3 Ramsey RESET test using powers of the fitted values of response variables

Model No.	Response variable	n		F-value	Prob>F	Remarks
1	N_Overuse_Boro	114	F (3, 85)	0.49	0.6928	Model has no omitted variables
2	P_Overuse_Boro	197	F (3, 168)	0.20	0.8962	-do-
3	K_Overuse_Boro	57	F (3, 30)	1.41	0.2583	-do-
4	N_Underuse_Boro	178	F (3, 149)	0.86	0.4656	-do-
5	P_Underuse_Boro	84	F (3, 55)	3.12*	0.0332	Model has omitted variables
6	K_Underuse_Boro	235	F (3, 206)	1.61	0.1888	Model has no omitted variables
7	N_Overuse_Aman	238	F (3, 208)	0.98	0.4047	-do-
8	P_Overuse_Aman	462	F (3, 295)	1.31	0.2706	-do-
9	K_Overuse_Aman	354	F (3, 324)	6.65**	0.0002	Model has omitted variables
10	N_Underuse_Aman	494	F (3, 464)	0.54	0.6551	Model has no omitted variables
11	P_Underuse_Aman	270	F (3, 240)	6.88**	0.0002	Model has omitted variables
12	K_Underuse_Aman	378	F (3, 348)	3.17*	0.0244	-do-

Note: Ho: Model has no omitted variables; '*' and '**' indicate 5% and 1% level of significance

Link function selection criteria for beta regression: If maximum likelihood is used to estimate parameters and the models are non-nested, then the Akaike Information Criterion (AIC) or the Bayes Information Criterion (BIC) can be used to perform model comparisons. These two criteria are very similar in form but arise from very different assumptions. The AIC is a fined technique based on in-sample fit to estimate the likelihood of a model to predict/estimate the future values. A good model is the one that has minimum AIC among all the other models. Again, the BIC is another criterion for model selection among a finite set of models; the model with the lowest BIC is preferred. It is based, in part, on the likelihood function and it is closely related to the AIC. A lower AIC or BIC value indicates a better fit. Both AIC and BIC were used in this study to perform model comparisons in order to select best fit link function model (Table 3.4 and 3.5).

Table 3.4 Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for selecting best model for *Boro* rice

Model No.	Model	Obs	11(Null)	11(Model)	df	AIC	BIC	Remarks
1	logit	114	169.26	196.4745	27	-340.0545	-265.0716	
	probit	114	169.26	197.0272	27	-341.1441	-266.1771	
	loglog	114	169.26	197.5720	27	-344.9490	-267.2667	Best fit model
	cloglog	114	169.26	196.2944	27	-338.5888	-264.7114	
2	logit	197	22.6044	83.8371	27	-113.6742	-25.0277	
	probit	197	22.6044	83.7659	27	-113.5317	-24.8852	
	loglog	197	22.6044	83.2348	27	-112.4695	-23.8230	
	cloglog	197	22.6044	84.1036	27	-114.2072	-25.5607	Best fit model
3	logit	57	62.2676	75.2061	25	-100.4123	-49.3360	
	probit	57	62.2676	74.8662	25	-99.7374	-48.6561	
	loglog	57	62.2676	74.5669	25	-99.1339	-48.0576	
	cloglog	57	62.2676	75.2757	25	-100.5515	-49.4752	Best fit model
4	logit	178	279.690	328.729	27	-603.458	-517.550	
	probit	178	279.690	328.899	27	-603.798	-517.889	
	loglog	178	279.690	328.935	27	-603.869	-517.961	Best fit model
	cloglog	178	279.690	328.642	27	-603.284	-517.376	
5	logit	84	60.7632	81.8889	27	-109.7771	-44.1451	
	probit	84	60.7632	82.4298	27	-110.8595	-45.2274	
	loglog	84	60.7632	83.2812	27	-112.5623	-46.9303	Best fit model
	cloglog	84	60.7632	81.5165	27	-109.0330	-43.4010	
6	logit	235	86.9671	152.1120	27	-250.2241	-156.8152	
	probit	235	86.9671	151.6934	27	-249.3869	-155.9781	
	loglog	235	86.9671	149.1531	27	-244.3062	-150.8974	
	cloglog	235	86.9671	154.7141	27	-255.4282	-162.0194	Best fit model

Model No.: 1= N_Overuse_Boro, 2= P_Overuse_Boro, 3= K_Overuse_Boro, 4= N_Underuse_Boro, 5= P_Underuse_Boro, 6= K_Underuse_Boro.

Table 3.5 Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for selecting best model for *T.Aman* rice

Model No.	Model	Obs	11(Null)	11(Model)	df	AIC	BIC	Remarks
7	logit	238	291.4312	334.0783	28	-612.1566	-514.933	
	probit	238	291.4312	333.7340	28	-611.4679	-514.2443	
	loglog	238	291.4312	333.2735	28	-610.5469	-513.3234	
	cloglog	238	291.4312	334.1882	28	-612.3764	-515.1528	Best fit model
8	logit	325	1.7226	57.6928	28	-59.3857	46.5614	
	probit	325	1.7226	57.6838	28	-59.3677	46.5794	
	loglog	325	1.7226	55.5552	28	-55.1105	50.8366	
	cloglog	325	1.7226	59.1279	28	-62.2558	43.6913	Best fit model
9	logit	354	170.5113	192.9784	28	-329.9567	-221.6164	
	probit	354	170.5113	192.5901	28	-329.1802	-220.8399	
	loglog	354	170.5113	191.8485	28	-327.6969	-219.3566	
	cloglog	354	170.5113	193.8396	28	-331.6792	-223.3389	Best fit model
10	logit	494	383.2510	455.8342	28	-855.6685	-737.9975	
	probit	494	383.2510	455.8938	28	-855.7876	-738.1166	
	loglog	494	383.2510	455.9116	28	-855.8233	-738.1523	Best fit model
	cloglog	494	383.2510	455.7275	28	-855.4550	-737.7840	
11	logit	270	28.9213	47.7317	28	-39.4634	61.2924	
	probit	270	28.9213	47.5620	28	-39.1239	61.6319	
	loglog	270	28.9213	46.1946	28	-36.3891	64.3667	
	cloglog	270	28.9213	49.1589	28	-42.3179	58.4380	Best fit model
12	logit	378	127.2501	171.3485	28	-286.6970	-176.5200	
	probit	378	127.2501	170.8790	28	-285.7579	-175.5809	
	loglog	378	127.2501	169.7209	28	-283.4419	-173.2648	
	cloglog	378	127.2501	172.0340	28	-288.0680	-177.8909	Best fit model

Model No.: 7= N_Overuse_Aman, 8= P_Overuse_Aman, 9= K_Overuse_Aman, 10= N_Underuse_Aman, 11= P_Underuse_Aman, 12= K_Underuse_Aman

3.2.7 Data management and analyses

The collected data were scrutinized, coded, cleaned, and entered in MS Excel first and then were exported to the STATA 15.0. All the collected quantitative and qualitative data were analyzed in accordance with the project objectives. Mostly, descriptive statistics were used for analysing the collected data. The Beta regression model was estimated to identify the agro-socio-economic factors affecting the nutrients use gaps between current farmer's practice and scientific recommendations. The collected data were analysed using MS Excel and STATA 15.0 software.

Chapter IV

SOCIOECONOMIC PROFILE OF RESPONDENT FARMERS

4.1 Introduction

As outlined in *Chapter II*, the socioeconomic characteristics of farmers are factors that can influence their farm decisions. The socioeconomic characteristics of the respondent farmers such as age, education, occupational status, farming experience, and land holding/farm size, etc. are discussed in this chapter.

4.2 Age Distribution

The age of farmers can influence crop production and management decisions. The age of farmers was examined by classifying the farmers into six groups: 20-30, 31-40, 41-50, 51-60, and above 61 years (Table 4.1). The average age of the respondent farmers is 42.7 years. The average age was highest for large category farmers (46 years) followed by medium category (44 year) and the lowest for female farmers (37 years). A good percentage of the respondent farmers belonged to the age group 31-45 years. Some studies suggest that farmers belonging to this age group have increased vigor and risk bearing ability. The age distribution of farmers according to study areas can be seen in Appendix Table 1.

Table 4.1 Percent distribution of respondent farmers according to age group

Age group (year)	Marginal & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women managed *(n=100)*	All category (n=750)
15-30	21.7	15.5	10.0	20.0	19.0
31-45	35.3	41.5	38.0	39.0	37.6
46-60	33.5	38.0	38.0	14.0	32.4
61-75	8.7	5.0	12.0	27.0	10.4
76 & above	0.8	--	2.0	--	0.6
Average (year)	43.0	44.0	46.0	37.0	42.7

4.3 Educational Status

There have been numerous studies conducted relating to education and agricultural productivity which have shown that there is a positive relationship between education and agricultural productivity (Okpachu et al., 2014; Asfaw and Admassie, 2004; Appleton and Balihuta, 1996). So, farmers' education is expected to play a role in increasing the farming output. The education level of the respondent farmers has been grouped into five categories: (1) illiterate, (2) primary, (3) secondary, (4) higher secondary and (5) degree and above. Information on the educational levels of the respondents is presented in Table 4.2. It is observed that 15.5% farmers do not have any formal education. Of the educated respondents, 38.3% farmers have secondary level education followed by 31.5% primary level. The number of respondents with higher secondary and degree level education is small (9.6% and 5.2%).

Among the women managed farmers, 44% have primary school education and 39% have secondary education. A small number are illiterate (14%) and a few have higher secondary level education (3%). Comparing the women managed households to male managed households it can be seen that they are neither the least educated or most educated among the respondents: a few women are illiterate; few have higher secondary level education or degrees; a higher proportion have primary school education; and, a similar number have secondary level education. District wise educational status of the farmers can be seen in Appendix Table 2.

Table 4.2 Percent distribution of farmers according to the level of education

Education level	Farmers' category				All category (n=750)
	Marginal & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women managed *(n=100)*	
Illiterate	17.3	16.0	2.0	14.0	15.5
Primary level (I-V)	33.5	23.0	24.0	44.0	31.5
Secondary level (VI-X)	36.3	39.5	48.0	39.0	38.3
Higher secondary level	9.3	13.5	10.0	3.0	9.6
Degree & above	3.8	8.0	16.0	--	5.2

4.4 Religious Status

There are four major religions in Bangladesh (Muslim, Hindu, Buddhism, and Christian). The majority of the respondent farmers belong to the Muslim community (80.4%) and the rest 19.6% belong to the Hindu community. The percent share of Hindu respondents was highest in the Khulna district (70%) followed by Thakurgaon district (24.6%). No respondent farmers were found from the Hindu community at Barguna and Rajshahi districts and very few (3.4%) in Mymensingh (Table 4.3).

Table 4.3 Percent distribution of farmers according to religion

Religion	Barguna	Khulna	Mymensingh	Rajshahi	Thakurgaon	All Area
A. Marginal & small						
Muslim	100	25.0	93.7	100	78.8	79.5
Hindu	--	75.0	6.3	--	21.2	20.5
B. Medium						
Muslim	100	37.5	100	100	75.0	82.5
Hindu	--	62.5	--	--	25.0	17.5
C. Large						
Muslim	100	40.0	100	100	40.0	76.0
Hindu	--	60.0	--	--	60.0	24.0
D. Women managed						
Muslim	100	30.0	100	100	80.0	82.0
Hindu	--	70.0	--	--	20.0	18.0
E. All category						
Muslim	100	30.0	96.6	100	75.4	80.4
Hindu	--	70.0	3.4	--	24.6	19.6

4.5 Marital Status

Most of the respondent farmers in the study areas are married. Table 4.4 shows that on average about 93% of the farmers are married and only 7% are unmarried. Slightly more of the women managed farm respondents are married than other categories (99%) and slightly less of the marginal and small farmers (93%).

Table 4.4 Percent of married sample farmers in the study areas

District	Farmers category				
	Marginal & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women managed *(n=100)*	All category *(n=750)*
Barguna	93	100	100	100	93
Khulna	96	95	90	95	96
Mymensingh	100	100	100	100	100
Rajshahi	85	95	100	100	85
Thakurgaon	91	85	100	100	91
All areas	93	95	98	99	93

4.6 Occupational Status

The work for which an individual is engaged throughout the year is known as their main occupation. As Bangladesh is an agro-based country, most of the people in the rural areas adopt agriculture as their main occupation. Respondent farmers were asked to report on their main occupation. Respondents' occupations were grouped into three major categories: farm, non-farm and off-farm categories. 'Farm' category was exclusively related to crop and livestock production. Non-farm category included wage labourer on others farms, and off-farm category included small business, service, driving, van/rickshaw pulling, self-employed other off-farm activities, and human labor in industrial sector.

Table 4.5 shows most of the male respondent farmers (88.0-93.6%) consider farming as their main occupation. Only a small number (6.0 – 12.6%) reported that working off-farm was their main occupation. In contrast, more than half (57%) of the female headed households reported farm related activities as their main occupation, and a significant percentage (40%) reported off-farm activities as their main occupation. Given that the survey was targeting farmers, the percentage of respondents reporting non-farm activities as their main occupation was very small in all farm categories and in all study areas.

Table 4.5 Percent distribution of farmers according to occupation

Occupation	Barguna	Khulna	Mymensingh	Rajshahi	Thakurgaon	All Area
A. Marginal & small						
Farm	93.8	98.7	76.3	95.0	85.0	89.8
Off-farm	6.2	1.3	22.4	5.0	11.2	9.2
Non-farm	--	--	1.3	--	3.8	1.0
B. Medium						
Farm	92.5	95.0	97.5	97.5	85.0	93.5
Off-farm	5.0	5.0	2.5	2.5	15.0	6.0
Non-farm	2.5	--	--	--	--	0.5
C. Large						
Farm	90.0	100.0	70.0	90.0	90.0	88.0
Off-farm	10.0	--	30.0	10.0	10.0	12.0
D. Women managed						
Farm	50.0	45.0	85.0	60.0	45.0	57.0
Off-farm	50.0	55.0	15.00	40.0	40.0	40.0
Non-farm	--	--	--	--	15.0	3.0
E. All category						
Farm	87.3	90.6	82.7	90.7	80.0	86.3
Off-farm	12.0	9.4	16.6	9.3	16.0	12.6
Non-farm	0.7	--	0.7	--	4.0	1.1

4.7 Farming Experience

Farming experience is often reported as an important factor for increasing farm productivity. It has been found that the farmers who have more experience in farming operations generally attain a higher level of technical efficiency (Rahman et al., 1999; Miah et al., 2014). It has also positive role in the adoption of modern technologies in crop production (Ainembabazi and Mugisha, 2014). The average experience of farmers in farming is 21 years (Table 4.6). Farmers of Mymensingh are more experienced (26 years) and that of Rajshahi are less experienced (18 years), and overall, large category farmers are more experienced than other categories of farmers (25 years). Women managed household respondents have the least farming experience with an average of 14 years across all study areas.

Table 4.6 Average farming experience of farmers in the study area

District	Farming experiences (year)				
	Marginal & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women managed *(n=100)*	All category *(n=750)*
Barguna	21	24	22	15	21
Khulna	23	22	21	13	22
Mymensingh	28	26	31	15	26
Rajshahi	20	17	19	13	18
Thakurgaon	20	19	30	13	20
All	22	22	25	14	21

4.8 Family Size

The average family size of the respondent farmers is 5.2 No./HH, this is higher than the national average of 4.06 No./HH (HIES, 2016). In different farmers' categories, the largest family size belonged to the large category farmers (7.0 No./HH) followed by medium (5.7 No./HH), marginal and small category farmers. The smallest family size belongs to the women managed households (4.6 No./HH). In different study areas, the largest family size was found in Mymensingh district (5.8 No./HH) and that of smallest in Thakurgaon district (4.6 No./HH) (Table 4.7).

Table 4.7 Average family size of the farmers in the study areas

District	Average family size (no./household)				
	Marginal & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women managed *(n=100)*	All category *(n=750)*
Barguna	4.8	5.4	9.3	4.8	5.3
Khulna	4.6	5.8	7.3	4.7	5.1
Mymensingh	5.6	6.7	6.2	5.0	5.8
Rajshahi	4.5	5.1	5.7	3.8	4.6
Thakurgaon	4.9	5.3	6.5	4.7	5.0
All	4.9	5.7	7.0	4.6	5.2

4.9 Working Persons in the Family

Physically or economically active persons are important for a family. The average number of working persons of the respondent families is 1.8 No./family (Table 4.8). Similar number of working persons (1.9 No./family) was found in Khulna, Mymensingh and Thakurgaon districts. Women managed farm households have the highest number of working persons (2.2 No./family) followed by large (2.1 No./family) and medium category farmers (1.9 No./family).

Table 4.8 Average number of working family members in respondent households

District	Working family members (no./household)				
	Marginal & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women managed *(n=100)*	All category *(n=750)*
Barguna	1.6	1.6	2.4	2.4	1.7
Khulna	1.7	2.0	2.8	2.1	1.9
Mymensingh	1.9	1.9	1.7	2.1	1.9
Rajshahi	1.7	1.9	1.6	2.2	1.8
Thakurgaon	1.8	2.1	2.1	2.0	1.9
All areas	1.7	1.9	2.1	2.2	1.8

4.10 No. of Students per Family

The average number of school/college/university going students of the respondent households is 2 No./family. In different categories of farmers, the highest number of students was found in the large category farmers (2.4 No./family), followed by medium and female managed farm households. Again, the highest number of students were reported in Mymensingh (2.4 No./family), followed by Thakurgaon and Khulna (Table 4.9).

Table 4.9 No. of students (school/college/university) per family in the study areas

District	No./household				
	Marginal & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women managed *(n=100)*	All category *(n=750)*
Barguna	1.7	1.7	2.3	1.4	1.7
Khulna	1.6	1.9	2.9	1.8	1.8
Mymensingh	2.0	2.4	2.7	2.4	2.2
Rajshahi	1.4	1.9	2.1	1.5	1.6
Thakurgaon	1.8	2.2	2.0	1.9	2.0
All areas	1.7	2.0	2.4	1.8	1.9

3.11 Farm Size

Land is the most important asset for farm households because farm families mostly depend on the land. Farm size is determined based on the total land area operated by the respondent farmers. It includes the area of own cultivated land plus rented in land minus rented out land. It also includes the homestead land (housing plot), fallow land, orchard and ponds. As shown in Table 4.10, the average farm size of all respondent farmers was 1.162 ha. As expected, large category farmers had the largest farm size (4.972 ha) followed by medium category farmers (1.343 ha) and women managed households (0.877 ha). The average farm size of female managed households (0.877 ha) is little bit higher than that of small and marginal category farmers (0.667 ha). Own cultivated land of female managed households (107.8 decimal) is slightly lower than that of small and marginal farmers (115.0 decimal), but their rented/mortgaged in lands (137.3 decimal) were much higher compared to marginal and small category farmers (86.7 decimal). Across the study areas, the largest average farm size (1.412 ha) was observed in Rajshahi district followed by those in Thakurgaon (1.252 ha) and Barguna districts (1.245 ha), and the smallest (0.705 ha) was in Khulna district (Appendix Table 3).

Table 4.10 Average farm size (decimal) of the farmers in the study areas

Category of land	Marginal & small	Medium	Large	Women managed	All category
1. Own cultivated land	115.0	270.7	838.6	107.8	203.8
2. Rented/mortgaged in land	86.7	147.0	369.1	137.3	128.3
3. Rented/mortgaged out land	86.7	160.1	170.2	79.7	110.9
4. Homestead	15.9	23.6	36.7	14.7	19.2
5. Ponds	17.9	29.6	111.2	18.2	27.3
6. Orchard	16.0	20.9	42.7	18.4	19.4
Farm size (in decimal)	164.7	331.6	1228.0	216.7	287.0
Farm size (in ha)	0.667	1.343	4.972	0.877	1.162

Farm size (decimal): (1+2+4+5+6)-3

Chapter V

STATUS OF NUTRIENT MANAGEMENT AT FARM LEVEL

Nutrient management is the science and resource conservation practices directed to link soil, crop, weather, and hydrologic factors for achieving optimal nutrient use efficiency, potential crop yields, ensuring crop quality, and economic returns, while reducing off-site transport of nutrients (fertilizer) that may impact the environment (Delgado and Lemunyon, 2006). It involves the interaction effect of soil, climate and crop management conditions to rate, source, timing and place of nutrient application (Wikipedia, 2018). An attempt has been made in this chapter to discuss the present situation of nutrient management, input use pattern and profitability of crop production.

5.1 Major Cropping Patterns in the Study Areas

Usages of agricultural land in Bangladesh is highly dynamic and there is unique biodiversity of crops throughout the year (Nasim, 2017). The yearly sequence or distribution of crops in a land is termed as cropping pattern (CP). The following graph shows the total number of cropping patterns that farmers in the study areas practiced. Most of the CPs are rice-based. In the study areas, a total of 124 CPs were identified of which the highest number of CPs was found in Rajshahi district (61) followed by Thakurgaon (34), Barguna (30), Mymensingh (25) and Khulna district (12) (Figure 5.1). This indicates that crop production in Rajshahi district is more diversified. When looking at different farm categories the highest number of CPs (87) were found with marginal and small category farmers and the lowest number of CPs (30) were found in women managed farms (Figure 5.2).

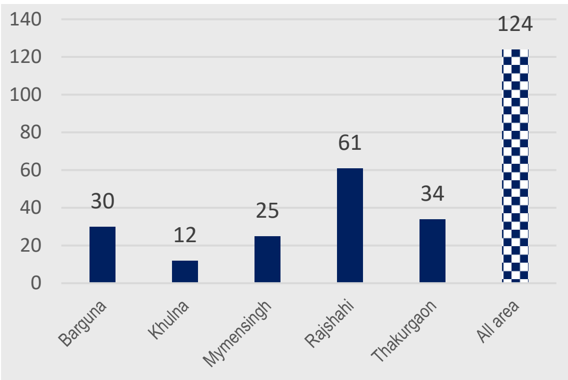


Fig 5.1 No. of cropping patterns in the study areas

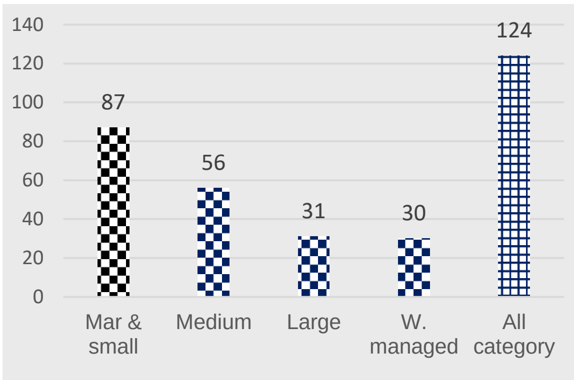


Fig 5.2 No. of cropping patterns practiced by farm category

Boro-Fallow-*T.Aman* is the most dominant CP which occupies 31.3% of the cultivated land in the study areas and about 32.67% farmers in the study area followed this CP (Table 5.1). It is the most dominant pattern in Mymensingh, Thakurgaon and Rajshahi districts. The second most dominant CP is Fallow-Fallow-*T.Aman*. Fallow-Fallow-*T.Aman* and Fallow-*T.Aus-T.Aman* were the dominant CPs in Khulna and Barguna districts, respectively. Among different farm categories and women managed households the dominant CPs are also *Boro-Fallow-T.Aman* and *Fallow-Fallow-T.Aman* occupying 32.67% and 13.60% of land, respectively (Table 5.2).

Table 5.1 Percentage of farmers practiced different cropping patterns by district

Major Cropping Pattern	Barguna *(n=150)*	Khulna *(n=150)*	Mymensingh *(n=150)*	Rajshahi *(n=150)*	Thakurgaon *(n=150)*	All area *(n=750)*
Boro-Fallow-T. Aman	10.67	2.67	81.33	34.00	34.67	32.67
Fallow-Fallow-T. Aman	15.33	50.33	-	-	2.33	13.60
Fallow-T.Aus-T. Aman	18.33	-	-	-	-	3.67
Watermelon-Fallow-T. Aman	-	42.33	-	-	-	8.47
Grass Pea-Fallow-T. Aman	8.67	-	-	-	-	1.73
Grass Pea-T.Aus-T. Aman	9.33	-	-	-	-	1.87
Maize-Fallow-T. Aman	0.33	-	-	5.00	20.00	5.07
Mustard+ Boro-Fallow-T. Aman	0.33	-	6.67	7.67	6.33	4.20
Mungbean-T.Aus-T. Aman	6.67	-	-	-	-	1.33
Onion-Maize-T. Aman	-	-	-	5.00	-	1.00
Potato-Maize-T. Aman	-	-	-	17.67	8.33	5.20
Potato-T.Aus-T. Aman	2.00	-	-	1.33	5.67	1.80
Other Patterns	28.33	4.67	12.00	29.33	22.67	19.40

Table 5.2 Percentage of different categories of farmers practiced cropping patterns

Major Cropping Pattern	Marginal & small (n=400)	Medium (n=200)	Large (n=50)	Women managed (n=100)	All category (n=750)
Boro-Fallow-Fallow	0.94	0.26	3.03	2.91	1.14
Boro-Fallow-T. Aman	34.50	35.13	34.34	30.23	34.14
Fallow-Fallow-T. Aman	13.29	13.85	11.11	13.37	13.30
Fallow-T.Aus-T. Aman	3.89	4.36	2.02	4.07	3.91
Fallow-Watermelon-T. Aman	8.19	6.92	8.08	9.30	7.97
Grass Pea-Fallow-T. Aman	1.48	3.08	3.03	0.00	1.85
Grass Pea-T.Aus-T. Aman	1.74	1.03	1.01	5.81	1.99
Maize-Fallow-T. Aman	5.10	4.87	2.02	4.65	4.77
Mungbean-T.Aus-T. Aman	1.21	1.54	1.01	2.33	1.42
Mustard+ Boro-Fallow-T. Aman	2.01	2.56	4.04	1.74	2.28
Potato-Maize-T. Aman	5.10	5.64	7.07	6.40	5.55
Potato-T.Aus-T. Aman	0.81	0.51	2.02	2.91	1.07
Others Pattern	21.74	20.26	21.21	16.28	20.63

5.2 Topography and Soil Types of Sample Plots

Crop production directly depends on the suitability of land and typology of land is highly correlated to the soil nutrient management. Therefore, land topography is an important issue to assess the nutritional status of the soil. The amount of fertilizer use also depends on the topography of land (FGD, 2019). We found in the study areas that about 45% of the farmers reported that they have medium high land followed by medium low land (34%), low land (17%) and high land (4%). More than 50% of the respondent farmers in Khulna, Mymensingh and Thakurgaon district reported that they have medium high land and conversely 50% of the farmers in Barguna and Rajshahi reported that they occupy medium low land.

We have found among different farm category households that there is a positive relationship between farm size and having medium high land meaning that large category farmers own more medium high land. The opposite relationship has been observed between farm size category and having low land. Among the women managed farmers most (45%) have medium high land followed by medium low land (31%) and low land (20%) (Table 5.3).

Table 5.3 Area-wise land type of the surveyed plots in the study areas

Land type	% of farmer's responses					
	Barguna	Khulna	Mymensingh	Rajshahi	Thakurgaon	All Area
A. Small & Marginal (n=80)						
Low land	12.5	13.8	18.7	21.2	25.0	18.3
Medium high land	33.8	61.2	43.7	26.2	46.2	42.2
Medium low land	51.2	21.2	33.8	43.8	27.5	35.5
High land	2.5	3.8	3.8	8.8	1.3	4.0
B. Medium (n=40)						
Low land	5.0	17.5	10.0	20.0	20.0	14.5
Medium high land	42.5	52.5	55.0	27.5	65.0	48.5
Medium low land	52.5	30.0	27.5	45.0	12.5	33.5
High land	-	-	7.5	7.5	2.5	3.5
C. Large (n=10)						
Low land	-	10.0	10.0	10.0	-	6.0
Medium high land	30.0	60.0	50.0	20.0	100.0	52.0
Medium low land	70.0	20.0	30.0	70.0	-	38.0
High land	-	10.0	10.0	-	-	4.0
D. Women managed (n=20)						
Low land	15.0	20.0	25.0	10.0	30.0	20.0
Medium high land	25.0	65.0	50.0	40.0	45.0	45.0
Medium low land	60.0	15.0	25.0	35.0	20.	31.0
High land	-	-	-	15.0	5.0	4.0
E. All category (n=150)						
Low land	10	15	17	19	23	17
Medium high land	35	59	48	28	55	45
Medium low land	54	23	30	45	20	34
High land	1	3	5	8	2	4

Soil is an important factor for maintaining nutrient management of the crop. Loam is a suitable soil type for crop production due to enough water holding capacity and provides necessary elements (www.toppr.com/guides/science/soil/types-of-soil-and-suitable-crops/). It is difficult for the farmers to identify actual soil types. However, it was found in the study areas, about 64% of the farmers reported that they have loamy soil followed by silt (21%), clay (12%), and sand (2%). A similar trend was found within the study districts although farmers in Khulna and Thakurgaon reported having more loamy soils than others. The highest percentage (64-70%) of respondent farmers belonging to different farm categories and including women managed households, reported that they have loamy soil. Silt and sandy soils were reported by 21.5% and 12% of farmers (across all categories) respectively (Table 5.4).

Table 5.4 Area-wise soil type of the surveyed plots in the study areas

Soil type	% of farmer's responses					
	Barguna	Khulna	Mymensingh	Rajshahi	Thakurgaon	All Area
A. Small & Marginal (n=80)						
Clay	5.0	3.8	17.5	22.5	15.0	12.8
Sand	2.4	-	2.5	-	1.2	1.2
Loam	63.8	88.8	36.2	57.5	78.8	65.0
Silt	28.8	7.4	43.8	20.0	5.0	21.0
B. Medium (n=40)						
Clay	5.0	2.5	15.0	22.5	10.0	11.0
Sand	2.5	2.5	2.5	-	5.0	2.5
Loam	70.0	65.0	37.5	52.5	85.0	62.0
Silt	22.5	30.0	45.0	25.0	-	24.5
C. Large (n=10)						
Clay	-	-	10.0	20.0	-	6.0
Sand	-	-	-	-	10.0	2.0
Loam	90.0	100.0	20.0	50.0	90.0	70.0
Silt	10.0	-	70.0	30.0	-	22.0
D. Women managed (n=20)						
Clay	5.0	-	30.0	30.0	5.0	14.0
Sand	5.0	-	-	-	20.0	5.0
Loam	75.0	85.0	35.0	55.0	70.0	64.0
Silt	15.0	15.0	35.0	15.0	5.0	17.0
E. All category (n=150)						
Clay	4.7	2.7	18.0	23.3	11.3	12.0
Sand	2.6	0.7	2.0	0.0	5.3	2.1
Loam	68.7	82.7	35.3	55.3	80.0	64.4
Silt	24.0	13.9	44.7	21.3	3.3	21.5

5.3 Training on Nutrient Management

Training is an important tool for increasing knowledge and skills of farmers and creating a forum for sharing ideas. Department of Agriculture Extension (DAE) provides training to the farmers usually on three major topics, i) crop production, ii) nutrient management, and iii) crop protection related training. The present study focused on nutrient management related training. It was found that on an average 5.64% farmers had received nutrient management related training (Table 5.5). The highest percentage of farmers receiving training was from Mymensingh district (8.12%), followed by Khulna (7.54%), Thakurgaon (6.30%), Rajshahi (4.10%) and Barguna (2.20%) districts. Again, the highest percentage of farmers receiving training was from medium farm category (7.50%) in the study areas followed by large (6%) category, women managed HH (5%) and marginal & small (4%) farm categories. Regardless of farmer category or study area, the number of training course on nutrient management is very limited. All the respondent farmers of the study areas received training from DAE.

Table 5.5 Farmers received nutrient management related training

District	% of farmers responded				
	Marginal & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women managed *(n=100)*	All category *(n=750)*
Barguna	3.75	5.00	-	-	2.20
Khulna	2.50	2.50	20.00	5.00	7.54
Mymensingh	5.00	12.50	-	15.00	8.12
Rajshahi	6.25	10.00	-	-	4.10
Thakurgaon	2.50	7.50	10.00	5.00	6.30
All Area	4.00	7.50	6.00	5.00	5.64

Table 5.6 shows the subject matter of training received by farmers of the study areas. Of the 26 farmers that received training, roughly half (53.85%) (Including three of the four women managed household respondents) of them received training on time and method of fertilizer application. A small percentage of farmers received training on soil quality enhancement (19.23%), use of organic fertilizer (11.54%), preparation of vermi-compost and its application (7.69%), use of urea super granular (3.85%), and use of Versatile Multi-Crop Planter (VMP) machine and its benefit (3.85%). In different study areas, only the farmers of Mymensingh district received training on the use of organic fertilizer and urea super granular, whereas the farmers of Thakurgaon district received training on using the VMP machine and its benefits. This likely reflects different project/program activities in these areas.

Table 5.6 Training received by farmers in different subjects on nutrient management

Subject matters	% of farmers received training					
	Barguna *(n=4)*	Khulna *(n=4)*	Mymensingh *(n=11)*	Rajshahi *(n=3)*	Thakurgaon *(n=4)*	All area *(n=26)*
Time and method of fertilizer application	50.00	75.00	36.37	66.67	75.00	53.85
Preparation of vermi-compost and its application	-	25.00	-	33.33	-	7.69
Soil quality enhancement	50.00	-	27.27	-	-	19.23
Use of organic fertilizer	-	-	27.27	-	-	11.54
Use of urea super granular	-	-	9.09	-	-	3.85
Use of VMP machine and its benefit	-	-	-	-	25.00	3.85

5.4 Soil Testing Scenario at Farm Level

Lack of soil testing facility is a common scenario in the study areas. Table 5.7 shows the percentage of farmers that tested soils of their fields in the study areas. A total of 5.47% farmers in all farm categories reported that they had tested their soil. Among different districts, 10% farmers from Mymensingh district tested their soil, followed by Khulna (6.67%), Barguna (6%), Thakurgaon (4%), and Rajshahi (0.67%) districts. In the case of women managed farms, soil testing was done only by farmers (5%) of Khulna and Mymensingh districts. Regarding farmer categories, the highest percentage (8.2%) of farmers that tested their soil were from medium category.

Table 5.7 Farmers tested soil of their crop field in the study areas

District	% of farmers tested				
	Marginal & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women managed *(n=100)*	All category *(n=750)*
Barguna	6.25	7.50	10.00	--	6.00
Khulna	5.00	7.50	10.00	10.00	6.67
Mymensingh	6.25	15.00	10.00	15.00	10.00
Rajshahi	1.25	--	--	--	0.67
Thakurgaon	1.25	12.50	--	--	4.00
All area	3.80	8.20	6.00	5.00	5.47

In operational terms, balanced fertilization can have three meanings: (a) the supply of all essential plant nutrients is adjusted in the proper ratios to crop demand; (b) the supply of plant nutrients equals the uptake of nutrients by the crop; and (c) the supply of plant nutrients equals the removal of nutrients from the field via the harvested crop (Oenema and Velthof, 2002). According to the farmers in the study areas a balanced fertilizer dose is a certain amount of different inorganic fertilizers to be applied to a specific crop for enhancing its proper growth and achieving higher yield (FGD, 2019). Farmers generally receive information regarding balanced fertilizer dose from the SAAOs or neighboring farmers (FGD, 2019).

Table 5.8 summarizes the advice that the 50 farmers received from the soil testing service provider after having their soil tested. About 46% farmers reported that they were advised to apply a balanced fertilizer dose, 10% farmers were advised to apply lime, and 20, 2.0 and 22% farmers were informed that their soils were deficient in K, P and Zn, respectively. All farmers of Rajshahi district were advised to apply balanced fertilizer dose. The farmers of Thakurgaon district said that they equally emphasize on application of lime, K and Zn fertilizers when they do not receive any advice about applying a balance fertilizer dose. There was no P deficiency reported in Mymensingh, Khulna, Rajshahi and Thakurgaon districts. No Zn deficiency was reported in Rajshahi district.

Table 5.8 Advice received from soil test by sampled farmers in the study areas

Advice	% of farmers received advice					
	Barguna (n=12)	Khulna (n=12)	Mymensingh (n=16)	Rajshahi (n=1)	Thakurgaon (n=9)	All Area (n=50)
Advice to apply balance fertilizer dose	50.0	50.0	62.5	100	--	46.0
Advice to apply lime	8.3	--	6.3	--	33.3	10.0
K deficiency in the soil	25.0	8.3	18.8	--	33.3	20.0
P deficiency in the soil	8.3	--	--	--	--	2.0
Zn deficiency in the soil	8.3	41.7	12.5	--	33.3	22.0

About 94.5% of the respondent farmers reported that they did not test their soil. Farmers reported various reasons for not testing their soils; 37.0% farmers stated about lack of awareness by, 33.4 % farmers gave less importance for soil testing, 18.6% farmers stated about less scope for soil testing, 7.2% farmers stated about inconvenience and hassle of soil testing, and 3.8% farmers follow neighboring farmers, not tested their soil. Although farmers of Mymensingh district reported that they were aware of benefits of soil testing, still they did not consider it was important compared to other regions (Table 5.9). It was observed that a good percentage of respondent farmers did not consider soil test was important. The reasons might be that their application of fertilizer is based mostly on their long experience in farming or that they don't have any idea about the results of soil test based crop production. Again, the main reason of not testing soil for women managed households and small & marginal farmers was lack of awareness, whereas medium and large category farmers did not test soil due to considering it less important (Table 5.9).

Table 5.9 Farmers responses for not testing soil in the study areas

Farmer's response	% of farmer's responses					
	Barguna	Khulna	Mymensingh	Rajshahi	Thakurgaon	All area
A. Small & Marginal (n=80)						
Lack of awareness	53.3	27.6	0.0	78.5	41.8	40.6
Give less importance	18.7	38.2	60.0	6.3	36.7	31.8
Less scope for testing soil	18.7	21.1	32.0	8.9	12.7	18.5
Inconvenience & hassle of testing soil	5.3	11.8	8.0	1.3	3.8	6.0
Gives priority to neighbor farmers	4.0	1.3	0.0	5.1	5.1	3.1
B. Medium (n=40)						
Lack of awareness	51.4	27.0	0.0	32.5	47.2	32.1
Give less importance	21.6	37.8	55.9	30.0	38.9	36.4
Less scope for testing soil	21.6	10.8	41.2	10.0	5.6	17.4
Inconvenience & hassle of testing soil	2.7	16.2	2.9	25.0	5.6	10.9
Gives priority to neighbor farmers	2.7	8.1	0.0	2.5	2.8	3.3
C. Large (n=10)						
Lack of awareness	33.3	33.3	0.0	20.0	10.0	19.2
Give less importance	33.3	44.4	77.8	40.0	50.0	48.9
Less scope for testing soil	11.1	22.2	22.2	20.0	40.0	23.4
Inconvenience & hassle of testing soil	11.1	0.0	0.0	0.0	0.0	2.1
Gives priority to neighbor farmers	11.1	0.0	0.0	20.0	0.0	6.4
D. Women managed (n=20)						
Lack of awareness	45.0	38.9	0.0	65.0	50.0	41.1
Give less importance	20.0	27.8	52.9	0.0	35.0	26.3
Less scope for testing soil	35.0	11.1	35.3	5.0	10.0	18.9
Inconvenience & hassle of testing soil	0.0	16.7	11.8	5.0	5.0	7.4
Gives priority to neighbor farmers	0.0	5.6	0.0	25.0	0.0	6.3
E. All category (n=150)						
Lack of awareness	50.4	29.3	0.0	60.5	42.2	37.0
Give less importance	20.6	37.1	59.2	14.0	37.9	33.4
Less scope for testing soil	21.1	17.1	34.2	9.4	12.3	18.6
Inconvenience & hassle of testing soil	4.3	12.8	6.6	8.0	4.2	7.2
Gives priority to neighbor farmers	3.6	3.6	0.0	8.1	3.5	3.8

5.5 Current CA Practices in Nutrient Management

Conservation Agriculture (CA) is not an actual technology, rather it refers to a wide array of specific technologies that are based on applying one or more of the three main CA principles (IIRR and ACT, 2005). The CA principles are practicing suitable crop rotation, retention of crop residue on the field, and minimum tillage (Hobbs et al., 2008). Farmers in the study areas mostly practice one or two CA principles. Complete CA practice is rare in the study areas. However, these practices vary by seasons and agro-ecological regions.

Irrespective of farmers category and study areas, respondent farmers reported practicing CA more in *Kharif-2* season (16.7%) than in *Rabi* (15.2%) and *Kharif-1* (9.1%) seasons. Regarding study areas, 38.7% and 26.7% farmers of Khulna district reported that they practice CA during *Kharif-2* and *Rabi* seasons, respectively. Again, 14.1% of the farmers in Thakurgaon and about 38.7% of the farmers in Khulna practiced CA during *Kharif-1* and *Kharif-2* season, respectively. In all seasons, the highest percentage of large farmers (24.1%) practiced CA followed by medium (14.5%) and small & marginal farmers (12.7%). Women managed households were the lowest (10.5%) users of CA in the study areas (Table 5.10).

Table 5.10 Farmers practice partial CA in different seasons

Season	% of farmers responded					
	Barguna (n=150)	Khulna (n=150)	Mymensingh (n=150)	Rajshahi (n=150)	Thakurgaon (n=150)	All Area (n=750)
A. Small & Marginal (n=80)						
Rabi	7.0	0.0	26.2	8.8	17.7	15.4
Kharif-1	12.5	5.9	0.0	3.3	5.0	7.4
Kharif-2	6.3	37.5	0.0	12.7	20.0	15.4
All seasons	**8.6**	**14.5**	**8.7**	**8.3**	**14.2**	**12.7**
B. Medium (n=40)						
Rabi	18.5	100.0	23.1	15.0	7.5	16.3
Kharif-1	11.8	0.0	0.0	0.0	35.7	10.6
Kharif-2	5.0	37.5	0.0	15.4	25.0	16.6
All seasons	**11.8**	**45.8**	**7.7**	**10.1**	**22.7**	**14.5**
C. Large (n=10)						
Rabi	12.5	0.0	40.0	20.0	20.0	23.1
Kharif-1	16.7	25.0	0.0	0.0	28.6	21.1
Kharif-2	10.0	60.0	0.0	40.0	30.0	28.0
All seasons	**13.1**	**28.3**	**13.3**	**20.0**	**26.2**	**24.1**
D. Women managed (n=20)						
Rabi	0.0	0.0	25.0	0.0	5.0	8.2
Kharif-1	18.8	0.0	0.0	0.0	0.0	7.1
Kharif-2	20.0	35.0	5.3	5.3	15.0	16.3
All seasons	**12.9**	**11.7**	**10.1**	**1.8**	**6.7**	**10.5**
E. All category (150)						
Rabi	9.5	26.7	26.1	10.0	13.4	15.2
Kharif-1	13.4	4.8	0.0	1.8	14.1	9.1
Kharif-2	8.0	38.7	0.7	14.3	21.3	16.7
All seasons	**10.3**	**23.4**	**8.9**	**8.7**	**16.3**	**13.7**

A crop rotation is the practice of growing a series of different types of crops in the same area over a sequence of seasons. Continuously growing the same crop tends to exploit the same rhizosphere soil which can lead to a decrease in available nutrients for plant growth and to a decrease in root development (Kumar, 2004). Crop rotation helps to maintain soil nutrients, reduce soil erosion, prevents pests and diseases, and maximize crop yield and profitability over time (Alam et al., 2019; Alam et al., 2016; Feizabady, 2013; Lauer, 2010).

Table 5.11 shows that 20.4% farmers reported that they practice crop rotation. The highest level of crop rotation was reported by the farmers of Rajshahi district (37.4%) followed by Thakurgaon (35.3%), Mymensingh (14.7%), Barguna (12.7%), and Khulna (2.0%) district. Among farm categories, 28% of large farmers reported that they rotate crops, the level of crop rotation reported by farmers in all other categories was similar. Respondent farmers mostly got crop rotation related information from the DAE followed by practicing it based on their own experience or information/advice from peer farmers, neighboring farmers, and research institutes.

Table 5.11 Farmers practiced crop rotation in the study areas

District	% of farmers practice crop rotation				
	Marginal & small (n=400)	Medium (n=200)	Large (n=50)	Women managed (n=100)	All category (n=750)
Barguna	8.8	12.5	30.0	20.0	12.7
Khulna	2.5	2.5	--	--	2.0
Mymensingh	16.3	12.5	10.0	15.0	14.7
Rajshahi	36.3	32.5	50.0	45.0	37.4
Thakurgaon	32.5	42.5	50.0	25.0	35.3
All area	19.3	20.5	28.0	21.0	20.4

Crop residue retention on the top of the soil with any number of tillage modifies soil properties by increasing and stabilizing the soil moisture content, altering fertility and temperature in the topsoil layer, reducing soil erosion, nematode and sunlight incidence on the soil surface (Silva et al., 2003; Velini and Negrisoli, 2000; Vidal and Theisen, 1999). It also substantially reduces the requirement of inorganic fertilizers and brings both environmental and economic benefits to the farmers (Tiwari, 2007).

It was found that more farmers retained crop residues during *Kharif-2* season (40.0%) than *Rabi* (35.1%) and *Kharif-1* (15.6%) seasons (Table 5.12). In Mymensingh district 80% farmers retained crop residues (boro rice straw) during the *Rabi* season. Whereas, in Barguna and Khulna districts the highest percentage *i.e.* 46.7% and 58.0% farmers, respectively retained crop residues during *Kharif-1* and *Kharif-2* seasons. Table 5.12 further reveals that the highest percentage of the large category farmers retained crop residues during different cropping seasons. Regarding women managed HH, 28% farmers reported that they retained crop residues during Rabi season, 18% farmers retained it during Kharif-1 season, and 42% farmers retained it during Kharif-2 season.

Table 5.12 Retention of crop residues in the study areas

District	% of farmers responses				
	Small & marginal (n=80)	Medium (n=40)	Large (n=10)	Women managed (n=20)	All category (n=150)
A. Rabi season					
Barguna	13.8	20.0	10.0	5.0	14.0
Khulna	0.0	2.5	0.0	0.0	0.7
Mymensingh	81.3	80.0	90.0	70.0	80.0
Rajshahi	31.3	37.5	20.0	15.0	30.0
Thakurgaon	51.3	45.0	70.0	50.0	50.7
All areas	35.5	37.0	38.0	28.0	35.1
B. Kharif-1 season					
Barguna	45.0	35.0	50.0	75.0	46.7
Khulna	2.5	0.0	20.0	0.0	2.7
Mymensingh	2.5	2.5	0.0	0.0	2.0
Rajshahi	16.3	5.0	40.0	5.0	13.3
Thakurgaon	12.5	15.0	20.0	10.0	13.3
All areas	15.8	11.5	26.0	18.0	15.6
C. Kharif-2 season					
Barguna	26.3	22.5	30.0	45.0	28.0
Khulna	55.0	62.5	60.0	60.0	58.0
Mymensingh	25.0	22.5	40.0	40.0	27.3
Rajshahi	50.0	52.5	70.0	20.0	48.0
Thakurgaon	35.0	42.5	40.0	45.0	38.7
All areas	38.3	40.5	48.0	42.0	40.0

5.6 Line Sowing and Transplanting

Table 5.13 reveals that 85.5% farmers of the study areas practice line sowing/transplanting of crops. The highest level of line sowing/transplanting was reported by farmers of Mymensingh district (95.3%), followed by Rajshahi (87.3%), Thakurgaon (80.7%), Barguna (80.0%), and Khulna (79.4%) districts. Among different farm categories, percent of farmers practicing line sowing/transplanting was found more or less similar for different farm categories, slightly higher in large category (90%) and less in women managed HH (83.8%). In most cases, respondent farmers were motivated to practice line sowing/transplanting by seeing the demonstration plots conducted by the DAE.

Table 5.13 Farmers practicing line sowing/transplanting of crops in the study areas

District	% of farmers practicing				
	Marginal & small (n=400)	Medium (n=200)	Large (n=50)	Women managed (n=100)	All category (n=750)
Barguna	77.5	85.0	90.0	75.0	80.0
Khulna	81.3	77.5	80.0	75.0	79.4
Mymensingh	95.0	97.5	90.0	95.0	95.3
Rajshahi	85.0	87.5	100	90.0	87.3
Thakurgaon	76.3	85.0	100	80.0	80.7
All area	84.7	86.9	90.0	83.8	85.5

5.7 Use of Manure

Using manure in the crop field is beneficial for soil health improvement and supplying plant nutrients. The farmers who use manure in the field generally apply less amount of inorganic fertilizers (FGD, 2019). On average, 64.2% of farmers said that they used manure in their crop fields. However, there were differences among the users in different districts and farm categories. About 91.3% farmers of Thakurgaon district used manure followed by that of Rajshahi (89.3%), Mymensingh (84.7%) and Khulna (59.3%) districts (Table 5.14). But only 23.4% farmers of Barguna district used organic manure. Table 5.14 also reveals that more or less similar percentage of women managed HH (62.5%), marginal & small farmers (61.9%), medium farmers (66.9%) and large farmers (75.0%) used organic manure.

Table 5.14 Use of manure in the crop fields in the study areas

District	% of farmer responded				
	Marginal & small (n=400)	Medium (n=200)	Large (n=50)	Women managed (n=100)	All category (n=750)
Barguna	18.8	30.0	20.0	30.0	23.4
Khulna	55.0	65.0	90.0	50.0	59.3
Mymensingh	81.3	87.5	90.0	90.0	84.7
Rajshahi	92.5	85.0	100.0	80.0	89.3
Thakurgaon	87.5	97.5	80.0	100.0	91.3
All area	61.9	66.9	75.0	62.5	64.2

5.8 Knowledge on Optimum Fertilizer Dose

Optimum fertilizer dose is an important production input for attaining potential yields of the crop. Farmers in the study areas generally consider balanced fertilizer dose as a certain amount of different inorganic fertilizers to be applied to a specific crop for enhancing its proper growth for achieving higher yield (FGD, 2019). Across the study areas 24% farmers reported that they know about the optimum/recommended fertilizer dose. However, there were differences among the study areas being 32.0% farmers of Mymensingh district, 25.4% of Thakurgaon, 26% of Rajshahi, 20% of Barguna, and 16.7% of Khulna districts knew about optimum/recommended fertilizer dose (Table 5.15). There was also variation among farm categories, being 29.5% of medium farmers, 24% of large farmers, and 23.5% of marginal & small farmers knew about optimum/recommended fertilizer dose. The lowest 15% of women managed HH also knew about optimum/recommended fertilizer dose.

Table 5.15 Farmers knew about the optimum/recommended dose of fertilizers

District	% of farmer responded				
	Marginal & small (n=400)	Medium (n=200)	Large (n=50)	Women managed (n=100)	All category (n=750)
Barguna	20.0	25.0	20.0	10.0	20.0
Khulna	10.0	32.5	20.0	10.0	16.7
Mymensingh	31.3	45.0	20.0	15.0	32.0
Rajshahi	30.0	22.5	30.0	15.0	26.0
Thakurgaon	26.3	22.5	30.0	25.0	25.4
All area	23.5	29.5	24.0	15.0	24.0

5.9 Knowledge About Fertilizer Adulteration

On an average, about 26% of the respondent farmers said that they had knowledge about adulteration of fertilizer and pesticides (Table 5.16). Percentage of farmers having knowledge about adulteration of fertilizer and pesticide was a bit higher in Thakurgaon and Rajshahi districts (34% and 28.7%, respectively) than that of other districts. Percentage of farmers having knowledge about adulteration was more or less similar among different farm categories.

Table 5.16 Farmers having knowledge about adulteration of fertilizers and pesticides

District	% of farmers responded				
	Marginal & small (n=80)	Medium (n=40)	Large (n=10)	Women managed (n=20)	All category (n=150)
Barguna	31.3	15.0	20.0	25.0	25.4
Khulna	15.0	32.5	40.0	25.0	22.7
Mymensingh	16.3	20.0	30.0	25.0	19.4
Rajshahi	35.0	25.0	30.0	10.0	28.7
Thakurgaon	31.3	47.5	10.0	30.0	34.0
All area	25.8	28.0	26.0	23.0	26.0

Adulterated fertilizers do not work properly on crop growth and productivity. Many of the respondent farmers in the study areas stated this problem. Some farmers reported that they had a "very bitter" experience with adulterated urea and TSP. These adulterated fertilizers did not mix with soil or work properly, or as expected. Some farmers reported that adulterated potash (MoP) fertilizer floated on water. Some farmers also reported that DAP is adulterated by mixing with SSP. (FGD, 2019). It is clear from Table 5.17 that 33.4% of the respondent farmers of the study areas experienced that fertilizers and pesticides did not work properly as expected. About 41.3% farmers of Mymensingh district experienced this problem, which was followed by that of Rajshahi (34.0%), Thakurgaon (30.7%), Khulna (28.7%) and Barguna (32.0%) districts. Among different farm categories, 36.5% of medium farmers experienced this problem, followed by marginal & small (34.8%), large (30.0%), and women managed (23%) farmers.

Table 5.17 Farmers having experience on fertilizers and pesticides not working as expected

District	% of farmers responded				
	Marginal & small (n=80)	Medium (n=40)	Large (n=10)	Women managed (n=20)	All category (n=150)
Barguna	38.8	30.0	20.0	15.0	32.0
Khulna	27.5	35.0	20.0	25.0	28.7
Mymensingh	40.0	45.0	50.0	35.0	41.3
Rajshahi	38.8	32.5	30.0	20.0	34.0
Thakurgaon	28.8	40.0	30.0	20.0	30.7
All area	34.8	36.5	30.0	23.0	33.4

5.10 Reasons of Using Different Doses of Fertilizers

Respondent farmers applied different types of fertilizers at varying doses in crop production. They change fertilizer dose not only from season-to-season but also from area-to-area and crop-to-crop. In the study areas, about 30.67% of farmers reported that demand for a specific crop was the main reason for varying fertilizer doses in different seasons (Table 5.18). Among the other reasons, crop rotation was reported by 28.03% farmers, soil fertility variation by 17.63%, own judgment by 10.80%, over fertilization in previous crop by 4.67%, weather conditions by 4.27%, retaining crop residue on field by 1.33%, and using organic fertilizer by 1.07% farmers for varying fertilizer doses. Regarding variation among districts, more farmers from

Mymensingh and Rajshahi (43.33% and 39.33% respectively) take decision based on the demand of specific crops, whereas in Barguna and Khulna more farmers (34.69% and 30.69% respectively) take decision based on crop rotation. Soil fertility was more likely to be considered by farmers from Khulna, Mymensingh and Thakurgaon. Similar observations were reported by different categories of farmers and women managed households in the study areas (Appendix Table 4). This result is positively supported by the statement of different group of farmers participated in FGD (2019).

Table 5.18 Reasons of using different fertilizer doses in different seasons

Reasons	% of farmers responded					
	Barguna (n=150)	Khulna (n=150)	Mymensingh (n=150)	Rajshahi (n=150)	Thakurgaon (n=150)	All area (n=750)
Specific crop demand	25.36	20.67	43.33	39.33	24.69	30.67
Crop rotation	34.69	24.69	26.67	23.33	30.69	28.03
Soil fertility	12.69	25.36	28.67	--	21.36	17.63
Own judgment	12.67	7.36	11.33	11.36	11.33	10.80
Over fertilization in the previous season or crop	1.36	--	4.03	--	18.00	4.67
Weather condition	8.67	6.69	2.03	2.00	2.00	4.27
Retain crop residue on field	3.36	--	2.03	--	1.33	1.33
Use organic fertilizer	0.69	0.67	2.03	1.33	0.67	1.07

5.11 Farmers' Perceptions on Nutrient Deficiency Symptoms

Table 5.19 summarizes the responses from farmers about how they perceive nutrient deficiency symptoms in their crops. The respondent farmers of the study areas identify nutrient deficiencies in two main ways: 1) by observing leaf color of the crops, stated by 78.2% farmers; and, 2) by observing physical growth of the crop, sated by 70.3% farmers. A small number of farmers (10.7% and 8.1%) identified nutrient deficiencies with the help of SAAO/peer farmers and by observing the number of effective tillers, respectively. In Thakurgaon observing the leaf colour isn't common among medium and large farmers. Farmers of Khulna and Thakurgaon seem to be getting more advice from SAAO, some women managed farmers and large farmers in Thakurgaon do not use leaf colour to identify nutrient deficiency symptoms.

After identifying nutrient deficiency symptoms, 40.1% farmers reported that they applied more fertilizer, 28.8% farmers consulted with SAAO, 19.1% with fertilizer dealers and 13.7% with peer farmers, and a small number (5.7%) applied pesticides/PGR (Table 5.20). Looking more closely at the districts, however, there were some differences. Fertilizer application was the main action of all farmers in response to identifying nutrient deficiency symptoms, but this was more common among farmers in Khulna (49.3%), Mymensingh (48.7%), and Rajshahi (47.3%) districts. Only 29.3% of Barguna farmers and 26.0% of Thakurgaon farmers reported applying more fertilizer. In case of consulting with SAAO, the highest response was found in Thakurgaon (43.3%), with fewer farmers reporting this action in Rajshahi (16.7%), Barguna (23.4%), and Khulna (24.0%) districts. In terms of consulting with fertilizer dealers, the highest response was found in Rajshahi (32.0%). A good percentage of farmers in Thakurgaon (23.4%) and Khulna (18.7%) also reported about consultation with fertilizer dealers, but it was less common in Mymensingh (8.7%) and Barguna (12.7%). For consulting peers, in Barguna farmers this was as common or more common (27.4%) than consultation with SAAO (23.4%). In Rajshahi and Thakurgaon 10% of farmers reported consulting their peers, whereas in Mymensingh it was only 8.7%. Applying pesticides/PGR was the action taken by 14.7% of farmers in Barguna which was much higher than other study areas.

Table 5.19 Means of identification of nutrient deficiency symptoms of crops

Means of identification	% of farmers responded					
	Barguna (n=150)	Khulna (n=150)	Mymensingh (n=150)	Rajshahi (n=150)	Thakurgaon (n=150)	All Area (n=750)
A. Small & marginal (n=80)						
Observing leaf color	82.5	86.3	83.8	81.3	97.5	86.3
Physical growth of crop	73.8	77.5	81.3	72.5	57.5	72.5
Tillering condition	18.8	8.8	15.0	7.5	8.8	11.8
Assistance of SAAO/Peer farmers	2.5	11.3	5.0	10.0	8.8	7.5
B. Medium farmer (n=40)						
Observing leaf color	85.0	90.0	87.5	95.0	50.0	81.5
Physical growth of crop	97.5	85.0	70.0	65.0	92.5	82.0
Tillering condition	12.5	10.0	10.0	7.5	7.5	9.5
Assistance of SAAO/Peer farmers	5.0	2.5	7.5	0.0	12.5	5.5
C. Large farmer (n=10)						
Observing leaf color	80.0	100.0	90.0	90.0	0.0	72.0
Physical growth of crop	90.0	30.0	70.0	40.0	100.0	66.0
Tillering condition	30.0	10.0	20.0	20.0	20.0	20.0
Assistance of SAAO/Peer farmers	0.0	0.0	10.0	10.0	50.0	14.0
D. Women managed (n=20)						
Observing leaf color	15.0	65.0	100.0	5.0	100.0	57.0
Physical growth of crop	75.0	65.0	60.0	70.0	0.0	54.0
Tillering condition	15.0	0.0	0.0	5.0	10.0	6.0
Assistance of SAAO/Peer farmers	0.0	35.0	0.0	25.0	25.0	17.0
E. All category (n=150)						
Observing leaf color	73.5	83.2	84.0	75.2	75.3	78.2
Physical growth of crop	78.8	72.5	72.7	65.7	62.0	70.3
Tillering condition	16.8	8.0	12.0	7.8	9.0	10.7
Assistance of SAAO/Peer farmers	2.7	10.2	5.3	8.5	13.8	8.1

Table 5.20 further highlights the different actions taken by different types of farmers' and women managed households varied to some extent. The highest percentage of large farmers (56%) applied more fertilizer to their crops after identifying nutrient deficiencies, and this response was much lower for women managed households (36%) and small & marginal farmers (40%). The percentage of farmers consulting with SAAO were more or less similar for small & marginal farmer, large farmer, and women managed households. The highest percentage of women managed households (20%) consulted with peer farmers and the lowest number of large farmers (6%) in the study areas. Medium category farmers consult with fertilizer dealers more than other categories of farmers.

Table 5.20 Type of actions taken after identifying nutrient deficiency symptoms

Type of action	% of farmers responded					
	Barguna (n=150)	Khulna (n=150)	Mymensingh (n=150)	Rajshahi (n=150)	Thakurgaon (n=150)	All Area (n=750)
A. Small & Marginal (n=80)						
Apply more fertilizer	27.5	42.5	51.3	47.5	31.3	40.0
Consult with SAAO	23.8	21.3	35.0	25.0	45.0	30.0
Consult with fertilizer dealers	10.0	27.5	10.0	30.0	21.3	19.8
Consult with peer farmers	18.8	13.8	10.0	10.0	12.5	13.0
Apply pesticides/PGR	21.3	0.0	1.3	7.5	0.0	6.0
B. Medium (n=40)						
Apply more fertilizer	30.0	57.5	37.5	47.5	20.0	38.5
Consult with SAAO	17.5	25.0	37.5	10.0	40.0	26.0
Consult with fertilizer dealers	15.0	12.5	12.5	35.0	30.0	21.0
Consult with peer farmers	47.5	7.5	5.0	7.5	2.5	14.0
Apply pesticides/PGR	0.0	12.5	2.5	5.0	0.0	4.0

Table 5.20 Continued……..

Type of action	% of farmers responded					
	Barguna (n=150)	Khulna (n=150)	Mymensingh (n=150)	Rajshahi (n=150)	Thakurgaon (n=150)	All Area (n=750)
Apply more fertilizer	40.0	90.0	60.0	60.0	30.0	56.0
Consult with SAAO	50.0	10.0	40.0	0.0	50.0	30.0
Consult with fertilizer dealers	10.0	0.0	0.0	30.0	20.0	12.0
Consult with peer farmers	10.0	0.0	0.0	20.0	0.0	6.0
Apply pesticides/PGR	0.0	0.0	0.0	20.0	0.0	4.0
D. Women managed (n=20)						
Apply more fertilizer	30.0	40.0	55.0	40.0	15.0	36.0
Consult with SAAO	20.0	40.0	40.0	5.0	40.0	29.0
Consult with peer farmers	30.0	25.0	15.0	10.0	20.0	20.0
Consult with fertilizer dealers	20.0	5.0	0.0	35.0	20.0	16.0
Apply pesticides/PGR	25.0	5.0	10.0	5.0	0.0	9.0
E. All category (n=150)						
Apply more fertilizer	29.3	49.3	48.7	47.3	26.0	40.1
Consult with SAAO	23.4	24.0	36.7	16.7	43.3	28.8
Consult with fertilizer dealers	12.7	18.7	8.7	32.0	23.4	19.1
Consult with peer farmers	27.4	12.7	8.7	10.0	10.0	13.7
Apply pesticides/PGR	14.7	4.0	2.7	7.3	0.0	5.7

5.12 Mode of Payment for Purchasing Inputs

Respondent farmers purchased various inputs such as seed, fertilizers, pesticides, plant growth regulators (PGR) and irrigation water for crop production. About 59% of the respondent farmers stated that they purchased inputs using a combination of cash and credit, followed by cash only (38.93%). Credit only purchases were not common (2.4%), likely because credit purchases result in a higher price of the inputs (Table 5.21). The most farmers in Thakurgaon district (76.64%) purchased inputs using a combination of cash and credit, and the most farmers in Barguna district (50.61%) purchased inputs using only cash. Farmer's category revealed that the highest proportion of women managed farms (70%) purchased inputs using both cash and credit followed by large (62%) and marginal & small category farmers (59.5%).

Table 5.21 Mode of payment for purchasing inputs in the study areas

Payment mode	% of farmers responded					
	Barguna (n=150)	Khulna (n=150)	Mymensingh (n=150)	Rajshahi (n=150)	Thakurgaon (n=150)	All Area (n=750)
A. Marginal & small	*n=80*	*n=80*	*n=80*	*n=80*	*n=80*	*n=400*
Credit	1.3	2.4	3.8	-	2.5	2.0
Cash	52.4	43.8	47.4	32.5	16.3	38.5
Both	46.3	53.8	48.8	67.5	81.2	59.5
B. Medium	*n=40*	*n=40*	*n=40*	*n=40*	*n=40*	*n=200*
Credit	2.5	5.0	5.0	2.5	5.0	4.0
Cash	60.0	47.5	52.5	40.0	27.5	45.5
Both	37.5	47.5	42.5	57.5	67.5	50.5
C. Large	*n=10*	*n=10*	*n=10*	*n=10*	*n=10*	*n=50*
Credit	-	10.0	-	-	-	2.0
Cash	20.0	10.0	60.0	60.0	30.00	36.0
Both	80.0	80.0	40.0	40.0	70.0	62.0
D. Women managed	*n=20*	*n=20*	*n=20*	*n=20*	*n=20*	*n=100*
Credit	-	-	-	-	5.0	1.0
Cash	40.0	20.0	35.0	35.0	15.0	29.0
Both	60.0	80.0	65.0	65.0	80.0	70.0
E. All category	*n=150*	*n=150*	*n=150*	*n=150*	*n=150*	*n=750*
Credit	1.36	3.28	3.36	0.67	3.33	2.40
Cash	50.61	39.36	47.95	36.67	20.03	38.93
Both	48.03	57.36	48.69	62.67	76.64	58.67

5.13 Selection Criteria of Input Dealer

The rural input dealers in Bangladesh are working as agricultural extension agents and provide information on fertilizer use, agricultural innovations, and knowledge to resource poor farmers. Farmers are increasingly relying on traders' suggestions for fertilizer use rather than public extension (Mottaleb et al., 2017). Therefore, the selection of a good input dealer can be crucial to the farmers as inputs are the base unit of production.

In selecting input dealers, farmers in the study areas gave emphasis to different criteria (Table 5.22). In the study areas overall, 47% of the respondent farmers said that while selecting an input dealer they give priority to good social relationship followed by capacity for them to provide advice about the quality and right dose of inputs (32.6%). However, Khulna, Mymensingh and Thakurgaon farmers prioritized on social relations, whereas farmers from Barguna and Rajshahi prioritized on the dealers' capacity to provide advice on the quality and right dose of inputs. Table 5.22 further revealed that women managed households put greater and equal emphasis on social relationships (41%) and the capacity of dealers (41%) to provide advice on quality and right dose of inputs. The small & marginal farmers in the study areas gave the lowest emphasis on credit sale of inputs in selecting input dealers and vice versa for large category farmers.

Table 5.22 Distribution of farmers according to input dealer selection

Selection criteria	% of farmers responded					
	Barguna (n=150)	Khulna (n=150)	Mymensingh (n=150)	Rajshahi (n=150)	Thakurgaon (n=150)	All Area (n=750)
A. Small & marginal (n=80)						
Social relation	26.1	55.0	55.0	32.5	71.3	48.0
Capacity to advice on input	46.3	26.2	27.5	52.4	13.7	33.3
Competitive price	21.2	8.8	12.5	6.3	10.0	11.7
Credit sale	6.3	10.0	5.0	8.8	5.0	7.0
B. Medium (n=40)						
Social relation	27.5	52.5	67.5	42.5	47.5	47.5
Capacity to advice on input	35.0	30.0	17.5	45.0	30.0	31.5
Competitive price	17.5	5.0	10.0	7.5	15.0	11.0
Credit sale	20.0	12.5	5.0	5.0	7.5	10.0
C. Large (n=10)						
Social relation	30.0	40.0	60.0	60.0	60.0	50.0
Capacity to advice on input	20.0	10.0	10.0	30.0	0.0	14.0
Competitive price	20.0	0.0	30.0	10.0	40.0	20.0
Credit sale	30.0	50.0	0.0	0.0	0.0	16.0
D. Women managed (n=20)						
Social relation	25.0	50.0	45.0	30.0	55.0	41.0
Capacity to advice on input	50.0	35.0	45.0	50.0	25.0	41.0
Competitive price	10.0	0.0	0.0	15.0	10.0	7.0
Credit sale	15.0	15.0	10.0	5.0	10.0	11.0
E. All category (n=150)						
Social relation	26.6	52.7	57.3	36.7	62.0	47.1
Capacity to advice on input	42.0	27.3	26.0	48.6	18.6	32.6
Competitive price	18.6	6.0	11.3	8.0	13.3	11.4
Credit sale	12.7	14.0	5.3	6.7	6.0	8.9

5.14 Nutrient Use Gaps and Profitability of *Boro* Rice Production

This study has attempted to determine the usage patterns of different fertilizers in *Boro* rice production at the farm level. Attempts have also been made to assess the nutrient use gaps, crop productivity and profitability of *Boro* rice in the study areas.

5.14.1 Fertilizer use and its gap in *Boro* rice production

Boro is one of the most important winter season irrigated rice crops in Bangladesh. Its seeding time starts from November and continues up to mid-January. Its seedling transplantation generally starts from December and harvest completed mostly within May. It significantly contributes to the total food grain production in Bangladesh. According to the national estimates (BBS, 2019), the total volume of rice grains production in 2017-18 stood at 362.78 lakh MT, of which *Boro* rice accounted for 195.76 lakh MT (53.96%) from 4.86 million hectares.

Farmers in the study areas use different types of fertilizers and manure for growing *Boro* rice. Table 5.23 reveals that irrespective of study areas, they used a lower dose of urea, MoP, Gypsum and $ZnSO_4$, and an over dose of TSP, Boron, and $MgSO_4$ fertilizers in *Boro* rice cultivation compared to recommended dose. Similar trend in fertilizer use were found in Mymensingh and Rajshahi districts. Thakurgaon farmers used lower doses of all types of fertilizers except Boron (Table 5.23).

Table 5.23 reveals that on an average farmers of the study areas use 44.7 kg/ha less urea compared to recommended dose (325 kg/ha). It might be mentioned that farmers use 103 kg of TSP+DAP as basal dose during final land preparation as the source of phosphorus. The DAP contains 18% N in addition to 20% P. That means, 100 kg of DAP contains N equivalent to 39 kg of urea. For this whenever farmers use DAP they avoid first topdressing of urea and use two topdressings instead of three topdressing of urea. In other words, the application of DAP as basal dose can supplement one-third of urea required for *Boro* rice cultivation. For that apparently the use of urea seems to be lower but in reality the crop gets much of this lower amount from DAP. So the apparent gap between recommended dose and farmers' dose of urea for *Boro* rice cultivation is not the real gap.

Most of the farmers of Thakurgaon grow potato widely before *Boro* rice and use about 2 times higher doses of almost all the major fertilizers (Table 5.36). Farmers of Rajshahi widely grow potato and mustard before *Boro* rice, in which they also use very high doses of all the major fertilizers. Huge amount of these excess fertilizers in both the areas retain in the soil as residues and can be used by the following *Boro* rice crops. This leads the farmers of those areas to use lesser amount of all the major fertilizers in the following *Boro* rice crop. So the apparent gap between recommended dose and farmers' dose of MoP and Gypsum for *Boro* rice cultivation is not the real gap.

Table 5.23 Current fertilizer using gaps between farmer's practice and scientific recommended dose (kg/ha) in *Boro* rice cultivation

Fertilizer	Mymensingh *(n=133)*		Rajshahi *(n=69)*		Thakurgaon *(n=55)*		All area *(n=257)*	
	Farmer's practice	Gap	Farmer's practice	Gap	Farmer's practice	Gap	Farmer's practice	Gap
Urea	273.2	-51.8	293.5	-31.5	281.0	-44.0	280.3	-44.7
TSP+DAP	101.8	1.8	122.1	22.1	82.2	-17.8	103.1	3.1
MoP	90.9	-39.1	93.9	-36.1	102.4	-27.6	94.2	-35.8
Gypsum	29.2	-70.8	48.3	-51.7	28.2	-71.8	34.1	-65.9
Boron	1.5	1.5	3.8	3.8	1.6	1.6	2.1	2.1
ZnSO4	1.5	-4.5	4.7	-1.3	1.9	-4.1	2.4	-3.6
MgSO4	0.1	0.1	2.6	2.6	0.8	0.8	0.9	0.9
Manure	2678	NA	2988	NA	3542	NA	2946	NA

Note: Recommended dose (kg/ha): Urea=325, TSP=100, MoP=130, Gypsum=100, ZnSo4=6 (FRG, 2012)
In Gap column, '+' sign indicates over use and '-' sign indicates under use of nutrients

5.14.2 Nutrient application gaps in *Boro* rice production

Irrespective of farmers' category and study areas, the respondent *Boro* farmers applied different soil nutrients like N, K, S, and Zn in slightly lower doses than that of recommendations. They only applied an over dose of P which was slightly higher compared to the recommendation. If we look into three different study areas, we can perceive that the respondent farmers of Mymensingh apply much lower amount of N, K, and S compared to the farmers of other two areas. It is clearly observed in farmer's category that women managed farms followed by marginal & small category farmers applied lower amounts of N, K, S and Zn compared to medium and large category farmers. Large category farmers applied all the nutrients at higher dose except S compared to scientific recommendations (Table 5.23).

5.14.3 Productivity and profitability of *Boro* rice production

The productivity of a crop depends on many factors such as time of sowing, seed quality, variety, crop protection, intercultural operations, weather, rate of manure and fertilizer use, inherent soil fertility, and so on. In the study areas the average yield of *Boro* rice was 6.18 t/ha which was much higher than that of national average of 4.02 t/ha (BBS, 2019). The highest yield was reported in Thakurgaon and the lowest was in Mymensingh district.

The average cost of *Boro* rice production was Tk. 1,09,264 (ca. AUD 1850/USD 1300) per hectare, of which the share of variable cost was 74.8% and the rest (25.2%) was fixed cost. Labour costs incurred the highest share (38.1%) of total cost followed by manure & fertilizer (11.3%) and irrigation (Table 5.25). *Boro* rice is reported to be a profitable crop in the study areas. The average gross return and net profit were estimated at Tk. 1,26,568 and Tk. 17,304 (ca. AUD 295/USD 208) respectively. The overall rate of return (BCR) was 1.16. The lowest net return was received by Mymensingh farmers and the highest net returns were received by Rajshahi farmers. The reasons behind receiving lower net profit were higher cost of production, lower yield and lower selling price of the output (Table 5.26)

Table 5.24 Current nutrient using gaps between farmer's practice and scientific recommendation (kg/ha) in *Boro* rice cultivation

Nutrients	Mymensingh		Rajshahi		Thakurgaon		All area	
	FP	Gap	FP	Gap	FP	Gap	FP	Gap
A. Marginal & small	*n=69*		*n=39*		*n=31*		*n=139*	
N	137.1	-12.9	145.1	-4.9	134.7	-15.3	138.8	-11.2
P	24.1	4.1	27.0	7.0	21.6	1.6	24.4	4.4
K	47.9	-17.1	50.5	-14.5	59.2	-5.8	51.1	-13.9
S	5.1	-12.9	9.9	-8.1	5.6	-12.4	6.6	-11.4
Zn	0.4	-0.9	0.9	-0.4	0.6	-0.7	0.6	-0.7
B. Medium	*n=37*		*n=20*		*n=13*		*n=70*	
N	145.8	-4.2	155.3	5.3	148.2	-1.8	149.0	-1.04
P	26.6	6.6	33.1	13.1	28.8	8.8	28.9	8.9
K	58.5	-6.5	58.4	-6.6	68.7	3.7	60.4	-4.6
S	7.6	-10.4	12.2	-5.8	8.4	-9.6	9.1	-8.9
Zn	0.7	-0.6	1.4	0.1	1.0	-0.3	1.0	-0.3
C. Large	*n=9*		*n=4*		*n=3*		*n=16*	
N	157.5	7.5	161.6	11.6	155.2	5.2	158.1	8.1
P	31.1	11.1	35.7	15.7	27.7	7.7	31.6	11.6
K	63.8	-1.2	67.6	2.6	70.8	5.8	66.1	1.1
S	13.5	-4.5	16.7	-1.3	16.2	-1.8	14.8	-3.2
Zn	1.3	0.3	2.4	1.1	1.5	0.2	1.6	0.5
D. Women managed	*n=18*		*n=6*		*n=8*		*n=32*	
N	126.3	-23.7	133.4	-16.6	132.6	-17.4	129.2	-20.8
P	19.8	-0.2	25.5	5.5	17.3	-2.7	20.2	0.2
K	47.6	-17.4	49.5	-15.5	53.7	-11.3	49.5	-15.5
S	5.5	-12.5	6.5	-11.5	6.6	-11.4	6.0	-12.0
Zn	0.3	-1.0	0.6	-0.7	0.2	-1.1	0.3	-1.0
E. All category	*n=133*		*n=69*		*n=55*		*n=257*	
N	139.4	-10.6	148.0	-2.0	138.7	-11.3	141.6	-8.4

Table 5.24 Continued……..

Nutrients	Mymensingh		Rajshahi		Thakurgaon		All area	
	FP	Gap	FP	Gap	FP	Gap	FP	Gap
P	24.7	4.7	29.1	9.1	23.0	3.0	25.5	5.5
K	51.9	-13.1	53.7	-11.3	61.3	-3.7	54.4	-10.6
S	6.4	-11.6	10.7	-7.3	7.0	-11.0	7.7	-10.3
Zn	0.5	-0.7	1.1	-0.2	0.7	-0.6	0.7	-0.6

Note: Recommended dose (kg/ha): N=150, P=20, K=65, S=12, for Thakurgaon s=18, Zn=1.3 (FRG, 2012)

'+' sign indicates over use and '-' sign indicates under use of nutrients

FP = Farmer's practice

Table 5.25 Per hectare cost of *Boro* rice production in the study areas

Particulars	Mymensingh (*n=133*)	Rajshahi (*n=69*)	Thakurgaon (*n=55*)	All area (*n=257*)
A. Variable cost (Tk/ha)	**83671**	**85841**	**72080**	**81773 (74.8)**
Human labour	44933	41941	33452	41673 (38.1)
Land preparation	6454	6530	6864	6562 (6.0)
Seed	2505	2615	2517	2537 (2.3)
Fertilizer	**9839**	**12026**	**8859**	**10217 (9.3)**
Urea	4536	4952	4271	4591 (4.2)
TSP	1833	2619	1962	2072 (1.9)
DAP	1192	941	105	892 (0.8)
MoP	1481	1502	1600	1512 (1.4)
Gypsum	356	567	365	415 (0.4)
ZnSO4	233	724	286	376 (0.3)
MgSO4	3	103	23	34 (0.0)
Boric Acid	205	618	247	325 (0.3)
Manure	1950	2180	2606	2152 (2.0)
Pesticides	2486	3573	3174	2925 (2.7)
Irrigation	11262	13320	10775	11710 (10.7)
Threshing	4242	3656	3833	3997 (3.7)
B. Fixed cost (Tk/ha)				
Land use cost	27788	28158	25935	27491 (25.2)
C. Total Cost (A+B)	**111459**	**113999**	**98015**	**109264 (100)**

Note: Figures in the parentheses are percentage of total cost

Table 5.26 Profitability (Tk/ha) of *Boro* rice production

Particulars	Mymensingh (*n=133*)	Rajshahi (*n=69*)	Thakurgaon (*n=55*)	All area (*n=257*)
Variable cost (VC)	83671	85841	72080	81773
Fixed cost (FC)	27788	28158	25935	27491
Total cost (TC)	111459	113999	98015	109264
Average yield (t/ha)	5.92	6.21	6.76	6.18
Average price (Tk./ton)	19197	19819	16966	18887
Return from grain	113646	123076	114690	116674
Return from by-product	10884	12869	3766	9894
Gross return (GR)	124530	135945	118456	126568
Gross margin (GR-VC)	40859	50104	46376	44795
Net profit (GR-TC)	13071	21946	20441	17304
Benefit cost ratio (BCR)				
BCR over VC	1.49	1.58	1.64	1.55
BCR over TC	1.12	1.19	1.21	1.16

5.15 Nutrient Use Gaps and Profitability of *T.Aus* Rice Production

5.15.1 Fertilizer use and nutrients gap in HYV *T.Aus* rice production

Transplanted *Aus* (*T. Aus*) is a less cultivated *Kharif-1* season (March-August) rainfed/ irrigated rice crop in Bangladesh. The government of Bangladesh has been trying to increase the area of this crop because of less requirement of irrigation water and better utilization of current fallow lands throughout the country. Its seeding time starts from late March and continues until late May. The seedling transplantation of this rice generally starts from mid-April and harvests completed between mid-July to mid-August depending on variety and transplanting time. It contributes little to the total food grain production in Bangladesh. The total volume of rice grains production in 2017-18 stood at 362.78 lakh MT of which *T. Aus* accounted for 27.10 lakh MT (7.47%) from 1.08 million hectares of lands (BBS, 2019).

Among the five study areas, only the respondent farmers of Barguna district cultivated *T. Aus* rice. The respondent farmers applied both organic and inorganic fertilizers in cultivating *T. Aus* rice. They applied an over dose of TSP and MoP by 14.5 kg and 4.1 kg per hectare respectively. Use of nitrogenous fertilizers including DAP was found very close to the recommended dose, though apparently the rate of urea application was found a bit lower. However, farmers used a lower dose of Gypsum and ZnSO4 by 15.2 kg and 2.2 kg per hectare respectively. Manure was also reported to be used to some extent although it was not recommended for *T. Aus* cultivation (Table 5.27).

Table 5.27 Current fertilizer using gaps between farmer's practice and scientific recommended dose in *T. Aus* rice cultivation in Barguna district

Fertilizer	Amount of fertilizer (kg/ha)		
	Farmer's practice (n=83)	Recommendation	Gap
Urea	138.9	141	-2.1
TSP+DAP	64.5	50	14.5
MoP	28.1	24	4.1
Gypsum	1.8	17	-15.2
$ZnSO_4$	0.4	2.6	-2.2
Manure	249	NA	249

Note: '+' sign indicates over use and '-' sign indicates under use of nutrients

5.15.2 Nutrient application gaps in *T. Aus* rice production

Irrespective farmers' category, the respondent farmers applied an over dose of P and K, and slightly lower dose of N, S, and Zn compared to their corresponding scientific recommendations. Again, the large category farmers applied all the nutrients at higher dose compared to recommended rates. Similarly, women managed farm households applied lower amounts of all types of nutrients except P. More or less similar using patterns were observed by the marginal and small category farmers in the study areas (Table 5.28).

5.15.3 Productivity and profitability of HYV *T. Aus* rice production

The average cost of *T. Aus* rice production was estimated at Tk. 78,627 (AUD 1335 / USD 944) per hectare of which the share of variable cost was 71.73% and the rest 28.27% was fixed cost. In terms of the various inputs, labour costs incurred the highest share (39.73%) of total cost followed by land preparation (9.49%), manure & fertilizer (6.46%) and irrigation (Table 5.29). For *T. Aus* rice cultivation, farmers in the study areas have to prepare fallow lands (for about 4-5 months) after *T. Aman* harvest. The preparation of these fallow lands needs higher number of tillage that increases the cost of land preparation.

The average yield of *T. Aus* rice was reported to be 3.99 t/ha in the study areas which was higher than the national average of 2.51 t/ha (BBS, 2019). *T. Aus* rice is reported to be a profitable crop in the study areas when only the cash cost is considered. The average gross return and gross margin were estimated at Tk. 78,528 (ca. AUD 1339/ USD 943) and Tk. 22,131 (ca. AUD 377.3/ USD 265.7) respectively. It is difficult to make *T. Aus* rice production profitable if all types of costs are considered. The benefit cost ratios (BCRs) on cash cost and full cost basis were 1.39 and 0.999 respectively (Table 5.30). The main reasons for producing negative return were lower yield, lower price of output and higher cost of land preparation compared to *Boro* and *T.Aman* rice.

Table 5.28 Current nutrient application and nutrient using gaps between farmer's practice and scientific recommendation in *T. Aus* rice cultivation in Barguna district

Nutrient element	Marginal & small *(n=48)*	Medium *(n=16)*	Large *(n=5)*	Women-managed *(n=14)*	All category (n=83)
A. Farmer's practice (kg/ha)					
N	60.0	76.1	73.7	55.5	63.2
P	13.0	15.0	17.9	11.2	13.4
K	12.3	18.0	26.6	10.6	14.0
S	1.0	1.8	3.3	0.6	1.2
Zn	0.2	0.3	0.7	0.1	0.2
B. Gap (kg/ha)					
N	-5.0	11.0	8.7	-9.5	-1.8
P	3.0	5.0	7.9	1.2	3.4
K	0.3	6.0	14.6	-1.4	2.0
S	-2.0	-1.2	0.3	-2.4	-1.8
Zn	-0.4	-0.3	0.1	-0.5	-0.4

Note: Recommended dose (kg/ha): N=65, P=10, K=12, S=3, Zn=0.6 (FRG, 2012)
'+' sign indicates over use and '-' sign indicates under use of nutrients

Table 5.29 Per hectare cost of *T. Aus* rice production at Barguna district

Particulars	Cost (Tk/ha)	% of total cost
A. Variable cost	**56397**	**71.73**
Human labour	31241	39.73
Land preparation	7461	9.49
Seed	2476	3.15
Fertilizers	**4892**	**6.22**
Urea	2479	3.15
TSP	1744	2.22
DAP	96	0.12
MoP	462	0.59
Gypsum	38	0.05
$ZnSO_4$	73	0.09
Manure	187	0.24
Pesticides	2628	3.34
Irrigation	4672	5.94
Threshing	2840	3.61
B. Fixed Cost		
Land use cost	22230	**28.27**
C. Total Cost (A+B)	**78627**	**100.00**

Table 5.30 Profitability of *T. Aus* Rice production at Barguna district

Particulars	Amount (Tk/ha)
Variable cost (VC)	56397
Fixed cost (FC)	22230
Total cost (VC+FC)	78627
Average yield (t/ha)	3.99
Average price (Tk./ton)	18075
Return from grain	72119
Return from by product	6409
Gross return (GR)	78528
Gross margin (GR-VC)	22131
Net profit (GR-TC)	-99
Benefit cost ratio (BCR)	
BCR over VC	1.39
BCR over TC	0.999

5.16 Nutrient Use Gaps and Profitability of *T. Aman* Rice Production

5.16.1 Fertilizer use and its gap in *T. Aman* rice production

Transplanted Aman (*T. Aman*) rice is an important and most widely grown crop in *Kharif-2* season (July- November) under rain-fed condition in Bangladesh. Its seeding time starts from late June and continues up to late August. Optimum time for its seedling transplantation is mid-July to mid-August and harvest duration generally continues from mid-November to mid-December. It also significantly contributes to the total food grain production in Bangladesh. In 2016-17, the total volume of rice grains production was 362.78 lakh MT of which the share of *T. Aman* rice was estimated at 139.93 lakh MT (35.29%) from 5.68 million hectares (BBS, 2019).

Farmers in the study areas used different types of fertilizers and cow dung manure in cultivation of *T. Aman* rice. Apparently, the farmers of the study areas seems to use a lower dose of urea (30.4 kg lower per ha), MoP (11.9 kg), Gypsum (37.9 kg), and ZnSO4 (2.9 kg) compared to the recommended doses and over dose of TSP (Table 5.31). In addition, all the respondent farmers used on average 931 kg of cow dung manure in their rice field. Similar trends of using different fertilizers were found in all study areas with a slight exception in Mymensingh and Thakurgaon districts, where farmers reported a lower dose of TSP fertilizer (Table 5.31).

Farmers stated various reasons for applying a lower dose of fertilizers in *T. Aman* rice cultivation. The reasons were (i) applying more fertilizer can make the rice plant grow taller and that may create lodging problem, (ii) if you use more fertilizer in Boro season it might have some residual effects on *T.Aman* rice field and therefore less fertilizer is needed, (iii) an over dose of fertilizer may cause blight diseases, and (iv) retention of rice straw in Boro season may improve soil fertility in *T.Aman* season.

It might be mentioned that farmers use high/over doses of fertilizers in most of the *Rabi* crops, especially for high value crops as also have been found for the case of potato and watermelon in this study (Table 5.36 and 5.44, respectively). All the fertilizers (except urea) leave significant amount of residues in the field, which is used by the following crops grown in Kharif seasons. Farmers of the study areas also have idea about such residual effects, which is clear from their above statement (ii). Again, the use of DAP is gradually increasing in the country including the study areas, which contains 18% N in addition to 20%P. Farmers of the study areas also know about N content in DAP. For such knowledge and knowledge on other related issues as mentioned in above statements (i, iii & ii) farmers use a bit lower doses of all the fertilizers in *T. Aman* rice compared to recommended doses using their own judgment.

It may also be mentioned that there are two types of recommendation in Fertilizer Recommendation Guide. One is for single crops based on soil test results and the other is on cropping pattern basis. In the cropping pattern based fertilizer recommendation *Rabi* crops are considered as the first crop and full doses of all the fertilizers are recommended for the *Rabi* crops. For the Kharif season crops grown after *Rabi* crops, the rate of application of all the major fertilizers except urea is reduced by 20-40% based on certain principles. This indicates that recommended doses of fertilizers (except urea) for *Kharif* season crops are lower compared to soil test based recommendation for single crops. In this study soil test based fertilizer recommendation for single crops has been used both for *Rabi* and *Kharif* season crops for comparison with the farmers' doses. Because of wide variety of crop combinations in the cropping patterns recommended doses for cropping patterns could not be used. This indicates that farmers' fertilizer dose for a certain Kharif crop has been compared with the higher recommended doses based on soil test results for the crop. Because of these reasons apparently fertilizer use gaps seems to be bigger. In reality the crops get nutrients from different sources like direct application of fertilizer and residual effect of fertilizers applied in the previous crops. As a result, in respect of crop requirement the gaps are not so wide. Crops meet their N requirement from basal application of DAP and from topdressing of urea.

Table 5.31 Current fertilizer using gaps between farmer's practice and scientific recommended dose (kg/ha) in *T.Aman* rice cultivation

Fertilizer	Barguna (*n=149*)		Khulna (*n=150*)		Mymensingh (*n=143*)		Rajshahi (*n=140*)		Thakurgaon (*n=150*)		All areas (*n=732*)	
	FP	Gap	FP	Gap	FP	Gap	FP	Gap	FP	Gap	FP	Gap
Urea	154.6	-40.4	153.5	-41.5	160.9	-34.1	184.4	-10.6	170.8	-24.2	164.6	-30.4
TSP+DAP	60.1	10.1	60.6	10.6	37.0	-13.0	51.3	1.3	46.6	-3.4	51.2	1.2
MoP	25.9	-10.1	37.4	1.4	37.1	-32.9	62.5	-7.5	59.1	-10.9	44.2	-11.9
Gypsum	1.7	-20.3	5.4	-16.6	10.4	-56.6	29.4	-37.6	8.0	-59.0	10.7	-37.9
ZnSO4	0.3	-4.1	2.2	-2.15	0.7	-3.65	3.2	-1.2	0.8	-3.55	1.4	-2.9
$MgSO_4$	--	--	--	--	--	--	1.2	1.2	--	--	0.23	0.23
Boron	--	--	0.3	0.3	0.4	0.4	2.1	2.1	0.5	0.5	0.64	0.64
Manure	814	NA	953	NA	930	NA	1089	NA	880	NA	931	NA

Note: Recommended dose (kg/ha): Urea=195, TSP=50, MoP=36 (for Barguna & Khulna) and 70 (for Mymensingh, Rajshahi, Thakurgaon), Gypsum= 22 (for Barguna & Khulna), 67 (for Mymensingh & Rajshahi) & 56 for Thakurgaon), ZnSo4=4.35 (FRG, 2012)

In Gap column, '+' sign indicates over use and '-' sign indicates lower use of nutrients

5.16.2 Nutrient application gaps in *T.Aman* rice production

Respondent *T. Aman* farmers used different types of soil nutrients in *T.Aman* rice cultivation (Table 5.32). Irrespective of farmers' category and study areas, they applied different types of soil nutrients namely N, K, S, and Zn at slightly lower doses than that of recommendations. They only used an over dose of P slightly higher than that of the recommendation. If we look into five study areas, we can see that the respondent farmers of Khulna have applied a slight over dose of P and K compared to the recommendations. In Mymensingh, all the respondent farmers have applied lower amounts of soil nutrients compared to recommendations. Again, if we look into the farmer's category we can see that women managed farms and marginal & small category farmers have applied lower amounts of all nutrients and large category farmers have applied all the nutrients at higher dose except S and Zn compared to scientific recommendations (Table 5.33).

Table 5.32 Status of current nutrient application (kg/ha) in *T.Aman* rice cultivation

Nutrients	Barguna (n=149)	Khulna (n=150)	Mymensingh (n=143)	Rajshahi (n=140)	Thakurgaon (n=150)	All areas (n=732)
A. Marginal & small	*n=80*	*n=80*	*n=75*	*n=73*	*n=80*	*n=388*
N	70.4	71.0	75.4	83.2	77.7	75.4
P	11.5	12.3	6.9	8.9	11.5	10.2
K	9.8	19.7	19.3	29.2	28.7	21.3
S	0.9	1.6	1.6	5.5	1.5	2.2
Zn	0.1	0.5	0.2	0.6	0.2	0.3
B. Medium	*n=40*	*n=40*	*n=40*	*n=39*	*n=40*	*n=199*
N	76.6	79.7	78.8	98.3	81.8	83.0
P	14.9	16.4	8.4	15.7	14.9	14.1
K	16.8	21.3	24.2	37.8	34.0	26.8
S	1.3	2.2	2.8	7.3	3.1	3.3
Zn	0.4	0.7	0.3	0.8	0.4	0.5
C. Large	*n=10*	*n=10*	*n=9*	*n=10*	*n=10*	*n=49*
N	84.5	85.3	87.3	96.8	93.7	89.6
P	16.2	15.0	14.9	15.8	18.0	16.0
K	22.1	24.6	30.5	44.6	39.2	32.2
S	3.3	3.1	5.9	10.8	7.9	6.2
Zn	0.7	0.8	0.9	0.9	0.8	0.8
D. Women managed	*n=19*	*n=20*	*n=19*	*n=18*	*n=20*	*n=96*
N	65.5	63.9	71.1	78.8	73.7	70.5
P	9.5	7.8	5.3	5.6	6.4	6.9
K	9.7	16.4	18.9	25.6	26.9	19.5
S	0.7	1.8	1.3	2.3	1.2	1.5
Zn	0.1	0.3	0.2	0.4	0.2	0.2
E. All category	*n=149*	*n=150*	*n=143*	*n=140*	*n=150*	*n=732*
N	72.4	73.8	73.4	82.5	79.9	76.4
P	12.5	13.0	7.6	10.9	12.2	11.2
K	12.5	20.0	21.3	32.2	30.6	23.3
S	1.1	1.9	2.2	6.0	2.3	2.7
Zn	0.2	0.5	0.3	0.7	0.3	0.4

Table 5.33 Current nutrient using gaps between farmer's practice and scientific recommendation (kg/ha) in *T. Aman* rice cultivation

Nutrients	Barguna (n=149)	Khulna (n=150)	Mymensingh (n=143)	Rajshahi (n=140)	Thakurgaon (n=150)	All areas (n=732)
A. Marginal & small	n=80	n=80	n=75	n=73	n=80	n=388
N	-19.6	-19.0	-14.6	-6.8	-12.3	-14.6
P	1.5	2.3	-3.1	-1.1	-0.9	-0.3
K	-8.2	1.7	-15.7	-5.8	-6.3	-6.9
S	-3.1	-2.4	-10.4	-6.5	-8.5	-6.2
Zn	-0.9	-0.5	-0.8	-0.4	-0.8	-0.7
B. Medium	n=40	n=40	n=40	n=39	n=40	n=199
N	-13.4	-10.3	-11.2	8.3	-8.2	-7.0
P	4.5	6.4	-1.6	5.7	1.8	3.4
K	-1.2	3.3	-10.8	2.8	-1.0	-1.4
S	-2.6	-2.0	-9.2	-4.7	-7.5	-5.2
Zn	-0.6	-0.3	-0.7	-0.2	-0.6	-0.5
C. Large	n=10	n=10	n=9	n=10	n=10	n=49
N	-5.5	-4.7	-2.7	6.8	3.7	-0.4
P	6.2	5.0	4.9	5.8	8.0	6.0
K	4.1	6.6	-4.5	9.6	4.2	4.0
S	-1.3	-1.2	-6.0	-1.2	-2.1	-2.4
Zn	-0.3	-0.2	-0.1	-0.1	-0.2	-0.2
D. Women managed	n=19	n=20	n=19	n=18	n=20	n=96
N	-24.5	-26.1	-18.9	-11.2	-16.3	-19.5
P	-0.5	-2.2	-4.7	-4.4	-3.6	-3.1
K	-8.3	-1.6	-16.1	-9.4	-8.1	-8.7
S	-3.2	-2.4	-9.7	-9.7	-7.9	-6.6
Zn	-0.9	-0.7	-0.8	-0.6	-0.8	-0.8
E. All category	n=149	n=150	n=143	n=140	n=150	n=732
N	-17.6	-16.2	-16.6	-7.5	-10.1	-13.6
P	2.4	3.0	-2.4	0.9	0.1	0.8
K	-5.5	2.0	-13.7	-2.8	-4.4	-4.9
S	-2.9	-2.2	-9.7	-6.0	-7.7	-5.7
Zn	-0.8	-0.5	-0.7	-0.3	-0.7	-0.6

Note: '+' sign indicates over use and '-' sign indicates under use of nutrients

Recommended dose (kg/ha): N=90, P=10, K=18 (for Barguna & Khulna) and 35 (for Mymensingh, Rajshahi, Thakurgaon), S= 4 (for Barguna & Khulna), 12 (for Mymensingh & Rajshahi) & 10 for Thakurgaon), Zn= 1.0 (FRG, 2012)

5.16.3 Productivity and profitability of *T. Aman* rice production

The average cost of *T. Aman* rice production was estimated at Tk. 80,858 per hectare of which 67.0% was variable cost and the rest (33.0%) was fixed cost. In terms of variable inputs, human labour incurred the highest share of the total cost (41.1%) followed by land preparation (7.8%), manure & fertilizer (7.2%), and crop threshing (Table 5.34).

The average yield of *T. Aman* rice was estimated at 4.14 t/ha in the study areas which was much higher than the national average of 2.464 t/ha (BBS, 2019). The highest yield (4.46 t/ha) was recorded at Rajshahi and the lowest (3.94 t/ha) was at Mymensingh district. The higher yields were attributed to the higher use of fertilizers. This rice is reported to be a profitable crop in the study areas. The average gross return and net profit/return were estimated at Tk. 99,747 (ca. AUD 1700.5/ USD 1197.6) and Tk. 18,890 (ca. AUD 322/ USD 227) respectively. Due to higher yield and price Rajshahi farmers received the highest gross as well as net return. The average benefit cost ratios (BCRs) on cash cost and full cost basis were 1.84 and 1.23 respectively (Table 5.35).

Table 5.34 Per hectare cost of *T. Aman* rice production in the study areas

Particulars	Barguna *(n=149)*	Khulna *(n=150)*	Mymensingh *(n=143)*	Rajshahi *(n=140)*	Thakurgaon *(n=150)*	All areas *(n=732)*
B. Variable cost	**53188**	**49963**	**53936**	**61882**	**52347**	**54164 (67.0)**
Human labor	32276	32255	35040	34498	32093	33199 (41.1)
Land preparation	7700	5296	6198	6043	6345	6319 (7.8)
Seed	2194	2509	2142	2118	1842	2162 (2.7)
Fertilizer:	**5120**	**4807**	**4802**	**6630**	**5035**	**5266 (6.5)**
Urea	2964	2387	2871	3202	2810	2842 (3.5)
TSP	1577	1104	685	977	1108	1095 (1.4)
DAP	78	495	413	367	0	268 (0.3)
MoP	449	583	610	1010	972	722 (0.9)
Gypsum	52	111	127	325	92	139 (0.2)
$ZnSO_4$	0	49	34	276	22	74 (0.1)
$MgSO_4$	0	0	0	64	0	12 (0.0)
Boron	0	78	62	409	31	113 (0.1)
Manure	37	819	578	703	589	543 (0.7)
Pesticides	2516	1727	1786	3000	2240	2248 (2.8)
Irrigation	387	0	270	5660	659	1349 (1.7)
Threshing	2958	2550	3120	3230	3544	3078 (3.8)
C. Fixed Cost						
Land use cost	25935	29640	25935	25935	25935	26694 (33.0)
C. Total Cost	**79123**	**79603**	**79871**	**87817**	**78282**	**80858 (100)**

Note: Figures in the parentheses are percentage of total cost

Table 5.35 Profitability (Tk/ha) of *T. Aman* rice production in the study areas

Particulars	Barguna *(n=149)*	Khulna *(n=150)*	Mymensingh *(n=143)*	Rajshahi *(n=140)*	Thakurgaon *(n=150)*	All areas *(n=732)*
Variable cost (VC)	**53188**	**49963**	**53936**	**61882**	**52347**	**54164**
Fixed cost (FC)	25935	29640	25935	25935	25935	26694
Total cost (TC)	**79123**	**79603**	**79871**	**87817**	**78282**	**80858**
Average yield (t/ha)	3.96	4.21	3.94	4.46	4.15	4.14
Price (Tk./ton)	20319	20400	22130	21739	20591	21017
Return from grain	80463	85884	87192	96956	85453	87065
Return from by product	9211	9809	15929	16836	12031	12682
Gross return (GR)	**89674**	**95693**	**103121**	**113792**	**97484**	**99747**
Gross margin	36486	45730	49185	51910	45137	45584
Net profit (GR-TC)	10551	16090	23250	25975	19202	18890
Benefit cost ratio						
BCR over VC	1.69	1.92	1.91	1.84	1.86	1.84
BCR over TC	1.13	1.20	1.29	1.30	1.25	1.23

5.17 Nutrient Use Gaps and Profitability of Potato Production

5.17.1 Fertilizer use and its gap in potato production

Potato is one of the popular irrigated tuber crops grown in *Rabi* season (16 October-15 March) in Bangladesh. It is mainly used as vegetable in the country. Its seeding time starts from mid-October and continues until end of November. Potato harvest is completed between mid-January and March depending on planting time. It contributes a lot to the total vegetable production in Bangladesh. The total volume of vegetable production (including potato) in 2017-18 stood at 1360.45 lakh MT of which potato accounted for 97.44 lakh MT (7.16%) from 0.477 million hectares of lands (BBS, 2019).

Among the five study areas, only the respondent farmers of Rajshahi and Thakurgaon district cultivated potato. They applied an over dose of urea, TSP, MoP and Gypsum fertilizers and about 2 ton of cow dung in potato cultivation. On an average, they applied 100.7 kg more urea, 135.6 kg more TSP and 100.5 kg more MoP and 35 kg more Gypsum per hectare compared to the respective recommended doses. Again, they used slightly lower dose of Boron and ZnSO4. The respondent potato farmers of Rajshahi district applied more fertilizer in general than that of Thakurgaon farmers except for Boron (Table 5.36).

Table 5.36 Current fertilizer using gaps between farmer's practice and scientific recommended dose (kg/ha) in potato cultivation

Fertilizer	Rajshahi (n=43)		Thakurgaon (n=35)		All area (n=78)	
	Farmer's use	Gap	Farmer's use	Gap	Farmer's use	Gap
Urea	401.9	108.9	383.7	90.7	393.7	100.7
TSP+DAP	309.9	159.9	255.7	105.7	285.6	135.6
MoP	284.6	104.6	275.4	95.4	280.5	100.5
Gypsum	96.7	40.7	85.2	29.2	91.5	35.5
Boron	5.2	-2.3	7.1	-0.4	6.1	-1.4
$ZnSO_4$	6.6	-1.9	6.6	-1.9	6.6	-1.9
$MgSO_4$	1.1	1.1	16.6	16.6	8.1	8.1
Manure	1553	1553	2415	2415	1940	1940

Note: Recommendation (kg/ha): Urea=293, TSP=150, MoP=180, Gypsum=56, ZnSO4=8.7, Boron=7.5, (FRG, 2012); In Gap column, '+' sign indicates over use and '-' sign indicates under use of nutrients

5.17.2 Nutrient application gaps in potato production

Respondent potato farmers applied different types of soil nutrients in potato cultivation. Irrespective of farmers' category and study areas, they applied all the soil nutrients at much higher doses than that of recommendations. Only ZnSO4 was used nearly at the recommended level meaning that the farm level use gap of ZnSO4 was negligible. The respondent farmers of Rajshahi applied more soil nutrients than that of Thakurgaon farmers. Again, if we look into the farmer's category we can see that women managed farms and marginal & small category farmers have applied lower amount of all the nutrients and large category farmers have applied all the nutrients at higher dose compared to scientific recommendations (Table 5.37).

Table 5.37 Current nutrient using gaps between farmer's practice and scientific recommendation (kg/ha) in potato cultivation

Nutrients	Rajshahi *(n=43)*		Thakurgaon *(n=35)*		All area *(n=78)*	
	F. practice	Gap	F. practice	Gap	F. practice	Gap
A. Marginal & small	*n=22*		*n=15*		*n=37*	
N	197.9	62.9	177.1	42.1	189.5	54.5
P	62.9	32.9	54.8	24.8	59.6	29.6
K	143.3	53.3	136.7	46.7	140.6	50.6
S	20.7	10.7	20.8	10.8	20.7	10.7
Zn	1.7	0.3	1.6	0.4	1.6	0.4
B. Medium	*n=11*	*n=11*	*n=12*	*n=22*	*n=23*	*n=23*
N	216.2	81.2	191.7	56.7	203.4	68.4
P	71.7	41.7	56.2	26.2	63.6	33.6
K	166.1	76.1	147.9	57.9	156.6	66.6
S	25.6	15.6	21.8	11.8	23.6	13.6
Zn	4.5	2.5	3.2	1.2	3.8	1.8
C. Large	*n=2*	*n=2*	*n=4*	*n=4*	*n=6*	*n=6*
N	225.7	90.7	197.7	62.7	207.0	72.0
P	75.1	45.1	60.5	30.5	65.4	35.4
K	164.9	74.9	169.0	79.0	167.7	77.7

Table 5.37 Continued……..

Nutrients	Rajshahi *(n=43)*		Thakurgaon *(n=35)*		All area *(n=78)*	
	F. practice	Gap	F. practice	Gap	F. practice	Gap
S	26.5	16.5	25.9	15.9	26.1	16.1
Zn	4.4	2.4	3.9	1.9	4.1	2.1
D. Women-managed	*n=8*	*n=8*	*n=4*	*n=4*	*n=12*	*n=12*
N	184.8	49.8	165.8	30.8	178.5	43.5
P	55.5	25.5	44.7	14.7	51.9	21.9
K	120.1	30.1	128.1	38.1	122.8	32.8
S	13.3	3.3	15.4	5.4	14.0	4.0
Zn	1.0	1.0	1.4	0.6	1.2	0.8
E. All category	*n=43*	*n=43*	*n=35*	*n=35*	*n=78*	*n=78*
N	201.4	66.4	183.2	48.2	193.2	58.2
P	64.3	34.3	53.5	23.5	59.5	29.5
K	145.8	55.8	143.2	53.2	144.7	54.7
S	20.8	10.8	21.1	11.1	20.9	10.9
Zn	2.4	0.4	2.4	0.4	2.4	0.4
K	164.9	74.9	169.0	79.0	167.7	77.7
S	26.5	16.5	25.9	15.9	26.1	16.1
Zn	4.4	2.4	3.9	1.9	4.1	2.1

Note: Recommended dose (kg/ha): N=135, P=30, K=90, S=10, and Zn=2 (FRG, 2012)
'+' sign indicates over use and '-' sign indicates under use of nutrients

5.17.3 Productivity and profitability of potato production

The average cost of potato production was estimated at Tk. 1,77,075 per hectare of which the share of variable and fixed costs were 79.1% and 20.9% respectively. For variable inputs, human labour incurred the highest share of total cost (29.4%) followed by seed (18.4%), manure & fertilizer (11.9%) and irrigation (Table 5.38).

The average yield of potato was recorded to be 26.77 t/ha in the study areas which was much higher compared to the national average of 20.428 t/ha (BBS, 2019). The highest yield (27.17 t/ha) was recorded in Rajshahi district and the lowest yield (26.17 t/ha) in Thakurgaon district. The highest yield was attributed to higher fertilizer use. Potato is a very profitable crop in the study areas. The average gross return and net return were estimated at Tk. 2,54,217 (ca. AUD 4334/ USD 3052) and Tk. 77,142 (ca. AUD 1315/ USD 926) per hectare, respectively. Due to higher yield and price Rajshahi farmers received the highest gross as well as net return compared to Thakurgaon farmers. The average benefit cost ratios (BCRs) on cash cost and full cost basis were 1.81 and 1.43 respectively (Table 5.39)

Table 5.38 Per hectare cost of potato production in the study areas

Particulars	**Rajshahi** *(n=43)*	**Thakurgaon** *(n=35)*	**All area** *(n=78)*
A. Variable cost	143533	135715	140025 (79.1)
Human labor	54305	49356	52084 (29.4)
Land preparation	9606	11479	10446 (5.9)
Seed	32650	32586	32621 (18.4)
Fertilizer	**19651**	**18934**	**19329 (10.9)**
Urea	6160	5322	5784 (3.3)
TSP	3660	4783	4164 (2.4)
DAP	2174	113	1249 (0.7)
MoP	4674	4370	4538 (2.6)
Gypsum	1090	1234	1155 (0.7)
$ZnSO_4$	880	1078	969 (0.5)
$MgSO_4$	72	839	416 (0.2)
Boron	941	1195	1055 (0.6)
Manures	1190	2507	1781 (1.0)
Pesticides	10595	8691	9741 (5.5)
Irrigation	12444	10370	11513 (6.5)
Other cost	3092	1792	2509 (1.4)
A. Fixed Cost			
Land use cost	37050	37050	37050 (20.9)
C. Total Cost (A+B)	**180583**	**172765**	**177075 (100)**

Note: Figures within parentheses are percentages of total cost

Table 5.39 Profitability of potato production in the study areas

Particulars	Rajshahi *(n=43)*	Thakurgaon *(n=35)*	All area *(n=78)*
Variable cost (VC)	143533	135715	140025
Fixed cost (FC)	37050	37050	37050
Total cost (TC)	180583	172765	177075
Average yield (t/ha)	27.17	26.27	26.77
Average price (Tk./ton)	9913	8970	9490
Gross return (GR)	269336	235642	254217
Gross margin (GM)	125803	99927	114192
Net profit (GR-TC)	88753	62877	77142
Benefit cost ratio (BCR)			
BCR over VC	1.88	1.74	1.81
BCR over TC	1.49	1.36	1.43

5.18 Nutrient Use Gaps and Profitability of Summer Maize Production

5.18.1 Fertilizer use and its gap in summer maize production

Maize is a widely grown crop in Bangladesh, which is grown both in *Rabi* (October-April) and *Kharif-1* season (March-July). The area and production of *Kharif-1* season maize (summer maize) is much lower than that of *Rabi* season maize. The intensive summer maize growing areas are Manikgonj, Chandpur, Rajshahi, Lalmonirhat, Rangpur, Dinajpur and Thakurgaon districts. According to the official estimates, the total volume of maize production in 2017-18 stood at 32.88 lakh MT of which summer maize accounted for 3.94 lakh MT (11.98%) from 63.74 thousand hectares of land (BBS, 2019).

Among the five study areas, the respondent farmers of Rajshahi and Thakurgaon district reported to cultivate summer maize. Maize is a fertilizer responsive crop. Higher doses of fertilizers are usually recommended for its successful production. However, respondent maize farmers applied both organic and inorganic fertilizers at much lower rates than the scientific recommendations because of same reasons as stated for T. Aman rice in section 5.16.1. Table 5.40 shows that they applied 41.6 kg less urea, 36.2 kg less TSP, 28.0 kg less MoP, 111.2 kg less Gypsum and 7.9 less ZnSO4 per hectare compared to their respective recommended doses. Summer maize is generally cultivated after harvesting potato in the study areas. Farmers use over doses of fertilizers for potato cultivation and that was the main reasons for using lower dose of fertilizer in summer maize cultivation (see FGD, 2019 in the Appendix).

Table 5.40 Current fertilizer using gaps between farmer's practice and scientific recommended dose (kg/ha) in summer maize (Kharif-1) cultivation

Fertilizer	Rajshahi (n=42)		Thakurgaon (n=31)		All area (n=73)	
	Farmer's use	Gap	Farmer's use	Gap	Farmer's use	Gap
Urea	249.1	-43.9	254.5	-38.5	251.4	-41.6
TSP+DAP	73.2	-41.8	86.4	-28.6	78.8	-36.2
MoP	31.4	-30.6	37.5	-24.5	34.0	-28.0
Gypsum	26.5	-123.5	55.4	-94.6	38.8	-111.2
Boron	0.4	0.4	1.1	1.1	0.7	0.7
$MgSO_4$	0.5	0.5	0.8	0.8	0.6	0.6
$ZnSO_4$	0.5	-8.2	1.3	-7.4	0.8	-7.9
Manure	62	62	512	512	253.1	253.1

Note: Recommendation (kg/ha): Urea=293, TSP=115, MoP=62, Gypsum=150, ZnSO4=8.7 (FRG, 2018)
In Gap column, '+' sign indicates over use and '-' sign indicates lower use of nutrients

5.18.2 Nutrient application gaps in summer maize production

Respondent summer maize farmers applied different types of soil nutrients in maize cultivation. Irrespective of farmers' category and study areas, they applied all the nutrients at lower dose than that of recommendations. Among study areas, the respondent farmers of Thakurgaon district applied more nutrients compared to Rajshahi farmers. Again, if we look into the farmer's category, we can see that women managed farms and marginal & small category farmers applied lower amounts of all the nutrients and large category farmers applied all the nutrients at higher dose compared to their respective recommendations (Table 5.41) because of same reasons as stated for *T. Aman* rice in section 5.16.1.

Table 5.41 Current nutrient using gaps between farmer's practice and scientific recommendation (kg/ha) in summer maize cultivation

Nutrients	Rajshahi *(n=42)*		Thakurgaon *(n=31)*		All area *(n=73)*	
	F. practice	Gap	F. practice	Gap	F. practice	Gap
A. Marginal & small	*n=21*		*n=12*		*n=33*	
N	113.5	-21.5	116.3	-18.8	114.5	-20.5
P	13.7	-9.3	16.2	-6.8	14.6	-8.4
K	15.0	-16.0	15.6	-15.4	15.2	-15.8
S	5.1	-22.0	10.5	-16.5	7.0	-20.0
Zn	0.1	-1.9	0.3	-1.7	0.2	-1.8
B. Medium	*n=11*		*n=12*		*n=23*	
N	121.4	-13.6	122.0	-13.0	121.7	-13.3
P	16.7	-6.3	19.6	-3.4	18.2	-4.8
K	19.5	-11.5	24.3	-6.7	22.0	-9.0
S	8.1	-19.0	13.5	-13.5	10.9	-16.1
Zn	0.2	-1.8	0.5	-1.5	0.4	-1.6
C. Large	*n=2*		*n=3*		*n=5*	
N	125.1	-9.9	127.1	-7.9	126.3	-8.7
P	17.2	-5.8	21.1	-2.0	19.5	-3.5
K	22.5	-8.6	24.0	-7.0	23.4	-7.6
S	14.4	-12.6	13.4	-13.6	13.8	-13.2
Zn	0.7	-1.3	1.0	-1.0	0.9	-1.1
D. Women-managed	*n=8*		*n=4*		*n=12*	
N	109.2	-25.8	110.3	-24.7	109.6	-25.5
P	12.7	-10.3	14.8	-8.3	13.4	-9.6
K	11.4	-19.6	13.8	-17.2	12.2	-18.8
S	2.6	-24.4	6.9	-20.1	4.0	-23.0
Zn	0.1	-1.9	0.3	-1.7	0.1	-1.9
E. All category	*n=42*		*n=31*		*n=73*	
N	115.3	-19.7	118.8	-16.2	116.8	-18.2
P	14.5	-8.5	17.8	-5.2	15.9	-7.1
K	15.8	-15.2	19.5	-11.5	17.4	-13.6
S	5.8	-21.2	11.5	-15.5	8.2	-18.8
Zn	0.2	-1.8	0.5	-1.5	0.3	-1.7

Note: Recommended dose (kg/ha): N=135, P=23, K=31, S=27, and Zn=2 (FRG, 2018)
'+' sign indicates over use and '-' sign indicates lower use of nutrients

5.18.3 Productivity and profitability of summer maize production

The average cost of production of summer maize was Tk.73,350 per hectare of which the share of variable and fixed costs were 74.7% and 25.3% respectively. In different variable inputs, the highest cost share was for human labour (37.0%) followed by fertilizer (10.5%), seed (9.3%), and irrigation (Table 5.42).

The average yield of summer maize was reported to be 4.88 t/ha in the study areas which was much lower than the national average of 6.18 t/ha (BBS, 2019). The highest yield (5.02 t/ha) was recorded at Thakurgaon district and the lowest yield (4.77 t/ha) was at Rajshahi district.

The highest yield was attributed to higher use of fertilizers. The yield of summer maize is much lower compared to the winter maize. However, summer maize is a profitable crop in the study areas. The average gross return and net return were estimated at Tk.84,461 (ca. AUD 1440/ USD 1014) and Tk. 11,111 (ca. AUD 189.4/ USD 133.4) respectively. Due to higher yield, Thakurgaon farmers received the highest gross as well as net return compared to Rajshahi farmers. The average benefit cost ratios (BCRs) on cash cost and full cost basis were 1.54 and 1.15 respectively (Table 5.43)

Table 5.42 Per hectare cost of summer maize (Kharif-1) production in the study areas

Particulars	Rajshahi *(n=42)*	Thakurgaon *(n=31)*	All area *(n=73)*
A. Variable cost	**55783**	**53527**	**54825** (74.7)
Human labor	28461	25333	27133 (37.0)
Land preparation	4324	4616	4448 (6.1)
Seed	6909	6765	6848 (9.3)
Fertilizer	**7156**	**8277**	**7632 (10.4)**
Urea	4074	4062	4069 (5.5)
TSP	1714	2081	1870 (2.5)
DAP	69	0	40 (0.1)
MoP	837	1007	909 (1.2)
Gypsum	296	665	453 (0.6)
$ZnSO_4$	88	217	143 (0.2)
$MgSO_4$	60	173	108 (0.1)
Boron	18	72	41 (0.1)
Manures	41	194	106 (0.1)
Pesticides	1637	1479	1570 (2.1)
Irrigation	3781	3980	3866 (5.3)
Threshing	3474	2883	3223(4.4)
B. Fixed Cost			
Land use cost	18525	18525	18525 (25.3)
C. Total Cost (A+B)	**74308**	**72052**	**73350 (100)**

Note: Figures within parentheses are the percentage of total cost

Table 5.43 Profitability of summer maize (Kharif-1) production in the study areas

Particulars	Rajshahi *(n=42)*	Thakurgaon *(n=31)*	All area *(n=73)*
Variable cost (VC)	55783	53527	54825
Fixed cost (FC)	18525	18525	18525
Total cost (TC)	**74308**	**72052**	**73350**
Average yield (t/ha)	4.77	5.02	4.88
Average price (Tk./ton)	16107	15895	16017
Return from grain	**76830**	**79793**	**78088**
Return from by product	6586	6084	6373
Gross return (GR)	**83416**	**85877**	**84461**
Gross margin (GM)	27633	32350	29636
Net profit (GR-TC)	9108	13825	11111
Benefit cost ratio (BCR)			
BCR over VC	1.50	1.60	1.54
BCR over TC	1.12	1.19	1.15

5.19 Nutrient Use Gaps and Profitability of Watermelon Production

5.19.1 Fertilizer use and its gap in watermelon production

Watermelon is an important fruit crop grown in *Rabi season* (October- April) in Bangladesh. Its seeding and harvesting period are mid-October to mid-January and mid-February to mid-June respectively. The intensive growing areas of watermelon are Noakhali, Patuakhali, Bhola, Barguna, Cox-bazar, Khulna, Gopalgong, Thakurgaon, and Panchagarh districts. According to the national statistics, the total area and production of watermelon in 2017-18 were 11.73 thousand hectares and 2.27 lakh MT respectively (BBS, 2019).

The respondent farmers of coastal areas (Khulna district) reported to cultivate watermelon extensively. The respondent farmers usually apply a higher dose of different fertilizers in watermelon cultivation. Table 5.44 shows that the applied amounts of most fertilizers were higher than their corresponding recommended doses. They only used lower dose of MoP, Boron and ZnSO4 which were 39.1 kg, 1.2 kg and 4.4 kg per hectare respectively. Farmers also used some cow dung and MgSO4 although they were not recommended.

Table 5.44 Current fertilizer using gaps between farmer's practice and scientific recommended dose in watermelon cultivation in Khulna district

Fertilizer	Amount of fertilizer (kg/ha)		
	Farmer's practice (n=63)	Recommendation (FRG, 2018)	Gap
Urea	457.7	228	229.7
TSP+DAP	204.8	180	24.8
MoP	68.9	108	-39.1
Gypsum	31.07	29	2.07
Boron	4.8	--	-1.2
$ZnSO_4$	2.6	7	-4.4
$MgSO_4$	5.7	--	5.7
Manure	1352	--	1352

Note: *'+' sign indicates over use and '-' sign indicates under use of nutrients*

5.19.2 Nutrient application gaps in watermelon production

Respondent farmers applied different types of nutrients in watermelon cultivation. Irrespective of farmers' category and study areas, they applied N much higher (141.9 kg/ha) than the recommendation. They used a slight over dose of P, K and S. Only Zn and B was used at a lower dose compared to their recommended doses. If we look into the farmer's category, we can also see the similar trend of nutrients use. However, women managed farms and marginal & small category farmers have applied a higher amount of K and large and medium category farmers have applied N, P, and S at higher dose compared to their counterparts (Table 5.45).

5.19.3 Productivity and profitability of watermelon production

The average cost of production of watermelon was Tk. 1,52,428 per hectare of which the share of variable costs was 75.7% and fixed costs was 24.3%. Table 5.46 reveals that the highest cost share was for human labour (37.2%) followed by manure & fertilizers (11.5%), irrigation (10.5%), and seed (7.9%).

The average yield of watermelon was estimated to be 49.95 t/ha in the study areas which was much higher than the national average of 19.35 t/ha (BBS, 2019). Watermelon is a very remunerative crop for the respondent farmers. They received on an average Tk. 2,66,833 (ca. AUD 4549/ USD 3204) as gross return and Tk. 1,14,406 (ca. AUD 1950.4/ USD 1374) as net return. The average benefit cost ratios (BCRs) on cash cost and full cost basis were 2.31 and 1.75 respectively (Table 5.47).

Table 5.45 Current nutrient application and nutrient using gaps between farmer's practice and scientific recommendation in watermelon cultivation in Khulna district

Nutrient element	Marginal & small *(n=33)*	Medium *(n=16)*	Large *(n=4)*	Women-managed *(n=10)*	All category (n=63)
A. Farmer's practice (kg/ha)					
N	240.9	266.7	286.3	208.3	246.9
P	45.7	50.9	55.8	37.4	46.7
K	40.7	45.2	43.6	35.0	41.5
S	10.7	11.0	11.1	6.3	10.3
Zn	1.6	1.7	1.0	0.6	1.5
B	0.7	0.8	0.6	0.7	0.7
B. Gap (kg/ha)					
N	136.0	161.7	181.3	103.3	141.9
P	9.7	14.9	19.8	1.4	10.7
K	13.3	8.8	10.4	19.0	12.5
S	5.7	6.0	6.1	1.3	5.3
Zn	0.1	0.2	-0.5	-0.9	-0.01
B	-0.3	-0.2	-0.4	-0.3	-0.3

Note: Recommended dose (kg/ha): N=105, P=36, K=54, S=5.0, Zn=1.5 (FRG, 2018)

5.46 Per hectare cost of watermelon production at Khulna district

Particulars	**Cost (Tk/ha)**	**% of total cost**
A. Variable cost	**115378**	**75.7**
Human labour	56751	37.2
Land preparation	8242	5.4
Seed	12019	7.9
Fertilizers	**16621**	**10.9**
Urea	7643.6	5.0
TSP	3653.1	2.4
DAP	1789.2	1.2
MoP	1085.2	0.7
Gypsum	835.8	0.5
ZnSO4	443.8	0.3
Boron	843.8	0.6
MgSO4	326.2	0.2
Manure	946.4	0.6
Pesticides	4751.0	3.1
Irrigation	16047.2	10.5
B. Fixed Cost		
Land use cost	37050	**24.3**
C. Total Cost (A+B)	**152428**	100.0

5.47 Profitability of watermelon production at Khulna district

Particulars	**Amount (Tk/ha)**
Variable cost (VC)	115378
Fixed cost (FC)	37050
Total cost (VC+FC)	152428
Average yield (t/ha)	49.95
Average price (Tk./ton)	5342
Gross return (GR)	266833
Gross margin (GR-VC)	151455
Net return (GR-TC)	114405
Benefit cost ratio (BCR)	
BCR over VC	2.31
BCR over TC	1.75

5.20 Overall Nutrients Application Gaps

It is clearly revealed from Table 5.48 that the respondent farmers in the study areas used different nutrients either over dose or under dose. The nutrient gap could be varied according to different references. However, potato growers applied over dose of nutrients assuming that the residual effect of nutrients will be used by the next season crop. Watermelon growers also applied over dose of all nutrients. *Kharif* maize farmers were in under dose categories. Farmers applied over dose of **P** in all the crops except *Kharif* maize. Among the farm categories, women managed farm households and small & marginal farmers used much lower doses of nutrients compared to medium and large category of farmers. A detailed explanation regarding fertilizer use gaps in different crops has been provided in 5.14.1 and 5.16.1 sections.

Table 5.48 Overall nutrients application gaps (kg/ha) in the study areas

Nutrient	*Boro* rice	*T. Aus*	*T. Aman*	Potato	Kharif maize	Watermelon
N	-8.4	-1.8	-13.6	58.2	-18.2	141.9
P	5.5	3.4	0.8	29.5	-7.1	10.7
K	-10.6	2.0	-4.9	54.7	-13.6	12.5
S	-10.3	-1.8	-5.7	10.9	-18.8	5.3

5.21 Comparative Cost and Return of Different Crops

The cultivations of different crops (except *T. Aus*) were found to be profitable in the study areas (Table 5.49). In investment point of view, *Boro* rice cultivation required the highest investment (Tk.1,09,264/ha) among cereal crops followed by *T.Aman*, *T.Aus* and *Kharif* maize. However, potato and watermelon cultivation incurred the highest cost (Tk.1,77,075/ha & 1,52,428/ha) among all the crops under study. Returns scenario of crop production revealed that watermelon cultivation produced the highest net return (Tk.1,14,405/ha) that was much higher than that of other crops under study. Among the cereal crops, *T.Aman* produced the highest net return (Tk.18,890/ha) followed by *Boro* rice and *Kharif* maize. More or less the rate of returns (BCR) of different crops showed the similar trend as observed in the net returns.

Table 5.49 Comparative cost and return (Tk/ha) of different crops grown in the study areas

Particular	*Boro* rice	*T. Aus*	*T. Aman*	Potato	*Kharif* maize	Watermelon
Total variable cost	81,773	56,397	54,164	1,40,025	54,825	1,15,378
Total cost	1,09,264	78,627	80,858	1,77,075	73,350	1,52,428
Gross return	1,26,568	78,528	99,747	2,54,217	84,461	2,66,833
Gross margin	44,795	22,131	45,584	1,14,192	29,636	1,51,455
Net return	17,304	-99	18,890	77,142	11,111	1,14,405
Benefit cost ratio						
On variable cost	1.55	1.39	1.84	1.81	1.54	2.31
On total cost	1.16	0.99	1.23	1.43	1.15	1.75

5.22 Returns to Inorganic Fertilizer Use

The profitability scenarios deliberated in the previous sections revealed that the farm level production of the sampled crops were profitable to the farmers in respect of both full costs and variable costs with slight exception of *T. Aus* rice production. However, an attempt has been made to assess the returns to overall use of inorganic fertilizer in different crop production at farm level. The findings in Table 5.50 show that the use of inorganic fertilizers in different crop production was very remunerative for the respondent farmers. The per kg cost of inorganic fertilizers application ranged from Tk. 18.03 to Tk.21.43, whereas its returns were estimated at Tk.20.51 to Tk.168.94 on total cost basis. It means that on the given technology and environment, the respondent farmers received on an average Tk.20.51 to Tk.168.94 as net return from different crops through applying one kilogram of inorganic fertilizers. Again, the rates of returns of fertilizer application appeared to range from 0.98 to 7.88 on total cost basis and 4.88 to 10.11 on variable cost basis meaning that one-taka investment in inorganic fertilizer application, keeping other factors constant, would result in Tk. 0.98 to Tk.7.88 on total cost basis and Tk.4.88 to Tk.10.11 on variable cost basis (Table 5.50).

Table 5.50 Returns to fertilizer use in different crop production in the study areas

Particulars	Boro rice	T. Aus	T. Aman	Potato	Maize	Watermelon
1. Total cost of inorganic fertilizer (Tk/ha)	10217	4892	5266	19329	7632	16621
2. Total inorganic fertilizer applied (kg/ha)	517.1	233.7	273	1072.1	403.8	775.57
3. Average cost of fertilizer (Tk/kg)	19.76	20.93	19.29	18.03	18.90	21.43
4. Total production cost except fertilizer (Tk/ha)	99047	73735	75592	157746	65718	135807
5. Total variable cost except fertilizer (Tk/ha)	71556	51505	48898	120696	47193	98757
6. Gross return (Tk/ha)	126568	78528	99747	254217	84461	266833
7. Returns to 1kg fertilizer use (Tk)*						
a. Return over TC	53.22	20.51	88.48	89.98	46.42	168.94
b. Return over VC	106.39	115.63	186.26	124.54	92.29	216.71
Rate of returns to fertilizer use						
Rate of return over TC (7a÷3)	2.69	0.98	4.59	4.99	2.46	7.88
Rate of return over VC (7b÷3)	5.38	5.52	9.66	6.91	4.88	10.11

$$* \text{Returns to fertilizer use (Tk)} = \frac{(\text{Gross return (Tk/ha)} - \text{Total production cost except inorganic fertilizer cost (Tk/ha)}}{\text{Quantity of inorganic fertilizers used (kg/ha)}}$$

Chapter VI

FACTORS INFLUENCING FERTILIZER USE AND NUTRIENT GAP BETWEEN FARMERS' PRACTICE AND RECOMMENDED DOSE

Fertilizer use in crop production is a common practice in the study areas. The respondent farmers use different types of fertilizers at varying rates depending on various agro-socio-economic and environmental factors. On the other side, they use either over dose or lower doses of fertilizers in producing different crops. An attempt was made through qualitative survey (FGD) to identify major factors that farmers consider in selecting the type and amount of fertilizers. Besides, beta regression model was used to identify factors influencing the gaps between current fertilizer practice by farmers and scientific recommendations.

6.1 Factors of Farmers' Decision Towards Fertilizer Use

Respondent farmers consider different agro-socio-economic and environmental factors in selecting the type and amount of fertilizers to use. The factors are discussed briefly in the following sections.

Type of crops: The requirement of fertilizer nutrients is different according to the types of crops. As for example, maize and potato need higher amount of nutrients whereas pulse crops need less nutrients. Most farmers are aware of this fact and apply fertilizers accordingly. This factor is ranked one by the respondent farmers. In the case of farmer's category, small, marginal and women managed households ranked this factor as one, whereas medium and large farmers ranked it as two (Table 6.1). The ranks assigned by respondent farmers vary from location to location. If we look at the district-wise importance of this factor, we can see that Rajshahi and Barguna farmers ranked it as one and Mymensingh, Thakurgaon and Khulna farmers ranked it as two (Table 6.2).

Soil fertility: This is an important factor that influence farmers taking decision on fertilizer use. Farmers don't know the exact nutrients available in the soil, but can gauge the fertility of soil through crop production. Therefore, most farmers consider fertility of their lands before applying the amount and type of fertilizers. Medium and large category farmers ranked this factor as one, whereas small, marginal and women managed households ranked it as two (Table 6.1). Ranking by study areas revealed that Thakurgaon and Khulna farmers ranked this factor as one, whereas it was 2 and 3 for Rajshahi/Barguna and Mymensingh respectively (Table 6.2).

Crop season: Crop season also influences farmers to take decision regarding fertilizer use. Generally, *Rabi* season (16 October-15 March) is longer than *Kharif-1* (16 March-15 July) and *Kharif-2* (16 July-15 October) seasons. Therefore, many crops grown in the *Rabi* season require higher amount of nutrients compared to the crops grown in *Kharif* seasons. Many farmers, therefore, consider crop season before applying the amount and type of fertilizers (Table 6.1). Ranking by study areas revealed that Mymensingh farmers considered it as a top ranked issue in deciding the type/amount of fertilizer to use, whereas Khulna and Barguna farmers considered it less important (rank 11 & 9). Thakurgaon and Rajshahi farmers ranked this factor as three (Table 6.2).

Land type: Crop production directly depends on the suitability and land type. Therefore, land type is an important issue to assess the nutritional status of the land. Most farmers opined that they apply higher amount of fertilizers in the high land compared to medium and low land. They believe that low land is more fertile than medium and high land because fertilizer residues and silt/clay soils wash out from high land and deposited in the low land. Therefore, all categories of farmers except medium farmers ranked this factor as three (Table 6.1). The ranks assigned by farmers on land type vary from study location to location. For instance, Mymensingh farmers put less importance (rank-7) on land type than other study areas in deciding the type and amount of fertilizer to use (Table 6.2).

Table 6.1 Different categories of farmers consider various factors in deciding the type and amount of fertilizers to use

Factors of decision making	Ranking by farmer's category				
	Small & Marginal	Medium	Large	Female	All groups
1. Type of crop	1	2	2	1	1
2. Soil fertility	2	1	1	2	2
3. Crop season	5	3	5	6	3
4. Land type	3	6	3	3	4
5. Availability and use of cow manure	4	5	6	4	5
6. Advice from extension/project staff	8	4	4	9	6
7. Practice of peer farmer/neighbour	6	7	8	5	7
8. Recommendation made by fertilizer dealer	9	7	7	8	8
9. Market value of the crop	9	8	13	9	9
10. Sowing type	10	8	10	10	10
11. Cost of fertilizer	7	10	14	7	11
12. Availability of fertilizer	11	9	12	11	12
13. Government fertilizer recommendations	12	11	11	12	13
14. Soil testing advice	13	12	9	13	14

Source: FGD, 2019 (see in the Appendix for details)

Availability and use of manure: The use of cow manure in crop production was stated to be decreased in the study areas due to mechanized tillage and the availability of chemical fertilizers at the grass root level. Couple of years ago, draft power was extensively used in crop cultivation, transportation and crop threshing that encouraged farmers in rearing more cattle at household level. But now the situation has been changed to a large extent. However, the farmers who use cow manure in the land they use less amount of chemical fertilizers. The overall ranking of this factor is fifth, but different rankings establish a negative relationship between farm size and cow dung use (Table 6.1). Again, the farmers of Mymensingh and Khulna considered the availability and use of cow manure as forth ranked important factor before taking decision on the type and amount of fertilizers to use. This factor ranked five, six and twelve by the farmers of Thakurgaon, Rajshahi and Barguna district respectively (Table 6.2).

Advice from extension/project staff: Respondent farmers usually take advice from extension personnel, staff of the NUMAN project, and peer farmers on different aspects of crop production including fertilizer management. It is worth of mentioning here that extension personnel are the most educated, trained and knowledgeable persons regarding crop production at farm level. Due to traditional knowledge, experience, and pre-determined mindset most farmers don't rely on the fertilizer dose recommended by extension personnel. Because of that reason they ranked this factor as six and thirteen for government fertilizer recommendations in the case of fertilizer application (Table 6.1). The advice of extension personnel or NUMAN project staff is more important to the farmers of Khulna and Rajshahi districts compared to the farmers of Barguna and Thakurgaon districts (Table 6.2).

Practice of neighbour: It has been stated in the previous section that farmers sometimes take advice from peer farmers on different aspects of crop production. They also take decision on the amount and type of fertilizers to use after consultation with their peer farmers/neighbour. The overall ranking made by different categories of farmers on this factor was seventh. The ranking depends on the importance of this factor, which ranged from 5 to 8 across the farm categories (Table 6.1). The farmers of Khulna and Mymensingh districts were influenced more by seeing the fertilizer management practices of their neighbouring/peer farmers compared to the farmers of Barguna and Thakurgaon districts (Table 6.2).

Recommendation made by fertilizer dealer: The sub-dealers of fertilizers and pesticides are the main sources of fertilizers at farm level. Farmers usually buy fertilizers from them both on cash and credit. Therefore, fertilizer dealer plays a major role to influence on farmers' decision making process in determining the type and amount of fertilizers to use. The overall rank of this factor stood eighth among different factors (Table 6.1). Table 6.2 reveals that the farmers of Thakurgaon and Barguna districts ranked this factor six, whereas it was eight for Mymensingh and Rajshahi. The overall rank of this factor is seventh for Khulna district (Table 6.2).

Table 6.2 Farmers in the study areas consider various factors in deciding the type and amount of fertilizers to use

Factors of decision making	Ranking by study areas				
	Mymensingh	Thakurgaon	Rajshahi	Barguna	Khulna
1. Type of crop	2	2	1	1	2
2. Quality of soil	3	1	2	2	1
3. Crop season	1	3	3	9	11
4. Topography of land	7	4	5	3	6
5. Availability and use of cow dung	4	5	6	12	4
6. Advice given by extension/project staff	5	10	4	8	3
7. Practice of peer farmer/neighbour	6	8	7	10	5
8. Recommendation of fertilizer dealer	8	6	8	6	7
9. Market value of the crop	12	9	12	4	12
10. Sowing method	14	7	9	11	9
11. Cost of fertilizer	9	11	10	5	13
12. Availability of fertilizer	13	12	13	7	14
13. Government's recommendation	10	13	11	13	8
14. Soil testing facility	11	14	14	14	10

Source: FGD, 2019 (see in the Appendix for details)

Market value of crop: Majority of the farmers have dearth of liquid/cash money for crop production. Usually they meet up their cash requirements through selling crops, small ruminant, poultry & household assets, and borrow from relatives & local money lender at higher interest rate. Most farmers opined that they can use higher amount of fertilizers if get higher or fair price of their crops. Therefore, this factor also influence farmers in deciding the type and amount of fertilizers to be used in crop production. The ranking of this factor provided by different categories of farmers based on the importance of influence ranged from 8 to 13 in the study areas (Table 6.1). The respondent farmers of Barguna district gave more importance on the market value of crops (especially for rice) in deciding the type and amount of fertilizer to use. The farmers of the remaining districts put less emphasis on it since the rank value ranged from 9 to 10 (Table 6.2).

Sowing method: Farmers follow either broadcast or line sowing method for crop establishment. However, majority of farmers in the study areas follow line sowing method for sowing seeds. Some respondent farmers opined that they applied less fertilizers to those crops which are sown in line than the crops under broadcast sowing. Therefore, sowing method of crop also influence farmers to some extent in deciding the amount of fertilizers to use. The overall ranking of this factor is tenth (Table 6.1). Irrespective of farmer's category the ranks assigned by the farmers of the study areas varied from 7 to 14 implying that this factor is not crucial to them like other factors discussed above (Table 6.2).

Cost of fertilizer: Cost of fertilizer is an important factors to the majority of small, marginal and female farmers in the study areas. Most farmers give emphasis on good crop production and in that case they don't care about the cost of fertilizer. It is worth of mentioning that majority of the farmers are happy with the current price of fertilizers. However, this factor influence farmers to some extent to decide the amount and type of fertilizers to use. Table 6.1 reveals that small, marginal and women managed households ranked this factor as seven, whereas it was ten for medium and large category farmers. The respondent farmers in the study areas also ranked this factor differently ranging from five to thirteen based on the importance of the factor (Table 6.2).

Availability of fertilizer: It is also an important factors that influence farmers to decide the type and amount of fertilizers to use in the study areas. The current availability of fertilizers is quite satisfactory to the farmers. That's why they ranked it twelve (Table 6.1). Irrespective farmer's category, the ranks assigned by the farmers of the study areas varied from 7 to 14 implying that this factor is not much important to them like other factors discussed above (Table 6.2).

Soil testing facility: Soil testing facility is not readily available in the study areas. That's why most farmers are not so aware of this issue. In other words, they don't consider soil test as an important factor. Some farmers realize the importance of soil testing in soil fertility management, but unable to do it for its unavailability at farm level. The overall ranking of this factor is fourteen (Table 6.1). If we look at the Table 6.2 we also see that the farmers of the study areas did not consider this as an important factor (Table 6.2).

6.2 Factors Affecting Fertilizer Use Gaps between Farmer's Practice and Recommended Dose: An Econometric Approach

The amount of nutrient use gaps (response variable) between current farmer's practice and scientific recommendation is likely to be influenced by a number of agro-socio-economic factors. In order to identify the major agro-socio-economic factors affecting fertilizer use gaps using beta regression model, we used 25 different types of variables and two types of data sets based on fertilizer use. The data sets were over dose users and lower dose users. We considered two major rice crops namely *Boro* and *T. Aman* rice for this analysis. However, for two crops we constructed six models for N, P, and K for over users (Models-1, -2, -3, -7, -8 and -9) and similarly constructed another six models for less users (Models-4, -5, -6, -10, -11 and -12). Thus the total number of models constructed for two crops is twelve. In the following sections, the significant variables influencing fertilizer using gaps are briefly discussed.

Gender: It was observed in the study areas that women managed households used fertilizers much lower than that of male managed households, which might be due to financial paucity and lack of knowledge about recommended dose. Therefore, this variable is notably responsible for creating gap between farmer's current practice and recommended dose. In *Boro* cultivation, the marginal coefficients of gender in Model-1 (over user of N) and Model-2 (over user of P) are positive and significant at 5% and 1% levels respectively, implying that 100% increase of the male farmer, keeping other factors constant, the probability of overall N and P using gaps would be increased by 6.18% and 58.55% respectively (Table 6.4). Similarly, in *T. Aman* cultivation, the marginal coefficients of gender in Model-8 (over user of P) and Model-9 (over user of K) are positive and significant at 5% and 1% levels respectively, implying that 100% increase by the male, keeping other factors constant, the probability of overall P and K using gaps would be increased by 16.38% and 19.28% respectively (Table 6.8). It means that male are the more over dose users of N and P than female.

The marginal coefficient of gender in Model-6 (over user of K) is negative and significant at 1% level, implying that 100% increase by male, keeping other factors constant, the probability of overall K using gaps in *Boro* cultivation would be decreased by 16.73% (Table 6.6).

Similarly, the marginal coefficients of this variable in Model-10, Model-11 and Model-12 (Table 6.10) are negative and significant at 1% level, implying that 100% increase by male, keeping other factors constant, the probability of overall N, P and K using gaps in *T. Aman* cultivation would be decreased by 14.14%, 19.06%, and 17.81% respectively. It further reveals that male farmers are the over dose users of N, P and K than female farmers.

Table 6.3 Beta regression coefficients influencing the over use of N, P & K fertilizers in *Boro* rice cultivation

Variables	**Model-1** for N			**Model-2** for P			**Model-3** for K		
	Coefficient	Std. Err	p>|z|	Coefficient	Std. Err	p>|z|	Coefficient	Std. Err	p>|z|
Constant	-1.7466	0.2547	0.000	-2.0618	0.7428	0.006	-3.8147	6.9230	0.582
Gender (male=1, otherwise 0)	0.30044	0.1454	0.039	2.11598	0.2577	0.000	--	--	--
Age (in year)	0.00030	0.0024	0.900	-0.0049	0.0042	0.245	-0.0125	0.0129	0.332
Education (No. of schooling)	0.00368	0.0059	0.536	-0.0168	0.0108	0.121	0.00256	0.0313	0.935
Occupation (1> occupation=1)	0.04037	0.0543	0.457	0.03501	0.1097	0.750	0.25526	0.3320	0.442
Small & marginal farmer (1, 0)	-0.1426	0.0739	0.054	-1.4369	0.1447	0.000	-0.1505	0.6478	0.816
Medium farmer (1,0)	-0.1394	0.0759	0.066	-0.6364	0.1342	0.000	0.08352	0.5078	0.869
Medium high land (1, 0)	0.04517	0.0686	0.510	0.01391	0.1011	0.891	0.21760	0.3108	0.484
Triple crops cultivation (1, 0)	0.09815	0.0782	0.209	0.14797	0.1575	0.348	0.47694	0.4173	0.253
Awareness (1, 0)	-0.0254	0.0762	0.739	0.05053	0.1446	0.727	0.35141	0.4490	0.434
Crop residue retention (1, 0)	0.08705	0.0588	0.139	-0.0041	0.1138	0.971	0.71016	0.3467	0.041
Crop rotation followed (1, 0)	0.06579	0.0718	0.360	0.08321	0.1080	0.441	-0.7853	0.3192	0.014
Line sowing (1, 0)	-0.0179	0.0950	0.851	-0.1106	0.1454	0.447	-0.6772	0.5123	0.186
Cultivate own land (1, 0)	0.04646	0.0859	0.589	0.06569	0.1651	0.691	-0.3278	0.7104	0.645
Ln_previous fertilizer (kg/ha)	0.01839	0.0260	0.478	0.02592	0.0572	0.650	0.46451	1.2090	0.701
Distance (km)	0.01401	0.0135	0.301	0.00102	0.0223	0.964	0.01800	0.0937	0.848
Optimum dose use (use=1, 0)	-0.0416	0.0577	0.471	-0.0452	0.0995	0.649	0.36329	0.2829	0.199
Crop demand (if yes =1, 0)	0.12871	0.0619	0.037	-0.0003	0.1113	0.998	0.06622	0.3603	0.854
Fertilizer price (Tk/kg)	0.01619	0.0061	0.008	0.00774	0.0107	0.467	0.02834	0.0351	0.420
Extension contact (1, 0)	0.05402	0.0526	0.305	-0.0405	0.0990	0.682	-0.5018	0.3951	0.204
Credit (receive=1, 0)	0.08054	0.0508	0.103	0.23182	0.0906	0.011	-0.0551	0.2743	0.841
Cattle (No./hh)	0.01168	0.0134	0.383	-0.0378	0.0218	0.083	-0.0263	0.0675	0.697
Societal membership (1, 0)	-0.1296	0.0605	0.032	-0.0278	0.1033	0.788	-0.7073	0.4159	0.089
Mymensingh dummy (1,0)	-0.0633	0.1225	0.605	0.27809	0.4905	0.571	-0.6282	0.6107	0.304
Rajshahi dummy (1,0)	0.19058	0.1306	0.144	0.66842	0.5438	0.219	0.96164	0.3910	0.014
Thakurgaon dummy (1,0)	-0.0677	0.1272	0.594	0.02418	0.5089	0.962	--	--	--
Number of observation (N)	114			197			57		
Wald chi^2	131.74***			287.62***			69.34***		
Log pseudo likelihood	197.57			84.10			75.28		

Note: Dependent variable (y) = Ratio of fertilizer use gap and recommended dose (value ranged from 0-1)
*'***' indicates significant at 1% level*

Age: Age is another factor that influence to some extent fertilizer use gaps at farm level. In *T. Aman* rice cultivation, the marginal coefficient of age is -0.0023 in Model-8 (over user of P) is negative and significant at 10% level, implying that 100% increase of age, keeping other factors constant, the probability of overall P using gaps would be decreased by 0.23% (Table 6.8). It means that the aged farmers have a tendency to use P at recommended level in *T.Aman* production.

Education: It is expected that educated farmers tend to use fertilizers at recommended level compared to non-educated farmers. In *Boro* rice cultivation, the marginal coefficient of education (-0.00196) in Model-4 (lower dose user of N) is negative and significant at 5% level. It implies that 100% increase of education, keeping other factors constant, the probability of overall N using gaps would be decreased by 0.196% (Table 6.6).

Table 6.4 Average marginal effect of beta regression coefficients on the over use of N, P & K fertilizers in *Boro* rice cultivation

Variables	**Model-1** for N			**Model-2** for P			**Model-3** for K		
	dy/dx	Std. Err	p>|z|	dy/dx	Std. Err	p>|z|	dy/dx	Std. Err	p>|z|
Gender (1=male, otherwise 0)	0.06178	0.0300	0.040	0.58551	0.0673	0.000	--	--	--
Age (in year)	0.00006	0.0005	0.900	-0.0013	0.0012	0.245	-0.0014	0.00147	0.331
Education (No. of schooling)	0.00076	0.0012	0.536	-0.0047	0.0030	0.118	0.00029	0.00356	0.935
Occupation (1> occupation=1)	0.00830	0.0111	0.457	0.00969	0.0303	0.749	0.02904	0.03745	0.438
Small & marginal farmer (1, 0)	-0.0293	0.0152	0.054	-0.3976	0.0363	0.000	-0.0171	0.07397	0.817
Medium farmer (1,0)	-0.0286	0.0155	0.064	-0.1761	0.0366	0.000	0.00950	0.05767	0.869
Medium high land (1, 0)	0.00929	0.0141	0.510	0.00385	0.0279	0.890	0.02476	0.03543	0.485
Triple crops cultivation (1, 0)	0.02018	0.0161	0.211	0.04095	0.0436	0.348	0.05427	0.04740	0.252
Awareness (1, 0)	-0.0052	0.0157	0.739	0.01398	0.0400	0.727	0.03998	0.05152	0.438
Crop residue retention (1, 0)	0.01790	0.0121	0.138	-0.0011	0.0314	0.971	0.08080	0.03730	0.030
Crop rotation followed (1, 0)	0.01353	0.0148	0.360	0.02303	0.0299	0.442	-0.0893	0.03610	0.013
Line sowing (1, 0)	-0.0037	0.0195	0.851	-0.0306	0.0402	0.447	-0.0770	0.05777	0.182
Cultivate own land (1, 0)	0.00955	0.0177	0.590	0.01818	0.0457	0.691	-0.0373	0.08078	0.644
Ln_previous fertilizer (kg/ha)	0.00378	0.0053	0.479	0.00717	0.0159	0.651	0.05285	0.13649	0.699
Distance (km)	0.00288	0.0028	0.302	0.00028	0.0061	0.964	0.00204	0.01068	0.848
Optimum dose use (use=1, 0)	-0.0086	0.0119	0.472	-0.0125	0.0278	0.650	0.04134	0.03327	0.214
Crop demand (if yes =1, 0)	0.02647	0.0127	0.038	-0.0001	0.0308	0.998	0.00753	0.04086	0.854
Fertilizer price (Tk/kg)	0.00333	0.0012	0.007	0.00214	0.0030	0.468	0.00322	0.00395	0.414
Extension contact (1, 0)	0.01111	0.0109	0.308	-0.0112	0.0274	0.682	-0.0571	0.04386	0.193
Credit (receive=1, 0)	0.01656	0.0104	0.103	0.06415	0.0246	0.009	-0.0063	0.03137	0.842
Cattle (No./hh)	0.00240	0.0027	0.380	-0.0105	0.0060	0.082	-0.0030	0.00771	0.698
Societal membership (1, 0)	-0.0266	0.0123	0.030	-0.0077	0.0286	0.788	-0.0805	0.04706	0.087
Mymensingh dummy (1,0)	-0.0130	0.0251	0.605	0.07696	0.1353	0.570	-0.0715	0.06885	0.299
Rajshahi dummy (1,0)	0.03919	0.0269	0.146	0.18497	0.1490	0.214	0.10942	0.04528	0.016
Thakurgaon dummy (1,0)	-0.0139	0.0261	0.594	0.00669	0.1408	0.962	--	--	--

Farmer category: Farmers' category is one of the most important variables that has significant influence on fertilizer use as well as fertilizer use gap between farmer's practice and recommended dose. In Chapter 5, it has been recognized that there is a positive correlation between farm size and fertilizer use meaning that higher the farm size the higher is the use of fertilizer.

It is expected that small and marginal farmers tend to use fertilizers at much lower dose compared to recommendation. In *Boro* rice cultivation, the marginal coefficients of this variable in Model-1 & -2 (over dose users of N & P) are -0.0293 and -0.3976 and significant at 10% and 1% levels respectively. It implies that an increase of small & marginal farmers by 100%, keeping other factors constant, the probability of overall N and P using gaps would decrease by 2.93% and 39.76% in the aggregate situation respectively (Table 6.4). Similarly, the marginal coefficients of this variable in Model-7, -8 & -9 (over dose users of N, P, & K in *T. Aman* cultivation) are negatives (-0.0578, -0.2330 and -0.1498) and significant at 1% levels, meaning that 100% increase of this variable, keeping other factors constant, the probability of N, P and K using gaps would be decreased by 5.78%, 23.30% and 14.98% in the aggregate situation respectively (Table 6.8).

Again in *Boro* rice cultivation, the marginal coefficients of this variable in Model-5 & -6 (under dose users of P & K) are -0.1381 and 0.1651 and significant at 10% and 1% levels, implying that 100% increase of this variable, keeping other factors constant, the probability of P and K using gaps would be decreased and increased by 13.81% and 16.51% respectively (Table 6.6). Similarly, the marginal coefficients of this variable in Model-10, -11 & -12 (under dose users of N, P, & K in *T. Aman* cultivation) are 0.1181, 0.2101 and 0.1090 and significant at 1%, 1% and 5% levels, implying that 100% increase of this variable, keeping other factors constant, the probability of N, P and K using gaps would be increased by 11.81%, 21.01% and 10.90% respectively (Table 6.10).

Table 6.5 Beta regression coefficients influencing the under use of N, P, & K fertilizers in *Boro* rice cultivation

Variables	**Model-4** for N			**Model-5** for P			**Model-6** for K		
	Coefficient	Std. Err	p>|z|	Coefficient	Std. Err	p>|z|	Coefficient	Std. Err	p>|z|
Constant	-0.04137	0.1770	0.815	0.1265	0.4791	0.792	0.3141	0.5373	0.559
Gender (1=male, otherwise 0)	-0.15966	0.1165	0.171	0.4194	0.2988	0.161	-0.7342	0.2107	0.000
Age (in year)	-0.00164	0.0015	0.297	0.0010	0.0050	0.838	-0.0034	0.0035	0.351
Education (No. of schooling)	-0.00978	0.0044	0.027	-0.0141	0.0112	0.210	0.0038	0.0111	0.734
Occupation (1> occupation=1)	-0.02470	0.0377	0.513	-0.0457	0.0946	0.629	-0.0720	0.0955	0.451
Small & marginal farmer (1, 0)	0.14007	0.1013	0.167	-0.4729	0.2996	0.105	0.7243	0.1869	0.000
Medium farmer (1,0)	-0.05187	0.1014	0.609	-0.4695	0.2823	0.096	0.2073	0.1847	0.262
Medium high land (1, 0)	0.07322	0.0351	0.037	0.1395	0.1148	0.225	0.1090	0.0889	0.221
Triple crops cultivation (1, 0)	-0.06354	0.0593	0.284	-0.1042	0.1310	0.427	0.0009	0.1390	0.994
Awareness (1, 0)	-0.07050	0.0489	0.150	-0.2028	0.1525	0.184	-0.3342	0.1473	0.023
Crop residue retention (1, 0)	0.01865	0.0425	0.661	0.0122	0.1211	0.920	0.0645	0.0933	0.489
Crop rotation followed (1, 0)	-0.11445	0.0693	0.099	-0.1279	0.1470	0.384	-0.1425	0.1156	0.218
Line sowing (1, 0)	-0.00668	0.0556	0.904	-0.0739	0.1296	0.568	-0.0866	0.1219	0.478
Cultivate own land (1, 0)	-0.04638	0.0445	0.298	0.0705	0.1527	0.644	-0.0844	0.1362	0.536
Ln_previous fertilizer (kg/ha)	-0.03820	0.0170	0.025	-0.1479	0.0653	0.024	0.0128	0.0486	0.793
Distance (km)	0.01749	0.0047	0.000	0.0259	0.0135	0.056	-0.0259	0.0118	0.029
Optimum dose use (use=1, 0)	-0.02051	0.0419	0.624	-0.0236	0.1208	0.845	0.1883	0.0966	0.051
Crop demand (if yes =1, 0)	0.00500	0.0388	0.898	0.0524	0.0870	0.547	0.0263	0.0871	0.763
Fertilizer price (Tk/kg)	-0.00889	0.0040	0.027	0.0126	0.0070	0.072	0.0145	0.0122	0.238
Extension contact (1, 0)	-0.03229	0.0377	0.392	-0.1836	0.1229	0.135	-0.0792	0.0930	0.395
Credit (receive=1, 0)	0.03648	0.0368	0.323	0.2223	0.0967	0.022	-0.1067	0.0877	0.224
Cattle (No./hh)	-0.02329	0.0102	0.022	-0.0166	0.0254	0.515	-0.0035	0.0228	0.878
Societal membership (1, 0)	-0.01645	0.0442	0.710	0.0981	0.1240	0.429	-0.0908	0.0904	0.316
Mymensingh dummy (1,0)	-0.33700	0.0698	0.000	-0.2711	0.1563	0.083	-1.2054	0.1637	0.000
Rajshahi dummy (1,0)	-0.47742	0.0861	0.000	-0.0943	0.3839	0.806	0.8685	0.2166	0.000
Thakurgaon dummy (1,0)	0.37690	0.0716	0.000	0.1681	0.1912	0.379	-1.4492	0.2039	0.000
Number of observation (N)	178			84			235		
Wald chi2	203.68***			146.44***			199.53***		
Log pseudo likelihood	328.93			83.28			154.71		

Note: Dependent variable (y) = Ratio of fertilizer use gap and recommended dose (value ranged from 0-1)
*'***' indicates significant at 1% level*

Medium farmers: Farmer's category is one of the most important variables in influencing nutrients use. It has already been stated that there is a positive correlation between farm size and nutrient use. However in *Boro* rice cultivation, the marginal coefficients of medium farmers in Model-1 & -2 (over dose users of N & P) are negative and significant at 10% and 1% levels which implied that 100% increase of medium farmer, keeping other factors constant, the probability of N and P using gaps would be decreased by 2.86% and 17.61% respectively (Table 6.4). Similarly in *T. Aman* cultivation, the marginal coefficients of medium farmer in Model-7, -8 & -9 (over dose users of N, P & K) are negatives and significant at 5% levels, implying that 100% increase of medium farmers, keeping other factors constant, the probability of N, P and K using gaps would be decreased by 3.12%, 8.92% and 9.90% respectively (Table 6.8).

Again, the marginal coefficient of medium farmers in Model-4 (under dose user of N in *Boro* cultivation) is positive and significant at 5% level meaning that 100% increase of medium farmer, keeping other factors constant, the probability of N using gaps would be increased by 1.47% (Table 6.6). Similarly in *T. Aman* cultivation, the marginal coefficient of medium farmer in Model-11 (under dose users of P) is positive and significant at 1% level which implied that the probability of P using gaps would be increased by 31.35% with an increase of 100% medium farmers, keeping other factors constant (Table 6.10).

Table 6.6 Average marginal effect of beta regression coefficients on the under use of N, P, & K fertilizers in *Boro* rice cultivation

Variables	**Model-4** for N			**Model-5** for P			**Model-6** for K		
	dy/dx	Std. Err	p>|z|	dy/dx	Std. Err	p>|z|	dy/dx	Std. Err	p>|z|
Gender (1=male, otherwise 0)	-0.03200	0.0234	0.173	0.1224	0.0868	0.158	-0.1673	0.0477	0.000
Age (in year)	-0.00033	0.0003	0.297	0.0003	0.0014	0.838	-0.0008	0.0008	0.351
Education (No. of schooling)	-0.00196	0.0008	0.027	-0.0041	0.0032	0.208	0.0009	0.0025	0.734
Occupation (1> occupation=1)	-0.00495	0.0075	0.512	-0.0133	0.0276	0.629	-0.0164	0.0217	0.451
Small & marginal farmer (1, 0)	0.02808	0.0204	0.170	-0.1381	0.0863	0.100	0.1651	0.0425	0.000
Medium farmer (1,0)	-0.01040	0.0203	0.609	-0.1371	0.0818	0.194	0.0473	0.0420	0.262
Medium high land (1, 0)	0.01467	0.0069	0.035	0.0407	0.0342	0.234	0.0248	0.0202	0.220
Triple crops cultivation (1, 0)	-0.01274	0.0118	0.282	-0.0304	0.0381	0.425	0.0002	0.0316	0.994
Awareness (1, 0)	-0.01413	0.0097	0.148	-0.0592	0.0442	0.181	-0.0762	0.0329	0.021
Crop residue retention (1, 0)	0.00374	0.0085	0.661	0.0036	0.0353	0.920	0.0147	0.0212	0.489
Crop rotation followed (1, 0)	-0.02294	0.0138	0.098	-0.0374	0.0435	0.391	-0.0325	0.0265	0.220
Line sowing (1, 0)	-0.00134	0.0111	0.904	-0.0216	0.0375	0.565	-0.0197	0.0276	0.476
Cultivate own land (1, 0)	-0.00929	0.0089	0.297	0.0206	0.0442	0.642	-0.0192	0.0310	0.535
Ln_previous fertilizer (kg/ha)	-0.00766	0.0033	0.024	-0.0432	0.0192	0.025	0.0029	0.0110	0.793
Distance (km)	0.00351	0.0009	0.000	0.0076	0.0038	0.052	-0.0059	0.0027	0.029
Optimum dose use (use=1, 0)	-0.00411	0.0083	0.624	-0.0069	0.0352	0.845	0.0429	0.0219	0.050
Crop demand (if yes =1, 0)	0.00100	0.0077	0.898	0.0153	0.0254	0.547	0.0060	0.0198	0.763
Fertilizer price (Tk/kg)	-0.00178	0.0008	0.027	0.0037	0.0020	0.067	0.0033	0.0027	0.236
Extension contact (1, 0)	-0.00647	0.0075	0.394	-0.0536	0.0364	0.141	-0.0180	0.0212	0.396
Credit (receive=1, 0)	0.00732	0.0073	0.321	0.0649	0.0279	0.020	-0.0243	0.0199	0.223
Cattle (No./hh)	-0.00467	0.0020	0.022	-0.0048	0.0074	0.515	-0.0008	0.0052	0.878
Societal membership (1, 0)	-0.00329	0.0088	0.710	0.0287	0.0362	0.429	-0.0207	0.0206	0.317
Mymensingh dummy (1,0)	-0.06756	0.0139	0.000	-0.0792	0.0457	0.084	-0.2747	0.0363	0.000
Rajshahi dummy (1,0)	-0.09571	0.0173	0.000	-0.0275	0.1118	0.806	-0.1979	0.0488	0.000
Thakurgaon dummy (1,0)	-0.07556	0.0144	0.000	0.0491	0.0555	0.377	-0.3303	0.0449	0.000

Triple crops: Some farmers in the study areas cultivate three crops in the same plot in a year. Therefore, it is expected that the nutrient use gap will be influenced much by the three crops cultivating farmers. The study reveals that only the under users of N in *T. Aman* rice cultivation influence N use gap to some extent. However, the marginal coefficient of this variable in Model-10 is negative and significant at 10% level which implied that the probability of N using gaps decrease by 0.93% with the increase of the triple crop cultivation by 100% keeping other factors constant (Table 6.10).

Awareness: Awareness regarding nutrient management is important in crop production. Therefore, it is expected that the farmers who are much aware about nutrient management, they will be closer to use the recommended of nutrients. The study reveals that only the under users of K in *Boro* rice cultivation influence K use gap to some extent. However, the marginal coefficient of awareness in Model-6 (under dose users of K) is negative and significant at 5% level, meaning that 100% increase of awareness, keeping other factors constant, the probability of K use gaps would be decreased by 7.62% (Table 6.6).

Table 6.7 Beta regression coefficients influencing the over use of N, P, & K fertilizers in *T. Aman* rice cultivation

Variables	**Model-7** for N			**Model-8** for P			**Model-9** for K		
	Coefficient	Std. Err	p>|z|	Coefficient	Std. Err	p>|z|	Coefficient	Std. Err	p>|z|
Constant	-2.5295	0.3695	0.000	-2.5986	0.7522	0.001	-1.9686	0.4460	0.000
Gender (1=male, otherwise 0)	0.3132	0.2375	0.187	0.4995	0.2323	0.032	0.8998	0.2453	0.000
Age (in year)	-0.0015	0.0044	0.731	-0.0069	0.0036	0.060	0.0046	0.0052	0.376
Education (No. of schooling)	0.0084	0.0127	0.509	-0.0088	0.0102	0.395	0.0090	0.0131	0.492
Occupation (1> occupation=1)	0.0065	0.0980	0.948	-0.0158	0.0834	0.849	0.0672	0.1079	0.534
Small & marginal farmer (1, 0)	-0.5680	0.1658	0.001	-0.7106	0.1377	0.000	-0.6991	0.2217	0.002
Medium farmer (1,0)	-0.3069	0.1453	0.035	-0.2720	0.1276	0.033	-0.4623	0.1878	0.014
Medium high land (1, 0)	-0.0899	0.0959	0.348	0.0853	0.0849	0.315	0.0442	0.1040	0.671
Triple crops cultivation (1, 0)	-0.0761	0.1524	0.618	0.0185	0.1098	0.866	-0.0462	0.1736	0.790
Awareness (1, 0)	-0.0297	0.1024	0.772	0.0492	0.0940	0.601	-0.1150	0.1228	0.349
Crop residue retention (1, 0)	0.0493	0.1270	0.698	0.1499	0.0835	0.073	-0.0557	0.1193	0.640
Crop rotation followed (1, 0)	-0.0339	0.1484	0.820	0.1581	0.0897	0.518	0.2873	0.1398	0.040
Line sowing (1, 0)	-0.2804	0.1217	0.021	0.1064	0.1351	0.431	-0.0494	0.1543	0.749
Cultivate own land (1, 0)	0.1845	0.2081	0.376	0.1160	0.1252	0.355	0.0889	0.1535	0.563
Ln_previous fertilizer (kg/ha)	0.0069	0.0381	0.856	0.3853	0.1137	0.001	-0.0310	0.0297	0.297
Distance (km)	0.0242	0.0273	0.375	-0.0270	0.0181	0.138	0.0504	0.0225	0.025
Optimum dose use (use=1, 0)	0.1668	0.1064	0.117	-0.3306	0.0985	0.001	-0.0300	0.1178	0.799
Crop demand (if yes =1, 0)	-0.1177	0.1027	0.252	-0.0305	0.0896	0.734	0.0290	0.1293	0.822
Fertilizer price (Tk/kg)	0.0040	0.0137	0.769	0.0136	0.0084	0.102	0.0134	0.0245	0.586
Extension contact (1, 0)	0.0625	0.1018	0.539	0.0677	0.0856	0.429	0.1424	0.1337	0.287
Credit (receive=1, 0)	0.1070	0.0980	0.275	0.0147	0.0839	0.861	-0.1740	0.1084	0.109
Cattle (No./hh)	0.0233	0.0191	0.224	-0.0075	0.0155	0.630	-0.0362	0.0170	0.034
Societal membership (1, 0)	-0.0661	0.1059	0.533	0.0320	0.0949	0.536	-0.0662	0.1125	0.556
Mymensingh dummy (1,0)	0.0148	0.2439	0.952	-0.4292	0.1509	0.004	-0.1060	0.2330	0.649
Rajshahi dummy (1,0)	0.2817	0.2230	0.207	-0.4339	0.1841	0.018	-0.2608	0.2452	0.288
Thakurgaon dummy (1,0)	-0.3765	0.2000	0.060	0.0027	0.1802	0.988	-0.0106	0.2292	0.963
Khulna dummy (1,0)	0.7637	0.1905	0.000	-0.7652	0.1843	0.000	0.2416	0.2003	0.228
Number of observation (N)	238			325			354		
Wald chi^2	171.66***			154.62***			79.08***		
Log pseudo likelihood	334.19			59.13			193.84		

Note: Dependent variable (y) = Ratio of fertilizer use gap and recommended dose (value ranged from 0-1)
*'***' indicates significant at 1% level*

Crop residue retention: Crop residue retention on the top of the soil substantially reduces the amount of inorganic fertilizers use which brings both environmental and economic benefits to the farmers (Tiwari, 2007). Therefore, the farmers who retain crop residues in the field expected to use less amount of nutrients. But in practice, this is not fully true at farm level. In *Boro* rice cultivation, the marginal coefficient of crop residue retention in Model-3 (over dose users of K) is positive and significant at 5% level, which implied that the probability of K use gap significantly increases by 8.08% with the increase of 100% of this variable in the aggregate situation, keeping other factors constant (Table 6.4). Again in *T.Aman* cultivation, the marginal coefficients of this factor in Model-8 (over dose users of P) and -10 (lower dose user of N) are positives and significant at 10% levels, implying that 100% increase of this factor, keeping other factors constant, the probability of P and N use gaps would be increased by 4.91% and 2.09% in the aggregate situation respectively (Table 6.8).

Table 6.8 Average marginal effect of beta regression coefficients on the over use of N, P, & K fertilizers in *T. Aman* rice cultivation

Variables	**Model-7** for N			**Model-8** for P			**Model-9** for K		
	dy/dx	Std. Err	p>|z|	dy/dx	Std. Err	p>|z|	dy/dx	Std. Err	p>|z|
Gender (1=male, otherwise 0)	0.0319	0.0242	0.189	0.1638	0.0757	0.030	0.1928	0.0518	0.000
Age (in year)	-0.0002	0.0004	0.731	-0.0023	0.0011	0.057	0.0010	0.0011	0.381
Education (No. of schooling)	0.0009	0.0012	0.510	-0.0029	0.0033	0.393	0.0019	0.0028	0.495
Occupation (1> occupation=1)	0.0007	0.0099	0.948	-0.0052	0.0273	0.849	0.0144	0.0230	0.533
Small & marginal farmer (1, 0)	-0.0578	0.0169	0.001	-0.2330	0.0434	0.000	-0.1498	0.0460	0.001
Medium farmer (1,0)	-0.0312	0.0148	0.035	-0.0892	0.0415	0.032	-0.0990	0.0400	0.013
Medium high land (1, 0)	-0.0092	0.0097	0.346	0.0280	0.0278	0.316	0.0095	0.0222	0.671
Triple crops cultivation (1, 0)	-0.0077	0.0154	0.617	0.0061	0.0360	0.866	-0.0099	0.0371	0.790
Awareness (1, 0)	-0.0030	0.0104	0.771	0.0161	0.0308	0.601	-0.0246	0.0266	0.355
Crop residue retention (1, 0)	0.0050	0.0129	0.698	0.0491	0.0272	0.072	-0.0119	0.0255	0.460
Crop rotation followed (1, 0)	-0.0034	0.0150	0.819	0.0191	0.0294	0.518	0.0615	0.0303	0.042
Line sowing (1, 0)	-0.0285	0.0124	0.022	0.0349	0.0441	0.430	-0.0106	0.0330	0.748
Cultivate own land (1, 0)	0.0188	0.0211	0.375	0.0380	0.0411	0.355	0.0190	0.0329	0.564
Ln_previous fertilizer (kg/ha)	0.0007	0.0038	0.856	0.1264	0.0369	0.001	-0.0066	0.0063	0.292
Distance (km)	0.0025	0.0028	0.379	-0.0088	0.0059	0.135	0.0108	0.0048	0.026
Optimum dose use (use=1, 0)	0.0170	0.0108	0.119	-0.1084	0.0317	0.001	-0.0064	0.0252	0.799
Crop demand (if yes =1, 0)	-0.0120	0.0104	0.251	-0.0100	0.0294	0.734	0.0062	0.0276	0.822
Fertilizer price (Tk/kg)	0.0004	0.0014	0.769	0.0045	0.0027	0.100	0.0029	0.0052	0.586
Extension contact (1, 0)	0.0064	0.0103	0.540	0.0222	0.0280	0.429	0.0305	0.0288	0.290
Credit (receive=1, 0)	0.0109	0.0099	0.272	0.0048	0.0275	0.861	-0.0373	0.0239	0.119
Cattle (No./hh)	0.0024	0.0019	0.224	-0.0025	0.0050	0.630	-0.0077	0.0037	0.038
Societal membership (1, 0)	-0.0067	0.0107	0.533	0.0105	0.0311	0.736	-0.0142	0.0240	0.556
Mymensingh dummy (1,0)	0.0015	0.0248	0.952	-0.1408	0.0491	0.004	-0.0227	0.0505	0.653
Rajshahi dummy (1,0)	0.0287	0.0224	0.202	-0.1423	0.0600	0.018	-0.0559	0.0540	0.301
Thakurgaon dummy (1,0)	-0.0383	0.0204	0.061	0.0009	0.0590	0.988	-0.0023	0.0491	0.963
Khulna dummy (1,0)	0.0777	0.0190	0.000	-0.2509	0.0595	0.000	0.0518	0.0420	0.219

Crop rotation followed: A crop rotation is the practice of growing a series of different types of crops in the same area over a sequence of seasons. It helps to maintain soil nutrients, reduce soil erosion, prevents plant diseases and pests and maximize crop yield potential and profitability over time (Alam et al., 2019; Alam et al., 2016; Feizabady, 2013). Therefore, the farmers who practice crop rotation in their field expected to use less amount of nutrients.

In *Boro* rice cultivation, the marginal coefficients of this factor in Model-3 (over dose users of K) and Model-4 (under dose user of N) are -0.0893 and -0.02294 which are significant at 5% and 10% levels respectively. It implies that 100% increase of this factor, keeping other factors constant, the probability of K and N use gaps would be decreased by 8.93% and 2.29% in the aggregate situation respectively (Table 6.4 and 6.6). Again in *T.Aman* cultivation, the marginal coefficients of this factor in Model-9 (over dose users of K) is positives and significant at 5% level, implying that 100% increase of this factor, keeping other factors constant, the probability of K use gaps would be increased by 6.15% (Table 6.8).

Line sowing: This factor to some extent influences the nutrient use gap in crop production. In *T.Aman* rice cultivation, the marginal coefficient (-0.0285) of line sowing in Model-7 (over dose users of N) is negative and significant at 5% level, indicating that the probability of N use gap decreases with the increase in line sowing in *T.Aman* rice cultivation, keeping other factors constant (Table 6.8).

Table 6.9 Beta regression coefficients influencing the under use of N, P, & K fertilizers in *T. Aman* rice cultivation

Variables	**Model-10** for N			**Model-11** for P			**Model-12** for K		
	Coefficient	Std. Err	p>|z|	Coefficient	Std. Err	p>|z|	Coefficient	Std. Err	p>|z|
Constant	-0.4977	0.1053	0.000	-1.1816	0.5307	0.026	-0.4675	0.3530	0.185
Gender (1=male, otherwise 0)	-0.4494	0.1138	0.000	-0.5948	0.2329	0.011	-0.7181	0.2211	0.001
Age (in year)	-0.0092	0.0014	0.422	-0.0034	0.0049	0.492	0.0021	0.0028	0.454
Education (No. of schooling)	0.0004	0.0039	0.926	-0.0012	0.0149	0.936	-0.0041	0.0113	0.713
Occupation (1> occupation=1)	0.0187	0.0320	0.561	0.1560	0.1302	0.231	0.0691	0.0785	0.379
Small & marginal farmer (1, 0)	0.3755	0.1131	0.001	0.6557	0.2323	0.005	0.4395	0.1997	0.028
Medium farmer (1,0)	0.1482	0.1104	0.180	0.9784	0.2642	0.000	0.0569	0.1969	0.773
Medium high land (1, 0)	0.0914	0.0320	0.004	0.0071	0.1144	0.951	0.0839	0.0756	0.267
Triple crops cultivation (1, 0)	-0.0296	0.0399	0.458	0.1611	0.1613	0.318	0.0080	0.0975	0.935
Awareness (1, 0)	-0.0472	0.0376	0.210	0.0823	0.1518	0.588	-0.0741	0.0977	0.449
Crop residue retention (1, 0)	0.0664	0.0350	0.058	-0.0283	0.1180	0.811	-0.0790	0.0742	0.287
Crop rotation followed (1, 0)	-0.0521	0.0467	0.265	0.0673	0.1807	0.710	-0.1292	0.1313	0.325
Line sowing (1, 0)	0.0414	0.0391	0.290	0.0866	0.1472	0.557	-0.0100	0.1002	0.921
Cultivate own land (1, 0)	0.0019	0.0441	0.966	0.0538	0.1808	0.766	-0.0710	0.0971	0.465
Ln_previous fertilizer (kg/ha)	0.0738	0.0134	0.000	0.1131	0.0357	0.002	-0.0017	0.0154	0.912
Distance (km)	-0.0127	0.0059	0.032	-0.0062	0.0170	0.717	0.0227	0.0174	0.193
Optimum dose use (use=1, 0)	-0.0397	0.0379	0.296	0.1745	0.1386	0.208	0.0251	0.0741	0.735
Crop demand (if yes =1, 0)	0.0241	0.0327	0.462	0.1513	0.1199	0.207	-0.1777	0.0985	0.071
Fertilizer price (Tk/kg)	-0.0074	0.0042	0.082	0.0181	0.0146	0.216	-0.0003	0.0169	0.985
Extension contact (1, 0)	-0.0019	0.0347	0.956	-0.2038	0.1156	0.078	-0.0839	0.1021	0.411
Credit (receive=1, 0)	-0.0313	0.0309	0.313	-0.0417	0.1197	0.728	-0.0607	0.0766	0.428
Cattle (No./hh)	0.0054	0.0062	0.388	-0.0080	0.0244	0.742	-0.0121	0.0153	0.431
Societal membership (1, 0)	-0.0428	0.0364	0.240	-0.1462	0.1394	0.294	0.0281	0.0869	0.746
Mymensingh dummy (1,0)	-0.1987	0.0674	0.003	-0.1801	0.2629	0.493	0.2204	0.1748	0.208
Rajshahi dummy (1,0)	-0.3208	0.0755	0.000	-0.2690	0.3420	0.432	-0.3668	0.2179	0.092
Thakurgaon dummy (1,0)	-0.1159	0.0745	0.120	-0.4705	0.3045	0.122	-0.2099	0.1701	0.217
Khulna dummy (1,0)	-0.0997	0.0554	0.072	-0.2952	0.2181	0.176	-0.4372	0.1472	0.003
Number of observation (N)	494			270			378		
Wald chi2	195.21***			46.73***			133.25***		
Log pseudo likelihood	455.91			49.16			172.03		

Note: Dependent variable (y) = Ratio of fertilizer use gap and recommended dose (value ranged from 0-1)
*'***' indicates significant at 1% level*

Fertilizer use in previous crop: Most respondent farmers in the study areas use over dose of inorganic fertilizers to some *Rabi* crops like potato, *Boro* rice, maize, etc and use less amount to the next crop assuming that the residue of inorganic fertilizers retain in the soil. Therefore, it is expected that this factor should have significant influence on nutrient use gap in crop production at farm level.

In *Boro* rice cultivation, the marginal coefficients of this variable in Model-4 & -5 (lower dose users of N & P) are -0.00766 and -0.0432 and significant at 5% levels, implying that 100% increase of this variable, keeping other factors constant, the probability of N and P using gaps would be decreased by 0.77% and 4.32% respectively (Table 6.6). Similarly in *T. Aman* cultivation, the marginal coefficients of this variable in Model-8 (over dose user of P), Model-10 & -11 (lower dose users of N & P) are positives and highly significant at 1% levels, implying that 100% increase of this variable, keeping other factors constant, the probability of P, N and P using gaps would be increased by 12.64%, 2.32% and 3.62% respectively (Table 6.8 & Table 6.10).

Distance: The farmers whose residences are closed to the input/output market can easily buy inputs and sell farm produces spending lower cost of transportation and less time. Besides, they can take immediate action towards nutrient management as needed. Therefore, distance from residence/crop field to input/output market is a crucial factor that has significant influence on the gap between farmer's practice and recommended dose.

In the case of under dose users of N, P and K in *Boro* rice cultivation, the marginal coefficients of distance in Model-4, -5 & -6 are 0.00351, 0.0076 and -0.0059 which are significant at 1%, 10% and 5% levels respectively. It implies that the probability of N & P using gaps will be increased by 0.35% and 0.76% respectively, and K using gaps decreased by 0.59% if distance is increased by 100%, keeping other factors constant (Table 6.6). Similarly in *T.Aman* rice cultivation, the marginal coefficients of this variable in Model-9 (over dose user of K) and Model-10 (lower dose users of N) are 0.0108 and -0.0040 and significant at 5% level, implying that 100% increase of this variable, keeping other factors constant, the probability of K and N use gaps would be increased and decreased by 1.08% and 0.40% respectively (Table 6.8 & Table 6.10).

Table 6.10 Average marginal effect of beta regression on the under use of N, P & K fertilizers in *T. Aman* rice cultivation

Variables	**Model-10** for N			**Model-11** for P			**Model-12** for K		
	dy/dx	Std. Err	p>|z|	dy/dx	Std. Err	p>|z|	dy/dx	Std. Err	p>|z|
Gender (1=male, otherwise 0)	-0.1414	0.3560	0.000	-0.1906	0.0742	0.010	-0.1781	0.0548	0.001
Age (in year)	-0.0004	0.0004	0.421	-0.0011	0.0015	0.491	0.0005	0.0007	0.453
Education (No. of schooling)	0.0001	0.0012	0.926	-0.0004	0.0047	0.936	-0.0010	0.0028	0.713
Occupation (1> occupation=1)	0.0059	0.0100	0.561	0.04998	0.0417	0.232	0.0171	0.0195	0.381
Small & marginal farmer (1, 0)	0.1181	0.0354	0.001	0.2101	0.0741	0.005	0.1090	0.0494	0.027
Medium farmer (1,0)	0.0466	0.0346	0.179	0.3135	0.0836	0.000	0.0141	0.0488	0.772
Medium high land (1, 0)	0.0288	0.0100	0.004	0.0023	0.0366	0.951	0.0208	0.0185	0.263
Triple crops cultivation (1, 0)	-0.0093	0.0125	0.059	0.0516	0.0515	0.317	0.0020	0.0241	0.935
Awareness (1, 0)	-0.0148	0.0118	0.210	0.0264	0.0487	0.588	-0.0184	0.0242	0.450
Crop residue retention (1, 0)	0.0209	0.0110	0.058	-0.0091	0.0378	0.811	-0.0196	0.0184	0.288
Crop rotation followed (1, 0)	-0.0164	0.0146	0.264	0.0216	0.0578	0.709	-0.0320	0.0324	0.324
Line sowing (1, 0)	0.0130	0.0123	0.291	0.0277	0.0473	0.558	-0.0025	0.0248	0.920
Cultivate own land (1, 0)	0.0006	0.0138	0.966	0.0172	0.0579	0.766	-0.0176	0.0239	0.462
Ln_previous fertilizer (kg/ha)	0.0232	0.0041	0.000	0.0362	0.0112	0.001	-0.0004	0.0038	0.912
Distance (km)	-0.0040	0.0018	0.032	-0.0020	0.0054	0.716	0.0056	0.0043	0.195
Optimum dose use (use=1, 0)	-0.0125	0.0119	0.296	0.0559	0.0445	0.209	0.0062	0.0183	0.735
Crop demand (if yes =1, 0)	0.0076	0.0103	0.462	0.0485	0.0383	0.206	-0.0441	0.0249	0.078
Fertilizer price (Tk/kg)	-0.0023	0.0013	0.081	0.0058	0.0046	0.215	-0.0001	0.0042	0.985
Extension contact (1, 0)	-0.0006	0.0109	0.956	-0.0653	0.0370	0.078	-0.0208	0.0255	0.414
Credit (receive=1, 0)	-0.0098	0.0097	0.313	-0.0134	0.0383	0.727	-0.0151	0.0190	0.428
Cattle (No./hh)	0.0017	0.0019	0.388	-0.0026	0.0078	0.742	-0.0030	0.0038	0.434
Societal membership (1, 0)	-0.0135	0.0114	0.240	-0.0468	0.0444	0.292	0.0070	0.0215	0.746
Mymensingh dummy (1,0)	-0.0625	0.0211	0.003	-0.0577	0.0843	0.494	0.0547	0.0431	0.205
Rajshahi dummy (1,0)	-0.1009	0.0234	0.000	-0.0862	0.1096	0.432	-0.0910	0.0549	0.098
Thakurgaon dummy (1,0)	-0.0364	0.0233	0.119	-0.1507	0.0971	0.121	-0.0521	0.0427	0.223
Khulna dummy (1,0)	-0.0314	0.0174	0.072	-0.0946	0.0699	0.176	-0.1084	0.0375	0.004

Optimum dose use: It is discussed earlier that most of the respondent farmers in the study areas used nutrients either over dose or lower dose compared to recommended dose. Optimum dose users were rare in the sample. However, the farmers who applied nutrients close to optimum dose should have some influence on the nutrient use gap. In *Boro* rice cultivation, the marginal coefficient of this factor in Model-6 (over dose users of K) is positive and significant at 5% level, indicating that the probability of K use gap increases with the increase in this factor, keeping other factors constant (Table 6.6). Again in *T.Aman* cultivation, the marginal coefficient (-0.1084) of this factor in Model-8 (over dose users of P) is negative and highly significant at 1% level, implying that 100% increase of this variable, keeping other factors constant, the probability of P use gaps would be decreased by 10.84% in the aggregate situation (Table 6.8)

Crop demand for nutrients: It has been stated in the previous section that many respondent farmers consider different agro-socio-economic factors in deciding the type and amount of fertilizers to use. Many farmers used nutrients observing the physical growth of crop or assuming the demand of nutrients. So, this factor is assumed to have some influence on the gap of fertilizer use between farmers' practice and recommended dose. The influence of this factor is only seen in the *Boro* rice cultivation. The marginal coefficient of this factor in Model-1 (over dose users of N) is positive and significant at 5% level, implying that 100% increase of this variable, keeping other factors constant, the probability of N use gaps would be increased by 2.65% in the aggregate situation (Table 6.4).

Fertilizer price: Farmers usually give priority on good production. They don't think about price and subsidy in case of applying fertilizers. Therefore, fertilizer price does not influence farmers much in deciding the type and amount of fertilizer to be used. Due to financial problem, fertilizer application is sometimes delayed (FGD, 2019). However, the analysis revealed that fertilizer price had significant influence on the fertilizer use gap between farmers' practice and recommended dose.

In *Boro* rice cultivation, the marginal coefficients of fertilizer price in Model-1 (over dose users of N), Model-4 & -5 (lower dose users of N & P) are 0.00333, -0.00178 and 0.0037 which are significant at 1%, 5% and 10% levels respectively. It implies that 100% increase of fertilizer price, keeping other factors constant, the probability of N using gaps in over dose users would be increased by 0.33% and in case of under dose users would be decreased by 0.18% (Table 6.6). Again, 100% increase of fertilizer price, keeping other factors constant, the probability of P using gaps in lower dose users would be increased by 0.37% (Table 6.6). Similarly, in *T.Aman* rice cultivation, the marginal coefficients of fertilizer price in Model-8 (over dose users of P) and Model-10 (lower dose users of N) are 0.0045 & -0.0023 and significant at 10% level meaning that 100% increase of this factor, keeping other factors constant, the probability of P and N using gaps would be increased by 0.45% (Table 6.8) and decreased by 0.23% respectively (Table 6.10).

Extension contact: The farmers who have frequent contact with extension personnel are expected to use fertilizers or nutrients close to recommended dose. In *T.Aman* rice cultivation, the marginal coefficient of extension contact is -0.0653 in Model-11 (lower dose user of P) and significant at 10% level indicating that 100% increase of extension contact, keeping other factors constant, the probability of overall P using gaps would be decreased by 6.53% in an aggregate situation (Table 6.10). Respondent farmers generally use over dose of P compared to its recommended dose. This result reveals that P use gap decreases with extension contact increases meaning that lower dose using farmers will be motivated by extension personnel towards the use of P at recommended level.

Credit: The farmers who received credit from any source are expected to use fertilizers or nutrients close to recommended dose or over dose. The marginal coefficient of credit received by *Boro* farmers is 0.0642 in Model-2 (over dose user of P) and 0.0649 in Model-5 (lower dose user of P) which are significant at 1% and 5% levels respectively. It implies that 100% increase of credit beneficiaries, keeping other factors constant, the probability of overall gap of P use would be increased by 6.42% and 6.49% in an aggregate situation (Table 6.4 & 6.6). Respondent farmers generally use over dose of P compared to its recommended dose. Therefore, the results is quite supportive to the present behaviour of the farmers.

No. of cattle owned: It is assumed that the use of organic fertilizer (cow dung) increases with the number of cattle increases in the household. FGD (2019) also revealed that the farmers who applied cow dung used less amount of organic fertilizers. So it should have significant impact on the nutrient use gap at farm level.

In *Boro* rice cultivation, the marginal coefficients of this variable in Model-2 (over dose users of P) and Model-4 (lower dose users of N) are -0.0105 and -0.00467 which are significant at 10% and 5% levels implying that 100% increase of this variable, keeping other factors constant, the probability of P and N using gaps would be decreased by 1.05% and 0.47% respectively (Table 6.4 & 6.6). Similarly in *T. Aman* rice cultivation, the marginal coefficient of this variable in Model-9 (over dose user of K) is negative and significant at 5% level, indicating that 100% increase of this variable, keeping other factors constant, the probability of K using gaps would be decreased by 0.77% (Table 6.8).

Societal membership: Some respondent farmers are involved in various social formal and informal organizations/institutions/clubs/NGOs etc. These include Farmer's Field School, IPM/ICM clubs, NGOs, and religious institutions. It is expected that those farmers are more dynamic and use fertilizer dose closer to the recommendation compared to other non-member farmers. In *Boro* rice cultivation, the marginal coefficients of this factor are -0.0266 in Model-1 (over dose user of N) and -0.0805 in Model-3 (over dose user of K) which are significant at 5% and 10% levels respectively. It implies that the probability of overall N and P using gaps will be decreased by 2.66% and 8.05% respectively in an aggregate situation, if this variable is increased by 100% keeping other factors constant (Table 6.4).

Regional dummy: There are regional variation in applying inorganic fertilizers in crop production. Therefore, sampled region should have significant impact on increasing or decreasing the fertilizer using gaps between current farmers' practice and scientific recommendations.

In *Boro* rice cultivation, the marginal coefficients of Mymensingh district dummy are -0.0676 in Model-4 (under dose user of N), -0.0792 in Model-5 (under dose user of P) and -0.2747 in Model-6 (under dose user of K) which are significant at 1%, 10% and 1% levels respectively (Table 4.6). These results indicate that the nutrient N, P, and K use gap in *Boro* rice cultivation will be decreased by 6.76%, 7.92%, and 27.47% respectively if the agro-climatic condition of Mymensingh region increased by 100%, keeping regions constant. Similarly, the coefficient of Mymensingh dummy is -0.0625 in Model-10 (under dose user of N) and highly significant at 1% level, implying that the probability of overall N using gaps in *T.Aman* rice cultivation will be decreased by 6.25% in an aggregate situation, if this variable is increased by 100% keeping other factors constant (Table 6.10).

Again in *Boro* rice cultivation, the marginal coefficients of Rajshahi dummy are -0.0957 in Model-4 (under dose user of N) and -0.1979 in Model-6 (under dose user of K) which are highly significant at 1% level (Table 4.6). These results indicate that the probability of N and K use gap will be decreased by 9.57% and 19.79% respectively if the agro-climatic condition of Rajshahi region changes by 100%, keeping other regions constant. Similarly, the coefficients of Rajshahi dummy are -0.1009 in Model-10 (under dose user of N) and -0.0910 in Model-12 (under dose user of K) and highly significant at 1% and 10% levels, implying that the probability of overall N and K using gaps in *T.Aman* rice cultivation will be decreased by 10.09% and 9.10% respectively in an aggregate situation, if these variables are increased by 100% keeping other regions constant (Table 6.10).

The *Boro* rice cultivation in Thakurgaon district, the marginal coefficients of Thakurgaon district dummy are -0.0756 in Model-4 (under dose user of N) and -0.3303 in Model-6 (under dose user of K) which are highly significant at 1% level, indicating that the probability of N and K use gap will be decreased by 7.56% and 33.03% respectively if the agro-climatic condition of Thakurgaon region changes by 100% keeping other regions constant (Table 4.6). Similarly, the coefficient of Thakurgaon district dummy is -0.0383 in Model-7 (over dose user of N) and significant at 10% level, implying that the probability of overall N using gaps in

T.Aman rice cultivation will be decreased by 3.83% in an aggregate situation, if this variable is increased by 100% keeping other regions constant (Table 6.8).

In *T.Aman* rice cultivation, the marginal coefficients of Khulna district dummy are 0.0777 in Model-7 (over dose user of N) and -0.2509 in Model-8 (over dose user of P) which are highly significant at 1% level, implying that the probability of N and P use gaps will be increased and decreased by 7.77% and 25.09% respectively if the agro-climatic condition of Khulna region changes by 100% keeping other regions constant (Table 4.8). Similarly, the coefficients of Khulna district dummy are -0.0314 in Model-10 (under dose user of N) and -0.1084 in Model-12 (under dose user of K) which are significant at 10% and 1% levels, implying that if these variables are increased by 100% the probability of overall N and K using gaps in *T.Aman* rice cultivation will be decreased by 3.14% and 10.84% in an aggregate situation respectively, keeping other regions constant (Table 6.10).

6.3 Concluding Remarks

Farmers of the study areas use high/over doses of fertilizers in most of the *Rabi* crops, especially in high value crops. All the fertilizers (except urea) leave significant amount of residues in the field, which is used by the following crops grown in Kharif seasons. Farmers of the study areas also have idea about such residual effects. Again, the use of DAP is gradually increasing in the country including the study areas, which contains 18% N in addition to 20% P. Farmers of the study areas also have knowledge about this. For such knowledge and knowledge on negative impacts of overuse of fertilizers farmers use a bit lower doses of all the fertilizers in *Kharif* crops compared to recommended doses using their own judgment. So, the apparent gaps in fertilizer use are not the real gap. In reality the crops get their nutrients from the external sources like direct application of fertilizers, residual effect of fertilizers applied in the previous crops and from inherent soil nutrient contents. So, in respect of crop requirement the nutrient application gaps are not the real gaps.

However, the estimated 12 models clearly revealed that the nutrient use gaps between current farmers' practice and scientific recommendation were influenced (positively or negatively) by a number of agro-socio-economic factors. The major significant factors were gender, category of farmers, crop residue retention, crop rotation, fertilizer use in previous crop, distance of input/output market, fertilizer price, level of extension contact, number of cattle owned, and study region.

Chapter VII

BARRIERS IN APPLYING BALANCED NUTRIENTS IN CROP PRODUCTION

The concept of 'balanced fertilization' or 'balanced use of nutrients' is a broad and very technical issue for soil scientists as well as agricultural economists, as the requirement of different nutrients such as nitrogen, phosphate, and potash - is based mostly on soil fertility and type of crops/varieties. This concept involves not only increases in physical output of crop it also maximizes profitability in terms of economic returns for every unit of fertilizer applied (Wakeel et al., 2017). The use of the right ratio of nutrients as per soil or crop requirement is known as 'balanced fertilization' (http://fert.nic.in/what-meant-term-balanced-fertilization). Farmers in the study areas generally consider balanced fertilizer dose as a certain amount of different inorganic fertilizers to be applied to a specific crop for enhancing its proper growth for achieving higher yield (FGD, 2019). This chapter highlights the barriers that farmers reported regarding use of balanced fertilizers at the farm level.

7.1 Barriers in Applying Balanced Fertilizers

In *Chapter V*, it is reported that the respondent farmers in the study areas use different types of organic and inorganic fertilizers in crop production. However, the study has found that farmers of the study areas were not applying macro- and micro-nutrient fertilizers as per recommended rates. The respondent farmers stated various reasons for not using balanced fertilizer doses in their crops. They were asked to comment on 30 specific potential barriers, the 10 main barriers reported by farmers are summarized in Table 7.1 and briefly discussed below. The reasons for not using balanced fertilizer dose stated in the Focus Group Discussion (FGD) are also highlighted in most of the subsequent sections. Note that Appendix Tables 5 to 8 include a break down for each farmer category highlighting some differences among farmer groups and among study areas, which are also discussed here.

7.1.1 Lack of relevant knowledge and skills

Fertilizer is regarded as crucial input for crop production. The use of balanced fertilizer has many positive implications on long-term soil fertility, soil health, crop yields, crop quality, pest and disease infestation, and overall crop profitability. Therefore, relevant knowledge and skills about using balanced fertilizer are important. Among the respondents, 98% of the farmers stated that they are lacking the relevant knowledge and skills to use a balanced fertilizer dose. The soil related relevant knowledge and skills are associated with soil nutrient management, appropriate dose of fertilizers for different crops, proper application time and methods, soil fertility status, etc. (Table 7.1). Lack of knowledge on fertilizers' ingredients and fertilizer use is also a barrier of balanced fertilizer use (FGD, 2019).

7.1.2 Lack of training on soil fertility management

Among the respondents, 77% of the farmers said that lack of training on soil fertility management is a barrier to use the recommended fertilizer dose. More farmers from medium and small & marginal categories in the study areas reported this problem than that of large and women managed categories. There is also difference in getting advice from SAAO and peer farmers among different farm categories (FGD, 2019).

7.1.3 Complexity of apply recommended fertilizer dose

A good percentage of the respondent farmers (73%) indicated that the complexity of applying the recommended fertilizer dose was one of the barriers to using balanced fertilizer rates. More farmers from women managed HH and small & marginal category farmers in the study areas reported this problem than that of large and medium category farmers. They mentioned that they used to applying fertilizers based on their traditional knowledge and experience, and that the recommended rates are too complex for them. According to some educated farmers the Fertilizer Recommendation Guide (2012) is not an easy-going book to use and some extension workers (SAAO) also have the same view. For example, the guide contains crop-wise fertilizer recommendations on per hectare basis that are difficult for the farmers to translate into per decimal or per *Katha* basis.

Table 7.1 Farmer's responses on the major barriers of applying balanced fertilizer dose in crop production

Type of barriers	% of farmers' responses				
	Marg & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Female *(n=100)*	All type *(n=750)*
1. Lack of relevant knowledge and skills	98	99	96	100	98
2. Lack of training on soil nutrient management	78	80	72	71	77
3. Recommended doses are complicated	75	66	70	77	73
4. Lack of extension advisory services	70	70	58	70	69
5. Lack of sufficient working capital	93	83	76	89	89
6. Higher price of fertilizers	85	76	60	89	82
7. Non-availability of soil testing facilities	70	60	66	62	66
8. Lack of connectivity with progressive farmers	36	36	24	33	35
9. Pre-determinant attitudes	61	62	54	55	60
10. Put less importance on low profit crop	46	44	48	51	46

7.1.4 Lack of extension advisory services

Farmers in the study areas generally get agriculture related advice from various extension services such as Agriculture Officer, Sub-Assistant Agricultural Officer (SAAO), neighbouring farmers, and from fertilizer dealers. Among the respondent farmers, 69% of the farmers said that lack of extension advisory services in the study areas is a barrier to use recommended doses of fertilizers. FGD (2019) revealed that respondent farmers used different types of fertilizers differently due to lack of proper extension services and get divergent advice from SAAO and peer farmers.

7.1.5 Lack of sufficient working capital

Now-a-days, crop production requires a large amount of cash in hand for hiring labour, buying fertilizer and pesticides, and harvesting of crops. About 89% of the respondent farmers reported a lack of working capital as one of the barriers to applying an adequate amount of fertilizer. More number of marginal & small and female farmers reported that this was a barrier compared to medium and large category farmers. Large category farmers use higher amounts due to their higher financial capability (FGD, 2019). The annual household income of marginal & small and female farmers also supported their statement that a lack of capital was a constraint (Table 7.2). Most farmers participated in FGD (2019) also pointed out this issue as a barrier to applying an adequate amount of fertilizer.

Table 7.2 Average annual income of the respondent farmers in the study areas

District	Small & marginal	Medium	Large	Women managed	All category
Barguna	180101	345911	523860	144790	242526
Khulna	167311	390979	477541	144085	244541
Mymensingh	193715	365497	671250	130453	262924
Rajshahi	246724	461720	957220	129343	335772
Thakurgaon	203285	380409	723978	166541	280331
All Area	198227	388903	670770	143042	273219

7.1.6 Higher price of fertilizer

The price of fertilizers and pesticides were reported to be high in the study areas. Specially, the prices of TSP, DAP, Boron and Zinc fertilizers were high to them. Some respondent farmers complained that price of fertilizers and pesticides were high in respect of the price of output (especially rice price was very low). Some others thought that the prices were reasonable and within the range of their buying capacity. However, an average of 81% respondent farmers said that they could not use the balanced fertilizer dose due to the higher price of fertilizers. This problem was more acute for the women managed and marginal & small farmers compared to large and medium farmers.

7.1.7 Non-availability of soil testing facilities

About 66% of farmers stated that they could not apply the balanced fertilizer dose due to non-availability of soil testing facilities in their locality. The study areas are mostly lacking soil testing facilities. Where there are soil testing laboratories they are far away from the residences of the respondent farmers. Among the farmers that had tested their soil some reported that they were annoyed with the unfriendly behaviour of the soil testing laboratory staff and for delays in providing soil test report. These things made the farmers discouraged about soil testing. This fact was also highlighted by different group of farmers participated in the FGD (2019).

7.1.8 Lack of connectivity with progressive farmers

About 35% of the respondent farmers said that they have less connectivity with progressive farmers and this was the reason for using their own dose of fertilizer. Progressive farmers usually maintain good relations with extension people, local leaders and important persons in the locality. Therefore, they have more access to improved agricultural technologies compared to other farmers and the farmers who are connected with the progressive farmers are often in a position to benefit from their experience and knowledge. Large and women managed category farmers reported less connectivity with progressive farmers compared to medium and small & marginal category farmers in the study areas.

7.1.9 Pre-determinant attitudes

About 60% of respondent farmers said that they could not apply the recommended fertilizer dose due to their pre-determined attitudes towards fertilizer application. They are also reluctant to use fertilizers at recommended dose because of their ignorance and traditional mind setup. Other farmers indicated that they apply an over dose of fertilizers on a competitive basis to produce a higher yield than other farmers (FGD, 2019). Medium and small & marginal category farmers reported this as being a barrier more than large and women managed category farmers in the study areas.

7.1.10 Put less importance on less profit crops

It was reported that respondent farmers generally put less importance to those crops (e.g. *Aus* rice, sugarcane, sweet potato, etc.) which are less profitable. Hence they are not conscious about the application of balanced fertilizer dose for these crops. On average, about 46% of the respondent farmers reported this as a barrier to using a balanced fertilizer dose. Large and female category farmers reported this as a barrier more than medium and small & marginal category farmers in the study areas.

7.2 Suggestions for Minimizing the Barriers

The respondent farmers in the study areas provided a number of suggestions for overcoming or minimizing the barriers to application of the proper dose of fertilizer. Their suggestions are shown in Table 7.3 and discussed below. Note that the suggestions of different categories of farmers in the study areas can be seen in Appendix Tables 9 to 12.

7.2.1 Soil testing facility

On an average 83% of the respondent farmers requested to create soil testing facilities at the *Union Parishad* level. Soil testing of a particular plot can significantly improve the soil fertility as well as crop productivity through applying balance dose of fertilizers. Therefore, it seems that farmers would benefit from better access to friendly, local and timely soil testing information. But, inadequacy of soil-testing facilities is a limiting factor for application of proper doses of fertilizers in the study areas.

7.2.2 Soil fertility management and compost preparation training

Among the respondents, 81% of farmers expressed their need for soil fertility management training. In addition, many farmers (37%) wanted to attend training on compost preparation. Literature shows that extension education training increases farmers' farming knowledge and skills and household income (Rani et al., 2014). Extension training can have a positive effect on adoption of improved crop production practices including balanced fertilization (Uzonna and Qijie, 2013). Therefore, training on soil fertility management is likely to help increase the productivity of soil and crop, and decrease the production cost as well. For proper use of recommended fertilizer dose, farmers require technical knowledge about soil fertility, crop characteristics, time and method of application, nutrient contents in fertilizer, and crop-specific recommended fertilizer dose. Short-term hands-on training programme could play a vital role in increasing the knowledge of the farmers about soil fertility management.

7.2.3 Extension services and attitudes of extension workers

Agricultural extension service means to transfer technology, support rural adult learning, assist farmers in problem-solving, and getting farmers actively involved in the agricultural knowledge and information system (Christoplos and Kidd, 2000). The study conducted by Abbeam et al., (2018) reaffirmed the critical role of extension services in enhancing farm productivity and household income. A lack of adequate extension services was reported to be a problem by many respondent farmers in the study areas. About 61% of the farmers stated that adequate extension services especially on soil fertility management should be available at local level. Many (78%) respondent farmers indicated that they expect more friendly attitude of extension workers.

7.2.4 Low price of fertilizer

Bangladesh has immense potentials for crop production, but even with favorable soil condition, crop production has not always been adequate meaning that farmers needed to boost its production through usage of improved technologies including balanced fertilizers. Many farmers in the study areas are discontent with the existing prices of fertilizers and pesticides. Many farmers, especially stated that the price of TSP, DAP, Boron and Zinc fertilizers were high in respect to, the price of paddy. About 72% respondent farmers suggested that the existing fertilizer prices should be low so that they can purchase and use them adequately. Government subsidies are one way to address the issues of fertilizer affordability, but this can also have an impact on the way farmers (under and over) use fertilizer.

Table 7.3 Farmer's suggestions to minimize the barriers of applying balanced fertilizer dose in crop production

Probable suggestions	Farmers category				
	Mar & small *(n=400)*	Medium *(n=200)*	Large *(n=50)*	Women *(n=100)*	All type *(n=750)*
1. Soil testing facilities should be locally available	85	85	86	75	83
2. Farmers should be trained on knowledge and skills of soil nutrient management	84	82	78	74	81
3. Attitude of extension workers should be friendly	80	77	70	75	78
4. Price of fertilizers should be low	72	73	64	73	72
5. Related extension services should be within reach of the farmers	61	64	58	57	61
6. Demonstrate crop production using recommended rate of nutrients/fertilizers	60	62	60	60	61
7. Provide credit facility with low interest rate and it should be hassle free	56	56	54	57	56
8. Need topography based fertilizer dose	53	50	58	43	51
9. Need water condition based fertilizer dose	50	49	58	42	49
10. Government supports on conservation tillage machineries should be extended	47	48	48	39	46
11. Conduct field day at the end of each cropping season	43	44	46	46	44
12. Need easy-going fertilizer recommendation guide	43	44	46	45	43
13. Farmers should be provided training on compost preparation	36	39	40	39	37

7.2.5 Conducting demonstrations and field days

Among the respondents, 61% farmers suggested to conduct different fertilizer trials/experiments on farmer's field and demonstrate crop production using recommended rate of fertilizers. Again, some farmers (44%) advised to conduct field days at the end of each cropping season to motivate farmers towards use of recommended dose of fertilizers. Literature shows that the adoption of agricultural technology is influenced considerably by the perception of farmers about the improvements the new technology renders (Adesina & Forson, 1995). Moreover, demand for new technology is driven by the subjective assessment of the attributes of a technology that is being promoted (Yapa and Mayfield, 1978; Nowak, 1992). Through demonstration and field days, farmers can easily understand how the technology works and embrace it as an alternative farming system. In Kenya, field days scored the highest in the effectiveness of information delivery both by the farmers and extension staff (NALEP, 2011). Therefore, on-farm experiments and demonstrations on different fertilizer trials along with field days can help motivate farmers to use adequate doses of fertilizers.

7.2.6 Credit facility

It has already been reported that many farmers said they could not apply an adequate amount of fertilizer due to a lack of operating capital. To address this they need adequate credit at an affordable cost. Among the respondents, 56% farmers thought that government should provide a credit facility with low interest rate and it should be "hassle free". The farmers, participated in the FGD (2019) also put emphasis on institutional credit for small and marginal and female farmers. Some farmers also supported providing loan facility to the fertilizer dealers to hold sufficient stocks to meet seasonal demand.

7.2.7 Land type based fertilizer dose

In the Fertilizer Recommendation Guide (FRG) 2012, fertilizer recommendations have been made on the basis of soil test results for single crops and on the basis of Agro-ecological Zones (AEZs) for cropping patterns. Farmers said that the fertilizer recommendations should also be based on land types. FGD (2019) revealed that land type was one of the important factors that influenced farmers in deciding the type and amount of fertilizers to use. More than half of the respondent farmers suggested this.

7.2.8 Water regime based fertilizer dose

Among the respondents, 49% farmers suggested that fertilizer recommendations should be based not only on crop and soil, but also should be based on hydrology of the land. Literature shows that water management in crop cultivation is crucial for deriving profitable yields and protecting water quality (Mujeri et al., 2012). Farmers generally apply fertilizers depending on rainfall and irrigation. Uncertainty of rainfall increases the risk for farmers to use fertilizers and they become reluctant to use fertilizers. Again, farmers in irrigated areas are opposite to that of rain-fed areas and are more likely to use fertilizers due to assured and timely irrigation.

7.2.9 Govt. support on CA tillage machineries

Forty six percent respondent farmers stated that existing government support on conservation agriculture (CA[1]) machineries should be extended throughout the country. Literature shows that CA is a win-win approach that reduces operational costs, including machinery, labour, and fuel while increasing soil fertility, crop yields and better utilizing natural resources (Roy et al., 2009). CA practices need different machineries for minimum tillage, seeding, and fertilization, but the machineries are costly and beyond the buying capacity of poor farmers. Therefore, Government support on CA tillage machineries could help to minimize the barriers of applying balanced fertilizer dose in crop production.

7.2.10 Easy-going fertilizer recommendation guide

Among the respondents, 43% farmers suggested that fertilizer recommendation guide should be easily understandable and practicable for farmers. It has been stated earlier that the FRG-2012 is targeted for the scientist, extension personnel, university teachers, agriculturist working in different GOs and NGOs, policy makers etc. and not for the farmers. It contains fertilizer recommendations on per hectare basis that are difficult for the farmers to translate into per decimal or per *Bigha* (33 decimals) basis. Again, most recommendations are given based on nutrient basis, not on fertilizer basis which is also difficult for the farmers to calculate amount of fertilizers.

It is worth mentioning here that Fertilizer Recommendation Guide is updated and published by BARC usually at five year interval. The last updated edition of FRG was published in 2018. For this time the guide has been published also in Bengali in addition to English version targeting to be used by the farmers. From now onwards BARC will continue updating and publishing the Bengali version along with English version.

[1]CA is a wide array of specific technologies that are based on applying one or more of the three main principles (IIRR and ACT, 2005). The principles are (a) reduce the intensity of soil tillage; (b) cover the soil surface adequately; and (c) diversify crop rotations (Hobbs et al., 2008).

Chapter VIII

CONCLUSIONS AND POLICY IMPLICATIONS

8.1 Conclusion

The study determined fertilizer use gaps between current farmers' practice and scientific recommendations; explored the agro-socio-economic factors affecting fertilizer use decision and nutrient use gaps at farm levels; and explored the major barriers to adoption of recommended fertilizer dose. The study revealed that farmers applied different types of fertilizers/ nutrients without considering scientific recommendations. They used much higher doses/over doses of all types of nutrients (NPKS) in high value crops like potato and watermelon, whereas used lower amounts in *Kharif* season crops like, *T. Aman*, maize etc. Except maize, respondent farmers applied much higher dose of P in different crops compared to recommended dose. However, the use of different nutrients were found close to the optimum dose only for *T. Aus* rice. In farm categories, women managed farm households and small & marginal farmers used much lower doses of nutrients compared to medium and large category farmers.

Farmers of the study areas use high/over doses of fertilizers in most of the *Rabi* crops, especially in high value crops. All the fertilizers (except urea) leave significant amount of residues in the field, which is used by the following crops grown in *Kharif* seasons. Farmers of the study areas also have idea about such residual effects. Again, the use of DAP is gradually increasing in the country including the study areas, which contains 18% N in addition to 20% P. Farmers of the study areas also have knowledge about this. For such knowledge and knowledge on negative impacts of overuse of fertilizers farmers use a bit lower doses of all the fertilizers in *Kharif* crops compared to recommended doses using their own judgment. So, the apparent gaps in fertilizer use are not the real gap. In reality the crops get their nutrients from the external sources like direct application of fertilizers, residual effect of fertilizers applied in the previous crops and from inherent soil nutrient contents. So, in respect of crop requirement the nutrient application gaps are not the real gaps.

The estimated 12 beta regression models clearly revealed that the nutrient use gaps between current farmer’s practice and scientific recommendation were positively or negatively influenced by a number of agro-socio-economic factors. The major significant factors were gender, category of farmers, crop residue retention, crop rotation, fertilizer use in previous crop, distance of input/output market, fertilizer price, level of extension contact, number of cattle owned, and study region.

The major barriers of adoption of balanced fertilizer dose at farm level were: (1) Lack of relevant knowledge and skills, (2) Lack of sufficient working capital, (3) High price of fertilizers, (4) Lack of training on soil fertility management, (5) Complexity of applying recommended fertilizer doses, (6) Lack of extension advisory services , (7) Non-availability of soil testing facilities, (8) Giving less importance to recommendation and pre-determined attitudes, (9) Giving less importance to less profit crops, and (10) Lack of connectivity with progressive farmers.

However, based on the findings of the study, the NUMAN project can undertake some initiatives to minimize the nutrient use gaps between current farmer’s practice and scientific recommendations. However, the following policy guidelines have been suggested for higher adoption of balanced fertilizer dose and minimizing the nutrient use gaps between current farmer’s practice and scientific recommendations.

8.2 Policy Implications

Some of the problems associated with applying balanced or optimum fertilizer dose at farm level could be overcome if technical assistance and financial support are made available by the government of Bangladesh. This support could be done into five areas: awareness creation, technology development, strengthening extension services, assurance of input quality and supply, and financial support. A brief discussion on these issues has been given below.

8.2.1 Awareness creation

Creating awareness among farmers, input dealers, extension agents and relevant stakeholders towards the benefits of applying balanced or optimum fertilizer dose in crop production for encouraging then to use balanced dose of fertilizers. Awareness can be increased through the following ways:

- Provide soil fertility management training to farmers, input dealers, extension agents and relevant stakeholders.
- Broadcast the benefits of applying optimum fertilizer dose in crop production.

8.2.2 Technology development

Development of appropriate technologies for using balanced or optimum fertilizer dose in crop production is very much important. Improvement is also needed on existing soil testing kit so that farmers can test their soil correctly with reasonable cost.

8.2.3 Strengthening extension services

Proper extension services have no alternatives of educating farmers towards efficient farming. However, the existing extension services may be strengthened through the following ways:

- Set up soil testing facilities at each union level.
- Ensure the frequent field visit of SAAO and other extension personnel.
- Conduct field demonstrations and field days on soil fertility management at farm level.
- Distribution of leaflets and booklets among farmers and input dealers on soil fertility management.
- Development of local service providers for CA machineries.
- Development of network between farmers and extension agents.

8.2.4 Assurance of input quality and supply

Government should assure the quality of fertilizers through strengthening its monitoring system for confirming cost-effective crop production. Again, assurance of adequate supply of fertilizers at local markets is also important for ensuring balanced fertilizer application at farm level.

8.2.5 Financial assistance

Providing short-term loan at reduced rate of interest to enable farmers in buying sufficient amount of fertilizers. Nevertheless, Government should give more subsidy on fertilizer for small and marginal farmers. CA machineries should also be promoted through subsidy.

8.3 Weaknesses of the Study

As also stated above that the apparent gaps in fertilizer/nutrient use depicted in this study are not the real gaps because of overlooking some related issues. Following points might be mentioned in this regards.

a. In this study, the residual effects of fertilizers used in previous crops have not been considered.

b. Cropping pattern (CP) based fertilizer recommendation has not been considered. In CP based fertilizer recommendation, *Rabi* crops are considered as the first crop and full doses of all the nutrients are recommended for those crops. But for *Kharif* crops, considering the residual effects, fertilizer doses are reduced a bit for all the nutrients except urea based on certain principles.

c. Farmers' fertilizer doses for *Kharif* crops have been compared with the full recommended doses, not with the CP based reduced recommended doses.

Due to these factors real gaps between farmers' practice and scientific recommendations regarding fertilizer/nutrient use has not been appeared properly.

8.4 Recommendations for Future Studies

Information regarding fertilizer doses for single crops have been collected through questionnaire survey and used in this study instead of cropping pattern based fertilizer recommendation. Cropping pattern based fertilizer recommendation is made considering residual effects of fertilizers applied in the previous crops. Following points might be considered in the future studies for understanding the real gaps between farmers' fertilizer doses and scientific recommendations:

a. Fertilizer use studies should be done on cropping pattern basis, not on single crop basis. The information regarding fertilizer use should be collected, analyzed and interpreted on cropping pattern basis, not on single crop basis.

b. Farmers' fertilizer doses for different crops in the cropping patterns should be converted into nutrient doses and compared with the recommended doses of nutrients for the pattern.

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Table 1. Percent distribution of respondent farmers according to age group

Age group	Barguna	Khulna	Mymensingh	Rajshahi	Thakurgaon	All area
A. Small & marginal	*n=80*	*n=80*	*n=80*	*n=80*	*n=80*	*n=400*
15-30	19	24	4	36	26	22
31-45	43	35	29	28	43	35
46-60	28	33	51	33	24	34
61-75	11	9	14	4	6	9
76-90	0	0	3	0	1	1
B. Medium	*n=40*	*n=40*	*n=40*	*n=40*	*n=40*	*n=200*
15-30	10	13	10	25	20	16
31-45	48	45	20	48	48	42
46-60	38	40	55	28	30	38
61-75	5	3	15	0	3	5
76-90	0	0	0	0	0	0
C. Large	*n=10*	*n=10*	*n=10*	*n=10*	*n=10*	*n=50*
15-30	20	20	0	10	0	10
31-45	50	40	30	40	30	38
46-60	20	30	50	30	60	38
61-75	0	10	20	20	10	12
76-90	10	0	0	0	0	2
D. Women managed	*n=20*	*n=20*	*n=20*	*n=20*	*n=20*	*n=100*
15-30	35	20	10	25	45	27
31-45	45	70	55	75	50	59
46-60	20	10	35	0	5	14
61-75	0	0	0	0	0	0
76-90	0	0	0	0	0	0
E. All category	*n=150*	*n=150*	*n=150*	*n=150*	*n=150*	*n=750*
15-30	19	20	6	30	25	20
31-45	45	43	30	40	44	40
46-60	29	31	50	27	25	32
61-75	7	6	13	3	5	7
76-90	1	0	1	0	1	1

Table 2. Percent distribution of farmers according to their educational status

Educational status	Barguna	Khulna	Mymensingh	Rajshahi	Thakurgaon	All Area
A. Marginal & Small (n=80)						
Illiterate	25	15	19	15	13	17
Primary level	39	33	26	36	34	34
Secondary level	26	44	44	29	39	36
Higher Secondary level	6	6	10	14	10	9
Degree or above	4	3	1	6	5	4
B. Medium (n=40)						
Illiterate	20	10	10	20	20	16
Primary level	40	30	20	13	13	23
Secondary level	28	48	48	43	33	40
Higher Secondary level	5	10	15	10	28	14
Degree or above	8	3	8	15	8	8
Large (n=10)						
Illiterate	0	0	10	0	0	2
Primary level	60	20	30	0	10	24
Secondary level	40	60	50	40	50	48
Higher Secondary level	0	10	0	30	10	10
Degree or above	0	10	10	30	30	16
Women managed (n=20)						
Illiterate	15	10	10	10	25	14
Primary level	65	30	40	40	45	44
Secondary level	20	50	45	50	30	39
Higher Secondary level	0	10	5	0	0	3
Degree or above	0	0	0	0	0	0
All category (n= 150)						
Illiterate	21	12	15	15	15	15
Primary level	44	31	27	28	28	31
Secondary level	27	47	45	36	37	38
Higher Secondary level	5	8	10	12	13	10
Degree or above	4	3	3	9	7	5

Table 3. Average land holding (decimal) and farm size (ha) of the respondent farmers

Farmers Categories	Barguna	Khulna	Mymensingh	Rajshahi	Thakurgaon	All area
A. Small & Marginal	*n=80*	*n=80*	*n=80*	*n=80*	*n=80*	*n=400*
Owned cultivated land	149.3	107.6	101.3	104.0	112.6	115.0
Rented/leased/mortgage in	185.7	0.0	97.3	55.3	95.0	86.7
Rented/leased/mortgage out	131.5	106.4	59.3	57.5	78.8	86.7
Homestead	20.2	15.4	15.6	13.9	14.3	15.9
Ponds	21.1	11.3	18.4	27.1	11.4	17.9
Orchard	14.2	13.0	12.6	27.6	12.7	16.0
Farm size (decimal)	259.0	40.9	185.9	170.4	167.2	164.7
Farm size (ha)	1.049	0.166	0.753	0.690	0.677	0.667
B. Medium	*n=40*	*n=40*	*n=40*	*n=40*	*n=40*	*n=200*
Owned land	242.8	245.7	285.7	298.5	280.9	270.7
Rented/leased/mortgage in	198.3	198.5	119.4	86.2	132.5	147.0
Rented/leased/mortgage out	150.0	215.8	192.5	115.4	126.6	160.1
Homestead	23.3	20.2	24.6	24.1	25.6	23.6
Ponds	22.9	16.7	25.0	69.7	13.7	29.6
Orchard	12.8	6.1	16.9	43.7	24.8	20.9
Farm size (Decimal)	349.9	271.4	279.1	406.8	350.9	675.8
Farm size (ha)	1.417	1.099	1.130	1.647	1.421	2.736
C. Large	*n=10*	*n=10*	*n=10*	*n=10*	*n=10*	*n=50*
Owned land	433.2	681.4	811.6	1019.2	1247.6	838.6
Rented/leased/mortgage in	0	450	422.1	651.8	321.7	369.1
Rented/leased/mortgage out	290.4	411.2	0	149.5	0	170.2
Homestead	28.6	46.8	38.7	35.7	33.5	36.7
Ponds	17.7	22.5	162.3	338.9	14.6	111.2
Orchard	12.8	33.4	26.3	111.6	29.2	42.7
Farm size (Decimal)	201.9	822.9	1461.0	2007.7	1646.6	1228.0
Farm size (Ha)	0.817	3.332	5.915	8.128	6.666	4.972
D. Women managed	*n=20*	*n=20*	*n=20*	*n=20*	*n=20*	*n=100*
Owned cultivated land	157.5	111.7	111.7	54.6	103.7	107.8
Rented/leased/mortgage in	396	124	91.3	0	75	137.3
Rented/leased/mortgage out	133	90.2	54.3	38.9	82.3	79.7
Homestead	20.8	14	19.7	10	9.2	14.7
Ponds	14.6	11.3	8.2	52	4.9	18.2
Orchard	13.6	18	6.1	39.5	14.7	18.4
Farm size (Decimal)	469.5	189.0	182.7	117.2	125.2	216.7
Farm size (ha)	1.901	0.765	0.740	0.474	0.507	0.877
E. All category	*n=150*	*n=150*	*n=150*	*n=150*	*n=150*	*n=750*
Owned land	194.3	183.2	199.2	210.3	232.0	203.8
Rented/leased/mortgage in	204.7	99.5	124.0	95.9	117.4	128.3
Rented/leased/mortgage out	147.3	168.4	90.2	76.6	86.8	110.9
Homestead	21.7	18.6	20.1	17.6	17.9	19.2
Ponds	20.5	13.5	28.4	62.6	11.4	27.3
Orchard	13.7	13.2	13.8	39.1	17.3	19.4
Farm size (Decimal)	307.5	174.2	295.3	348.8	309.2	287.0
Farm size (ha)	1.245	0.705	1.196	1.412	1.252	1.162

Table 4. Reasons for using fertilizer differently in different seasons in the study area

Reasons	% of response					
	Barguna	Khulna	Mymensingh	Rajshahi	Thakurgaon	All area
A. Small & marginal (n=80)						
Crop requirement/Crop rotation	31.3	26.3	27.5	27.5	26.3	27.8
Own judgment	12.5	3.8	12.5	13.8	5.0	9.5
Seasonal demand	31.3	25.0	40.0	40.0	23.8	32.0
Soil fertility	8.8	26.3	27.5	-	26.3	17.8
Weather condition	7.5	3.8	1.3	2.5	2.5	3.5
Use organic fertilizer	1.3	-	3.8	-	-	1.0
Use excess fertilizer in previous crop/season	1.3	-	1.3	-	30.0	6.5
Retain crop residue on field	3.8	-	3.8	-	2.5	2.0
B. Medium (n=40)						
Crop requirement/Crop rotation	47.5	17.5	27.5	22.5	35.0	30.0
Own judgment	10.0	10.0	7.5	2.5	25.0	11.0
Seasonal demand	7.5	20.0	37.5	50.0	27.5	28.5
Soil fertility	25.0	32.5	32.5	-	15.0	21.0
Weather condition	7.5	10.0	2.5	-	-	4.0
Use organic fertilizer	2.5	-	7.5	-	7.5	3.5
Use excess fertilizer in previous crop/season	5.0	-	-	-	-	1.0
C. Large (n=10)						
Crop requirement/Crop rotation	30.0	-	10.0	40.0	60.0	28.0
Own judgment	10.0	-	10.0	-	20.0	8.0
Seasonal demand	30.0	20.0	70.0	50.0	-	34.0
Soil fertility	-	20.0	50.0	-	20.0	18.0
Weather condition	10.0	10.0	-	-	10.0	6.0
Use organic fertilizer	-	-	-	10.0	10.0	4.0
D. Women managed (n=20)						
Crop requirement/Crop rotation	25.0	45.0	30.0	-	25.0	25.0
Own judgment	20.0	20.0	15.0	25.0	5.0	17.0
Seasonal demand	35.0	5.0	55.0	10.0	35.0	28.0
Soil fertility	10.0	10.0	15.0	-	15.0	10.0
Weather condition	15.0	10.0	5.0	5.0	-	7.0
Use organic fertilizer	-	5.0	-	5.0	-	2.0
Use excess fertilizer in previous crop/season	-	-	10.0	-	-	2.0

Table 5. Percent responses of the marginal and small category farmers on major barriers in applying balanced fertilizer dose in crop production

Type of barriers	Barguna (n=80)	Khulna (n=80)	Mymensingh (n=80)	Rajshahi (n=80)	Thakurgaon (n=80)	All area
1. Lack of relevant knowledge and skills	99	100	99	98	96	98
2. Lack of sufficient working capital	84	95	93	96	96	93
3. Higher price of fertilizers/inputs	75	79	98	96	78	85
4. Lack of training on soil nutrient management	75	75	89	80	71	78
5. Complexity to apply recommended fertilizer doses	54	61	94	89	76	75
6. Lack of extension advisory services	74	69	49	75	81	70
7. Non-availability of soil testing facilities	56	56	79	74	84	70
8. Put less importance on recommendation and pre-determinant attitudes	45	69	74	69	50	61
9. Give less importance on low profit crop	40	36	65	55	33	46
10. Lack of connectivity with progressive farmers	33	24	41	58	26	36

Table 6. Percent responses of the medium category farmers on major barriers in applying balanced fertilizer dose in crop production

Type of barriers	Barguna (n=80)	Khulna (n=80)	Mymensingh (n=80)	Rajshahi (n=80)	Thakurgaon (n=80)	All area
1. Lack of relevant knowledge and skills	98	100	98	98	100	99
2. Lack of sufficient working capital	63	80	90	85	95	83
3. Higher price of fertilizers/inputs	70	78	90	83	60	76
4. Lack of training on soil nutrient management	75	78	83	78	85	80
5. Complexity to apply recommended fertilizer doses	43	40	93	80	73	66
6. Lack of extension advisory services	58	68	58	85	80	70
7. Non-availability of soil testing facilities	43	40	65	78	75	60
8. Put less importance on recommendation and pre-determinant attitudes	65	60	80	58	45	62
9. Give less importance on low profit crop	33	30	78	53	28	44
10. Lack of connectivity with progressive farmers	35	38	50	50	5	36

Table 7. Percent responses of the large category farmers on major barriers in applying balanced fertilizer dose in crop production

Type of barriers	Barguna (n=80)	Khulna (n=80)	Mymensingh (n=80)	Rajshahi (n=80)	Thakurgaon (n=80)	All area
1. Lack of relevant knowledge and skills	90	90	100	100	100	96
2. Lack of sufficient working capital	80	100	70	80	50	76
3. Higher price of fertilizers/inputs	60	70	60	80	30	60
4. Lack of training on soil nutrient management	60	50	80	90	80	72
5. Complexity to apply recommended fertilizer doses	70	50	90	80	60	70
6. Lack of extension advisory services	60	70	70	60	30	58
7. Non-availability of soil testing facilities	60	20	90	80	80	66
8. Put less importance on recommendation and pre-determinant attitudes	60	70	30	70	40	54
9. Give less importance on low profit crop	40	30	70	60	40	48
10. Lack of connectivity with progressive farmers	20	20	30	40	10	24

Table 8. Percent responses of the female farmers on major barriers in applying balanced fertilizer dose in crop production

Type of barriers	Barguna (n=80)	Khulna (n=80)	Mymensingh (n=80)	Rajshahi (n=80)	Thakurgaon (n=80)	All area
1. Lack of relevant knowledge and skills	100	100	100	100	100	100
2. Lack of sufficient working capital	80	90	95	90	90	89
3. Higher price of fertilizers/inputs	80	90	90	95	90	89
4. Lack of training on soil nutrient management	60	80	85	60	70	71
5. Complexity to apply recommended fertilizer doses	70	55	95	85	80	77
6. Lack of extension advisory services	85	75	45	55	90	70
7. Non-availability of soil testing facilities	50	35	70	75	80	62
8. Put less importance on recommendation and pre-determinant attitudes	55	55	75	65	25	55
9. Give less importance on low profit crop	50	35	65	55	50	51
10. Lack of connectivity with progressive farmers	40	40	45	30	10	33

Table 9. Percent responses of the marginal & small farmers on probable suggestions for minimizing barriers of applying balanced fertilizer dose in crop production

Probable suggestions	Barguna (n=80)	Khulna (n=80)	Mymensingh (n=80)	Rajshahi (n=80)	Thakurgaon (n=80)	All area
1. Soil testing facilities should be available	91	74	86	96	75	85
2. Farmers should be trained on knowledge and skills of soil nutrient management	88	88	86	78	79	84
3. Friendly attitude of extension workers	75	89	83	73	81	80
4. Price of fertilizers, pesticides and weedicides should be low	76	79	76	71	56	72
5. Related extension services should be within reach of the farmers	53	55	65	73	58	61
6. Demonstrate crop production using recommended rate of nutrients/fertilizers	60	36	88	68	50	60
7. Provide credit facility with low interest rate and it should be hassle free	51	33	71	63	64	56
8. Recommended fertilizer dose should be appropriate with land topography	50	40	66	55	55	53
9. Fertilizers, pesticides and weedicides should be available in the market	45	19	74	56	63	51
10. Recommended fertilizer dose should be suitable for soil and water condition	56	29	61	61	44	50
11. Government supports on conservation tillage machineries should be extended	51	29	59	56	40	47
12. Applying cost should be low	45	36	65	51	33	46
13. Conduct field day at the end of each cropping season	41	23	54	60	39	43
14. Easy to apply of fertilizers, pesticides and weedicides	44	33	59	50	29	43
15. Recommendations should emphasize labour saving	40	35	60	50	25	42
16. Farmers should be provided compost (vermin-compost, tri-compost, etc.) preparation training	21	5	54	68	33	36

Table 10. Percent responses of the medium farmers on probable suggestions for minimizing barriers of applying balanced fertilizer dose in crop production

Probable suggestions	Barguna (n=40)	Khulna (n=40)	Mymensingh (n=40)	Rajshahi (n=40)	Thakurgaon (n=40)	All area
1. Soil testing facilities should be available	80	78	90	93	83	85
2. Farmers should be trained on knowledge and skills of soil nutrient management	85	93	88	70	73	82
3. Friendly attitude of extension workers	83	80	73	80	68	77
4. Price of fertilizers, pesticides and weedicides should be low	75	85	83	63	58	73
5. Related extension services should be within reach of the farmers	65	65	60	70	58	64
6. Demonstrate crop production using recommended rate of nutrients/fertilizers	50	48	73	73	65	62
7. Provide credit facility with low interest rate and it should be hassle free	40	38	73	70	58	56
8. Recommended fertilizer dose should be appropriate with land topography	38	48	63	60	43	50
9. Fertilizers, pesticides and weedicides should be available in the market	40	15	75	65	50	49
10. Recommended fertilizer dose should be suitable for soil and water condition	40	48	53	58	45	49
11. Government supports on conservation tillage machineries should be extended	53	38	60	50	40	48
12. Applying cost should be low	43	33	55	50	53	47
13. Conduct field day at the end of each cropping season	35	33	45	60	45	44
14. Easy to apply of fertilizers, pesticides and weedicides	43	23	60	60	33	44
15. Recommendations should emphasize labour saving	45	25	63	45	28	41
16. Farmers should be provided compost (vermin-compost, tri-compost, etc.) preparation training	30	8	63	58	35	39

Table 11. Percent responses of the large farmers on probable suggestions for minimizing barriers of applying balanced fertilizer dose in crop production

Probable suggestions	Barguna (n=10)	Khulna (n=10)	Mymensingh (n=10)	Rajshahi (n=10)	Thakurgaon (n=10)	All area
1. Soil testing facilities should be available	70	90	100	80	90	86
2. Farmers should be trained on knowledge and skills of soil nutrient management	70	100	80	90	50	78
3. Friendly attitude of extension workers	70	80	80	70	50	70
4. Price of fertilizers, pesticides and weedicides should be low	70	80	80	70	20	64
5. Related extension services should be within reach of the farmers	30	40	70	90	60	58
6. Demonstrate crop production using recommended rate of nutrients/fertilizers	50	40	90	70	50	60
7. Provide credit facility with low interest rate and it should be hassle free	40	10	70	60	90	54
8. Recommended fertilizer dose should be appropriate with land topography	40	40	90	90	30	58
9. Fertilizers, pesticides and weedicides should be available in the market	60	10	70	70	50	52
10. Recommended fertilizer dose should be suitable for soil and water condition	40	40	80	70	60	58
11. Government supports on conservation tillage machineries should be extended	40	0	60	70	70	48
12. Applying cost should be low	60	70	60	70	30	58
13. Conduct field day at the end of each cropping season	40	10	60	60	60	46
14. Easy to apply of fertilizers, pesticides and weedicides	50	40	60	60	20	46
15. Recommendations should emphasize labour saving	50	30	60	60	30	46
16. Farmers should be provided compost (vermin-compost, tri-compost, etc.) preparation training	10	0	60	70	60	40

Table 12. Percent responses of the female farmers on probable suggestions for minimizing barriers of applying balanced fertilizer dose in crop production

Probable suggestions	Barguna *(n=20)*	Khulna *(n=20)*	Mymensingh *(n=20)*	Rajshahi *(n=20)*	Thakurgaon *(n=20)*	All area
1. Soil testing facilities should be available	75	70	85	75	70	75
2. Farmers should be trained on knowledge and skills of soil nutrient management	85	100	65	60	60	74
3. Friendly attitude of extension workers	90	80	75	65	65	75
4. Price of fertilizers, pesticides and weedicides should be low	70	80	80	60	75	73
5. Related extension services should be within reach of the farmers	55	70	65	55	40	57
6. Demonstrate crop production using recommended rate of nutrients/fertilizers	70	40	75	75	40	60
7. Provide credit facility with low interest rate and it should be hassle free	55	35	65	60	70	57
8. Recommended fertilizer dose should be appropriate with land topography	50	40	55	35	35	43
9. Fertilizers, pesticides and weedicides should be available in the market	65	15	80	45	60	53
10. Recommended fertilizer dose should be suitable for soil and water condition	45	45	40	60	20	42
11. Government supports on conservation tillage machineries should be extended	45	30	45	45	30	39
12. Applying cost should be low	65	35	50	65	60	55
13. Conduct field day at the end of each cropping season	60	25	50	50	45	46
14. Easy to apply of fertilizers, pesticides and weedicides	60	20	70	40	35	45
15. Recommendations should emphasize labour saving	55	20	35	50	25	37
16. Farmers should be provided compost (vermin-compost, tri-compost, etc.) preparation training	40	5	70	65	15	39

FOCUS GROUP DISCUSSION (FGD, 2019)

1.0 DECISION MAKING ABOUT THE FERTILIZER DOSE

	Questions	Mymensingh	Thakurgaon	Rajshahi	Barguna	Khulna
1.	What do you mean by balanced fertilizer dose (BFD)?	• Most farmers do not know about BFD. • Apply all kinds of fertilizers together. • Some farmers assume that fertilizer dose recommend by service providers after soil test. • BFD is not equally workable /important for all categories of land.	• Amount of fertilizers that needs for good crop yield. • Apply right amount of fertilizers on appropriate time. • Apply right amount of fertilizers after seeing crop condition. • They presume that crop yield hamper if right amount of fertilizers is not applied.	• The amount and type of fertilizers need to apply for making soil condition good/fertile/strong. • Apply right amount of fertilizers at different stages of crop growth. • Apply all kinds of fertilizers together to meet up the soil requirement.	• Apply fertilizers according to the types and fertility of lands. • Apply right amount of fertilizers at right time after seeing crop condition. • Female farmers presume that crop logging occurs due to apply over dose and crop growth hamper due to apply lower dose. So, apply right amount of fertilizers based on crop condition.	• Apply fertilizers according to the types and fertility of lands. • Apply right amount of fertilizers at right time after seeing crop condition. • Some farmers assume that fertilizer dose recommend by service providers after soil test is called BFD.
2.	What are the main factors do you consider in deciding the type and amount of fertilizer to use?	• See the Table-1 below	• See the Table-2 below	• See the Table-3 below	• See the Table-4 below	• See the Table-5 below
3.	What are the reasons for applying fertilizers at varying amounts or differently?	• Use about double amount compared to year 1980 due to use less cow dung & retention of crop residues. • Amounts depends on financial capability, soil fertility, soil type, cropping, knowledge, & topography. • Use higher amount in Rabi season (dry soil & longer period) and lower amount in Aman season due to crop residue retention (water hyacinth, boro rice, weeds) and fertilizer residues. • Not used TSP assuming soil fertility is good. • Use higher dose of fertilizers (3 times) in high land. • Some farmers use higher amounts of TSP & MoP after testing their soil	• Lack of knowledge on soil • Use higher amount of urea compared to before (5-7 years) due to less functioning of urea. • Use less TSP & MoP due to use cow dung. • Because of crop types or fertilizer demand of crops (potato, maize, T.Aman). • Large farmers use higher amounts due to their higher financial capability. • Due to competition among farmers • Use higher amounts due to the presence of weeds. • Land topography & soil fertility • Difference in getting advice from SAAO & farmer	• Lack of knowledge on fertilizer's ingredients and fertilizer use. • Amounts depends on financial capacity, crop type, soil fertility, soil type, crop growth, topography. • Use less amount of urea than before due to use DAP. • Use less TSP & MoP due to use higher cow dung. • Depends on farmers' perceptions. They assume that TSP plays crucial role in increasing soil fertility. Its action is prolonged. • Influence of neighbouring or peer farmers • Difference in getting advice from SAAO & farmer • Price of fertilizer & rice crop	• Amounts apply depends on financial capacity, crop type, soil type, soil fertility, topography, presence of crop residues, price and availability of fertilizers. • In the past they used only urea, started using TSP & urea since 3-4 years. • Use less amount of MoP in high land since it increases soil salinity & makes soil hard. • Difference in crop cultivation methods & perceptions • Price of fertilizer & rice crop • Difference in getting advice from SAAO & farmer	• Lack of knowledge on soil & fertilizer use. • Amounts use depends on crop type, crop duration, soil fertility, soil type, crop growth, salinity, topography, tidal flood. • Use less TSP & MoP due to use higher cow dung. • Use higher amounts of urea, TSP & MoP seeing leaf colour and after knowing their deficiency in the soil. • Use less urea due to use DAP • Difference in crop cultivation methods & perceptions • Difference in getting advice from SAAO • Due to competition among farmers. Use fertilizer on competitive basis
4.	Do you have any idea on fertilizer recommendations by government for different crops? What are the sources?	• Know partially • Fertilizer requirement is different for different crops. • SAAO, dealer & farmers	• Know partially • Fertilizer requirement is different for different crops. • SAAO, dealer & farmers • Training, leaflet, husband	• Know partially • Fertilizer requirement is different for different crops. • SAAO, dealer & farmers	• Most marginal, small and female farmers do not know. • Most large farmers know it. • SAAO, dealer & training	• Don't know. • All the crops are not grown here due to salinity.
5.	Do you know that there is a *fertilizer recommendation guide (FRG)*? If yes, have you used it? Is this	• Most have no idea on FRG • Some farmers have received recommended dose for some crops	• Most farmers have no idea on FRG • Some farmers have received recommended dose for some crops	• Most farmers have no idea on FRG • Some farmers have received recommended dose through leaflet & participating training.	• Most farmers have no idea on FRG • FRG is not applicable for low-educated & illiterate farmers.	• Most farmers have no idea on FRG • Some large and female farmers have FRG or booklets for fertilizer recommended dose.

	guide workable for farmers? If not, pl. explain	through leaflet & participating training. • They don't rely on it, because it is not applicable for all types of lands. • FRG is not applicable for low-educated farmers.	through leaflet & participating training. • They don't rely on it, because it is not applicable for all types of lands.	• They don't rely on it, because it is not applicable for all types of lands & for low-educated farmers.		• They don't read and rely on it, because it is not applicable for all types of lands.
6.	Uses of TSP and MoP have been increased now-a-day compared to previous years. If it is true, what are the reasons behind it?	• **YES (since 10-12 years)** • It was not available and prices were also high (60-80/kg) • It is now available & price is also low (30-32/kg) • Protects crop logging & increases crop yield. • Due to use less amount of cow dung & compost • Need less urea if use it.	• **YES (since 8-10 years)** • In the past, farmers did not know the advantage of these fertilizers • It was not available and prices were also high (60-80/kg) • It is now available & price is also low (30-32/kg) • It increases crop yield. • Influenced by its good demonstration results • Reduction in cow dung use	• **YES** • It increase crop yield. • Influenced by its good demonstration results • Due to use less amount of cow dung & compost • Decrease soil fertility due to mechanized tillage & repeated use of chemical fertilizers. • Use over dose on a competitive basis	• **Not widely (since 3-4 yrs)** • MoP increases soil salinity. It is used only in low land. • Protect crop logging & increases crop yield. • Increases grain maturity and weight. • Influenced by its good demonstration results	• **YES, use about double** • Influenced by its good demonstration results. It increases crop productivity • Due to use less amount of cow dung & compost • Decrease soil fertility due to mechanized tillage

Table 1.1 Farmers of Mymensingh district consider various factors in deciding the type/amount of fertilizers to use

Factors of decision making	Small & Marginal		Medium farmer		Large farmer		Female farmer		All groups	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1. Crop season	28	1	28	1	21	4	28	1	105	1
2. Type of crop	26	2	25	2	17	5	26	2	94	2
3. Quality of soil	23	3	24	3	23	3	23	3	93	3
4. Availability and use of cow manure	23	3	21	4	17	5	21	4	82	4
5. Advice given by extension/project staff	17	5	18	5	17	5	16	6	68	5
6. Practice of Neighbour	18	4	18	5	11	8	19	5	66	6
7. Topography of land	11	8	13	7	26	2	13	7	63	7
8. Fertilizer dealer's recommendation	14	7	15	6	16	6	13	7	58	8
9. Cost of fertilizer	15	6	10	9	2	12	16	6	43	9
10. Govt. fertilizer recommendations	7	9	12	8	14	7	9	9	42	10
11. Soil testing advice	5	10	4	13	28	1	4	11	41	11
12. Market value of the crop	11	8	7	11	4	11	10	8	32	12
13. Availability of fertilizer	7	9	9	10	8	9	6	10	30	13
14. Sowing type	5	10	6	12	6	10	6	10	23	14

Note: The highest and the lowest scores are 28 and 2 respectively of an individual factor for a group of farmers.

Table 1.2 Farmers of Thakurgaon district consider various factors in deciding the type/amount of fertilizers to use

Factors of decision making	Small & Marginal		Medium farmer		Large farmer		Female farmer		All groups	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1. Quality of soil	27	1	26	1	20	5	28	1	101	1
2. Type of crop	26	2	26	1	22	4	24	3	98	2
3. Crop season	24	3	26	1	24	2	18	5	92	3
4. Topography of land	21	4	19	3	23	3	25	2	88	4
5. Availability and use of cow manure	20	5	21	2	25	1	21	4	87	5
6. Fertilizer dealer's recommendation	15	6	15	5	17	7	15	7	62	6
7. Sowing type	20	5	9	7	11	9	14	8	54	7
8. Practice of neighbour	11	8	10	6	15	8	15	7	51	8
9. Market value of the crop	9	9	17	4	5	12	16	6	47	9
10. Advice given by extension/project staff	12	7	8	8	19	6	7	9	46	10
11. Cost of fertilizer	7	10	10	6	2	13	14	8	33	11
12. Availability of fertilizer	7	10	8	8	7	11	7	9	29	12
13. Govt. fertilizer recommendations	9	9	5	9	9	10	4	10	27	13
14. Soil testing advice	2	11	10	6	11	9	2	11	25	14

Table 1.3 Farmers of Rajshahi district consider various factors in deciding the type/amount of fertilizers to use

Factors of decision making	Small & Marginal		Medium farmer		Large farmer		Female farmer		All groups	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1. Type of crop	28	1	26	1	28	1	28	1	110	1
2. Quality of soil	23	2	25	2	23	3	22	2	93	2
3. Crop season	14	6	23	3	25	2	21	3	83	3
4. Advice given by extension/project staff	17	4	16	7	18	4	17	5	68	4
5. Topography of land	17	4	18	5	15	6	16	6	66	5
6. Availability and use of cow manure	15	5	15	8	15	6	19	4	64	6
7. Practice of Neighbour	15	5	19	4	10	8	13	8	57	7
8. Fertilizer dealer's recommendation	15	5	11	9	15	6	15	7	56	8
9. Sowing type	12	7	17	6	11	7	13	8	53	9
10. Cost of fertilizer	20	3	6	12	5	10	15	7	46	10
11. Govt. fertilizer recommendations	6	9	9	10	17	5	4	11	36	11
12. Market value of the crop	10	8	7	11	5	11	9	9	31	12
13. Availability of fertilizer	5	10	6	12	8	9	8	10	27	13
14. Soil testing advice	2	11	2	13	2	12	2	12	8	14

Note: The highest and the lowest scores are 28 and 2 respectively of an individual factor for a group of farmers.

Table 1.4 Farmers of Barguna district consider various factors in deciding the type/amount of fertilizers to use

Factors of decision making	Small & Marginal		Medium farmer		Large farmer		Female farmer		All groups	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1. Type of crop	24	2	25	2	23	2	24	2	96	1
2. Quality of soil	15	5	28	1	26	1	22	3	91	2
3. Topography of land	24	2	15	6	23	2	27	1	89	3
4. Market value of the crop	25	1	19	4	15	6	22	3	81	4
5. Cost of fertilizer	24	2	14	7	6	9	24	2	68	5
6. Fertilizer dealer's recommendation	14	4	18	5	17	4	16	5	65	6
7. Availability of fertilizer	18	3	19	4	17	4	11	7	65	7
8. Advice given by extension/project staff	11	6	21	3	22	3	6	9	60	8
9. Crop season	15	5	14	7	16	5	10	8	55	9
10. Practice of Neighbour	15	5	10	8	10	7	19	4	54	10
11. Sowing type	10	7	14	7	10	7	12	6	46	11
12. Availability and use of cow manure	9	8	7	9	16	5	11	7	43	12
13. Govt. fertilizer recommendations	4	9	4	10	7	8	4	10	19	13
14. Soil testing advice	2	10	2	11	2	10	2	11	8	14

Table 1.5 Farmers of Khulna district consider various factors in deciding the type/amount of fertilizers to use

Factors of decision making	Small & Marginal		Medium farmer		Large farmer		Female farmer		All groups	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1. Quality of soil	27	1	25	2	25	2	27	1	104	1
2. Type of crop	22	3	21	3	22	3	25	2	90	2
3. Advice given by extension/project staff	15	5	27	1	26	1	22	3	90	2
4. Availability and use of cow manure	22	3	21	3	21	4	21	4	85	3
5. Practice of neighbour	24	2	15	7	16	7	25	2	80	4
6. Topography of land	18	4	18	5	16	7	15	6	67	5
7. Fertilizer dealer's recommendation	12	7	13	8	19	5	17	5	61	6
8. Govt. fertilizer recommendations	13	6	16	6	17	6	14	7	60	7
9. Sowing type	12	7	13	8	16	7	11	9	52	8
10. Soil testing advice	15	5	13	8	14	8	3	12	45	9
11. Crop season	4	9	19	4	11	9	10	10	44	10
12. Market value of the crop	15	5	9	9	7	11	11	9	42	11
13. Cost of fertilizers	12	7	5	11	4	12	13	8	34	12
14. Availability of fertilizers	8	8	8	10	9	10	7	11	32	13

Note: The highest and the lowest scores are 28 and 2 respectively of an individual factor for a group of farmers.

Table 1.6 Farmers in the study areas consider various factors in deciding the type/amount of fertilizers to use

Factors of decision making	Small & Marginal		Medium farmer		Large farmer		Female farmer		All groups	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1. Type of crop	126	1	123	2	112	2	127	1	488	1
2. Quality of soil	115	2	128	1	117	1	122	2	482	2
3. Crop season	85	5	110	3	97	5	87	6	379	3
4. Topography of land	91	3	83	6	103	3	96	3	373	4
5. Availability and use of cow manure	89	4	85	5	94	6	93	4	361	5
6. Advice given by extension/project staff	72	8	90	4	102	4	68	9	332	6
7. Practice of neighbour	83	6	72	7	62	8	91	5	308	7
8. Fertilizer dealer's recommendation	70	9	72	7	84	7	76	8	302	8
9. Market value of the crop	70	9	59	8	36	13	68	9	233	9
10. Sowing type	59	10	59	8	54	10	56	10	228	10
11. Cost of fertilizer	78	7	45	10	19	14	82	7	224	11
12. Availability of fertilizer	45	11	50	9	49	12	39	11	183	12
13. Govt. fertilizer recommendations	30	12	33	11	51	11	24	12	138	13
14. Soil testing advice	26	13	31	12	57	9	13	13	127	14

Note: The highest and the lowest scores are 140 and 10 respectively of an individual factor for a group of farmers.

Table 1.7 Raking of various factors according to study locations

Rank	Mymensingh	Thakurgaon	Rajshahi	Barguna	Khulna
1	Crop season	Quality of soil	Type of crop	Type of crop	Quality of soil
2	Type of crop	Type of crop	Quality of soil	Quality of soil	Type of crop
3	Quality of soil	Crop season	Crop season	Topography	Advice of SAAO
4	Availability of cow dung	Topography	Advice of SAAO	Market value of the crop	Availability of cow manure
5	Advice of SAAO	Availability of cow manure	Topography	Cost of fertilizer	Practice of neighbour
6	Practice of neighbour	Dealer's recommendation	Availability of cow manure	Dealer's recommendation	Topography
7	Topography	Sowing type	Practice of Neighbour	Availability of fertilizer	Dealer's recommendation
8	Dealer's recommendation	Practice of Neighbour	Dealer's recommendation	Advice of SAAO	Govt.'s recommendations
9	Cost of fertilizer	Market value of the crop	Sowing type	Crop season	Sowing type
10	Govt.'s recommendation	Advice of SAAO	Cost of fertilizer	Practice of Neighbour	Soil testing advice
11	Soil testing advice	Cost of fertilizer	Govt.'s recommendations	Sowing type	Crop season
12	Market value of the crop	Availability of fertilizer	Market value of the crop	Availability of cow manure	Market value of the crop
13	Availability of fertilizer	Govt.'s recommendations	Availability of fertilizer	Govt.'s recommendation	Cost of fertilizers
14	Sowing type	Soil testing advice	Soil testing advice	Soil testing advice	Availability of fertilizers

2.0 AVAILABILITY AND ACCESS TO FERTILIZER

	Questions	Mymensingh	Thakurgaon	Rajshahi	Barguna	Khulna
1.	Who do you buy fertilizer from?	• Sub-dealer in local market with cash or credit • Some large farmers by from dealers in distant market with lower price (Tk 1.0-2.0/kg).	• Sub-dealer and retailers in local market with cash or credit • Some large farmers by from dealers in distant market with lower price (Tk 1.0-2.0/kg).	• Sub-dealer and retailers in local market with cash or credit • Some large farmers by from dealers in distant market with lower price (Tk 1.0-2.0/kg).	• Sub-dealer and retailers in local market with cash or credit • Some large farmers by from dealers in distant market with lower price (Tk 1.0-2.0/kg).	• Sub-dealer and retailers in local market with cash or credit
2.	Where are the fertilizer dealers located?	• Sub-dealer- 0.5-2 km • Dealer- 5-10 km	• Sub-dealer- 0.25-3.50 km • Dealer- 1.0-1.5 km	• Sub-dealer- 0.50-1.50 km • Dealer- 3.0-3.5 km	• Sub-dealer- 0.50-2.5 km • Dealer- 8.0-12.0 km	• Sub-dealer- 0.50-1.0 km • Dealer- 5-40 km
3.	Are they your only supplier of fertilizer?	• YES	• YES	• YES	• YES	• YES
4.	Have you experienced any difficulties accessing fertilizer from them?	• NO • Sub-dealers charge higher price (2-3/kg) due to cost of transportation & profit	• Infrequently • Sub-dealers charge higher price (2-3/kg) • Sell very old fertilizer	• Infrequently • Sub-dealers charge higher price (2-3/kg) • Sometimes dealers create artificial crisis for good fertilizers to raise the price.	• Infrequently • Sub-dealers charge higher price (2-3/kg) • Sometimes dealers create artificial crisis during production season to raise the price.	• Infrequently • Sub-dealers charge higher price (2-5/kg) showing various reasons (transportation, company brand, quality, scarcity) • Sometimes dealers create artificial crisis for good fertilizers to raise the price.
5.	Do they always have what you want? If no, what reason do they give you for not having what you want?	• YES	• YES, but • Sometimes fertilizer supply delayed by 6-7 days.	• YES	• YES, but • Sometimes fertilizer supply delayed by 3-4 days.	• YES, but • Sometimes fertilizer supply delayed by 3-4 days

	Questions	Mymensingh	Thakurgaon	Rajshahi	Barguna	Khulna
6.	Do you think that dealers should be provided loan facility for ensuring proper supply of fertilizers in the market?	• Most farmers' opinion is No need credit. • Fertilizer supply is enough. Its price is also low. • Access to Bank credit is not easy for them.	• Most farmers' opinion is No need credit. • They are rich. They will use this loan money for other purposes. • Access to Bank credit is not easy for them.	• Most farmers' opinion is No need credit. • They are rich. They will use this loan money for other purposes. • Access to Bank credit is not easy for them.	• Most farmers' opinion is No need credit. • Some farmers opined that provision of credit will help retailers to increase the stock.	• Most farmers' opinion is that they need no credit. • They opined that provision of credit will help sub-dealers to increase the stock.

3.0 INFORMATION ON PRICE AND COST OF FERTILIZER

	Questions	Mymensingh	Thakurgaon	Rajshahi	Barguna	Khulna
1.	Can you always afford to apply the fertilizer that you want?	• Most farmers can afford • Some farmers use less	• Most farmers can afford • Some farmers use less	• Most farmers can afford • Some farmers can't apply the fertilizer that they want	• Most farmers can afford • Some farmers can't apply the fertilizer that they want	• NO, due to financial scarcity and tidal flood. •
2.	What happens when you don't have enough money, how do you manage this challenge, what do you priorities?	• Farmers give priority on good production • Buy fertilizer from sub-dealer on credit • They give higher price for fertilizer in case of credit	• Farmers give priority on good production • Buy fertilizer from sub-dealer on credit • Small, marginal and female farmers apply less amount of fertilizer.	• Farmers give priority on good production • Buy fertilizer from sub-dealer on credit • Lend money from relatives, friends, shopkeeper, NGOs • Sell small ruminant and poultry • Fertilizer application delayed.	• Farmers give priority on good production • Buy fertilizer from sub-dealer on credit • Lend money from local money lender (interest @120%), NGO, relatives • Sell small ruminant, poultry & household assets • Fertilizer application delayed. Sometimes not applied	• Farmers give priority on good production • Buy fertilizer from sub-dealer on credit • Sell paddy at lower price or advance sale of paddy (Tk.2000/5md) • Lend money from local money lender (interest @120%), NGO @18% • Sell small ruminant, poultry & household assets
3.	When choosing which fertilizers to apply does the price of the fertilizer influence the type of fertilizer you use? What about the amount?	• Price does not influence much the type and amount of fertilizer to be used. • Sometimes application may be delayed. • Current fertilizer price is within the capacity of majority farmers.	• Price does not influence much the type and amount of fertilizer to be used. • Sometimes application may be delayed. • Price is not a factor in case of good quality fertilizers.	• Price does not influence much the type and amount of fertilizer to be used. • Sometimes application may be delayed. • Female farmers could not use desired fertilizers adequately due to higher price.	• Price does not influence much the type and amount of fertilizer to be used. • Sometimes application may be delayed. • Female farmers could not use desired fertilizers adequately due to higher price.	• Price does not influence much the type and amount of fertilizer to be used. • Sometimes application may be delayed. • Some farmers could not use desired fertilizers due to higher price.
4.	What about subsidized fertilizer, do you know which fertilizers are subsidized by the Government?	• Most farmers know Urea as a subsidized fertilizer and have little idea on other two subsidized fertilizers TSP and MoP.	• Most farmers know Urea as a subsidized fertilizer and have little idea on other two subsidized fertilizers TSP and MoP.	• Most farmers know Urea as a subsidized fertilizer and have little idea on other two subsidized fertilizers TSP and MoP.	• Most farmers know Urea as a subsidized fertilizer and have little idea on other two subsidized fertilizers TSP and MoP.	• Most farmers know Urea as a subsidized fertilizer and have little idea on other two subsidized fertilizers TSP and MoP.
5.	Would you say you use the subsidized fertilizers more or less?	• Most farmers don't think about subsidy in case of applying fertilizers. • Small, marginal and female farmers apply less amount of fertilizers due to higher price.	• Most farmers don't think about subsidy in case of applying fertilizers.	• Most farmers don't think about subsidy in case of applying fertilizers.	• Most farmers don't think about subsidy in case of applying fertilizers. • Small, marginal and female farmers apply less amount of fertilizers due to higher price.	• Most farmers don't think about subsidy in case of applying fertilizers. • Paddy become grain less due to the use of excessive urea.

4.0 INFORMATION ON AND ADVICE REGARDING FERTILIZER

	Questions	Mymensingh	Thakurgaon	Rajshahi	Barguna	Khulna
1.	Question for those farmers who don't seek out information or advice about the fertilizer they apply in a cropping season. Why they don't seek out information or advice?	• Over confidence on their experience • DAE personnel advise them to apply fertilizers maintaining 7 days interval. This system takes longer time. • DAE system does not work properly and produce less yield • Face hassle (mostly DAE Information Centre remains closed)	• Over confidence on their own experience • Non-availability of SAAO • Put less importance on it and due to their laziness	• Over confidence on their own experience • DAE system does not work properly and produce less yield • DAE office is far away from their residences • Put less importance on it and their laziness • Farmers' don't know where to go and who to ask.	• Over confidence on their experience • DAE system does not work properly and produce less yield • Farmers' don't know where to go and who to ask.	• Over confidence on their experience • DAE system does not work properly and produces less yield • DAE office is far away from their residences • Small farmers opined that they produced better yield than those farmers who took advice from SAAO.
2.	What type of information and advice do you want to know?	• Appropriate dose of different fertilizers for various crops. • Proper system of applying fertilizers	• Appropriate dose of different fertilizers for various crops. • Proper system of applying fertilizers • Status of soil and crop	• Appropriate dose of different fertilizers for various crops. • Proper system of applying fertilizers	• Appropriate dose of fertilizers and pesticides for various crops. • Proper system of applying fertilizers and pesticides • What should do when irrigation water is scarce?	• Appropriate dose of fertilizers and pesticides for various crops. • Proper system of applying fertilizers and pesticides • Proper cultivation system
3.	Question for those farmers who sometimes/ occasions seek out information/ advice. Why they ask & who from?	• Most farmers consult with SAAO and peer farmers regarding sources of good seed, crop protection technique, & fertilizer • Some consult with sub-dealers regarding fertilizer and pesticides use	• Most farmers consult with SAAO and peer farmers. • Some consult with sub-dealers regarding fertilizer and pesticides use	• Most farmers consult with SAAO and peer farmers. • Some consult with sub-dealers regarding fertilizer and pesticides use	• Most farmers consult with SAAO and peer farmers. • Some consult with sub-dealers regarding fertilizer and pesticides use	• Most farmers consult with SAAO, peer farmers, sub-dealers, company agent • Dealers induced them to apply more fertilizers
4.	Are you satisfied with their advice/ information?	• Most farmers are not satisfied with SAAO's advice regarding fertilizer use because it is not effective and profitable	• Most farmers are satisfied because their advices are effective. • Some farmers have doubt on their advice regarding fertilizer dose • Small and female farmers opined that the advice of SAAO regarding fertilizer use is costly.	• Most farmers are not satisfied with SAAO's advice regarding fertilizer use because it is not effective and profitable • Sometimes, they seek out advice or information from more than one persons	• Most farmers are not satisfied with SAAO's advice regarding fertilizer use because it is not effective and profitable. • Sometimes, they seek out advice or information from more than one persons	• Most farmers are not satisfied with SAAO's advice regarding fertilizer use because it is not effective and profitable. • Small & marginal farmers could not apply adequate amount of fertilizer due to financial paucity.
5.	Question for those farmers who always seek out information/advic e. How could advice or information be improved?	• Soil test facility should be created at local level. • Soil test technique should be simple & user friendly.	• Soil test facility should be created at local level. • Soil test technique should be simple & user friendly.	• Soil test facility should be created at local level.	• Soil test facility should be created at local level. • Frequent group meeting among farmers and SAAO	• Soil test facility should be created at local level. • Frequent group meeting among farmers and SAAO • Frequent visit of SAAO
6.	What type of person or institution that would be most useful for the dissemination of information?	• Soil and fertilizer related information may be disseminated through DAE • Research Institutes	• Soil and fertilizer related information may be disseminated through DAE • Research Institutes	• Soil and fertilizer related information may be disseminated through DAE • Research Institutes • Through IPM club	• Soil and fertilizer related information may be disseminated through DAE • Research Institutes	• Research Institutes • Soil and fertilizer related information may be disseminated through SAAO and project personnel

	Questions	Mymensingh	Thakurgaon	Rajshahi	Barguna	Khulna
7.	What are the techniques/methods that would be most useful for information dissemination?	• Create local level soil testing facility • Face to face training • Recommended dose through Booklet • Video and power point presentation • Setting demonstration plots	• Soil test through soil testing kit. • Face to face training • Booklets and mobile apps will not be effective for illiterate farmers	• Soil test through soil testing kit. • Face to face training • Setting demonstration plots • Booklets and mobile apps will not be effective for illiterate farmers	• Soil test through soil testing kit. • Face to face training • Setting demonstration plots • Mobile apps is easy but will not be effective much for illiterate farmers	• Create local level soil test facility • Face to face training through DAE personnel
8.	What type of training do you need to ensure BFD application & soil heath improvement? How the training should be organized?	• Hand on training on fertilizer management • Demonstration plot will be useful to attract others • Training should be started one month before of crop season at local level • Training should be organized twice a year	• Hand on training on fertilizer management • Training should be started one month before of crop season at local level • Training should be organized twice a year	• Hand on face training on fertilizer management and identification of good fertilizers. • Training should be started one month before of crop season at local level	• Hand on training on fertilizer (inorganic & organic) management. • Training on high value crops and cropping patterns • Training should be started one month before of crop season at local level	• Hand on training on fertilizer and crop management, soil test • Training should be started one month before of crop season at local level

5.0 OTHER INFORMATION RELATED TO FERTILIZER USE

	Questions	Mymensingh	Thakurgaon	Rajshahi	Barguna	Khulna
1.	Are there soil test facilities in this area? How long these facilities are from your residence?	• No soil test facility • SRDI is far from 15-20 km • Most farmers are unknown about soil test center.	• No soil test facility • SRDI is far from 70 km. • Most farmers are unknown about soil test center.	• No soil test facility • SRDI is far from 30-35 km. • Most farmers are unknown about soil test center.	• No soil test facility • SRDI is far from 25-35 km • Most farmers are unknown about soil test center.	• No soil test facility • SRDI is far from 15-20km • Most farmers are unknown about soil test center.
2.	How farmers' awareness on soil test could be improved?	• Through training • Demonstrate crop production according to soil test results	• Through training • Create soil test facility at local level	• Through training • Create soil test facility at local level	• Through training • Create soil test facility at local level	• Through training • Create soil test facility at local level
3.	What types of hassles do you face during soil test?	• Soil test report is not delivered timely • Has to visit soil test office frequently for one test	• No comment	• It is better to use that money to be used for testing soil and transportation for buying fertilizers.	• No comment	• No comment
4.	What are the facilities/ services that need to be created by the govt. or any other agency for encouraging farmers to use balanced fertilizer dose?	• Soil and fertilizer test facility should be created at local level • Soil test kit should be locally available • Form and train a group of LSP/ToT in the areas • Prices of soil and fertilizer testing kits should be low.	• Soil and fertilizer test facility should be created at local level • Soil test kit should be available at local level • Fertilizer price should be low • Provide credit facility for marginal and female farmers at low interest rate	• Soil test kit should be available • Soil and fertilizer test facility should be created at local level	• Soil test facility should be created at local level • Soil test kit should be locally available • Ensure fair price of crop Provide credit facility for marginal and female farmers at low interest rate	• Soil test facility should be created at local level • Ensure fair price of crop • Reduce fertilizer price Provide credit facility for marginal and female farmers at low interest rate
5.	Why small & marginal and female farmers use less amount of fertilizers? If they are given institution credit with low interest rate, will they be more optimum fertilizer users?	• Lack of financial paucity • Use plenty of compost • Lack of institutional credit • Less access to credit purchase from sub-dealers • Lands close to homestead are more fertile, so use less fertilizers • They will be benefited if they will be provided credit.	• Lack of financial paucity • Lack of institutional credit • Less access to credit purchase from sub-dealers • Use plenty of compost • They will be benefited if they will be provided credit.	• Lack of financial paucity • Lack of institutional credit • Due to wrong or inappropriate advice from large farmers. • They will be benefited if they will be provided credit.	• Lack of financial paucity • Lack of institutional credit • Higher price of fertilizer • Lack of knowledge • They will be benefited if they will be provided credit.	• Lack of financial paucity • Lack of knowledge • Higher price of fertilizer • Use plenty of compost • They will be benefited if they will be provided credit.

SOME SNAPSHOTS ON FGD, 2019

FGD-1: Bhabokhali, Sadar, Mymensingh

FGD-2: Sutiakhali, Sadar, Mymensingh

FGD-3: Kochubari, Sadar, Thakurgaon

FGD-4: Singgia, Sadar, Thakurgaon

FGD-5: Pourosova block, Durgapur, Rajshahi

FGD-6: Pananagar, Durgapur, Rajshahi

FGD-7: Chila, Amtoli, Barguna

FGD-8: Nilgonj, Amtoli, Barguna

FGD-9: Bajua, Dacop, Khulna

FGD-10: Baruikhali, Dacop, Khulna

Source: The Financial Express, January 08, 2019

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Youtube, August 17, 2018.

Source: Crop survival in a hot climate,
The Star e-paper, August 18, 2014

Source: A Working Manual on Cultivation of Maize
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BARI and ATC-P/Katalyst, February, 2018

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