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Sustainable food security through cropping system analysis using different farming technologies at northern region of Bangladesh

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Abstract

Productivity of the cropping system is critical to the food security of Bangladesh. However, many concerns about the sustainability of cropping system exist because of lack of advance knowledge of farming. In this context, a study was performed in the agro-ecological zone of the Tista Mendar Floodplain agro ecological zone (AEZ-3) at Jaldhaka subdistrict under Nilphamary district of Bangladesh. By reorganization of existing cropping patterns (using Linear Programming Model) gross output (7% to 21%), gross margin (12% to 20%) and labour employment (6% to 20%)have been increased from plan1(existing plan) to plan2 (by reorganization of existing lands). The cause of increase gross output, gross margin andlabour employment was some cultivated land from less efficient cropping patterns has been transferred to more efficient cropping patterns. Again, by reorganization of existing and improved cropping patterns, some lands of existing patterns have been shifted to improved cropping pattern. As a result, gross out (17% to 31%), gross margin (27% to 32%) and labour employment (13% to 26%) have been raised from plan1 to plan 3 (by combination of improved technologies with existing technologies). The result of on farm demonstration showed gross output, gross margin and labour employment have been increased 24% to 53%, 32% to 51% and 12% to 47% from plan1 to plan 3, respectively. So, this study suggest, optimum farm plan with the combination of existing and improved cropping pattern will increase farm output and generate additional employment and improved food security.

Key words: Food security, cropping system analysis, farming systems and improvetechnologies

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Introduction

Increasing food production to meet growing demands is a major global challenge, particularly in the population-dense and impoverished South Asia, where smallholder agriculture predominates (Fischer et al., 2009).Sustainable intensification has been widely proposed as an important agricultural development policy goal (Godfray et al., 2010). In Bangladesh, most potentially arable land is already in production, and future food needs can only be met through intensification (FAO, 2014). Bangladesh with an area of 1, 47, 570 sq Km is the most densely populated (about 1008 Persons per km) country of the world. Its present population is about 159 million which is increasing annually at the rate of about 1.42 percent (BBS, 2011). By the year 2050 AD, the population will increase to about 200 million (FAO, 2014). On the other hand, the cultivable land is decreasing by 1% every year. So Bangladesh has to produce additional food for millions of people every year. Bangladesh is predominantly a rice growing country and rice is the staple food. Rice occupies about 80 % of the total cropped area and is cultivated in three seasons a year. In rice based cropping system Transplant aman rice (summer rice/rainfed rice)-Fallow-Boro rice (winter rice/irrigated rice) is a dominant cropping pattern where cropping intensity is 200 %. In the pace of per capita land availability decrease and production shortage the existence of fallow land in rice based cropping system is very inconsistent to national perspective. Though it is late, however the recent attention to these lands may open new era to rational development initiative, and can add new dimension to agricultural development. Intensive and diversify use of these lands will help to increase production, ease market pressure on commodities, it's availability, farmers income generation, employment opportunity and livelihood improvement as well as reduce the food insecurity.

Lack of High Yielding Variety (HYV) seed, lack of improved technology and cash money for buying inputs are major problems in the study area. Transplant aman rice (rice cultivation under summer season)-Tobacco-Jute is a major cropping pattern in the study area and more than 80% farmers of the regions cultivated tobacco as a cash money. Transplant aman rice -Fallow-Boro rice (rice cultivation under winter season) is a second important cropping pattern in this area. Many farmers do not use micronutrient (Zinc and Boron) in their land. As a result, there is a yield gap between potential yield and average yield of their cultivated crops.

Previous economic studies of cropping systems in Bangladesh have focused on the impacts of farming on profitability, food security, and salinity intrusion (Rasul and Thapa, 2004;Ferdous and Islam, 2008; Ferdous et al., 2011; Anowar et al 2012;Datta et al., 2015; Datta et al., 2017; Kabir et al. 2017a,b; Ahmed et al., 2017a,b; Anwar et al., 2017). Some have assessed the profitability of farming system for food security in northern region of Bangladesh (Ferdous et al. 2016). Many studies (Alam et al., 1997, 2013; Ali, 2105; Anowar et al., 2015; Mahamood et al., 2016; Ferdous et al., 2017b,c; Anwar et al., 2017) have reported that lack of resources optimization is one of the major causes for increasing income and employment of the farmers.

Considering the above issues, the investigation was undertaken to assess existing technology of the farmers of northern region and to produce optimum farm plans for marginal, small and medium farmers by reorganization of existing resources and by combination of improved technologies with existing technologies.

Materials and Methods

The farm accounting data for this empirical application have been collected from Nilphamari district through a farm management survey. A sample of 90 farms from two villages (technologically poor villages) have been surveyed taking 30 from marginal (farm size less than 50 decimals), 30 from small (farm size less than 150 decimals), and 30 from medium farm (farm size less than 250 decimals) groups using random sampling technique method. Input output data of all crops and livestock of the sample farmers have been included in data analysis. Linear programming (LP) model have been used to produce optimum farm plans for marginal, small and medium farms with existing technology and with improved technology for increasing employment and food accessibility of the farming of the regions (Table 1).

***Analytical Technique*:** The selection of suitable cropping patterns, factors of production and the special technique in the structure of restrictions allow in the two models of Programming that have the same objective function. This is a linear function of all activities of enterprises and factors of production that produce optimum farm plans for marginal, small and medium farms of the study area (Anwar et al., 2017).

Table1. General structure of developed technological matrix (base matrix) of average medium, small and marginal farms based on survey data

Variable Common Resources & Constraints	Cropping Patterns					Price Per Kg							Sign of Constraints
	CP1	CP2	CP3	-	Poultry	R	J	P	T	M	C	H	
A. Lands													
HL													<= +
MHL													<= +
MLL													<= +
Livestock													<= +
Poultry													<= +
B.Labours													
January													<= +
February													<= +
March													<= +
April													<= +
May													<= +
June													<= +
July													<= +
August													<= +
September													<= +
October													<= +
November													<= +
December													
C. Capita													
Mechanical power													<= +
Manure													<= +
Seed													<= +
Fertilizer													<= +
Irrigation													<= +
Insecticide													
Yield, R<=0						1							
J<=0							1						
V<=0								1					
W<=0									1				
M<=0										1			
P_O<=0											1		
P_L<=0			....									1	

The deterministic linear programming model for this study for each area is specified as:-

$$Z = \sum (C_{ji} + L_{jn})$$
$$= \{(C_{sji}X_{sji} - V_{sji}) + (L_{sji}S_{sjn} - V_{sji})\} + \{(C_{mji}X_{ji} - V_{mji}) + (L_{mji}X_{mjn} - V_{mji})\} + \{(C_{lji}X_{lji} - V_{lji}) + (L_{lji}X_{ljn} - V_{lji})\}$$

C_{ji} =Total gross margin (Tk/ha) from j^{th} crop activity in i^{th} land.

X_{ji} =Total area (ha) from j^{th} crop activity in i^{th} land.

L_{jn} =Number of livestock fromjth activity.

C_{sji} =Gross return (Tk/ha) from medium farmers from their j^{th} crop activity in the i^{th} land.

X_{sji} =Area(ha) of medium farmers from their j^{th} crop activity in the i^{th} land.

V_{sji} =Variable cost (Tk) of medium farmers from their j^{th} crop activity in the i^{th} land.

L_{sji} = Gross return (Tk/number) of medium farmers from their j^{th} livestock activity in the i^{th}number.

X_{sjn} = Number of livestock of medium farmers from their j^{th} activity.

V_{sji} = Variable cost (Tk) of medium farmers from their j^{th} activity in the i^{th}number.

C_{mji} = Gross return (Tk/ha) from medium farmers from their j^{th} crop activity in the i^{th}land.

X_{mji} = Area(ha) of medium farmers from their j^{th} crop activity in the i^{th}land.

V_{mji} = Variable cost (Tk) of medium farmers from their j^{th} crop activity in the i^{th}land.

L_{mji} = Gross return (Tk/number) of medium farmers from their j^{th} livestock activity in the i^{th}number.

X_{mjn} = Number of livestock of medium farmers from their j^{th} activity.

V_{mji} = Variable cost (Tk) of medium farmers from their j^{th} activity in the i^{th}number.

C_{lji} = Gross return (Tk/ha) from medium farmers from their j^{th} crop activity in the i^{th}land.

X_{lji} = Area(ha) of medium farmers from their j^{th} crop activity in the i^{th}land.

V_{lji} = Variable cost (Tk) of medium farmers from their j^{th} crop activity in the i^{th}land.

L_{lji} = Gross return (Tk/number) of medium farmers from their j^{th} livestock activity in the i^{th}number.

X_{ljn} = Number of livestock of medium farmers from their j^{th} activity.

V_{lji} = Variable cost (Tk) of medium farmers from their j^{th} activity in the i^{th}number.

For sustainable food security, increasing food accessibility and employment, optimum farm plans by reorganization of improved technology have been conducted among six farmers in the study villages during 2009-2010. Improved cropping patterns Transplant Aman rice (Bina dhan -7) – Potato+Maize+ Mung bean and Transplant Aman rice (Bina dhan -7) – Maize+Mung bean (developed by OFRD, Rangpur) have been selected to conduct as a trial in the study villages. A homestead model (Table 2) vegetables production program has been conducted among six farmers in the study villages for growing year round vegetables production and also to solve the nutritional problem and for woman employment generation.

Data of the on farm demonstration of optimum farm plans were collected timely. A statistical method SPSS was used to analyze the data in order to produce descriptive statistics.

Table 1. Model of year round vegetables and creeper production (Rangpur Model) (Ferdous et al., 2016).

Niche/space		Year round homestead vegetable pattern		
		Rabi **(Mid Oct–Mid Mar)**	**Pre-monsoon *Kharif-1* (Mid Mar–Mid Jun)**	***Kharif-2*** **(Mid Jun–Mid Oct)**
1.Open sunny space				
	Bed 1	Radish	Joseph's coat	Water spinach
	Bed 2	Cabbage	Stem amaranth	Coriander
	Bed 3	Brinjal + Joseph's coat	Indian spinach	Spinach
	Bed 4	Tomato + Chinese mallow	Okra	Joseph's coat
	Bed 5	Garlic	Tossa jute	Okra
2. Roof top		Bottle gourd	Ash gourd	Ash gourd
3.Trellis		French bean	Snake gourd	Snake gourd
4. Fence		Bitter gourd	Ribbed gourd	Ribbed gourd
5.Boundary		Papaya	Papaya	Papaya
6. Marshy land		Tannia	Tannia	Tannia
7.Partially shady place		Ginger and turmeric	Ginger and turmeric	Ginger and turmeric

Results and Discussion

Socio economic Factors: Socio-economic Conditions/factors of the farmers in the study areas have been shown in the Table 3.

Table 3. Socio-economic Conditions/factors of the farmers in the study area

SN	Socio-Economic Conditions/factors	Study area Jaldhaka, Nilphamari
A.	Level of education (%)	
	Illiterate	24
	Under SSC	67
	Above SSC	7
B.	House hold Income	
	Agriculture	81
	Agriculture + Service	2
	Agriculture + Business	4
	Agriculture + Day labour	13
B.	Farm Size (ha)	
	Medium	0.80
	Small	0.36
	Marginal	0.12
C.	Irrigation (%)	
	Lack of irrigation	20
	High cost of irrigation	38
B.	Seed (%)	
	Price is very high	51
	Not available in time	28
	Lack of HYV seed	56
C.	Fertilizer (%)	
	Price is high	8
	Not available in time	18
D.	Insecticide (%)	
	Disease/pest problem	75
	Price is high	81
	Not available in time	23
	Lack of knowledge	81
E.	Lack of Labour (%)	88
F.	Human labour wage is High (%)	96
G.	Low yield of Crop (%)	59
H.	High Cost of Production (%)	71
I.	Lack of Improved technology (%)	74
J.	Lack of money for buying inputs (%)	61

Note: % indicates opinion of the farmers in percentage

At Jaldhaka, Nilphamari, average farm size for medium, small and marginal farms were 0.80 ha, 0.36 ha, and 0.12 ha, respectively. The main occupation was agriculture which was more than 80 percent of the study area. Lack of high yielding variety (HYV) seed is a major constraint for higher production in the study area.

Existing agricultural technology: Existing agricultural technology has been a primary factor contributing to increases in farm productivity in developing countries over the past half-century. Although there is still widespread food insecurity, the situation without current technology development would have been unimaginable. Existing agricultural technology focuses the common technological process used in agriculture. Existing Agricultural Technologies of the farmers of Jaldhaka, Nilphamari has been presented in the Table 4.

Table 4. Existing Agricultural Technology of Jaldhaka, Nilphamari

Existing Technology	% Use by the farmer
Homestead Vegetable Production	
Roof top	75
Trellis	51
Major Cropping Patterns	
High land	
Transplantaman rice -Tobacco-Jute	43
Transplantaman rice -potato-Maize	46
Transplantaman rice - Fallow- Chilli	8
Medium high land	
Transplantaman rice --Maize	10
Transplantaman rice -Tobacco-Jute	55
Transplantaman rice –Boro rice	30
Medium lowland	100
Transplant Aman rice -Fallow-Boro rice	
Variety	BR 11, BR 33
Transplantaman rice	Local
Tobbaco	Granula, Cardinal
Potato	Tosha,
Jute	BR 28, Hybrid
Boro rice	Local
Chilli	Hybrid
Maize	
Farm Machinery	
Power tiller	90
Shallow- tube well	100
Organic Matter (Less than 5 tha^{-1})	100%
Fertilizer	100%
Use of Insecticide and fungicide	90%

***Major cropping patterns*:** T. aman-Tobacco-Jute/Boro is a major cropping pattern in the three study areas and more than 80% farmers of the regions cultivated tobacco as a cash money. T. aman-Fallow-Boro is a second important cropping pattern at Jhaldhaka, Nilphamari. Above 90 percent farmers use power tiller for cultivating land and Shallow-tube well for irrigation.

***Fertilizer application*:** Most of the farmers use organic fertilizer in crop production in the three locations. Especially, in cause of HYV crop all the farmers use fertilizer while 60% farmers use organic matter in their land. Many farmers do not use micronutrient (Zinc and Boron) in their land. As a result, there is a yield gap between potential yield and average yield of their cultivated crops (Ferdous et al., 2017a).

***On farm demonstration result of the cropping pattern T. aman-Potato+Maize+Mungbean*:** This cropping pattern was demonstrated at the farmers' field condition in Katali, Jaldhaka, Nilphamari during 2010-2011 with 6 dispersed (Ferdous et al., 2016) replications. The categories of the farmer were medium, small and marginal. Demonstration areas were for medium farm 46 decimal, small farm 31 decimal and marginal farm 15 decimal. Planting and harvesting time were according to Table 5. T. aman was transplanted in the month of July and was harvested in the month of October. After harvesting T. aman immediately planted potato. After 35 days of planting potato, maize was planted as relay cropping. Before 20 days of maize harvest, Mung bean was planted. Per hectare input use and cost of the cropping pattern were according to Table 7. Per hectare net return of the cropping pattern was Tk 176611 (Table 8). The highest net return was gained by potato (Tk 101622) and followed by maize (Tk. 52411), T. aman (Tk. 15530) and mung bean (Tk. 7048). Similar results were obtained by Anwar et al. (2017) in the *Monga* region of Bangladesh. Other studies (Ferdous et al., 2011; Anowar et al., 2012; Ferdous et al., 2014; Sarker et. al., 2010; Khatun et al., 2014;) have also reported that different cropping pattern and diversified farming systems are most profitable for marginal and small farmers in Bangladesh.

***On farm demonstration result of the cropping pattern T. aman–Maize–Mungbean*:** This cropping pattern was demonstrated at the farmers' field condition in Jaldhaka, Nilphamari during 2010-2011 with 6 dispersed replications. The categories of the farmer were medium and small. Demonstration areas of the pattern Jaldhaka Nilphamari were 31 decimal for medium farm and 22 decimal for small farm. Planting and harvesting time were according to Table 7. T. aman was transplanted in the month July and was harvested in the month October. After harvesting T. aman immediately planted maize. Before 20 days of maize harvest, Mung bean was planted. Per hectare cost and return of the cropping pattern was according to Table 8. Per hectare net return of the cropping patterns Tk 69587 for Jaldhaka, Nilphamari. The highest net return was gained by maize and followed by T. aman and mung bean (Table 9).Similar results were obtained by Anwar et al. (2017) in the *Monga* region of Bangladesh. Other studies (Ferdous et al., 2011; Anowar et al., 2012; Rahman et al. 2008; Rahman et al., 2011) have also reported that rice based farming systems are most profitable for marginal and small farmers in Bangladesh.

***On farm demonstration result of optimum farm plan*:** Optimum farm plans (combining improved technology) produced on survey data using LP model were demonstrated among medium, small and marginal farms in Jaldhaka, Nilphamari. The aim of the demonstration was to prove that existing farm plans were mal allocated and optimum farm plans (combining improved technology) were more efficient. Besides, these plans also verify the results between the survey data and on farm demonstration data.

At Jaldhaka, Nilphamari seven cropping patterns such as T. aman (BR 11) -Tobacco- Jute, T. aman (BR 11)-Potato-Maize, T. aman-Fallow-Chilli, T. aman (Binadhan 7)–Potato+Maize+Mungbean, T. aman (BR

11)–Fallow-Maize, T. aman (Binadhan 7)-Maize+Mung and T. aman-Fallow-Boro participate in optimum farm plan. In high land, among four cropping patterns, the T. aman (Binadhan 7) –Potato +Maize + Mungbean is comparatively more efficient compared to the all existing patterns. Similarly, in medium high land, among the four cropping patterns, the pattern T. aman (Binadhan 7)-Maize+Mung is comparatively more efficient (Table 5 & 6). In the three categories of farm gross output, gross margin and labour employment have been increased 25 to 53 percent, 36 to 46 percent and 13 to 42 percent, respectively (Table 10). Similar results were obtained by Anwar et al. (2017) in the *Monga* region of Bangladesh.

Table 5. Existing and Optimum Plan for land (decimal) utilization under medium, small and marginal farms in khutamar Union of Jaldhaka subdistrict, Nilphamari.

Categories of land	Crop Rotations	Types of Farms								
		Medium			Small			Marginal		
		Plan 1	Plan 2	Plan 3	Plan 1	Plan 2	Plan 3	Plan 1	Plan 2	Plan 3
High Land	T. aman-Tobacco-Jute	45	33	-	32	20	-	20	11	8
	T. aman-potato-Maize	54	47	20	14	22	8	5	12	-
	T. aman- F- Chilli	11	30	31	5	9	10	4	6	6
	T. aman-potato-Maize-Mung	-	-	46	-		31	-	-	15
Medium High Land	T. aman--Maize	22	20	-	15	6	-			
	T. aman-Tobacco-Jute	18	22	15	-	17	-			
	T. aman--Boro	32	30	26	22	14	14			
	T. aman-Maize+Mung	-	-	31	-	-	22			
Medium Low Land	T. aman-Fallow-Boro	15	15	15						
	Area of total Crop	197	197	197	88	88	88	29	29	29

Plan 1 indicates existing farm plan, Plan 2 indicates by reorganization of existing plan using LP model, Plan 3 indicates by reorganization of existing and improved technologies/patterns using LP model, Transplant aman rice= T. aman

***On farm demonstration result of year round vegetable production model*:** The government to Bangladesh has placed great emphasis on vegetables, especially, homestead vegetables production around the year to meet the nutritional and caloric need of the growing population and for increasing complement opportunities and income of the farmers. Since inception, Bangladesh Agricultural Research Institute (BARI) has been successfully contributing to national agricultural production by evolving technologies that are suitable for the country's climate and appropriate for the farmers' condition. On farm division, BARI

Table 6. Gross output (GO) and gross margin (GM) for average medium, small and marginal farmers under plan1, plan2 and plan3 in Kutamara, Jaldhaka, Nilphamari.

Name of Crops	Types of Farms								
	Medium			Small			Marginal		
	Plan1	Plan2	Plan3	Plan1	Plan2	Plan3	Plan1	Plan2	Plan3
Gross output (taka)	158505	169968	186192	69303	83973	86817	27885	32549	35307
		7.23%	17.47%		21.17%	25.27%		16.73%	26.62%
Gross margin	74839	65693	94839	21798	24862	27837	8873	10134	11442
		14.50%	26.72%		14.06%	27.70%		14.21%	28.35%
Labour (No)	452	480	521	208	237	244	87	105	110
		6.19%	15.27%		13.94%	17.31%		20.69%	26.44

Table 7. Planting and harvesting time of the cropping pattern developed by OFRD, Rangpur.

Cropping Pattern	**Planting Time**	**Harvesting time**
T. aman (Binadhan7) – Potato +Maize + Mungbean		
T. aman(Bina dhan 7)	2nd week of July	2nd week of October
Potato	3rd week of October	Last week of december
Maize	Last week of November	3rd week of April
Mungbean	Last week of March	In the month of May
T. aman(Bina dhan 7) –Maize – Mungbean		
T. aman(Bina dhan7)	2nd week of July	2nd week of October
Maize	last week of October	Last week of March
Mungbean	First week of March	In the month of May

Transplant aman rice= T. aman

Table 8. Per hectare cost and return of Transplant aman rice – Potato -Maize + Mungbean cropping pattern at Jaldhaka, Nilphamari.

Items	T. aman	Potato	Maize	Mungbean	Total
Production Cost					
Variable Cost	30395	77622	41540	19952	169509
Fixed Cost	8000	12000	10000	-	30000
Total Cost	38395	89622	51540	19952	199509
Return					
Yield	3250	23119	7586	540	-
By Product Yield	3450	-	7000	-	-
Gross Return	53925	184952	105618	27000	371495
Net Return	15530	101622	52411	7048	176611
Benefit Cost Ratio (BCR)	1.40	2.06	2.05	1.35	1.86

Transplant aman rice= T. aman

Table 9. Per hectare cost and return of T.Aman -Maize -Mungbean cropping pattern at Jaldhaka, Nilphamari.

Items	Jaldhaka, Nilphamari			
	T.Aman	Maize	Mungbean	Total
Production Cost				
Variable Cost	30395	51530	20194	102119
Fixed Cost	12000	15000	3000	30000
Total Cost	42395	66530	23194	132119
Return				
Yield	3230	8507	612	-
By Product Yield	3450	7000	-	-
Gross Return	53515	117591	30600	201706
Net Return	11120	51061	7406	69587
BCR	1.26	1.76	1.32	1.53

Transplant aman rice= T. aman

Table 10. Gross output (GO), gross margin (GM) and labour for average medium, small and marginal farmers under plan1 and plan3 in Jaldhaka, Nilphamari

Name of Crops	Types of Farms					
	Medium		Small		Marginal	
	Plan1	Plan3	Plan1	Plan3	Plan1	Plan3
Gross output (taka)	158505	197363	69303	92026	27885	42725
		24.51%		32.78%		53.22%
Gross margin	74839	101558	21798	31762	8873	12815
		35.70%		45.71%		44.42%
Labour (No)	452	507	208	261	87	123
		12.34%		25.77%		42%

developed location wise year round vegetable production model for supplying vegetables, fuel, timber and employing family members. Moreover, year round vegetable production model increases vegetable consumption and increases nutrition of farm family. Especially, marginal and small farmers can easily meet up nutrition by in taking vegetables from their homestead production. This demonstration was conducted Katali, Jaldhaka subdistrict, Nilphamari with 6 dispersed replications to expand year round vegetable production.

***Vegetable production through homestead vegetables production model*:** Farmers produced vegetables from each and every possible production units efficiently for own consumption and surplus to sell for more cash income. In 2010, an average farm of Jaldhaka, Nilphamari produced 80 kg vegetables around the year whereas after demonstration the year round vegetable production model an average farm produced 458 kg vegetables which was 476 percent higher compared to the year 2010 (Table 11). It is noted that most of the farmers to produce vegetables by following the production units of the model but sometimes they dropped.

Other studies (Ferdous and Islam, 2008; Kabir et al., 2017a; Ferdous et al., 2016) have also reported that homestead gardens and diversified farming systems are most profitable for marginal and small farmers in Bangladesh.

Table11. Homestead vegetables production (Kg) before and after demonstration of year round vegetable production model (Rangpur Model).

Production unit/Resource	Jaldhaka, Nilphamari		
	Production (Kg) in 2010	Production (Kg) in 2011	% increase
Open place	21	141	557
House roof	13	44	233
Trellis	28	104	276
Partially Shady area		7	100
Marshy land	5	30	495
Fences		8	100
Backyard	12	124	915
Total	80	458	476

Conclusion

The solution of the linear programming model produces optimum plans by reorganization of existing resources for Marginal, small and medium farms at Nilphamry district. Optimum plans differ in the three categories of farms due to resource and constraints. Gross output, gross margin and thereby efficiency have increased in these plans. Cultivated land has been shifted from existing cropping patterns to suitable cropping patterns by the solution of the model based on gross margin and resource constraints. On farm demonstration of optimum plan showed that T. aman Binadhan 7)–Potato+Maize+Mungbean**,** T. aman (BINA 7)–Maize–Mung bean, and year round homestead vegetable production model were more efficient cropping pattern/technology compared to existing cropping patterns.

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References

Ahmed NU, Ferdous Z, Mahmud NU, Hossain A, Zaman MAU (2017b). Effect of split application of nitrogen fertilizer on the yield and quality of potato (*Solanum tuberosum*). *Int. J. Nat. Soc. Sci.* 4(2): 60–66.

Ahmed NU, Mahmud NU, Zaman MA, Ferdous Z, Halder SC (2017a). Effect of Different Salinity Level on Tomato (*Lycopersiconesculentum*) Production under Climate Change Condition in Bangladesh.*Annu. Res. Rev. Biol.* 13(3): 1–9.DOI :10.9734/ARRB/2017/33613

AlamMM, Karim MR, Ladha JK (2013). Integrating best management practices for rice with farmers' crop management techniques: A potential option for minimizing rice yield gap.*Field Crops Res.* 144: 62–68.

Alam MS, Elias SM, Murshed SMM (1997). Medium Farm planning under Risk: An Application of Parametric Linear Programming. *Bangladesh J. Agric.Econ*. 20: 29–55.

Ali J(2015). Adoption of Diversification for Risk Management in Vegetable Cultivation.*Int. J. Veg. Sci.* 21(1): 9–20

Anowar M, Ferdous Z, Islam M (2012). Determination of nutrient management for potato-mungbean-T.aman based cropping pattern. Bangladesh *J. Prog. Sci. Tech*. 10:173–176

Anowar M, Parveen A, Ferdous Z, Kafi AH, Kabir ME (2015). Baseline survey for farmer livelihood improvement at farming system research and development, Lahirirhat, Rangpur.*Int. J. Bus. Manag. Soc. Res.* 2:92–104.

Anwar M, Ferdous Z, Sarker MA, Hasan AK, Akhter MB, Zaman MAU, Haque Z,Ullah H (2017). Employment Generation, Increasing Productivity and Improving Food Security through Farming Systems Technologies in the Monga Regions of Bangladesh.*Annu. Res. Rev. Biol.*16(6):1–15DOI: 10.9734/ARRB/2017/35645

Bangladesh Bureau of Statistics (BBS), Statistical Year Book of Bangladesh (2011). Bangladesh Bureau of Statistics (BBS), Statistics Division, Ministry of Planning, Bangladesh Secretariat. The Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

Datta A, Shrestha S, Ferdous Z, Win CC (2015). Strategies for Enhancing Phosphorus Efficiency in Crop Production Systems. In: A Rakshit, HB Singh, A Sen (Eds.), Nutrient Use Efficiency: from Basics to Advances. pp. 59–71. *Springer*, ISBN 978-81-322-2169-2

Datta A, Ullah H, Ferdous Z (2017). Water Management in Rice. In: BS Chauhan, K Jabran, G Mahajan (Eds.), Rice Production Worldwide. pp. 255–277. *Springer,http://link.springer.com/chapter/10.1007/978-3-319-47516-5_11*

FAO (2014). Save and Grow: A Policymaker's Guide to the Sustainable Intensification of Smallholder Crop Production. United Nations Food and Agriculture Organization, Rome, pp. 102.

Ferdous MZ, Anwar MM, Haque Z, Mahamud NU, Hossain MM (2014). Comparative performance of two magnesium sources on yield and yield attributes of potato. *Bangladesh J. Environ. Sci*. 27: 98–10.

Ferdous Z, Anwar M, Rahman MA, Yasmine F, Nain J (2011). Fertilizer management for maize-mungbean-T.aman based cropping pattern. *J. Agrofor. Environ.* 5:129–132

Ferdous Z, Anwar M, Uddin N, Ullah H, Hossain A (2017c). Yield performance of okra (*Abelmoschusesculentus*) through integrated nutrient management. *Int. J. Biosci.*10 (1): 294–301. http://dx.doi.org/10.12692/ijb/10.1.294-301

Ferdous Z, Datta A, Anal AK, Anwar M, Khan MR (2016). Development of home garden model for year round production and consumption for improving resource-poor household food security in Bangladesh.*NJAS – Wagen. J. Life Sci*. 2016. 78: 103–110. http://doi.org/10.1016/j.njas.2016.05.006

Ferdous Z, Datta A, Anwar M (2017a). Effects of plastic mulch and indigenous microorganism on yield and yield attributes of cauliflower and tomato in inland and coastal regions of Bangladesh. *J. Crop Improv*.31: 261–279 doi:10.1080/15427528.2017.1293578.

Ferdous Z, Hossain A, Mahmud NU, Ali R, Ahmed NU (2017b). Effect of poultry manure and lime in combination with chemical fertilizer on groundnut production in char areas under tista mender flood plain agro ecological zone in Bangladesh.*Int. J. Sustain. Crop Prod.* 12(1):10–14

Ferdous Z, Islam MR (2008). Homestead winter vegetables production and utilization system in changini village of Comilla district. *Bangladesh J. Agriculturist*. 1:183–185.

Fischer RA, Byerlee D, Edmeades GO (2009). Can technology deliver on the yield challenge to 2050? In: Expert Meeting on How to Feed the World in 2050. FAO, Rome, 24–26 June.

Godfray J, Beddington J, Crute I, Haddad L, Lawrence D, Muir J, Pretty J, Robinson S, Thomas S, Toulmin C (2010). Food security: the challenge of feeding 9 billion people. *Science*. 327, 812–818.

Kabir M J, Alauddin M, Crimp S (2017a). Farm-level adaptation to climate change in Western Bangladesh: An analysis of adaptation dynamics, profitability and risks.*Land Use Policy*. 64:212–224.

Kabir M J, Cramb R, Gaydon DS, Roth CH (2017b). Bio-economic evaluation of cropping systems for saline coastal Bangladesh: II. Economic viability in historical and future environments.*Agric. Syst.* 155:103–115.

Khatun MUS, M Z Ferdous, Islam MK, Anowa rMM (2014). Performance of some high yielding garlic varieties at two locations of Bangladesh. *J. Bangladesh Agril. Univ*. 12(2): 235–239.

Mahamood NU, Ferdous Z, Anwar M, Ali R, Sultana M (2016). Yield maximization of maize through nutrient management.*Progressive Agriculture* 27 (4): 428–434.

Rahman MM, Goswami BK, Karim MM, Ikbal M, Ferdous MZ (2008). Effect of fungicide, date of sowing and varietal reaction on white rust(Albugo sp. of red Amaranth (*Amaranthus*sp.) seed crop. *B. J. Agriculturist.* 1 (1): 159–161.

Rahman MM, Yasmine F, Rahman MA, Ferdous Z,Kar PS (2011). Performance of poultry bio-slurry as a source of organic manure on potato production. *J. Agrofor. Environ*. 5:81–84

Rasul G, Thapa GB (2004). Sustainability of ecological and conventional agricultural systems in Bangladesh: an assessment based on environmental, economic and social perspectives. *Agric. Syst*. 79 (3):327–351

Sarker MAI, Ferdous Z, Anwar M, Mahamud NU, Ali M (2010). Performance of poultry bio-slurry as a source of organic manure on wheat production. *Bangladesh J. Environ. Sci.* 19:36–38.