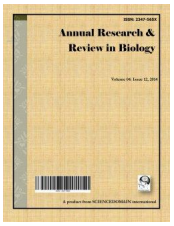

Annual Research & Review in Biology

16(6): 1-15, 2017; Article no.ARRB.35645
ISSN: 2347-565X, NLM ID: 101632869

Employment Generation, Increasing Productivity and Improving Food Security through Farming Systems Technologies in the *Monga* Regions of Bangladesh

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MA and ZF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MAS, AKH, MBA and MAUZ managed the analyses of the study. Authors ZH and HU managed the literature searches, improved the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/35645
Editor(s):
(1) Gabriela Civeira, Faculty of Agriculture and Agrifood Sciences, University of Morón, Argentina.
(2) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Suleiman G. Purokayo, Modibbo Adama University of Technology (MAUTECH), Nigeria.
(2) Supaporn Poungchompu, Khon Kaen University, Thailand.
Complete Peer review History: http://www.sciencedomain.org/review-history/20918

Original Research Article

Received 23rd July 2017
Accepted 1st September 2017
Published 11th September 2017

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ABSTRACT

Monga is seasonal food insecurity in ecologically vulnerable and economically weak parts of north-western Bangladesh, primarily caused by an employment and income deficit before Transplanted *aman* paddy (summer rice) harvest. It mainly affects those rural poor, who have an undiversified income that is directly or indirectly based on agriculture. Rangpur and Lalmonirhat districts under greater Rangpur region are severely affected by *Monga*. For increasing employment and food accessibility in these regions this study was undertaken. The farm accounting data for this empirical application have been collected from two districts (Rangpur and Lalmonirhat) of greater Rangpur through a farm management survey. A sample of 90 farms from each district has been surveyed taking 30 from marginal, 30 from small and 30 from medium farm groups using random sampling technique method. Farmers get lower return due to lack of crop diversification. Linear programming model used to produce optimum farm plans for marginal, small and medium farms (i) by reorganization of existing resources (ii) by combination of improved technologies with existing technologies. For increasing food accessibility and employment, optimum farm plans by reorganization of improved technology have been conducted among six farmers in the study villages at 2010-2011. By reorganization of existing cropping patterns (using Linear Programing 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 plan 2 (by reorganization of existing lands). The cause of increase gross output, gross margin and labour 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.

Keywords: Employment creation; sustainable food security; farming systems; Monga.

1.INTRODUCTION

Bangladesh has made impressive achievements in ensuring food availability during the last three decades, yet over 60 million people are claimed to be vulnerable (in terms of food insecurity) to hunger every day. *Monga*, an outcome of fluctuations in income and employment, originated from some socioeconomic shocks as well as climate factors, is a seasonal scarcity of employment, and hence income during the lean period from mid-September through mid-November in Bangladesh [1]. During the lean period, households' per capita income falls, and limited access to food diffuses over the rural poor (e.g., landless, marginal land holders, etc.), concentrated in most of the greater Rangpur area (i.e. Kurigram, Gaibandha, Lalmonirhat, Nilphamari), and the vicinity [2].

More than 50% farmers of this region live in below the poverty line. Nilphamari, Rangpur and Lalmonirhat districts under greater Rangpur region are severely affected by *Monga*. Extreme shrinkage in job opportunities for the marginal agricultural laborers is the root because with case of this situation [3]. The small, marginal and land less farmer suffers shortage of food in the Month of April, September to November in these region. Again, in this period agriculture employment opportunities are few [3]. Per capita Gross domestic product (GDP) of the farmers is far below the national average [4]. More than 50% farmers of this region live in under poverty line. This situation mainly arise lack of wage employment, lack of use of improved technologies, lack of crop diversification and lack of non-farm activities.

However, the viability and sustainability of agriculture in Bangladesh depends not only on biophysical responses but also on the economic returns to alternative cropping options. Moreover, sustainability is a forward-looking concept, requiring optimum uses of resources for future trends in key indicators. The integration of expert opinion (of both farmers and scientists) and the careful use for farmers resources for economic

outcomes can help to quantify the profitability, risk, and long-term persistence of agricultural systems. Previous economic studies of cropping systems in Bangladesh [5-9] have focused on the impacts of farming on profitability, food security, and climatic condition [10]. Some have assessed the profitability of farming system for food security in northern region of Bangladesh [11]. Many studies [12-15] have reported that lack of resources optimization is one of the major causes for increasing income and employment of the farmers.

Most of the farmers are illiterate and less educated about improved technology. Maximum farmers of the regions do not know how much inputs are required for produce optimum level of output. Employment and income of the farmers in the *Monga* regions will be increased by increasing efficiency of the farmers, and efficiency will be increased by reorganization of existing resources and by using improved technologies that are available in the regions. The main objective were to assess existing technology of the farmers of *Monga* regions, to produce optimum farm plans for marginal, small and medium farmers, reorganization of existing resources through combination of improved technologies with existing technologies in the farmers field of *Monga* regions.

2. MATERIALS AND METHODS

A multistage stratified random sampling was employed to obtain representative sample. At later stage, out of several sub districts, one sub district (Upazila) was selected purposely from each district. The farm accounting data for this empirical application have been collected from two districts (Rangpur and Lalmonirhat) of greater Rangpur through a farm management survey. A sample of 90 farms from two villages (technologically poor villages) of one sub-district for each district 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 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.

2.1 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 two study areas. 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 fromj^{th} 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 theirj^{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.

Data of the on farm demonstration of optimum farm plans were collected timely. A statistical method SPSS (Statistical Package for Social Science) was used to analyze the data in order to produce descriptive statistics.

3. RESULTS AND DISCUSSION

3.1 Socio–economic Factors

Socio economic conditions are economic and sociological combined total measure of a farm household based on income, education, occupation and constraints to increase income or production. Socio-Economics Conditions/factors of the farmers in the study areas have been shown in the Table 2. Level of education is higher in lalmonirhat compared to Rangpur. At Gangachara, Rangpur, average farm size for medium, small and marginal farms were 0.77 ha, 0.49 ha, and 0.11 ha, respectively. At Hatibandha, Lalmonirhat, average farm size for medium, small and marginal farms were 0.75 ha, 0.38 ha, and 0.09 ha, respectively. Size of the farm are about to similar in both study areas. The main occupation was agriculture which was more than 80 percent of the two study areas. About 24 to 35 percent farmers reported that they have lack of irrigation facility in the two study areas. Lack of high yielding variety (HYV) seed is a major constraint for higher production in the study areas [16]. Above 80 percent farmers of the areas also reported, incase of price and availability, inorganic fertilizer is not a problem. On the other hand, the farmers reported that lack of labour, wage of labour, lack of improved technology and cash money for buying inputs are major problems in the study areas.

3.2 Land Tenure Status

Land tenure system found in the two study areas are same and it was complex and mainly of three types, namely: owners, lease and share cropping. Share cropping system contract is usually executed 50% of their crop yield share with land owner but in cause of input cost for intensive crop (Boro rice/winter rice/irrigated rice, potato etc.) land owner provide 50% of the fertilizer cost. In annual cash rent system right of cultivation was restored to the tenant farmer to a period of one year against a payment of cash (BDT. 30000 - 40000/ per hectare) to the owner. Again, in lease system the owner leased out a parcel of land for a period of time usually three years but not less than two years against a receipt of handsome money (BDT. 150000/ per hectare).

3.3 Credit System

Bangladesh Krishi Bank and Sonali Bank are the only government organization that provides loan to different agricultural sector. Some NGOs like BRAC, Grameen Bank they also provides loan to the farmers in a high interest rate. The farmers avail of loans from the relatives, rich man and neighbors. Rate of interest in such case is too high 5 - 10% per month.

3.4 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 Gangachara, Rangpur and Hatibandha, Lalmonirhat has been presented in the Table 3.

3.4.1 Major cropping patterns

Transplanted aman rice-Tobacco-Jute/Boro rice is an major cropping pattern in the two study areas and more than 80% farmers of the regions cultivated tobacco as a cash money. Transplanted aman rice -Fallow- Boro rice is a second important cropping pattern in both of the areas. Above 90 percent farmers use power tiller for cultivating land and Shallow- tube well for irrigation.

The area mostly falls under high and medium high land areas of the Tista Meander Floodplain with an extent of 946,803 ha. The soils of this region are moderately acidic (pH of 4.6–6.5), low in organic matter content on

the higher land (<1%), but moderate in the lower parts (~ 2%). Overall, the fertility level is low to medium, but the status of K and CEC is medium in most of the places.

Gangachara, Rangpur	Hatibandha, Lalmonirhat
In High land	**In High land**
Transplanted aman rice -Tobacco-Jute	Transplanted aman rice -Tobacco-Jute
Transplanted aman rice -potato-Boro rice	Transplanted aman rice -Tobacco-Maize
	Transplanted aman rice -Fallow-Brinjal
In Medium high land	**In Medium high land**
Transplanted aman rice -Tobacco-Boro rice	Transplanted aman rice -Maize
Transplanted aman rice -Tobacco-Jute	Transplanted aman rice -Fallow-Groundnut
	Transplanted aman rice -Tobacco-Jute
In Medium lowland	**In Medium lowland**
Transplanted aman rice -Fallow-Boro rice	Transplanted aman rice -Fallow-Boro rice

Table 1. General structure of developed technological matrix (base matrix) of average medium, small and marginal farms based on survey data

	Cropping patterns					Price Per Kg							Sign of Cons traints
→						R	J	P	T	M	C	H	
Variable Common Resources & Constraints ↓	CP1	CP2	CP3	…….	poultry								
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	

Table 2. Socio-economics conditions/factors of the farmers in the study areas

Socio-economic conditions/factors	Study area	
	Gangachara, Rangpur	Hatibandha, Lalmonirhat,
A. Level of education (%)		
Illiterate	40	35
Under SSC	52	61
Above SSC	8	4
B. House hold Income		
Agriculture	82	80
Agriculture + Service	3	3
Agriculture + Business	2	6
Agriculture + Day labour	3	11
B. Farm Size (ha)		
Medium	0.77	0.75
Small	0.49	0.38
Marginal	0.11	0.09
C. Irrigation (%)		
Lack of irrigation	24	35
High cost of irrigation	35	38
B. Seed (%)		
Price is very high	56	61
Not available in time	31	28
Lack of HYV seed	67	62
C. Fertilizer (%)		
Price is high	10	12
Not available in time	24	25
D. Insecticide (%)		
Disease/pest problem	85	80
Price is high	88	85
Not available in time	29	21
Lack of knowledge	84	83
E. Lack of Labour (%)	82	92
F. Human labour wage is High (%)	95	94
G. Low yield of Crop (%)	55	58
H. High Cost of Production (%)	65	74
I. Lack of Improved technology (%)	87	82
J. Lack of money for buying inputs (%)	65	72

Note: % indicates opinion of the farmers in percentage

3.4.2 Fertilizer application

Most of the farmers use organic fertilizer in crop production at both the 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.

3.5 Optimum Farm Plan

3.5.1 Optimum farm plan by reorganization of existing resources

Many steps may be considered for increasing agricultural production, for example, technology improvement, increased credit supply and improvement of rural infrastructure. The most important step may be the reorganization of farm enterprises for efficient utilization of existing resources (land, labour and capital). A farmer's net income and efficiency cannot be maximized without optimal crop combination, which ensures efficient utilization of available resources [17].

In Kolkondo Union of Gangachara subdistrict, Rangpur, the farm size of medium, small and marginal were 191, 120 and 26 decimal, respectively. The solution of the model produces optimum farm plans for the three types of farms that exist in Rangpur and Lalmonirhat district. The comparison between existing and optimum plans shows the required adjustment to improve efficiency of the farming in the region. In the case

of medium and small farming, 4 cropping patterns are competing for the use of land. By definition, the participation of a cropping pattern in the optimum plan depends on gross margin per unit of most limited resource. However, the existing categories of land (high land, medium high land and medium low land) restrict the competition between the cropping patterns for each category of land. In high land, the cropping pattern Transplanted aman rice (BR 11) – Tobacco (*Nicotiana tabacum*)- Jute and Transplanted aman rice (BR 11) –Potato (*Solanum tuberosum*)- Boro rice were competing for the use of land. The pattern Transplanted aman rice (BR 11) -Potato- Boro rice was more efficient compared to the pattern Transplanted aman rice (BR 11) -Tobacco- Jute considering farm resource and constraints. As a result, some land of Transplanted aman rice (BR 11) – Tobacco – Jute has been shifted to the pattern Transplanted aman rice (BR 11) -Potato- Boro rice using LP model (Table 4). Likewise, in medium high land, some land has been shifted in comparatively more efficient cropping pattern. By reorganization of existing land (using L.P Model) gross output 6 to 26 percent, gross margin 6 to 20 percent and labour employment 9 to 12 percent have been increased from plan1(existing plan) to plan2 (optimum plan by reorganization of existing resource) (Table 6).

In Shindhurna Union of Hatibandha Upozilla, Lalmonirhat, the farm size of medium, small and marginal farm were 185, 93 and 23 decimal, respectively. Similarly, By reorganization of existing land (using L.P Model) gross output (13 – 17 percent), gross margin (12 – 20 percent) and labour employment (12 – 17 percent) have been increased from plan1 to plan2 (Table 7).

Table 3. Existing agricultural technology of Gangachara, Rangpur and Hatibandha, Lalmonirhat

Existing technology	% Use by the farmer	Existing technology	% Use by the farmer
Homestead Vegetable Production		Homestead Vegetable Production	
Roof top	85	Roof top	62
Trellis	63	Trellis	34
Major Cropping Patterns		Major Cropping Patterns	
High land		High land	
T. aman-Tobacco-Jute	91	T. aman-Tobacco-Jute	71
T. aman-Potato-Boro rice	14	T. aman-Tobacco-Maize	70
		T. aman- Fallow- Brinjal	9
Medium high land		Medium high land	
T. aman-Tobacco-Boro rice	65	T. aman-- Maize	15
T amon-Tobacco-Jute	35	T. aman-Fallow-Groundnut	40
		T. aman-Tobacco-Jute	38
Medium lowland		Medium lowland	
T. aman-Fallow-Boro rice	100	T. aman-Fallow-Boro rice	100
Variety		Variety	
T. aman	BR 11	T. aman	BR 11, BR 33
Tobbaco	Local	Tobbaco	Local
Potato	Granula, Cardinal	Jute	Tosha
Jute	Tosha,	Boro rice	BR 28, Hybrid
		Brinjal	Local
Boro rice	BR28, Hybrid	Groundnut	Dhaka1, Local
Farm Machinery		Farm Machinery	
Power tiller	100	Power tiller	90
Shallow- tube well	100	Shallow- tube well	100
Organic Matter	60	Organic Matter	100
Fertilizer	100	Fertilizer	100
Use of Insecticide and fungicide	80	Use of Insecticide and fungicide	90

Transplanted aman rice=T. aman

Table 4. Existing and Optimum plan for land (decimal) utilization under medium, small and marginal farms in Kolkondo Union of Gangachara sub-district, Rangpur

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	38	32	21	20	18	10	11	5	5
	T. aman-potato-Boro rice	18	24	15	13	15	10	15	21	9
	T. aman-Cauliflower/Cabbage - Onion-Jute	-	-	23	-	-	13	-	-	12
Medium High Land	T. aman-Tobacco-Boro rice	86	61	32	54	33	20			
	T. aman-Tobacco-Jute	25	50	27	18	39	24			
	T. aman-Maize+Mung	-	-	52	-	-	28			
Medium Low Land	T. aman-Fallow-Boro rice	24	24	24	15	15	15			
	Average farm size	191	191	191	120	120	120	26	26	26

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, Transplanted aman rice=T. aman

Table 5. Existing and optimum plan for land (decimal) utilization under medium, small and marginal farms in haldibari Union of Hatibandha Upozella, Lalmonirhat

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	41	31	20	22	12	10	18	10	5
	T. aman-Tobacco-Maize	35	30	17	16	10	8	-	-	-
	T. aman-F- Brinjal	20	34	23	12	28	14	5	13	8
	T. aman-Cauliflower/Cabbage - Maize	-	-	36	-	-	18	-	-	10
Medium High Land	T. aman-- Maize	32	21	18	15	9	5			
	T. aman-F- Groundnut	14	15	13	12	18	-			
	T. aman-Tobacco-Jute	17	27	-	-	-	7			
	T. aman-Maize+Mung	-	-	32	-	-	15			
Medium Low Land	T. aman-Fallow-Boro	26	26	26	16	16	16			
	Area of total crop	185	185	185	93	93	93	23	23	23

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, Transplanted aman rice =T. aman

3.5.2 Optimum farm plan by combination of existing and improved cropping patterns

Inefficient use of existing resources and lack of proper extension of modern technologies are mainly the causes of low crop production in the country. On farm research division of BARI has been carrying out their research programs on technologies with sustainable high yields. Already, the division has developed many high yielding varieties (HYV), modern crop production

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

Name of crops	Types of farms								
	Medium			Small			Marginal		
	Plan1	Plan2	Plan3	Plan1	Plan2	Plan3	Plan1	Plan2	Plan3
Gross output (taka)	159921	176728 10.51%	199404 24.69%	102841	113286 10.16%	129871 26.28%	25988	27442 5.59%	31478 21.82%
Gross margin	51591	61702 19.60%	67099 30.06%	33661	40219 19.48%	45099 33.98%	8767	9314 6.25%	11234 28.14%
Labour (Number)	437	484 10.72%	497 13.87%	282	317 12.47%	334 18.64%	70	76 8.77%	80 14.29%

Table 7. Gross output (GO) and gross margin (GM) for average medium, small and marginal farmers under plan1, plan2 and plan3 in Shindhurna, Hatibandha, Lalmonirhat

Name of crops	Types of farms								
	Medium			Small			Marginal		
	Plan1	Plan2	Plan3	Plan1	Plan2	Plan3	Plan1	Plan2	Plan3
Gross output (taka)	135814	154390 13.68%	168133 23.80%	70469	82843 17.56%	92393 31.11	22587	25617 13.41%	29255 29.52%
Gross margin	43705	48989 12.09%	55514 27.02%	24103	28904 19.92%	31986 32.71	7301	8381 14.79%	9691 32.74%
Labour (Number)	384	431 12.24%	445 15.89%	215	251 16.74%	267 24.19	104	116 11.54%	121 16.35%

technologies and has recommended inputs of each individual crop to increase efficiency in the country. On farm research division, Rangpur has been developed many cropping patterns/technologies for mitigation *Monga*. Among them Transplanted aman rice (Bina dhan 7) – Cauliflower - Onion – Jute, Transplanted aman rice (Bina dhan 7) – Potato - Maize – Mung bean, Transplanted aman rice (Bina dhan 7) – Maize – Mungbean based cropping pattern have been combined with existing cropping patterns for producing optimum farm plan (using LP model) in the region. This plan shows the required adjustment to improve efficiency of the farming in the region.

In Kolkondo Union of Gangachara subdistrict, Rangpur, cultivated land of existing patterns have been shifted to the developed cropping patterns (Transplanted aman rice (Bina dhan 7) -cauliflower/Cabbage - Onion-Jute and Transplanted aman rice (BR 49) -Maize+Mung). As a result, gross output 22 to 26 percent, gross margin 28 to 33 percent and labour employment 14 to 18 percent have been increased in plan3 (reorganization existing and improved cropping pattern) (Table 6). In Shindhurna Union of Hatibandha subdistrict, Lalmonirhat, land of existing patterns have been shifted to the improved cropping patterns (Transplanted aman rice (Bina dhan 7) -cauliflower/Cabbage - Onion-Jute and Transplanted aman rice (BR 49) -Maize+Mung). As a result, gross output 24 to 31 percent, gross margin 27 to 33 percent and labour employment 16 to 24 percent have been increased in plan 3 (Table 7). Other studies [7,8,11] have also reported that homestead gardens and diversified farming systems are most profitable for marginal and small farmers in Bangladesh.

3.6 Results of on Farm Demonstration

To address the *Monga* problem through extension of improved cropping pattern may help creation of job opportunity to some extent. Side by side total production and income of the farmer will be increased. Under such situation, three developed cropping pattern by OFRD, BARI, Rangpur (Transplanted aman rice (Bina dhan 7) – Potato+Maize**+**Mungbean**,** Transplanted aman rice (Bina dhan 7) –Maize – Mungbean, and Transplanted aman rice (Bina dhan 7) – Cauliflower- Onion-Jute) cropping pattern combined with existing cropping patterns (plan 3) for employment generation and food accessibility in the regions.

3.6.1 On farm demonstration result of the cropping pattern transplanted aman rice–maize – mungbean

This cropping pattern was demonstrated at the farmers' field condition in Gangachara, Rangpur and Hatibandha, Lalmonirhat during 2010-2011 with 6 dispersed replications [18] in each location. The categories of the farmer were medium and small. Demonstration areas of the pattern Gangachara Rangpur were 52 decimal for medium farm and 28 decimal for small farm. Demonstration areas were for medium and small farm were 32 decimal and 15 decimal, respectively in Hatibandha, lalmonirhat. Planting and harvesting time were according to Table 10. Transplanted aman rice was transplanted in the month of July and was harvested in the month of October. After harvesting Transplanted amanrice immediately planted maize. Before 20 days of maize harvest, Mungbean was planted. Per hectare cost and return of the cropping pattern was according to Table 9. Per hectare net return of the cropping patterns BDT. 61071 for Gangachara, Rangpur and BDT. 67097 for hatibandha, Lalmonirhat (80BDT.=1 $US). The highest net return was gained by maize and followed by Transplanted aman rice and mungbean (Table 9). Other studies [8,19,20,21] have also reported that rice based farming systems are most profitable for marginal and small farmers in Bangladesh.

Table 8. 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
T. aman (Bina dhan 7) – Cauliflower- Onion-Jute		
T. aman (Bina dhan7)	2nd week of July	2nd week of October
Cauliflower	3rd week of October	Last week of December
Onion	Last week of December	Last week of March
Jute	First week of March	2nd week of July

Transplanted aman rice=T. aman

Table 9. Per hectare cost and return of Transplanted aman rice -Maize - Mungbean cropping pattern at Gangachara, Rangpur and Hatibandha, Lalmonirhat

Items	Gangachara, Rangpur				Hatibandha, Lalmonirhat			
	T. Aman	Maize	Mungbean	Total	T. Aman	Maize	Mungbean	Total
Production Cost (BDT)								
Variable Cost	31395	58280	23608	113483	30845	58930	19810	109585
Fixed Cost	10000	10000	4000	24000	10000	10000	4000	24000
Total Cost	41595	68280	27608	137483	40845	68930	23810	133585
Return								
Yield (kg ha^{-1})	3357	7056	717		3445	7524	745	
By Product Yield(kg ha^{-1})	3550	7000	--		3500	7000	--	
Gross Return (BDT)	63976	98728	35850	198554	58620	104812	37250	200682
Net Return (BDT)	22381	30448	8242	61071	17775	35882	13440	67097
BCR	1.54	1.45	1.30	1.44	1.44	1.52	1.56	1.50

Transplanted aman rice=T. aman, 80 (BDT.)= 1 $USD

Table 10. Per hectare cost and return of T. Aman – Cauliflower- Onion-Jute cropping pattern at Gangachara, Rangpur and Hatibandha, Lalmonirhat

Items	Gangachara, Rangpur					Hatibandha, Lalmonirhat				Total
	T. aman	Cauliflower	Onion	Jute	Total	T. aman	Cauliflower	Onion	Jute	
Production Cost (BDT)										
Variable Cost	31595	70820	57265	38250	197930	30845	86890	59894	30518	208147
Fixed Cost	10000	10000	5000	5000	30000	10000	10000	5000	5000	30000
Total Cost	41595	80820	62265	43250	227930	40845	96890	64894	35518	238147
Return										
Yield (kg ha^{-1})	3055	25522	8348	2318		3588	28816	7650	2311	
By Product Yield (kg ha^{-1})	3342			7000		3540	--	--	8000	
Gross Return (BDT)	52222	204176	150264	53360	460022	60948	230528	130050	49598	471124
Net Return (BDT)	10627	123356	87999	10110	232092	20103	133638	65156	14080	232977
BCR	1.26	2.53	2.41	1.23	2.02	1.49	2.38	2.01	1.40	1.98

Transplanted aman rice=T. aman, 80 (BDT.)= 1 $USD

3.6.2 On farm demonstration result of the cropping pattern transplanted aman rice – cauliflower- onion-jute

This cropping pattern was demonstrated at the farmers' field condition in Gangachara, Rangpur and Hatibandha, Lalmonirhat during 2010-2011 with 6 dispersed replications [11]. The categories of the farmer were medium, small and marginal. Demonstration areas were for medium farm 23 decimal, small farms 13 decimal and marginal farm 12 decimal in Gangachara, Rangpur. Again, demonstration areas were for medium farm 36 decimal, small farm 18 decimal and marginal farm 10 decimal in hatibandha, Lalmonirhat. Planting and harvesting time were according to Table 4. Transplanted aman rice was transplanted in the month July and was harvested in the month October. After harvesting Transplanted aman rice immediately planted cauliflower. Cauliflower was harvested in the month of December, and then planted onion. Before 20 days of onion harvest, Jute was sown. Per hectare cost and return of the cropping pattern were according to Table 10. Per hectare net return of the cropping patterns BDT. 232092 for Gangachara, Rangpur and BDT.232977 for hatibandha, lalmonirhat. The highest net return was gained by cauliflower and followed by onion, Transplanted aman rice and mungbean (Table 10).

3.7 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 Gangachara, Rangpur and Hatibandha, Lalmonirhat. 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.

In Gangachara, Rangpur six cropping patterns such as Transplanted aman rice (BR 11) - Tobacco- Jute, Transplanted aman rice (BR 11) - Potato-Boro, Transplanted aman rice (Bina dhan 7) -cauliflower/Cabbage - Onion-Jute, Transplanted aman rice (BR 11) -Tobacco-Boro, Transplanted aman rice (Bina dhan 7) - Maize+Mung and Transplanted aman rice - Fallow-Boro participate in optimum farm plan. In high land, among three cropping patterns, the Transplanted aman rice (Bina dhan 7) - cauliflower/Cabbage - Onion-Jute is comparatively more efficient compared to existing pattern. Similarly, in medium high land, among the three cropping pattern the pattern Transplanted aman rice (Bina dhan 7) - Maize+Mung is comparatively more efficient (Table 8). In the three categories of farm gross output have been increased 32 to 35 percent, gross margin have been increased 32 to 47 percent and labour employment have been increased 17 to 35 percent (Table 11).

In hatibandha, Lalmonirhat eight cropping patterns such as Transplanted aman rice n (BR 11) -Tobacco- Jute, Transplanted aman rice (BR 11)-Tobacco-Maize, Transplanted aman rice - Fallow- Brinjal, Transplanted aman rice (Binadhan 7) -cauliflower/Cabbage - Onion-Jute, Transplanted aman rice (BR 11) -Maize, Transplanted aman rice (Bina dhan 7) - Maize+Mung and Transplanted aman rice - Fallow-Boro participate in optimum farm plan. In high land, among four cropping patterns, the Transplanted aman rice (Bina dhan 7) - cauliflower/Cabbage - Onion-Jute is comparatively more efficient compared to existing pattern. Similarly, in medium high land, among the four cropping patterns the pattern

Table 11. Gross output (GO), gross margin (GM) and labour for average medium, small and marginal farmers under plan1 and plan3 in Gangachara, Rangpur

Name of crops	Types of farms					
	Medium		Small		Marginal	
	Plan1	Plan3	Plan1	Plan3	Plan1	Plan3
Gross output (BDT)	159921	211368 32.17%	102841	137663 33.86%	25988	35152 35.26%
Gross margin (BDT)	51591	69111 33.96%	33661	44391 31.87%	8767	12845 46.52%
Labour (Number)	437	511 17.17%	282	344 21.99%	70	94 35%

80 (BDT.) = 1 $USD

Table 12. Gross output (GO), gross margin (GM) and labour for average medium, small and marginal farmers under plan1 and plan3 in Hatibandha, Lalmonirhat

Name of crops	Types of farms					
	Medium		Small		Marginal	
	Plan1	Plan3	Plan1	Plan3	Plan1	Plan3
Gross output (BDT)	135814	178221 31.22%	70469	97936 38.97%	22587	32070 41.98%
Gross margin (BDT)	43705	63359 44.97%	24103	36035 49.50%	7301	11011 50.82%
Labour (Number)	384	439 15%	215	275 27.91%	104	153 47.56%

80 (BDT.) = 1 $USD

Transplanted aman rice (Bina dhan 7) - Maize+Mung is comparatively more efficient (Table 10). In the three categories of farm gross output, Gross margin and labour employment have been increased 31 to 42 percent, 45 to 51 percent and 15 to 48 percent, respectively (Table 12 above). Diversification of agriculture is necessary to minimize risk. Diverse cropping pattern is an effective strategy to achieve income growth, food and nutritional security, poverty alleviation, employment generation, promotion of exports, substitute import, judicious use of land, nutrient management and water resources [22-24], sustainable agricultural development, and environmental improvement [15,25].

4. CONCLUSIONS

The solution of the linear programming model produces optimum plans by reorganization of existing resources for marginal, small and medium farms in the two study areas. Optimum plans differ in the three categories of farms due to resource and constraints. Gross output, gross margin and efficiency measures have shown an 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 improved cropping pattern Transplanted aman rice (BINA 7) –Maize – Mungbean, and Transplanted aman rice (Bina dhan 7) – Cauliflower- Onion-Jute were more efficient cropping pattern/technology compared to existing cropping patterns. These results can be used by policymakers, agribusiness companies, and researchers. Policymakers and agricultural planners may better focus on agricultural diversified cropping systems to promote agricultural development because it offers opportunities to reduce production and price risks, increase flexibility, increase agricultural income, and sustain productivity and growth.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20918