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 plan 1 (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 plan 1 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 plan 1 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 improve technologies

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

| Variable          | Cropping Patterns | Price Per Kg | Sign of Constraints |
|-------------------|-------------------|--------------|---------------------|
| Common Resources & 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. Capital        |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| Mechanical power  |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| Manure            |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| Seed              |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| Fertilizer        |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| Irrigation        |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| Insecticide       |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| Yield, R<=0       |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| J<=0              |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| V<=0              |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| W<=0              |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| M<=0              |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |
| P_L<=0            |                  |              |                |         | <= + | <= + | <= + | <= + | <= + | <= + | <= + |

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

\[
Z = \sum (C_{ij} + L_{ijn}) = \{S_{ij}X_{ij} - V_{ij}\} + \{L_{ij}X_{ij} - V_{ij}\} + \{C_{mij}X_{ij} - V_{ij}\} + \{L_{mij}X_{mij} - V_{mij}\} + \{C_{ij}X_{ij} - V_{ij}\} + \{L_{ij}X_{ij} - V_{ij}\}
\]

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

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

\(L_{ijn}\) = Number of livestock from \(j^{th}\) activity.

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

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

\(V_{sij}\) = Variable cost (Tk) of medium farmers from their \(j^{th}\) crop activity in the \(i^{th}\) land.
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 |
|-----------------|----------------------------------------|
|                 | Rabo (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 | 75 |
| Roof top | 75 |
| Trellis | 51 |
| Major Cropping Patterns | |
| Transplantaman rice -Tobacco-Jute | 43 |
| Transplantaman rice -potato-Maize | 46 |
| Transplantaman rice - Fallow- Chilli | 8 |
| High land | |
| Transplantaman rice --Maize | 10 |
| Transplantaman rice -Tobacco-Jute | 55 |
| Transplantaman rice –Boro rice | 30 |
| Medium high land | 100 |
| Transplant Aman rice -Fallow-Boro rice | |
| Variety | BR 11, BR 33 |
| Homestead Vegetable Production | |
| Transplantaman rice | Local |
| Tobbaco | Granula, Cardinal |
| Potato | Tosh, |
| 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 ²) | 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 Jhalda, 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 July and was harvested in the month October. After harvesting T. aman immediately planted potato. 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 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; 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
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     | 14     | 22       | 8      | 5      | 12  |
|                    | T. aman- F-Chilli       | 11             | 30     | 31     | 5        | 9      | 10     | 4   |
|                    | 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  |

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 plan 1, plan 2 and plan 3 in Kutamara, Jaldhaka, Nilphamari.

| Name of Crops | Gross output (taka) Plan1 | Gross output (taka) Plan2 | Gross output (taka) Plan3 | Gross margin Plan1 | Gross margin Plan2 | Gross margin Plan3 |
|---------------|---------------------------|---------------------------|---------------------------|-------------------|-------------------|-------------------|
| T. aman (Bina dhan7) – Potato + Maize + Mungbean | 15850 | 169968 | 186192 | 7.23% | 17.47% | 21.17% |
| T. aman (Bina dhan7) – Potato Maize Mungbean | 69303 | 83973 | 86817 | 21.17% | 25.27% | 16.73% |
| T. aman (Bina dhan7) – Maize – Mungbean T. aman (Bina dhan7) Maize Mungbean | 74839 | 65693 | 94839 | 14.50% | 26.72% | 14.06% |

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

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

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 | 199509 |
| 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                             | 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% | 44.78% | 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%   |       |       |       |

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 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.
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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