Transforming Triple Cropping System to Four Crops Pattern: An Approach of Enhancing System Productivity through Intensifying Land Use System in Bangladesh


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1. Introduction

Trend of available agricultural land over the time is decreasing with an amount to 1.33 lac ha in 1976 (91.83% of total land area) that is decreased to 1.27 ha in 2000 with yearly loss of 23,391 ha. The area is further dropped to 1.21 lac ha in 2010 with yearly loss of 56,537 ha. A sum of 1.13 lac ha land has been lost during the past 34 years from 1976 to 2010. Rate of cropland shifting to nonagricultural land (housing, industry, etc.) is alarming as it is associated with the food security of the country. Total cropland was estimated to be 9,761,450 ha, 9,439,541 ha, and 8,751,937 ha in 1976, 2000, and 2010 with an average decrease of 0.14% during 1976 to 2000 and 0.73% during 2000–2010, respectively. Hasan et al. reported the rate of change over the 34 years is 0.30% which is still declining [1].
As per Bangladesh Bureau of Statistics (BBS) [2], around 3795 and 1688 thousand ha of land remain under double and triple cropped area, respectively, which means that 48.41% and 21.53% of the country’s net cropped area has avenues partly or a major portion to be brought under quadruple cropping system. The area of cropland is decreasing, that is why there is no option of horizontal expansion but intensifying land use system through multiple cropping or by growing more and more crops on the same piece of land in a calendar year. However, the agriculture is heading towards a new paradigm to address the country’s food security a concerned issue of Bangladesh. Alauddin and Tisdell [3] investigated that food production has been increased to 3.67 folds over the period of time, from an estimated amount of 1.01 m ton in 1971 during the independence of Bangladesh to 3.71 m ton in 2016 as recorded in BBS [2]. Cultivation of modern crop varieties, improvising cultural operations, and crop protection measures as well as increasing crop intensity (Figure 1) collectively contributed to such achievement.

Mustard-onion-T. Aman rice is a popular cropping pattern in Durgapur Upazilla of Rajshahi district under High Ganges River Floodplain. Upazila agricultural office of DAE claims that there are 2000 hectare of land in the upazila in which the pattern mustard-onion-T. Aman rice is being practiced during 2012 cropping year. Mustard is usually grown in Rabi season. Sowing is started in the last week of October to 1st or 2nd week of November, and the crop is harvested in the end of January to mid-February followed by cultivation of onion planted at 2nd week to end of February. After harvest of onion in April, farmers go for T. Aman rice cultivation in the end of July to 2nd or 3rd week of August. Thus, after harvest of onion, the land remains fallow from last week of April to July until T. Aman rice being transplanted. Some commercial maize hybrids grown in Kharif season mature in 95 to 105 days. Therefore, there is a chance of developing four crops pattern as maize can easily be grown as relay crop with onion in between the fallow period as shown in Figure 2. Tanveer et al. [4] reviewed the benefits of relay cropping that enhanced sustainable system productivity through efficient use of available resources like microclimate, nutrients dynamics [5–8]. Inclusion of fourth crop in the sequence will increases system productivity as well as improve farmer’s economic condition. Keeping that in the point of view, the study was undertaken to increase diversification and intensification of existing Mustard-onion-T. Aman rice cropping pattern in terms of productivity, production efficiency, land use efficiency, and economic return.

2. Materials and Methods

2.1. Site Selection. The experiment was conducted at the farmers’ field of Pali, Durgapur, under the Multilocation Testing Site (MLT), Shibpur, Puthia, Rajshahi, during 2014-15 to 2015-16 to assess the performance of alternate four crops pattern against existing three crops pattern (mustard-onion-T.
2.4.1. Land Use Efficiency. Land use efficiency (LUE) was estimated by the total duration of crops in the sequence divided by 365 days and expressed in % as outlined by Jamwal [11]:

$$\text{LUE} = \frac{\sum \text{Dc}}{365} \times 100,$$

(2)

where Dc = duration of crops in the sequence.

2.4.2. Production Efficiency. Production efficiency (PE) was calculated by taking total economic yield of the sequence on wheat equivalent basis divided duration of crops using per formula by Jamwal [11]:

$$\text{PE} = \frac{\text{REY}}{\sum \text{Dc}},$$

(3)

where REY = rice equivalent yield in a sequence and Dc = duration of crops in that sequence.

2.4.3. Marginal Benefit Cost Ratio (MBCR). The economic analysis was done following the method suggested by CIMMYT [12]. The MBCR can be computed as the marginal
Table 2: Productivity of component crops (mustard and onion) in different cropping patterns.

<table>
<thead>
<tr>
<th>Cropping pattern</th>
<th>Cropping year 2013-14</th>
<th>Cropping year 2014-15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seed yield of mustard (t·ha⁻¹)</td>
<td>Bulb yield of onion (t·ha⁻¹)</td>
</tr>
<tr>
<td>Mustard-onion/maize-T. Aman rice</td>
<td>1.56</td>
<td>14.60</td>
</tr>
<tr>
<td>Mustard-onion-T. Aman rice</td>
<td>1.48</td>
<td>14.82</td>
</tr>
<tr>
<td>Level of significance</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>SE (±)</td>
<td>0.35</td>
<td>0.51</td>
</tr>
<tr>
<td>CV (%)</td>
<td>4.23</td>
<td>5.47</td>
</tr>
</tbody>
</table>

Table 3: Productivity of component crops (maize and T. Aman rice) in different cropping patterns.

<table>
<thead>
<tr>
<th>Cropping pattern</th>
<th>Cropping year 2013-14</th>
<th>Cropping year 2014-15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield of maize (t·ha⁻¹)</td>
<td>Yield of T. Aman rice (t·ha⁻¹)</td>
</tr>
<tr>
<td></td>
<td>Grain</td>
<td>Stover</td>
</tr>
<tr>
<td>Mustard-onion/maize-T. Aman rice</td>
<td>7.65</td>
<td>8.43</td>
</tr>
<tr>
<td>Mustard-onion-T. Aman rice</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Level of significance</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SE (±)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CV (%)</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 4: System productivity (REY*) of component crops in different cropping patterns.

<table>
<thead>
<tr>
<th>Cropping pattern</th>
<th>System REY (t·ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013-14</td>
</tr>
<tr>
<td>Mustard-onion/maize-T. Aman rice</td>
<td>28.96</td>
</tr>
<tr>
<td>Mustard-onion-T. Aman rice</td>
<td>21.51</td>
</tr>
<tr>
<td>Level of significance</td>
<td>0.05</td>
</tr>
<tr>
<td>SE (±)</td>
<td>2.65</td>
</tr>
<tr>
<td>CV (%)</td>
<td>6.21</td>
</tr>
</tbody>
</table>

*Magnitude increased the system’s equivalent yield. Generally, farmers use excess amount of fertilizers for preceding crop onion. Therefore, maize can be grown with a minimum support regarding input cost. However, maize produced 7.65 ton grain and 8.43 ton stover ha⁻¹ in 2013-14 and 8.39 ton grain and 9.13 ton stover ha⁻¹ in 2014-15 which contributed to a higher REY of 29.95 t·ha⁻¹ in four crop-based pattern (Tables 3–5). Correia et al. [14] observed 209.57% higher yield from maize as intercropped/relayed with mucuna.

3. Results and Discussion

3.1. Yield of Mustard. Mustard was the first crop in both the cropping patterns. There was no significant difference of mustard yield in between the cropping patterns. However, numerically higher yield (1.56 t·ha⁻¹ in 2013-14 and 1.61 t·ha⁻¹ in 2014-15) was observed in the improved pattern followed the existing one (Table 2).

3.2. Yield of Onion. Onion was the second crop in both the sequences and planted in the late Rabi season (February). There was no significant difference between the cropping patterns on the bulb yield of onion. However, from the 1st year observation, numerically higher bulb yield was recorded in the existing cropping pattern (mustard-onion-T. Aman rice) than four crops pattern. The 2nd year trend was contrary to the first year result though the difference was statistically nonsignificant (Table 2).

3.3. Yield of Maize. Maize was the included crop in the improved pattern and grown as a relay crop with onion in Kharif-I season (April), whereas, in the existing pattern, this period remained fallow. From the two years’ observation, it was clear that maize can effectively be grown as relay with onion to fit it in the four crops pattern by saving time. Inclusion of maize in the fallow period characteristically increased the system’s equivalent yield. Generally, farmers use excess amount of fertilizers for preceding crop onion. Therefore, maize can be grown with a minimum support regarding input cost. However, maize produced 7.65 ton grain and 8.43 ton stover ha⁻¹ in 2013-14 and 8.39 ton grain and 9.13 ton stover ha⁻¹ in 2014-15 which contributed to a higher REY of 29.95 t·ha⁻¹ in four crop-based pattern (Tables 3–5). Correia et al. [14] observed 209.57% higher yield from maize as intercropped/relayed with mucuna.

3.4. Yield of T. Aman Rice. T. Aman rice is the common crop in the Kharif-II (July–October) season in both cropping patterns. Grain yield of T. Aman rice is a complex character depending on a large number of environmental, morphological, and physiognomical characters. Grain yields also depend upon their yield components. However, there was no significant difference on grain yield of rice in between the cropping patterns but numerically higher (2.25% in 2013-14 and 6.47% in 2014-15) grain yield observed in the imposed pattern might be due to the residual effect of fertilizers applied to the preceding maize crop (Table 3). Jabbar et al. [15] observed the positive impact on residual soil fertility when crops are grown as inter/relay cropping system.
3.5. System Productivity. System productivity was considered as rice equivalent yield (REY). The system REY significantly differed between the cropping patterns. However, data are presented in Table 2. In general, the pattern involving four crops produced significantly higher REY than that having three crops pattern. However, mustard-onion/maize-T. Aman rice showed higher productivity in terms of REY (28.96 t·ha⁻¹ in 2013-14 and 30.95 t·ha⁻¹ in 2014-15) with a mean REY 29.95 t·ha⁻¹ (Table 5) than mustard-onion-T. Aman rice cropping pattern (21.76 t·ha⁻¹). Total productivity increased by 37.63% in the maize-included four crop pattern. Mondal et al. [16] also claimed of having 49 to 67% higher productivity from the maize-included four crops pattern. Mondal et al. [16] also showed variation on production efficiency (PE) (Table 5).

3.6. Production Efficiency (PE). The cropping patterns showed variation on production efficiency (PE) (Table 5). The pattern having four crops generated the higher PE (88.10 kg⁻¹·ha⁻¹·day⁻¹). This is due to the higher productivity of this sequence in which the contribution of maize is quite obvious. However, the mustard-onion-T. Aman rice gave the 9.33% lower PE (80.58 kg⁻¹·ha⁻¹·day⁻¹) in the sequences. Higher PE associated with improved cropping pattern coupled with modern management practices were noted by Nazrul et al. [17], Khan et al. [18, 19], and Krishna and Reddy [20]. Though not studied here, inter/relay crops could increase system production by suppressing the weed growth [21].

3.7. Land Use Efficiency (LUE). Land use efficiency (LUE) varied according to the cropping patterns (Table 5). In general, patterns intensified by four crops resulted in 19.18% higher LUE than the triple cropping system. The higher LUE (93.15%) was recorded in mustard-onion/maize-T. Aman rice whereas the lower LUE (73.97%) was recorded in mustard-onion-T. Aman rice cropping pattern. The results are in agreement with Kamrozzaman et al. [22].

3.8. Economic Performance. Based on two years’ observation, economic performance of the patterns is presented in Table 6. Cropping pattern attributed a remarkable impact on variable cost, marginal return, and marginal benefit cost ratio (MBCR). The annual gross return, cultivation cost, marginal return, and marginal cost were considered for assessing the suitability of the cropping pattern. In general, inclusion of the fourth crop (maize) markedly enhanced both the return and cultivation cost. Though maize accounted for 19.64% higher cultivation cost, consequently it contributed to 37.63% higher return in the four crops pattern. The mustard-onion/maize-T. Aman rice had a maximum gross return (Tk. 539180 ha⁻¹) along with a higher cultivation cost (Tk. 285542 ha⁻¹), which also contributed to higher marginal return (Tk. 147540 ha⁻¹) and MBCR (3.14) than mustard-onion/maize-T. Aman rice-based three crops pattern.

4. Conclusion

Relaying maize with onion is a simple but an effective time space saving technology for shifting the thee crops pattern to four crops (mustard-onion/maize-T. Aman rice) one. Considering systems REY, LUE, PE, and economic performances of the two-year crop cycle, it is revealed that four crops pattern is the best option for greater productivity and profitability over the triple cropping system.

Disclosure

The authors do certify that the statements made by them are true and correct to the best of their knowledge and belief. They understand that any false statements or any unfair means may provide grounds for the withdrawal or cancellation of the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of the article.

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References


