Cropping Systems and Land Use Pattern in Rajshahi Region

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ABSTRACT

Attempts have been made in this paper to overview the existing cropping patterns, crops diversity and cropping intensity in Rajshahi region. The study was conducted in all the upazilas of four districts of Rajshahi region during 2014-15 using pre-tested semi-structured questionnaires. The most predominating crop in this area was rice where exclusive rice based patterns occupied 40.48% of NCA. Boro-Fallow-T. Aman was the dominant cropping pattern, occupied 22.83% of NCA in 27 upazilas out of 32. The second dominant cropping pattern in Rajshahi region was Boro-Fallow-Fallow. It occupied 7.23% of NCA of the region and existed in 28 upazilas. Wheat-Fallow-T. Aman was the 3rd dominant pattern and practiced in 4.34% of the NCA in 14 upazilas. The data also revealed that the wheat based patterns stands for 14.7% of NCA. Mustard-Boro-T. Aman was the 4th dominant cropping pattern. A total of 172 cropping patterns were recognized in this region and the maximum (36) numbers of cropping patterns were identified in Paba upazila nearly followed by Durgapur (35) and Chapainawabganj upazila (34) while the lower numbers of cropping patterns were identified in Charghat (11) followed by Bagha (12) upazila of Rajshahi district. The range of cropping intensity values was recorded 171−253%. The maximum value was for Badalgachhi of Naogaon district and minimum for Bagha of Rajshahi district. The overall CDI of Rajshahi region was calculated 0.970 and the average cropping intensity at regional level was 218%.

Key words: Crop diversity index, cropping pattern, fruit orchard, Barind tract and drought

INTRODUCTION

In Bangladesh, Rajshahi region especially the Barind Tract is different from other parts of the country due to its undulating topography having compact and low fertile soils. The High Barind Tract, lying in Rajshahi, Chapai Nawabganj and Naogaon districts, is one of the distinct areas of Barind, occupying 160,000 ha, roughly 21% of the region. The region experienced high temperature with limited soil moisture storage along with low and erratic rainfall (Ali, 2000). The maximum temperature can exceed 40°C in May and minimum temperature can fall to 6°C in January. Most of the rainfall occurs from June to September and moisture depletion starts from October and in December no residual moisture is available for crop emergence (Idris and Huq, 1987). Land in the High Barind Tract exhibits grey terrace soil, silty loam to silty clay in texture, and is poorly drained, with a 6–8-cm thick plow pan and low organic matter content (0.8–1.2%). These situations make the area drought prone along with poor crop productivity. The east and southeast of the Barind is the lower Atrai Basin of Naogaon and Natore district. During the rainy season a vast area of lowland is flooded completely where silts and organic matter from aquatic weeds are deposited on soil and therefore the fertile soils of the specific areas are specially suited to Boro rice cultivation.

Cropping pattern is the yearly sequence, temporal and spatial arrangement of crops in a given land area. Cropping pattern depends on physical, historical, social, economic and institutional factor as well as government

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policies (Agarwall and Kassam, 1976). Rajshahi region is specially suited to lentil, chickpea, tomato and potato. Mango, litchi, palmyra palms and guava are also the major fruit crops in this area. Cropping pattern in a specified region is not static; day by day it is changing. The cropping pattern and the changes depend on a large number of factors like climate, soil type, rainfall, irrigation facilities, agricultural technology and other inputs, marketing and transport facilities and growth of agro industries (Gadge, 2003; Rashid et al., 2005). Recently a number of farmers are converting their crops into mango orchard and continuing cultivation of field crops in the young mango orchard. Like other parts of the country, monsoon T. Aman rice is the major crop in Rajshahi region and backbone of the rural economy. Since 1985, the Barind Multipurpose Development Authority (BMEDA) developed a network by installing deep tube wells bringing 162,000 ha land under irrigation across the entire Barind of Bangladesh. Diversified cropping pattern may be an option for the farmers as a coping strategy against risks (Mandal and Bezbaruah, 2013). Typology of different cropping systems is the base for the managers of these systems to intensify production (Shriar, 2000). There is a strong need for judicious and appropriate use of limited resources in case of intervention selection that does not lead to increased maladaptation or inequity in the society over long term. Existing trends of available agricultural lands is most essential requirement for any land use planning related to farming and food security in a sustainable manner. Therefore, an increased understanding of arable land use based on the cropping system is essential for the appropriate intervention in sustainable way. In these context, existing cropping patterns along with their diversity of such complex agricultural region are very crucial for risk minimization and overall productivity improvement. The present study was designed with the following specific objectives to:

- understand the existing cropping patterns scenario in Rajshahi region
- visualize the existing land use pattern at upazila and regional level
- determine the crop diversity and cropping intensity at local and regional level.

**METHODOLOGY**

Thirty-two upazilas of Rajshahi, Naogaon, Chapainawabganj and Natore districts under Rajshahi agricultural region were the locale of this study. Data were collected using double stage procedure. At initial stage, data were collected through pre-tested semi-structured questionnaire from 32 pre-assigned Sub-Assistant Agriculture Officers (SAAO) of each upazila during February 2016 at upazila level. The SAAOs were purposively preselected by Agriculture Extension Officers (AEO), Additional Agriculture Officer (AAO) and Upazila Agriculture Officer (UAO) or altogether. Prior to data collection, the pre-tested questionnaire was explained along with proper guidelines to the AEOs or UAOs or both and handed over to them at each Deputy Director’s office of the Directorate of Agricultural Extension (DAE) during monthly meeting for the sake of accurate data collection. The scientists of RFS Division collected the filled questionnaires. They also checked and analyzed those to find the inconsistencies of the supplied data before validation workshop. All the inconsistencies among the information were documented. The collected data along with documented inconsistencies were discussed in district level workshop for necessary correction and validation. Second stage of data collection was daylong data validation workshop at district level. The workshop dates were 25 April for Naogaon; 26 April for Natore; 16 August for Rajshahi; and 17 August 2016 for Chapainawabganj. Four field-workers i.e. one SAPPO and three SAAOs experienced and engaged in crop-based data documentation, all officers from all upazilas viz UAOs, AEOs, AAEOs, DD (DAE), DD (Horticulture), DD of Seed Certification Agency, DTO and ADDs, one representative from Agricultural Training
Institute (ATI) and scientists of BRRI regional station, Kushtia, and Rajshahi participated in the data validation workshop. The number of participants of validation workshop ranged from 56 to 98 in each district. All the participants were divided into three to four groups for data validation. Each group was facilitated by two RFSD scientists to finalize and validate the data and authenticated data were captured. Crop diversity index was calculated by using the following equation described by Kshirsagar et al. (1997).

\[ CDI_i = 1 - \sum_{j=1}^{n} \left( \frac{a_{ij}}{A_i} \right)^2 \]

Where, \( CDI_i = \) Crop Diversity Index
\( a_{ij} = \) Area planted to the \( j^{th} \) crop in the \( i^{th} \) location
\( A_i = \) Total area planted under all crops

The index is zero for a land area growing only one crop. It approaches unity as the level of diversity increases. Compilation and processing of collected data were done using MicroSoft Excel programme. Descriptive statistics were used to facilitate the presentation of the findings.

RESULTS AND DISCUSSION

Land use
Table 1 presents status of agricultural land utilization in the region. The net cropped area of the Rajshahi region is 693,620 ha. Crops occupying the particular land for round the year were considered under annual crops. The major annual crops reported in the region were pineapple, sugarcane, banana, papaya, betel leaf, ginger and turmeric. The annual crops area in different upazilas ranged from 40 to 7,940 ha. The annual crops area accounted only 5.96% of the net cropped area (NCA) in the region. At a glance the region possesses 10.73% single cropped area (SCA), 48.38% double cropped area (DCA), 33.58% triple cropped area (TCA). The quadruple cropped area QCA also exists as a very negligible portion (0.67%) and is limited in only six upazilas viz Badalgachhi, Manda, Mohadevpur and Raninagar of Naogaon district, and Bagha and Mohanpur of Rajshahi district. Compared with DCA and TCA the SCA remained much lower in each and every upazilas. In Rajshahi region, DCA remained higher in Singra upazila of Natore district followed by Godagari upazila of Rajshahi district. Chapainawabganj sadar and Shibganj upazilas are the exceptions where TCA occupied the biggest share of NCA.

Cropping patterns of Rajshahi
In total 172 cropping patterns were observed in Rajshahi region of which eight cropping patterns with exclusive rice crop covers over 40% of the NCA. There were 40 cropping patterns with exclusive non-rice crop covering over 7% of the NCA. Rest of the NCA i.e. about 53% area is covered by 124 rice - non rice cropping patterns (Appendix 1).

Rice and non-rice crops at a glance
A wide range of cropping patterns were recognized in the study area and the important feature of the region is that eight patterns were composed of absolutely rice crops. Of all lands used for cultivation, 40.48% was used only for rice production showing that the farmers are engaged with the traditional rice farming and it is also applicable in Bangladesh (Haque et al., 2012). Boro-Fallow-T. Aman was the most predominant cropping pattern in this area (Table 2). Out of 32 upazilas, the Boro-Fallow-T. Aman cropping pattern remained in 27 upazilas and 22.83% of the NCA belonged to this pattern. Single Boro was the 2nd dominant pattern, which occupied about 7.23% of the net cropped area in 28 upazilas. Boro-T. Aus-T. Aman cropping pattern exists in 17 upazilas which was the 3rd dominant cropping pattern and occupied 3.65% of NCA in the region. Single T. Aman was also common in eight upazilas which covered 2.75% of NCA. Very negligible portion i.e less than 1% NCA was practiced by Fallow-Aus-T. Aman cropping system in this region.

In the current investigation, 40 cropping patterns were identified that was free from rice. Among thm first 24 have been arranged in descending order in Table 3. The rest 16 patterns
Table 1. Land use of different upazilas in Rajshahi region (area in hectare), 2014-15.

| Upazila       | Area of upazila | Annual crop | SCA | DCA | TCA | QCA | Other | NCA | C.I. (%) |
|---------------|-----------------|-------------|-----|-----|-----|-----|-------|-----|----------|
| 01 Bholahat   | 12352           | 2200        | 500 | 5100| 3030| 0    | 170   | 11000| 203     |
| 02 Chapainawabganj | 45192        | 550         | 6050| 4520| 17640| 0    | 190   | 28950| 238     |
| 03 Gomastapganj | 31812          | 410         | 5430| 13340| 5410 | 0    | 120   | 24710| 198     |
| 04 Nachol     | 28368           | 60          | 2600| 17860| 4400 | 0    | 140   | 25060| 207     |
| 05 Shibganj   | 52543           | 7940        | 700 | 5330| 16500| 0    | 150   | 30640| 226     |
| 06 Atra       | 28300           | 40          | 6800| 13950| 2700 | 0    | 150   | 23640| 182     |
| 07 Badalgachhi| 21083           | 320         | 120 | 9090 | 4140 | 0    | 100   | 23450| 238     |
| 08 Dhamoirhat | 30082           | 250         | 1300| 13820| 7980 | 0    | 100   | 23450| 228     |
| 09 Manda      | 71744           | 360         | 4010| 14790| 11120| 80   | 150   | 30510| 223     |
| 10 Mohadebpur | 39552           | 160         | 30  | 15670| 14090| 1000 | 110   | 31060| 251     |
| 11 Naogaon sadar | 27444        | 250         | 5630| 6810 | 7610 | 0    | 150   | 20450| 209     |
| 12 Niamatpur  | 44993           | 340         | 3300| 17500| 11650| 0    | 150   | 32940| 224     |
| 13 Porsha     | 27205           | 430         | 3500| 12070| 5820 | 0    | 110   | 21930| 209     |
| 14 Patnitala  | 37927           | 240         | 3500| 14430| 11930| 0    | 190   | 30290| 224     |
| 15 Raninagar  | 24810           | 70          | 2200| 12910| 5260 | 50   | 180   | 20670| 215     |
| 16 Shapahar   | 24462           | 40          | 3300| 12480| 3750 | 0    | 170   | 19740| 202     |
| 17 Bagatipara | 13992           | 3500        | 130 | 1240 | 2995 | 0    | 135   | 10160| 172     |
| 18 Baraigram  | 30000           | 1680        | 1000| 11000| 10240| 0    | 160   | 24080| 232     |
| 19 Gurudaspur | 19940           | 630         | 1040| 8620 | 5260 | 0    | 180   | 15730| 223     |
| 20 Lalpur     | 32987           | 2590        | 280 | 1770 | 6820 | 0    | 130   | 11590| 234     |
| 21 Natore     | 27700           | 4830        | 0   | 4250 | 7300 | 0    | 150   | 16530| 215     |
| 22 Naldanga   | 19500           | 1700        | 3500| 5000 | 3600 | 0    | 150   | 13950| 188     |
| 23 Singra     | 52778           | 150         | 7200| 27900| 7820 | 0    | 130   | 43200| 201     |
| 24 Charghat   | 16458           | 730         | 950 | 1840 | 5200 | 0    | 160   | 8880 | 240     |
| 25 Bagha      | 18426           | 4350        | 1700| 4850 | 2250 | 0    | 150   | 13300| 171     |
| 26 Bagmara    | 36558           | 450         | 2800| 14370| 9790 | 900  | 190   | 28500| 229     |
| 27 Durgapur   | 22200           | 480         | 1510| 3680 | 7800 | 0    | 110   | 13580| 243     |
| 28 Godagar    | 47526           | 40          | 120 | 36580| 2700 | 0    | 150   | 39590| 206     |
| 29 Mohanpur   | 16276           | 50          | 2250| 1020 | 7660 | 200  | 170   | 11350| 252     |
| 30 Paba       | 29783           | 570         | 1370| 5030 | 8290 | 0    | 160   | 15420| 242     |
| 31 Puthia     | 19264           | 3600        | 1170| 2880 | 6150 | 0    | 150   | 13950| 210     |
| 32 Tanor      | 29580           | 150         | 450 | 15850| 5980 | 0    | 120   | 22550| 224     |

Rajshahi region | - | 41320 | 74440 | 335570 | 232885 | 4630 | 4775 | 693620 | 218 |

Table 2. Cropping patterns with exclusive rice in Rajshahi region, 2014-15.

| Cropping pattern      | Area (ha) | % of NCA | Frequency (no. of upazila) |
|-----------------------|-----------|----------|---------------------------|
| 01 Boro−Fallow−T. Aman | 158390  | 22.83    | 27                        |
| 02 Boro−Fallow         | 50130   | 7.23     | 28                        |
| 03 Boro−Aus−T. Aman    | 25290   | 3.65     | 17                        |
| 04 Fallow−Fallow−T. Aman | 19100 | 2.75     | 8                         |
| 05 Boro−B.Aman         | 11650   | 1.68     | 8                         |
| 06 Boro−Aus−Fallow     | 9500    | 1.37     | 9                         |
| 07 Fallow−Aus−T. Aman  | 6120    | 0.88     | 3                         |
| 08 Boro−Sesbania−T. Aman | 580  | 0.08     | 3                         |
| Total                  | 280760  | 40.48    | -                         |
with negligible area coverage arranged in Table 8 with other patterns of different categories. Aggregate of the 40 patterns have had 7.43% of NCA. In critical comparison it is clear that exclusive rice area is about six folds of exclusive non-rice area. In Rajshahi region, crop diversity is much wider than that of other regions like Sylhet and Chittagong, where exclusive rice area covers 37 folds and 23 folds, respectively, of exclusive non-rice area (Muttaleb et al., 2017; Shahidullah et al., 2017). Appropriate cropping patterns may facilitate maximum possible land utilization as well as efficient use of other scarce resources in a sustainable manner. Diversified cropping pattern may be an option for the farmers as a coping strategy against risks (Mandal and Bezbaruah, 2013). Typology of different cropping systems, is the base for the managers of these systems to intensify production (Shriar, 2000).

Non-rice cereal crops

Table 4 presents detailed existing cropping patterns for non-rice cereal crops with area coverage. Forty-four cropping patterns were identified for non-rice cereal cropping systems covering 143,730 ha which represents 20.72% of NCA in the region. The dominant cropping pattern was the Wheat-Fallow-T. Aman which was practiced on 30,130 ha (4.34% of NCA) in 14 upazilas of Rajshahi region. Next cropping pattern under this combination was Wheat-Aus-T. Aman and existed in 2.31% of the NCA in 14 upazilas. Out of 44 cropping patterns under non-rice cereal systems, 22 patterns were wheat based and the aggregate area under wheat based patterns stands for 16.58% of NCA in this area. In Bangladesh, there is a vast market of wheat for human consumption and maize seeds for feed industries. Local production of wheat and maize is extremely insignificant to meet up the demand. The situation is increasing our dependency on import causing a great pressure on foreign currency (BBS, 2014). Loam and sandy-loam soil of the comparative dry area is very suitable for maize cultivation. Wheat cultivation with its better yield in this region is specially favoured by long winter season that is normally unavailable in southern parts of the country. Light textured soil with low water-holding capacity as well as less availability of irrigation water are driving forces that discourage the farmers for modern boro cultivation. During the harvesting period of wheat the crop is privileged by clear sun-shine and low humidity. All these are the factors this area is dominated by wheat-based cropping systems (FAO, 1988).

Pulse crops

Fifty cropping patterns are holding different pulse crops (Table 5). Among them blackgram is covering the largest area whereas pea in the smallest area. Thirteen cropping patterns of blackgram in-together cover 31,720 ha representing 4.57% of NCA in the Rajshahi region. Mungbean holds the second position in pulse crop cultivation in the region. There are 10 cropping patterns for mungbean covering 24,020 ha (3.46% of NCA). In some area of Rajshahi region specifically in Barind tract, Boro cultivation faces some constraints such as scarcity of irrigation water and low-water holding capacity of soil. Moreover, high market price of pulse crops is a driving force for ample cultivation of pulse crops. Among the Rabi crops stress-tolerant mungbean, blackgram, grasspea can easily be grown as relay system and other cropping systems (FAO, 1988).

Oil-seed crops

Twenty-eight cropping patterns have been arranged in descending order according to area coverage (Table 6). Mustard is the most important one among the oil-seed crops in Rajshahi region. There are 13 cropping had been led by mustard alone which in-together covers 66,050 ha (9.52% of NCA). The pattern Mustard−Boro−T. Aman has the highest coverage (3.70% of the NCA) and was recorded in 17 upazilas out of 32 followed by Mustard−Boro−Fallow (1.88% of NCA). Oil is an essential ingredient of human food and also for feed industries. The country is almost dependent on import for oil. Mustard is a very potential crop that can be grown widely in various parts of the country (BBS, 2014). At present, the lion-share
Table 3. Cropping patterns with exclusive non-rice in Rajshahi region, 2014-15.

| Cropping pattern                                      | Area (ha) | % of NCA | Frequency (no. of upazila) |
|-------------------------------------------------------|-----------|----------|---------------------------|
| 01 Vegetable–Vegetable–Vegetable                      | 10715     | 1.54     | 19                        |
| 02 Wheat–Jute–Fallow                                  | 6720      | 0.97     | 6                         |
| 03 Garlic–Jute–Fallow                                 | 4310      | 0.62     | 4                         |
| 04 Vegetab–Vegetab–Fallow                            | 3500      | 0.54     | 6                         |
| 05 Maize–Fallow–Blackgram                             | 3350      | 0.50     | 2                         |
| 06 Lentil–Fallow–Fallow (Orchard)                     | 2780      | 0.43     | 5                         |
| 07 Wheat–Mungbean–Fallow                             | 2670      | 0.40     | 4                         |
| 08 Potato–Jute–Fallow                                | 2450      | 0.35     | 3                         |
| 09 Onion–Vegetab–Vegetab                              | 2370      | 0.34     | 11                        |
| 10 Wheat–Mung–Fallow (Orchard)                        | 2150      | 0.31     | 3                         |
| 11 Onion–Jute–Fallow                                 | 2010      | 0.29     | 5                         |
| 12 Garlic–Vegetab–Vegetab                             | 1030      | 0.15     | 10                        |
| 13 Maize–Fallow–Fallow                                | 1000      | 0.14     | 2                         |
| 14 Potato–Chilli–Fallow                               | 980       | 0.14     | 6                         |
| 15 Lentil–Vegetab–Vegetab                              | 760       | 0.11     | 2                         |
| 16 Wht–Sesame–B.gram (Orchard)                        | 730       | 0.11     | 2                         |
| 17 Chilli–Vegetab–Fallow                              | 600       | 0.09     | 5                         |
| 18 Wheat–Vegetab–Vegetab                              | 500       | 0.07     | 2                         |
| 19 Wheat–Jute–Blackgram                               | 370       | 0.05     | 2                         |
| 20 Wheat–Chilli–Fallow                                | 290       | 0.04     | 3                         |
| 21 Potato–Maize–Fallow                                | 270       | 0.04     | 3                         |
| 22 Chilli–Fallow–Fallow                               | 240       | 0.04     | 3                         |
| 23 S.Potato–Fallow–Fallow                             | 220       | 0.03     | 4                         |
| 24 Groundnut–Fallow–Fallow                            | 210       | 0.03     | 2                         |
| 25-40 Other 16 patterns (in Table 8)                   | 1540      | 0.22     |                           |
| **Total**                                             | **51765** | **7.43** |                           |

of mustard cultivation is related to the land for double rice. If technology transfer activities could be strengthen much more area of the aforesaid category will be possible to make room for the mustard crop (FAO, 1988).

Vegetables and spices crops
A total of 66 cropping patterns were identified in Rajshahi region for vegetables and spices crops. Potato and other vegetables belong to Rabi, Kharif-I and Kharif-II, spices crops viz onion, garlic, coriander, blackcumin and chilli had been included in this list (Table 7). Total area coverage under spices and vegetables is 106,355 ha (15.27% of NCA). Among them Potato–Boro-T. Aman is holding the largest coverage with 15,610 ha (2.31% of NCA) distributed to 12 upazilas. The 2nd contributing pattern in this category was year-round vegetables, which occupied 1.54% of NCA with its widest spreading into 19 upazilas.

Sporadic and distinct cropping patterns
Boro–Aus–Blackgram is an extremely location specific cropping pattern which is limited only in Chapainawabganj sadar upazila with an area of 8,000 ha. Felon–Fallow–T. Aman is another exception which is practiced in Porsha upazila of Naogaon district. This pattern has occupied an area of 6,400 ha of under Barind tract. The third one is the single T. Aman with fruit garden/orchard. The system practiced only in Porsha with an area coverage of 1,000 ha. Rice is cultivated from the time of garden establishment and it is continued up to 7 or 8 years age of fruit trees. The fourth one is Wheat–Aus–Blackgram which is absolutely
Table 4. Cropping patterns for wheat and maize in Rajshahi region, 2014-15.

| Cropping pattern                              | Area (ha) | % of NCA | Frequency (no. of upazila) |
|------------------------------------------------|-----------|----------|---------------------------|
| 01 Wheat−Fallow−T. Aman                        | 30130     | 4.34     | 14                        |
| 02 Wheat−Aus−T. Aman                           | 16010     | 2.31     | 14                        |
| 03 Wheat−Mungbean−T. Aman                      | 12570     | 1.81     | 17                        |
| 04 Wheat−Aus−Blackgram                         | 12030     | 1.73     | 3                         |
| 05 Wheat−Jute−T. Aman                          | 10270     | 1.48     | 18                        |
| 06 Wheat−Aus−Fallow                           | 7020      | 1.01     | 8                         |
| 07 Wheat−Jute−Fallow                           | 6720      | 0.97     | 6                         |
| 08 Potato−Maize−T. Aman                        | 5350      | 0.77     | 11                        |
| 09 Potato−Maize−Aus                            | 4000      | 0.58     | 3                         |
| 10 Maize−Fallow−T. Aman                        | 3780      | 0.54     | 8                         |
| 11 Wheat−F−T. Aman(Orchard)                    | 3700      | 0.53     | 2                         |
| 12 Maize−Fallow−Blackgram                      | 3350      | 0.48     | 2                         |
| 13 Wheat−Maize−T. Aman                         | 2920      | 0.42     | 4                         |
| 14 Lentil−Maize−T. Aman                        | 2890      | 0.42     | 6                         |
| 15 Wheat−Mungbean−Fallow                       | 2670      | 0.38     | 4                         |
| 16 Wheat−Mung−Fallow(Orchard)                  | 2150      | 0.31     | 3                         |
| 17 Wheat−Sesame−T. Aman                        | 2100      | 0.30     | 7                         |
| 18 Maize−B.Aman                                | 2000      | 0.29     | 2                         |
| 19 Wheat−Aus−Onion                             | 1900      | 0.27     | 1                         |
| 20 Maize−Aus−Blackgram                         | 1300      | 0.19     | 1                         |
| 21 Wheat−Vegetab−T. Aman                       | 1160      | 0.17     | 6                         |
| 22 Wheat−B.Aman                                | 1150      | 0.17     | 2                         |
| 23 Onion−Maize−T. Aman                         | 1050      | 0.15     | 3                         |
| 24 Maize−Fallow−Fallow                         | 1000      | 0.14     | 2                         |
| 25 Wht−Sesame−B.gram(Orchard)                  | 730       | 0.11     | 2                         |
| 26 Potato−Maize−Aus−Vegetab                   | 700       | 0.10     | 1                         |
| 27 Wheat−Vegetab−Vegetab                       | 500       | 0.07     | 2                         |
| 28 Maize−Aus−T. Aman                           | 440       | 0.06     | 3                         |
| 29 Vegetab−Maize−Fallow                        | 430       | 0.06     | 1                         |
| 30 Maize−Maize−Fallow                          | 400       | 0.06     | 1                         |
| 31 Onion−Maize−Fallow                          | 400       | 0.06     | 1                         |
| 32 Wheat−Jute−Blackgram                        | 370       | 0.05     | 2                         |
| 33 Boro−Maize−Blackgram                        | 350       | 0.05     | 1                         |
| 34 Boro−Maize−Fallow                           | 350       | 0.05     | 1                         |
| 35 Maize−Aus−Fallow                            | 300       | 0.04     | 1                         |
| 36 Potato−Maize−Vegetab                        | 300       | 0.04     | 1                         |
| 37 Wheat−Chilli−Fallow                         | 290       | 0.04     | 3                         |
| 38 Potato−Maize−Fallow                         | 270       | 0.04     | 3                         |
| 39-44 Other six patterns (table 8)             | 680       | 0.10     | -                         |

Total maize and wheat 143730 20.72

Rajshahi region is a diversified cropping zone. Forty-four rare cropping patterns with negligible area coverage in the specific one or two upazilas had been identified in this region (Table 8). However, total area coverage of these patterns was only 0.54% of NCA. Out
of 43 patterns, each of nine patterns namely Groundnut−Aus−Fallow, Lentil−B. Aman, Lentil−Jute−Fallow, Lentil−Jute−Fallow, Lentil−Jute−Fallow, Vegetab−Onion−Jute−T. Aman, Wheat−Fallow−Fallow, Wheat−Jute−Vegetab and Wheat−Sesame−Fallow occupied the same areas of 200 ha land in different nine upazilas of this region.

Most dominant cropping pattern
Boro-Fallow-T. Aman was the major cropping pattern in Rajshahi region and the pattern was common in 27 upazilas which occupied 22.83% of NCA in the region (Table 9). The highest area coverage under Boro-Fallow-T. Aman pattern was found in Singra (19,100 ha) upazila of Natore district followed by Dhamoirhat (13,000 ha), Mohadebpur (12,800 ha), Patnitala (12,600 ha) and Raninagar (12,600 ha) upazilas of Naogaon district indicated that Naogaon district was the dominant rice growing zone. Although the higher area coverage was found in Singra upazila but the percent of upazila net cropped area with this pattern remained higher in Raninagar (61%) upazila followed by Dhamoirhat upazila (56%) of Naogaon district.

Table 5. Cropping patterns of pulses crops in Rajshahi region, 2014-15.

| Cropping pattern | Area (ha) | % of NCA | Frequency (no. of upazila) |
|------------------|-----------|----------|---------------------------|
| 01 Wheat−Mungbean−T. Aman | 12570 | 1.81 | 17 |
| 02 Wheat−Aus−Blackgram | 12030 | 1.73 | 3 |
| 03 Boro−Aus−Blackgram | 8000 | 1.15 | 1 |
| 04 Felon−Fallow−T. Aman | 6400 | 0.92 | 1 |
| 05 Lentil−Fallow−T. Aman | 4370 | 0.63 | 6 |
| 06 Maize−Fallow−Blackgram | 3350 | 0.48 | 2 |
| 07 Lentil−Maize−T. Aman | 2890 | 0.42 | 6 |
| 08 Lentil−Fallow−Fallow(Orchard) | 2780 | 0.40 | 5 |
| 09 Wheat−Mungbean−Fallow | 2670 | 0.38 | 4 |
| 10 Garlic−Mungbean−T. Aman | 2500 | 0.36 | 2 |
| 11 Lentil−Jute−T. Aman | 2410 | 0.35 | 6 |
| 12 Wheat−Mung−Fallow(Orchard) | 2150 | 0.31 | 3 |
| 13 Chickpea−Fallow−T. Aman | 2110 | 0.30 | 5 |
| 14 Boro−Fallow−Blackgram | 2000 | 0.29 | 4 |
| 15 Grasspea−Boro−Aus | 1800 | 0.26 | 1 |
| 16 Lentil−Mungbean−T. Aman | 1750 | 0.25 | 5 |
| 17 Mustard−Mungbean−T. Aman | 1700 | 0.25 | 2 |
| 18 Mustard−Aus−Blackgram | 1500 | 0.22 | 1 |
| 19 Vegetab−Aus−Blackgram | 1500 | 0.22 | 1 |
| 20 Grasspea−B.Aman | 1380 | 0.20 | 3 |
| 21 Maize−Aus−Blackgram | 1300 | 0.19 | 1 |
| 22 Onion−Aus−Blackgram | 870 | 0.13 | 2 |
| 23 Lentil−Vegetab−Vegetab | 760 | 0.11 | 2 |
| 24 Wht−Sesame−B.gram(Orchard) | 730 | 0.11 | 2 |
| 25 Lentil−Aus−T. Aman | 710 | 0.10 | 3 |
| 26 Lentil−Sesame−T. Aman | 710 | 0.10 | 3 |
| 27 Lentil−Aus−Fallow | 620 | 0.09 | 2 |
| 28 Mungbean−Aus−T. Aman | 600 | 0.09 | 1 |
| 29 Wheat−Jute−Blackgram | 370 | 0.05 | 2 |
| 30 Boro−Maize−Blackgram | 350 | 0.05 | 1 |
| 31 Grasspea−Fallow−T. Aman | 350 | 0.05 | 4 |
| 32 Lentil−Sesame−Fallow | 300 | 0.04 | 1 |
| 33 Grasspea−Aus−Blackgram | 250 | 0.04 | 1 |
| 34-50 Other 17 patterns (Table 8) | 1410 | 0.20 | |
| Total pulse crop | 85190 | 12.23 | |
Table 6. Cropping patterns of oil-seed crops in Rajshahi region, 2014-15.

| Cropping pattern                      | Area (ha) | % of NCA | Frequency (no. of upazila) |
|---------------------------------------|-----------|----------|---------------------------|
| 01 Mustard−Boro−T. Aman               | 25650     | 3.70     | 17                        |
| 02 Mustard−Boro−Fallow                | 13050     | 1.88     | 9                         |
| 03 Mustard−Boro−Aus                   | 10200     | 1.47     | 8                         |
| 04 Mustard−Fallow−T. Aman             | 6000      | 0.87     | 7                         |
| 05 Mustard−Aus−T. Aman                | 3800      | 0.55     | 4                         |
| 06 Wheat−Sesame−T. Aman               | 2100      | 0.30     | 7                         |
| 07 Mustard−Boro−B.Aman                | 1800      | 0.26     | 1                         |
| 08 Mustard−Boro−Aus−T. Aman           | 1700      | 0.25     | 4                         |
| 09 Mustard−Mungbean−T. Aman           | 1700      | 0.25     | 2                         |
| 10 Mustard−Aus−Blackgram              | 1500      | 0.22     | 1                         |
| 11 Wht−Sesame−Blackgram (Orchard)     | 730       | 0.11     | 2                         |
| 12 Lentil−Sesame−T. Aman              | 710       | 0.10     | 3                         |
| 13 Lentil−Sesame−Fallow               | 300       | 0.04     | 1                         |
| 14 Onion−Sesame−Fallow                | 280       | 0.04     | 1                         |
| 15 Mustard−Aus−Fallow                 | 250       | 0.04     | 1                         |
| 16 Groundnut−Fallow−Fallow            | 210       | 0.03     | 2                         |
| 17-28 Other 12 patterns (in Table 8)  | 1120      | 0.16     | -                         |
| **Total oil-seed crop**               | **71100** | **10.21**|                           |

The lowest area coverage as well as percent of upazila net cropped area under Boro-Fallow-T. Aman cropping pattern in Rajshahi region existed in Charghat upazila decreasingly followed by Paba upazila of Rajshahi district. In the country-wide compilation of data it was observed that Boro−F−T. Aman was the most dominant cropping pattern in Bangladesh covering 2.31 million ha (27% of NCA in the country) with its distribution in 426 upazilas of 63 districts (Nasim et al., 2017).

**Second dominant cropping pattern**

The second most dominant cropping pattern in Rajshahi region was Boro-Fallow-Fallow. It occupied 7.23 of NCA of the region and existed in 28 upazilas (Table 10). The area coverage under single Boro remained higher in Singra upazila of Natore holds the largest area 7,200 ha which is equivalent to 14.36% of the total area for the pattern in the region. Naldanga upazila of Natore district stands fifth position for area coverage (3,500 ha), however, this upazila had allocated the biggest share i.e. 28.57% of its NCA. The lowest area (50 ha) coverage under Boro-Fallow-Fallow cropping pattern has been identified in Chapainawabganj sadar and Charghat upazila of Rajshahi district. Out of nine upazilas of Rajshahi district, only Bagmara upazila holds considerable area 2,800 ha (9.98% of upazila NCA) under this single Boro cropping pattern. This pattern is frequent and concurrently experienced by early flashflood in April and cold injury at reproductive stage. Diversified cropping pattern may be resort for the farmer as a coping strategy with flood related risk (Mandal and Bezbaruah, 2013) but scope of diversification is limited due to environmental and climatic condition (FAO, 1988). In the country-wide compilation of data it was observed that the single Boro was the 2nd dominant cropping pattern in Bangladesh covering 1.14 million ha (13% of NCA in the country) with its distribution in 342 upazilas of 59 districts (Nasim et al., 2017).

**Third dominant cropping pattern**

Third dominant cropping Wheat-Fallow-T. Aman occupied the 30,130 ha of land and represented 4.34% of NCA in Rajshahi region (Table 11). This pattern distributed over 14 upazilas where Shapahar ranked top position covering 7,500 ha of land. Godagari and Nachol ranked the 2nd and 3rd position under Wheat-Fallow-T. Aman cropping pattern covering 6,000 ha and 5,000 ha of land, respectively.
Table 7. Cropping patterns for vegetables and spices crops in Rajshahi region, 2014-15.

| Cropping pattern                                      | Area (ha) | % of NCA | Frequency (no. of upazila) |
|-------------------------------------------------------|-----------|----------|---------------------------|
| 01 Potato−Boro−T. Aman                                  | 15610     | 2.25     | 12                        |
| 02 Vegetable−Vegetable−Vegetable                       | 10715     | 1.54     | 19                        |
| 03 Potato−Boro−Aus                                      | 7200      | 1.04     | 4                         |
| 04 Garlic−B.Aman                                        | 6200      | 0.89     | 3                         |
| 05 Potato−Boro−Fallow                                   | 5800      | 0.84     | 2                         |
| 06 Onion−Aus−Fallow                                    | 4450      | 0.64     | 5                         |
| 07 Garlic−Jute−Fallow                                   | 4310      | 0.62     | 4                         |
| 08 Potato−Fallow−T. Aman                                | 4050      | 0.58     | 6                         |
| 09 Vegetab−Aus−Fallow                                   | 3680      | 0.53     | 4                         |
| 10 Vegetab−Vegetab−T. Aman                              | 3550      | 0.51     | 7                         |
| 11 Vegetab−Vegetab−Fallow                               | 3500      | 0.50     | 6                         |
| 12 Onion−Jute−T. Aman                                   | 2750      | 0.40     | 6                         |
| 13 Chilli−Aus−T. Aman                                   | 2600      | 0.37     | 2                         |
| 14 Potato−Aus−T. Aman                                   | 2600      | 0.37     | 5                         |
| 15 Potato−Jute−Fallow                                   | 2450      | 0.35     | 3                         |
| 16 Onion−Vegetab−Vegetab                                | 2370      | 0.34     | 11                        |
| 17 Garlic−Jute−T. Aman                                  | 2320      | 0.33     | 8                         |
| 18 Onion−Jute−Fallow                                   | 2010      | 0.29     | 5                         |
| 19 Potato−Jute−T. Aman                                  | 1980      | 0.29     | 5                         |
| 20 Onion−Fallow−T. Aman                                 | 1840      | 0.27     | 7                         |
| 21 Vegetab−Aus−T. Aman                                  | 1640      | 0.24     | 5                         |
| 22 Vegetab−Fallow−T. Aman                               | 1550      | 0.22     | 4                         |
| 23 Potato−Aus−Fallow                                   | 1300      | 0.19     | 4                         |
| 24 Garlic−Vegetab−Vegetab                               | 1030      | 0.15     | 10                        |
| 25 Potato−Chilli−Fallow                                 | 980       | 0.14     | 6                         |
| 26 Lentil−Vegetab−Vegetab                               | 760       | 0.11     | 2                         |
| 27 Potato−Vegetab−T. Aman                               | 700       | 0.10     | 2                         |
| 28 Chilli−Fallow−T. Aman                                | 670       | 0.10     | 6                         |
| 29 Garlic−Aus−Fallow                                   | 660       | 0.10     | 5                         |
| 30 Boro−Vegetab(Float/Norm)                             | 630       | 0.09     | 2                         |
| 31 Chilli−Vegetab−Fallow                                | 600       | 0.09     | 5                         |
| 32 Wheat−Vegetab−Vegetab                                | 500       | 0.07     | 2                         |
| 33 Garlic−Aus−T. Aman                                   | 490       | 0.07     | 3                         |
| 34 Garlic−Fallow−T. Aman                                | 410       | 0.06     | 4                         |
| 35 Chilli−Aus−Fallow                                    | 400       | 0.06     | 3                         |
| 36 Garlic+Muskmelon−B.Aman                              | 320       | 0.05     | 2                         |
| 37 Garlic+W.Melon−B.Aman                                | 320       | 0.05     | 2                         |
| 38 Vegetab−Boro−T. Aman                                 | 300       | 0.04     | 2                         |
| 39 Wheat−Chilli−Fallow                                  | 290       | 0.04     | 3                         |
| 40 Potato−Maize−Fallow                                  | 270       | 0.04     | 3                         |
| 41 Vegetab−Jute−T. Aman                                 | 270       | 0.04     | 2                         |
| 42 Potato−Boro−Aus−T. Aman                              | 230       | 0.03     | 2                         |
| 43 Coriander−Fallow−Fallow                              | 220       | 0.03     | 2                         |
| 44 Chilli−Fallow−Fallow                                 | 240       | 0.03     | 3                         |
| 45 Chilli−Vegetab−T. Aman                               | 210       | 0.03     | 2                         |
| 46-66 Other 21 patterns (in Table 8)                     | 1380      | 0.20     | -                         |
| **Total veg. and spices crops**                         | 106355    | 15.27    |                           |
| Cropping pattern                  | Area (ha) | % of NCA | Frequency | Upazila                      |
|----------------------------------|-----------|----------|-----------|------------------------------|
| 01  Groundnut− Aus−Fallow         | 200       | 0.03     | 1         | Lalpur                       |
| 02  Lentil−B.Aman                 | 200       | 0.03     | 1         | Gurudaspur                   |
| 03  Lentil−Jute−Fallow            | 200       | 0.03     | 1         | Nachol                       |
| 04  Lentil−Vegetab−T. Aman        | 200       | 0.03     | 1         | Nachol                       |
| 05  Lentil−Jute−Fallow            | 200       | 0.03     | 1         | Gurudaspur                   |
| 06  Vegetab−Onion−Jute−T. Aman    | 200       | 0.03     | 1         | Mohanpur                     |
| 07  Wheat−Fallow−Fallow           | 200       | 0.03     | 1         | Bagatipara                   |
| 08  Wheat−Jute−Vegetab            | 200       | 0.03     | 1         | Naogaon sadar                |
| 09  Wheat−Sesame−Fallow           | 200       | 0.03     | 1         | Bagatipara                   |
| 10  Grasspea−Jute−T. Aman         | 190       | 0.03     | 2         | Manda+Bagatipara+Paba        |
| 11  Fallow−Fallow−Blackgram       | 170       | 0.02     | 3         | Dhamoirhat+Shibganj          |
| 12  Chilli−Jute−T. Aman           | 170       | 0.02     | 2         | Paba+Bagatipara              |
| 13  Grasspea−Boro−Fallow          | 150       | 0.02     | 1         | Paba                         |
| 14  Mustard−Fallow−Fallow         | 150       | 0.02     | 1         | Paba                         |
| 15  Garlic−Fallow−Fallow          | 120       | 0.02     | 1         | Lalpur                       |
| 16  Potato−Sesame−Aus             | 120       | 0.02     | 1         | Bagmara                      |
| 17  Groundnut−Fallow−T. Aman      | 100       | 0.01     | 1         | Atrai                        |
| 18  Boro−Sesbania−Fallow          | 80        | 0.01     | 1         | Godagari                     |
| 19  Boro−Vegetab−T. Aman          | 70        | 0.01     | 1         | Paba                         |
| 20  Coriander−Fallow−T. Aman      | 50        | 0.01     | 2         | Chapai sadar +Gomastapur     |
| 21  Grasspea−Mungbean−T. Aman     | 50        | 0.01     | 1         | Lalpur                       |
| 22  Mustard−Maize−T. Aman         | 50        | 0.01     | 1         | Manda                        |
| 23  Grasspea−Sesame−T. Aman       | 40        | 0.01     | 1         | Lalpur                       |
| 24  Pea−Aus−Vegetab               | 40        | 0.01     | 2         | Paba+Nachol                  |
| 25  Pea−Fallow−T. Aman            | 40        | 0.01     | 2         | Chapai sadar +Gomastapur     |
| 26  Blackgram−Jute−Fallow         | 30        | 0.00     | 1         | Manda                        |
| 27  Coriander−Vegetab−Fallow       | 30        | 0.00     | 1         | Naogaon sadar                |
| 28  Potato−Sesame−T. Aman         | 30        | 0.00     | 1         | Durgapur                     |
| 29  Blackcumin−Jute−T. Aman       | 20        | 0.00     | 1         | Gurudaspur                   |
| 30  Chickpea−Aus−T. Aman          | 20        | 0.00     | 1         | Paba                         |
| 31  Chilli−Fallow−Fallow          | 20        | 0.00     | 1         | Badalgachhi                  |
| 32  Coriander−B.Aman               | 20        | 0.00     | 1         | Gurudaspur                   |
| 33  Coriander−Jute−T. Aman        | 20        | 0.00     | 2         | Gurudaspur+Dhamoirhat        |
| 34  Grasspea−Jute−Fallow          | 20        | 0.00     | 1         | Manda                        |
| 35  Maize−Jute−T. Aman            | 20        | 0.00     | 1         | Durgapur                     |
| 36  Pea−Jute−Fallow               | 20        | 0.00     | 1         | Lalpur                       |
| 37  Potato−Mungbean−T. Aman       | 20        | 0.00     | 2         | Durgapur+Chapai sadar        |
| 38  Coriander−Sesame−T. Aman      | 10        | 0.00     | 1         | Mohadebpur                   |
| 39  Grasspea−Fallow−Fallow        | 10        | 0.00     | 1         | Gomastapur                   |
| 40  Maize−Vegetab−T. Aman         | 10        | 0.00     | 1         | Durgapur                     |
| 41  Mungbean−Fallow−T. Aman       | 10        | 0.00     | 1         | Charghat                     |
| 42  Potato−Groundnut              | 10        | 0.00     | 1         | Ranimagar                    |
| 43  Potato−Groundnut−T. Aman      | 10        | 0.00     | 1         | Ranimagar                    |
| 44  Vegetab−Fallow−Fallow         | 10        | 0.00     | 1         | Durgapur                     |
| **Total**                         | **3730**  | **0.54** |           |                              |
The lowest area coverage (100 ha) under this cropping pattern existed in Chapai sadar upazila decreasingly followed by Porsha and Raninagar upazila where each of two upazila held only 150 ha of land.

**Fourth dominant cropping pattern**

The fourth dominant cropping pattern in Rajshahi region was Mustard-Boro-T. Aman existed in 17 upazilas representing 3.70% share of NCA (Table 12). The area coverage under this pattern remained higher (4,700 ha each) in Patnitala and Manda upazilas of Naogaon district. The distribution of %NCA under this pattern in Patnitala and Manda upazilas was 15.6% for both. Dhamoirhat upazila ranked in 3rd in terms of area coverage (3,000 ha) and % NCA (12.93%) for this pattern. Out of top 11 upazilas of Rajshahi region, the Mustard-Boro-T. Aman cropping pattern existed in top 10 upazilas of Naogaon district covering 88% (22600 ha) of total Mustard-Boro-T. Aman area in the region indicating that the Naogaon district remained predominated with this pattern. In the country-wide compilation of data it was observed that Mustard−Boro−T. Aman was the 6th dominant cropping pattern in Bangladesh covering 1.85 lac ha (2.16% of NCA in the country) with its distribution in 203 upazilas of 51 districts (Nasim *et al.*, 2017).

**Fifth dominant cropping pattern**

Fifth dominant cropping pattern Boro-Aus-T. Aman existed in 17 upazilas of Rajshahi region covering 25,290 ha of land (Table 13). The pattern represented 3.65% of NCA where Niamatpur upazila of Naogaon district ranked
Table 10. Distribution of the 2nd dominant Boro−Fallow−Fallow cropping patterns in Rajshahi region, 2014-15.

| Upazila         | Area (ha) | % of upazila NCA | % of the pattern in region |
|-----------------|-----------|------------------|----------------------------|
| 01 Singra       | 7200      | 16.72            | 14.36                      |
| 02 Atrai        | 5900      | 25.00            | 11.77                      |
| 03 Naogaon sadar| 5500      | 27.23            | 10.97                      |
| 04 Manda        | 4000      | 13.27            | 7.98                       |
| 05 Naldanga     | 3500      | 28.57            | 6.98                       |
| 06 Baghmara     | 2800      | 9.98             | 5.59                       |
| 07 Porsha       | 2500      | 11.63            | 4.99                       |
| 08 Shapahar     | 2500      | 12.69            | 4.99                       |
| 09 Gomastapur   | 2300      | 9.47             | 4.59                       |
| 10 Mohanpur     | 2250      | 19.91            | 4.49                       |
| 11 Raninagar    | 2100      | 10.19            | 4.19                       |
| 12 Durgapur     | 1500      | 11.45            | 2.99                       |
| 13 Paba         | 1100      | 7.41             | 2.19                       |
| 14 Baraigram    | 1000      | 4.46             | 1.99                       |
| 15 Gurudaspur   | 1000      | 6.62             | 1.99                       |
| 16 Patnitala    | 800       | 2.66             | 1.60                       |
| 17 Nachol       | 600       | 2.40             | 1.20                       |
| 18 Shibganj     | 600       | 2.64             | 1.20                       |
| 19 Niamatpur    | 500       | 1.53             | 1.00                       |
| 20 Bagha        | 500       | 5.59             | 1.00                       |
| 21 Bholahat     | 500       | 5.68             | 1.00                       |
| 22 Tanor        | 450       | 2.01             | 0.90                       |
| 23 Puthia       | 400       | 3.86             | 0.80                       |
| 24 Dhamoirhat   | 300       | 1.29             | 0.60                       |
| 25 Bagatipara   | 130       | 2.89             | 0.26                       |
| 26 Godagari     | 100       | 0.25             | 0.20                       |
| 27 Chapai sadar | 50        | 0.18             | 0.10                       |
| 28 Charghat     | 50        | 0.61             | 0.10                       |
| Rajshahi region | 50130     | 7.23             | 100.00                     |

the top position in terms of area coverage (6,000 ha) and % NCA (18.4%). Next to Niamatpur, Gomastapur upazila of Chapainawabganj district occupied the highest area (3,600 ha) and % of NCA (14.8%) for the pattern. Patnitala and Raninagar upazilas of Naogaon district ranked in 3rd position with this pattern in terms of area coverage and %NCA, respectively. The area coverage as well as of %NCA under Boro-Aus-T. Aman cropping system remained lower in Mohanpur upazila of Rajshahi district represented only 0.02% of total Boro-Aus-T. Aman area in the region.

**Crop diversity and cropping intensity**
A wide variation was observed in cropping patterns and crops among the different upazilas of Rajshahi region (Table 14). A total of 172 cropping patterns were recognized in this region. The maximum (36) numbers of cropping patterns were identified in Paba upazila nearly followed by Durgapur (35) and Chapainawabganj upazila (34) while the lower numbers of cropping patterns were found in Charghat (11), which is decreasing followed by Bagha (12) upazila of Rajshahi district. It was evident that Rajshahi region represented a lower rainfall area in the country and thus BMDA established lots of deep tube-wells for irrigation purpose. It has been assumed that lower number of cropping patterns existed in those upazilas where irrigation facilities were limited. The higher number of cropping patterns is generally related to higher level of diversity for cropping pattern.
Table 11. Distribution of the 3rd dominant Wheat−Fallow−T. Aman cropping patterns in Rajshahi region, 2014-15.

| Upazila        | Area (ha) | % of upazila NCA | % of the pattern in region |
|----------------|-----------|------------------|---------------------------|
| 01 Shapahar    | 7500      | 38.07            | 24.89                     |
| 02 Godagari    | 6000      | 15.17            | 19.91                     |
| 03 Nachol      | 5000      | 20.00            | 16.59                     |
| 04 Gomastapur  | 4600      | 18.93            | 15.27                     |
| 05 Niamatpur   | 2500      | 7.67             | 8.30                      |
| 06 Paba        | 1100      | 7.41             | 3.65                      |
| 07 Bholahat    | 1100      | 12.50            | 3.65                      |
| 08 Durgapur    | 730       | 5.57             | 2.42                      |
| 09 Manda       | 700       | 2.32             | 2.32                      |
| 10 Bagatipara  | 300       | 6.67             | 1.00                      |
| 11 Dhamoirhat  | 200       | 0.86             | 0.66                      |
| 12 Raninagar   | 150       | 0.73             | 0.50                      |
| 13 Porsha      | 150       | 0.70             | 0.50                      |
| 14 Chapai sadar| 100       | 0.35             | 0.33                      |
| Rajshahi region| 30130     | 4.34             | 100.00                    |

The highest (0.972) diversity index for cropping pattern was found Bagatipara upazila of Natore district followed by Puthia (0.965) upazila of Rajshahi district while the lowest value of diversity for cropping pattern remained in Raninagar upazila of Naogaon district. Crop diversity index (CDI) ranged from 0.528 in Bagmara upazila to 0.989 in Puthia upazila of Rajshahi district. Next to Puthia, the CDI remained higher (0.979) in Charghat and Durgapur upazila of Rajshahi district indicated that this district represented a diversified cropping zone. The highest cropping intensity (253%) remained in Badalgachhi upazila of Naogaon district closely followed by Mohanpur (252) upazila of Rajshahi district. Next to Mohanpur upazila, the highest cropping intensity existed in Mohadebpur upazila of Naogaon district while the lowest cropping intensity was found in Bagha (171%) upazila of Rajshahi district. However, the average cropping intensity in Rajshahi region was 218%. In a simultaneous study, the investigators identified 316 cropping patterns for whole Bangladesh; where the CDI value was 0.952 at national level and the

Table 12. Distribution of the 4th dominant Mustard−Boro−T. Aman cropping patterns in Rajshahi region, 2014-15.

| Upazila     | Area (ha) | % of upazila NCA | % of the pattern in region |
|-------------|-----------|------------------|---------------------------|
| 01 Patnitala| 4700      | 15.64            | 18.32                     |
| 02 Manda     | 4700      | 15.59            | 18.32                     |
| 03 Dhamoirhat| 3000     | 12.93            | 11.70                     |
| 04 Naogaon sadar | 2500 | 12.38            | 9.75                      |
| 05 Niamatpur | 2100     | 6.44             | 8.19                      |
| 06 Mohadebpur | 1600   | 5.18             | 6.24                      |
| 07 Raninagar | 1400     | 6.80             | 5.46                      |
| 08 Shapahar  | 1000      | 5.08             | 3.90                      |
| 09 Porsha    | 1000      | 4.65             | 3.90                      |
| 10 Tanor     | 850       | 3.79             | 3.31                      |
| 11 Badalgachhi| 600    | 3.77             | 2.34                      |
| 12 Nachol    | 600       | 2.40             | 2.34                      |
| 13 Naldanga  | 500       | 4.08             | 1.95                      |
| 14 Paba      | 400       | 2.69             | 1.56                      |
| 15 Gomastapur| 400       | 1.65             | 1.56                      |
| 16 Shibganj  | 200       | 0.88             | 0.78                      |
| 17 Bholahat  | 100       | 1.14             | 0.39                      |
| Rajshahi region| 25650 | 3.70             | 100.00                    |
Table 13. Distribution of the 5th dominant Boro−Aus−T. Aman cropping patterns in Rajshahi region, 2014-15.

| Upazila     | Area (ha) | % of upazila NCA | % of the pattern in region |
|-------------|-----------|------------------|---------------------------|
| 01 Niamatpur| 6000      | 18.40            | 23.72                     |
| 02 Gomastapur| 3600     | 14.81            | 14.23                     |
| 03 Patnitala| 2900      | 9.65             | 11.47                     |
| 04 Singra   | 2800      | 6.50             | 11.07                     |
| 05 Raninagar| 2500      | 12.14            | 9.89                      |
| 06 Chapai sadar| 2040    | 7.18             | 8.07                      |
| 07 Shapahar | 1000      | 5.08             | 3.95                      |
| 08 Naogaon sadar| 1000   | 4.95             | 3.95                      |
| 09 Godagari | 900       | 3.35             | 2.77                      |
| 10 Tanor    | 700       | 3.13             | 2.77                      |
| 11 Nachol   | 700       | 2.80             | 2.77                      |
| 12 Baraigram| 500       | 2.23             | 1.98                      |
| 13 Bholahat | 300       | 3.41             | 1.19                      |
| 14 Natore sadar| 100    | 0.85             | 0.40                      |
| 15 Porsha   | 100       | 0.47             | 0.40                      |
| 16 Dhamoirhat| 100      | 0.43             | 0.40                      |
| 17 Mohanpur | 50        | 0.44             | 0.20                      |
| Rajshahi region| 25290  | 3.65             | 100.00                    |

Table 14. Crop diversity and cropping intensity in Rajshahi region, 2014-15.

| Upazila     | No. of identified pattern | No. of crop | Diversity index for cropping pattern | Crop diversity index (CDI) | C.I. (%) |
|-------------|---------------------------|-------------|--------------------------------------|---------------------------|---------|
| 01 Bholahat | 13                        | 09          | 0.923                                | 0.923                     | 203     |
| 02 Chapainawabganj| 34                  | 19          | 0.862                                | 0.942                     | 238     |
| 03 Gomastapur| 29                      | 18          | 0.859                                | 0.929                     | 199     |
| 04 Nachol   | 20                        | 11          | 0.876                                | 0.943                     | 207     |
| 05 Shibganj | 14                        | 13          | 0.869                                | 0.925                     | 226     |
| 06 Atrai    | 18                        | 13          | 0.853                                | 0.933                     | 190     |
| 07 Badalgachhi| 19                    | 12          | 0.694                                | 0.897                     | 253     |
| 08 Dhamoirhat| 21                     | 16          | 0.665                                | 0.867                     | 228     |
| 09 Manda    | 32                        | 19          | 0.884                                | 0.951                     | 223     |
| 10 Mohadebpur| 23                     | 12          | 0.762                                | 0.914                     | 251     |
| 11 Naogaon sadar| 26                 | 17          | 0.814                                | 0.926                     | 209     |
| 12 Niamatpur| 16                        | 09          | 0.810                                | 0.918                     | 224     |
| 13 Porsha   | 16                        | 11          | 0.831                                | 0.922                     | 209     |
| 14 Patnitala| 15                        | 12          | 0.775                                | 0.907                     | 227     |
| 15 Raninagar| 18                        | 13          | 0.596                                | 0.823                     | 215     |
| 16 Shapahar | 15                        | 11          | 0.803                                | 0.906                     | 202     |
| 17 Bagatipara| 15                     | 13          | 0.972                                | 0.978                     | 172     |
| 18 Baraigram| 21                       | 12          | 0.930                                | 0.969                     | 232     |
| 19 Gurudaspur| 29                     | 17          | 0.929                                | 0.969                     | 223     |
| 20 Lalpur   | 20                       | 17          | 0.905                                | 0.949                     | 234     |
| 21 Natore   | 20                       | 14          | 0.953                                | 0.970                     | 215     |
| 22 Naldanga | 12                       | 07          | 0.852                                | 0.931                     | 188     |
| 23 Singra   | 17                       | 13          | 0.749                                | 0.881                     | 201     |
| 24 Cherghat | 11                       | 07          | 0.955                                | 0.979                     | 240     |
| 25 Bagha    | 12                       | 07          | 0.933                                | 0.956                     | 171     |
| 26 Bagmara  | 22                       | 13          | 0.664                                | 0.528                     | 206     |
| 27 Durgapur | 35                       | 21          | 0.940                                | 0.979                     | 243     |
| 28 Godagari | 29                       | 18          | 0.859                                | 0.934                     | 206     |
| 29 Mohanpur | 15                       | 08          | 0.801                                | 0.916                     | 252     |
| 30 Paba     | 36                       | 24          | 0.911                                | 0.958                     | 242     |
| 31 Puthia   | 21                       | 17          | 0.965                                | 0.989                     | 210     |
| 32 Tanor    | 16                       | 11          | 0.799                                | 0.902                     | 224     |
| Rajshahi region| 172                  | 34          | 0.928                                | 0.970                     | 218     |
national average of cropping intensity was 200% (Nasim et al., 2017). Diversification of crops helps risk reduction as diversification allows a producer to balance low price in one or two crops with reasonable prices in other. (Blade and Slinkard, 2002). The farmers of Kerala diversified their cropping pattern to minimize risk from due to crop failures and price fluctuations (Mahesh, 1999).

CONCLUSION

The survey results conducted in 32 upazilas of Rajshahi region indicated that the Boro-Fallow-T. Aman was the most predominant cropping pattern. The number of cropping pattern ranged from 11 to 35 while the cropping intensity values varied from 171 to 253%. The average cropping intensity of the region is 218% which is higher than the national average. A wide ranged also existed in CDI. Based on the findings following recommendations were made.

• Initiative to be taken to increase productivity of exclusive rice based cropping pattern. As rice is the synonym of the primary food security, the high yielding stress tolerant varieties of rice along with recommended crop management packages to be adopted.

• The upazila s having unique or exceptional cropping patterns with large area coverage might be studied in-depth to extrapolate to similar environments.

• In the single Boro area suitable vegetables might be grown on floating bed system in wet season.

• A large portion of single T. Aman area might be intensified by the inclusion of some stress-tolerant Rabi crops like felon, grasspea etc.

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### Appendix 1. List of cropping patterns in Rajshahi region, 2014-15.

| Cropping pattern | Area (ha) | Cropping pattern | Area (ha) |
|------------------|-----------|------------------|-----------|
| 001 Boro−Fallow−T. Aman | 158390 | 065 Mustard−Boro−Aus−T. Aman | 1700 |
| 002 Boro−Fallow−Fallow | 50130 | 066 Mustard−Mungbean−T. Aman | 1700 |
| 003 Wheat−Fallow−T. Aman | 30130 | 067 Vegetab−Aus−T. Aman | 1640 |
| 004 Mustard−Boro−T. Aman | 25650 | 068 Vegetab−Fallow−T. Aman | 1550 |
| 005 Boro−Aus−T. Aman | 25290 | 069 Boro−Jute−T. Aman | 1500 |
| 006 Fallow−Fallow−T. Aman | 19100 | 070 Mustard−Aus−Blackgram | 1500 |
| 007 Wheat−Fallow−T. Aman | 15610 | 071 Vegetable−Fallow−T. Aman | 1400 |
| 008 Potatoes−Boro−T. Aman | 12590 | 072 Grasspea−B. Aman | 1380 |
| 009 Wheat−Fallow−T. Aman | 10270 | 073 Potatoes−B. Aman | 1300 |
| 010 Wheat−Fallow−T. Aman | 9500 | 074 Soil−Fallow−T. Aman(Orchard) | 1200 |
| 011 Vegetable−Fallow−T. Aman | 8000 | 075 Vegetab−Fallow−T. Aman | 1150 |
| 012 Vegetable−Fallow−T. Aman | 7200 | 076 Vegetab−Fallow−T. Aman | 1100 |
| 013 Vegetable−Fallow−T. Aman | 6400 | 077 Vegetab−Fallow−T. Aman | 1050 |
| 014 Vegetable−Fallow−T. Aman | 6200 | 078 Vegetab−Fallow−T. Aman | 1000 |
| 015 Vegetable−Fallow−T. Aman | 5800 | 079 Vegetab−Fallow−T. Aman | 950 |
| 016 Vegetable−Fallow−T. Aman | 5350 | 080 Vegetab−Fallow−T. Aman | 900 |
| 017 Vegetable−Fallow−T. Aman | 5000 | 081 Vegetab−Fallow−T. Aman | 850 |
| 018 Vegetable−Fallow−T. Aman | 4700 | 082 Vegetab−Fallow−T. Aman | 800 |
| 019 Vegetable−Fallow−T. Aman | 4500 | 083 Vegetab−Fallow−T. Aman | 750 |
| 020 Vegetable−Fallow−T. Aman | 4200 | 084 Vegetab−Fallow−T. Aman | 700 |
| 021 Vegetable−Fallow−T. Aman | 3900 | 085 Vegetab−Fallow−T. Aman | 650 |
| 022 Vegetable−Fallow−T. Aman | 3600 | 086 Vegetab−Fallow−T. Aman | 600 |
| 023 Vegetable−Fallow−T. Aman | 3300 | 087 Vegetab−Fallow−T. Aman | 550 |
| 024 Vegetable−Fallow−T. Aman | 3000 | 088 Vegetab−Fallow−T. Aman | 500 |
| 025 Vegetable−Fallow−T. Aman | 2700 | 089 Vegetab−Fallow−T. Aman | 450 |
| 026 Vegetable−Fallow−T. Aman | 2400 | 090 Vegetab−Fallow−T. Aman | 400 |
| 027 Vegetable−Fallow−T. Aman | 2100 | 091 Vegetab−Fallow−T. Aman | 350 |
| 028 Vegetable−Fallow−T. Aman | 1800 | 092 Vegetab−Fallow−T. Aman | 300 |
| 029 Vegetable−Fallow−T. Aman | 1500 | 093 Vegetab−Fallow−T. Aman | 250 |
| 030 Vegetable−Fallow−T. Aman | 1200 | 094 Vegetab−Fallow−T. Aman | 200 |
| 031 Vegetable−Fallow−T. Aman | 900 | 095 Vegetab−Fallow−T. Aman | 150 |
| 032 Vegetable−Fallow−T. Aman | 600 | 096 Vegetab−Fallow−T. Aman | 100 |
| 033 Vegetable−Fallow−T. Aman | 300 | 097 Vegetab−Fallow−T. Aman | 50 |
| 034 Vegetable−Fallow−T. Aman | 100 | 098 Vegetab−Fallow−T. Aman | 10 |
| 035 Vegetable−Fallow−T. Aman | 50 | 099 Vegetab−Fallow−T. Aman | 5 |
| 036 Vegetable−Fallow−T. Aman | 25 | 100 Vegetab−Fallow−T. Aman | 2 |
| 037 Vegetable−Fallow−T. Aman | 12 | 101 Vegetab−Fallow−T. Aman | 1 |
| 038 Vegetable−Fallow−T. Aman | 6 | 102 Vegetab−Fallow−T. Aman | 0.5 |
| 039 Vegetable−Fallow−T. Aman | 3 | 103 Vegetab−Fallow−T. Aman | 0.25 |
| 040 Vegetable−Fallow−T. Aman | 1.5 | 104 Vegetab−Fallow−T. Aman | 0.125 |
| 041 Vegetable−Fallow−T. Aman | 0.75 | 105 Vegetab−Fallow−T. Aman | 0.0625 |
| 042 Vegetable−Fallow−T. Aman | 0.375 | 106 Vegetab−Fallow−T. Aman | 0.03125 |
| 043 Vegetable−Fallow−T. Aman | 0.1875 | 107 Vegetab−Fallow−T. Aman | 0.015625 |
| 044 Vegetable−Fallow−T. Aman | 0.09375 | 108 Vegetab−Fallow−T. Aman | 0.0078125 |
| 045 Vegetable−Fallow−T. Aman | 0.046875 | 109 Vegetab−Fallow−T. Aman | 0.00390625 |
| 046 Vegetable−Fallow−T. Aman | 0.0234375 | 110 Vegetab−Fallow−T. Aman | 0.001953125 |
| 047 Vegetable−Fallow−T. Aman | 0.01171875 | 111 Vegetab−Fallow−T. Aman | 0.0009765625 |
| 048 Vegetable−Fallow−T. Aman | 0.005859375 | 112 Vegetab−Fallow−T. Aman | 0.00048828125 |
### Appendix 1. Continued.

| Cropping pattern            | Area (ha) | Cropping pattern            | Area (ha) |
|-----------------------------|-----------|-----------------------------|-----------|
| 049 Onion−Vegtab−Vegetab    | 2370      | 113 Maize−Aus−Fallow        | 300       |
| 050 Garlic−Jute−T. Aman     | 2320      | 114 Potato−Maize−Vegetab    | 300       |
| 051 Wheat−Mung−F (Orchard)  | 2150      | 115 Vegetab−Boro−T. Aman    | 300       |
| 052 Chickpea−Fallow−T. Aman | 2110      | 116 Vegetab−Jute−Fallow    | 300       |
| 053 Vegetab−Onion−Aus       | 2100      | 117 Wheat−Chilli−Fallow     | 290       |
| 054 Wheat−Sesame−T. Aman    | 2100      | 118 Onion−Sesame−Fallow    | 280       |
| 055 Onion−Jute−Fallow       | 2010      | 119 Potato−Maize−Fallow    | 270       |
| 056 Boro−Fallow−Blackgram   | 2000      | 120 Vegetab−Jute−T. Aman    | 270       |
| 057 Maize−B.Aman             | 2000      | 121 Grasspea−Aus−Blackgram | 250       |
| 058 Potato−Jute−T. Aman     | 1980      | 122 Mustard−Aus−Fallow      | 250       |
| 059 Wheat−Aus−Onion         | 1900      | 123 Chilli−Fallow−Fallow    | 240       |
| 060 Onion−Fallow−T. Aman    | 1840      | 124 Potato−Boro−Aus−T. Aman| 230       |
| 061 Grasspea−Boro−Aus       | 1800      | 125 Coriander−Fallow−Fallow| 220       |
| 062 Mustard−Boro−B.Aman     | 1800      | 126 S.Potato−Fallow−Fallow  | 220       |
| 063 Potato−Boro−Jute−T. Aman| 1800      | 127 Chilli−Vegetab−T. Aman  | 210       |
| 064 Lentil−Mungbean−T. Aman | 1750      | 128 Groundnut−Fallow−Fallow| 210       |
| 129-172 Other 44 patterns (Table 8) | 3730     |                             |           |