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Cropping Systems and Land Use in Sylhet Region

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ABSTRACT

Towards the sustainable food security for a particular area, the policymakers, researchers, extension and development agents need the detailed information of cropping patterns, cropping intensity and crop diversity. Sylhet, a potential region of enormous potentiality of growing crops across the *haor* area lying below the northeastern Himalyan foothills experience the highest rainfall in the world to make the basin prone to flashflood. That is why, a study was conducted in the region considering all the upazillas during 2016 using the pretested semi-structured questionnaire and validated by appropriate informants with a view to documenting the existing cropping patterns, cropping intensity and crop diversity in the region. As per the study the region is dominated by the rice based cropping pattern. The non-rice based cropping pattern are either few or the area under those cropping patterns are not enough to satisfy the non-rice food requirement of people of the region. Beside these, the cropping patterns and crop diversity appeared as below the expected level. Therefore, much thrust is needed to initiate research and development activities to diversify the single or double-cropped cropping pattern with the introduction of appropriate crops and crop varieties even other non-crop agricultural commodities.

Key words: Cropping pattern, land use intensity, diversity index and Sylhet basin

INTRODUCTION

The cropping pattern is an important indicator of agricultural land use. It has implications for agricultural growth in general and livelihood improvement of the millions of farmers. Environmental or Agro-ecological conditions, and related risks or relative advantages are the main determinants of cropping pattern along with several socioeconomic factors (Mandal and Bezbaruah, 2013). Available data on total available arable lands of the country is not conclusive and seem to be varied due to the methodology and timeframe followed by the organizations (Hasan *et al*., 2013). Statistics on the conversion rate of agricultural lands to non-agricultural activities also vary with the studies, i.e. an annual change of about 0.13% (Rahman and Hasan, 2003) or 0.27% between the years of 1976-77 and 2010-11 (BBS 2011). Furthermore, climate change showed recurrent floods, droughts and unpredicted rainfall patterns that worsen the existing pressure on land, water and natural resources (Shirsath, 2017). Sylhet agricultural region is a complex region with a multitude of diverse micro-environments (FAO, 1988) with variable landscape ranged from hills to very lowlands. This region is consists of six dominant agroecological zones namely, Old Meghna Estuarine Floodplain, Eastern Surma-Kusiyara Floodplain, Sylhet Basin, Northern and Eastern Piedmont Plains, Northern and Eastern Hills and Akhaura Terrace (FAO, 1988). The yearly decreasing trend of cropland was 3,122 ha (0.33%) during 1976-2010 in Sylhet division (Hasan *et al*., 2013). Cropping intensity of Sylhet agricultural region is almost stagnant for last two decades (BBS 2011, 2014, 2015) even though agriculture is the main source of income of farmers (Banglapedia, 2004). The rapid increase in human population creates additional pressure on natural resources at above optimal levels of their inherent potential, which resulted in the loss of biodiversity, serious soil erosion leading to depletion of plant nutrient, gradual degradation and decline in productivity and carrying capacity, etc (Borthakur *et al*., 1998). Even though appropriate cropping

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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 the option for the farmers as a coping strategy against different risks (Mandal and Bezbaruah, 2013). Typology of different cropping systems is the base for the managers of these systems to intensify production (Shriar, 2000). Hence, judicious and appropriate use of limited resources in the case of intervention selection that does not lead to increased mal adoption or inequity in the society over the long term. Existing trends of available agricultural lands is an 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 systems, patterns along with diversity are very essential for the appropriate intervention in a sustainable way. But very few studies are available related to cropping systems and patterns. In this context, existing cropping patterns along with their diversity of such complex agricultural region are very crucial to minimize risk and to improve overall crop productivity. Accordingly, the present study was designed with the following objectives to:

- Build up a database on major existing cropping patterns in the Sylhet region
- Determine the crop diversity at the local and the regional level.

METHODOLOGY

Thirty-eight upazilas of Sylhet, Sunamganj, Habiganj and Maulvibazar district under Sylhet agricultural region were the locale of this study. Data were collected using double stage procedure through semistructured questionnaire. At the initial stage, data were collected through pre-tested semi-structured questionnaire from 38 pre-assigned Sub-Assistant Agriculture Officers (SAAO) of each upazila during September 2016 at upazila level. The SAAOs were purposively selected by Agriculture Extension Officer (AEO) or Additional Agriculture Officer (AAO) or Upazila Agriculture Officer (UAO)or their united decision. 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 Directorate of Agricultural Extension (DAE) during monthly meeting for the sake of accurate data collection. The filled questionnaires were collected, checked and analyzed to find the inconsistencies of the supplied data before validation workshop. All the inconsistencies among the information were documented. Second stage of data collection was a daylong data validation workshop at district level during 23 to 26 October 2016. Participants of validation workshop were 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, Habiganj. The number of participants of validation workshop ranged from 59 to 88. All the participants were divided into three to four groups for data validation. Each group was facilitated by two RFSD scientists. After thorough discussion on collected data along with documented inconsistencies by each group, authenticated data were captured. Crop diversity index was calculated by using the following equation described by Kshirsagar *et al*. (1997).

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

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 Micro Soft Excel programme. Descriptive

statistics were used to facilitate the presentation of the findings.

RESULTS AND DISCUSSION

Land use

Table 1 presents the status of agricultural land utilization. The net cropped area of the Sylhet region is 773,480 ha. Crops occupied the particular land for around the year were considered under annual crops. Crops that completed life span within one year were regarded as annual crops (Martin and Leonard, 1953). The major annual crops reported in the region were pineapple, sugarcane, banana, papaya, betel leaf, ginger and turmeric. The coverage of annual crops varied from zero to 1,040 ha accounted to only 0.60 % of the net cropped area (NCA) in the region. The coverage was exclusively poor compared to those of the other crops due to the mal-adjustment with the land type and climatic conditions. The annual erratic and uneven distribution of rainfall is responsible for the varying intensities of flood from the natural to the extreme (flash flood in March-April). At a glance, the region possesses 57% single cropped area (SCA), 37% double cropped area (DCA), 6% triple cropped area (TCA). All the upazilas were dominated by SCA followed by DCA except three upazilas (Table 1). These type of cropping patterns are due to the availability of adequate water or excess water that does not permit cultivation of more crops in this region. Another cause may be conservativeness of absentee landowner. Mean cropping intensity of Sylhet region was 148%. According to BBS cropping intensity of Sylhet agricultural region is almost stagnant at around 150% for last few decades and much lower than the national average 192%. The area that could not be defined under SCA, DCA, TCA or QCA was considered as others whose coverage is less than 1% of the NCA. An overwhelming majority of single or double cropping pattern with exclusive rice due to land type and class along with the environmental and climatic factors that is unsuitable for non-rice crops (FAO, 1988).

Cropping patterns of Sylhet

In total 87 cropping patterns were observed in Sylhet region of which eight cropping patterns with exclusive rice crop covers over 90% of the NCA. There were 21 cropping patterns with exclusive non-rice crops covering over 2% of the NCA. Rest of the NCA i.e. around 8% area is covered by 58 rice - non-rice cropping patterns (Appendix 1).

Rice and non-rice crops at a glance

Table 2 presents eight cropping patterns where rice is the only crop round the year. It comprises 90.24% of the NCA in the region. Among them, single rice, double rice and triple rice areas are 56%, 28% and 2%, respectively. It reflects the unparallel dominance of rice in the cropping systems in Sylhet region. According to FAO (1988), modern and local rice varieties are the main crop in medium lowland and lowland in this region. In case of individual pattern single Boro i.e. Boro−Fallow−Fallow has the highest coverage (39.64%) and was recorded in 36 upazilas out of 38 upazilas. The second dominant pattern Boro-Fallow-T. Aman occupied 15.74% of NCA which was reported in 37 upazilas. Single T. Aman i.e. Fallow-Fallow-T. Aman covered third highest area (15.29%) with its existence in only 30 upazilas. Another important pattern Fallow-Aus-T. Aman found in 29 upazilas with the fourth position (12.62%) in respect of area coverage. Thus, the overwhelming majority (90.24%) is under exclusive rice systems. The dominance of exclusive rice-based cropping systems is due to lion share of land under medium and lowland ecosystems where recession of floodwater usually delayed. This situation is also worsened by high rainfall. Ultimately, soils of this region remain wet most of the time due to the cumulative effect of these factors. In this circumstance, soils of this region are more suitable for wetland crops than for dryland crops in Kharif season. The delayed recession of floodwater tends to delay the establishment of dryland Rabi crops until after the optimum date (FAO, 1988). Farmers of Tripura state of India have been following rice-rice systems from centuries in India due to food habit and agro-climatic situations (Anup *et al.*, 2015).

Table 1. Land use of different upazilas in Sylhet region (area in hectare), 2014-15.

	Upazila	Area of upazila	Annual crop	SCA	DCA	TCA	QCA	Other	NCA	C.I. (%)
01	Ajmiriganj	22400	0	10850	4550	0	0	100	15500	130
02	Bahubal	30100	550	5900	8100	1800	0	100	16450	172
03	Baniachang	48246	0	22960	14320	50	0	170	37500	139
04	Chunarughat	42696	310	460	13500	8160	0	180	22610	233
05	Habiganj	25139	180	4000	9010	6400	0	140	19730	211
06	Lakhai	19042	10	8360	6815	205	0	120	15510	147
07	Madhabpur	22427	140	0	11070	4800	0	130	16140	229
08	Nabiganj	30262	10	18820	5795	200	0	185	25010	125
09	Barlekha	44905	450	5215	5225	655	0	105	11650	157
10	Juri	18630	70	3550	5695	1140	0	115	10570	176
11	Kamalganj	48526	620	1850	13070	2390	0	140	18070	200
12	Kulaura	54500	70	12000	7030	3220	0	100	22420	160
13	Maulvibazar	34419	60	14700	10350	360	0	90	25560	143
14	Rajnagar	33815	100	8010	11870	160	0	160	20300	161
15	Sreemangal	45093	450	3600	13030	1710	0	110	18900	188
16	Biswambarpur	24900	150	8000	8630	175	0	95	17050	153
17	Chhatak	44067	10	16530	3300	0	0	70	19910	117
18	Dharampasha	53123	100	30910	3750	550	0	190	35500	114
19	Derai	42093	0	28470	2250	0	0	80	30800	107
20	Dowarabazar	28492	70	13615	7700	1055	0	130	22570	144
21	Jagannathpur	37591	80	24600	2230	550	0	70	27530	112
22	Jamalganj	30938	10	21320	4280	0	0	100	25710	117
23	Sulla	26085	0	17150	6020	0	0	130	23300	126
24	Sunamganj South	30317	10	21000	2090	0	0	110	23210	109
25	Sunamganj	29083	10	10500	7430	930	0	40	18910	149
26	Tahirpur	31425	70	14710	7720	300	0	120	22920	136
27	Balaganj	37592	0	13900	12500	1100	0	150	27650	153
28	Beanibazar	25072	0	9300	4300	200	0	150	13950	134
29	Biswanath	21450	0	7300	7800	1300	0	150	16550	163
30	Companiganj	27803	10	12235	5575	785	0	105	18710	138
31	Fenchuganj	11480	0	5400	2750	200	0	150	8500	138
32	Goainghat	48273	10	15000	6800	1850	0	150	23810	144
33	Golapganj	27355	10	4900	11500	200	0	100	16710	172
34	Jaintapur	17883	1040	7010	5665	650	0	125	14490	148
35	Zakiganj	26955	10	13660	5480	520	0	140	19810	133
36	Kanaighat	41225	10	11745	10110	1200	0	145	23210	154
37	Surma	19449	0	6400	8500	0	0	150	15050	157
38	Sylhet	30570	10	3500	7140	950	0	110	11710	178
	Sylhet region	-	4630	437430	282950	43765	0	4705	773480	148

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

	Cropping pattern	Area (ha)	% of NCA	Frequency (no. of upazila)
1	Boro−Fallow−Fallow	304800	39.64	36
2	Boro −Fallow− T. Aman	121020	15.74	37
3	Fallow −Fallow− T. Aman	117560	15.29	30
4	Fallow−Aus− T. Aman	97055	12.62	29
5	Boro−B.Aman	23830	3.10	11
6	Boro−Aus− T. Aman	17840	2.32	12
7	Fallow− B.Aman	10140	1.32	15
8	Boro−Aus−Fallow	1600	0.21	2
	Total	693845	90.24	-

In the current investigation, 21 cropping patterns were identified that was free from rice (Table 3). The aggregate of 21 patterns has had only 2.44% of NCA. In critical comparison, it is clear that exclusive rice area is about 37 folds of the exclusive non-rice area. Among these 21 patterns, vegetable production system has the highest coverage that practised on or around the homestead area. Very limited lands are available for Rabi crops cultivation in this region (FAO, 1988). Cropping pattern diversification cannot be a risk minimization strategy in the Tripura state of India even though it clearly helps farmers to raise their farm income (Mandal and Bezbaruah, 2013). Anup *et al.* (2015) reported that about 15-20% land under different vegetables like colocasia, okra, amaranthus, brinjal, cucurbits, etc are grown in during rainy season and potato, sweet gourd, cole crops, leafy vegetables etc are grown during winter season on medium upland adjacent to rice fields in the Indian state of Tripura.

Boro/*Haor* ecosystem

Deepwater rice ecosystem

Deepwater is a special type of ecosystem in the country. In the context of Sylhet region, this ecosystem represents a considerable portion. Table 4 presents the cropping patterns under deep water ecosystem. Among the listed 13 patterns Boro−B. Aman cropping pattern covers the largest area of 23,830 ha which represents 3.08% of the region's NCA. This pattern is distributed over 11 upazilas out of 38. The second highest Fallow-B. Aman cropping pattern covers 10,140 hectares and distributed over 15 upazilas. The first two patterns jointly covered 4.39% NCA which is more than four-fifths of the total deep-water rice area in the region. The water level of this ecosystem ranges between 150 and 400 cm, and water usually remains 3-4 months. Special rice varieties known as 'floating rice' are planted in these areas. In past Bangladesh had a land coverage of 3 million hectares for deepwater rice (Jackson *et al.*, 1972). In course of time, the continuous effort on modern agriculture shifted DWR area mainly to modern Boro. Now the area under deepwater rice in Bangladesh is reduced to 0.4 million hectares (Nasim *et al.*, 2017). Though this cropping system is less productive than other modern cropping systems, the specific fragile ecosystem still struggling because of no other alternatives.

Vegetables and spices crops

Fifty-one cropping patterns were identified for vegetables and spices crops covering an area of 60,810 ha which represents 7.86% of the NCA in the region (Table 6). Potato and other vegetables of Rabi, Kharif-I and Kharif-II; Spices

Table 3. Cropping patterns with exclusive non-rice in Sylhet region, 2014-15.

	Cropping pattern	Area (ha)	% of NCA	Frequency (no. of upazila)
01	Vegetab−Vegetab−Fallow	5890	0.76	19
02	Vegetab−Vegetab−Vegetab	5395	0.70	16
03	Vegetab−Fallow−Fallow	5370	0.69	14
04	Chilli−Fallow−Fallow	735	0.10	10
05	Coriander−Fallow−Fallow	265	0.03	7
06	Fallow−Fallow−Blackgram	200	0.03	3
07	S.Potato−Fallow−Fallow	180	0.02	4
08	Potato−Jute−Fallow	150	0.02	1
09	Groundnut−Fallow−Fallow	115	0.01	4
10	Mustard−Fallow−Fallow	100	0.01	2
11	Vegetab−Fallow−Blackgram	70	0.01	2
12	Coriander−Vegetab−Fallow	60	0.01	3
13	Chilli−Vegetab−Fallow	55	0.01	5
14	Wheat−Vegetab−Vegetab	50	0.01	1
15-21	Other seven patterns (in Table 7)	85	0.01	1
	Total non-rice area	18720	2.44	

Table 4. Cropping patterns under deep water rice ecosystem in Sylhet region, 2014-15.

	Cropping pattern	Area (ha)	% of NCA	Frequency (no. of upazila)
01	Boro−B.Aman	23830	3.08	11
02	Fallow−B.Aman	10140	1.31	15
03	Mustard−B.Aman	2690	0.35	4
04	Wheat−B.Aman	435	0.06	3
05	Vegetab−B.Aman	200	0.03	1
06	Coriander−B.Aman	120	0.02	1
07	Blackgram−B.Aman	110	0.01	3
08	Chilli−B.Aman	80	0.01	1
09	Lentil−B.Aman	70	0.01	1
10	Potato−B.Aman	70	0.01	1
11	S.Potato−B.Aman	30	0.00	1
12	Grasspea−B.Aman	25	0.00	1
13	Onion−B.Aman	10	0.00	1
	Total DWR area	37810	4.89	

Table 5. Cropping patterns with pulses and oil-seed crops in Sylhet region, 2014-15.

	Cropping pattern	Area (ha)	% of NCA	Frequency (no. of upazila)
01	Mustard−B.Aman	2690	0.35	4
02	Groundnut−Fallow− T. Aman	1245	0.16	4
03	Mustard−Fallow− T. Aman	950	0.12	11
04	Vegetab−Groundnut− T. Aman	800	0.10	1
05	Mustard−Boro− T. Aman	560	0.07	4
06	Mustard−Aus− T. Aman	510	0.07	6
07	Mustard−Boro−Fallow	340	0.04	4
08	Fallow−Fallow−Blackgram	200	0.03	3
09	Mustard−Jute− T. Aman	200	0.03	1
10	Mustard−Aus−Fallow	140	0.02	4
11	Groundnut−Fallow−Fallow	115	0.01	4
12	Blackgram−B.Aman	110	0.01	3
13	Lentil−Jute− T. Aman	100	0.01	1
14	Mustard−Fallow−Fallow	100	0.01	2
15	Lentil−B.Aman	70	0.01	1
16	Vegetab−Fallow−Blackgram	70	0.01	2
17	Lentil−Aus− T. Aman	60	0.01	2
18-25	Other eight patterns (in Table 7)	130	0.02	
	Total pulses and oil-seed crops	8390	1.08	

(chilli, onion, garlic, coriander) are included in this list. The most contributing cropping pattern is Vegetable−Fallow−T. Aman covering 2% of NCA which distributed in 23 upazilas. The second one is Vegetable−Aus− T. Aman covering over 1.18% of NCA and it is available in 19 upazilas out of 38 upazilas. Vegetables like colocasia, okra, amaranthus, brinjal, cucurbits, etc are grown in medium upland adjacent to rice fields during the rainy season and potato, sweet gourd, cole crops, leafy vegetables etc are grown during the winter season in Tripura (Anup *et al.,* 2015).

Rare cropping patterns

In the present investigation, 26 cropping patterns have been identified as rare cropping patterns with a negligible area (5-30 ha) coverage with seldom existence (Table 7). These are location specific system and are limited in one or two upazilas of the region. Total area coverage of the 26 patterns is only 0.048% of NCA. Among

Table 6. Cropping patterns with vegetables and spices crops in Sylhet region, 2014-15.

	Cropping pattern	Area (ha)	% of NCA	Frequency (no. of upazila)
01	Vegetab−Fallow− T. Aman	15495	2.00	23
02	Vegetab−Aus− T. Aman	9130	1.18	19
03	Vegetab−Vegetab−Fallow	5890	0.76	19
04	Vegetab−Vegetab− T. Aman	5780	0.75	13
05	Vegetab−Vegetab−Vegetab	5395	0.70	16
06	Vegetab−Fallow−Fallow	5370	0.69	14
07	Fallow−Vegetab− T. Aman	2470	0.32	9
08	Potato−Aus− T. Aman	2170	0.28	11
09	Vegetab−Aus−Fallow	1980	0.26	4
10	Potato−Fallow− T. Aman	1570	0.20	15
11	Vegetab−Groundnut− T. Aman	800	0.10	1
12	Chilli−Fallow−Fallow	735	0.10	10
13	Chilli−Fallow− T. Aman	500	0.06	8
14	S.Potato−Fallow− T. Aman	475	0.06	10
15	Potato−Vegetab− T. Aman	380	0.05	3
16	Chilli−Aus− T. Aman	300	0.04	6
17	Coriander−Fallow− T. Aman	275	0.04	6
18	Coriander−Fallow−Fallow	265	0.03	7
19	Chilli−Aus−Fallow	240	0.03	2
20	Vegetab−B.Aman	200	0.03	1
21	S.Potato−Fallow−Fallow	180	0.02	4
22	Potato−Jute−Fallow	150	0.02	1
23	Potato−Jute− T. Aman	150	0.02	1
24	Coriander−B.Aman	120	0.02	1
25	Potato−Boro−Fallow	100	0.01	1
26	Chilli−B.Aman	80	0.01	1
27	Potato−B.Aman	70	0.01	1
28	Vegetab−Fallow−Blackgram	70	0.01	2
29	Coriander−Vegetab−Fallow	60	0.01	3
30	Chilli−Vegetab−Fallow	55	0.01	5
31	Potato−Aus−Fallow	50	0.01	1
32	Wheat−Vegetab−Vegetab	50	0.01	1
33	Wheat−Vegetab− T. Aman	40	0.01	2
34-51	Other 18 patterns (in Table 7)	215	0.03	-
	Total vegetab and spices crops	60810	7.86	

these, the top three patterns viz Onion−Aus− T. Aman, Sweet potato−B.Aman and Wheat−Jute−Fallow were holding the same area i.e. 30 ha for each in Kamalganj, Biswambarpur, Lakhai and Tahirpur. The smallest area was recorded for nine cropping patterns whose coverage was only five hectares for each.

Most dominant cropping pattern

Boro−Fallow−Fallow was the most dominant cropping pattern in Sylhet region. It covers 39.64% of NCA in the region and is available in 36 upazilas out of 38 upazilas (Table 8). The highest area under this cropping was recorded 29,500 ha in Dharampasha upazila which represents 9.68% of the total Boro−Fallow−Fallow area of the region and the lowest covered area was found in Kamalganj upazila. This pattern is frequent and concurrently experienced by early flash at in April and cold injury at reproductive stage. Diversified cropping pattern may be a resort for the farmer as a coping strategy with flood-related risk (Mandal and Bezbaruah, 2013) but scope of diversification is limited due to situational, environmental and climatic condition (FAO, 1988). Farmers of eastern India remained confined to their traditionally perceived

Table 7. Rare cropping patterns covering non-significant area in Sylhet region, 2014-15.

	Cropping pattern	Area (ha)	% of NCA	Frequency	Upazila
01	Onion−Aus− T. Aman	30	0.004	2	Kamalganj+Biswambarpur
02	S.Potato−B.Aman	30	0.004	1	Lakhai
03	Wheat−Jute−Fallow	30	0.004	1	Tahirpur
04	Grasspea−B.Aman	25	0.003	1	Madabpur
05	Boro−Fallow−Blackgram	20	0.003	2	Dowarabazar+Companiganj
06	Lentil−Vegetab−Vegetab	20	0.003	1	Rajnagar
07	Maize−Fallow− T. Aman	20	0.003	2	Biswambarpur+Jagannathpur
08	Potato−Sesame−Aus	20	0.003	1	Barlekha
09	Garlic−Aus− T. Aman	15	0.002	1	Biswambarpur
10	Grasspea−Fallow− T. Aman	15	0.002	2	Barlekha+Rajnagar
11	Potato−Sesame− T. Aman	15	0.002	2	Barlekha+Kamalganj
12	Garlic−Jute−Fallow	10	0.001	1	Golapganj
13	Onion−B.Aman	10	0.001	1	Lakhai
14	Onion−Jute−Fallow	10	0.001	1	Golapganj
15	Onion−Jute− T. Aman	10	0.001	1	Lakhai
16	Potato−Mungbean− T. Aman	10	0.001	1	Kamalganj
17	W.Melon−Aus− T. Aman	10	0.001	1	Kamalganj
18	Chilli−Vegetab− T. Aman	5	0.001	1	Companiganj
19	Garlic−Fallow−Fallow	5	0.001	1	Dowarabazar
20	Garlic−Fallow− T. Aman	5	0.001	1	Dowarabazar
21	Garlic−Vegetab−Vegetab	5	0.001	1	Dowarabazar
22	Lentil−Fallow− T. Aman	5	0.001	1	Barlekha
23	Maize−Aus−Fallow	5	0.001	1	Companiganj
24	Onion−Fallow− T. Aman	5	0.001	1	Dowarabazar
25	Onion−Vegtab−Vegetab	5	0.001	1	Dowarabazar
26	Vegetab−Jute− T. Aman	5	0.001	1	Dowarabazar
	Total	345	0.048		-

farming system i.e. low productive mono-cropped farming (Sasmal, 2015). 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).

Second dominant cropping pattern

The second dominant cropping pattern in Sylhet region is Boro−Fallow−T. Aman. It belongs to 15.74% of NCA of the region and spread over 37 upazilas (Table 9). Sunamganj sadar upazila of Sunamganj district holds the highest area of 7,000 ha under the Boro-Fallow- T. Aman cropping pattern. 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).

Third dominant cropping pattern

Single T. Aman cropping pattern holds the third largest area coverage 117,560 hectares in Sylhet region. This area is 15.29% of NCA in the region and is distributed over 30 upazilas. Maulvibazar upazila occupied highest area of 8,700 ha for single T. Aman pattern which stands for 7.40% areaof this pattern in the region and lowest area (170 ha) for the same pattern was observed in Sreemangal upazila (Table 10). It was observed that the single T. Aman was the third dominant cropping pattern in Bangladesh covering 5.09 lac ha (6% of NCA in the country) with its distribution in 162 upazilas of 36 districts (Nasim *et al*., 2017).

Table 8. Distribution of the most dominant Boro−Fallow−Fallow cropping patterns in Sylhet region, 2014-15.

	Upazila	Area (ha)	% of upazila NCA	% of the pattern in region
01	Dharampasha	29500	83.10	9.68
02	Derai	27100	87.99	8.89
03	Jamalganj	21000	81.68	6.89
04	Sunamganj South	19900	85.74	6.53
05	Baniachang	19200	51.20	6.30
06	Jagannathpur	18600	67.56	6.10
07	Sulla	16200	69.53	5.31
08	Tahirpur	14000	61.08	4.59
09	Nabiganj	11000	43.98	3.61
10	Chhatak	10000	50.23	3.28
11	Ajmiriganj	9100	58.71	2.99
12	Dowarabazar	8800	38.99	2.89
13	Sunamganj	8500	44.95	2.79
14	Balaganj	8200	29.66	2.69
15	Biswambarpur	8000	46.92	2.62
16	Lakhai	7600	49.00	2.49
17	Companiganj	7500	40.09	2.46
18	Maulvibazar	6000	23.47	1.97
19	Rajnagar	6000	29.56	1.97
20	Bahubal	5000	30.40	1.64
21	Jaintapur	4500	31.06	1.48
22	Habiganj	4000	20.27	1.31
23	Goainghat	4000	16.80	1.31
24	Kulaura	3600	16.06	1.18
25	Fenchuganj	3600	42.35	1.18
26	Biswanath	3500	21.15	1.15
27	Sreemangal	3400	17.99	1.12
28	Baanibazar	3400	24.37	1.12
29	Surma	2500	16.61	0.82
30	Golapganj	2300	13.76	0.75
31	Barlekha	2100	18.03	0.69
32	Sylhet	1750	14.94	0.57
33	Juri	1700	16.08	0.56
34	Zakiganj	1700	8.58	0.56
35	Kanaighat	1500	6.46	0.49
36	Kamalganj	50	0.28	0.02
	Sylhet region	304800	39.14	100.00

Fourth dominant cropping pattern

Fourth dominant cropping pattern Fallow−Aus− T. Aman has occupied 97,055 hectares representing 12.62% share of NCA in Sylhet region (Table 11). This pattern is distributed over 29 upazilas where Chunarughat ranked in top position. This upazila has 10,500 ha area under Fallow−Aus−T. Aman which is only 46.44% of upazila NCA. Kamalganj upazila ranks in the second position with 8,800 ha area for this pattern, however, this upazila has allotted the biggest share (48.70%) of its NCA. Aus–T. Aman pattern is almost common on high land and medium highland floodplain ridges soils (FAO, 1988).

Fifth dominant cropping pattern

Fifth dominant cropping pattern Boro−B. Aman had been covering 23,830 ha representing 3.10% share of NCA in Sylhet region (Table 12). This

Table 9. Distribution of the 2nd dominant Boro−Fallow− T. Aman cropping pattern in Sylhet region, 2014-15.

	Upazila	Area (ha)	% of upazila NCA	% of the pattern in region
01	Sunamganj	7000	37.02	5.78
02	Tahirpur	6000	26.18	4.96
03	Balaganj	6000	21.70	4.96
04	Rajnagar	5400	26.60	4.46
05	Sulla	5400	23.18	4.46
06	Sreemangal	5300	28.04	4.38
07	Biswambarpur	5000	29.33	4.13
08	Companiganj	5000	26.72	4.13
09	Dowarabazar	4900	21.71	4.05
10	Golapganj	4500	26.93	3.72
11	Maulvibazar	4200	16.43	3.47
12	Madhabpur	4000	24.78	3.31
13	Jamalganj	3900	15.17	3.22
14	Kamalganj	3600	19.92	2.97
15	Surma	3500	23.26	2.89
16	Baniachang	3000	8.00	2.48
17	Chunarughat	3000	13.27	2.48
18	Juri	3000	28.38	2.48
19	Biswanath	3000	18.13	2.48
20	Goainghat	3000	12.60	2.48
21	Sylhet	2700	23.06	2.23
22	Habiganj	2500	12.67	2.07
23	Dharampasha	2500	7.04	2.07
24	Kanaighat	2500	10.77	2.07
25	Baanibazar	2400	17.20	1.98
26	Chhatak	2200	11.05	1.82
27	Derai	2200	7.14	1.82
28	Jagannathpur	2100	7.63	1.74
29	Ajmiriganj	2050	13.23	1.69
30	Barlekha	2000	17.17	1.65
31	Nabiganj	1900	7.60	1.57
32	Sunamganj South	1900	8.19	1.57
33	Lakhai	1620	10.44	1.34
34	Jaintapur	1500	10.35	1.24
35	Kulaura	1150	5.13	0.95
36	Bahubal	1000	6.08	0.83
37	Fenchuganj	100	1.18	0.08
	Sylhet region	121020	15.74	100.00

pattern is distributed over 11 upazilas where Baniachang ranked in top position. This upazila had 9,300 ha area for Boro−B. Aman pattern which is 24.80% of upazila NCA. Companiganj and Kanaighat upazila had only nominal area coverage for this system.

Sixth dominant cropping pattern

Sixth dominant cropping pattern Boro− Aus- T. Aman had been covering 17,840 hectares representing 2.32% share of NCA in Sylhet region (Table 13) and distributed over 12 upazilas. Chunarughat ranked in top position with 5,500 ha area which is 24.33% of upazila NCA.

Crop diversity and cropping intensity

Bio-diversity plays important role in a good production of food, fodder, fuel, medicinal plants, aromatic plants and non-timber produce along with ecosystem service and climate regulation service (Manju and Sharma, 2016). The higher number of available crops under cultivation in an area dictates its higher diversity. The number of cropping patterns is also a gross indicator of crop diversity. A total of 87 cropping patterns were identified in the whole

Table 10. Distribution of the 3rd dominant Fallow−Fallow− T. Aman cropping pattern in Sylhet region, 2014-15.

	Upazila	Area (ha)	% of upazila NCA	% of the pattern in region
01	Maulvibazar	8700	34.04	7.40
02	Kanaighat	8500	36.62	7.23
03	Kulaura	8400	37.47	7.15
04	Jaintapur	8300	57.28	7.06
05	Goainghat	8000	33.60	6.81
06	Nabiganj	7780	31.11	6.62
07	Chhatak	6000	35.19	5.10
08	Jagannathpur	6000	26.58	5.10
09	Balaganj	5700	20.61	4.85
10	Beanibazar	5000	35.84	4.25
11	Zakiganj	5000	25.24	4.25
12	Dowarabazar	4700	15.26	4.00
13	Companiganj	4500	24.05	3.83
14	Biswanath	3800	22.96	3.23
15	Baniachang	3500	9.33	2.98
16	Surma	3500	23.26	2.98
17	Barlekha	2700	23.18	2.30
18	Golapganj	2400	14.36	2.04
19	Sunamganj	2000	10.58	1.70
20	Kamalganj	1800	9.96	1.53
21	Fenchuganj	1800	21.18	1.53
22	Sylhet	1750	14.94	1.49
23	Juri	1650	15.61	1.40
24	Rajnagar	1650	8.13	1.40
25	Dharampasha	1100	5.52	0.94
26	Sunamganj South	1100	4.74	0.94
27	Derai	1000	2.82	0.85
28	Bahubal	600	3.65	0.51
29	Chunarughat	460	2.03	0.39
30	Sreemangal	170	0.90	0.14
	Sylhet region	117560	15.29	100.00

area of Sylhet region under this investigation. The highest number of cropping patterns was 34 identified in Dowarabazar upazila and that was 32 in Barlekha and 25 in Companiganj (Table 14). The lowest number of cropping patterns was identified 4 in Sulla followed by 6 in Derai. Higher number of cropping patterns is generally related to higher crop diversity indices. The upazilas having the lower number of cropping patterns were related to either low land or waterlogging or both. Sulla and Derai upazila face both limitations. The lowest diversity index for cropping pattern was recorded 0.219 in Derai followed by 0.255 in Sunamganj south. In a study, Shahidullah *et al*. (2006) also found the lowest values for all the diversity and intensity parameters in the salt-affected area of greater Noakhali. The highest value of diversity index for cropping pattern was found 0.844 in Sylhet sadar upazila that was followed by 0.842 in Juri upazila. Cropping pattern diversification clearly helps farmers to raise their farm income and has significant implications for making farming a remunerative profession in the Tripura state of India (Mandal and Bezbaruah, 2013). Diversified cropping pattern is an important strategy to cope with risk and uncertainty associated with agriculture due to unusual climatic and biological factors (Shiyani and Pandya, 1998). Since the lowest CDI was reported 0.313 in Derai followed by 0.367 in Sunamganj south. The highest value of CDI was observed 0.923 in Madhabpur followed by 0.915 in Habiganj sadar upazila.

Table 11. Distribution of the 4th dominant Fallow−Aus− T. Aman cropping pattern in Sylhet region, 2014-15.

	Upazila	Area (ha)	% of upazila NCA	% of the pattern in region
01	Chunarughat	10500	46.44	10.82
02	Kamalganj	8800	48.70	9.07
03	Sreemangal	7700	40.74	7.93
04	Bahubal	6000	36.47	6.18
05	Kulaura	5600	24.98	5.77
06	Habiganj	5000	25.34	5.15
07	Kanaighat	5000	21.54	5.15
08	Rajnagar	4700	23.15	4.84
09	Jaintapur	4500	31.06	4.64
10	Golapganj	4200	25.13	4.33
11	Maulvibazar	3700	14.48	3.81
12	Biswanath	3600	21.75	3.71
13	Goainghat	3500	14.70	3.61
14	Zakiganj	3500	17.67	3.61
15	Surma	3000	19.93	3.09
16	Balaganj	2750	9.95	2.83
17	Sylhet	2500	21.35	2.58
18	Dowarabazar	2200	9.75	2.27
19	Barlekha	2100	18.03	2.16
20	Fenchuganj	2100	24.71	2.16
21	Madhabpur	1400	8.67	1.44
22	Juri	1300	12.30	1.34
23	Biswambarpur	1100	6.45	1.13
24	Beanibazar	900	6.45	0.93
25	Lakhai	525	3.38	0.54
26	Nabiganj	400	1.60	0.41
27	Sunamganj	230	1.22	0.24
28	Chhatak	200	1.00	0.21
29	Companiganj	50	0.27	0.05
	Sylhet region	97055	12.62	100.00

Table 12. Distribution of the 5th dominant Boro−B. Aman cropping pattern in Sylhet region, 2014-15.

	Upazila	Area (ha)	% of upazila NCA	% of the pattern in region
01	Baniachang	9300	24.80	39.03
02	Madhabpur	3800	23.54	15.95
03	Nabiganj	3300	13.19	13.85
04	Ajmiriganj	2200	14.19	9.23
05	Lakhai	2000	12.89	8.39
06	Rajnagar	1000	4.93	4.20
07	Balaganj	900	3.25	3.78
08	Habiganj	800	4.05	3.36
09	Bahubal	500	3.04	2.10
10	Companiganj	20	0.11	0.08
11	Kanaighat	10	0.04	0.04
	Sylhet region	23830	3.10	100.00

Table 13. Distribution of the 6th dominant Boro−Aus− T. Aman cropping pattern in Sylhet region, 2014-15.

	Upazila	Area (ha)	% of upazila NCA	% of the pattern in region
01	Chunarughat	5500	24.33	30.83
02	Habiganj	4500	22.81	25.22
03	Madhabpur	3400	21.07	19.06
04	Kulaura	1600	7.14	8.97
05	Bahubal	700	4.26	3.92
06	Juri	500	4.73	2.80
07	Kamalganj	490	2.71	2.75
08	Sreemangal	350	1.85	1.96
09	Biswanath	300	1.81	1.68
10	Jaintapur	300	2.07	1.68
11	Nabiganj	100	0.40	0.56
12	Maulvibazar	100	0.39	0.56
	Sylhet region	17840	2.32	100.00

Hajjar *et al.* (2008) reported that genetic diversity of crop play an important role in enhancing the provision many services concurrently in multifunctional and sustainable agriculture through positive interactions or complementary functions. The range of cropping intensity values was recorded 107-233%. The maximum value was for Chunarughat upazila of Habiganj district and minimum for Derai upazila of Sunamganj district. As a whole, the CDI of Sylhet region was calculated 0.877 and the average cropping intensity at the regional level was 148%. In a simultaneous, the investigators identified 316 cropping patterns for whole Bangladesh; where the CDI value was 0.952 at the national level and the national average of cropping intensity was 200% (Nasim *et al.*, 2017). Diversified cropping pattern may enable the farmers compulsion of extracting the maximum possible utilization of land in the flood-free period (Mandal and Bezbaruah, 2013). Singh and Sidhu (2006) reported that a number of crops like sun hemp, cluster beans and sorghum had almost disappeared and there is reduced varietal diversification in rice and wheat. Crop diversification index of the wheat-rice system has decreased from 0.75 in 1975-76 to 0.58 in 2006-07 in Punjab though diversification forces pests to continuously relocate and re-colonize their preferred host plants from year to year (Tscharntke *et al.*, 2005, 2007).

CONCLUSION

Agricultural land is decreasing due to many factors and landscapes of Sylhet agricultural region are heterogeneous with the dominance of lowland. The cropping intensity of the Sylhet region was far lower (148%) than the national average (192%). The dominant cropping patterns were Boro-Fallow-Fallow, Boro-Fallow-T. Aman, Fallow-Fallow-T. Aman, Fallow-Aus-T Aman, Boro-B.Aman, Boro-Aus-T. Aman and Fallow-B.Aman in the region. Thus, overwhelming majority cropping patterns are consists of absolutely rice crop. The non-rice based cropping patterns were very few or area under those cropping patterns were much lower which are challenges to food and nutritional security for the people of the Sylhet region. Cropping patterns and crop diversity are also not up to the expected level. Based on the findings of the study, the following recommendations were made.

- Initiative has to be taken to increase the 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. Vegetable cultivation through the raised bed or floating method also needs to adopt in the suitable wetland area of this region.

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

	Upazila	No. of identified pattern	No. of crop	Diversity index for cropping pattern	Crop diversity index (CDI)	C.I. (%)
01	Ajmiriganj	07	06	0.607	0.741	130
02	Bahubal	14	08	0.746	0.861	172
03	Baniachang	11	09	0.659	0.784	139
04	Chunarughat	07	06	0.693	0.876	233
05	Habiganj	15	14	0.817	0.915	211
06	Lakhai	21	16	0.711	0.843	147
07	Madhabpur	15	12	0.823	0.923	229
08	Nabiganj	17	12	0.686	0.780	125
09	Barlekha	32	16	0.836	0.910	157
10	Juri	16	10	0.842	0.913	176
11	Kamalganj	22	18	0.688	0.853	200
12	Kulaura	09	07	0.779	0.873	160
13	Maulvibazar	09	06	0.775	0.866	143
14	Rajnagar	16	12	0.776	0.862	161
15	Sreemangal	13	10	0.706	0.847	188
16	Biswambarpur	20	20	0.676	0.819	153
17	Chhatak	08	05	0.642	0.724	117
18	Dharampasha	14	12	0.298	0.446	114
19	Derai	06	05	0.219	0.313	107
20	Dowarabazar	34	25	0.745	0.846	144
21	Jagannathpur	11	11	0.486	0.585	112
22	Jamalganj	09	09	0.309	0.469	117
23	Sulla	04	03	0.460	0.623	126
24	Sunamganj South	07	06	0.255	0.367	109
25	Sunamganj	09	08	0.647	0.682	149
26	Tahirpur	12	11	0.552	0.719	136
27	Balaganj	10	07	0.806	0.889	153
28	Beanibazar	08	06	0.770	0.848	134
29	Biswanath	08	06	0.814	0.894	163
30	Companiganj	25	12	0.708	0.808	138
31	Fenchuganj	08	07	0.712	0.806	138
32	Goainghat	08	08	0.802	0.883	144
33	Golapganj	15	13	0.811	0.884	172
34	Jaintapur	15	10	0.763	0.873	148
35	Zakiganj	11	09	0.716	0.806	133
36	Kanaighat	13	10	0.787	0.878	154
37	Surma	08	07	0.814	0.879	157
38	Sylhetsadar	13	08	0.844	0.912	178
	Sylhet region	87	29	0.778	0.877	148

- Overwhelming majority cropping patterns are consist of either single rice/double rice/triple rice crop. To enhancing the existing productivity of these rice-cropping patterns, adoption of high yielding varieties along with the integration of other suitable crops, livestock, fisheries and management technologies for the judicious and efficient use of on-farm resources are essential to sustain the productivity, soil health and enhance the carrying capacity of the ecosystem.
- The upazilas having higher cropping pattern index might be studied in depth to extrapolate potential cropping patterns to other upazilas of similar environments.
- Research and development programmes can be taken in hand to diversify the single and double-cropped cropping pattern with the inclusion of appropriate new crops, crop varieties and non-crop species.

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

	Cropping pattern	Area (ha)		Cropping pattern	Area (ha)
01	Boro−Fallow−Fallow	304800	32	Wheat−Fallow− T. Aman	325
02	Boro−Fallow− T. Aman	121020	33	Chilli−Aus− T. Aman	300
03	Fallow−Fallow− T. Aman	117560	34	Coriander−Fallow− T. Aman	275
04	Fallow−Aus− T. Aman	97055	35	Coriander−Fallow−Fallow	265
05	Boro−B.Aman	23830	36	Chilli−Aus−Fallow	240
06	Boro−Aus− T. Aman	17840	37	Fallow−Fallow−Blackgram	200
07	Vegetab−Fallow− T. Aman	15495	38	Mustard−Jute− T. Aman	200
08	Fallow−B.Aman	10140	39	Vegetab−B.Aman	200
09	Vegetab−Aus− T. Aman	9130	40	S.Potato−Fallow−Fallow	180
10	Vegetab−Vegetab−Fallow	5890	41	W.Melon−Fallow− T. Aman	170
11	Vegetab−Vegetab− T. Aman	5780	42	Potato−Jute−Fallow	150
12	Vegetab−Vegetab−Vegetab	5395	43	Potato−Jute− T. Aman	150
13	Vegetab−Fallow−Fallow	5370	44	Wheat−Aus− T. Aman	150
14	Mustard−B.Aman	2690	45	Mustard−Aus−Fallow	140
15	Fallow−Vegetab− T. Aman	2470	46	Coriander−B.Aman	120
16	Potato−Aus− T. Aman	2170	47	Groundnut−Fallow−Fallow	115
17	Vegetab−Aus−Fallow	1980	48	Blackgram−B.Aman	110
18	Boro−Aus−Fallow	1600	49	Lentil−Jute− T. Aman	100
19	Potato−Fallow− T. Aman	1570	50	Mustard−Fallow−Fallow	100
20	Groundnut−Fallow− T. Aman	1245	51	Potato−Boro−Fallow	100
21	Mustard−Fallow− T. Aman	950	52	Chilli−B.Aman	80
22	Fallow−Jute− T. Aman	890	53	Lentil−B.Aman	70
23	Vegetab−Groundnut− T. Aman	800	54	Potato−B.Aman	70
24	Chilli−Fallow−Fallow	735	55	Vegetab−Fallow−Blackgram	70
25	Mustard−Boro− T. Aman	560	56	Coriander−Vegetab−Fallow	60
26	Mustard−Aus− T. Aman	510	57	Lentil−Aus− T. Aman	60
27	Chilli−Fallow− T. Aman	500	58	Chilli−Vegetab−Fallow	55
28	S.Potato−Fallow− T. Aman	475	59	Potato−Aus−Fallow	50
29	Wheat−B.Aman	435	60	Wheat−Vegetab−Vegetab	50
30	Potato−Vegetab− T. Aman	380	61	Wheat−Vegetab− T. Aman	40
31	Mustard−Boro−Fallow	340	62-87	Other 26 patterns (Table 7)	345