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Village-Level Studies on Rice-Based Cropping Systems in the Low-Lying Areas of Bangladesh

I. Cropping patterns and their distribution in *Haor* and *Bil* areas†

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Abstract: Research on rice-based cropping systems was carried out in two villages situated in the low-lying areas of Bangladesh; Jawar located on the fringe of a *haor* in Kishoreganj District and Taker Bhitee facing a *bil* in Mymensingh District.

Using the local land classification system, the entire village areas were classified into more detailed land units in order to analyze the relationship between toposequences and the distribution of cropping patterns. A plotwise observation of field crops grown in the *boro*, *aus* and *aman* seasons was conducted and seasonal variations in the water regime were observed from 1986 to 1988.

Fourteen major cropping patterns, of which 10 are rice-based, were found to exist in both villages almost identically. The performance of the existing cropping patterns was almost the same in the two villages and their distribution was found to be closely related to toposequences, and subsequently to water regime. *Aus*- and *aman*-rice-based cropping patterns were distributed in the *kandhilla jami* (high lands), while the single crop of *boro* rice was the predominant pattern over *shail jami*/*boro jami* (low lands) in Jawar. *Boro*-rice-based cropping patterns have tended to expand since the introduction of modern irrigation devices. A similar pattern of distribution was observed in Taker Bhitee. Overall, the research showed that the performance of cropping patterns was a result of villagers' adaptation to the given environment in the low-lying areas.
Key words: Bangladesh, *Boro* rice, Cropping pattern, Land classification, Toposequence, Water regime.

バングラデシュ低地におけるイネ基幹作付体系の村落レベルの研究　第1報　ハオールおよびビール地帯における作付様式とその分布：ムハマッド セリム*・安藤和雄*・内田晴夫**・田中耕司***（*京都大学農学部・**農林水産省農業工学研究所・***京都大学東南アジア研究センター）

要　旨：バングラデシュ低地に位置する2カ村でイネを基幹とする作付体系の調査を行った．一つはキショルゴンジ県の広大な低地，ハオール地帯縁辺部に位置するジョワール村で，もう一つはマイメンシン県に散在する凹地（ビール）に面するタカルビティ村である．

調査にあたっては，両村のトポシークェンスと作付様式の分布との関係を詳しく分析するために，村人による土地分類に依拠しつつ，村の全域を標高に応じて細かい土地単位に区分した．また，ボロ，アウス，アマンの3作期に栽培される作物の全筆調査を実施し，あわせて1986年から88年にかけて水文条件の季節変化を観察・測定した．

両村に共通して14タイプの作付様式が認められ，うち10タイプがイネ基幹の様式であった．作付様式の構成や分布は，両村で大きな違いは認められず，その分布はトポシークェンス，従って水文条件の季節変化に密接に関連して成立していることが明らかになった．ジョワール村では，アウスイネ基幹およびアマンイネ基幹の作付様式はカンダイラ・ジョミと呼ばれる高位部の土地に分布し，ボロイネ単作はシャイル・ジョミあるいはボロ・ジョミと呼ばれる低位部の土地での優占的な作付様式であった．ボロイネ基幹の作付様式は，浅管井戸などの近代的な灌漑方式の導入後，高位部低地や低位部高地に拡大している．作付様式の同様な分布パターンは，タカルビティ村でも認められた．以上より，現行の作付様式はバングラデシュ低地特有の条件に適合した，村人の環境への適応の結果であることが明らかにされた．
キーワード：作付様式，水文条件，土地分類，トポシークェンス，バングラデシュ，ボロイネ．

A predominant feature of the peasant sector in Bangladesh is the cultivation of food crops, mainly rice. Rice is grown under irrigated, rainfed or deep-water conditions in four dis-

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tinct rice-growing seasons, namely *aus*, transplant *aman*, broadcast *aman* and *boro*[1]. *Aus* rice is non-photosensitive and grown mainly by broadcasting under rainfed condition from March to August. *Aman* is photosensitive and grown either by transplanting or by broadcasting according to water conditions. It is broadcast in March/April or transplanted in July/August and harvested by November/December. *Boro* is grown by transplanting in the dry season mainly under irrigated condition from November/December to April/May.

In 1986/87, about 2.90 million ha of rice were planted with *aus*, 1.35 million ha with broadcast *aman*, 4.70 million ha with transplant *aman* and 1.65 million ha with *boro*[4]. This shows that out of a total cropped area of some 14 million ha 75% is cultivated with rice. Therefore, the cropping systems of the country are essentially rice-based[7]. According to Gomez and Zandstra[6], the manifestation of cropping patterns is highly environment-specific. Although the land in Bangladesh is generally flat, a slight difference in elevation becomes a determining factor in crop productivity and in the selection of cropping patterns. Cropping patterns, therefore, show a great variation from place to place due to the variation in topography, particularly in the depth of flooding. Komoguchi[8] concludes that crop cultivation, particularly that of rice in Bangladesh, is designed with close relation to seasonal fluctuations in the water regime. Satoh[10] also reveals that the dominance of deep-water rice in the southwestern lowlands and of *boro* rice in the northeastern lowlands is closely related to the water regime in both areas. As modernized measures or systems of water control have not been established so far in most of the low-lying areas, toposequence and subsequently the water condition play a vital role in the establishment of rice-based cropping patterns.

In the low-lying areas of the northeastern part of Bangladesh where swampy depressions like *haor*s and *bil*s are found, the winter rice, *boro*, is extensively grown. *Bil*s are depressions which never lose water even in the dry season. *Haor*s are vast saucer-shaped basins which are fully inundated and look like lakes during the rainy season but dry in the dry season. A *haor* may contain several *bil*s within its area. In these low-lying areas *boro* rice is the most important economic product not only for subsistence but also for commercial purposes[9].

Our research, therefore, was conducted with the general aim of understanding the role of rice-based cropping systems on the village economy and rural development. Research activities were focused, initially, on identifying the existing cropping patterns and clarifying their relationship to features of the natural environment such as its topography and water regime. This paper presents results of this first stage.

Research Methods

Research sites

Two villages, Jawar and Taker Bhitee, were selected as research sites. The location of the villages is shown in Fig. 1. Jawar is located on the western fringe of Hulia Haor, and this makes it subject to annual flooding in the rainy season. The village belongs to Tarail Upazila (*upazila* is a local administrative unit under a district), located 6 km to the east of Tarail and 18 km north of Kishoreganj, the capital of Kishoreganj District. Jawar village consists of three *mauza*s (cadastral units having definite boundaries), Biri Jawar, Chang Jawar and Ratanpur[3]. Taker Bhitee, situated

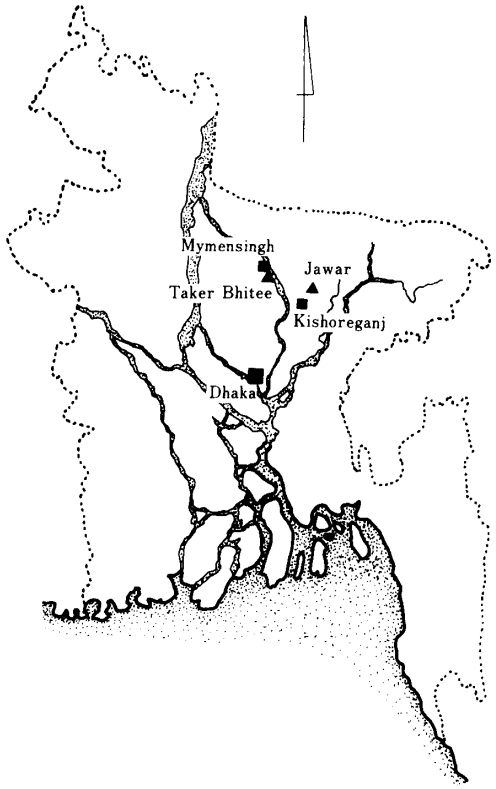

Fig. 1. Location of the two villages studied.

on the flood plain of the Old Brahmaputra River, faces a *bil* called Geramari, and most of the village area is submerged in the rainy season also. The village belongs to Ghagra Mauza of Mymensingh Sadar Upazila and is located about 7 km to the south of Mymensingh, the capital of Mymensingh District.

Survey methods

In both villages various types of intensive surveys were conducted ; a survey of all households, a monitoring survey of sample households, an in-field survey of sample plots, and a plotwise crop - coverage survey. The hydrologic conditions were also observed from 1986 to 1988 with the cooperation of the villagers. This report is based on the results obtained from the all-household and the plotwise crop-coverage surveys and the observation of hydrologic conditions.

In the all-household survey, information on all members of each household such as their age, sex, education, occupation and land holding etc. was recorded mainly by interviewing the householders themselves. A household unit was defined as a family whose members use a common cooking stove (*khana*)[2].

In the plotwies crop-coverage survey, each and every plot was observed in each cropping season of the calender year, namely *aman* in 1986, *boro* in 1986/87 and *aus* in 1987, and all the crops grown there were identified. The plotwise information on crop coverage thus obtained was arranged on the *mauza* maps and the area of cultivation of different crops and the coverage of cropping patterns were measured by tracing them by digitizer.

Seasonal changes in the movement of the water-front were observed every 15 days in order to identify the rise and recession of flooding, and front lines at each stage were drawn on the *mauza* maps. The water depth was measured every day from September 1986 to April 1988 at some selected points in the villages. In total 40 measurement points were installed in Jawar and 4 in Taker Bhitee, so that changes in the water depth of entire areas of the villages could be estimated.

Our work on land classification began with the collection of local concepts and local terms indicating topography and land use in both villages. Since the villagers' own criteria were closely related to land use, particularly to rice cultivation, their classifications were utilized as the foundation for our own land classification system. Based on this local classification, land units were further classified in more detail according to differences in elevation, using the results of water-front observations, and water depth measurements. Following the classification of land units thus obtained, the relationship between existing cropping patterns and the toposequences over the villages was analyzed.

Results and Discussion

General information on the two villages

The total number of households ammounted to 1334 in Jawar (with a population of 6924 as of August 1987), of which 32% were owner -farmer households and 54% were landless. The remaining 14% were engaged in non-agricultural occupations. The landless male householders were mainly agricultural labourers. Compared to Jawar, Taker Bhitee is a small village consisting of 65 households with a total population of 303. Out of the total householders 34% were owner farmers and 35% were landless farmers. The remaining 31% were engaged in non-agricultural occupations.

Both villages experience deep inundation by flood water every year during the rainy season which starts from May and lasts until September. Jawar occupies 941 ha of land, of which 770 ha is cultivated with various crops. Most of the village area except the homesteads and the higher reaches of cultivated land is inundated under normal flood conditions. The total area of Taker Bhitee is about 81 ha, of which 89% was found to be under cultivation. The rest of the land consists of homesteads, roads and *bil*. Land surrounding the *bil* is inundated in the rainy season.

Topography and water regime

The entire area of Jawar is separated into three major topographical units : levee, flood plain and backswamp. The levee on which the homesteads are located declines from the west to the southeast. On the north and east sides of the levee lies a flood plain. The eastern part of the flood plain is wholly submerged in the rainy season and is called Hulia Haor. On the southern side of the levee, there is a large backswamp which contains a number of *bil*s.

Taker Bhitee contains the same topographical units as Jawar. Homesteads are situated on

the natural levee and farm fields extend to the flood plain on the western side of the village. A big depression called Geramari Bil, around which farm fields are situated, is located in a backswamp on the western end of the village.

The annual rainfall from April 1987 to March 1988 in Jawar village was 2740 mm with bimodal peaks in July and September. Of the total rainfall about 75% was recorded from June to September. During the same one year period 2050 mm of rain fell in Taker Bhitee with a peak of 498 mm in July. About 75% of the total rainfall occurred from June to September also.

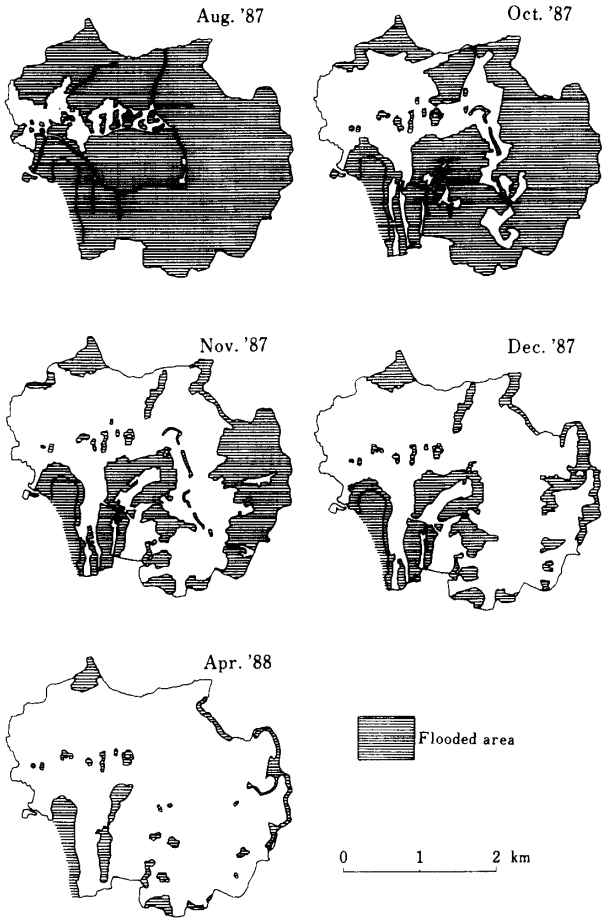

Fig. 2. Seasonal changes in the flooded areas of Jawar.

Due to the heavy rainfall beginning in May, flood water overflows the *bil*s and the inundation expands gradually from low lands to high lands in both villages. The depth as well as the duration of inundation varies from place to place depending on the topographic situation. At the peak of the flood, entire areas of the villages are usually flooded, with the exception of the higher parts of the high lands, homesteads and roads. The seasonal changes in flooded areas in Jawar are shown in Fig. 2. In September or October only the high lands begin to emerge as the flood water recedes. By the month of December the water recedes further, and this makes most of the farm lands in the low lands suitable for cultivation. Later on, each *bil* becomes separated and shrinks in area to a minimum in April. Such flood conditions as described above are a prominent factor controlling crop growing and the performance of cropping patterns in the villages.

The toposequences and changes in water-level from August 1987 to April 1988 in Jawar are illustrated in Fig. 3. There are 20 *bil*s of different sizes which are sporadically distributed all over the village. As the elevation of the land surface varies to a great extent, a wide variation in water levels is thus observed between high and low lands, from 0 to 7 m in different loations. The high lands are subject to shallow flooding with a short period of inundation. In contrast, water remains for longer periods in the lowest lands, particularly surrounding the *bil*s.

Land classification

The villagers of Jawar classify land into four major categories according to its utilization : *bari* (homestead), *bichra* (gardens and fields adjacent to *bari*), *kandhilla jami* (high land), and *shail jami*/*boro jami* (*boro* rice-growing land). The latter two are divided further into sub-categories according to their elevation, as

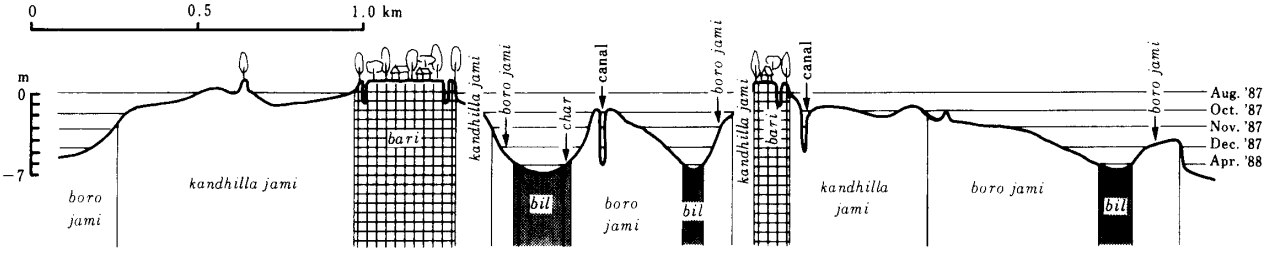

Fig. 3. Toposequences and changes in the water-level in Jawar.

Table 1. Local and our detailed classification of farm lands.

Local land classification of Jawar		Land unit (our classification)	Local land classification of Taker Bhitee		Land type*	Characteristics of land type
kandhilla jami	*uchu* (high)	H-H	*kandha*	*taner jami*	high	Above normal flood level
		H-L			medium high	Max. depth of flooding normally less than 91 cm
	majhari (medium)	M-H	*baiet*			
		M-L				
	nichu (low)	L-H	*nama*		medium low	Max. depth of flooding normally between 91 and 182 cm
		L-L				
shail jami or *boro jami*	*maath* or *khilla*	B-H	*biler korcha*	*bondhoker jami* or *biler jami*	low	Max. depth of flooding normally more than 182 cm
		B-H-L				
	petty	B-M	*biler majhra*		very low	Deeply flooded during monsoon, depth of water rising as high as 10m at maximum
		B-L	*biler nama*			
	char	*char*				

* After Brammer[5]. This classification is commonly used in Bangladesh for classifying land topography.

follows; *uchu* (high), *majhari* (medium) and *nichu* (low) types of *kandhilla jami*, and *maath* or *khilla* at the highest, *petty* in the middle, and *char* at the lowest in *shail/boro jami*.

On *bari* and *bichra* the villagers grow fruits such as bananas and various summer and winter vegetables with short growing periods such as potatoes and amaranth. Situated adjacent to the homesteads, the *bichra* receives the homestead waste and is usually fertile. In addition, its easy access makes it suitable for more intensive cropping than on any other land types in the village. In addition to vegetables and fruits, commercial crops such as tobacco, jute and mustard are often grown in *bichra*.

Rice and various other crops such as jute, wheat, mustard and pulses are grown on the *kandhilla jami*. The villagers call the section of *kandhilla jami* where transplant *aman* is grown *roaicha jami*, and the section where broadcast *aman* used to be grown *bawa jami*. Villagers recognize *kandhilla jami* as less flood-prone land where at least one or two crops can be grown without being subjected to flooding.

Khilla jami is land which has been made suitable for *boro* rice cultivation by lowering the original land surface and piling up the soil to make high surrounding bunds in order to preserve the flood water till the dry season for *boro* rice cultivation. *Maath jami* is land which previously remained mostly uncultivated. After shallow tubewells (STW) began to be introduced into the village this type of land was converted to *boro* rice fields.

Petty literally means fish belly, and this indicates that the *petty jami* is the most fertile among various types of *boro jamis*. Because of its high fertility and water holding capacity, the *petty jami* has long been utilized for *boro* rice cultivation. Some parts of *petty jami* which receive water from the surrounding lands throughout the *boro* growing season are called *lunga jami*, and they are recognized as the best of *petty jami* as they have high fertility and sustain good crops despite little care or labour expenditure.

Char jami is situated in the inner portion of a *bil*. The villagers transplant *boro* rice towards the center of the *bil* as the water recedes. *Char jami* is often created artificially by making bunds at the lower side of the *bil* which results

Table 2. Area and percentage of major cropping patterns in the two villages.

No.*	Season			Jawar		Taker Bhitee	
	Aus	*Aman*	*Boro*	Area (ha)	(%)	Area (ha)	(%)
1	A/J	FAL	FAL**	10.3	1.3	0.3	0.4
2	A/J	FAL	WCP	20.7	2.7	0.0	0.0
3	FAL	AMN	FAL	42.2	5.5	3.5	4.8
4	FAL	AMN	WCP	9.4	1.2	2.6	3.6
5	A/J	AMN	FAL	66.4	8.6	3.8	5.3
6	A/J	AMN	WCP	29.4	3.8	10.9	15.1
7	FAL	FAL	BOR	404.6	52.5	29.4	40.7
8	FAL	AMN	BOR	12.0	1.6	8.7	12.1
9	FAL	FAL	WCP-BOR	5.1	0.7	—	—
10	AUS	AMN	BOR	—	—	1.2	1.7
11	FAL	FAL	WCP	33.3	4.3	1.2	1.7
12	FAL	FAL	SED	16.4	2.1	2.3	3.2
13	Others			17.2	2.2	0.1	0.1
14	FAL	FAL	FAL	103.0	13.4	8.2	11.4
Total				770.0	100	72.2	100

* Serial number of cropping pattern.

** A/J = *aus* rice/jute, AUS = *aus* rice, AMN = *aman* rice, BOR = *boro* rice, WCP = winter crop, FAL = fallow, SED = seedling nursery (no crops are grown after uprooting of seedlings)

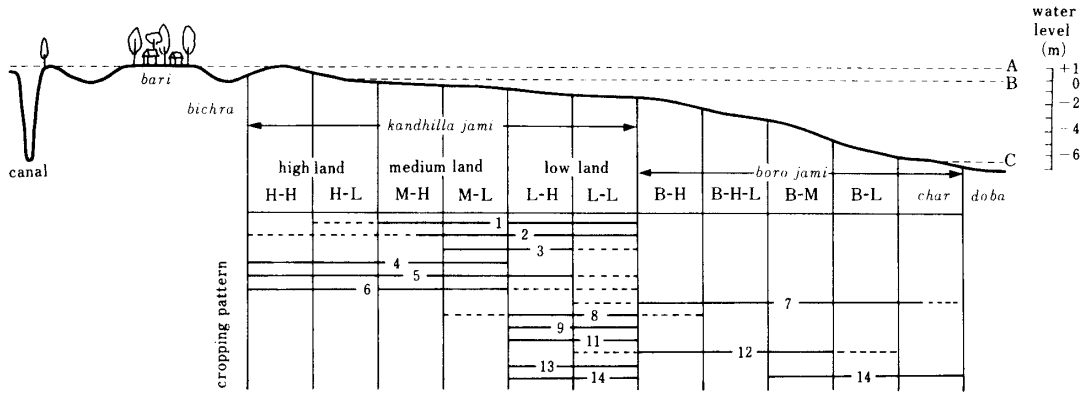

Fig. 4. Schematic cross-section showing the distribution of major cropping patterns of Jawar.

1) Abbreviations from H-H (high-high) to *char* indicate detailed land classifications according to elevation.

2) Solid lines indicate the major distribution of each cropping pattern and dotted lines, its minor distribution.

3) A : the water-level in a big flood year, B : in a normal flood year, and C : at the lowest point of recession.

4) *doba* : Central portion of a *bil* where the water stagnates during the dry season.

in the land surface being raised through soil deposition during the rainy-season flooding.

The local and the more detailed land classifications used in our research are shown in Table 1 together with the standard classification of topography adopted in

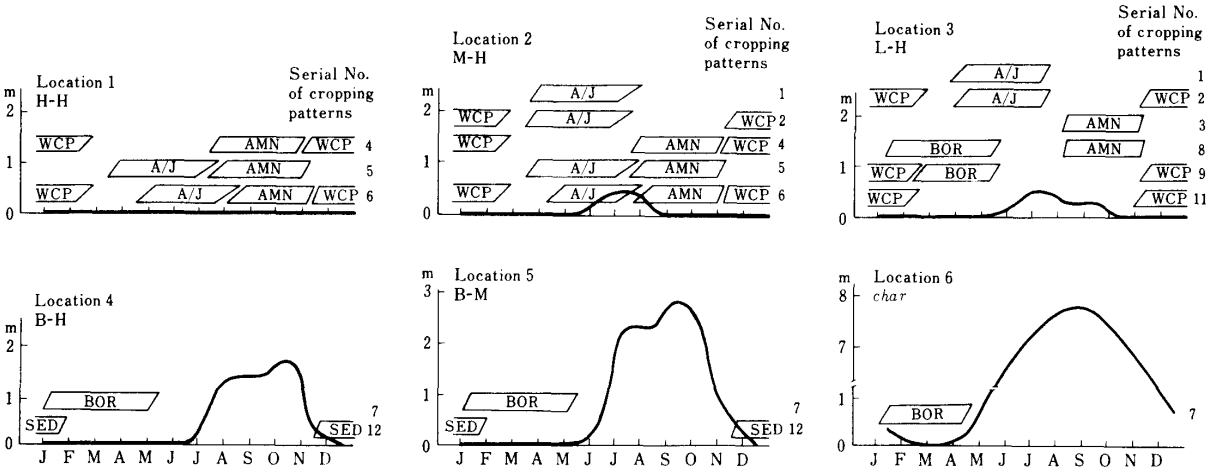

Fig. 5. Seasonal changes in the depth of inundation and cropping patterns adopted in some selected locations of Jawar.
Abbreviation of crop names and serial number of cropping patterns are identical to those shown in Table 2.

Bangladesh[5]. *Kandhilla jami* was divided into six land units; high-high (H-H), high-low (H-L), medium-high (M-H), medium-low (M-L), low-high (L-H) and low-low (L-L). The *shail/boro jami* was divided into five units; boro-high (B-H), boro-high-low (B-H-L), boro-medium (B-M), boro-low (B-L) and *char*. B-H and B-H-L are identical with *maath* and *khilla jami*, and B-M and B-L with *petty jami*.

The land of Taker Bhitee is locally classified into two broad groups, *taner jami* and *bondhoker jami/biler jami*. The *taner jami* (land above a *bil* area) is sub-categorized into *kandha*, *baiet* and *nama*. *Kandha* land is located in the highest areas and corresponds to the H-H to H-L land units of Jawar. Here *bhita* (homestead), *palan* (land adjacent to homestead, the same as *bichra* in Jawar) and crop-growing land which is called *dhaner jami* (or again *kandha jami*) are situated. In respect to elevation, *baiet jami* and *nama jami* are next to *kandha jami*, and are identical to the M-H to M-L and L-H to L-L categories of Jawar, respectively.

The *bondhoker jami* or *biler jami* (land within *bil*) is sub-categorized into *biler korcha*, *biler majhra* and *biler nama*, and these correspond closely to B-H to B-H-L, B-M, and B-L to *char* of Jawar, respectively.

Existing cropping patterns and their distribution

Based on the plotwise survey on crop coverage in Jawar and Taker Bhitee, existing cropping patterns throughout the year were determined for the entire areas of both villages. Although nearly 70 kinds of crop sequences were found in Jawar and 40 in Taker Bhitee, they can be clustered into 14 major cropping patterns including fallowing, as shown in Table 2. Major cropping patterns are almost indentical in the two villages but the frequency of occurrence differs between the two.

Out of the 14 major cropping patterns, 10 are rice-based. They are grouped, based on the common classification of rice in Bangladesh, into *aus*-based, *aman*-based, and *boro*-based cropping patterns; patterns No.1 and 2 shown in Table 2 are *aus*-based, Nos.3 to 6 are *aman*-based, and Nos. 7 to 10, *boro*-based. The most dominant cropping pattern is the single cropping of *boro* rice, covering 52.5% and 40.7% of the total cultivated areas of Jawar and Taker Bhitee, respectively.

Fig.4 schematically illustrates our detailed land classification and the distribution of different cropping patterns in Jawar. The *aus*-based patterns are distributed from M-H to L-L, while the *aman*-based patterns are distributed in the higher lands from H-H to L-H. The *boro*-based patterns combined with *aman* rice or mustard are distributed from L-H to L-L, which have been rather recently established after STWs were installed as a new means for irrigation. The single cropping of *boro* rice is solely distributed over the entire area of *boro jami* which extends from B-H to *char* lands.

A similar distribution of cropping patterns was found in Taker Bhitee. However, it is a distinguishable feature of Taker Bhitee that the higher lands of *taner jami* have been planted with *boro* rice under the double or triple rice cropping patterns since the introduction of deep tubewells (DTWs) in the village in 1982.

Relationship between toposequences and cropping patterns

The distribution and performance of major cropping patterns are related mainly to differences in land elevation, and subsequently to the time flood waters rise and recede. Fig. 5 shows examples of seasonal changes in the depth of inundation at six different locations in Jawar, and includes the representative cropping patterns adopted at each location.

In flood-free areas like location 1 in Fig. 5 on H-H land patterns 4, 5 and 6 are practiced. These are *aman*-based cropping patterns where local varieties as well as modern varieties with long growing periods are grown. The major rice varieties planted are Mongir, Biroi, Kalizira, Hazishail, Pajam, BR 11 and BR 3 for the *aman* season and Agali, Kachiloin, Bogi, Chandina and Mala for the *aus* season. The number of cropping patterns adopted in this land unit is limited but crop accumulation is high. Intensive cropping patterns such as *aus* or jute followed by transplant *aman* and winter crops like pulses, wheat or mustard are practiced here.

At location 2 on M-H land, inundated to a depth of less than 0.5 m from June to August, *aus*-based cropping patterns (1 and 2) are dominant. *Aus* rice or jute are harvested before the peak of the flooding and winter crops such as mustard are grown after the complete recession of flood waters (Pattern 1). The main varieties of *aus* planted are local, such as Agali, Kachiloin and Bogi. Patterns 4, 5 and 6 are occasionally practiced in this location depending on the extent of flooding. When floods recede earlier than usual *aman* rice varieties such as Mongir, Biroi and Kalizira can be grown just after the recession.

The flooding lasts longer on the lower parts of *kandhilla jami*. At location 3 on L-H land, where inundation lasts until September, a number of cropping patterns are practiced depending on the timing and extent of rise or recession of the flood waters. In the lower parts of this land unit where early flooding is likely to occur, an *aman*-based cropping pattern like No. 3 is dominant. The local *aman* varieties such as Biroi and Mongir are basically used. In contrast, *aus*-based cropping patterns (1 and 2) become dominant in the higher parts of this land unit as the harvest of *aus* or jute can be completed before the flood comes. The lowest parts of this land unit are most susceptible to an annual fluctuation in flood levels. When the flood level is high and inundation lasts longer, in stead of growing local *aman* rice, only winter crops such as mustard and chilli are grown after the recession of water (Pattern 11).

The installation of STWs has created a considerable change in cropping patterns in the lower parts of *kandhilla jami* such as L-H and L-L, that is, the intensification of cropping through the introduction of *boro* rice in the dry season. Cropping patterns 8 and 9 are those which have been newly established since the STWs were installed.

Cropping pattern 7, single cropping of *boro* rice, is predominant in *boro jami*. Deep flooding during the rainy season and the sudden rise of flood waters at the beginning of the early monsoon do not allow any rice to be grown in the rainy season here. At location 4 on B-H and location 5 on B-M, both modern and local varieties with longer growing periods are grown since the flood recedes earlier and rises later than in the lower parts of *boro jami* such as B-L and *char*. Only the long-stature, local *boro* rice with its short growing period can be transplanted in the shallow standing water in *char* and harvested in April.

When *boro* rice is grown, *boro-jami*, with the exception of *lunga jami* and *char*, is irrigated supplementally with a local irrigation device called *don*. *Boro* rice cultivation has increased in B-H since the STWs were installed. Although the single cropping of *boro* rice is a traditional practice in this land unit, the introduction of STWs enabled a considerable expansion of this pattern through the increase in the water supply. The *boro*-based cropping patterns like 8 and 9 in L-H, L-L and B-H or pattern 7 in B-H are those established after the introduction of STWs.

Most of cropping patterns found in Jawar exist in Taker Bhitee, and their distributional pattern is also quite similar to that in Jawar.

Pattern 9, a *boro*-based pattern combined with winter crops, is not practiced in Taker Bhitee because no STWs are installed there. Pattern 8, transplant *aman* followed by *boro* rice, and pattern 10, the triple cropping of rice, which was not found in Jawar, are widely practiced in the higher parts of *taner jami*. These two patterns have been adopted since a DTW was installed in the village in 1982.

Changing aspects of cropping patterns

Existing cropping patterns show a clear difference in character between *kandhilla jami* and *boro jami*; that is, intensive accumulation of cropping in the former and extensive expansion of single cropping of *boro* rice in the latter. The development of cropping patterns in the low-lying areas such as these chosen for our research can be said, in other words, to be achieved by vertical accumulation at the higher elevations and by horizontal expansion at the lower levels. Although the intensification of land utilization is not to be expected in such very low-lying areas as *boro jami* in Jawar, it is nevertheless possible to achieve through the accumulation of crops in slightly elevated areas such as *kandhilla jami* in Jawar, despite the fact that it is subjected to annual flooding. The establishment of a variety of cropping patterns in *kandhilla jami* is thought to be a result of such efforts to increase the intensity of cropping.

Until the early twentieth century broadcast *aman* (deep-water rice) was the predominant crop grown in the lower part of the *kandhilla jami* in Jawar, either grown solely or mixed-grown with *aus* rice. These cropping patterns were completely replaced by patterns 8 and 9 after the introduction of STWs in 1975. In Taker Bhitee the installation of DTW brought about a similar change; here the *boro*-based cropping patterns were established, replacing former cropping patterns such as single cropping of *aman* or double cropping of *aus* and *aman*. These types of changes in cropping patterns are commonly found throughout the country. Due to the installation of STWs or DTWs and the introduction of modern varieties, the total area under broadcast *aman* has begun to decrease*. Between 1974/75 and 1987/88 the acreage of broadcast *aman* decreased by some 25%; on the other hand the *boro* growing area increased by 67.2% in Bangladesh[4]. This increase of *boro* rice growing has considerably contributed to recent increases in cropping intensity.

The remarkable expansion of *boro* rice cultivation found in the two villages in the last two decades is said to be a prominent factor promoting change in cropping patterns. As *boro* rice is safer and can assure farmers of a higher return[11], it plays an important role as a measure of the intensification of land utilization and of the extensive expansion of rice-growing acreage, and hence is a key factor in transforming and improving cropping patterns in the low-lying areas of Bangladesh in the future.

Despite adverse conditions such as heavy monsoon precipitation and deep inundation, various cropping patterns have been established in the two villages. Modern technological innovations such as modern varieties and mechanical irrigation systems like STWs and DTWs have greatly contributed to recent changes in cropping patterns, particularly to the establishment of the *boro*-based cropping patterns in *kandhilla jami* and *taner jami*. Besides using these modern technologies, villagers have tried to carry out the present set of cropping patterns with conventional technology also, in such a way that they can utilize the given resources to the maximum extent. The existence of a variety of cropping patterns as well as the use of various types of local rice varieties enables them to select an adequate combination of cropping patterns so that they can adapt to annual fluctuations in flooding in *kandhilla jami* and *taner jami*. Their traditional technologies to transform the land surface and the water regime, which consist of digging up the ground, the construction of high bunds and irrigation with *don*, have greatly contributed to the reclamation and expansion of *boro*-rice growing areas in *boro jami*. In this sense, the use of cropping patterns in the two villages can be said to be a result of the farmers' adaptation, with both traditional and modern technology, to the given natural environment of the low-lying areas.

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