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

II. Toposequence, hydrology, land classification and cropping patterns in the Bogra District of the Barind Tract*

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Abstract : An intensive village-level survey on the change of land use and cropping systems was conducted in the village of Aira (Bogra District of the Barind Tract, a Pleistocene terrace) from the *Aman* season 1992 to the *Boro* season 1993. The village's land is classified locally into nine categories according to its utilization, location and soil characters. Based on this classification, the relationship between the toposequences and the establishment of cropping patterns in the village was investigated. Single cropping of transplanted *Aman* rice (T. *Aman*) was predominant, while deep-water *Aman* rice, *Aus* rice and *Rabi* crops were grown in limited areas before the 1970s due to shallow inundation during the wet season and the limitation of water sources during the dry season. Since the introduction of shallow tube-wells (STWs) in the late 1970s, however, the major cropping pattern has drastically changed from the [T. *Aman*-fallow] pattern to [T. *Aman*-*Boro*]. The rapid expansion of *Boro*-rice cultivation was achieved because (1) *Boro* rice did not interfere with the traditional main crop of T. *Aman* and (2) STW irrigation removed the hindrance of soil hardness during the dry season. Although the villagers have experienced a drastic change in cropping patterns, they have maintained their tradition of varietal choice, which seems to be adaptive to the variation of the micro toposequence.
Key words : Bangladesh, Cropping pattern, Land classification, Multiple cropping, Shallow tube-well irrigation, Toposequence.

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2報　ボグラ県バリンド台地におけるトポシークェンス（地形系列），水文条件，土地分類と作付様式：Md. Abdur RASHID・安藤和雄**・田中耕司**・海田能宏**（京都大学農学部・**京都大学東南アジア研究センター）

要　旨：バングラデシュの更新世台地（バリンド台地）に位置するボグラ県アイラ村において，農業的土地利用と作付体系の変容に関する村落レベルの調査を，1992年のアマン季から1993年のボロ季にかけて行った．村内の土地は，その利用，位置，土壌条件などにより9つの類型に分類される．その土地分類を基礎に，同村におけるトポシークェンスと作付体系成立の関係について考察した．1970年代以前においては，雨季の湛水不足と乾季の水源枯渇により，移植アマン稲の一毛作体系を主流とする稲作が行われ，深水アマン稲やアウス稲，ラビ作物の栽培は非常に限られていた．しかしながら，1970年代末の浅井戸灌漑の導入以来，水田の作付様式は従来の［移植アマン稲—休閑］から［移植アマン稲—ボロ稲］の水稲二期作へと急速に変化した．この急激なボロ稲の導入・拡大は，一つにはボロ稲の導入が従来の移植アマン稲の栽培と抵触しなかったこと，また一つには浅井戸灌漑の導入が乾季の土壌固結による耕起作業の困難さを取り除いたことにより可能となった．このような急速な作付様式の変化を経験しつつも，村人は村内の微地形の変異に対応した品種選択の伝統をいまも維持しており，このなかに水田の立地条件に対する村人の対応力がうかがえた．
キーワード：浅井戸灌漑，作付様式，多毛作，土地分類，トポシークェンス（地形系列），バングラデシュ．

The Barind Tract, situated in the northwestern part of Bangladesh, is an anomaly in the major landscape of deltaic flat lands. Natural conditions such as its higher elevation, clayey soil, limited rainfall and lack of water sources in the dry season provide a different foundation for the development of cropping patterns in comparison with those in the deltaic areas of Bangladesh. Our research was, therefore, conducted in a village of the Barind Tract

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from the *Aman* season 1992 to the *Boro* season 1993 in order to understand the agro-ecological conditions and their role in establishment and development of cropping patterns.

Research Methods

1. The research village

The study village, Aira in Sherpur Thana (a *thana* is the lowest administrative unit under a district), Bogra District, is located on the eastern edge of the Barind Tract, in the border area between the Barind Tract and the Karatoya floodplain (see Fig. 1). The total land area of the village is about 200 ha, the total number of households is 209, and the total population is 864.

2. Methods of field surveys

Different types of intensive surveys were conducted: (1) census survey, (2) interviews with village elders, (3) plot-wise observation, and (4) document survey.

A total of 107 owner-farmer households were selected as the subject of the census survey in order to collect empirical data on existing cropping patterns, farming practices and varietal choice, and information on land types and average productivity of individual plots.

Several selected village elders were interviewed in order to identify the cropping patterns practiced before the 1970s.

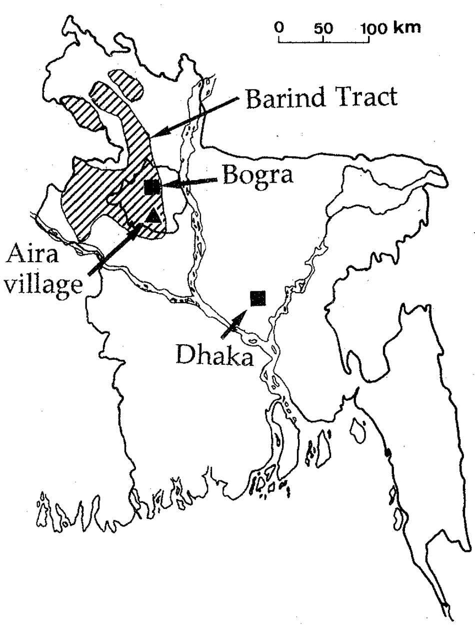

Fig. 1. Location of the study village.

In the plot-wise observation, data on crop coverage of every plot in the village were collected from the *Aman* crops in 1992 through *Rabi* crops in 1993, and the local land categories were identified. Information on the *Aus* crops prior to the 1992 *Aman* crops was collected by interviewing the villagers. All the information obtained by the plot-wise survey was arranged on the *mouza* map, a cadastral map prepared in 1992 in a revisional survey by land record office.

The document survey was conducted at the Settlement Office at Sherpur and the District Record Room of Bogra, where the *mouza* map and the records of land registration (*khatian*) and land use (*milan khasra*) were collected. Soil data were collected at the Soil Resources Development Institute (SRDI) at Bogra. Based on these documents and interviews with village elders, the cropping patterns before the 1970s were determined.

Using the local land categories as a frame of reference, the relationship between the toposequences and the establishment of cropping patterns was investigated.

Results

1. The physical setting of farm lands

(1) Local classification of land

The land of the village is classified locally into nine land types according to its utilization, location and soil characteristics: *barir bhita*, *kachla jami*, *balley chora*, *puran pukur chora*, *modha chora*, *dakshin chora*, *kandor jami*, *khari chora* and *kharir gaber*, of which the eight types other than *barir bhita* (homestead) are used for crop cultivation. The major categories of land classification are *bhita*, *jami* and *chora*. *Bhita* means high land attached to the homestead, where vegetables and trees are generally grown, while field crops like rice and pulses are cultivated in *jami* and *chora*. The farmers usually call land located near the homestead *jami* and that far from the homestead *chora*. *Jami* literally means land or soil, and *chora* means an area of land consisting of *jami* plots with similar characteristics. Fig. 2 shows the distribution of land types as classified by the villagers. The highest lands, *barir bhita* and *kachla jami*, are located in the middle of the village. The highest paddy land (*balley chora*) is distributed on the eastern side, and the lowest (*khari chora* and *kharir gaber*) on the

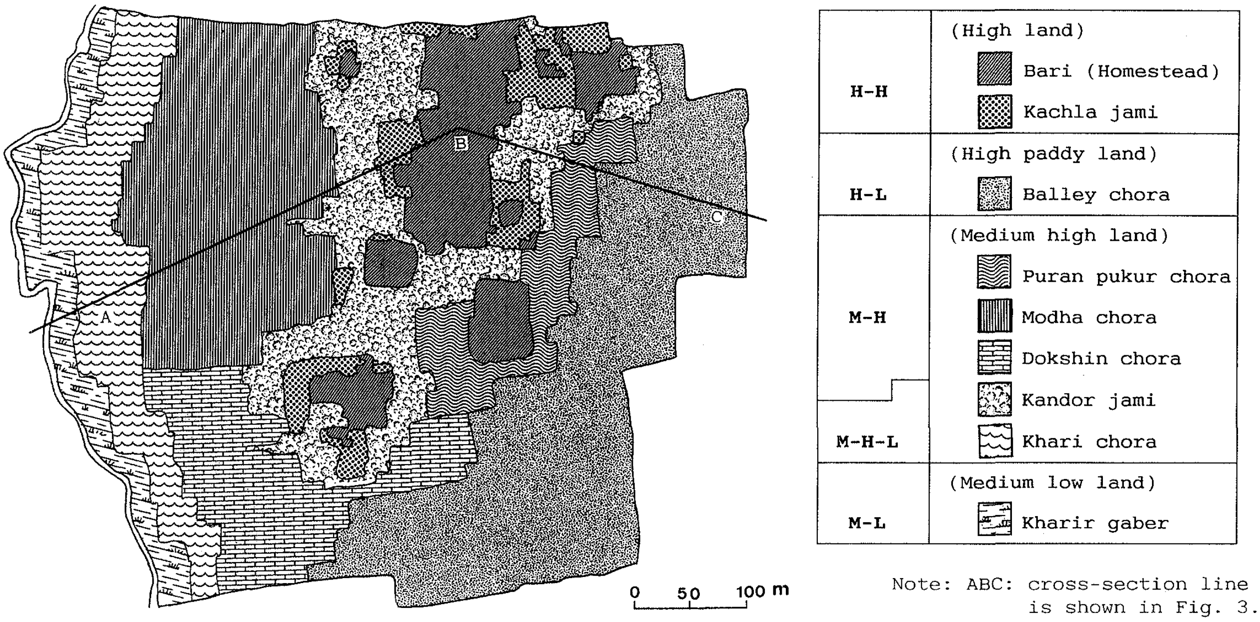

Fig. 2. Land classification and local taxonomy of Aira.

western side, along the *khari* (canal).

The characteristics, particularly soil and water conditions, of each land type are summarized in Table 1. *Barir bhita* is artificially raised by about 50-60 cm above the ground surface of paddy fields to avoid inundation, providing a place for housing and growing perennial fruit trees and bamboos. This land is actually the highest in elevation and recognized by the villagers as *uchu jami* (high land). *Kachla jami* (nursery land) is located around *barir bhita* or artificial tanks and generally used for growing seedlings of rice, vegetables and other crops like mustard and pulses. This also belongs to *uchu jami*. *Balley chora* (sandy paddy land) belonging to *uchu jami* is located in the eastern and southern parts of the village. The word *bali* literally means sand, and this implies that the soil of *balley chora* is mostly sandy. Because of its sandy texture, its water-holding capacity is poor. *Puran pukur chora* (old-tank paddy land) belongs to *majhari uchu jami* (medium-high land) and is situated around the *puran pukur* (old tank) next to *balley chora* to the west. The land surface is lower than *balley chora* but slightly higher than *modha* and *dakshin chora*. The soil texture is sandy loam, and its water-holding capacity is moderately poor. *Modha chora* (middle land) is located in the middle of western paddy fields of the village and also belong to *majhari uchu jami*. Its soil fertility and water-holding capacity are moderate. *Dakshin chora* (southern paddy land) also belongs to *majhari uchu jami*. Although it has the same characteristics as *modha chora*, the villagers recognize it as an independent land unit because of its location. *Kandor jami* (fertile land) is favoured with the most fertile soil in the village. Its soil texture varies from silty loam to clay loam, and its water-holding capacity is high. This land belongs to either *majhari uchu jami* or *majhari nichu jami* (medium-low land). *Khari chora* (canal-side paddy land) belongs to *majhari nichu jami* and is located next to the *modha chora* to the west, alongside the *khari*. The soil is clayey and its water-holding capacity is high. The land is frequently inundated by heavy rain in the monsoon season. *Kharir gaber* (inundated paddy land) is recognized as *nichu jami* (low land) and is located along the canal. It is the lowest land and flooded by the *khari* in the monsoon season. The soil is most clayey and a major portion is suitable only for local transplanted *Aman* (T. *Aman*) rice.

(2) Land-unit division

According to the standard classification generally adopted in Bangladesh, land is classified based on inundation depth as follows: land above normal flood-level is classified as high land, shallowly flooded (inundation depth upto 90 cm) as medium-high land, moderately deeply flooded (90-180 cm) as medium-low land, and deeply flooded (deeper

Table 1. Characteristics of local land-types (soil and water conditions) of the study village.

Land type	Soil condition			Water condition						Land productivity[3] (t/ha)	
	Water[1] holding capacity (days)	Texture	Fertility	Time of inundation (month)				Depth of inundation[2] (cm)		Normal inundation (rainfall)	Maximum inundation (rainfall)
				Start	Maximum	Recede	Dry	Normal	Maximum		
Barir bhita	—	—	—	Above normal flood-level				—	—	Used for homestead	
Kachla jami	3—4	Silty	Less	Above normal inundation				—	—	1.1	1.8
Balley chora	2—3	Sandy	Moderate	end Jul.	end Aug.	end Sep.	mid Oct.	0 —	15	1.6	3
Puran pukur chora	3—4	Silt clay	Moderately good	mid Jun.	early Sep.	end Sep.	mid Nov.	20 —	30	2	3.5
Modha chora	4—5	Clay	Fertile	early Jul.	early Sep.	early Oct.	end Nov.	25 —	35	3	4
Dakshin chora	4—5	Clay	Fertile	early Jul.	early Sep.	early Oct.	early Nov.	25 —	35	3	4
Kandor jami	6—7	Clay loam	Highly fertile	mid Jun.	Sep.	early Nov.	early Dec.	40 —	65	5	3.5
Khari chora	5—6	Clayey	Fertile	mid Jun.	Sep.	early Dec.	early Jan.	75 —	95	2	1.6
Kharir gaber	5—6	Clayey	Fertile	early Jun.	Sep.	early Dec.	early Jan.	75 —	95	2	1.6

1) Interval without watering in the dry season after which land in the *Boro* rice field becomes cracked.
2) Depth of inundation indicates the depth which occurs at the peak of the rainy season from late August to early September.
3) Land productivity means the yield (unhulled rice) of most popular rice varieties grown in accordance with the variation in toposequence of land. It was estimated by interviewing farmers.

Source: Field survey, 1992/93.

than 180 cm) as low land[5]. As shown in Table 2, the greater part of the paddy lands in the village are medium-high land in the standard classification. The range of inundation depth adopted by the standard classification, however, is too wide for it to be applicable to identify the micro variation in topography and to investigate its relationship with the development of cropping patterns, particularly in village-level studies. Since the villagers classify their farm lands precisely based on their empirical recognition as described above, we decided to follow the local classification and to combine it with our criteria of land classification which have been applied commonly to all village-level studies that we have conducted in Bangladesh[8].

The farmers strictly explained that the inundation depth of 65 cm at the peak of rainy season from late August to early September is a condition which plays a significant role in the selection of high-yielding varieties (HYVs). Due to their tendency to be rather short, the high-yielding varieties can be grown successfully only where maximum inundation does not exceed this depth. Usually the height of the high-yielding varieties grown by the farmers is 95-115 cm. Farmers reported that the high-yielding varieties such as BR11 are very susceptible to water fluctuation. They bear poor yield, 1.3-1.6 t/ha during excessive inundation, particularly in a year of heavy rainfall. Based on this, as shown in Table 2, we divided the medium land into M-H (medium-high) and M-H-L (medium-high-low) land with this inundation depth as the dividing line. In this way, a more precise classification based on inundation depth was adopted in our village-level studies. The land classification following our criteria is shown in Table 2 in comparison with the local and standard classifications.

(3) Toposequence, hydrology and soil characters

As shown schematically in Fig. 3, the land surface is gently undulating and has micro variation in elevation, hydrology and soil characters. The elevation of paddy lands gradually decreases from east to west. The paddy lands are inundated only by rainfall in the monsoon season and the maximum depth of water varies on average from 15 cm in high-low (H-L) land to 95 cm in medium-low (M-L) land. The soil of the higher lands, particularly *balley chora*, is mostly sandy and subjected to shallow flooding with a short period of inundation, while the lowest lands, particularly *kharir gaber*, are favoured with clayey soil and the floodwater remains for a longer period.

As most of the paddy lands in the village are inundated only by the seasonal rainfall, the farmers have to preserve rainwater by making high dikes around the paddy fields in order to grow *Aman* rice in the monsoon season. The *Rabi* crop is totally dependent on groundwater lifted by shallow tube-wells (STWs; normally, they have the capacity of 15 L sec^{-1} of discharge and 8 m of suction lift), as no surface water is available in the dry season.

Table 2. Division of land classification.

Local division		Standard division	Research division
Uchu jami	Barir bhita	High land	H-H
	Kachla jami	High land	
	Balley chora	Medium-high land	H-L
Majhari uchu jami	Puran pukur chora	Medium-high land	M-H
	Modha chora	Medium-high land	
	Dakshin chora	Medium-high land	
	Kandor jami	Medium-high land	M-H/M-H-L
Majhari nichu jami	Khari chora	Medium-high land	M-H-L
Nichu jami	Kharir gaber	Medium-low land	M-L

Source : Field survey, 1992/93.

2. Former cropping patterns

As shown in Fig. 4, single cropping of T. *Aman* was predominant, while deep-water *Aman* rice (DWA), *Aus* rice (early rainy-season rice grown in April/May to July/August) and *Rabi* crops (upland crops such as mustard, potato, chick peas, lentils and cucumber grown in the dry *Rabi* season from November to March) were grown in very limited areas before the 1970s. This is attributable firstly to the hardness of soil and the lack of rainfall in the pre-monsoon and dry seasons, and secondly to the comparatively shallow inundation during the monsoon season. Due to the first reason, villagers could not grow *Aus* rice in the pre-monsoon season and *Rabi* crops in the dry season, and due to the second reason, DWA was restricted to the canal-side areas. *Rabi* crops such as mustard were also grown in limited areas located close

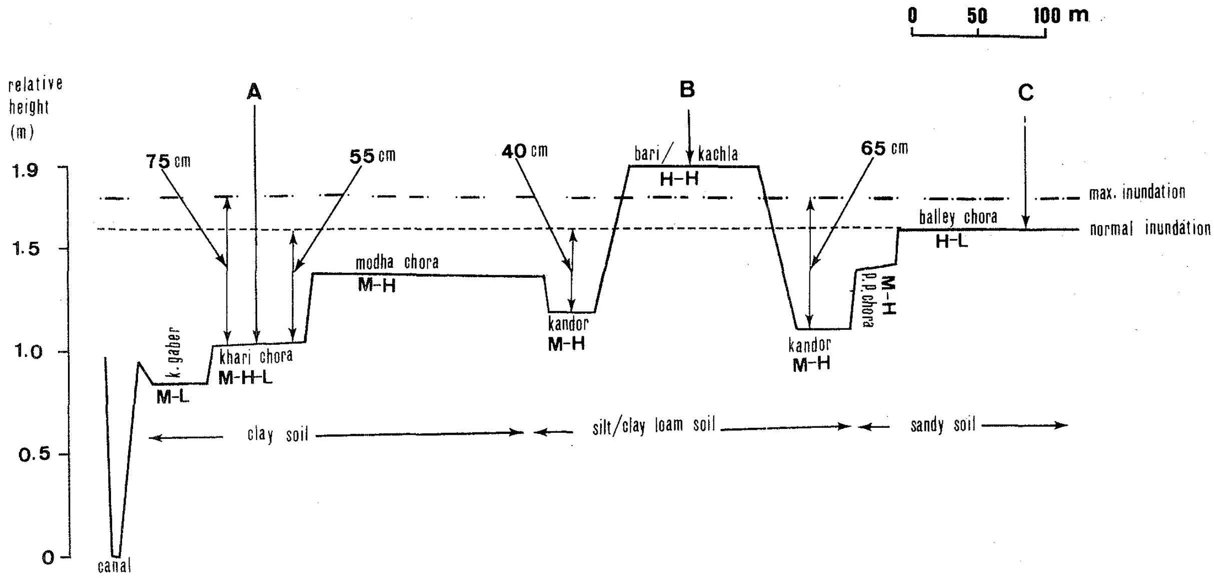

Fig. 3. Toposequence, hydrology and soil characters of Aira.

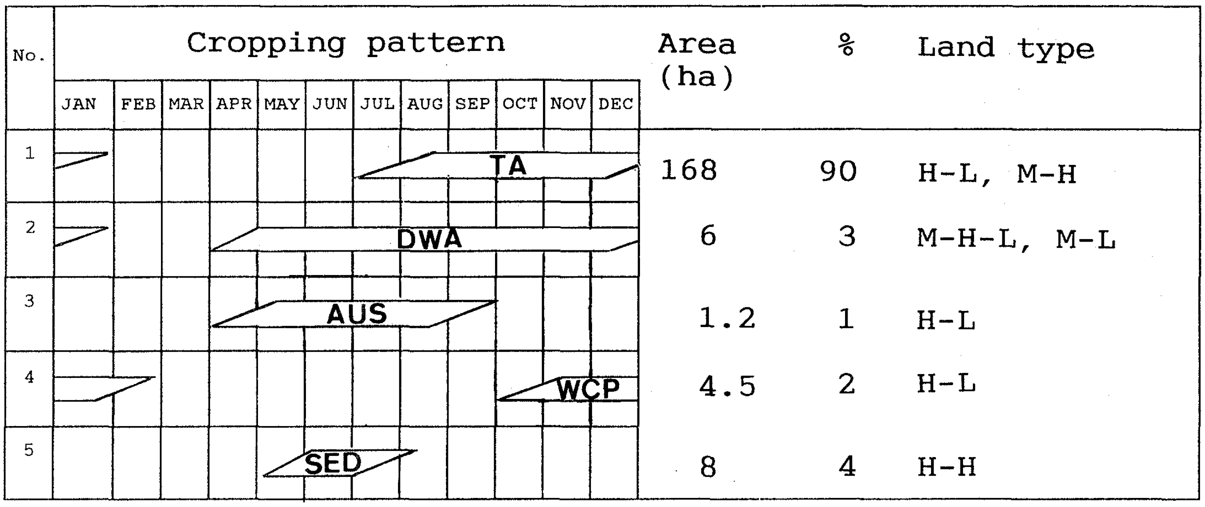

Fig. 4. Cropping patterns before the 1970s and its relationship with land units in Aira village.
Notes : TA : transplanted *Aman*, DWA : deep-water *Aman*,
AUS : *Aus* rice (early rainy season rice), WCP : winter crops (mustard), SED : nursery bed for local varieties of rice seedlings.
Source : Cadastral survey records (1920-29)[1] and interviews with village elders (1992/93).

to artificial tanks because of the need for irrigation water.

The land records of the village reveal that all the lands were planted with only one crop in 1929[1] and that the area cultivated with *Aus* rice and *Rabi* crops was just 1.35 and 4.5 ha, respectively, although the land planted with *Aman* rice was 174 ha. Agricultural statistics of 1944-45 also reveal that Mirzapur union, to which Aira village belonged, was a single-cropping area of *Aman* rice, which occupied 85% of net cultivated area. Single cropping of *Aus* and *Rabi* crops occupied only 13% and 2%, respectively. During this period there was no *Boro* rice cultivated in the area[3].

According to the SRDI classification, Aira village belongs to the Lauta-Ekhdala-Gulta soil association. This association includes seasonally, shallowly flooded, and poorly drained soils developed on shallowly weathered clay in the Barind Tract[4,5], and this imposes a great limitation on farming practices under the wet conditions: the surface soil becomes soft and sticky when wet and hard and cracked when dry. When the rainy season ends, the surface soil layer rapidly dries, leaving a lot of moisture in the sub-soil. When the soil is ploughed under such conditions, it will form large clods and no crops other than transplanted rice can be grown[7]. This physical condition provided another limitation to developing intensified cropping patterns.

3. Cropping patterns since the introduction of STWs

The initiative for developing modern irrigation with STWs was taken by the government in the mid-1970s, because farmers were unwilling or unable to afford large investment for installing low-lift pump or deep tube-well. Since the government began to provide subsidy to individual farmers or cooperatives in 1978/79, the STW installation has rapidly increased over the country. Our study village also was not an exception.

No.	Cropping pattern	Area (ha)	%	Land type
1	B, TA	149	84	H-L, M-H, M-H-L
2	KHR, AUS, TA	6	3	H-L, M-H
3	B, AUS, TA	5	3	H-L
4	B, TA, S	2.4	1	M-H
5	WC, B, TA	2	1	H-L, M-H
6	WC, AUS, TA	1.2	1	M-H
7	TA	4	2	M-L
8	WC, S, TA	4	2	H-H
9	S, WC	4.4	3	H-H

Fig. 5. Cropping patterns and its relationship with land units in Aira village in 1992/93.

Notes : TA : transplanted *Aman*, DWA : deep-water *Aman*, DWA : deep-water *Aman*, B : *Boro* rice, WC : winter crops [potato, mustard, pulses (modern/local varieties), egg-plant, green chili and onion], S : nursery bed for modern/local varieties of rice seedlings, KHR : *Khira* (cucumber).

Source : Field survey, 1992/93.

A number of rice-based cropping patterns have been developed in the village since the first introduction of STWs in 1979. They are grouped into nine patterns of crop sequences (Fig. 5), of which the most predominant is double cropping of *Aman* and *Boro* rice.

The major cropping patterns have drastically changed from the [T. *Aman*-fallow] to the [T. *Aman*-*Boro*] pattern. As a result, 84% of the net cultivated area has come to be planted with T. *Aman* and *Boro* rice, and this indicates that the lands which were formerly left fallow during the dry season have been converted to *Boro*-rice lands. The pattern [DWA-fallow] previously distributed in M-H-L *kandor* and M-L lands has been mostly replaced by the combination of HYV T. *Aman* and HYV *Boro* in M-H-L *kandor* land, and that of local T. *Aman* and HYV *Boro* in M-H-L and part of the M-L land. Single cropping of T. *Aman* rice with long-stemmed varieties such as Patjag and Khatobadha has come to be practiced in very limited areas in M-L land, accounting for 4 ha or 2% of the net cultivated area. The H-L, M-H and M-H-L lands previously used for single cropping of local T. *Aman* have been converted to several minor patterns (Nos. 2 to 6 in Fig. 5) consisting of three crops a year. Such intensification of cropping patterns, particularly those observed in *Rabi* crop cultivation, has been developed in M-H lands since the introduction of irrigation facilities, which removed the problems of soil hardness and shortage of soil moisture in the dry season.

In *kachla jami*, high-high (H-H) land according to our classification, which was formerly left fallow after its use for seedbeds, triple cropping such as in pattern No. 8 in Fig. 5 has been established; and in part of the *kachla jami* which was formerly left fallow all year round, double cropping such as in pattern No. 9 is practiced. Such variation in the cropping patterns in *kachla jami* is also a positive effect of the introduction of STW irrigation.

Discussion

1. Relationship between toposequence and cropping intensity

Table 3 shows the change of cropping intensity over the last two or three decades in relation to the micro variation in toposequence in the study village. Before the 1970s, no significant difference in cropping intensity was observed between the land categories, because crop growing was restricted to the monsoon season. In contrast, the cropping intensity in the early 1990s shows a significant correlation with the toposequence. The land of higher elevation has higher cropping intensity.

The farmers' decision regarding what upland crops to grow in the dry season is made in accordance with the characteristics of land type: soil-lightness and good permeability have a particularly high correlation with the establishment of intensified cropping combined with upland crops. The soil texture of H-H and H-L lands varies from sandy to silty clay, and these soils provided ideal conditions for growing *Rabi* crops after the introduction of STW irrigation. In addition, the field plots in H-H land are usually small enough to allow the practice of intensified cropping patterns. This condition has also promoted the establishment of multiple cropping patterns.

In the M-H land, cropping intensity ranges between 203% and 213% with an average of 208%. Every field plot was planted with two or more crops, and no single-cropped plot was observed. Relatively good soil conditions and the availability of irrigation water allow double cropping over the entire area of M-H land. However, the combination of crops is not as

Table 3. Change of cropping intensity in accordance with the variation in toposequence.

Land-type	H-H	H-L	M-H	M-H-L	M-L
Cropping intensity[1)]					
Before 1970s	100	100	100	100	100
Early 1990s	232	226	208	200	157

1) $\text{Cropping intensity} = \frac{\text{Gross cropped area (GCA)}}{\text{Net cropped area (NCA)}} \times 100$

Source: Field survey, 1992/93.

diversified as in H-H and H-L lands, because double cropping of HYV rice is predominant. According to some farmers, upland crops in the *Rabi* season are less profitable than HYV rice, particularly in *kandor jami*. Situated adjacent to the homestead and sometimes receiving homestead wastes, the soil of *kandor jami* is favoured with water and nutrient supply, and villagers recognize it as more fertile and less drought-prone land where HYV rice can be grown with less management than elsewhere. Since the M-H land situated at lower elevation has clay-loam soil and can retain moisture for a longer time, it provides the most suitable conditions for HYV rice production in the village. Even in the triple-cropping area of 2.2 ha, all the crops planted are rice, consisting of HYV *Aman*, HYV *Boro* and *Boro* seedlings.

The M-H-L and M-L lands show a different land capability. In both types triple cropping was not practiced; and particularly in M-L land, single cropping with current fallow occupied a comparatively high proportion. In M-L land, cropping intensity reaches only 157%, because nearly half of the land is cultivated with just a single crop. The lower cropping intensity in M-L land is attributable to its locational and soil conditions: it occupies the lowest elevation by the canal and has heavy clay soil. Since the soil becomes severely cracked and irrigation water cannot be retained due to seepage through the cracks, the villagers cannot prevent the heavy loss of irrigation water. This physical constraint restricts a part of the lowest M-L lands to single cropping of rice (T. *Aman*), even though

Table 4. Rice varieties grown in different seasons in Aira.

Growing season		Varieties		Plant type		Maturity	
		HYV	LIV/LV	HYV	LIV/LV	HYV	LIV/LV
Aman :	1.	BR11*	—	short	—	medium	—
	2.	Mala	—	short	—	early	—
	3.	Sharna	—	short	—	medium	—
	4.	—	Khatobadha	—	long	—	late
	5.	—	Pajira	—	long	—	late
	6.	—	Patjag	—	long	—	late
	7.	Pajam	—	medium	—	medium	—
	8.	Zadu	—	short	—	medium	—
	9.	—	Batraj	—	long	—	early
	10.	—	Khomon	—	medium	—	early
	11.	—	Kalizira	—	long	—	early
	12.	—	Changamagur	—	long	—	late
Boro :	1.	Chandina	—	short	—	medium	—
	2.	—	Pari*	—	medium	—	early
	3.	—	Kalimbom*	—	medium	—	early
	4.	BR14*	—	medium	—	medium	—
	5.	BR11*	—	short	—	late	—
Aus :	1.	—	Pari*	—	medium	—	early
	2.	—	Kalimbom*	—	medium	—	early
	3.	BR12	—	short	—	early	—
	4.	BR14*	—	medium	—	medium	—
	5.	BR7	—	short	—	medium	—
	6.	BR26	—	short	—	medium	—

1) Varieties are listed in the order of their cultivated areas in each season.
2) Varieties marked with * were grown in two seasons.
3) HYV : high-yielding varieties, LIV : local improved varieties, LV : local varieties.
4) Normal growing periods of early, medium and late maturing varieties are shown in Table 5.
Source : Field survey, 1992/93.

water is available for irrigation.

As shown in Table 3, the crop production of the village has been dramatically enhanced during the last two or three decades. However, according to soil survey information, the land in this area is still classified as very poor to moderate agricultural land by the Bangladesh soil survey department[2,5]. This classification is based solely on the reconnaissance surveys conducted in 1963-73[6]. As great changes in crop production have generally been observed in Bangladesh over the last two decades, a new classification is required in order to reflect the real situation of land capability. The Barind Tract is one such area whose classification should be revised.

2. Varietal choice and farmers' strategy for adaptation

In the study village, a total of 19 distinct rice varieties were grown by the 107 farm households, including 7 early, 8 medium, and 4 late-maturing varieties (Table 4). Each household planted on average 4-5 varieties: 2-3 early, 3-4 medium, and 1-2 late-maturing varieties. The diversity of rice varieties was also tremendous: from very short-duration varieties ripening in only three months to those requiring almost nine months to mature; from varieties highly sensitive to photo-period to those totally insensitive; and from short-statured to long-stemmed varieties. Even among *Boro*-rice varieties, which are transplanted almost simultaneously by utilizing STW irrigation, early-maturing varieties like Kalimbom and Pari were chosen by farmers for planting in plots located on more elevated lands or in remote areas, which were more prone to damage by drought in the dry season.

Table 5 shows the change of cropping patterns and farmers' choice of rice varieties in different land categories. Although the cropping patterns have drastically changed, farmers have maintained the tradition of varietal choice in accordance with the variation of toposequence. Short-duration, early-maturing varieties are planted on sandy soils in H-H and H-L lands. As the soils are less moisture-retentive, early-maturing varieties are preferred in this area. Medium-maturing varieties are grown on silty soils in M-H land because the moisture-retentiveness is relatively better and drought damage rarely happens. Late-maturing, long-stemmed varieties are grown in clayey soils in M-L land in order to avoid the danger of flooding due to heavy rainfall in the monsoon season. Most farmers tend to combine all three types of varieties in order to minimize these risks and to make full use of the variation in toposequence. In addition to their varietal choice, farmers pay particular attention to early-maturing varieties. As early-maturing varieties can be harvested in the so-called hungry seasons (usually twice a year, one month before each of the *Aman*- and the *Boro*-rice harvests), they tend to plant early-maturing varieties more widely than before. These varieties are also favoured because they can more easily be combined with other crops in order to establish triple cropping, as in patterns No. 2, 3, 4, 5, 6 and 8 in Fig. 5 in H-H, H-L and M-H lands.

Table 5. Toposequence and transformation of varietal choice in major cropping patterns in Aira.

Land type	H-H	H-L	M-H	M-H-L	M-L
Cropping Pattern					
Before 1970s	SED-X	TA-X	TA-X	TA-X	DWA-X
Early 1990s	S-WC/TA	TA-B	TA-B	TA-B	TA-X
Varietal Choice					
Before 1970s	—	LV (e)	LV (m)	LV (m)	LV (l DWA)
Early 1990s	LV (e)	MV/LIV (e)	MV (m)	MV (m)	LV (l TA)

Abbreviation of crop names are the same as in Figures 4 and 5. LV : local varieties, LIV : local improved varieties, MV : modern varieties, e : early maturing (90—95 days), m : medium maturing (145—155 days), l : late maturing (nine months for DWA and 165—170 days for local TA), X : fallow.

Source : Field survey, 1992/93

Conclusion

The prevailing natural conditions in the Barind Tract formerly did not allow farmers to grow more than one crop a year. However, with the transformation of the environment through the introduction of STW-irrigation technology, transplanted HYV *Boro* rice began to be introduced and, as a result, rice-based multiple cropping patterns have been established in the village. Even though *Boro*-rice cultivation is relatively free from the limitations of the given natural conditions, rice-based cropping patterns established since the introduction of *Boro* rice show a close relationship with natural conditions, particularly with the variation in toposequences. In particular, farmers have paid special attention to crop combination and varietal choice in order to establish multiple cropping in the newly transformed environment. The attitudes or adaptive capabilities developed by the farmers over the years may be defined as an environment-adaptive[9] way to overcome the various natural constraints in the Barind Tract.

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