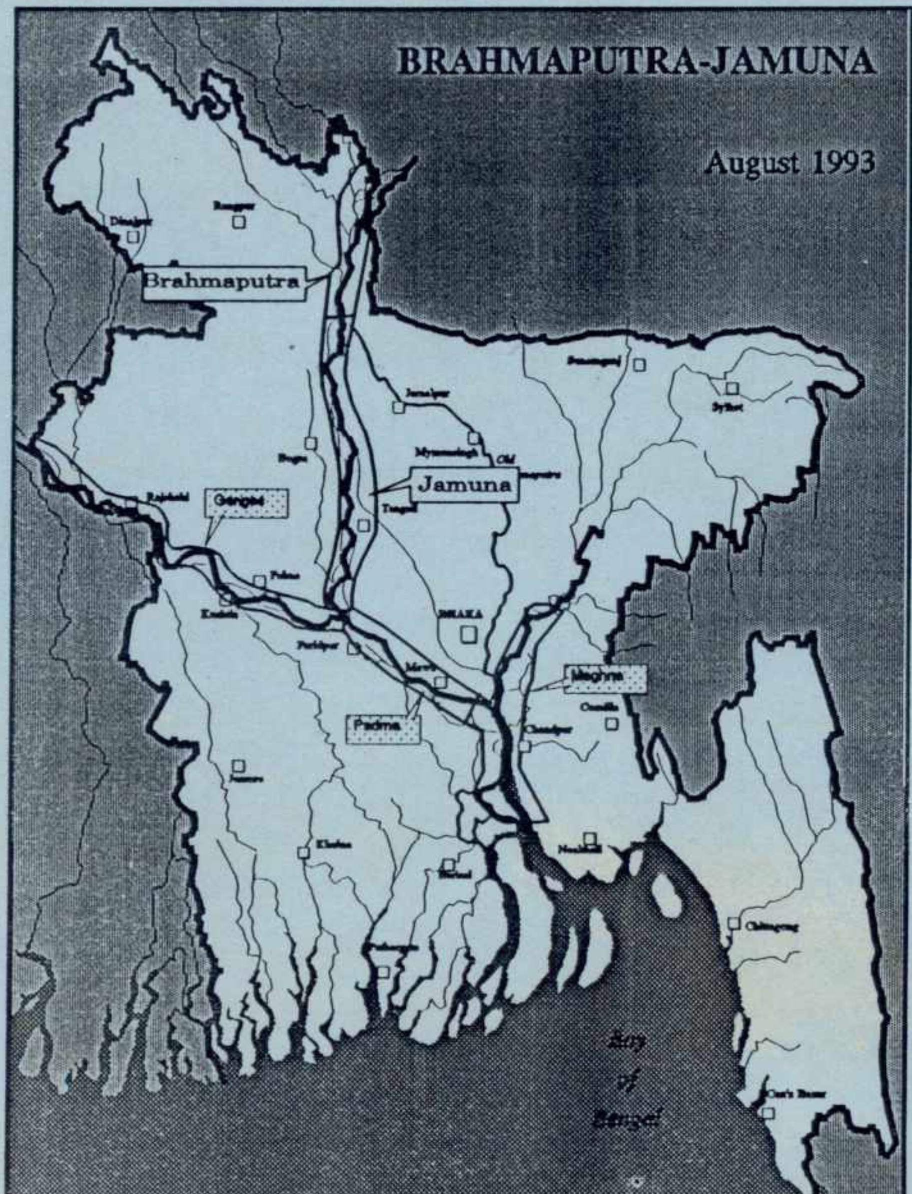
BANGLADESH FLOOD ACTION PLAN

Prepared for
The Flood Plan Coordination Organization (FPCO)
of the
Ministry of Irrigation Water Development and Flood Control

THE DYNAMIC PHYSICAL AND SOCIOECONOMIC ENVIRONMENT OF RIVERAIN CHARLANDS



Environmental Study (FAP 16)
Geographic Information System (FAP 19)

ISPAN
IRRIGATION SUPPORT PROJECT FOR ASIA AND THE NEAR EAST
Sponsored by the U.S. Agency for International Development

BANGLADESH FLOOD ACTION PLAN

THE DYNAMIC PHYSICAL AND SOCIOECONOMIC ENVIRONMENT OF RIVERAIN CHARLANDS: BRAHMAPUTRA-JAMUNA

ENVIRONMENTAL STUDY (FAP 16)
GEOGRAPHIC INFORMATION SYSTEM (FAP 19)

DRAFT

Prepared for

The Flood Plan Coordination Organization (FPCO)
of the
Ministry of Irrigation Water Development and Flood Control

August 1993

ISPAN
IRRIGATION SUPPORT PROJECT FOR ASIA AND THE NEAR EAST
Sponsored by the U.S. Agency for International Development

20

TABLE OF CONTENTS

APPENDICES

TABLES

FIGURES

PHOTOGRAPHIC PLATES

FOREWORD

This report is one in a series of reports covering the immediate riverain lands of the major rivers of Bangladesh—the Jamuna, Ganges, Padma, and Meghna. Riverain charlands are defined in this study as areas freqently subject to erosion and accretion within and adjacent to the main rivers of Bangladesh and unprotected by embankments. This report covers the work of Phase 1 of ISPAN's resource inventory of riverain chars, the charlands of the Brahmaputra-Jamuna River. It includes a summary of the river's morphological changes. This was based on maps dating from 1830, 1914, and 1953 as well as a more detailed analysis of eight satellite images from 1973 through 1992. The study was carried out by ISPAN under Flood Action Plan Supporting Studies FAP 16 (Environmental Study) and FAP 19 (Geographic Information System). The first phase of the study started in early 1992, and was extended into 1993 in order to return to the field to collect additional data.

There are two major data sources: a field inventory of resources and satellite image analysis. The field inventory was developed by using a questionnaire to interview key informants in charland areas. The inventory was carried out by Development Planners and Consultants (DP&C) under contract to ISPAN. The image analysis, which was done by FAP 19, consisted of developing and analyzing maps of land use and changes in the physiography of the land. A socioeconomic component was added to the study in 1993; it comprises both rapid rural appraisals (RRAs) and formal interview surveys, which build on the previous work of FAP 14 and FAP 23 and are reported separately.

This draft is circulated to obtain comments and feedback on both style and content, before drafting the reports on the other main rivers. The full set of reports is shown in the table below.

Overview Reports	Inventory Reports	Supporting Reports
Summary Report		
Socioeconomic Overview		
	The Dynamic Physical and Socioeconomic Environment of Riverain Charlands: Brahmaputra-Jamuna	Upper Jamuna RRA Middle Jamuna RRA
	The Dynamic Physical and Socioeconomic Environment of Riverain Charlands: Meghna	Upper Meghna RRA Meghna Confluence RRA
	The Dynamic Physical and Socioeconomic Environment of Riverain Charlands: Padma	Padma RRA
	The Dynamic Physical and Socioeconomic Environment of Riverain Charlands: Ganges	Ganges RRA
	Charland Flood Proofing	

ACKNOWLEDGEMENTS

This report is the result of a team effort involving many of the staff of both FAP 16 and FAP 19, which was coordinated by Keith Pitman, Chief of Party, ISPAN. It has depended heavily on field work undertaken by more than 20 enumerators organized through field work contract with Development Planners and Consultants.

The FAP 16 team was responsible for designing and analyzing the inventory reported in Chapters 3 and 4. Under the direction of Stan Hirst (FAP 16 Team Leader), Alan Bird led and coordinated the study in 1992, and Paul Thompson led and coordinated the study in 1993. Aminul Islam was responsible for the 1992 surveys, and Sachindra Halder supervised the 1993 surveys. Mamoon Hamid was responsible for the databases and tables.

The FAP 19 team was responsible for the satellite image analysis (Chapter 2) and for mapping the inventory data (Chapter 3). Under the direction of Tim Martin (FAP 19 Team Leader), Mike Pooley and David Savory coordinated the GIS work. Image analysis was by Scott Bartling, Jay Hart, Iffat Hoque, and Eric Pfirman. Colin Thorne interpreted the channel dynamics and river morphology data. Abdul Matin Miazi prepared the maps in Chapter 3. The following worked on the GIS: Nazmul Alam, Ahmadul Hasan, Mustafa Kamal, and Nasreen Khan. Ground truthing of land cover was by Golam Monowar Kamal, Masud-uz-Zaman, and Shanawaz Siddiqui.

GLOSSARY

acre	-	0.4047 ha
aman	-	Late monsoon season paddy planted before or during the monsoon and harvested November-December
aus	-	Early monsoon paddy planted in March-April and harvested in June-July
B. aman	-	Broadcast aman paddy, usually grown in deeper water
babla	-	Gum arabic tree
BARC	-	Bangladesh Agricultural Research Council
BBS	-	Bangladesh Bureau of Statistics
BCAS	-	Bangladesh Centre for Advanced Studies
beel	-	Bangla term for an area of open water away from a river
bigha	-	A local unit of area most commonly equalling 0.33 acre or 0.14 ha
boro	-	Dry season paddy transplanted in December-January and harvested in April-May
BRAC	-	Bangladesh Rural Advancement Committee
BWDB	-	Bangladesh Water Development Board
china	-	A variety of millet
decimal	-	Unit of area equal to 0.01 acre
DEM	-	Digital elevation model
dhaincha	-	A nitrogen-fixing plant used as live fencing, fuel, and building material
district	-	A large administration unit under the authority of a Deputy Commissioner, now known as a zila
EIA	-	Environmental Impact Assessment
FAP	-	Flood Action Plan
FCD/I	-	Flood Control and Drainage or Flood Control, Drainage, and Irrigation
FPCO	-	Flood Plan Co-ordination Organization
FWC	-	Family Welfare Centre
GIS	-	Geographic Information System
gur	-	Locally produced molasses
ha	-	Hectares = 2.4711 acres
HSC	-	Higher School Certificate
HYV	-	High Yielding Variety
jangal	-	Ground cover shrubs used for fuel and as herbs
jhau	-	Tamarisk bush used as fuel and an herb
job	-	Grain similar to wheat
JPPS	-	Jamalpur Priority Project Study
kaisa	-	A variety of catkin grass (*Saccharum spontaneum*) giving three cuttings a year
kayem	-	Bangla for permanent or old
kaon	-	Fox-tail millet
kg	-	Kilogram = 1.11 sheer
khal	-	Bangla term for a drainage channel or canal either natural or man-made
kharif	-	Summer/wet season
mashkalai	-	A type of pulse
maund	-	A unit of weight, 1 Maund = 40 sheer = 37.5 kilograms
mauza	-	A village revenue collection and cadastral mapped unit
MPO	-	Master Plan Organisation (of Ministry of Irrigation Water Development and Flood Control)

musur	-	Lentil
NGO	-	Non-government Organization
PoE	-	Panel of Experts (of FPCO)
rabi	-	Winter/Dry Season
RDRS	-	Rangpur Dinajpur Rural Development Service (an NGO)
sadar	-	The urban core (administrative headquarters town) of a thana or district
SCI	-	Service Civil International (an NGO)
sheer	-	A unit of weight = 1/40 maund = 0.94 kg
shon	-	A variety of catkin grass (*Saccharum spontaneum*) giving one cutting a year
SPARRSO	-	Space Research and Remote Sensing Organisation
SPOT	-	System Pour Observation de la Terre
SRDI	-	Soil Research Development Institute
SSC	-	Secondary School Certificate
suji	-	An improved variety of *kaon* (fox-tail millet)
T. aman	-	Transplanted aman paddy
thana	-	A sub-division of a zila, or district
Tk.	-	Taka, Bangladesh currency, US$ 1 equalled approximately Tk. 40 in late 1992-early 1993
TM	-	Thematic Mapper
ton	-	An imperial ton = 1016 kg
til	-	Type of oil seed
union	-	Sub-division of a thana, formerly known as upazila
upazila	-	Previous name for a thana (subdivision of a zila or district)
WHO	-	World Health Organisation
zila	-	A large administration unit formerly known as a district

NOTE: Table D.2 contains a more complete list of plant names.

EXECUTIVE SUMMARY

The residents of chars and mainland adjacent to main rivers have a precarious existence, subject as it is to erosion and flooding that can destroy crops and homesteads, render land unproductive, and kill livestock. In short, they are among the most hazard-prone people of Bangladesh. Structural flood protection is unlikely to benefit these people, and embankments may even increase the risks to which they are exposed by raising flood levels. Reliable information about these areas and the people who live in them has always been scarce. The limited accessibility of chars and their constantly changing environment has made studying them a complicated undertaking. As a result, prior to this study, what little information was available did not cover in any detail all the main river charlands. This study, then, fulfills the need—foreseen in the Government of Bangladesh/World Bank Flood Action Plan of 1989—for a socioeconomic study of the people and resources of these perilous lands.

"Charland" is the Bengali term for a "mid-channel island that periodically emerges from the riverbed as a result of accretion" (Elahi, Ahmed, and Mafizuddin 1991). For this study, the definition was widened to include areas of erosion and accretion along the banks of the river. Land, which was studied on mauza level, was classified as follows:

- Island chars.
- Right and left bank attached charland.
- Right and left bank setback land.
- Right and left bank unprotected mainland (other than setback land).

The figure below illustrates this classification system.

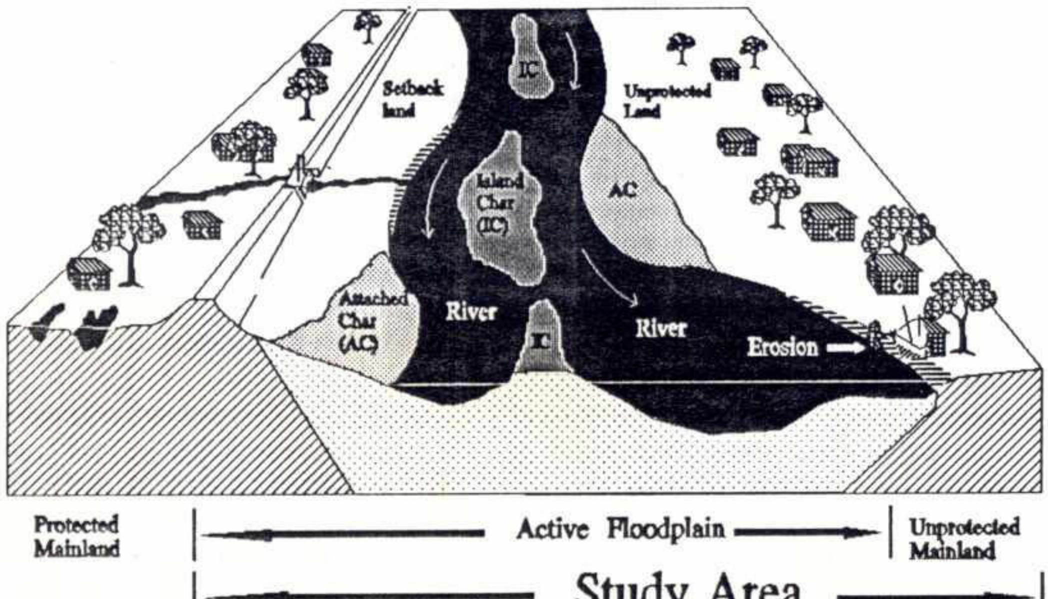


Figure 4: Charland Classification

The study area is bounded mainly by the alignments of existing and proposed embankments along the main river. The western boundary consists of the Brahmaputra Right Embankment and, in the north, the Kurigram embankment. The left bank boundary consists of the Indian border in the far north and, south of there, existing and proposed embankment alignments, including what would form the FAP 3.1 controlled flooding embankment between the Old Brahmaputra off-take and Jagannathganj Ghat.

Its overall length of nearly 3,000 km and a catchment area of around 560,000 km^2, make the Brahmaputra one of the world's greatest rivers. Annual river flow is characteristically high from June through September, a result of Himalayan snowmelt and monsoon rains, and very low in the winter. Annual flood peaks are on the order of 60,000 cumecs, three times the peak flow of the Mississippi (Coleman, 1968), and may exceed 100,000 cumecs in a 100-year return period flood (FAP 1, 1992).

The Brahmaputra-Jamuna basin is fed by runoff from the highest and most tectonically active mountain range in the world, the Himalayas. These young alpine mountains are naturally subject to severe erosion, and as a result, the Brahmaputra carries a very heavy sediment load. Estimates put it on the order of 5 million metric tons per day in flood (Coleman, 1968), and between 140 million (FAP 22, 1992) and 500 million m^3 per year (FAP 1, 1992), on average. The combination of large and variable discharges of water and sediment is responsible for the Brahmaputra's braided pattern of multiple, shifting anabranches separated by chars ("braid bars"). Braided rivers are characterized by unstable banklines and rapid rates of lateral movement, and the pattern of channels and chars within the Brahmaputra changes annually in response to the year's sequence of flows.

Sometime between 1780 and 1830, one particularly violent change caused the Brahmaputra to veer some 70 km westward from its course, swinging to the west of the Madhupur Forest Tract. The new river channel it created, called the Jamuna, is still adjusting to the shift in location, while the old course, now called the Old Brahmaputra, has become a withering distributary.

Analysis of maps dating from 1830, 1914, and 1953, as well as eight dry season satellite images from various dates between 1973 and 1992, shows that the river has been steadily moving westward. Since 1830, the centerline of the Jamuna has shifted west at an average of 28 m per year, although it has moved less at nodal points such as the one near Bahadurabad ghat (middle reach), and just north of Aricha near the Ganges confluence, it has moved east since 1973.

The channel has also been widening, increasing from an average of 6.2 km in 1830 to 10.6 km in 1992. Furthermore, although the long-term widening trend (1830-1992) has averaged 27 m per year, analysis of the trend from 1973 to 1992 shows that widening has proceeded at an average of 140 m per year. The west bank has eroded at an average of about 100 m per year between 1973 and 1992, but there are considerable local and short-term variations in erosion. Local bank erosion rates can be much higher, but rarely continue for many years. Analysis of erosion rates at half-kilometer intervals along the right bank showed that in 80 percent of cases the duration of "catastrophic" erosion (more than 350 m per year) was two to four years. There is a less than 10 percent chance that catastrophic erosion will persist at a site for more than four years, or that erosion of 200-350 m per year will persist for more than seven years. Conversely, periods of very low rates of river bank erosion, less than 25 m per year, have a less than 50 percent chance of lasting more than five years before higher rates of erosion recur.

Tables 1 and 2 summarize some of the most important inventory data by land type. The inventory estimates the total 1992 study area population to have been 1.82 million, of which 0.51 million lived in mauzas covering the 282 existing island chars. The attached char population was 0.41 million and there were 0.90 million people on unprotected mainland, including setback land. Between 1981 and 1992 the total charland population grew by 17 percent. But within this period there were major shifts in the distribution of people due to bank erosion. Between 1980 and

Table 1 Qualitative Summary of Differences between Char Land Types

Characteristic	Island Char	Attached Char	Unprotected Mainland
Land	Much sand and water, 48% vegetated.	Moderate sand and water, 61% vegetated.	Little sand or water, 91% vegetated.
Population	Lowest density, average 320 per km^2, but growth greater than national average since 1981.	Density slightly higher than islands (342 per km^2), but low growth.	Highest density, 773 per km^2. Caught up with national average since 1981 due to rapid growth as erosion victims concentrated in remaining mainland areas near their eroded land.
Migration in 1991	More in-migration, permanent moves as land reappears or in response to erosion elsewhere, and temporary moves to use seasonally available land.	More in-migration, particularly seasonal in-migration; attached chars may be subject to more rapid morphological change.	Localized out-migration linked to bank erosion, relatively less in-migration. Mauzas may be near capacity following past in-migration and bank erosion.
Infrastructure	Relatively poor high school and health facility provision. Access to mainland facilities constrained by river channels.	Relatively poor high school and health facility provision. Primary school provision same as other char types.	Relatively good high school and health facility provision. More markets.
Livestock	Low numbers relative to land area, but slightly higher per household than other land types.	Relatively low numbers.	High numbers relative to land, but this reflects population density not greater ownership.
Boats	Better availability of mechanized boats, but coverage patchy.	Boat availability same as in unprotected mainland.	About 100 households per mechanized boat.
Deaths	Concentrations of flood and disease deaths, particularly in upper and middle reaches.	1988 flood death incidence same as island chars, but relatively high in west bank.	High incidence of death due to disease, mainly in east bank, but fewer flood-related deaths.
Floods	Extensively flooded in 1988 for 22 days on average; about 58 percent flooded in 1991	Extent and duration of flooding in 1988 and 1991 similar to island chars.	1988 flood extensive and longer duration (28 days), about 33 percent flooded in 1991.

Source: FAP 16 Charland Study

Table 2 Summary of Mauza Inventory Data by Char Land Type

Parameter	Island Char	Attached Char	Unprotected Mainland	Bangladesh*
Area (ha)	148,248	119,010	115,756	14.4 million
Percentage water	31	21	7	na
Percentage sand	21	18	2	na
Percentage vegetated	48	61	91	na
1992 population	512,996	407,052	897,712	109.9 million
Population per km^2 in 1992	320	342	776	763
Percentage increase, 1981-92	33	8	14	26
Cultivable land per capita (ha) in 1992	0.14	0.18	0.12	0.09
% permanently out-migrating in 1991	3	4	2	na
% seasonally in-migrating in 1991	3	6	3	na
% mauzas with primary school	62	61	61	74
% mauzas with high school	10	7	17	13
% mauzas with health facility†	8	11	22	4
% households mainly farming	46	45	44	na
% households mainly day laboring	42	43	36	na
Cattle per household	0.88	0.71	0.84	1.33
Households per mechanized boat	79	97	99	na
1988 flood-related deaths per 100,000	81	81	57	1.4
% mauzas reporting livestock death in 1988 flood	79	67	32	na
1988 % area flooded	91	84	93	46
1991 % area flooded	58	52	33	na
1988 mean flood duration (days)	22	23	28	na
1991 mean flood duration (days)	12	13	11	na

Source: FAP 16/19 inventory and satellite image analysis

*Source: BBS (1993), except flood data, which is from Rogers, *et al.* (1989). Population figures are for 1991. Comparisons are for rural Bangladesh.

†Facilities below the union health center level, such as private doctors, may have been included in the inventory.

1992, 50,000 ha of mainland eroded and only 6,000 ha accreted, a loss of 23 percent of the mainland in the study area. This mainland was estimated to have supported 400,000 people in 1981, therefore, bank erosion must have forced 26 percent of the 1981 study area population to move between 1981 and 1992. It appears that many moved to island chars, while others moved to the diminishing area of setback land or left the charlands altogether.

Population growth in the mauzas within the 1980 banklines was very rapid over the period, increasing 92 percent as people moved to occupy new charland and were forced onto chars by bank erosion. Moreover, population density in the remaining unprotected mainland continued to increase, particularly on the west bank, where in 1992 it reached 1,342 persons per km^2 in mauzas unaffected by erosion, compared with 773 persons per km^2 in equivalent east bank mauzas. It appears that the higher rate of west bank erosion due to the changing river course has forced people into an ever-narrower band of land between the river and Brahmaputra Right Embankment (BRE).

FAP 1 (1992) predictions of the bankline in 2011 over 190 km of the river's 246 km length, imply erosion of about 49,500 ha. At current population densities and growth rates, that land would support about 578,000 people, but 31 percent of those people might be accommodated on 15,400 ha of newly accreted attached chars. This erosion would make 578,000 people homeless, 179,000 of whom might find homes and land on newly accreted attached chars within the Jamuna charlands, the remaining 399,000 people would have to seek shelter in the island chars, in the diminishing setback land, or outside the charlands. The problem is likely to be worse in the lower reach of the river, where population densities are highest on the unprotected mainland. These estimates ignore the risk of earthquake, which could result in more dramatic changes in river course.

Future erosion is clearly a threat to the "permanent" settlements on the Jamuna mainland, but for the 500,000 or so people living on mid-channel chars it is an ever-present danger. Analysis of images covering 1973-92 shows that only 30 percent of vegetated land on chars persisted for 14 or more years. In fact, 66 percent of the total within-bank area changed between channel and char at least twice during the 19 years. The majority of the mid-channel population, therefore, must have moved at least once during the period due to normal erosion or submergence of their land (excluding peak floods).

In 1991 relatively few households migrated away, only 2 percent left their mauza, although there were locally higher rates, particularly in the lower west bank. On the other hand, 4 percent of households present in the study area in 1992 had moved into their mauza in the previous year, mainly to colonize accreting east bank attached chars. Seasonally, in-migration was more common than out-migration. This appears to be an adjustment to the hydrologic cycle, whereby people move into island chars and attached chars to cultivate and raise livestock during the dry season and leave when the land is flooded.

Based on analysis of March 1992 Landsat imagery, the study area covered about 383,000 ha; of this, 21 percent was water, 14 percent was sand, and 65 percent was cultivated or vegetated. Within the banklines, 52 percent of the area was either sand or water and 48 percent was vegetated or cultivated. The area of vegetated (productive) island chars has grown more or less proportionally with the widening of the river, increasing by about 26,000 ha between 1980 and 1992. The proportion of vegetated char within the banklines has only increased from 45 to 48 percent.

The resource base of the Jamuna charlands is dominated by farming: 46 percent of households work the land for a living, and 40 percent depend on day laboring, which is predominantly agricultural. Only 5 percent of households fish for a living, although for 10 percent of households fishing is a secondary source of income. There is more cultivable land in charlands than is available nationally (0.14 ha per capita compared with 0.09 ha for the nation), and on the mainland 70 to 80 percent of mauza areas are reported to be cultivated. Many island char mauzas have less than 50 percent of land cultivated. Dry-land crops, mainly millet and groundnuts, are dominant in about 30 percent of mauzas, which are concentrated in the main channel chars. Aus and aman paddy are also locally important in the middle reaches of the river, but boro paddy is mainly grown in the unprotected mainland, particularly in the lower east bank. Despite the abundant supply of water, there is very little irrigation and virtually no HYV boro grown in the chars.

Despite the impression of plentiful grazing and high livestock numbers, reported numbers of cattle and buffaloes in the charlands are lower (only 0.82 per household) than in Bangladesh as a whole (but there are slightly higher than average numbers of goats and sheep). It may be that seasonal flooding, or losses in the 1987 and 1988 floods have depressed cattle numbers.

Floods are the main natural hazard faced by char dwellers, and there were severe ones in 1987 and 1988. In 1987, based on satellite image analysis, only 9 percent of the char area within the banklines was above water during the flood peak. In 1988 more than 90 percent of the area of mauzas in the study area was reported to have been flooded (including unprotected mainland) and flooding lasted an average of 24 days. By comparison, in 1991, which was a "high normal" flood year, 51 percent of land was reportedly flooded. There was a trend toward more extensive flooding in the north and less extensive in the south, and durations fell from north to south but averaged 12 days. There have been minimal flood deaths in the study area since 1988, but in that year more than 860 people were reportedly killed as a result of flooding, particularly in the upper and middle reaches of the river. Epidemic diseases were reported to have killed more people during the period 1988-92, particularly in the island chars of the upper and middle reaches.

Provision of services and infrastructure is the key to improving the lives of char people given the hazards with which they live. Health care facilities in the study area are concentrated in the unprotected mainland. Despite the fact that there appear to be more facilities relative to the population than in other parts of Bangladesh, in 31 percent of inhabited mauzas there was no recollection of a visit by a health worker. The char areas fare relatively well in primary education: about 61 percent of inhabited mauzas have a primary school (the same as in the unprotected mainland, but less than in Bangladesh as a whole), but many children still do not live close to a school. There are 28 percent more children per high school in the charlands than in Bangladesh as a whole, and those schools are concentrated on the mainland, which, because access requires boat transport, makes them inaccessible for most families.

Access problems limit the use of both health and education facilities, and river transport is also vital for coping with floods and erosion in the island chars. Local boat transport is entirely within the private sector, and mechanized boats have come to play an important role in linking the chars with such mainland facilities as markets. Availability of mechanized boats is slightly higher in the island chars (about 80 households per boat) compared with the unprotected mainland (about 100 per boat). Yet flooding and erosion could mean that a whole village would need to evacuate by boat in a short time. There are an average of 13 households per non-mechanized boat throughout the area, but small boats are hazardous during peak floods.

This is the first study to collect data for the whole of the Jamuna charlands. The inventory data and Geographic Information System that have resulted from this study offer a means of directing development programs to likely priority areas in terms of service provision and program location. The maps that form the core of this report already draw attention to high-priority needs. More detailed assessment using the GIS would assist in local planning and directing needs assessment to the areas with greatest hazards and least services.

A number of studies and proposed projects will affect the charlands. Bank protection, for example, might reduce erosion rates and, therefore, population displacement. Flood proofing measures, such as shelters and emergency transport services, could assist people in coping with both existing flood risks and future risk levels. In addition to programs directed specifically at charland hazards, there is a more general need that government and non-government development work give proper attention to the charlands, and that planning and service provisions be appropriate to the charland environment and society. Improved crop and livestock farming, for example, could involve research and development on dry-land farming, irrigation in chars, and livestock cooperatives or groups to improve access to credit and transport. Infrastructure investment, however, should avoid sites with a high erosion risk and structures built on island chars should be movable.

There are 1.82 million people living in the Jamuna charlands who will continue to be at risk from flooding. At present, flood risk is greater in the upper reach of the river, which experienced more extensive flooding for longer durations in 1991 compared with the middle and lower reaches. Flood modelling by FAP 25 indicates that confinement of the river by the proposed Jamuna multipurpose bridge, and by sealing and extending existing embankments, may raise flood levels and increase the risk of flooding for the 0.58 million people living in the middle and northern lower reaches. The proposed bridge may also result in major changes in the pattern of sediment transport and river morphology both up- and downstream of the bridge site. This could affect many char dwellers and alter the conclusions of this report. Modelling of such impacts linked with the charland inventory is needed.

Many char people are also at risk from erosion. Most of those on island chars can expect to move at least once in the next 20 years because of erosion. Using FAP 1 predictions for the banklines in the year 2011, an estimated 578,000 people may lose their homes and land to bank erosion by that year. This will increase the population pressure both on the island chars and the remaining mainland. River training works may be a viable way to stem this loss of land and consequent population displacement from the river banks. Measures to stabilize and prolong the lives of island chars could also benefit the 0.51 million people living on these chars.

20

Chapter 1

INTRODUCTION

1.1 Background to the Study

1.1.1 History

The original design of the Flood Action Plan (World Bank, 1989) included among its components a socioeconomic study of the active floodplains of the Brahmaputra-Jamuna, Ganges, Padma, and Meghna rivers. The active floodplain was defined at that time as areas within the main river channels and nearby areas of mainland, both of which are frequently subject to erosion and accretion and cannot be protected from floods. The aims of the active floodplain study were to:

- assess present agricultural practices, settlement patterns, and disaster responses;
- estimate the number of affected households on chars (mid-channel islands created by accretion) and within a short distance of the river banks;
- estimate the number of households on existing embankments; and
- prepare guidelines to be used in feasibility studies to ensure that in project planning full account is taken of the active floodplain populations.

As the detailed terms of reference (TOR) of FAP 14, the Flood Response Study, were being drawn up by the government of Bangladesh and finalized with donor agencies, it became apparent that the intended study would not immediately be possible. First a more general study was needed to establish—for the full range of flood environments inside and outside the chars—the context in which flood response occurred. In addition, the active floodplain study required the use of remote sensing data and satellite image interpretation, but the facilities and trained staff to achieve this within the FAP would not be ready until at least late 1991.

During 1991, the first full year of FAP studies, it became clear that regional studies were unable to devote sufficient resources to the specialized work of socioeconomic study of the active floodplain. Most used the main rivers as their study area boundaries. Of the regional studies only FAP 3.1, the Jamalpur Priority Project, attempted detailed socioeconomic studies in the chars, investigating those along the reach of the Jamuna adjacent to the project in 1992 (see Section 1.1.4). FAP 14, the Flood Response Study, undertook detailed household surveys in 10 active floodplain villages.

Finally, in 1992 ISPAN and the Flood Plan Coordination Organization (FPCO) agreed to undertake an inventory of resources and people in the main river charlands. This study, then, fulfills the need—foreseen in the Government of Bangladesh/World Bank Flood Action Plan of 1989—for a socioeconomic study of the people and resources of the active floodplain. Although it does not consider in detail the populations living long-term on embankments along the main rivers, analysis of erosion and accretion patterns has been added.

The inhabitants of the charlands are among the most hazard-prone people of Bangladesh, exposed as they are to floods and erosion. Structural flood protection measures are unlikely to benefit these people, and embankments may even raise flood levels within the charlands, increasing the risks to which they are exposed. Reliable information about these areas and the people who live in them has always been scarce. The difficulty of gaining access to chars and their constantly changing environment has made studying them a complicated undertaking. As a result, prior to this study, what little information was available did not cover in any detail all the main river charlands.

1.1.2 The Charland Study

This Charland Study is a special study under the Bangladesh Flood Action Plan (FAP). It was executed jointly by FAP 16, the Environmental Study, and FAP 19, the Geographic Information System (GIS), both of which are undertaken by the Irrigation Support Project for Asia and the Near East and funded by USAID.

This study has two objectives. The first is to develop databases and a geographic information system (GIS) that can be used as planning tools both for direct interventions in the charlands and for other interventions (such as embankments) that may affect the char areas. The second objective is to use the data collected, along with additional socioeconomic studies, to make general policy recommendations for the charlands and to test and develop means of rationally assessing the potential benefits of flood proofing measures in these areas.

The objectives have been addressed with five tasks.

- Making an inventory of resources, people, and infrastructures in the Brahmaputra-Jamuna, Meghna, Padma, and Ganges charlands and collecting additional information on hazards (led by FAP 16).
- Using digital satellite images to analyze physical changes and land use in these areas, and integrating this analysis with inventory data using a GIS (FAP 19).
- Conducting supplementary socioeconomic studies using rapid rural appraisal (RRA) methods in six river reaches (building on the Flood Response Study, FAP 14).
- Conducting detailed studies of flood losses and flood proofing potential in two areas along the Jamuna River (building on the Flood Proofing Study, FAP 23).
- Integrating the results of the above tasks into a comprehensive report.

This document is the Preliminary Report of Phase 1 of the FAP 16/19 Charland Study. It consists of a series of satellite images and summaries of the analysis of morphological changes in the Brahmaputra-Jamuna River system. It includes analysis, maps, summary data tables, and lists showing population, land and resource use, and hazards for each mauza.[1] (Notes follow each chapter.)

The study's primary product is a database derived from the field inventory returns that, when combined with data derived from Landsat imagery, forms an interactive GIS. Some of the more important results from the inventory and the GIS, particularly those concerning human population and resources, appear as figures in this report.

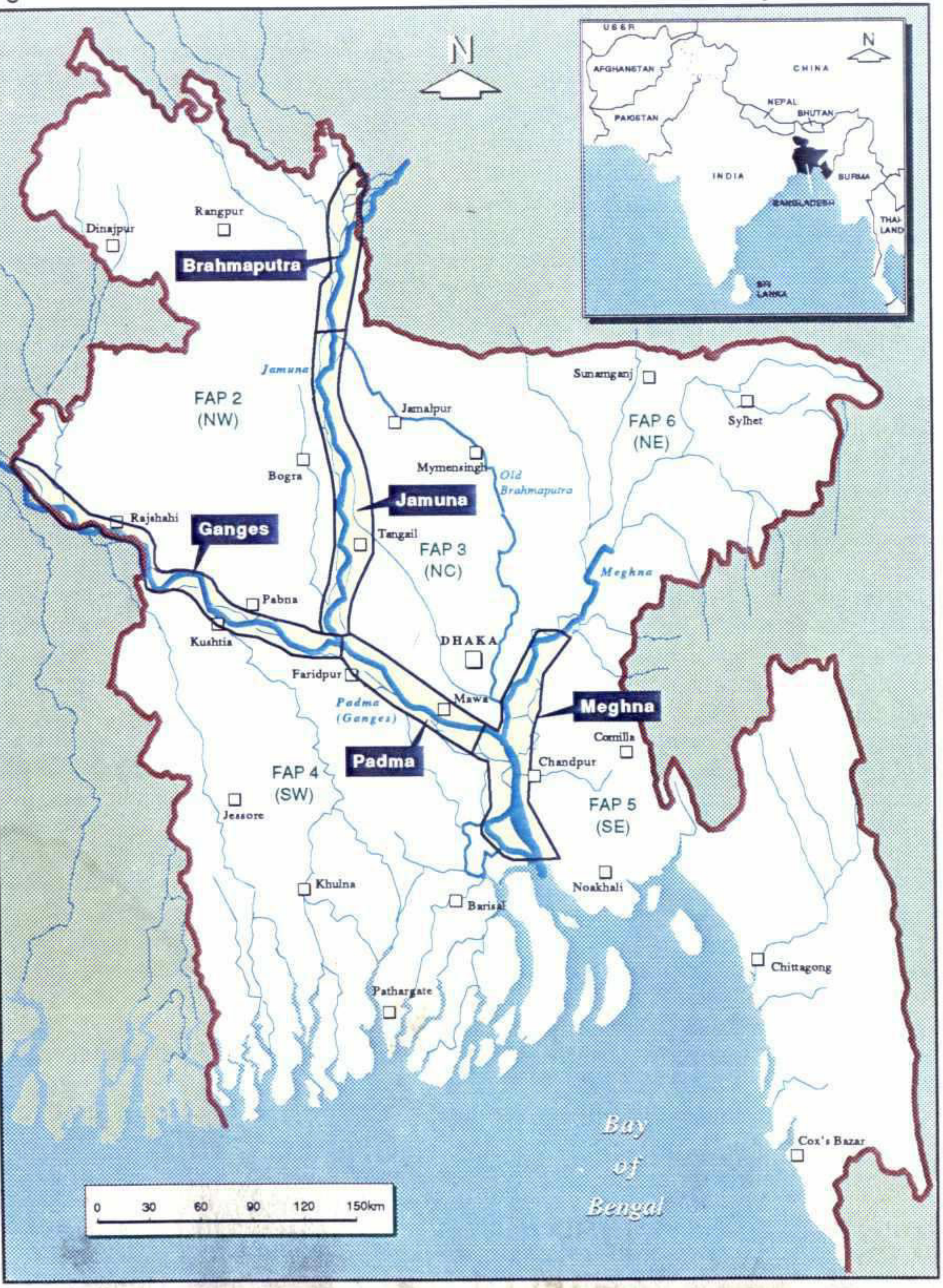
1.1.3 Delineation of the Study Area

The study area originally was limited to "charland," the Bengali term for a "mid-channel island that periodically emerges from the riverbed as a result of accretion" (Elahi, Ahmed, and Mafizuddin 1991). However, both this study, and the FAP 3.1 study of the Jamalpur area and middle Jamuna chars, found the definition too narrow, particularly in the context of the FAP planning methodology. For example, there are mid-channel islands that were not formed by accretion but, rather, appear to be remnants of the mainland that were cut off as the river encircled it. There also are accreting chars that are attached to the mainland. In addition, there are relatively stable relic chars that are now assimilated into the mainland, such as those in the area of the Old Brahmaputra River. Relic chars outside the main river active floodplains were excluded from this study.

Phase 1 of the inventory covered the Brahmaputra-Jamuna River system (see Figure 1.1). That this river has two names in Bangladesh reflects a major historical change in its course. From the Indian border[2] in the north to the off-take of the Old

Figure 1.1

Charland Study Location



Brahmaputra the river is known as the Brahmaputra, and has within known times followed this course. Between 1780 and 1830, however, the river changed course from the off-take with the Old Brahmaputra (which formed its old course), and took a direct southerly route to join the Ganges. This relatively new river channel is known as the Jamuna. For simplicity, the river is hereafter referred to as the Jamuna, and Brahmaputra is reserved for the study area north of the Old Brahmaputra off-take.

The study area boundary is the alignment of existing and proposed embankments along the main river; the area within the boundaries currently is flood-prone and will likely remain so. The existing Brahmaputra Right Embankment comprises most of the western boundary and has been studied by FAP 1. Further north, the Kurigram embankment forms the study area boundary. The left bank boundary is more complex: In the far north the Indian border serves the purpose. Further south, existing and proposed embankments that would form the proposed FAP 3.1 controlled flooding embankment between the Old Brahmaputra off-take and Jagannathganj Ghat make up the boundary. Similar existing embankments or proposed alignments were followed south of that area.

The Landsat image of March 8, 1992, shows 282 island chars over 350 m long (islands smaller than this tend to be uninhabited sandbanks) in the study area. Of these, 56 are more than 3.5 km in length. The study area also includes substantial areas of attached chars and adjacent mainland. During 1992 the study area was enlarged to include all unprotected mainland as well as charland. Surveys to collect inventory data were undertaken in these extra areas in April 1993 and the results have been incorporated into this report.

For this study, the Brahmaputra-Jamuna River system has been split into three major reaches: upper, middle, and lower. The middle reach also has been studied in detail by FAP 3.1 (FAP 3.1, 1993). The lower reach was subdivided into a northern portion, which covers the unprotected part of the proposed FAP 3.2 sub-regional study, and a southern portion, which is the area downstream of the proposed Jamuna bridge.

1.1.4 Other FAP Studies

Phase 1 of the FAP 16/19 Charland Study had particularly close links with FAP 1 and FAP 3.1 and is a necessary next step in expanding on the findings of those studies.

The FAP 3.1 feasibility study concluded that the likely impact of any proposed controlled flooding intervention in the area would be to induce a rise in the peak flood levels on unprotected land (FAP 3.1, 1993). In order to further analyze the potential impact of flood control in the middle reach of the Jamuna, FAP 3.1 pointed to the necessity for gathering baseline data on the number of people and the areas of land likely to be affected, as well as details of resource availability and use. That need for baseline data was instrumental in designing the study approach and methodology for the FAP 16/19 Charland Study.

Baseline data from the FAP 16/19 Charland Study is also essential in weighing the implications for the future flooding regime of the Jamuna if the Jamuna multipurpose bridge is constructed. As part of their hydraulic modelling exercise, FAP 25 has evaluated the effects of the Jamuna bridge in four of its eight intervention scenarios. The results of this work have implications for flood risk and, hence, resource availability and use in the char areas.

The results of the FAP 19 satellite image analysis of bank erosion was jointly analyzed with FAP 1 for that project's specific use. The Charland Study has consulted the following other relevant FAP studies:

- FAP 1, The Brahmaputra Right Embankment
- FAP 2, Northwest Regional Study (right bank of the Jamuna and Brahmaputra)
- FAP 3, North Central Regional Study (left bank of the Jamuna)
- FAP 3.1, Jamalpur Priority Project

- FAP 14, Flood Response Study
- FAP 18, Topographic Mapping
- FAP 21/22, Bank Protection and River Training
- FAP 23, Flood Proofing Study
- FAP 24, River Surveys Program
- FAP 25, Flood Modelling and Management Project

Potential further uses of the Jamuna charland inventory data and GIS are discussed in Chapter 5.

1.2 Methodology

The Charland Study incorporated data generated from a time series of digital Landsat imagery and field data (questionnaires) collected at the mauza level. These elements were integrated through a database and GIS that displayed the data as digital maps. This methodology evolved during Phase 1 of the study in an effort to determine whether the adopted techniques were appropriate to the diverse situations found in the chars. The methodology is summarized below to demonstrate the reasons for the form the study took, and to acknowledge the likely limitations of the data and its use. Figure 1.2 (next page) shows the Jamuna study area and places mentioned in the text.

1.2.1 Phase 1 Reconnaissance

As part of Phase 1 a reconnaissance of the Brahmaputra-Jamuna River system was carried out. The goal of the survey was, first, to gain enough knowledge of the area to design and field test the draft inventory questionnaire, and second, to assess the usefulness of Landsat imagery as the main mapping tool of char physiography.

Three case study areas were initially considered:

- Adjacent and north of the town of Aricha in the southern part of the lower reach (visited April and June 1992).
- North and west of the town of Bhuapur in the northern part of the lower reach (visited May 1992).
- North and west of the town of Bahadurabad in the upper part of the middle reach (visited May 1992).

At about the same time (in April 1992), FAP 3.1, in connection with its detailed household investigation, carried out a reconnaissance of much of the middle reach between the Old Brahmaputra offtake north of Bahadurabad and south to Madarganj. The leader for the FAP 16/19 study was also a member of the FAP 3.1 reconnaissance team.

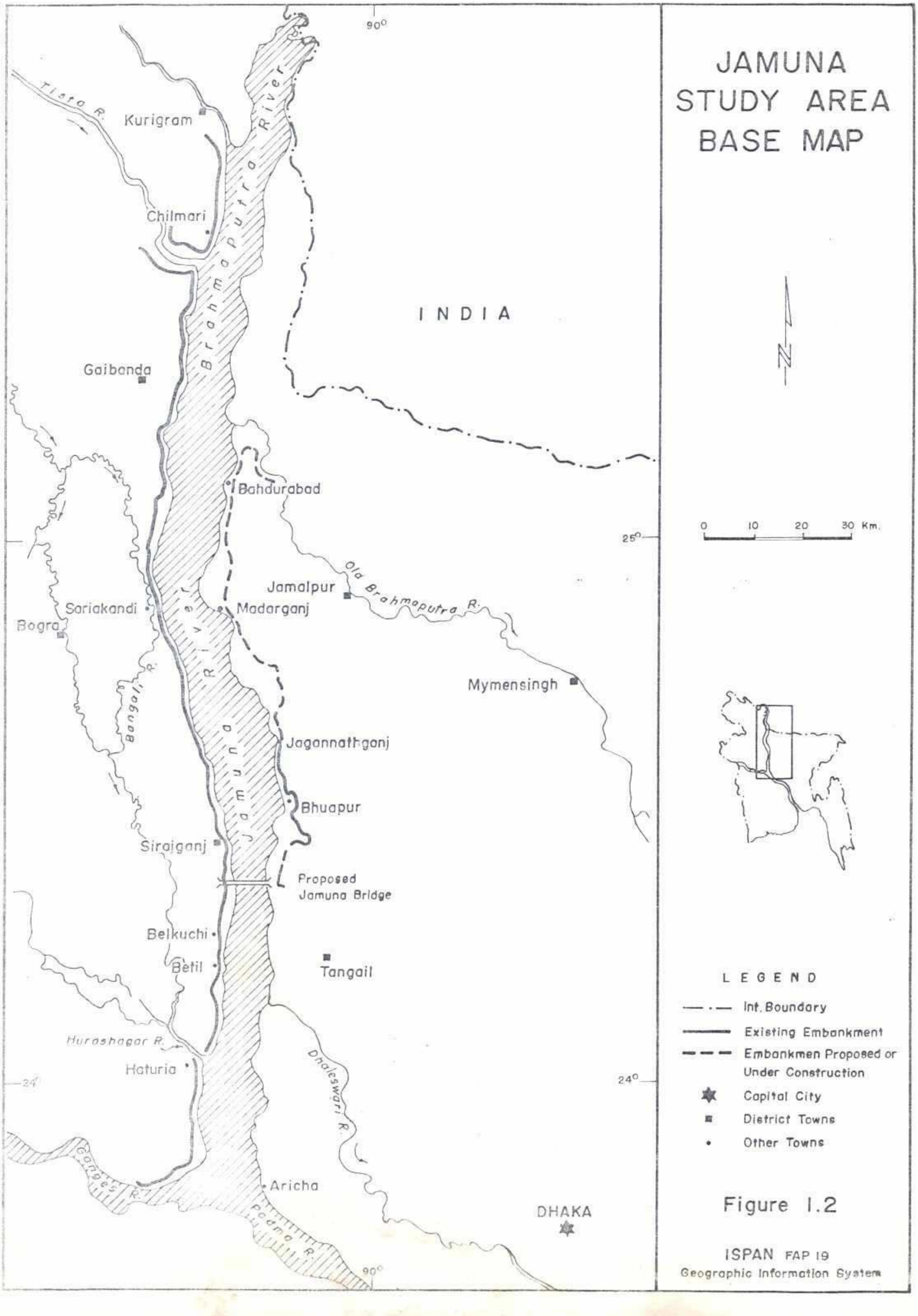
During the FAP 3.1 reconnaissance it became evident that mauza boundaries, established around 1905, were well known by char people and seemed to be the only viable unit for obtaining summary data. Moreover, Bangladesh Bureau of Statistics (BBS) national census data are available on a mauza basis, allowing a cross-check with 1991 census data (when it becomes available) and comparison with earlier BBS data. After completion of the FAP 3.1 reconnaissance, detailed planning of the FAP 16/19 study began.

A second reconnaissance was performed during April and June 1992 for the purpose of "ground truthing" the satellite imagery. The first step in this process was to use the most up-to-date imagery available (March 8, 1992) to generate a land cover classification map for the study area. A field team then followed a route from the Indian border, along the full length of the study area, to Aricha. Along the way, land cover information was collected from 245 test sites by field observation and interviews with local people. A global positioning system (GPS) was used for test site location calculations and navigation. Field data from these sites was then compared with the classification map to assess the accuracy of the classification.

Further details of the methodology and results of the ground truthing are in Chapter 2.

1.2.2 Charland Case Studies

At nine of the sites used in the ground truthing, informal village meetings also were held to test the questionnaire and to provide cross-checks on the



JAMUNA STUDY AREA BASE MAP

Figure 1.2

ISPAN FAP 19
Geographic Information System

digital analysis being carried out for dating the length of time between land accretion and erosion. Interviews in the nine case study villages highlighted issues that were thought to be specific to certain previously unvisited reaches of the river. The dynamic nature of the area and the need for the most recent satellite imagery became apparent during the field testing. Also evident was that rigidly defined mapping and data collection units were needed for the inventory work. Hence, existing mauza units were used for all systematic field data collection, despite the fact that they do not correspond to present land units (such as islands or attached chars). Details of the case studies are in Appendix D.

1.2.3 Inventory Questionnaire

The inventory used a fixed questionnaire and key-informant discussion/interview method in each of the char area mauzas. First, the mauza was identified and located on a map; then the name and BBS classification and code were checked. Next, key informants, individuals who could speak for the entire mauza, were identified. If such informants could not be found, separate returns were completed for the mauza's constituent villages. In all there were 82 mauzas with more than one identifiable constituent piece, and there were 126 more questionnaire returns than mauzas. The preliminary draft of this questionnaire was field tested and then modified. The final version is in Appendix C.

The questionnaire was pre-coded and had some 400 data fields (discrete pieces of information) that covered:

- identification of the mauza;
- physiography of the mauza;
- mauza population, including seasonal and permanent in- and out-migration;
- infrastructure and service provision;
- broad socioeconomic parameters (occupations, agriculture, livestock);
- environmental hazards; and
- social conflicts.

1.2.4 Mauza Mapping

A suitable map base was required for the production of presentation maps of the mauza inventory data. Figure 1.3 shows the mauza and district boundaries for the study area. An existing set of maps showing mauza boundaries, scaled 1 inch to 1 mile and called Police Station maps, was used by the GIS for this purpose. Along the Jamuna these maps date from between 1905 and 1927.[3] Copies were rescaled to 1:100,000 and then overlaid on a print of the 1992 Landsat satellite image. The locations of the existing and proposed embankments were then plotted onto the overlay. Data for this mapping were compiled from various sources, including:

- The Brahmaputra Right Embankment Study. The location of the existing right embankment was obtained from the 1:50,000 maps of FAP 1. Those maps were superimposed onto the March 1989 1:50,000 SPOT imagery to verify location, then reduced to 1:100,000 and overlayed on the 1992 Landsat image.
- The location of the proposed FAP 3.1 left embankment was plotted from an overlay onto the November 10, 1990, 1:50,000 SPOT image, then reduced to 1:100,000 and overlayed on the Landsat image.
- The locations of existing and proposed embankments in the FAP 3 North Central Regional Study area (the left bank of the Jamuna River south of the FAP 3.1 study area) were taken from 1:50,000 BWDB maps held by FAP 3, which were reduced to 1:100,000 scale and overlayed on the Landsat imagery.

Once the embankment locations had been plotted, there remained a considerable amount of land that could be classified as mainland, but which is presently unprotected and will likely remain so. A decision was made, therefore, to include in the study mauzas that had any part of their land on the unprotected side of the embankment. The study

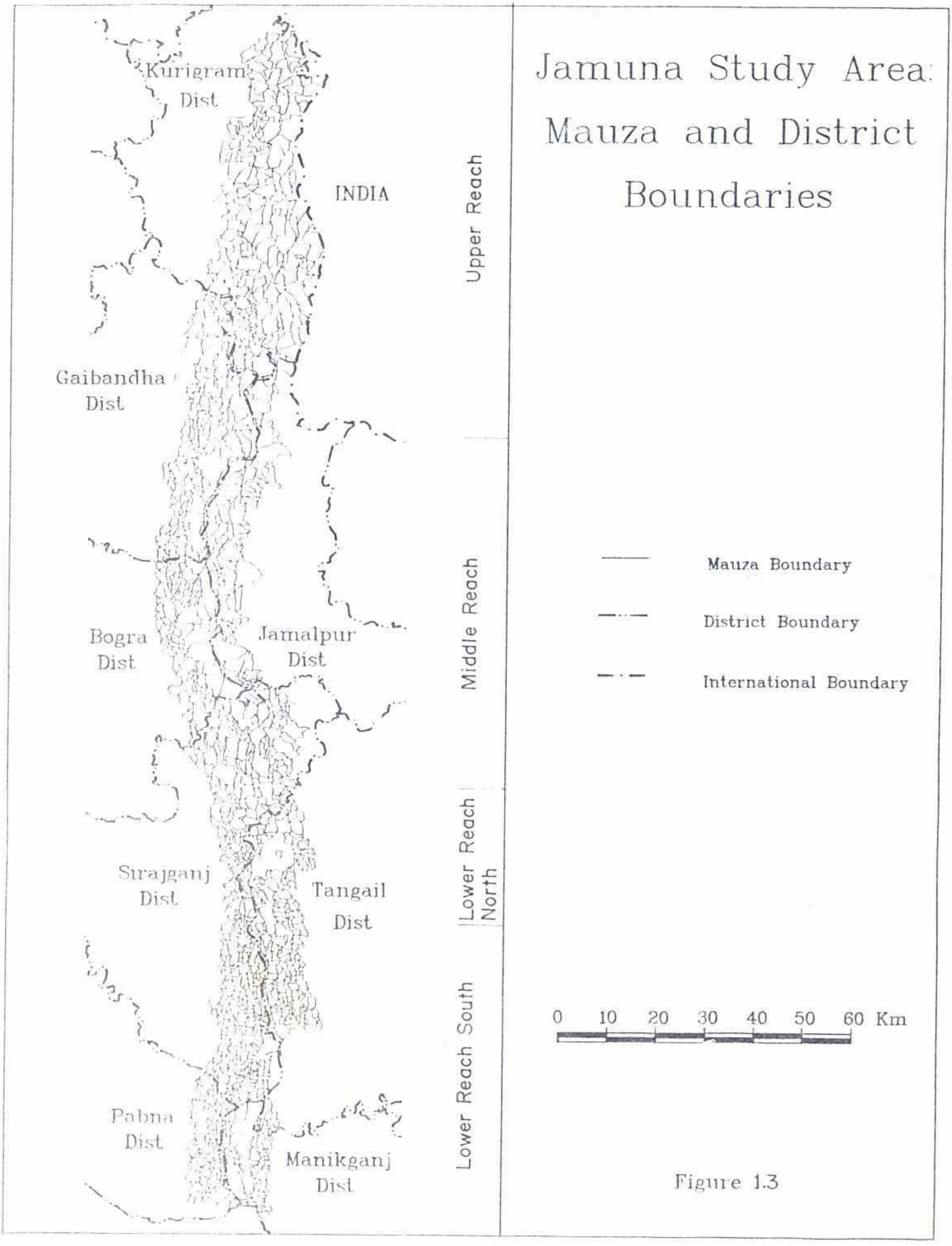

Jamuna Study Area:
Mauza and District
Boundaries
Kurigram
Dist
INDIA
Gaibandha
Dist
Bogra
Dist
Jamalpur
Dist
Sirajganj
Dist
Tangail
Dist
Pabna
Dist
Manikganj
Dist
Upper Reach
Middle Reach
Lower Reach
North
Lower Reach South
Mauza Boundary
District Boundary
International Boundary
0 10 20 30 40 50 60 Km

Figure 1.3

area was thus enlarged to include all potentially unprotected land (based on existing and proposed embankments), and not just those mauzas that are predominantly island and attached charland. This addition brought the total number of mauzas to 1,443, some 247 more than had previously been envisaged for the study.

The Police Station maps were cross-checked with the relevant BBS Small Area Atlases to ensure that there were no major differences in mauza boundaries, and the BBS mauza codes ("geocodes") were used for mauza identification. Copies of the Landsat imagery and overlay mauza maps were then verified in the field, with particular attention given to unallocated areas on the Police Station maps, which were located in the main river channel when the maps were produced. The result, which was used for GIS data presentation and analysis, was a map of mauzas overlaid on the latest Landsat imagery.

1.2.5 Charland Classification

Land and mauzas in the study area were classified into the following four types (subdivided into left and right bank as appropriate):

- Island chars.
- Right and left bank attached charland.
- Right and left bank setback land.
- Right and left bank unprotected mainland (other than setback land).

Figure 1.4 illustrates this charland classification system.

Island chars are defined as land that requires a crossing of a channel of the main river to reach even in the dry season. Attached charland is accessible from the mainland without a channel crossing during the dry season, yet is inundated or surrounded by water during the peak of a "normal" flood (normal monsoon). "Setback land" is mainland that lies on the river side of flood protection embankments; it is distinguished from other unprotected mainland because the embankments not only may act as refuges during floods but also may increase the height of flood water in the area. "Unprotected mainland" has no embankment between it and the main river and is inundated during higher than normal floods. Unprotected mainland has been surveyed up to: the extent of recent floods, features that restrict flooding (such as roads), or the Indian border (in the far north of

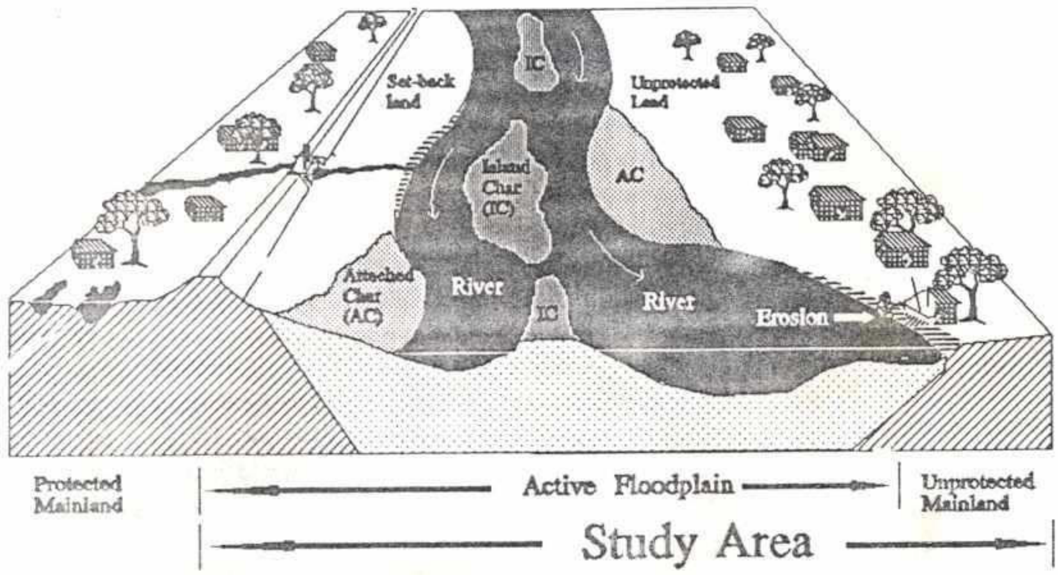


Figure 1.3 Charland Classification

the study area). In the summary tables the "unprotected mainland" category includes both setback land and other unprotected mainland.

This final char classification evolved from earlier work jointly undertaken by FAP 3.1 and FAP 16/19.[4]

Embankments rarely, if ever, follow mauza boundaries. Secondary source data and FAP 16/19 inventory data were collected for whole mauzas, including the protected part of mauzas split by embankments. Therefore, for the analysis totals, such as those for area or population, calculations were based on the mauza total proportionally reduced for the mauza area not protected by the embankment.

The breakdown of the study area according to this classification system is shown in Chapter 3 (Figure 3.1), where it is presented with a land use classification derived directly from the satellite image analysis.

1.2.6 Mauza Database and GIS

Output tables summarizing the data for reaches and land types are in Appendix E. A summary listing of the salient features of each mauza is in Appendix F (separate volume).

The verified mauza map was digitized using the GIS software PC ARC/INFO (ESRI) to provide a base map. Questionnaire data was displayed in map form using ERDAS, which also allowed the mapped questionnaire data to be digitally superimposed on the Landsat imagery, so that the derived char physiography information could be related to the field-collected questionnaire data. It should be noted, though, that the mauza boundaries were digitized from the Police Station maps rescaled to a paper copy of the image, and that some distortions are likely to have been introduced by this process. These do not affect the GIS data from the inventory, nor the analysis of image-based data, but they may affect some of the analysis that combined these two data sources. The inventories of the Meghna, Padma, and Ganges have attempted to overcome this problem.

1.2.7 GIS and Satellite Image Analysis

The Landsat image analysis on char physiography is detailed in Chapter 2 of this report. This analysis was carried out by digitally relating a time series of eight dry season images acquired since 1973, allowing the following parameters to be mapped:

- char history over the past 19 years;
- bank erosion patterns over the past 19 years;
- current land use and cover; and
- vegetation/cultivation periods over the past 19 years.

Analysis and mapping of bankline and within-bank trends are also reported in Chapter 2.

The charland classification map was digitized and superimposed onto the questionnaire database so that each mauza could be subdivided into char types. This allowed the portions of mauzas lying within protecting embankments to be discounted, assuming for example that densities of people and livestock were uniform across the mauza. Many mauzas have more than one char type. In each mauza, the areas of each char type are known, but not the distribution of people and resources. It was impossible to estimate the number of people within a mauza by char type because of wide variation in population density in mauzas with a singe char type.

An alternative methodology was adopted: to classify each mauza by its predominant char type even if this covered less than 50 percent of the mauza area. For example, a mauza with 60 percent water, 30 percent island char, and 10 percent attached char is classified as island char. Using this method, summary output tables (Appendix E) were produced by river reach and predominant char type. The tables are analyzed and interpreted in Chapters 3 and 4.

NOTES

1. A mauza is the government's smallest revenue unit with a fixed cadastre.

2. For all maps included in this report the international boundary has been derived from available map sources. The boundary is approximate, and should not be taken as authoritative.

3. The mauza boundaries and administration units in the study area were fixed in 1905, and have been only slightly modified since then, despite significant changes in the river channel. The 1905 boundaries, therefore, reflect the river channel alignment at that time, with the main district boundary following either the center of the river or one of its banks. Some land that was on the west bank in 1905 is now on the east bank due to river movement, nonetheless, it is still administered by the west bank and the people there consider themselves to be from the west bank.

4. FAP 3.1 devised a 12-type charland classification system for the analysis and interpretation of data from the middle Jamuna. That classification was based on char location, size, age, stability, cultivation, and habitation. While this was useful for deciding which households to survey, it proved unwieldy for broad data interpretation and analysis. A north-south division was tried because initial results from the FAP 25 hydraulic modelling work showed that embankment construction and the Jamuna bridge project made the peak flood risk higher in the south than in the north of the reach. From a planning perspective, however, it became apparent that the division between the west and east banks was more significant since policy interventions have so far been considered separately by different regional studies. A five-type classification emerged: island chars; attached charland, split between the west and east bank; and land between the attached charland and any existing or proposed embankments, again split between the west and east bank. This latter class has been termed "setback land" since the embankments are set back behind this land; it is mainland that lies between rivers and existing and proposed embankments. For the Jamuna Charland Study it was important to include areas in the upper reach that can be severely flooded by the main river but that might be termed "unprotectable" and for which there are no plans to build flood protection embankments. This results in the distinction between setback land and other unprotected mainland in this study.

Chapter 2

CHAR AND CHANNEL DYNAMICS

2.1 Summary

Seasonal and long-term changes in the physical and morphological characteristics of the Brahmaputra-Jamuna charlands affect the settlement patterns and social and economic activities of the their inhabitants. To better understand the dynamic nature of the chars, FAP 19 undertook a study of historical maps and modern satellite images. This study, which was performed in part with the collaboration of FAP 1, is reported more fully in a separate FAP 19 report on the dynamics of the Brahmaputra-Jamuna River.

It was found that since 1830 the Brahmaputra-Jamuna has been moving westward and becoming wider, resulting in an annualized bank erosion rate of approximately 50 m per year on the right (west) bank, and more recent erosion on the order of 100 m per year. Analysis of short-term changes based on a series of eight satellite images covering the 19-year period from 1973 to 1992, determined that rapid bank erosion, which results in local bay formation, rarely persists for more than four years. Slow erosion likewise is a temporary phenomenon; at any given site in most reaches it tends to persist for less than 12 years. The movement of dry season river channels or branches and chars within the widening channel is highly complex, but it is evident that the area of chars has increased in proportion to the widening. Most locations in the channel have been char at some time in the 19-year period, but it is rare for a char to have persisted for more than about 11 years.

Rates of bank retreat in reaches with concentrations of island chars are higher during high-flow years and lower during low-flow years. Erosion rates since 1973 show no decreasing overall trend, and there seems every reason to expect that the widening that has been going on for 200 years will continue for some time at about the present rate, unless engineering intervention prevents it. On this basis it can be assumed that the right bank will retreat at an average rate of about 100 m per year along most of the river over the next 20 years. Widening will be somewhat faster adjacent to islands than in nodal reaches, so the characteristic hourglass shape of a node-island-node geomorphic unit will be maintained and perhaps amplified. The braiding intensity is expected to increase only slowly as floodplain is destroyed and the river widens, because sedimentation will enlarge existing islands and merge newly accreted chars onto the sides of islands nearly as fast as separate chars and divided reaches are created. In this respect at least, the pattern of channels and chars is perhaps approaching a dynamic equilibrium.

2.2 Background

Three great rivers drain through Bangladesh and have been responsible for building the vast alluvial fan that forms its landscape. The Ganges and Brahmaputra are the larger, both ranking among the top 10 rivers in the world. When considering the present hydrology and geomorphology of these rivers and the fan they continue to build, it is important to bear in mind their dynamic nature over both the geological time scale and the recent past.

The Ganges rises in India on the southern flanks of the Himalayas and flows southeastward into Bangladesh. It once followed a course well to the west of its present position in Bangladesh, building a delta in the area of Jessore and reaching the Bay of Bengal along the course of the present Hoogly River. In the 15th or 16th century it began to swing eastward to follow a course close to that of the present day Gorai River, and the Hoogly became a right bank distributary. It then continued to migrate eastward, and by the mid-18th century maps show it flowing along what is now the Arial Khan River. Until that time, there had been no confluence of the Ganges with either the Brahmaputra or the Meghna rivers, but this situation was to change radically in the next few years.

The Brahmaputra rises on the northern flanks of the Himalayas, its source only a short distance from that of the Ganges. It flows almost due east through China as the Tsangpo before turning south and entering India. It then flows southwest through Assam as the Brahmaputra before turning almost due south as it enters Bangladesh. Until the late 18th century the curve of the river continued, producing a southeasterly course that took the Brahmaputra to the east of the Madhupur Forest Tract and into the southern end of the Sylhet Basin, where it joined the smaller Meghna River, and the combined flow entered the Bay of Bengal along the present course of the Meghna Estuary.

This drainage pattern is clear on Major Rennel's map of around 1780, but by the time of the Wilcox map of 1830 the situation had changed drastically. Sometime in the intervening period, the Brahmaputra broke through the higher ground along its southern flank around Gaibanda to shift 60 km and adopt a new course to the west of the Madhupur Forest Tract. In Bangladesh the reach of river this shift created is called the Jamuna, the name Brahmaputra being retained by the former course, which has dwindled to become little more than a high-flow distributary. There is evidence that this change did not occur catastrophically, but took place gradually over a period of perhaps 30 years between 1790 and 1830.

As a result of this shift the Brahmaputra-Jamuna formed a new confluence with the Ganges, creating a very large river called the Padma. For a few years the Padma followed the old course of the Ganges, along the Arial Khan, but soon the great increase in the volume of flow led to a last major avulsive shift when the Padma broke through a neck of higher terrace land separating it from the Meghna. For the first time the three large rivers met near Chandpur, the situation which still prevails today.

With an overall length of nearly 3,000 km and a catchment area of around 560,000 km^2, the Brahmaputra is one of the world's greatest rivers. The river's average discharge of around 20,000 cumecs and bankfull discharge of about 44,000 cumecs (FAP 22, 1992) make it the fourth largest freshwater flow in the world. The annual hydrograph of the river is characterized by high flow during the summer and very low flow during the winter. Summer high flows are driven by a combination of snowmelt runoff from the Himalayas together with local monsoon rainfall, particularly in the Assam valley and in Bangladesh. Annual flood peaks are on the order of 60,000 cumecs, three times the peak flow of the Mississippi (Coleman, 1968), and may exceed 100,000 cumecs in a 100-year return period flood (FAP 1, 1992).

The basin is also bounded by the highest and most tectonically active mountain range in the world, the Himalayas. The Himalayas are being uplifted by compression of the Earth's crust due to collision between the Indian and Asian tectonic plates and the young alpine mountains so produced are naturally subject to severe erosion. As a result, the Brahmaputra carries a very heavy sediment load. Estimates of the Brahmaputra's sediment load are on the order of 5 million metric tons per day in flood (Coleman, 1968), and on average between 140 million (FAP 22, 1992) and 500 million m^3 per year (FAP 1, 1992).[1] This makes the Brahmaputra third among the rivers of the world in terms of sediment load. The combination of large and variable discharges of water and sediment is responsible for the Brahmaputra's braided pattern of multiple, shifting anabranches separated by chars ("braid bars"). Braided rivers are characterized by unstable banklines and rapid rates of lateral movement, and the pattern of channels and chars within the Brahmaputra changes annually in response to the year's sequence of flows.

2.3 Methodology

2.3.1 Common Base for Mapping

A satellite image is converted to a map by georeferencing it to a standard map projection, scaling it, and then displaying or printing it in various colors, which represent the spectral response of the Earth's surface to electromagnetic energy. The colors must then be interpreted to obtain information on geographic or vegetative features. For this study maps derived from the most recent satellite images were compared with maps covering the area of Bangladesh dating from 1830, 1914, and 1953 to determine long-term trends. A sequence of satellite images for the 19-year period from 1973 to 1992 was used for more detailed analysis of the river dynamics over the past 20 years with particular emphasis on bankline movement, low-flow channel alignment, and char distribution.

Banklines of the Jamuna River were digitized from the best available copies of the 1830, 1914, and 1953 maps. The 1830 map, drawn by Wilcox, was fitted to the Bangladesh Transverse Mercator (BTM) projection by matching up villages and other recognizable features with those on modern maps. The 1914 and 1953 maps, which used more conventional cartography, were more easily matched to the BTM. The historic maps were only used to digitize banklines; islands, tributaries and distributaries were ignored. These historic bankline positions were then plotted on maps derived from satellite images, which were examined to identify old channel scars and controlling physical features to verify the historic banklines.

FAP 19 and FAP 1 worked together to verify the reference frames and check the accuracy of the 1830 and 1914 maps. It was concluded with confidence that the maps can be co-registered with later maps and images. The historic maps are surprisingly accurate when checked against readily identifiable features, such as meander scars in the Tertiary terraces that back the floodplain and can be identified on both the maps and the most recent satellite images. Hence, in this study the course of the river following the major shift from the east to west side of the Madhupur Forest Tract is known with reasonable accuracy. This was a major step forward as it allowed a long-term perspective to be taken when considering river width and pattern evolution.

2.3.2 Satellite Image Selection

A series of dry season satellite images for 1973 through 1992 was selected to study changes in river and charland geometry and vegetation. The river banks, as well as the chars, could be mapped with a precision and consistency that enabled local characterization in greater detail than could be compiled from available map sources. Satellite image archives in the United States, France and Thailand, as well as Bangladesh SPARRSO, were

Table 2.1 Satellite Imagery Used for the Jamuna Char Study

Date	Path/Row	Sensor
Feb. 21, 1973	148/42, 43	MSS
Jan. 10, 1976	148/42, 43	MSS
Feb. 22, 1978	148/42, 43	MSS
Feb. 21, 1980	148/42, 43	MSS
Feb./March 1984	138/42, 43	MSS
Feb. 7, 1987	138/42, 43	MSS
Jan. 30, 1990	138/43	TM
Dec. 10, 1990*	138/42	TM
March 8, 1992	138/42, 43	TM

*No suitable image was available in any of the archives for the northern image frame for the 1989-90 dry season. This means that changes between 1990 and 1992 represent the consequences of only one monsoon in the area north of the Old Brahmaputra offtake, but for two monsoon seasons south of that point.

searched to identify a suitable time series for the Jamuna area, and 16 images, listed in Table 2.1, were selected for the study.

Two Landsat frames were required for each image date as the boundary between them fell near the offtake of the Old Brahmaputra River. Two Landsat satellite sensors were used: the Multi-Spectral Scanner (MSS) data, which has an 80 m ground resolution,[2] was selected as the primary source because of its long record period and the low cost, but for 1990 through 1992 the Thematic Mapper (TM) sensor was used because it provided high-resolution images (to 30 m) more suitable for analyzing current conditions.

Landsat MSS data for dry season dates between mid-January and mid-March were selected for the years 1973, 1976, 1978, 1980, and 1984. After SPARRSO agreed to allow use of the 1990 Landsat TM imagery, this list was augmented with an additional MSS image for 1987 (from FAP 21/22) and a 1992 TM image set (purchased jointly by FAP 16 and FAP 1).

2.3.3 Image Preprocessing and Rectification

The 16 images listed in Table 2.1 were acquired on nine-track computer tape, read into FAP 19's ERDAS image processing system, and preprocessed to remove noise from data transmission and storage. Each image was then rectified to geographic coordinates and fixed to the BTM projection using control points selected from the 1989 SPOT image prints. The SPOT image prints, at 1:50,000 scale, were supplied to FAP 19 by the FPCO. A common pixel size of 80 by 80 m was selected for both MSS and TM images to provide a consistent foundation for analysis.

Each satellite scene was clipped to a precise rectangular area and the paired north and south scenes were stitched together. Pixel color and brightness in both images was then harmonized to give a consistent appearance to the composite map. The result was a set of eight maps (Figures 2.1a and b) covering the entire Brahmaputra-Jamuna River from its entry into Bangladesh via India to the confluence with the Ganges River, a distance of some 240 km.

2.3.4 Satellite Image Classification

To create precise, comparable maps of river channel features, each digital satellite image grid cell, or pixel, was classified according to its image brightness and color. A full-size georeferenced Landsat MSS image contains about 7.5 million pixels in each of four spectral bands. Each pixel corresponds to a ground resolution of about 80 by 80 m, or 0.64 ha.

The multispectral image classification methodology evolved through a series of tests using standard classification techniques described in Richards (1986). Generally speaking, similar surfaces or types of ground cover produce a distinct range of spectral responses known as a signature. Digital algorithms were used to recognize and statistically define these spectral patterns in the image data. Next, the pixels were sorted into one of the proposed classes (signatures) through the use of a mathematically-based decision rule (maximum likelihood). Finally, the land cover features to which each proposed class corresponded were identified, and analogous categories were combined. The final product was an image composed of 12 classes consisting of three categories each of water, sand, cultivated/bare soil, and natural vegetation.

2.3.5 Accuracy Assessment of Image Classification

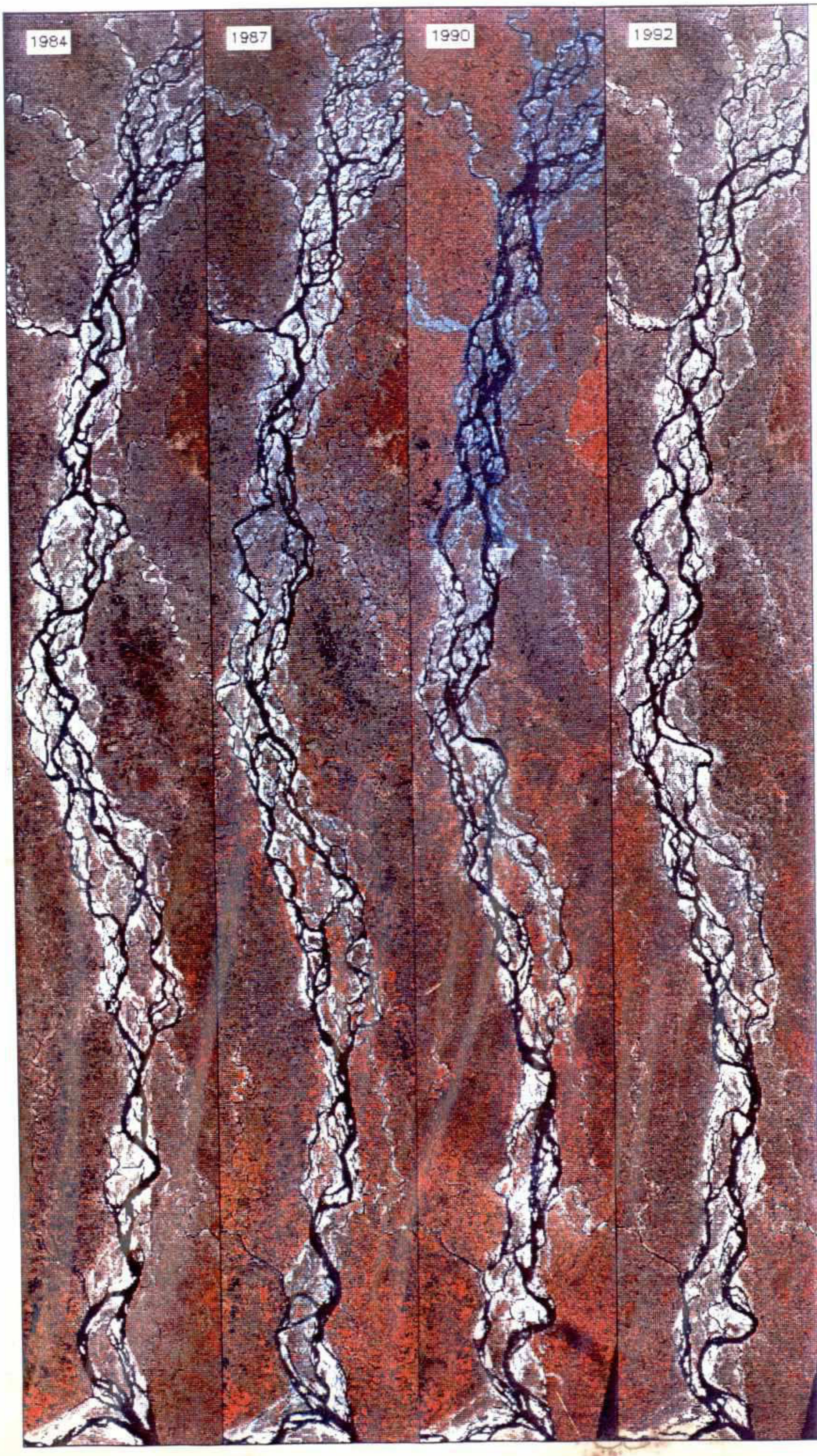
The accuracy of the image interpretation was checked in the field between March and June 1992. The evaluation was based on a comparison of actual ground conditions with those interpreted from the image ("ground truthing") at 245 sites along the entire course of the river in Bangladesh (Figure 2.2). Waterways and water bodies, land cover, and agronomic practices were observed in the field, then compared with spectral signatures at the truthing locations from color prints of the 1992 satellite image.

DRY SEASON SATELLITE IMAGES 1973-80

0 10km

Source: ISPAN, Landsat images.

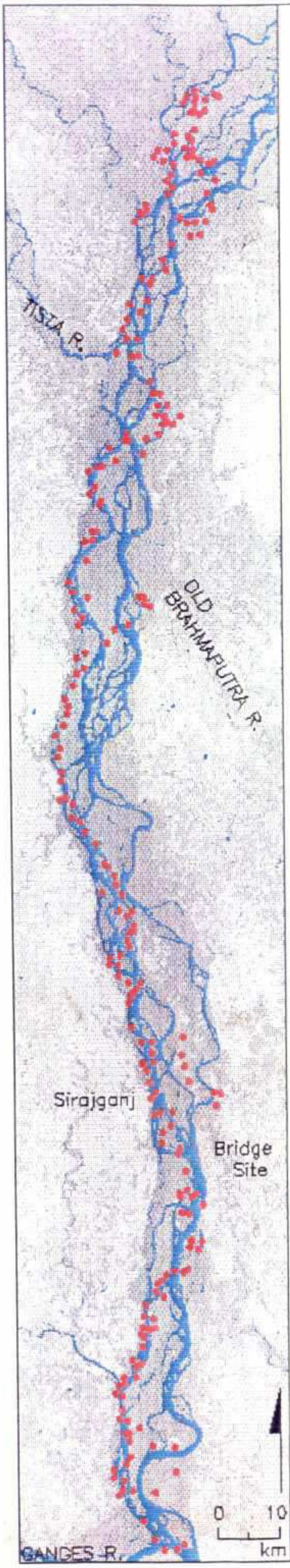
Figure 2.1a



DRY SEASON SATELLITE IMAGES 1984-92

Source: ISPAN, Landsat images.

Figure 2.1b



SATELLITE IMAGE GROUND TRUTH SITES

LEGEND

● Groundtruth Sites

Source: ISPAN, 1992
Field Data and image

Figure 2.2

The evaluation of the accuracy of digital image classification used the results from the March 8, 1992, Landsat image. For each ground site a polygon was depicted on the satellite image. The polygons were selected for image areas with relatively uniform spectral characteristics for ground areas of approximately 10 to 20 ha. After locations were verified through the use of a hand-held global positioning system (GPS) receiver, FAP 16/19 staff noted land cover and conditions, and local people were questioned about conditions at the time the image was taken (March).

Field information was used to assign a class to the polygon for each field ground truth site. There were a total of six classes, which corresponded to types of cultivation and vegetation and one class each for sand and water. Using a computer cross-referencing program, each pixel, representing a ground area of 0.64 ha on the 1992 classified Landsat image, was compared with the polygon class for the ground sample site. Since interpretations for the various classes of vegetation and cultivation were the same, these classes were aggregated, so that eventually only three categories were used to assess agreement between ground information and the digitally processed satellite image.

Overall classification accuracy was determined according to the percentage of ground truth sites correctly classified. Table 2.2 summarizes the results of this exercise and shows that overall classification accuracy was 88 percent.

The two most accurate classes were water, for which the image classification was 96 percent accurate, and cultivated plus vegetation, which was 91 percent accurate. Errors between cultivated plus vegetated lands and sand are thought to be attributable to two types of misclassification: moist, sandy areas classified as cultivated land, and very dry cultivated areas being classified as sand. In addition, some errors may be attributed to the time lapse of about three months between the time the image was taken and the formal ground truthing observations, inaccurate responses from interviews, or variability in sample areas.

Since the satellite image processing was initiated in 1992, it was not possible to perform an accuracy assessment of the seven images spanning 1973 through 1990. It is expected, though, that assessments of those images would yield similar accuracies since all images were recorded during the dry season and all were subjected to the same image classification procedures.

Criteria for bankline interpretation from each of the eight satellite images were determined after discussions and checks with various experts, including river morphologists and engineers from FAPs 1, 21/22, and 25. Images were displayed at full resolution on large-format, high-resolution computer monitors, and the river bankline and char boundaries were digitized and saved as BTM map coordinates. After review and finalization, a map of each year's river channel area and features (banklines, water, sand, and char) was created. The great advantage of these maps was that features could be quantified and compared, and statistics and spatial patterns compiled, through the FAP 19 GIS. Detailed analysis of changes over the 19-year

Table 2.2 Comparison of 1992 Image Classification with Verified Land Type

	Area Verified in the Field		Classified Correctly		Classified Incorrectly	
Land Type	Area (ha)	%	Area (ha)	%	Area (ha)	%
Water	775	19	746	96	29	4
Sand	867	21	639	74	228	26
Vegetated/ Cultivated	2,396	60	2,170	91	226	9
Total	4,038	100	3,550	88	483	12

Source: FAP 19 ground truthing

period and more general comparisons with the 1830, 1914, and 1953 maps are described below.

2.4 Riverbank Erosion and Accretion

2.4.1 Context

There is considerable anecdotal evidence of severe bank erosion and very rapid rates of bankline retreat along the Jamuna-Brahmaputra. Most of these reports lack a sound factual basis, and much of the evidence used to document rapid retreat, in fact, may relate to exceptions rather than the overall pattern. This study attempted to quantify the actual rates of bank erosion along the river based on satellite images and historical maps. This analysis was undertaken using the FAP 19 GIS.

The analysis results made it possible to predict bank erosion rates, which have been used to gauge the vulnerability of the Brahmaputra Right Embankment (BRE) to breaching in the near future (FAP 1, 1993); estimate potential erosion loss of mainland area (FAP 1, 1993; and this report); and estimate the population at risk (Chapter 4).

2.4.2 Channel Morphology

The Brahmaputra has only followed its present course between the Tista and Ganges confluences for about 200 years—in geomorphological terms a very short time. There is no reason, therefore, to suppose that the river has had sufficient time to develop a channel morphologically adjusted to accommodate the range of flows and sediment loads from upstream inputs. The river channel, in other words, may still be in a process of unsteady adjustment, with the three-dimensional geometry of the channel evolving toward a form that is in dynamic equilibrium with the flow and sediment regimes. If this is the case then the characteristics of past and present channel evolution should give a reasonable indication of the future trends, at least over short and medium time scales.

The three-dimensional geometry of the channel is defined by its long-profile, cross-section, and planform pattern. FAP 1 (1993) found from analysis of the long-profile and specific gauge records for the Jamuna that there were no statistically significant trends in water levels for specific discharges over the period of record since 1963-64, nor did there appear to be any trend in bed level. In fact, the water conveyance capacity of the braided channel as a whole is remarkably steady and uniform. While there are short-term changes in the cross-sectional area, particularly channel depth, there are no sustained trends due to scouring or sedimentation. In contrast, the positions of the banks and low flow channels have changed radically over the past 200 years and continue to change today.

The maps produced by FAP 19 also have allowed an examination of historical and current patterns of planform evolution. The FAP studies of the Brahmaputra-Jamuna are probably the first to base such an examination on accurate maps with a common reference frame and scale combined with reliable, quantitative data on distributions and rates of channel planform adjustment. The results, which are described in detail in the following sections, show that the river has been migrating westward since at least 1830 and continues to do so. The analysis also shows that the planform is continuing to evolve actively through changes in braiding intensity and a long-term trend toward an increase in the active floodplain area.

2.4.3 Channel Migration

In 1830 the river was essentially a single thread channel—although it had some divided reaches—and its planform was meandering. Along most of its length it was well to the east of its present (1992) position. Its history since then has been one of migration, widening and braiding, mostly through charland formation (medial bar building) and associated bank erosion. The historical and image-derived maps of the river clearly show that over much of its length the channel is migrating westward. Figure 2.3 shows the historic bankline positions of the Brahmaputra-Jamuna for 1830, 1914, 1953, and 1973 compared with the 1992 bankline. The maximum westward movement of

HISTORIC BANKLINE POSITIONS OF THE BRAHMAPUTRA (JAMUNA) RIVER

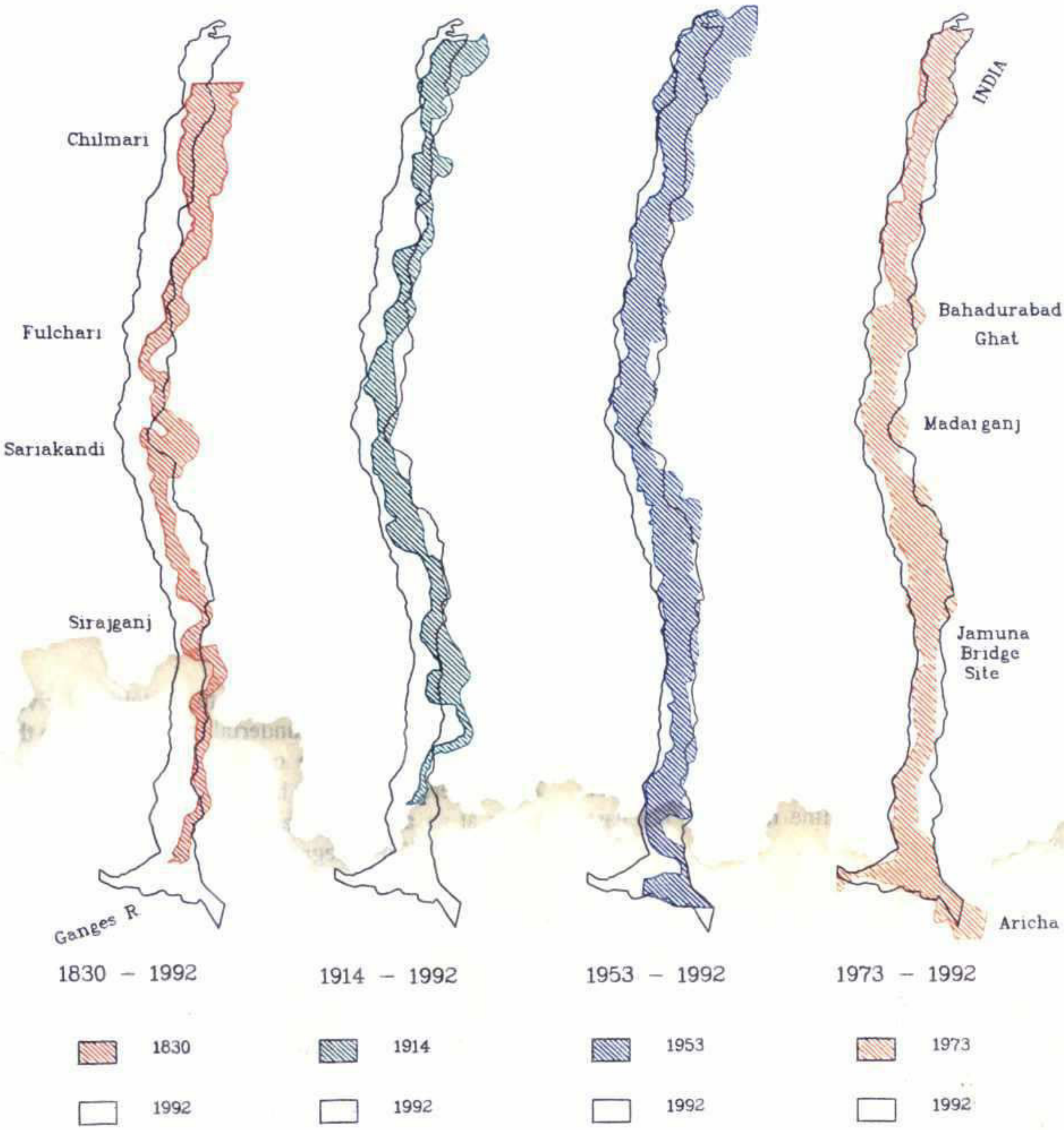


Figure 2.3

the bankline in the 162 years is about 13 km just south of Chilmari and the confluence with the river Tista and, at its southern end near Haturia in Pabna District, 11 km. The annual average erosion rate for these reaches is about 70 to 80 m per year, while the average westward movement along the entire river is approximately 50 m per year for this 162-year period.

Figure 2.4 summarizes and simplifies migration by plotting successive center lines calculated from the banklines of Figure 2.3. This dramatically shows the westward movement of the channel since 1830. The overall rate of center line migration averaged across 20 reaches, each 10 km long, has ranged only between 18 and 31 m per year for the same period (hence, the river has also been widening westward, see Section 2.4.4), but there are large variations between reaches. For example, the lack of change in the center line around northing 130 km; and eastward movement at northings 70-80 km until 1953, where the channel has since swung westward. The center line from the more detailed 1973-1992 bankline map series reveals development of channel sinuosity in the braid belt. This sinuosity is primarily responsible for westward migration of the channel, and this is particularly apparent for most of the reach above Sirajganj. Since 1973 one exception to the general westward trend is in the southern reach, where the centerline has exhibited a marked tendency to move eastward north of Aricha—this is shown in Figure 2.4 where at 0 km the center line moved 3 km east between 1973 and 1992.

2.4.4 Channel Widening

Channel widening, shown in Figure 2.5, is as significant as the overall westward migration of the center line in understanding overall changes in the Jamuna channel. The figure shows that width fluctuates along the length of the river with a series of wider and narrower reaches, and that most points on the channel have changed width considerably over time—including periods of narrowing. Width variation is also shown to have been relatively less at the proposed Jamuna bridge site (a range of 5 km). In 1830 the river had an average width of 6.2 km, but by 1992 the average width had increased to 10.6 km (Table 2.3). Overall, the channel has widened at a long-term rate of 27 m a year, but since 1914 it has widened at an average rate of 65 m per year. As Table 2.3 shows, however, the most critical change has been widening of the narrowest reaches of the river: by 1992 the minimum width between banks was greater than the mean of 1830.

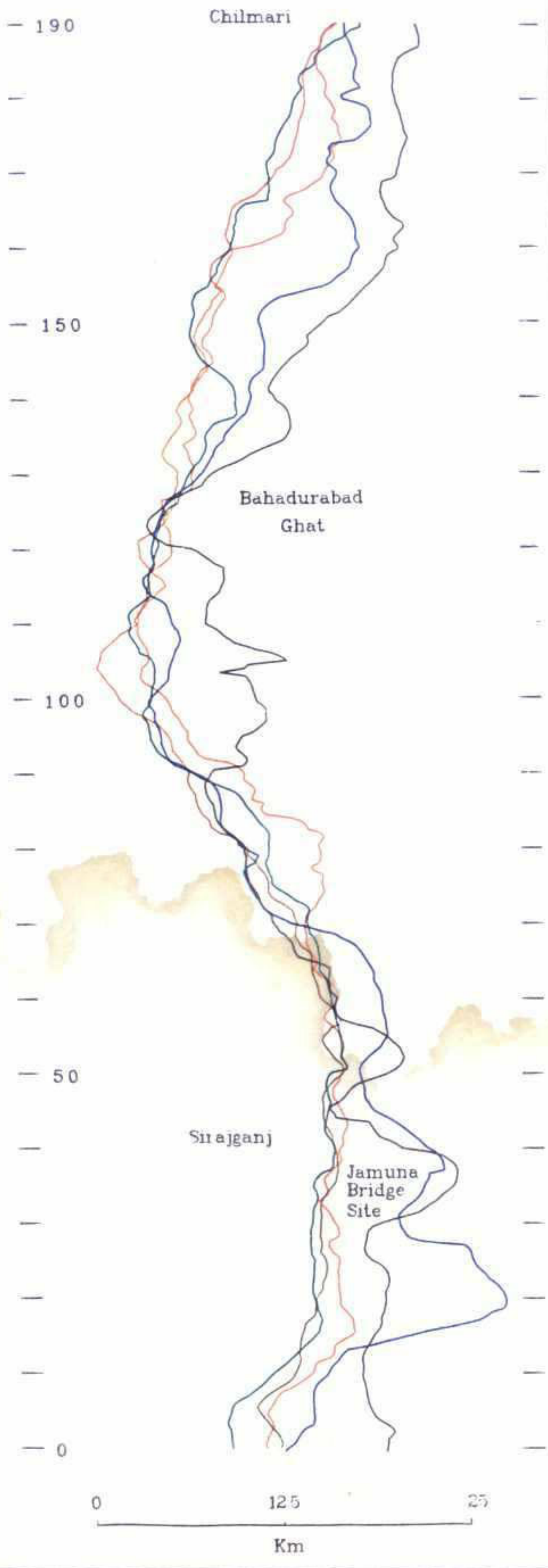
Figure 2.6 shows net change in river banklines between 1973 and 1992 and was developed by digitally comparing bankline delineations. Over 19 years there has been an overall widening of the river caused by consistent erosion along most of the west (right) bank, ranging from 2 to 4 km. The east (left) bank has only a few areas of accretion and is mostly eroded. With the exception of a small segment in the extreme north, the only accretion on the right bank between 1973 and 1992 is a narrow strip, about 6 km in length, just north of the river training works established at Sirajganj in 1976. Finally, a trend can be observed at the Jamuna bridge site, where minimal erosion has taken place since 1973; but immediately downstream there has been a significant widening of the river for a stretch of some 50 km.

More detailed analysis using the satellite-derived maps for 1973-92 was undertaken to determine the annual rate of change of channel width (Figure 2.7). Overall, the river has widened in the past 19 years at an average rate of about 140 m per year based on a linear regression of data in Table 2.4 (R^2 = 0.96). Average rates of widening differ

Table 2.3 Average Width (km) of the Jamuna 1830-1992

Year	Average	Maximum	Minimum
1830	6.242	16.37	1.44
1914	5.551	11.96	1.06
1953	9.053	15.00	2.67
1973	8.084	15.04	2.91
1992	10.611	15.57	6.34

Sources: 1830, Wilcox's Map; 1914, Survey of India; 1953, Survey of Pakistan; 1973 and 1992, Landsat images



Center Line Migration (1830 – 1992)

Westward Migration from 1830's Centerline(m)

Northing (Km)	1914	1953	1973	1992
190	4746	5477	3692	5254
180	3539	4481	6722	6070
170	4030	4939	8564	8130
160	2660	11041	11180	11010
150	4070	7206	8582	8075
140	1641	5744	2611	6082
130	639	1316	1464	2234
120	2646	3468	2261	1321
110	2245	4637	5029	4480
100	6953	5951	6930	9077
90	1110	-2152	1224	1497
80	-34	-4962	-1619	-188
70	-1169	-2016	-2169	-1561
60	-2976	82	469	1145
50	1962	3201	3945	3111
40	-1673	4186	4581	4572
30	-1050	3355	4810	4[illegible]78
20	-7970	3103	4836	4655
10	2341	3444	6023	4577
0	6678	8137	10433	7255
Mean	1519	3532	4478	4554

1830
1914
1953
1973
1992

Figure 2.4

ISPAN FAP19 Geographic Information System

DOWNCHANNEL WIDTH VARIATION
1830-1992

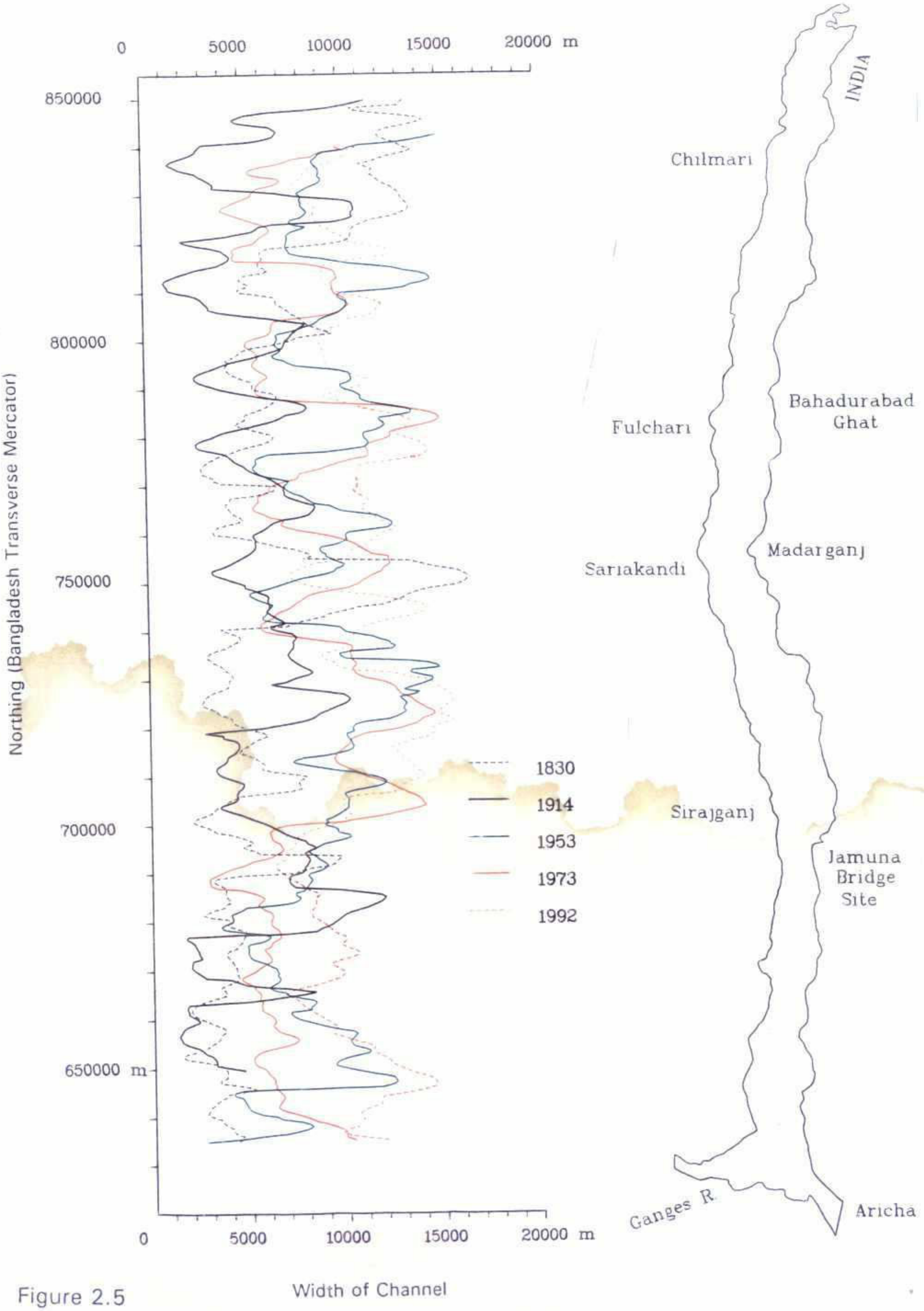
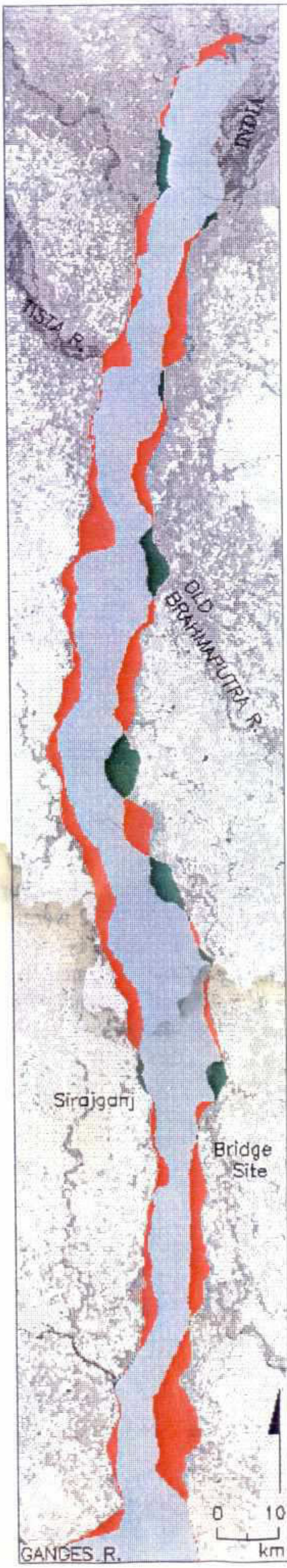


Figure 2.5

RIVER BANK EROSION AND ACCRETION 1973-92



LEGEND

- No Change
- Accretion
- Erosion

Source: ISPAN, Landsat images of 1973-92

Figure 2.6

Table 2.4 Average Width of the Jamuna, 1973-1992

Year	Average Width (km)
1973	8.08
1976	8.31
1978	8.72
1980	8.95
1984	9.23
1987	9.69
1990	10.68
1992	10.61

Source: FAP 19 Landsat image analysis

greatly between pairs of images, from a maximum of 330 m per year during 1987-90 to a narrowing of 36 m per year during 1990-92. This suggests that bank erosion was worse during the peak floods of 1987 and 1988, while the following period had minimal erosion because flows were below normal and probably also because of bank relaxation following the exceptionally heavy retreat in the preceding period. The series of peaks for widening during 1987-90 (purple in Figure 2.7) represent rather evenly spaced zones of severe bank erosion (widening) interspersed with less severely eroding, stable, or even accreting banks. The average spacing of erosion spikes is around 8 km, which corresponds to the spacing of embayments in the right bank cut by aggressive bends in the nearest branches of the channel (anabranches).

As Figure 2.7 shows, the pattern of erosive spikes contains some large gaps and areas of narrowing. For example, just north of Shariakandi there are no significant spikes. This "nodal" reach lies between two island char clusters, where bank erosion is expected to be less severe. Within-channel changes are discussed in Section 2.5, but the spatial distribution of severe bank erosion does tie in somewhat to the morphological pattern of channel form. From Figure 2.7 it appears that the rate of narrowing is locally considerably higher than rates of widening. Since the exceptional narrowing north of Bahadurabad in 1990-92 was based on analysis of the December 1990 image, which reflected different flow conditions from the other images, this may have introduced inconsistency in the image interpretation. Even so, over the longer period of 1973-92 there appears to be a trend from higher rates of narrowing and widening in the north to almost negligible narrowing and recent widening at Nagabari (near section EE).

2.4.5 Predictors for Short-term Bank Erosion Rates

The data used to derive Figure 2.7 were analyzed by FAP 19 and FAP 1 to estimate short- and medium-term erosion rates, and to develop simple short-term bank erosion predictors for the right bank. Figure 2.8 illustrates the cumulative nature of erosion and accretion over this period in the river reach closest to the Bangali River. Although some extensive areas of bank accretion are shown, accretion is excluded in the following analysis since accreted deposits are usually easily re-eroded and present little protection from renewed bank erosion.

The Jamuna was divided into 21 sub-reaches, each 10 km long and containing 20 sampling cross-sections at 0.5 km intervals along the bank. Mean erosion rates for 1973-92 were estimated for each sub-reach. Since 10 km is larger than the characteristic size of an embayment in the Jamuna bank, and since 20 years is much longer than the life span of an eroding channel bend, it may be assumed that within each 10 km sub-reach over a 19-year period the distribution of erosion is random, so that a normal distribution can be used to describe the probability of a particular erosion rate being equalled or exceeded.

It was found that 19-year average erosion rates are much lower than those often quoted in the literature concerning the Brahmaputra-Jamuna. The highest 19-year erosion rate for a 10 km sub-reach is just under 160 m per year, which, although serious, would not usually be considered exceptional for this river. Thus, rapid erosion is rarely sustained.

RATE OF CHANGE OF WIDTH OF JAMUNA

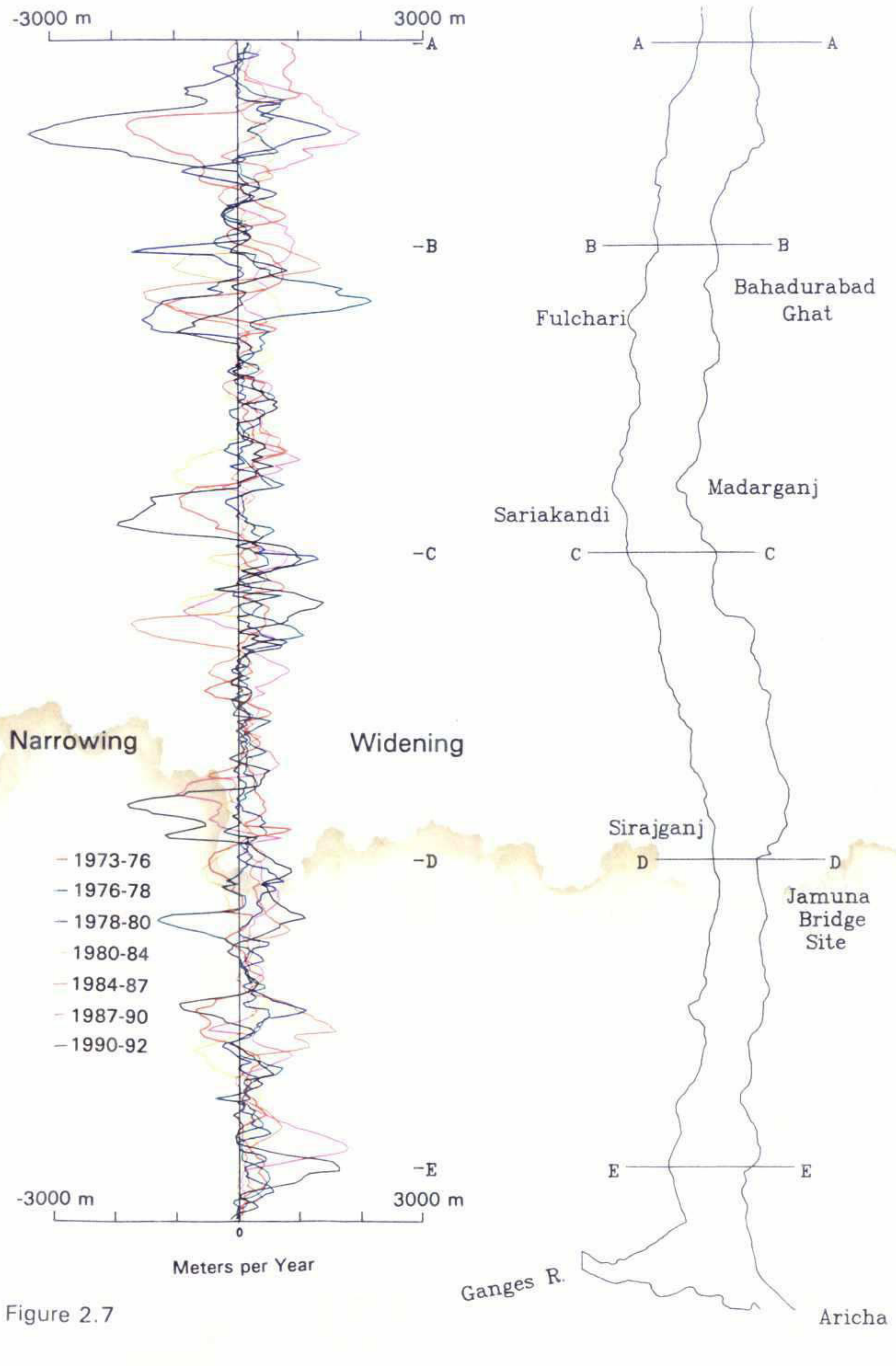
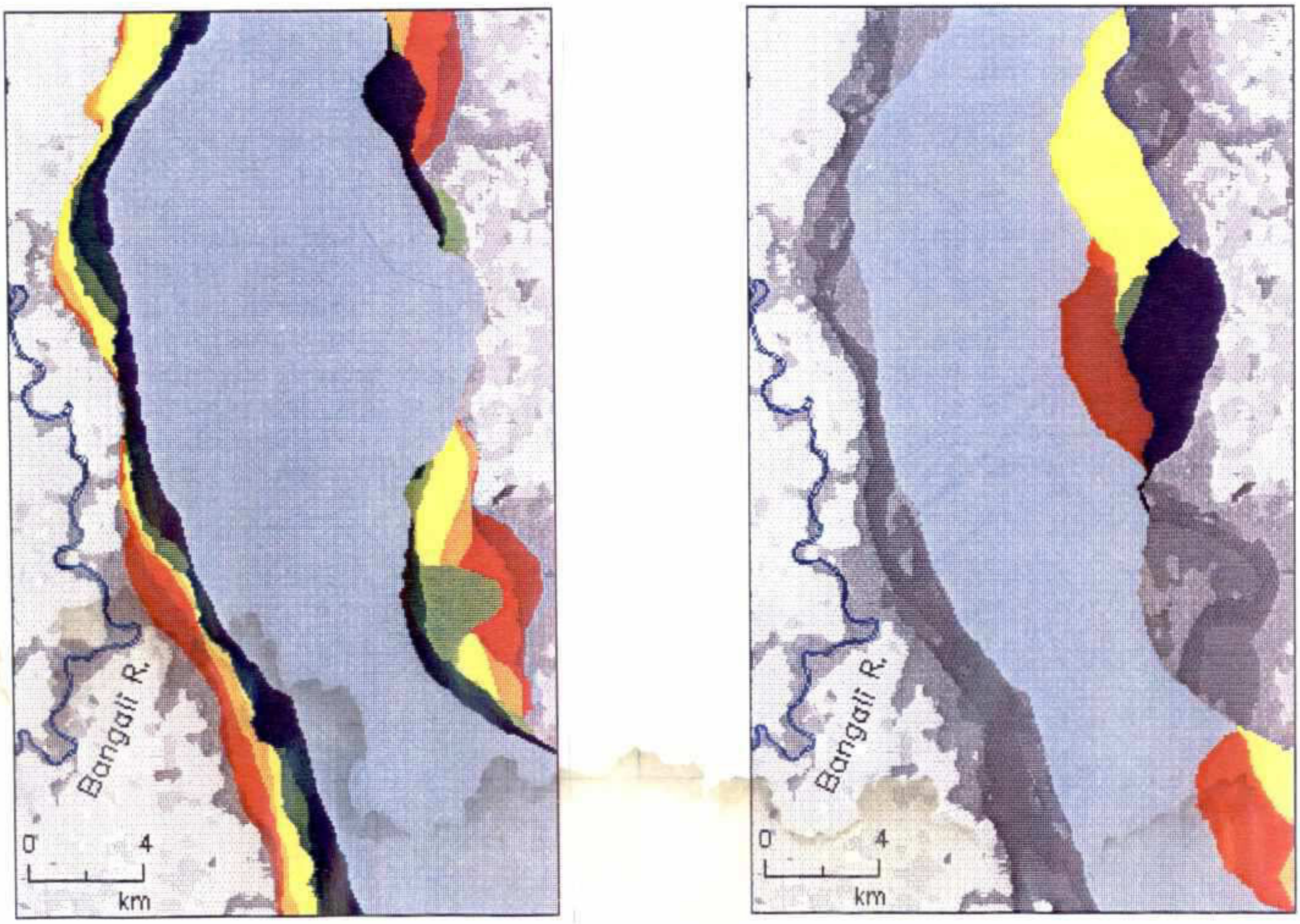


Figure 2.7

CUMULATIVE RIVER BANK CHANGES

CUMULATIVE EROSION | CUMULATIVE ACCRETION



PERIOD OF EROSION

- Channel (1992)
- 1973-76
- 1976-78
- 1978-80
- 1980-84
- 1984-87
- 1987-90
- 1990-92

These images were prepared via digital processing of a series of satellite images dating 1973-92. The area above is the middle reach of the Brahmaputra (Jamuna) shown at full resolution to illustrate the detail of the data set.

Figure 2.8

Figure 2.9 is a cumulative frequency plot of 19-year mean erosion rates for all available sampling points or cross-sections (excluding net accretion sites). The median erosion rate is about 80 m per year, and erosion rates greater than 400 m per year are exceptional, occurring at less than 5 percent of the sites. For shorter periods erosion rates were found to follow a rather similar probability function. The short-term (2-4 year) median erosion rate varies only between about 50 and 110 m per year. This range reflects the inclusion of major flood events and low-flow years in the period of record (1987-90 has already been noted as including a period of rapid erosion).

Time and space must be taken into account when evaluating erosion rates. Very high rates can occur over periods of one or a few years, but they are not sustained for many years at the same location and they do not occur at all locations simultaneously. Similarly, some locations have enjoyed periods of slow erosion rates or bank accretion, but the duration of such quiet periods is short. To investigate the probability distributions for the duration of higher and lower than average periods of erosion, the time distributions of erosion at individual sampling locations were plotted.

Figure 2.10 is a cumulative plot of the frequency and duration of three rapid bank erosion categories: catastrophic, a rate higher than 350 m per year; very rapid, 200-350 m per year; and rapid, 150-200 m per year. It shows an inverse relationship between the severity of erosion and the number of years over which that erosion rate is sustained. In 80 percent of cases the duration of a period of catastrophic erosion is two to four years. There is less than a 10 percent chance that catastrophic erosion will persist at a site for more than four years. The distribution of periods of very rapid erosion is very similar: the median duration (50 percent of cases) is again three years, but there is a 10 percent chance of very rapid erosion persisting for more than seven years. Rapid erosion is more likely to be sustained: the median duration is just over six years and there is a 10

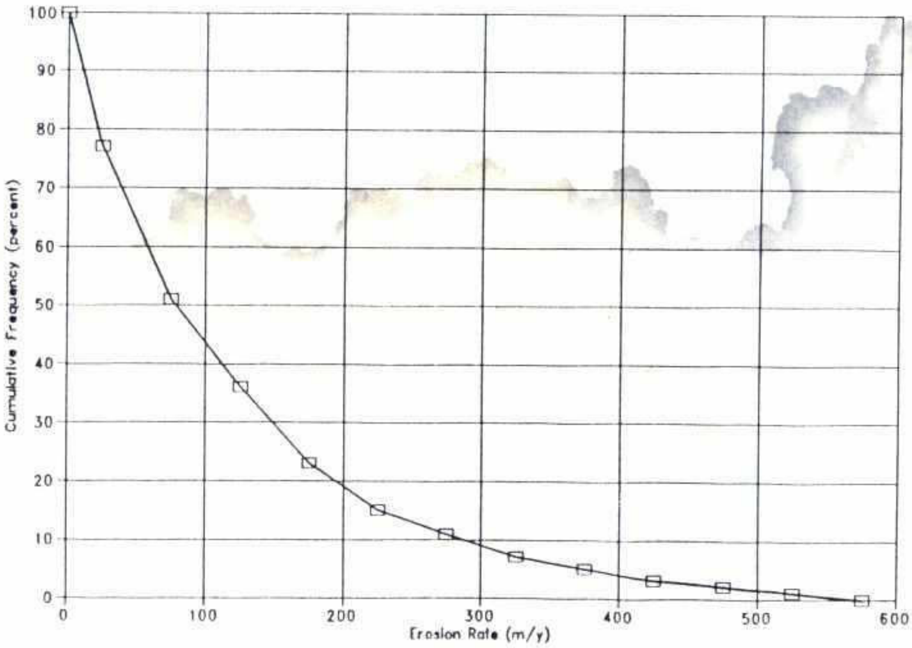


Figure 2.9: Distribution of Right Bank Erosion (1973-1992)

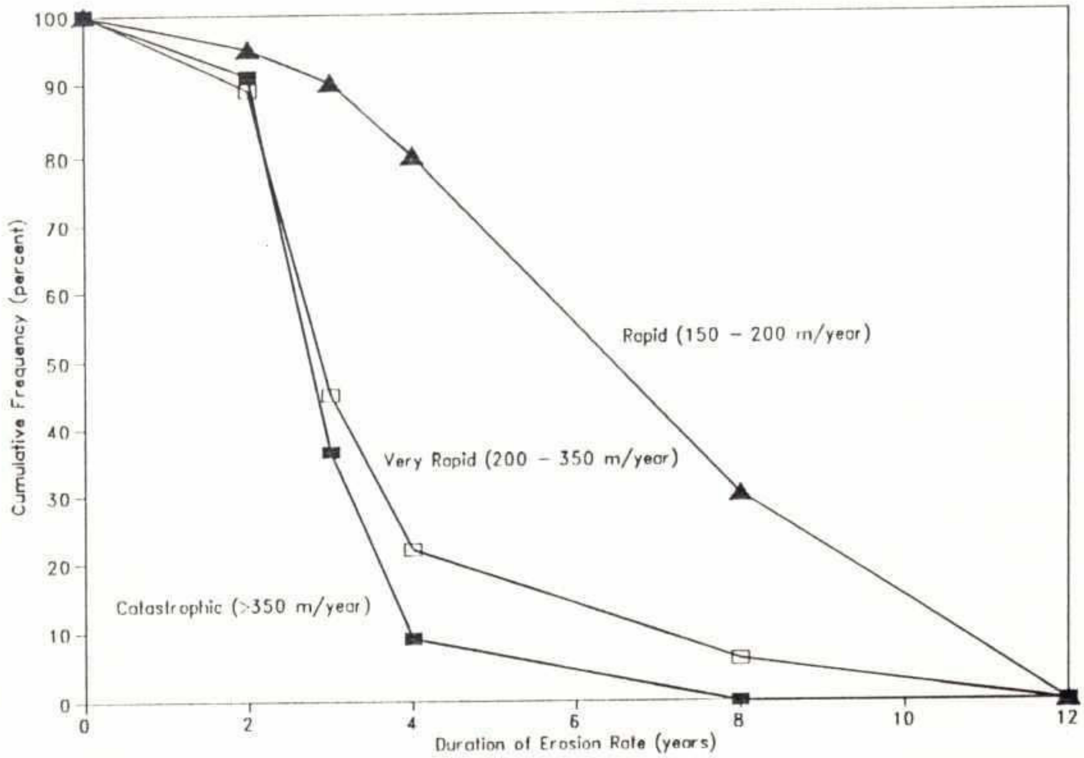


Figure 2.10: Duration of Faster than Average Erosion Rates on the Right Bank

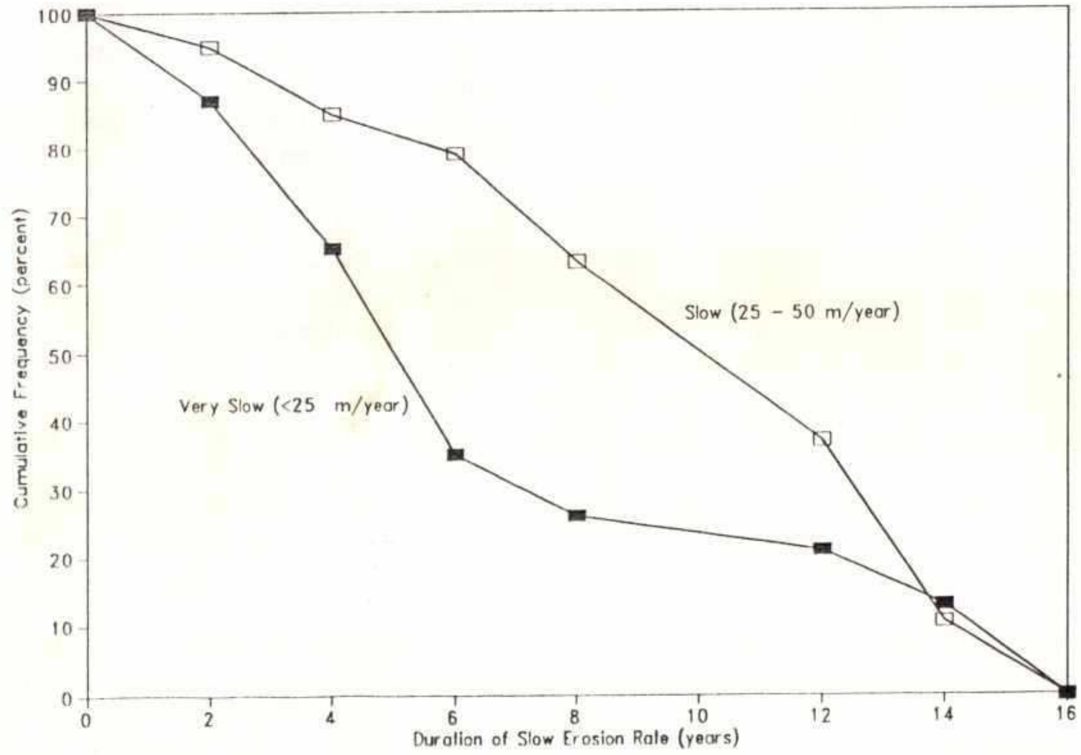


Figure 2.11: Duration of Less than Average Erosion Rates on the Right Bank

percent chance of rapid erosion continuing longer than 11 years. The faster than average erosion rates in Figure 2.10 are generally due to bay formation at bends in bank-side channels (anabranches). For example, FAP 22 (1992) reports erosion rates along the outer banks of major bends of 200-700 m per year, but such bays last an average of five to eight years.

Figure 2.11 shows the cumulative frequency plot for two categories of slower than average erosion rates: slow, 25-50 m per year, and very slow, less than 25 m per year. Periods of slow erosion tend to be limited, but of longer duration than faster erosion periods. The median duration for very slow erosion is five years, and for slow erosion it is 10 years. The likelihood that slow erosion will continue in a given reach of the right bank could be estimated from Figure 2.11. Over the long term the historical data showed that erosion is fairly evenly distributed spatially and that promontories tend to be destroyed after a number of years. Hence, the fact that a particular reach of bank has been spared from average or above average bank retreat for some time may actually be a sign that severe erosion is likely to occur in the near future.

2.4.6 Medium-term Bank Retreat Predictors

While the above analysis is useful for short-term predictions, when making medium- to long-term predictions of bankline movement, it is necessary to use typical erosion rates for medium and long periods. FAP 1 (1993) used data from the FAP 19 GIS to predict the likely bankline position in 2011 with a 50 percent probability of exceedence (the mean erosion rate operating for 19 years) and one with a 5 percent probability of exceedence (an erosion rate equal to the mean plus 2.6 times the standard deviation). The first of these predictions has been used in Chapter 4 to estimate the population that might be affected by bankline erosion. No clear evidence was found that erosion was either accelerating or decelerating over the past 19 years.

A system of macro-bends is apparent in the river channel, and Figure 2.4 shows that the curvature of two concave bends in the right (west) bank (one from Tista to Kazipur, the other from Sirajganj to Ganges) has been increasing. While the rate of shift and development for the Tista-Kazipur bend has slowed since the 19th century, it has not ceased, and there is no reason to suppose that it will do so in the foreseeable future. The same is probably also true of the southern Sirajganj-Ganges bend. If this is so then recent erosion rates could be maintained, leading to several km of further westward migration of the bankline due to channel migration.

Bank erosion is likely to continue to threaten the BRE. Retiring the BRE is only likely to buy time, since the westward migration of the Brahmaputra-Jamuna can be expected to continue for many years. The only natural limit to its westward movement may be the more consolidated, erosion-resistant sediments of the Bogra Barind. By analogy with the situation on the left bank north of Bhuapur (where eastward erosion has possibly been halted by more consolidated Madhupur Forest Tract Tertiary deposits), Tertiary deposits and terraces may constrain or at least slow the river's wanderings. In the coming decades and centuries it is reasonable to assume that the Brahmaputra-Jamuna will rework most of the floodplain west and north of Sirajganj unless steps are taken to prevent it.

While most of the westward migration will be incremental as a result of bank erosion at an average rate of about 100 m per year, the danger of a rapid, major avulsion when the river encounters and captures smaller rivers draining the western floodplain is also very real. In such an event, a breach of the BRE may result in a new course for the right bank anabranch. This would effectively convert from floodplain to island char the strip of land between the new channel and the previous bankline. This possibility is already evident for the Bangali River (Figure 2.8). The Bangali is very close to the Jamuna at the northernmost macro-bend in the braided channel—a 1993 satellite image shows the distance between the banklines of the two rivers to be only about 1 km. Without intervention, development of that bend is expected to lead to a breakthrough of the deep water, right bank Jamuna channel within this decade. This may lead to a long-term change in the course of the Jamuna channel down the Bangali floodplain.

2.5 Within-Bank Dynamics

2.5.1 Summary of Char Morphology

The geomorphology of braided rivers is much less well understood than that of single-thread, meandering rivers, although some general morphological principles are believed to govern the relationship of channel form to fluvial and sedimentary processes. For instance, Leopold and Wolman (1957) established the basic mechanics of braiding through the deposition of a medial bar (char), which then deflects the flow to each side of it, producing erosional bays in each bank. Flow diverges as it approaches a medial bar and then converges toward the tail of the bar. As the bays grow, the increasing channel width creates space for the medial bar to grow, while the sediment from bank erosion fuels continued bar building and produces clusters of bars that eventually merge to form larger and more permanent island clusters. At the downstream end of an island cluster flow converges, scouring the bed to produce a deeper, narrower channel. In time, a mature braided pattern develops, with longer, wider reaches containing substantial islands and multiple anabranches, separated by shorter, narrower sections where the flow converges to form a node or crossing.

Comparison of the historical maps confirms this process, showing that medial bars gradually grew and evolved into island clusters, which then merged to form the large island chars and attached chars that are evident in today's river. The spacing of the island clusters has increased over the years and is about 20 to 30 km at present. Almost char-free nodal reaches between the islands have always existed, but they too have widened over the years and nodes are generally less well defined today than they are in the 1973 satellite image (see Figures 2.1a and b). As the river has widened, island chars have also widened, so the actual width of the water surface has remained almost constant (see below). Consequently, there has been a net loss of floodplain area and a gain in char area. This trend persists because the expanded islands and island clusters deflect the channel flow toward the river's banks, causing rapid erosion. In turn, the sediment-laden current is deflected and dumps additional char-building sediments midstream.

Assessment of the 1992 dry season Landsat image shows that on March 8, 1992, the Brahmaputra-Jamuna had a total of 56 large island chars longer than 3.5 km. There were an additional 226 small island chars of between 0.35-3.5 km length; this includes both chars that show as pure sand (and are categorized as sand in the following sections) and ones that were vegetated. Very small islands of under 350 m length have not been counted but appeared invariably to consist of sand.

Changes in the river channel over short time spans are very complex. Figure 2.12 illustrates the pattern of erosion and accretion taken from dry season satellite imagery for a 34 km reach of the Jamuna between Shariakandi and Madarganj from 1973 through 1992 (reading clockwise from top left to bottom left). Each map represents the changes in area and position of the river channel (grey), mainland erosion or conversion to charland (orange and pink), areas of accretion (light brown and yellow), and changes in charland (shades of green).

2.5.2 Image Analysis of Within-Bank Changes

The within-bank area on each of the images was classified as explained in Section 2.3.4. Char[3] areas are distinct from the other predominant landscape components of water, including saturated zones along water edges, and sand, including areas of sparse grass cover. The classifications are in grid-cell format and are the result of digital image processing as described in Section 2.3. The classified image data made mapping and quantification of within-channel changes possible, and

WITHIN BANKLINE CHANGES NEAR SHARIAKANDI 1973-92

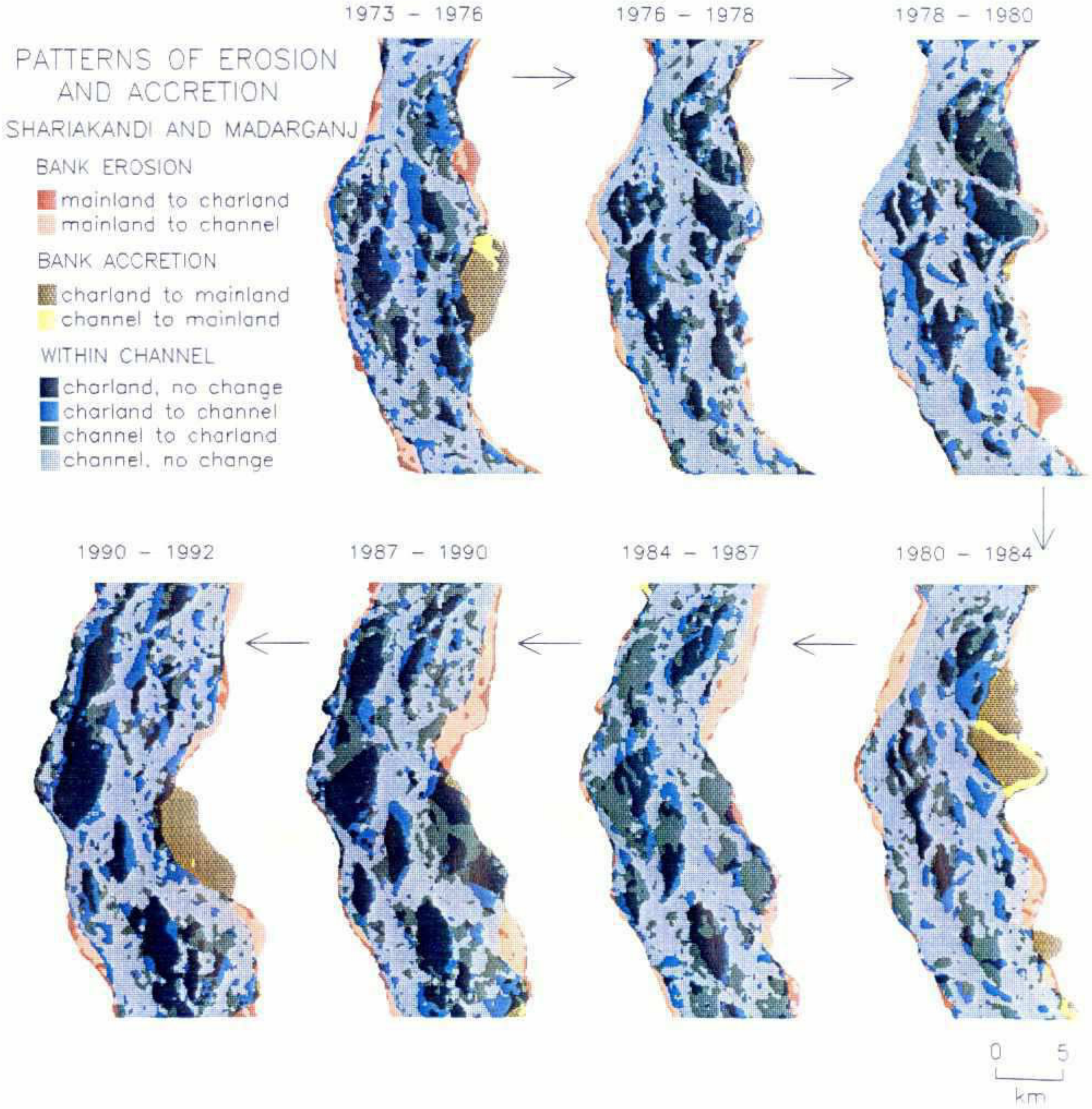


Figure 2.12

Table 2.5 Trends in Within-Bank Area 1973-1992

Area	1973	1976	1978	1980	1984	1987	1990	1992
Total (ha)	204,239	211,239	218,043	223,395	229,014	239,810	261,052	258,533
% water/sand	54	56	53	55	55	52	55	52
% of 1973 area	100	104	107	109	112	117	128	127
Water/sand as % of 1973 area	100	107	104	110	114	113	130	122
Vegetated as % of 1973 area	100	100	110	108	110	123	125	132

Source: FAP 19 satellite image analysis

Table 2.6 Trends in Within-Bank Areas by Reach 1973-1992

Reach	1992 Area (ha)	1992 Area as % of 1973	Average % under water-sand 1973-92	1992 water-sand as % of 1973	1992 vegetation as % of 1973
Kurigram	22,243	101	46	106	98
Chilmari	18,211	140	60	121	173
Rowamari	18,607	135	59	126	147
Gaibanda	14,238	173	63	168	183
Fulchari	27,214	115	53	113	117
Islampur	17,094	130	58	133	126
Shariakandi	18,084	129	61	139	117
Sarishabari	24,469	110	46	106	113
Sirajganj	26,000	106	48	110	103
Kalihati	9,209	184	71	204	150
Tangail	13,073	151	61	116	227
Nagarpur	13,166	142	55	118	185
Daulatpur	15,724	219	51	178	271
Sibalay	21,201	109	55	91	133

Source: FAP 19 satellite image analysis

resulted in an improved understanding of channel and char evolution in this braided river system.

For each of the 14 reaches, split into left and right banks of the river, it was possible to use the image data to measure changes in water, sand, char, and total area.[4] Table 2.5 summarizes this data and not only confirms the overall widening but also shows a remarkably constant percentage of the within-bank area under either water or sand in the dry season (approximately the normal monsoon channel area). Hence, the area of vegetated (productive) island chars has increased more or less proportionally with the widening of the river.

There are considerable differences between reaches, however, in the composition of within-bank area. Table 2.6 combines left and right bank areas of the 14 reaches, and shows that the combined area of water and sand varies between 46 and 71 percent of total within-bank area. The reaches where widening has been greatest during 1973-92—Gaibanda, Kalihati, and Daulatpur—are highlighted. The overall trend for the proportions of water-sand and vegetation to remain constant over time does not hold for some reaches. There are more reaches where the area of vegetated char has increased relative to water and sand, notably in the Chilmari reach and the whole river from Tangail south; here char formation appears to have compensated more for erosion than in other reaches. Whereas at Islampur-Shariakandi and Kalihati the area of water and sand has increased considerably relative to vegetated char.

Table 2.7 Frequency of Change Between Char and Channel 1973-92

Number of Changes	Percent of Within-bank Area
No change	10
One	24
Two	30
Three	25
Four	10
Five	1

Source: FAP 19 satellite image analysis

Figure 2.13 is a record of the sequence of low-flow channel positions, showing the 1973 channel in blue and later channels in colors from yellow to brown. The darker red and brown colors along the edges of this map are indicative of the recent outward movement of low-flow channels resulting in river widening, as discussed above. Considerable highly complex within-channel erosion is also apparent in the figure, and is analyzed further in the following sections.

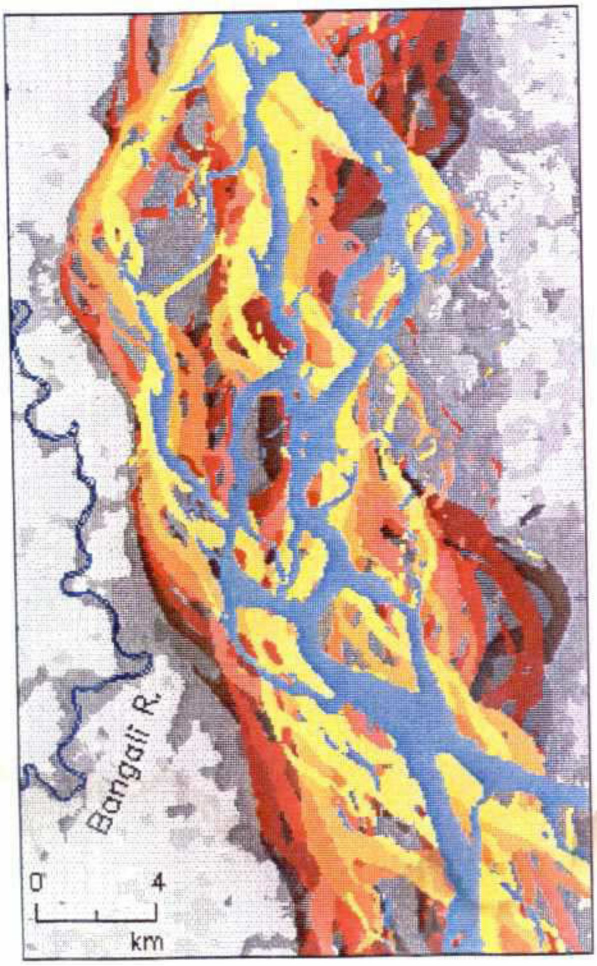
2.5.3 Incidence of Char and Channel

In Figures 2.14 and 2.15 changes in the river are summarized by the frequency of occurrence of low-flow channel and char, respectively, at each map position through the eight dates spanning 1973 through 1992.

As the low-flow incidence map (Figure 2.14) shows, inflow across the Indian border has been dominated by channels near the left bank. South of there to the Old Brahmaputra River offtake, however, the flow has been mostly midchannel, thereafter followed by a section with no obvious predominant channel positions until the midchannel narrowing at the Jamuna bridge site. Finally, for most of the period there has been a long meander before the river joins with the Ganges.

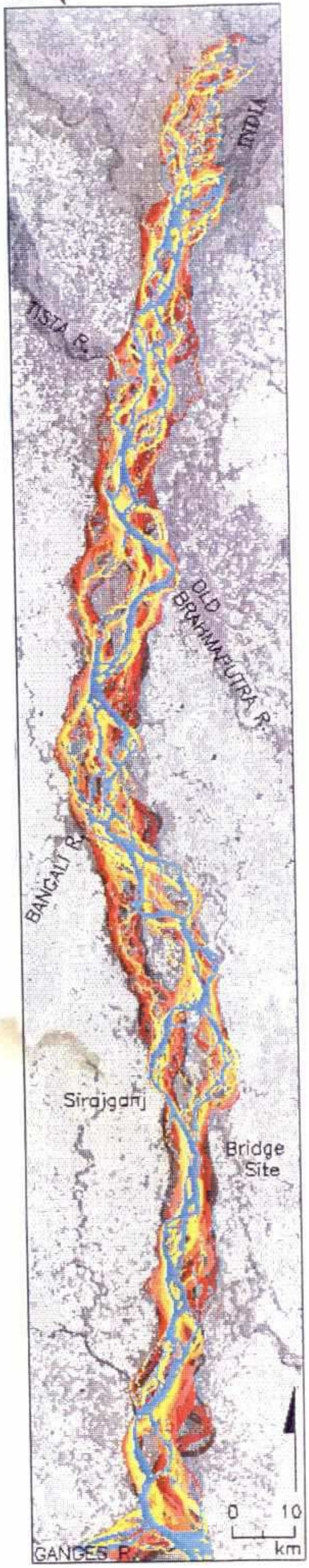
According to the char incidence map (Figure 2.15), chars have consistently appeared in images at several places: the northernmost braids by the Indian border, opposite the Old Brahmaputra junction, north and east of Sirajganj, and in the southernmost reach above the Ganges confluence. Aside from these clusters of apparently stable chars, other reaches show greater volatility with particular chars rarely persisting through more than four images in the series. These figures do not take account of the time series of changes between char and channel, but the incidence of such changes was calculated for all the reaches. Table 2.7 shows that only 10 percent of the combined within-bank area has not changed between 1973 and 1992. Most commonly there have been two to three changes implying, for example, a sequence of char-channel-char-channel or vice

SUCCESSIVE
LOW FLOW CHANNELS



LEGEND

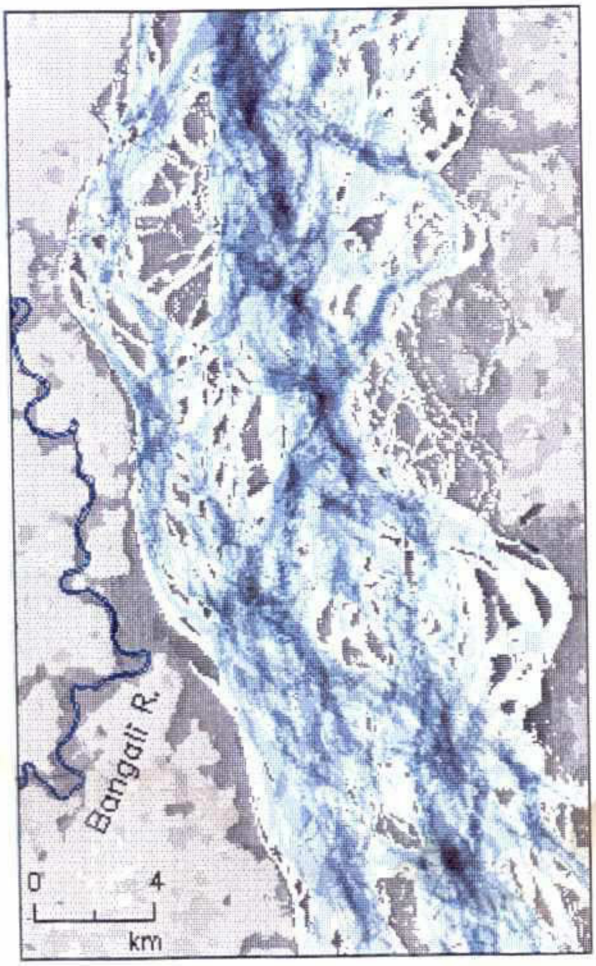
- 1973
- 1976
- 1978
- 1980
- 1984
- 1987
- 1990
- 1992



These images were prepared via digital processing of a series of satellite images dating 1973-92. On the right is the entire Bangladesh course of the Brahmaputra (Jamuna) River. Above is the middle reach shown at full resolution to illustrate the detail of the data set.

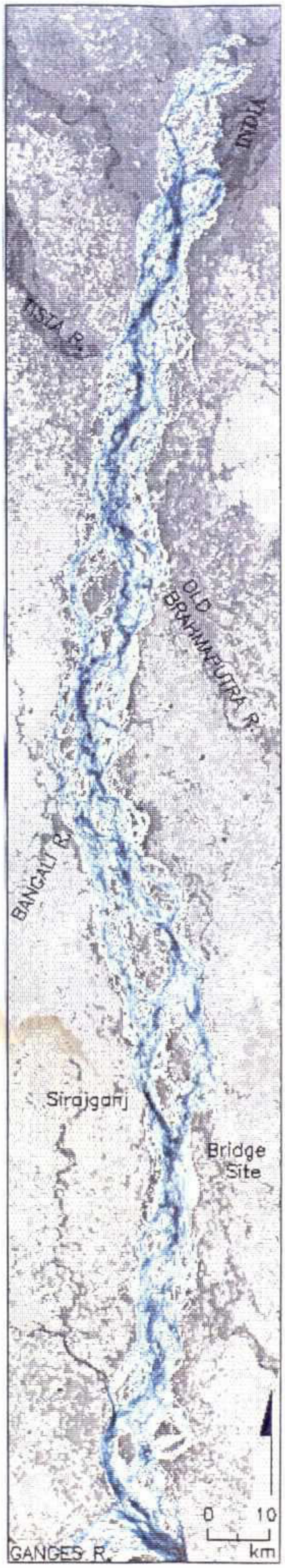
Figure 2.13

INCIDENCE OF LOW FLOW CHANNELS



NUMBER OF CHANNEL CLASSIFICATIONS IN IMAGE SERIES

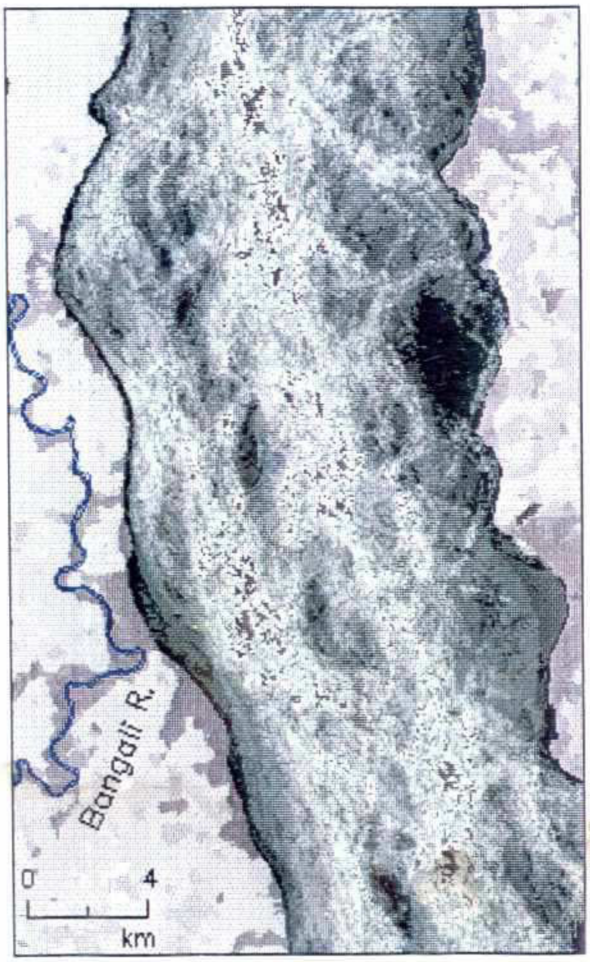
1
2
3
4
5
6
7
8



These images were prepared via digital processing of a series of satellite images dating 1973-92. On the right is the entire Bangladesh course of the Brahmaputra (Jamuna) River. Above is the middle reach shown at full resolution to illustrate the detail of the data set.

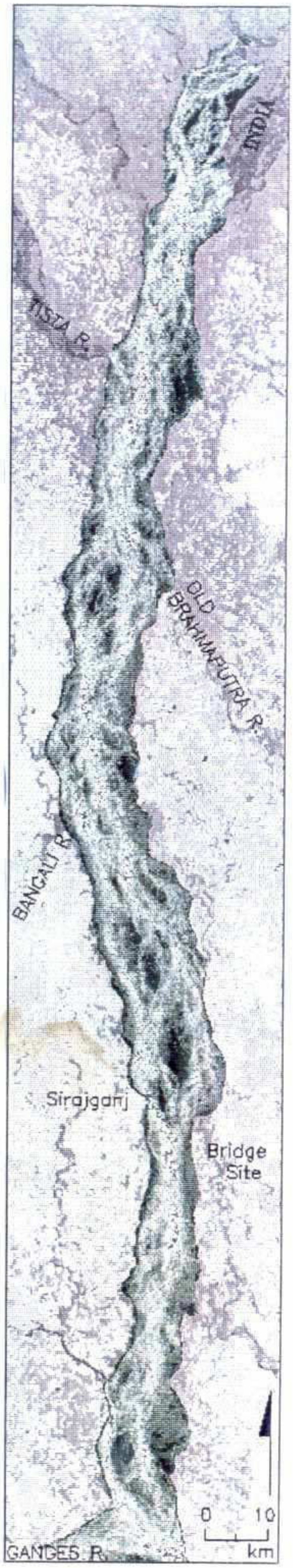
Figure 2.14

INCIDENCE OF CHAR



NUMBER OF CHAR CLASSIFICATIONS IN IMAGE SERIES

1
2
3
4
5
6
7
8



These images were prepared via digital processing of a series of satellite images dating 1973-92. On the right is the entire Bangladesh course of the Brahmaputra (Jamuna) River. Above is the middle reach shown at full resolution to illustrate the detail of the data set.

Figure 2.15

versa over the 19-year period. Therefore, chars are rarely stable in the medium term and most people living on them must have moved during the 19-year period.

2.5.4 Char Ages and Erosion

The char age profile in Figure 2.16 shows how long a 1992 vegetated char has existed; water and sand are colored dark and pale blue, respectively. There is a predominance of young chars in the map with ages of up to five years (yellow and yellow-green). It may be that the 1987 and 1988 floods lowered the age distribution of current chars. Of more importance are the positions of the long-standing chars (red), for example, north of Sirajganj, opposite the offtake of the Old Brahmaputra, and in the northernmost braided reaches.

Char persistence is the number of years during which a given location showed unbroken char presence between 1973 and 1992. Since many within-bank locations that were water or sand in 1992 had previously been char, the life of these chars was measured. When a location was char during two separate periods, the averge persistence was determined. Over the whole river Table 2.8 shows that chars most often persist from one to seven years, but 30 percent have lasted for 14 or more years. The right column of Table 2.8 shows that most of the present (1992) chars are young compared with the pattern of persistence of past chars. A minority (29 percent) have existed for 11 or more years. If it is assumed that past persistence implies that chars will continue unbroken existence at a particular location, then interventions such as flood shelters and more permanent settlements might be viable. The enlargement of the middle reach in Figure 2.16 illustrates how more stable chars could be identified for more detailed planning.

Table 2.8 Char Age and Persistence (years)

Char Persistence (1973-1992)	Percent*	Char Age (in 1992)	Percent†
1-3	16	1-3	16
4-7	27	4-7	8
8-10	8	8-10	6
11-13	8	11-13	3
14-15	12	14-15	1
16-18	6	16-18	1
19-20	5	19-20	1
over 20	7	over 20	6
No char	11	No char	58

*Mean percent of within-bank area by years of unbroken char presence.

†Mean percent of within-bank area by years since last submerged.

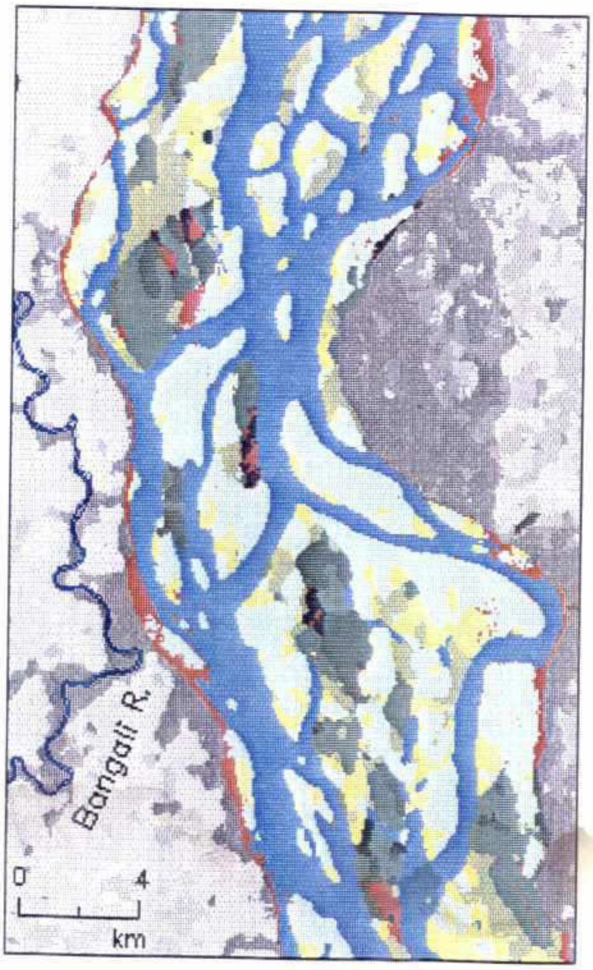
Source: Satellite image analysis

Figure 2.17 confirms the within-channel dynamics. Areas that were char in 1992 are dark green, and pale green through red show the number of years before 1992 when erosion of chars last occurred, hence, there are relatively few areas that have always been water and have not been char over the past 20 years (blue). Past river channels and bank accretion are not shown. This map is most useful for determining whether current river channels are longstanding or recently eroded. It also shows that in the five years up to 1992 the channel has moved toward both banks at and below the Jamuna bridge site. Trends toward erosion of island chars can also be identified from the dates of past erosion fringing existing chars.

2.6 Flood Season Image

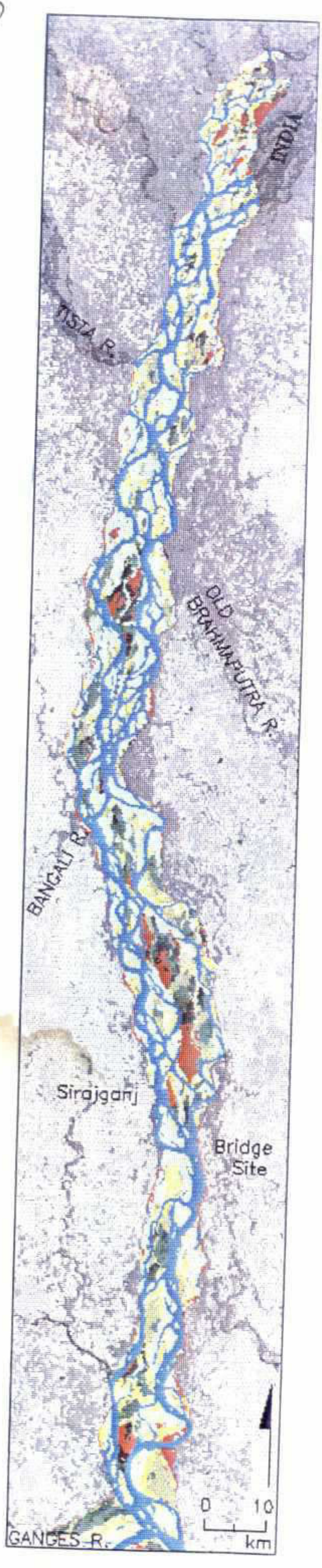
The satellite images used in the analysis of Sections 2.4 and 2.5 were from the dry season in order to study bank and within-bank changes in a common frame at times of similar discharge. Moreover, because of persistent cloud cover, aerial photographs and images of monsoon floods are rarely available. However, SPARRSO located and loaned a cloud-free digital

AGE OF CHAR



AGE OF CHAR SINCE EMERGENCE

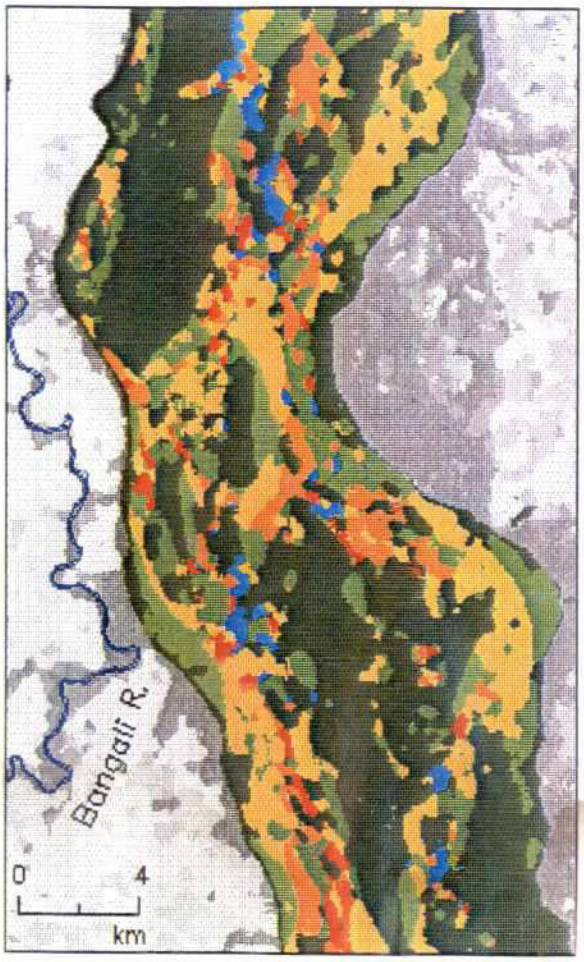
- 1992 Water
- 1992 Sand
- 1-2 Years
- 2-5 Years
- 5-8 Years
- 8-11 Years
- 11-14 Years
- 14-17 Years
- 17-19 Years
- ≥ 19 Years

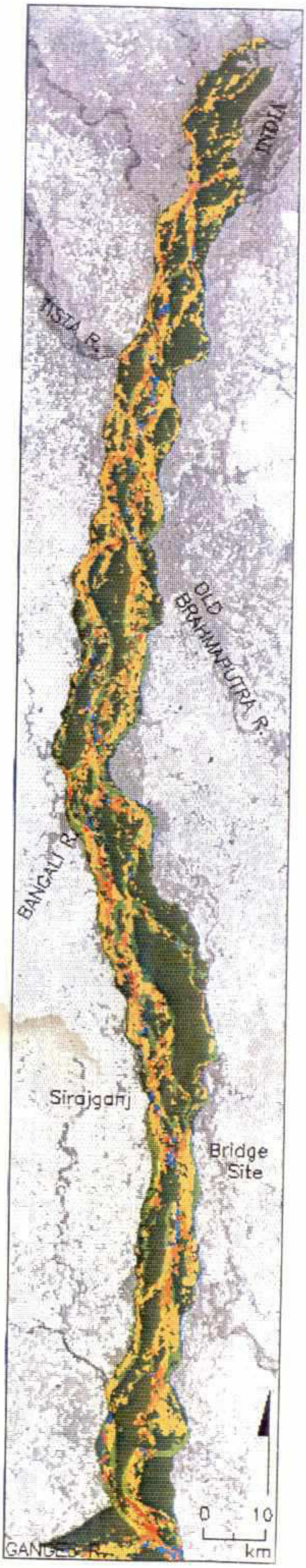


These images were prepared via digital processing of a series of satellite images dating 1973-92. On the right is the entire Bangladesh course of the Brahmaputra (Jamuna) River. Above is the middle reach shown at full resolution to illustrate the detail of the data set.

Figure 2.16

CHAR EROSION HISTORY





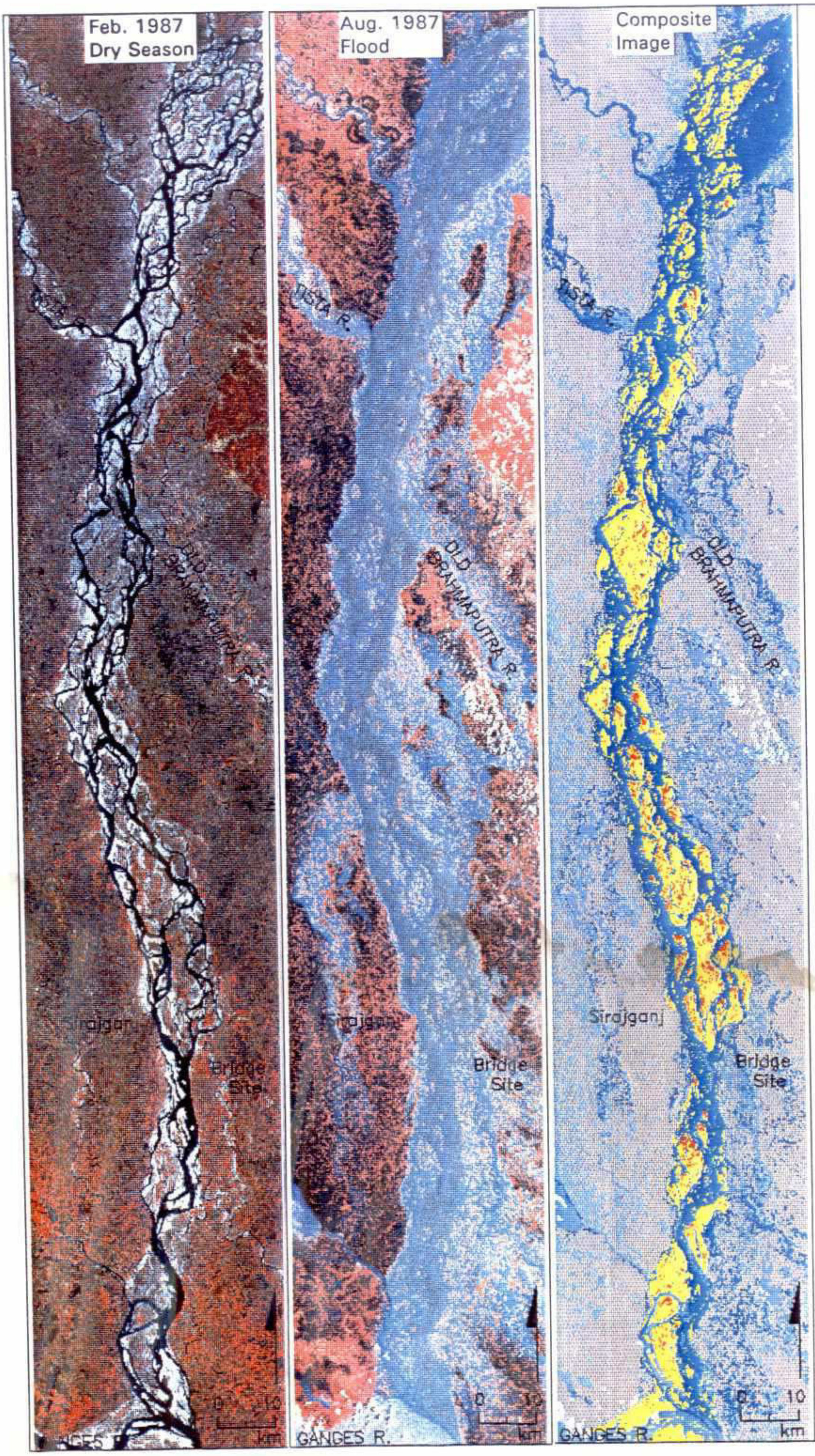
These images were prepared via digital processing of a series of satellite images dating 1973-92. On the right is the entire Bangladesh course of the Brahmaputra (Jamuna) River. Above is the middle reach shown at full resolution to illustrate the detail of the data set.

Figure 2.17

Landsat image from August 18, 1987, which was the approximate peak of the 1987 flood. The three maps in Figure 2.18 show this flood image next to a dry season image taken the same year. On the right is a recombination of classified results from the two images, showing both flooded and non-flooded chars.

In total, 90.4 percent of the dry season char surfaces were classified as flooded in August 1987. Unprotected mainland areas adjacent to the river are also shown flooded. Hence, not only are the chars highly mobile and temporary, but they are almost completely inundated by a flood that has been estimated to have a return period of once in 20 years at Chilmari, once in 12 years at Sirajganj, and once in 23 years at Baruria near the Ganges confluence (FAP 25, 1992). Reference has already been made to the influence of flood peaks on short-term bank erosion, but floods are likely to cause similar within-bank changes.

These flood- and erosion-prone chars are home to substantial numbers of people. Chapter 3 presents the results of the inventory of people and resources both within the banklines and in unprotected mainland along the river, and concludes with further information on hazards and floods.



1987 FLOOD SCENARIO

LEGEND

COMPOSITE OF DRY SEASON & FLOOD IMAGE

- Mainland
- Water
- Char, Flooded
- Char, Flood Free

Source: ISPAN and SPARRSO Landsat images

Figure 2.18

NOTES

1. The variability of estimates depends on whether bed load is included in the calculation.

2. A resolution of 80 meters means that anything smaller than this size cannot be detected; in practice, an object or site may have to be larger to ensure appearance in any one pixel. A pixel is the rectangular area on the earth's surface for which a single spectral response is given; pixel size nominally is 80 x 80 m for Landsat MSS and 30 x 30 m for Landsat TM.

3. Throughout the remainder of this section the term "char" refers to the same landscape component: a surface within the banklines that is either vegetated or under cultivation.

4. Because the northernmost reach adjoins the Indian border there was no left bank division of that reach.

Chapter 3

RESULTS OF THE POPULATION AND RESOURCE INVENTORY

3.1 Introduction

This chapter presents results of the Inventory Survey, which has been linked to the satellite image analysis using a geographic information system (GIS). Important variables for mapping were selected after preliminary assessment of the mauza data listings. Land resources in the study area are assessed in Section 3.2 (Figures 3.1 and 3.2). Thereafter, the results of the inventory analyses are mapped and interpreted for the following subjects:

- population of the study area in 1981 (census) and 1992 (inventory), changes in population, and availability of cultivable land (Section 3.2.2; Figures 3.3-3.6);
- migration into and out of the study area mauzas in 1991 (Section 3.3; Figures 3.7-3.10);
- infrastructure, primarily education and health facilities (Section 3.4; Figures 3.11-3.14);
- household occupations (Section 3.5.1);
- agriculture (Section 3.5.2; Figures 3.15 and 3.16);
- livestock relative to land and people (Section 3.5.4; Figures 3.17-3.20);
- boat availability (Section 3.5.5; Figures 3.21 and 3.22);
- loss of life in the 1988 flood and from other hazards (Section 3.6.1; Figures 3.23 and 3.24); and
- flood experience and risk (Sections 3.6.2-3.6.4; Figures 3.25-3.28).

In order to interpret the maps and tables correctly, it is necessary to understand some limitations to the methodology of the Inventory Survey.

The inventory-derived maps show mauzas that were uninhabited in 1992 as a separate category (pale blue in the relevant figures). In general, the uninhabited mauzas are either submerged throughout the year, or have only sand and catkin grass above water during the dry season and are generally submerged in the monsoon. Submergence was verified by superimposing mauza boundaries on the land use classification map derived from satellite imagery. Since the survey interviews were conducted some two to four months after the satellite image was taken, rising water levels may have already forced the abandonment of some temporary settlements on newly accreted chars. Those, therefore, would be unaccounted for in the survey.

It was impossible to complete questionnaires for some charland mauzas because, at the time of the survey, either no one was living there or key informants were not available to speak for the mauza. Mauzas for which data were not collected are pale green in the relevant figures. Some of the unprotected mainland mauzas were surveyed in 1993 to obtain data that had been missed in the first phase of field work because the study area was redefined during the course of the study. The same questionnaire was used in 1993 as in 1992, and the interviewers were instructed to ask for information on the situation in 1991-92 in order to be consistent with the original database.

There are 172 mauzas split by existing embankments on the right bank (mainly the Brahmaputra

Right Embankment, or BRE), and an additional 147 split by embankments on the left bank. The GIS was used to estimate the unprotected area in these mauzas, and this estimate has been used to calculate the population and resources in the study area. This apportionment method was inappropriate for data that are indivisible or known to be unevenly distributed inside and outside the embankment. For example, data on predominant hazards and extent and duration of flooding were assumed in the tables to apply to the unprotected part of the mauza. Although the tables are correctly adjusted, in the maps entire mauzas are colored—including the unprotected portion—therefore giving the impression of a slightly wider study area than is actually the case.

The questionnaire data, summarized in output tables (in Appendix E of this report), have been presented by river reach and predominant charland type (defined in Section 1.2.7 and shown in Figure 3.1). The "unprotected mainland" category in the tables includes both setback land between the river and embankments (existing and proposed) and other unprotected areas where there is open floodplain adjoining the river and no proposal for embankment construction. The tables cover attributes similar to those in the maps. The tables are an important aid to map interpretation, since general patterns are sometimes difficult to see owing to the small and variable size of the mauzas and to fragmented distributions.

LAND AND POPULATION

3.2 Land and Population

3.2.1 Land Area

Based on the digitized thana maps and embankment alignments, of 426,091 ha in the surveyed mauzas the study area constitutes 383,014 ha. As discussed in Section 1.2.7, mauzas were categorized by their dominant char type. A breakdown of the area is shown in Table 3.1, which combines the setback and unprotected mainland of Figure 3.1 into one category—unprotected mainland.

Table 3.1 Study Area Size by Category (total = 383,014 ha)

Category	Area (ha)	Percent
Island Char	148,248	39
Attached Char	119,010	31
Unprotected Mainland	115,756	30
Upper Reach	138,063	36
Middle Reach	119,421	31
Lower North	34,518	9
Lower South	91,012	24

Source: Table E.1

The gross areas in Table 3.1 include areas under water in the 1992 dry season. Since water area in the dry season is greater in the island char mauzas than in other areas, those mauzas comprise the highest percent of the study area. The gross areas for mauzas were obtained from the digitized mauza map (Figure 1.2).

In most cases, the total gross areas were used to calculate density figures; exceptions have been specifically noted. Since this calculation method is the national standard used by the Bangladesh Bureau of Statistics (BBS), it makes analysis of these data consistent with data derived from other sources such as previous national censuses, but it underestimates actual population density on dry season land.

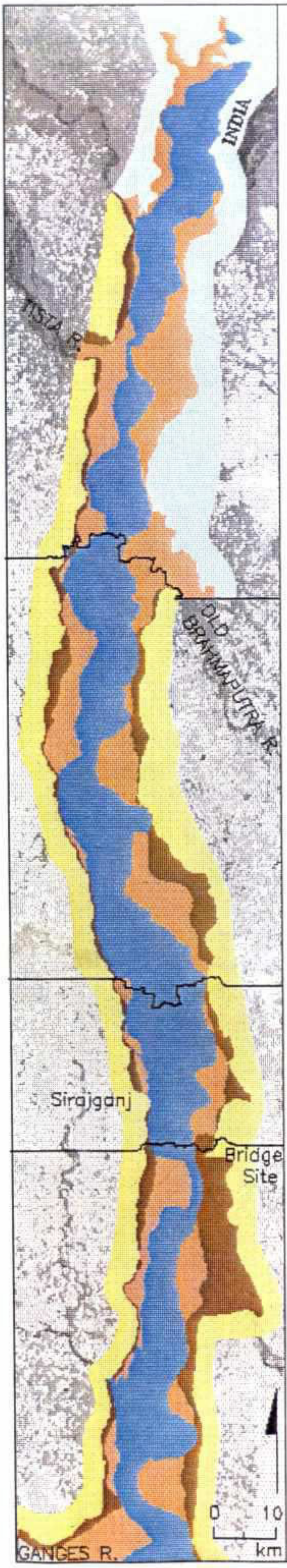
The digital land type classification, derived from the 1992 Landsat imagery and shown in Figure 3.2, was correlated with the mauza data and digitized mauza map. The land categories used were: water, sand, and cultivated/vegetated. The digitized mauza land classification includes all three categories, if present. In Table 3.2 then, a mauza classified as "island char" in the field survey typically is 31 percent water, 21 percent sand, and 48 percent cultivated/vegetated. The percentages in the table were cross-checked with the cultivation percentages collected in the inventory (Table E.5); this is interpreted in Section 3.3.2.

Mauzas with the least usable dry season land are concentrated in the island chars, particularly in the middle and lower reaches, and to a lesser extent in the attached chars. Tables E.2, E.3, and E.4 give breakdowns of water, sand, and vegetated areas, respectively. The 14 percent of the study area that is sand, together with the dry season river channel, is assumed to form the normal monsoon river channel; although some of the vegetated areas of island and attached chars are also normally under water in the monsoon. Not surprisingly then, 56 percent of sand was in island char mauzas. Sand has limited economic value but constitutes a significant portion of island and attached char mauzas. Therefore, these areas have relatively lower economic productivity per ha of land. The exception is that some areas classified as sand grow catkin grass, an important resource for grazing, cut-and-carry fodder, fuel, and building material for house construction and homestead flood protection. Catkin grass is particularly important in island chars where cultivated land is limited and population pressure, often due to forced displacement by erosion, is high.

Table 3.2 Study Area Land Type (percent)

Digital Land Classification	Mauza Classification: Island Char	Attached Char	Unprotected Mainland	All Areas
Water	31	21	7	21
Sand	21	18	2	14
Cultivated/Vegetated	48	61	91	65

Source: Tables E.1, E.2, E.3, E.4



CHARLAND CLASSIFICATION

Upper Reach

Middle Reach

Lower Reach North

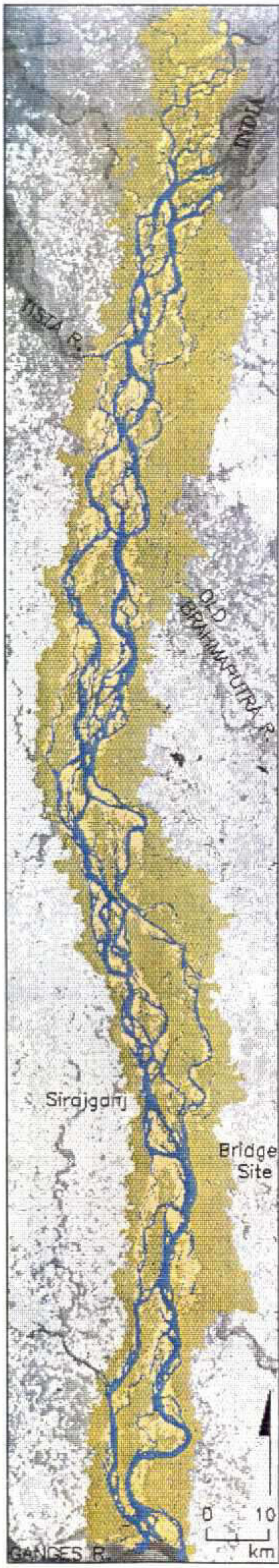
Lower Reach South

LEGEND

- Attached Char
- Setback Land
- Unprotected Land
- Protected Land
- River Channel and Island Char

Source: Satellite image data

Figure 3.1



LAND COVER CLASSIFICATION 8 MARCH 1992

LEGEND

- Water
- Sand
- Land

Source: Satellite image data

Figure 3.2

3.2.2 Mauza Population Data

The 1981 population, mapped in Figure 3.3 and summarized in Tables 3.3 and E.6, is taken from the BBS National Census data (BBS Small Area Atlases), and is apportioned to the mauzas that lie wholly or partly within the study area (see Section 3.1). There were just over 1.55 million people living in the area in 1981, mostly in unprotected mainland.

Table 3.3 Study Area Population in 1981 and 1992

	1981		1992	
	Population	Percent	Population	Percent
Category	Total = 1,550,810		Total = 1,817,762	
Island Char	387,005	25	512,996	28
Attached Char	377,625	24	407,053	22
Unprotected Mainland	786,180	51	897,713	49
Upper Reach	497,713	32	661,463	36
Middle Reach	430,447	28	422,689	23
Lower North	149,448	10	162,273	9
Lower South	473,202	30	571,337	32

Source: Tables E.6, E.7; BBS Small Area Atlases and Charland Study Field Survey

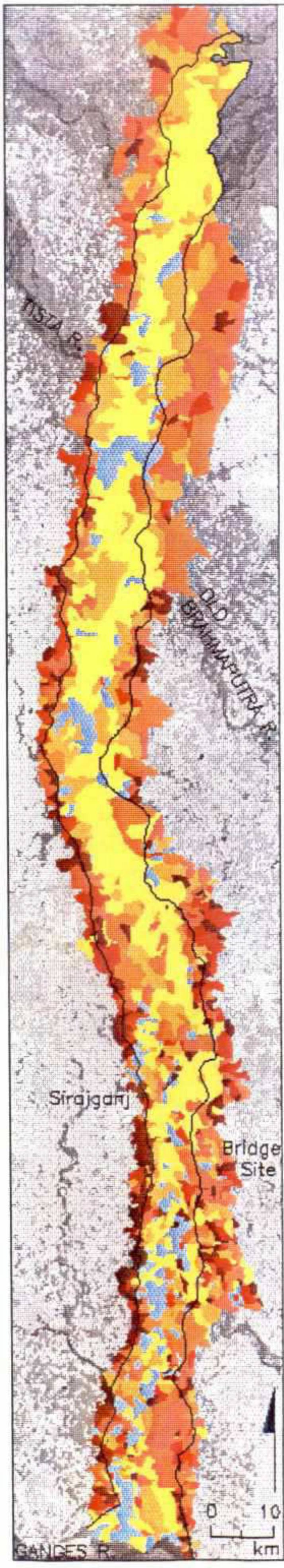
Figures 3.3 and 3.4 show population density in 1981 and 1992, respectively. Of the total 1,443 mouzas, the number of uninhabited mauzas (blue) increased from 242 in 1981 to 339 in 1992. While the upper reach had the largest population, it is also the largest reach. Figure 3.3 shows that the lower reach had the highest population densities in 1981, and the upper reach had the next highest. Population densities were higher in the unprotected mainland than in the island chars, and the highest populations were concentrated on setback land, particularly on the west bank lower reach, where nearby bank edge erosion had been worst prior to 1981 (and people had presumably been forced by erosion onto the nearby mainland). In addition, erosion in some mauzas had forced people to move to a number of adjacent small island chars, increasing the density on those chars. Overall population density in 1981 was 405 people per km^2 (including sand and water; Table 3.4), considerably lower than the Bangladesh average of 605 people per km^2. Figure 3.3 clearly shows low population densities (1 to 200 people per km^2; yellow in the figure) concentrated between the two banklines.

Population estimates[1] from the 1992 inventory indicate that of 2.2 million people in the surveyed mauzas, the study area population was 1,817,761. Table 3.3 shows a population breakdown by char type and reach based on Tables E.7, E.8, and E.9. In the unprotected mainland most of the population is on the east bank, which has a larger area.

Population density in 1992 was highest (1,750 per km^2 of total area; about 2,200 per km^2 in inhabited mauzas) in the lower reach and in the center of the west bank unprotected land of the middle reach (brown and dark red in Figure 3.4). There are other areas of high population density in the lower reach on the east bank unprotected land and on some island char mauzas, particularly those in the lower reach (Figure 3.4). Very low population densities (under 200 people per km^2; yellow in the figure) are concentrated in the island chars (which average only 320 people per km^2). Average densities in the attached chars are mostly 200 to 400 people per km^2 (pale orange). Variation in population density is likely to be linked with land productivity, recent erosion experience, and flood risks. Data in Table 3.4 are consistent with population estimates for the middle reach derived from FAP 3.1 sample surveys, which indicate a population density in 1992 of 304 per km^2 in island chars and 691 per km^2 overall (FAP 3.1, 1993).

The difference in population density between 1981 and 1992 is shown in Figure 3.5 and summarized in Tables 3.4 and E.10. The study area has experienced an overall population increase of 17 percent,

90



1981 POPULATION DENSITY BY MAUZA

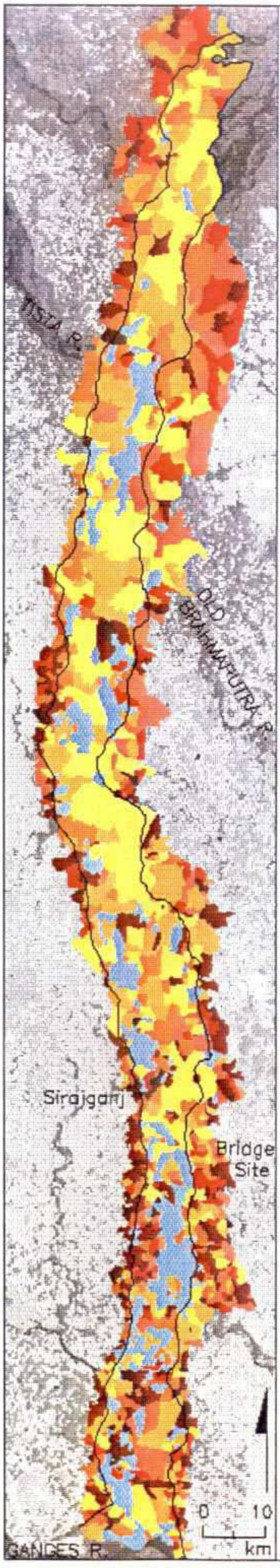
LEGEND

POPULATION PER SQ. KM IN 1981

- Uninhabited
- 1-200
- 201-400
- 401-600
- 601-800
- 801-1000
- 1001-2000
- GT 2000
- ~ Bankline, 1992

Source: Bangladesh Bureau of Statistics, 1981 census data

Figure 3.3



1992 POPULATION DENSITY BY MAUZA

LEGEND

POPULATION PER SQ. KM IN 1992

- Uninhabited
- 1-200
- 201-400
- 401-600
- 601-800
- 801-1000
- 1001-2000
- GT 2000
- ~ Bankline, 1992

Source: ISPAN, 1992 Field data

Figure 3.4

Table 3.4 Overall Population Densities and Growth 1981-1992

Category	1981 People per km²	1991/2* People per km²	Percent Change, 1981-92
Island Char	261	320	+33
Attached Char	317	342	+8
Unprotected Mainland	679	776	+14
Study Area Average	405	475	+17
Bangladesh Average	605	763	+26

Source: BBS Small Area Atlases; BBS (1993); FAP 16/19 Inventory.
*1991 population density is for the whole of Bangladesh; 1992 is for the Jamuna charland study area. Areas are whole mauzas including water, which accounts for the low population densities.

a simple average of 1.5 percent per annum, during the period 1981-92 (Tables E.8 and E.9). The population of Bangladesh, on the other hand, increased 26 percent between the 1981 census and 1991 census (BBS, 1993). Although population in the study area has grown less than the national average, it has experienced a complex pattern of declines and increases that appear to be related to the morphological changes shown in Chapter 2.

In Figure 3.5, yellow highlights the small number of mauzas that remained uninhabited between 1981 and 1992. Figure 3.5 shows that areas where there has been a population decline since 1981 (blue) include:

- mauzas that were inhabited in 1981 but became uninhabited due to channel movements;
- eroding island chars in the middle and lower reaches; and
- attached chars and unprotected mainland concentrated on the west bank south of the Tista confluence, in the middle reach, and in the southern lower reach; and on the east bank in the middle reach. All these areas have experienced bank erosion in recent years.

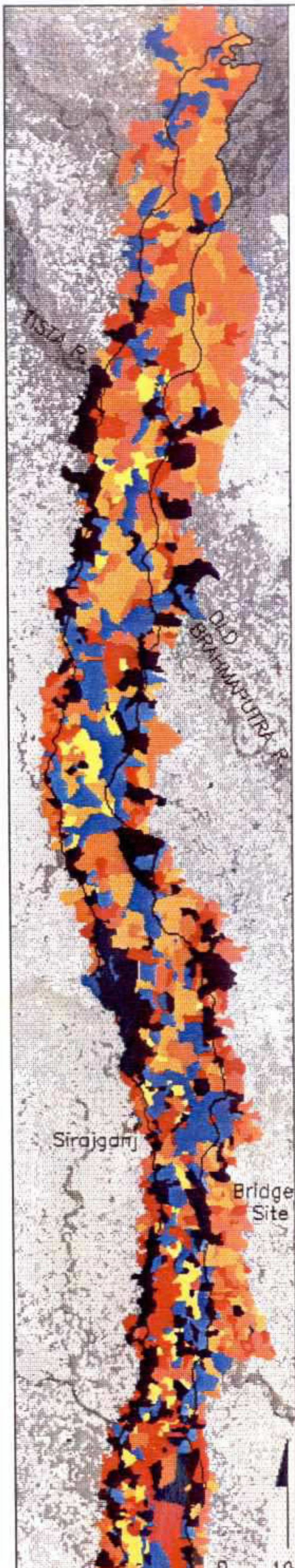
In particular, the population on unprotected mainland and attached chars, on both banks of the middle reach, declined between 1981 and 1992 (although there was low population growth in the island chars of that reach), this appears to be linked with channel widening and consequent bank erosion.

Areas that gained the most population (dark red) are island char mauzas adjacent to eroded island chars and mainland areas. In addition, attached chars and setback areas adjacent to eroding land had particularly high population gains. Figure 3.5 shows a particularly complex pattern in the Lower Jamuna. Here the attached east bank chars experienced a population decline (probably due to bank erosion) and island chars and unprotected mainland experienced large population increases, which suggests that people may have moved to these areas (Table E.10).

Moderate population gains (around 200 people per km²; dark orange and pale red) mostly occurred in the upper reach on unprotected mainland with no erosion and on island chars. It follows then that the areas with population trends similar to the rest of Bangladesh are the most stable areas: unprotected mainland and setback areas of Rowamari and Tangail on the east bank and the upper reach island chars where the braided river is long established and relatively stable (Chapter 2).

Table 3.4 shows that the Jamuna charlands had relatively low populations in 1981, and population has grown less than in Bangladesh as a whole since that time. The exception is unprotected mainland, which had a higher than average population density in both 1981 and 1992. It seems that bank erosion of the attached chars and unprotected mainland may have resulted in people moving out of the Charland Study area and, to a limited extent, onto island chars from the unprotected mainland. Chapter 4 provides further analysis of changes in population relative to erosion.

Population densities also can be related to available dry season vegetated/cultivated land (Figure 3.6, Tables E.11 and E.12). Relating population to



CHANGE IN POPULATION DENSITY 1981-1992

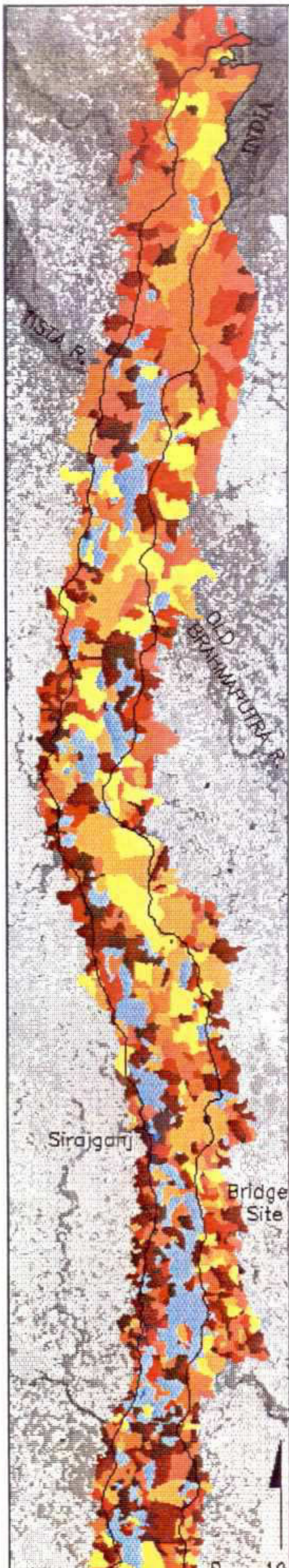
LEGEND

CHANGE IN POPULATION PER SQ. KM

- < -200
- -200 to 0
- No Change
- 0 to 100
- 101 to 200
- 201 to 300
- GT 300
- Bankline, 1992

Source: ISPAN, 1992 Field data and Bangladesh Bureau of Statistics, 1981 census data

Figure 3.5



RATIO OF HUMAN POPULATION TO CULTIVATED/ VEGETATED LAND

LEGEND

- Uninhabited
- 1-200
- 201-400
- 401-600
- 601-800
- 801-1000
- 1001-2000
- GT 2000
- Populated, no Cult
- Bankline, 1992

Source: ISPAN, 1992 Field data and Satellite image data

Figure 3.6

land use rather than gross mauza area avoids complications introduced by the extent of dry season water area, which is higher for island chars (Table 3.2). Although land availability is known to vary from season to season, monsoon season land areas are unknown. The inventory case studies (Appendix D) found that much of the agricultural and livestock economy of the study area depends on dry season land, and land classified as sand—unlikely to provide good grazing—was found to be normally inundated during the monsoon. Figure 3.6 relates population with the dry season vegetated area, which is mainly cultivated land, plus grasses in the chars and trees in the mainland areas.

Table 3.5 Cultivable Land Per Capita

Land Type	Hectares Per Person 1991/92	People Per km²
Island Char	0.14	720
Attached Char	0.18	562
Unprotected Mainland	0.12	855
Study Area*	0.14	731
FAP 3.1 Middle Jamuna†	0.08	1,250
FAP 14 Char Villages‡	0.06	1,667
Bangladesh Average	0.09	1,111

Sources: Charland Study; FAP 3.1 (1993); FAP 14 (1992); BBS (1993)
*Averages for vegetated and cultivated land based on satellite image interpretation.
†Includes very densely populated setback land in the middle reach.
‡Data are from five villages, two of which were in the Jamuna study area, and may underestimate absentee landownership.

The 1992 population relative to productive land is lower (yellow and pale orange in Figure 3.6) on average in the main river channel and associated charland in the upper, middle, and northern lower reaches (where it is rarely above 650 people per km²). Table 3.5 shows that there is more usable land available per capita in the attached and island chars. That population densities are lower than the Bangladesh average presumably reflects lower land productivity and the risks of flood and erosion in the main river channel. In the southern lower reach the island and attached chars are as densely populated (more than 800 people per vegetated km²; red and brown) as the mainland in other reaches; this may reflect local in-migration due to bank erosion rather than more productive agriculture. In particular, the western setback land of the southern lower reach shows by far the highest population to vegetated land ratio (2,124 people per km²); this may be associated both with erosion and with nearby economic opportunities from river trade routes and towns such as Sirajganj. These people may well be displaced by bank erosion in the near future. Little difference was found in population densities on dry season nonflooded land (vegetated plus sand; Table E.12) compared to vegetated land. Overall land availability in the Brahmaputra/Jamuna charlands is nonetheless higher than the national average (Table 3.5).

A total of 284,943 households were reported from the entire study area in 1992 (Table E.13). Mean household size is six people and is almost constant throughout the reaches and charland types. The exception is the most densely populated area, the western unprotected mainland in the lower south reach, where there is an average of 10 people per household (Table E.14). The reasons for this are unclear and any further analysis would require more detailed data at the household level, either from the 1991 BBS census, when it becomes available, or from field studies.

MIGRATION

3.3 Migration

Just as the land areas of the charlands are dynamic, so to is the human population of these areas. To assess the dynamism of the charlands' human population, data on in- and out-migration were collected in each mauza for 1991. Migration, of course, can be either permanent or temporary. People move permanently because of erosion of their homesteads, to take advantage of newly accreted land, or sometimes to find work in other areas. Temporary movements are made to take advantage of seasonal economic opportunities, which may be outside the charlands (out-migration to work in urban areas, for example), or on the chars, where people can use land that is only available in the dry season (in-migration).

3.3.1 Permanent Migration

Permanent in- or out-migration (Figures 3.7 and 3.8) in the surveyed mauzas appears to be closely associated with patterns of erosion and accretion. Only in the center of the middle reach did there seem to be a population turnover involving both in- and out-migration. Chapter 2 has already shown that this area, just north of where the Bangali River and Jamuna are at their closest, has experienced complex channel changes involving substantial erosion and accretion; therefore, the large mauzas in this area have experienced both erosion and accretion within their boundaries. It would appear the human population in 1991 was still in the process of adjusting to these morphological changes. The movements may well have been local—between adjacent mauzas—as households moved to take residence where their land had accreted. Such movements were found to be a common response to submergence and accretion of island chars in the Bhuapur area to the south of this reach (Charland Study RRA).

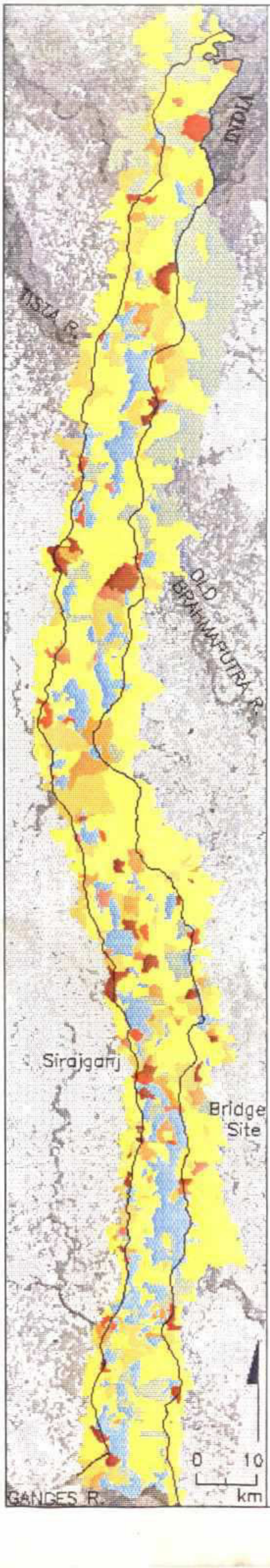
Although only 2 percent (just under 6,000 households) of the study area population permanently moved out of mauzas in 1991 (Tables E.15 and E.16), migration was localized, and could be as high as 50 percent of households in a mauza. Erosion is a strong influence on permanent out-migration patterns: 37 percent of all such migration in 1991 in the study area occurred in erosion-prone island chars, and an additional 14 percent occurred in the west bank of the lower south reach (eroding attached chars and unprotected mainland; Figure 3.7).

One area with substantial out-migration is in the northern lower reach. Despite bank protection works near Sirajganj, 5 percent of households in the setback area left their mauzas in 1991. Six percent of households in the east bank attached chars also migrated in this reach (Bhuapur Thana), reflecting local erosion and accretion in an area where households often own a dispersed portfolio of land and move to wherever their land has emerged above water (Charland Study RRA).

The highest incidence of out-migration relative to population was in the east bank attached charland (5 percent of households). This primarily occurred in the upper and middle reaches; there was negligible out-migration from the east bank lower south reach, where the attached charland has been attracting in-migrants (Figure 3.8).

In 1991 there were 84 percent more permanent in-migrations than out-migrations for mauzas in the study area (Table E.17). Four percent of households present in 1992 had moved into their mauza in the previous year (Table E.18). Permanent migration, therefore, is estimated to have resulted in a net increase of 1.5 percent in the study area households in 1991. In-migration was concentrated in the char areas—only 2 percent of households are in-migrants in the unprotected mainland compared with about 6 percent in island and attached chars. It may be that people are moving to take advantage of newly accreted chars, and that they are beginning to return to the island and attached chars after leaving during the severe floods of 1987 and 1988, and as chars subsequently reemerge and stabilize. They may also be moving in from overcrowded unprotected and protected mainland areas, which appear to have taken people displaced by bank erosion.

Permanent in-migration is most concentrated in the



PERMANENT OUT-MIGRATION BY MAUZA

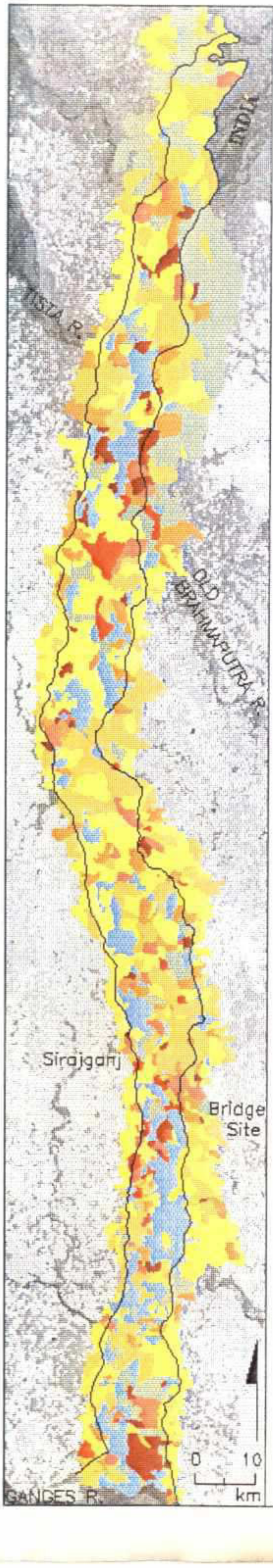
LEGEND

PROPORTION OF TOTAL MAUZA POPULATION, 1991

- Uninhabited
- 0 %
- 1- 5 %
- 6-10 %
- 11-15 %
- 16-20 %
- GT 20 %
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.7



PERMANENT IN-MIGRATION BY MAUZA

LEGEND

PROPORTION OF TOTAL MAUZA POPULATION, 1992

- Uninhabited
- 0 %
- 1- 5 %
- 6-10 %
- 11-15 %
- 16-20 %
- GT 20 %
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.8

east bank attached charlands, particularly in the southern lower reach (14 percent) and, to a lesser extent (8 percent), in the northern lower reach (Figure 3.8). In-migration in these areas can be attributed to the stabilization of newly accreted land that allows former residents to repopulate, erosion of nearby mauzas, and growth in the chars near Aricha, probably due to erosion on the west bank and work opportunities near the ferry ghat.

Table 3.6 Incidence of Migration in 1991 (percent)

Type of Migration*	Island Chars	Attached Chars	Unprotected Mainland
Permanent Out-migration	3	4	2
Permanent In-migration	6	6	2
Seasonal Out-migration	1	2	1
Seasonal In-migration	3	6	3

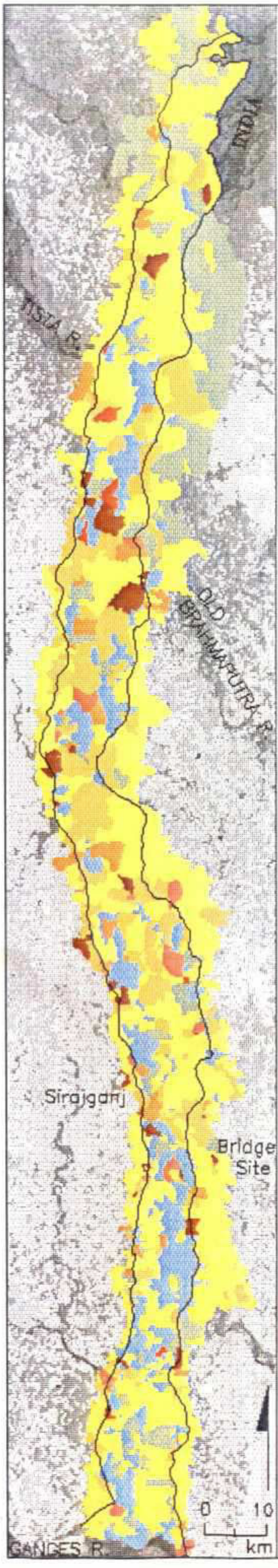
Source: Tables E.15 to E.22.
*Permanent migrants are a percentage of households in mauzas with available data; seasonal migrants are a percentage of people.

3.3.2 Seasonal Migration

Seasonal migration often involves only some of the male members of households, so data were collected on the total number of people seasonally leaving the mauza (out-migration from their mauza of residence), or seasonally visiting the mauza (in-migration to a temporary abode). A total of just over 18,000 people, about 1 percent of the population from the available mauza data (Tables 3.6, E.19 and E.20), were said to have migrated out of their mauza on a temporary basis. While this migration is fairly evenly distributed across the study area (Figure 3.9), it occurs most often in the middle reach west bank attached charland. Figure 3.9 also indicates some higher concentrations of seasonal out-migration in the upper reach island chars. These migration patterns are likely related to seasonal land availability in the char areas and to wet season economic opportunities on the mainland (but no clear relationship between seasonal out-migration and flood extent or duration in 1991 is apparent). The reconnaissance case studies (Appendix D) identified formal systems of transhumance (seasonal movement of livestock) in the upper reach island charland. This may well be a more widespread phenomenon and may explain part of the complexity of migration patterns.

There were 3.2 times more seasonal in-migrants than seasonal out-migrants in the study area in 1991 (Figure 3.10 and Tables 3.6, E.21 and E.22). Two possible reasons are that people move to island and attached chars for dry season farming, or that they move to setback areas for wage labor during the monsoon. Seasonal in-migration occurs most often in the upper and middle reach west bank attached charland (and to a lesser extent in the adjacent unprotected mainland) of the upper and middle reaches. Figure 3.10 shows other mauzas where temporary in-migration was more common, particularly in the area around the off-take of the Old Brahmaputra and on isolated island chars in all reaches of the river. This is likely to be a response to local morphological changes.

78



SEASONAL OUT-MIGRATION BY MAUZA

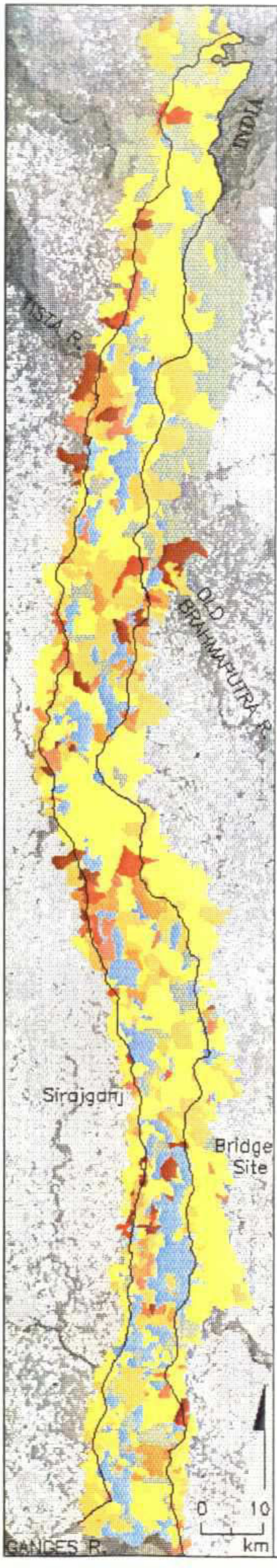
LEGEND

PROPORTION OF TOTAL MAUZA POPULATION, 1991

- Uninhabited
- 0 %
- 1- 5 %
- 6-10 %
- 11-15 %
- 16-20 %
- GT 20 %
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.9



SEASONAL IN-MIGRATION BY MAUZA

LEGEND

PROPORTION OF TOTAL MAUZA POPULATION, 1991

- Uninhabited
- 0 %
- 1- 5 %
- 6-10 %
- 11-15 %
- 16-20 %
- GT 20 %
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.10

SERVICE AND INFRASTRUCTURE PROVISION

3.4 Service and Infrastructure Provision

Among the data collected as part of the inventory was information on the type and level of services provided to people. Only education and health services are mapped, as these services are considered the most important government service issues in the area, as shown by case studies conducted by both FAP 14 and FAP 3.1. No attempt was made to obtain size details of the education and health facilities. The school and health facility distribution patterns are thus expressed as the number of people served by the facility in the mauza. The maps disregard the fact that many facilities have cross-mauza catchments. Moreover, access to many facilities is likely to be uneven due to communications difficulties in both dry and wet seasons. The RRA case studies show that transport problems limit the achieved charland catchments of high schools and health facilities.

3.4.1 Schools

Figure 3.11 shows that primary schools are widespread even in the island chars, with an even coverage of 61 percent of mauzas throughout the study area (Table 3.7). There are, nonetheless, many mauzas in the attached chars of the upper reach (west) without primary schools (colored yellow); as is the case in many attached and island char mauzas in the lower reach. There are, the survey found, many fewer secondary education opportunities (high schools) in the Brahmaputra-Jamuna charlands. Figure 3.12 shows only 85 high schools in the mauzas where data were available (12 percent of surveyed mauzas, Table 3.7), these being concentrated in the unprotected mainland. Potential students in the chars are generally separated from high schools by main river channels and several miles distance.

The age range for primary school children is six to 10 and for high school children, 10 to 15. The 1981 census of Bangladesh found that 16.3 percent of the country's population was between the ages of five and nine (the age group closest to that of primary schools) and 13.4 percent was between 10 and 14 years old (the age group closest to that of high schools). Assuming that these percentages still apply to the study area—and to Bangladesh—implies that in 1992 the study area had 296,000 children between five and nine years old and 243,600 in between 10 and 14. For the study area mauzas with facilities data, this amounts to an average of 446 children per primary school (compared with 372 per school for all of Bangladesh) and 1,940 children per high school (compared with a Bangladesh average of 1,513). There is less education infrastructure in the Jamuna charlands, therefore, than the national average. Moreover, the existence of a school does not ensure that education is available; in many char schools in the middle Jamuna teachers were absent or had not been posted (FAP 3.1, 1993).

3.4.2 Health Care

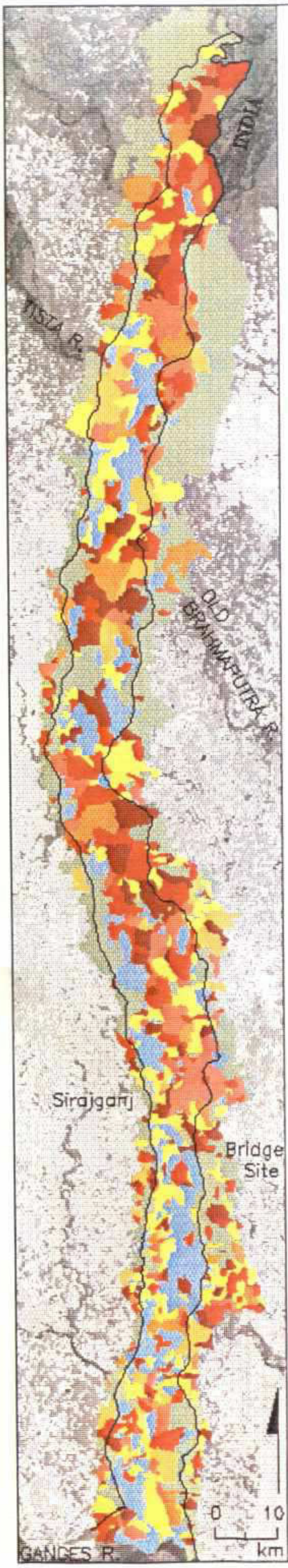
Figure 3.13 shows there are only 94 mauzas (13 percent; Table 3.7) with health facilities in the study area. Health facilities were defined as physi-

Table 3.7 Health and Education Services Provided in Mauzas*

Charland Type	Number of Mauzas	Inhabited Mauzas	Primary School (%)	High School (%)	Health Facility (%)
Island Char	529	316	62	10	8
Attached Char	395	273	61	7	11
Unprotected Mainland	512	494	61	17	22
Total	1,436	1,083	61	12	13

Source: FAP 16/19 Inventory field data.

*Percentages are calculated for inhabited mauzas, excluding mauzas for which no data were obtained on service provision.



PRIMARY SCHOOLS BY MAUZA

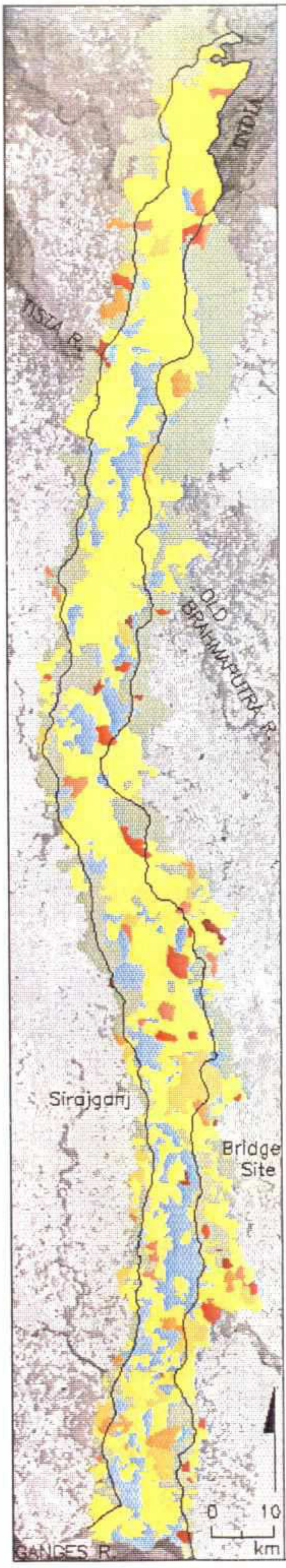
LEGEND

TOTAL POPULATION PER SCHOOL

- Uninhabited
- 1-1000
- 1001-2000
- 2001-3000
- 3001-4000
- GT 4000
- No School
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.11



SECONDARY SCHOOLS BY MAUZA

LEGEND

TOTAL POPULATION PER SCHOOL

- Uninhabited
- 1-1000
- 1001-2000
- 2001-3000
- 3001-4000
- GT 4000
- No School
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.12

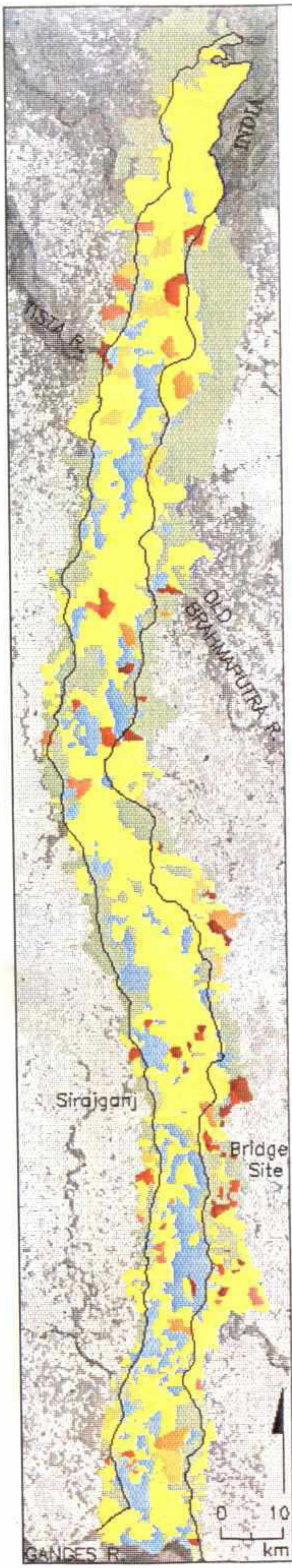
cal infrastructure (either a government hospital, health care center, or family planning center or an NGO health care facility) present in the mauza. Provision, the survey found, is biased toward the unprotected mainland and appears to be patchy; there is a concentration of facilities in the northern lower reach and the adjacent part of the southern lower reach. Although there are more than 19,000 people per hospital or health care center in the study area, this appears to be considerably better than the national average: In 1991 there were 2,819 government and non-government health care facilities (BBS, 1993)—only about one facility for every 38,980 people. Despite the appearance of adequate health service provision, many people in island and attached chars live 10 km or more from the nearest medical facility and must travel long distances by foot and boat in the dry season or by boat in the monsoon season to take advantage of the service.

Key informants were also asked when their mauza had last been visited by a health worker. Figure 3.14 shows relatively good coverage. The majority of those that had been visited, 44 percent, were visited in the first half of 1992 prior to the field survey (dark red), and an additional 19 percent had been visited in the previous year (red). Thirty-one percent of inhabited mauzas appear never to have been visited (or do not remember when they were last visited; yellow on the map), and coverage appears to be worst in the upper reach. It may be that these mauzas are relatively less accessible, but mechanized boats are available in the area (Section 3.5.5).

3.4.3 Markets

The distribution of markets (important markets, *hats*, and small bazaars) in the study area also was investigated. In the 67 percent of inhabited mauzas where market data was recorded, there are a total of 138 mauzas (19 percent) with markets; most of these are periodic markets *(hats)*, but 21 larger markets or growth centers were also reported. It would appear that there are more markets in the unprotected mainland, and fewest in the upper reach island chars. The data have not been mapped since data from the unprotected mainland are limited. It may be, however, that potential to introduce cash crops, for example, is limited in the upper reach by the lack of nearby markets.

Additional data on infrastructure available from the inventory will be useful in planning improved access to facilities, and designing income-generating programs for the char people in specific areas.



HEALTH FACILITIES BY MAUZA

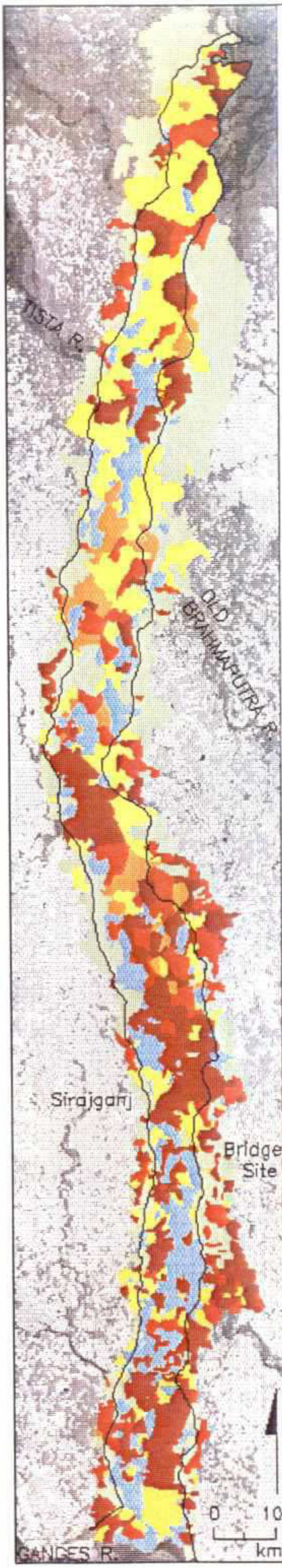
LEGEND

TOTAL POPULATION PER HEALTH FACILITY

- Uninhabited
- 1-1000
- 1001-2000
- 2001-3000
- 3001-4000
- GT 4000
- No Health Facility
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.13



LAST VISIT BY HEALTH WORKER

LEGEND

YEAR OF VISIT

- Uninhabited
- 1992
- 1991
- Before 1991
- No Visit
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.14

RESOURCE AVAILABILITY AND USE

3.5 Resource Availability and Use

3.5.1 Occupations and Overall Resource Base

This section documents a high dependence on cultivation, particularly dry land crops, in the chars. Livestock are also a key part of the economy, which reflects relatively abundant grazing in the chars, although, as will be seen, this does not result in higher densities of animals per hectare. The Brahmaputra-Jamuna is relatively less important than the Meghna and lower Padma for commercial fishing, as national statistics (BBS, 1993) show. There is a relatively high level of boat ownership, boats being an important resource both for normal communications and for evacuation, when erosion and floods force people to leave their homes. The pattern of competition and social conflict for the changing land resource is complex, and these issues have been further studied during rapid rural appraisals (RRAs) in 1993.

Overall, 46 percent of households reported agriculture as their primary occupation (Table 3.8). Dependence on agriculture was relatively high in the middle reach (island chars and east bank) and relatively low in the upper reach (Tables E.23 and E.24). In the latter area livestock rearing is relatively important, and there may be proportionately more landless laboring households on the island chars here (as found in the case studies in Appendix D).

Table 3.8 shows a higher dependence on day labor, primarily agricultural work, in the chars compared with the unprotected mainland, where more households are active in business. The FAP 14 data, from a wider range of flood environments, show even greater involvement in business and services (combined in the same category). Low involvement in business in the study area may reflect the relative isolation of charlands from trading centers. This is apparent in the middle reach, where FAP 3.1 sample surveys showed only 2 percent of household heads had trading as a main occupation in the island chars, but 10 percent in attached chars and setback land (FAP 3.1, 1993).

The surveys concentrated on land-based resources because the survey method was not appropriate for a detailed investigation of fisheries. While fishing is important as a source of food, only 5 percent of households reported fishing as a main occupation (Tables 3.8; E.25, E.26) compared with 30 per-

Table 3.8 Main Occupations of Charland Households (percent)

Occupation	Island Char	Attached Char	Unprotected Mainland	Study Area	FAP 14 Average
Farming	46	45	44	46	38
Day Labor	42	43	36	40	30
Fishing	5	6	5	5	6
Business	3	3	7	5	15
Other	4	3	7	4	12
Total Households	75,791	46,956	42,047	164,794	7,723
Percent Fishing for Second Income	10	12	8	10	na

Source: FAP 16/19 Field Survey; FAP 14 Final Report

*Data is only for mauzas with all occupation data recorded. "Other" consists mainly of households engaged in unpaid domestic work. These households, as well as others that report no income, may receive remittances from people working away from home. Differences from Appendix E tables are due to inclusion of mauzas with partial occupation data in the appendix.

cent in five char villages studied by FAP 14 (FAP 14, 1992), which included villages in the Padma and Padma-Meghna confluence. Even so, fishing is a secondary source of income for an additional 10 percent of households in the Brahmaputra-Jamuna. These are higher percentages than were found in the middle reach, where about 7 percent of household heads reported fishing as a first or second occupation (FAP 3.1, 1993). Most households that have fishing as their primary economic activity are concentrated in the lower reach, particularly on the southern west bank attached charland and on northern east bank attached charland and island chars (15 percent of households with fishing as a main occupation). In addition, catching fish fry is an important activity in this northern lower reach near Bhuapur (Charland Study RRA survey).

The pattern of low dependence on fish is consistent with national statistics (BBS, 1993), which show that in 1988-89 the Brahmaputra-Jamuna contributed only 4 percent of the total main river catch (including the lower Meghna; 16 percent if the lower Meghna is excluded).

3.5.2 Agriculture

As Section 3.2.1 explains, cultivated areas were mapped using the mauza questionnaire returns (Figure 3.15; summarized in Table E.5) and interpretation of satellite imagery (Figure 3.2). Comparison of the two demonstrated that, although the overall mean percentage of cultivated area was similar in the two sources, it varied considerably from mauza to mauza. If the inventory estimates of land cover are used, they imply that some 75 percent of vegetated land is cultivated. The questionnaire returns, however, imply that more land in the island chars is cultivated than is interpreted as vegetated (including cultivated) from the image (some "sand" may have been planted with dry season crops). Also, only 43 percent of vegetated west bank unprotected mainland is cultivated. In these areas erosion may result in relatively high homestead densities. The respondents' estimates of cultivated areas, while thought to be reasonable, have nonetheless not been used further in the analysis in this chapter.

Figure 3.15 shows that unprotected mainland generally is reported to be 70 to 80 percent cultivated. There is a strong correlation between uncultivated mauzas and uninhabited mauzas (previous figures), these were usually wholly submerged during the 1992 dry season, but a number of uninhabited mauzas are reported to be seasonally cultivated. The remaining island and attached char mauzas show wider variation in the percentage of cultivation. A few small isolated island chars show extensive cultivation, but large areas have only up to 50 percent of land cultivated. The latter are mauzas dominated by river channels and sand. Medium cropping levels (50 to 80 percent of land) are widely scattered across the area in all reaches and char types.

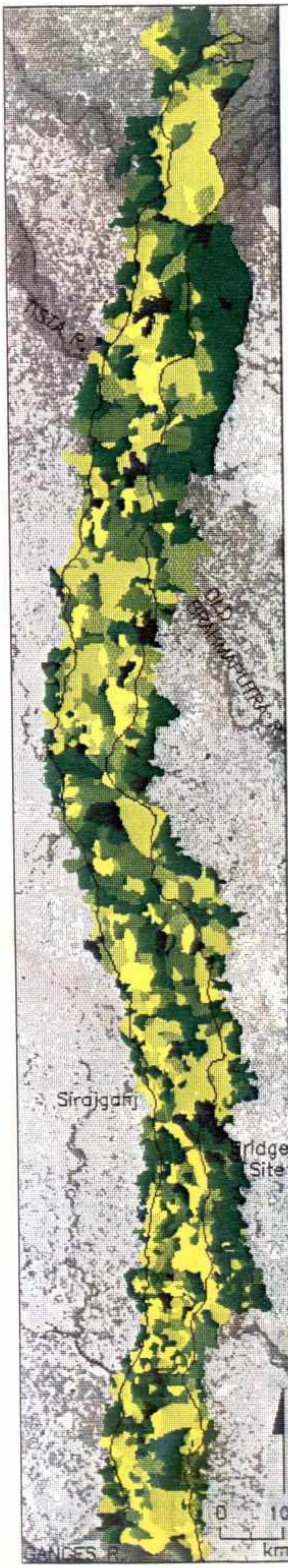
It is impossible to tell from the data either cropping intensities or the level of crop cover by season, but information from the reconnaissance (Appendix D) and from socioeconomic surveys in 1993 indicates that dry season cultivation in the chars is relatively more important than in the unprotected mainland. Therefore, the island and attached char mauzas may be relatively less intensely cultivated than is apparent from Figure 3.15 and in comparison with the unprotected mainland.

A detailed cropping pattern was not obtained from the inventory, but sufficient data were collected to identify the main crop or crop combinations in a mauza. Figure 3.16 and Table 3.9 show that dry land crop systems predominate and appear to be concentrated on the younger island chars and mauzas, which are likely to have predominately sandy soils. These systems mainly comprise millets (orange and pale brown, mainly *kaon* and *china*), groundnuts (brown), and the "other"

Table 3.9 Predominant Crop Types/Associations

Crop Types/Associations	Mauzas (no.)	Cultivated Mauzas (%)
Kaon/China	127	17
Kaon/China/Groundnut	17	2
Groundnut	54	7
Kaon/China fb* Aman	37	5
Wheat	57	8
Boro	161	21
Aus	57	8
B Aus + Aman†	109	14
Aman	51	7
Other‡	87	11
Cultivated, with Data	757	100 (53% of all mauzas)
No Cultivation	348	24
No Data Recorded	331	23

Source: Inventory field survey.
*fb followed by
†B Aus + aman is mixed broadcast aus and aman paddy sown together but harvested during and after the monsoon, respectively.
‡Includes jute, sugarcane, *dhaincha*, catkin grass, and diverse rabi season crops with similar percentages of many crops.



PROPORTION OF LAND CULTIVATED BY MAUZA

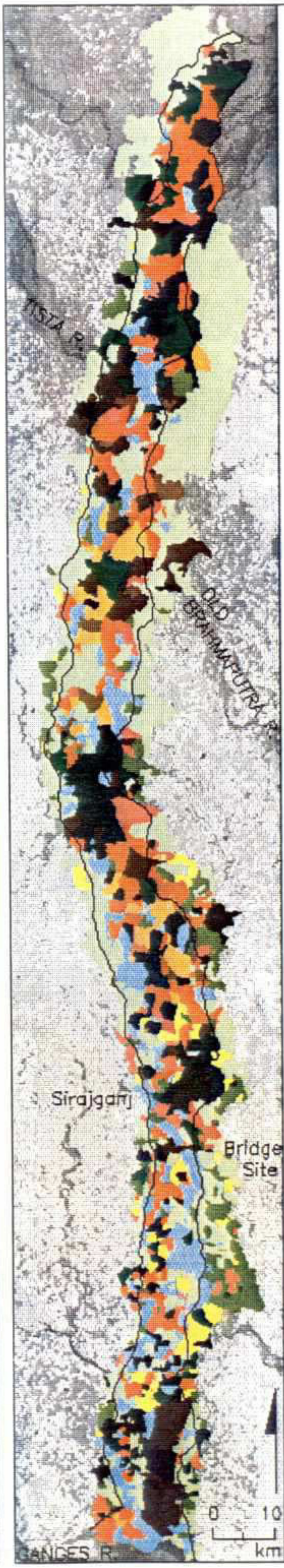
LEGEND

PROPORTION CULTIVATED IN 1992

- 0 %
- 1-50 %
- 51-60 %
- 61-70 %
- 71-80 %
- 81-100 %
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.15



CROP TYPE BY MAUZA

LEGEND

PREDOMINANT CROP IN 1991

- No Cultivation
- Kaon/China
- Kaon/Ground Nut
- Ground Nut
- Kaon/Aman
- Wheat
- Boro Paddy
- Aus
- Aus/Aman
- Aman
- Others
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.16

category (pink), which mostly includes combinations of these and other rabi season crops. In a few mauzas other monsoon season crops are important. Groundnuts appear to be more important in the southern lower reach attached chars. Generally, because the study area faces some of the highest flood risks in the country, monsoon season cultivation is hazardous in many island char areas. Moreover, the maximum amount of land is available in the dry season, but at that time there is little rainfall and the light, sandy soils of the chars are not suitable for irrigation. Therefore, this is a region where water is abundant in the monsoon season and even in the dry season there is ample water in the river channels, but dry land farming systems predominate.

On the other hand, Figure 3.16 shows concentrations of mauzas where aus or mixed aus and aman (dark greens) are dominant crops in the island and attached chars; these tend to be located on the older island chars, where there is more likely to be silty soil. They are concentrated in the upper and middle reaches of the study area, particularly north of the Tista river, close to the Bangali river, and near Bhuapur. In the unprotected mainland, boro (mainly HYVs) is relatively important, particularly in the east bank of the lower reach, south. This reflects the availability of groundwater irrigation, the existence of less sandy soils, and probably greater investment in irrigation because of a perceived lower risk of erosion loss. Local boro is grown on residual moisture in silty lowlands in the chars, but it is very rarely a dominant crop.

Analysis of the series of satellite imagery for 1973 through 1992 reveals that in the char areas, vegetated land (which is predominantly cultivated) expanded, particularly around larger island chars and attached charland, into recently accreted areas. Most of these more stable areas are on the east bank of the middle reach.

DD

3.5.3 Social Conflict

The dynamism of charlands, where the chief economic resource—land—is constantly changing under the influence of erosion and accretion, brings with it the potential for considerable social friction. Past studies of the Jamuna and lower Meghna char areas have found the combination of changes in land and movements of people to be a potent source of social conflict (Elahi *et al.*, 1991; Adnan, 1976; Zaman, 1989).

Although the Inventory Survey included questions on social conflict, little strife was reported. This finding is inconsistent not only with past studies but also with the information from socioeconomic RRAs undertaken for the Charland Study in 1993. Those RRAs found that land grabbing by the powerful was occurring in accreted areas. For the present study people may have been unwilling to admit to such conflict in response to a questionnaire. It may also be that the finding reflects circumstances similar to those found by FAP 3.1. Small informal group discussions during FAP 3.1's study suggested that there are fewer land disputes in the Jamuna-Brahmaputra charlands than on the mainland or in newly accreted coastal areas (FAP 3.1, 1993).

It seems that the nature of such conflict in the Brahmaputra-Jamuna is generally less overtly violent than in coastal areas, and power over land is exercised by manipulating the administrative system and through local patrons *(matbars)*. Thus, virtually all land, even currently submerged land, is already allocated, and owners continue to pay land tax, rarely reporting submerged land in the hope that it will eventually reappear. Such a system keeps land from becoming *khas* land and reverting to the government upon re-emergence. Therefore, it avoids the need to reallocate land when it does emerge. Instead, the resurveying of emerged land is usually controlled, and may be manipulated, by the patrons in the local power structure. In the Bhuapur area (Charland Study RRA) people either find this system satisfactory or find it unwise to argue with their patron's decisions on land allocation. Even so, much accreted land appears to be allocated without recourse to the local administration according to who owned it prior to its erosion. This land allocation method demonstrates that char society has developed strategies to deal with constantly changing and adverse environmental conditions with minimum government intervention.

২২

3.5.4 Livestock

Livestock was divided into three categories: large (cattle and buffaloes), small (sheep and goats), and poultry. Data were collected to determine the mean number of animals per household and the number of animals per km² of non-flooded land during the dry season. The latter is an indicator of grazing land and fodder availability. The density of animals on cultivated lands could be an indicator of the availability of draft animals for land preparation, and of crop residual fodder for stall-fed animals (but the distributions were similar to those for dry season land area, and cultivated area data have limited reliability, therefore they are not presented here).

A total of just over 140,000 cattle and buffaloes were reported in the 70 percent of inhabited mauzas for which data were collected—an overall density of 54 animals per km² of dry season land (Tables E.27, E.28, and E.29). There are relatively high concentrations of large livestock to land area (and cultivated area) in all the unprotected mainland except for the upper reach east bank, which has the lowest density of large livestock in the study area. The southern lower reach island chars also have higher than average cattle densities (red in Figure 3.17). There appears to be some correlation between livestock and human population; areas with high cattle densities also have high population densities.

Data on the number of large livestock per 100 households reveal that, in all but the middle reach of the study area, there are slightly more animals per household on island chars than on other land types (Figure 3.18; Tables 3.10 and E.30). The low level of large cattle ownership in the central part of the middle reach (yellow in the figure) correlates with an area of relatively extensive cultivation that is dominated by monsoon season paddy. The relatively fewer livestock in this area is possibly the result of less grazing land. The exception is on the upper reach east bank attached charland, which has higher concentrations than other non-island char areas. Overall, there are no consistent differences in cattle availability per household; only in a few areas, mainly attached chars and unprotected mainland, is there an average of more than one animal per household. Availability of large livestock per household appears to be less than the national average, despite the favorable fodder resource (Table 3.10).

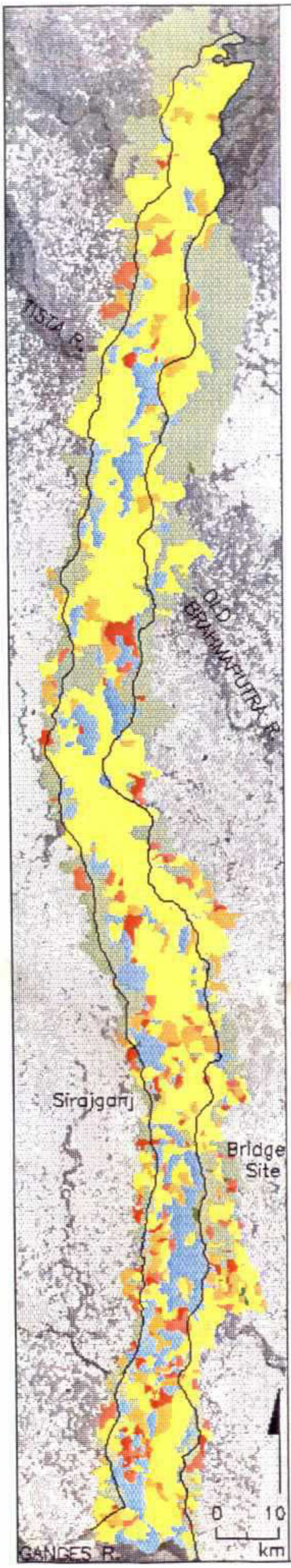
It is unclear whether seasonal flooding constrains large livestock numbers, but grazing may be underexploited due, for example, to lack of funds to purchase cattle or replace flood losses. It may also be that numbers were lower at the time of the survey than in the dry season, since the RRA surveys found in some areas that seasonal cattle fattening enterprises are an adaptation charland farmers make to their hazardous environment. In the upper reach, for instance, there may be higher livestock numbers because cattle are imported from India for fattening prior to sale in the urban markets of Bangladesh. Some of the animals are owned by mainland dwellers who share out cattle to char people to take advantage of seasonal grazing opportunities on the chars. Local assessment of livestock tenure systems and distributions is needed if cattle shelters are to be considered for flood proofing, as the needs and criteria for providing livestock shelters are likely to be spatially different than those for homestead flood proofing.

Table 3.10 Livestock Ownership Per Household

Land Category	Large Livestock	Small Livestock	Poultry
Island Chars	0.88	1.30	3.61
Attached Chars	0.71	1.09	3.39
Unprotected Mainland	0.84	1.04	3.12
Charland Average*	0.82	1.15	3.37
Bangladesh Average†	1.33	0.96	4.99

*Figures are from mauzas with data on livestock ownership (approximately 750 inhabited mauzas).

†Based on 1983/4 Agriculture and Livestock Census and 1981 Population Census.



DENSITY OF LARGE LIVESTOCK TO LAND AREA

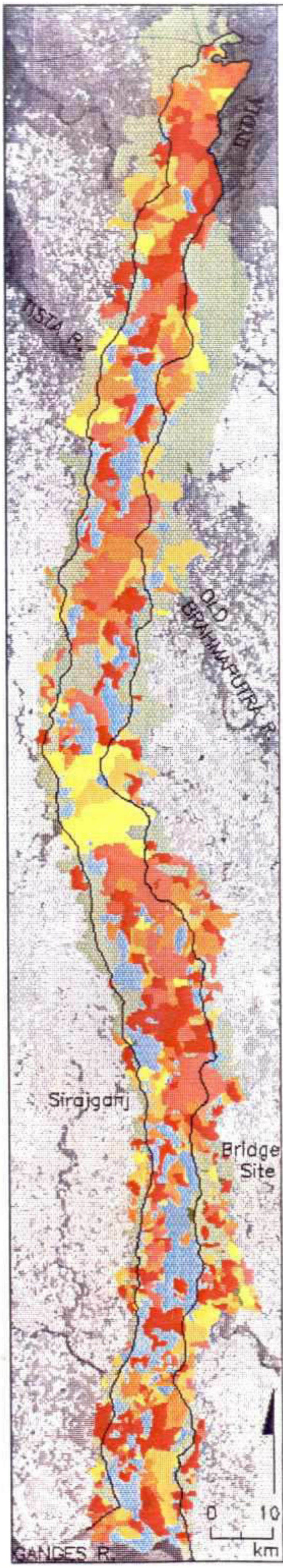
LEGEND

ANIMALS PER SQ. KM DRY SEASON LAND

- Uninhabited
- 0
- 1-100
- 101-200
- 201-350
- GT 350
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.17



LARGE LIVESTOCK PER 100 HOUSEHOLDS

LEGEND

ANIMALS PER 100 HOUSEHOLDS

- Uninhabited
- 0
- 1-25
- 26-50
- 51-75
- 76-100
- GT 100
- No Data recorded
- Bankline, 1992

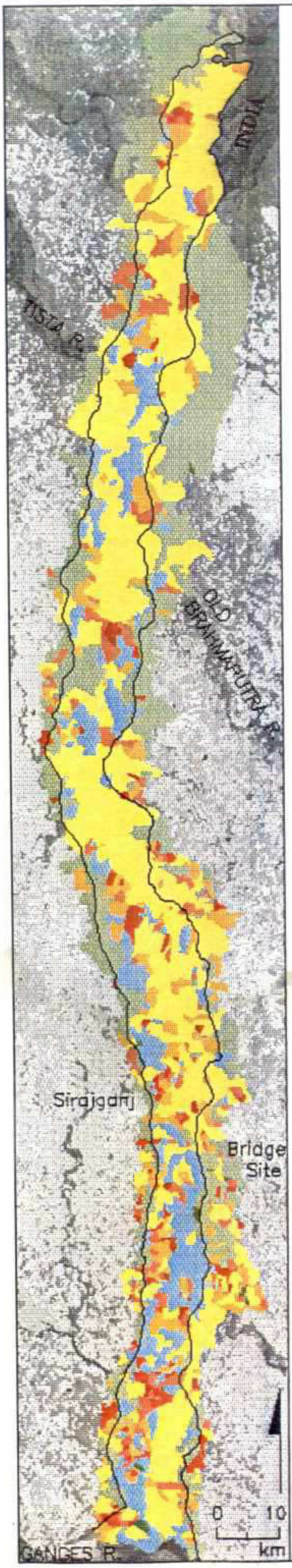
Source: ISPAN, 1992
Field data

Figure 3.18

The distribution of sheep, goats, and other small stock is similar to that for large livestock, but it exhibits local variations (Figure 3.19 and Tables E.31 and E.32). Overall, there are about 100 small stock per km^2 of dry season land, the highest concentrations (red) occurring on unprotected mainland, particularly on the west bank of the lower reach. It may be that flood risk and losses keep numbers down in the char areas. Since the number of animals per household (Table 3.10; E.33) is higher on island chars than in other areas, particularly in the upper reach, the overall density may simply reflect human population density (since a high proportion of households must own small stock). In the island char areas there are relatively more per household probably because of greater availability of grazing.

There is a low number of poultry in the area compared with the national average (Table 3.10): just over three birds per household. Poultry ownership per household is somewhat higher (red) on island chars, particularly in the lower reach, and more generally in the southern lower reach (Figure 3.20; Tables E.34 to E.36).

Data on 1988 flood-related livestock losses are limited, but livestock losses were reported in 59 percent of inhabited mauzas with available data (Tables E.45 and E.46). Most island char mauzas, 79 percent, experienced livestock losses. Livestock population is high relative to human population in those areas, but flood-related human losses were high in the upper and middle reaches and low in the lower reach. Measures to protect livestock may thus be needed even where threats to human life from floods are lower.



DENSITY OF SMALL LIVESTOCK TO LAND AREA

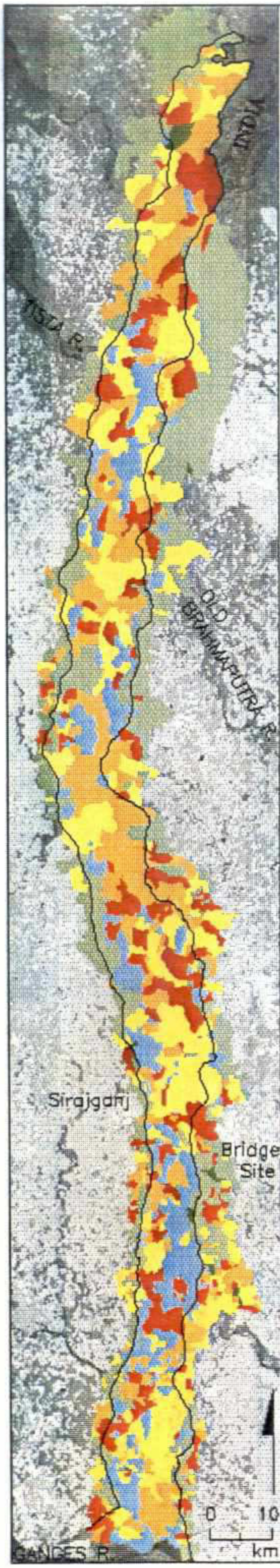
LEGEND

ANIMALS PER SQ. KM DRY SEASON LAND

- Uninhabited
- 0
- 1-100
- 101-200
- 201-350
- GT 350
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.19



NUMBERS OF POULTRY PER HOUSEHOLD

LEGEND

POULTRY PER HOUSEHOLD

- Uninhabited
- No Poultry
- 1-2
- 3-4
- ≥ 5
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.20

3.5.5 Boat Availability

Small, non-mechanized boats are a vital household resource in the char areas, both as a means of transport in the monsoon and a means of saving life and property in severe floods. FAP 14 found that 26 percent of households in a sample of char villages took shelter on boats during a severe flood (FAP 14, 1992). Figure 3.21 shows that, although it is rare for every household in a mauza to own a boat, there is a high level of boat ownership in the area. Non-mechanized boats include "country boats", which operate as commercial cargo carriers, but the majority in this category are small boats for household use. It is possible that the number of the smallest boats, dinghies, has been underestimated in this survey. The study survey found that there are 13 households per non-mechanized boat (Table 3.11). Boat ownership appears to be highest in the lower reach and is lower in the unprotected mainland areas, particularly in the upper and middle reaches, where there are 20 to 40 households per boat (Tables E.37 and E.38).

Although boats are a source of employment for very few of the study area households, since the late 1980s mechanized boats have become increasingly important as a means of transport in riverain areas, including the Jamuna (Charland Study RRA surveys). These boats have helped improve the reliability of communications to market places and the mainland, and they are the main means of speedy evacuation of people, livestock, and property when erosion or severe floods strike. Figure 3.22 shows that mechanized boats are concentrated in the char areas, as one might expect, and there are relatively high ownership levels in the middle and northern lower reach chars. There are other concentrations of boat ownership in the braided section of the Brahmaputra near the Indian border and on island chars in the southern lower reach (red in the map). Overall, there are 90 households per mechanized boat in the study area (Table 3.11), but there are fewer boats in unprotected mainland and attached chars on the west bank, and more in the island chars and east bank mauzas (Tables E.39 and E.40).

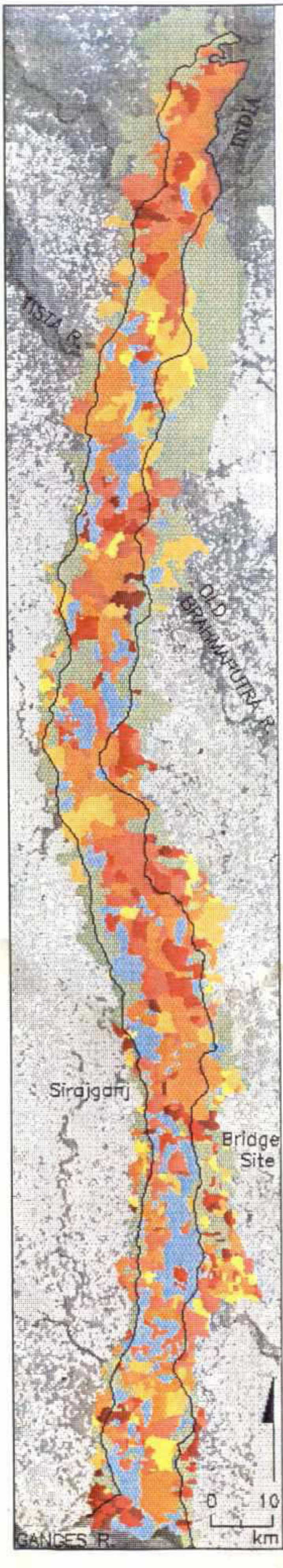
Figure 3.22 highlights areas, such as the southern part of the upper reach, where there could be a shortage of boats in a severe flood. Along most of the river local mechanized boats now have the potential to provide transport and evacuation services during severe floods, especially if these privately owned boats can be contracted by local government to assist the poorest households, which may be unable to afford to evacuate, as well as to carry medical and relief services and supplies.

Table 3.11 Boat Availability*

Land Category	Non-mechanized Boats (no.)	Households Per Non-mechanized Boat	Mechanized Boats (no.)	Households Per Mechanized Boat
Island Char	6,048	13	960	79
Attached Char	4,000	13	528	97
Unprotected Mainland	5,737	13	752	99
Total	15,785	13	2,240	90

Source: Tables E.37 to E.40

*Data is based on approximately 700 inhabited mauzas with available data.



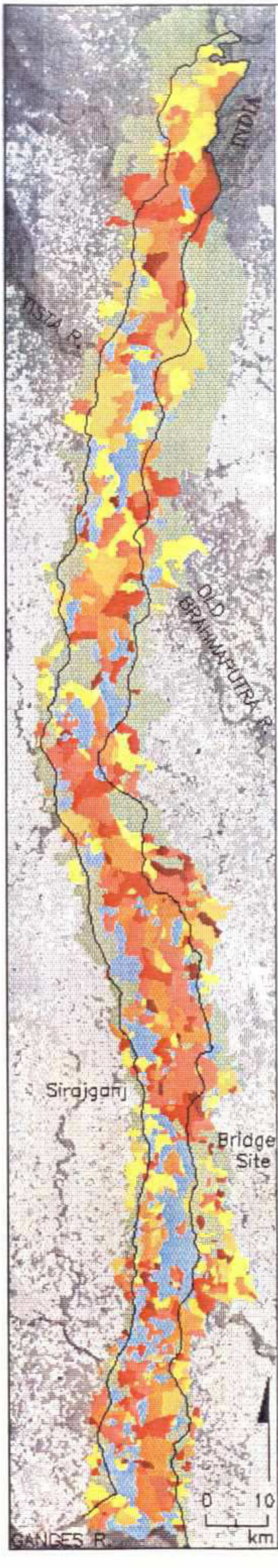
HOUSEHOLDS PER NON-MECHANIZED BOAT

LEGEND

- Uninhabited
- 1-3
- 4-7
- 8-15
- 16-40
- GT 40
- No Boat
- No Data recorded
- ~ Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.21



HOUSEHOLDS PER MECHANIZED BOAT

LEGEND

- Uninhabited
- 1-20
- 21-50
- 51-100
- 101-200
- GT 200
- No Boat
- No Data recorded
- ~ Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.22

HAZARDS

3.6 Hazards

3.6.1 Health Hazards and Loss of Life

Epidemic diseases have been the primary human health hazard in the study area. If it is assumed that the 1988 flood had a 1-in-50 year recurrence interval, that lesser floods do not cause deaths, and that disease deaths over the five year period of 1988 to 1992 are typical, then on an average annual basis there are 17 times more deaths from disease than from flood in the study area. The predominant hazards resulting in death are mapped in Figure 3.23; they include: the 1988 flood, epidemic disease since 1988, flooding since 1988, tornados/cyclones, and "famine." The causes of death shown in Figure 3.23 exclude deaths by natural causes and are based on the period 1988 to 1992, except for flood-related deaths. Very few deaths were attributed to erosion, although its destructive forces often leave households landless and impoverished. Tornados appear to kill few people overall, and have been significant only in a few mauzas in the northern lower reach. Very few deaths related to flooding were reported since 1988; while the few deaths that were attributed to famine may have been the result of food shortages in 1988.

The number of deaths attributed to the 1988 flood are shown separately in Figure 3.24. The 867 human deaths reported to be caused by the 1988 flood were concentrated on island chars, particularly in the middle and upper reaches (Figure 3.24; Table E.41). There were high concentrations in specific mauzas, particularly those that are low, sandy, newly formed, and have high population densities. The central middle reach appeared to be particularly affected, and this area also has low cattle ownership (possibly a legacy of flood losses), and somewhat lower non-mechanized boat ownership. In addition, mortality rates (expressed as a proportion of the 1992 population) indicate that the middle reach west bank attached charland was seriously affected by the 1988 flood: 4.5 people per 1,000 were reportedly killed in that area, compared to an overall death rate in the study area of 0.7 per 1,000 (Table E.42). This area was adjacent to sections of the BRE that were breached in that year.

Deaths due to disease and epidemic outbreaks have been more widespread, but also are concentrated in middle and upper reach island chars (Figure 3.23; Tables E.43 and E.44). The mauzas in which they occurred, however, were different than those where flood deaths occurred. The disease deaths appear to be concentrated in the more permanent, isolated island chars with higher population densities. There were few mauzas that had health facilities where epidemic disease was reportedly a main cause of death. Improved health care services, while a priority for the area, should be adjusted to flooding, and especially to erosion risk, since many chars have been shown to have submerged and re-emerged within the past 20 years (Chapter 2).

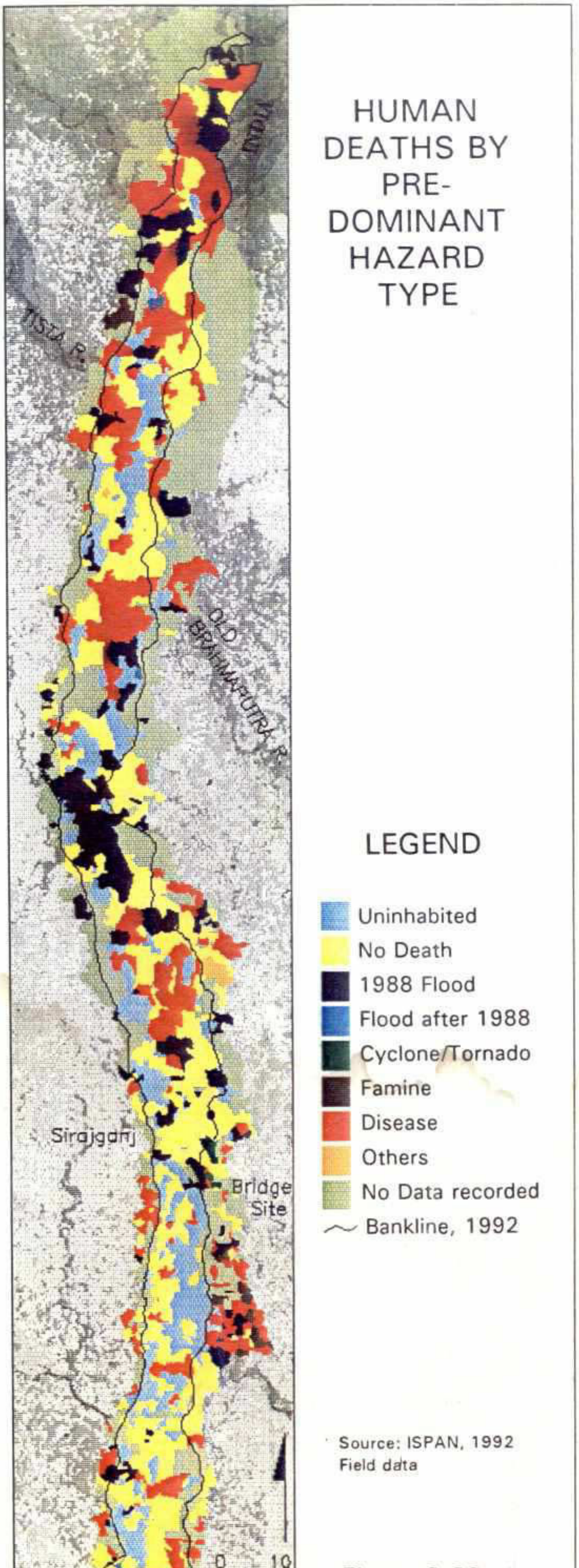


Figure 3.23

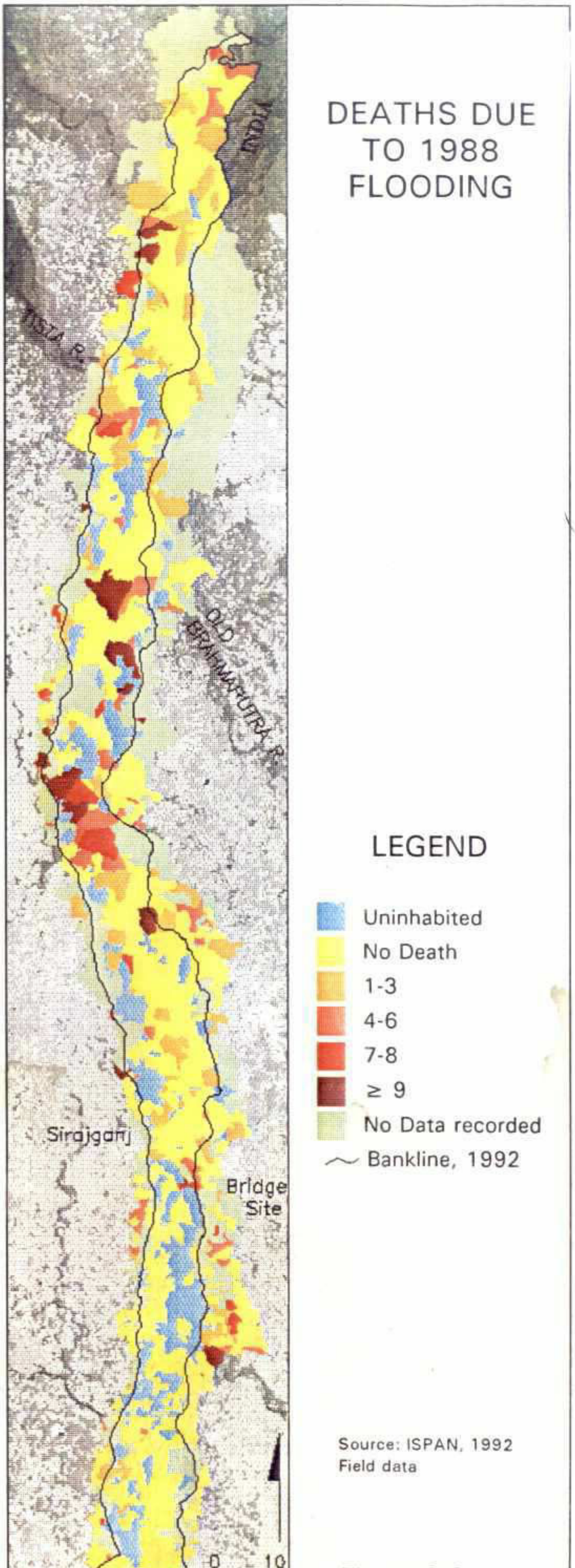


Figure 3.24

208

3.6.2 Recent Flood Experience

Estimates of flood extent and duration were collected in each mauza for: 1988 (severe flood year), 1990 (considered a normal flood year), and 1991 (considered a high normal flood year). In retrospect, it would have been useful to have data on the 1987 flood because a peak-flood satellite image is available for that year and clearly depicts the extent of the peak flood problems in both charland and unprotected mainland (Figure 2.18). Maps for "flooding" in 1990 have not been included since they showed a pattern similar to the 1991 data, but the areas and durations reported are summarized in Tables E.50 to E.52.

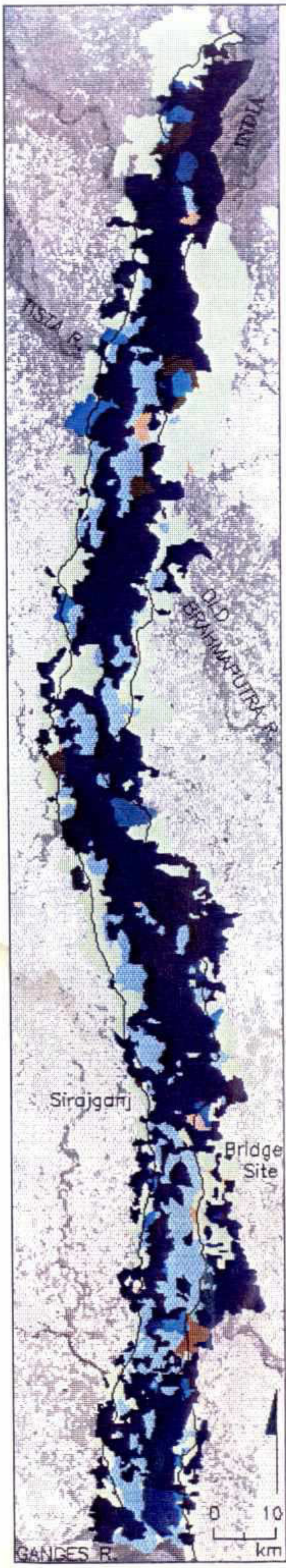
3.6.3 Flood Extent

Informants were asked to estimate the percentage of dry season land area under water at the peak flood level in 1988 and 1991. Figure 3.25 shows that in 1988 virtually the whole of the dry season land in the study area was completely flooded (dark blue). The uninhabited mauzas are predominantly river channel in any case. A few isolated mauzas reported no flood, and slightly more in the unprotected mainland reported 80 percent or less flood coverage (paler blue). Tables E.47 and E.48 indicate that, overall, about 90 percent of land in the study area (including unprotected mainland) reportedly was flooded in 1988, but there was somewhat less extensive flooding in the island and attached chars of the southern lower reach. By comparison, analysis of satellite images for the August 1987 flood (see Section 2.6) showed that 90 percent of dry season within-bank land was flooded in a less extreme flood.

There was a very different pattern of flooding in 1991: About 51 percent of the total land area was flooded, but there was a clear trend from north to south—from 65 percent flooded in the upper reach to 33 percent flooded in the southern lower reach. Likewise, there is a clear trend toward greater flooding in the chars: 58 percent of island chars were flooded, while only 33 percent of unprotected mainland was flooded (Tables E.53 and E.54). Figure 3.26 reveals that extensive flooding was localized. In the upper reach north of the Tista (Kurigram District) extensive flooding was reported. Interview surveys in this area to assess flood impacts for the Charland Study confirmed that flooding there was worse than normal in 1991. Further south, although there is a general trend, the elevation of chars presumably resulted in local variations (because land levels vary considerably within mauzas it has not been possible to investigate relative differences in char height between reaches). Thus, the central middle reach appears to have had little flooding in 1991, whereas the southern middle reach and northern lower reach reported more extensive flooding. Further south the unprotected mainland in Tangail District was mostly not flooded.

Thus, although 1991 was thought to be a "high normal" year at Bahadurabad; away from the upper reach flood extents in 1991 were only marginally greater than they were in 1990 due to high levels but a short duration peak. For example, only 19 percent of houses were flooded in the Bhuapur charland area in 1991 compared with 83 percent in 1988 (Charland Study interview surveys).

While it is possible that recall problems affected the Inventory Surveys, the patterns of flood extent are consistent across a number of mauzas in each sub-reach, and so are more likely related to local differences in topography and hydrologic conditions.



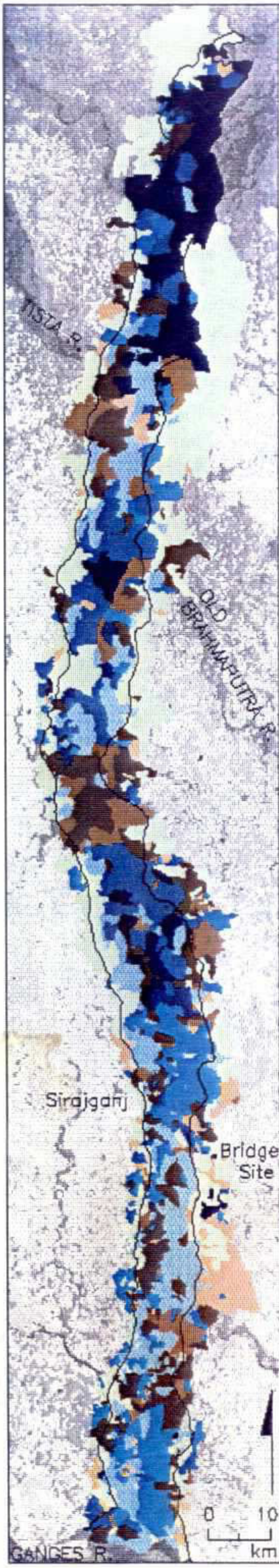
PEAK FLOOD EXTENT 1988

LEGEND

- Uninhabited
- No Flood
- 1-20%
- 21-40%
- 41-60%
- 61-80%
- 81-99%
- 100%
- No Data recorded
- ~ Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.25



PEAK FLOOD EXTENT 1991

LEGEND

- Uninhabited
- No Flood
- 1-20%
- 21-40%
- 41-60%
- 61-80%
- 81-99%
- 100%
- No Data recorded
- ~ Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.26

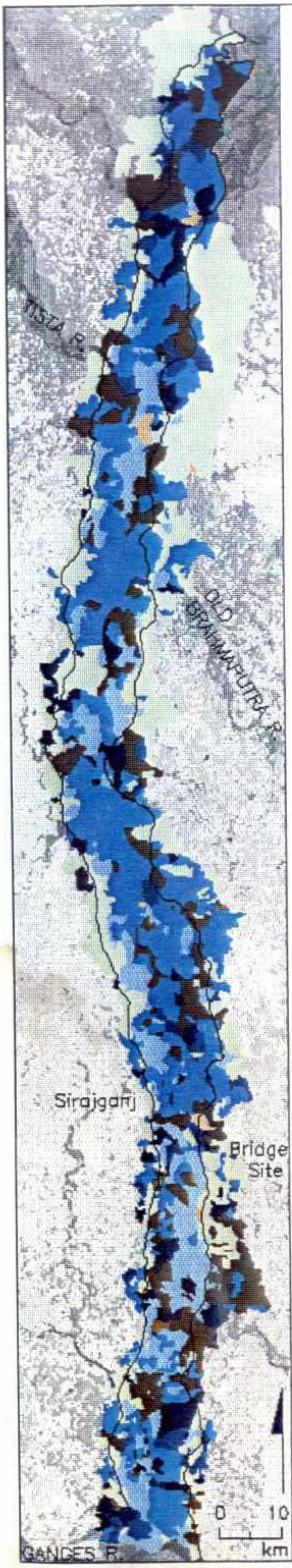
202

3.6.4 Flood Duration

Flood duration is equally important in assessing the severity of flooding, since it indicates the length of time that people may be marooned on, or evacuated to, embankments and higher land. A duration (in days) for the flood peak in each year was obtained from the Inventory Survey in each mauza. This showed that the flood peak was twice as long in 1988 as in 1991 (or 1990), lasting an average 24 days in 1988 but only 12 days in 1991 (Tables E.49, E.52, E.55). There appears to be a trend for longer duration flooding in the west bank (unprotected mainland and attached chars) in both 1988 and 1991 compared with the east bank. Figure 3.27 shows that flood durations were similar throughout the area in 1988, but with a shorter duration of 11 to 20 days in the unprotected mainland in Tangail District in the southern lower reach.

In 1991, flood peak durations were again reported to be similar through the study area, except for much shorter durations (mostly five to nine days) in the northern lower reach (Figure 3.28). Of course, in the non-flooded areas of the southern lower reach there was no duration to record. Those areas with more extensive flooding in 1991 also appear to have had somewhat longer flood durations.

PEAK FLOOD DURATION 1988



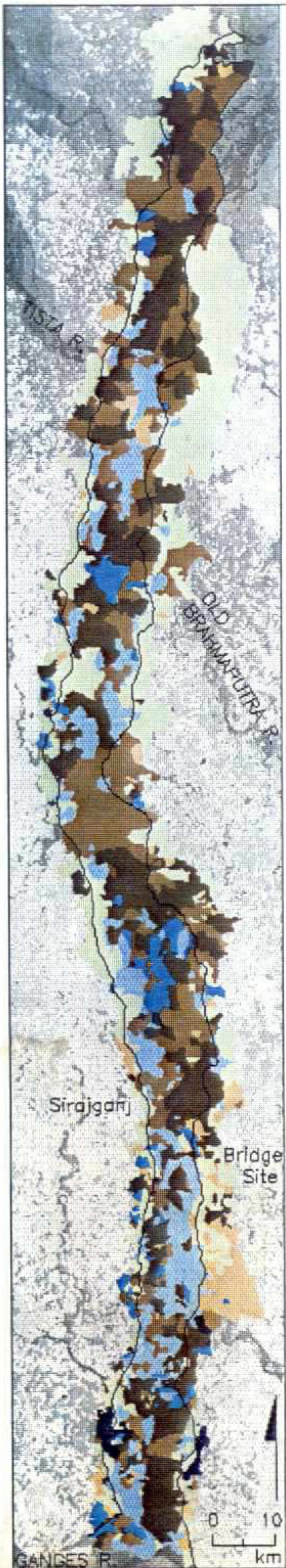
LEGEND

- Uninhabited
- No Flood
- 1-10 days
- 11-20 days
- 21-30 days
- 31-40 days
- > 40 days
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.27

PEAK FLOOD DURATION 1991



LEGEND

- Uninhabited
- No Flood
- 1-10 days
- 11-20 days
- 21-30 days
- 31-40 days
- > 40 days
- No Data recorded
- Bankline, 1992

Source: ISPAN, 1992
Field data

Figure 3.28

3.4.5 Flood Risk

Overall, flood severity and risk appear higher in the upper reach of the river than in the lower reaches. This gives a general indication of priority areas for flood proofing interventions under the present river regime. FAP 25 flood modelling, using a simulation with the proposed FAP 3.1 embankment and the proposed Jamuna bridge in place, indicated that flood risks are likely to increase. Flood levels in the model are 0.54 m higher under peak flood conditions (approximately a 1988 flood magnitude) at Sirajganj with proposed embankments (FAP 25, 1992). They are an additional 0.5 m higher at the bridge site with the bridge in place (FAP 3.1, 1993). The increase in flood levels due to confinement should diminish with distance upstream of the bridge site. The result may be to increase flood levels and, therefore, extents in normal monsoon and moderate flood conditions in the middle and northern lower reaches, making the flood risk there comparable with that in the upper reach. This has policy implications for flood proofing, since the existing adjustments to flooding made by char inhabitants upstream of the bridge site would become less effective. The area just upstream of the proposed bridge site also has relatively higher char population densities and higher livestock ownership, while adjacent areas upstream suffered most flood related deaths in 1988. Flood proofing and emergency preparedness measures will be an important component of the mitigation measures needed for any such construction programs.

More reliable data are needed for further analysis, preferably mapped outputs from the hydraulic model using a digital elevation model (DEM), if current accurate ground level data become available. Failing this, a series of satellite images on a rising and falling flood would be useful, or images of flood peaks in successive years. Unfortunately, it is currently difficult to procure either the cloud-free data or radar images that would be required.

The inventory data [illegible] should be seen as a way of prioritizing [illegible] of the river for different types of interve[illegible] but more detailed study of flood impacts, local topography, and flood risks in particular reaches are needed before appropriate local flood proofing interventions can be designed. In 1993, this survey was followed up in Kurigram and Bhuapur with rapid rural appraisals and household interview surveys. These surveys were designed to quantify flood losses in the two reference years of 1988 and 1991.

NOTES

1. Population data from the 1991 census are not yet published for the Jamuna area. The estimates reported here were based on information from Union Parishad Chairmen or Members wherever possible, and reflect the local "official" figures at the time of the survey. The household numbers given in the inventory are believed to be generally reliable, and household sizes inferred in the inventory are consistent with Bangladesh averages. In Bhuapur and Kurigram, household lists were obtained from the union parishads, then updated by a survey team with the help of local residents to form sampling frames for a household survey (reported elsewhere). This indicated that in Bhuapur there were about 48 percent more households in the inventory than in the updated household lists; Kurigram had about 22 percent more than in the inventory. Some of these differences are due to erosion, which was reported to have occurred in the year between the two surveys, and the Bhuapur chars are more dynamic than those in Kurigram. There is a risk that the numbers, although not the proportions, derived from the inventory may be too high.

Chapter 4

ANALYSIS OF INVENTORY DATA WITH CHANNEL DYNAMICS

4.1 Data Sets

The Landsat satellite images and analysis of river morphology reported in Chapter 2 constitute a database for the Brahmaputra-Jamuna that is independent of mauza boundaries (the minimum unit in the satellite data set is a grid cell or pixel, which represents a ground area of 80 x 80 m). Moreover, the inventory data on populations and resources is not easily divisible below the mauza level—the primary data collection unit. Therefore, as Chapter 1 notes, there are limits to the degree the two data sets can be integrated. This chapter presents the results of some possible analyses that link the data sets.

The objective of this analysis has been to estimate the potential aggregate impact of bank erosion on population and migration. This has been done for:

- population density relative to age of land (Section 4.2);
- 1991 migration, as recorded in the inventory survey, related to erosion in 1990-92 (Section 4.3); and
- longer-term bank changes (erosion) between 1980 and 1992 relative to 1981 and 1992 populations (Section 4.4).

Correlations were attempted for a variety of other mauza-level information from the inventory, such as data on deaths and health care facilities, but no clear relationships were found.

4.2 Population Density and Age of Land

The total 1992 population of the Jamuna Charland Study area is estimated to have been about 1.82 million people (Section 3.2); compared with 1.55 million in 1981. This represents an increase of 17 percent. The 1992 population density of the area was 475 people per km^2 (total area, including water), but there were locally higher densities. On the west bank of the lower reach south, for instance, there were just under 2,000 people per km^2 of dry season land (Table E.12), which was the highest population density in the study area. By comparison, the national population density in the 1991 census was 763 people per km^2 (BBS, 1993).

Population density estimates from the 1992 inventory are mapped in Figure 3.4. This has been linked with the results of a satellite image analysis (Chapter 2), establishing the age of study area land in March 1992 according to its presence in a sequence of dry season images from 1973 to 1992. For each mauza, the land area in each age category has been calculated, and summed for each population density, giving the age distribution of land for each population density category. Areas of water are obviously excluded from the calculations.

Table 4.1 shows that uninhabited mauzas typically comprised recently accreted land (and extensive water areas), and that more densely populated mauzas consist of relatively older land. Even in

Table 4.1 Population Density by Age of Land (percent)

Year Land Last Accreted	1992 Population Density (people per km^2)							
	0	1-200	201-400	401-600	601-800	801-1000	1001-2000	2001+
1990-91	57	42	33	30	31	22	28	26
1987-89	19	20	19	18	27	19	18	8
1984-86	7	15	15	16	13	11	13	16
1980-83	2	9	7	7	7	9	13	11
1978-79	1	2	4	2	1	3	4	3
1976-77	1	2	4	2	0	3	4	3
1973-75	2	1	2	4	0	1	3	8
pre-1973	11	11	17	21	21	31	21	25
Mean Age of Land	5.9	7.1	9.1	10.3	9.7	12.7	10.2	12.4

Source: Inventory data and FAP 19 satellite image analysis

the most densely populated mauzas, however, about 25 percent of land had accreted just before the inventory survey. Assuming that the land age in each age band is the midpoint, and that land accreted before 1973 has an average age of 30 years (probably an underestimate), results in the mean ages shown in Table 4.1. There is an evident moderate trend for more densely populated mauzas to comprise older land, a trend that would be more accentuated if pre-1973 land was assumed to be older.

The fact that older land seems to be more densely populated is probably related to the productivity of land on older, more stable chars. As the accreted land matures, the organic material in its soil may increase, enhancing agricultural productivity. Older chars have also been found (Chapter 2) to exhibit greater stability and to be less likely to submerge the longer they have been above water. Hence there has been more time for people to move onto older chars. Nonetheless, much of the oldest land in the study area, and its dense population, is now threatened by river erosion.

4.3 Recent Changes in Population and Land

For each mauza, the area in each of the following categories was calculated based on the 1990 and 1992 Landsat images:

- within channel as of 1990 (50 percent of the study area, including water, some attached charland, and island chars, hence the disparity with data in Chapter 3, which categorizes mauzas by land type);
- eroded in the period 1990-92 (3 percent of the study area); or
- mainland not eroded as of 1992 (47 percent, including much of the attached charland that has not recently eroded).

These areas were compared with the permanent out-migration pattern (shown in Figure 3.7) to assess the relationship between out-migration and bank erosion. Table 4.2 shows that 76 percent of the study area is in mauzas that did not experience out-migration, while in 4 percent of the area at least 20 percent of households permanently migrated in 1991. Table 4.2 reveals little difference in the extent of erosion between mauzas according to their recent out-migration experience, however. Thus, most of the area of mauzas reporting out-migration of 20 percent or more households in 1991 remained in the river channel (between the 1990 banklines), suggesting that local island char erosion rather than bank erosion was a major factor behind 1991 migration. Additionally, just as much mainland area experienced permanent out-migration as eroded and channel areas did.

The limited migration reported in 1991 seems to

Table 4.2 Permanent Out-migration in 1991 by Land Category

Land Category	Area	%	Out-migration as a Percentage of Households					
			None	1-5	6-10	11-15	16-20	>20
Within 1990 Bankline	204,699	59	59	56	59	46	69	54
Uneroded Mainland	132,157	38	37	40	38	48	28	40
Eroded Area 1990-92	11,772	3	3	4	3	6	4	6
Total Area	348,628		263,715	41,371	20,326	4,977	5,648	12,591

Source: Inventory and FAP 19 satellite image data
*Excludes mauzas with missing migration data.

have been widely dispersed, and factors other than bank erosion may be behind decisions to migrate. One year of data is insufficient to understand the magnitude of erosion impacts in the study area.

4.4 Changes in Population and Mainland 1980-92

4.4.1 Aggregate River Bank Changes

This section is based on calculation of areas lost to erosion or accreted along the west and east banks of the river between 1980 and 1992. The areas have been summed on a mauza basis, then related with population data from the 1981 census and 1992 inventory. The whole area of surveyed mauzas has been used in the analysis, including areas protected by embankments. This was done because population densities for mainland areas were averaged over protected and unprotected areas and because future erosion may affect land that is presently protected. Mauzas entirely within the channel in 1980 and 1992, and mauzas entirely on the mainland (not touching the bankline) in 1980 and 1991, were identified separately to check population trends in the two charland types that were unaffected by bank erosion. Mauzas within the channel have still experienced erosion and accretion, but this analysis concentrates only on bank erosion. The total areas are from the same image analysis as was used in Section 2.5, but here they have been summed for all mauzas in the study area. The mauza defined area is slightly different (less than one percent larger), therefore, from the within-channel areas defined for trend analysis in the within-bank area during 1973-92.

Table 4.3 shows that, in the mauzas surveyed, 24 percent of the 1980 mainland had been eroded by 1992. Moreover, within the study area (unprotected land), about 30 percent of the 1980 mainland had been eroded by 1992 and converted into channel (river and chars combined). Table 4.4 breaks down this erosion by reach and bank, along with the small area of net accretion in the same period (which amounts to only 14 percent of the

Table 4.3 Summary of Study Area

	Area (ha)
Mainland, 1980	214,505
Channel, 1980	211,586
Total, 1980	426,091
Mainland Eroded 1980-92	50,032
As Percentage of 1980 Mainland Area	23.7

Source: FAP 19 satellite image analysis

Table 4.4 Net Area of Bank Erosion and Accretion, 1980-92

Reach	Eroded (ha)		Accreted (ha)	
	West	East	West	East
Upper	11,470	8,005	128	740
Middle	8,364	4,414	0	4,833
Lower North	1,066	1,592	780	194
Lower South	4,216	10,905	69	23
Total	25,116	24,916	977	5,790

Source: FAP 19 satellite image analysis

net eroded area). It should be remembered that this analysis ignores many morphological changes that occurred during the period. For example, some areas may have eroded and accreted within the period of analysis.

4.4.2 Population Dynamics

Table 4.5 summarizes the 1981 and 1992 population in the study area. The population displaced by erosion can be estimated if two assumptions are made: first, that all of the 1981 population living in mauzas intersected by the bankline actually lived on the mainland (a few may have been on island chars, but population density is lower there) and, second, this population was evenly distributed over land whether it eroded in the next 12 years or was not lost. The population changes that would have occurred after 1981 on that eroded land are unknown, as is the year of erosion for any particular location.[1] Table 4.5 summarizes the 1981 population and the population estimated to have been displaced by bank erosion in this period, a total of 398,416 people—about 26 percent of the study area population in 1981.

Normal population growth most likely would have resulted in somewhat more people being displaced as erosion progressed. Moreover, it is likely that households moved more than once during this period because of successive bank erosion events, but the history of population displacement cannot be gauged from the available data.

Table 4.5 Population by Land Status, 1980-92

Population in:	1981		1992	
	millions	%	millions	%
Inventory Area	1.87		2.21	
Unprotected Area	1.55	100	1.82	100
Within Banklines	0.24	15	0.45	25
Eroded Area 1980-92	0.40	26	0	

Source: 1981 BBS census and 1992 FAP 16 inventory

Overall, land capable of supporting almost 400,000 people in 1981 was lost to bank erosion. Population density on this land averaged 796 persons per km^2 of land (based on Table 4.6), which is very similar to the density for all mainland (outside the river channel) in that year (787 persons per km^2 of land). Eroded land in the upper reach, however, had a considerably lower population density than land in the lower reach. Accretion resulted in a small compensating gain of land, but in 1992 this area could only support an average of 819 persons per km^2 of land, or a total of about 55,000 persons (the majority of them in the middle reach east bank and northern lower reach). The net impact was that mainland which had supported 343,020 people was lost to bank erosion, although the area of island chars increased in the same period.

As Chapter 2 explains, the river channel was widening during the period studied. While it has not been possible to relate population changes with in-channel morphology, the population trend in mauzas remaining completely in-channel over the period has been assessed. Table 4.7 shows a dramatic increase in the population of these mauzas between 1981 and 1992. This is consistent

220

with the analysis in Section 3.2.2. The area of vegetated land in the channel (island chars) increased in this period by 22 percent, or about 23,600 ha, compared with a loss of about 43,000 ha of mainland (Table 2.5).

It would appear that about 45 percent of the victims of bank erosion have moved to the river channel. If the channel population can be assumed to have otherwise grown at the same rate as the national average, then there were 156,000 people more than expected living in the river channel mauzas by 1992. Despite the likely absorption of some of the erosion-displaced population the carrying capacity of the channel is lower than it is for the mainland, and the gain in charland does not fully compensate for the loss of mainland. The surplus population not accommodated on the increased charland area is estimated to be 187,000 and some of those people have either settled on the lower south west bank (Table 4.8) or migrated out of the area.

The equivalent figures for mainland mauzas not affected by erosion during the period show much lower population growth, consistent with national averages, but also much higher population density (Table 4.8). It would appear, however, that the overall mainland population (including erosion-affected mauzas) has changed little, increasing only 7 percent between 1980 and 1992. In the southern lower reach population increased by only 13 percent in all mainland areas, but Table 4.8 shows exceptionally high population growth (almost 140 percent) in the west bank mauzas not affected by erosion. In a few cases mainland may have been reclassified

Table 4.6 1981 Population of Land Lost to Bank Erosion 1980-92

	Percent of 1981 Population		Population Density (per km^2)	
Reach	West	East	West	East
Upper	25	25	476	563
Middle	41	25	1,090	990
Lower North	5	10	1,052	1,142
Lower South	29	40	1,527	643
Total	221,376	177,040	881	711

Source: Inventory data apportioned according to area estimates from FAP 19 image analysis

Table 4.7 Population Growth in Within-Bankline Mauzas (area = 127,762 ha)

Reach	1981 Population per km^2	1992 Population per km^2	Percent Increase
Upper	117	262	123
Middle	179	267	49
Lower North	356	549	50
Lower South	189	518	174
Mean	185	356	92
Total	236,669	454,200	217,531

Source: BBS 1981 Census; inventory data; FAP 19 satellite image analysis

Table 4.8 Population Growth in Unaffected Mainland Mauzas (area = 83,542 ha)

	Percent Growth 1981-92	
Reach	West	East
Upper	13.6	20.4
Middle	32.4	8.9
Lower North	30.7	28.8
Lower South	138.7	26.9
Average	60.5	21.1
Total Population 1992	300,714	472,812
People per km^2 1981	836	639
People per km^2 1992	1,342	773

Source: BBS Census 1981; inventory 1992

322

as island char when separated by newly formed channels. It may be that while many bank erosion victims have moved onto island chars, the remainder, especially in the southern lower reach, have moved to the edge of the setback land (the embankment) and away from immediate erosion risk.

4.4.3 Future Change

As part of a morphological study of bank erosion FAP 1 projected the likely Jamuna banklines in the year 2011 between Chilmari and Natuabari on the west bank and between corresponding points on the east bank (FAP 1, 1992), a length of 190 km (out of a total length of 246 km for the Jamuna Charland Study area). This data has been used to estimate the area expected to erode and accrete in each reach for the 77 percent of the river covered by FAP 1. Table 4.9 indicates that bank erosion may account for a net loss of 34,120 ha during the 20-year period. This is an area similar to that eroded in the previous 12 years along the whole river, although it may be partly compensated for by accretion of new chars.

Many people will be forced to move in the next 20 years if these predictions are correct. The mainland population density in 1992 averaged 926 people per km^2, and assuming that erosion is evenly spread over the projected period and that population growth continues at an average of 26 percent per decade, then about 578,000 people might be displaced by erosion. Newly accreted land may support 31 percent of those erosion victims, assuming that the same population density would be possible on the new land as on the eroded land. Given the already high population densities within the main channel (720 people per vegetated km^2 in island chars, Table E.11), it seems increasingly unlikely that erosion victims will be able to sustain themselves by staying within the study area.

Table 4.9 Predicted Area (ha) of Mainland Erosion and Accretion, 1992-2011

	Erosion		Accretion	
Reach	West	East	West	East
Upper	7,804	5,432	35	3,616
Middle	12,474	3,414	0	7,410
Lower North	2,660	852	28	3,826
Lower South	4,309	12,605	515	0
Total	27,247	22,303	578	14,852
	49,550		15,430	
Net Erosion Loss	**34,120**			

Source: GIS reprocessing of digitized 1992 bankline and FAP 1 predictions

The situation is likely to be particularly severe in the southern lower reach—a net loss of 16,399 ha is predicted for only 70 percent of this reach, and the remainder of the reach may be just as erosion-prone. Population densities for this reach on the banks and island chars are already the highest in the river and may already be close to capacity. Permanent out-migration consequently may be most severe in this area.

4.5 Implications of Analysis

The conclusion that many people have been displaced by erosion along the Brahmaputra-Jamuna is not new. There have been other, more detailed studies of erosion impacts and changes in char areas: Currey (1985) in Chilmari, and Elahi *et al.* (1991) in the Sirajganj area. Using the inventory together with satellite image analysis for a series of years, however, makes reliable aggregate estimates of erosion impacts possible for the first time. A picture of historical erosion impacts could be developed by adding mauza-level population data from earlier censuses, comparative analysis of bankline changes from the 1973 and 1980 Landsat images, and the historic maps referred to in Chapter 2. With the addition of data from more recent images and short field surveys, the databases could be used as a baseline to monitor continued channel changes and their impacts over time.

Erosion and accretion are not new phenomena along the Jamuna, but this analysis draws attention to what may become an increasingly tragic human problem as ever more densely populated areas are eroded. The island chars formed within the migrating and widening channel seem unlikely to be able to take up this displaced population. Flood proofing may offer a partial solution for the residents of chars where flood risk does not preclude settlement. Yet the erosion threat also limits the ability to build flood proof settlements, since the investment is likely to be washed away in a few years.

The future may lie in flood proof embankment settlements that are periodically retired or are protected from erosion; localized stabilization of island chars to increase their longevity; and assisting communities to stay together and earn a livelihood in the face of flood and erosion risk. As part of the charland study more detailed case studies of flood and erosion impacts using RRA methods were undertaken in the Kurigram-Nageswari and the Bhuapur areas in 1993. Sample household surveys were also undertaken in these areas to assess flood impacts in 1988 and 1991, and to provide a basis for estimating potential flood proofing benefits. The results of these studies are reported separately.

NOTES

1. Mauzas affected by erosion of both banks or for which the bank involved was not identified have been omitted. Those 68 mauzas held only about 2 percent of the total population. Their omission, therefore, is unlikely to affect the analysis.

228

Chapter 5

CONCLUSIONS AND FUTURE USE OF CHARLAND DATABASE

5.1 Objectives

The original aim of the inventory was to provide baseline data for development planning, and particularly, although not exclusively, for planning under the FAP. This report comprises analysis of population, resources, and morphology data of charlands of the Jamuna River. Section 5.2 briefly summarizes some of the findings from the inventory. Section 5.3 considers the future uses of the charland GIS and databases, with particular reference to development activities along the Jamuna. The baseline data in the GIS is available for more localized analysis and planning than was possible for this report.

5.2 Summary of Findings

The study has demonstrated that data can be collected and mapped for the char areas despite the very dynamic nature of their land and population. Conducting a survey of the chars requires up-to-date maps, which are only obtainable by processing satellite images taken two to three months prior to the survey. Otherwise, conditions will have changed so much that the physical details shown in the maps will have altered (as shown in the sequence of images in Figure 2.1). Suitable maps normally are available for the annual dry season (December through March). The Charland Study has established a link between cadastral maps of mauza boundaries and digital, image-based maps of land use. These maps can be related to show accurately changes over time relative to mauza boundaries. They also enable mauza-level data, collected from key informants, to be related with maps of land use and channel changes derived from satellite image analysis.

The method has evolved, and improved charland inventories and GIS databases are under preparation for the other main river charlands. The result is a powerful planning tool that could be refined and updated as the Jamuna's morphology and population continue to change.

Tables 5.1 and 5.2 summarize some of the most important inventory data by land type. As the data show, there are important variations in population and resource bases and in hazards between reaches, within reaches by char type, and even more localized differences that have been identified by mapping the data. This report presents only very aggregated maps, but more detailed maps, covering smaller reaches of the Jamuna, can be produced for specialized uses.

Analysis of a series of Landsat images made between 1973 and 1992 revealed the dynamic nature of the charlands over that period, including channel migration, movement, and widening and complex patterns of submergence, erosion, and accretion of island chars (Chapter 2). Analysis of those images and historical maps revealed longer term trends of channel movement. The processes of bank erosion and channel changes have been studied through use of a GIS, which allows accurate measurement of changes between historical maps and satellite images. There has been an overall tendency for the river to move westward and widen, for mainland to be eroded, and for island chars to be formed. Chapters 3 and 4 reveal that the general result is that densely populated

Table 5.1 Qualitative Summary of Differences between Char Land Types

Characteristic	Island Char	Attached Char	Unprotected Mainland
Land	Much sand and water, 48% vegetated.	Moderate sand and water, 61% vegetated.	Little sand or water, 91% vegetated.
Population	Lowest density, average 320 per km^2, but growth greater than national average since 1981.	Density slightly higher than islands (342 per km^2), but low growth.	Highest density, 773 per km^2. Caught up with national average since 1981 due to rapid growth as erosion victims concentrated in remaining mainland areas near their eroded land.
Migration in 1991	More in-migration, permanent moves as land reappears or in response to erosion elsewhere, and temporary moves to use seasonally available land.	More in-migration, particularly seasonal in-migration; attached chars may be subject to more rapid morphological change.	Localized out-migration linked to bank erosion, relatively less in-migration. Mauzas may be near capacity following past in-migration and bank erosion.
Infrastructure	Relatively poor secondary school and health facility provision. Access to mainland facilities constrained by river channels.	Relatively poor secondary school and health facility provision.	Relatively good secondary school and health facility provision. More markets.
Livestock	Low numbers relative to land area, but slightly higher per household than other land types.	Relatively low numbers.	High numbers relative to land, but this reflects population density not greater ownership.
Boats	Better availability of mechanized boats, but coverage patchy.	Boat availability same as in unprotected mainland.	About 100 households per mechanized boat.
Deaths	Concentrations of flood and disease deaths, particularly in upper and middle reaches.	1988 flood death incidence same as island chars, but relatively high in west bank.	High incidence of death due to disease, mainly in east bank, but fewer flood-related deaths.
Floods	Extensively flooded in 1988 for 22 days on average; about 58 percent flooded in 1991	Extent and duration of flooding in 1988 and 1991 similar to island chars.	1988 flood extensive and longer duration (28 days), about 33 percent flooded in 1991.

Source: FAP 16 Charland Study

Table 5.2 Summary of Mauza Inventory Data by Char Land Type

Parameter	Island Char	Attached Char	Unprotected Mainland	Bangladesh*
Area (ha)	148,248	119,010	115,756	14.4 million
Percentage water	31	21	7	na
Percentage sand	21	18	2	na
Percentage vegetated	48	61	91	na
1992 population	512,996	407,052	897,712	109.9 million
Population per km^2 in 1992	320	342	776	763
Percentage increase, 1981-92	33	8	14	26
Cultivable land per capita (ha) in 1992	0.14	0.18	0.12	0.09
% permanently out-migrating in 1991	3	4	2	na
% seasonally in-migrating in 1991	3	6	3	na
% mauzas with primary school	62	61	61	74
% mauzas with secondary school	10	7	17	13
% mauzas with health facility†	8	11	22	4
% households mainly farming	46	45	44	na
% households mainly day laboring	42	43	36	na
Cattle per household	0.88	0.71	0.84	1.33
Households per mechanized boat	79	97	99	na
1988 flood deaths per 100,000	81	81	57	1.4
% mauzas reporting livestock death in 1988 flood	79	67	32	na
1988 % area flooded	91	84	93	46
1991 % area flooded	58	52	33	na
1988 mean flood duration (days)	22	23	28	na
1991 mean flood duration (days)	12	13	11	na

Source: FAP 16/19 inventory and satellite image analysis

*BBS (1993), except flood data, which is from Rogers, *et al.* (1989). Population figures are for 1991. Comparisons are for rural Bangladesh.

†Facilities below the union health center level, such as private doctors, may have been included in the inventory.

land is eroded and replaced with less densely populated and more hazardous island chars. About 400,000 people were probably displaced between 1980 and 1992 by aggregate changes in bankline alone. Other things being equal, the trend is likely to continue in the foreseeable future. In particular, lower reach areas with very high population densities may be eroded in the next two decades.

5.3 Future Uses of Jamuna Charland GIS

5.3.1 Overall Future

The charland GIS needs to have a continued and stable life if other institutions and projects are to make use of the wealth of detailed data it contains. While this report presents details of the satellite image and inventory analyses for the entire length of the Jamuna, similar analysis would be possible for smaller planning areas within this study area. If the databases were expanded, similar analysis could be done for the cyclone-prone coastal belt. To effectively achieve this the charland GIS will need to be operated, maintained, and updated by an organization that can work with studies inside and outside the FAP to identify the planning needs the GIS can meet. It must also be able to carry out detailed analysis and additional studies, and then produce tailored outputs for specific users. This need might be met by institutionalizing the capabilities of FAP 19 within an organization dedicated to planning and applied research on natural resource and hazard management.

Water resources development planning in the Jamuna charlands falls between the boundaries of the FAP regional studies, but detailed feasibility studies are expected to address impacts in adjacent char areas. Thus, FAP 3.1's Jamalpur subregional project included the adjacent charlands in its study, and it is envisaged that the proposed FAP 3.2 feasibility study would do the same. To date, FAP 3.1's study has used data only down to the union level, but the proposed detailed design stage of their work would need mauza-level data.

This is only one of many ongoing studies and planned or possible interventions that could be users of the Jamuna charland GIS. Linkages between these interventions and the charland databases and GIS are discussed in the following sub-sections.

5.3.2 Brahmaputra Right Embankment

FAP 1 aims to increase the effectiveness of the Brahmaputra Right Embankment and reduce the risk of catastrophic failure from bank erosion and peak floods. Much of the analysis of river and char physiography reported in Chapter 2 was undertaken jointly with FAP 1 and contributed to that project's river morphology studies. Many of the Jamuna charland study outputs, therefore, have already been used by FAP 1. In addition, FAP 1 requires detailed data on conditions at specific erosion-prone sites where bank protection is being considered. At Sirajganj, FAP 1 used a household socioeconomic survey to assess the livelihood implications for families forced to resettle if proposed embankments are built, and to develop strategies to address those implications. In the future, the charland database and GIS could be used in other priority sites for preliminary assessment and screening of potential impacts.

5.3.3 Bank Protection and River Training

FAP 21/22 is considering river training and bank protection needs and strategies for the river as a whole, including char areas. The project will include bank protection trials in several locations, including the left bank of the Jamuna at Bahadurabad Ghat. FAP 21/22 has also studied char physiography and river morphology (FAP 22, 1992) through detailed local studies and analysis of satellite images. The Charland Study complements this with more aggregate data on changes in the river, including historical trends, and integrates population and resource data with the morphological analysis. The river morphology surveys to be conducted by FAP 24 will also complement this data. A joint study of FAPs 21/22 and 24 is expected to result in modelling of planform changes in the braided river. The satellite image and inventory analysis of FAP 16/19 should be integrated with this. Understanding physical changes and the technical effectiveness of possible protection works are not sufficient to determine and design socially and economically viable interventions. The charland inventory and GIS are the basis for preliminary erosion impact assessment, as well as assessment of the potential social and settlement benefits of bank protection and char stabilization. They could be used to set priorities for more detailed feasibility study and implementation.

5.3.4 The Middle Reach

FAP 3.1 studied the entire middle reach of the Jamuna. Due to concerns about the potential impacts of flood protection works on unprotected land, the study area was extended to include adjacent charland, and the results were included in the study's Final Feasibility Report (FAP 3.1, 1993). This char area is now an intrinsic part of the proposed intervention program, not just as a result of the overall analysis of the likely impacts, but also as an area deserving its own assessment for appropriate development interventions. This study has made extensive use of the FAP 16 charland inventory, and in fact, the two studies were developed in parallel.

FAP 3.1 has proposed an integrated rural development program for the unprotected land. That program is centered around flood proofing, but includes an income diversification component to reduce the risk of livelihood loss due to flooding (FAP 3.1, 1993). Detailed design of this intervention program is likely to make extensive use of the FAP 16/19 charland study, specifically for information concerning erosion and accretion patterns; and for mauza-level data on flood proofing, resources, services, and human and livestock population densities. For detailed design work the mauza database would need to be linked with flooding simulations for "with" and "without" intervention scenarios derived from hydrological modelling carried out by FAP 25. The GIS could also be used to evaluate whether mauzas selected for NGO-led group discussions to assess people's needs are representative of the range of conditions in the FAP 3.1 area.

5.3.5 The Lower Reach

A detailed feasibility study for proposed works downstream of the FAP 3.1 area has been proposed as FAP 3.2. The GIS database and the inventory could be used as baseline data on the unprotected areas adjacent to any proposed embankments, which will need to be studied and included in the overall project planning and development program. The study presumably would include the adjacent charland upstream of the site of the proposed Jamuna bridge and downstream of the FAP 3.1 middle reach.

5.3.6 Other Flood Proofing Programs

As a follow-up to FAP 23, a variety of pilot flood proofing interventions are being proposed for the Brahmaputra-Jamuna. The 1993 charland household sample interview surveys in Kurigram and Bhuapur areas were designed to provide data and analysis that will aid the design of such projects. It is hoped that future flood proofing programs could use a combination of the GIS and inventory data to identify broad problems and program priorities, then follow up with more detailed local surveys to tailor implementation to local needs.

5.3.7 Jamuna Multi-purpose Bridge

Approach roads for the Jamuna multi-purpose bridge are already under construction, an impact assessment has been conducted by the World Bank, and a resettlement planning document is expected. All the activities associated with the Jamuna bridge will need baseline data, particularly for the upstream area where flood risks are expected to increase as a result of river confinement. The existing river morphology will need study, and a monitoring program will need to be established. The charland study provides a basis for this work. This could continue with remote sensing monitoring, which could be linked with hydraulic modelling by FAP 25 and the charland inventory to identify potential impacts, and so form a starting point for designing a mitigation program.

5.3.8 Local Government

Government services are limited in the char areas, although the inventory shows that there are some provisions. The inventory can be used to identify areas reporting low service provision or no facilities relative to population, and to plan additional service. In addition, detailed information from this study on past and future erosion and accretion patterns will be important in ensuring that appropriate services are provided without a high risk of infrastructure loss. The Local Government Engineering Department (LGED) is currently preparing updated maps for all thanas, which will be incorporated in a GIS. The infrastructure data in the LGED maps could be combined with hazard and resource data in the charland inventory and the image analysis of morphological changes to form an integrated planning tool.

5.3.9 NGOs

Some NGOs are already working in the charlands, although their programs are located primarily on the attached chars and setback areas. One such NGO has conducted a trial flood proofing program near Bhuapur and is aware of the data requirements for setting it up. There are also NGOs in the neighboring mainland areas that are interested in extending their operations into the island chars to provide support through self-help programs. These NGOs could use the inventory data to identify priority issues and their locations and extent for planning their programs.

5.4 Longer-Term Institutional Approaches

The riverain charland areas appear to have been somewhat neglected, having rarely been the focus of government or NGO development programs. In part this reflects the highly mobile nature of charland resources and the population living on them. It is difficult for any administration with fixed boundaries to come to grips with something as temporary as charland. Under the FAP some official attention, in the form of studies, has now been given to riverain chars (but not coastal chars), and a national database on these diverse and complex areas is being compiled. This information needs to be properly used and taken into account by the full range of ministries and departments that could and should be actively involved in improving the livelihoods of char people.

While the charlands are covered by normal development activities, to the extent that these activities are suited to the chars, government programs suited to the unique needs of char people have yet to be devised and implemented. This might be done by a specific program or development board involving relevant agencies, which would have the advantage of promoting the more integrated and interdisciplinary approach that seems to be needed in the chars. Alternatively, it might be accomplished by ensuring that each agency, in its own planning and service provision, take note of the problems and needs of the char areas. The government will, as a first step, need continued interactive access to the charland GIS and database.

220

PHOTOGRAPHIC PLATES

Plate 1 High flood risk settlement on an unstable Island Char in the middle reach. The sand shown in this dry season photograph is under water in the monsoon.

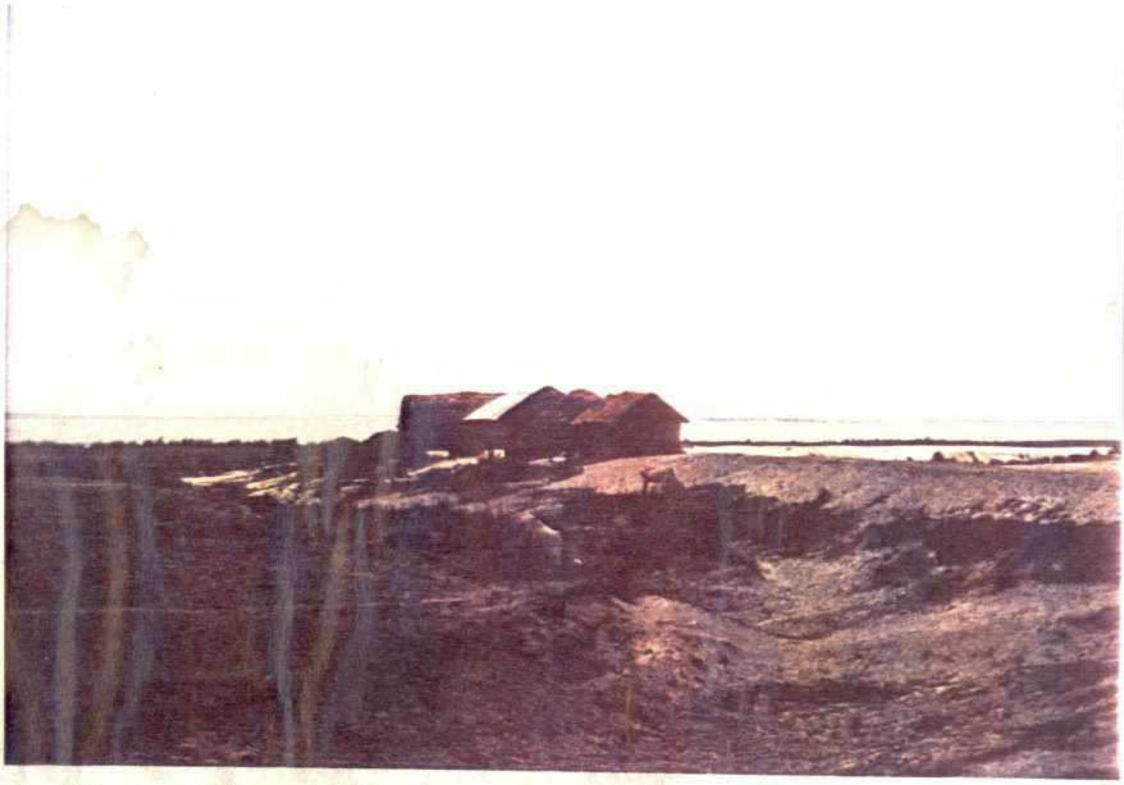


Plate 2 Homesteads recently relocated to the remaining portion of a CARE built embankment on an eroding Island Char

Plate 3 Main bank erosion on the left bank of the lower reach north of Aricha. Note that the homesteads are located on the embankment which has been breached by erosion

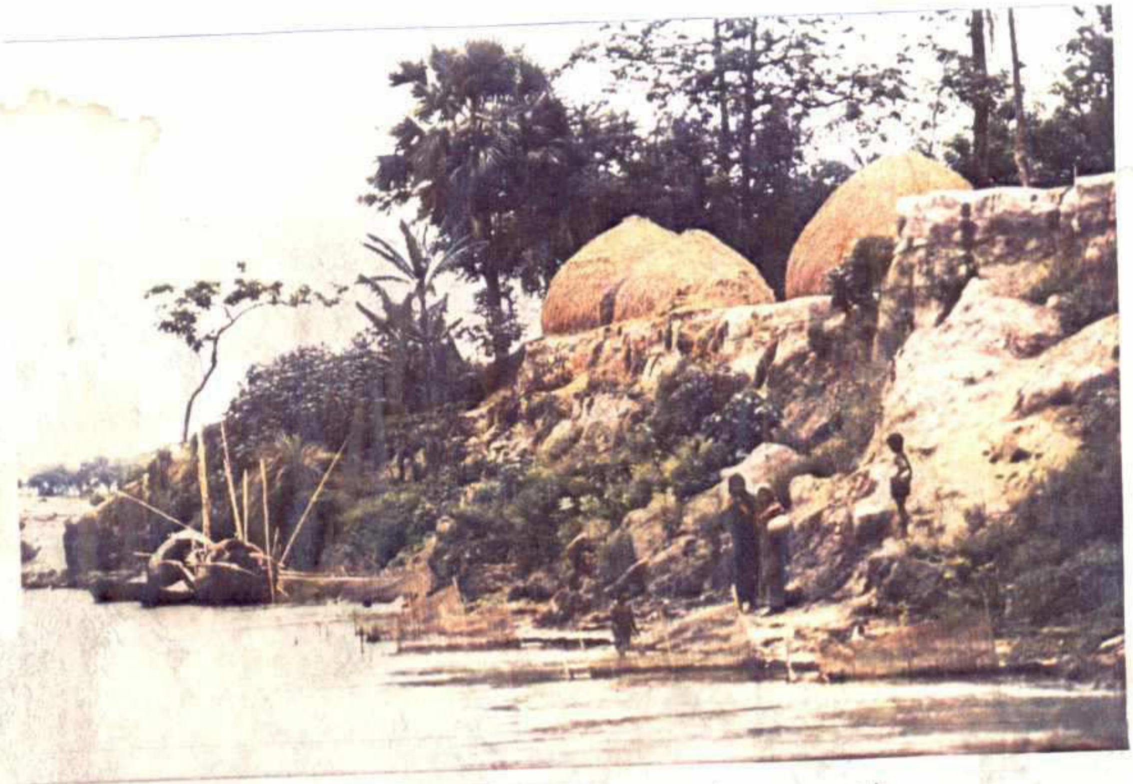


Plate 4 Main bank erosion on the left bank of the lower reach

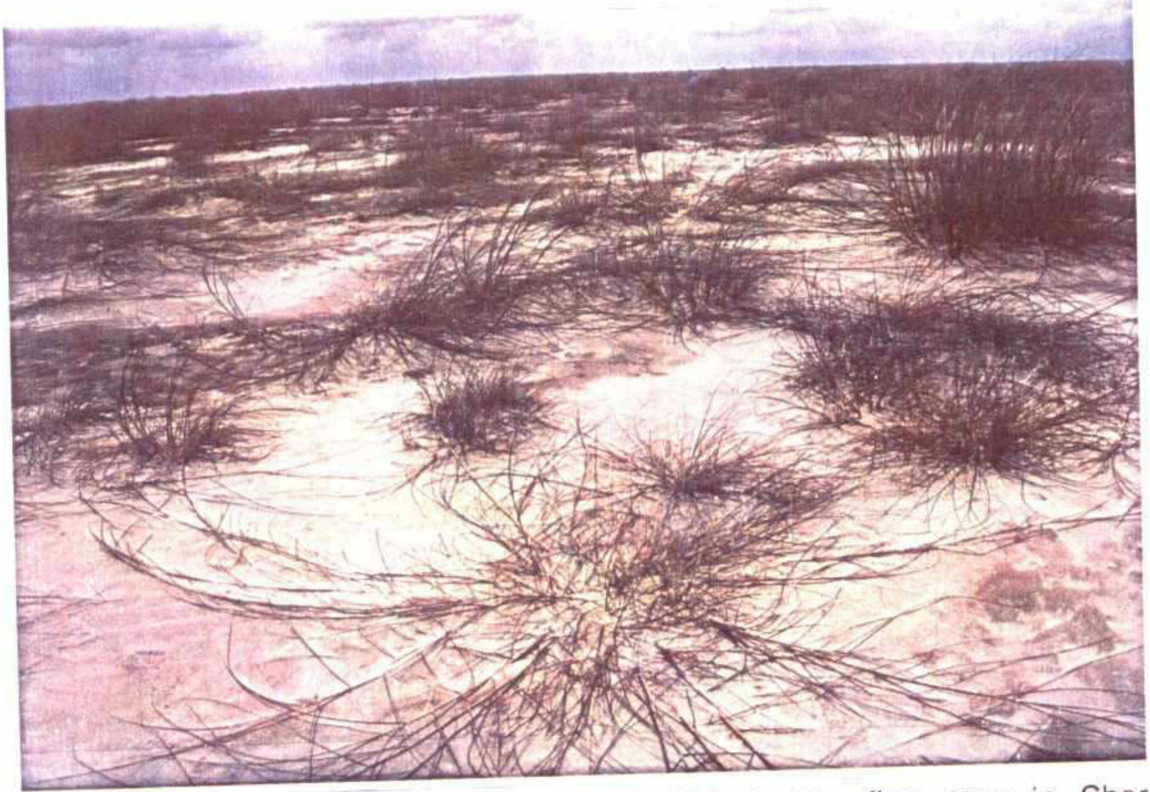


Plate 5 Catkin grass, the colonization of which is the first step in Char stabilization

Plate 6 Abundant livestock in the upper reach

Plate 7 Transport of cattle by mechanized boat

Plate 8 Typical small mechanized boat operating as passenger ferry

Plate 9 Sudden pre-monsoonal storm in the lower reach during April

Plate 10 Ground truthing the Landsat imagery with the GPS and farmer interviews

APPENDIX A

REFERENCES

Adnan, S. 1976. Land, Power and Violence in Barisal Villages. Dacca: University Village Study Group, Working Paper No. 6.

BBS. 1993. *1992 Statistical Yearbook of Bangladesh*. Dhaka: Bangladesh Bureau of Statistics.

Coleman, J.M. 1968. Brahmaputra River: Channel Processes and Sedimentation. *Sedimentary Geology* 3: 129-239.

Currey, B. 1985. Socio-economic and nutritional re-survey of Chilmari Upazila. Dhaka: Ministry of Local Government, Rural Development and Cooperatives, Intensive Rural Works Programme.

Elahi, K, Ahmed, K.S. and Mafizuddin, M.. 1991. *Riverbank Erosion, Flood and Population Displacement in Bangladesh*. Savar, Dhaka: Jahangirnagar University Riverbank Erosion Impact Study.

FAP 1. 1992. River Training Studies of the Brahmaputra River - Draft Final Report. Dhaka: Flood Plan Coordination Organisation, Ministry of Irrigation, Water Development and Flood Control. (Report prepared by Sir William Halcrow & Partners).

FAP 1. 1993. River Training Studies of the Brahmaputra River - Draft Final Report Annex 2 - Morphology. Dhaka: Flood Plan Coordination Organisation, Ministry of Irrigation, Water Development and Flood Control. (Report prepared by Sir William Halcrow & Partners).

FAP 3.1. 1993. Jamalpur Priority Project Study Final Feasibility Report Annex 9 Char Study Report. Dhaka: Flood Plan Coordination Organisation, Ministry of Irrigation, Water Development and Flood Control. (Report prepared by SOGREAH/Halcrow/Lahmeyer).

FAP 14. 1992. Draft Final Report - Flood Response Study. Dhaka: Flood Plan Coordination Organisation, Ministry of Irrigation, Water Development and Flood Control. (Report prepared by Irrigation Support Project for Asia and the Near East).

FAP 22. 1992. Bank Protection and River Training (AFPM) Pilot Project FAP 21/22. Draft Final Report Planning Study: Main Report on River Training/AFPM FAP 22. Dhaka: Flood Plan Coordination Organisation, Ministry of Irrigation, Water Development and Flood Control. (Report prepared by Rhein-Rhur Ing., Compagnie Nationale du Rhone, and associates).

FAP 25. 1992. Flood Hydrology Study, Main Report - Flood Modelling and Management. Dhaka: Flood Plan Coordination Organisation, Ministry of Irrigation, Water Development and Flood Control. (Report prepared by KrügerConsult in association with BCEOM).

Leopold, L.B. and Wolman, M.G. 1957. River channel patterns, braided, meandering and straight. *U.S. Geological Survey, Professional Papers*, 282-B: 39-85.

Richards, J.A. 1986. *Remote Sensing Digital Image Analysis: an introduction*. Berlin: Springer-Verlag.

Rogers, P. Lydon, P, and Seckler, D. 1989. *Eastern Waters Study: Strategies to manage Flood and Drought in the Ganges-Brahmaputra Basin.* Arlington, Virginia: Irrigation Support Project for Asia and the near East.

World Bank. 1989. Bangladesh: Action Plan for Flood Control. Washington D.C: The World Bank, Asia Region Country Department I.

Zaman, M.Q. 1989. The Social and Political Context of Adjustment to Riverbank Erosion Hazard and Population Resettlement in Bangladesh. *Human Organisation* 48(3): 196-205.

১২৮

APPENDIX B

LIAISON AND CONTACTS

In adition to liaison and collaboration with the officials of the Flood Plan Co-ordination Organisation, and members of the FPCO Panel of Experts; as part of the day to day work of the study, liaison has been made with the following organisations on both a formal and informal basis.

AID AGENCIES

USAID
United Nations Development Program
Caisse Centrale de Cooperation Economique

FLOOD ACTION PLAN REGIONAL STUDIES

FAP 1:	Brahmaputra Right Bank Strengthening
FAP 2:	Northwest Region
FAP 3:	North Central Region
FAP 3.1:	Jamalpur Priority Project
FAP 6:	Northeast Region

FLOOD ACTION PLAN SUPPORTING STUDIES

FAP 17:	Fisheries Study
FAP 20:	Compartmentalization Pilot Project
FAP 21/22:	Bank Protection and River Training
FAP 25:	Flood Modelling and Management Project, including Surface Water Modelling Center

NON FAP PROJECTS AND PROGRAMMES

Jamuna Bridge Environmental Study
Forestry Master Plan Project

GOVERNMENT DEPARTMENTS AND PARASTATAL ORGANISATIONS

SPARRSO
Jamuna Fertilizer Company Ltd,
National Herbarium

NON GOVERNMENTAL ORGANISATIONS, RESEARCH INSTITUTIONS AND SPECIALISTS

Action Aid Bangladesh
Bangladesh Centre for Advanced Studies (BCAS)
Centre for Development Research, Bangladesh (CDRB)
Development Planners and Consultants
Department of Geography, Jahangirnagar University
Jamuna Char Integrated Development Project
Mennonite Central Committee
Oxfam
PACT
Rangpur Dinajpur Rural Services
Research and Advisory Services
Save the Children (UK)
Service Civil International
Winrock International

APPENDIX C

QUESTIONNAIRE FOR THE JAMUNA CHARLAND INVENTORY

Checklist A
For primary level investigation

FCODE : |_|_|_|_|_|

BANGLADESH FLOOD ACTION PLAN

FAP-16 ENVIRONMENTAL STUDY

POPULATION AND RESOURCE INVENTORY OF CHAR LANDS IN THE JAMUNA RIVER SYSTEM

MAUZA/VILLAGE KEY INFORMANTS INVENTORY

Name and Identification of Participating Informants

Sl.	Name	Age	Identification
1			
2			
3			
4			
5			
6			

1.Present/Past Chairman/Member 2.Teacher 3.Non-Govt.Officer/Worker
4.Local Quack 5.Imam/Religious Leader 6.Govt. Officer/Worker
7.Local Elite 8.Officer/Representative of Local Club/Organisation

NOTE : IF THERE IS MORE THAN ONE VILLAGE IN THE MAUZA YOU WILL HAVE TO FILL OUT A QUESTIONNAIRE FOR EACH VILLAGE

A. *Mauza/Village Identification*

Locate Mauza/Village on the base map, mark the approximate actual boundaries, write the name and BBS applicable code appropriately

CODE

A.1 Mauza Name : __________

A.2 Village name : __________
(if more than one village in the Mauza

A.3 Char Name : __________
A.4 District : __________
A.5 Upazila : __________
A.6 Union : __________
A.7 Distance from Nearest mainland : .....km
A.8 Bank (1 Left/2 Right) ....

B. Physiographic Background of the CharLand
B.1 Classification Code (It could be more than one) :
1.Island Char 2.Attached Char 3.Set-back Land :...
B.2 1.Non-Cultivated 2.Cultivated :................
B.3 1. Inhabited 2. Non-Inhabited :................
B.4 Year of the formation of Char :................ Year
B.5 Area accreted in 1991 :............... Acres
B.6 Year of natural vegetation growth started :........Year
B.7 Year first settled :.................Year
B.8 Year cultivation started :.................Year

202

B.9 Major type of topsoil
1. Sandy (Bele) :............% of area
2. Sandy-Loam/Silt-Loam (Doas) :............% of area
3. Clay (Etel) :............% of area

B.10 Part of Total Mouza

Type of Char	Acre	%
Island Char		
Attached Char		
Submersed Land		
Set-Back Land		

B.11 Year of erosion before 1988
B.12 Has there been any errosion of charland after 1988 ?
B.13 Has there been erosion in the last 12 months. Yes/No
B.13.1 If No, which year erosion last stopped :.....Year
B.13.2 If Yes, Direction of Erosion :
(it copuld be more than one)
1. Eastward 2. Westward 3. Northward 4. Southward..
B.13.3 If Yes area lost due to erosion in 1991 :....Acres

B.14 Has all land ever been submerged to the river for more than a full year?............. Yes/ No
B.14.1 If Yes,the year it was last totally inundated.

B.15 The year it last re-appeared
B.16 When was the land legally recorded if ever(If yes)
B.17 Total area of land in the Mauza/Village: %
B.18 % of Mauza/Village land under cultivation :.......%
B.19 Area of land in the Mauza/Village under local people .... Acres..............%

C. Migration, Population and Households Numbers in the Village/Mauza

C.1 Population in the Village/Mauza
- Total number of households :.......nos.
- Total Population :.......nos.

C.2 Migration in Last year :

	Nos	Area	Reason
Permanent in-migration (HH)			
Permanent out-migration (HH)			
Seasonal in-migration(Person)			
Seasonal out-migration(Person)			

Area Code : 1. Another Island Char
2. Attached Char or Setback Land 3. Nearby Mainland
4. Other District 5. Other (Specify)............
Main Reason Codes: 1. Bank Erosion 2. Char Erosion
3.Flood 4.Seaking Employment 3.Other(Specify) ....

C.3 Settlement History

Type of Settlers	HHs Nos	HHs %
Original Settler		
Permanantly in Migrated		
Temporarily Sheltered		
Wants to go back char(For setback)		

C.4 Main Pattern of Settlement

1. Temporary	2. Permanent

Settlment Pattern

Nucleated 1	Scattered 2	Clustered 3	Linear 4	Mixed 5

C.5 Structural Characteristics of Houses :

Main Residential Housing Structure	Nos.	%
Kutcha		
Semi-pucca (Corr Iron Roof)		
Pucca		
Total Houses		

D. Infrastructure and Services

D.1 Sources used for Drinking water :

Sources of Water	Nos		% of HH
1. Tubewell with handpump			
2. Hand-Dug Well			
3. Pond/Beel/Tank	Yes	No	
4. River	Yes	No	

26

D.2 Is there a pour/flush latrine programme? Yes/No

If Yes, numbers built .... Nos.

D.3 Availability of health care facilities :

Health care facilities	Nos.
1. Government Hospital	
2. Healthcare Centre	
3. Family Planning Centre	
4. NGO Healthcare Facility	
5. Traditional Doctor	
6. Pharmacy	

D.4 Communications and Innstitutions:

1. Road Length in Village/Mouza Kms
   Brick Paved Kms
   Earthen Kms
   Cart track (Halot) Kms
2. Flood Embankments Length Kms
3. Launch Ghats Nos.
4. Kheya Ghats Nos.
5. Motorised boats locally owned Nos
6. Non-motorised boats locally owned Nos.
7. Telephones Nos.
8. Radios Nos
9. Televisions Nos
10. Banks Nos
11. NGOs working in Village/Mauza Nos
12. Names of NGO's ____________________

____

D.5 Educational Institutions

1. Primary Schools -------------------- Nos
2. Junior High Schools(up to class viii)-- Nos
3. High Schools ---------------------- Nos
4. Madrashas ------------------------- Nos
5. Colleges -------------------------- Nos

D.6 Markets in Mauza:

Types	Nos	Weekly Frequency
1. Growth Centres		
2. Primary Markets		
3. Hats		
4. Bazars		
5. Independent Shops		
6. Ferrywalas		

D.7 Mauza/Village visited by the Govt. Institutional personnel for the last time:

Institutions	Year	Month
Agricultural Extension Officer		
Police Officer		
Health Worker		
Social Welfare Officer		
Vetenary Officer		
Family Welfare Visitor		
NGO Reperesentative		
Others		
1 ______		
2 ______		
3 ______		

E. Socio-Economic Conditions

E.1 Primary and Secondary Occupation in Mauza/Village

Occupation	Primary % of HHs	Secondary % of HHs
1. Agriculture		
2. Fishery		
3. Business		
4. Day labour (agri/non-agr)		
5. Household Works (Paid)		
6. Household Works (Without Pay)		
7. Others (specify)		
8. No Income Generating Activity		

E.2 Agricultural Production

Crops	Planting Week/Month	Harvesting Week/Month	Area Cultivated (Dec.)
1. Knun/ china			
2. Ground nut			
3. Pulses			
4. Onion			
5. Til			
6. Chillieds			
7. Wheat			
8. Potatoes			
9. Sweet Potatoes			
10. Mustard			
11. Boro paddy			
12. Aus paddy			
13. Jute			
14. Aman paddy			
15. Sugar cane			
16. Dhaincha			
17. Cat Kin			
18. Others(Specify)			

W MO W MO Decimal

E.3 Agricultural Landuse:

Cropping Intensity	Cultivated area in the Village/Mouza	
	Acre	%
Single Cropping Double Cropping Tripple Cropping Inter Cropping		

E.4 Livestock and Poultry -Estimated Numbers

Type	Nos.
Milk cow Bullock Buffalo Goat/ sheep Chiken/ duck Others (specify)	

F.1 Hazard Occurances and Damage during the last 5 years

Hazard	No of Occasions	Damage (Code)	Nos. if Human Death
1988 Flood			
Flood after 1988			
Cyclone/Tornado			
Drought			
Erosion			
Sand Carpeing			
Hailstorm			
Whirlwind			
Famine			
Diseases			
Other (Specify)			

Damage : 1. Crop 2. Housing 3. Livestock
4. Infrastructure(Roads/Buildings) 5. Poultry
6. Human Death 7. Other (Specify).......

F.2 Flood Extents at Peak Times in Village/Mouza :

Year	Area covered %	Duration (days)
1988 -		
1990 -		
1991 -		

289

G.1 Social Conflict

G.1	Have there been disputes over land in the Mauza? ....Yes/No	
G.1.1	If Yes, has Violence been used? ....Yes/No	
G.1.1.1	If happend, is owner settler in this char? Yes/No	
G.2	If Yes, were there any Deaths? ....Yes/No	
G.2.1	If Yes, No. of Deaths .... Nos.	
G.3	Date of Last major incidence? .../..../.... Date	D D M M Y Y

ADDITIONAL COMMENTS BY ENNUMERATOR ON ANY SPECIAL ISSUES IN HE MAUZA/VILLAGE WHICH ARE NOT COVERED IN THE QUESTIONAIRE:

Signature of the Supervisor
Date : ....

Signature of the Enumerator
Date : ....

267

APPENDIX D

CASE STUDIES

D.1 Selection Criteria

Reconnaissance village case study interviews were conducted before the inventory study in an effort to obtain preliminary settlement history and resource use information, as well as basic socioeconomic data for selected settlements within the study area. The inventory questionnaire was developed on the basis of this survey. Nine settlements were selected, five specifically because they were located in relatively inaccessible areas near the Indian border. Little was already known about the area and no member of the study team had previously visited it.

D.2 Fieldwork Checklist

A checklist was used in every village to ensure interviewing consistency; a copy of it follows the tables in this appendix. The field team held village meetings and informal group discussions with the villagers. The study profiles are at the end of this appendix and are summarized in Table D.1.

D.3 Summary

The interviews revealed great diversity in the type and range of human settlement patterns and resource use. The complex settlement patterns of the charlands include both permanent and temporary in- and out-migration, as well as transhumance (regular annual movement of people and cattle to make use of seasonally available charland). Because temporary migration depends on the period being considered, for the inventory, migrants were defined as those who moved into or out of the mauza in 1991.

The settlement history of the study area is characterized by rigid mauza and village territorial boundaries that were fixed about 90 years ago. Due to the dynamics of the landscape these boundaries bear little relation to the current land extents. These mauza boundaries are still strictly followed so far as land records and administration are concerned, and all land in the mauzas visited is allocated/owned.

People remain in their mauza area until erosion completely claims their land and they are forced to "temporarily" move to an adjacent area and wait for their land to reappear. Such temporary residence has fundamental implications for inventory data collection as some mauzas can be completely submerged, even during the dry season, yet people maintain their land rights as they "temporarily" reside nearby.

The inventory provides a "snapshot" of where people were in mid-1992 and their movements in the previous year. The 1993 socioeconomic surveys were designed to enrich this data with insights from case study areas. Information collected for the case studies consisted of: resource use, economic conditions, flood impacts, social organization, and the patterns of movements over time induced by river course changes.

The area is flood-prone and the main agricultural system is dry-land farming. This is partly due to the fact that more land is available during the dry season, when river levels are low. The productivity of that land is limited, however, since the sandy soils appear to be unsuited to irrigation. Figure D.1 show a simplified cropping calendar.

It appeared that more people have livestock than on the mainland, probably because of the plentiful grazing, particularly on catkin grass *(Saccharum spontaneum)*. Catkin grass is an important resource of the chars, both for grazing and for its land stabilization properties. The pastoral system requires careful study to determine who actually owns the livestock and under what conditions grazing occurs on other people's land; this was not easily determined during the reconnaissance, but it has been further investigated during a rapid rural appraisal (RRA) of the Kurigram area chars. In addition to agriculture and livestock practices, plants and trees play an important economic role in char homestead areas (Table D.2).

Flooding depths and risks were surprisingly varied among the small sample of villages and do not appear to be closely related to char type. The specific location of homesteads seems to be more important, suggesting that flood proofing strategies should address individual household needs instead of the village as a whole.

The provision of services also is variable and is probably a function of access. Some of the larger chars, and particularly mainland fragments, often are well provided with service facilities. Other chars have virtually nothing, particularly with regard to health and education.

D.4 Conclusions

Due to the variability and limitations of these case studies, drawing conclusions from the results is neither easy nor recommended. The case study summaries simply illustrate typical conditions in some of the mauzas covered by the inventory. The inventory data analysis in Chapter 3 of this report, plus the socioeconomic RRA surveys and flood loss interview surveys (which will be reported separately), are designed to assess the issues raised here.

The reconnaissance was useful for highlighting issues and processes, but any proposed intervention strategy for the charlands should consider the fact that decisions on resource management are made at the household level. Results from the 500-household sample survey carried out by FAP 3.1 have also identified issues regarded as important at the household level. The household surveys undertaken as part of the 1993 socioeconomic component of this study are designed to complement the FAP 3.1 study with household data on flood and erosion impacts for the upper reach and for the reach just south of FAP 3.1's study area. This will provide a more complete picture of the situation in areas of different char physiography.

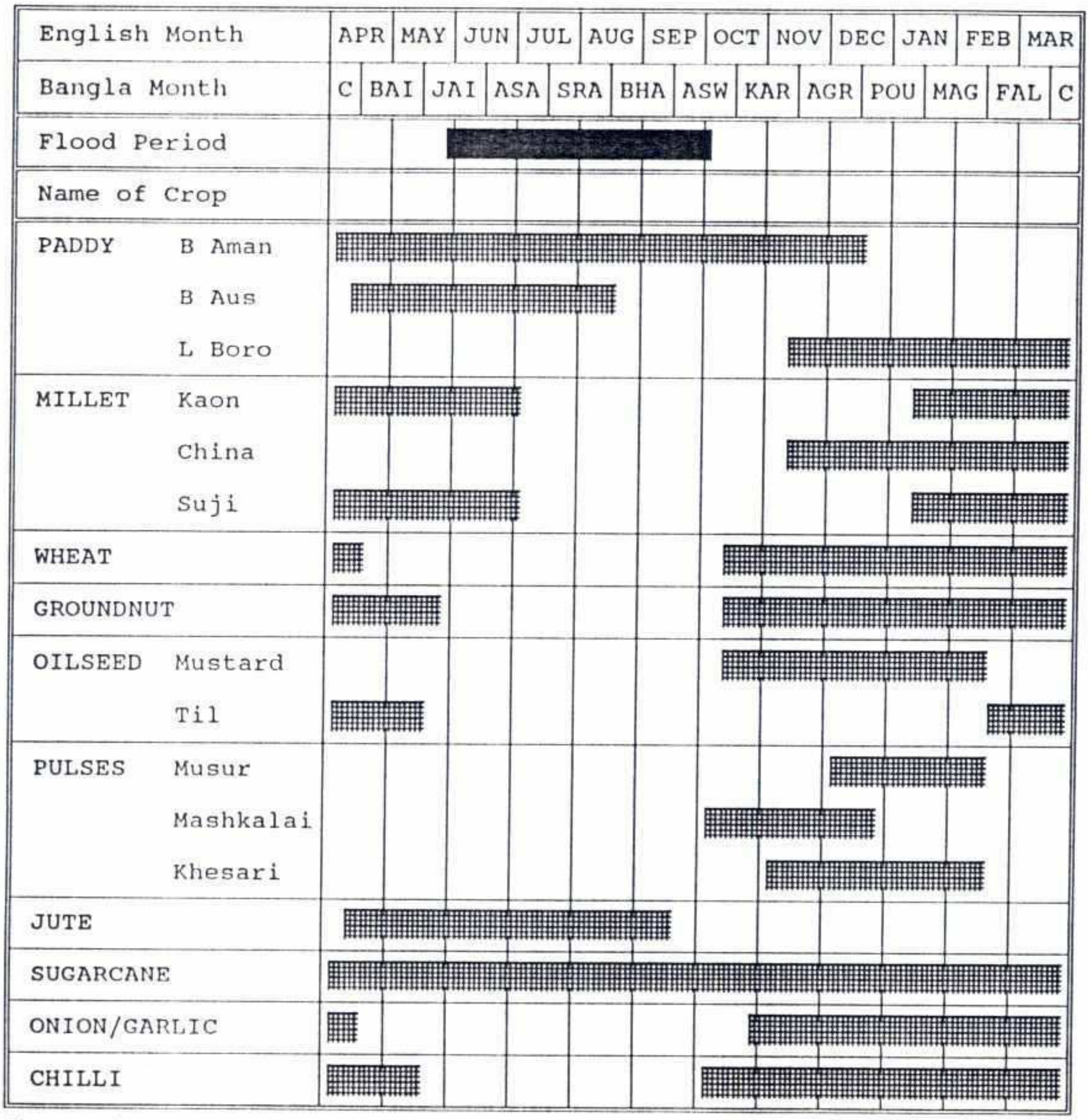
Table D.1 Summary of Jamuna Reconnaissance Case Studies

Variables	Char Case Study Number D1	D2	D3	D4	D5	D6	D7	D8	D9
Type of Char (Code)	A	I	I	I	S	I	I	I	I
Year of Last Major Accretion	1959	1960	1955	1982	OLD	1984	1984	1988	1986
Year of Last Resettlement	1958	1963	1969	1982	OLD	1988	1984	1988	NO
Type of Settlement	P+S	P+S	P	P	P+T	P	P	S+P	N
1988 Flood Depth (m) in Homestead	1	0.6	1.5	3.5	1.75	3.5	1.75	2.2	3
Accretion	N	Y	N	N	N	N	N	N	Y
Erosion	S	M	N	S	L	L	S	N	N
Sand Carpeting	N	Y	Y	Y	N	Y	Y	N	N
Soil Type (% of total land)	L=65 S=20 C=15	L=60 S=30 C=10	L=45 S=40 C=15	L=25 S=60 C=15	L=30 S=50 C=20	L=20 S=70 C=10	L=30 S=60 C=10	L=20 S=75 C=5	L=15 S=85
Major Crops	M,G, As	M, Sp, Mx	Mx, M,J, P,W, Sp	As,B, W, M	Sc,J, As,M, Ms	G,M, As	As, W,J,O, M,C, Gr	Mx,B, Sp,Sc M,P, T,V	G,SpM, Mx T,P W
Cropping Intensity (%)	S=55 D=45	S=60 D=40	S=40 D=60	S=70 D=30	S=40 D=60	S=25 D=75	S=30 D=70	S=40 D=60	S=70 D=30
Livestock Resources (% of households owning)	C=60 G=80 P=90 M=50	C=40 G=80 P=90 M=30	C=60 G=70 P=100 M=45	C=75 G=80 P=80 M=50	C=45 G=50 P=75 M=30	C=25 G=50 P=50 M=10	C=65 G=90 P=95 M=12	C=70 G=85 P=80 M=25	NONE
Full Time Fishing	S	N	N	N	S	N	N	N	-
Seasonal Out-migration for Employment	S	S	N	N	N	S	N	S	-
Infrastructure Facilities (% households with access)	T=60	T=90 P=1 R=1	T=90 P=1 R=1	T=100	T=100 P=4 R=2 H=1	T=75	T=90	T=85	-
Landless (% households)	50	0	0	0	12	65	40	0	-
Fuel Source	Cd,Cg	Cg	Cd, Js	Cg, Cd	Cg, Cd,Js	Cg	Ms, Cd,Js	Cg, Dc,Cd	-

Key:

- **Types of Char:** A Attached char, I Island char, S Setback area
- **Type of Settlement:** P Permanent, T Temporary, S Seasonal, N None
- **Erosion/Accretion:** S Severe, M Moderate, L Low, N No
- **Sand Carpeting:** Y Yes, N No
- **Soil Type:** L Loam, S Sandy, C Clay/Silt
- **Major Crops:** As Aus, Am Aman, B Boro, Mx Aus Aman mixed, M Millet, V Vegetable, G Grass, Sp Sweet potato, J Jute, W Wheat, Sc Sugarcane, P Pulse, O Onion, Gr Garlic, C Chilly, Ms Mustard, T Til (Oil Seed)
- **Cropping Intensity:** S Single, D Double
- **Livestock Resources:** C Cow, G Goat, P Poultry, M Milk-selling household (% of cow owner)
- **Full Time Fishing:** S Significant, N Non-significant
- **Temp. Migration for Emp:** S Significant, N Non-significant
- **Infra. Facilities:** T Tubewell, P Primary school, R Religious school, H High school
- **Fuel Source:** Cd Cowdung, Cg Catkin grass, Js Jute stick, Ms Dry stalk of millet, Dc Dhaincha

Figure D.1 Simplified Cropping Calendar for Jamuna Charland



Source: Charland Study Reconnaissance

Table D.2 Homestead Plants and Trees in the Brahmaputra-Jamuna Chars

Local Name	English Name	Botanical Name	Use
Aam	Mango	*Mangifera indica*	Fruit, timber, fodder
Babla	Gum Arabic	*Acacia nilotica*	Timber, fuel, soil protection
Bannya		*Crataeva nurvala*	Fuel
Bansh	Bamboo	*Bambusa spp.*	Housing material, wind protection, fuel
Bishkatali		*Polygonum orientale*	Medicine, soil stabilization, fuel
Boroi	Plum	*Zizyphus Jujuba*	Fruit, fuel
Chapri/Murali		*Eranthemum album*	Soil stabilization, fodder
Dhaincha		*Polygonum fagopyrum*	Nitrogen fixation, dyeing
Dholkalmi		*Ipomoea fistulosa*	Soil stabilization, wave protection, fuel
Dumur	Ficus	*Ficus hispida*	Medicine, fuel
Gab	Mangosteen	*Diospyros peregrina*	Fruit, water-proofing boats and fishing nets
Hugra		*Xanthium indicum*	Soil stabilization, vegetable, fuel
Helencha		*Enhydra flactuans*	Vegetable, medicine
Jaam	Black Berry	*Eugenia jambolana*	Fruit, timber
Jhau	Casuarina	*Casuarina spp.*	Fuel
Jiga		*Lannea coromandelica*	Fuel, fencing
Kaisa	Catkin grass	*Saccharum spontaneum*	Soil stabilization, housing material, fodder, fuel
Kanthal	Jack fruit	*Artocarpus heterophyllus*	Fruit, timber, fodder
Kola	Banana	*Musa spp.*	Fruit, wave and wind protection, raft building, fodder, fencing, detergent (made from burnt tree)
Lebu	Lemon	*Citrus aurantifolia*	Fruit
Mander	Mader	*Erythrina spp.*	Soil stabilization, fuel, fencing
Nalkhagra	Reed	*Phragmites karka*	Fuel, fencing, handicraft
Nim	Nim	*Melia azadirachta*	Medicine, timber, fuel
Pepe	Papaya	*Carica papaya*	Fruit, vegetable
Peyara	Guava	*Psidium guajava*	Fruit, fuel
Pitraj		*Aphanamixis polystachya*	Non-edible oil, detergent, fuel, timber
Sheorah		*Strebulus asper*	Fuel
Shon	Sun grass	*Imperata cylindrica*	Soil stabilization, housing material, fodder, fuel
Venna	Castor	*Ricinus communis*	Medicine, non edible oil, fuel

Source: Reconnaissance Survey

Note: Botanical names are those most commonly used in Bangladesh, species are listed in alphabetical order by local name.

CHARLAND CHECK LIST - RECONNAISSANCE SURVEY

Name of Settlement:
Longitude:
Latitude:
Ground Truthing Site No:
Date of Survey:

1 Location

Union, Thana and Zila
Set-back, Attached or Island Char
Nearest to West or East bank
Nearest flood control embankment

2 Land History

Year the land last accreted
Soil types and cover amounts

3 Settlement and Land Tenure

3.1 Settlement History
Year human settlement first commenced.
Year settlement last recommenced if char totally lost to the river.
Settlement pattern--nucleated, clustered, continuous linear, intermittent linear.

3.2 Human Population
Total human population, number of households, average household size.

3.3 Land Tenure
Total area of land, is it increasing or decreasing faster or slower than human population rate.
The percent of landlessness and the distribution of land ownership, the degree of tenants/renting/share-cropping.

4 Land and Agricultural Use

4.1 Agricultural Cropping
Total cropped area, average per household.
Main crop types grown in order of importance, yields.
Percent double cropped, percent single cropped.

4.2 Livestock
Approximate numbers per household.
Fodder availability and types.
Milk production.
Draught animal use.

4.3 Fishing
Number of full-time professional fishermen.
Percent of households catching fish occasionally for self consumption.

5 Socioeconomic Conditions

5.1 Primary Occupations
Main occupation
Percent wage paid people and what economic activities.

5.2 Literacy
Number and type of educational institutions.
Education and literacy levels in village

5.3 Household Fuel Sources
Types and rough percentage use

5.4 Health and Sanitation
Heath and medical facility provision
Main drinking water sources
Sanitation facilities

6 Housing and Infrastructure

Housing materials and degree of permanence.
Any other public buildings and infrastructure.

7 Hazards

Flooding, erosion, sand carpeting and others.
Number and year of occurrence.
Flood levels 1988, 1991 for cultivated land and homesteads.
Flood response
Erosion and accretion, amount and where and when.

D1.5 Socioeconomic Conditions

D1.5.1 Primary Occupations

Seventy-five percent of households are landless, making their living either by sharecropping or by day labor; and 25 percent are marginal farmers. There is a small group of commercial fishermen who organized a cooperative in 1989 and took a lease on some lucrative fishing grounds. This activity provides an income much greater than agricultural labor, in which the fishermen formerly were occupied.

D1.5.2 Literacy

The mauza has one primary school, which goes up to Class 3. This school was built recently.

D1.5.3 Household Fuel Sources

The lower portion of the catkin grass plant, cow dung, rice bran, and bamboo twigs are the main domestic fuels used in both the dry and monsoon seasons. There is sufficient fuel year-round.

D1.5.4 Health and Sanitation

There are six tubewells in the mauza, two of which were provided by the government. Less than half of the population use tubewell water for drinking. All households prefer to use river water for cooking. During floods it is necessary to drink river water, because tubewells are submerged. During the monsoon season diarrhoea and fever are common problems. In the dry season people suffer from various ailments, including chicken pox, diarrhoea, cholera, and skin rashes. Health visitors come regularly to provide immunizations and family planning assistance, but there is no formal health facility in the mauza. The nearest source of medical treatment is the town of Jatrapur, which is 2.5 miles away by boat. Other sources are the Health and Family Welfare Centre (HFWC) at Panchachi, 8 to 10 km. distant, or Kurigram Sadar, 20 km. Most medical care is too expensive for most Parbatipur residents. Some have had to sell their belongings to get money for medical treatments.

D1.6 Housing and Infrastructure

Walls and partitions of houses are made of catkin grass; and roofs are thatched with catkin over bamboo frames. Floors are of raised earth.

D1.7 Hazards

Erosion and flooding reportedly are severe and increasing problems for the settlement. During the peak of the 1988 flood the water depth was 3 m in the cultivable areas and all the permanent homesteads were inundated to a depth of at least 1 m. People were forced to leave their homesteads and seek refuge on union-built raised road embankments 1-2 km away. This required boat transport organized on the local people's own initiative. A large amount of livestock had to be carried to the road embankment. Where this was not possible, people built raised platforms from tree branches, bushes (*jangal*), and catkin grass. In the peak of the 1991 flood (mid-July) homesteads were again inundated, this time to a depth of about 0.6 m. Flood water reportedly stays in the area for 1-1.5 months.

Erosion is cited as an increasing occurrence over the past four to five years. This is the main reason for out-migration of the permanent resident households. Of those households, the poorer ones appear to move short distances to neighboring chars where they continue agricultural activities. The more affluent, who have a wider range of opportunities, go farther, particularly to upazila or district headquarters towns, for what they perceive to be less risky and better livelihood opportunities.

CHAR CASE STUDY PROFILES

CASE STUDY D1

Name of Settlement:	CHAR PARBATIPUR
Longitude:	89° 45.30'
Latitude:	25° 46.52'
Ground Truthing Site No:	6
Date of Survey:	19 June 1992
Updated in RRA:	11 May 1993

D1.1 Location

The mauza of Char Parbatipur is in Jatrapur Union under Kurigram Sadar Thana of Kurigram Zila. The mauza is divided by a channel of the Brahmaputra. The eastern part is a now-uninhabited char that is divided from the mainland by a small stream; crops are cultivated on the portions of this char that are not blanketed with sand. The western part, where all inhabitants now live (in 1993), is on the mainland.

D1.2 Land History

The island part of the mauza last accreted between 1953 and 1955. Around 1981 the western portion was subjected to extensive erosion, which claimed some 25 percent of the total land mass. Prior to this erosion event there were approximately 700 households in the mauza, but at least 300 of them were forced to move their houses, either within or out of the mauza; and 100 households migrated out of the area at that time. The others shifted eastward to their own or others' lands or moved to the adjacent mauza of Gobindapur, also on the mainland.

Since that time, approximately 25 percent of the land in the eastern portion of the mauza was submerged for some time, forcing residents to move once again over to the west; this land re-emerged three to five years ago. When visited in 1993 by the RRA team, villagers said their life consists of moving around within the mauza every few years as erosion and accretion patterns dictate. In the dry season of 1993 approximately 50 percent of the mauza was under water.

D1.3 Settlement and Land Tenure

D1.3.1 Settlement History

Settlement of the char commenced around 1958, about three years after its most recent accretion. Houses are distributed among three neighborhoods called "north," "south," and "east" ("west" is in the neighboring mauza). These neighborhoods have been so frequently rearranged over the years, that some people denied even having named neighborhoods. Houses in two of the neighborhoods are arranged in a clustered pattern; and in one, they are in a linear pattern.

D1.3.2 Human Population

The total population is estimated to be 1,500 people in 310 households, an average of 4.8 people per household.

D1.3.3 Land Tenure

Parbatipur is unusual in that half of its land is under absentee land ownership. This, together with major sand carpeting and erosion, means that the majority of the residents are surviving on minimal resources.

D1.4 Land and Agricultural Use

All crops are rain-fed, as there is no irrigation in Parbatipur. Rabi crops are most important, particularly millet, wheat, and pulses. Small areas are dedicated to either mixed aus and aman or to B. aman (L). Fifty percent of the land is single cropped; 30 percent is double cropped; and 20 percent is triple cropped.

CASE STUDY D2

Name of Settlement:	SHANTIR CHAR
Longitude:	89° 47.56'
Latitude:	25° 52.27'
Ground Truthing Site No:	13
Date of Survey:	20 June 1992

D2.1 Location

Shantir Char is in Noonkhowa Union under Nageshwari Thana of Kurigram Zila. It is on a medium-large island char northwest of the main river channels. At this place the river is highly braided.

D2.2 Land History

The land last accreted in 1960. The soil is loamy in the central part of the char, but the periphery is sandy.

D2.3 Settlement

D2.3.1 Settlement History

Settlement of the char commenced around 1962-63, two to three years after its accretion. The settlement pattern is linear but in interrupted, noncontinuous strings.

D2.3.2 Human Population

The total population of the settlement is about 1,400 people in about 175 households (eight people per household). A considerable number of household heads work seasonally away from the area, mainly in urban centers. There has been very little permanent out-migration in the past 20 years. About 25 households have migrated into the area in that time, mainly to work as tenants of large, established landlords.

D2.3.3 Land Tenure

There is vast inequity in landholding, and a few established dominant landlords own a large proportion of the land. They have brought in their own tenants rather than letting their land to existing residents.

D2.4 Land and Agricultural Use

Paddy, millet, and sweet potato are grown on the char. In addition, the predominant natural vegetation cover of catkin grass is used as a commercial renewable resource. Paddy (both aman and aus) covers 60 percent of the cultivated area. Improved varieties of millet (*kaon*, *suji*, and *china*) are rabi (dry season) crops. Yields of sweet potato are 240-300 maunds/acre (23 metric tons/ha). This is generally grown for consumption and, since it stores well, is often kept as emergency contingency food. Of the total cultivable area about 40 percent is double cropped and the remaining 60 percent is single cropped. Catkin grass covers 60 percent of the land area. During the wet season, when river levels are higher, the upper portion of catkin grass is used as animal fodder.

D2.5 Socioeconomic Conditions

D2.5.1 Primary Occupations

Sedentary cultivation is the predominant economic activity, but there is considerable sharecropping and wage laboring due to the inequity in landholding and loss of land to sand carpeting. Agriculture is unable to support all of the population on a full-time basis. As a result, a significant number of households depend on members working away seasonally and sending money back. These activities cover a wide range of manual labor and lower-level artisanal skills such as rickshaw pullers, sawyers, agricultural laborers, and boatmen. Destinations of such seasonally migrant workers are generally the larger urban centers in the region such as Rangpur, Dinajpur, Sirajganj, and Sharishabari. There are no full-time professional fishermen. About 40 percent of the households have cattle, 80 percent goats, and nearly all have some poultry (although ducks are not kept). Milk traders visit the char daily and purchase a total of 100 to 200 litres a day, paying a rate of Tk. 8 to Tk. 10 per litre.

D2.5.2 Literacy

The literacy rate in the char is reported to be relatively high, around 50 percent. About 15 percent of the people have passed Secondary School Certificate (SSC) exams and 5 people have a Higher School Certificate (HSC). There is a primary school adjacent to the area and one madrasha (religious school) has been established in the village.

D2.5.3 Household Fuel

Almost all households use dry catkin grass and stems for cooking fuel, but this is supplemented with driftwood brought down by the Brahmaputra flood waters. The driftwood is collected from the char shore, then dried and stored. The amount available for collection varies, and the 1988 flood provided significantly greater quantities than previous wet seasons. The use of cow dung as fuel is insignificant.

D2.5.2 Health and Sanitation

There is widespread use of hand-pumped shallow tubewells for drinking water supply and thatched, screened latrines for sanitation.

D2.6 Housing and Infrastructure

The walls and partitions of about 75 percent of the houses are constructed from catkin grass, and the remainder are made of jute sticks and corrugated iron. The roofs of 85 percent of houses are made from catkin thatch, the remainder are of corrugated iron. All of the house floors are made of raised earth. The primary school was established in 1969, and there are two mosques in the village.

D2.7 Hazards

During the peak of the 1988 flood the water depth was 1.6 m in the cultivable areas, and all the permanent homesteads were inundated to a depth of about 0.6 m. In the peak flood of mid-July 1991 cultivable land was flooded to a depth of 1.0 m, and many homesteads were right on the flood-limit level. During the 1988 flood people used raised platforms in their houses to store seed and food crops. They constructed raised wooden platforms reinforced with locally available plant materials (*jangal*) to temporarily support their livestock. Flood waters generally recede within 10 to 15 days in the homestead areas. Peak flooding is reported to be a problem for homestead security.

The western side of the char was recently effected by erosion, while the eastern side is accreting. There is a problem with sand carpeting of agricultural land and this is cited as a major reason for the lack of agricultural labor and the increasing trend for seasonal wage labor outside the area.

28

CASE STUDY D3

Name of Settlement:	**NARAYANPUR**
Longitude:	89° 50.24'
Latitude:	25° 53.71'
Ground Truthing Site No:	20
Date of Survey:	20 June 1992

D3.1 Location

The village of Char Narayanpur is in Narayanpur Union under Nageshwari Thana of Kurigram Zila. It lies on a large island char in a heavily braided section of the Brahmaputra very close to the Indian border. There are no major flood protection embankments close by.

D3.2 Land History

The land last started accreting in 1955. The soil is approximately 45 percent loam, 40 percent sand, and 15 percent clay.

D3.3 Settlement and Land Tenure

D3.3.1 Settlement History

Settlement of the char started around 1969, about 14 years after its most recent accretion started. The area has seen significant in-migration during the past five years (1988-1992).

D3.3.2 Human Population

The total population is estimated to be about 2,500 people in 300 households (average household size is 8.3 persons).

D3.3.3 Land Tenure

All of the land considered suitable for cultivation is farmed, and about 75 percent is cultivated directly by its owner. About 25 percent of landowning households occupy less than 2 acres (0.8 ha) and 10 percent occupy less than 0.5 acre (0.2 ha). Present land values are said to be Tk. 9,000-12,000 per acre (Tk. 22,240-29,650 per ha).

D3.4 Land and Agricultural Use

Aus and aman are the predominant types of paddy grown in the area, and yields are quoted to be 20-25 maunds/acre (1.78-2.22 metric tons/ha). Millet is also grown, particularly *kaon* and *suji*, and yields are 25 maunds/acre (2.22 metric tons/ha) and 35 maunds/acre (3.11 metric ton/ha), respectively. Local jute crops have yields of 30-35 maunds/acre (2.66-3.11 metric tons/ha); and pulses, including *mushur* (lentils) and *maskalai*, have yields of 10-12 maunds/acre (0.89-1.07 metric tons/ha). HYV boro cultivation is considered uneconomical and impractical due to the predominance of light, sandy soils.

D3.5 Socioeconomic Conditions

D3.5.1 Primary Occupations

About 75 percent of the households mainly depend on cultivation; 25 percent work at a variety of activities, among them small trading and business, for wages. Professional fishermen are rare, but almost all households occasionally fish for consumption. Many households have a cow and most have goats and/or sheep. All households have some poultry, including some ducks. Significant numbers of households sell milk daily to visiting traders at a rate of Tk. 8 to Tk. 10 per litre. Eggs are sold at local markets (*hats*).

D3.5.2 Literacy

A primary school has recently been started in the area, but in the past there have been no educational facilities. As a result, literacy levels are low. Recently, a formal and open education program was set up by RDRS (Rangpur Dinajpur Rural Services, a large NGO) and there is one madrasha (religious school).

D3.5.3 Household Fuel Sources

Dried cow dung and jute sticks are the most common sources of cooking fuel. The leaves and branches of any suitable natural vegetation also are used.

D3.5.4 Health and Sanitation

There is no formal health facility in the area, the nearest source of medical treatment is the Health Centre at Madarganj, which is 12 km or a 3-hour boat trip distant. Fevers, diarrhoea, and dysentery are the most commonly reported health problems. Almost all of the population use tubewells for drinking water; river water is used only for bathing and washing. Most of the people use latrines shielded by thatched catkin fences. There is reportedly a serious poisonous snake problem, and a significant number of people, livestock, and particularly poultry fall victim to snakes every year.

D3.6 Housing and Infrastructure

The walls of about 80 percent of the houses are constructed of woven catkin grass, 15 percent use jute sticks, and the remaining 5 percent are of corrugated iron. About 90 percent of the roofs are thatched with catkin grass, the remainder are of corrugated iron. Floors are made of raised earth, and vary between 0.15 m and 0.5 m above the surrounding ground level.

Owing to its location close to the Indian border and on the eastern side of the main river channel, the area is relatively isolated and access is difficult. The only means of access is by boat, which is required year-round. The existing supply of boats is said to be unable to satisfy demand levels.

The public infrastructure consists of the school, an earth road constructed by RDRS, and a Bangladesh Rifles border outpost. In addition, RDRS has a targeted comprehensive rural development program for the area that includes the following components:

- introduction of treadle pumps for limited irrigation;
- a transplanted aman paddy program;
- groundnut seed distribution;
- earth road construction;
- a roadside tree plantation program;
- construction of a raised field for flood refuge;
- formal and open education programs;
- a development and training program for destitute women; and
- a credit program for women.

D3.7 Hazards

Flooding is a major hazard in the area and during the 1988 flood all the agricultural land and homesteads were inundated. The homesteads were flooded to a depth of approximately 1.5 m. This lasted for two to three weeks and was worsened by a strong river current. Many households built raised platforms in their homes by placing beds (*chowki*) on top of each other. They also built bamboo platforms in their courtyards to store food, seed, fuel, and other essential items above the flood water level. Raised areas for livestock were made of bundled catkin grass and bushes. Sand carpeting is a problem once flood waters recede, reducing the area of cultivable land for some time and cutting yields.

CASE STUDY D4

Name of Settlement:	**KALIALGA**
Longitude:	89° 48.15'
Latitude:	25° 47.55'
Ground Truthing Site No:	31
Date of Survey:	20 June 1992

D4.1 Location

The village of Kalialga is in Jatrapur Union under Kurigram Sadar Thana of Kurigram Zila. It lies in the upper reach of the river on a medium-size island char in a very braided part of the river near the Indian border.

D4.2 Land History

The land last accreted in 1982, and when surveyed, it was about 1 m above water level. The soil type is predominately sandy around the banks of the island with higher proportions of silt in the interior.

D4.3 Settlement and Land Tenure

D4.3.1 Settlement History

Settlement of the char started in 1982, immediately after its accretion. The settlement pattern is linear.

D4.3.2 Human Population

The total settlement population is about 200 people in 25 households, making for a relatively large average household size of eight people. There has been no significant permanent out-migration in the past five years.

D4.3.3 Land Tenure

All households in the area own and farm some land. East of the area there is increased population pressure due to the recent loss of cultivable land to river erosion. About 70 percent of the households occupy less than 2.5 acres (1.0 ha) of land, the remaining 30 percent have more.

D4.4 Land and Agricultural Use

In December 1991, 90 percent of the cultivable land was cropped. The main crops are aus paddy, wheat, and *kaon*. Boro paddy is cultivated in small, lower areas of the char where suitable land exists during the low-flow period and water is available. There is some late aman cropping, but this is dependent on the availability of suitable unflooded land that is sufficiently wet. In general there is little late-monsoon cultivation as the available land is sandy and has poor moisture retention. At the time of the survey a considerable amount of the land was under catkin grass. Yields quoted were:

Aus paddy:	9-12 maunds/acre (0.8-1.07 metric tons/ha)
Jute:	4-5 maunds/acre (0.35-0.44 metric tons/ha)
Wheat:	6-7 maunds/acre (0.53-0.62 metric tons/ha)
Millet:	7-10 maunds/acre (0.62-0.89 metric tons/ha)

D4.5 Socioeconomic Conditions

D4.5.1 Primary Occupations

Agriculture is the predominant economic activity, and it sustains almost all of the households for 8 to 10 months of the year. Most households occupy and cultivate land themselves. There are no professional fishermen in the area, but most households fish for consumption on an occasional basis. Other seasonal economic activities include temporary wage labor in both rural and urban locations away from the area. Those households that are unable to find such work are often forced to sell some of their land or seek credit to get them through the lean period. Almost all families have cattle, goats, and poultry, but sheep are less common. Cattle are particularly prized since they are the only commodity that can be given as dowry. Milk is produced, but communications are poor, so it is made into curd (*dhoi*) and taken to market every three to five days. The nearest market, which is 15 km away, is only accessible by boat.

D4.5.2 Literacy

The area has no formal education facilities; as a result, literacy levels are very low. Only two people have passed the SSC and they only did so recently and had to study outside the area.

D4.5.3 Household Fuel Sources

Catkin grass is the major domestic fuel source, but dry cow dung, tree branches, and bushes also are used.

D4.5.4 Health and Sanitation

The char has no formal health facility, and the nearest source of medical treatment is the Health and Family Welfare Centre at Jatrapur Bazaar, which is 15 km away and accessible only by boat. Diarrhoea, dysentery, fevers, and skin diseases are the most commonly reported problems. All households use one tubewell for drinking water and all have individual homestead latrines shielded by thatched fences.

D4.6 Housing and Infrastructure

Most houses have walls of catkin grass, and the roofs of all but four are thatched with catkin grass, the others have corrugated iron roofs. Floors are of earth, raised to 0.75 m above ground level. Homesteads are surrounded by banana plants, *jigha* (gum arabic trees), and catkin grass. The island is relatively inaccessible because it is close to the Indian border and close to the least accessible bank of the river. The nearest major center is 15 km away and all communications are by boat.

D4.7 Hazards

The area has a very high flood risk because it is low-lying accreted land. During the 1988 flood the whole area was totally inundated to a depth of three to four meters for about two weeks. People built raised platforms in their courtyards to store essential commodities such as food grain and seed. They also constructed raised areas for their livestock using catkin grass and bushes. The 1991 flood was also severe and lasted longer, about 20 days. Residents were forced to adopt response measures similar to those taken in 1988. River bank erosion is a serious hazard to the char's eastern side, where it has taken cultivable land, although no person has as yet been rendered totally landless as a result. Sand carpeting is also a problem after annual inundation. The carpeting smothers better land in sand and results in poor moisture retention for dry season farming.

CASE STUDY D5

Name of Settlement:	**GANDER ALGA**
Longitude:	89° 47.92'
Latitude:	25° 41.61'
Ground Truthing Site No:	42
Date of Survey:	21 June 1992

D5.1 Location

Gander Alga is in Saheber Alga Union under Ulipur Thana of Kurigram District. It lies in the upper reach of the river close to the Indian border on unprotected east bank mainland that is very unlikely ever to be embanked. It is quite remote, and most communications is by boat.

D5.2 Land History

The land has been part of the mainland for a considerable time—the 1937 district map shows it as attached charland. When surveyed for this study, the land was 2.5 m to 3.5 m above water level. The soil is predominately sandy loam.

D5.3 Settlement and Land Tenure

D5.3.1 Settlement History

Settlement of the area is longstanding and now comprises about 300 households distributed in clusters. The households include long-term permanent residents of the area as well as temporary residents who have been displaced from nearby charlands and are waiting to return to their land. About 25 temporary resident households recently returned to their land, which has been re-emerging over the past five years.

D5.3.2 Human Population

The total population of the area is estimated to be 2,700 people in 300 households (average household size is nine people).

D5.3.3 Land Tenure

There is considerable inequality in land ownership. Twelve percent of households have no cultivable land at all, and share-cropping is fairly widespread. About 20 percent of the households own up to 0.5 acre (0.2 ha) and 50 percent own three to four acres (1.2-1.6 ha). The remaining 18 percent have holdings of more than four acres (1.6 ha).

D5.4 Land and Agricultural Use

A wide range of crop types are grown in the area, including aus and aman paddy. The light soils, which have poor water retention, are unsuited to HYV boro cultivation. Sugarcane is a major crop. The cane is locally processed using buffalo-powered crushers to produce *gur*, which is then sold outside the area. Sugarcane production costs are said to be Tk. 16,000 per acre, and profit levels are about Tk. 10,000 per acre. Average crop yields were reported to be:

Aus paddy:	10-15 maunds/acre (0.89-1.33 metric tons/ha)
Aman paddy:	16-20 maunds/acre (1.42-1.78 metric tons/ha)
Sugarcane:	40-50 maunds/acre (3.56-4.45 metric tons/ha) (*gur*)
Jute:	15-18 maunds/acre (1.33-1.60 metric tons/ha)
Millet:	12-14 maunds/acre (1.07-1.25 metric tons/ha)
Mustard oil:	7-8 maunds/acre (0.62-0.71 metric tons/ha)

D5.5 Socioeconomic Conditions

D5.5.1 Primary Occupations

Agriculture is the predominant economic activity, but it provides only a precarious existence even for those with medium-sized farms (three to four acres of land). Farming is only possible for about seven months of the year, and most farmers must sustain themselves with secondary activities for the rest of the time. Supplemental economic activities include: livestock trading, milk production, and *gur* trading. Landless households mainly work as agricultural laborers or share-croppers, although some have full-time paid occupations, including fishing and serving as boatmen.

D5.5.2 Literacy

There are four primary schools, one secondary school, and a madrasha (religious school) in the area. The literacy rate is about 25 percent. Ten people are educated to a masters degree level, 50 to graduate level, and 80 to HSC.

D5.5.3 Household Fuel Sources

Catkin grass, dried cow dung, tree branches, bushes, leaves, and jute sticks are all used as domestic fuel. Catkin grass grows on nearby charland where it is collected by char dwellers for sale at mainland *hats* and bazaars.

D5.5.4 Health and Sanitation

There is no government Health and Family Welfare Centre in the area, the nearest is at Ulipur, 20 km away by boat on the west bank of the mainland. People rely on village doctors, except in serious cases when they are forced to travel to Ulipur. Diarrhoea, dysentery, fever, and intestinal disorders are the most commonly reported problems. All households use tubewells as a source of drinking water. Some use other people's tubewells, but there are a sufficient number for all the present population. Only a few households have fenced latrines and most use open ground.

D5.6 Housing and Infrastructure

Homesteads are generally located on land that is 1.0 m to 1.5 m above the level of farmland. About 90 percent of the homesteads have walls and roofs made of catkin grass. Floors are of earth raised 0.30 m to 0.75 m above homestead courtyard level. Homesteads are surrounded by a wide variety of well-established trees. Despite being on the mainland, access is still quite poor as the village lies in the long narrow strip of land hemmed in by the Indian border to the east and the Brahmaputra to the west.

D5.7 Hazards

Flooding is not perceived as a major problem to the area. In a "normal" peak flood only agricultural land is inundated and then for only 10 to 15 days. During the peak flood of 1988 homesteads were flooded to a depth of 1.5 m to 2.0 m for a about 30 days. People constructed bamboo platforms for storage of food and other essential commodities. Some households constructed stronger wooden platforms for their livestock. Others raised the ground level using piles of bushes. Main river bank erosion is a problem for some people but is not particularly severe.

CASE STUDY D6

Name of Settlement:	**SHAPER CHAR**
Longitude:	89° 41.38'
Latitude:	25° 24.48'
Ground Truthing Site No:	67
Date of Survey:	22 June 1992

D6.1 Location

Shaper Char is in Mollar Char Union under Gaibandha Sadar Thana of Gaibandha District (Zila). It is in the downstream part of the upper reach on a large mid-channel island char. The Brahmaputra Right Embankment (BRE) is about 7 km to the west. Access to the area requires a boat throughout the year.

D6.2 Land History

The land last accreted in 1984 and the soils are mainly sandy, particularly on the periphery of the char. There is an on-going process of soil stabilization and conversion of the sandy soils to greater fertility by catkin grass colonization. The land was 1.2 to 2.0 m above the water level at the time it was surveyed.

D6.3 Settlement and Land Tenure

D6.3.1 Settlement History

Settlement commenced in 1988, about four years after the land accreted. People came from a nearby char (Kachir Char). They previously had been living on what was called "Shaper Char," but that emergent char was in a different location than the present village, and it has since eroded away.

D6.3.2 Human Population

The total population is estimated to be 850 people in 125 households (average household size is about seven people).

D6.3.3 Land Tenure

There is considerable pressure on cultivable land because there is only enough of it to provide sustainable full-time farming livelihoods for 5 percent of households, who own about 50 percent of the cultivable land. The average landholding is two to three acres (0.8-1.2 ha). Although 65 percent of the population has land, much of that property is subject to sand carpeting and unusable for cultivation.

D6.4 Land and Agricultural Use

All of the presently cultivable area is double cropped, but 35 percent of the total area is under catkin grass. Aus is the only paddy suited to the growing conditions. Dry-land cropping of millets (*kaon* and *china*) is widespread and often provides two or even three crops a year. Groundnuts are the most profitable crop. They are planted in December as the river level declines and are harvested in April before the river rises with the first snowmelt run-off. Catkin grass is extensively utilized as a cash crop resource. Crop yields reported are:

Groundnut:	15-20 maunds/acre (1.33-1.78 metric tons/ha)
Millet (*kaon*):	12-15 maunds/acre (1.07-1.33 metric tons/ha)
Millet (*china*):	20-25 maunds/acre (1.78-2.22 metric tons/ha)
Aus paddy:	10-15 maunds/acre (0.89-1.33 metric tons/ha)

D6.5 Socioeconomic Conditions

D6.5.1 Primary Occupations

Only six of the 125 households, which have land unaffected by sand carpeting, are able to survive solely on cultivation of their own land. All the other households must work outside the village. The activities they engage in include paid agricultural labor on the mainland and working as boatmen. Twenty-five percent of the households have cattle and 50 percent have goats and poultry. Only 5 percent sell milk. Average production is about 1.5 litres per producing household, and the milk sells for Tk. 10-12 per litre.

D6.5.2 Literacy

There are no educational facilities in the area, children must travel outside the mauza to study. Thirty people are educated to Class 10 level and 10 have passed the SSC.

D6.5.3 Household Fuel Sources

Catkin grass is the predominant source of cooking fuel, but dried cow dung is also used.

D6.5.4 Health and Sanitation

There is no health care facility in the area, the nearest treatment is available at a Family Health and Welfare Centre in Gaibandha District Headquarters 25 km away. Diarrhoea, dysentery, and fever are the most commonly reported problems. There are only three tubewells in the area. Although these are privately owned, all inhabitants are allowed free use of them; still, local people consider them insufficient. About 50 percent of households have fenced latrines and the remainder use open ground.

D6.6 Housing and Infrastructure

The walls of all homestead housing are made of catkin grass and 40 percent have roofs made of the same material, the remaining 60 percent have corrugated iron roofs. Floors are of earth raised 0.15 m to 0.50 m above ground level. Homesteads are surrounded by newly planted banana trees, *dhaincha* (a nitrogen-fixing plant used for live fencing), and *jigha* (gum arabic) trees. The local people say access is poor because all journeys require boat transportation, which is perceived as time-consuming.

D6.7 Hazards

The area was uninhabited during the 1988 flood, but was inundated to a depth of three to four meters. Even in a "normal" year flood water covers most of the cultivable land for three months. The 1991 flood was serious and caused livestock, poultry, and crop losses. People built platforms in their homesteads and made raised areas for their livestock using vegetation. When floods recede sand carpeting is a serious problem and a major reason for the lack of cultivable land.

২৫৭

CASE STUDY D7

Name of Settlement:	**UJAN MIAKHOLA**
Longitude:	89° 40.16'
Latitude:	24° 44.14'
Ground Truthing Site No:	112
Date of Survey:	23 June 1992

D7.1 Location

Ujan Miakhola is in Khas Rajbari Union under Kazipur Thana of Sirajganj Zila. It is in the downstream part of the middle reach of the river on a small mid-river island char. The BRE is 4 km to the west, and the nearest settlements with markets, Baraitali and Meghai, are 5 km away on the mainland. Access to the area requires a boat throughout the year.

D7.2 Land History

The land last accreted in 1984 and was then part of a larger island char. In 1987 the land was split off from Shanbandhar Char by the changing course of the main river channel. There is continuing erosion on its western edge. The soils are mainly sandy loams with low water retention. The land was two to three meters above the river water level at the time it was surveyed.

D7.3 Settlement and Land Tenure

D7.3.1 Settlement History

Settlement started immediately after accretion in 1984. The people came from surrounding chars, from which they had been forced to leave by erosion. The village consists of four *paras* (subdivisions). Settlement is linear but intermittent.

D7.3.2 Human Population

The total population is about 5,000 people in 700 households (average household size is about seven people).

D7.3.3 Land Tenure

About 60 percent of the inhabitants are landless; 20 percent have 0.5-1.0 ha, 15 percent have 1.0-2.5 ha, and the remaining 5 percent own more than 2.5 ha of land.

D7.4 Land and Agricultural Use

Aus is the only type of paddy suited to the soils. Dry-land cropping of millet is important, as is cultivation of wheat, onions, garlic, and jute. Quoted crop yields are:

Wheat:	15-20 maunds/acre (1.33-1.78 metric tons/ha)
Millet (*kaon*):	12-15 maunds/acre (1.07-1.33 metric tons/ha)
Onion:	45-60 maunds/acre (4.00-5.34 metric tons/ha)
Jute:	15-21 maunds/acre (1.33-1.87 metric tons/ha)
Aus paddy:	10-15 maunds/acre (0.89-1.33 metric tons/ha)

D7.5 Socioeconomic Conditions

D7.5.1 Primary Occupations

Only an estimated 5 percent of the households, the largest landowners, can depend on cultivating their own land for survival, and even then there can be difficulties at some times of the year. About 70 percent of households are dependent upon wage labor for their livelihoods. They mainly work at agricultural labor and as boatmen. There are hardly any professional fishing households.

Nearly all the char households have at least one cow, and 30 percent have three or four. Goats and poultry, which can serve as realizable assets during difficult times, are also widely owned. About 12 percent of the households sell milk on a daily basis to mainland markets, which are about 3 km distant.

D7.5.2 Literacy

There are no educational facilities in the area, students have to travel 5 km by boat to Baraitali and Meghai to study. About 200 people have passed the SSC, 100 the HSC, and five are graduates (four have masters degrees).

D7.5.3 Household Fuel Sources

Millet straw (both *kaon* and *china*) predominates as a source of cooking fuel, but dried cow dung and jute sticks are sometimes used.

D7.5.4 Health and Sanitation

The nearest medical facilities are 5 km distant at the Family Health and Welfare Centers in Meghai and Natuarpara. Diarrhoea, fever, and skin diseases are the most commonly reported problems. Almost all households use tubewells for drinking water, and most have fenced latrines.

D7.6 Housing and Infrastructure

All homesteads have walls made of jute sticks, and 60 percent have roofs thatched with wheat straw. Floors are made of raised earth. Access depends entirely upon river transport, and the five engine boats available in the area are considered insufficient to satisfy demand.

D7.7 Hazards

During the 1988 flood the homestead areas were inundated to a depth of 1.5 to 2 m. People temporarily left the area with their livestock, traveling by boat to take refuge on the BRE. A shortage of engine boats made this migration difficult. A perceived lack of security prompted nearly every household to leave one member behind as a guard. Valuables were secured on platforms built at roof level, above the peak flood. The 1991 flood inundated the cultivable land to a depth of about 1 m for six weeks.

There is progressive bank erosion on the western side of the char, and sand carpeting is a widespread problem, reducing still further the area of productive land available for farming. Farming in the dry season, when most land is available, is constrained by lack of rainfall and poor moisture retention in the light, sandy soils.

CASE STUDY D8

Name of Settlement:	GORJAN BAINPUR
Longitude:	89° 43.35'
Latitude:	24° 08.32'
Ground Truthing Site No:	170
Date of Survey:	24 June 1992

D8.1 Location

Gorjan Bainpur is in Sonatoli Union under Shajadpur Thana of Pabna Zila. It lies in the downstream part of the river's lower reach on the western side of a large but fragmented mid-river island char. The char had 18 villages at the time of the survey. The BRE is 1 km to the west, and the nearest large settlement is the thana headquarters at Shajadpur, which is about 15 km west on the mainland and accessible only by a boat and road journey. Access to the area requires a boat throughout the year.

D8.2 Land History

The land last accreted during the 1988 flood. The soils are mainly sandy loams with low water retention. The land was about 1 m above the river level at the time of survey. Local people consider the soil best suited to dry-land crops such as sweet potatoes, millet, and pulses. It is considered unsuitable for aus or aman paddy.

D8.3 Settlement and Land Tenure

D8.3.1 Settlement History

Settlement of the area started soon after the land accreted in 1988. The people came from nearby mauzas on the right bank of the Jamuna. The majority of the present inhabitants, however, are seasonal in-migrants practicing a formalized system of transhumance. They move onto the char during the dry season and remain for the cultivation period, returning to their primary homesteads on the mainland for the wet season. Over the past two years more of the seasonal in-migrants have remained on the char for the rainy season. The settlement pattern is linear but intermittent. Local people do not perceive char land to be permanent (*kaeym*) in terms of agricultural production unless it has existed for a least 10 years.

D8.3.2 Human Population

The seasonal peak population of the area is about 370 people in 50 households (average household size is about seven people). Of these, about 30 households are temporary, seasonal in-migrants.

D8.3.3 Land Tenure

All households own some land in the area: 30 percent have 1.0-1.5 ha, 40 percent have 2.0-3.0 ha, 20 percent have 3.5-6.0 ha, and the remaining 10 percent own more than 6.0 ha.

D8.4 Land and Agricultural Use

Aus and aman paddy are grown in the area but aus yields can be greatly reduced by floods and poor soil moisture retention. There is also some limited boro paddy cultivation in a few areas next to the river edge where there is sufficient water (yields were quoted as 20 to 30 maunds per acre (1.78 ot 2.66 metric tons/ha). Dry-land cropping of millet, pulses, and sweet potatoes is extensive. Vegetables are also grown, and in 1991 sugarcane was cultivated for the first time.

Dhaincha is cultivated for building material and fuel, and is planted in flood-prone areas to act as a silt trap. Large areas are under catkin grass, which is commercially exploited for building materials, fuel, and fodder. There are two varieties: *kaisa*, which is quick growing and can be harvested three times a year; and *shon*, which is only cut annually. Cut catkin grass can be sold in the market for a return of about Tk. 10,000 to Tk. 12,000 per acre; but the cost of cutting, transporting, and marketing the crop are

২৫২

reportedly so high that the net profit is poor. Local people report that at least a one acre block of land must be harvested at one time to make it a worthwhile proposition.

D8.5 Socioeconomic Conditions

D8.5.1 Primary Occupations

About 75 percent of households rely on agriculture for their livelihood. There is a specialized group of weavers who comprise about 20 percent of the households. They have paid employment on the mainland and travel there every day.

Seventy percent of households have cattle and 85 percent have goats, but sheep are rare. About 25 percent of the cattle owners sell milk. There are no full-time fishing households; but many people fish for consumption, and large catches are sometimes sold on the mainland. The only outlets for agricultural produce are on the mainland, which requires a boat journey. Products sold out of the area include livestock, poultry, vegetables, some fish, dry cow dung, dry *dhaincha*, catkin grass, and roots.

D8.5.2 Literacy

There is a primary school in the area, but students must travel to the mainland or larger, more established neighboring chars for higher education.

D8.5.3 Household Fuel Sources

Catkin grass, *dhaincha*, and tamarisk bushes (*jhau*) are the predominant sources of fuel, but dried cow dung is also sometimes used.

D8.5.4 Health and Sanitation

The nearest medical facility is the Family Health and Welfare Centre at Shajadpur Thana headquarters 15 km west, which requires a boat trip followed by road travel. Diarrhoea, dysentery, and fever are the most commonly reported problems. About 85 percent of households use tubewells for drinking water, but in peak floods some of these go under water and some households then use river water. Only 30 percent of households have fenced latrines, the remainder use open ground.

D8.6 Housing and Infrastructure

All homesteads have catkin grass walls, 40 percent have roofs thatched with the same material, the rest have roofs of corrugated iron. House plinths are 0.15 to 0.75 m above the ground level, which is the same as the cultivated land. Homesteads are surrounded by banana trees, *dhaincha* bushes, tamarisk trees, and catkin grass. Access depends entirely upon boat transport.

D8.7 Hazards

There is severe flood risk in the area. Even during the 1991 flood the entire area, including homesteads, was inundated to a depth of 1.5 to 3 m for two to three weeks. People temporarily left the area by mechanized boats, taking their livestock and poultry with them, to take refuge on the BRE. They returned to their homesteads after three to four weeks. There is reportedly a serious problem with venomous snakes during floods as these are forced onto the unflooded land. Water-borne snakes reportedly caused the death of three people during the 1991 floods. Even in the wet season, paddy cultivation is constrained by lack of rainfall and poor moisture retention in the light, sandy soils.

CASE STUDY D9

Name of Settlement:	**CHAR PECHAKOLA**
Longitude:	9° 40.32'
Latitude:	4° 02.45'
Ground Truthing Site No:	180
Date of Survey:	25 June 1992

D9.1 Location

Char Pechakola is in Haturia Nakalia Union of Bera Thana of Pabna Zila. It is in the downstream part of the lower reach of the river. At low-flow times it is attached to a large island char, but usually it is a small uninhabited island char near the west bank but separated by a main river channel. Mainland access to the char requires a boat throughout the year.

D9.2 Land History

The land last accreted in 1985-6. The soils are very sandy. The land was 1.2 m higher than river level at the time it was surveyed.

D9.3 Settlement and Land Tenure

D9.3.1 Settlement History

There is no settlement on this low-lying char because of high flood risk in the wet season.

D9.3.2 Land Tenure

Although there are no homesteads on the char, land rights are held by people living on neighboring chars 1 to 3 km away. Of the landowners, 65 percent have up to 2.0 ha, 25 percent have 2.0-4.0 ha, and the remaining 10 percent have more than 4.0 ha. Almost all of the landowners have other land on neighboring chars.

D9.4 Land and Agricultural Use

The majority of the land is under catkin grass and most landowners consider their land on adjacent chars to be of more use. Aus and aman paddy have recently been grown on the char, but yields are very low. Dry-land farming predominates, and groundnuts are the most important crop. Millet, sweet potato, wheat, *job* (barley), *til* (oilseed), and pulses are all grown in the dry season. Reported crop yields were:

Groundnuts:	20-25 maunds/acre (1.78-2.22 metric tons/ha)
Millet:	15-20 maunds/acre (1.33-1.78 metric tons/ha)
Sweet potato:	70-80 maunds/acre (6.22-7.12 metric tons/ha)
Aus paddy:	7-9 maunds/acre (0.62-0.80 metric tons/ha)
Aman paddy:	8-9 maunds/acre (0.72-0.80 metric tons/ha)

D9.5 Socioeconomic Conditions

The households farming this land are not resident and travel 1 to 3 km daily by boat. The land here forms only a small part of their total landholding. Even so they have sufficient land to maintain a reasonable livelihood.

D9.7 Hazards

Flood risk to the area is high. During the 1988 flood the whole area was inundated to a depth of about three meters. In 1991 it flooded to a depth of two meters.

240

APPENDIX E

SUMMARY DATA TABLES BY RIVER REACH AND CHAR LAND TYPE

Table E.1 Gross Unprotected Study Area By Reach And Char Type (Hectares)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	23912	21560	39280	18940	34371	40500	58283	138063
Middle	7352	14256	54351	29280	14182	43536	21534	119421
Lower North	2003	1526	23805	3328	3855	4854	5859	34518
Lower South	5825	14239	30812	15880	24255	30119	30080	91012
Total	39092	51581	148248	67429	76663	119010	115756	383014

Source: Landsat Imagery, FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992.

Table E.2 Water Areas By Reach and Char Type From March 1992 Imagery (Hectares)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	2012	5544	11811	3478	371	9022	2383	23217
Middle	964	3421	18373	3838	837	7259	1801	27433
Lower North	333	566	5891	294	309	860	642	7392
Lower South	671	3063	9731	4413	2715	7476	3387	20594
Total	3981	12595	45806	12023	4232	24618	8213	78637

Source: Landsat Imagery, FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992.

Table E.3 Sand Areas By Reach and Char Type From March 1992 Imagery (Hectares)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	733	5231	8512	2619	359	7850	1091	17454
Middle	421	3413	12541	3002	267	6416	687	19644
Lower North	80	328	4519	177	21	505	101	5125
Lower South	372	3217	5593	3972	265	7189	637	13419
Total	1606	12189	31165	9770	911	21960	2517	55642

Source: Landsat Imagery, FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992.

Table E.4 Total Vegetated/Cultivated Areas From March 1992 Imagery (Hectares)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	21167	10784	18956	12843	33641	23627	54808	97392
Middle	5951	7422	23431	22431	13071	29853	19022	72306
Lower North	1586	632	13395	2857	3526	3490	5111	21996
Lower South	4781	7959	15459	7495	21273	15454	26054	56967
Total	33485	26797	71242	45627	71510	72424	104995	248661

Source: Landsat Imagery, FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992.

Table E.5 1991 Cultivated Land Areas Calculated From Questionnaire Returns and Digitized Mauza Mapping (Hectares)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	15,250	12,519	21,872	9,784	24,947	22,303	40,197	84,373
Middle	4,104	7,003	27,689	17,316	8,682	24,319	12,785	64,794
Lower North	1,037	691	12,950	2,344	2,827	3,035	3,864	19,849
Lower South	2,834	6,276	15,251	7,552	14,577	13,828	17,411	46,491
Total	23,225	26,489	77,763	36,996	51,033	63,485	74,258	215,506

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992

Table E.6 Human Population Numbers BBS Data 1981

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	157235	56439	51016	42008	191015	98447	348250	497713
Middle	64545	45615	148402	79812	92073	125427	156618	430447
Lower North	17217	8339	81444	19019	23429	27358	40646	149448
Lower South	88865	64367	106143	62026	151801	126393	240666	473202
Total	327862	174760	387005	202865	458318	377625	786180	1550810

Source: 1981 Census data. Apportioned by Predominant Charland Type 1992

Table E.7 Human Population Numbers 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	205937	70988	96252	63124	225162	134112	431099	661463
Middle	61805	42402	161307	76205	80970	118607	142775	422689
Lower North	17802	9401	88410	17032	29628	26433	47430	162273
Lower South	101529	68463	167027	59438	174880	127901	276409	571337
Total	387073	191254	512996	215799	510640	407053	897713	1817762

Source: Landsat Imagery, FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992.

Table E.8 Aggregated Population Densities 1992 per km Square of Total Area

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	861	319	245	333	655	331	740	479
Middle	841	297	297	260	571	272	663	354
Lower North	889	616	371	512	769	545	810	470
Lower South	1743	481	542	374	721	425	919	628
Total	990	371	346	320	666	342	776	475

Source : Tables E.1 and E.7

Table E.9 Human Population Densities 1992 per km Square of Total Area

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	861	387	284	377	659	383	756	540
Middle	814	402	367	296	674	330	727	464
Lower North	1024	1278	450	609	889	785	944	631
Lower South	2195	682	858	536	788	608	1163	935
Total	1084	486	438	380	717	425	863	607

Source: Landsat Imagery, FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992

Note: Excludes uninhabited mauzas, calculated on mauza basis using apportioned data.

Table E.10 Change in Population Density 1981 to 1992 (per km Square of Total Area)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	204	67	115	111	99	88	142	119
Middle	-37	-23	24	-12	-78	-16	-64	-6
Lower North	29	70	29	-60	161	-19	116	37
Lower South	217	29	198	-16	95	5	119	108
Total	151	32	85	19	68	25	96	70

Source: Tables E.1, E.6 and E.7

Table E.11 Human Population Densities 1992 per km Square of Cultivated/Vegetated Land Area

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	793	658	508	492	669	568	787	679
Middle	1039	571	688	340	619	397	751	585
Lower North	1122	1488	660	596	840	757	928	738
Lower South	2124	860	1080	793	822	828	1061	1003
Total	1156	714	720	473	714	562	855	731

Source: Table E.4 and E.7

Table E.12 Human Population Densities 1992 per Km Square of Dry Season Unflooded Land Area

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	940	443	350	408	662	426	771	576
Middle	970	391	448	300	607	327	724	460
Lower North	1069	979	494	561	835	662	910	598
Lower South	1970	613	793	518	812	565	1036	812
Total	1103	491	500	390	705	431	835	597

Source: Tables E.3, E.4 and E.7

Table E.13 Household Numbers 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	28,463	11,256	15,635	10,753	37,416	22,008	65,879	103,522
Middle	10,535	7,139	27,503	12,919	14,129	20,059	24,664	72,226
Lower North	2,987	1,553	14,221	2,815	5,103	4,369	8,090	26,680
Lower South	9,872	10,957	24,217	8,548	28,921	19,505	38,793	82,515
Total	51,857	30,905	81,576	35,036	85,569	65,941	137,426	284,943

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992

Table E.14 Mean Household Sizes 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	7	6	6	6	6	6	7	7
Middle	6	6	6	6	6	6	6	6
Lower North	6	6	6	6	6	6	6	6
Lower South	10	6	7	7	6	7	8	7
Total	8	6	6	6	6	6	7	6

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992

Table E.15 Number of Permanent Out-Migrant Households 1991

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	104	167	352	720	2	887	106	1345
Middle	203	241	1001	609	32	850	235	2086
Lower North	212	24	569	172	85	196	297	1062
Lower South	497	336	270	40	300	376	797	1443
Total	1016	768	2192	1541	419	2309	1435	5936

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 144 Mauzas with Missing Data.

249

Table E.16 Permanent Out-Migrant Households 1991 as Percentage of Char/Reach Type 1992 Household Numbers

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	0.9	1.8	2.5	7.2	-	4.6	0. 7	2.3
Middle	1.3	2.7	3.6	5.7	0.1	4.5	0. 7	2.4
Lower North	4.8	1.3	4.5	5.8	1.2	3.9	2.8	3.7
Lower South	2.7	3.2	1.3	0.6	0.9	2.2	1.6	1.6
Total	1.9	2.5	2.9	5.1	0.6	3.9	1.2	2.3

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 144 Mauzas with Missing Data.

Table E.17 Number of Permanent In-Migrant Households 1991

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	271	276	958	469	668	745	939	2642
Middle	191	549	1380	653	512	1202	703	3285
Lower North	168	80	604	224	217	304	385	1293
Lower South	225	771	1205	930	570	1701	795	3701
Total	855	1676	4147	2276	1967	3952	2822	10921

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 144 Mauzas with Missing Data.

Table E.18 Permanent In-Migrant Households 1991 as Percentage of Char/Reach Type 1992 Household Numbers

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	1.2	3.0	7.1	5.0	9.8	4.0	3.2	4.3
Middle	0.9	6.1	5.1	4.8	2.0	5.3	1.5	3.4
Lower North	2.4	3.6	4.6	7.8	2.5	6.0	2.5	3.8
Lower South	1.0	7.3	5.8	13.9	1.6	9.8	1.4	3.9
Total	1.2	5.4	5.6	7.0	2.6	6.2	1.9	3.8

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 144 Mauzas with Missing Data

Table E.19 Number of Seasonal Out-Migrants in 1991

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	848	1821	2353	211	273	2032	1121	5506
Middle	553	2219	2536	1102	128	3321	681	6538
Lower North	250	174	756	144	173	318	423	1497
Lower South	1193	970	868	30	1634	1000	2827	4695
Total	2844	5184	6513	1487	2208	6671	5052	18236

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 144 Mauzas with Missing Data.

Table E.20 Seasonal Out-Migrants 1991 as Percentage of Char/Reach Type 1992 Population

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	0.7	3.0	2.7	0.4	0.7	1.8	0.7	1.4
Middle	0.9	4.9	1.6	1.6	0.2	2.9	0.5	1.4
Lower North	1.0	1.7	1.0	0.8	0.5	1.2	0.8	0.9
Lower South	0.6	1.6	0.6	0.1	0.8	1.0	0.7	0.7
Total	0.7	3.0	1.4	0.8	0.6	1.9	0.7	1.1

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 144 Mauzas with Missing Data.

Table E.21 Number of Seasonal In-Migrants in 1991

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	4801	6092	2282	620	238	6712	5039	14033
Middle	3021	4529	6904	4057	1177	8586	4198	19688
Lower North	839	313	906	299	413	612	1252	2770
Lower South	4653	2843	5635	2685	5628	5528	10281	21444
Total	13314	13777	15727	7661	7456	21438	20770	57935

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 144 Mauzas with Missing Data.

Table E.22 Seasonal In-Migrants in 1991 as Percentage of Char/Reach Type 1992 Population

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	5.8	10.5	2.7	1.1	0.6	6.0	4.9	4.8
Middle	4.3	18.9	4.7	5.7	1.7	11.0	2.9	5.3
Lower North	3.7	4.7	1.3	1.8	1.4	3.0	2.4	2.1
Lower South	2.4	4.4	3.9	5.7	3.4	4.9	2.9	3.4
Total	4.0	10.2	3.5	4.1	2.4	7.1	3.3	4.1

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 144 Mauzas with Missing Data.

Table E.23 Number of 1992 Households with Agriculture as their Main Occupation

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	1479	3266	5751	3664	1219	6930	2698	15379
Middle	1508	1463	13864	5182	2765	6645	4273	24782
Lower North	605	336	5630	519	1517	855	2122	8607
Lower South	2443	3662	9849	3243	7089	6905	9532	26286
Total	6035	8727	35094	12608	12590	21335	18625	75054

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 325 Mauzas with Missing Data.

Table E.24 Percentage of Households with Agriculture as their Main Occupation in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	41.5	37.5	36.8	35.9	30.0	36.6	37.9	37.0
Middle	39.1	32.4	57.8	54.8	48.1	47.4	44.5	50.8
Lower North	41.1	30.3	40.6	31.7	45.1	31.1	43.6	40.4
Lower South	51.6	43.2	42.6	44.5	43.7	43.8	47.2	45.0
Total	45.5	38.2	45.8	44.2	43.7	41.5	44.5	44.2

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 325 Mauzas with Missing Data.

Table E.25 Number of 1992 Households with Fishing as their Main Occupation

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	68	341	337	149	138	490	206	1033
Middle	183	116	1159	588	274	704	457	2320
Lower North	18	48	1114	163	81	211	99	1424
Lower South	256	1307	1472	242	1288	1549	1544	4565
Total	525	1812	4082	1142	1781	2954	2306	9342

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 330 Mauzas with Missing Data.

Table E.26 Percentage of Households with Fishing as their Main Occupation in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	1.6	4.0	2.2	1.5	3.4	2.6	2.2	2.3
Middle	3.7	3.5	4.8	6.2	4.7	5.4	4.3	4.8
Lower North	0.9	4.3	8.0	15.3	2.3	9.6	1.8	6.2
Lower South	4.4	15.4	6.4	3.9	7.9	10.5	6.4	7.2
Total	3.2	8.2	5.3	4.2	5.9	6.0	4.7	5.3

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 330 Mauzas with Missing Data.

Table E.27 Total Number of Large Livestock (Milk Cows, Buffaloes, and Bullocks)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	2781	5876	12733	8154	1693	14030	4474	31237
Middle	1823	3081	18650	6087	7249	9168	9072	36890
Lower North	2880	199	13527	1345	2963	1544	5843	20914
Lower South	2944	5759	22554	4886	14980	10645	17924	51123
Total	10428	14915	67464	20472	26885	35387	37313	140164

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 327 Mauzas with Missing Data.

Table E.28 Large Livestock per Cultivated km Square in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	125	59	58	89	48	73	94	70
Middle	158	87	74	41	192	53	181	85
Lower North	492	32	109	89	166	73	266	136
Lower South	198	105	153	69	155	85	166	138
Total	185	77	91	63	150	68	163	100

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 327 Mauzas with Missing Data.

Table E.29 Large Livestock per km Square of Dry Season Land in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	91	48	46	57	32	53	66	53
Middle	131	59	58	28	127	36	128	62
Lower North	392	25	79	79	24	63	50	63
Lower South	144	27	77	50	30	34	40	47
Total	140	38	64	43	39	41	55	54

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 339 Mauzas with Missing Data.

Table E.30 Number of Large Livestock per 100 Households in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	74	67	81	80	44	74	65	74
Middle	68	89	78	64	110	72	93	81
Lower North	194	18	97	83	94	57	132	104
Lower South	54	70	98	67	92	69	75	81
Total	74	70	88	71	92	71	84	82

Source: FAP 16 Field Survey. Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 339 Mauzas with Missing Data.

Table E.31 Total Number of Small Livestock (Goat/Sheep)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	3829	7719	24707	10650	3329	18369	7158	50234
Middle	3042	6090	31618	10888	8371	16978	11412	60008
Lower North	2863	568	13337	2017	2979	2585	5842	21764
Lower South	4133	9330	30094	6608	20072	15938	24204	70236
Total	13866	23708	99755	30163	34751	53870	48616	202242

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 327 Mauzas with Missing Data.

Table E.32 Density of Small Livestock in 1992 to Dry Season Land Area

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	120	63	90	74	63	69	96	83
Middle	173	117	98	51	139	68	149	95
Lower North	403	72	78	122	132	106	215	108
Lower South	185	104	152	68	145	85	156	133
Total	174	89	103	64	130	74	145	103

Source: Landsat Imagery, FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 327 Mauzas with Missing Data.

Table E.33 Ratio of Small Livestock to 100 Human Households in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	97	89	158	104	86	97	93	116
Middle	89	177	132	115	120	136	108	125
Lower North	199	51	96	128	92	97	133	108
Lower South	70	112	130	91	124	102	100	110
Total	92	114	130	106	115	109	104	115

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 327 Mauzas with Missing Data.

Table E.34 Total Number of Poultry in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	9600	26817	54895	35142	9660	61959	19260	136114
Middle	10730	11668	77520	29828	27279	41496	38009	157026
Lower North	8073	1794	37875	9118	11771	10912	19844	68631
Lower South	16436	35836	105757	20529	47072	56365	63508	225630
Total	44838	76116	276047	94617	95782	170733	140620	587400

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 327 Mauzas with Missing Data.

Table E.35 Density of Poultry to Dry Season Land Area in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	303	221	200	244	183	233	252	223
Middle	589	214	241	139	487	158	516	258
Lower North	1145	229	221	538	483	442	684	334
Lower South	708	393	533	211	340	300	434	425
Total	558	273	286	200	370	228	434	301

Source: Landsat Imagery,FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 327 Mauzas with Missing Data.

Table E.36 Ratio of Poultry Per 100 Human Households in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	243	311	351	344	248	329	245	313
Middle	304	324	323	313	420	316	374	338
Lower North	566	161	273	565	336	402	424	335
Lower South	267	426	458	282	290	360	280	352
Total	294	348	361	331	328	339	312	337

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 327 Mauzas with Missing Data.

Table E.37 Number of Non-Mechanized Boats in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	268	521	1151	427	121	948	389	2488
Middle	181	301	1929	913	571	1214	752	3895
Lower North	874	50	1071	177	288	227	1162	2460
Lower South	1026	1295	1897	316	2408	1611	3434	6942
Total	2349	2167	6048	1833	3388	4000	5737	15785

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 331 Mauzas with Missing Data.

Table E.38 Households Per Non-Mechanized Boat in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	34	17	14	24	32	20	33	19
Middle	41	16	12	10	19	12	24	15
Lower North	3	22	13	9	17	12	7	10
Lower South	15	7	12	23	8	10	10	11
Total	15	11	13	16	12	13	13	13

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 331 Mauzas with Missing Data.

Table E.39 Number of Mechanized Boats in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	55	68	152	101	34	169	89	410
Middle	15	49	290	91	193	140	208	638
Lower North	37	10	200	63	30	73	67	340
Lower South	113	62	318	84	275	146	388	852
Total	220	189	960	339	532	528	752	2240

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 348 Mauzas with Missing Data.

Table E.40 Households Per Mechanized Boats in 1992

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	164	129	103	101	113	112	144	116
Middle	492	83	82	105	57	97	89	88
Lower North	79	112	68	26	159	38	115	71
Lower South	138	137	73	87	73	108	92	88
Total	159	119	79	85	75	97	99	90

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 348 Mauzas with Missing Data.

Table E.41 Number of Human Deaths (Indirect and Direct) from the 1988 Flood

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	26	62	150	16	4	78	30	259
Middle	28	101	186	34	36	136	64	385
Lower North	3	6	43	7	9	13	12	68
Lower South	25	5	11	8	106	13	131	155
Total	82	175	389	65	155	240	237	867

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 344 Mauzas with Missing Data.

Table E.42 1988 Flood Deaths per 100,000 People (1992 Population)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	38	111	156	27	18	68	35	79
Middle	136	449	134	64	79	178	101	134
Lower North	58	88	51	65	57	74	58	56
Lower South	24	12	7	20	89	15	51	33
Total	43	131	81	40	76	81	57	71

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 344 Mauzas with Missing Data.

Table E.43 Number of Human Deaths from Epidemic Disease 1988-92

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	17	65	276	43	14	108	31	415
Middle	11	11	239	57	79	68	90	397
Lower North	4	0	46	9	31	9	35	90
Lower South	96	18	32	27	415	45	510	587
Total	128	94	593	136	539	230	666	1489

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 343 Mauzas with Missing Data.

Table E.44 Deaths From Epidemic Disease in 1988-92 per 100,000 People (1992 Population)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	26	116	287	72	62	94	32	123
Middle	32	43	172	101	160	83	111	130
Lower North	146	0	54	84	129	51	136	78
Lower South	91	34	21	68	381	49	210	129
Total	66	67	124	82	264	75	146	122

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 343 Mauzas with Missing Data.

Table E.45 Number of Mauzas Reporting Large and Small Livestock Deaths from the 1988 Flood

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	8	25	46	25	8	50	16	112
Middle	5	21	61	33	14	54	19	134
Lower North	3	2	50	4	3	6	6	62
Lower South	23	27	74	13	23	40	46	160
Total	39	75	231	75	48	150	87	468

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 343 Mauzas with Missing Data.

Table E.46 Percentage of Mauzas in each Reach/Char Type Reporting Large and Small Livestock Deaths from the 1988 Flood

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	62	81	92	78	89	79	73	83
Middle	25	78	80	77	45	77	37	68
Lower North	38	33	81	40	15	38	21	58
Lower South	49	56	70	46	18	53	26	45
Total	44	67	79	66	26	67	32	59

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 343 Mauzas with Missing Data.

Table E.47 Total Area Flooded at Peak Flood Time 1988 (Hectares)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	3325	14712	29944	11468	5165	26180	8490	64614
Middle	1865	4947	39098	20945	6520	25893	8385	73376
Lower North	739	729	18761	1640	2576	2369	3315	24445
Lower South	2391	7251	14530	8190	13398	15442	15789	45760
Total	8319	27640	102332	42243	27660	69883	35979	208195

Source: Landsat Imagery, FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 327 Mauzas with Missing Data.

Table E.48 Percentage of Area Flooded at Peak Flood Time 1988

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	83	94	88	74	97	84	89	87
Middle	98	71	97	93	100	88	99	94
Lower North	94	100	93	69	96	76	95	92
Lower South	96	85	79	73	88	78	91	83
Total	91	87	91	82	93	84	93	89

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note: 327 Mauzas with Missing Data.

Table E.49 Mean Days Duration of Flooding 1988

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	29	26	24	24	24	25	26	25
Middle	49	22	25	22	27	22	36	27
Lower North	37	26	24	24	33	25	34	27
Lower South	28	24	18	22	23	23	24	22
Total	34	24	22	23	25	23	28	24

Source: Landsat Imagery, FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 327 Mauzas with Missing Data.

Table E.50 Total Area Flooded at Peak Flood Time 1990 (Hectares)

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	2362	8629	26253	10807	2943	19436	5305	50995
Middle	967	4136	26309	13021	3103	17156	4071	47535
Lower North	212	179	11143	675	542	854	755	12751
Lower South	1054	4879	7949	5019	4126	9898	5180	23028
Total	4595	17823	71655	29521	10715	47344	15311	134309

Source: Landsat Imagery,FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 327 Mauzas with Missing Data.

Table E.51 Percentage of Area Flooded at Peak Flood Time 1990

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	44	55	77	70	55	62	49	67
Middle	58	60	65	58	42	58	46	60
Lower North	20	24	55	30	17	29	18	46
Lower South	44	57	45	45	29	51	33	42
Total	45	56	64	57	35	57	38	56

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 327 Mauzas with Missing Data.

Table E.52 Mean Days Duration of Flooding 1990

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	9	14	13	11	14	12	11	12
Middle	28	14	15	13	13	14	19	15
Lower North	8	6	11	10	4	9	5	9
Lower South	15	19	15	17	14	19	14	16
Total	16	16	14	13	13	15	14	14

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 327 Mauzas with Missing Data.

Table E.53 **Total Area Flooded at Peak Flood Time 1991 (Hectares)**

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	2331	8640	24993	10888	3481	19527	5813	50333
Middle	716	4253	22729	11669	2327	15922	3043	41695
Lower North	195	93	10623	435	651	528	846	11996
Lower South	1080	3250	6670	4771	2234	8021	3314	18006
Total	4323	16236	65016	27763	8693	43999	13016	122030

Source: Landsat Imagery, FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 327 Mauzas with Missing Data.

Table E.54 **Percentage of Area Flooded at Peak Flood Time 1991**

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	40	55	73	70	66	63	51	65
Middle	48	61	56	51	34	54	38	52
Lower North	13	12	53	19	25	18	22	43
Lower South	45	38	38	43	17	41	24	33
Total	41	51	58	54	29	52	33	51

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992
Note : 327 Mauzas with Missing Data.

Table E.55 **Mean Days Duration of Flooding 1991**

River Reach	Unprotd Mainland West	Attached West	Island Char	Attached East	Unprotd Mainland East	Sub Total Attached	Sub Total Unprotd Mainland	Total
Upper	7	13	12	11	12	12	9	12
Middle	23	14	12	11	10	12	15	13
Lower North	8	5	11	6	5	6	6	9
Lower South	14	17	14	14	10	16	11	13
Total	15	15	12	11	10	13	11	12

Source: FAP 16 Field Survey Mauza Estimates Apportioned by Predominant Charland Type 1992.
Note : 327 Mauzas with Missing Data.