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BANGLADESH FLOOD ACTION PLAN

FAP 16 Environmental Study

Special Studies Program

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EFFECTS OF FLOOD PROTECTION ON THE FERTILITY OF SOILS AT THE CHANDPUR IRRIGATION PROJECT

July 1993

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IRRIGATION SUPPORT PROJECT
FOR ASIA AND THE NEAR EAST

Funded by the U.S. Agency for International Development

in collaboration with
BANGLADESHI INSTITUTE OF NUCLEAR AGRICULTURE
BANGLADESHI AGRICULTURAL RESEARCH COUNCIL

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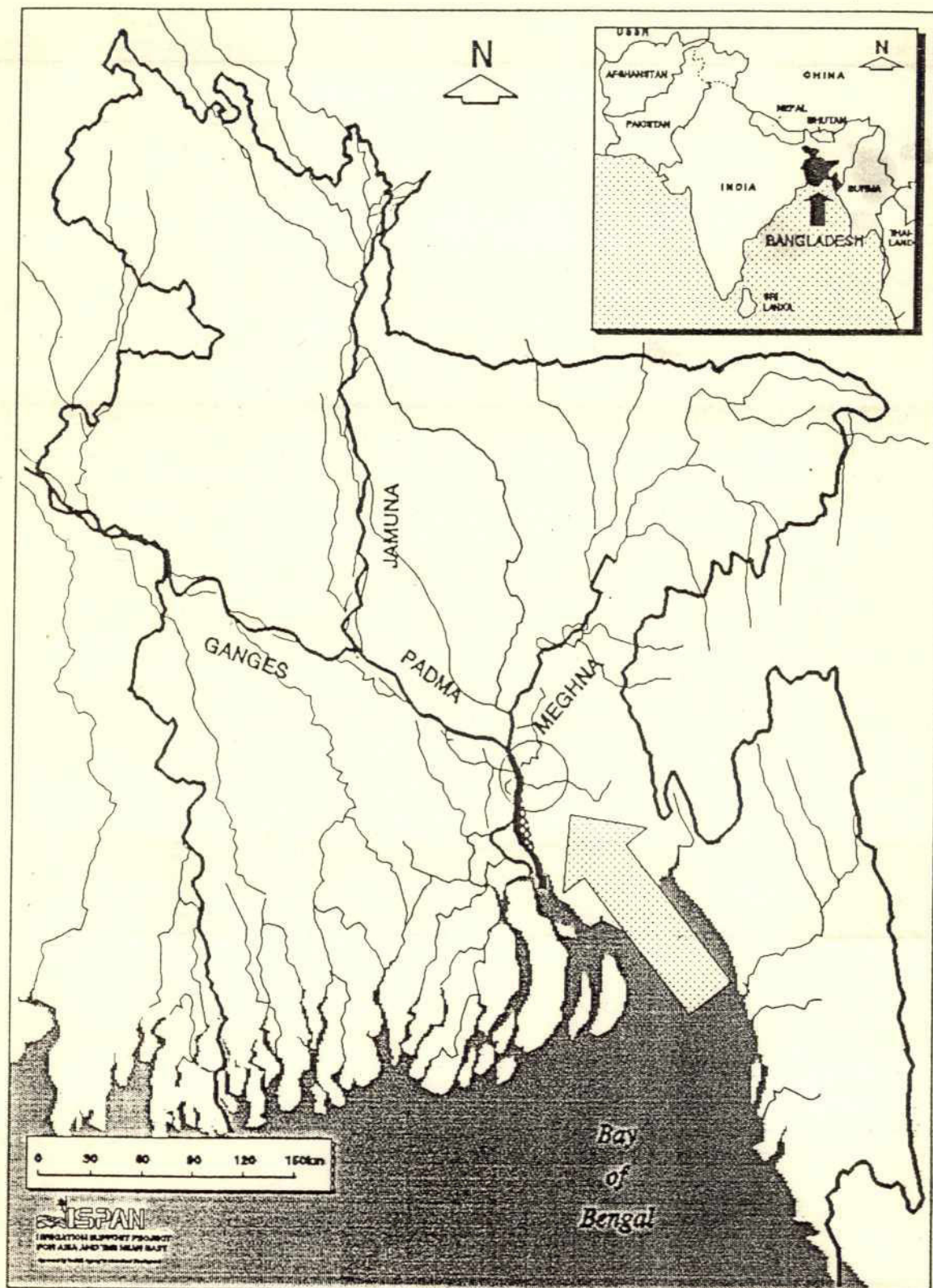
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 **ISPAN** IRRIGATION SUPPORT PROJECT
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Frontispiece. Location of Chandpur Irrigation Project

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Madna and Chandpur soils, making it unlikely that they were locally translocated.

The study showed that deposited sediments along the Meghna River in the vicinity of the CIP have a high nutritive value for crop production. The value of the sediments lies in their worth as substrates for crop production and their high content of nitrogen and potassium, both normally deficient in local soils. The high nitrogen content is probably attributable to particulate organic allochthonous material and algal biomass, both of which are high in flood water draining large expanses of previously inundated lands. The nitrogen content of the sediment was low in relation to levels of fertilizer normally applied, and probably low in relation to the amounts of nitrogen fixed by the abundant BGA populations. The sediments also were found to be substantially higher in EC, organic matter, calcium, sulphur, potassium, and manganese than local soils, but significantly lower in copper and zinc. Nutrient concentrations in lower-elevation sediments were significantly higher than in those deposited at upper elevations. The higher clay content of lower elevation deposits may contribute to the higher nutrient content through higher proportions of adsorbed ions.

The study showed that soil nutrients are affected by many factors in an area subjected to flooding and flood protection, some of these being: types of crops grown, types and rates of fertilizer applications, elevation of the soils relative to the local flooding levels, and the sediment content of the rivers supplying the floodwaters.

Meghna River water, the analysis found, is high in TDS — probably sodium, chlorides, and bicarbonates — but contains only moderate amounts of dissolved calcium; low levels of magnesium, potassium, and other inorganic soil nutrients; and only traces of ammonium nitrogen. Dakatia River water had similar potassium and sulphur content but was lower in calcium, magnesium, phosphorus, manganese, and especially TDS. Soil nutrients contributed as dissolved forms in incoming floodwater were probably slight by comparison to those transported in the form of sediments.

A principal components analysis indicated that protection from flooding brings about a discernible shift in nutrient content, but an even greater shift occurs in protected soils during the monsoon rains. Monsoon flooding and associated changes in cropping, the study found, lower the pH and the organic matter, calcium, magnesium, iron, and manganese content of most soils. Levels of potassium, nitrogen, phosphorus and sulphur increase because of fertilizer applications inside the embankment, and fertilizer applications and sediment deposition outside the embankment. No flooding-induced changes in zinc levels were found.

The major difference between the protected and unprotected areas was in flood protection and associated crop production: within the embankments production was two to three times higher than it was outside because of the protection provided and because of associated changes in cropping patterns and the use of high yielding varieties (HYVs). Such increases in production required high rates of fertilizer application, which are necessary for such crops as potatoes, HYV *boro* and HYV transplanted *aman*. The high crop production rates of the protected areas could probably not be obtained in flood prone areas, even with the annual deposition of nutritive sediments.

Levels of potassium, nitrogen, phosphorous, sulphur, boron, copper, zinc, and electrical conductivity all rose in protected soils on the Meghna side of the CIP after the monsoon cropping and harvesting season. All of these nutrients, with the exception of copper and boron, were present in the fertilizers applied, principally Triple Sulphur Phosphate (TSP), Single Super Phosphate (SSP), muriate of potash (MP) and zinc sulphate. The rise in electrical conductivity was associated with the high levels of calcium, potassium, and ammonium cations and sulphate and chloride anions in the dissolving fertilizer applications.

Nutrient depletion within the CIP is high overall, and is especially so in upper elevation soils, which support crops of potatoes, HYV *boro*, and HYV *aman*. Fertilizer additions replace most of nutrients removed by cropping, but potassium is

SUMMARY

Rice productivity in Bangladesh is low compared with that of other rice-growing areas of the world because of poor soil fertility, limited use of costly fertilizers, risk of flood damage, and only moderate achievements in irrigation. Past attempts to ameliorate this situation have placed 30 percent of the country under flood control, drainage and irrigation (FCD/I) projects, intended to improve hydrologic conditions for the benefit of crop production. These FCD/I projects generally impede flooding during the monsoon season and prevent deposition of river-borne sediments on soils within protected areas.

Although the linkage between flooding and soil fertility has long been recognized, previous investigations of pedological changes in flood-protected areas have been limited. Those studies, however, indicate the likelihood of widespread deficiencies in elements such as zinc and sulphur, possibly due to the intense cultivation of rice following flood protection. This report, on a study of soil fertility in one project area, adds to this knowledge base. Prior to this study there had been no systematic investigation of the effects on soils of excluding the annual deposition of river-borne sediments.

This report presents the results of a one-year comparative study of flood-protected and flood-exposed soils in the Chandpur Irrigation Project (CIP). The objectives of the study were to compare nutrient characteristics of soils inside and outside the protective embankment, measure the nutrient qualities of deposited sediments, and examine the soil nutrient relationships of other potentially significant factors such as blue-green algal (BGA) distribution and abundance, dissolved nutrient levels of river and irrigation water, and the effects of fertilization and changes in cropping patterns.

Eight sites were selected and sampled twice each in a balanced sampling design based on river frontage (Meghna or Dakatia rivers), protection (outside or inside the embankment), relative

elevation (medium highlands or medium lowlands), and timing relative to monsoon flooding (pre-monsoon and post-monsoon). At each site in each period, 20 topsoil samples were collected. Twenty sediment sampling trays were placed in flood exposed sites prior to the monsoon flooding and collected after floods had subsided. Soil and sediment samples were assayed for texture, pH, organic matter, electrical conductivity, and available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper, boron, and manganese. Water samples also were collected on four occasions from four open river and canal sites and one site inside the CIP during the monsoon period, and from a number of internal irrigation canals during the dry season. Water samples were analyzed for pH, total dissolved solids (TDS), electrical conductivity (EC), and available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper, boron, and manganese. BGA samples were taken from rice plants and surface water in the sampling sites and subjected to microscopic examination for identification and volumetric assessment of BGA abundance. Among the other data collected from the sample areas were cropping patterns, rates of fertilizer application and crop production.

Little or no sedimentation occurred in the sampling sites along the Dakatia River because floodwater there was mainly sediment-free rainwater. Sediment deposition along the Meghna was probably lower than normal because of the abnormally low flooding intensities and water levels of 1992. The sediment samples from the Meghna sites were sandy loams and had a different texture than the local soils, which are loams and clay loams. The deposited sediments obviously were translocated soils from elsewhere, and were probably a combination of agricultural soils eroded from the upper Meghna and upper Padma basins and transported to the CIP sites. Their physical and chemical composition was quite different from that of the local

applied in quantities too low to adequately replace what is used and is notably deficient in all soils in the CIP. Soils in the unprotected areas support less nutrient-exhaustive crops and produce lower yields. These soils are supplemented with fertilizers as well as high amounts of organic manure. Local farmers are of the opinion that crop production within the CIP is becoming increasingly dependent on high application rates of fertilizers.

Based on the findings of this study, river-borne sediments are valuable sources of soil nutrients and their exclusion from agricultural lands by embankments is a major potential negative impact of flood control developments. The potential loss of nutrient sediments in such developments should be balanced against the fact that flood protection permits more intensive cropping and higher crop production. The study also demonstrated that sedimentation of agricultural lands from river-derived floodwater is heterogenous, occurs mainly in areas close to the mainstem rivers, and may be minimal or absent in areas flooded by smaller rivers.

Controlled flooding appears to be an appropriate way to take advantage both of the increased production associated with flood protection and the free nutrient content of deposited sediments.

Through controlled flooding, sediment rich water could potentially be permitted access to agricultural lands at key periods in the cropping cycle, but could be excluded during subsequent periods when crops are susceptible to flood damage and when sediment concentrations may be declining due to subsiding flood levels. It would seem desirable, however, to examine the efficiency of sediment deposition on lands when flood waters enter primarily via regulators rather than overbank spills, since restrictive canal and regulator openings are likely to act as sediment traps.

The report recommends that controlled flooding be further examined as an option for flood control in agricultural areas and that ways be specifically sought to ensure effective transfer of river-borne sediments to agricultural lands at key periods in the cropping cycles. It suggests that the nutritive value of sediment deposition be quantified in an economic sense to permit its consideration in project cost-benefit analysis. It further recommends that consideration be given to repeating the soil comparison study in other regions in Bangladesh, especially in the upper Meghna, Jamuna and Ganges basins, where different sedimentary regimes and local geochemistry might produce different information and conclusions from those arrived at here.

STUDY PARTICIPANTS

The study was designed and managed by Abu Md. Ibrahim of ISPAN. The report was prepared by Stanley M. Hirst and A.M. Ibrahim of ISPAN, Dr. Z. Karim of the Bangladesh Agricultural Research Council (BARC), and Drs. Md. Idris Ali and A.K. Podder of the Bangladesh Institute of Nuclear Agriculture (BINA).

Chemical analysis of soil samples was undertaken under the direction of Dr. Md. Idris Ali of BINA, while Dr. A.K. Podder of BINA and Dr. A. Aziz of Dhaka University undertook the

examination and analysis of blue-green algal samples. Dr. Stanley M. Hirst of ISPAN carried out the statistical analyses. Dr. Z. Karim of BARC served as study advisor.

Md. Faruque of ISPAN collected soils samples and land use and cropping data, and maintained liaison with cooperating farmers in the study area. Assistance in collection of field data was given by Md. Masuduzzaman, Shah Newaz Siddiqi, Golam Monowar Kamal and Raguib-uddin Ahmed of ISPAN.

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mitted access to their lands for soil, water and algal sample collection and who provided detailed data on their cropping and land management practices. The Executive Engineer (O&M) and other officials of the BWDB, Chandpur, are thanked for their support during the field work.

Chapter 1

INTRODUCTION

Bangladesh has a total area of 148,393 km², of which about 90 percent comprises one of the largest deltaic plains in the world, formed by the confluence of the Brahmaputra (Jamuna), Ganges and Meghna rivers. The remaining 10 percent is comprised of the undulating, forested Hill Tracts. About two-thirds of the national area is cultivable, and of this about 60 percent is subject, on average, to seasonal flooding from river overbank spillage as well as heavy rainfall (World Bank 1992).

Agriculture is highly attuned to seasonal flooding, and the linkage between flooding and soil fertility has long been recognized. The Bengali term *barsha* refers to normal, beneficial flooding of agricultural land which does not significantly affect homes and villages. Bentley (1925) compared situations in east and west Bengal and was the first on record to claim that embankments reduced soil fertility by preventing flooding.

Water control measures, many at a small scale, have been extensively developed to reduce sporadic flooding damage to agricultural crops and property, and to improve drainage and irrigation. Large-scale destructive floods such as occurred in 1987 and 1988 are comparatively rare, but of sufficient negative impact to infrastructure and livelihoods as to have prompted an international response in the form of the Bangladesh Flood Action Plan (FAP) which seeks to reduce flood damages through construction of protective embankments and related water control measures.

At present about 30 percent of the net cultivated area in Bangladesh is covered by flood control, drainage and irrigation (FCD/I) projects (World Bank 1992). The most flood prone soils are either on active floodplains within and close to river channels, in the northern and eastern areas which receive flash floods from neighboring hills, and/or in flood plain basins. FCD/I projects aim at improving the hydrologic regime of these flood prone soils for the benefit of crop

production. Rice productivity in Bangladesh is low compared to other rice-growing areas of the world; responsible factors cited are poor soil fertility, limited use of costly fertilizers and a lack of irrigation (Sattar 1991). Irrigation permits the growing of high yielding varieties (HYV) of rice in the dry season. HYVs plus fertilizers have led to 37 percent rise in agricultural production since 1970 (MOEF 1991), but in the past decade average HYV yields have remained static or have decreased. Possible reasons cited for this (MOEF 1991) are year-round waterlogging of soils leading to the formation of toxic compounds, and the loss of zinc and sulphur through deep percolation. About 3.9 million ha land are presently deficient in sulphur, and 1.74 million ha deficient in zinc (MOEF 1991).

FCD/I projects generally reduce both the depth and duration of seasonal flooding and thereby increase the surface area in the highland and medium highland categories. FCD/I projects located near the major rivers generally impede river water flooding during the monsoon season, and hence soils within the protected areas do not receive fresh river-borne sediments. Finer sediments are commonly looked upon by local farmers as nutrient sources (ISPAN 1991, 1992), in contrast to coarse sands which are detrimental to crop production and which have to be removed from lands following flooding.

The pedological effects of FCD/I development so far undertaken in Bangladesh have been subjected to only limited investigation. Zinc and sulphur deficiencies are documented in intensively cultivated soils of the Chandpur Irrigation Project (CIP), Dhaka-Narayanganj-Demra Project (DNBP) and the Ganges-Kobadak Project (Andriess 1982). This is suggested to be due, at least partly, to the higher extraction of trace elements that takes place under high cropping intensities with HYV's, and partly due to elements being less available for uptake by plant roots under submerged conditions of higher

frequency and longer duration, i.e. less fallow conditions.

Soil analyses in the CIP indicate an adequate supply of potassium, while phosphates are deficient and the nitrogen content very low (CIRDAP 1987). Most sampled areas have sufficient supplies of calcium, magnesium and iron, but sulphur, boron, manganese and zinc contents are low. Both Andriesse (1982) and CIRDAP (1987) refer to the high iron content of soils, believed to be related to a low soil pH. These two studies were confined to investigations inside flood-protected areas only, which limits the scope of understanding the effects of flood protection measures on the physical and chemical characteristics of these soils.

FCD/I development may affect soil fertility in one or more ways:

- reducing or eliminating the periodic addition of new sediments;
- eliminating or reducing topsoil flooding and the associated topsoil chemical changes which may affect nutrients;
- increasing or decreasing the extent of water-logging and the associated physiological changes to root efficiency;
- bringing about changes from natural flood-associated soil moisture regimes to irrigation-induced soil moisture regimes; and/or
- leading to cropping intensification and the associated increased use of inorganic fertilizers.

Because of heterogeneous soil characteristics in flood plains, such changes of environmental factors may have different effects on the availability of nutrients in different areas.

Increased development of FCD/I projects is expected to take place under the FAP with consequent wide-reaching implications for soil fertility, crop production and land management. The potential effects of such flood control on soil fertility, through the restriction of sediment inputs and possibly other changes, has been indicated as a major concern by FAP participants (e.g. ISPAN 1991, BCEOM *et al.* 1993).

The study reported here was undertaken by ISPAN in collaboration with the Bangladesh

Institute for Nuclear Agriculture (BINA) and the Bangladesh Agricultural Research Council (BARC) to provide additional data, information and insights into soil fertility status and its relationship to flooding and sediment deposition. Time and budgetary constraints within the FAP 16 Environmental Study limited the study effort to a one-year examination of soil fertility in one major location only. After consideration of a number of potential study sites, the Chandpur Irrigation Project (see frontispiece) was selected because of the presence of two major rivers providing sediment, one carrying heavy sediment loads (Meghna) and the other relatively lighter loads (Dakatia), the availability of flood-protected and flood-exposed locations within the same soil series, the availability of background soils data, and the willing cooperation of local farmers. It was recognized from the outset that this would not provide general answers to all queries related to FCD/I and soil fertility because of the reported wide-ranging variations in soil and flooding conditions in Bangladesh.

BACKGROUND

2.1 Soil Development in the Bangladesh Floodplain

The Bengal Lowlands are one of the oldest alluvial plains in the world. The recent alluvial lowland is divided into two regions - the Brahmaputra-Jamuna floodplain and the Ganges floodplain, with the Barind formation between them (Umitsu 1987). The youngest surfaces lie adjacent to the present rivers.

Sediments in the Brahmaputra-Jamuna floodplain are mainly sandy with a gravel bed at a depth of 50 to 100m (probably late Quaternary). The formations above this are coarse sand and gravel mixes at the lower levels and finer silts at the upper levels. Variations in sediment characteristics are due to changes in the sedimentary environment and changes in the upper reaches of the rivers. The uppermost part of the sediments is made up of oxidized alluvium (Umitsu 1987). The plains are formed of riverine sediments and are generally of dark and loose material with a high water content and a variable organic matter content.

The morphology of the river plain is distinctive and consists of a series of ridges and depressions, river levees, slopes and swamps, braided streams, meander scars and typical river channels. On the micro scale the topography is highly variable, but macroscopic slopes are very slight (Murray *et al.* 1992). Six broad morphological types are distinguishable (Brammer 1989):

- Active young floodplains (chars) along major river channels; experience bank erosion and new deposition of seasonal alluvium; have mixed silty/sandy deposits; undergo severe flooding 2-5m in depth.
- River meander floodplains, characterized by basin and ridge topography such as haors, baors, backswamps and beels; heavy clays and silts dominate; seasonal

flooding with rainwater up to 5m, 1-2m on ridges.

- Estuarine floodplains; level relief and few channels; deep silty deposits; seasonally flooded by rainwater; soils and estuary waters become saline in dry season.
- Tidal floodplains; level basins drained by tidal creeks; clay soils; flooded at high tide by river and/or rainwater; saline soils.
- Alluvial fans and piedmont plains; deposition occurs after flash flooding events, silt-bearing water leads to sand, loam and clay patterns of soil development.
- Major floodplain basins; flooding to 5m occurs seasonally; central haors are wet year-round; rainwater flooding with flash flooding brings silts.

River alluvia along the Ganges and in the estuarine zone contain lime (Murray *et al.* 1992). Ganges tidal, Brahmaputra river and estuarine alluvia are neutral to moderately alkaline but not calciferous, while alluvial fans and Brahmaputra river deposits are slightly acidic. Both Meghna and Jamuna floodplain soils are typically neutral to slightly alkaline (Whitton *et al.* 1988a), although the Jamuna floodplain receives much more silt.

Topsoils which do not receive annual depositions of alluvium are generally acidic, while alluvium-rich soils are neutral or calcareous (Murray *et al.* 1992). In dry periods redox reactions in topsoils lead to acidification. This is permanent except where biological activity brings a constant new supply of material to the surface or alluvial deposition occurs. During ponding and submergence soils are neutralized and leaching occurs rapidly. Only active floodplains and surrounding areas receive significant depositions of silts on an annual basis.

2.2 Sediments and Sediment Deposition

Rahman *et al.* 1990 estimate the mean annual discharge of the Brahmaputra to be 19,200 m³/s and the mean annual sediment runoff to be 1370 tonnes/km². For the Ganges the mean annual discharge is 11,610 m³/s and mean annual sediment runoff 492 tonnes/km². The estimated mean discharge for the Meghna is 3513 m³/s. Sediment runoff has not been estimated for the Meghna. From these data Murray *et al.* (1992) estimate a net overall annual deposition in the delta of 2 billion tonnes, calculated roughly from input-output comparisons. This translates into an average annual deposition rate of 0.8 cm. The suspended sediment load of the Brahmaputra-Ganges systems is characterized by coarser fractions in the Himalayan tributaries and finer material downstream.

Rivers tend to deposit sediments on their beds and along their banks at low or falling discharges, and to resuspend these sediments at high or rising discharges. For some rivers such as the Mississippi in the U.S.A., seasonal changes in water level and river slope are factors leading to remobilization of suspended sediments; there are as yet no data on these phenomena for the Brahmaputra, Ganges and Meghna systems (Murray *et al.* 1992).

Sediment deposition on cultivable lands varies regionally, according to the main river sediment source (Brahmaputra, Ganges or Meghna) and the subsidiary sources, the distance from the river banks, and probably a number of other, as yet undetermined, factors. For a deepwater rice area at Manikganj, supplied with floodwaters from the Brahmaputra (Jamuna), Whitton *et al.* (1988a) recorded sediment deposition occurring from early July to the first week in November. Sediment deposition was highest in July (215 g/m²/week) and lowest by November (35 g/m²/week). Whitton *et al.* (1988a) found measured annual sediment deposition to range from a low of 36 g/m² at Daudkandi on the Meghna River (recorded twice in separate years) to 5353 g/m² at Mohadebpur near the Jamuna-Ganges confluence. The median deposition for all sites was 408 g/m² (~4 tonnes/ha). Sites near the Meghna had the lowest deposition (36 to 187 g/m²),

while sites near the Jamuna had the highest deposition.

The nutritive value of deposited sediments remains contentious. For most world rivers, suspended sediments absorb a number of aqueous ionic constituents (Meade 1988, Milliman 1991, cited by Murray *et al.* 1992) and thus play a major role in geochemical cycling by transporting these ions through the hydrological system. The amounts and rates of sediment transportation via adsorption are affected by various factors, including deforestation, farming practices and damming, as well as the effects of local embankments. Bangladeshi farmers almost unanimously extol the virtues of new silts deposited on their lands as sources of nutrients. However, Brammer (1976) suggests river alluvium is probably relatively infertile as it contains little organic matter or nutrients which are available to crops in the short-term. He indicates three alternative sources of soil fertility arising from seasonal flooding:

- nitrogen-fixing activities of blue-green algae (BGA);
- decomposition of deep water rice plants and other submerged vegetation; and
- nutrient release resulting from shifts from acid or alkaline reactions (dry soils) to neutral ones (submerged soils).

Particulate organic carbon (POC) is a commonly measured component of river water, and Depetris *et al.* (1991, cited by Murray *et al.* 1992) note that POC is positively correlated with suspended solids, especially during rising river stages; increased discharges cause dilution of POC concentrations.

2.3 Water-Soluble Nutrients

Dissolved ions in river waters are a potential source of nutrients to flooded soils. The upland zones of the Ganges and Brahmaputra basins are dominated by calcium, magnesium and bicarbonates, while sodium, potassium, sulfates and chlorides come from the lower basins (Degens *et al.* 1991, cited by Murray *et al.* 1992). Chloride concentrations tend to be higher in the Ganges, which is roughly twice as saline as the Brahmaputra, and are derived from flooded soils. Dis-

solved solids in the Ganges average 178 mg/l, and in the Brahmaputra 100 mg/l; the Ganges transports 70 million tonnes/year dissolved solids, while the Brahmaputra moves 60 million tonnes/year (Murray *et al.* 1992). Despite these large masses of transported nutrients, suspended solids still dominate over dissolved solids in the major river systems entering Bangladesh, e.g. a 10:1 ratio between suspended and dissolved solids was measured in the Brahmaputra at Gauhati in India (Subramanian and Ittekkot 1991, cited by Murray *et al.* 1992).

Dissolved organic carbon (DOC) is a commonly measured and interpreted component of the dissolved solids loading of river water, and Depetris *et al.* (1991, cited by Murray *et al.* 1992) note that DOC concentrations increase with increasing discharge, especially during intensive floods. A significant source of DOC is amino acids and carbohydrates derived from biological activity on the floodplains.

Karim *et al.* (1991) measured the amounts of nutrients in irrigation water from the major Bangladesh rivers and found it to vary with the river and with the crop in question. For *boro* rice, about 55 percent of the potassium requirement (59 kg/ha) was provided by Ganges irrigation water. The contributions were lower for transplanted *aman* (35 percent) and for wheat (33 percent). The contribution to the phosphorus requirement for *boro* varied from 5 kg/ha from the Ganges to 7 kg/ha from the Meghna. Supply of sulphur to *boro* crops was similar for the Jamuna (33 kg/ha) and Ganges (31 kg/ha).

2.4 Biological Nitrogen Fixation

Biological nitrogen fixation (BNF) of aerobic nitrogen by microorganisms, especially blue-green algae (BGA), has been credited with being a major source of nutrient nitrogen for floodplain crops in Bangladesh, especially rice. Martinez and Catling (1982) estimated that BGA growing in paddy fields could fix up to 30 kg nitrogen/ha, a substantial proportion of the nitrogen requirements of rice. Murray *et al.* (1992) calculated that nitrogen fixed through BGA in the Bangladesh floodplain (possibly 180,000 tonnes/year) may be 35-40 percent of

the amount applied as nitrogenous fertilizer. BGA are not dominant organisms in the Bangladesh soil or aquatic environment, and have been found to comprise <2 percent of total algal populations in surveyed samples (Khan and Venkataraman 1991). Highest numbers are found in alkaline soils, with much lower densities in acidic soils (Watanabe and Roger 1984, Khan and Venkataraman 1991). Thirty three species of BGA belonging to 22 genera have been identified from 25 deepwater rice sites within the Jamuna, Meghna and Ganges floodplains (Catling *et al.* 1981). *Anabaena*, *Gloeotricha*, *Oscillatoria*, *Nostoc*, *Carococcus* and *Lyngbya* spp. are most abundant. Fourteen genera were found to be rare. Many species are epiphytic on leaf sheaths, others on nodal roots. BGA are typically less common in water samples. Catling *et al.* (1981) found BGA to decline in numbers when floods receded in October and standing waters became cloudy, malodorous and anaerobic. They note that deepwater rice areas are likely to have more BGA than others due to the large expanse of stem area under well-oxygenated, clear water.

Rother *et al.* (1988), one of the few groups of workers to actually examine the role of BGA in nitrogen fixation under Bangladesh conditions, found that nitrogen fixation is less important during the actual flood season than in moist soils in the period immediately preceding flooding. More than twice as much nitrogen was fixed in the pre-flooding period at their study site at Manikganj. They also found that BGA were much more abundant in fallow fields than in flooded paddy fields. Despite its value as a nitrogen source, fixation by BGA was not responsible for all nitrogen available in deepwater rice areas (Rother *et al.* 1988). They estimated that soluble nitrogen in floodwater contributed ~6 percent of deepwater rice requirements (on an areal per ha basis), and BGA on soils in the area contributed ~11 percent. They speculated that the remainder of the required nitrogen came from lateral transport from fallow areas (where BGA are very abundant) or some other nitrogen-fixing system. BGA growth in flooded paddy fields appear to be favored by higher contents of magnesium and calcium in the water (Whitton *et al.* 1988b).

Chapter 3

STUDY AREA

The Chandpur Irrigation Project (CIP) is a major FCD/I project located on the left bank of the Meghna River, south of Chandpur town in the districts of Chandpur and Lakshmipur (Map 1, Annex 1). The CIP comprises an area of 53,000ha on both sides of the South Dakatia river. Gross cultivable area is estimated at 36,000ha, with a total irrigable area of 29,000ha.

The project effectively started in 1975 and includes flood protection, drainage and irrigation, as well as other infrastructural improvements such as navigation facilities, roads and agricultural extension services. The project area is protected from the Meghna and Dakatia rivers by 101km of flood control embankment of average height of 3-4m. Drainage facilities include two regulators at Char Bagadi with reversible pumps of capacity 35 m³/s used for both drainage and irrigation. The southern regulator at Hajimara has a capacity of 652 m³/s and provides drainage only. Irrigation water is first lifted into the south Dakatia River which then feeds a network of tributaries, khals and irrigation canals. Lifting of irrigation water is via low-lift pumps hired out to farmers' groups in units of 16ha each.

Total population in the project area in 1976 was measured at 658,000, with 102,000 farm families (Andriessse 1976). About 77 percent of the farmers owned their land, 17 percent were owners/tenants, and 6 percent were purely tenants. The average gross farm area at that time was about 0.4ha, with a net cultivable area of 0.3ha per farm. In 1976 about 50 percent of the farms were smaller than 0.2ha, 20 percent were between 0.2 and 0.4ha, and 15 percent were between 0.4 and 0.6ha. Homesteads and tanks covered 25 percent of the area. Based on national growth rates, it is calculated that the 1992 population density in the area is about 906,000 persons (density 1700/km²), with farm families totalling about 150,000. Gross farm area is estimated to average only 0.3ha, with average

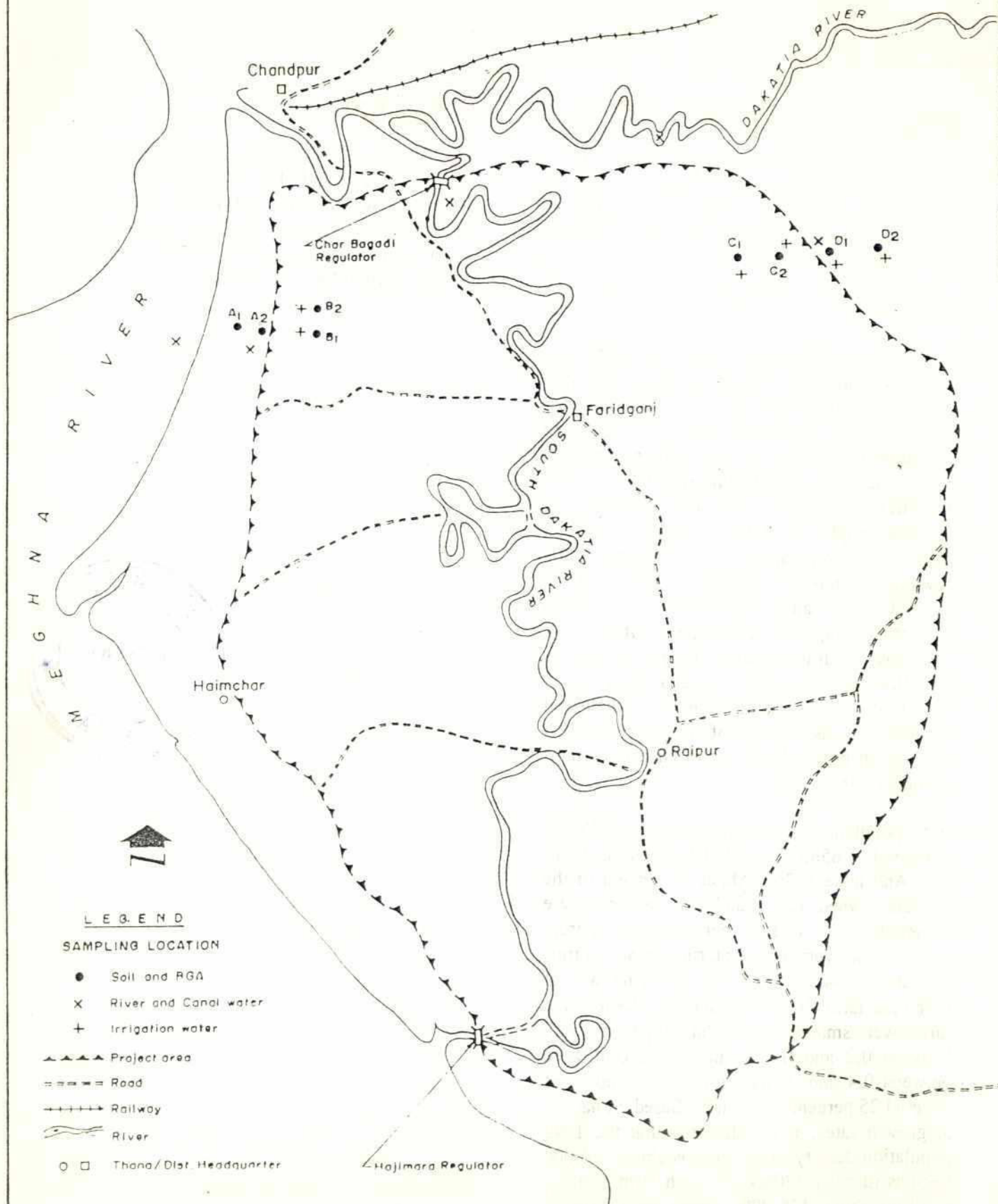
cultivable area of about 0.2ha.

The area has 220-230 days of kharif (wet season) growing period, 120-145 days of rabi (dry season) growing period and 40-50 days of pre-kharif transition period. The area remains under a minimum temperature of < 15°C for about 50-70 days during the dry season.



CHANDPUR IRRIGATION PROJECT

0 1 2 3 4 Miles



LEGEND

SAMPLING LOCATION

- Soil and RGA
- X River and Canal water
- + Irrigation water

▲▲▲▲ Project area

== Road

+ + + + Railway

~~~~~ River

○ □ Thana/Dist. Headquarter

Hajimara Regulator



## Chapter 4

## METHODS

## 4.1 Study Design

A two-fold approach to the examination of the role of sediment deposition on soil nutrient quality was employed, i.e.

- comparison of soils from flood-protected and flood-exposed areas which are otherwise similar in pedogenesis, elevation, land use and other factors; and
- collection and examination of sediments deposited on flood prone areas.

The desirable requirement for effective statistical treatment of comparative samples is to hold all "treatments" (i.e. soil uses, fertilizer applications, cropping uses, period of sampling, etc.) constant in the sampled locations, while varying only the factor to be tested (i.e. addition of deposited sediment). In practice, such a situation is almost impossible to find in an intensively cropped region such as Bangladesh, except under very tightly controlled situations where the land is under the full and long-term control of the study team. As soon as flood control measures are implemented, as at CIP, land use, cropping and associated practices of fertilization usually change to make use of the flood protection status. The alternative approach is to measure the associated treatments such as cropping patterns, fertilizer applications, etc. and to account for resultant changes in soil nutrient status through statistical comparison and analysis (covariance analysis).

## 4.2 Field Sampling

## Reconnaissance

A reconnaissance field study was carried out inside and outside the CIP project area from 10th to 15th March, 1992. Potential sampling sites were visited along a transect extending across both protected and unprotected areas from the highest to the lowest point, and crossing all major soil series and land types in the area. Two sampling blocks were selected, one on either

side of the CIP representing sites exposed to the high-sediment Meghna River environment, and to the low sediment Dakatia River environment respectively. At each location, blocks were divided into two, one part outside the existing embankment and one inside. Furthermore, two sub-locations were selected within each block, one at higher elevations in medium highland/highland land types, and another at lower elevations in medium lowland/lowland land types. Protected and unprotected blocks occurred within one of four soil series - Chandpur, Madna, Tippera and Burichang - occurred both inside and outside the embankment. These were dissimilar in physical and chemical characteristics and represented different toposequences. After field examination and consultation with local BWDB project officials, sampling sites in each block were chosen, representing lands belonging to from two to seven individual farmers each.

## Soils

Collection of soil samples from eight sampling blocks within the four sampling sites (Meghna inside and outside, Dakatia inside and outside) was undertaken from 17 March 1992 to 15 April 1992 (pre-monsoon samples), and repeated again from 7 through 24 December (post-monsoon samples). Each soil sample was a composite sample drawn from a combination of 25 sub-samples taken from the topsoil (0-10cm depth) within the same fields (Annex 2). Sampling was replicated 20 times within the same soil series and land types in adjacent fields of 8-10 m<sup>2</sup> each. The number of samples collected totalled 320 (2 river sources x 2 flood protection situations x 2 elevations x 2 seasons x 20 replications in each). Samples were placed in heavy duty polyethylene bags, sealed, and transported via ricksha to Faridganj from where they were transferred to the BINA laboratories in Mymensingh for chemical and physical analysis.



## Sediments

Within each flood exposed sampling block, a series of five specially constructed wooden trays was placed at ground level and securely anchored. Each tray measured 50cm x 50cm and was equipped with a plastic liner and a 10cm high lip to hold deposited sediment while excluding soil moving laterally across the ground surface under the moving flood waters. Trays were placed *in situ* 1 and 2 August 1992 and retrieved in November following flood water subsidence. Land owners were paid a moderate fee to guard trays and prevent their unauthorized removal. Collected sediment samples were treated the same as soil samples.

## Water

Water samples were collected at three depths (surface, 1m and 2m depths) from the Meghna River, Dakatia River and the three inlets nearest to the study area on 4-5 August, 25-26 August, 16-17 September, and 5-6 October 1992. Samples contained suspended sediments at the time of collection, these were filtered out at the laboratory so that analytical results reflected only dissolved nutrients.

Irrigation water samples were collected during the *boro* irrigation season (March and April). Replicate samples of water just below the surface were taken from the irrigation canals closest to the respective soil sampling sites. All water samples were sealed and transported to BINA for chemical analysis.

## Blue Green Algae

The abundance and diversity of BGA on the soil surface in standing water and on rice stems were monitored through the monsoon season. Samples of water and rice stems at water level were collected separately at 20 day intervals in each of the fields from which soil samples are taken. Three replicate samples each of water and rice stems at water level were collected from each sampling block on 4-5 August, 25-26 August, 16-17 September and 6-7 October 1992, and on 19-20 March and 24-25 April 1993.

Each field was subdivided into three equal parts and at least four or five samples (both water and rice plant) were collected from each part and combined into a composite sample. Approximately 100ml per composite water sample was collected in polythene bags and 4 percent formalin added as a preservative. Tillers of rice plants sample were randomly selected starting from the margin of a field to the centre. The plant was collected by cutting from the soil surface up to water level and placed in a polythene bag with 4 percent formalin solution. With few exceptions, the method for collecting BGA samples was similar to that described by Klarer and Hickman (1975).

## Other Data Collection

Land use and crop management data covering the current and past three years for each sampling blocks were collected by interviewing the farmers in the sample areas during April and May 1992. Information collected included cropping patterns, crop yields, management practices (tillage, irrigation), type and quantity of fertilizers used, manuring practices, insecticides used, depth and duration of seasonal inundation and sediment deposition within each of the sampling blocks.

## 4.3 Laboratory Analyses

### Soil and Water Samples

Physical and chemical analyses were carried out on soil, sediment and water samples by the laboratories of BINA, using standard techniques (Hunter 1984). Soil and sediment samples were analyzed for texture, pH, organic matter, available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper, boron, manganese and electrical conductivity. Water samples were analyzed for pH, total dissolved solids, available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper, boron, manganese and electrical conductivity. All chemical analyses on soils, sediment and water samples were done following standard procedures. Soil and sediment pH was measured using a glass electrode in 1:2.5 soil:water suspension. Electrical conductivity was measured



using a conductivity bridge.  $\text{NH}_4$  nitrogen, calcium and magnesium were determined on 1N potassium chromate extracts, with a calorimetric procedure for  $\text{NH}_4$  nitrogen, and atomic absorption spectrophotometry on the others. Sulphur and boron were determined on calcium phosphate extracts using a turbidimetric procedure for sulphur and a calorimetric measurement for boron. Organic matter was determined by the wet oxidation procedure (Walkley 1946). Phosphorus, potassium, iron, manganese and zinc were determined on sodium EDTA extracts (0.25 N Na  $\text{HCO}_3$  / 0.01M EDTA / 0.01 N  $\text{NH}_4\text{F}$  with 0.5g Superfloc 127 per 10 liters). Phosphorus was measured calorimetrically and the other nutrients by atomic absorption spectrophotometry. Measurement of nutrients in water samples was done following ASI procedures, and dissolved solids were determined following Standard Methods for Analysis for Soils, Plant Tissues, Water and Fertilizers (1990).

#### Blue Green Algae

In the laboratory BGA samples were scraped from the plants and placed in glass vials in which the total volume was made up to 20 ml. with 4 percent formalin. From the shaken sample 0.1ml was transferred to a slide, covered by a cover glass and examined. Five such slides were prepared from each vial. Within each slide five randomly selected microscopic fields were studied at a magnification of 300 and a mean estimate of filament density made.

Nitrogen fixation by BGA in topsoils and in surface waters was not measured since this is already well established and would involve sophisticated experimental and laboratory installation beyond the scope of this study.

#### 4.4 Statistical Analyses

A total of 320 soil samples were collected from the CIP and analyzed for 14 soil nutrient parameters. Equal numbers of replicate samples (20) were collected in each location subjected to a combination of two alternative treatments for each of four factors, i.e. rivers (Meghna, Daktia), river flood protection status (protected, not protected), site elevation (upper, lower eleva-

tions) and time of collection relative to the monsoon period (pre-, post-). Data for each of the measured nutrients were examined for statistical distributions and generally found close enough to normal distributions for the application of standard robust parametric analytical procedures. Small numbers of outliers and extreme cases were detected by the statistical analyses, but were too few in number to significantly affect the interpretation of the statistical results.

Soil samples were compared using analysis of covariance (ANOCOVA) based on a general least squares model; river environment (Meghna and Daktia), site elevation (upper, lower), protection status (outside, inside embankment) and period (pre- and post-monsoon) were used as treatments, with equal numbers of replicates (20) within each class. Rates of fertilizer application in each field from which the soil sample had been collected were treated as continuous covariates. Manure application to fields prior to sampling had been recorded in a qualitative way only (applied, not applied), and this was entered into the ANOCOVA as a categorical variable.

There were no replicate water samples collected in the sampling design, but following examination of the variances and means pooled alternatively for collection site within period and period within collection site, it was decided that the samples from the separate depth strata could be treated as replicates from one sampling site.

The statistical significance of any of the four factors (rivers, protection, elevation and period) in relation to the soil nutrient contents was determined in each case by reference to a four-way ANOCOVA in which the size of the mean square attributable to the factor in question was tested against the mean square error while the effects of all other factors and covariates were held constant.

In addition to the specific comparisons for each sampled nutrient, global comparisons of soils and sediments in terms of their nutrient content were made using principal components analysis (PCA). PCA is a statistical method whereby a matrix of highly correlated variables (soil nutri-



ent concentrations in this case) is reduced to a smaller matrix by computation of principal components based on the extent of correlation between and among the variables. There is no correlation between principal components themselves. The first two components extracted accounted for approximately 60 percent of total variation observed in the set of 14 variables, and were used to plot two-dimensional comparisons between various soils and between soils and deposited sediments.



## SOILS AND LAND TYPES

## 5.1 Soils

The project area falls within Agroecological Zone (AEZ) 17 (Lower Meghna River Floodplain), with minor areas in AEZ 18 (Young Meghna Estuarine Floodplain) and AEZ 19 (Old Meghna Estuarine Floodplain (Map 2). Four subregions of AEZ 17 occur in the CIP and contain either calcareous flood protected (17a) or non-flood protected (17b) soils, or non-calcareous flood protected (17c) or non-flood-protected (17d) soils. Soils in subregions 17a and 17b are slightly calcareous because of the admixture of Ganges river alluvium with the Meghna sediments. Soils on highlands and medium highlands are lighter in texture and consistence than those in adjoining medium lowlands and depressions. Most higher elevation soils are olive silt loams, with grey gleyans along subsoil cracks. Lower elevation soils are mainly olive silty clay loams with dark grey gleyans. Soils in the extreme south show slightly saline patches in the dry season, while elsewhere soils are non-saline. Soils of AEZ 18 are grey to olive, finely stratified, calcareous, silty alluvium which becomes saline in the dry season. AEZ 19 soils occupy deeply flooded sections, and are partly protected by the CIP embankment. Raised cultivation platforms, constructed from both calcareous and non-calcareous materials, are numerous in the south and centre.

Soil survey data for the CIP are based on a survey carried out in 1966-67 by the Soil Resources Development Institute (SRDI 1966), and updated in 1984 (Ibrahim 1984) for inclusion in the Agroecological Zones report (FAO 1988) (Map 3). The *Madna* series occupies the higher elevation sites ( $A_1$  and  $B_1$ ) in the Meghna floodplain. The soils are characterized by a light grey to grey mottled brown, friable, loam topsoil overlying an olive to olive-grey, friable, sandy loam subsoil with weak coarse prismatic and subangular blocky structure. This is underlain by a partially stratified olive to olive grey silt loam to sandy loam substratum. The *Chandpur* series

occurs in the lower elevation sites ( $A_2$  and  $B_2$ ) in the floodplain, and soils are characterized by an olive, firm loam topsoil overlying a grey to olive, firm, silty loam with moderately thick grey cutans. This is underlain by an olive to grey, friable, silt loam substratum. The *Tippura* series lies within the higher elevations of the old Meghna estuarine floodplain ( $C_1$  and  $D_2$ ), where soils have olive to olive grey mottled yellowish brown, friable, loam and silty loam topsoils overlying olive grey mottled yellowish brown, silt loam with moderate coarse prismatic and blocky structure. At the lower elevations the *Burichang* series occurs ( $C_2$  and  $D_1$ ), characterized by dark to dark grey loam topsoil overlying very dark grey silty clay loam subsoil with strong coarse prismatic and blocky structure and dark grey cutans. A comparative soil classification for the various series appears in Table 5.1. Texture analyses for soil samples taken from the sample plots (two integrated samples per location) are shown in Figure 5.1 and compared to the texture of the deposited sediments (Meghna outside embankment only).

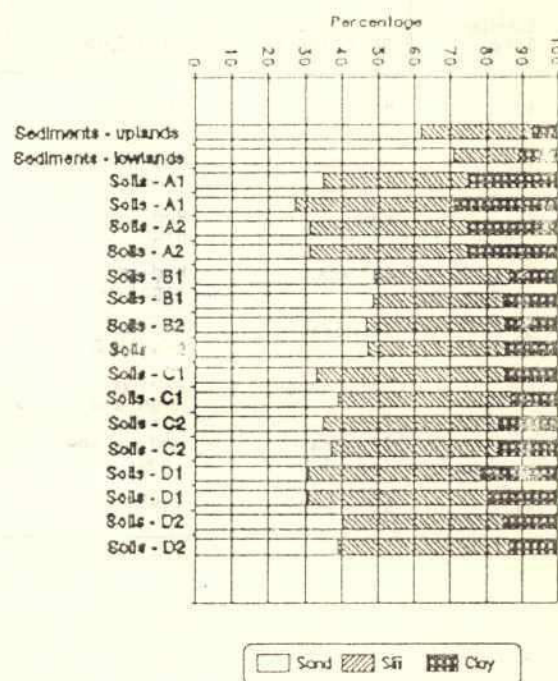


Figure 5.1. Texture of soil and sediment samples, CIP.



## 5.2 Land Types and Seasonal Flooding

Before the implementation of the CIP, major soils of the area were typically flooded to depths of 90-200cm by rain- and river water for 4-6 months during the monsoon season. Since 1976, the soils inside the project area have been protected against floods. Surface inundation depths in the sampling sites (B<sub>1</sub>, B<sub>2</sub>, C<sub>1</sub>, C<sub>2</sub>) now typically reach only 30-90cm during the monsoon period. Soils outside the project area on the

Meghna River front (sampling sites A<sub>1</sub> and A<sub>2</sub>) are still subject to seasonal tidal inundation during the period mid-June to the end of October. The area is exposed to erosion by the Meghna River, and topsoils receive a deposition of fresh sediments each year. The area outside the embankment on the Dakatia River side is flooded mainly by rain water. Summary data on flooding, land types and soil phases of the sampling sites are shown in Table 5.2.

Table 5.1. Soil Classification of Soil Series of Sampling Sites

| Soil Series | Parent Material               | General Soil Type                       | FAO Soil Unit            | USDA Soil Family |
|-------------|-------------------------------|-----------------------------------------|--------------------------|------------------|
| Madna       | Lower Meghna River Alluvium   | Calcareous grey flood-plain soil        | Chromi Calcaric Gleysols | Aeric Haplaquept |
| Chandpur    | Lower Meghna River Alluvium   | Calcareous grey flood-plain soil        | Chromi Calcaric Gleysols | Aeric Haplaquept |
| Tippera     | Old Meghna Estuarine Alluvium | Noncalcareous dark grey floodplain soil | Chromi Eutric Gleysols   | Aeric Haplaquept |
| Burichang   | Old Meghna Estuarine Alluvium | Noncalcareous dark grey floodplain soil | Chromi Eutric Gleysols   | Aeric Haplaquept |

Source: FAO/UNDP (1988)

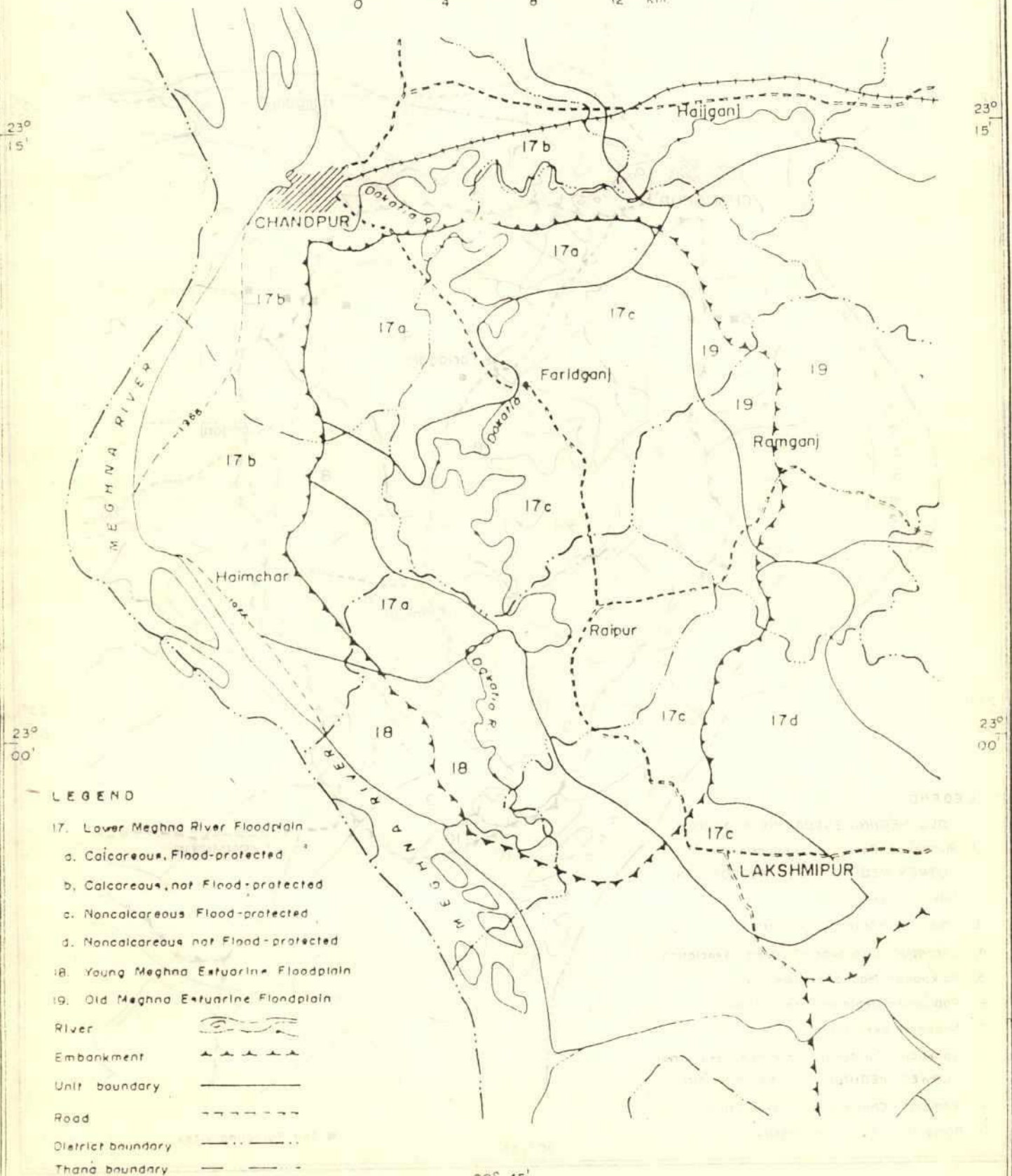
Table 5.2. Land Types and Flooding Depths and Duration in Sampled Sites at CIP.

| Sample Site    | Soil Series | Land Type       | Flooding Depth (cm) | Flooding Duration in 1993 |                  |
|----------------|-------------|-----------------|---------------------|---------------------------|------------------|
|                |             |                 |                     | From                      | Until            |
| A <sub>1</sub> | Madna       | Medium highland | 80-95               | 10 June-20 June           | 15 Oct - 30 Oct  |
| A <sub>2</sub> | Chandpur    | Medium low-land | 110-120             | 30 June-15 June           | 20 Oct - 1 Nov   |
| B <sub>1</sub> | Madna       | Medium highland | 20-30               | 20 June-1 July            | 30 Sept - 15 Oct |
| B <sub>2</sub> | Chandpur    | Medium highland | 40-60               | 15 June-25 June           | 15 Oct - 30 Oct  |
| C <sub>1</sub> | Tippera     | Medium highland | 40-70               | 10 June-20 June           | 20 Oct - 30 Oct  |
| C <sub>2</sub> | Burichang   | Medium highland | 80-90               | 8 June-20 June            | 20 Oct - 30 Oct  |
| D <sub>2</sub> | Tippera     | Medium low-land | 100-120             | 7 June-15 June            | 15 Oct - 25 Oct  |
| D <sub>1</sub> | Burichang   | Lowland         | 170-210             | 30 May-10 June            | 20 Oct - 30 Oct  |



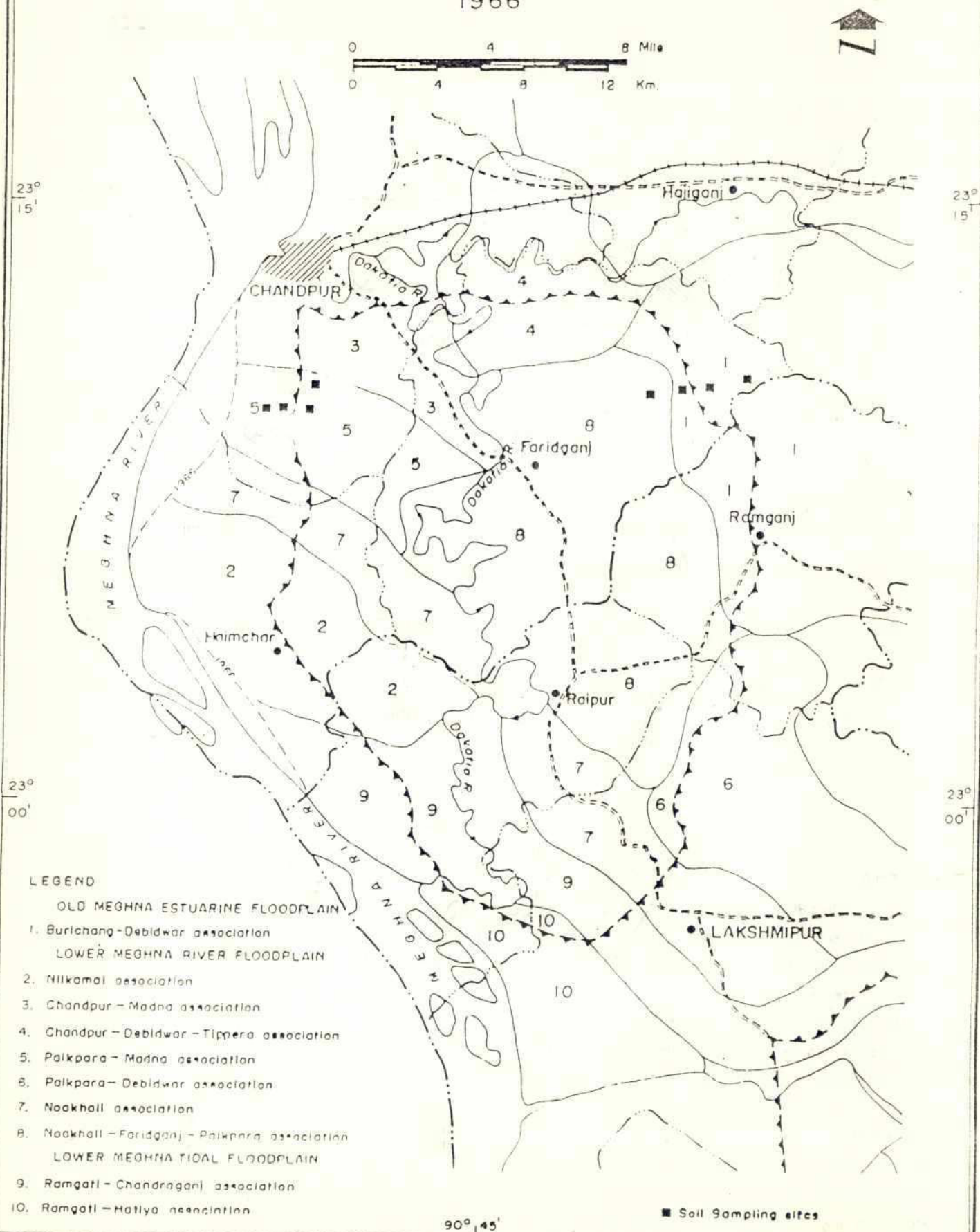
# AGROECOLOGICAL REGIONS MAP OF CHANDPUR IRRIGATION PROJECT 1988

0 4 8 12 Mile  
0 4 8 12 Km





# SOIL ASSOCIATION MAP OF CHANDPUR IRRIGATION PROJECT 1966





## CROPPING PATTERNS AND CROP PRODUCTION

## 6.1 Cropping Patterns

Before implementation of the CIP the major cropping pattern of the area was mixed *aus* and *aman*, followed by dryland crops in the winter, practiced on an estimated 60 percent of the cultivable area. Jute was grown instead of *aus* on about 10 percent of the cultivable area. In areas that did not drain quickly after monsoon floods, i.e. the lower elevations in the old Meghna estuarine floodplain, *B. aman* was the main crop; the soils were usually left fallow in the dry season. On higher parts of the landscape, mainly in the south, *T. aman* was grown, preceded by *B. aus*, and followed usually by dryland *rabi* crops. This latter cropping pattern occupied 30 percent of the cultivable area. Before 1975, *boro* was virtually non-existent in the project area. Cropping intensity prior to CIP implementation was about 160 percent.

Since project implementation there has been a rapid increase in *boro* cultivation. The increase in *boro* area has taken place at the cost of *rabi* and *aus* crops in the area. The dryland *rabi* area decreased from about 21,870ha to 7695ha over the period 1975 to 1981. Chillies and pulses declined while cultivation of potato and wheat increased. Areas under jute decreased from 3645ha in 1976 to 1013ha in 1982.

Reduced flood depths inside the project area have eliminated the use low yielding varieties of *B. aman* in favor of introduced *T. aman* crops, but the area of high yielding variety (HYV) *T. aman* still comprises only about 30 percent of total area under *T. aman*. HYVs may be constrained by drainage problems that still occur over considerable areas. Cropping intensity of the project in 1981 was about 177 percent.

Cropping practices outside the project area have also changed significantly. *Boro* is cultivated on about 15-20 percent of the cultivable area on the Meghna side of the embankment, and has become one of the major crops in the deeply

flooded areas outside the embankment on the Dakatia side. On the Meghna side, transplanted deepwater (T.D.) *aman* is grown in the area where previously *B. aman* was grown. Cropping intensity outside the areas increased since the implementation of the project.

Present cropping patterns in the soil sampling blocks are shown in Figure 6.1. Irrigated cropping patterns are practiced in all the sampling sites except in  $A_1$  and  $A_2$ . Inside the project areas, high cropping intensities were observed in blocks  $B_1$  and  $B_2$  (200-300 percent). BR-11, BR-14 and IR-8 are the HYVs grown in the *aman* and *boro* cropping seasons.

## 6.2 Crop Production

Crop production inside the project areas is satisfactory by national standards (Table 6.1). Annual paddy production in the  $B_1$  and  $B_2$  blocks ranges between 9.5-10.5 tonnes/ha. Production outside the embankment in blocks  $A_1$  and  $A_2$  ranges between 1.5-2.5 tonnes/ha. Higher production inside the areas is mainly due to the use of HYVs. Crop production in blocks  $C_1$  and  $C_2$  is not as high (7.2-8.5 tonnes/ha) as in  $B_1$  and  $B_2$ , but the figure is significantly higher than outside in blocks  $D_1$  and  $D_2$  (5.0-6.5 ton/ha).

Crop production is constrained at the lower elevations in  $C_2$  by heavy rainfall in the monsoon season, when *T. aman* is damaged by drainage congestion. Farmers usually attempt a second transplantation to recover the loss. Existing flood depths do not permit HYV practice in the *aman* season. Crops are frequently damaged outside the project area towards the Dakatia side. Farmers of block  $D_1$  do not cultivate *khariif* crops because of the risk of crop damage by floods. Farmers report losses of *B. aman* crops by flood in block  $D_2$ .

Based on information collected from farmers in the area, the yield levels of *boro* crops inside the CIP are fairly stable, except in  $B_1$  where they



| River Frontage | Embankment | Elevation | Sub-Group | J       | F      | M | A        | M    | J                | J | A | S           | O | N | D   |
|----------------|------------|-----------|-----------|---------|--------|---|----------|------|------------------|---|---|-------------|---|---|-----|
| Meghna         | Outside    | Upper     | 1         | P'tato  |        |   |          |      | Mixed Aus & Aman |   |   |             |   |   | Po  |
|                |            |           | 2         | Lentils |        |   |          | Jute |                  |   |   | T.D. Aman   |   |   | Len |
|                | Outside    | Lower     | 1         | Lentils |        |   |          | Jute |                  |   |   | T.D. Aman   |   |   | Len |
|                |            |           | 2         | Mus     | Chilli |   |          |      |                  |   |   | T.D. Aman   |   |   | Mus |
|                | Inside     | Upper     | 1         | Po      |        |   | Boro (H) |      |                  |   |   | Aman (H)    |   |   | Po  |
|                |            |           | 2         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (H) |   |   |     |
|                |            |           | 3         | Po      |        |   | Boro (H) |      |                  |   |   | T. Aman (H) |   |   | Po  |
|                |            |           | 4         | Po      |        |   | Boro (H) |      |                  |   |   | T. Aman (H) |   |   | Po  |
|                | Inside     | Lower     | 1         | Po      |        |   | Boro (H) |      |                  |   |   | T. Aman (H) |   |   | Po  |
|                |            |           | 2         | Po      |        |   | Boro (H) |      |                  |   |   | T. Aman (H) |   |   | Po  |
|                |            |           | 3         | Po      |        |   | Boro (H) |      |                  |   |   | T. Aman (H) |   |   | Po  |
|                |            |           |           |         |        |   |          |      |                  |   |   |             |   |   |     |
| Dakatia        | Outside    | Upper     | 1         |         |        |   | Boro (H) |      |                  |   |   | B. Aman     |   |   |     |
|                |            |           | 2         |         |        |   | Boro (H) |      |                  |   |   | B. Aman     |   |   |     |
|                |            |           | 3         |         |        |   | Boro (H) |      |                  |   |   | B. Aman     |   |   |     |
|                |            |           | 4         |         |        |   | Boro (H) |      |                  |   |   | B. Aman     |   |   |     |
|                | Outside    | Lower     | 1         |         |        |   | Boro (H) |      |                  |   |   |             |   |   |     |
|                |            |           | 2         |         |        |   | Boro (H) |      |                  |   |   |             |   |   |     |
|                |            |           | 3         |         |        |   | Boro (H) |      |                  |   |   |             |   |   |     |
|                |            |           | 4         |         |        |   | Boro (H) |      |                  |   |   |             |   |   |     |
|                | Inside     | Upper     | 1         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (H) |   |   |     |
|                |            |           | 2         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (L) |   |   |     |
|                |            |           | 3         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (H) |   |   |     |
|                |            |           | 4         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (L) |   |   |     |
|                |            |           | 5         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (L) |   |   |     |
|                |            |           | 6         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (H) |   |   |     |
|                |            |           | 7         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (L) |   |   |     |
|                | Inside     | Lower     | 1         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (L) |   |   |     |
|                |            |           | 2         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (L) |   |   |     |
|                |            |           | 3         |         |        |   | Boro (H) |      |                  |   |   | T. Aman (L) |   |   |     |

Figure 6.1. Present cropping patterns in sampled areas, CIP.



are decreasing slightly. A slight upward trend is reported for D<sub>1</sub> and D<sub>2</sub>. Although T. *aman* production in 1992 was good due to favorable

agroclimatic conditions, data for other years have shown a declining trend in yield levels. 28

Table 6.1. Crop Yields (tonnes/ha) in Sampled Areas at CIP Study Sites.

|                    | Meghna  |           |         |           | Dakatia |         |         |         |
|--------------------|---------|-----------|---------|-----------|---------|---------|---------|---------|
|                    | Upper   |           | Lower   |           | Upper   |         | Lower   |         |
|                    | Outside | Inside    | Outside | Inside    | Outside | Inside  | Outside | Inside  |
| Mixed aus and aman | 1.5     | -         | -       | -         | -       | -       | -       | -       |
| T.O. aman          | 2.5     | -         | 2.1-2.4 | -         | -       | -       | -       | -       |
| B. aman            | -       | -         | -       | -         | 1.4-1.6 | -       | -       | -       |
| T. aman (H)        | -       | 3.9-4.3   | -       | 4.5-4.7   | -       | 1.8-3.4 | -       | -       |
| T. aman (L)        | -       | -         | -       | -         | -       | 2.6-2.7 | -       | 2.5-3.1 |
| Boro (H)           | -       | 4.9-6.1   | -       | 5.9-6.1   | 4.9-5.1 | 4.6-5.1 | 5.0-5.1 | 5.9-6.1 |
| Jute               | 2.7     | -         | 2.2     | -         | -       | -       | -       | -       |
| Potatoes           | 22.1    | 19.3-22.1 | -       | 19.5-21.0 | -       | -       | -       | -       |
| Mustard            | -       | -         | 1.8     | -         | -       | -       | -       | -       |
| Chilli             | -       | -         | 1.3     | -         | -       | -       | -       | -       |
| Lentils            | 0.8     | -         | 1.3     | -         | -       | -       | -       | -       |



## AGRICULTURAL PRACTICES AND INPUTS

### 7.1 Agricultural Practices

Soils inside the project area are intensively used for agriculture. In blocks B<sub>1</sub>, B<sub>2</sub> and C<sub>1</sub> sites are cultivated by tractors and spades, while in C<sub>2</sub> only country ploughs are used for land preparation. Soils in the study area are tilled 3-4 times in preparation for boro, jute and potato crops, and 2-3 times for T. *aman* crops. Minimum land tilling was noted to take place in preparation for mustard and chili crops. Soils outside the embankment are tilled by country plough and spades. In the A<sub>1</sub> and A<sub>2</sub> blocks no land preparation was made for pulses, and seeds were simply broadcast into standing *aman* crops. Boro and jute crops were weeded 3-4 times in most cases, T. *aman* twice, and potato only once throughout the growing period.

After harvesting of crops, plant residues in the fields are mixed with the soil as organic manure or burned and added as ash (A<sub>2</sub> block only). In the B<sub>1</sub> and B<sub>2</sub> blocks most of the crop remains were removed and very little remained to be mixed with the soil.

### 7.2 Fertilizer and Manure Applications

Chemical fertilizers were applied by farmers for all the crops of the sampling sites of the study area (Figure 7.1 to 7.6). Fertilizers were used more inside the project area than outside because of the higher cropping intensities and preponderance of HYVs. The B<sub>2</sub> block has the highest record of fertilizer use, while minimum fertilizer applications were recorded for A<sub>2</sub>. Urea, triple super phosphate (TSP), single super phosphate (SSP), muriate of potash (MP), and zinc sulphate were commonly applied in most blocks. Manure, in the form of cow dung, and ash were applied to a limited number of fields.

The rate and timing of application of fertilizers varied from site to site. Major fertilizer applications were observed for potato crops, both inside and outside the project. In the B<sub>1</sub> and

B<sub>2</sub> blocks, application of urea ranged between 328-642 kg/ha, SSP between 822-1316 kg/ha and MP 198-395 kg/ha. Farmers used these high application rates to carry over nutrients for their next major *boro* crop. During *boro* cultivation, only urea and zinc sulphate were applied at the rate of 66-132 and 16-25 kg/ha respectively at the transplanting period of this crop. In *boro* fields not preceded by potatoes, amounts of urea ranging from 197-330 kg/ha were applied in three installments at intervals of 20 days each. TSP, MP and zinc sulphate were applied once only, along with the first application of urea at rates of 166-370, 91-99 and 8-12 kg/ha respectively.

Fertilizers were applied in smaller quantities to T. *aman* crops which are grown only inside the CIP area. HYV T. *aman* received 110-264 kg/ha of urea. Other fertilizers were not applied. For local T. *aman* crops, 70-110 kg/ha of urea were applied. Use of TSP and MP in very low doses was recorded in some plots. Farmers also used fertilizer on seedbeds of HYV crops.

Jute crops in sites A<sub>1</sub> and A<sub>2</sub> received fairly high doses of fertilizers. Applications of urea ranged between 132-189, TSP between 118-132 and MP 118 kg/ha. Cow dung and ash were also added as manure. T.D. *aman* received only urea fertilizer at the rate of 33 - 118 kg/ha.

### 7.3 Insecticides

B. *aus* crops in site A<sub>1</sub> were badly damaged by stem borer (*majra*) and the yield from such damaged crops was only 0.2 tons/ha. In other sites damage due to insects was observed to be slight. Common insect pests on the *boro* crop were Hispa (*pamri*) and stem borers. Farmers generally applied Azodin and Dimecron at rates of 0.90 kg/ha and 1.16 kg/ha respectively during March and April. The rates and timing of application of insecticides were more or less the same both inside and outside the project.



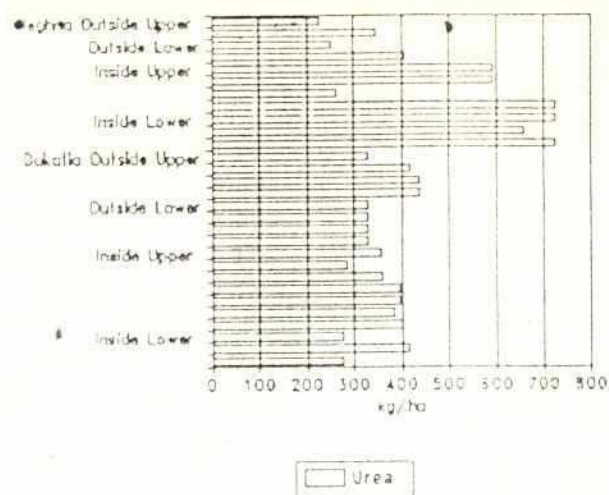


Figure 7.1. Rates of urea application to sampled areas, CIP.

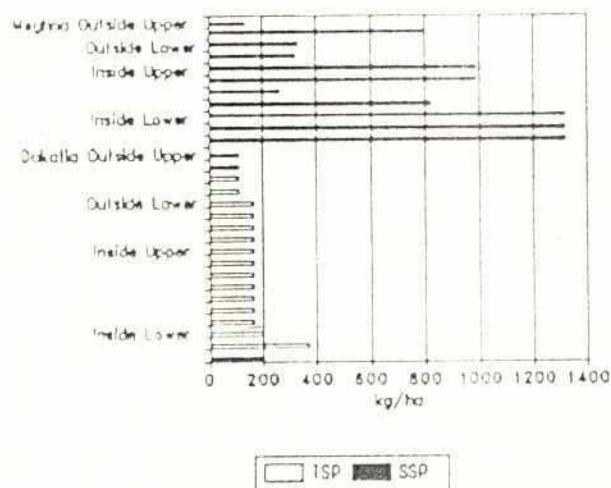


Figure 7.2 Rates of phosphate application to sampled areas, CIP.

Swarming caterpillar (*leda poka*), stem borers and grass hoppers (*faring*) were the insects most observed in T. aman crops. Azodin, Dimecron and Marshall were applied in fields at the rate of 0.9 kg/ha, 0.9-1.1 kg/ha and 0.4 kg/ha respectively. T.D. aman crops were infested with insects locally known as *tut*, *meoa* and *jara*. To control these insects, Dimecron at the rate of 0.80 kg/ha and Furadan at the rate of 16 kg/ha were used. Common insects on B. aman crops were Hispa and stem borers, for which

farmers applied Dimecron at the rate of 0.87 kg/ha.

#### 7.4 Irrigation

Irrigation water was mainly used on *boro* crops. Boro transplantation started as soon as the irrigation water was available in the field. During the growing period, water was applied 4-6 times to the fields.



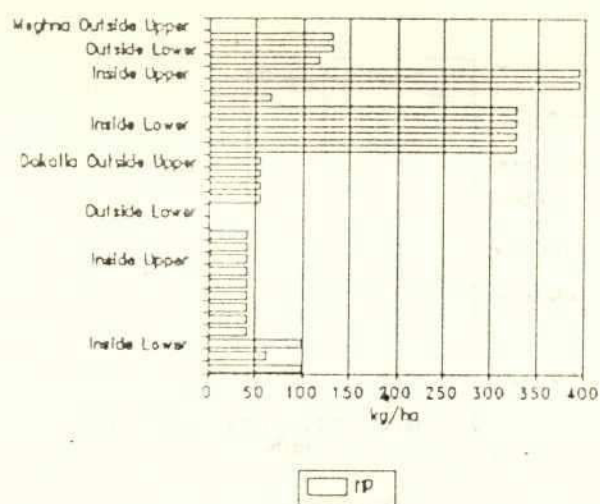


Figure 7.3. Rates of application of muriate of potash to sampled areas, CIP.

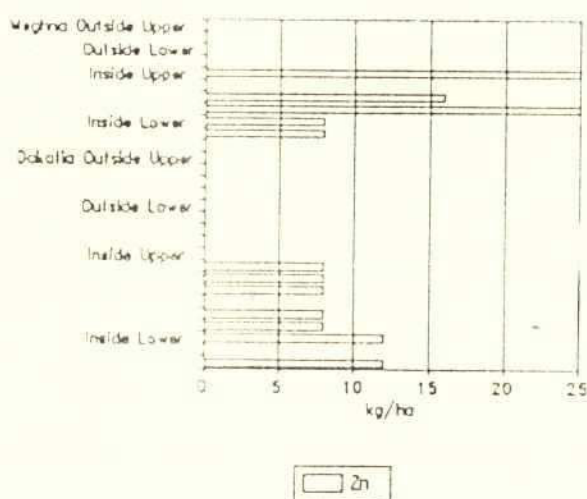


Figure 7.4. Rates of application of zinc fertilizer to sampled areas, CIP.



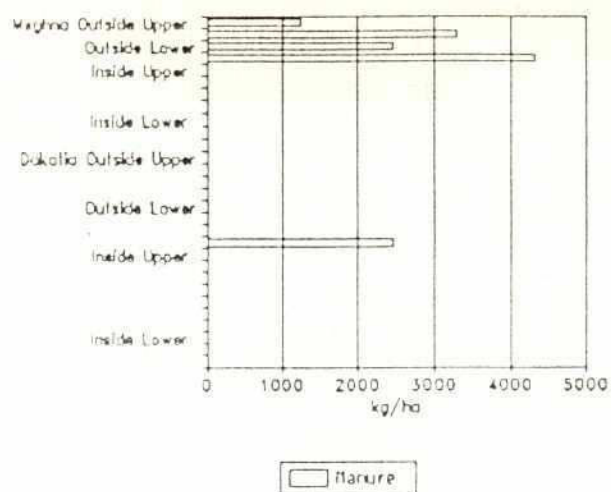


Figure 7.5. Rates of manure application to sampled areas, CIP.



## DISSOLVED NUTRIENTS

## 8.1 River Water During Monsoon

The complete set of monsoon season surface water samples from the study area comprised 60 individual samples (Annex 3) collected from five locations (two on the Meghna, two on the Dakatia and one inside the embankment from the main drainage canal). Each site was sampled four times during the monsoon period, one sample drawn from each of three depth strata. No significant differences were detected between strata for any of the 14 parameters (Annex 4), and these were thus treated as replicate samples for each sampling site. Results of the water sample analyses are shown in Figures 8.1 to 8.11. Levels of ammonium nitrogen, copper and boron in the samples were at or below detectable limits.

All waters in the vicinity of the study area were neutral to very slightly acidic (Figure 8.1). Statistically significant differences occurred between sampling periods but not between sites. Meghna River water was high in total dissolved solids (TDS) (Figure 8.2), but contained only moderate amounts of dissolved calcium and low levels of magnesium and potassium ions (Figures 8.3, 8.6 and 8.9). The bulk of the TDS thus probably consisted of sodium, chlorides and bicarbonates, which are generally high in the Ganges/Brahmaputra basin (Murray *et al.* 1992), and possibly dissolved organic carbon (DOC) which is typically high in large rivers during floods (Depetris *et al.* 1992, cited by Murray *et al.* 1992). Other dissolved inorganic soil nutrients were low in the Meghna waters, although during the late monsoon, when river levels were subsiding, zinc concentrations in the Meghna doubled and iron levels in both the Meghna and the Dakatia rose about five-fold, suggesting runoff of leachates at this period.

In comparison to Meghna River water, Dakatia waters were significantly lower in calcium, magnesium, phosphorus, manganese and especially TDS, but not in potassium and sulphur.

The relatively lower levels of most dissolved elements was indicative of the high rainwater and local drainage content of the Dakatia, as opposed to the extensive floodplain-derived runoff which made up the bulk of the Meghna waters.

The results of the water analyses indicated that for most soil nutrients considered in this study, the inputs from the Meghna River in the form of dissolved ions were moderate for calcium and low for others. The highest inputs were in dissolved forms which were not specifically analyzed, possibly DOC, bicarbonates and

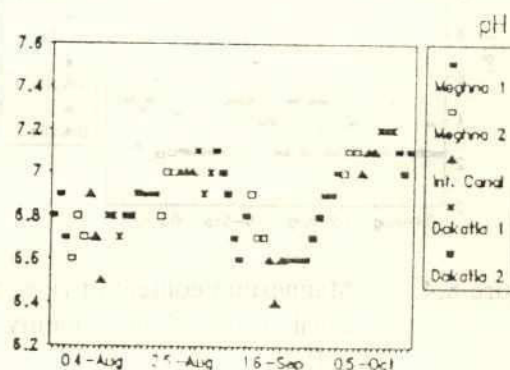


Figure 8.1. pH of river and canal water in vicinity of CIP.

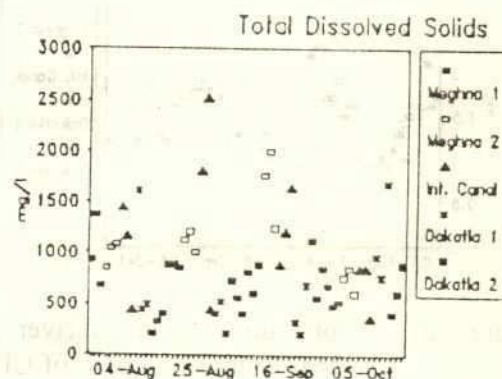


Figure 8.2. Total dissolved solids contents of river and canal water in vicinity of CIP.

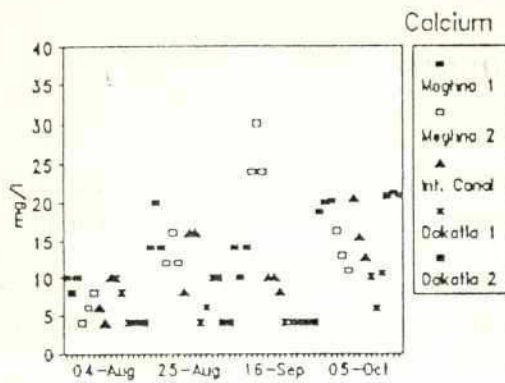


Figure 8.3. Calcium content of river and canal water from vicinity of CIP.

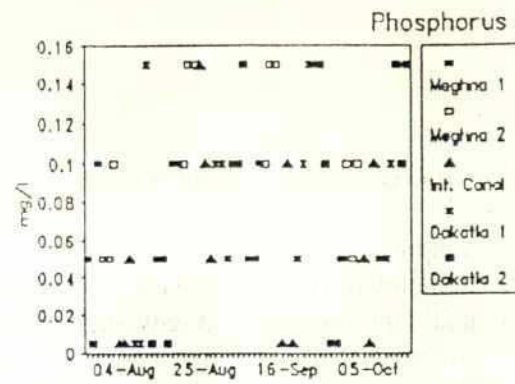


Figure 8.6. Phosphorus content of river and canal water in vicinity of CIP.

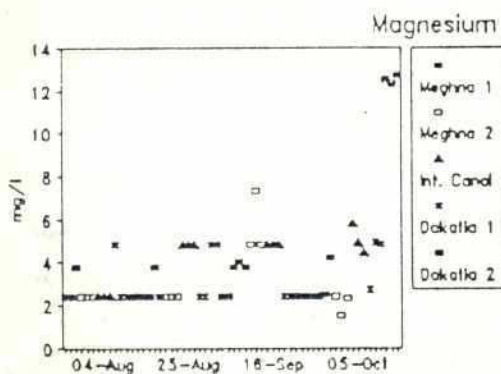


Figure 8.4. Magnesium content of river and canal water from vicinity of CIP.

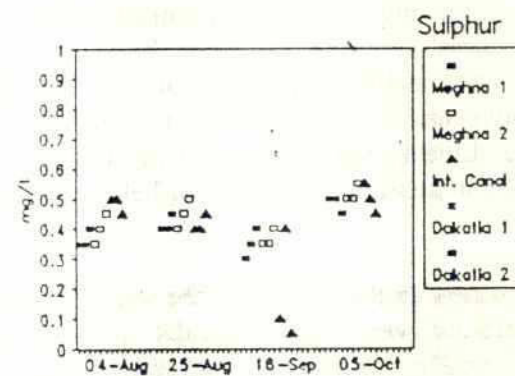


Figure 8.7. Sulphur content of river and canal water in vicinity of CIP.

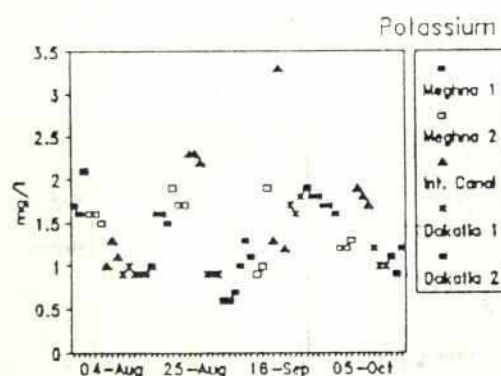


Figure 8.5. Potassium content of river and canal water in vicinity of CIP.

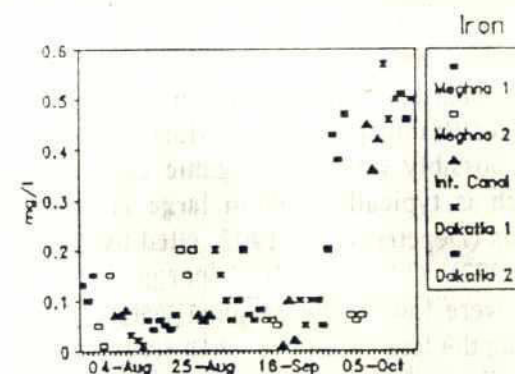


Figure 8.8. Iron content of river and canal water in vicinity of CIP.



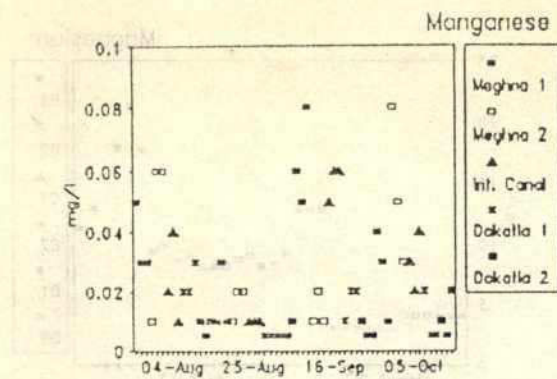


Figure 8.9. Manganese content of river and canal water in vicinity of CIP.

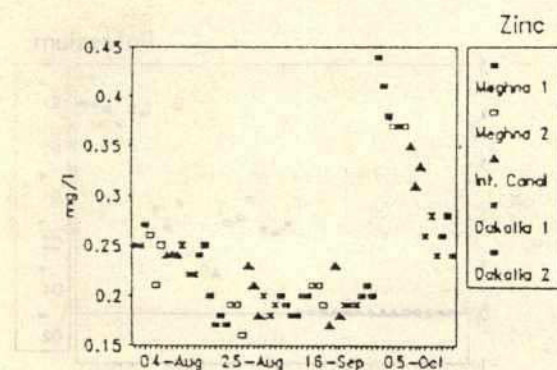


Figure 8.10. Zinc content of river and canal water in vicinity of CIP.

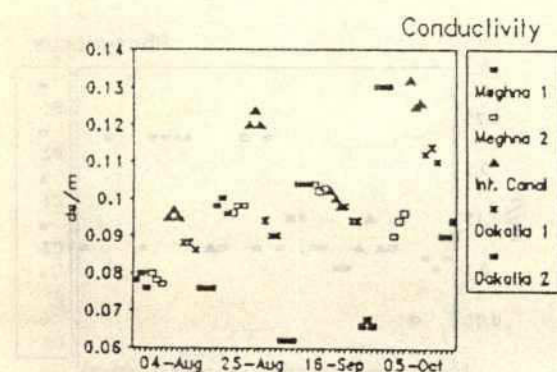


Figure 8.11. Electrical conductivity of river and canal water in vicinity of CIP.

chlorides. Dissolved nitrogen inputs were very low. Dissolved nutrient inputs from the Dakatia were significantly lower than the Meghna for all nutrients except potassium and sulphur.

## 8.2 Dry Season Irrigation Water

Two sets of dry season irrigation water samples were collected, in March and April 1993 (Annex 3). These were collected from irrigation canals supplying water to the plots where soil samples were collected (with the exception of those outside the embankment on the Meghna side, where no irrigation was practiced). Water in the irrigation canal was pumped from the Dakatia River and delivered to feeder canals via gravity.

Irrigation water was slightly more alkaline than outside river water (Figure 8.12) and had considerably lower total dissolved solids content (Figure 8.13), and a lower electrical conductivity (Figure 8.23). Most nutrients were present in higher concentrations than in river water (Figures 8.14 to 8.22), which suggests that differences in dissolved solids was due to lower concentrations of chlorides, sulphates and sodium in the irrigation water. Ammonium nitrogen was detected in the irrigation canals but only in non-quantifiable traces. Copper was found in small concentrations in the irrigation water, but was not previously detected in measurable quantities in outside river water.

The general pattern for calcium, copper, potassium and magnesium was to increase in concentration during the irrigation period. Other nutrients remained at approximately the same concentrations throughout the dry season. All nutrients were present in higher concentrations than in the outside river water. Some of these nutrients were present in fertilizer applications (calcium, potassium) and water concentrations may have been the result of run-off or direct fertilizer application to the water surface. However, many of the nutrients were not present in fertilizers, suggesting that the increased concentrations were due to topsoil leaching.

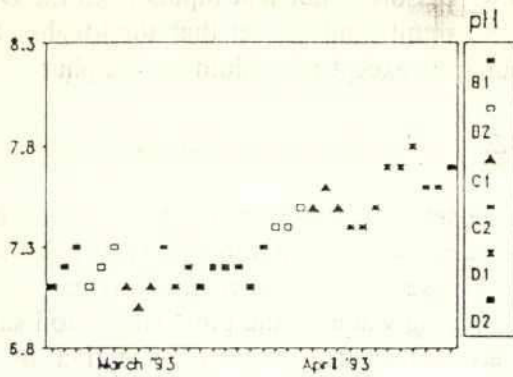


Figure 8.12. pH of dry-season irrigation water in CIP. Legends indicate sampling area supplied by irrigation water.

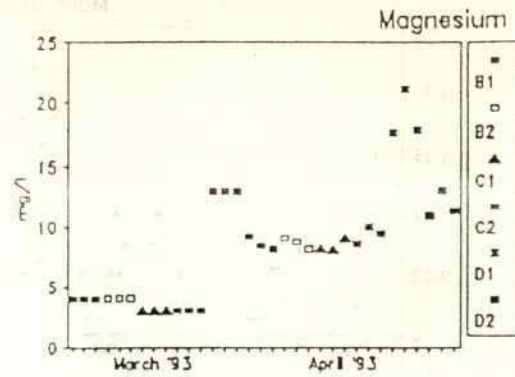


Figure 8.15. Magnesium content of dry-season irrigation water in CIP.

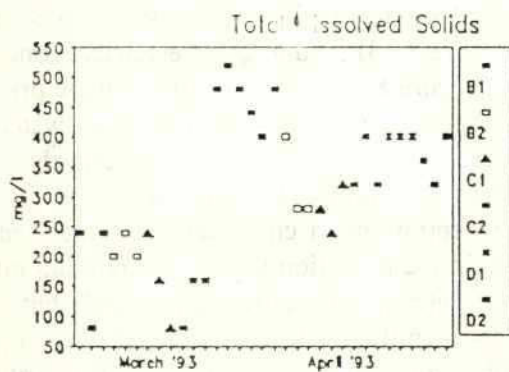


Figure 8.13. Total dissolved solids content of dry-season irrigation water in CIP.

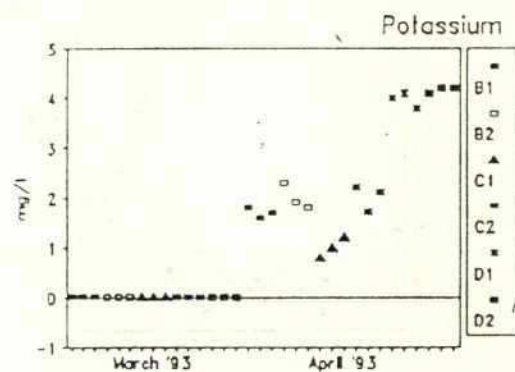


Figure 8.16. Potassium content of dry-season irrigation water in CIP.

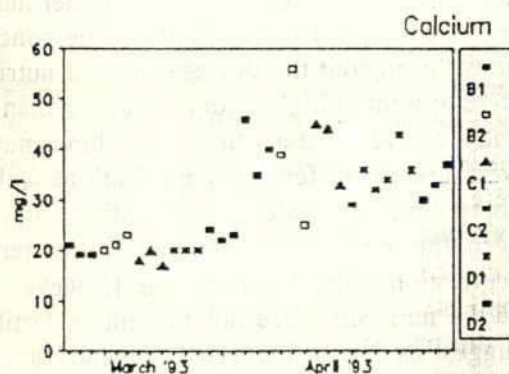


Figure 8.14. Calcium content of dry-season irrigation water in CIP.

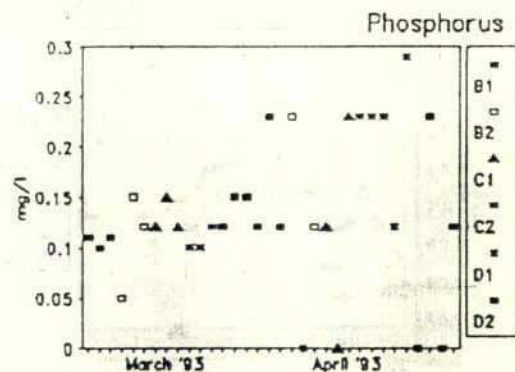


Figure 8.17. Phosphorus content of dry-season irrigation water in CIP.



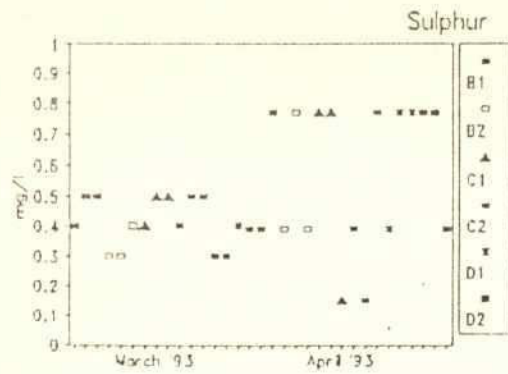


Figure 8.18. Sulphur content of dry-season irrigation water in CIP.

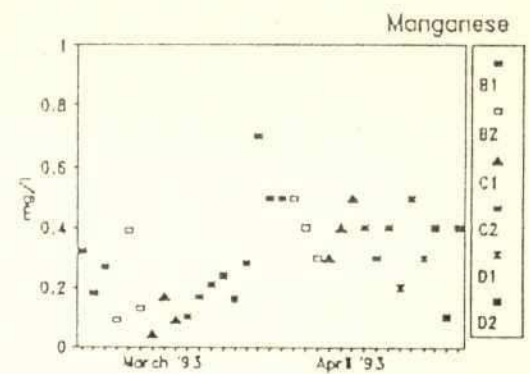


Figure 8.21. Manganese content of dry-season irrigation water in CIP.

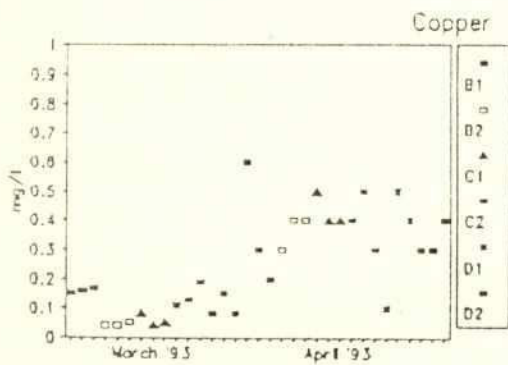


Figure 8.19. Copper content of dry-season irrigation water in CIP.

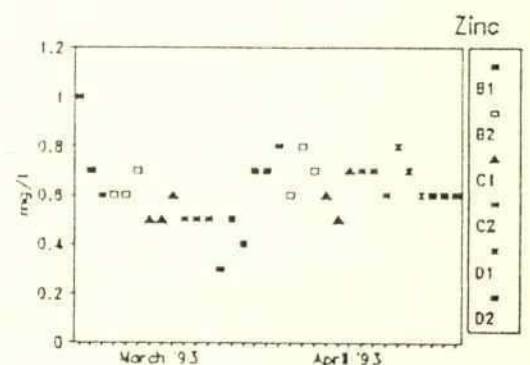


Figure 8.22. Zinc content of dry-season irrigation water in CIP.

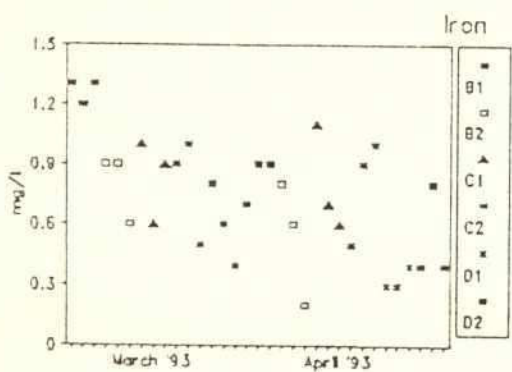


Figure 8.20. Iron content of dry-season irrigation water in CIP.

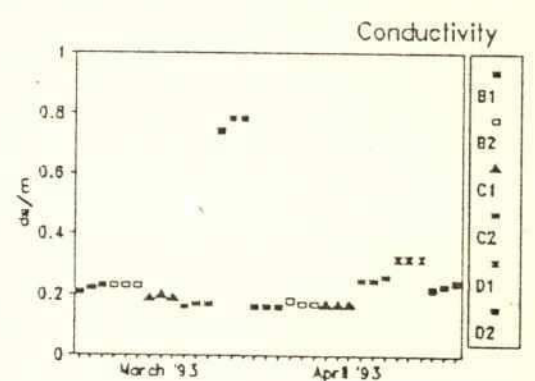


Figure 8.23. Electrical conductivity of dry-season irrigation water in CIP.

## BLUE-GREEN ALGAL DISTRIBUTION AND ABUNDANCE

With few exceptions, BGA were found to be abundant in all sampled sites and in all of the four sampled periods during the monsoon (Figures 9.1, 9.2). Exceptions to this were samples of floating BGA which were not found in water samples inside the embankment in October, and it likely that by this time floating BGA had all settled in the paddies and were attached to some form of substrate.

A total of 16 species belonging to 7 genera of nitrogen fixing BGA were identified from both flood-protected and unprotected fields (Annex 5). The numbers of filaments of different species varied widely from location to location. Some genera occurred throughout the flood period, i.e. *Aulosira*, *Nostoc*, *Anabaena* and *Gloeotrichia*. A gradual increase in the number of BGA, both floating and attached, was recorded from the beginning of flooding, and attained a maximum after about 80 days (total 2927 filaments) of the 130 days total flood period. Thereafter the numbers of BGA filaments gradually declined in the unprotected areas.

BGA filament numbers were higher when occurring free in water samples than when attached to rice plants. The relative abundance of A genera and species recorded from the Dakatia River sites was higher in the unprotected areas (total filaments 2927) than in the protected areas (total filaments 1446) during September, probably because flood water contained higher nutrient concentrations than rain water. A similar situation was observed in the Meghna River sites, where 1006 filaments were recorded in the unprotected area and 575 filaments in the protected area during the same period. Heterocystous BGA filaments were encountered in negligible numbers in the *boro* season (March-April).

Overall BGA abundance was greater in the Dakatia River sites than the Meghna River sites due to the clearer water which permitted more efficient photosynthesis. BGA abundance from

area to area may also have differed because of soil tillage practices.

The occurrence of flowing sediment laden waters outside the embankment on the Meghna side appeared to have little effect on BGA abundance when they were attached to plant substrates, but floating BGA were relatively much less abundant on the Meghna side than on the Dakatia side of the study area, likely because of the greater volumes of water and the relatively greater dilution factors.

The biological nitrogen fixation by BGA could not be estimated in this experiment due to shortage of time, equipment and field facilities. It is difficult to calculate the actual amount of nitrogen fixation by BGA in particular ecological situations since many biotic and environmental factors are involved. In most sampling periods the total number of BGA filaments was much higher in unprotected areas than in protected areas, so it was likely that the fixation of atmospheric nitrogen was higher there as well. A rough calculation based on literature data indicates that atmospheric nitrogen fixation in the unprotected areas along the Dakatia River could have approximated 16-20 kg N/ha. This amount of nitrogen addition to rice fields is fairly small compared to chemical fertilizer applications, but the long-term effect on soil quality is superior to that of chemical fertilizers because of the absence of soil and water pollution and the associated contribution to the humus content of the soil.



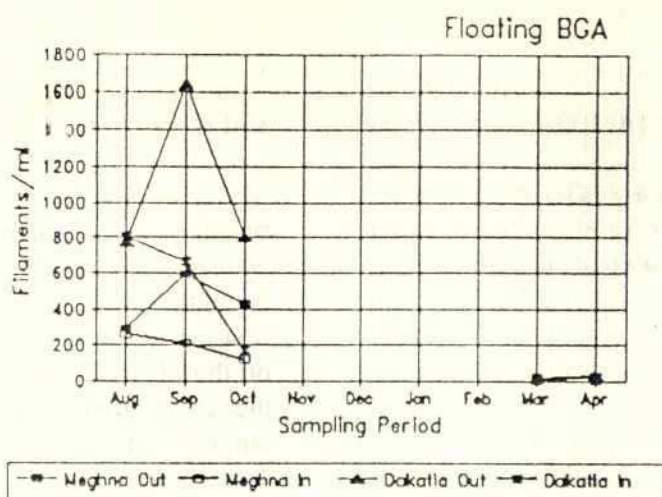


Figure 9.1. Abundance of floating BGA in water samples, CIP.

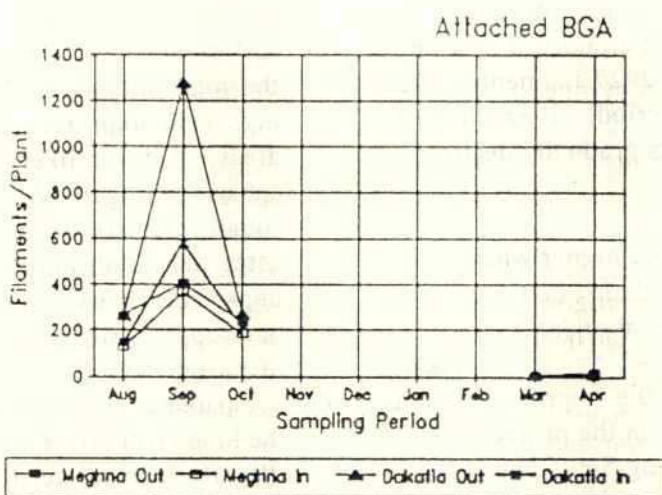


Figure 9.2. Abundance of attached BGA on rice culms, CIP.

### NUTRIENT CONTENT OF DEPOSITED SEDIMENTS

A major finding of the study was that there were little or no deposited sediments along the Dakatia side of the CIP embankment, as evidenced by a lack of deposited sediments in the collection trays, and thus it was concluded that most flooding was derived from sediment-free rainwater. This is probably the most common phenomenon in this area, as confirmed by the views of local farmers. Dakatia River flooding, with some sediment deposition may occur in years of exceptionally high floods, however, hence occasional deposition of river-borne sediments cannot be completely discontinued.

Sampling intensity of sediments deposited within the unprotected areas by the Meghna River was lower than planned for two reasons. The 1992 flood year was an exceptionally low one, and little flooding occurred in some sections, with little or no sediment deposition in the collection trays. Several collection trays were removed by local people before they could be recovered by the study team. A total of nine deposited sediment samples were eventually retrieved along the Meghna side of the embankment, five at the lower elevations within the medium lowlands and four in the medium highlands. Recovered sediment samples were all sandy loams.

Table 10.1. Texture of Deposited Sediments along Meghna River, CIP.

| Location         | Percent |      |      |
|------------------|---------|------|------|
|                  | Sand    | Silt | Clay |
| Upper Elevations | 62      | 31   | 7    |
| Lower Elevations | 71      | 18   | 11   |

In terms of nutrient content, deposited sediment samples were substantially higher in some nutrients than the surrounding soils on which they were deposited, substantially lower for others and intermediate between pre- and postmonsoon soil nutrient levels in a few (Table 10.1). Calcium and sulphur (in sediments deposited at lower elevations), and potassium, manganese and nitrogen were significantly higher in deposited sediments than in soils, the latter two substantially

so. By contrast, copper and zinc contents of the sediments at the upper elevations were quite significantly lower than those in the soils. The conductivity and organic matter content of sediments recovered at the lower elevations were significantly higher than that in the surrounding soils. Iron, magnesium, sulphur (upper elevations) and zinc (lower elevations) concentrations in sediments were intermediate between levels measured in soils during the pre- and postmonsoon periods respectively, suggesting that addition of these sediments was likely responsible for the elevation of soil concentrations over the flooding period.

With the exception of copper and phosphorus, nutrient concentrations of sediments deposited at the lower elevations was significantly higher than those deposited at upper elevations. The duration of flooding at the various elevations varied by a few days at most (Table 5.1), hence this was not likely to have been a causative factor in nutrient deposition. Differential textural analysis (Table 10.1) indicates a higher sand and higher clay content of sediments deposited at lower elevations. It is possible that the higher clay content may have contributed to the increased concentrations of nutrients at lower elevations because of the adsorbed ions.

Principal components analysis using the first two extracted components (Figures 10.1, 10.2) confirms the considerable differences between the nutrient content of deposited sediments and the nutrient contents of the Chandpur and Madna soils on which they were deposited, and confirms that the deposited sediments were indeed introduced from outside the area and were not simply local soils redeposited by moving flood waters.



Table 10.2. Comparison of Soil Nutrient Concentrations in Deposited Sediments and in Soils in Unprotected Areas Adjacent to Meghna River.

|                           | Pre-Monsoon | Deposited Sediments | Post-Monsoon |
|---------------------------|-------------|---------------------|--------------|
| <b>Number of Samples</b>  |             |                     |              |
| Upper Elevations          | 20          | 5                   | 20           |
| Lower Elevations          | 20          | 4                   | 20           |
| <b>pH</b>                 |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 5.8         | 6.6                 | 5.7          |
| SD                        | 0.2         | 0.1                 | 0.1          |
| Minimum                   | 5.5         | 6.5                 | 5.6          |
| Maximum                   | 6.1         | 6.7                 | 5.8          |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 5.6         | 6.3                 | 5.3          |
| SD                        | 0.1         | 0.0                 | 0.1          |
| Minimum                   | 5.4         | 6.3                 | 5.1          |
| Maximum                   | 5.8         | 6.4                 | 5.5          |
| <b>Organic Matter %</b>   |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 3.0         | 2.4                 | 2.3          |
| SD                        | 0.2         | 0.4                 | 0.2          |
| Minimum                   | 2.7         | 1.7                 | 2.0          |
| Maximum                   | 3.3         | 2.9                 | 2.9          |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 3.0         | 5.1                 | 2.6          |
| SD                        | 0.2         | 0.5                 | 0.3          |
| Minimum                   | 2.5         | 4.4                 | 2.1          |
| Maximum                   | 3.3         | 5.8                 | 3.1          |
| <b>Calcium meq/100g</b>   |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 10.1        | 9.4                 | 9.0          |
| SD                        | 0.5         | 0.3                 | 0.7          |
| Minimum                   | 9.0         | 8.9                 | 8.0          |
| Maximum                   | 10.7        | 9.9                 | 10.2         |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 10.3        | 12.0                | 11.0         |
| SD                        | 0.4         | 1.4                 | 2.5          |
| Minimum                   | 8.9         | 10.6                | 8.3          |
| Maximum                   | 10.8        | 14.0                | 17.0         |
| <b>Magnesium meq/100g</b> |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 5.7         | 3.5                 | 3.0          |
| SD                        | 0.4         | 0.4                 | 0.3          |
| Minimum                   | 4.8         | 3.1                 | 2.6          |
| Maximum                   | 6.2         | 4.3                 | 3.5          |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 4.4         | 4.5                 | 2.3          |
| SD                        | 0.3         | 0.5                 | 0.2          |
| Minimum                   | 3.8         | 4.0                 | 2.0          |
| Maximum                   | 4.8         | 4.9                 | 2.6          |
| <b>Potassium meq/100g</b> |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 0.19        | 0.27                | 0.15         |
| SD                        | 0.03        | 0.04                | 0.04         |
| Minimum                   | 0.15        | 0.22                | 0.10         |
| Maximum                   | 0.25        | 0.32                | 0.26         |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 0.18        | 0.44                | 0.21         |
| SD                        | 0.03        | 0.07                | 0.06         |
| Minimum                   | 0.15        | 0.35                | 0.12         |
| Maximum                   | 0.25        | 0.53                | 0.35         |
| <b>Nitrogen µg/g</b>      |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 17.0        | 55.0                | 17.5         |
| SD                        | 7.3         | 29.2                | 3.6          |
| Minimum                   | 10          | 25                  | 14           |
| Maximum                   | 30          | 100                 | 23           |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 23.0        | 193.8               | 18.4         |
| SD                        | 8.1         | 27.2                | 3.6          |
| Minimum                   | 10          | 150                 | 14           |
| Maximum                   | 40          | 225                 | 23           |
| <b>Phosphorous µg/g</b>   |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 20.8        | 20.8                | 18.8         |
| SD                        | 9.7         | 1.2                 | 4.0          |
| Minimum                   | 10          | 20                  | 13           |
| Maximum                   | 43          | 23                  | 28           |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 17.1        | 19.8                | 23.6         |
| SD                        | 3.7         | 3.3                 | 2.5          |
| Minimum                   | 10          | 16                  | 20           |
| Maximum                   | 22          | 25                  | 28           |
| <b>Sulphur µg/g</b>       |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 47.9        | 44.2                | 41.2         |
| SD                        | 9.2         | 27.9                | 7.3          |
| Minimum                   | 29          | 23                  | 29           |
| Maximum                   | 59          | 97                  | 57           |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 31.1        | 156.8               | 51.7         |
| SD                        | 7.4         | 4.7                 | 10.4         |
| Minimum                   | 17          | 150                 | 38           |
| Maximum                   | 44          | 162                 | 71           |
| <b>Boron µg/g</b>         |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 0.7         | 0.8                 | 0.8          |
| SD                        | 0.2         | 0.4                 | 0.2          |
| Minimum                   | 0.4         | 0.2                 | 0.6          |
| Maximum                   | 0.9         | 1.3                 | 1.0          |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 0.4         | 1.0                 | 0.8          |
| SD                        | 0.3         | 0.3                 | 0.2          |
| Minimum                   | 0.1         | 0.7                 | 0.6          |
| Maximum                   | 0.9         | 1.3                 | 1.0          |
| <b>Copper µg/g</b>        |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 10.7        | 6.8                 | 12.4         |
| SD                        | 0.7         | 2.2                 | 1.7          |
| Minimum                   | 9.5         | 3.6                 | 10.0         |
| Maximum                   | 12.0        | 10.2                | 17.1         |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 10.9        | 6.1                 | 14.5         |
| SD                        | 0.8         | 0.9                 | 2.2          |
| Minimum                   | 8.7         | 5.4                 | 11.2         |
| Maximum                   | 12.0        | 7.6                 | 19.2         |
| <b>Iron µg/g</b>          |             |                     |              |
| <u>Upper Elevations</u>   |             |                     |              |
| Mean                      | 527         | 300                 | 302          |
| SD                        | 135.3       | 116.9               | 125.7        |
| Minimum                   | 330         | 197                 | 80           |
| Maximum                   | 775         | 505                 | 511          |
| <u>Lower Elevations</u>   |             |                     |              |
| Mean                      | 616         | 706                 | 838          |
| SD                        | 63.8        | 198.0               | 115.5        |
| Minimum                   | 505         | 398                 | 574          |
| Maximum                   | 756         | 937                 | 1100         |

Continued

Table 10.2.Continued.

|                                              | Pre-<br>Monsoon | Deposited<br>Sediments | Post-<br>Monsoon |
|----------------------------------------------|-----------------|------------------------|------------------|
| <b>Manganese <math>\mu\text{g/g}</math></b>  |                 |                        |                  |
| <u>Upper Elevations</u>                      |                 |                        |                  |
| Mean                                         | 62.5            | 129.4                  | 30.0             |
| SD                                           | 22.5            | 62.4                   | 8.7              |
| Minimum                                      | 23              | 47                     | 13               |
| Maximum                                      | 88              | 226                    | 50               |
| <u>Lower Elevations</u>                      |                 |                        |                  |
| Mean                                         | 78.4            | 427.3                  | 50.2             |
| SD                                           | 17.0            | 190.7                  | 7.5              |
| Minimum                                      | 41              | 141                    | 38               |
| Maximum                                      | 105             | 653                    | 65               |
| <b>Zinc <math>\mu\text{g/g}</math></b>       |                 |                        |                  |
| <u>Upper Elevations</u>                      |                 |                        |                  |
| Mean                                         | 4.8             | 2.5                    | 3.5              |
| SD                                           | 0.3             | 0.6                    | 1.5              |
| Minimum                                      | 4.1             | 1.7                    | 1.0              |
| Maximum                                      | 5.5             | 3.1                    | 6.3              |
| <u>Lower Elevations</u>                      |                 |                        |                  |
| Mean                                         | 3.5             | 3.8                    | 4.3              |
| SD                                           | 1.0             | 0.6                    | 1.7              |
| Minimum                                      | 1.7             | 2.9                    | 1.9              |
| Maximum                                      | 5               | 4.7                    | 7.3              |
| <b>Conductivity <math>\text{ds/m}</math></b> |                 |                        |                  |
| <u>Upper Elevations</u>                      |                 |                        |                  |
| Mean                                         | 0.35            | 0.22                   | 0.12             |
| SD                                           | 0.10            | 0.06                   | 0.02             |
| Minimum                                      | 0.14            | 0.16                   | 0.08             |
| Maximum                                      | 0.58            | 0.33                   | 0.17             |
| <u>Lower Elevations</u>                      |                 |                        |                  |
| Mean                                         | 0.18            | 0.50                   | 0.15             |
| SD                                           | 0.02            | 0.09                   | 0.04             |
| Minimum                                      | 0.13            | 0.41                   | 0.09             |
| Maximum                                      | 0.21            | 0.62                   | 0.27             |



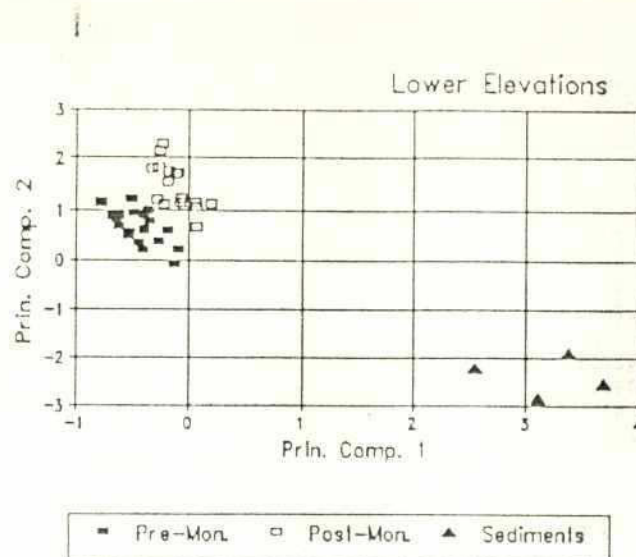


Figure 10.1. Principal components comparison of nutrient content of deposited sediments and surrounding soils in lower elevation areas adjacent to Meghna River, CIP.

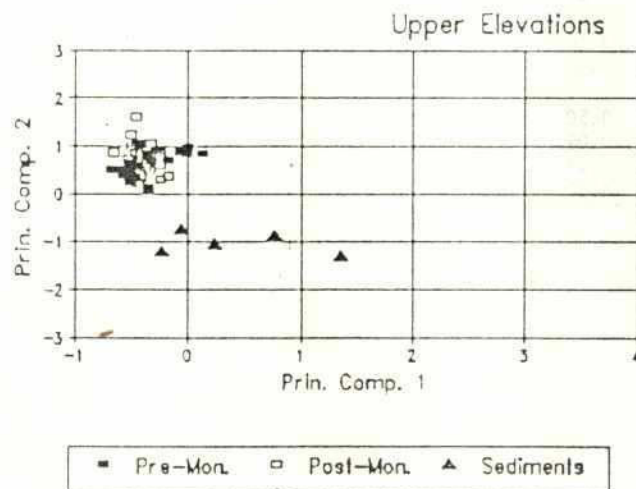


Figure 10.2. Principal components comparison of nutrient content of deposited sediments and surrounding soils in upper elevation areas adjacent to Meghna River, CIP.



## Chapter 11

## NUTRIENT STATUS OF SOILS

Summary statistics for the results of the analyses are presented in Annexes 6, 7 and 8.

Soil nutrient concentrations were highly correlated with each other (Annex 9). Most nutrients were positively correlated with other, but notable exceptions were iron and manganese, which although positively correlated to each other, were negatively correlated with other nutrients. Soil organic matter and soil pH were also negatively correlated with soil nutrient contents, but soil pH was positively correlated with iron content. Soils on the Dakatia side of the study area were higher in iron content than on the Meghna side, especially soils at lower elevations in the medium lowlands.

The patterns of change in soil nutrient concentrations from the pre- to the post-monsoon period were noted to be similar in both protected and unprotected areas on the Meghna side of the study area. Where soil concentrations rose after flooding (e.g. calcium, potassium, phosphorus, sulphur, boron, copper and zinc) or declined after flooding (e.g. magnesium and manganese), these directional changes occurred on both sides of the embankment.

Most of the fertilizer levels applied were correlated to each other (Annex 9); urea, TSP and MP applications were positively correlated to each other, but negatively related to manure and ash applications, which were made only in the areas outside the embankment on the Meghna side where phosphate, MP and urea applications were much lower than on the inside (Figures 7.1 to 7.6).

### pH

No significant differences were found between the mean pH of soils on the Meghna side (range 5.1-6.5) and on the Dakatia side (range 5.4-7.1) of the study area (Figure 11.1). Soil pH was slightly but significantly higher inside the embankments (mean 5.9) than outside (mean 5.7)

because of the prolonged wetness of the inside soils, and significantly lower after monsoon flooding (mean 5.6) than before (mean 6.0), probably because of soil oxidation. The pH of river and canal water supplying the cropped areas was only slightly acidic (Annex 3), much less acidic than the soils, and became significantly less acidic (neutral in fact) as the monsoon season progressed. There were no statistically significant differences in the pH of water in the various locations in the study area. The soil pH in lands receiving urea fertilization prior to sampling was significantly higher (6.0 and higher in plots receiving  $\geq 197$  kg/ha urea) than in those not receiving urea (mean 5.8). Similarly TSP application increased soil pH slightly but significantly ( $\geq 6$  in plots receiving TSP, mean of 5.8 in others). The pH in lands receiving manure applications prior to sampling was slightly but significantly lower (mean 5.7) than those not receiving it (mean 5.9). Other fertilizer applications had no detectable effect on soil pH. Deposited sediments had a significantly higher pH (6.3-6.7) than the soils on which they were deposited (5.1-6.1). Thus, every treatment to which the soils were subjected (water, sediments, fertilizers) tended to reduce acidity, which remained fairly low, probably due to redox reactions.

### Organic Matter

Organic matter content of soils was measured to be significantly higher on the Dakatia side of the study area (mean 3.7 percent) than on the Meghna side (mean 3.0 percent). It was higher inside the embankments (mean 3.8 percent) than outside (mean 3.0 percent), higher in lower elevation soils (mean 3.6 percent) than in higher elevation soils (mean 3.2 percent), and lower after the monsoon period (from mean of 3.6 to 3.2 percent). Fertilizer applications had no measurable effect on soils organic content, with the exception of lands which received manure which were found to have a lower organic matter content (mean 3.0 percent) than those not



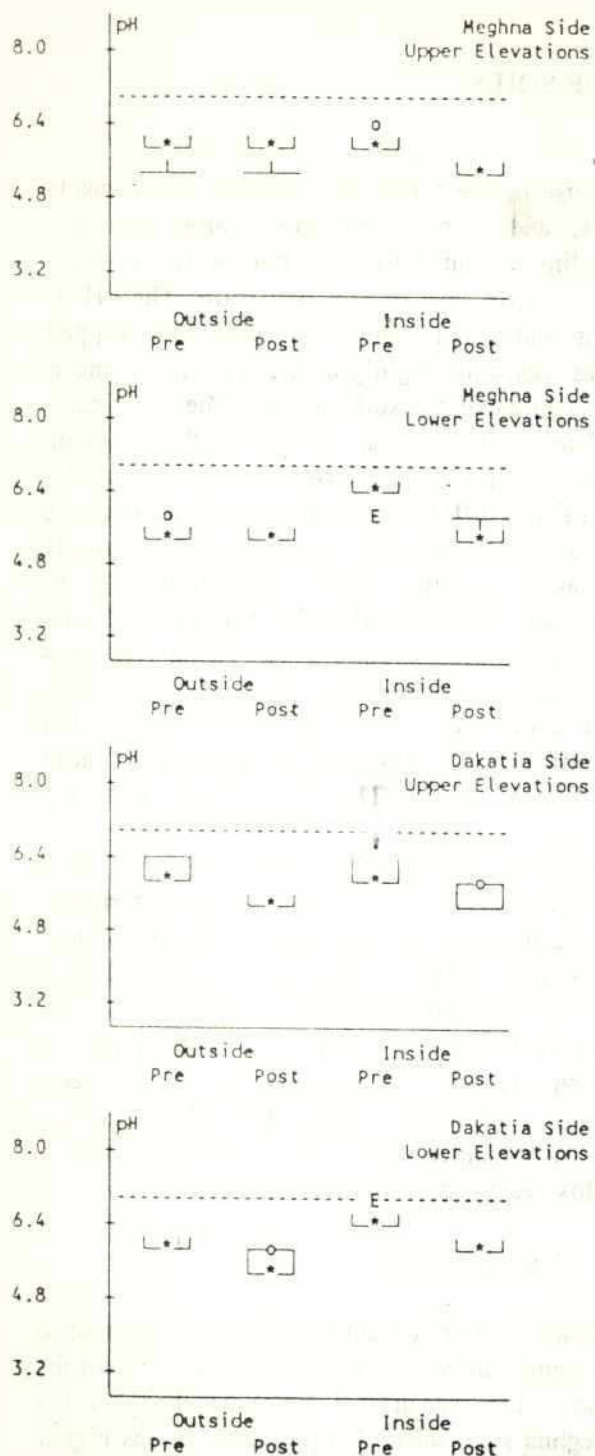


Figure 11.1. pH of soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme. Horizontal lines demarcate acidic and alkaline ranges.

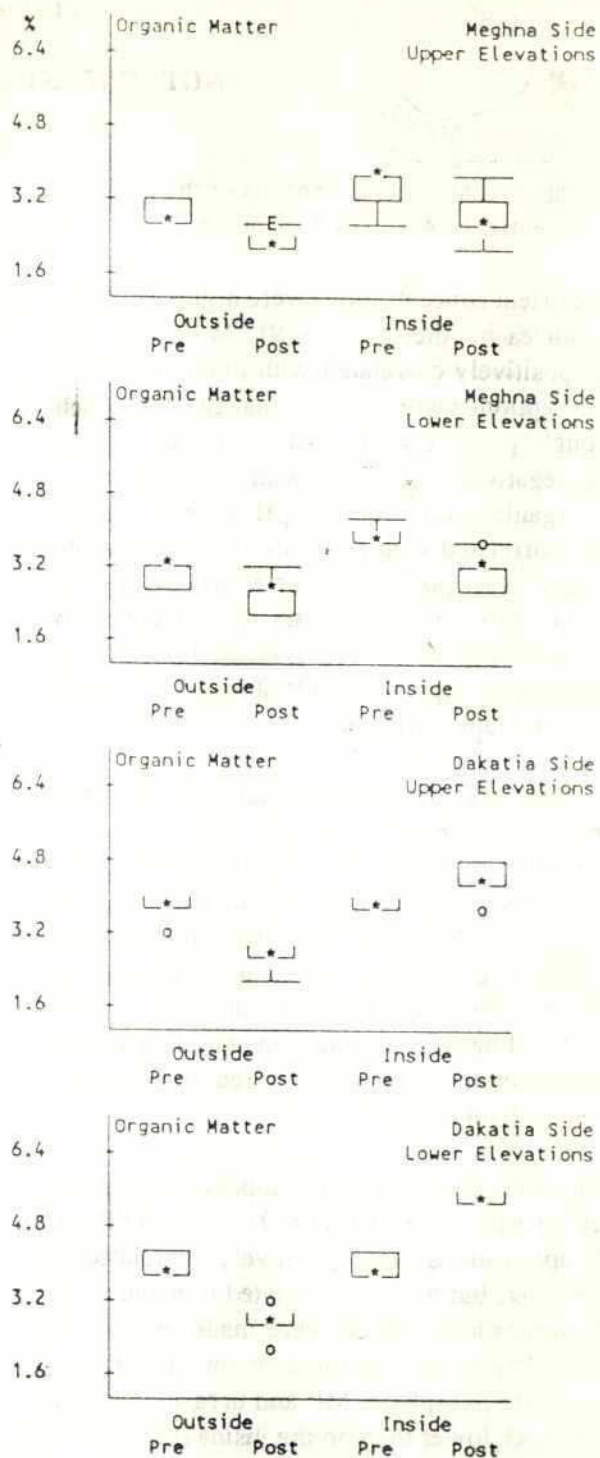


Figure 11.2. Organic matter content of soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value.

receiving it (mean 3.5 percent). Manured areas were all outside the Meghna embankment. The rates of crop production were much higher within the embanked area than outside, based on the cultivation of high yielding *T. aman* and *boro* paddy and potatoes, and consequently the build-up of organic residues would be expected to be higher in these locations.

The organic matter content of the deposited sediments was significantly higher than that of the surrounding soils at the lower elevational sites (mean of 5.1 percent, compared to 2.6-3.0 percent for soils), but not significantly different at the higher elevations (mean of 2.4 percent, compared to 2.3-3.0 percent for soils). The locational differences in organic matter content, the relatively low organic content of soils outside the embankments despite the inputs via the sediments, and the positive correlation between sediment organic content and sediment nitrogen content, suggest that the organic materials in the sediments were labile, probably particulate organic materials such as algae and allochthonous fragments, and soluble nitrogenous materials such as amino acids, which are broken down rapidly within the soil biological environment.

#### Calcium

The calcium content of soils on the Meghna side of the study area was measured to be markedly higher (mean 10.3 meq/100g) than those on the Dakatia side (mean 6.3 meq/100g), which is consistent with the distribution of calciferous gleysolic soils in the area. Soils at the lower elevations, inside and outside the embankments on either side of the study area, respectively, had similar calcium concentrations, but higher elevation soils inside the embankment were significantly higher in calcium than higher elevational soils outside. Calcium content was higher in soils at lower elevations (mean 9.0 meq/100g) than in upper elevation soils (mean 7.6 meq/100g), and was lower after the monsoon (mean 8.0 meq/100g) than before (mean 8.6 meq/100g). All measured calcium concentrations were well within the optimum ranges for crop nutrition.

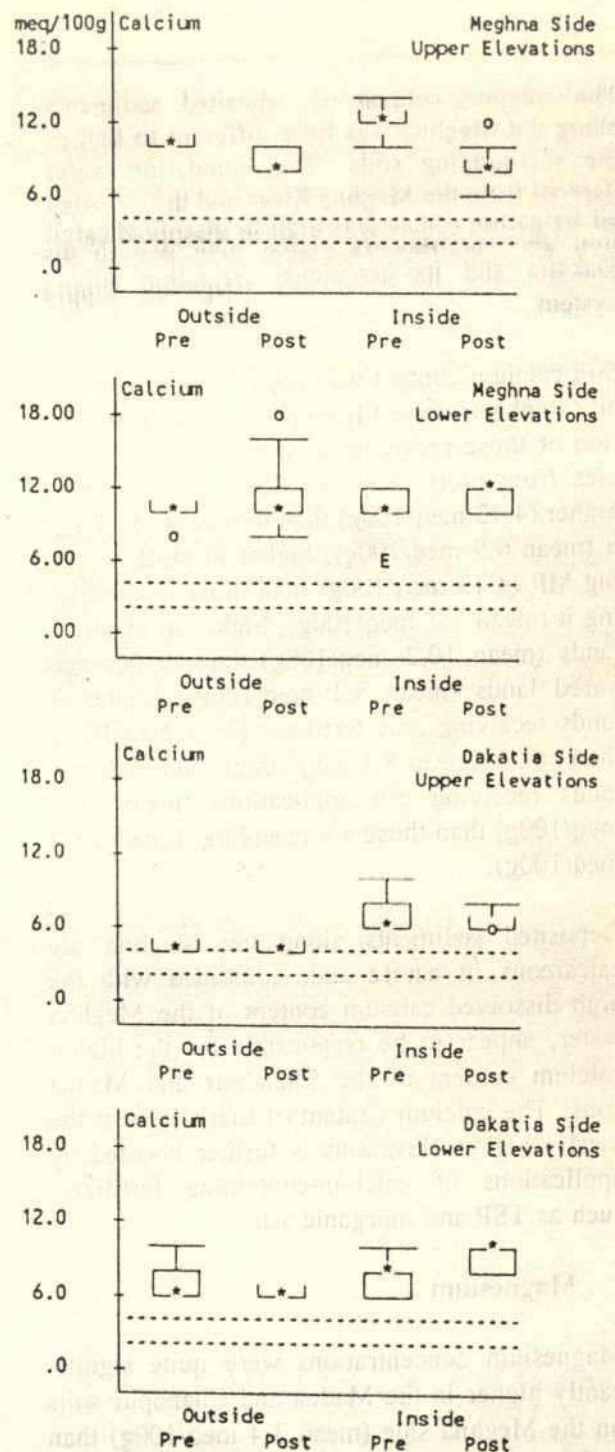


Figure 11.3. Calcium concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value. Horizontal lines demarcate low, medium and optimum ranges for crop nutrition.



The calcium content of deposited sediments along the Meghna was little different to that of the surrounding soils. The inundating water derived from the Meghna River and the associated irrigation canals was high in dissolved calcium and magnesium. Higher magnesium was found in the Dakatia and its associated irrigation supply system.

Soil calcium content was significantly higher in all samples from fertilized plots, with the exception of those receiving urea applications. Samples from plots receiving SSP and TSP were higher (4-13 meq/100g) than those not receiving it (mean 6.9 meq/100g), higher in plots receiving MP (4-13 meq/100g) than those not receiving it (mean 7.7 meq/100g), higher in manured lands (mean 10.2 meq/100g) than in non-manured lands (mean 8.1 meq/100g), higher in lands receiving zinc fertilizer (7-13 meq/100g) than others (mean 8.1 meq/100g), and higher in lands receiving ash applications (mean 10.0 meq/100g) than those not receiving it (mean 8.3 meq/100g).

Deposited sediments along the Meghna are calcareous in nature and, combined with the high dissolved calcium content of the Meghna water, appear to be responsible for the higher calcium content of the Chandpur and Madna soils. The calcium content of these soils at the locally higher elevations is further boosted by applications of calcium-containing fertilizers such as TSP and inorganic ash.

### Magnesium

Magnesium concentrations were quite significantly higher in the Madna and Chandpur soils on the Meghna side (mean 3.4 meq/100g) than in Tippera and Burichanga soils on the Dakatia side (mean 2.4 meq/100g). No significant differences were detected in protected and unprotected soils in any treatment plots or in soils at different elevations. Soils were significantly lower in magnesium after the monsoon (mean 2.1 meq/100g) than before (mean 3.7 meq/100g). Except for some post-monsoon samples on the Dakatia side, outside the embankment, all measured magnesium concentrations were within the optimum range for crop production.

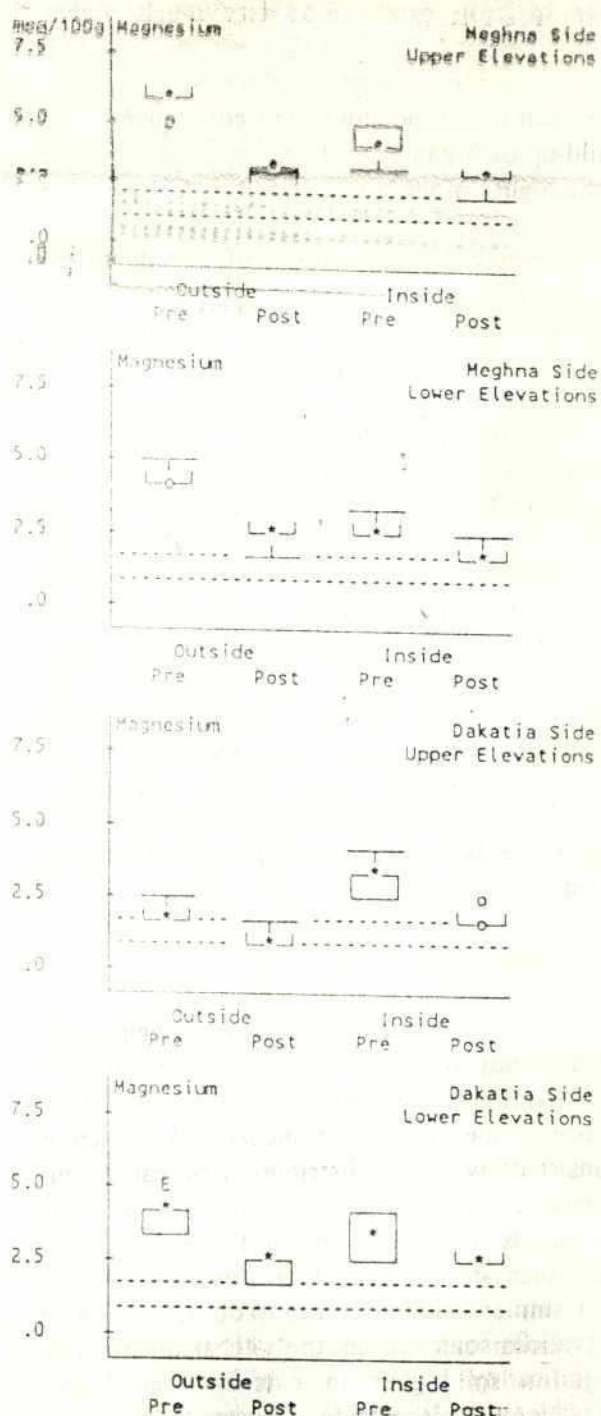


Figure 11.4. Magnesium concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value. Horizontal lines demarcate low, medium and optimum ranges for crop nutrition.

Plots receiving TSP prior to sampling had higher magnesium concentrations (range 2-5 meq/100g) than those not receiving it (mean 2.1 meq/100g) as did soils receiving zinc fertilizers (range 3-4 meq/100g as against a mean of 2.7 meq/100g in plots not receiving zinc). Magnesium concentrations were much higher (mean 5.0 meq/100g) in manured fields than in non-manured ones (mean 2.6 meq/100g).

### Potassium

As with magnesium, potassium concentrations were much higher in soils on the Meghna side (mean 0.24 meq/100g) than in those on the Dakatia side (0.09 meq/100g). They were slightly higher inside the embankments (mean 0.19 meq/100g) than outside (0.14 meq/100g), higher in lower elevation soils (mean 0.20 meq/100g) than upper elevation soils (mean 0.13 meq/100g), and much higher after the monsoon period (mean 0.24 meq/100g) than before (mean 0.09 meq/100g). They were higher in soils fertilized with MP (range 0.04-0.24 meq/100g versus a mean of 0.13 meq/100g) and with TSP (range 0.06-0.78 meq/100g versus a mean of 0.14 meq/100g). Manured soils were slightly but significantly higher in potassium (mean 0.18 meq/100g versus 0.16 meq/100g). Potassium concentrations in soils on the Dakatia side of the CIP, both in- and outside the embankment were in the range of potential deficiency in terms of crop nutrition. Soils on the Meghna side were mainly in the moderate range, i.e. deficiencies could have been problematical for some crops.

### Nitrogen

All soil samples were found to be very low in nitrogen content, and generally deficient in terms of crop nutritive capabilities. Soils of the Meghna side of the study area were quite significantly higher in ammonium nitrogen (mean 26 ppm) than those on the Dakatia side (mean 16 ppm), and soils protected by the embankments were similarly quite significantly higher in nitrogen (mean 25 ppm) than unprotected soils (mean 18 ppm). These differences correlated well with the higher applications of urea on the Meghna side and in the areas inside the CIP. However, samples from urea-treated soils were not statisti-

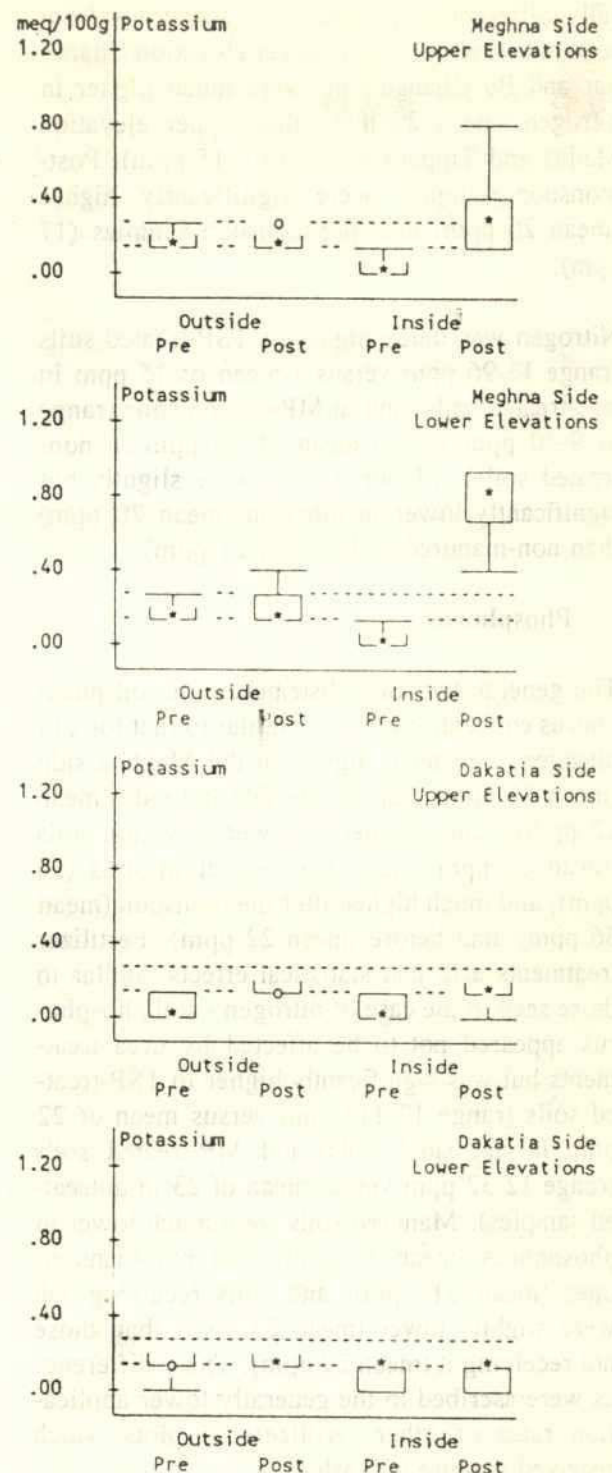


Figure 11.5. Potassium concentrations in soil samples from CIP. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value. Horizontal lines demarcate low, medium and optimum ranges for crop nutrition.



cally different in nitrogen concentrations from soils not receiving urea. Lower elevation Chandpur and Burichanga soils were much higher in nitrogen (mean 27 ppm) than upper elevation Madna and Tippera soils (mean 15 ppm). Post-monsoon samples were significantly higher (mean 26 ppm) than pre-monsoon samples (17 ppm).

Nitrogen was much higher in TSP-treated soils (range 13-96 ppm versus a mean of 15 ppm in non-treated soils) and in MP-treated soils (range of 9-70 ppm versus mean of 16 ppm in non-treated soils). Manured soils were slightly but significantly lower in nitrogen (mean 20 ppm) than non-manured soils (mean 21 ppm).

### Phosphorus

The general statistical distribution of soil phosphorus concentrations was similar to that for soil nitrogen, i.e. much higher on the Meghna side (mean 36 ppm) than on the Dakatia side (mean 22 ppm), much higher in lower elevation soils (mean 39 ppm) than upper elevation soils (20 ppm), and much higher after the monsoon (mean 36 ppm) than before (mean 22 ppm). Fertilizer treatments also had statistical effects similar to those seen in the case of nitrogen - soil phosphorus appeared not to be affected by urea treatments but was significantly higher in TSP-treated soils (range 12-115 ppm versus mean of 22 ppm in untreated soils) and MP-treated soils (range 12-32 ppm versus mean of 23 in untreated samples). Manured soils were much lower in phosphorus (mean 19 ppm) than non-manured ones (mean 31 ppm), and soils receiving ash were slightly lower (mean 23 ppm) than those not receiving it (mean 29 ppm). These differences were ascribed to the generally lower application rates of other fertilizers in plots which received manure and ash.

### Sulphur

Although overall soil sulphur concentrations were much higher in samples from the Meghna side of the study area (mean 54 ppm) than in those from the Dakatia side (mean 17 ppm), the difference was not shown to be significant in the analysis of variance, likely because of strong

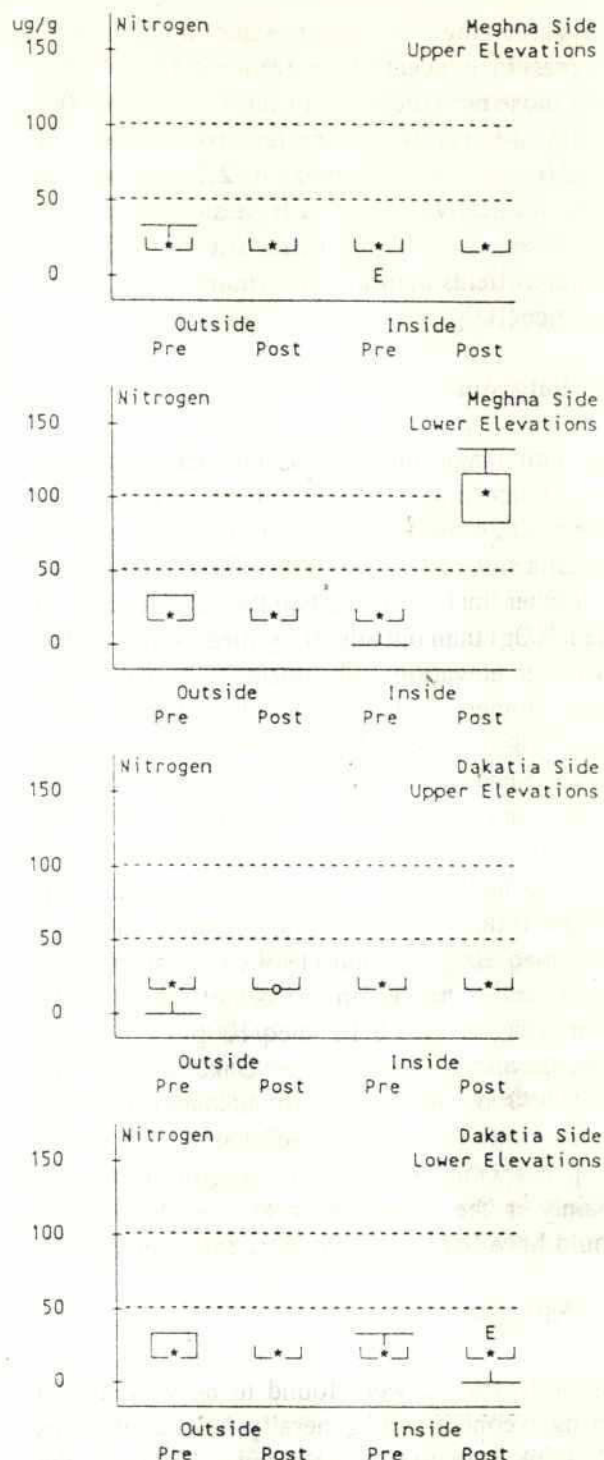


Figure 11.6. Nitrogen concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value. Horizontal lines demarcate low, medium and optimum ranges for crop nutrition.

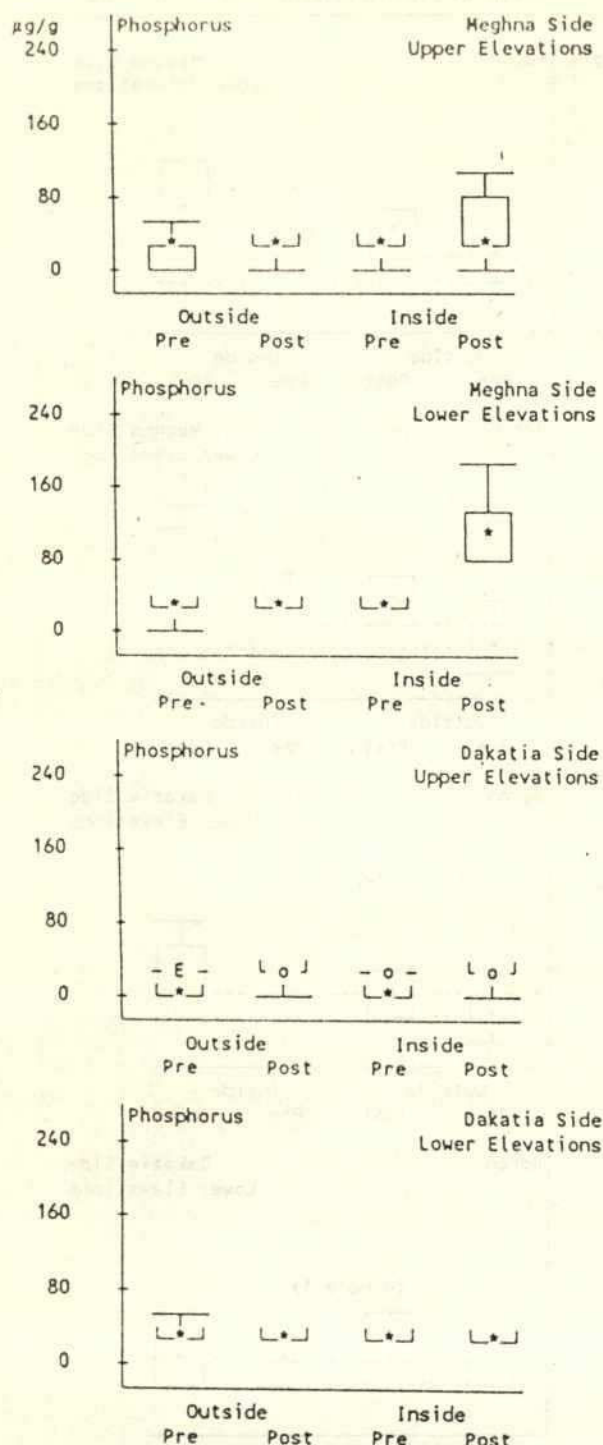


Figure 11.7. Phosphorus concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value.

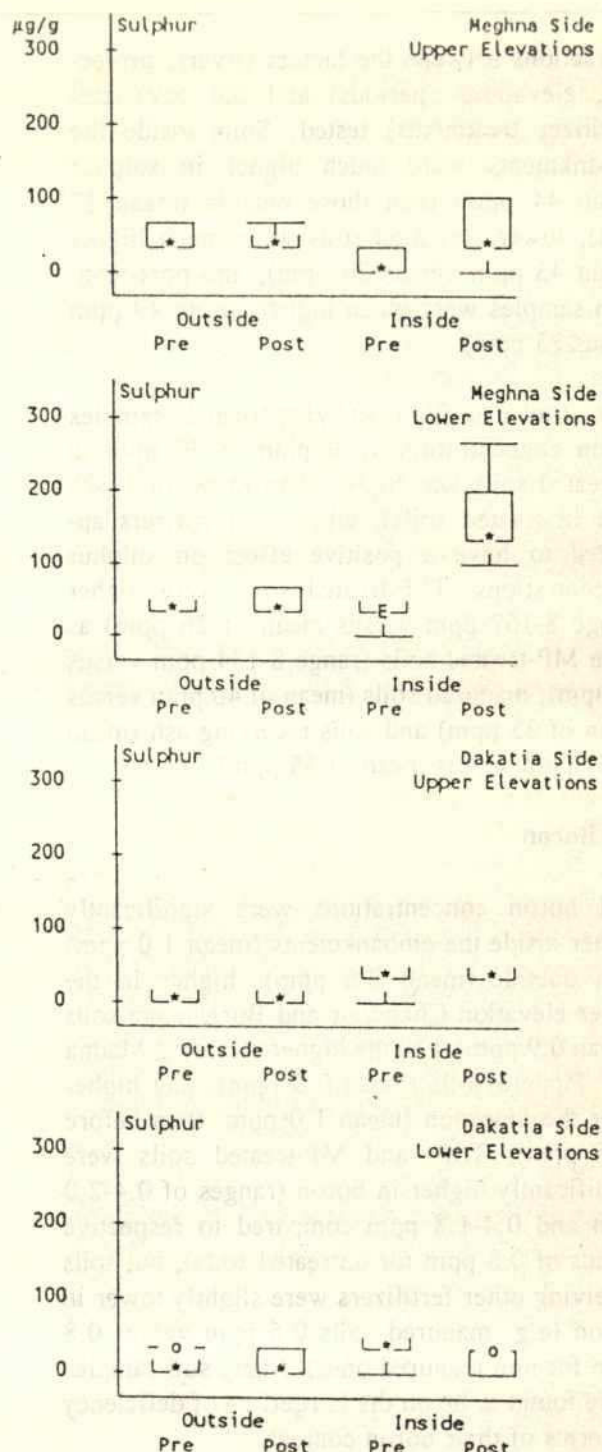


Figure 11.8. Sulphur concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value.



interactions between the factors (rivers, protection, elevations, periods) and the covariates (fertilizer treatments) tested. Soils inside the embankments were much higher in sulphur (mean 44 ppm) than those outside (mean 27 ppm), lower elevation soils were much higher (mean 43 ppm versus 29 ppm), and post-monsoon samples were much higher (mean 49 ppm versus 23 ppm).

With the exception of zinc-treated samples (mean concentration of sulphur at 39 ppm in untreated soils was higher than range of 11-28 ppm in treated soils), all of the fertilizers appeared to have a positive effect on sulphur concentrations. TSP-treated soils were higher (range 8-167 ppm versus mean of 26 ppm) as were MP-treated soils (range 8-134 ppm versus 29 ppm), manured soils (mean of 40 ppm versus mean of 35 ppm) and soils receiving ash (mean of 51 ppm versus mean of 35 ppm).

### Boron

Soil boron concentrations were significantly higher inside the embankments (mean 1.0 ppm) than outside (mean 0.6 ppm), higher in the lower elevation Chandpur and Burichanga soils (mean 0.9 ppm) than the higher elevation Madna and Tippera soils (mean 0.8 ppm), and higher after the monsoon (mean 1.0 ppm) than before (0.6 ppm). TSP- and MP-treated soils were significantly higher in boron (ranges of 0.4-2.0 ppm and 0.4-1.8 ppm compared to respective means of 0.8 ppm for untreated soils), but soils receiving other fertilizers were slightly lower in boron (e.g. manured soils 0.6 ppm versus 0.8 ppm for non-manured ones). Many soil samples were found to be on the borderline of deficiency in terms of their boron content.

### Copper

Copper concentrations in soils were similar to the nutrients discussed above in terms of the effects of protection (higher (mean 12.2 ppm) at lower elevations than higher elevations (mean 9.6 ppm) and higher after the monsoon (mean 13.5 ppm than before mean 8.3 ppm). However, copper was notably different from many other nutrients in that concentrations in soils

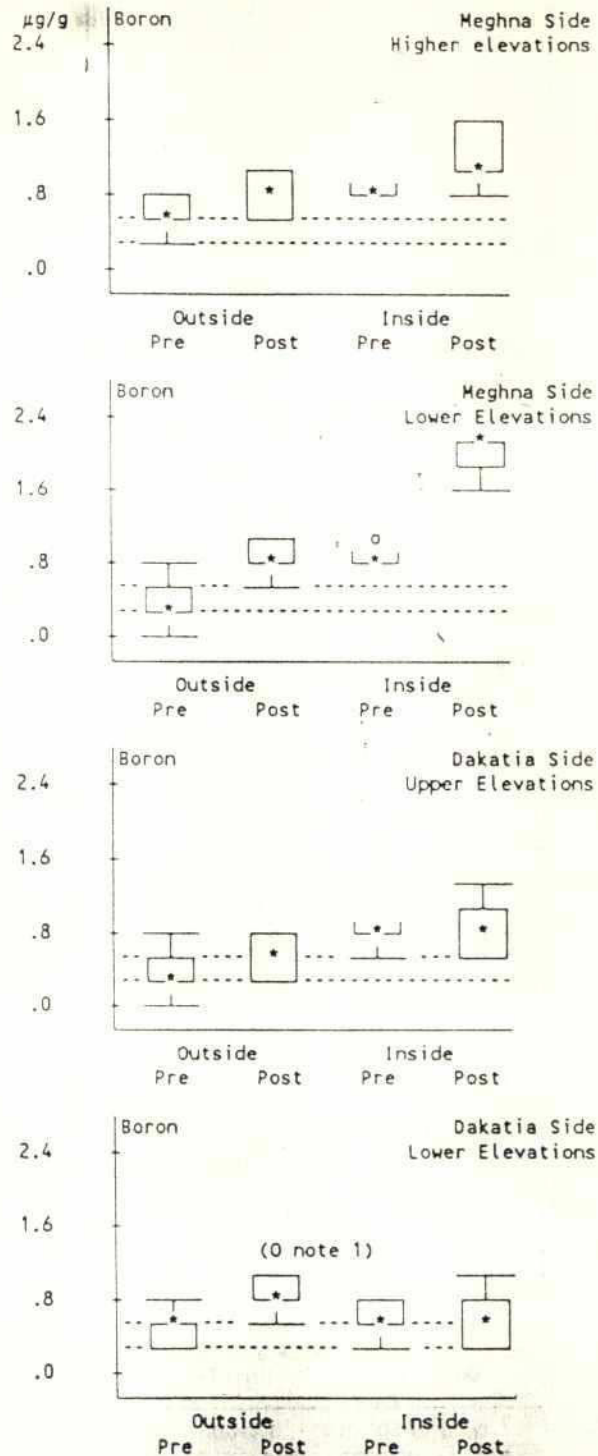


Figure 11.9. Boron concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier. Horizontal lines demarcate low, medium and optimum ranges for crop nutrition.

unprotected from river flooding were significantly higher (mean 11.2 ppm) than those within the embankments (mean 10.5 ppm), although actual differences were relatively small, usually  $\leq 0.5$  ppm). No significant effects were found for fertilizer treatments in respect of copper concentrations.

### Iron

Soil iron concentrations were much higher on the Dakatia side of the study area (mean 780 ppm) than on the Meghna side (mean 490 ppm). As with copper, iron concentrations were higher outside the embankments (mean 752 ppm) than inside (519 ppm), but they followed the general pattern of distribution for other nutrients in being significantly higher at lower elevations (mean 798 ppm) than upper elevations (mean 472 ppm). A significant variation from other nutrients was noted in that iron concentrations in post-monsoon samples were markedly lower (mean 467 ppm) than in pre-monsoon samples (804 ppm).

Apart from a relatively small number of ash-treated soils which were higher in iron (mean 854 ppm) than untreated ones (mean 628 ppm), and from samples of urea-treated soils which were not different to untreated ones in respect of iron concentrations, other fertilizer-treated soils were lower in iron concentrations than untreated soils (i.e. TSP-treated ranged from 408-1220 ppm compared to 437 ppm for untreated, MP-treated soils ranged from 330-1030 ppm compared to 579 for untreated, manured soils had a mean of 571 ppm compared to a mean of 644 ppm for non-manured).

### Manganese

Soil manganese concentrations were significantly higher on the Meghna side (mean 41 ppm) than on the Dakatia side (mean 27 ppm), higher outside the embankments (mean 44 ppm) than inside (mean 25 ppm), higher in lower-elevation soils (mean 40 ppm) than others (mean 29 ppm), and lower after the monsoon (mean 25 ppm) than before (44 ppm). Fertilizer treatments had no significant effect on soil manganese, except for manured soils which had very much higher

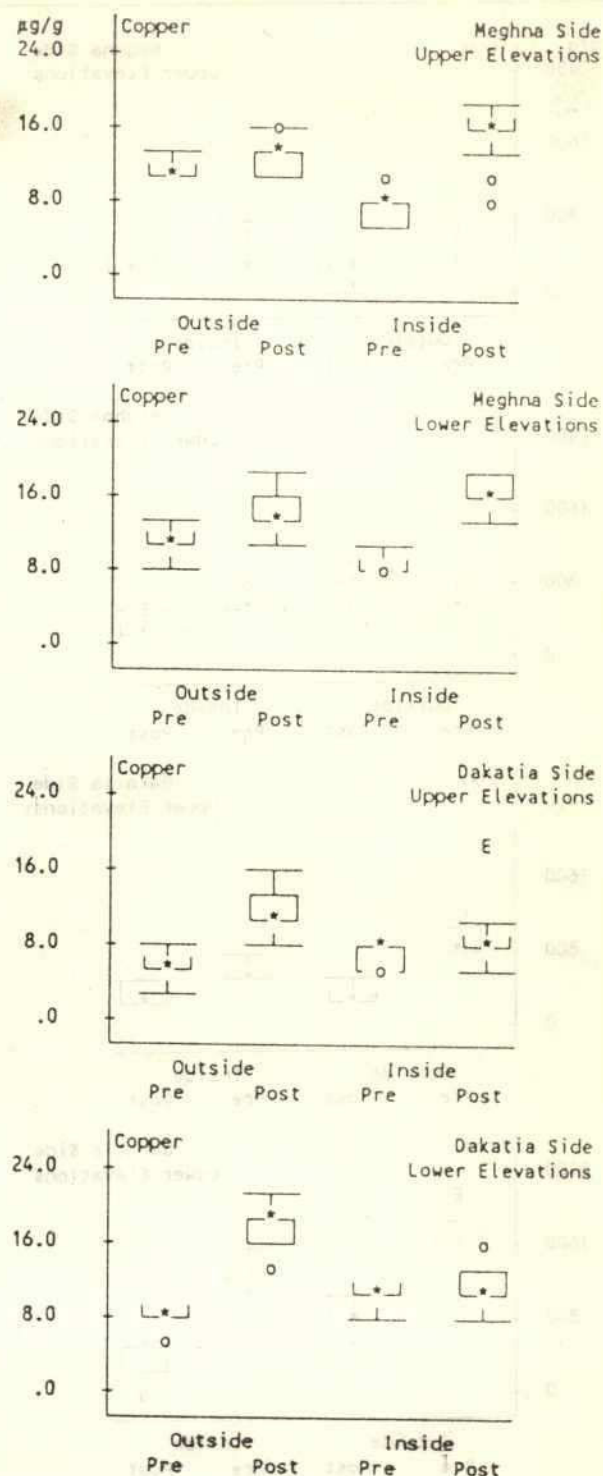


Figure 11.10. Copper concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value.





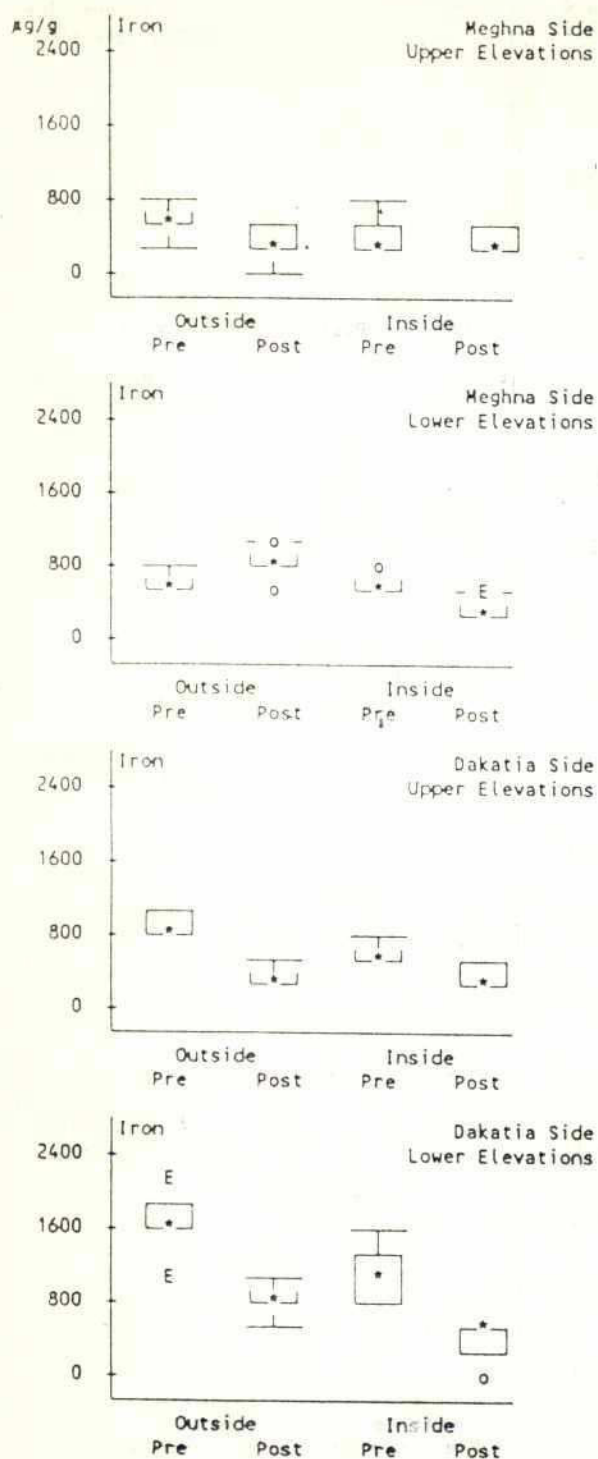


Figure 11.11. Iron concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value.

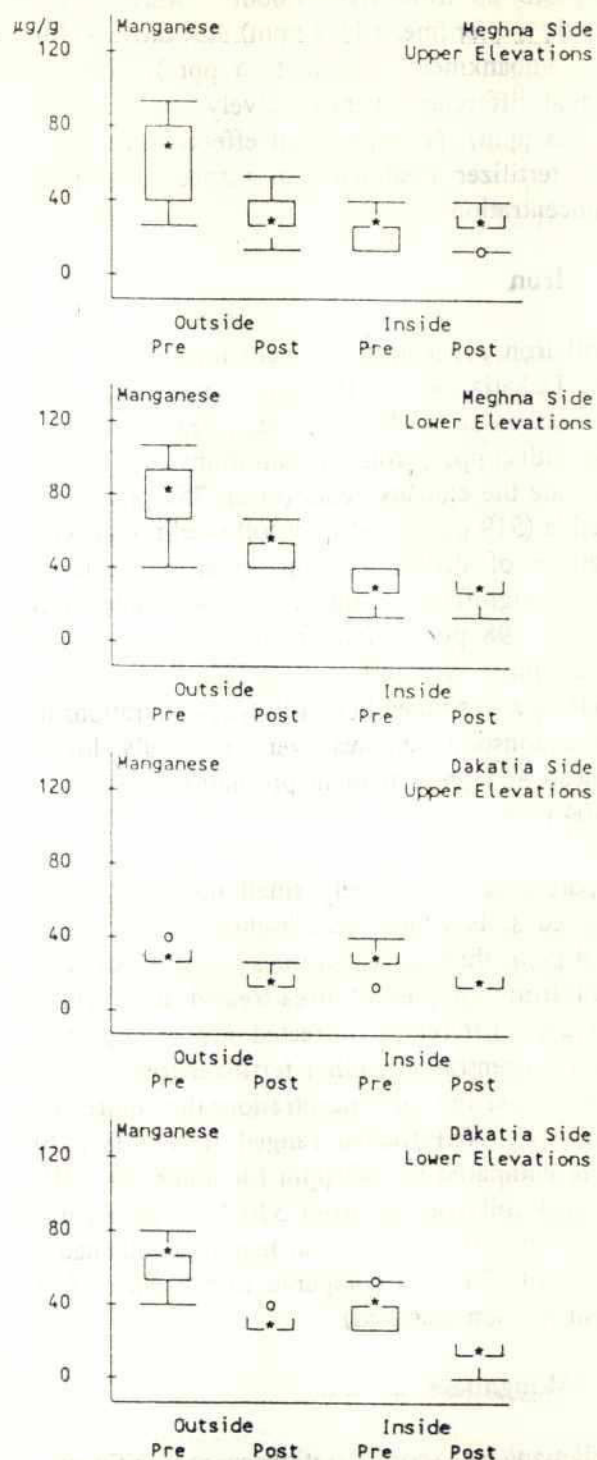


Figure 11.12. Manganese concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value.

concentrations (mean 70 ppm) than others (mean 29 ppm).

### Zinc

Meghna River side soils were significantly higher in zinc (mean 4.0 ppm) than Dakatia side soils (mean 2.3 ppm). Embankment-protected soils were slightly but significantly higher (mean 3.3 ppm) than unprotected ones (mean 3.0 ppm). Contrary to the situation with most other measured nutrients, zinc concentrations were found to be significantly higher in upper elevation Madna and Tippera soils (mean 3.4 ppm) than lower elevation soils; (mean 2.9 ppm). No significant changes in zinc concentrations were detected following monsoon inundation. Manured soils were notably higher in zinc (mean 4.1 ppm) than non-manured ones (mean 3.0 ppm).

The analysis of covariance indicated soil zinc concentrations to be significantly related to the levels of application of zinc fertilizers to soils prior to sampling. However, the relationship was not linear. Soils receiving zinc fertilization at levels of 16-20 kg/ha prior to sampling were found to have mean zinc levels of 4.2 ppm, compared to a mean level of 3.2 ppm in untreated soils. However soils receiving small to moderate zinc applications of 4-12 kg/ha had zinc concentrations lower than untreated soils (mean of 2.0 to 3.1 ppm) and soils receiving the highest rates of zinc fertilizer (>28 kg/ha) had lower concentrations (mean 2.7 ppm) than untreated soils. Numbers of zinc-treated samples were relatively small (total of 52) compared to samples from untreated soils (268), and the results must be treated with circumspection.

### Electrical Conductivity

River-flood protected soils had significantly higher rates of electrical conductivity (mean 0.27 ds/m) than unprotected soils (mean 0.19 ds/m), and soils receiving manure had slightly lower ECs (mean 0.23 ds/m) than non-manured soils (mean 0.26 ds/m). No other significant effects could be found.

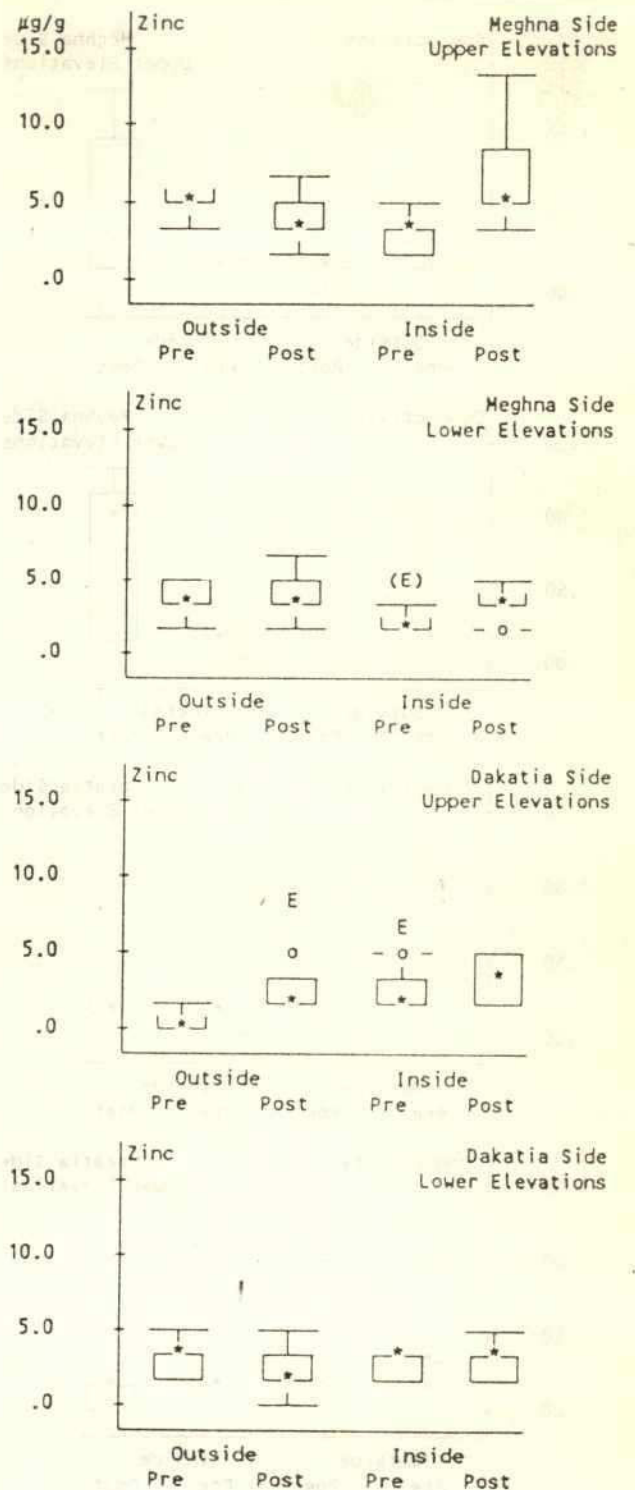


Figure 11.13. Zinc concentrations in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value.



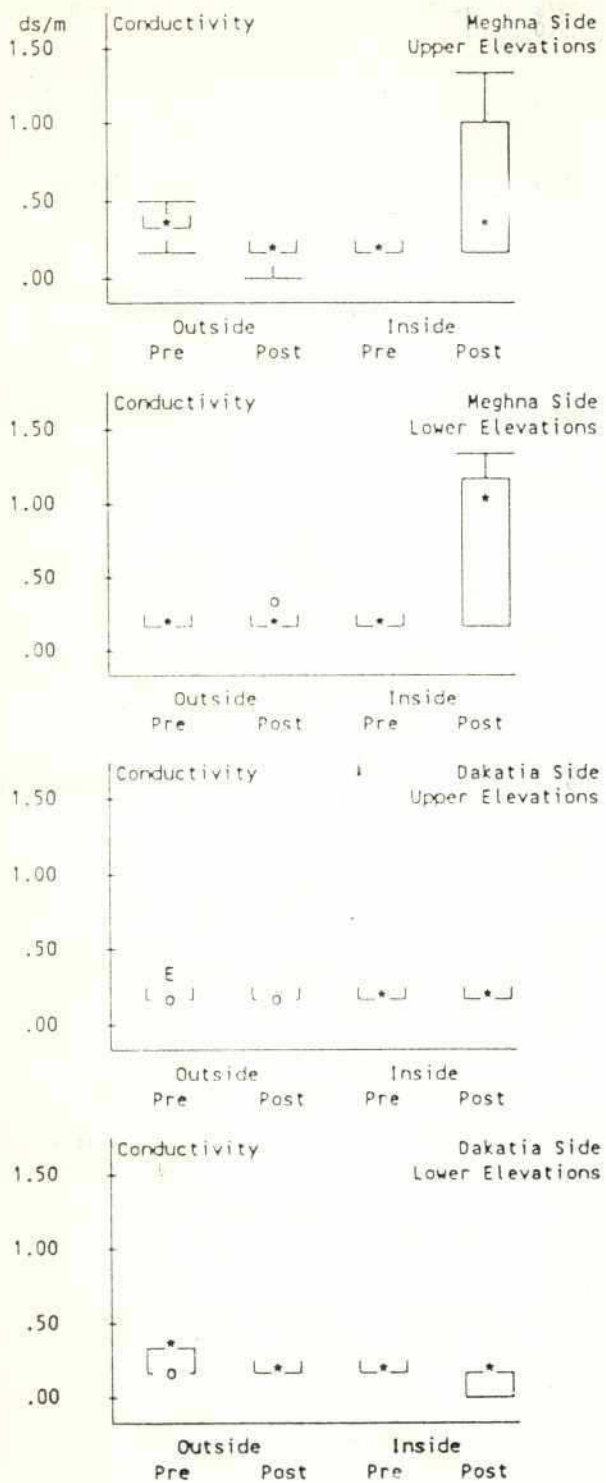


Figure 11.14. Electrical conductivity in soil samples from CIP study area. Data blocks shown are normal ranges and 95 percent confidence intervals; \* = median, o = outlier, E = extreme value.

## Chapter 12

## DISCUSSION

In accordance with the basic objectives of the study, the key questions to be considered are to what extent flood protection by the embankment at the CIP has changed the nutrient status of the soils, and to what extent the exclusion of annual sediment deposition within the CIP has contributed to any such changes. As pointed out earlier in the report, protection of agricultural lands induces marked changes in cropping practices and associated uses of agricultural inputs, especially fertilizers and crop types, and hence there are a number of additional questions which must be addressed in order to adequately consider the primary questions. These are to what extent changes in cropping and fertilizing have changed the nutrient status of protected soils, and to what extent factors other than sediment deposition, e.g. dry season irrigation, have changed the topsoils. These questions are addressed by a series of comparisons between the nutrient contents of soils in protected and unprotected sites, in different localities within the study area, at different times relative to the monsoon flooding periods, and in relation to their respective cropping and fertilizing treatments.

### 12.1 Effects of Flood Protection on Soil Fertility

Soils inside the CIP differed quite significantly from those on the outside. They contained significantly less clay and more sand than on the outside, were slightly less acidic, had a slightly higher organic matter content, and were higher in potassium, nitrogen, phosphorus, sulphur, boron and zinc. They contained less copper, iron and manganese. No significant differences could be found in respect of calcium and magnesium content. Significant differences in soil nutrient content could however also be ascribed in part to differences in soil series, elevation and timing relative to the monsoon inundation periods. The differences due to these various factors are not always in the same direction, i.e. one factor may induce a higher level in a nutrient while another induces a lower level.

Madna and Chandpur soils along the Meghna River were similar in acidity to those on the Dakatia side, and contained notably lower concentrations of copper, iron and organic matter, but all other nutrients were significantly higher than in the Tippera and Burichanga soils along the Dakatia. Monsoon flooding and associated changes in cropping tended to lower the pH, organic matter, calcium, magnesium, iron and manganese content of most soils, but levels of potassium, nitrogen, phosphorus, sulphur, boron and copper were increased. No flooding-induced changes in zinc levels were detected. The effects of the various factors - river flood protection, elevation and monsoon flooding - could not be isolated in the study design, and there doubtless exist many complex interactions between them. An overall comparison between soil samples based on a principal components analysis using the first two extracted components (Figure 12.1) indicates that in the Meghna soils, protection from river flooding has caused a discernible shift in nutrient content, but a much greater fluctuation is caused during the monsoon flooding period, probably because of fertilizer applications and soil tillage practices (see below). In the Dakatia soils (Figure 12.2), protection from river flooding has also caused a discernible shift in overall nutrient content.

The major differences inside and outside the CIP embankment along the Meghna River are the cropping practices and the associated levels of use of some fertilizers. Fertilizer applications within and outside the CIP are not uniform and, in many cases, they are unbalanced. Some cropping sequences, e.g. potato-boro (H)-Taman (H) within the CIP along the Meghna River received very high rates of fertilizers, while in similar situations on the Dakatia side they received much less. Some (but not all) plots in the protected areas received TSP and SSP applications up to twice as high, and MP applications up to three times as high as those in the unprotected plots on the river side of the embankment because of the high boro cropping intensity.



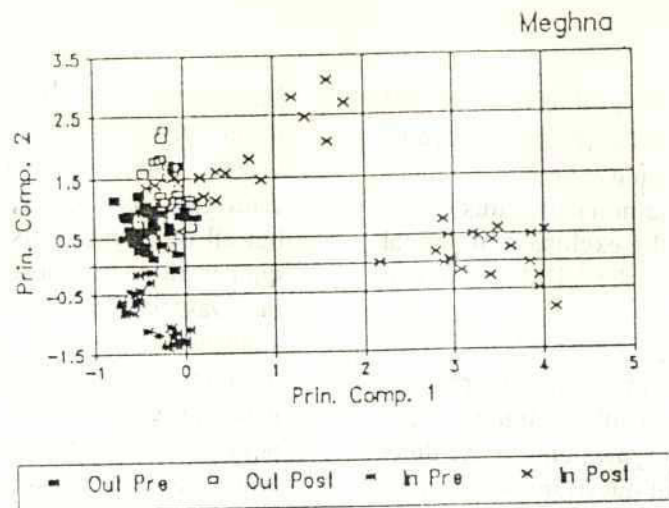


Figure 12.1. Principal components comparison of soil samples collected on the Meghna River side of the CIP.

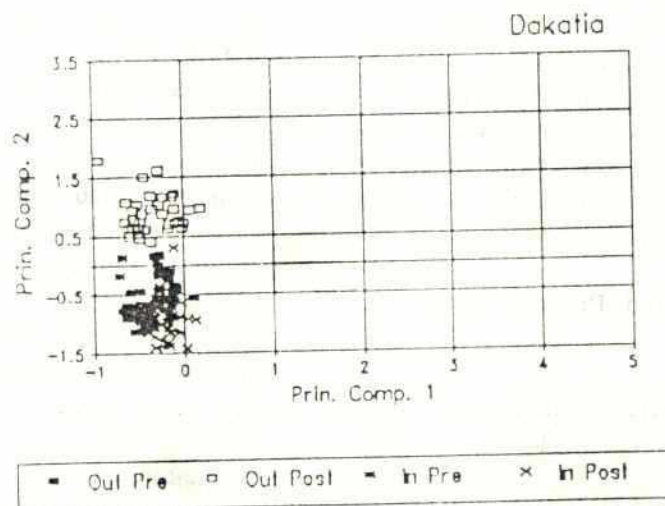


Figure 12.2. Principal components analysis of soils samples collected on the Dakatia River side of the CIP.

Unprotected areas on the Meghna side conversely received high applications of manure (1-4 tonnes/ha). The slightly lower soil pH outside the Meghna embankment may have been due to these manure applications (significant association through covariance analysis).

Levels of potassium, nitrogen, phosphorous, sulphur, boron, copper, zinc and electrical conductivity all rose appreciably in protected

soils on the Meghna side after the monsoon cropping and harvesting season. All of these nutrients, with the exception of copper and boron, were present in the fertilizers applied, principally TSP, SSP, MP and zinc sulphate. The rise in electrical conductivity was associated with the high levels of calcium, potassium and ammonium cations, and sulphate and chloride anions in the dissolving fertilizer applications.

The patterns of nutrient differences between river flood and unprotected protected soils on the Dakatia side of the CIP were unlike those on the Meghna side in several respects. There were no major differences in fertilizer applications between protected and unprotected areas on the Dakatia side since there were no major differences in cropping patterns between the two areas. There were consequently no increases in concentrations of zinc, conductivity, boron, phosphorus, potassium or nitrogen in the post-monsoon period.

The origin of the higher boron and copper levels in post-monsoon samples in the flood protected Meghna soils is not clear. Boron is a micronutrient which is normally present in very small amounts in soils and water. The concentrations in water were too low to be accurately quantified by standard laboratory techniques, but levels may have been quite high enough in the flood waters to cause elevated soil levels. It may have been present in sufficient quantities in either irrigation water within the CIP or even in fertilizers applied. The higher copper levels require further investigation.

An estimate of the annual balance of the basic nutrients - nitrogen, phosphorus, potassium and sulphur - in the protected and unprotected areas was computed (Tables 12.1, 12.2) through consideration of the rates of fertilizers applied and the amounts of biomass removed during cropping. Both annual uptake and addition of fertilizer nutrients are much higher in the protected than in the unprotected areas on the Meghna River sites, but nutrient depletion within the CIP is high in all cases. The depletion of nutrients in the upper elevation soils which support crops of potatoes, *boro* (H) and *T. aman* (H) is especially high. Fertilizer additions appeared in most cases to replace the nutrients removed by cropping, with the exception of potassium, which was added in quantities too low to adequately replace that which was removed, and potassium is notably deficient in all soils in the CIP (see chapter 11). Soils in the unprotected area supported less nutrient-exhaustive crops producing lower yields, and these soils were supplemented with fertilizers as well as high amounts of organic manure. Similar

situations exist in the lower elevation areas along the Dakatia River, where the nutrient depletion rates were also quite high.

Local farmers were of the opinion that crop production within the CIP was increasingly dependent on higher application rates of fertilizers, and this is borne out by the observations in this study. HYV *aman* production in the low elevation soils in the CIP near the Dakatia River was measured at only 1.8 tonnes/ha, probably because of soil nutrient deficiencies, including potassium and nitrogen.

## 12.2 Role of Deposited Sediments in Soil Fertility

The sediments deposited in the agricultural lands along the Meghna River outside of the CIP embankment proved to be productive soils in their own right. Sediments deposited on the medium highlands and medium lowlands were all sandy loams, with nutrient concentrations similar to those of the underlying soils in the case of calcium, magnesium, phosphorous, boron, iron and zinc. They were substantially higher in potassium, manganese and nitrogen than the local soils, and significantly lower in copper. Sediments on the medium highlands had organic matter content similar to local soils, but those deposited in the medium lowlands were significantly higher in organic content.

Deposited sediments were obviously sandy soils translocated from elsewhere, and were probably a combination of agricultural soils eroded from the upper Meghna and upper Padma basins, and transported to the CIP sites. Their physical and chemical composition was quite different from that of the local Madna and Chandpur soils, making it unlikely that they were locally translocated.

The value of the deposited sediments lies in their immediate value as substrates for crop production outside the embankment. Their specific value lies in their high content of nitrogen and potassium, both of which are deficient normally in local soils. All potassium-based fertilizers in Bangladesh are imported at considerable cost, while nitrogenous fertilizers are both imported



Table 12.1. Estimated Uptake and Depletion of Combined Major Nutrients (N,P,K,S) in CIP Sample Areas.

| Cropping patterns                  | Annual Crop Uptake (kg/ha) | Addition of Fertilizer Nutrient (kg/ha) |
|------------------------------------|----------------------------|-----------------------------------------|
| <u>Meghna: Unprotected</u>         |                            |                                         |
| Upper Elevations (A <sub>1</sub> ) |                            |                                         |
| Potato-Mixed aus & aman            |                            |                                         |
| Lentil-Jute -T.D. aman             | 329                        | 256                                     |
| Lower Elevations (A <sub>2</sub> ) |                            |                                         |
| Lentil-Jute-T.D. aman              |                            |                                         |
| Chili-T.D.aman-Mustard             | 463                        | 279                                     |
| <u>Meghna: Protected</u>           |                            |                                         |
| Upper Elevations (B <sub>1</sub> ) |                            |                                         |
| Potato-Boro(H)-T.aman (H)          | 669                        | 551                                     |
| Lower Elevations (B <sub>2</sub> ) |                            |                                         |
| Potato-Boro(H)- T.aman (H)         | 666                        | 744                                     |
| <u>Dakatia: Unprotected</u>        |                            |                                         |
| Upper Elevations (D <sub>2</sub> ) |                            |                                         |
| B.aman-Boro (H)                    | 306                        | 242                                     |
| Lower Elevations (D <sub>1</sub> ) |                            |                                         |
| Boro (H)                           | 239                        | 205                                     |
| <u>Dakatia: Protected</u>          |                            |                                         |
| Upper Elevations (C <sub>1</sub> ) |                            |                                         |
| T. aman (L)-Boro (H)               |                            |                                         |
| T. aman (H)-Boro (H)               | 373                        | 229                                     |
| Lower Elevations (C <sub>2</sub> ) |                            |                                         |
| T. aman (L)-Boro (H)               | 394                        | 215                                     |

Table 12.2. Estimated Nutrient Uptake and Fertilizer Supplementation of Selected Nutrients in CIP Study Plots.

| Frontage | Protection Status | Elevation | Plot No.       | Nutrient Uptake (kg/ha) |    |     |    | Fertilizer Addition (kg/ha) |     |     |     |
|----------|-------------------|-----------|----------------|-------------------------|----|-----|----|-----------------------------|-----|-----|-----|
|          |                   |           |                | N                       | P  | K   | S  | N                           | P   | K   | S   |
| Meghna   | Outside           | Upper     | A <sub>1</sub> | 144                     | 26 | 142 | 17 | 132                         | 44  | 33  | 48  |
|          |                   | Lower     | A <sub>2</sub> | 207                     | 33 | 198 | 25 | 152                         | 26  | 62  | 39  |
|          | Inside            | Upper     | B <sub>1</sub> | 258                     | 44 | 339 | 28 | 250                         | 61  | 148 | 91  |
|          |                   | Lower     | B <sub>2</sub> | 257                     | 44 | 338 | 27 | 319                         | 103 | 164 | 158 |
| Dakatia  | Outside           | Upper     | D <sub>2</sub> | 117                     | 19 | 158 | 12 | 192                         | 22  | 28  | -   |
|          |                   | Lower     | D <sub>1</sub> | 93                      | 15 | 122 | 09 | 151                         | 32  | 22  | -   |
|          | Inside            | Upper     | C <sub>1</sub> | 142                     | 24 | 192 | 15 | 175                         | 32  | 22  | -   |
|          |                   | Lower     | C <sub>2</sub> | 150                     | 25 | 204 | 15 | 128                         | 37  | 50  | -   |

and manufactured locally, but also at high cost to agricultural production.

The source of the high nitrogen content in the sediments was probably particulate organic allochthonous material and algal biomass, all of which are high in flood waters draining large expanse of previously inundated lands. It should be noted that the sediment value lies in its nature as a substrate, not simply as added fertilizing

medium. Although high by local standards, the nitrogen content of the added sediment is low in relation to levels of added fertilizer normally applied. Using estimates of sediment deposition calculated for the Meghna River by Whitton *et al.* (1988a), nitrogen addition from deposited sediments amounts to something like 100-150g/ha, compared to 50-60kg/ha nitrogen for a typical urea application. This is also probably orders of magnitude lower than the amounts of

nitrogen added locally to the soils by the abundant BGA (see below).

Despite the deposited sediments having higher nutrient contents than local soils in many cases, it was also observed that post-monsoon soil samples taken outside the embankment along the Meghna River had similar or even lower nutrient concentrations after the subsidence of the floods than before. Nutrient depletion though crop uptake was one factor responsible, and was probably a major cause in the case of potassium which has a high crop uptake rate and was deficient in most soils. For other elements, notably nitrogen, crop uptake plus chemical breakdown may have played a role in depleting post-monsoon soil concentrations. Noting that lower elevation soils often had higher nutrient levels than upper elevation soils in the post-monsoon period (e.g. calcium, potassium, phosphorus, sulphur, copper, manganese and zinc), and that this was not always explained by higher fertilizer applications at the lower elevations, it is possible that leaching of soil nutrients by moving and subsiding flood waters may have been a factor in reducing nutrient levels in unprotected soils. Late season concentrations of iron and zinc in Meghna River water were noted to rise sharply as the flooding season progressed, possibly indicating that leaching was taking place.

The concentrations of various soil nutrients in deposited sediments were quantified in the study but not the actual amounts of sediment deposited. Determination of the latter was constrained by time, resources and, most importantly, lack of full control over the management of the study sites. It was clear, however, that sedimentation was a significant edaphic factor along the Meghna River but not the Dakatia. The distribution of sediments over the agricultural lands along the Meghna prior to the construction of the embankment is unknown. It may have been extensive, or may have been limited to a relatively narrow band along the river. This is an important item of knowledge to be obtained from further research, since the extent of sedimentation prior to flood control embanking obviously determines the extent of impact of flood control on soil quality and agricultural

production. Moreover, the amounts of sediment deposited in various sites and at various elevations relative to the river source need to be quantified for computation of total nutrient loadings and comparison to agricultural crop requirements and required fertilizer supplementation.

### 12.3 Role of Water Soluble Nutrients in Soil Fertility

The waters inundating the flooded sites outside the CIP were high in TDS, but contained only moderate to low concentrations of the key plant nutrients. Calcium was present in moderate quantities in Meghna River water and probably contributed to the characteristically high calcium content of Meghna River soils. Ammonium nitrogen was detected in traces only. Nitrate and nitrite nitrogen contents were not assayed. Dakatia River water was generally low in most dissolved nutrients, reflecting the high proportion of local runoff and rainwater in that river. Study results suggested that soluble nutrients were added to soils in moderate to small quantities, but the significance was small in relation to particulate and adsorbed nutrients carried by the sediments themselves.

### 12.4 Role of BGA in Soil Fertility

The major finding of the study was that BGA were abundant in water and attached to rice plants in both flood-protected and flood-exposed situations. They were much more abundant in the clear waters near the Dakatia sampling sites than in the more turbid Meghna waters. Differences between the different river sites were much greater than differences between protected and exposed sites on the same river frontage. BGA was in fact slightly more abundant outside the Meghna embankment than inside it. The data suggest that the role of BGA in supplying nitrogen through biological fixation was probably not significantly different in protected and exposed sites along the Meghna or the Dakatia respectively.



## 12.5 Nutrient Depletion in Flood Protected Lands

The study results point out the significant increases in crop production which follow on the use of HYVs and triple cropping patterns, both practices made possible by flood protection. However, there is a associated high rate of extraction of soil nutrients which is not balanced (in the case of the CIP at least) by the use of fertilizers. Rice crops cover over 80 percent of

the CIP and annually remove a large amount of nutrients, particularly potassium which is a key nutrient in river-borne sediments. The long-term implications to soil quality, sustainability of production and economic gains are obvious. The present cropping system in the CIP needs to be made more diverse in terms of crops, and should include more pulses and oilseeds. There is an obvious need to increase the use of green manuring crops.

## Chapter 13

## CONCLUSIONS AND RECOMMENDATIONS

The study proved that deposited sediments along the Meghna River in the vicinity of the CIP have a high nutritive value for crop production. The conventional wisdom frequently voiced by farmers, i.e. that sediment deposition within agricultural lands is desirable for soil fertility, was essentially substantiated for the area under study. The study further showed that soil nutrients are affected by many factors in an area subjected to flooding and flood protection, including the types of crops grown, the types and rates of fertilizer applications, the elevation of the soils relative to the local flooding levels, and the sediment content of the rivers supplying the floodwaters. BGA were found to be abundant during the monsoon season and likely contribute significantly to nitrogen fixation in both flood-protected and flood exposed soils.

Crop production within the flood protected area was two to three times higher than that outside the embankments because of the protection provided and because of associated changes in cropping patterns and the use of HYVs. Such increases in production required high rates of fertilizer application. Such high crop production rates could not be obtained in flood prone areas, even with the annual deposition of nutritive sediments, such as occurs along the Meghna River at CIP.

The appropriate way to gain advantage from both positive factors, i.e. increased production from flood protection and the benefits of sediment deposition (which is essentially free nutrient substrate) would appear to be some form of controlled flooding, where sediment rich water is permitted access to agricultural lands at key periods in the cropping cycle, but is held out during subsequent periods when crops are susceptible to flood damage and when sediment concentrations may be declining due to subsiding flood levels. Controlled flooding is a key concept in the Flood Action Plan, primarily via the compartmentalization approach which relies on controlled flooding and associated water manage-

ment practices by local farmers and community groups. It would seem desirable however to examine the efficiency of sediment deposition on lands when flood waters enter primarily via regulators rather than overbank floods, since restrictive canal and regulator openings are likely to act as sediment traps.

The results reported in this study refer to the CIP area where the samples were collected. Care should be taken in extrapolating from the situation in the relatively low sediment environment of the lower Meghna River to the higher sedimentary environment of the Jamuna, or from the lower Meghna, which receives sediments from a wide variety of sources, to the upper reaches of the country which may receive sediment from more limited sources and sources closer to the eroding foothills in India. However, the widespread view held by farmers in all parts of Bangladesh that normal seasonal flooding (*barsha*) and associated sediment deposition is beneficial suggests that sediments are valuable sources of soil nutrients in other regions.

The study findings indicate that river-derived sedimentation is an important factor in soil fertility in the Bangladesh floodplain. It should be taken into full consideration in water resource development, especially where there is a likelihood of its exclusion by embankments. The extent of sedimentation is probably a result of several factors, including suspended sediment concentrations in river water, maximum flood stage, duration of maximum flood stage and local topography. In order to properly include the benefits of sediment deposition in pre-project assessment and to fully address the negative impacts of its exclusion from the post-project situation, it would be necessary to know the amounts of sediment deposited in various sites and in which sites it is not an important pre-project consideration because of distance from the flood source, local topography, etc. Measurement of all these factors would be impractical for every environmental impact assessment



of a flood control, drainage and/or irrigation project. A better understanding of the process in various flooding cases would permit assessment of likely impacts in any specific case, based on observations of average river stage during flooding, project area topography, spatial relationship of the project area to the mainstem river, and the quantity and quality of suspended sediments in the main rivers at various stages of the flood cycle.

It is recommended that:

- a. controlled flooding be further examined as an option for flood control in agricultural areas and that ways be specifically sought to ensure effective transfer of river-borne sediments to agricultural lands at key periods in the cropping cycles;
- b. consideration be given to repeating the soil comparison study in other regions in Bangladesh, especially in the upper Meghna and Jamuna basins where different sedimentary regimes and local geochemistry might produce different information and conclusions from those made here; and
- c. consideration be given to undertaking specific studies with a view to enlarging the overall knowledge of river-derived sedimentation of agricultural lands to establish the cause-and-effect links between the spatial aspects of sediment deposition and the quantifiable hydrological and topographic parameters of flooding.

Chapter 14

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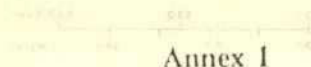
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CH

MOUZA LAKHIMPUR  
TALUK CHANDPUR  
DIST. CHANDPUR 1210



Annex 1

Location of Soil Sampling Plots, Chandpur Irrigation Project

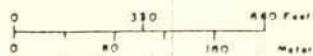




MOUZA : LAXMIPUR

THANA : CHANDPUR

DIST : CHANDPUR



LEGEND

Plot No

1576, 1584, 1723, 1838

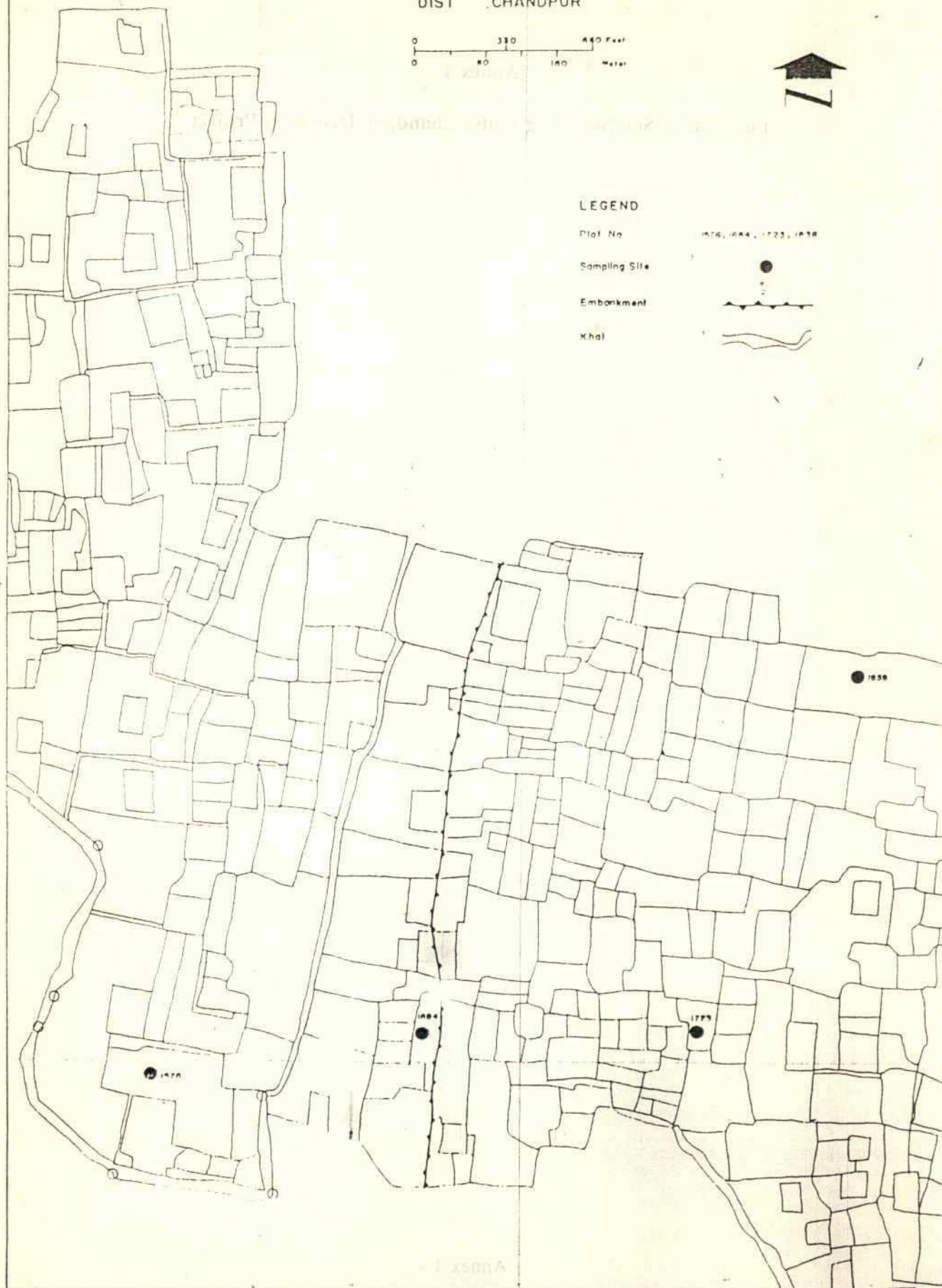
Sampling Site



Embankment



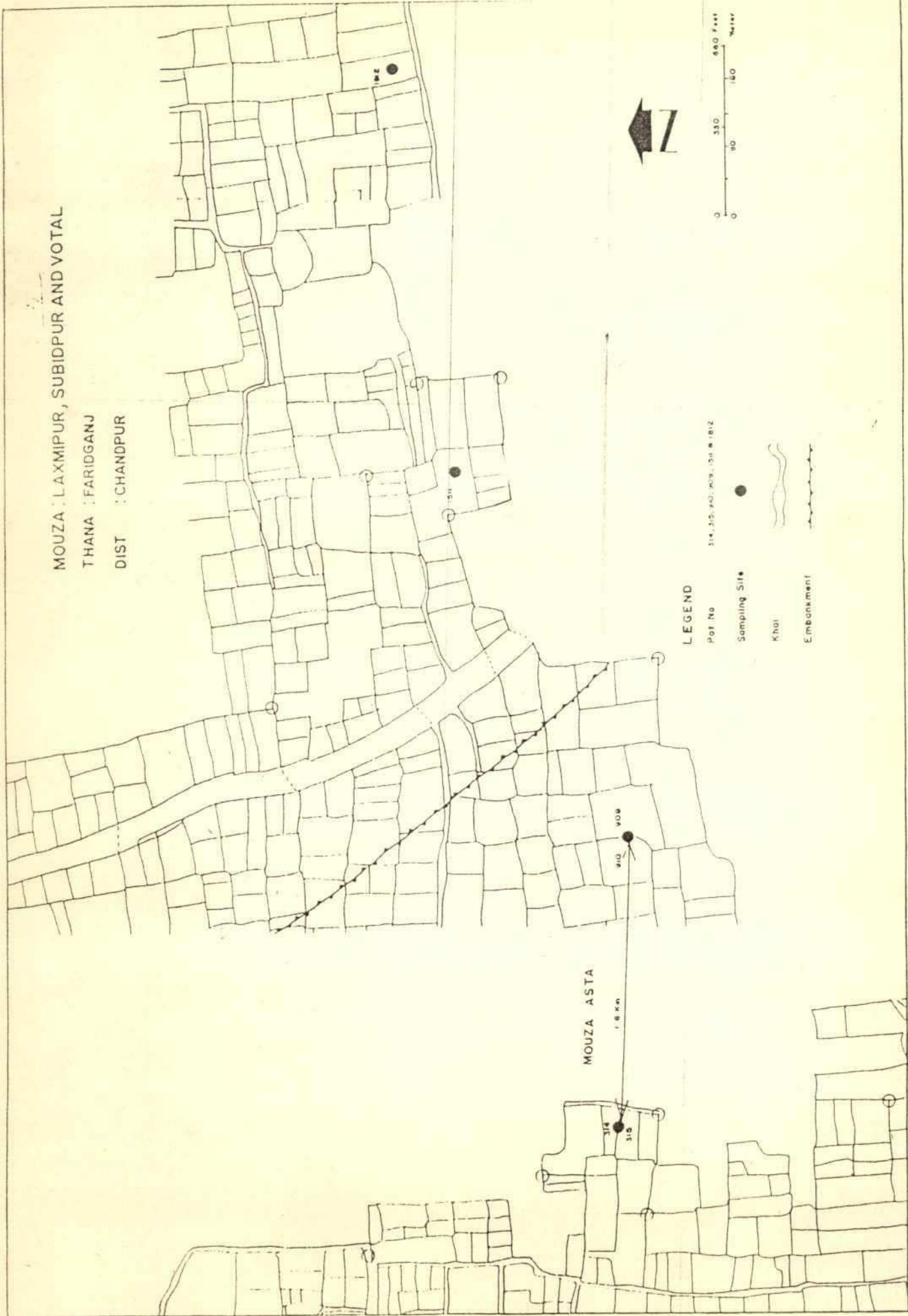
Khal



MOUZA : LAXMIPUR, SUBIDPUR AND VOTAL

THANA : FARIDGANJ

DIST : CHANDPUR



LEGEND

Pot No 314, 315, 316, 317, 318, 319, 320, 321, 322

Sampling Site

Khali

Embankment



# SOIL SAMPLING DESIGN FOR A<sub>1</sub>

Meter



|    |    |    |          |    |    |
|----|----|----|----------|----|----|
| 0  | 8  | 16 | 24       | 32 | 40 |
|    | 1  | 2  | 3        | 4  | 5  |
| 8  |    |    |          |    |    |
|    | 6  | 7  | I<br>8   | 9  | 10 |
| 16 |    |    |          |    |    |
|    | 11 | 12 | 13       | 14 | 15 |
| 24 |    |    |          |    |    |
|    | 16 | 17 | II<br>18 | 19 | 20 |
| 32 |    |    |          |    |    |

A. Location  
Village: Laksmipur, Mouza: Laksmipur  
Union: Sakhua, Thana: Chandpur

B. Land owner:

I. Md. Rahman Khan  
S/o. Late Hashem Khan

II. Abdul Halim Khan  
S/o. Late Haji Umed Khan

22

Annex 2

Soil Sampling Designs at the Chandpur Irrigation Project



# SOIL SAMPLING DESIGN FOR A<sub>2</sub>

Meter



|    |    |    |            |    |    |
|----|----|----|------------|----|----|
| 0  | 8  | 16 | 24         | 32 | 32 |
| 8  | 1  | 2  | 3          | 4  | 5  |
| 16 | 6  | 7  | 8<br>(1)   | 9  | 10 |
| 24 | 11 | 12 | 13         | 14 | 15 |
| 32 | 16 | 17 | 18<br>(II) | 19 | 20 |

A. Location:  
Village: Laksmipur, Mouza: Laksmipur (sheet-4)  
Union: Shakhua, Thana: Chandpur  
Dist.: Chandpur

B. Land owner:

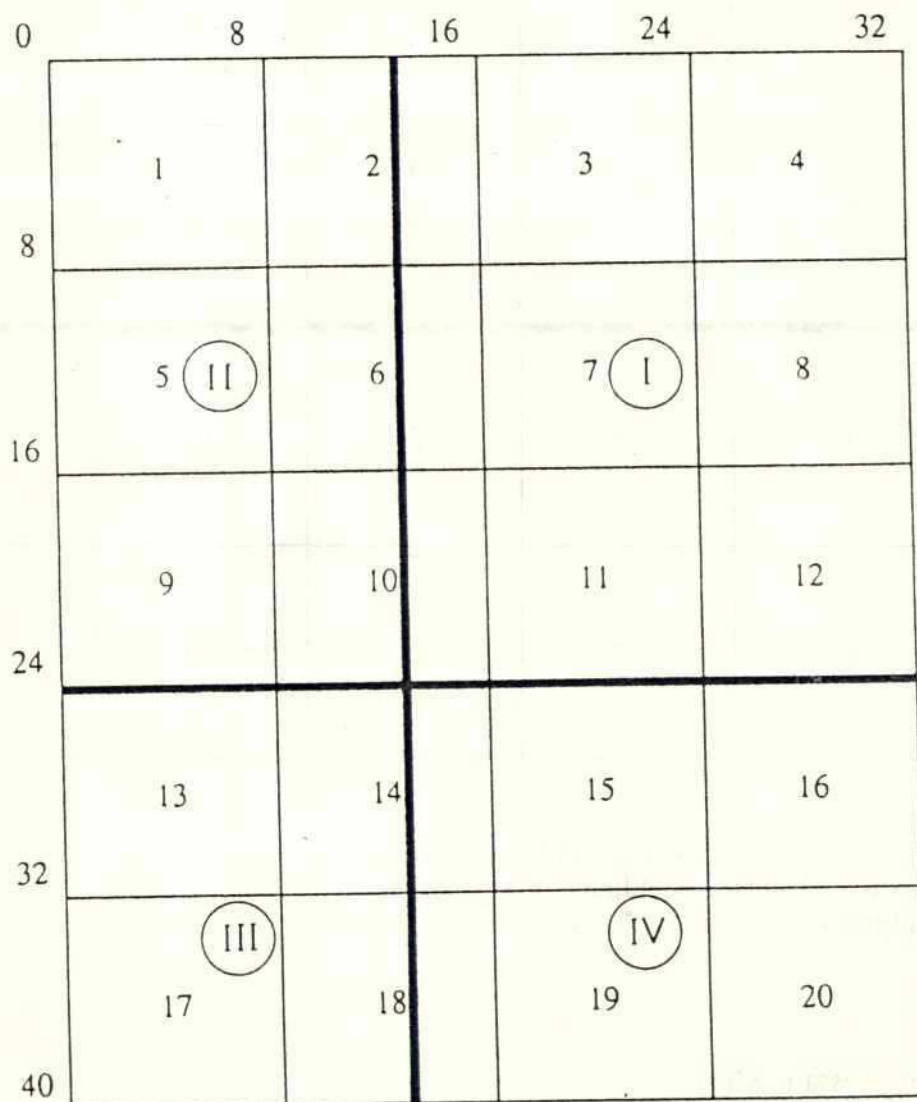
I. Amir Hossain Khan  
S/o. Late Abdul Gafur Khan

II. Anwarullah Gazi  
S/o. Late Mana Gazi

98

# SOIL SAMPLING DESIGN FOR B<sub>1</sub>

Meter



A. Location:  
 Village: Laksmipur, Mouza: Laksmipur (sheet-4)  
 Union: Shakhua, Thana: Chandpur  
 Dist.: Chandpur

B. Land owner:

I. Yunus Khan  
 S/o. Late Hussain Khan

III. Hakim Khan  
 S/o. Late Gafur Khan

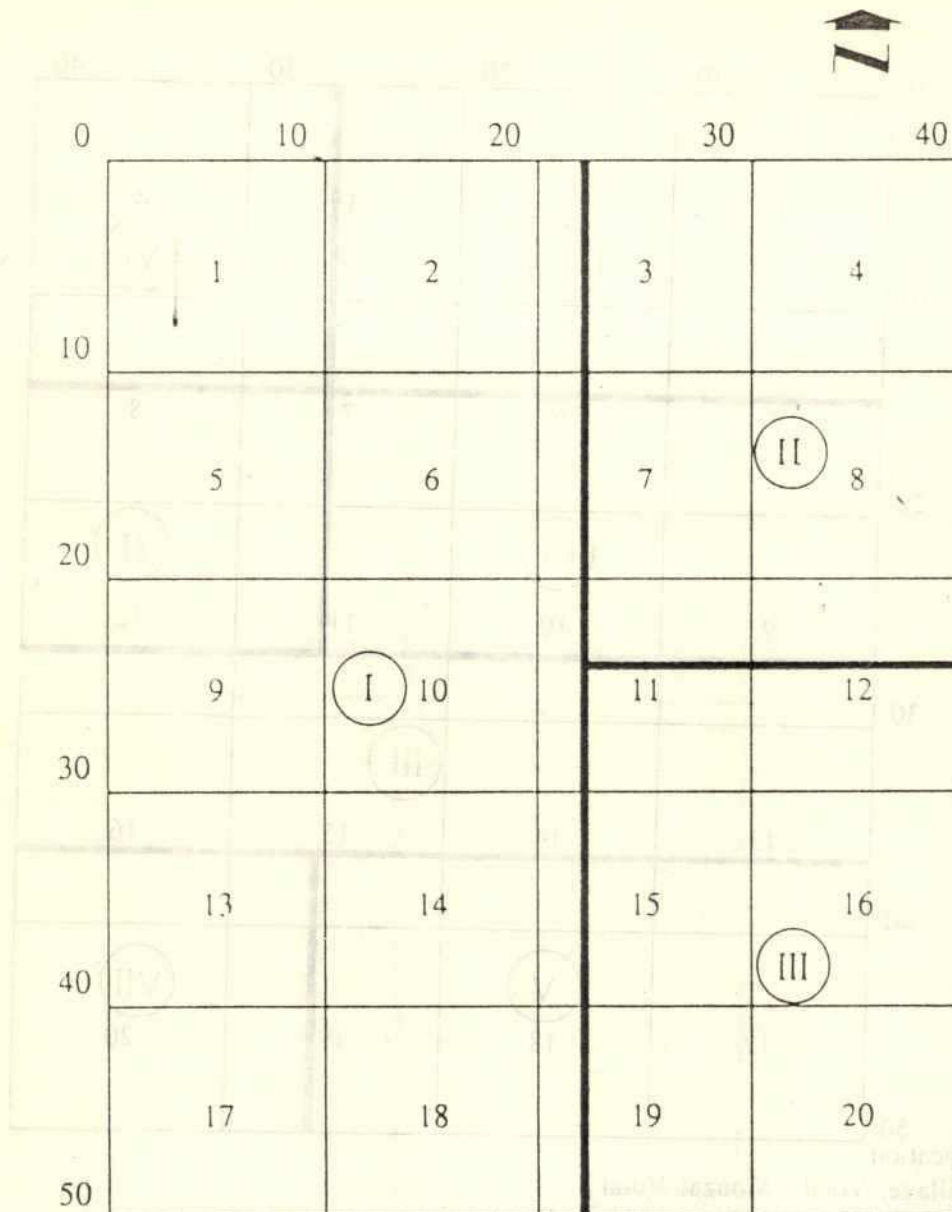
II. Sattar Mridha  
 S/o. Late Mantazuddin Mridha

IV. Khairun Nesa  
 Husband: Md. Waliullah



# SOIL SAMPLING DESIGN FOR B<sub>2</sub>

Meter



## A. Location

Village: Laksmipur, Mouza: Laksmipur (sheet-4)

Union: Shakhua, Thana: Chandpur

Dist.: Chandpur

## B. Land owner:

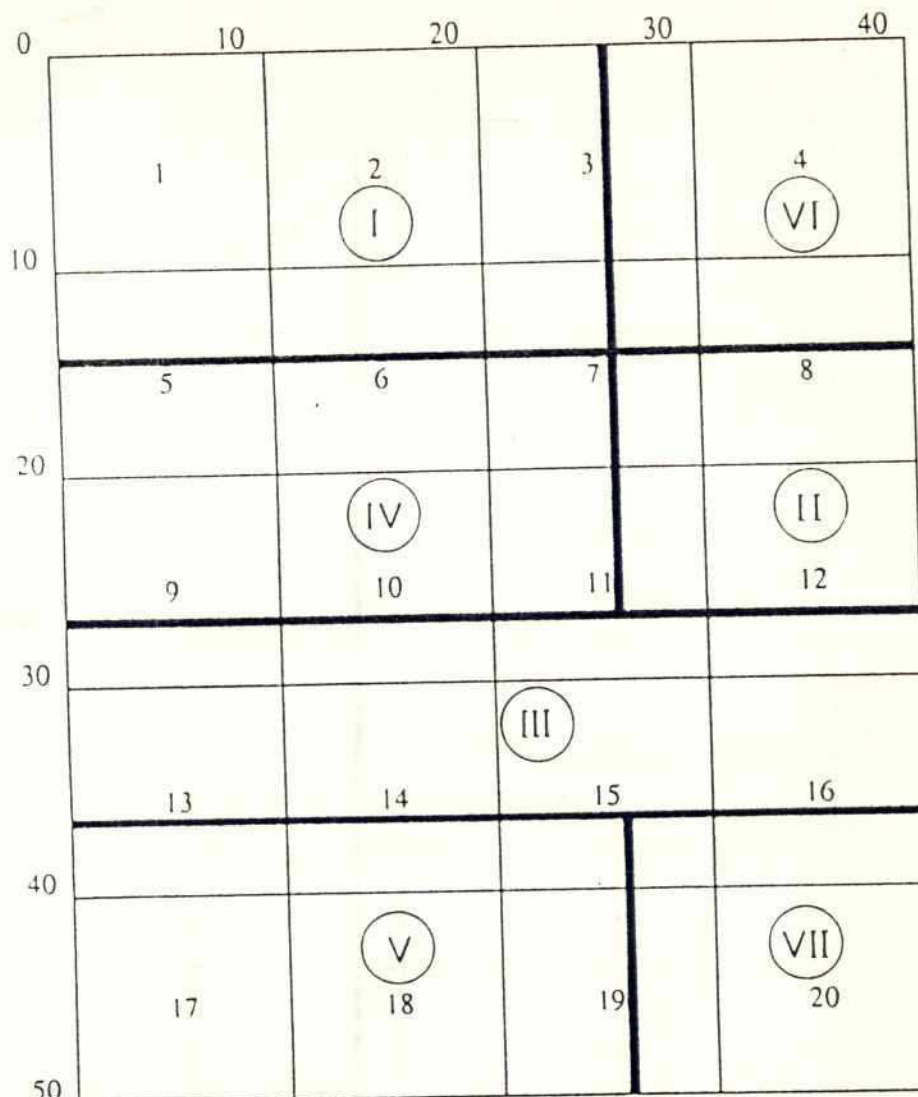
I. Momtazuddin Ukil  
S/o. Late Jamaluddin Ukil

III. Ilias Ukil  
S/o. Late Samsuddin Ukil

II. Serazul Ukil  
S/o. Late Samsuddin Ukil

# SOIL SAMPLING DESIGN FOR C<sub>1</sub>

Meter



A. Location  
Village: Votal, Mouza: Votal  
Union: Guptieast (5 no.), Thana: Faridganj  
Dist.: Chandpur

B. Land owner:

I. Abdul Satter  
S/o. Late Munsur Ali

II. Anamia Bepari  
S/o. Late Salimuddin Bepari

III. Abul Bashar  
S/o. Late Sobhan Ali

IV. Samsul Haque  
S/o. Late Rehanuddin

V. Sona Mia Bepari  
S/o. Late Salimuddin

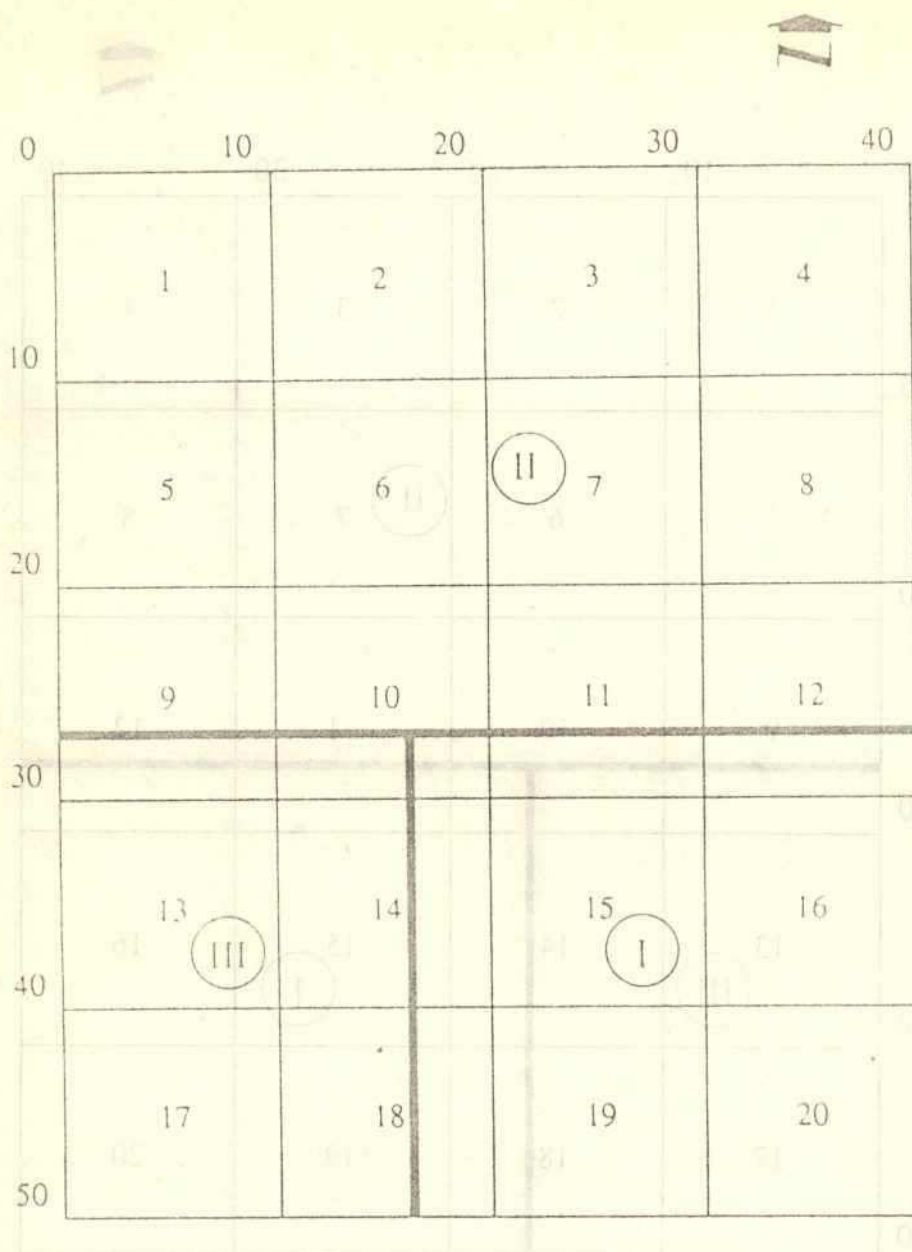
VI. Noor Mohammad  
S/o. Late Abdul Hashem

VII. Siddique Mia  
S/o. Late Abdul Aziz



# SOIL SAMPLING DESIGN FOR C<sub>2</sub>

Meter



## A. Location

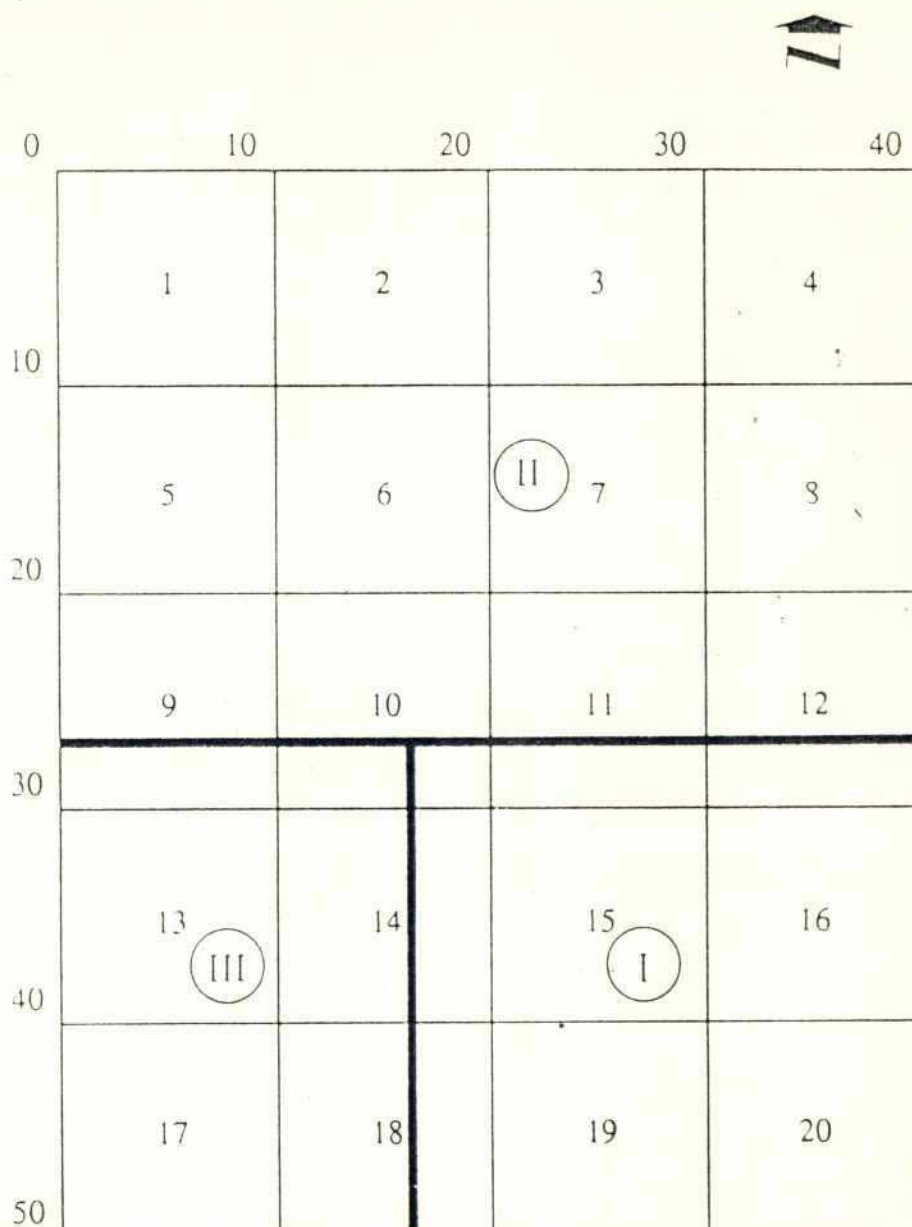
Village: Subidpur, Mouza: Subidpur  
Union: Subidpur, Thana: Faridganj  
Dist.: Chandpur

## B. Land owner:

- |                                                      |                                                          |
|------------------------------------------------------|----------------------------------------------------------|
| I. Shafiullah Bhuiyan<br>S/o. Late Elahi Box Bhuiyan | III. Shahidullah Bhuiyan<br>S/o. Late Jinnat Ali Bhuiyan |
| II. Altaf Bhuiyan<br>S/o. Late Aminuddin Bhuiyan     |                                                          |

# SOIL SAMPLING DESIGN FOR C<sub>2</sub>

Meter



A. Location  
 Village: Subidpur, Mouza: Subidpur  
 Union: Subidpur, Thana: Faridganj  
 Dist.: Chandpur

B. Land owner:

I. Shafiullah Bhuiyan  
 S/o. Late Elahi Box Bhuiyan

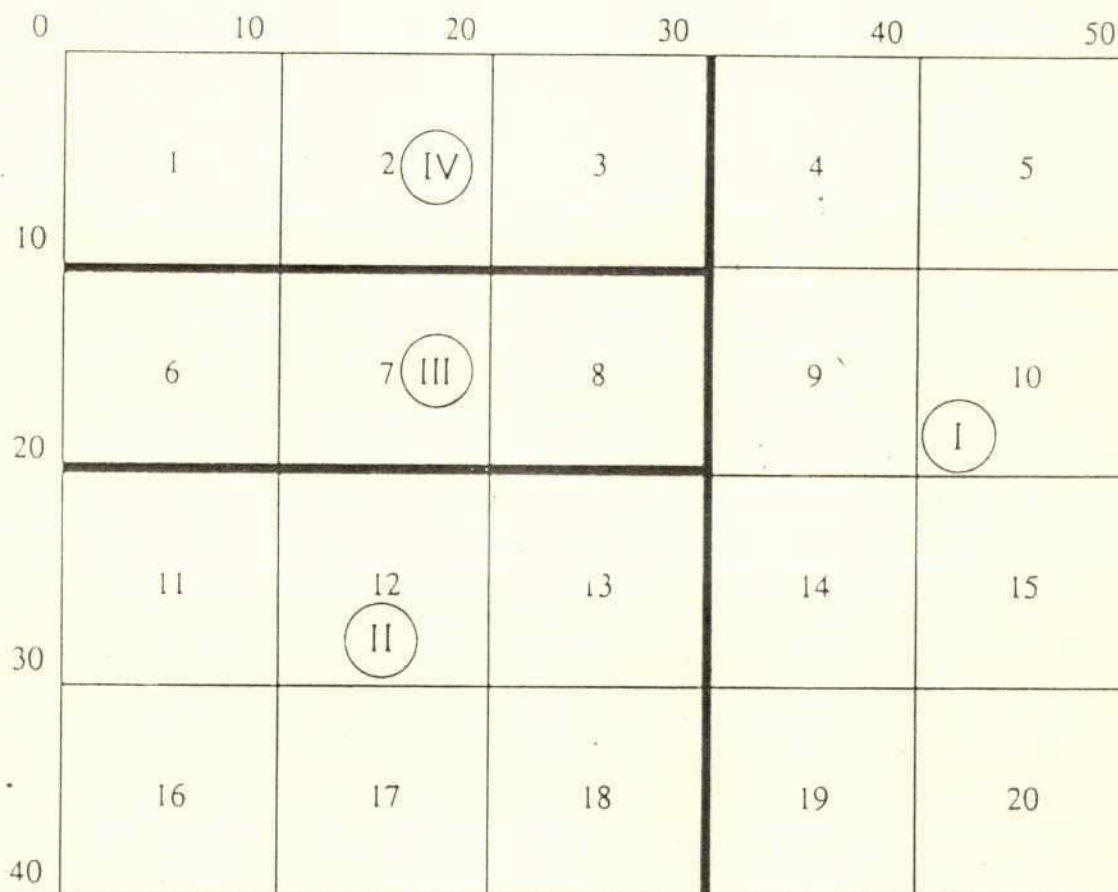
III. Shahidullah Bhuiyan  
 S/o. Late Jinnat Ali Bhuiyan

II. Altaf Bhuiyan  
 S/o. Late Aminuddin Bhuiyan



SOIL SAMPLING DESIGN FOR D<sub>2</sub>

Meter



A. Location  
 Village: Laksmipur, Mouza: Laksmipur  
 Union: Guptieast, Thana: Faridganj  
 Dist.: Chandpur

B. Land owner:

I. Md. Ibrahim  
 S/o. Late Abdul Mazid

III. Md. Ibrahim  
 S/o. Md. Bepari

II. Ruhul Amin  
 S/o. Late Hamid Bepari

IV. Abul Khaer  
 S/o. Md. Bepari

## Annex 3

## Crop Nutrient Content of Surface Water Samples, CIP



### Annex 3.1.

## Monsoon Season

| Site                            | Date      | pH        | EC<br>ds/m | Ca<br>mg/L | Mg<br>mg/L | K<br>mg/L | NH <sub>4</sub> N<br>mg/L | P<br>mg/L | S<br>mg/L | B<br>mg/L | Cu<br>mg/L | Fe<br>mg/L | Mn<br>mg/L | Zn<br>mg/L |      |      |
|---------------------------------|-----------|-----------|------------|------------|------------|-----------|---------------------------|-----------|-----------|-----------|------------|------------|------------|------------|------|------|
| Meghna River 1                  | 05-Aug-92 | Mean      | 6.8        | 0.1        | 9.3        | 2.9       | 1.8                       | 0.0       | 0.1       | 0.4       | 0.0        | 0.0        | 0.0        | 0.3        |      |      |
|                                 |           | Std       | 0.1        | 0.0        | 0.9        | 0.7       | 0.2                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 987        |      |      |
|                                 | 1         | 26-Aug-92 | Mean       | 6.9        | 0.1        | 16.0      | 2.9                       | 1.6       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 282  |      |
|                                 |           | Std       | 0.0        | 0.0        | 2.8        | 0.7       | 0.0                       | 0.0       | 0.1       | 0.4       | 0.0        | 0.0        | 0.1        | 0.0        | 867  |      |
|                                 | 1         | 17-Sep-92 | Mean       | 6.7        | 0.1        | 12.7      | 3.9                       | 1.1       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 19   |      |
|                                 |           | Std       | 0.1        | 0.0        | 1.9        | 0.1       | 0.1                       | 0.0       | 0.1       | 0.4       | 0.0        | 0.0        | 0.1        | 0.1        | 760  |      |
|                                 | 1         | 10-Oct-92 | Mean       | 6.9        | 0.1        | 19.6      | 3.1                       | 1.7       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 118  |      |
|                                 |           | Std       | 0.0        | 0.0        | 0.6        | 0.8       | 0.0                       | 0.0       | 0.0       | 0.5       | 0.0        | 0.1        | 0.4        | 0.0        | 560  |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            | 86   |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            |      |      |
| Meghna River 2                  | 04-Aug-92 | Mean      | 6.7        | 0.1        | 6.0        | 2.4       | 1.6                       | 0.0       | 0.1       | 0.4       | 0.0        | 0.0        | 0.0        | 0.0        | 987  |      |
|                                 |           | Std       | 0.1        | 0.0        | 1.6        | 0.0       | 0.0                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.1        | 0.0        | 0.0        | 105  |      |
|                                 | 2         | 25-Aug-92 | Mean       | 6.9        | 0.1        | 13.3      | 2.4                       | 1.8       | 0.0       | 0.1       | 0.5        | 0.0        | 0.2        | -0.0       | 0.2  | 1107 |
|                                 |           | Std       | 0.1        | 0.0        | 1.9        | 0.0       | 0.1                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 82   |      |
|                                 | 2         | 16-Sep-92 | Mean       | 6.8        | 0.1        | 26.0      | 5.6                       | 1.3       | 0.0       | 0.1       | 0.4        | 0.0        | 0.0        | 0.0        | 0.0  | 1667 |
|                                 |           | Std       | 0.1        | 0.0        | 2.8        | 1.2       | 0.4                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 317  |      |
|                                 | 2         | 05-Oct-92 | Mean       | 7.1        | 0.1        | 13.3      | 2.1                       | 1.2       | 0.0       | 0.1       | 0.5        | 0.0        | 0.1        | 0.1        | 0.4  | 733  |
|                                 |           | Std       | 0.0        | 0.0        | 2.2        | 0.4       | 0.0                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 100  |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            |      |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            |      |      |
| Inside CIP<br>at Regu-<br>lator | 3         | 04-Aug-92 | Mean       | 6.7        | 0.1        | 6.7       | 2.4                       | 1.1       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 1013 |      |
|                                 |           | Std       | 0.2        | 0.0        | 2.5        | 0.0       | 0.1                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 421  |      |
|                                 | 3         | 25-Aug-92 | Mean       | 7.0        | 0.1        | 13.3      | 4.8                       | 2.3       | 0.0       | 0.1       | 0.4        | 0.0        | 0.1        | 0.0        | 0.2  | 1587 |
|                                 |           | Std       | 0.0        | 0.0        | 3.8        | 0.0       | 0.0                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 863  |      |
|                                 | 3         | 16-Sep-92 | Mean       | 6.5        | 0.1        | 9.3       | 4.8                       | 1.9       | 0.0       | 0.0       | 0.2        | 0.0        | 0.0        | 0.1        | 0.2  | 123  |
|                                 |           | Std       | 0.1        | 0.0        | 0.9        | 0.0       | 1.0                       | 0.0       | 0.0       | 0.2       | 0.0        | 0.2        | 0.0        | 0.0        | 312  |      |
|                                 | 3         | 05-Oct-92 | Mean       | 7.1        | 0.1        | 16.2      | 5.0                       | 1.8       | 0.0       | 0.1       | 0.5        | 0.0        | 0.0        | 0.4        | 0.0  | 680  |
|                                 |           | Std       | 0.0        | 0.0        | 3.3        | 0.6       | 0.1                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 226  |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            |      |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            |      |      |
| Dakatia<br>River                | 4         | 04-Aug-92 | Mean       | 6.8        | 0.1        | 7.3       | 3.2                       | 0.9       | 0.0       | 0.1       | 0.0        | 0.0        | 0.0        | 0.0        | 840  |      |
|                                 |           | Std       | 0.0        | 0.0        | 2.5        | 1.1       | 0.0                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 538  |      |
|                                 | 4         | 25-Aug-92 | Mean       | 7.0        | 0.1        | 6.7       | 3.2                       | 0.9       | 0.0       | 0.1       | 0.0        | 0.0        | 0.2        | 0.0        | 0.2  | 373  |
|                                 |           | Std       | 0.1        | 0.0        | 2.5        | 1.1       | 0.0                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 132  |      |
|                                 | 4         | 16-Sep-92 | Mean       | 6.6        | 0.1        | 4.0       | 2.4                       | 1.7       | 0.0       | 0.1       | 0.0        | 0.0        | 0.1        | 0.0        | 0.2  | 400  |
|                                 |           | Std       | 0.0        | 0.0        | 0.0        | 0.0       | 0.1                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 204  |      |
|                                 | 4         | 05-Oct-92 | Mean       | 7.2        | 0.1        | 8.8       | 4.1                       | 1.1       | 0.0       | 0.1       | 0.0        | 0.0        | 0.5        | 0.0        | 0.3  | 1133 |
|                                 |           | Std       | 0.0        | 0.0        | 2.1        | 1.0       | 0.1                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 395  |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            |      |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            |      |      |
| Dakatia<br>River                | 5         | 04-Aug-92 | Mean       | 6.8        | 0.1        | 4.0       | 2.4                       | 0.9       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 307  |      |
|                                 |           | Std       | 0.0        | 0.0        | 0.0        | 0.0       | 0.0                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 82   |      |
|                                 | 5         | 25-Aug-92 | Mean       | 7.0        | 0.1        | 6.0       | 3.2                       | 0.6       | 0.0       | 0.1       | 0.0        | 0.0        | 0.0        | 0.0        | 0.2  | 560  |
|                                 |           | Std       | 0.1        | 0.0        | 2.8        | 1.1       | 0.0                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.1        | 0.0        | 0.0        | 131  |      |
|                                 | 5         | 16-Sep-92 | Mean       | 6.7        | 0.1        | 4.0       | 2.4                       | 1.8       | 0.0       | 0.1       | 0.0        | 0.0        | 0.0        | 0.0        | 0.2  | 840  |
|                                 |           | Std       | 0.1        | 0.0        | 0.0        | 0.0       | 0.0                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.1        | 0.0        | 0.0        | 229  |      |
|                                 | 5         | 05-Oct-92 | Mean       | 7.1        | 0.1        | 21.0      | 12.5                      | 1.1       | 0.0       | 0.1       | 0.0        | 0.0        | 0.5        | 0.0        | 0.3  | 627  |
|                                 |           | Std       | 0.0        | 0.0        | 0.2        | 0.2       | 0.1                       | 0.0       | 0.0       | 0.0       | 0.0        | 0.0        | 0.0        | 0.0        | 197  |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            |      |      |
|                                 |           |           |            |            |            |           |                           |           |           |           |            |            |            |            |      |      |

Annex 3.2. Nutrient Content of Dry Season (March) Surface Water Samples from CIP Study Area

| Sample Site | pH | EC ds/m | Ca mg/l | Mg mg/l | K mg/l | NH <sub>4</sub> mg/l | P mg/l | S mg/l | B mg/l | Cu mg/l | Fe mg/l | Mn mg/l | Zn mg/l | TDS mg/l |
|-------------|----|---------|---------|---------|--------|----------------------|--------|--------|--------|---------|---------|---------|---------|----------|
| B1R1        | 7  | 0.21    | 0.2     | 0       | 0      | Trace                | 0.1    | 4      | Trace  | 0.15    | 1.3     | 0.32    | 1       | 240      |
| B1R2        | 7  | 0.22    | 0.2     | 0       | 0      | Trace                | 0.1    | 5      | Trace  | 0.16    | 1.2     | 0.18    | 0.7     | 80       |
| B1R3        | 7  | 0.23    | 0.2     | 0       | 0      | Trace                | 0.1    | 5      | Trace  | 0.17    | 1.3     | 0.27    | 0.6     | 240      |
| B2R1        | 7  | 0.23    | 0.2     | 0       | 0      | Trace                | 0      | 3      | Trace  | 0.04    | 0.9     | 0.09    | 0.6     | 200      |
| B2R2        | 7  | 0.23    | 0.2     | 0       | 0      | Trace                | 0.2    | 3      | Trace  | 0.04    | 0.9     | 0.39    | 0.6     | 240      |
| B2R3        | 7  | 0.23    | 0.2     | 0       | 0      | Trace                | 0.1    | 4      | Trace  | 0.05    | 0.6     | 0.13    | 0.7     | 200      |
| C1R1        | 7  | 0.19    | 0.2     | 0       | 0      | Trace                | 0.1    | 4      | Trace  | 0.08    | 1.0     | 0.04    | 0.5     | 240      |
| C1R2        | 7  | 0.20    | 0.2     | 0       | 0      | Trace                | 0.2    | 5      | Trace  | 0.04    | 0.6     | 0.17    | 0.5     | 160      |
| C1R3        | 7  | 0.19    | 0.2     | 0       | 0      | Trace                | 0.1    | 5      | Trace  | 0.05    | 0.9     | 0.09    | 0.6     | 80       |
| C2R1        | 7  | 0.17    | 0.2     | 0       | 0      | Trace                | 0.1    | 5      | Trace  | 0.13    | 1.0     | 0.17    | 0.5     | 160      |
| C2R2        | 7  | 0.17    | 0.19    | 0       | 0      | Trace                | 0.12   | 5      | Trace  | 0.19    | 0.5     | 0.21    | 0.5     | 160      |
| C1R3        | 7  | 0.16    | 0.21    | 0       | 0      | Trace                | 0.1    | 4      | Trace  | 0.11    | 0.9     | 0.01    | 0.5     | 80       |
| D2R1        | 7  | 0.74    | 0.2     | 0.1     | 0      | Trace                | 0.1    | 3      | Trace  | 0.08    | 0.8     | 0.24    | 0.3     | 480      |
| D2R2        | 7  | 0.78    | 0.2     | 0.1     | 0      | Trace                | 0.2    | 3      | Trace  | 0.15    | 0.6     | 0.16    | 0.5     | 520      |
| D2R3        | 7  | 0.78    | 0.2     | 0.1     | 0      | Trace                | 0.2    | 4      | Trace  | 0.08    | 0.4     | 0.28    | 0.4     | 480      |

Annex 3.3. Nutrient Content of Dry Season (April) Surface Water Samples from CIP Study Area

| Sample Site | pH  | EC ds/m | Ca mg/l | Mg mg/l | K mg/l | NH <sub>4</sub> mg/l | P mg/l | S mg/l | B mg/l | Cu mg/l | Fe mg/l | Mn mg/l | Zn mg/l | TDS mg/l |
|-------------|-----|---------|---------|---------|--------|----------------------|--------|--------|--------|---------|---------|---------|---------|----------|
| B1R1        | 7.2 | 0.16    | 46      | 9.20    | 1.80   | Trace                | 0.12   | 0.39   | Trace  | 0.6     | 0.7     | 0.7     | 0.7     | 440      |
| B1R2        | 7.1 | 0.16    | 35      | 8.50    | 1.60   | Trace                | 0.23   | 0.39   | Trace  | 0.3     | 0.9     | 0.5     | 0.7     | 400      |
| B1R3        | 7.3 | 0.16    | 40      | 8.20    | 1.70   | Trace                | 0.12   | 0.77   | Trace  | 0.2     | 0.9     | 0.5     | 0.8     | 480      |
| B2R1        | 7.4 | 0.18    | 39      | 9.10    | 2.30   | Trace                | 0.23   | 0.39   | Trace  | 0.3     | 0.8     | 0.5     | 0.6     | 400      |
| B2R2        | 7.4 | 0.17    | 56      | 8.80    | 1.90   | Trace                | Trace  | 0.77   | Trace  | 0.4     | 0.9     | 0.3     | 0.8     | 280      |
| B2R3        | 7.5 | 0.17    | 25      | 8.20    | 1.80   | Trace                | 0.12   | 0.39   | Trace  | 0.4     | 0.2     | 0.3     | 0.7     | 280      |
| C1R1        | 7.5 | 0.17    | 45      | 8.20    | 0.80   | Trace                | 0.12   | 0.77   | Trace  | 0.5     | 1.1     | 0.3     | 0.6     | 280      |
| C1R2        | 7.6 | 0.17    | 44      | 8.10    | 1.00   | Trace                | Trace  | 0.77   | Trace  | 0.4     | 0.7     | 0.4     | 0.5     | 240      |
| C1R3        | 7.5 | 0.17    | 33      | 9.10    | 1.20   | Trace                | 0.23   | 0.15   | Trace  | 0.4     | 0.6     | 0.5     | 0.7     | 320      |
| C2R1        | 7.4 | 0.25    | 29      | 8.60    | 2.20   | Trace                | 0.23   | 0.39   | Trace  | 0.4     | 0.5     | 0.4     | 0.7     | 320      |
| C2R2        | 7.4 | 0.25    | 36      | 10.09   | 1.70   | Trace                | 0.23   | 0.15   | Trace  | 0.5     | 0.9     | 0.3     | 0.7     | 400      |
| C2R3        | 7.5 | 0.26    | 32      | 8.50    | 2.10   | Trace                | 0.23   | 0.77   | Trace  | 0.3     | 1.0     | 0.4     | 0.6     | 320      |
| D1R1        | 7.7 | 0.32    | 34      | 17.70   | 4.00   | Trace                | 0.12   | 0.39   | Trace  | 0.1     | 0.3     | 0.2     | 0.8     | 400      |
| D1R2        | 7.7 | 0.32    | 43      | 21.10   | 4.10   | Trace                | 0.29   | 0.77   | Trace  | 0.5     | 0.3     | 0.5     | 0.7     | 400      |
| D1R3        | 7.8 | 0.32    | 36      | 17.90   | 3.80   | Trace                | Trace  | 0.77   | Trace  | 0.4     | 0.4     | 0.3     | 0.6     | 400      |
| D2R1        | 7.6 | 0.22    | 30      | 11.00   | 4.10   | Trace                | 0.23   | 0.77   | Trace  | 0.3     | 0.4     | 0.4     | 0.6     | 360      |
| D2R2        | 7.6 | 0.23    | 33      | 13.10   | 4.20   | Trace                | Trace  | 0.77   | Trace  | 0.3     | 0.8     | 0.1     | 0.6     | 320      |
| D2R3        | 7.7 | 0.24    | 37      | 11.40   | 4.20   | Trace                | 0.12   | 0.39   | Trace  | 0.4     | 0.5     | 0.4     | 0.6     | 400      |



## ANNEX 4

## Analysis of Variance: Water Samples from Chandpur

All effects assessed simultaneously, each effect adjusted for all other effects.

## A. Examining Differences Between Samples Taken From Different Strata

## Variable: pH

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0023          | .0012        | .0308   | .9697   |
| Within Groups  | 57   | 2.1570         | .0378        |         |         |
| Total          | 59   | 2.1593         |              |         |         |

## Variable: Ca

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .5320          | .2660        | .0062   | .9938   |
| Within Groups  | 57   | 2447.1640      | 42.9327      |         |         |
| Total          | 59   | 2447.6960      |              |         |         |

## Variable: Mg

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .1120          | .0560        | .0097   | .9903   |
| Within Groups  | 57   | 327.4840       | 5.7453       |         |         |
| Total          | 59   | 327.5960       |              |         |         |

## Variable: K

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0810          | .0405        | .1593   | .8531   |
| Within Groups  | 57   | 14.4930        | .2543        |         |         |
| Total          | 59   | 14.5740        |              |         |         |

Variable: NH<sub>4</sub>N

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0000          | .0000        |         |         |
| Within Groups  | 57   | .0000          | .0000        |         |         |
| Total          | 59   | .0000          |              |         |         |

## Variable: P

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0126          | .0063        | 2.6508  | .0793   |
| Within Groups  | 57   | .1357          | .0024        |         |         |
| Total          | 59   | .1484          |              |         |         |

## Variable: S

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0072          | .0036        | .3235   | .7259   |
| Within Groups  | 33   | .3683          | .0112        |         |         |
| Total          | 35   | .3756          |              |         |         |

## Variable: B

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0000          | .0000        |         |         |
| Within Groups  | 57   | .0000          | .0000        |         |         |
| Total          | 59   | .0000          |              |         |         |

## Variable: Cu

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0144          | .0072        | 1.0392  | .3603   |
| Within Groups  | 57   | .3953          | .0069        |         |         |
| Total          | 59   | .4098          |              |         |         |

Variable: Fe

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0137          | .0069        | .2601   | .7719   |
| Within Groups  | 57   | 1.5022         | .0264        |         |         |
| Total          | 59   | 1.5159         |              |         |         |

Variable: Mn

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0000          | .0000        | .0129   | .9872   |
| Within Groups  | 57   | .0239          | .0004        |         |         |
| Total          | 59   | .0240          |              |         |         |

Variable: Zn

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0022          | .0011        | .2574   | .7739   |
| Within Groups  | 57   | .2469          | .0043        |         |         |
| Total          | 59   | .2491          |              |         |         |

Variable: EC

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | .0000          | .0000        | .0152   | .9849   |
| Within Groups  | 57   | .0192          | .0003        |         |         |
| Total          | 59   | .0192          |              |         |         |

Variable: TDS

| Source         | D.F. | Sum of Squares | Mean Squares | F Ratio | F Prob. |
|----------------|------|----------------|--------------|---------|---------|
| Between Groups | 2    | 299253.3333    | 149626.6667  | .6490   | .5264   |
| Within Groups  | 57   | 13141680.00    | 230555.7895  |         |         |
| Total          | 59   | 13440933.33    |              |         |         |

B. Examining Differences Between Samples Taken From Different Sites at Different Periods

Variable: pH

| Source of Variation | Sum of Squares | DF | Mean Square | F      | Signif of F |
|---------------------|----------------|----|-------------|--------|-------------|
| Main Effects        | 1.615          | 7  | .231        | 28.839 | .000        |
| SITE                | .054           | 4  | .014        | 1.698  | .170        |
| PERIOD              | 1.561          | 3  | .520        | 65.028 | .000        |
| 2-way Interactions  | .224           | 12 | .019        | 2.337  | .022        |
| SITE PERIOD         | .224           | 12 | .019        | 2.337  | .022        |
| Explained           | 1.839          | 19 | .097        | 12.101 | .000        |
| Residual            | .320           | 40 | .008        |        |             |
| Total               | 2.159          | 59 | .037        |        |             |

Variable: Ca

| Source of Variation | Sum of Squares | DF | Mean Square | F      | Signif of F |
|---------------------|----------------|----|-------------|--------|-------------|
| Main Effects        | 1206.771       | 7  | 172.396     | 25.937 | .000        |
| SITE                | 582.699        | 4  | 145.675     | 21.917 | .000        |
| PERIOD              | 624.072        | 3  | 208.024     | 31.297 | .000        |
| 2-way Interactions  | 975.058        | 12 | 81.255      | 12.225 | .000        |
| SITE PERIOD         | 975.058        | 12 | 81.255      | 12.225 | .000        |
| Explained           | 2181.829       | 19 | 114.833     | 17.277 | .000        |
| Residual            | 265.867        | 40 | 6.647       |        |             |
| Total               | 2447.696       | 59 | 41.486      |        |             |



## Variable: Hg

| Source of Variation | Sum of Squares | DF | Mean Square | F      | Signif of F |
|---------------------|----------------|----|-------------|--------|-------------|
| Main Effects        | 97.574         | 7  | 13.939      | 22.273 | .000        |
| SITE                | 37.826         | 4  | 9.456       | 15.110 | .000        |
| PERIOD              | 59.748         | 3  | 19.916      | 31.823 | .000        |
| 2-way Interactions  | 204.989        | 12 | 17.082      | 27.295 | .000        |
| SITE PERIOD         | 204.989        | 12 | 17.082      | 27.295 | .000        |
| Explained           | 302.563        | 19 | 15.924      | 25.445 | .000        |
| Residual            | 25.033         | 40 | 0.626       |        |             |
| Total               | 327.596        | 59 | 5.552       |        |             |

## Variable: K

| Source of Variation | Sum of Squares | DF | Mean Square | F     | Signif of F |
|---------------------|----------------|----|-------------|-------|-------------|
| Main Effects        | 1.641          | 5  | 0.328       | 2.113 | .099        |
| SITE                | 0.684          | 2  | 0.342       | 2.202 | .132        |
| PERIOD              | 0.957          | 3  | 0.319       | 2.054 | .133        |
| 2-way Interactions  | 202.412        | 6  | 3.402       | 2.589 | .045        |
| SITE PERIOD         | 202.412        | 6  | 3.402       | 2.589 | .045        |
| Explained           | 204.052        | 11 | 18.548      | 2.372 | .037        |
| Residual            | 3.727          | 24 | 0.155       |       |             |
| Total               | 7.779          | 35 | 0.222       |       |             |

## Variable: NH4N

| Source of Variation | Sum of Squares | DF | Mean Square | F | Signif of F |
|---------------------|----------------|----|-------------|---|-------------|
| Main Effects        | 0.000          | 5  | 0.000       |   |             |
| SITE                | 0.000          | 2  | 0.000       |   |             |
| PERIOD              | 0.000          | 3  | 0.000       |   |             |
| 2-way Interactions  | 0.000          | 6  | 0.000       |   |             |
| SITE PERIOD         | 0.000          | 6  | 0.000       |   |             |
| Explained           | 0.000          | 11 | 0.000       |   |             |
| Residual            | 0.000          | 24 | 0.000       |   |             |
| Total               | 0.000          | 35 | 0.000       |   |             |

## Variable: P

| Source of Variation | Sum of Squares | DF | Mean Square | F     | Signif of F |
|---------------------|----------------|----|-------------|-------|-------------|
| Main Effects        | 0.039          | 5  | 0.008       | 5.063 | .003        |
| SITE                | 0.022          | 2  | 0.011       | 7.076 | .004        |
| PERIOD              | 0.017          | 3  | 0.006       | 3.721 | .025        |
| 2-way Interactions  | 0.009          | 6  | 0.001       | 0.924 | .495        |
| SITE PERIOD         | 0.009          | 6  | 0.001       | 0.924 | .495        |
| Explained           | 0.048          | 11 | 0.004       | 2.806 | .017        |
| Residual            | 0.037          | 24 | 0.002       |       |             |
| Total               | 0.085          | 35 | 0.002       |       |             |

## Variable: S

| Source of Variation | Sum of Squares | DF | Mean Square | F      | Signif of F |
|---------------------|----------------|----|-------------|--------|-------------|
| Main Effects        | 0.194          | 5  | 0.039       | 9.026  | .000        |
| SITE                | 0.009          | 2  | 0.005       | 1.081  | .355        |
| PERIOD              | 0.185          | 3  | 0.062       | 14.323 | .000        |
| 2-way Interactions  | 0.078          | 6  | 0.013       | 3.016  | .024        |
| SITE PERIOD         | 0.078          | 6  | 0.013       | 3.016  | .024        |
| Explained           | 0.272          | 11 | 0.025       | 5.748  | .000        |
| Residual            | 0.103          | 24 | 0.004       |        |             |
| Total               | 0.376          | 35 | 0.011       |        |             |

## Variable: B

| Source of Variation | Sum of Squares | DF | Mean Square | F | Signif of F |
|---------------------|----------------|----|-------------|---|-------------|
| Main Effects        | .000           | 7  | .000        |   |             |
| SITE                | .000           | 4  | .000        |   |             |
| PERIOD              | .000           | 3  | .000        |   |             |
| 2-way Interactions  | .000           | 12 | .000        |   |             |
| SITE PERIOD         | .000           | 12 | .000        |   |             |
| Explained           | .000           | 19 | .000        |   |             |
| Residual            | .000           | 40 | .000        |   |             |
| Total               | .000           | 59 | .000        |   |             |

## Variable: Cu

| Source of Variation | Sum of Squares | DF | Mean Square | F     | Signif of F |
|---------------------|----------------|----|-------------|-------|-------------|
| Main Effects        | .089           | 7  | .013        | 3.660 | .004        |
| SITE                | .044           | 4  | .011        | 3.175 | .023        |
| PERIOD              | .045           | 3  | .015        | 4.306 | .010        |
| 2-way Interactions  | .182           | 12 | .015        | 4.372 | .000        |
| SITE PERIOD         | .182           | 12 | .015        | 4.372 | .000        |
| Explained           | .271           | 19 | .014        | 4.110 | .000        |
| Residual            | .139           | 40 | .003        |       |             |
| Total               | .410           | 59 | .007        |       |             |

## Variable: Fe

| Source of Variation | Sum of Squares | DF | Mean Square | F       | Signif of F |
|---------------------|----------------|----|-------------|---------|-------------|
| Main Effects        | 1.078          | 7  | .154        | 95.953  | .000        |
| SITE                | .081           | 4  | .020        | 12.577  | .000        |
| PERIOD              | .997           | 3  | .332        | 207.120 | .000        |
| 2-way Interactions  | .374           | 12 | .031        | 19.401  | .000        |
| SITE PERIOD         | .374           | 12 | .031        | 19.401  | .000        |
| Explained           | 1.452          | 19 | .076        | 47.604  | .000        |
| Residual            | .064           | 40 | .002        |         |             |
| Total               | 1.516          | 59 | .026        |         |             |

## Variable: Mn

| Source of Variation | Sum of Squares | DF | Mean Square | F      | Signif of F |
|---------------------|----------------|----|-------------|--------|-------------|
| Main Effects        | .011           | 7  | .002        | 10.577 | .000        |
| SITE                | .007           | 4  | .002        | 12.286 | .000        |
| PERIOD              | .004           | 3  | .001        | 8.298  | .000        |
| 2-way Interactions  | .008           | 12 | .001        | 4.465  | .000        |
| SITE PERIOD         | .008           | 12 | .001        | 4.465  | .000        |
| Explained           | .018           | 19 | .001        | 6.716  | .000        |
| Residual            | .006           | 40 | .000        |        |             |
| Total               | .024           | 59 | .000        |        |             |

## Variable: EC

| Source of Variation | Sum of Squares | DF | Mean Square | F       | Signif of F |
|---------------------|----------------|----|-------------|---------|-------------|
| Main Effects        | .015           | 7  | .002        | 619.470 | .000        |
| SITE                | .009           | 4  | .002        | 657.923 | .000        |
| PERIOD              | .006           | 3  | .002        | 568.198 | .000        |
| 2-way Interactions  | .004           | 12 | .000        | 95.375  | .000        |
| SITE PERIOD         | .004           | 12 | .000        | 95.375  | .000        |
| Explained           | .019           | 19 | .001        | 288.462 | .000        |
| Residual            | .000           | 40 | .000        |         |             |
| Total               | .019           | 59 | .000        |         |             |



## Variable: Zn

| Source of Variation | Sum of Squares | DF | Mean Square | F       | Signif of F |
|---------------------|----------------|----|-------------|---------|-------------|
| Main Effects        | .194           | 7  | .028        | 86.313  | .000        |
| SITE                | .015           | 4  | .004        | 11.697  | .000        |
| PERIOD              | .179           | 3  | .060        | 185.801 | .000        |
| 2-way Interactions  | .042           | 12 | .003        | 10.858  | .000        |
| SITE PERIOD         | .042           | 12 | .003        | 10.858  | .000        |
| Explained           | .236           | 19 | .012        | 38.657  | .000        |
| Residual            | .013           | 40 | .000        |         |             |
| Total               | .249           | 59 | .004        |         |             |

## Variable: TDS

| Source of Variation | Sum of Squares | DF | Mean Square | F     | Signif of F |
|---------------------|----------------|----|-------------|-------|-------------|
| Main Effects        | 3490586.667    | 7  | 498655.238  | 3.467 | .005        |
| SITE                | 3038666.667    | 4  | 759666.667  | 5.281 | .002        |
| PERIOD              | 451920.000     | 3  | 150640.000  | 1.047 | .382        |
| 2-way Interactions  | 4196746.667    | 12 | 349728.889  | 2.431 | .018        |
| SITE PERIOD         | 4196746.667    | 12 | 349728.889  | 2.431 | .018        |
| Explained           | 7687333.333    | 19 | 404596.491  | 2.813 | .003        |
| Residual            | 5753600.000    | 40 | 143840.000  |       |             |
| Total               | 13440933.333   | 59 | 227812.429  |       |             |



## Annex 5.2. Samples Collected September 1992

| Species                                                | Meghna River Sites |                   | Dakatia River Sites |                   |
|--------------------------------------------------------|--------------------|-------------------|---------------------|-------------------|
|                                                        | Outside Embankment | Inside Embankment | Outside Embankment  | Inside Embankment |
| 1. Floating BGA (filaments/ml.)                        |                    |                   |                     |                   |
| a) <i>Aulosira Prolifica</i><br>(20-70 cells/fil)      | 0                  | 14                | 116                 | 137               |
| b) <i>Anabaena Oscillarioides</i><br>(25-50 cells/fil) | 137                | 13                | 75                  | 49                |
| c) <i>Anabaena fucillehornii</i><br>(15-25 cells/fil)  | 53                 | 42                | 10                  | 117               |
| d) <i>Cylindrospermum maitus</i><br>(60-70 cells/fil)  | 111                | 10                | 120                 | 12                |
| e) <i>Scytonema mirabile</i><br>(100-125 cells/fil)    | 112                | 10                | 160                 | 140               |
| f) <i>Scytonema subtile</i><br>(50-60 cells/fil)       | 43                 | 11                | 7                   | 80                |
| g) <i>Nostoc linckia</i><br>(35-60 cells/fil)          | 142                | 110               | 1157                | 133               |
| 2. Attached BGA (filaments/plant)                      |                    |                   |                     |                   |
| a) <i>Nostoc punctiforme</i><br>(15-20 cells/fil)      | 140                | 117               | 123                 | 133               |
| b) <i>Gloeotrichia pilgerii</i><br>(15-25 cells/fil)   | 19                 | 60                | 118                 | 110               |
| c) <i>Gloeotrichia natans</i><br>(20-30 cells/fil)     | 137                | 115               | 10                  | 111               |
| d) <i>Microchaete uberrima</i><br>(30-50 cells/fil)    | 112                | 73                | 1031                | 224               |



## Annex 5.3. Samples Collected October 1992

| Species                                                | Meghna River Sites |                   | Dakatia River Sites |                   |
|--------------------------------------------------------|--------------------|-------------------|---------------------|-------------------|
|                                                        | Outside Embankment | Inside Embankment | Outside Embankment  | Inside Embankment |
| <b>1. Floating BGA (filaments/ml.)</b>                 |                    |                   |                     |                   |
| a) <i>Aulosira prolifica</i><br>(20-70 cells/fil)      | 43                 | -                 | 111                 | -                 |
| b) <i>Anabaena affinis</i><br>(30-35 cells/fil)        | 20                 | -                 | 165                 | -                 |
| c) <i>Anabaena oscillarioides</i><br>(25-50 cells/fil) | 72                 | -                 | 32                  | -                 |
| d) <i>Cylindrospermum maius</i><br>(60-70 cells/fil)   | 116                | -                 | 113                 | -                 |
| e) <i>Scytonema subtile</i><br>(50-60 cells/fil)       | 0                  | -                 | 69                  | -                 |
| f) <i>Nostoc linckia</i><br>(35-60 cells/fil)          | 113                | 47                | 212                 | 118               |
| g) <i>Anabaena cylindrica</i><br>(60-70 cells/fil)     | 61                 | 71                | 100                 | 54                |
| <b>2. Attached BGA (filaments/plant)</b>               |                    |                   |                     |                   |
| a) <i>Nostoc punctiforme</i><br>(15-20 cells/fil)      | 111                | 141               | 88                  | 40                |
| b) <i>Gloeotrichia pilgerii</i><br>(15-25 cells/fil)   | 72                 | 18                | 72                  | 112               |
| c) <i>Gloeotrichia natans</i><br>(20-30 cells/fil)     | 54                 | 22                | 110                 | 62                |

## Annex 5.4. Samples Collected March 1993

| Species                                                | Meghna River Sites |                   | Dakatia River Sites |                   |
|--------------------------------------------------------|--------------------|-------------------|---------------------|-------------------|
|                                                        | Outside Embankment | Inside Embankment | Outside Embankment  | Inside Embankment |
| <b>1. Floating BGA (filaments/ml.)</b>                 |                    |                   |                     |                   |
| a) <i>Anabaena affinis</i><br>(30-35 cells/fil)        | -                  | 2                 | 5                   | 3                 |
| b) <i>Anabaena oscillarioides</i><br>(25-50 cells/fil) | -                  | 4                 | 3                   | 1                 |
| c) <i>Scytonema subtile</i><br>(50-60 cells/fil)       | -                  | 8                 | 8                   | 6                 |
| <b>2. Attached BGA (filaments/plant)</b>               |                    |                   |                     |                   |
| a) <i>Nostoc punctiforme</i><br>(15-20 cells/fil)      | -                  | 3                 | 4                   | 2                 |
| b) <i>Gloeotrichia natans</i><br>(20-30 cells/fil)     | -                  | 2                 | 3                   | 1                 |

Samples Collected Aug. 1992

## Annex 5

| Species                              | Relative Abundance of Blue Green Algae<br>in CIP Sampling Areas |      |      |      | Inside<br>Embankment | Inside<br>Embankment |
|--------------------------------------|-----------------------------------------------------------------|------|------|------|----------------------|----------------------|
|                                      | ment                                                            | ment | ment | ment | ment                 | ment                 |
| 1. <i>Flourensia</i> (71-<br>ment)   | 00                                                              | 3    | 13   | 23   |                      |                      |
| 2. <i>Microcystis</i> (71-<br>ment)  | 124                                                             | 12   | 4    | 173  |                      |                      |
| 3. <i>Microcystis</i> (71-<br>ment)  | 1                                                               | 3    | 108  | 108  |                      |                      |
| 4. <i>Microcystis</i> (71-<br>ment)  | 8                                                               | 63   | 18   | 19   |                      |                      |
| 5. <i>Microcystis</i> (71-<br>ment)  | 1                                                               | 3    | 33   | 101  |                      |                      |
| 6. <i>Microcystis</i> (71-<br>ment)  | 1                                                               | 12   | 33   | 10   |                      |                      |
| 7. <i>Microcystis</i> (71-<br>ment)  | 11                                                              | 7    | 38   | 9    |                      |                      |
| 8. <i>Microcystis</i> (71-<br>ment)  | 14                                                              | 8    | 81   | 10   |                      |                      |
| 9. <i>Microcystis</i> (71-<br>ment)  | 3                                                               | 11   | 3    | 48   |                      |                      |
| 10. <i>Microcystis</i> (71-<br>ment) | 3                                                               | 3    | 11   | 13   |                      |                      |
| 11. <i>Microcystis</i> (71-<br>ment) | 0                                                               | 0    | 28   | 0    |                      |                      |
| 12. <i>Microcystis</i> (71-<br>ment) |                                                                 |      |      |      |                      |                      |
| 13. <i>Microcystis</i> (71-<br>ment) | 12                                                              | 9    | 30   | 30   |                      |                      |
| 14. <i>Microcystis</i> (71-<br>ment) | 120                                                             | 111  | 203  | 106  |                      |                      |
| 15. <i>Microcystis</i> (71-<br>ment) | 2                                                               | 0    | 33   | 10   |                      |                      |



## Annex 5.1. Samples Collected August 1992

| Species                                              | Meghna River Sites |                   | Dakatia River Sites |                   |
|------------------------------------------------------|--------------------|-------------------|---------------------|-------------------|
|                                                      | Outside Embankment | Inside Embankment | Outside Embankment  | Inside Embankment |
| <b>1. Floating BGA (filaments/ml.)</b>               |                    |                   |                     |                   |
| a) <i>Aulosira prolifica</i><br>(20-70 cells/fil)    | 92                 | 2                 | 239                 | 321               |
| b) <i>Nostoc linckia</i><br>(35-60 cells/fil)        | 154                | 129               | 4                   | 173               |
| c) <i>Nostoc spongiaeforme</i><br>(30-35 cells/fil)  | 1                  | 3                 | 295                 | 108               |
| d) <i>Anabaena cylindrica</i><br>(60-70 cells/fil)   | 8                  | 67                | 18                  | 19                |
| e) <i>Anabaena sphaerica</i><br>(30-80 cells/fil)    | 1                  | 3                 | 33                  | 101               |
| f) <i>Cylindrospermum maius</i><br>(60-70 cells/fil) | 4                  | 12                | 32                  | 10                |
| g) <i>Anabaena volzii</i><br>(25-35 cells/fil)       | 11                 | 7                 | 35                  | 0                 |
| h) <i>Scytonema mirabile</i><br>(100-125 cells/fil)  | 14                 | 8                 | 81                  | 10                |
| i) <i>Scytonema subtile</i><br>(50-60 cells/fil)     | 3                  | 11                | 2                   | 48                |
| j) <i>Gloeotrichia natans</i><br>(20-30 cells/fil)   | 3                  | 4                 | 11                  | 15                |
| k) <i>Anabaena affinis</i><br>(30-35 cells/fil)      | 0                  | 13                | 28                  | 0                 |
| <b>2. Attached BGA (filaments/plant)</b>             |                    |                   |                     |                   |
| a) <i>Nostoc spongiaeforme</i><br>(30-35 cells/fil)  | 115                | 9                 | 36                  | 30                |
| b) <i>Nostoc microscopium</i><br>(40-50 cells/fil)   | 150                | 111               | 203                 | 106               |
| c) <i>Microchaete uberrima</i><br>(30-50 cells/fil)  | 2                  | 6                 | 25                  | 10                |

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Annex 6

Soil Fertility Comparisons: CIP Sample Sites

| Sample ID | Date     | Location | Soil Fertility Data |     |     |       | Notes |
|-----------|----------|----------|---------------------|-----|-----|-------|-------|
|           |          |          | N                   | P   | K   | Other |       |
| 1         | 10/15/00 | Site 1   | 1.2                 | 0.5 | 1.8 |       |       |
| 2         | 10/15/00 | Site 2   | 1.5                 | 0.6 | 2.0 |       |       |
| 3         | 10/15/00 | Site 3   | 1.1                 | 0.4 | 1.7 |       |       |
| 4         | 10/15/00 | Site 4   | 1.3                 | 0.5 | 1.9 |       |       |
| 5         | 10/15/00 | Site 5   | 1.4                 | 0.6 | 2.1 |       |       |
| 6         | 10/15/00 | Site 6   | 1.2                 | 0.5 | 1.8 |       |       |
| 7         | 10/15/00 | Site 7   | 1.5                 | 0.6 | 2.0 |       |       |
| 8         | 10/15/00 | Site 8   | 1.1                 | 0.4 | 1.7 |       |       |
| 9         | 10/15/00 | Site 9   | 1.3                 | 0.5 | 1.9 |       |       |
| 10        | 10/15/00 | Site 10  | 1.4                 | 0.6 | 2.1 |       |       |
| 11        | 10/15/00 | Site 11  | 1.2                 | 0.5 | 1.8 |       |       |
| 12        | 10/15/00 | Site 12  | 1.5                 | 0.6 | 2.0 |       |       |
| 13        | 10/15/00 | Site 13  | 1.1                 | 0.4 | 1.7 |       |       |
| 14        | 10/15/00 | Site 14  | 1.3                 | 0.5 | 1.9 |       |       |
| 15        | 10/15/00 | Site 15  | 1.4                 | 0.6 | 2.1 |       |       |
| 16        | 10/15/00 | Site 16  | 1.2                 | 0.5 | 1.8 |       |       |
| 17        | 10/15/00 | Site 17  | 1.5                 | 0.6 | 2.0 |       |       |
| 18        | 10/15/00 | Site 18  | 1.1                 | 0.4 | 1.7 |       |       |
| 19        | 10/15/00 | Site 19  | 1.3                 | 0.5 | 1.9 |       |       |
| 20        | 10/15/00 | Site 20  | 1.4                 | 0.6 | 2.1 |       |       |
| 21        | 10/15/00 | Site 21  | 1.2                 | 0.5 | 1.8 |       |       |
| 22        | 10/15/00 | Site 22  | 1.5                 | 0.6 | 2.0 |       |       |
| 23        | 10/15/00 | Site 23  | 1.1                 | 0.4 | 1.7 |       |       |
| 24        | 10/15/00 | Site 24  | 1.3                 | 0.5 | 1.9 |       |       |
| 25        | 10/15/00 | Site 25  | 1.4                 | 0.6 | 2.1 |       |       |
| 26        | 10/15/00 | Site 26  | 1.2                 | 0.5 | 1.8 |       |       |
| 27        | 10/15/00 | Site 27  | 1.5                 | 0.6 | 2.0 |       |       |
| 28        | 10/15/00 | Site 28  | 1.1                 | 0.4 | 1.7 |       |       |
| 29        | 10/15/00 | Site 29  | 1.3                 | 0.5 | 1.9 |       |       |
| 30        | 10/15/00 | Site 30  | 1.4                 | 0.6 | 2.1 |       |       |
| 31        | 10/15/00 | Site 31  | 1.2                 | 0.5 | 1.8 |       |       |
| 32        | 10/15/00 | Site 32  | 1.5                 | 0.6 | 2.0 |       |       |
| 33        | 10/15/00 | Site 33  | 1.1                 | 0.4 | 1.7 |       |       |
| 34        | 10/15/00 | Site 34  | 1.3                 | 0.5 | 1.9 |       |       |
| 35        | 10/15/00 | Site 35  | 1.4                 | 0.6 | 2.1 |       |       |
| 36        | 10/15/00 | Site 36  | 1.2                 | 0.5 | 1.8 |       |       |
| 37        | 10/15/00 | Site 37  | 1.5                 | 0.6 | 2.0 |       |       |
| 38        | 10/15/00 | Site 38  | 1.1                 | 0.4 | 1.7 |       |       |
| 39        | 10/15/00 | Site 39  | 1.3                 | 0.5 | 1.9 |       |       |
| 40        | 10/15/00 | Site 40  | 1.4                 | 0.6 | 2.1 |       |       |
| 41        | 10/15/00 | Site 41  | 1.2                 | 0.5 | 1.8 |       |       |
| 42        | 10/15/00 | Site 42  | 1.5                 | 0.6 | 2.0 |       |       |
| 43        | 10/15/00 | Site 43  | 1.1                 | 0.4 | 1.7 |       |       |
| 44        | 10/15/00 | Site 44  | 1.3                 | 0.5 | 1.9 |       |       |
| 45        | 10/15/00 | Site 45  | 1.4                 | 0.6 | 2.1 |       |       |
| 46        | 10/15/00 | Site 46  | 1.2                 | 0.5 | 1.8 |       |       |
| 47        | 10/15/00 | Site 47  | 1.5                 | 0.6 | 2.0 |       |       |
| 48        | 10/15/00 | Site 48  | 1.1                 | 0.4 | 1.7 |       |       |
| 49        | 10/15/00 | Site 49  | 1.3                 | 0.5 | 1.9 |       |       |
| 50        | 10/15/00 | Site 50  | 1.4                 | 0.6 | 2.1 |       |       |
| 51        | 10/15/00 | Site 51  | 1.2                 | 0.5 | 1.8 |       |       |
| 52        | 10/15/00 | Site 52  | 1.5                 | 0.6 | 2.0 |       |       |
| 53        | 10/15/00 | Site 53  | 1.1                 | 0.4 | 1.7 |       |       |
| 54        | 10/15/00 | Site 54  | 1.3                 | 0.5 | 1.9 |       |       |
| 55        | 10/15/00 | Site 55  | 1.4                 | 0.6 | 2.1 |       |       |
| 56        | 10/15/00 | Site 56  | 1.2                 | 0.5 | 1.8 |       |       |
| 57        | 10/15/00 | Site 57  | 1.5                 | 0.6 | 2.0 |       |       |
| 58        | 10/15/00 | Site 58  | 1.1                 | 0.4 | 1.7 |       |       |
| 59        | 10/15/00 | Site 59  | 1.3                 | 0.5 | 1.9 |       |       |
| 60        | 10/15/00 | Site 60  | 1.4                 | 0.6 | 2.1 |       |       |
| 61        | 10/15/00 | Site 61  | 1.2                 | 0.5 | 1.8 |       |       |
| 62        | 10/15/00 | Site 62  | 1.5                 | 0.6 | 2.0 |       |       |
| 63        | 10/15/00 | Site 63  | 1.1                 | 0.4 | 1.7 |       |       |
| 64        | 10/15/00 | Site 64  | 1.3                 | 0.5 | 1.9 |       |       |
| 65        | 10/15/00 | Site 65  | 1.4                 | 0.6 | 2.1 |       |       |
| 66        | 10/15/00 | Site 66  | 1.2                 | 0.5 | 1.8 |       |       |
| 67        | 10/15/00 | Site 67  | 1.5                 | 0.6 | 2.0 |       |       |
| 68        | 10/15/00 | Site 68  | 1.1                 | 0.4 | 1.7 |       |       |
| 69        | 10/15/00 | Site 69  | 1.3                 | 0.5 | 1.9 |       |       |
| 70        | 10/15/00 | Site 70  | 1.4                 | 0.6 | 2.1 |       |       |
| 71        | 10/15/00 | Site 71  | 1.2                 | 0.5 | 1.8 |       |       |
| 72        | 10/15/00 | Site 72  | 1.5                 | 0.6 | 2.0 |       |       |
| 73        | 10/15/00 | Site 73  | 1.1                 | 0.4 | 1.7 |       |       |
| 74        | 10/15/00 | Site 74  | 1.3                 | 0.5 | 1.9 |       |       |
| 75        | 10/15/00 | Site 75  | 1.4                 | 0.6 | 2.1 |       |       |
| 76        | 10/15/00 | Site 76  | 1.2                 | 0.5 | 1.8 |       |       |
| 77        | 10/15/00 | Site 77  | 1.5                 | 0.6 | 2.0 |       |       |
| 78        | 10/15/00 | Site 78  | 1.1                 | 0.4 | 1.7 |       |       |
| 79        | 10/15/00 | Site 79  | 1.3                 | 0.5 | 1.9 |       |       |
| 80        | 10/15/00 | Site 80  | 1.4                 | 0.6 | 2.1 |       |       |
| 81        | 10/15/00 | Site 81  | 1.2                 | 0.5 | 1.8 |       |       |
| 82        | 10/15/00 | Site 82  | 1.5                 | 0.6 | 2.0 |       |       |
| 83        | 10/15/00 | Site 83  | 1.1                 | 0.4 | 1.7 |       |       |
| 84        | 10/15/00 | Site 84  | 1.3                 | 0.5 | 1.9 |       |       |
| 85        | 10/15/00 | Site 85  | 1.4                 | 0.6 | 2.1 |       |       |
| 86        | 10/15/00 | Site 86  | 1.2                 | 0.5 | 1.8 |       |       |
| 87        | 10/15/00 | Site 87  | 1.5                 | 0.6 | 2.0 |       |       |
| 88        | 10/15/00 | Site 88  | 1.1                 | 0.4 | 1.7 |       |       |
| 89        | 10/15/00 | Site 89  | 1.3                 | 0.5 | 1.9 |       |       |
| 90        | 10/15/00 | Site 90  | 1.4                 | 0.6 | 2.1 |       |       |
| 91        | 10/15/00 | Site 91  | 1.2                 | 0.5 | 1.8 |       |       |
| 92        | 10/15/00 | Site 92  | 1.5                 | 0.6 | 2.0 |       |       |
| 93        | 10/15/00 | Site 93  | 1.1                 | 0.4 | 1.7 |       |       |
| 94        | 10/15/00 | Site 94  | 1.3                 | 0.5 | 1.9 |       |       |
| 95        | 10/15/00 | Site 95  | 1.4                 | 0.6 | 2.1 |       |       |
| 96        | 10/15/00 | Site 96  | 1.2                 | 0.5 | 1.8 |       |       |
| 97        | 10/15/00 | Site 97  | 1.5                 | 0.6 | 2.0 |       |       |
| 98        | 10/15/00 | Site 98  | 1.1                 | 0.4 | 1.7 |       |       |
| 99        | 10/15/00 | Site 99  | 1.3                 | 0.5 | 1.9 |       |       |
| 100       | 10/15/00 | Site 100 | 1.4                 | 0.6 | 2.1 |       |       |



| Parameter             | Meghna River Side  |      |      |                   |       |       | Dakatia River Side |      |      |                   |       |       |      |      |      |      |      |
|-----------------------|--------------------|------|------|-------------------|-------|-------|--------------------|------|------|-------------------|-------|-------|------|------|------|------|------|
|                       | Outside Embankment |      |      | Inside Embankment |       |       | Outside Embankment |      |      | Inside Embankment |       |       |      |      |      |      |      |
|                       | Pre-               | Post | Pre- | Post              | Upper | Lower | Pre-               | Post | Pre- | Post              | Upper | Lower |      |      |      |      |      |
| pH                    | Mean               | 5.8  | 5.7  | 5.6               | 5.3   | 6.1   | 5.5                | 6.4  | 5.5  | 6.1               | 5.5   | 6.0   | 5.6  | 6.1  | 5.7  | 6.3  | 6.1  |
|                       | SD                 | 0.2  | 0.1  | 0.1               | 0.1   | 0.1   | 0.1                | 0.1  | 0.1  | 0.1               | 0.1   | 0.1   | 0.1  | 0.1  | 0.1  | 0.1  | 0.3  |
|                       | Minimum            | 5.5  | 5.6  | 5.4               | 5.1   | 5.9   | 5.3                | 6.0  | 5.4  | 6.0               | 5.4   | 5.8   | 5.5  | 6.0  | 5.6  | 6.2  | 5.9  |
|                       | Maximum            | 6.1  | 5.8  | 5.8               | 5.5   | 6.3   | 5.6                | 6.5  | 5.7  | 6.2               | 5.6   | 6.1   | 6.0  | 6.3  | 6.0  | 6.4  | 7.1  |
| Organic Matter %      | Mean               | 3.0  | 2.3  | 3.0               | 2.6   | 3.4   | 2.7                | 3.9  | 3.1  | 3.5               | 2.6   | 4.0   | 2.8  | 3.7  | 4.5  | 4.0  | 5.4  |
|                       | SD                 | 0.2  | 0.2  | 0.2               | 0.3   | 0.2   | 0.3                | 0.2  | 0.3  | 0.1               | 0.2   | 0.1   | 0.2  | 0.1  | 0.2  | 0.2  | 0.1  |
|                       | Minimum            | 2.7  | 2.0  | 2.5               | 2.1   | 2.9   | 2.4                | 3.5  | 2.5  | 3.3               | 2.3   | 3.8   | 2.3  | 3.5  | 4.0  | 3.6  | 5.2  |
|                       | Maximum            | 3.3  | 2.9  | 3.3               | 3.1   | 3.6   | 3.5                | 4.2  | 3.9  | 3.8               | 2.9   | 4.2   | 3.3  | 3.8  | 4.6  | 4.4  | 5.4  |
| Calcium meq/100g      | Mean               | 10.1 | 9.0  | 10.3              | 11.0  | 11.9  | 8.6                | 10.6 | 11.3 | 4.1               | 3.7   | 7.2   | 5.7  | 7.1  | 6.4  | 7.4  | 9.1  |
|                       | SD                 | 0.5  | 0.7  | 0.4               | 2.5   | 0.7   | 1.2                | 1.1  | 0.7  | 0.2               | 0.4   | 1.0   | 0.5  | 1.2  | 0.4  | 1.1  | 0.6  |
|                       | Minimum            | 9.0  | 8.0  | 8.9               | 8.3   | 10.8  | 6.8                | 6.4  | 9.7  | 3.8               | 3.2   | 5.9   | 5.1  | 5.7  | 5.4  | 5.7  | 8.1  |
|                       | Maximum            | 10.7 | 10.2 | 10.8              | 17.0  | 13.3  | 12.0               | 11.6 | 12.5 | 4.7               | 4.8   | 9.1   | 6.7  | 10.7 | 7.2  | 9.0  | 10.4 |
| Magnesium meq/100g    | Mean               | 5.7  | 3.0  | 4.4               | 2.3   | 4.4   | 2.4                | 2.8  | 2.0  | 1.9               | 1.0   | 3.8   | 2.2  | 3.0  | 1.9  | 3.3  | 2.5  |
|                       | SD                 | 0.4  | 0.3  | 0.3               | 0.2   | 0.5   | 0.3                | 0.2  | 0.1  | 0.2               | 0.2   | 0.5   | 0.2  | 0.4  | 0.1  | 0.5  | 0.2  |
|                       | Minimum            | 4.8  | 2.6  | 3.8               | 2.0   | 3.4   | 1.8                | 2.5  | 1.8  | 1.6               | 0.8   | 3.3   | 1.9  | 2.3  | 1.6  | 2.3  | 2.2  |
|                       | Maximum            | 6.2  | 3.5  | 4.8               | 2.6   | 5.2   | 2.8                | 3.3  | 2.2  | 2.2               | 1.4   | 5.3   | 2.4  | 4.0  | 2.1  | 3.9  | 2.9  |
| Potassium meq/100g    | Mean               | 0.19 | 0.15 | 0.18              | 0.21  | 0.05  | 0.32               | 0.05 | 0.78 | 0.06              | 0.11  | 0.09  | 0.14 | 0.06 | 0.11 | 0.07 | 0.09 |
|                       | SD                 | 0.03 | 0.04 | 0.03              | 0.06  | 0.02  | 0.23               | 0.02 | 0.16 | 0.02              | 0.02  | 0.02  | 0.03 | 0.02 | 0.03 | 0.01 | 0.02 |
|                       | Minimum            | 0.15 | 0.10 | 0.15              | 0.12  | 0.02  | 0.12               | 0.01 | 0.44 | 0.03              | 0.07  | 0.06  | 0.09 | 0.03 | 0.03 | 0.05 | 0.06 |
|                       | Maximum            | 0.25 | 0.26 | 0.25              | 0.35  | 0.14  | 0.80               | 0.10 | 1.00 | 0.09              | 0.14  | 0.15  | 0.19 | 0.10 | 0.17 | 0.09 | 0.14 |
| Ammonia Nitrogen µg/g | Mean               | 17   | 17   | 23                | 18    | 11    | 14                 | 13   | 97   | 13                | 14    | 21    | 16   | 16   | 17   | 19   | 11   |
|                       | SD                 | 7.3  | 3.6  | 8.1               | 3.6   | 3.0   | 2.5                | 3.9  | 13.5 | 4.0               | 1.9   | 5.9   | 4.5  | 3.8  | 3.5  | 7.2  | 6.9  |
|                       | Minimum            | 10   | 14   | 10                | 14    | 5     | 11                 | 5    | 80   | 5                 | 11    | 10    | 11   | 10   | 11   | 10   | 8    |
|                       | Maximum            | 30   | 23   | 40                | 23    | 20    | 17                 | 20   | 125  | 20                | 17    | 30    | 23   | 22   | 23   | 30   | 41   |
| Phosphorus µg/g       | Mean               | 21   | 19   | 17                | 24    | 22    | 44                 | 31   | 115  | 12                | 16    | 34    | 34   | 10   | 16   | 31   | 23   |
|                       | SD                 | 9.7  | 4.0  | 3.7               | 2.5   | 8.1   | 32.3               | 5.7  | 29.2 | 3.0               | 1.7   | 5.2   | 3.1  | 4.8  | 3.0  | 5.2  | 2.7  |
|                       | Minimum            | 10   | 13   | 10                | 20    | 10    | 13                 | 19   | 70   | 7                 | 13    | 24    | 26   | 5    | 13   | 19   | 19   |
|                       | Maximum            | 43   | 28   | 22                | 28    | 37    | 104                | 39   | 182  | 20                | 20    | 40    | 38   | 24   | 27   | 39   | 27   |
| Sulphur µg/g          | Mean               | 48   | 41   | 31                | 52    | 14    | 59                 | 23   | 167  | 8                 | 10    | 14    | 15   | 24   | 29   | 19   | 21   |
|                       | SD                 | 9.2  | 7.3  | 7.4               | 10.4  | 4.3   | 31.1               | 7.0  | 51.4 | 1.4               | 2.8   | 2.5   | 3.1  | 4.5  | 5.2  | 2.7  | 6.5  |
|                       | Minimum            | 29   | 29   | 17                | 38    | 9     | 14                 | 49   | 107  | 6                 | 5     | 9     | 9    | 15   | 24   | 13   | 14   |
|                       | Maximum            | 59   | 57   | 44                | 71    | 23    | 94                 | 49   | 275  | 10                | 14    | 20    | 19   | 29   | 38   | 23   | 38   |
| Continued             |                    |      |      |                   |       |       |                    |      |      |                   |       |       |      |      |      |      |      |

Continued

Annex 6 (Continued)

| Parameter                 | Meghna River Side  |      |          |                   |       |      | Dakatia River Side |      |          |                   |       |      |      |      |      |      |      |
|---------------------------|--------------------|------|----------|-------------------|-------|------|--------------------|------|----------|-------------------|-------|------|------|------|------|------|------|
|                           | Outside Embankment |      |          | Inside Embankment |       |      | Outside Embankment |      |          | Inside Embankment |       |      |      |      |      |      |      |
|                           | Pre-               | Post | Pre-Post | Upper             | Lower | Post | Pre-               | Post | Pre-Post | Upper             | Lower | Post |      |      |      |      |      |
| Boron<br>µg/g             | Mean               | 0.7  | 0.8      | 0.5               | 0.8   | 0.9  | 1.3                | 0.9  | 2.0      | 0.4               | 0.6   | 0.5  | 0.9  | 0.8  | 0.8  | 0.6  | 0.6  |
|                           | SD                 | 0.2  | 0.2      | 0.3               | 0.2   | 0.1  | 0.3                | 0.1  | 0.3      | 0.2               | 0.2   | 0.2  | 0.2  | 0.1  | 0.2  | 0.2  | 0.2  |
|                           | Minimum            | 0.4  | 0.6      | 0.1               | 0.6   | 0.7  | 0.8                | 0.7  | 1.1      | 0.1               | 0.3   | 0.2  | 0.6  | 0.5  | 0.6  | 0.3  | 0.4  |
|                           | Maximum            | 0.9  | 1.0      | 0.9               | 1.0   | 0.9  | 1.7                | 0.9  | 2.2      | 0.8               | 0.8   | 0.7  | 1.4  | 0.9  | 1.4  | 0.9  | 1.0  |
| Copper<br>µg/g            | Mean               | 10.7 | 12.4     | 10.9              | 14.5  | 6.9  | 15.3               | 8.5  | 16.6     | 4.9               | 11.2  | 7.6  | 17.7 | 6.7  | 8.3  | 10.0 | 11.6 |
|                           | SD                 | 0.7  | 1.7      | 0.8               | 2.2   | 1.2  | 2.4                | 0.6  | 1.6      | 0.8               | 1.9   | 0.5  | 1.3  | 1.0  | 2.7  | 1.0  | 1.9  |
|                           | Minimum            | 9.5  | 10.0     | 8.7               | 11.2  | 4.9  | 8.5                | 6.9  | 13.5     | 3.4               | 7.5   | 6.3  | 14.6 | 4.5  | 5.3  | 7.8  | 7.8  |
|                           | Maximum            | 12.0 | 17.1     | 12.0              | 19.2  | 10.3 | 19.2               | 9.6  | 19.7     | 6.7               | 15.1  | 8.4  | 20.0 | 8.5  | 18.5 | 11.7 | 15.8 |
| Iron<br>µg/g              | Mean               | 527  | 302      | 616               | 838   | 427  | 366                | 550  | 295      | 899               | 311   | 1714 | 809  | 596  | 351  | 1102 | 462  |
|                           | SD                 | 135  | 126      | 64                | 116   | 106  | 109                | 68   | 104      | 82                | 135   | 179  | 128  | 92   | 93   | 227  | 155  |
|                           | Minimum            | 330  | 80       | 505               | 574   | 303  | 216                | 453  | 158      | 749               | 136   | 1131 | 530  | 471  | 186  | 787  | 121  |
|                           | Maximum            | 775  | 511      | 756               | 1100  | 675  | 612                | 726  | 647      | 1057              | 625   | 2067 | 1098 | 824  | 518  | 1507 | 650  |
| Manganese<br>µg/g         | Mean               | 62   | 30       | 78                | 50    | 25   | 28                 | 31   | 26       | 27                | 15    | 61   | 29   | 30   | 12   | 36   | 11   |
|                           | SD                 | 22.5 | 8.7      | 17.0              | 7.5   | 7.0  | 5.3                | 8.0  | 3.4      | 3.8               | 1.9   | 12.1 | 3.7  | 5.9  | 1.7  | 7.7  | 2.8  |
|                           | Minimum            | 23   | 13       | 41                | 38    | 13   | 17                 | 15   | 17       | 20                | 12    | 36   | 24   | 13   | 8    | 25   | 5    |
|                           | Maximum            | 88   | 50       | 105               | 65    | 41   | 28                 | 43   | 32       | 36                | 20    | 83   | 37   | 39   | 15   | 53   | 15   |
| Zinc<br>µg/g              | Mean               | 4.8  | 3.5      | 3.5               | 4.3   | 3.3  | 6.9                | 2.1  | 3.3      | 0.7               | 2.4   | 2.7  | 2.0  | 2.4  | 3.1  | 2.6  | 2.8  |
|                           | SD                 | 0.3  | 1.5      | 1.0               | 1.7   | 1.1  | 2.9                | 0.9  | 0.7      | 0.1               | 1.6   | 1.0  | 1.1  | 1.3  | 1.3  | 0.6  | 0.7  |
|                           | Minimum            | 4.1  | 1.0      | 1.7               | 1.9   | 2.0  | 3.9                | 1.4  | 1.6      | 0.5               | 1.0   | 1.0  | 0.7  | 1.0  | 1.0  | 1.5  | 1.6  |
|                           | Maximum            | 5.5  | 6.3      | 5.0               | 7.3   | 5.7  | 13.6               | 5.7  | 4.5      | 1.0               | 8.4   | 4.2  | 4.3  | 6.3  | 5.4  | 3.9  | 4.3  |
| Conduc-<br>tivity<br>ds/m | Mean               | 0.35 | 0.12     | 0.18              | 0.15  | 0.18 | 0.58               | 0.16 | 0.69     | 0.21              | 0.14  | 0.27 | 0.15 | 0.14 | 0.16 | 0.13 | 0.10 |
|                           | SD                 | 0.10 | 0.02     | 0.02              | 0.05  | 0.02 | 0.47               | 0.03 | 0.50     | 0.03              | 0.03  | 0.05 | 0.02 | 0.03 | 0.02 | 0.02 | 0.03 |
|                           | Minimum            | 0.14 | 0.17     | 0.13              | 0.09  | 0.15 | 0.09               | 0.11 | 0.11     | 0.15              | 0.11  | 0.12 | 0.11 | 0.11 | 0.12 | 0.11 | 0.07 |
|                           | Maximum            | 0.58 | 0.17     | 0.21              | 0.27  | 0.22 | 1.40               | 0.21 | 1.30     | 0.31              | 0.19  | 0.33 | 0.18 | 0.22 | 0.20 | 0.17 | 0.18 |



## Annex 5.5. Samples Collected April 1993

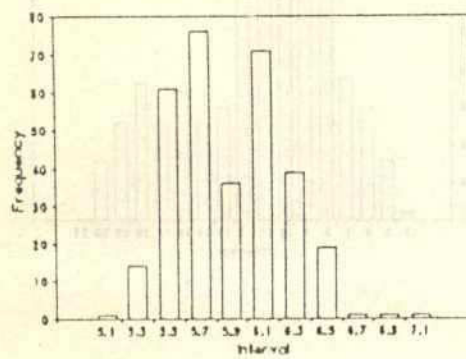
| Species                                               | Meghna River Sites |                   | Dakatia River Sites |                   |
|-------------------------------------------------------|--------------------|-------------------|---------------------|-------------------|
|                                                       | Outside Embankment | Inside Embankment | Outside Embankment  | Inside Embankment |
| 1. Floating BGA (filaments/ml.)                       |                    |                   |                     |                   |
| a) <i>Anabaena proloifica</i><br>(30-35 cells/fil)    | -                  | 4                 | 10                  | 5                 |
| b) <i>Anabaena affinis</i><br>(25-50 cells/fil)       | -                  | 4                 | 4                   | 3                 |
| c) <i>Anabaena oscillariodes</i><br>(25-50 cells/fil) | -                  | 6                 | 5                   | 6                 |
| d) <i>Scytonema subtile</i><br>(50-60 cells/fil)      | -                  | 10                | 9                   | 5                 |
| 2. Attached BGA (filaments/plant)                     |                    |                   |                     |                   |
| a) <i>Nostoc punctiforme</i><br>(15-20 cells/fil)     | -                  | 6                 | 7                   | 8                 |
| b) <i>Gloeotrichia natans</i><br>(15-25 cells/fil)    | -                  | 4                 | 3                   | 3                 |

## ANNEX 7

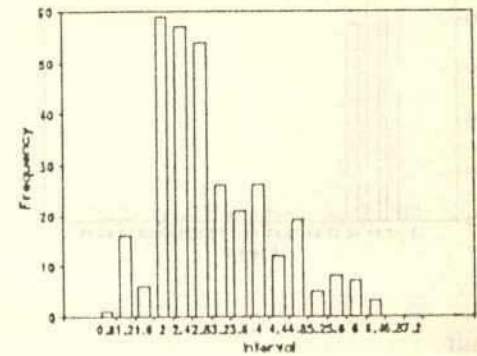
29

## Frequency Distributions of Soil Nutrient Concentrations

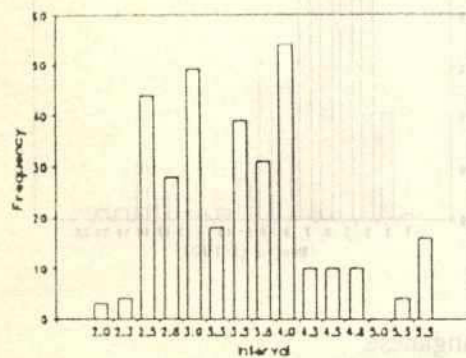
pH



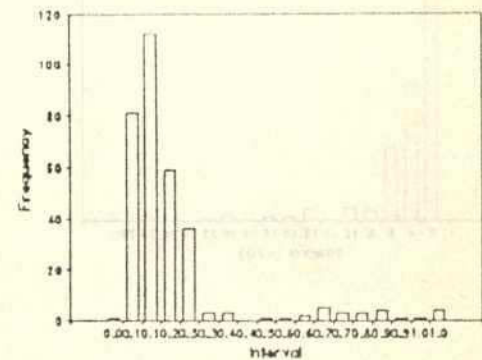
Magnesium



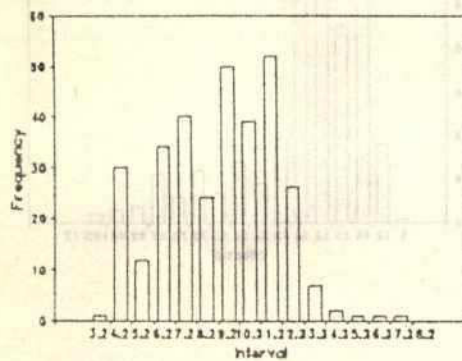
Organic Matter



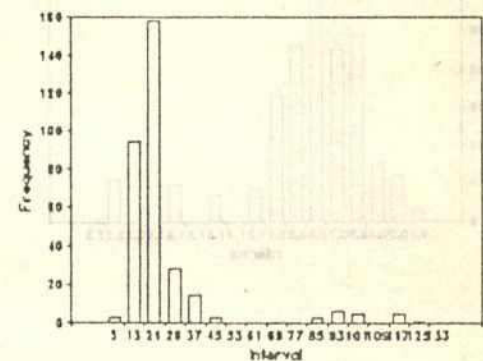
Potassium



Calcium

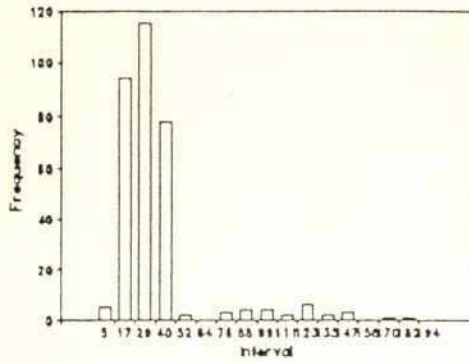


Nitrogen

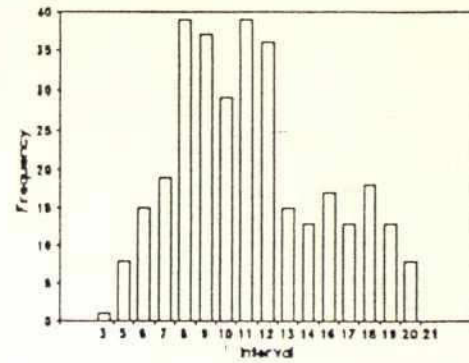




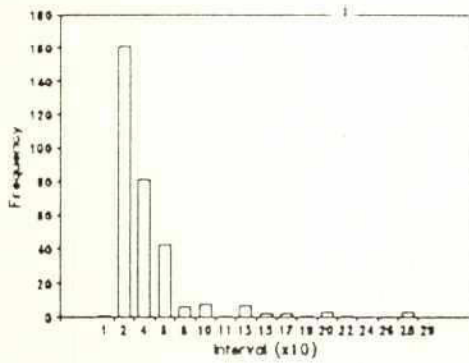
Phosphorus



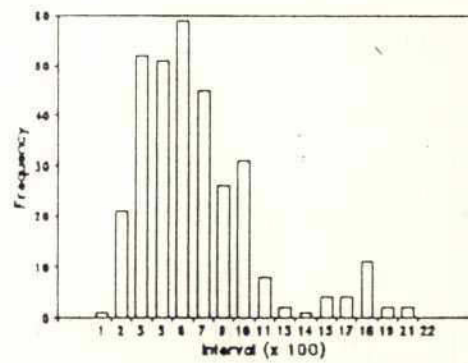
Copper



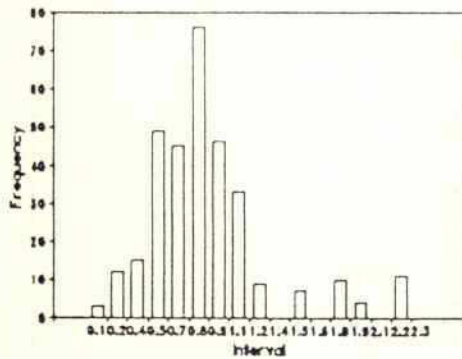
Sulphur



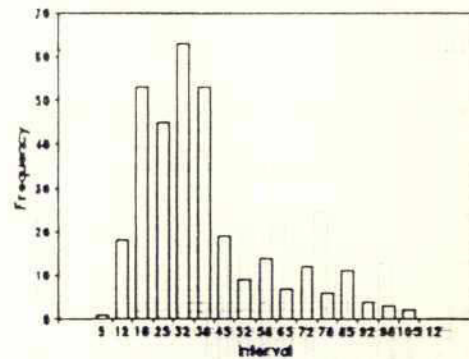
Iron



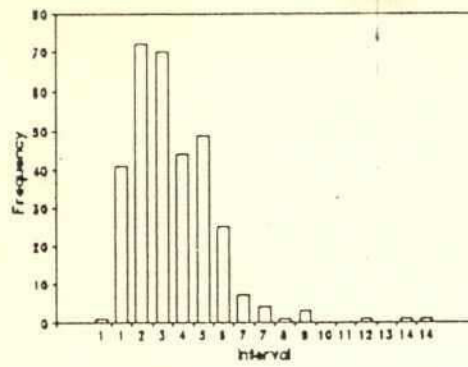
Boron



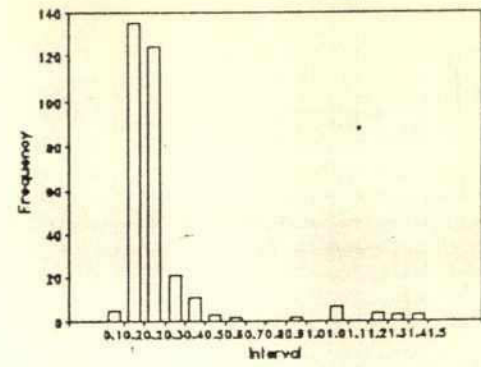
Manganese



Zinc



Conductivity





## Annex 8

## Analysis of Covariance: Soil Samples from CIP Sample Sites

All effects assessed simultaneously, each effect adjusted for all other effects.

| Variable: pH        |                |     |             |         |             |  |
|---------------------|----------------|-----|-------------|---------|-------------|--|
| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |  |
| Covariates          | 3.455          | 6   | .576        | 30.505  | .000        |  |
| UREA                | .152           | 1   | .152        | 8.059   | .005        |  |
| TSP/SSP             | .415           | 1   | .415        | 21.998  | .000        |  |
| MP                  | .020           | 1   | .020        | 1.077   | .300        |  |
| MANURE              | 1.507          | 1   | 1.507       | 79.830  | .000        |  |
| ZINC                | .041           | 1   | .041        | 2.166   | .142        |  |
| ASH                 | .031           | 1   | .031        | 1.644   | .201        |  |
| Main Effects        | 2.658          | 4   | .664        | 35.196  | .000        |  |
| RIVER               | .024           | 1   | .024        | 1.262   | .262        |  |
| PROT                | .189           | 1   | .189        | 10.015  | .002        |  |
| ELEV                | .192           | 1   | .192        | 10.195  | .002        |  |
| PERIOD              | 1.595          | 1   | 1.595       | 84.495  | .000        |  |
| 2-way Interactions  | 5.490          | 6   | .915        | 48.468  | .000        |  |
| RIVER PROT          | .728           | 1   | .728        | 38.560  | .000        |  |
| RIVER ELEV          | .729           | 1   | .729        | 38.600  | .000        |  |
| RIVER PERIOD        | 1.301          | 1   | 1.301       | 68.928  | .000        |  |
| PROT ELEV           | 2.708          | 1   | 2.708       | 143.433 | .000        |  |
| PROT PERIOD         | .242           | 1   | .242        | 12.801  | .000        |  |
| ELEV PERIOD         | .189           | 1   | .189        | 10.020  | .002        |  |
| Explained           | 30.631         | 16  | 1.914       | 101.412 | .000        |  |
| Residual            | 5.720          | 303 | .019        |         |             |  |
| Total               | 36.351         | 319 | .114        |         |             |  |

| Variable: Organic Matter |                |     |             |         |             |  |
|--------------------------|----------------|-----|-------------|---------|-------------|--|
| Source of Variation      | Sum of Squares | DF  | Mean Square | F       | Signif of F |  |
| Covariates               | 26.598         | 6   | 4.433       | 78.188  | .000        |  |
| UREA                     | .072           | 1   | .072        | 1.263   | .262        |  |
| TSP/SSP                  | .036           | 1   | .036        | .636    | .426        |  |
| MP                       | .017           | 1   | .017        | .294    | .588        |  |
| MANURE                   | 14.622         | 1   | 14.622      | 257.908 | .000        |  |
| ZINC                     | .000           | 1   | .000        | .001    | .971        |  |
| ASH                      | .018           | 1   | .018        | .320    | .572        |  |
| Main Effects             | 25.731         | 4   | 6.433       | 113.458 | .000        |  |
| RIVER                    | .940           | 1   | .940        | 16.573  | .000        |  |
| PROT                     | 2.109          | 1   | 2.109       | 37.203  | .000        |  |
| ELEV                     | 10.794         | 1   | 10.794      | 190.391 | .000        |  |
| PERIOD                   | 4.507          | 1   | 4.507       | 79.502  | .000        |  |
| 2-way Interactions       | 48.945         | 6   | 8.158       | 143.881 | .000        |  |
| RIVER PROT               | 16.822         | 1   | 16.822      | 296.699 | .000        |  |
| RIVER ELEV               | .678           | 1   | .678        | 11.952  | .001        |  |
| RIVER PERIOD             | 25.844         | 1   | 25.844      | 455.841 | .000        |  |
| PROT ELEV                | 1.225          | 1   | 1.225       | 21.605  | .000        |  |
| PROT PERIOD              | 41.075         | 1   | 41.075      | 724.468 | .000        |  |
| ELEV PERIOD              | .173           | 1   | .173        | 3.051   | .082        |  |
| Explained                | 191.058        | 16  | 11.941      | 210.616 | .000        |  |
| Residual                 | 17.179         | 303 | .057        |         |             |  |
| Total                    | 208.237        | 319 | .653        |         |             |  |

## Annex 8 (Continued)

Variable: Calcium

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 80.730         | 6   | 13.455      | 12.431  | .000        |
| UREA                | .002           | 1   | .002        | .002    | .963        |
| TSP/SSP             | 20.810         | 1   | 20.810      | 19.226  | .000        |
| MP                  | 8.587          | 1   | 8.587       | 7.933   | .005        |
| MANURE              | 20.701         | 1   | 20.703      | 19.127  | .000        |
| ZINC                | 3.081          | 1   | 3.081       | 2.846   | .093        |
| ASH                 | 18.660         | 1   | 18.660      | 17.240  | .000        |
| Main Effects        | 599.474        | 4   | 149.869     | 138.461 | .000        |
| RIVER               | 460.985        | 1   | 460.985     | 425.895 | .000        |
| PROT                | 2.220          | 1   | 2.220       | 2.051   | .153        |
| ELEV                | 166.579        | 1   | 166.571     | 153.899 | .000        |
| PERIOD              | 6.732          | 1   | 6.732       | 6.219   | .013        |
| 2-way Interactions  | 140.817        | 6   | 23.469      | 21.683  | .000        |
| RIVER PROT          | 92.582         | 1   | 92.582      | 85.535  | .000        |
| RIVER ELEV          | 11.572         | 1   | 11.572      | 10.691  | .001        |
| RIVER PERIOD        | 25.809         | 1   | 25.809      | 23.845  | .000        |
| PROT ELEV           | 17.499         | 1   | 17.499      | 16.167  | .000        |
| PROT PERIOD         | 19.641         | 1   | 19.641      | 18.146  | .000        |
| ELEV PERIOD         | 29.717         | 1   | 29.717      | 27.455  | .000        |
| Explained           | 1864.094       | 16  | 116.506     | 107.638 | .000        |
| Residual            | 327.964        | 303 | 1.082       |         |             |
| Total               | 2192.059       | 319 | 6.872       |         |             |

Variable: Magnesium

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 11.087         | 6   | 1.848       | 15.551  | .000        |
| UREA                | .005           | 1   | .005        | .046    | .831        |
| TSP/SSP             | 6.483          | 1   | 6.483       | 54.566  | .000        |
| MP                  | 3.985          | 1   | 3.985       | 33.539  | .000        |
| MANURE              | 3.166          | 1   | 3.166       | 26.648  | .000        |
| ZINC                | 2.077          | 1   | 2.077       | 17.478  | .000        |
| ASH                 | .394           | 1   | .394        | 3.315   | .070        |
| Main Effects        | 13.610         | 4   | 3.402       | 28.635  | .000        |
| RIVER               | 7.869          | 1   | 7.869       | 66.225  | .000        |
| PROT                | .247           | 1   | .247        | 2.078   | .150        |
| ELEV                | .011           | 1   | .011        | .092    | .762        |
| PERIOD              | 10.675         | 1   | 10.675      | 89.841  | .000        |
| 2-way Interactions  | 78.518         | 6   | 13.086      | 110.137 | .000        |
| RIVER PROT          | 8.436          | 1   | 8.436       | 71.003  | .000        |
| RIVER ELEV          | 65.096         | 1   | 65.096      | 547.865 | .000        |
| RIVER PERIOD        | .786           | 1   | .786        | 6.618   | .011        |
| PROT ELEV           | 7.152          | 1   | 7.152       | 60.190  | .000        |
| PROT PERIOD         | .292           | 1   | .292        | 2.461   | .118        |
| ELEV PERIOD         | .024           | 1   | .024        | .201    | .654        |
| Explained           | 414.147        | 16  | 25.884      | 217.848 | .000        |
| Residual            | 36.002         | 303 | .119        |         |             |
| Total               | 450.148        | 319 | 1.411       |         |             |



## Annex 8 (Continued)

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## Variable: Potassium

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 1.812          | 6   | .302        | 38.812  | .000        |
| UREA                | .017           | 1   | .017        | 2.129   | .146        |
| TSP/SSP             | .278           | 1   | .278        | 35.770  | .000        |
| MP                  | .177           | 1   | .177        | 22.729  | .000        |
| MANURE              | 1.139          | 1   | 1.139       | 146.403 | .000        |
| ZINC                | .000           | 1   | .000        | .021    | .885        |
| ASH                 | .000           | 1   | .000        | .021    | .884        |
| Main Effects        | 1.341          | 4   | .335        | 43.068  | .000        |
| RIVER               | .048           | 1   | .048        | 6.189   | .013        |
| PROT                | .536           | 1   | .536        | 68.883  | .000        |
| ELEV                | .298           | 1   | .298        | 38.349  | .000        |
| PERIOD              | .811           | 1   | .811        | 104.228 | .000        |
| 2-way Interactions  | 3.020          | 6   | .503        | 64.660  | .000        |
| RIVER PROT          | .692           | 1   | .692        | 88.908  | .000        |
| RIVER ELEV          | .257           | 1   | .257        | 33.060  | .000        |
| RIVER PERIOD        | 2.030          | 1   | 2.030       | 260.792 | .000        |
| PROT ELEV           | .122           | 1   | .122        | 15.698  | .000        |
| PROT PERIOD         | .002           | 1   | .002        | .306    | .581        |
| ELEV PERIOD         | .033           | 1   | .033        | 4.249   | .040        |
| Explained           | 8.975          | 16  | .561        | 72.068  | .000        |
| Residual            | 2.358          | 303 | .008        |         |             |
| Total               | 11.333         | 319 | .036        |         |             |

## Variable: Nitrogen

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 27418.382      | 6   | 4569.730    | 41.159  | .000        |
| UREA                | 6.618          | 1   | 6.618       | .060    | .807        |
| TSP/SSP             | 10131.671      | 1   | 10131.671   | 91.254  | .000        |
| MP                  | 4395.888       | 1   | 4395.888    | 39.593  | .000        |
| MANURE              | 8656.215       | 1   | 8656.215    | 77.965  | .000        |
| ZINC                | 2.084          | 1   | 2.084       | .019    | .891        |
| ASH                 | 1540.401       | 1   | 1540.401    | 13.874  | .000        |
| Main Effects        | 17831.344      | 4   | 4457.836    | 40.151  | .000        |
| RIVER               | 2424.739       | 1   | 2424.739    | 21.839  | .000        |
| PROT                | 3135.800       | 1   | 3135.800    | 28.244  | .000        |
| ELEV                | 10252.023      | 1   | 10252.023   | 92.338  | .000        |
| PERIOD              | 4898.694       | 1   | 4898.694    | 44.122  | .000        |
| 2-way Interactions  | 41329.258      | 6   | 6888.210    | 62.041  | .000        |
| RIVER PROT          | 3887.690       | 1   | 3887.690    | 35.016  | .000        |
| RIVER ELEV          | 11299.121      | 1   | 11299.121   | 101.769 | .000        |
| RIVER PERIOD        | 21212.741      | 1   | 21212.741   | 191.059 | .000        |
| PROT ELEV           | 4207.970       | 1   | 4207.970    | 37.900  | .000        |
| PROT PERIOD         | .452           | 1   | .452        | .004    | .949        |
| ELEV PERIOD         | 189.646        | 1   | 189.646     | 1.708   | .192        |
| Explained           | 102337.663     | 16  | 6396.104    | 57.609  | .000        |
| Residual            | 33641.184      | 303 | 111.027     |         |             |
| Total               | 135978.847     | 319 | 426.266     |         |             |

## Annex 8 (Continued)

Variable: Phosphorus

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 26205.418      | 6   | 4367.570    | 22.106  | .000        |
| UREA                | 84.223         | 1   | 84.223      | .426    | .514        |
| TSP/SSP             | 7936.272       | 1   | 7936.272    | 40.168  | .000        |
| MP                  | 3426.905       | 1   | 3426.905    | 17.345  | .000        |
| MANURE              | 11467.660      | 1   | 11467.660   | 58.042  | .000        |
| ZINC                | 444.703        | 1   | 444.703     | 2.251   | .135        |
| ASH                 | 1062.926       | 1   | 1062.926    | 5.380   | .021        |
| Main Effects        | 37627.136      | 4   | 9406.784    | 47.611  | .000        |
| RIVER               | 1326.917       | 1   | 1326.917    | 6.716   | .010        |
| PROT                | 9802.428       | 1   | 9802.428    | 49.613  | .000        |
| ELEV                | 24206.977      | 1   | 24206.977   | 122.520 | .000        |
| PERIOD              | 7844.204       | 1   | 7844.204    | 39.702  | .000        |
| 2-way Interactions  | 38805.668      | 6   | 6467.611    | 32.735  | .000        |
| RIVER PROT          | 14775.627      | 1   | 14775.627   | 74.784  | .000        |
| RIVER ELEV          | 527.044        | 1   | 527.044     | 2.668   | .103        |
| RIVER PERIOD        | 25611.337      | 1   | 25611.337   | 129.628 | .000        |
| PROT ELEV           | 3551.210       | 1   | 3551.210    | 17.974  | .000        |
| PROT PERIOD         | 88.915         | 1   | 88.915      | .450    | .503        |
| ELEV PERIOD         | 93.554         | 1   | 93.554      | .474    | .492        |
| Explained           | 165735.993     | 16  | 10358.500   | 52.428  | .000        |
| Residual            | 59865.557      | 303 | 197.576     |         |             |
| Total               | 225601.550     | 319 | 707.215     |         |             |

Variable: Sulphur

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 64185.596      | 6   | 10697.599   | 28.043  | .000        |
| UREA                | 10.977         | 1   | 10.977      | .029    | .865        |
| TSP/SSP             | 22725.192      | 1   | 22725.192   | 59.573  | .000        |
| MP                  | 11710.212      | 1   | 11710.212   | 30.698  | .000        |
| MANURE              | 29318.737      | 1   | 29318.737   | 76.858  | .000        |
| ZINC                | 4478.375       | 1   | 4478.375    | 11.740  | .001        |
| ASH                 | 1637.669       | 1   | 1637.669    | 4.293   | .039        |
| Main Effects        | 49145.249      | 4   | 12286.312   | 32.208  | .000        |
| RIVER               | 625.016        | 1   | 625.016     | 1.638   | .202        |
| PROT                | 23401.024      | 1   | 23401.024   | 61.345  | .000        |
| ELEV                | 12064.593      | 1   | 12064.593   | 31.627  | .000        |
| PERIOD              | 18964.031      | 1   | 18964.031   | 49.713  | .000        |
| 2-way Interactions  | 122404.144     | 6   | 20400.691   | 53.480  | .000        |
| RIVER PROT          | 9606.215       | 1   | 9606.215    | 25.182  | .000        |
| RIVER ELEV          | 19188.369      | 1   | 19188.369   | 50.302  | .000        |
| RIVER PERIOD        | 73389.114      | 1   | 73389.114   | 192.387 | .000        |
| PROT ELEV           | 5957.134       | 1   | 5957.134    | 15.616  | .000        |
| PROT PERIOD         | 5.667          | 1   | 5.667       | .015    | .903        |
| ELEV PERIOD         | 2781.331       | 1   | 2781.331    | 7.291   | .007        |
| Explained           | 405077.778     | 16  | 25317.361   | 66.368  | .000        |
| Residual            | 115584.779     | 303 | 381.467     |         |             |
| Total               | 520662.247     | 319 | 1632.170    |         |             |



## Annex 8 (Continued)

## Variable: Boron

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 5.742          | 6   | .957        | 18.237  | .000        |
| UREA                | .018           | 1   | .018        | .352    | .553        |
| TSP/SSP             | 1.162          | 1   | 1.162       | 22.136  | .000        |
| MP                  | 1.166          | 1   | 1.166       | 22.217  | .000        |
| MANURE              | 2.858          | 1   | 2.858       | 54.457  | .000        |
| ZINC                | .458           | 1   | .458        | 8.731   | .003        |
| ASH                 | .339           | 1   | .339        | 6.461   | .012        |
| Main Effects        | 9.043          | 4   | 2.261       | 43.082  | .000        |
| RIVER               | .170           | 1   | .170        | 3.235   | .073        |
| PROT                | 6.740          | 1   | 6.740       | 128.447 | .000        |
| ELEV                | .549           | 1   | .549        | 10.460  | .001        |
| PERIOD              | 2.560          | 1   | 2.560       | 48.784  | .000        |
| 2-way Interactions  | 8.210          | 6   | 1.368       | 26.077  | .000        |
| RIVER PROT          | 3.955          | 1   | 3.955       | 75.369  | .000        |
| RIVER ELEV          | .670           | 1   | .670        | 12.762  | .000        |
| RIVER PERIOD        | 5.767          | 1   | 5.767       | 109.894 | .000        |
| PROT ELEV           | .042           | 1   | .042        | .800    | .372        |
| PROT PERIOD         | 1.256          | 1   | 1.256       | 23.934  | .000        |
| ELEV PERIOD         | .538           | 1   | .538        | 10.248  | .002        |
| Explained           | 40.924         | 16  | 2.558       | 48.744  | .000        |
| Residual            | 15.900         | 303 | .052        |         |             |
| Total               | 56.824         | 319 | .178        |         |             |

## Variable: Copper

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 772.405        | 6   | 128.734     | 48.439  | .000        |
| UREA                | 3.646          | 1   | 3.646       | 1.372   | .242        |
| TSP/SSP             | 2.827          | 1   | 2.827       | 1.064   | .303        |
| MP                  | 2.895          | 1   | 2.895       | 1.089   | .297        |
| MANURE              | 391.691        | 1   | 391.691     | 147.383 | .000        |
| ZINC                | 3.468          | 1   | 3.468       | 1.305   | .254        |
| ASH                 | 1.110          | 1   | 1.110       | .418    | .519        |
| Main Effects        | 944.965        | 4   | 236.241     | 88.891  | .000        |
| RIVER               | 2.162          | 1   | 2.162       | .813    | .368        |
| PROT                | 135.318        | 1   | 135.318     | 50.917  | .000        |
| ELEV                | 532.331        | 1   | 532.331     | 200.302 | .000        |
| PERIOD              | 368.230        | 1   | 368.230     | 138.555 | .000        |
| 2-way Interactions  | 758.756        | 6   | 126.459     | 47.583  | .000        |
| RIVER PROT          | 324.235        | 1   | 324.235     | 122.001 | .000        |
| RIVER ELEV          | 117.000        | 1   | 117.000     | 44.024  | .000        |
| RIVER PERIOD        | 333.069        | 1   | 333.069     | 125.325 | .000        |
| PROT ELEV           | 9.484          | 1   | 9.484       | 3.569   | .060        |
| PROT PERIOD         | 409.622        | 1   | 409.622     | 154.130 | .000        |
| ELEV PERIOD         | 43.497         | 1   | 43.497      | 16.367  | .000        |
| Explained           | 4115.423       | 16  | 257.214     | 96.783  | .000        |
| Residual            | 805.265        | 303 | 2.658       |         |             |
| Total               | 4920.688       | 319 | 15.425      |         |             |

## Annex 8 (Continued)

Variable: Iron

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 2296815.913    | 6   | 382802.652  | 19.011  | .000        |
| UREA                | 44418.800      | 1   | 44418.800   | 2.206   | .139        |
| TSP/SSP             | 459982.567     | 1   | 459982.567  | 22.843  | .000        |
| MP                  | 169716.490     | 1   | 169716.490  | 8.428   | .004        |
| MANURE              | 425471.167     | 1   | 425471.167  | 21.130  | .000        |
| ZINC                | 758020.792     | 1   | 758020.792  | 37.644  | .000        |
| ASH                 | 274094.015     | 1   | 274094.015  | 13.612  | .000        |
| Main Effects        | 14980128.987   | 4   | 3745032.247 | 185.984 | .000        |
| RIVER               | 1104163.994    | 1   | 1104163.994 | 54.834  | .000        |
| PROT                | 2022364.216    | 1   | 2022364.216 | 100.434 | .000        |
| ELEV                | 6766293.950    | 1   | 6766293.950 | 336.024 | .000        |
| PERIOD              | 1960175.967    | 1   | 1960175.967 | 97.345  | .000        |
| 2-way Interactions  | 8038825.397    | 6   | 1339804.233 | 66.537  | .000        |
| RIVER PROT          | 5548.762       | 1   | 5548.762    | .276    | .600        |
| RIVER ELEV          | 1953303.112    | 1   | 1953303.112 | 97.004  | .000        |
| RIVER PERIOD        | 561764.724     | 1   | 561764.724  | 27.898  | .000        |
| PROT ELEV           | 2056723.600    | 1   | 2056723.600 | 102.140 | .000        |
| PROT PERIOD         | 695027.235     | 1   | 695027.235  | 34.516  | .000        |
| ELEV PERIOD         | 661032.808     | 1   | 661032.808  | 32.828  | .000        |
| Explained           | 41068132.288   | 16  | 2566758.268 | 127.469 | .000        |
| Residual            | 6101304.699    | 303 | 20136.319   |         |             |
| Total               | 47169436.988   | 319 | 147866.574  |         |             |

Variable: Manganese

| Source of Variation | Sum of Squares | DF  | Mean Square | F       | Signif of F |
|---------------------|----------------|-----|-------------|---------|-------------|
| Covariates          | 4434.122       | 6   | 739.020     | 7.867   | .000        |
| UREA                | 45.434         | 1   | 45.434      | .484    | .487        |
| TSP/SSP             | 345.154        | 1   | 345.154     | 3.674   | .056        |
| MP                  | 202.041        | 1   | 202.041     | 2.151   | .144        |
| MANURE              | 2310.654       | 1   | 2310.654    | 24.597  | .000        |
| ZINC                | 78.067         | 1   | 78.067      | .831    | .363        |
| ASH                 | 31.630         | 1   | 31.630      | .337    | .562        |
| Main Effects        | 14501.870      | 4   | 3625.468    | 38.594  | .000        |
| RIVER               | 1215.559       | 1   | 1215.559    | 12.940  | .000        |
| PROT                | 3088.952       | 1   | 3088.952    | 32.882  | .000        |
| ELEV                | 10417.654      | 1   | 10417.654   | 110.897 | .000        |
| PERIOD              | 1313.311       | 1   | 1313.311    | 13.980  | .000        |
| 2-way Interactions  | 14042.647      | 6   | 2340.441    | 24.914  | .000        |
| RIVER PROT          | 20.905         | 1   | 20.905      | .223    | .637        |
| RIVER ELEV          | 86.202         | 1   | 86.202      | .918    | .339        |
| RIVER PERIOD        | 3469.211       | 1   | 3469.211    | 36.930  | .000        |
| PROT ELEV           | 6070.304       | 1   | 6070.304    | 64.619  | .000        |
| PROT PERIOD         | 2.644          | 1   | 2.644       | .028    | .867        |
| ELEV PERIOD         | 1376.067       | 1   | 1376.067    | 14.648  | .000        |
| Explained           | 108992.279     | 16  | 6812.017    | 72.515  | .000        |
| Residual            | 28463.768      | 303 | 93.940      |         |             |
| Total               | 137456.047     | 319 | 430.897     |         |             |



### Annex 8 (Continued)

Variable: Zinc

| Source of Variation | Sum of Squares | DF  | Mean Square | F      | Signif of F |
|---------------------|----------------|-----|-------------|--------|-------------|
| Covariates          | 62.576         | 6   | 10.429      | 5.510  | .000        |
| UREA                | 8.171          | 1   | 8.171       | 4.317  | .039        |
| TSP/SSP             | .546           | 1   | .546        | .289   | .592        |
| MP                  | .687           | 1   | .687        | .363   | .547        |
| MANURE              | 10.930         | 1   | 10.930      | 5.774  | .017        |
| ZINC                | 19.880         | 1   | 19.880      | 10.504 | .001        |
| ASH                 | .383           | 1   | .383        | .203   | .653        |
| Main Effects        | 110.376        | 4   | 27.594      | 14.579 | .000        |
| RIVER               | 38.824         | 1   | 38.824      | 20.512 | .000        |
| PROT                | 28.357         | 1   | 28.357      | 14.982 | .000        |
| ELEV                | 17.939         | 1   | 17.939      | 9.478  | .002        |
| PERIOD              | .293           | 1   | .293        | .155   | .694        |
| 2-way Interactions  | 148.266        | 6   | 24.711      | 13.056 | .000        |
| RIVER PROT          | 3.123          | 1   | 3.123       | 1.650  | .200        |
| RIVER ELEV          | 48.504         | 1   | 48.504      | 25.627 | .000        |
| RIVER PERIOD        | 17.229         | 1   | 17.229      | 9.103  | .003        |
| PROT ELEV           | 52.382         | 1   | 52.382      | 27.675 | .000        |
| PROT PERIOD         | .022           | 1   | .022        | .012   | .914        |
| ELEV PERIOD         | 9.204          | 1   | 9.204       | 4.863  | .028        |
| Explained           | 515.106        | 16  | 32.194      | 17.009 | .000        |
| Residual            | 573.498        | 303 | 1.893       |        |             |
| Total               | 1088.604       | 319 | 3.413       |        |             |

Variable: Conductivity

| Source of Variation | Sum of Squares | DF  | Mean Square | F      | Signif of F |
|---------------------|----------------|-----|-------------|--------|-------------|
| Covariates          | 1.527          | 6   | .255        | 7.744  | .000        |
| UREA                | .007           | 1   | .007        | .215   | .643        |
| TSP/SSP             | .129           | 1   | .129        | 3.916  | .049        |
| MP                  | .125           | 1   | .125        | 3.807  | .052        |
| MANURE              | 1.104          | 1   | 1.104       | 33.580 | .000        |
| ZINC                | .079           | 1   | .079        | 2.415  | .121        |
| ASH                 | .042           | 1   | .042        | 1.264  | .262        |
| Main Effects        | 1.180          | 4   | .295        | 8.978  | .000        |
| RIVER               | .011           | 1   | .011        | .345   | .557        |
| PROT                | 1.043          | 1   | 1.043       | 31.728 | .000        |
| ELEV                | .018           | 1   | .018        | .538   | .464        |
| PERIOD              | .321           | 1   | .321        | 9.772  | .002        |
| 2-way Interactions  | 4.075          | 6   | .679        | 20.662 | .000        |
| RIVER PROT          | 1.652          | 1   | 1.652       | 50.257 | .000        |
| RIVER ELEV          | .004           | 1   | .004        | .122   | .727        |
| RIVER PERIOD        | 1.981          | 1   | 1.981       | 60.283 | .000        |
| PROT ELEV           | .003           | 1   | .003        | .079   | .778        |
| PROT PERIOD         | .042           | 1   | .042        | 1.277  | .259        |
| ELEV PERIOD         | .000           | 1   | .000        | .006   | .936        |
| Explained           | 8.515          | 16  | .532        | 16.192 | .000        |
| Residual            | 9.959          | 303 | .033        |        |             |
| Total               | 18.473         | 319 | .058        |        |             |

## Annex 9

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## Correlation Matrices for Soil Nutrients, CIP.

## A. Between soil nutrients

|    | pH       | OM       | Ca       | Mg       | K        | N        |
|----|----------|----------|----------|----------|----------|----------|
| pH | 1.0000   | .5889**  | -.0591   | .2225**  | -.4476** | -.2671** |
| OM | .5889**  | 1.0000   | -.0561   | .0004    | -.2841** | -.1158   |
| Ca | -.0591   | -.0561   | 1.0000   | .5017**  | .3135**  | .2701**  |
| Mg | .2225**  | .0004    | .5017**  | 1.0000   | -.1704*  | -.1585*  |
| K  | -.4476** | -.2841** | .3135**  | -.1704*  | 1.0000   | .8066**  |
| N  | -.2671** | -.1158   | .2701**  | -.1585*  | .8066**  | 1.0000   |
| P  | -.2270** | -.1058   | .3381**  | -.1745** | .8338**  | .7886**  |
| S  | -.3826** | -.2243** | .4379**  | -.0913   | .8911**  | .8175**  |
| B  | -.3063** | -.2035** | .3312**  | -.2185** | .6794**  | .6390**  |
| Cu | -.5965** | -.4034** | .1758**  | -.2296** | .5460**  | .3681**  |
| Fe | .2409**  | .2003**  | -.2004** | .1815**  | -.2649** | -.1472*  |
| Mn | -.1581*  | -.2408** | .2954**  | .6120**  | -.0044   | .0224    |
| Zn | -.3834** | -.2304** | .3242**  | .1721*   | .3227**  | .0255    |
| EC | -.2453** | -.1705*  | .1692*   | -.0342   | .6541**  | .4145**  |

|    | P        | S        | B        | Cu       | Fe       | Mn       |
|----|----------|----------|----------|----------|----------|----------|
| pH | -.2270** | -.3826** | -.3063** | -.5965** | .2409**  | -.1581*  |
| OM | -.1058   | -.2243** | -.2035** | -.4034** | .2003**  | -.2408** |
| Ca | .3381**  | .4379**  | .3312**  | .1758**  | -.2004** | .2954**  |
| Mg | -.1745** | -.0913   | -.2185** | -.2296** | .1815**  | .6120**  |
| K  | .8338**  | .8911**  | .6794**  | .5460**  | -.2649** | -.0044   |
| N  | .7886**  | .8175**  | .6390**  | .3681**  | -.1472*  | .0224    |
| P  | 1.0000   | .8427**  | .6472**  | .4773**  | -.0697   | -.0560   |
| S  | .8427**  | 1.0000   | .6856**  | .4586**  | -.2863** | .0005    |
| B  | .6472**  | .6856**  | 1.0000   | .4965**  | -.3619** | -.1990** |
| Cu | .4773**  | .4586**  | .4965**  | 1.0000   | -.2154** | -.0058   |
| Fe | -.0697   | -.2863** | -.3619** | -.2154** | 1.0000   | .4300**  |
| Mn | -.0560   | .0005    | -.1990** | -.0058   | .4300**  | 1.0000   |
| Zn | .2188**  | .2965**  | .1986**  | .3288**  | -.1792** | .1599*   |
| EC | .5834**  | .4944**  | .4434**  | .3033**  | -.1016   | .0310    |

|    | Zn       | EC       |
|----|----------|----------|
| pH | -.3834** | -.2453** |
| OM | -.2304** | -.1705*  |
| Ca | .3242**  | .1692*   |
| Mg | .1721*   | -.0342   |
| K  | .3227**  | .6541**  |
| N  | .0255    | .4145**  |
| P  | .2188**  | .5834**  |
| S  | .2965**  | .4944**  |
| B  | .1986**  | .4434**  |
| Cu | .3288**  | .3033**  |
| Fe | -.1792** | -.1016   |
| Mn | .1599*   | .0310    |
| Zn | 1.0000   | .3998**  |
| EC | .3998**  | 1.0000   |

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N of cases: 320

1-tailed Significance: \* - .01 \*\* - .001





## Annex 9 (Continued)

## B. Between soil nutrients and rates of fertilizer application

|    | Urea     | TSP      | MP       | Manure   | Zinc     | Ash      |
|----|----------|----------|----------|----------|----------|----------|
| pH | .4698**  | .0506    | .0180    | -.1742** | .1352*   | -.2693** |
| OM | .1349*   | -.0724   | -.0873   | -.1795** | .0027    | -.1877** |
| Ca | .3234**  | .5418**  | .4705**  | .2630**  | .2639**  | .1129    |
| Mg | .2102**  | .0824    | -.0083   | .6819**  | .3814**  | -.1102   |
| K  | .0468    | .4237**  | .4387**  | .0383    | -.1305*  | .0767    |
| N  | .1613*   | .4545**  | .4238**  | -.0187   | -.0663   | -.0194   |
| P  | .2436**  | .5265**  | .5213**  | -.1447*  | -.1206   | -.0425   |
| S  | .0901    | .4543**  | .4494**  | .0339    | -.1517*  | .0687    |
| B  | .1572*   | .5095**  | .4945**  | -.2256** | -.1119   | -.0209   |
| Cu | -.3683** | .0654    | .1083    | -.0075   | -.2212** | .1562*   |
| Fe | .1463*   | -.1811** | -.2073** | -.0629   | -.0656   | .1025    |
| Mn | .0240    | -.0838   | -.0870   | .6566**  | .2083**  | .0977    |
| Zn | -.1293   | .1032    | .1455*   | .2061**  | -.0426   | .0546    |
| EC | .1625*   | .3362**  | .3665**  | .0490    | -.1036   | -.0345   |

N of cases: 320 1-tailed Significance: \* - .01 \*\* - .001

## C. Between rates of fertilizer applications to sampled areas

|        | Urea    | TSP      | MP      | Manure   | Zinc    | Ash    |
|--------|---------|----------|---------|----------|---------|--------|
| Urea   | 1.0000  | .7748**  | .7598** | -.1660*  | .2521** | -.0626 |
| TSP    | .7748** | 1.0000   | .9328** | -.1776** | .3019** | .0966  |
| MP     | .7598** | .9328**  | 1.0000  | -.1581*  | .1679*  | .1098  |
| Manure | -.1660* | -.1776** | -.1581* | 1.0000   | .2282** | -.0679 |
| Zinc   | .2521** | .3019**  | .1679*  | .2282**  | 1.0000  | -.0694 |
| Ash    | -.0626  | .0966    | .1098   | -.0679   | -.0694  | 1.0000 |

N of cases: 320 1-tailed Significance: \* - .01 \*\* - .001

