ASSESSMENT OF SOIL SALINITY AND ITS IMPACT ON AGRICULTURE AFTER THE CYCLONE SIDR

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by

Sayed Mohammad Nazim Uddin

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The thesis titled '**Assessment of Soil Salinity and Its Impact on Agriculture after the Cyclone SIDR**' submitted by Sayed Mohammad Nazim Uddin, Roll No: M10062825F, Session: October 2006, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Science in Water Resources Development on 22 July, 2009.

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Sayed Mohammad Nazim Uddin
Roll No: M10062825F
Session: October, 2006

Dedicated
To
My Parents

ABSTRACT

Sarankhola Upazila in Bagerhat district was severely affected by cyclone SIDR. Preliminary investigations showed that the salinity level of soil was increased which affected the cropping and fishing practices in the region. Some of the coastal polders have also been damaged during the cyclone event. Farmers were forced to change their cropping practices at the post cyclone stage. In the present study, change in soil salinity after the cyclone and its impact on agriculture is being investigated in the study area.

Soil samples were collected from all the unions of highly affected areas of Bagerhat district. Samples were taken from topsoil after cyclone SIDR and both from topsoil and subsoil after the monsoon of 2008. Crop yield of the sampling plots were recorded through farmer's interview. General information was collected throngh Focus Gronp Discussion (FGD).

From the analysis of soil salinity after cyclone SIDR, results show that in Rayenda union, which was inside polder, soil salinity varied from 1.11 dS/m to 1.93 dS/m while in Southkhali union soil salinity varied from 2.72 dS/m to 4.7 dS/m inside polders and 4.87 dS/m outside polders. Samples from Dhansagor union, which is inside polder but was inundated during the storm surge show salinity more than 6 dS/m. Samples from Khontakata union, which is inside polders, show soil salinity 4.4 dS/m. Most of the soil samples were basic in nature.

After the monsoon the soil samples were also analyzed for both topsoil and subsoil of same sampling plots. The soil salinity of every sampling plot was reduced after the monsoon. The soil salinity reduced by 76.6, 46.6 and 19.3 percent in the Rayenda union. In the Southkhali union, it reduced by 49.1, 31.5 and 72.6 percent. In Dhansagor and Khontakata union it reduced by 84.0 and 77.9 percent respectively.

It was observed that particle size as well as soil pH influences the salinity reduction. Coarser particle size enhances soil salinity reduction; on the other hand higher soil pH restricts salinity reduction.

The yield of Aman in 2008 season was reduced by as high as 63 percent compared to previous average yield. Local T. Aman was cultivated in the all-respective plots of the study area. The soil salinity and some other factors contributed to yield reduction. In Jilbunia village of Rayenda union, the average yield of Aman crop before the SIDR was 1.94 ton/ha, but it was decreased after the SIDR, which turned into 1.38 ton/ha. About 29 percent yield was decreased. In another two villages of Rayenda union, at Lakurtola and at Rajeshor, production decreased by 63 percent and 32 percent respectively. In Southkhali union there were three sampling plots named N. Southkhali, Gabtola (inside polder) and Gabtola (outside polder). The yield of Aman crop during monsoon decreased

in the first two plots by 43 percent and 41 percent respectively. No crop was cultivated in the outside polder of Gabtola sampling area during the 2008 monsoon. In Rajapur village of Dhansagor union and in the N. Khontakata of Khontakata union the yield decreased by 50 percent and 41 percent, respectively. It was also found that not only soil salinity contributed to yield reduction, but also other factors like lack of irrigation water at the grain formation stage, low quality of seeds and pests were the likely reasons behind yield reduction.

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LIST OF ABBREVIATIONS

BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
BWDB	Bangladesh Water development Board
dS	deci-Siemens
EC	Electrical Conductivity
HYV	High Yielding Variety
SRDI	Soil Resource Development Institute
USDA	United State Department of Agriculture

GLOSSARY

Acre	Unit of land measurement; one acre (ac) equal to 0.41 hectare
Aman	Rice grown in kharif-2 season
deci- Siemens	Unit of salinity expressed as decimeter of Siemens one dS/m equal to 640 Parts Per Million (PPM)
Hectare	Unit of land measurement; one hectare equal to 2.471 acre
me	Milli equivalent, Capacity of a cation to exchange hydrogen
mohos	Reciprocal of ohm, which express Conductance of Electricity
Millimohos	1000 millimohos equal to one dS/m
mmho/cm	millimohos per centimeter, unit of Electrical Conductivity
Siemens	An International System Unit of salinity; it is used by the name of a Scientist Siemens who introduced this unit
Tonne(t)	Measurement of weight ; one tonne equal to one-thousand kilogram)
µmho/cm	micro-mhos per centimeter, unit of Electrical Conductivity
µg	Microgram, equivalent to one thousand gram

CHAPTER ONE

INTRODUCTION

1.1 General

Agriculture is a major sector of Bangladesh's economy and the coastal area of Bangladesh is very fertile for growing rice. The coastal region contributes about 16% of the total rice production of the country (PDO-ICZMP, 2004). Increase in salinity intrusion and increase in soil salinity, due to natural or anthropogenic reasons will have serious negative impacts on agriculture in this. region. The presently practiced rice varieties may not be able to withstand increased salinity. The food production does not seem to have a better future in context of climate change either. By 2050, rice production may fall by 10 % and wheat by 30 % in Bangladesh (IPCC, 2007).

Tropical cyclones could become more intense. Combined with sea-level rise, this impact would result in enhanced risk of loss of life and properties in coastal low-lying areas of Bangladesh. Crop production and aquaculture in the coastal areas would be threatened by a combination of thermal and water stresses, sea level rise, increased flooding, and strong winds associated with intense tropical cyclones (IPCC, 2001).

Changes in sea level, which will have significant impact on salinity intrusion, will continue to be dominated by inter-annual variability, and by extreme events such as storm surges (Hay et. al. 2005). Strong cyclonic event causes storm surge and inundates vast areas in the coastal zone and as a result increases soil salinity. In such areas agricultural productiou may become impossible because of accumulation of salt on soil surface. In this manner, rice productiou in vast stretches of coastal areas is hampered due to high soil salinity (Latha, 2004). So farmer sometimes plant salinity resistant verities to get rid of this problem.

1.2 Background of the Study

Almost every year, Bangladesh experiences disasters of one kind or another - such as tropical cyclones, storm surges, coastal erosion, floods, and droughts - causing heavy loss of life and property and jeopardizing the development activities (Ali, 1999). Cyclone SIDR hit the Southwest coast of Bangladesh during. the evening of the 15 November 2007. The storm arrived as a Category-4 Super Cyclone with peak wind speed of 250 km/hour. SIDR continued to travel in the North-North-East direction, affecting parts of central Bangladesh, where it was subsequently downgraded into a Category-3 cyclone. Approximately 30 of Bangladesh's 64 districts were affected by the storm mainly within the administrative divisions of Barisal and Khulna (UN, 2007). Around 95 percent standing crop in eleven coastal districts was affected badly by the cyclone SIDR and shrimp and cattle farming were also damaged immensely (CEGIS, 2007).

Sarankhola upazila at Bagerhat district was one of the worst affected districts by cyclone SIDR. Preliminary investigation showed that the salinity level of soil and water were increased which affected the cropping and fishing practices in the region. Farmers were forced to change the cropping practices at the post cyclone stage. In the present study, the change in salinity level of the soil in the affected area and the cropping practices of the local farmers have been taken in to consideration.

All types of anthropogenic components in coastal region of Bangladesh are affected by tropical cyclone. It damages agricultural lands by inundating with high saline water from sea. Farmers may face problem to produce agricultural commodities, especially rice, from several months up to a few years after the cyclonic event in high saline soil. Although salinity problem in the soil after cyclonic event is a short-term problem, it has the potential to create threat against food security. Coastal polders are also highly affected by cyclone and breached polders may contribute to increase soil salinity during spring tide and create great problem in agricultural production. Cyclone SIDR created both of these problems in the affected areas. The present study illustrates the impact of cyclone SIDR on the soil salinity status of the study area and it demonstrates the alteration process of soil salinity in context of cropping practices and presence of coastal polders.

1.3 Objectives

The overall objective of the present study is to determine the salinity alteration process in the study area in context of the cropping practices after the cyclone event and also to analyze the possible impacts of polders in this regard.

Specific objectives of the study are as follows:

- To determine the soil salinity status of inundated and un-inundated soil, inside and outside polders after the cyclone event.

- To determine the soil salinity status of the same areas after the monsoon season.
- Assess the salinity recovery process in the study area.

1.4 Organization of the Thesis

In the present chapter, formulation of the research problem has been done. It highlights the objectives of the current research and also rationale of the study. Chapter two includes the literature review for the study. It illustrates the cyclonic events in Bangladesh and its impact in increasing of soil salinity in the coastal areas as well as the impact of soil salinity on agriculture. The necessary information about the study area is provided in chapter three. Chapter four presents the methodology adopted in the present research. Chapter five illustrates the resnlts of the study. It covers the soil salinity status after cyclone SIDR and after monsoon of 2008. It also explains the impact of soil salinity on agriculture after cyclone SIDR. Conclusions of the study and some recommendations are listed in chapter six.

1.5 Limitations

There are several limitations of the present study: (a) Due to severe accessibility problem after the cyclone SIDR and also after the monsoon of 2008, samples were colleted near the riverbanks and also near the damaged polders of the study area. So they may not be exactly representative of the entire study area, (b) only one year of data on soil salinity may not be sufficient to explain the salinity recovery process in the study area, (c) crop production was estimated from the farmers interview of the respective sampling plots which may not provide the actual data and (d) selection of farmers for interview was on convenience/availability method, which is a non- probability method and it may not emphasize the actual view of the farmers of that area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, a review of relevant literatures on cyclones, soil salinity and its impact on agricultural production has been presented. The literature review is primarily directed to an overview of the soil salinity regarding disasters with special emphasis on cyclone SIDR.

2.2 Cyclones in Bangladesh

Bangladesh is widely recognized to be one of the most climate vulnerable countries in the world. It experiences frequent natural disasters, which cause loss of life, damage to infrastructure and economic assets, and adversely impact on lives and livelihoods, especially of poor people (IUCN 2008)

The Bay of Bengal is the ideal breeding ground for tropical cyclones. Here severe cyclones occur mostly during pre-monsoon (April-May) and post-monsoon (October-December) periods. These cyclones generate surges up to a height of several meters, which sweep through the flat coastal region killing people, animal and destroy other fauna and flora. Records of last 200 years show that at least 70 major cyclones hit the coastal belt of the country. It is also recorded that during the last 35 years, nearly 900,000 people died due to catastrophic cyclones. The Noakhali-Chittagong coast received 40 percent of the cyclones, which is considered to be the most vulnerable area for the cyclones. The Chittagong-Cox's Bazar coast received around 27 percent of the cyclones, whereas Khulna/Sundarban and Barishal-Noakhali coasts are relatively less vulnerable (Rahman, 2001).

UNDP has identified Bangladesh to be the most vulnerable country in the world to tropical cyclones and the sixth most vulnerable country to flood, as shown in Table 2.1.

Table 2.1: Most vulnerable countries to floods or cyclones

Tropical cyclone			Floods**		
Rank	Country	Deaths*	Rank	Country	Deaths*
1	Bangladesh	32.1	1	Venezuela	4.9
2	India	20.2	2	Afghanistan	4.3
3	Philippines	8.3	3	Pakistan	2.2
4	Honduras	7.3	4	China	1.4
5	Vietnam	5.5	5	India	1.2
6	China	2.8	6	Bangladesh	1.1

Source: UNDP 2004, *Deaths/1,00,000 people exposed to floods or cyclones, **Of major flood affected countries reporting an average of over 200 deaths/year;

Over a period of 100 years, 508 cyclones have affected the Bay of Bengal region, of which 17 percent made landfall in Bangladesh. A severe cyclone occurs almost once every three years in this country; although the frequency of cyclones is not unusual compared to other cyclone hotspot countries, as much as 53 percent of the cyclones that hit Bangladesh claimed more than 5000 lives (Ali 1999). Table 2.2 shows the major cyclones affecting Bangladesh since 1960.

Table 2.2: Cyclones affecting Bangladesh since 1960 prior to SIDR

Date	Season	Max. Wind Speed (km/hr)	Storm Surge Height (m)	Deaths
9-Oct, 1960	Post-monsoon	162	3	3000
30-Oct,1960	Post-monsoon	210	4.5-6	5149
9-May,1961	Pre-monsoon	146	2.4-3	11466
28-May, 1963	Pre-monsoon	203	4.2-5.1	11520
11-May, 1965	Pre-monsoon	210	4.5-6	873
1-Oct, 1966	Post-monsoon	146	4.5-9	850
12-Nov, 1970	Post-monsoon	223	6-9	500000
9-Dec, 1973	Post-monsoon	122	1.5-4.5	183
25-May, 1985	Pre-monsoon	154	3-4.5	11069
29-Nov, 1988	Post-monsoon	162	1.5-3	2000
29-Apr, 1991	Pre-monsoon	225	6-7.5	138000
31-May, 1991	Pre-monsoon	110	1.9	

Date	Season	Max. Wind Speed (km/hr)	Storm Surge Height (m)	Deaths
29-April,1994	Pre-monsoon	210	-	400
21-Nov,1995	Post-monsoon	210	-	650
16-May,1997	Pre-monsoon	225	3.05	126
25-Sep,1997	Post-monsoon	150	1.83-3.05	-
16-May,1998	Pre-monsoon	150	1.83-2.44	-
19-Nov,1998	Post-monsoon	90	1.22-2.44	-

Source: Cyclone Shelter Preparatory Study (CSPS) 1996, BUET, 2008

During the cyclone of 29 April 1991, in total 140,000 people were killed, 840,000 houses were completely destroyed while another 910,000 houses suffered partial damage. During this cyclone, people not only lost their houses but also food, clothing, utensils and other belongings, which were swept away by tidal waves. Besides these, farmers also suffered heavily due to loss of standing crops, deaths of livestock and poultry and intrusion of saline water into their lands. Loss of livestock resulted in the deficiency of plowing animals, which badly affected rice and other cultivation.

2.3 Disasters and Soil Salinity

Several studies indicate that the coastal zone vulnerability would be acute due to the combined effects of climate change, sea level rise, subsidence, and changes of upstream river discharge, cyclone and breaching of coastal embankments (BCAS, 1994 and WB, 2000). Four key types of primary physical effects i.e. saline water intrusion; drainage congestion; extreme events; and changes in coastal morphology have been identified as key vulnerabilities in the coastal area of Bangladesh (WB, 2000).

UN (2005) stated the following findings after the 2004 Tsunami in Sri Lanka

- Caused locally significant changes in on-shore land form profiles,
- Plugged estuary outlets,
- Damaged or removed coastal vegetation,
- Caused sand casting on productive lands, and,
- Resulted iu salt-water intrusion into surface and sub-surface fresh water sources.

FAO (2005) stated that the deterioration of soil fertility due to the salt pollution of agricultural fields has been a major concern since the 26th of December 2004 when the tsunami ravaged thousands of kilometers of coast along the shore of the Indian Ocean penetrating from 0.5 km up to several kilometers inland.

During the 2004 tsunami agriculture was the second sector affected after fisheries. FAO estimated that in the conntries hardest hit by the disaster (Indonesia, Sri Lanka, Maldives, India and Thailand) a total of 47,000 ha of agricultural land was damaged by huge waves and sea floods leading to massive crop losses and deterioration of land fertility.

Tsunami salinity had two origins:

i. Seawater infiltration during the flood and resulting salt fixation along the topsoil profile.
ii. Saline sea deposits (Sand or clay).

The duration of the inundation had a direct impact on the quantity of infiltrated salt and it depended mainly on the local post-tsunami drainage capacity; i.e. existence of coastal dykes and infiltration capacity of surface soil.

It is true that reclaiming soils in arid countries, which have become salinized due to irrigation practices or natural accumulation, can take years, but in the case of sea flash floods it is obvious that the nature, duration and type of impact are very different.

FAO (2005) predicted in early January of 2005 that in general in the tropical humid conditions of the Indian Ocean salt-affected fields would return to their pre-tsunami state in a matter of months. Since then, this prediction has been largely verified, and surveys after tsunami show that, the fields which were well watered by rain or irrigation and well drained, the situation has returned to normal and farmers have already started to re-cultivate their fields.

2.4 Cyclone SIDR 2007

On 15 November 2007, Cyclone SIDR struck the southwest coast of Bangladesh with winds up to 240 km/hr. The category-4 storm was accompanied by surges up to 6 meters in some areas, breaching coastal and river embankments, flooding low-lying areas and causing extensive physical destruction.

Cyclone SIDR was first observed on 9 November 2007, Southwest of Andaman Islands, with weak low level circulation near the Nicobar Islands. It showed indications of the formation of a tropical cyclone on 11 November while located a short distance south of the Andaman Islands, and by 13 November, the depression had turned into a cyclonic storm with a core of hurricane force winds. Cyclone SIDR hit Bangladesh's offshore islands at approximately 6:30 pm on the evening of 15 November and made landfall across the Barisal cost at 9:00 pm during ebb tide. At landfall SIDR was a category-4 storm with a diameter of nearly 1000 km and sustained winds of up to 240 km/hr.

Storm surge analysis by Institute of Water Modeling indicated surge levels of 5.5 to 6 meters at the outfall of Baleswar River, 5 meters at Sharankhola and Bagerhat and 3.5 meters at Hiron point. These levels exceeded the sea facing embankment, which are at more than 6 meters in Barguna district (GoB, 2008).

Around 95 percent standing crops in eleven coastal districts were affected badly by the cyclone SIDR and the farming of shrimp and cattle were also damaged immensely. The shrimp hatcheries in Satkhira, Khulna and Cox's Bazar were badly affected. It was predicted that SIDR would take its toll on the livelihood of ultra-poor people, as inflation rate would increase (CEGIS, 2007). It was feared that seed losses and fertilizer shortages would further constrain early agriculture sector recovery (IFRC, 2007).

2.5 Classification of Soil as per Salinity

According to United States Department of Agriculture (USDA) since 50% reduction in yield takes place at EC_e of 4 dS/m for most agricultural crops, this was proposed as critical value to distinguish between saline and non-saline soils as described by Chhabra (1996).

Usually it is difficult to fix a limit of salinity where the plant will fail to grow. With the increase of salinity the plants generally suffer a slow death. There are some saline sensitive crops (e.g. grape, lentil etc.), which show impact when EC_e value is above 2 dS/m.

Soil salinity was classified by Karim et al. (1990), where the plants response was taken into consideration. Table 2.3 provides this salinity classification of soil.

Table 2.3: Soil salinity classes and crop growth

Soil salinity	(ECe, dS/m)	Effect on crops/plants
Non-saline (S_0)	<2	Salinity effects negligible
Slightly saline (S_1)	2-4	Yields of sensitive crops may be restricted
Moderately saline (S_2)	4-8	Yields of many crops restricted
Saline (S_3)	8-16	Yield satisfactory only for tolerant crops
Highly saline (S_4)	>16	Only a few very tolerant crops yield satisfactory

Source: Karim et al. (1990)

Soil salinity is divided into six classes by SRDI on the basis of salt present in it, which is shown in Table 2.4.

Table 2.4: Soil salinity classes by SRDI

Salinity classes	Salinity (EC_e, dS/ m)
Non-saline (S_0)	<2
Very slightly saline (S_1)	2-4
Slightly saline (S_2)	4-8
Moderately saline (S_3)	8-12
Strongly saline (S_4)	12-16
Extremely saline (S_5)	>16

(Source: SRDI, 1999)

2.6 Saline Area of Bangladesh

In Bangladesh, about 0.17 million hectares (20.4 %) of new land has been affected by various degrees of salinity over the last three decades (SRDI, 2002). Due to several reasons like river water withdrawal from upstream, introduction of brackish water shrimp cultivation, faulty management of sluice gates, regular saline tidal water flooding in unpoldered area, upward capillary movement of soluble salts due to presence of high saline ground water at shallower depth etc., soil salinity in these areas increases considerably (SRDI, 2002). More than 20 % of land in Satkhira, Khulna and Bagerhat has been found within the salinity level of 16,000 micro-mhos (Karim et al., 1990). The southwest region experienced about 43.19 % newly saline affected area over last three decades that changed the soil pattern of the region. A comparative picture of saline land in six districts of southwest region, where about 44.5 % of the area is salinity affected, is shown in the Table 2.5. Among these, Khulna and Bagerhat are in the highest level (SRDI, 2001).

Table 2.5: A comparative picture of saline affected land of six districts

Districts	Total cultivable land (ha)	Salt affected land (ha)	Percentage of salt affected area
Satkhira	228125	147080	64
Khulna	211328	145250	69
Bagerhat	206409	125130	61
Norail	Not Available	16050	N.A.
Gopalgang	87072	10200	12
Jessore	95071	10860	11.4

Source: SRDI (2001)

Table 2.6 shows the distribution of extent of different categories of soil salinity in Khulna and Begerhat districts.

Table 2.6: Extent of different categories of soil salinity in Khulna and Bagerhat

Districts	Salinity Categories				Total Area (Thousand hectares)
	S-1	S-2	S-3	S-4	
	Area (Thousand hectares)				
Khulna	3.90	95.54	13.80	9.80	123.04
Bagerhat	28.30	77.08	2.60	0.00	107.98

Source: Karim *et al.*, 1990

2.7 Salt Tolerant Crops

In the past decades, the focus of research to elevate salt tolerance of plants mainly referred to biochemical and physiological aspects (Koyro and Huchzermeyer 1999). Genes responsible for salt tolerance of some crops (e.g. soya bean, tomatoes, grasses, rice) have been identified (Jaradat 1999). However, in spite of the large efforts put into the understanding of biochemical and physiological processes in plants grown under saline conditions, results are disappointing with respect to their relevance for crop yields under brackish or saline agriculture (Flowers 2004, Yamaguchi and Blumwald 2005, Jones 2006).

From the experimental results of Schleiff (2008), it was confirmed that root morphology is not only a very important factor for nutrient absorption by roots, but also for water uptake by roots from saline soils. The results of a pot experiment with onions and rape, where the water uptake rates by roots from a densely rooted salinized sandy loam soil were determined from the transpiration rates (pot water losses) during a 4-day period, revealed that short root hairs contribute to a lower salt tolerance (onions), whereas long root hairs enhance water uptake from saline soils and crop salt tolerance (rape).

Salt tolerant varieties

Rice production for coastal areas has been a major challenge to breeders and researchers. Though some 90,000 varieties have been screened at the International Rice Research Institute (IRRI), the donors for salt tolerance have always been traditional cultivars and non-dwarf varieties (Yeo et al., 1990).

Crops vary in their relative tolerance to soil salinity. Selection of crop for their tolerance is thus an important aspect for the management of saline soils (Rahman and Ahsan, 2001). Kumar et al. (2001) reported that rainwater conservation in the saline region to increase production of local varieties was successful, and it increased the production of local variety significantly. Sana (2004) observed that in kharif season 95.98 % land is used for rice cultivation whereas 56.75% land is used for the cultivation of local varieties of rice, and in rabi season only 43.97 % land is used for vegetable cultivation in saline areas of southeast region of Bangladesh. Salt tolerant crops may be an alternative for increasing cropping intensity in these problematic soils. It is suggested that rice variety BRRI-dhan 33 (15 days early), BINA mustard varieties and HYV boro rice variety – BINA-dhan 6 (potential yield 8 ton/ha) instead of T. aman and boro will certainly be able to increase the production per unit area and increase land use intensities 200 to 300 % (Sarker et al., 2000).

Latha (2003) stated that several varieties have been bred so far for salinity tolerance but the degree of tolerance has often been inadequate. It is important therefore to identify new sources of tolerance. Recently research has focused on identifying and developing varieties that contain salt tolerance up to EC = 12 dS/m with yield of 4.1 tones/ha and consisting grain quality. The only known source of tolerance to salt stress among the wild relatives of rice is *Porteresia coarctata*, which grows in abundance along the Eastern and Western coasts of India, Pakistan and Bangladesh. *Porteresia* is a monotypic genus occurring as an associate of mangroves along the coastal belts where the soil is inundated twice a day with saline river or seawater of 20 to 40 dS/m. The species can also withstand submergence with saline water for quite a long period. In deep forests of Sunderban, West Bengal, India, it is generally completely submerged by tidal water for as long as 10-11 h every day. The mean tidal level (MTL) of these areas is 1.10 m from the base and the plant grows up to a height of 1 m with a very hard stem and thick leathery leaves. Several useful traits are attributed to this tetraploid genus, which was poorly studied until recently. Studies into this wild relative of rice are now receiving attention due to its inherent capacity of tolerating high levels of salinity. *Porteresia* shows sustained growth despite the fact that it grows in highly saline environments. *Porteresia* helps to bind peripheral soils in mangrove forests and its distribution pattern shows a decrease in abundance in several mangrove areas because of both natural and anthropogenic pressures.

2.8 Impact of Salinity on Agriculture

Chowdhury (2007) studied the relationship between salinity and crop production in different hydrological regimes downstream of Muhuri Regulator at Mirsarai upazila in Chittagong district. It was found that salinity of the study area was less than 4 dS/m and rice being a semi-tolerant crop no significant relationship was detected between soil salinity and rice yield in aman season. In rabi season, salinity was also found less than 4 dS/m except in unprotected area. A positive correlation was found between soil salinity and khesari yield, which was found to be significant in unprotected area. Water salinity inside the cross dam was around 0.1 dS/m (rabi season), which is considered excellent for irrigation. But outside the cross dam it ranged in between 4.8-5.4 dS/m in aman season and 12.4-20.8 dS/m in rabi season, which was extremely toxic for irrigation

HYV rice in boro season can be cultivated in old and new protected area by utilizing Feni river water inside the Muhuri regulator and closure dam for irrigation purpose. But it cannot be cultivated due to salinity problem (>4 dS/m) in unprotected area and lack of irrigation water in affected area. But in these areas khesari can be grown successfully by utilizing residual soil moisture (Chowdhury, 2007)

Qadir et al. (2008) summarized the works of Garcia & Castro (1992), and Wertis & Ungar (1986), and stated that soil salinity reduces primary production of some natural terrestrial grass ecosystems and affects allocation of resources to plant reproductive structures. Excessive levels of ions such as Na+ and Cl- in waters and soils may cause ion-specific effects in plants leading to toxicity or deficiency of certain nutrients. Under salt-affected conditions, concentrations of Na+ and Cl- often exceed those of most macronutrients by one or two orders of magnitude, and by even more in the case of micronutrients. Thus, salt-affected soils may have depressed nutrient–ion activities and extreme ratios of Na+, Ca2+, Na+/K+, Mg2+/Ca2+ and Cl-/NO_3- (Curtin and Naidu, 1998; Grattan and Grieve, 1999). As a result, the salt-stressed plants become susceptible to high osmotic stress, ion-specific toxicity and nutritional disorders. The collective effect of such stresses and disorders affects crop growth and yield (Grattan and Grieve, 1999), depending upon several edaphic and environmental factors. These include ambient soil salinity and sodium levels, composition of soil solution and exchange complex, soil pH and redox potential, the particular nutrient in question, salinity/sodicity tolerance level, nutrient requirement of the plant species, as well as several environmental factors.

Table 2.7 Average root zone salinity at specified yield potentials

Crop		Root zone salinity (dS/m) at specified yield potentials		
Common name	Botanical name	50%	80%	100%
Wheat	*Triticum aestivum* L	13	9	6
Rice	*Oryza sativa* L.	7	5	3
Potato	*Solanum tuberosum* L.	7	4	2
Maize	*Zea mays* L.	6	3	2

Source: Qadir et al. 2008

Salt movement in the soil

FAO (2005) stated that water is taken up by the fine roots of plants through the process of osmosis, which involves the movement of water from regions of low salt concentration (such as the soil) to regions of high salt concentration (such as the inside of root cells). When salt concentrations in the soil are high, the movement of water from the soil to the root is slowed down. When the salt concentrations in the soil are higher than inside the root cells, the soil will draw water from the root, and the plant will wilt and die. This is the basic way (Plasmolysis) in which salinization affects plant production.

The damaging effects of salt on plants are caused not only by osmotic forces, but also by toxic levels of sodium and chloride. Fruit crops and woody ornamentals are especially sensitive to high levels of these elements. Also, the high pH value (a measure of the acid/alkaline balance) caused by excess sodium may result in micronutrient deficiencies.

Salt affects plant growth mainly through: (a) toxicity from excessive uptake of salt substances such as sodium, (b) reduced water uptake, known as water stress and (c) reduction in uptake of essential nutrients particularly potassium. Early signs of salinity damage are (a) darker leaves than the normal color of bluish-green, (b) smaller leaves and (c) stems with shorter spaces between leaf nodes. When the problem gets more serious, leaves (a) become yellow (chlorotic) and (b) are affected by "burning" (firing, browning) and the death of leaf edges.

Storm surge or tsunami seawater causes salt accumulation to the soil surface, but in most cases land is inundated for a relatively short period, and the salt is washed away by abundant rainfall during monsoon. The recent FAO survey has found that residual high content of salt is in the layers of clay and silt left behind by the seawater. The clay/silt layer can be identified easily by cracks that spread across the surface of the soil. In many areas, trenching or digging down to a depth of just 20 cm will reveal a fine gray layer.

Salt in the soil is best washed away by fresh water, but because this clay/silt layer is relatively impermeable, the filtration process, called leaching, is slow. When cracks appear, the rainfall runs into these cracks and desalinization is even slower. In some relatively dry zones the salt has already accumulated on the surface and crystallized. As a result the salinity problems may persist for a long period unless measures are taken to remove the salt by flushing and/or leaching.

For rice cropping, an EC (e) value of less than 4 at the time of transplanting is the best for root formation. If this is achieved and if subsequent water management is appropriate, there will be no salinity problem throughout the cropping season.

FAO (2005) provided the following salinity value in regarding the rice and non-rice crop production:

- If the EC (e) is less than 4, the yield loss will be less than 10%
- If the EC (e) is more than 4, the yield loss will be 10 – 20%
- If the EC (e) is more than 6, the yield loss will be 20 – 50%
- If the EC (e) is more than 10, the yield loss will be more than 50%

For other crops: sensitive plants (such as papaya, mango and banana) are affected at about 2% reduction, And the tolerant plants (e.g. coconut, tamarind) are only affected at 8-10% or more yield reduction.

Ragab (2008) stated that increasing water salinity in sandy soil up to 4.85 dS/m reduces the grain yield by 23 %, while to 16 % reduction is found in calcareous soil. The yield reduction increases by increasing salinity of irrigation water and reaches its maximum at 8.86 dS/m salinity level. Grain yield, was negatively correlated with hardly available water, water salinity and soil EC, while the relations were highly positive with easily available water.

SRDI (2001) revealed that salinity largely reduces the yield of rice in the coastal areas of the country, mainly in Khulna, Patuakhali and Chittagang districts. The salinity of these regions is either derived from tidal flooding with saline water at high spring tides or from periodic inundations with salt water during cyclonic storm surges and reduced fresh water supply.

Salinity hampers the growth of crops at germination and early vegetative stage (Karim, 2000). Tata (1992) stated that salinity has great effect on germination of different species but in all cases it is not similar. Some species are more salt tolerant, some are semi-tolerant and some are less tolerant. Diversity index value is decreasing due to salinity (Kamal, 1997). It is mentioned that rice production suffers 10 % yield reduction when the salinity tolerance limit of 20,000 micro-mhos is exceeded and when water salinity exceeds 48,000 micro-mhos, yield is reduced by 50 %. Chaffey *et al.,* (1985) stated that for mangrove species, an optimal range of salinity is needed for maximum growth. Hyper salinity may cause damage or even mortality of species. Die-back of *sundari* may be due to an adverse increase in soil salinity.

Salinity reaches its peak level during April and May when it causes the major damage (Kumar *et al.*, 2001). Rice seedlings are extremely sensitive to this salinity or excessive accumulation of soluble salts (Mohiuddin, *et al.,* 1997). Noman (2002) showed that the species like fruit and/ or food producing trees are found to decrease in number due to salinity. The affected species by salinity are mainly *Musa* spp., *Psidium guajava, Mangifera indica, Artocaupus heterophylus, Citrus limon, Engenia javauea* etc. Some species were found to be growing poorly and some species seemed to show unsatisfactory survival condition in saline zones (Karim, 2000; Karim *et al.*, 1990). Especially in the early stage of plant growth, salinity inhibits the uptake of nutrients by the roots as a result of competition between the nutrient and saline ions. It also changes the land use pattern of the area by changing the agricultural practices (BARC, 1998).

2.9 Salinity Management

Qadir et al. (2008) mentioned that crop diversification may play a key role in salinity management; which aims to: (1) provide insight into different aspects of salt affected land and saline water resources; (2) synthesize the research-based knowledge on the ability of different crops to withstand salinity and sodicity and (3) highlight emerging examples of crop diversification and management to achieve maximum benefits and sustainability of saline land and water resources.

Kabir et al. (2003) stated that 145 numbers of polders having more than 5000km of embankment were constructed in the sixties to protect the coastal low-lying area from saline inundation in order to increase agriculture production without consideration of safety against cyclonic surges

CHAPTER THREE

OVERVIEW OF THE STUDY AREA

3.1 Introduction

This chapter contains an overview of the study area. Sarankhola upazila was selected for the present study, as it was one of the most severely affected areas and relatively accessible compared to some other affected areas. The chapter provides a general description of different important features like geographical location, demographic features, land formation, major river systems, agricultural production, and climatic condition of the study area, which are essential to obtain sufficient understanding of the area.

3.2 Area and Geographical Location

Sarankhola Upazila occupies a total area of 756.61 sq. km. Including 594.58 sq. km. forest area and 22.40 sq. km. river area. It is located between 22°13' and 22°24' north latitudes and between 89°46' and 89°54' east longitudes. The Upazila is bounded on the north by Morrelgonge Upazila, on the east by Mathbaria Upazila of Pirozpur district and Patharghata Upazila of Barguna District, on the south by the Bay of Bengal and on the west by Mongla Upazilla. Main rivers are Balleshower, Bhola, Bogi, Horinghata and Chandpai, the Sundarban covers major area of the Upazila. A map of the study area is provided in Figure 3.1

3.3 Demographic Features

According to the population census of 2001 the total population of the upazila is 114083 of which 61,799 are males and 52,284 are females. The sex ratio of the upazila is 118 male per 100 female against 105 males per 100 females in 1991. The decadal growth rate for the Upazila is 5.77%.

3.4 Climate

The area has average maximum temperature of 30.95^{0}C and average minimum temperature of 21.77^{0}C. Rainfall is heavy, usually over 1716 mm per year. Three seasons out of six seasons are dominant in this area. Monsoon period prolong from May to October and 89.04% of rainfall occur in this time. Winter season starts in the month of November and ends in February. During this time weather remains dry and cold,

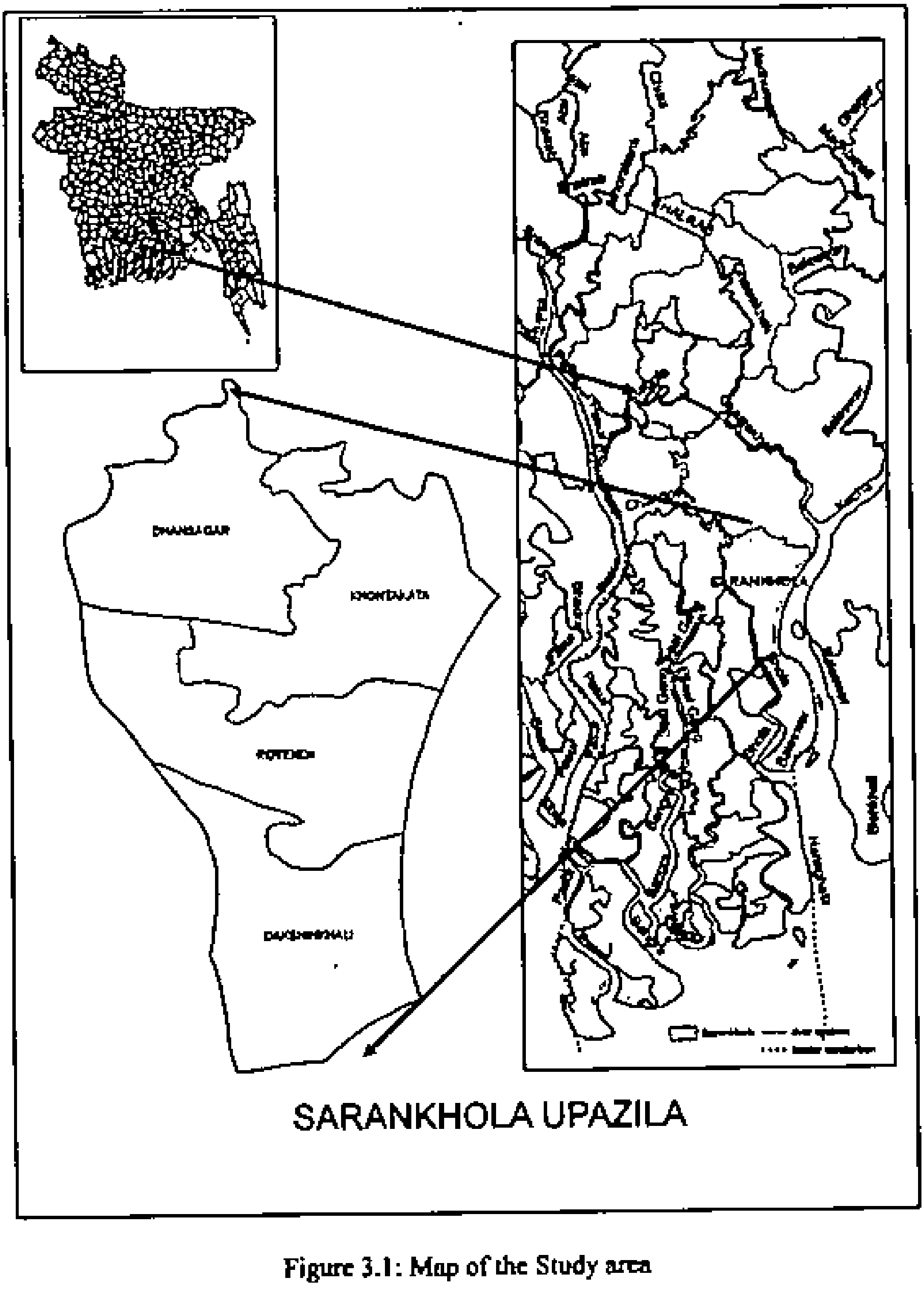

Figure 3.1: Map of the Study area

sometimes rain occurs. March and April are considered as summer and at this time weather remains very hot and moisture contents of the air is very low. Sometimes storm and hailstorm may occur. The average humidity from May to October is 84%, Average sunshine hour from November to April is 8.12. Wind speed is high in April and May, which is 2 m/s. The climatic condition such as max and min temperature (^{0}C), rainfall (mm), Humidity, sunshine hour, wind speed and cloud cover of the study area are shown in Table 3.1

Table 3.1 Observed monthly rainfall (mm) of different stations around the study area during 2008 and normal rainfall in those months

Station	May		June		July		August		September	
	O	N	O	N	O	N	O	N	O	N
Khulna	98	227	129	331	476	352	135	349	274	239
Patuakhali	81	227	281	488	1044	560	288	489	462	341
Barisal	68	241	208	437	604	416	429	398	279	313

O = Observed; N = Normal

3.5 Water Resources and Major Rivers

Surface water

The main sources of surface water are rivers, canals and ponds. The study area is surrounded by rivers (Figure 3.1): the Baleshwer River flows on its east, Bogi River on its South, Bhola River on its west and Dhansagor River flows on its Northern side.

Both Dhansagor and Bogi Rivers are connected with Bhola River on western part and with Baleshwer on eastern part of the area. Besides these many canals and small rivers are interconnected with each other and build a river network in the upazila. The Baleshwer River and the Bhola River are deeper and discharge much more water than others. During dry season water of all the rivers except Baleshwer River turns into high saline water. Sometimes Baleshwer River water is affected by salinity during dry season by other river water. All types of boats, steamers and launches move through the Baleshwer and Bhola Rivers all the year round. Table 3.2 shows some of the characteristics of the major rivers in the study area

Ground water

The ground water is affected by high level of salinity. Water from most of the hand tube-wells is affected by salinity. So the groundwater is not suitable for irrigation purpose. Most of the people of the study area use filtered pond water (Pond sand filter). They also use rainwater-harvesting system during raiuy season.

Sources of drinking water

In Sarankhola upazila, 22% dwelling households drink tubewell water, 12.06% drink tap water 4.79% drink deep tubewell water 59.62% drink pond water and the remaining 1.56% dwelling households drink water from other sources.

Table 3.2: Characteristics of the major rivers in the study area

Description	Name of the river		
	Baleshwer	Bhola	Bogi
Off take	Kaligonga River in Pirozpur Sadar Upazila, Pirozpur	Lower region of Sundarban, Mongla, Bagerhat	Bhola River, Sarankhola.
Outfall	Bay of Bengal, Pathorghata Upa of Barguna District & Sarankhola Upazila of Bagerhat district	Bay of Bengal, Sarankhola, Bagerhat.	Baleshwer river, Sarankhola, Bagerhat
Length	146 Km	40 Km	3 Km
Avg. Width	3000 m	100 m	150 m
Depth	9 m	30 m	15 m
Catchments	486 sq. km	240 sq. km	12 sq. km
Discharge type	Perennial	Filled by sediment	Perennial
Time of Min discharge and depth	November to December 5.5 m	No data	February to March 8 m
Time of Max discharge and depth	July to August 9 m	------	July to August 12 m
Normal flooding	River bank is over flooded during normal flood.	------	Riverbank is over flooded during normal flood
Embankment	-----------	20 km	3 km
Tidal action	Yes	Yes	Yes

Source: BWDB-2005

3.6 Topography of the Study Area

Figure 3.2 shows the topography of the study area extracted from the 300m digital elevation model of Bangladesh. Most of the areas of Dhansagor and Khontakata unions show relatively low elevation compared to other areas.

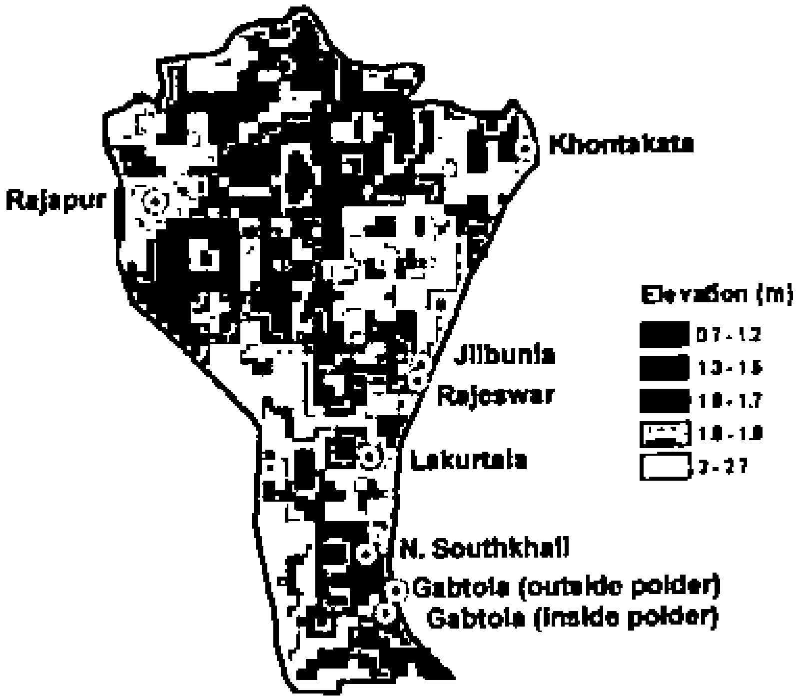

Figure 3.2: Topography for the Study Area

3.7 Polders

Polders were established in 1960s on both sides of the study area. The length of polder along the Baleshwer River is about 20 km and the length along the Bhola River is about 25 km.

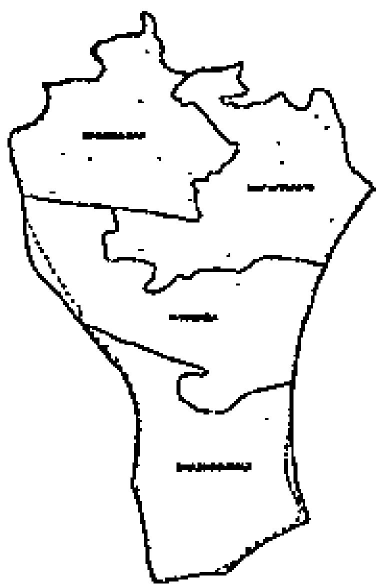

Figure 3.3: Polders in the study area

3.8 Soil Characteristics and Soil Salinity

Sarankhola upazila has been divided into four groups according to the soil properties by SRDI. Table 3.3 shows these groups and their characteristics.

Table 3.3: Soil groups and their characteristics

SL No	Soil Group	Texture	pH	Salinity (EC -dS/m)
1	Ramgoti	Loam	7.1-7.9	4.1-17.7
2	Bajoa	Clay-loam/ loam	7.4-7.5	11.5-31.5
3	Jhalokathi	Clay-loam/loam	4.4-6.4	1.4-24.4
4	Barisal	Clay/Clay-loam	4-5.8	2-13.8

Source: SRDI 1998

3.9 Cropping Pattern

In Sarankhola upazila 48.74% of the dwelling households own agricultural land. Percentage of ownership of agricultural land is 44.35% in urban area as against 50.03% in rural area. A total of 51.85% of dwelling households depend on agriculture as the main source of income with 32.17% on cropping, livestock, forestry and fishery and 19.68% on agricultural labor (BBS 2001).

Most of the lands are used either as mono cropping or as duel cropping lands. Farmers produce transplanted Aman, T. Aus and Boro crops. Both HYV and local varieties are produced including Aloron (HYV), Abdul high (Local), Dudhkalam (Local) and other local and HYV varieties. Table 3.4 shows the land areas for agricultural production from 2004 to 2006.

Table 3.4: Land areas for agricultural production from 2004 to 2006

Crops	2003-04 (ha)	2004-05 (ha)	2006-07 (ha)	2007-08 (ha)
Mono crop	4238	5230	5264	5260
Two crop	4500	3829	3596	3600
Three crop	1050	375	440	445
Crop intensity (%)	167.4	160	148.12	148.25

Source: Upazila Agriculture Office, Sarankhola, Bagerhat.

The rice verities produced by the farmers in the study area is shown in Table 3.5

Table 3.5: Rice varieties produced in the study area

Cropping Period	Month	Type of Crop	Varieties
Robi	Nov-Feb	Boro	BRRI- 28, 29, 47*
Pre-Kharif	March-May	Aus	BR-3, 14, 26, 27
Kharif	June- October	T. Aman (HYV)	BR-3, 11, 10, 22, 23 BRRI-33, 40, 41, 44, 45

Source: Upazila Agriculture Office, Sarankhola, Bagerhat

* BRRI Dhan-47 is the saline tolerant vaerity.

Traditional local varities of T. Aman such as Lal Mota, Sada mota, Horbi Maloti, Kalijira and Didhkalam are also produced in the area. Of them Dudhkalam is the best one and its production is near about 4.5 tons/hectare which is equivalent to the production of HYV.

Salt tolerant rice BRRI Dhan-47

This is the salt tolerant variety produced in salinity-affected areas of Bangladesh like Satkhira, Khulna and Bagerhat. But in the study area very few lands are used to cultivate this variety. The average yield to grain of this variety is 6.1 ton/ha (Salam et. al. 2007). The parent seed no of BRRI-47 is IR 63307-4B-4-3. This is the output of crossbreeding of IR-515111-B-B-34-B and TCCP 266-2-49-B-B-3. Satkhira was the first selected area for its cultivation during Boro Season. It can tolerate salinity up to 14 dS/m during seedling stage. It is able to tolerate salinity up to 6 dS/m at all stages. It is taller and wider than BRRI-28. It can also adapt easily in the area of salinity 8 dS/m during Boro season

3.10 Rice Production

Rice is the main agricultural commodity of the study area. The production of rice depends on its variety, soil condition, soil moisture availability, saline water protection by polders, fresh water availability, fertilizer management, irrigation management as well as proper agricultural management. Soil salinity is the great concern of the study area. It increases day by day and affect rice production. The polders of the area were severely damaged by Cyclone SIDR. Saline water inundated the cultivable land and contributed to increase salinity, which ultimately affected the agricultutal production.

Salt water accumulated on soil surface. Farmers mainly produced both local and HYV of T. Aus and T. Aman in the area. Table 3.6 shows the yearly production of the area.

Table 3.6: Yearly production of rice in the study area.

Year	Types of crops	Cultivated land (Ha)	Production (M. Ton)
2003-04	T. Aus	1011	2542
	T. Aman	9153	16113
	Wheat	1	2.5
	Kheshari	3000	2700
2004-05	T. Aus	960	2656
	T. Aman	9140	16759
	Wheat	1	2.5
	Kheshari	2500	2250
2006-07	T. Aus	850	2550
	T. Aman	9300	22750
	Boro	7	32.20
	Wheat	2	5
	Kheshari	2731	2189.6
2007-08	T. Aus	850	2720
	T. Aman	9300	8360(SIDR affected)
	Boro	20	96
	Wheat	3	7.8
	Kheshari	2728	SIDR affected

Source: Upazila Agriculture Office, Sarankhola, Bagerhat.

3.11 Cyclone SIDR in the Study Area

Sarankhola upazila was one of the worst affected areas by super cyclone SIDR. This flat low-lying area is characterized by rice fields (only one crop a year), the Baleshwar River and proximity to the Sundarbans mangrove forest. The Bay of Bengal is only 40 km to the south of the study area.

People in the study area are mostly farmers, but along the river - outside high embankments - there are also a number of fishing communities, who use small fishing boats in the river, or join as crew on ocean fishing trawlers in the Bay of Bengal.

The mangrove is an additional source of income, as many of the farmers and fishermen in the area traditionally have been going into the Sundarban mangrove to collect honey, firewood and *sundari*-leaves (for thatching). Actually this is prohibited as the Sundarban is a protected area, being the largerst mangrove in the world, a natural reserve and the home of numerous animals and birds - the Royal Bengal Tiger being the most famous.

Still, until the cyclone SIDR struck, the government was not strict in enforcing this law. But after SIDR hit the area and destroyed around one third of the trees in the mangrove forest, the government is now trying to enforce the ban on entry into the mangrove, and thus this additional source of income, after the cyclone, is out of reach for the fisherfolks and farmers in the adjacent areas. Table 3.7 shows the storm surge height at different unions of Sarankhola District during SIDR which was obtained by interviewing the local people.

Table 3.7: Storm surge height at different unions of Sarankhola

Union	Height of storm surge above polder (m)
Southkhali	3.7
Ryenda	3.0
Khontakata	1.2
Dhansagor	0.6

3.11.1 Impact on fisherfolks

The entire fishermen community was seriously affected by cyclone SIDR. Their fishing boats, nets and other fishing materials were totally damaged. There was no way to earn their livelihood. Inland water resources were also affected and inlannd fishes were washed away by flooding dne to storm surge.

3.11.2 Household Damaged

SIDR damaged a total of 21,793 houses of the upazila out of which 13,451 were completely damaged. According to the Upazila Parishad, after the cycloue, about 60 thousand people of these damaged houses were living in makeshift shelters and tents on the embankment and roads, using open latrines. The homeless people of the upazila also took shelters on the banks of the rivers Baleshwar and Bogi, on the Bogi-Southkhali road, Southkhali-Tafalbari road, Khontakata road, and on Tafalbari-Rayenda embankment. Most of the people whose houses were partly damaged happened to lose their latrines. Few months after the cyclone, barring a few affluent people, the inhabitants of the partly damaged houses were yet to rebuild their latrines, and were using open places as latrines.

3.11.3 Water and Sanitary Condition

The water and sanitary condition was very unfevorable because of feacal pollution by open latrins. As a result, not only water but the environment was being polluted as bad stench coming from latrines has been spreading all over the area, causing health hazard, huge number of the affected people have been suffering from different water borne diseases. Out of 1,300 ponds used for drinking water at the upazila, 1,211 had been polluted by SIDR, and renovated again after SIDR by the department of public health engineering and some non-governmental organizations. Locals alleged a number of ponds that were renovated by the DPHE and NGOs were not up to the mark as they could not be used for drinking water. Figure 3.3 shows some affected agricultural lands at Southkhali and at Rayenda union.

Figure 3.4: Photos of affected agricultural land, left: Southkhali and right: Rayenda

3.11.4 Damaged polder

Polders of the study area were seriously damaged due to high storm surge during cyclone SIDR. Polders in the Southkhali union were damaged more than other unions. At many places, polders were washed away and serious destruction occurred. Polders in Rayenda union were also seriously damaged. In Khontakata union, damage was relatively less and some blocks were washed away. Figure 3.4 shows some affected polders at Southkhali and at Rayenda union.

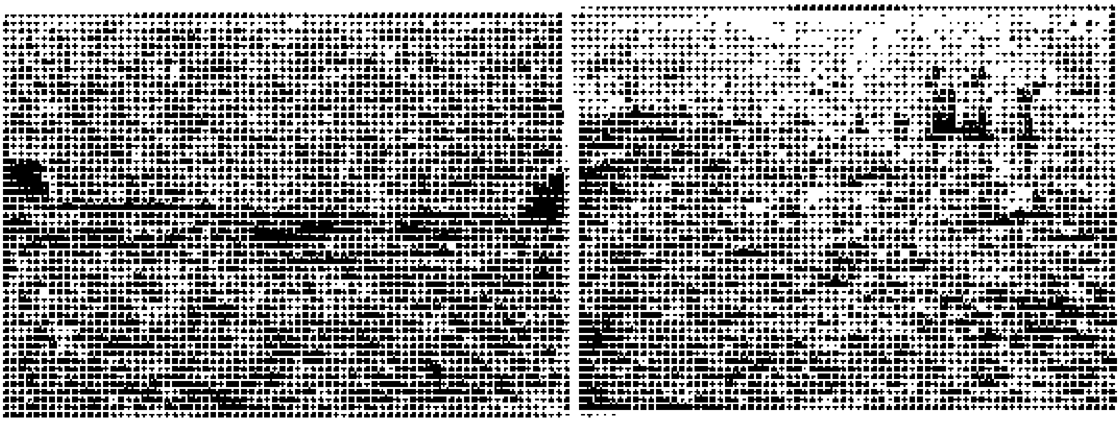

Figure 3.5: Photos of damaged polders, left: Southkhali and right: Rayenda

3.11.5 Crops Damaged by Cyclone SIDR

Standing crops of the study area were highly affected by Cyclone SIDR. About 82.24% lands of T. Aman were totally damaged in that time. 100% lands of Kheshari were damaged (UAO 2007). Table 3.7 shows the damaged crops and lands (Ha) in the study area on 15th Nov'2007.

Table 3.8: Damaged crops and lands (ha) in the study area by cyclone SIDR

Union	Affected farmers	Aman (HYV)	Aman (Local)	Aman Total	Kheshari	Vegetable	Mustard	Banana	Others
Dhansagor	2427	1210	1130	2340	700	35	4	9	5.48
Khontakata	2792	1105	1165	2270	450	94	2	14	10.93
Rayenda	2749	781	797	1578	550	45	10	14	8.11
Southkhali	2212	717	743	1460	925	22	4	10	9.48
G.Total	10180	3813	3835	7648	2625	196	20	47	34

Source: Upazila Agriculture Office, Sarankhola, Bagerhat. Date: 12/12/07

3.11.6 Assistance from Different Organizations

Many government and non-government organizations provided relief commodities just after SIDR in Sarankhola upazila. They also provided houses for homeless people, boats and nets for affected fishermen, cash for work and food for work activities, rikshaw and van for jobless people to improve their livelihood, seeds of crops and vegetables for farmers to produce agricultural commodities

CHAPTER FOUR
METHODOLOGY

4.1 Introduction

This chapter presents the sequential order and description of different steps followed during the study. It includes transect walk, mass gathering, open discussion with the local people, individual interview and FGD to get a clear idea about the study area. Sample collections and analytical procedures are briefly described in the following sub-sections.

4.2 Sampling Process

Sarankhola upazila was one of the highly affected areas of the Bagerhat District. Major portions of the polder along the Baleshwer River near Southkhali union of this upazila were seriously damaged. During and after SIDR, because of seriously damaged polders, the area was inundated by seawater which increased soil salinity in agricultural lands. The impact of soil salinity on agriculture after cyclone SIDR was identified through farmers' interview. Soil samples were collected and analyzed in the IWFM laboratory of BUET to determine salinity. Crop production data after cyclone SIDR and after monsoon of the respective plot were collected. Mainly rice crops were considered for impact of salinity after cyclone SIDR. The sampling process of the study is as follows;

(a) The polder along the riverside was highly affected by cyclone SIDR. The communication system in the study area was also very difficult in that time. Boats were used in the Baleshwer River to collect most of soil samples accept Dhansagor near the polder in the study area. A total of 8 sampling plots were selected from 4 unions. There were 3 sampling plots from each of the highly affected 2 unions and 1 sampling plot per union from the remaining 2 unions.

(b) Among the 8 sampling plots, one of the plot was located out side the polder-protected areas.

(c) Because of 8 sampling plots, a total of 8 farmers were selected for individual interview of the respective plots to collect relevant data from the plots.

(d) Three samples were collected from topsoil from each sampling plots by using core and made a mixture to form a composite sample. One composite sample per plot, i.e. a total of 8 soil samples were collected from the 8 sampling plots for salinity measurement, after cyclone SIDR.

(e) After monsoon season of 2008, soil samples both from topsoil (0-7cm) and subsoil (7-14cm) were collected from respective sampling plots by applying same method.

(f) A total of 8 Focus Group Discussions (FGD) were conducted near the 8 sampling plots to collect agricultural information as well as information of damaged polders and other relevant data after the cyclone SIDR

(g) Yield data of the cultivated crops were collected from the farmers of the respective plots by conducting individual interviews.

(h) All collected soil samples were analyzed as per ASTM standard procedure at IWFM laboratory of BUET.

4.3 Sampling Locations

Tables 4.1 shows the sample collection dates from different sampling plots after cyclone SIDR and after the monsoon of 2008. Figure 4.1 shows the sampling locations.

Table 4.1: Sample collection after cyclone SIDR and after the monsoon of 2008

Sampling Site	Union	Village	Top Soil Collection Date	Top and Subsoil Collection Date	Location
1	Rayenda	Jilbunia	29/03/08	02/12/08	Inside polder
2	Rayenda	Rajeshor	29/03/08	02/12/08	Inside polder
3	Rayenda	Lakurtala	30/03/08	02/12/08	Inside polder
4	Southkhali	N. Southkhali	1/4/2008	29/11/08	Inside polder
5	Southkhali	Gabtola	1/4/2008	24/10/08	Inside polder
6	Southkhali	Gabtola	1/4/2008	24/10/08	Outside polder
7	Dhansagor	Rajapur	3/4/2008	03/11/08	Inside polder
8	Khontakata	N.Khontakata	26/03/08	01/12/08	Inside polder

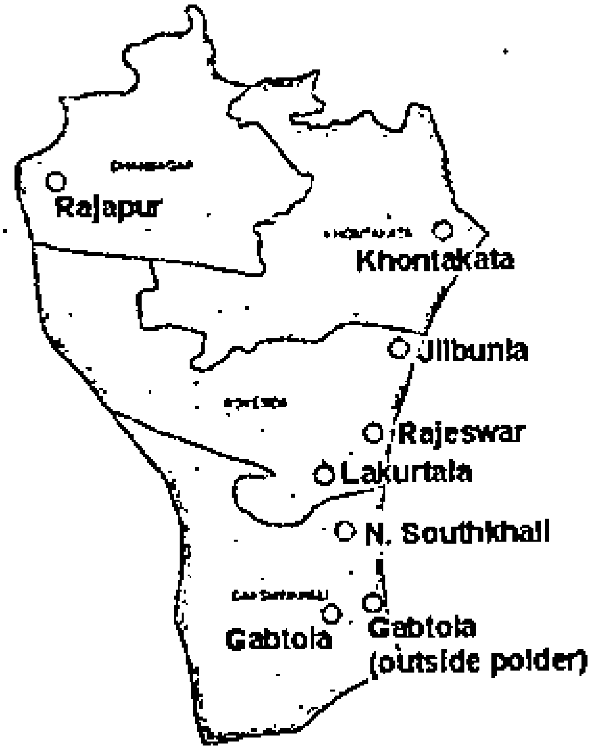

Fig 4.1 Sampling locations at different unions of Sarankhola

4.4 Soil Sampling

4.4.1. Collection Procedure of Soil Samples from the Study Area

(a) Site of sample collection

Soil samples were collected from rice fields of the affected areas, which were inundated by storm surge flooding. Coordinates of each sampling points were determined using GPS. Information of the coordinates was later used in GIS maps.

b) Time of sampling

Samples were collected twice, first after cyclone SIDR during March and April of 2008 and later during November and December of 2008 after rainy season when the lands were free of inundation by rainwater. The topsoil was considered after SIDR because of immediate effect and salt accumulation on surface layer of the soil. But both topsoil and subsoil were considered after monsoon because of downwards movement of salt during rainy season *(c) Number of collected soil samples after SIDR*

A total of 8 composite topsoil samples were collected after SIDR from 8 locations of four Unions taking one sample from each location; three each from Southkhali and Rayenda unions and two each from Khontakata and Dhansagor unions

(d) Number of collected soil samples after monsoon

A total of 16 composite samples were collected after monsoon from both topsoil (0-7cm) and subsoil (7-14cm) at the same locations of four unions six each from Southkhali and Rayenda unions as well as two each from Khontakata and Dhansagor unions.

(e) Collection method

Soil samples were collected randomly by core sampling method from topsoil and subsoil. Mixing three samples from each sampling plot made a composite sample.

(f) Laboratory analysis of the soil samples

Soil samples were properly cleaned, poured into polythene bags and labeled after collection. All labeled samples were air dried for preparation to analyze soil salinity.

(g) Soil Particle size analysis

Sieve analysis and hydrometer analysis were followed for grain size analysis of the samples to find out the relation between particle size of soil and soil salinity retention capacity.

4.5 Measurement of the Salinity

Electrical Conductivity (EC) and total concentration of salt in solution are closely related as described by FAO (1999). So EC of the saturated soil extract (EC_e) for evaluating soil salinity or EC of the water (EC_w) for evaluating water salinity is based on average EC (Electric Conductivity) of saturated soil extract or water. EC_e is defined as the electrical conductivity of the soil water solution after the addition of a sufficient quantity of distilled water to bring the soil water content to saturation. EC_w is defined as the EC of water at 25^0 C. Salt concentration changes as the soil water content changes. EC_e and EC_w are typically expressed in deci-Siemens per meter (dS m^{-1}).

Soil Salinity Assessment

Methodology of the soil salinity determination of the collected soil samples of the study area provided in detail in APPENDIX I. A set of relevant photo is provided in Figure 4.2.

The following regression factors which is followed by SRDI, has been utilized for salinity calculation:

If meter reading is 0.01 to 1.99

Regression factor, Y = 0.122 + (1.323 * Meter reading)

If meter reading is 2 to 14.99

Regression factor, Y = 1.267 + (1.269 * Meter reading)

If meter reading is greater than15

Regression factor, Y = 8.31 + (0.895 * Meter reading)

Figure 4.2: Photos of salinity measurement

4.6 Particle Size Analysis

The soil samples were analyzed in the laboratory to determine the particle size of the soil grains as soil particle size may have an influence on soil salinity change during rainy season. Combination of two general procedures of analysis such as sieve and hydrometer analysis were followed for this section of analysis. Specific gravity of the soil samples were also analyzed in this regard.

4.6.1 Sieve Analysis

Standard procedures were followed in this regard, as provided in APPENDIX-I.

4.6.2 Hydrometer Analysis

Standard procedures were also followed in this regard, as provided in APPENDIX-I. A set of photo is shown in Figure 4.3.

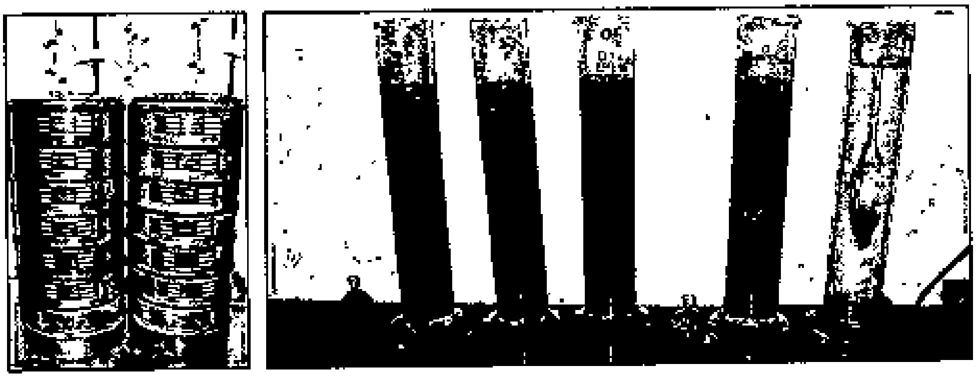

Figure 4.3: Photos of sieve analysis and hydrometer analysis apparatus

4.7 Crop Yield Record

Data of rice production after monsoon in the sampling plots were recorded by interviewing the farmers of the respective plot after harvesting.

4.8 Farmers' Interview for Primary Data Collection

For collecting information on the agricultural production especially rice production for Kharif season, the farmers of the respective plots were interviewed.

4.8.1. Questionnaire Survey

The farmers of the respective sampling plots were interviewed for collecting the rice production data after rainy season. During interview the information such as size of the sampling plot, name of variety cultivated in the last Kharif (Aman) season, amount of production, previous production records of the respective plots, causes of decreasing or increasing production, problem faced after Cyclone SIDR regarding production, farmers' opinion regarding polders etc. were taken into consideration.

4.8.2. Focus Group Discussion (FGD)

Focus Group Discussion (FGD) is a method being applied widely for qualitative research to gather information from homogeneons group of people. In the qualitative research, it is necessary to extract peoples' feeling, attitudes, perceptions, reactions, and emotions as well as that is possible in collecting pragmatic information through FGD (Neogi 2001).

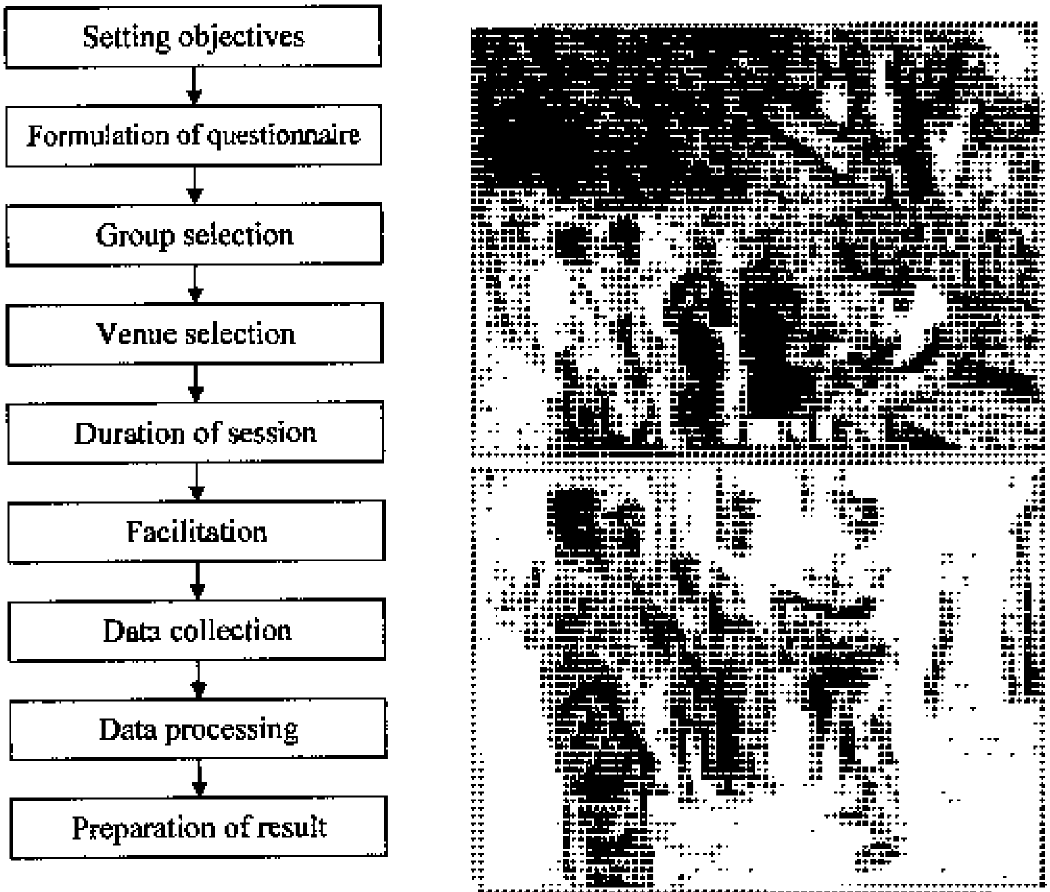

Figure 4.4 Left: steps of conducting FGD, Right: Photos of FGD being conducted

A total of 8 FGD were carried out to collect relevant data from the 4 unions of the study area. During each FGD the open questions were asked to a group of farmers to discuss spontaneously with each other by interaction. Figure 4.4 shows the steps followed to conduct FGD and some photos of FGD at the sampling locations.

4.9 Secondary Data Collection

Secondary data were collected from the following sources: (i) relevant documents of Bangladesh Bureau of Statistics (BBS), (ii) Published and unpublished reports and documents of relevant government (BWDB, SRDI, BARC, DAE etc) and autonomous body (CEGIS), reports or maps from relevant organization, IWFM library and also from internet. Salinity, local rainfall, river discharge, other climatic data, agricultural relevant data, damaged agricultural data after Cyclone SIDR were collected from Bangladesh Soil

Research and Development Institute (SRDI). Bangladesh Agricultural Research Council (BARC), Water Development Board (BWDB), Bangladesh Bureau of Statistics (BBS), Upazila Agriculture Office of Sarankhola.

4.10 Data Analysis

After completion of the field survey, all the interview results were grouped and interpreted according to the research objectives. At the beginning of the data processing, all the qualitative data were converted into quantitative form and local units into standard units. The data obtained through questionnaire were coded and tabulated in a data sheet.

CHAPTER FIVE

RESULTS AND DISCUSSIONS

5.1 Introduction

This chapter consists of the results on soil salinity status after the cyclone SIDR in November 2007 and also the status after monsoon of 2008. pH, Particle size distribution and soil texture analysis results are also provided in this chapter. The salinity alteration process has been discussed regarding pH, grain size and soil texture and also the impact of soil salinity on agricultural production has been assessed in this chapter.

5.2. pH, Soil Salinity and Particle Size Distribution

Soil salinity is one of the major problems in the coastal areas of Bangladesh. Although cyclone SIDR struck the coastal area during the ebb tide on 15th November'2007, it contributed to increase soil salinity after the event by inundating the vast areas of coastal lands. Most of the agricultural lands were fallowed before the monsoon of 2008.

5.2.1 pH and Soil Salinity after Cyclone SIDR

Table 5.1 shows the pH of the soil samples collected after cyclone SIDR from different sampling plots. Soil samples from N. Southkhali and Rajapur showed acidic nature and rest of the samples were basic in nature with highest pH values at Lakurtala (8.4).

Table 5.1: pH of Soil Samples collected after cyclone SIDR

Sampling Location	pH
Jilbunia	7.5
Rajeshor	8.0
Lakurtala	8.4
N. Southkhali	6.8
Gabtola	7.2
Gabtola (outside)	8.3
Rajapur	6.4
N. Khontakata	7.2

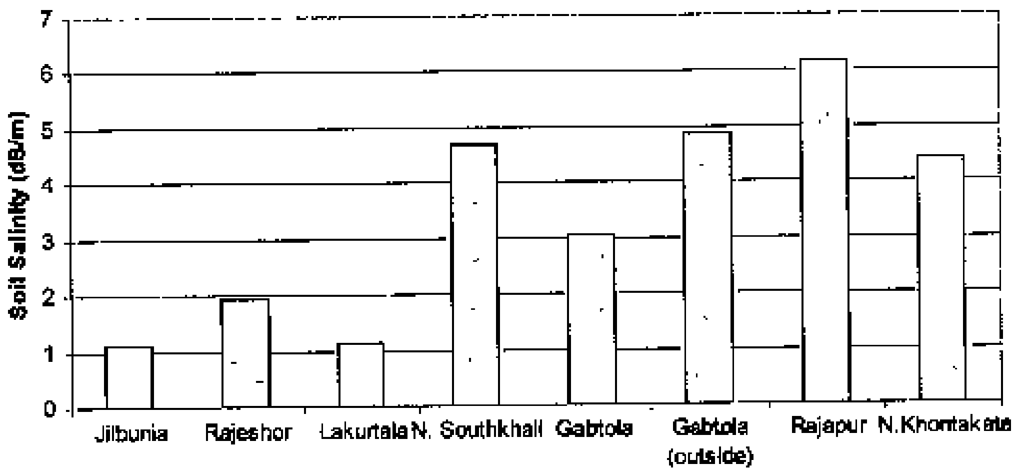

Figure 5.1: Soil salinity after cyclone SIDR at different sampling plots

Figure 5.1 shows the soil salinity of samples after cyclone SIDR. The soil salinity varied from 1.11 dS/m to 6.17 dS/m. The highest soil salinity of the sampling plots was 6.17 dS/m in the Rajapur Village of Dhansagor union. In Jilbunia, Lakurtola and Rajeshor Villages of Rayenda Union the measured soil salinity was 1.11, 1.14 and 1.93 dS/m respectively. Soil salinity range in the Southkhali union was higher than that in the Rayenda union, probably the plots are near Sundarbans and highly damaged polders area. Gabtola and North Southkhali are two villages of Southkhali union, which are located inside the polder. The soil salinity of the sampling plots of these two villages was 3.06 and 4.7 dS/m respectively. The soil salinity outside of the polder of Gabtola Village in Southkhali union was 4.87 dS/m, which was higher than that inside the polder due to regular flooding of the Baleshwer. Soil salinity at Rayenda Union appears to be lower than that of the other three unions, which is probably due to the location of the union. Southkhali is the southern most union and Dhansagor and Khontakata Unions are located alongside Bhola and Baleshwer Rivers respectively. Rajapur village of Dhansagor union is located near Bhola River. The water of this river is comparatively higher saline than other rivers in the study area.

5.2.2 Soil Salinity after Monsoon of 2008

Soil salinity was also analyzed after the monsoon of 2008 for both topsoil and subsoil. Figure 5.2 show the soil salinity of topsoil and subsoil respectively, at different sampling

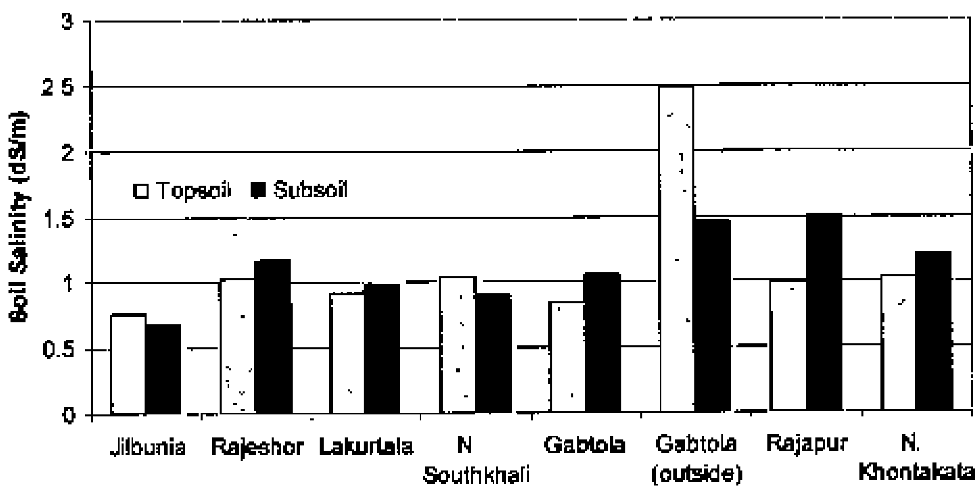

Figure 5.2: Soil salinity of topsoil and subsoil after the monsoon of 2008

plots, after the monsoon of 2008. The soil salinity after the monsoon varied from 0.76 dS/m to 2.48 dS/m on the topsoil and it varied from 0.68 dS/m to 1.45 dS/m in subsoil. The highest soil salinity of topsoil from the sampling plots was 2.48 dS/m located outside the polder at Gabtola of Southkhali union and 1.45 dS/m in subsoil. Three sampling plots in the Jilbunia, Lakurtala and Rajeshor Villages of Rayenda Union consisted of soil salinity 0.76, 0.92 and 1.03 dS/m on the topsoil and 0.68, 0.98 and 1.17 dS/m in subsoil respectively. In the Southkhali union soil salinity range was higher than that of Rayenda union. Gabtola and North Southkhali are the two villages of Southkhali inside the polder. The soil salinity inside polder of the sampling plots of Gabtola and N. Southkhali of Southkhali union was 0.84 and 1.04 dS/m on topsoil and 1.05 and 0.91 dS/m in subsoil respectively. The soil salinity outside the polder of Gabtola of Southkhali union was 2.48 dS/m on topsoil and 1.45 dS/m in subsoil, which was higher than those inside the polders. Detail data for soil salinity is provided in APPENDIX-II.

5.2.3 Particle Size Distribution

From the grain size analysis of the soil samples in the laboratory, the result shows that the soil samples from N. Khontakata, N.Southkhali and Lakurtola were loamy sand soil where sand varies from 77 to 79 percent and other five soil samples from Jilbunia, Rajapur, Rajeshor, Gabtola inside polder and Gabtola outside polder were sandy loam soil where percentage of sand varies from 65 to 73.

Table 5.2: Soil textural classification and D_{50} of soil samples

Union	Village	Soil type	Percentage	Soil texture	D_{50} (mm)
Rayenda	Jilbunia, Inside polder	Sand	68	Sandy loam	0.25
		Silt	23		
		Clay	9		
Rayenda	Rajeshor, Inside polder	Sand	65	Sandy loam	0.18
		Silt	32		
		Clay	3		
Rayenda	Lakurtala, Inside polder	Sand	79	Loamy sand	0.3
		Silt	18		
		Clay	3		
Southkhali	N. Southkhali inside polder	Sand	77	Loamy sand	0.3
		Silt	19		
		Clay	4		
Southkhali	Gabtola bazaar, inside polder	Sand	73	Sandy loam	0.3
		Silt	20		
		Clay	7		
Southkhali	Gabtola, outside polder	Sand	69	Sandy loam	0.25
		Silt	23		
		Clay	8		
Dhansagor	Rajapur, Inside polder	Sand	72	Sandy loam	0.35
		Silt	18		
		Clay	10		
Khontakata	N.Khontakata Inside polder	Sand	79	Loamy sand	0.35
		Silt	18		
		Clay	3		

Table 5.2 shows the textural classification of the collected soil samples as well as d_{50} of soil samples. Detail figures of grain size distribution and textural analyses are provided in APPENDIX-III.

5.2.4 Comparison between Reduction of Soil Salinity, Particle Size and pH

In all the sampling plots, soil salinity after monsoon reduced compared to that before monsoon. Figure 5.3 shows the soil salinity after cyclone SIDR and after the monsoon of 2008 of top soil samples along with the percentage of reduction at different sampling plots. In N.Southkhali, Gabtola inside polder and Gabtola outside polder of Southkhali union soil salinity were reduced by 31.5, 72.6 and 49.1 percent respectively after the monsoon. In the Rayenda union 76.6, 19.3 and 46.6 percent were reduced in Jilbunia, Lakurtola and Rajeshor village, respectively. In Khontakata and Dhansagor union it also reduced by 77.9 and 83.9 percent respectively. Soil salinity reduction in Rajapur of Dhansagor union was higher than other sampling plots.

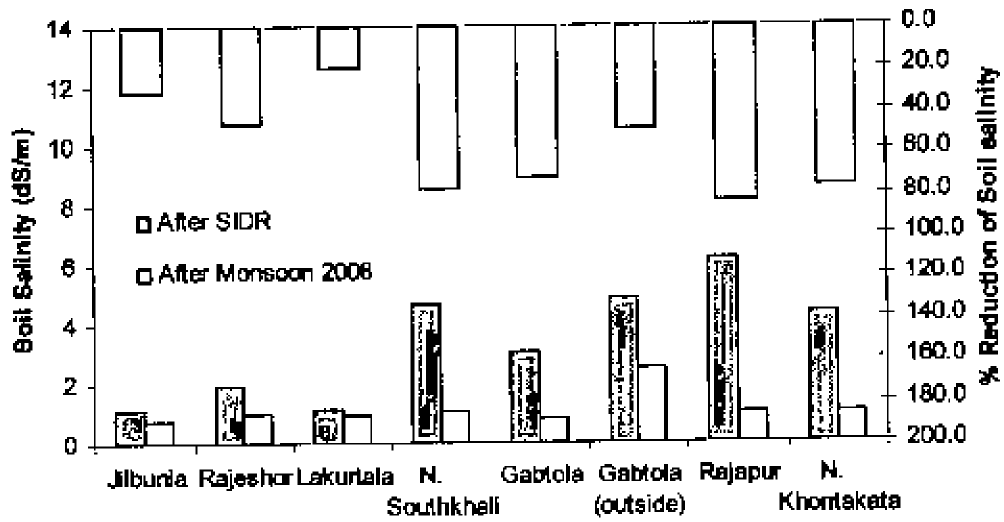

Fig 5.3: Soil salinity after cyclone SIDR, after monsoon of 2008 along with percent reduction of soil salinity

Table 5.3 shows the effect of particle size on salinity reduction at different sampling plots. More than 70 % reduction of soil salinity was observed at sampling plots where d_{50} was 0.3mm or higher, e.g. at North Southkhali Village and Gabtola Village of Southkhali Union, at Rajapur Village of Dhansagor Union and at Khontakata Union. Exception appeared at Lakurtola Village of Rayenda Union where soil salinity did not reduce at a high rate despite the d_{50} of soil sample being 0.3mm, which might be due to its loamy nature of soil texture.

Table 5.3 D_{50} of soil samples and % reduction of soil salinity

Sampling plots	Location	d_{50} (mm)	% reduction of soil salinity
Jilbunia, Rayenda	Inside polder	0.25	31.5
Rajessor, Rayenda	Inside polder	0.18	46.6
Lakurtala, Rayenda	Inside polder	0.3	19.2
N.southkhali, Southkhali	Inside polder	0.3	77.9
Gabtola, Southkhali	Inside polder	0.3	72.5
Gabtola, Southkhali, outside	Outside	0.25	49.1
Rajapur, Dhansagor	Inside polder	0.35	84.0
Khontakata	Inside polder	0.35	76.6

A scatter plot of percentage reduction of soil salinity against the grain size (mm) was made, as shown in Figure 5.4, to analyze the effect of grain size on soil salinity reduction. A positive (but weak) correlation has been observed between the above mentioned two parameters, indicating that even though larger grain size enhances salinity reduction it is not the only factor which controls salinity reduction.

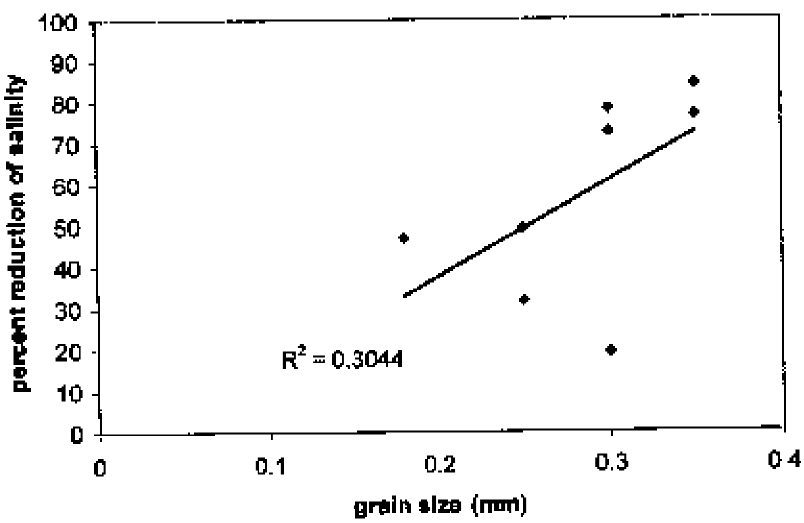

Figure 5.4: Particle size (mm) vs. percent reduction of soil salinity

Another scatter plot of percentage reduction of soil salinity against the pH of soil samples was made, as shown in Figure 5.5, to analyze the effect of pH on soil salinity reduction. For this case a negative correlation, with larger correlation coefficient, has been observed between the above mentioned two parameters. This indicates that at higher pH level salinity reduction has been attenuated which might be due to the high exchange rate of Sodium at elevated pH level and sodium being adsorbed to soil surface. At low pH ion exchange capacity reduces and sodium becomes more mobile (labile) to be removed from the soil surface.

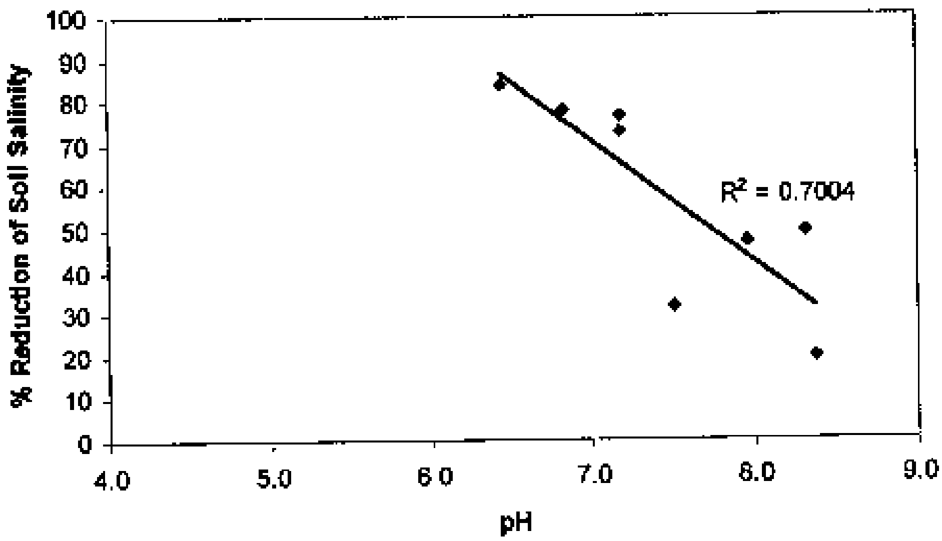

Figure 5.5: pH vs. percent reduction of soil salinity

Even though rainfall data for the stations around the study area was collected, they could not be utilized to explain the spatial variation of salinity reduction; because the number of stations around the study area was not sufficient for such analyses and also as there was no station at the south-west side of the study area because of the location of Sunderbans.

5.3 Yield of Rice

The yield of rice in every sampling plot reduced after SIDR compared to the previous yield during Aman season. The previous average yield of Aman crop in the Rayenda union varied from 1.64 to 2.24 ton/ha. It was 2.77 ton/ha in the Southkhali union. In Khontakata and Dhansagor union the average yield was 2.77 ton/ha and 3.28 ton/ha respectively. After the cyclone SIDR, the yield of Aman rice varied from 0.82 ton/ha to 1.38 ton/ha in Rayenda union. It was 1.57 ton/ha and 1.64 ton/ha in the N.Southkhali and Gabtola of Southkhali union respectively. In Khontakata and Dhansagor union the average yield was 1.94 ton/ha and 1.38 ton/ha. Table 5.4 summarizes the yield of Aman at sampling plots, which was obtained through farmers' interview.

Table 5.4: Yield of Aman at Sampling Plots

Union	Village	Size of sampling plot (hectare)	Previous average production (Ton/ha)	Production in 2008 (Ton/ha)
Rayenda	Jilbunia	0.27	1.94	1.38
Rayenda	Rajeshor	0.34	1.64	1.11
Rayenda	Lakurtala	0.14	2.24	0.82
Southkhali	N. Southkhali	0.40	2.77	1.57
Southkhali	Gabtola	0.20	2.77	1.64
Southkhali	Gabtola (outside polder)	No Cultivation	No Cultivation	No Cultivation
Dhansagor	Rajapur	0.40	2.77	1.38
Khontakata	N. Khontakata	0.67	3.28	1.94

5.3.1 Impact on Crop Production

The agricultural production was affected by the cyclone SIDR. According to the farmers, the agricultural lands were inundated by salt water during the cyclone SIDR and also after the SIDR during high tide due to the damage of coastal polders. The saline water and also some other factors seriously reduced the yield.

As shown in Table 5.4, in Jilbunia village of Rayenda union, the average yield of Aman crop before the SIDR was 1.9 ton/ha, but it reduced after the SIDR and which turned into 1.4 ton/ha, i.e. about 29 percent yield was reduced. In other two villages of Rayenda union, Lakurtala and Rajeshor production reduced by 63 percent and 32 percent respectively. In Southkhali union there were three sampling spots named N. Southkhali, Gabtola (inside polder) and Gabtola (outside polder). The yield of Aman crop during monsoon decreased in the first two plots by 43 and 41 percent respectively. No crop was cultivated in the plot outside polder of Gabtola sampling area during the last monsoon. In Rajapur village of Dhansagor union and the N. Khontakata of Khontakata union the yield decreased by 50 percent and 41 percent, respectively.

Figures 5.6 and 5.7 show the Aman production before and after cyclone SIDR at the sampling plots and percent reduction of Aman production at the sampling plots, respectively. It can be noted that percent reduction of Aman production is highest at Lakurtola Village of Rayenda Union where salinity reduction after the monsoon of 2008 was the lowest.

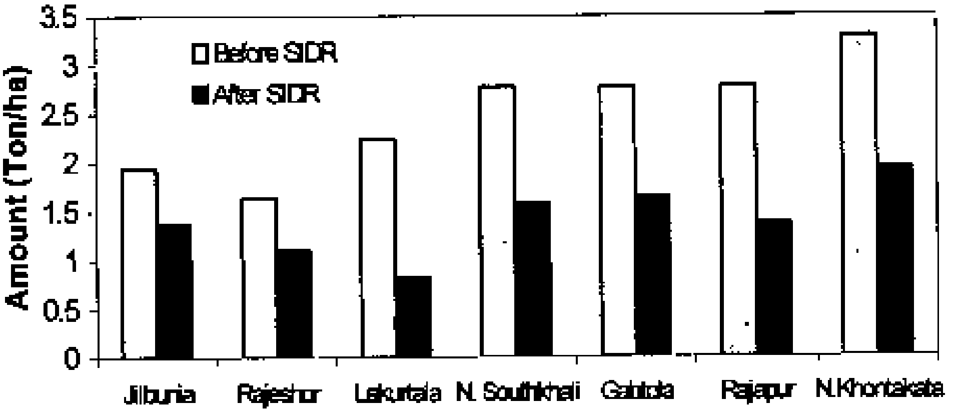

Fig 5.6: Aman production before and after SIDR at the sampling plots

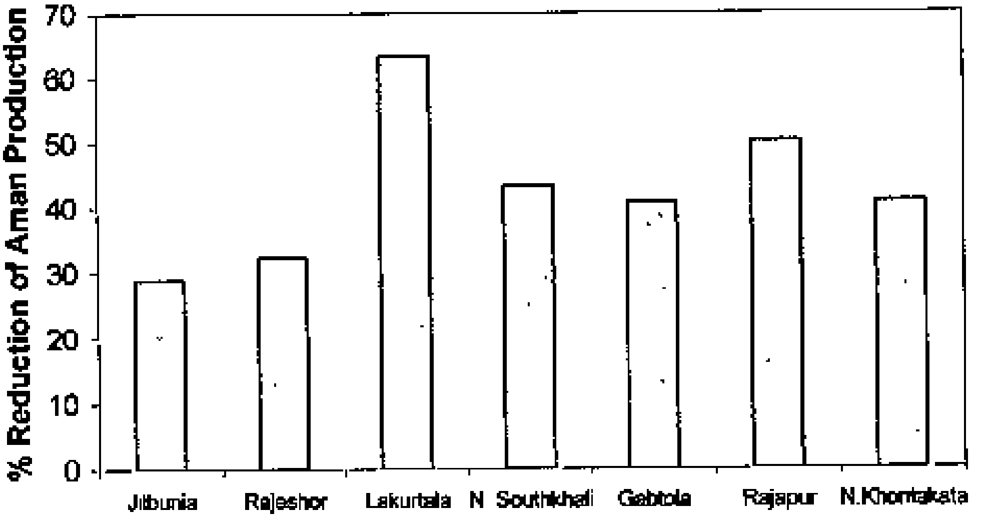

Fig 5.7: Percent reduction of Aman prodnction

In Table 5.5 a comparison is made between the impact of initial soil salinity after cyclone SIDR and percentage of salinity reduction during the monsoon of 2008, on the reduction of Aman production in 2008 compared to previous years. From Table 5.7 it is evident that yield reduction is maximum (63%) at Lakurtala Village of Rayenda Union where salinity reduction was lower than other plots and initial soil salinity was only 1.14 dS/m. On the other hand, yield reduction was 50%) at Rajapur Village of Dhansagar Union, North Southkhali and Gabtola Villages of Southkhali Union and at Khontakata Union where soil salinity reduction was high (more than 70%) where initial soil salinity was also high.

Table 5.5 Initial soil salinity after the cyclone SIDR and yield reduction

Union	Village	Location	Initial Soil Salinity dS/m	Percent salinity reduction	Percent yield reduction
Rayenda	Jilbunia	Inside polder	1.11	31.5	29
Rayenda	Rajeshor	Inside polder	1.93	46.6	32
Rayenda	Lakurtala	Inside polder	1.14	19.3	63
Southkhali	N. Southkhali	Inside polder	4.7	77.9	43
Southkhali	Gabtola	Inside polder	3.06	72.5	40
Dhansagor	Rajapur	Inside polder	6.17	84.0	50
Khontakata	N.Khontakata	Inside polder	4.4	76.6	42

In Table 5.6 a ranking is prepared on the basis of soil salinity observed, its category and the potential impact on crop production as predicted by SRDI. According to this ranking crop production should be affected at North Southkhali, Rajapur and North Khontakata Villages, Gabtola (outside polder) Village being not used for cultivation. This prediction is conformal to the information of Table 5.5 where all these villages show high percentage of yield rednction at the sampling plots, with the exception of Lakurtala Village. In this sampling plot yield rednction was highest despite initial salinity of only 1.11dS/m.

Table 5.6: Ranking of unions on the basis of soil salinity status after the cyclone SIDR

Sampling plots	Location	Soil salinity after SIDR	SRDI Category	Effect on crop plants
Jilbunia	Inside polder	1.11	Non-saline	Salinity effects negligible
Rajeshor	Inside polder	1.93	Non-saline	Salinity effects negligible
Lakurtala	Inside polder	1.14	Non-saline	Salinity effects negligible
N. Southkhali	Inside polder	4.7	Moderately saline	Yields of many crops restricted
Gabtola	Inside polder	3.06	Slightly saline	Yields of sensitive crops may be restricted
Gabtola	outside polder	4.87	Moderately saline	Yields of many crops restricted
Rajapur	Inside polder	6.17	Moderately saline	Yields of many crops Restricted
N.Khontakata	Inside polder	4.4	Moderately saline	Yields of many crops restricted

Source: Karim et. al. (1990) (The category and effect on plants)

5.4. Discussion

5.4.1. Farmers' opinion

All farmers of the respective sampling plots of the study area cultivated local T. Aman in monsoon season (2008). The farmers of the respective sampling plots were interviewed by a previously prepared questionnaire, as shown in APPENDIX-IV.

It was found from farmers' interview that, all farmers cultivated local T. Aman in the 2008 monsoon after cyclone SIDR. According to them, the main cause of yield reduction of crops was soil salinity; of them 4 farmers said that serious soil salinity was the root cause of their yield reduction after the cyclone SIDR, 2 farmers said that the soil salinity contributed slightly and 1 farmer mentioned about the salinity including the attack of pests. The sampling plot of outside polder in Gabtola of Southkhali union was fallowed. The plot had an owner but there was no cultivation in that plot because of everyday flooding during spring tide. The farmers of Southkhali Union (southern-most) informed that a thin layer of salt on the surface of the topsoil was formed after the cyclone SIDR. All farmers have knowledge about the soil salinity that can affect crop production.

The farmers were asked about their interest in local verities of Aman crops cultivation and possible problems after the cyclone SIDR in the respective sampling plots. Their responses are summarized in Table 5.7. The main problem in decreasing Aman crop yield in all sampling plots was the soil salinity problem and the second main problem was related to financial matters for HYV cultivation instead of Local T. Aman. Farmers from Rayenda union informed that, the other cause of yield reduction was the pests. Farmers of 4 sampling plots from Rayenda and Dhansagor union said that lack of rainwater during the last growth stage (monsoon of 2008) and lack of irrigation at that time was the main cause behind yield reduction.

Table 5.7: Possible causes in yield reduction and agricultural production after the cyclone SIDR.

problems / plots	Soil salinity	Lack of irrigation Water	Rainwater scarcity	Financial	Attack of Pests
Jilbunia	1	1	1	1	1
Rajeshor	1	1	1	1	1
Lakurtala	1	1	1	1	1
N. Southkhali	1	0	0	1	0
Gabtola	1	0	0	1	0
Rajapur	1	1	1	1	0
N.Khontakata	1	0	0	1	0
Total	7	4	4	7	3

The farmers were asked about the saline water in the Baleshwer and Bhola Rivers. According to the farmers, the River water turns into saline during dry season and appears is up to May every year. During this period, the river water is not used for irrigation purposes. The water of the Bhola River is comparatively higher saline than Baleshwer River water. They said that the Bhola River water is the source of salt in that period. During the cyclone SIDR the Baleshwer River water was fresh and the time was ebb tide in the river and the Bhola River water was slightly saline. According to them, saline water came from the rivers after the cyclonic event due to the serious damages of polders. The saline water inundated the land during reguler spring tide in the rivers after the cyclone SIDR.

According to the farmers, the existing polders are not sufficient to protect from cyclones, but they informed that the polders could protect saline water from the nearby rivers.

According to the aged farmers, the agricultural production before the polder construction was not sufficient and saline water from the rivers during spring tide hampered the production. But after the construction of polders, they can easily produce agricultural commodities, especially rice, inside the polder-protected areas. They also informed that, after cyclone SIDR they were provided with HYV seeds by some of the NGOs to cultivate in their lands. In most of the time the seeds provided by the NGOs were of low quality.

They were asked to give some suggestions about the improvement of polders.

Their suggestion in regarding improvement of polders is bellow:

- Polders should be raised than present height.
- Polders should be covered by concrete blocks on the riverside
- Participation of local people should be ensure
- Tree plantation is essential on the riverside of near the polders for natural protection
- Corruption should be reduced in polder construction.
- Polder management is essential after construction

They were not aware about the new BRRI Dhan-47, but they know about other some HYV, which produce higher production than local varieties. They are financially not capable to produce HYV. The seeds of HYV are more expensive than local varieties.

They were also asked about the impact of SIDR on agriculture after the cyclone event. Most of agricultural commodities on the land were damaged. Some farmers cultivated vegetables after the SIDR and produced huge production because of high silt content of inundated water during storm surge. But the soil was not suitable for rice production might be due to salt content.

They were asked about the removal of salt from their lands after the cyclone SIDR. According to them, it will be taken at least two flooding seasons to remove most of salt from land to cultivate. They know that the salt can be washed away from their lands by rainwater during rainy season.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the present study it was found that soil salinity was the main reason behind yield reduction of Aman rice in most of the sampling plots of the study area after cyclone SIDR. Although saline water inundated the area during the cyclone, soil salinity got amplified during the regular spring tide in the rivers after the cyclonic event. The salinity problem due to storm surge by any cyclonic event appears to be a short-term problem. From one to two flood seasons are required to improve the salinity status in affected areas. This short-term problem can hamper the food security of the poor people in the locality. The following are the conclusions in a summarized manner:

- The soil salinity after the cyclone SIDR varied from 6.17 dS/m to 1.14 dS/m on the topsoil.
- The soil salinity after the monsoon were reduced and varied from 2.48 dS/m to 0.76 dS/m on topsoil and 1.45 dS/m to 0.68 dS/m in subsoil.
- The soil salinity of every sampling plot was reduced after the monsoon. The soil salinity rednced by 76.6, 46.6 and 19.3 percent in the Rayenda union. In the Southkhali union, it reduced by 49.1, 31.5 and 72.6 percent. In Dhansagor and Khontakata it reduced by 84.9 and 77.9 percent respectively.
- It was observed that particle size as well as soil pH influences the salinity reduction. Coarser particle size enhances soil salinity reduction; on the other hand higher soil pH restricts salinity reduction.
- The percentage of yield reduction of Aman varied from 29 percent to 63 percent. Although soil salinity was the main cause of the yield reduction, other causes might be lack of irrigation during the final growth stage, lack of rainfall, pest/insects etc.
- All the farmers from the respective sampling plots cultivated the local T.Aman during the monsoon, instead of HYV and salinity tolerant varieties of rice.

6.2 Recommendations

The following recommendations have been suggested based on the above study:

- Research of similar nature is recommended that covers more areas, at different districts in the coastal zone of Bangladesh with different hydrological regime, to have more comprehensive idea about the soil salinity due to storm surge after any cyclonic event in the coastal zones.
- Financial assistances are essential from Government or other NGOs for affected farmers to cultivate salinity tolerant verities and HYV cultivation after the quick assessment of soil salinity status due to storm surge by cyclonic events.
- Polders should be covered by manmade mangrove forest in the riverside. They will act as natural shield from cyclone.
- To assess the soil salinity alteration process in a comprehensive manner it is recommended that such study to be covers over a period of two to three years.
- Government should take measures to encourage the farmers in the coastal zone to cultivate HYV or salinity tolerant varieties of crops after such cyclonic events to ensure food security.

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APPENDIX I

LABORATORY ANALYSES PROCEDURES

SOIL SALINITY ASSESSMENT

Methodology of the soil salinity determination of the collected soil samples of the study area is explained as follows;

Apparatus for soil salinity test:

1. 250 gm biker, 50 gm biker and 1000 gm biker
2. 100 ml cylinder,
3. Electronic balance, BAL-3, gt-410, measuring range 0.001gm to 410gm
4. Magnetic stirrer, HB 501
5. Whatman no-1 filter paper, Ashless-43 micron (0.043 mm)
6. Funnel, stand
7. Hanna Instruments H198311 Waterproof Combo Conductivity Meter (EC Meter)
8. Hanna Instruments H198128 Waterproof Combo pH meter
9. Distilled water
10. Tissue paper
11. Container for soil samples

Procedure:

Each soil sample was air dried carefully to remove moisture. After air-drying each soil sample was divided into three parts. Each of the three samples was analyzed separately to get more accurate result. An amount of 50 gm soil was taken in a 250gm biker by using an electronic balance. Then soil and distilled water were taken in the biker at a 1:5 ratios. For proper mixing of soil sample with the distilled water, a magnetic stirrer was used for 15 minutes. Then the biker was kept for at least 12 hours. After 12 hours the supernatant water of the mixture was collected through filtration process. EC meter was used to test the EC of the filtered water sample. pH meter was also used to take the pH of the filtered water accordingly.

The following are the number of samples (Tested)

The number of Tested sample after SIDR= 8*3=24 samples

The number of Tested sample after monsoon= 8*2*3=48 samples

Soil salinity calculation

ECe = Electrical Conductivity of saturated extract

EC1 = Electrical Conductivity at 1:1 ratio of soil and water

EC2 = Electrical Conductivity at 1:2 ratio of soil and water

EC5 = Electrical Conductivity at 1:5 ratio of soil and water

EC_1 = 5 * Meter Reading

If meter reading is = 0.01 to 1.99

Regression factor, Y = 0.122 + (1.323 * Meter reading)

If meter reading is = 2 to 14.99

Regression factor, Y = 1.267 + (1.269 * Meter reading)

If meter reading is = > 15

Regression factor, Y = 8.31 + (0.895 * Meter reading)

PARTICLE SIZE ANALYSIS

The soil samples were analyzed in the laboratory to determine the grain sizes of the soil samples. Soil grain size may have an influence on soil salinity change during rainy season. Two general procedures of analysis such as sieve and hydrometer analysis were followed for this section of analysis. Specific gravity of the soil samples were also analyzed in this regard.

Sieve Analysis

Apparatus and Supplies

Special: Set of sieves (4, 8, 16, 30, 50, 100 and 200 No of sieves)

General: Brush (for cleaning sieves)

Electronic balance (0.1 g sensitivity)

Desiccators

Large pan

Mortar and pestle

Mechanical shaker

Procedure

i. Each sieve was weighed after cleaning properly.

ii. Soil sample was taken into mortar to pestle for breaking down the soil into its individual particles.

iii. Then the soil was dried in the oven. Particular amount of soil sample was taken into the top sieve (No 4 sieve).

iv. After setting all sieves properly the set of sieves was taken on the mechanical shaker for shaking about 15 minutes.

v. Each sieve and the pan were weighed by electronic balance with the soil retained on them.

vi. The weigh from step-v was subtracted the weigh from step-i. Thus the weigh of soil in the each sieve was obtained.

vii. The soil retaining on the last pan was taken into other container for hydrometer analysis and the data from the weigh of soil from each sieve were used for calculation to obtain percent finer of the soil sample.

Calculation

The following is the method for calculation:

a. Percentage retained on any sieve

= Wt. of soil retained/ total soil wt. * 100%

b. Cumulative retained on any sieve

= Sum of percentages retained on all coarser sieves

c. Percentage finer than any sieve size

= 100% - cumulative percentage retained

Hydrometer Analysis

Apparatus and supplies

Special: Hydrometer

Mixture

Deflocculating agent

Constant temperature bath

General: Two graduated cylinders (1-litre capacity)

Distilled water supply

Electric balance (0.1 g sensitivity)

Magnetic stirrer

Desciccator

Thermometer (graduated to 0.1° C)

Syringe

Large evaporating dishes

Spatula

Timer

Biker

Procedure

The soil sample retained from the pan during sieve analysis was used for hydrometer analysis. The following steps were followed in this analysis:

i. 50g of soil were taken in a biker and put distilled water for mixing to make thin paste.

ii. Deflocculating agent was added into the paste and further mixing for separating the individual soil particles.

iii. The suspension was taken on the magnetic stirrer for mixing about 15 minntes until the soil was broken down into its individual particles.

iv. When the mixture was completed, the graduated jar was filled by distilled water for using to store the hydrometer in between reading.

v. The specimen was washed into the graduated cylinder and distilled water was added up to 1000 cc mark.

vi. A rod made stirrer carefully mixed the solutiou.

vii. After shaking it for approximately 1 minute, the graduate was replaced on the table, the hydrometer was then inserted in the suspension and the timer was started.

viii. Hydrometer readiugs were taken at total elapsed time intervals of 0.25, 0.50, 1 and 2 minutes without removing the hydrometer.

ix. After that time-to-time hydrometer readings were taken just before starting the time.

x. After each reading hydrometer was washed by distilled water carefully. An evaporation protector was set on the top of the jar for reducing evaporation.

Calculation

After completing all steps the following equations were applied for calculation:

a. The effective diameter, D, was computed from

$$D = 18n / (\text{Gamma})_s - (\text{Gamma})_w * Zr / t$$

Where, n = viscosity of water at the temperature of the test.

$(\text{Gamma})_s$ = unit weight of soil grains

$(\text{Gamma})_w$ = unit weight of water at the temperature of the test.

Zr = distance from surface of suspension to the center of volume of the hydrometer.

t = total elapsed time

b. The percent finer, N, was computed from

$$N = G / G - 1 * V / Ws\ (\text{Gamma})_c\ (r - r_w) * 100\%$$

Where, G = specific gravity

V = volume of suspension (1000 cc)

Ws = weight of dry soil

$(\text{Gamma})_c$ = unit weight of water at temperature 20° C

r = hydrometer reading in suspension

r_w = hydrometer reading in water at same temperature as suspension

APPENDIX –II

PRIMARY DATA AND TABLES

Table A: Soil salinity after the cyclone SIDR

Union	Village	Location	Collection Date	Salinity (dS/m)
Rayenda	Jilbunia	Inside polder	29/03/08	1.11
Rayenda	Rajeshor	Inside polder	29/03/08	1.93
Rayenda	Lakurtala	Inside polder	30/03/08	1.14
Southkhali	N. Southkhali	Inside polder	1/4/2008	4.7
Southkhali	Gabtola	Inside polder	1/4/2008	3.06
Southkhali	Gabtola	Outside polder	1/4/2008	4.87
Dhansagor	Rajapur	Inside polder	3/4/2008	6.17
Khontakata	N.Khontakata	Inside polder	26/03/08	4.4

Table B: Soil salinity after monsoon of 2008

Union	Village	Layer of soil	Date of collection	Soil salinity dS/m	Location
Rayenda	Jilbunia	Topsoil	02/12/08	0.76	Inside polder
		Subsoil	02/12/08	0.68	
Rayenda	Rajeshor	Topsoil	02/12/08	1.03	Inside polder
		Subsoil	02/12/08	1.17	
Rayenda	Lakurtala	Topsoil	02/12/08	0.92	Inside polder
		Subsoil	02/12/08	0.98	
Southkhali	N. Southkhali	Topsoil	29/11/08	1.04	Inside polder
		Subsoil	29/11/08	0.91	
Southkhali	Gabtola	Topsoil	24/10/08	0.84	Inside polder
		Subsoil	24/10/08	1.05	
Southkhali	Gabtola	Topsoil	24/10/08	2.48	Outside polder
		Subsoil	24/10/08	1.45	
Dhansagor	Rajapur	Topsoil	03/11/08	0.99	Inside polder
		Subsoil	03/11/08	1.51	
Khontakata	N.Khontakata	Topsoil	01/12/08	1.03	Inside polder
		Subsoil	01/12/08	1.21	

Table C: D_{50} of soil samples and % reduction of soil salinity

Sampling plots	Location	d_{50}	% reduction
Jilbunia, Rayenda	Inside polder	0.25	31.5
Rajessor, Rayenda	Inside polder	0.18	46.6
Lakurtala, Rayenda	Inside polder	0.3	19.2
N.southkhali, Southkhali	Inside polder	0.3	77.9
Gabtola, Southkhali	Inside polder	0.3	72.5
Gabtola, Southkhali, outside	Outside	0.25	49.1
Rajapur, Dhansagor	Inside polder	0.35	84.0
Khontakata	Inside polder	0.35	76.6

Table D: Yield of Aman at Sampling Plots

Union	Village	Size of sampling plot (hectare)	Previous average production (Ton/ha)	Production in 2008 (Ton/ha)
Rayenda	Jilbunia	0.27	1.94	1.38
Rayenda	Rajeshor	0.34	1.64	1.11
Rayenda	Lakurtala	0.14	2.24	0.82
Southkhali	N. Southkhali	0.40	2.77	1.57
Southkhali	Gabtola	0.20	2.77	1.64
Southkhali	Gabtola (outside polder)	No Cultivation	No Cultivation	No Cultivation
Dhansagor	Rajapur	0.40	2.77	1.38
Khontakata	N.Khontakata	0.67	3.28	1.94

Table E: Yield reduction of Aman crop after SIDR

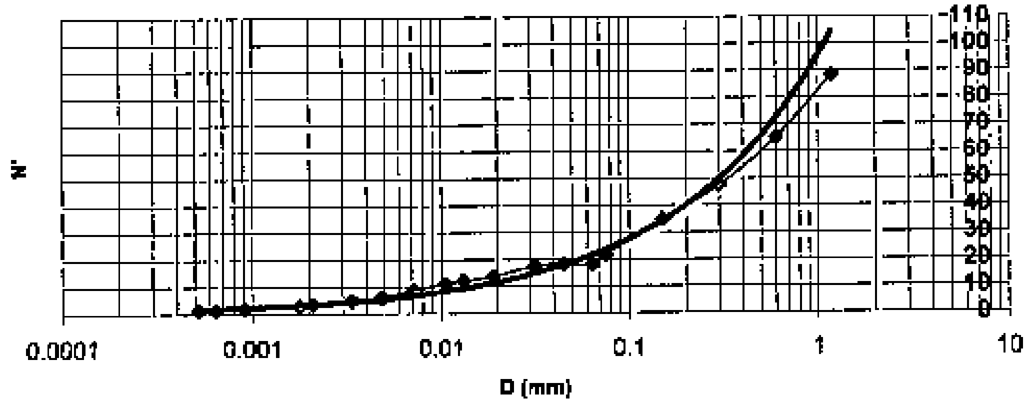
Union	Village	Previous average yield of Aman crop ton/ha	Yield of Aman crop during monsoon 2008 ton/ha	Yield loss ton/ha	Percent yield loss
Rayenda	Jilbunia	1.94	1.38	0.56	29
Rayenda	Rajeshor	1.64	1.11	0.53	32
Rayenda	Lakurtala	2.24	0.82	1.42	63
Southkhali	N. Southkhali	2.77	1.57	1.2	43
Southkhali	Gabtola	2.77	1.64	1.13	41
Dhansagor	Rajapur	2.77	1.38	1.39	50
Khontakata	N.Khontakata	3.28	1.94	1.34	41

Table F: Initial soil salinity after the cyclone SIDR and yield reduction

Union	Village	Location	Initial Soil Salinity dS/m	Percent salinity reduction	Percent yield reduction
Rayenda	Jilbunia	Inside polder	1.11	31.5	29
Rayenda	Rajeshor	Inside polder	1.93	46.6	32
Rayenda	Lakurtala	Inside polder	1.14	19.3	63
Southkhali	N. Southkhali	Inside polder	4.7	77.9	43
Southkhali	Gabtola	Inside polder	3.06	72.5	40
Dhansagor	Rajapur	Inside polder	6.17	84.0	50
Khontakata	N.Khontakata	Inside polder	4.4	76.6	42

APPENDIX –III

GRAIN SIZE DISTRIBUTION AND SOIL TEXTURAL CLASSES



N. Southkhali inside polder

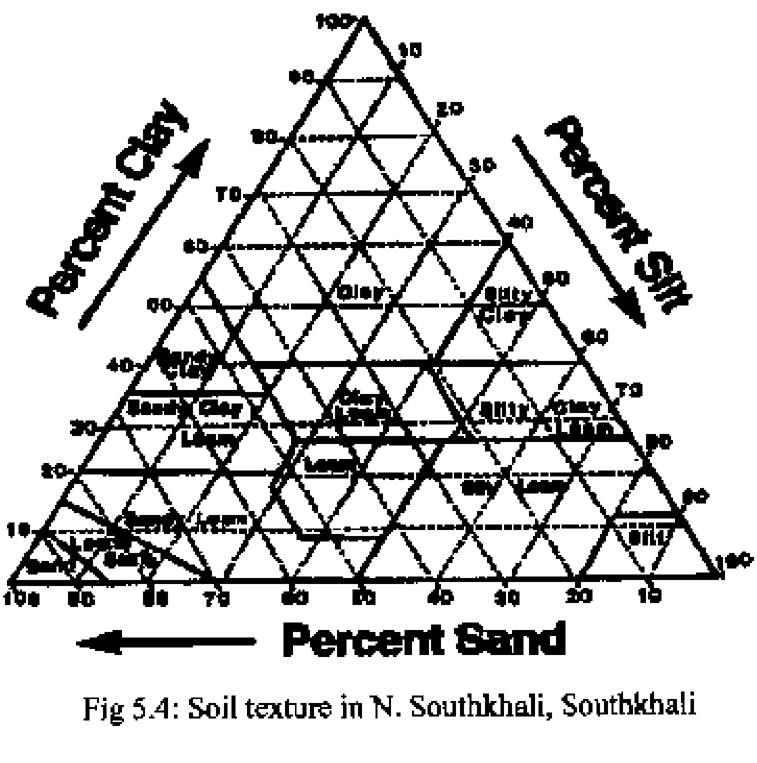
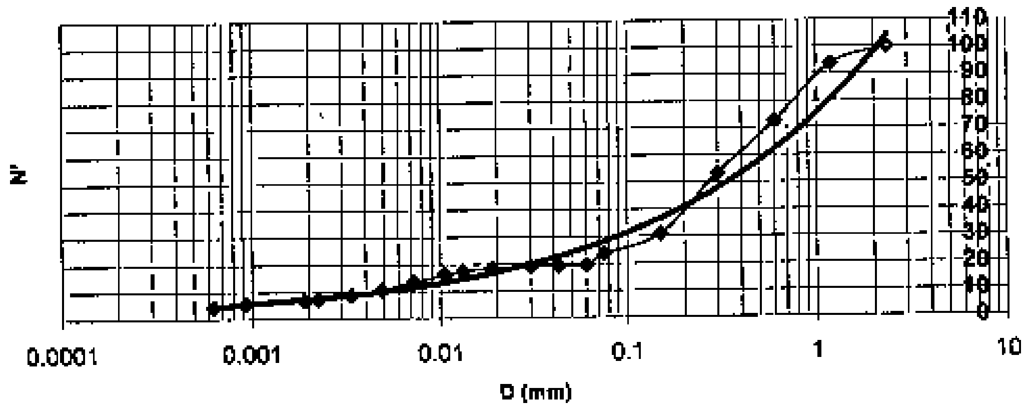


Fig 5.4: Soil texture in N. Southkhali, Southkhali

Sand = 77 %
Silt = 19 %
Clay = 4 %
Soil texture = Loamy sand



Rajapur, Dhansagor

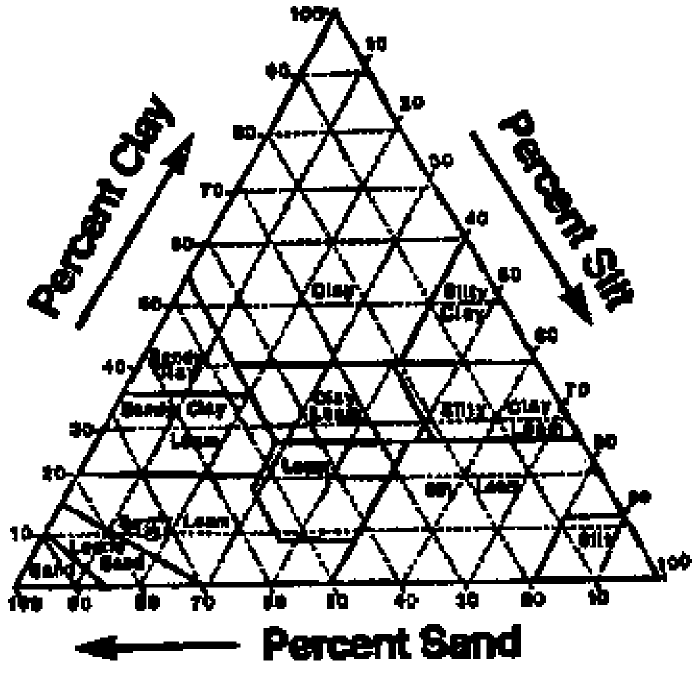
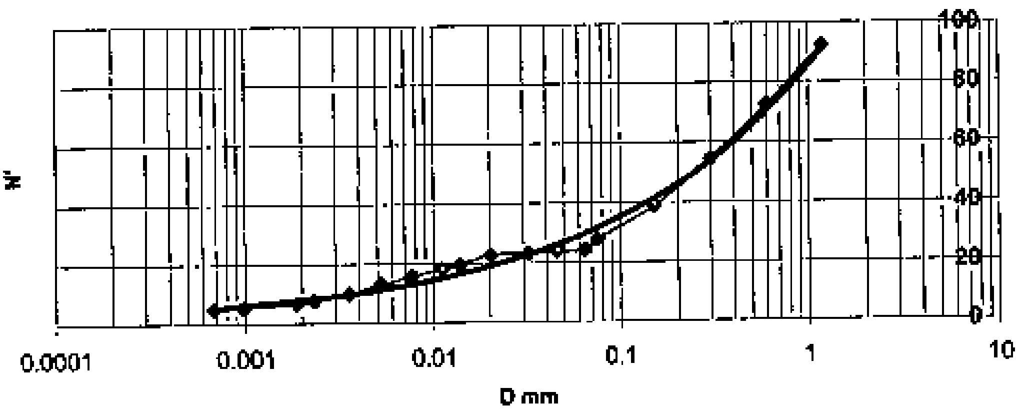


Fig 5.5: Soil texture of Rajapur, Dhansagor

Sand = 72 %
Silt = 18 %
Clay = 10 %
Soil texture =Sandy loam



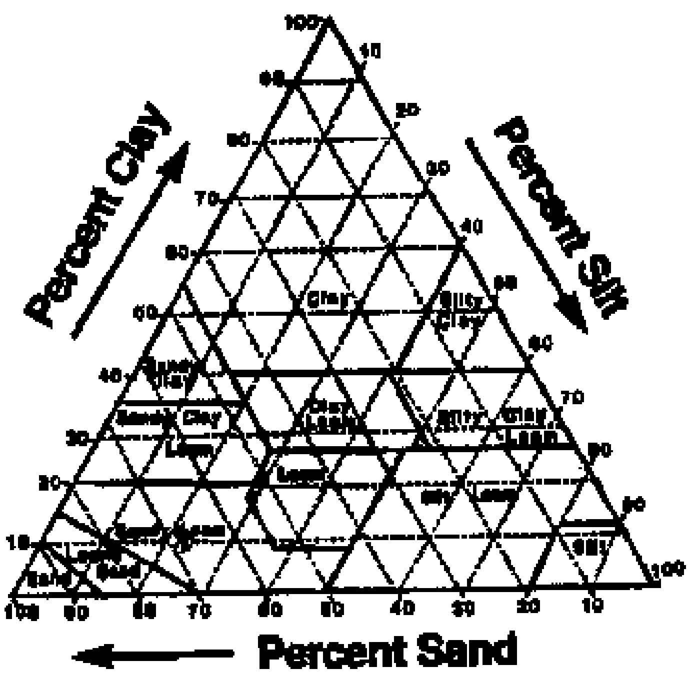
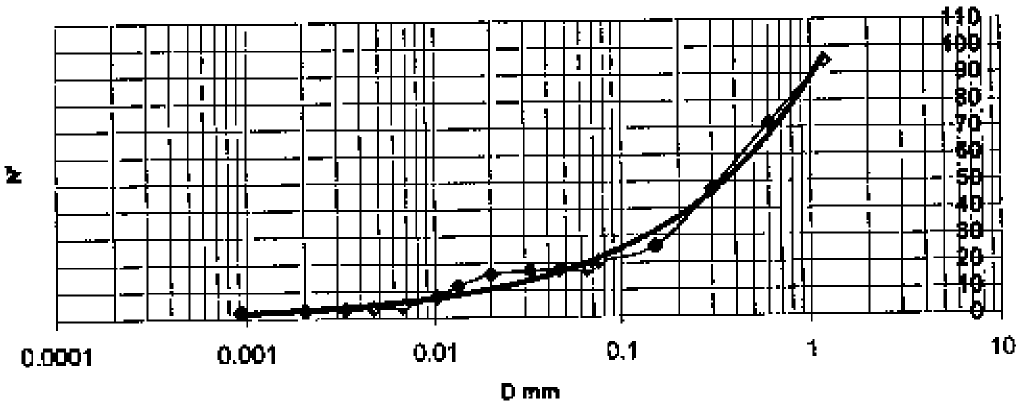


Fig 5.6: Soil texture in Jilbunia, Rayenda

Sand = 68 %
Silt = 23 %
Clay = 9 %
Soil texture =Sandy loam



N. Khontakata, Khontakata

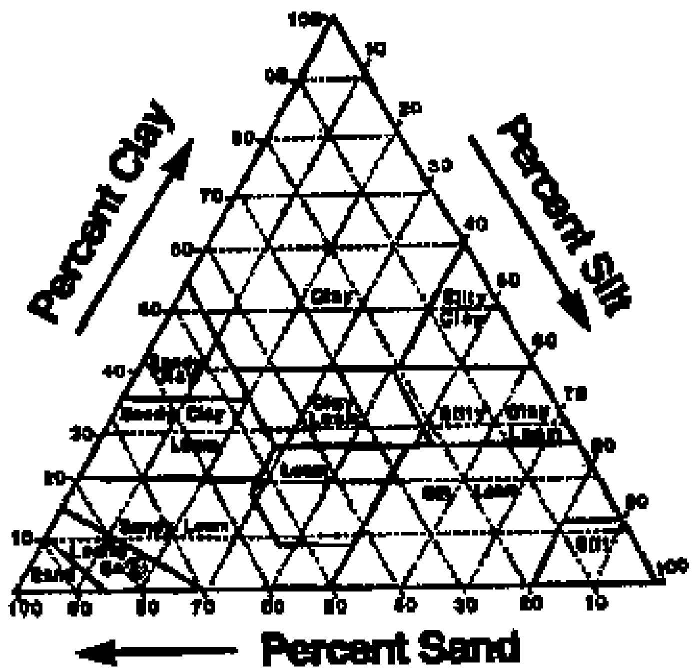
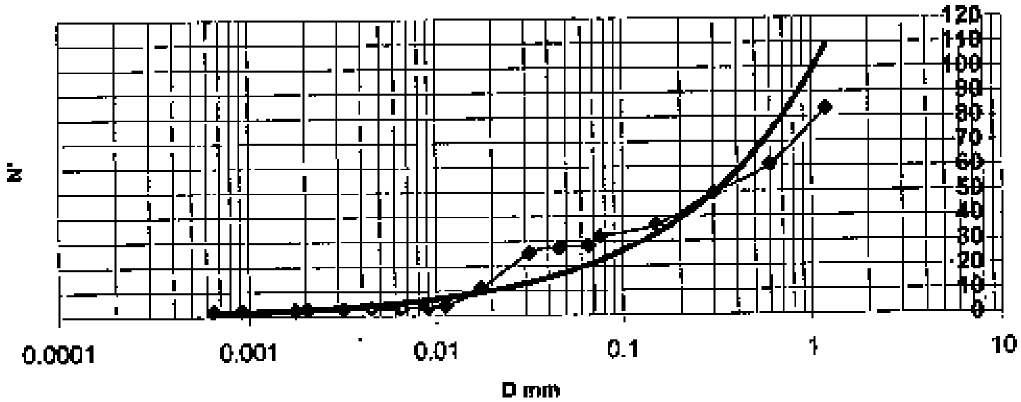


Fig 5.7: Soil texture in N.Khontakata

Sand = 79 %
Silt = 18 %
Clay = 3 %
Soil texture = loamy sand



Lakurtala, Rayenda

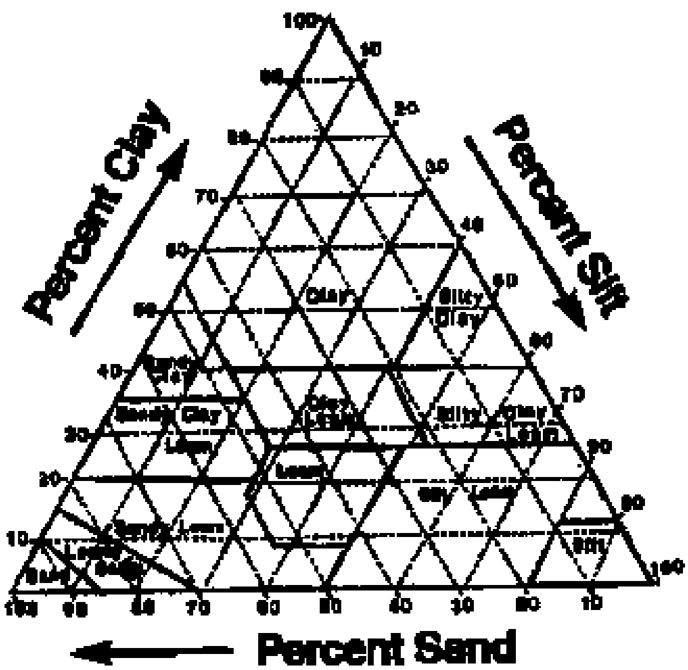
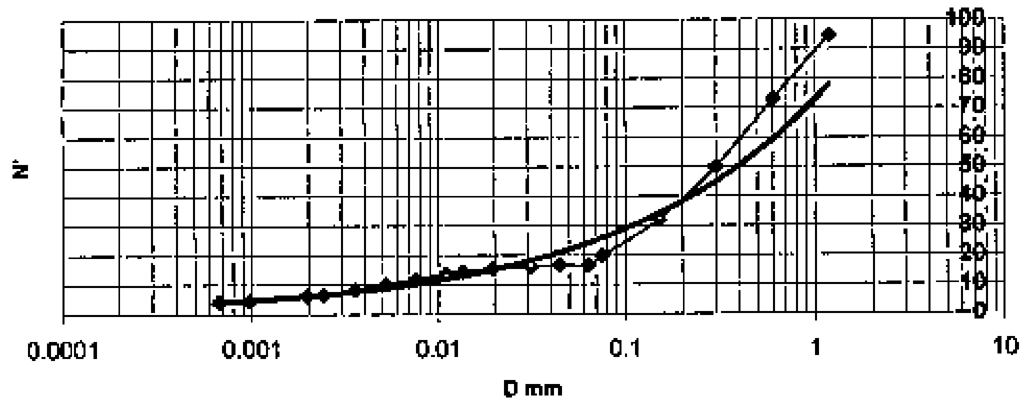


Fig 5.8: Soil texture in Lakurtala, Rayenda

Sand = 79 %
Silt = 18 %
Clay = 3 %
Soil texture = loamy sand



Gabtola bazaar, Southkhali

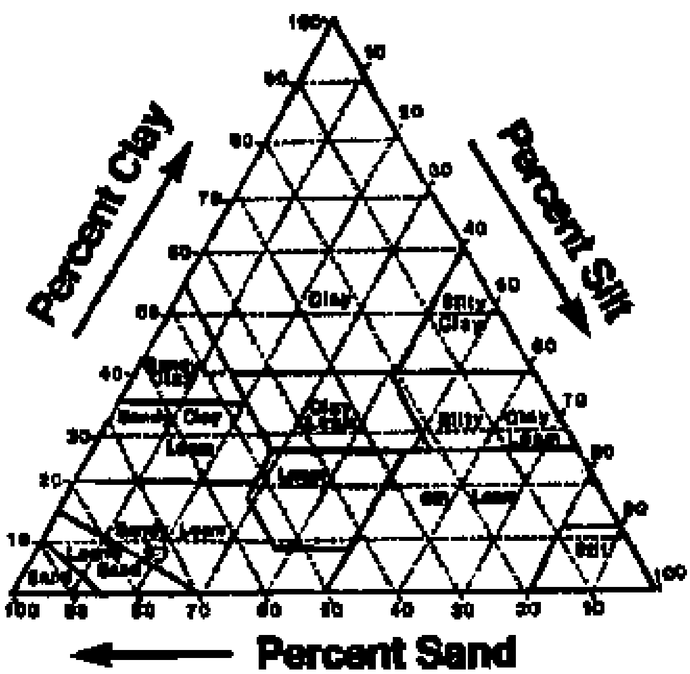
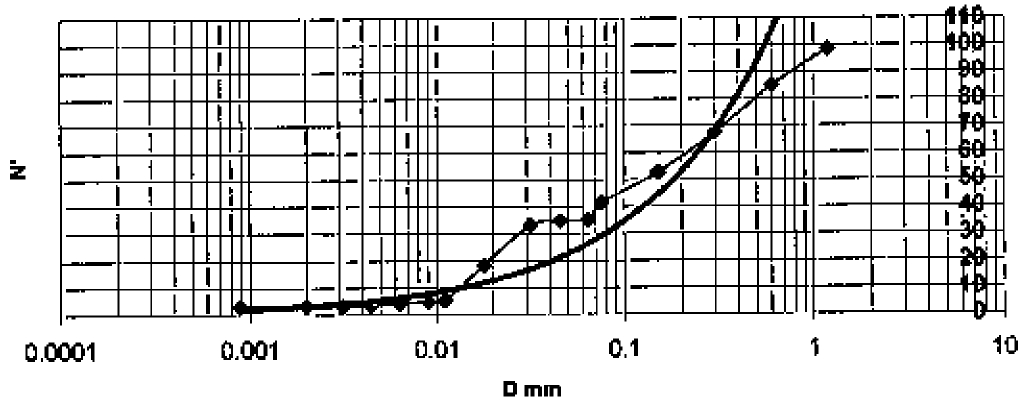


Fig 5.9: Soil texture in Gabtola bazaar, Southkhali

Sand = 73 %
Silt = 20 %
Clay = 7 %
Soil texture =Sandy loam



Rajessor, Rayenda

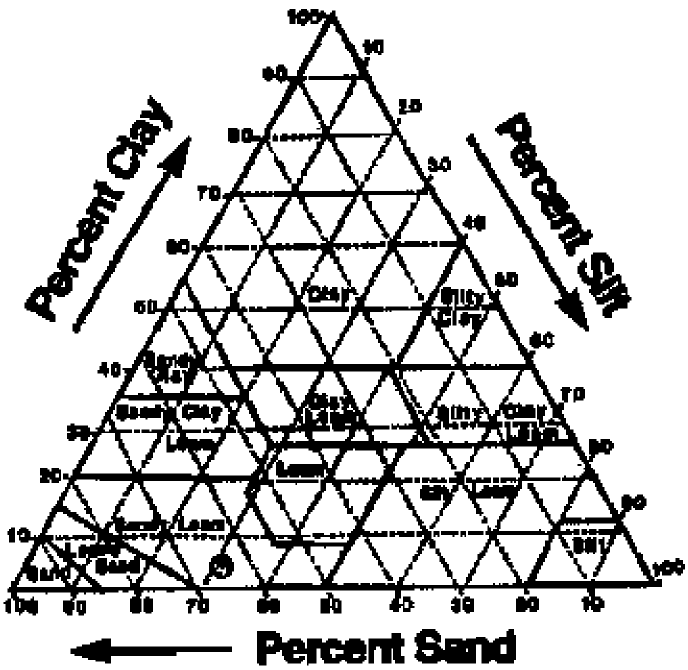
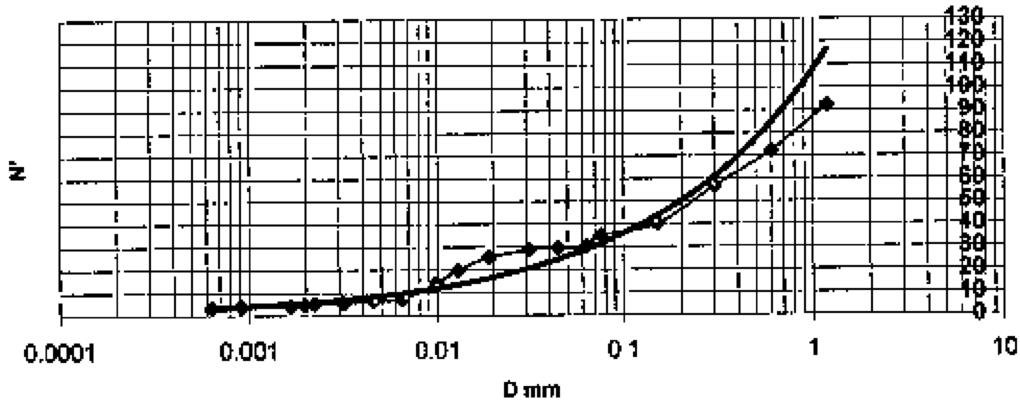


Fig 5.10: Soil texture in Rajessor, Rayenda

Sand = 65 %
Silt = 32 %
Clay = 3 %
Soil texture =Sandy loam



Gabtola, Southkhali,outside polder

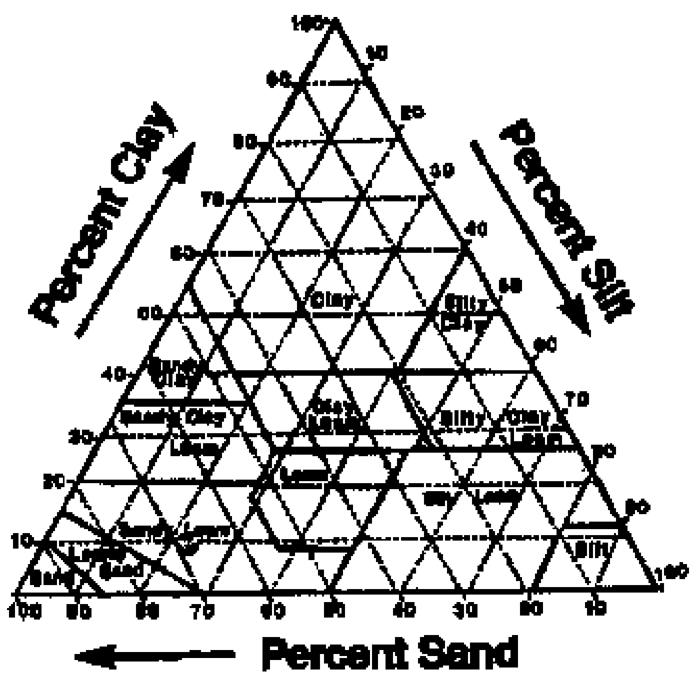


Fig 5.11: Soil texture in Gabtola outside polder, Southkhali

Sand = 69 %
Silt = 23 %
Clay = 8 %
Soil texture =Sandy loam

APPENDIX-IV

QUESTIONNAIRE OF FARMERS' INTERVIEW FROM THE SAMPLING PLOTS

উপজেলাঃ শরনখোলা, জেলা বাগেরহাট

ইউনিয়নঃ গ্রামঃ

১. কৃষকের নাম :

২. বয়সঃ

৩. ঠিকানাঃ

৪. নমুনাকৃত জমির চাষের পরিমানঃ

৫. কোন শস্য চাষ করা হয়েছে শেষ আমন সিজনে-
(ক) টি আমন ধানের স্থানীয় জাত
(খ) বি.আর.আর.আই ধানের উচ্চ ফলনশীল জাত
(গ) অন্য কোন শস্য (শস্যের নাম
(ঘ) পতিত

৬. শেষ আমনে সিজনে উৎপাদনের পরিমান

৭. নিজ নিজ জমিতে পূর্বেও গড় উতপাদনঃ

৮. উৎপাদন বৃদ্ধি বা হ্রাসের কারন সমূহ যেমনঃ লবনাক্ততা/ সারের প্রকার/সেচ/ বীজের গুনগত মান/ সঠিক ব্যবস্থাপনার অভাব।

৯. কৃষি উৎপাদনের উপর কি লবনাক্ততার প্রভাব আছে? হ্যা/না

১০. কোন মাসে বলেশ্বর এবং ভোলা নদীতে লবনাক্ততা বৃদ্ধি পায়?

১১. কোন নদীতে লবনাক্ততা বেশি হয়?

১২. সিডরের পরে চাষাবাদে কোন ধরনের সমস্যা হয়েছে-

(ক) লবনাক্ততা বৃদ্ধি
(খ) পানিসেচের অভাব
(গ) অতিরিক্ত বৃষ্টিপাত
(ঘ) জলাবদ্ধতা
(ঙ) অর্থনৈতিক
(চ) অন্যান্য
(ছ) সমস্যা নেই

১৩. সিডরের পরে লবনাক্তেতা সমস্যা বৃদ্ধি- বৃদ্ধি/হ্রাস/ পরিবর্তন হয় নি

১৪. আপনি কি বি.আর.আর.আই ধানের লবনাক্ত সহনশীল উন্নত জাত সম্পর্কে জানেন? হ্যা / না

১৫. চাষযোগ্য জমিকে রক্ষা করার জন্য বাধ কি যথেষ্ট ছিল? হ্যা/ না

১৬. বাধ সম্পর্কে কি আপনার কোন পরামর্শ আছে?

১৭. ঐ এলাকাতে কি মাটিতে লবনাক্তেতা সমস্যা আছে।?

১৮. কৃষিতে সিডরের প্রভাব সম্পর্কে কি আপনার কোন মতামত আছে।

১৯. নমুনা জমির উৎপাদন হ্রাসের কারনগুলো কি কি-

২০. আপনার কি লবন পানি বা সেলাইন ওয়াটার সম্পর্কে কোন ধারনা আছে?

২১. আপনার কৃষিচাষের পরিবর্তনের জন্য কি কোন প্রতিষ্ঠান বা কোন লোক প্রভাবিত করেছিল

২২. আপনার কি মনে হয় যে বাধটা লবনপানি কে রোধ করতে পারবে

২৩. আপনার কি মনে হয় যে বাধটা কৃষির উৎপাদন বৃদ্ধি করতে পারবে?

২৪. আপনার কি বি.আর.আর.আই-৪৭ ও এর উৎপাদন ক্ষমতা সম্পর্কে ধারনা আছে?

২৫. কোন ঝড়ের পর বৃষ্টির পানি দ্বারা লবনপানি দুর হতে কতবছর প্রয়োজন?