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IMPACT OF SALINITY INTRUSION ON TREES AND AGRICULTURAL CROPS IN THE COASTAL AREA OF BANGLADESH: A PERCEPTION ANALYSIS IN PAIKGACHA, KHULNA

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DECLARATION

I, Rahul Biswas, declare that this thesis is the result of my own works and it has not been submitted or accepted for a degree in other university.

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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

Abstract

Intrusion of salinity with gradual increasing rate in coastal areas of Bangladesh results in declining the species growth and survival rate. The study was carried out to explore the impacts of salinity intrusion on tree species and agricultural crops in Paikgachha upazilla of Khulna district during July to November 2016. A comparative study among the years 1976, 1996 and 2016 has been conducted to know about species occurrence in the study area. A semi-structured questionnaire was used to collect information from 120 respondents. People’s opinion shows that during the last 40 years, 27% of the tree species and 58% of the agricultural crops has been reduced in the study area. Trees and agricultural crops reduction were 19% and 44% respectively from 1976 to 1996 and 8% and 14% respectively for last twenty years. Multiple comparisons with Least Significant Difference (LSD) test shows that within the study area the percentage of tree species in 1976 has significant difference with 1996 ($P<0.05$) and highly significant difference with 2016 ($P<0.01$), while the percentage of agricultural crops in 1976 has highly significant difference from 1996 and 2016 ($P<0.01$). Although, some salt-tolerant species have been increased, the study shows that the tree species and agricultural crops have greatly been reduced day by day due to salinity intrusion. Finally the possible solution of salinity intrusion problem in coastal area was suggested.

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LIST OF ABBREVIATIONS

ANOVA	=	Analysis of Variance
BBS	=	Bangladesh Bureau of Statistics
BWDB	=	Bangladesh Water Development Board
DoF	=	Department of fisheries
FAO	=	Food and Agriculture Organization
g	=	Gram
HL	=	Highland
IPCC	=	Intergovernmental Panel on Climate Change
JRC	=	Joint River Commission
LL	=	Lowland
LSD	=	Least Significant Difference
mg	=	Milligram
MHL	=	Medium Highland
MLL	=	Medium Lowland
NAPA	=	National Adaptation Programme of Action of Bangladesh
pH	=	Negative logarithm of Hydrogen ion concentration
SRDI	=	Soil Research Development Institute
TSP	=	Triple Superphosphate
UNEP	=	United Nations Environment Programme
WARPO	=	Water Resources Planning Organization

CHAPTER ONE

INTRODUCTION

1.1 Back ground and Justification of Studies

Bangladesh is one of the most densely populated countries in the world with a population of 152.5 million and with an annual growth rate of 1.37 (BBS, 2011). The total area of Bangladesh is 147, 570 km^2. The coastal region of Bangladesh covers an area of about 47,201 km^2 extending along the Bay of Bengal. This region now covers 19 coastal districts facing, or in proximity to, the Bay of Bengal (Islam *et al*., 2006). The coastal zone constitutes 20% of the area and 28% of the population of Bangladesh (Islam, 2004a). Salinity intrusion is a growing problem in the coastal areas around the globe, especially in the low-lying developing countries (Nicholls *et al*., 2007). The cultivable areas in coastal districts are affected by varying degrees of soil salinity. It has been recognized that in the coastal zone 8,142 km^2 (5.5% of the country) land is salt affected and it is increasing at the rate of 146 km^2 per year (SRDI, 2001). The salinity intrusion in coastal areas of Bangladesh has increased over the last decades (SRDI, 2003). A comparative study of the salt affected area between 1973 to 2009 showed that about 0.223 million ha (26.7%) new land is effected by various degrees of salinity during about the last four decades. It was also found that between 2000 to 2009 about 35,440 hectares (3.5%) of new land is affected by various degrees of salinity during last 9 years only (SRDI, 2010). The effect of salinity on the bio-environment is severe and there is a significant reduction in vegetation in the salt affected areas (Dutta, 2001). Soil salinity is making the environment non-conductive for tree growth (FAO, 2003). Although homesteads are the main source of fruit and timber production in the coastal areas but increased salinity hinders growth and survivability of trees in this region. Salinity causes unfavorable environment and hydrological situation that restrict the normal growth and crop production throughout the year (Haque, 2006). Crop production of the salt affected areas in the coastal regions differs considerably from non-saline areas. Because of salinity, special environmental and hydrological situation exists, that restrict the normal crop production throughout the year. In the recent past, with the changing degree of salinity of some areas due to further intrusion of saline water, normal crop production becomes very risky. Crop yields, cropping intensity, production levels and people's quality of livelihood are much lower than that in other parts of the country (BBS, 2001). It is estimated that a net reduction of 0.5 million MT of rice production would take place due to a 0.3 m sea level rise in coastal areas of Bangladesh (World Bank, 2000). Along with other factors shrimp cultivation plays a major role to increase soil salinity particularly in southwestern coastal areas (SRDI, 2003). The saline soils are mainly found in Khulna, Barisal, Patuakhali, Noakhali and Chittagong districts of the coastal and offshore lands. This study focuses particularly on Paikgassha upazilla of Khulna Division in the context of salinity.

Due to salinity intrusion, indigenous rice varieties have been reduced by 75% in Paikgacha. Crop diversity index value of Paikgacha has been reduced from 2.77 to 0.69. It has reduced plant diversity index value from 3.40 to 2.53 in Paikgacha. Dominancy of saline tolerant species has also increased in this region of Paikgacha (Uddin *et al*., 2010).

At the beginning of shrimp culture, lands are cleared and bushes and forest is cut down. On the other hand, shrimp cultivation started, tree species and vegetations can disappear fast due to excess salinity and inundation. In the farm areas most of the tree species and vegetations are completely cleared. Sometimes trees on the duke and embankment are excluded but due to seepage and leakage of saline water the trees disappear subsequently. Vegetation outside of the shrimp farm also disappeared due to saline water seepage. Water logging can have negative effect on the growth of vegetation and trees. Salinity along with water logging severely affected the vegetations. Different species of shrubs and herbs or grass that are used for fuel or other domestic uses are lost gradually due to higher saline level in water logged areas (karim, 2004). Gupta (1990) reported that salinity affect vegetation diversity in terms of plant growth and yields of plants by general osmotic effect and specific ion effect. To ensure the effect of salinity intrusion on tree and crop species, 45 literatures have been reviewed in which about 40 literatures show that salinity intrusion has direct impact on the growth and development of tree and crop species in this region. In where, except the salinity intrusion the others reasons are cyclones, tidal surges, floods, riverbank erosions, shore line recession, house building, infrastructure, urban development, industry and others.

1.2 Objectives of Study

The objectives of the study are:

- To assess the present and past condition of soil and water salinity using a combination of people's perception and secondary data.
- To assess people's perception on the present and past trees and agricultural crops.
- To find out the effects of salinity intrusion on tree species and agricultural crops.

CHAPTER TWO

LITERATURE REVIEW

2.1 Salinity

Soil and water salinity is a common hazard in many parts of the coastal zone. All soils contain some water soluble salts. Plants absorb essential plant nutrients in the form of soluble salts, but excessive accumulation of soluble salts, called soil salinity, suppresses plant growth. Salts in the soils occur as ions. Ions are released from weathering minerals in the soils. When precipitation is insufficient (December-June) to leach ions from soil profile, salt accumulate in the soil and soil salinity can result in Bangladesh. Poor drainage and/or poor irrigation water often contribute to this. Water salinity can be categorized as surface water, river water, gher water (water within shrimp cultivation) and ground water including shallow tube well and deep tube well (SRDI, 2010). Soil may be saturated with soluble salts due to sea water flooding. In the southwest region, surface water salinity has been accentuated by the reduction in the dry season upland flows entering the Gorai distributaries. Salinity now reaches as far as Khulna city affecting the supply of clean water for domestic and industrial use. A number of industries in Khulna are facing shortage of fresh water during the dry season. Consequently, no new heavy industry was set up in the recent years in the Khulna region despite increasing infrastructure facilities (road, sea-port, etc.). Groundwater salinity is also high in Noakhali (WARPO, 2005). Under climate change induced increasing salinity along the coastal rivers; the above processes will be aggravated. This in turn will further complicate the current state of water logging. It is inferred that water logging will be spread over a larger area, involving many smaller river basins within the Ganges Dependent Area. Salinity has put severe forms of constraints in terms availability of safe drinking water. Both surface and ground water salinity exceeded 20 dS/m in 2009 in 17 coastal towns in the dry season (March–May). This rate is a strong threat for human health and risk for normal agricultural production. Almost 50 coastal towns out of 102 are severely affected by high salinity intrusion due to shrimp cultivation, upstream fresh water shortage and climate change impacts. Urban drinking water supply is a challenging issue for the 3 metropolitan cities located in the coastal region such as Chittagong, Barisal and Khulna (WARPO, 2005).

Accordingly 75% land area of Sathkhira, 66% of Bagerhat, 32% Khulna and 72% of Barguna districts are affected by salinity intrusion which is a threat for drinking water supply to the urban citizens (Islam, 2007 and Islam, 2010). Salinity intrusion in the coast varies seasonally. In the rainy season (June–October) intrusion of saline water is low due to extreme flow of fresh water, but in the dry season, especially in winter, saline water goes upward gradually. In the rainy season where saline water ingresses to 10% of country's area, in the dry season saline water reaches to country's 40% area even.

Due to the changing climate, the ingression of salinity is being increased through: increased sea level causing water ingression in the rivers, decreasing trend of fresh water flow from the upstream causing intrusion of saline water, upward pressure of the saline and fresh water interface in the level of underground aquifer, downward seepage of saline water from surface and salinity of underground water. The pace of evaporation in winter will increase soil salinity and frequency and intensity of tidal surges will increase ingression of saline water (Shamsuddoha and Chowdhury, 2007).

2.2 Why salinity is a constrains

Salinity limits vegetative and reproductive growth of plants by inducing severe physiological dysfunctions and causing widespread direct and indirect harmful effects, even at low salt concentrations (Shannon *et. al.*, 1994). Salinity adversely influences several aspects of reproductive growth, including flowering, pollination, fruit development, yield and quantity of food, and seed production. Symptoms of salt injury in plants resemble drought. Both conditions are characterized by water stress (wilting) and reduced growth. Severe injury caused by prolonged exposure or high salinity results in stunted plants and tissue death. Reduced growth caused by salinity is a progressive condition that increases as salinity increases above a plant's tolerance threshold (SRDI, 2010).

Salinity inhibits the growth of vegetative, with shoot growth typically reduced more than root growth. It induces injury, inhibits seed germination and vegetative and reproductive growth, after plant morphology and anatomy, and often kills nonhalophytes. Plant anatomy and xylem cells are often altered by salinity. In both nonhalophytes and halophytes, salinity reduces the total number of seeds germination. Seed germination of many nonhalophytes may be inhibited by

0.5% salt (Kozlowski, 1997). For examples, seeds of many halophytes remain viable for a long when they exposed to strong salt solutions but ready to germinate after the salt stress is relieved (Woodell, 1985)

It has been estimated that about a third of the world's irrigated land and half of the land in semiarid and coastal regions is influences by excess salinity, that about 10 million ha of irrigated land are abandoned annually because of excess salinity (Abrol *et. al.*, 1988). Salinity reduces the rate of photosynthesis of both nanhalophytes and halophytes. Salinization transforms fertile and productive land to barren land, often leads to loss of habitat and reduction of biodiversity (Ghassemi *et. al.*, 1995).

Salinity is a major attribute of seawater and undoubtedly has some adverse effects on both plants and animals (Bailey and james, 2000). It affects the general health of both mangrove and non-mangrove plants (Hossain *et. al.*, 2001). This salinity induced osmotic stress causes oxidative damage, reducing biosynthesis of compound osmo-protectors. Basically plants record their environment and respond with resistance or adaptation mechanisms (Shao *et. al.*, 2007b; Shao *et. al.*, 2008). A plant stress adaptation mechanism depends on the degree of stress tolerance, growth, and different development stages, evolution in time which increases their complexity (Shao *et. al.*, 2005a). The effect of the tides is manifested in a regular alternation of rise and fall of the water level of the sea and the estuarine/tidal channels and creeks. The flow repeatedly inundates the soils and impregnates them with soluble salts, thereby rendering the soils and subsoil water saline. The high tide during summer rises up to 1.3 meter above the general ground level (Haque, 2006).

2.3 Factors Affecting Salinity in Coastal Area of Bangladesh

Salinity in the coastal areas is controlled by the tidal inundation, salinity of tidal waters, fresh water discharge from rivers, rainfall, temperature, wind action evaporation, humanity, etc. Clarke and Hannon (1970) observed that soil salinity is the consequences of the interaction among frequency of tidal inundation, evaporation and supply of fresh water. Other factors that can affect the soil salinity include soil type and topography, amount and seasonality of rainfall, depth of impervious subsoil, run on from adjacent terrestrial areas, and run off.

Salinity increases due to the increase of temperature, which enhances evaporation. Rainfall decreases the salinity through addition of freshwater in the coastal ecosystem and that makes the site suitable for halophytes. Humidity plays role to influence the evapotranspiration that can control the salt movement in the soil. High salinity is accompanied with high temperature and wind causes salt accumulation at the soil surface. The extent of plant cover also has a significant influence on evaporation loss from the mangrove community (Hutchings and Saenger, 1987).

2.4 Salinity condition in Coastal Area of Bangladesh

The coastal areas of Bangladesh lie in the southern part of the country. The Sundarbans is the nearest forest that can be associated with and subjected to saline water, and it may be the result of frequent fluctuations of salinity levels. The coastal areas with the mangrove swamp are inundated twice daily and thus tidal inundation regulates the salinity levels of coastal areas. The duration and depth of tidal inundation depend on many factors like the distance from the main rivers and sea including local relief and sediment load in the inundating water (Rahman, 1995)

Saline soil contains an excess of soluble salts, especially sodium chloride. In other words, soils that develops under the influence of the electrolyte of sodium salts, with a nearly neutral reaction. Dominant salts are sodium sulphate and sodium chloride, but seldom sodium nitrate, magnesium sulphate, or magnesium chloride. They are non-sodic soils containing soluble salts in such quantities that they interfere with the growth of most crop plants. The pH of the saturated saline soil is usually less than 8.3. These soils are geographically associated with arid, semi-arid, sub-humid and humid areas as well. The estimates indicate that Bangladesh has about 2.8 million ha of land affected by salinity and poor quality water. The total area includes deltaic floodplains and offshore islands. This comes to about one-fifth of the total areas of Bangladesh and lies around the northern apex of the Bay of Bengal. The saline soils are mainly found in Khulna, Barisal, Patuakhali, Noakhali and Chittagong districts of the coastal and offshore lands. Due to a number of environmental factors the coastal soils are slightly moderately saline on the surface, and highly saline in sub-surface layers and substrata (Chanratchakool, 2007).

The salinity of the Sundarbans and its adjacent coastal areas increases from the east to west and north to south. Based on the degree of salinity, the area is divided into three saline zones-less saline moderately saline and strong saline zones (Siddiqi, 2001). The concerned area for this study was under strongly saline zones. The Increase of soil salinity during last 36 years (1973 to 2009) is presented in Figure 2.1.

Figure 2.1 Increase of soil salinity during last 36 years (1973 to 2009).

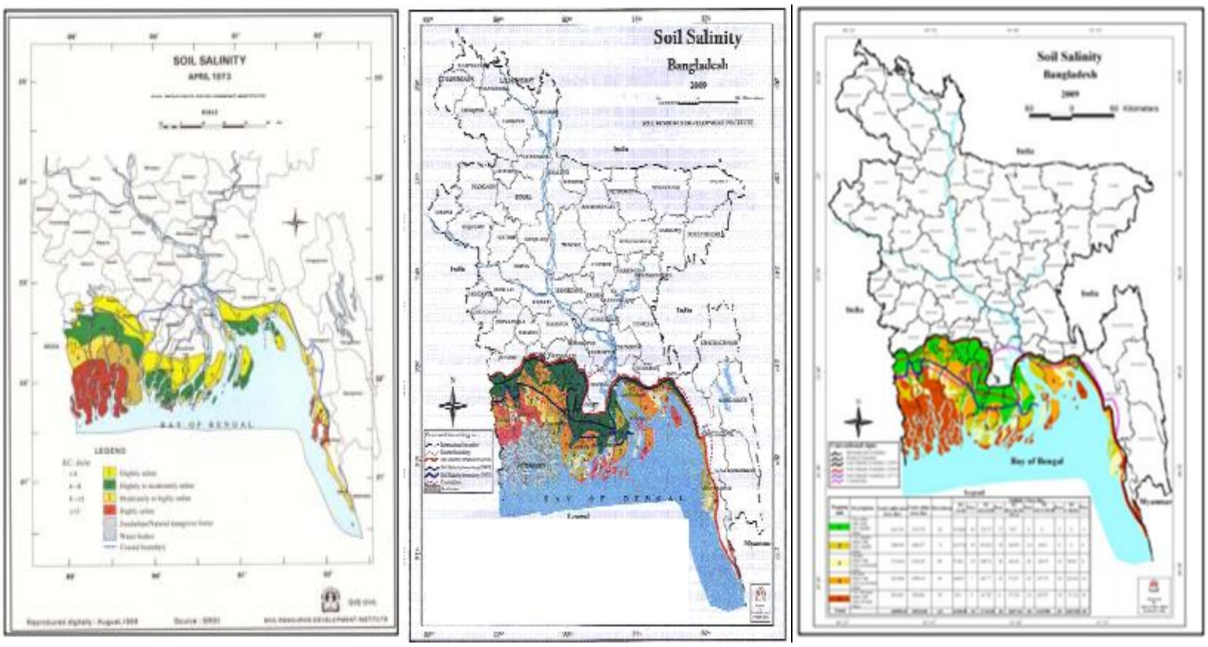


Fig 2.1(a). Soil salinity map of Bangladesh, 1973

Fig 2.1(b). Soil salinity map of Bangladesh ,2000

Fig 2.1(c). Soil salinity map of Bangladesh, 2009

(*Source: SAARC Agriculture Centre, 2013 and Sarkar, 2012*)

2.5 Salinity intrusion in Coastal Area of Bangladesh

Glossary of River Terminology (2016) by Texas Parks and Wildlife Department defined salinity intrusion is the movement of saltwater into a body of freshwater. It can occur in either surface water or groundwater bodies.

European Environment Agency defined saltwater intrusion is a natural process that occurs in virtually all coastal aquifers. It consists in salt water (from the sea) flowing inland in freshwater aquifers. This behavior is caused by the fact that sea water has a higher density (which is because it carries more solutes) than freshwater. This higher density has the effect that the pressure beneath a column of saltwater is larger than that beneath a column of the same height of freshwater. If these columns were connected at the bottom, then the pressure difference would trigger a flow from the saltwater column to the freshwater column.

Saltwater intrusion refers to the process by which sea water infiltrates coastal groundwater systems, thus mixing with the local freshwater supply. Groundwater is stored in the pores and fractures of rock beneath the surface, and the rock formations containing groundwater are referred to as aquifers (Barlow, 2003). Aquifers are naturally replenished (or recharged) by way of precipitation (rain, snow) that seeps into the ground and eventually reaches the water table. The water table is simply the boundary between the upper portion of the ground that is only partially saturated with water (unsaturated zone) and the lower portion where all the pore spaces and fractures are fully saturated with water. The elevation of the water table at any point is often referred to as the "hydraulic head." Groundwater generally flows from areas of higher elevation (high hydraulic head) to lower elevations (lower hydraulic head), and the difference between these hydraulic heads is referred to as the hydraulic gradient. All other factors being equal, the bigger the difference in water table elevations between two points (i.e., the higher the hydraulic gradient), the faster groundwater will flow toward lower elevations (Barlow, 2003).

Salinity intrusion is a growing problem in the coastal areas around the globe, especially in the low-lying developing countries. The problem becomes exacerbated particularly in the dry season when rainfall is inadequate and incapable of lowering the concentration of salinity on surface water and leaching out salt from soil. Coastal agriculture experiences a yield reduction or in some cases devastation due to tidal inundation and salinity (Nicholls *et. al.*, 2007).

Saltwater intrusion occurs naturally in many areas but can become problematic when groundwater is withdrawn (pumped) from the aquifer; this reduces the hydraulic head in the aquifer, subsequently slowing or stopping the seaward flow of freshwater, which in turn allows saltwater to move further inland (Khublalryan *et al*., 2008). Excessive pumping of groundwater can also induce saltwater intrusion through "up-coning," when deeper saline waters from the underlying saltwater wedge are drawn toward a pumping well. In either case, a portion of the aquifer becomes contaminated with saltwater, thus compromising any nearby wells as viable freshwater sources (Bear and Cheng, 2010). The rate of salinity intrusion in coastal Bangladesh is faster than it was predicted a decade ago (Agrawala *et al*., 2003). Based on observable symptoms, it is therefore assumed that agricultural lands in the coastal area will be affected by salinity; soil quality will be degraded which will eventually contribute to loss of agricultural production and thus threat food security (Sarwar, 2005). NAPA (National Adaptation

Programme of Action of Bangladesh) has warned that the impact of saline water ingression in estuary and underground water is likely to be accelerated by sea level rise, land subsidence and low flow river condition. Different climate scenarios also indicate for a worrying future. World Bank study predicted a 1 m sea level rise at the end of the century which might affect 17.5% of total land mass of the country (World Bank, 2000).

2.6 Causes of Salinity intrusion in Bangladesh

There are multiple reasons of salinity intrusion in the coastal area of Bangladesh. It includes natural, socioeconomic and political systems. All these systems are interlinked to each other. (Mahmuduzzaman, 2014).

2.6.1 Natural Systems

The natural systems include geographical location, sedimentation, sea level rise, cyclone, storm surge and tidal surge (Mahmuduzzaman, 2014).

2.6.1.1 Critical Geographical Location of the Country

The country lies between the Himalayas in the north and the Bay of Bengal in the south. Water salinity in the coastal zone highly depends on the ice melting of the Himalayas and the discharge of Ganga, Brahmaputra and Meghna rivers. The annual average discharge of these rivers is 1.5 million cases which are generally characterized by seasonal variation. The peak flow (80%) in monsoon and lean flow (20%) in winter/dry season are responsible for salinity. Decreasing in ice melting reduces river water discharge and consequently enhances the salinity in the coastal zone of the country (Mahmuduzzaman, 2014).

2.6.1.2 Sedimentation

The two Himalayan rivers, the Ganges and Brahmaputra, are among the most sediment-laden rivers in the world. The Ganga, Brahmaputra and Meghna rivers system carries 2.4 billion tons of sediment to the Bay of Bengal through the country. Part of the sediment goes to the Bay of Bengal and part of its deposits on the river beds and builds char lands. This fluvio-morphological activity reduces fresh water discharge to the estuary which leads to increased salinity in the tidal rivers and canals (Mahmuduzzaman, 2014).

2.6.1.3 Sea Level Rise

Wigley and Raper (1987) commented that the relative contributions of thermal expansion and ice melting increase volume of ocean water of the earth and rise in the sea level. And sea level rise is one of the major causes for salinity intrusion in the coastal belt of Bangladesh. Bangladesh is highly vulnerable to saline water inundation due to sea level rise. World Bank (2000) showed 10 cm, 25cm and a 1.0 m rise in sea level by 2020, 2050 and 2100; affecting 2%, 4% and 17.5% of total land mass respectively.

2.6.1.4 Cyclone and Storm Surge

The peak intensity and precipitation may increase to worsen the situation of the inland and riverine flooding. Moreover, the higher mean sea level will intensify the storm surges. According to IPCC Third Assessment report, frequencies of tropical cyclone in Bangladesh will be intensified. Bangladesh experienced the deadliest cyclones in 1970, 1990, and 1992 and in 2007. The coastal zone of the country is still carrying salinity which intruded during *Sidr* and *Aila* (Mahmuduzzaman, 2014). Many tree and agricultural crops has been reduced for this effect.

2.6.1.5 Tidal Flooding

Bangladesh faces semi diurnal tide i.e., two flood tide and two ebb tides in a day in a 6 hour consecutive time interval. Coincidence of heavy rainfall and flood tide occurred during monsoon urban area located in the coastal part of our country faces flooding due to water logging. During the monsoon period it makes high tide and overflow saline water surrounding the coastal region (Mahmuduzzaman, 2014).

2.6.1.6 Back Water Effect

Backwater effect is a special type of saline water movement which takes place at the mouth of the river when fresh water is not sufficient enough for counterpart tide water moving towards river from sea and identified different causes of backwater effect, among them i) South west monsoon wind ii) astronomical tides iii) storm surge are responsible for backwater effect and it is particularly important during flood seasons. (Mahmuduzzaman, 2014).

2.6.1.7 Changes in Ground Water Flow

When groundwater levels in aquifers are depleted faster than they can recharge this is directly related to the position of the interface and determines the amount of saltwater that can intrude into the freshwater aquifer system. Since saltwater intrusion is directly related to the recharge rate of the groundwater, this allows for the other factor that may contribute to the encroachment of seawater into the freshwater aquifers (Mahmuduzzaman, 2014).

2.6.2 Socioeconomic Systems

Socioeconomic systems include anthropogenic activities such as shrimp farming, weak infrastructure and their poor maintenance, increased GHG emission, temperature rise and so on (Mahmuduzzaman, 2014).

2.6.2.1 Continuous Shrimp Cultivation in Agricultural Land

Shrimp aquaculture has raised serious concern about the impact of saltwater intrusion into the surrounding agricultural lands. The spectacular rise of the demand of brackish water shrimp (*Penaeus monodon*) in the international market has stimulated the merest of its production. Presently its culture has taken a massive horizontal expansion and engulfed almost the entire coastal belt of the country. Shrimp culture reduced the availability of cropping land by increasing soil salinity. The practice of shrimp culture needs saline water as an input to the shrimp pond as a result salinity intrusion increase with expansion of shrimp culture. The extent of salinity in groundwater is also increasing because of continuous shrimp cultivation in the fresh agricultural land (Mahmuduzzaman, 2014).

2.6.2.2 Weak Structure and Poor Maintenance

The primary goal of launching polderization in Bangladesh was to protect the coastal inhabitant from regular natural disasters and to boost the agricultural production. But due to the poor maintenance, coastal polders in many places have started creating salinity intrusion to the agricultural fields. Most of the sluice gates have been damaged through which saline water continuously inters into the inland. In addition, shrimp farmers cut the embankment to get saline water in their shrimp fields which also make the embankment weak. This weak embankment is easily damaged due to tidal pressure, particularly during full moon and the saline water enters in the polders (Mahmuduzzaman, 2014).

2.6.2.3 Anthropogenic Climate Change Induced Factors

Climate variables, such as precipitation, surface runoff, and temperature can play a big role in affecting saltwater intrusion. With lower precipitation amount and warmer temperature, the recharge rate will be much less due to lack of groundwater present and increase evaporation (Ranjan, 2007).

2.6.3 Political Systems

The political systems include weak water governance systems at local level, cross-boundary river policy, construction of barrages by the neighboring countries, etc (Mahmuduzzaman, 2014).

2.6.3.1 Weak Water Governance Systems at Local Level

Weak water governance systems at local level are another cause of salinity increase. Because salinity intrusion is not only natural phenomenon; it's also a human one. Numerous human activities—such as unplanned shrimp culture, insufficient or poorly maintained infrastructure, and inadequate management systems—can result in salinity intrusion (Mahmuduzzaman, 2014).

2.6.3.2 Cross Boundary River Policy

A total of 57 major rivers of Bangladesh have entered the country, of which 54 rivers are from India and 3 rivers are from Myanmar (Rounak, 2013). But among the 54 rivers coming from India more than twenty five rivers face one or more upstream diversion basically in dry months causing water scarcity during non-monsoon months. This causes of salinity increase in soil and water of coastal belt off Bangladesh. The Farakka barrage and Gorai River has appeared to exacerbate the intrusion of saline water of the southwest part of Bangladesh (Khan, 1993).

2.6.3.3 Lack of Capacity of Local Government

The lack of capacity of local government in Bangladesh is a cause for salinity intrusion. With the change of government, the policy of local government also kept changing. Independent reviews observed that Bangladesh has not been successful in establishing a decentralized system of governance and accountability. A World Bank review of the decentralization process in 19 countries ranks Bangladesh lowest in the decentralization scale (Williams, 1998).

2.6.3.4 Structural Intervention in Upstream Neighboring Country

The water withdrawal system of human intervention in terms of the barrage and dam in the upstream neighboring country, have already affected upstream fresh water flow. Due to geographical situation Bangladesh is most vulnerable to water withdrawal system by the upstream neighboring country. Farakka barrage is one of the worst factors for the decreasing water flow condition for internal river system of Bangladesh (Mahmuduzzaman 2014).

2.7 Importance and scope of agroforestry practices in the coastal area of Bangladesh

Large scale change in land use from long term plant species to perennials can be the solution to the increasing trends of salinity. A number of studies have demonstrated that increasing the area of perennial plants will have substantial negative effects on stream flow. Reducing of water for irrigation may increase the benefits of dry-land salinity (Rahman and Bhattacharya, 2014). Increased pressure of growing population demand more food. Thus it has become increasingly important to explore the possibilities of increasing the potential of these (saline) lands for increased production of crops. It necessitates an appraisal of the present state of land areas affected by salinity (Haque, 2006).

Trees and crops growing around the house provide shade and reduce atmospheric temperature, thus creating a favorable microclimate for family, plants and animals during summer. The trees also help in soil conservation and serve as windbreak. The economic aspects of trees not be mentioned in detail. We get fuel wood, wood, food, fodder, gum, tannin, medicines and many other products from trees. Trees also provide jobs and incomes often needed to supplement inadequate returns from agriculture (Alam and Mohiuddin, 1992).

In Bangladesh societal contest, a household is a collection of members sharing a blood-line, and is, therefore, synonymous in most causes with a family or families, and, in some cases, an extended family. The household land areas are used for housing, cooking space, sources of water supply, latrine, crop processing, animal sheds and limited grazing space, place of worship, local products, as well as for growing flower, fruit, vegetables and herbs, and trees for timber. These forests thus, are, this a valuable resource providing food, fodder, building material and many ingredients for ethno and herbal medicine and prophylactic. In addition, they provide facilities for various social, cultural and religious activities of villagers. They can therefore be used to promote social and economic welfare of the rural people in a significant way (Siddiqi and Khan, 1999).

Homestead forest in Bangladesh is a particularly appropriate form of agro forestry, being operational units for subsistence in which different crops including trees are grown in mixture with livestock and fish culture is also quite common in the homestead forest (Millat-eMustafa, 1996). Homestead farming is an age-old practice and is prevalent throughout the country and is considered as the unique source of income generation of landless and marginal farmers.

Even when vegetation coverage is reducing at such rapid rate some species are growing well in saline condition. *Acacia nilotica* (Linn.) Willd.*ex* Del., *Phoenix sylvestris* Roxb., *Cocos nucifera* Linn. And *Eucalyptus camaldulensis* Dehn are more salt tolerant species (Dutta and Iftekhar, 2004).

2.8 Present status and development of agroforestry practices in the coastal area of Bangladesh

The effect of salinity causes significant reduction in vegetation in the salt affected areas (Dutta and Iftekhar, 2004). They studied tree species survival in the homestead forests salt affected areas and they have found that in reduction of tree growth (2% per year) and vegetation coverage (1.87% per year). Soil salinity is greatly responsible for affecting cultivable land in coastal districts. It has been recognized that 8,142 km^2 (5.5% of the country) land is salt affected and it is increasing at the rate of 146 km^2 per year (SRDI, 2003).

Based on a survey conducted during 2009, SRDI (2010) reported that about 0.0354 million hectares of new land was affected by various degree of salinity during last 9 years from the year 2000 to 2009 only. Along with other factors shrimp cultivation plays a major role to increase soil salinity particularly in southwestern coastal areas. About 20% of the net cultivable land of Bangladesh coastal region is affected by different degrees of salinity (Karim *et al.*, 1990). Soil salinity is the most dominant limiting factor towards crop growth in the coastal belt especially during the dry season. This reduces the crop area and restricts the cultivation of *aus* (summer rice), *boro* (dry season rice) and other *rabi* (dry season) crops (Islam and Ahmad, 2004). Homesteads play a vital role in providing timber, fuelwood, fodder, and fruits. Record of 70% of timber, 90% of fuelwood, 48% sawn and veneer logs and almost 90% of bamboo requirement is available from homegardens of Bangladesh (Uddin *et al*., 2002). Most of the homesteads of landlord houses contained improved cultivars of different fruits and other aesthetic plants, which are very much important from horticultural and breeding point of view. Homesteads represent a land use system involving deliberate management of multipurpose trees and shrubs in limited association with seasonal vegetables (Fernandes and Nair, 1986). The people's observation shows similarly with the information available on the salt tolerant capacity of the species. In comparing the biological tolerance to salinity have ranked the species in following order *Acacia nilotica* > *Eucalyptus camaldulensis* > *Azadirachta indica* > *Acacia auriculiformis* > *Dalbergia sissoo* > *Albizia lebbek* > *Leucaena leucocephala* (Parkash, 1992).

People in the southwest region are highly dependent on the natural resource base in sustaining their livelihoods. Agriculture and fishery are important economic sectors, employing a large proportion of the population, and aquaculture is increasingly being pursued as an alternative livelihood option for rural households (Islam, 2003). Salinity are not limited to economic activities, like agricultural crops production, fish and shrimp, and availability of water suitable for agriculture and industrial uses. River water salinity has also important implications for the natural environment, such as functioning of the Sundarban ecosystem, sedimentation rates in tidal rivers, and human health. Human health is especially influenced by sole dependence on saline water for domestic purposes (BWDB *et al.,* 1998).

2.9 Constrains in developing agroforestry practices in the coastal area of Bangladesh

Bangladesh, a low-lying deltaic land, is particularly vulnerable to climate change and its associated hazards. It has been described that the rate of salinity intrusion in coastal area of our country is faster than it was predicted a decade ago. It has been found that constraints increased with increasing intensity of salinity. Soil salinity is the most dominant limiting factor in the region, especially during the dry season (Haque, 2006). The trees are affected by different diseases and gradually disappearing from the villages of the study area due to salinity, like, top dying, leaf shedding and root rot (Dutta and Iftekhar, 2004). It has been found that *Achras Zapota* Linn., *Cocos nucifera* Linn., *Psidium guajava* Linn., Swietenia macriphylla king are disappearing due to these diseases at a larger rate than other species (Dutta and Iftekhar, 2004). Salinity is a major problem, which is expected to exacerbate by climate change and sea level rise.

Salinity intrusion due to reduction of freshwater flow from upstream, salinity affected of groundwater and fluctuation of soil salinity are major concern of Bangladesh. Cyclones and tidal surge is adding to the problem. Tidal surge brings in saline water inside the polders in the coastal area. Due to drainage congestion, the area remains waterlogged, increasing the salinity (Abedin, 2010). Salinity intrusion is increasing in developing countries due to natural and anthropogenic reasons and soil salinity is causing decline in soil productivity and crop yield, which results in severe degradation of bio-environment and ecology (Dutta and Iftekhar, 2004). Soil salinity is believed to be mainly responsible for low land use as well as low cropping intensity (Rahman and Ahsan, 2001). Increase in salinity intrusion and increase in soil salinity will have serious negative impacts on agriculture (Hossain, 2009). Most of the people of coastal area are converting now their agriculture field to shrimp culture due to high salinity. Moreover, Shrimp farming being a profitable business, most of the coastal polders constructed during 1950s and 60s by the water development board to protect agricultural land from inundation of salt water have now been turned into large shrimp culture ghers (ponds) (Khan *et. al*., 2006). Most of the people are encroached to cultivate shrimp culture for more economic return. During Cyclones Sidr and Aila, in 2007 and 2009 respectively, sea water was driven into ponds and rivers in Khulna, Bagerhat and Satkhira districts in southern Bangladesh, and some fields remained flooded by sea water long enough to raise levels of salinity in the soil and in underground aquifers used for irrigation (Rasell *et. al*., 2013). About 60 and 15 percent of arable land (total 1.0 mha croplands) of southwestern and southeastern respectively are affected by salinity in the dry period. This salinity is caused by cyclone and storm surges, high spring tide inundation and capillary actions. Its affect the soil surface and root zones, which decreases the crop production about 0.13 M.T. in every year (Rahman and Bhattacharya, 2014). The study found that 830,000 million hectares of land at coastal Bangladesh were affected by soil salinity at different degrees. It is estimated that a net reduction of 0.5 million MT of rice production would take place due to a 0.3 m sea level rise in coastal areas of Bangladesh (Islam *et. al.*, 2004).

The agricultural development in the coastal saline belt is constrained by various physical, chemical and social factors. The main obstacle to intensification of crop production in the coastal areas is seasonally high content of salts in the root zone of the soil. The salts enter inland through rivers and channels, especially during the later part of the dry (winter) season, when the downstream flow of fresh water becomes very low. The increase in water salinity of these areas has created suitable habitat for shrimp cultivation. Along with other factors, shrimp cultivation played a major role to increase salinity, particularly in the southwestern coastal regions.

2.10 Present status and development of shrimp culture in the coastal area of Bangladesh

The distribution of the shrimp farming areas over districts in south west region are Khulna, Bagerhat and Satkhira and in the south east region are Cox's bazar and Chittagong. Shrimp farming also found in small in Jessore and Bhola districts (Karim, 1986).

Production of rice is a vital issue of Bangladesh, both in terms of providing the employment opportunity and fulfilling the dietary requirements of its population. Undoubtedly, with the increased use of modern farming methods the overall production of rice has been increasing significantly for over the last couple of decades. Thus, agricultural land use in coastal areas of Khulna is very poor, which is much lower than country's average cropping intensity (Anisuzzaman *et al*., 2015). Presently land under shrimp culture has increased to about 0.11 ha about 75% of this land is located in the Khulna, Bagerhat and Sathkhira district in the south west and the rest in the Cox's Bazar district in the south eastern region of the country. According to an estimate, the area suitable for shrimp culture in the country is about 0.2 m ha. In Khulna areas, shrimp culture and salt production are carried out alternatively (Karim *et al.,* 1990). Shrimp aquaculture in the coastal zones is expanding rapidly in agricultural lands; especially areas which were mainly used for rice production are being converted into aquaculture ponds. Shrimp areas in Bangladesh have already expanded from 51812 ha in 1983 to 137996 ha in 1994 and to 141353 ha in 2002 (DoF, 2002). In greater Khulna alone, about 31,200 ha of land in 1982-1983 and about 94,850 ha of land in 1993-1994 were brought under shrimp cultivation (Haque, 2006).

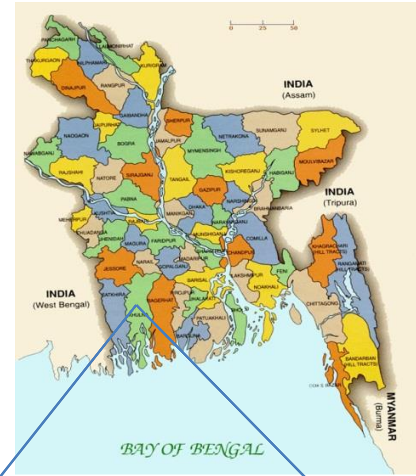
2.11 Environmental effect of shrimp culture

Salinity causes unfavorable environment and hydrological situation that restrict the normal rice production throughout the year in those particular areas (Anisuzzaman *et al*., 2015). Permanent loss of natural vegetation that reflected in the geo-morphological changes due to consecutive year round shrimp culture found in khulna region. In some homesteads betelnut, coconut, palmyra is seen to grow but they do not bear fruits. High rate of economic return in shrimp farming is constantly inducing the farmers to convert more and more paddy field into shrimp farm. This has resulted in over exploitation of shrimp juveniles from the wild leading to ecological imbalance, changes in cropping pattern, interest conflict leasing of land of small farmers, depriving them from their rights to own land and other socio-economic and environmental consequences (Karim, 2004). Unplanned growth of shrimp culture in coastal areas of Khulna, Sathkhira and Bagerhat districts has serious effects on alteration of coastal ecology. Vast areas of tidal land previously used for rice cultivation in Khulna and Bagherhat districts have been changed to shrimp farm. Inundation of arable lands by saline water to cultivate shrimp has become a common occurrence (Miah *et al*., 1990). Waste products are being produced continuously during shrimp culture in a mixture of gases, liquids, semi-solid and solid forms (Latt, 1999). Shrimp farming are suffering from a large number of management related problems that are resulted in low profits and environmental degradation (SRDI, 2010). Unfortunately, there are realized and potential adverse environmental effects on estuarine ecosystems as a result of shrimp farming. The effects can be categorized as wetland destruction for construction of shrimp farms, hypernutrification of estuarine ecosystems by shrimp pond effluent, "biological pollution" of native shrimp stocks through escapement of aquaculture stocks, water use and entrainment of estuarine biota, and impacts of shrimp farm chemicals on estuarine systems (Hopkins *et al*., 1995).

CHAPTER THREE

MATERIALS AND METHODS

3.1. General information of the study area



The study will be carried out at Paikgacha (22° 28-22° 43' N, 89° 09'- 89° 23' E) in Khulna district of Bangladesh, as it is one of the worst salinity affected areas. Paikgachha Upazila (Khulna district), with an area of 411.19 sq. km, is bounded by Tala and Dumuria upazilas on the north, Koyra upazila on the south, Batiaghata and Dacope upazilas on the east, Tala and Assasuni upazilas on the west. The main rivers of that area are Kobadak, Shibsa, Vadra. The Haria, Deluchi, Harrakhali, Narai, Gangkhali, Katakhai and Karulia are small rivers. The river's water intrusion has effects on tree and crop species.

Paikgachha has 10 Unions and one Paurashava, 172 Mauzas/Mahallas, and 212 villages. The names of the union parisods in Paikgacha are Lata, Kapilmuni, Haridhakhali, Raruli, Chadkhali, Laskar, Gadaipur, Sholadana, Deluti, Garuikhali and Paikgacha Paurashava. Here, most of the lands are agro-aquaculture and shrimp (Bagda with white fish) zone based. Only Garuikhali Union is agricultural zone. The soil pH value of high and medium highland areas of the upazila ranges from 5.0-6.8. The lower, medium and higher level of soil salinity is 2dS/m, 8.04 dS/m and 16 dS/m respectively.

Fig.3.1: Map of the study area

Table: 3.1 Union-wise Present Land Use Information and Identified Land Zoning of Paikgacha Upazila

Name of the Union	Total Area of the Union (ha)	Net Cultivable Area, NCA (ha)	Land Type (ha)	Soil Texture	Soil pH	Soil Salinity (dS/m)	Present Land Use (%)	Recommended Land Zoning
Chandkhali	4174	3130	HL- 408 MHL- 2190 MLL- 62 LL- 470	Clay loam to clay	5.5-7.5	8-12	Agriculture= 75 Settlement= 18 Water= 11 Bagda-Golda with white fish= 41	Agro-Aquaculture (Bagda with white fish) Zone
Deluti	5297	3772	HL- 75 MHL-2830 MLL-300 LL-567	Clay	5.5-6.5	5-10	Agriculture= 71 Settlement= 10 Water= 26 Bagda-Golda with white fish= 23	Agro-Aquaculture (Bagda with white fish) Zone
Gadaipur*	2580	1900	HL- 350 MHL- 280 MLL- 1270	Silt loam to Clay loam	6-8	4-8	Agriculture= 74 Settlement= 26 Water= 12 Bagda-Golda with white fish= 48 Urban=11	Shrimp (Bagda with white fish) Zone
Garuikhali*	4241	2527	HL- 126 MHL- 1668 MLL- 253 LL- 480	Clay loam to clay	5.5-7.5	8-12	Agriculture= 60 Settlement= 10 Water= 19 Bagda-Golda with white fish= 10	Agricultural Zone
Haridhali	1934	1280	HL- 563 MHL- 550 MLL- 167	Silt loam to Clay loam	7.0-8.5	2-6	Agriculture= 66 Settlement= 46 Water= 22 Bagda-Golda with white fish= 19	Agro-Aquaculture (Bagda with white fish) Zone
Kapilmuni*	3791	2512	HL- 1500 MHL- 1012	Silt loam to Clay loam	5.5-8.0	4-10	Agriculture= 66 Settlement= 22 Water= 19 Bagda-Golda with white fish= 57	Agro-Aquaculture (Bagda with white fish) Zone
Laskar	4276	2960	HL- 120 MHL-770 MLL- 1180 LL- 890	Clay loam to clay	5.5-7.5	8-16	Agriculture= 70 Settlement= 10 Water= 14 Bagda-Golda with white fish= 71	Shrimp (Bagda with white fish) Zone
Lata*	4738	800	HL- 50 MHL- 640 MLL- 110	Clay loam to clay	5.5-7.5	8-16	Agriculture= 17 Settlement= 7 Water= 16 Bagda-Golda with white fish= 70	Shrimp (Bagda with white fish) Zone
Raruli	2480	1840	HL- 590 MHL- 1150 MLL- 100	Silt loam to Clay loam	7.0-8.5	2-6	Agriculture= 74 Settlement= 35 Water= 20 Bagda-Golda with white fish= 40	Agro-Aquaculture (Bagda with white fish) Zone
Sholadana*	4893	2180	HL- 218 MHL- 436 MLL- 654 LL-872	Clay	4.5-6.5	8-18	Agriculture= 45 Settlement= 9 Water= 20 Bagda-Golda with white fish= 69	Shrimp (Bagda with white fish) Zone
Paikgacha* Paurashava	898	207	HL- 180 MHL-27	Silt loam to Clay loam	7.0-8.5	2-6	Agriculture= 23 Settlement= 4 Water= 23 Bagda-Golda with white fish= 20 Urban= 31	Urban and Commercial Zone

Source: BBS (2001), Field Survey (2009-2010), SRDI Data from CEGIS & SPARAASO (2009-2010)

[*Here * indicates the areas in where this study has taken place*]

Table 3.2 Soil salinity class in Paikgacha upazila during 2000 and 2009

Year	Salinity Class and Area (ha)				
	S_1 2.0-4.0 dS/m	S_2 4.1-8.0 dS/m	S_3 8.1-12.0 dS/m	S_4 12.1-16.0 dS/m	S_5 >16.0 dS/m
2000	1,650	5,260	11,160	7,660	5,210
2009	2,230	3,030	6,930	8,920	8,810

Source: SRDI (2000), SRDI (2012)

3.2 Climatic Condition of the area

The Paikgacha upazila lies between 22° 28 /and 22° 43' North latitude and 89° 09'/and 89° 23' East longitude in Khulna district of Bangladesh. The climate of this area is classified as tropical. This region is humid during summer and pleasant in winter. Summer begins from mid-April and continues till mid June. It is extremely hot, stay and comparatively dry. The annual average temperature of this area is 26.3 °C (79.3 °F) and monthly means varying between 12.4 °C (54.3 °F) in January and 34.3 °C (93.7 °F) in May. The summers here have a good deal of rainfall, while the winters have very little. Annual average rainfall of this area is 1,809.4 millimeters (71.24 in). Approximately 87% of the annual average rainfall occurs between May and October. The recorded rainfall in paikgacha upazila in 2005 was 3003 mm, which was about 1000 mm higher than the long-term average for that locality (Alam *et al*., 2010). The months of October and November are the transition period from the rainy season to winter and this period are marked by fair weather with moderate temperature and high humidity (BBS, 2001).

3.3 Source of information

The whole study in Paikgacha upazila is based on the information which is collected from the respondents of the study area and this is supported by some secondary data.

3.3.1 Primary Data

The primary data has been collected directly from the respondents of the study area. During the field survey, formal and informal discussion with the respondents and also direct observation of the six unions of the upazila were conducted to acquire required information.

3.3.2 Secondary Data

The secondary data was mainly collected from forest, agriculture, soil and water related sector of Paikgacha upazila and Khulna district and all other literatures were collected from published sources available in the books, national and international journals, publications, newspapers, web sites and others published and unpublished documents of government and non-government. The source of secondary data in Paikgacha upazila has been collected from the following institutes:

- Social Forestry Plantation Center, Paikgacha, Khulna
- Department of Agriculture extension, Paikgacha, Khulna
- Bangladesh Fisheries Research Institute, Brackishwater station, Paikgacha, Khulna
- Soil Resource Development Institute(SRDI), Regional Office, Khulna

3.4 Selection of the Respondents

The respondents were selected whose ages were more than sixty. The respondents were interviewed with a pre-formulated questionnaire. The survey was designed to gather information relating to age, sex, education status, total monthly income, occupation and the land use pattern of the respondents of the study area.

3.5 Data Collection

Pre-testing of the questionnaire was done through a reconnaissance survey in Paikgacha upazila. The final survey was done in November 2016. .

3.6 Data Compilation and Analysis

The collected information and literature have carefully been reviewed and sorted according to the sequence. The unnecessary part of the collected information and data has been discarded from the final paper to avoid the bulky size of the thesis paper. The collected information was compiled to make a meaningful paper. In course of compilation, sincere advice from my supervisor was taken time to time. After sorting information, data are then analyzed and compiled sequentially and systematically. Microsoft Excel and SPSS have been used to process and analyze the collected data. Table, bar-chart, pie-chart, flow-chart, ANOVA test and LSD test have been used to analyze the data.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 The demographic profile of the respondents in the study area

The respondents selected for such studies whose ages were not less than sixty. The result shows that majority (33%) of the respondents had farm sizes between 2-3 acres while few respondents (25%) had above 3 acres. Education standard in study area is generally low. Study shows that majority of the respondents (42%) had acquired secondary school followed by primary school education (26%). However, a proportion of respondents (8%) had no formal education. Monthly income range of the respondents has been classified into four classes. The classes are (1) below 5000 tk (2) 5001-10000 tk (3) 10001-15000 tk (4) above 15000 tk. Majority of the respondents (36%) had medium income (5001-10000 tk) where few portion of the respondents (18%) had low income (below 5000 tk). Table 4.1 represents the demographic profile of the respondents in the study area.

Table: 4.1 The demographic profile of the respondents in the study area

Selected characteristics	Categories	Farmer percentage
Farm size (ha)	Less than 1 acre	14
	1-2 acre	28
	2-3 acre	33
	Above 3 acre	25
Level of education	Illiterate	8
	Primary	26
	Secondary	46
	Above secondary	20
Monthly income (tk)	Low (upto tk 5000)	18
	Medium (tk 5001-10000)	36
	Medium high (tk 10001-15000)	25
	High (above tk 15000)	21

Source: Field survey, 2016.

4.2 Land Use Pattern, Soil Status and Salinity Level of the Study Area

Now a days, most of the lands of Paikgacha upazila are used for shrimp culture although before 40 years the major proportion of the lands were used for agricultural purposes. According to respondents, the present land use pattern of the study area is contributing 45% for shrimp pond 37% for agricultural land, 9% for homestead area, 6% for urban area and 3% for fallow land.

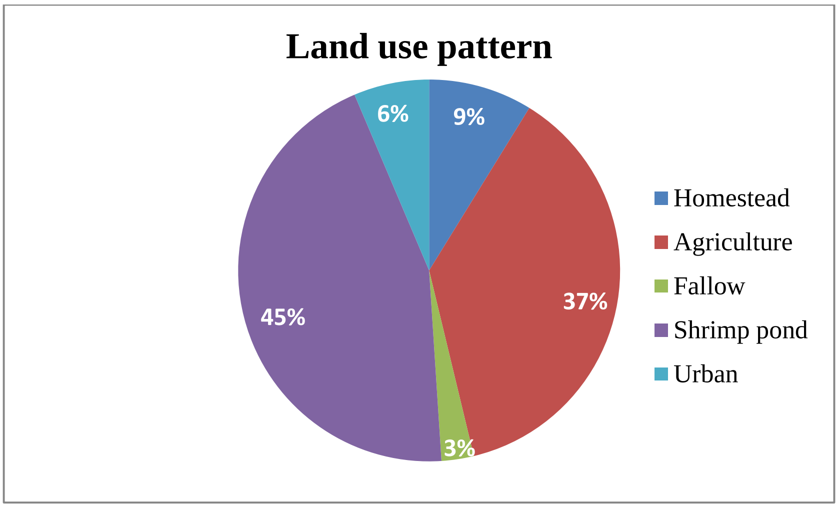


Figure: 4.1 Land use pattern of the study area

Among the land categories of the study area such as highland, medium highland, medium lowland and lowland, most of the lands are included under medium highland. The main soil texture of the study area is silt loam to clay loam and clay loam to clay. The average soil pH and soil salinity of salinity of Paikgacha upazila are 6.18 and 8.04 dS/m respectively. The land zoning is mostly agro-aquaculture meaning Bagda with white fish. According to BBS (2001), highland, medium highland, medium lowland and lowland of Paikgacha upazila are 4180, 11553, 4096 and 3279 ha respectfully. The major portion of the respondents has given their opinion that salinity level in their locality has increased in last 30 years. The respondents (84%) from mostly salinity affected areas have identified that the pick-up of saline water was started from 1983 to1987. Majority of the people (66%) have thought that salinity level at their locality is very high and most of them are the inhabitants of the Lata, Soladana and Paurashava unions. But a considerable portion (28%) of the respondents thinks that salinity level at their locality is medium, whereas very few people (6%) think that salinity level is low in their locality. The respondents opinion mentioning high salinity (>16 dS/m) shows negative relationship with the average salinity of the unions whereas the sequencing of the opinions mentioning medium and low salinity show positive relationship.

4.3 Effect of Salinity

4.3.1 Reduction of Major Tree Species

According to most of the respondents (>65%), the number and growth of tree species is being decreased due to high salinity day by day. In general the respondents have recognized that salinity exerts negative effect on the growth of tree species. The reduction in the growth of tree species also contributes in the overall reduction of vegetation coverage. The major forest land uses of Paikgacha upazila are rural settlements with homestead vegetation called homestead forest/community forest cover mainly the high and medium highland areas. No natural forest was identified in the upazila. The land type of high land to medium high land shows the general characteristics of forest land suitability for hill/plain land forest (soil salinity 2-8 dS/m) and medium low land to low land shows the forest land suitability for mangrove forest (soil salinity 8-16 dS/m). People's opinion on the tree species reduction shows positive relation with salinity and highest reduction observed in Paikgacha Paurashava, Lata, Soladana and Gaurukhali unions. The present distribution of the homestead forest of different unions including Paurashava , Lata, Soladana and Gaurukhali are 3.96%, 7.09%, 8.55% and 10.25% respectively (Land Zoning report, 2009-2010).

People's opinion of the study area shows that during the last 40 years 27% of the tree species has been reduced in the study area. Similarly, during the last 20 years it has greatly been reduced in 8%. From 1976 to 1996 this reduction was 19%.

Figure 4.2 shows that there is a significant difference on the percentage of tree species in last 40 years ($F=4.33$; d.f.=2,270; $P=0.01405$). Multiple comparisons with Least Significant Difference (LSD) test shows that within the study area the percentage of tree species of 1976 has significant difference with 1996 ($P<0.05$) and highly significant difference with 2016 ($P<0.01$). But the percentage of tree species of 1996 has no significant difference with 2016 ($P>0.05$).

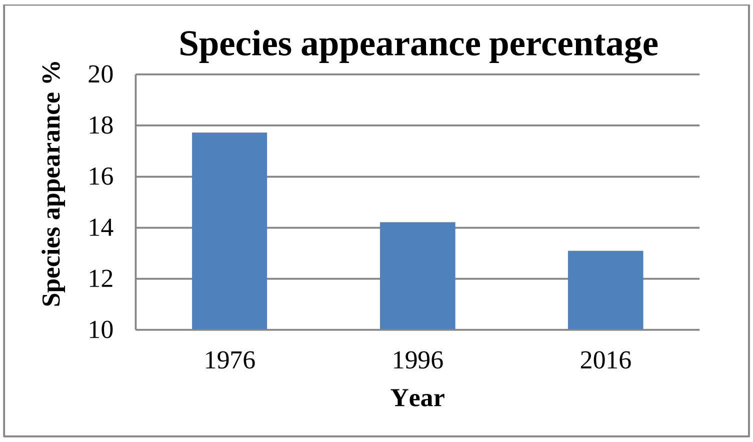


Figure: 4.2 People's perception on forty years status of tree species

Table 4.2 represents the appearance of most significant species in the year of 1976, 1996 and 2016 respectively. It shows the species composition of 1996 and 2016 are more or less same. But species composition types of 1976 were very different from the recent time.

Table 4.2 People's opinion on the most observed tree species according to sequence

Species serial no:	1976	1996	2016
1	*Mangifera indica*	*Phoenix sylvestris*	*Azadirachta indica*
2	*Artocarpus heterophyllus*	*Mangifera indica*	*Albizia lebbeck*
3	*Cocos nucifera*	*Artocarpus heterophyllus*	*Acacia nilotica*
4	*Phoenix sylvestris*	*Cocos nucifera*	*Excoecaria agallocha*
5	*Syzygium cuminii*	*Borasus flabellifer*	*Acacia catechu*
6	*Borasus flabellifer*	*Acacia catechu*	*Sonneratia apetala*
7	*Areca catechu*	*Tamarindus indica*	*Avicennia officinalis*
8	*Syzygium aqueum*	*Acacia nilotica*	*Feronia limonia*
9	*Tamarindus indica*	*Albizia lebbeck*	*Sonneratia casualaris*
10	*Psidium guajava*	*Areca catechu*	*Tamarindus indica*
11	*Zizyphus mauritiana*	*Zizyphus mauritiana*	*Eithecellobium dulce*
12	*Terminalia arjuna*	*Excoecaria agallocha*	*Senna siamea*
13	*Manilkara sapota*	*Sonneratia apetala*	*Citrus limon*
14	*Musa sapientum*	*Avicennia officinalis*	*Thespesia populnea*
15	*Bambusa spp*	*Syzygium cuminii*	*Mangifera indica*
16	*Terminalia belerica*	*Psidium guajava*	*Zizyphus mauritiana*
17	*Albizia procera*	*Eithecellobium dulce*	*Eucalyptus camaldulensis*
18	*Terminalia chebula*	*Sonneratia casualaris*	*Swietenia mahagoni*
19	*Litchi chinenses*	*Syzygium aqueum*	*Artocarpus heterophyllus*
20	*Nypa fruticans*	*Manilkara sapota*	*Cocos nucifera*

Source: Field survey, 2016.

People's observation on the disappearance of tree species is presented in table 4.3. Tree species are disappearing due to salinity. According to people's observation the most ten disappearing tree species are *Terminalia belerica*, *Terminalia chebula*, *Areca catechu*, *Borasus flabellifer*, *Diospyros peregrine*, *Phoenix sylvestris*, *Syzygium aqueum*, *Cocos nucifera*, *Terminalia catappa* and *Syzygium cuminii*.

Table: 4.3 People's observation on the disappearance of tree species

Species	Reduction in last 40 years (%)
Terminalia belerica	98
Terminalia chebula	97
Areca catechu	77
Borasus flabellifer	73
Diospyros peregrine	68
Phoenix sylvestris	67
Syzygium cuminii	63
Cocos nucifera	60
Terminalia catappa	60
Syzygium aqueum	57
Punica granatum	38
Albizia procera	33
Terminalia arjuna	30
Zizyphus mauritiana	21
Psidium guajava	20
Spondias pinnata	19
Tamarindus indica	9

Source: Field survey, 2016.

The direct answers of the respondents about tree species whether increased, decreased or remained same in their locality, are presented in Figure 4.3. Most of the respondents (65%) have thought that tree species have decreased in this selected area. But a considerable portion (27%) of the respondents thinks that tree species have increased in their locality/village. Whereas very few people (8%) think that the number of tree species is as usual now by comparing the previous situation.

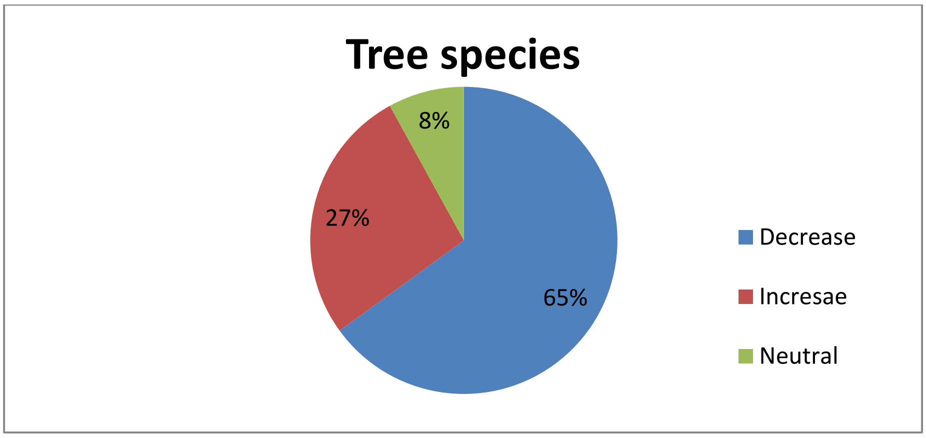


Figure: 4.3 People's opinion on tree species

The vegetation coverage is reducing due to increasing soil salinity in different countries (Ghana, Kenya, Tanzania, China, Pakistan, Indonesia, Vietnam, Thailand, Hungary, Turkey, Argentina, Cuba, Egypt, Australia, etc) (FAO, 2003).

4.3.2 Enhancement of Some species survival

The major species of the study area have decreased. But according to the respondents (>80%) some species survival has increased in the area. These species have ranked in the following order: *Eucalyptus camaldulensis* > *Azadirachta indica* > *Acacia nilotica* > *Feronia limonia* > *Excoecaria agallocha* > *Sonneratia apetala* > *Albizia lebbeck* > *Acacia catechu* > *Senna siamea* > *Avicennia officinalis* > *Sonneratia casualaris* > *Thespesia populnea* > *Citrus limon* > *Eithecellobium dulce* > *Swietenia mahagoni*

Even when vegetation coverage is reducing at such rapid rate, some species are growing well in saline condition (Dutta and Iftekhar, 2004). Plants vary in response to soil salinity. Salt tolerant plants are better able to adjust internally to the osmotic effects of high salt concentrations than salt –sensitive plants. Sail tolerant plants are more able to adjust and are injured at relatively low salt concentrations (SRDI, 2010).

4.3.3 Reduction of Agricultural crops

Due to the degradation of soil properties for continuous saline water inundation the production of agricultural crops has greatly been decreased in the study area. The agricultural area has been reduced faster than it was predicted a decade ago. Now the production of *aus* paddy is near zero percentage. But the production of *boro* and *amon* has greatly increased (these are mainly Horkoz, BRRI dhan-23L, BRRI dhan-23, BRRI dhan-40, BRRI dhan-41, HR-1, HR-14 etc.). Transplanted *aman* is cultivated in the rainy season as the salinity decreases during that period. The land suitability analysis for agricultural crops of the upazila shows that Sholadana, Lata, Kapilmuni unions and Paurashava are non-suitable for crops production due to acid soil, moderate to high salinity and soil remains mostly under saline water for shrimp culture (Alam *et at*., 2010). The remaining unions namely Gadaipur and Garuikhali are found moderate suitable for crops production due to very slight to moderate salinity in dry season, lack of irrigation water, soil nutrient and organic matter deficiency. Field preparation activities included the application of cow dung, urea and triple super phosphate (TSP), Zinc sulfate, nimbicidin (extract of neem seed) at 2t/ha, 70 kg/ha, 35 kg/ha, 3 ml/l and 1.5 l/ha respectfully.

People's opinion shows that during the last 40 years 58% of the agricultural crops have been reduced in the study area. Similarly, during the last 20 years the number has greatly reduced in 14%. From 1976 to 1996 this reduction was 44%.

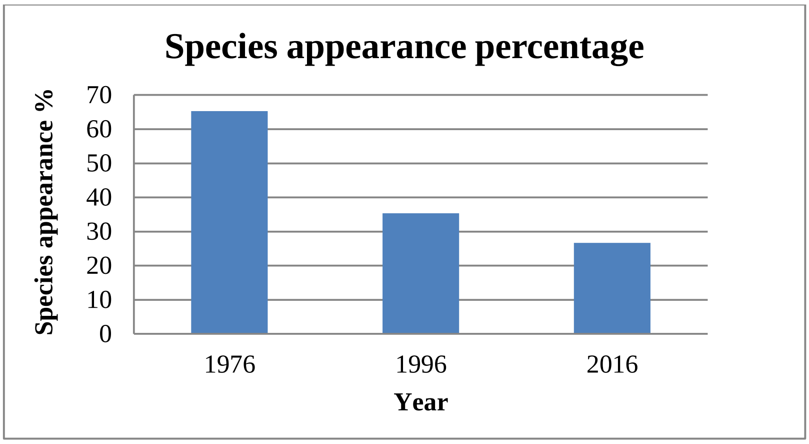


Figure: 4.4 People's perception on forty years status of agricultural crops

Day by day, the agriculture crops of the study area have reduced due to the effect of salinity (F=54.19061; d.f.= 2,72; P=4.37605E-15). Multiple comparisons with LSD test shows that within the study area the percentage of agricultural crops of 1976 has highly significant difference from 1996 and 2016 ($P<0.01$). But the percentage of agricultural crops of 1996 has significant difference with 2016 ($P<0.05$).

Table 4.4 represents the appearance of most observed agricultural crops in the year of 1976, 1996 and 2016 respectively.

Table: 4.4 People's opinion on the most observed agricultural crops according to sequence

Species serial no:	1976	1996	2016
1	*Oryza sativa*	*Oryza sativa*	*Oryza sativa*
2	*Corchorus capsularis*	*Capsicum annuum*	*Curcuma domestica*
3	*Curcuma domestica*	*Allium cepa*	*Allium sativum*
4	*Zingiber officinale*	*Allium sativum*	*Capsicum annuum*
5	*Capsicum annuum*	*Carica papaya*	*Allium cepa*
6	*Allium cepa*	*Curcuma domestica*	*Brassica campestris*
7	*Allium sativum*	*Brassica campestris*	*Corchorus capsularis*
8	*Brassica campestris*	*Corchorus capsularis*	*Carica papaya*
9	*Citrullus vulgaris*	*Lens culinaris*	*Lens culinaris*
10	*Daucus carota*	*Zingiber officinale*	*Pisum sativum*
11	*Vigna mungo*	*Pisum sativum*	*Daucus carota*
12	*Zea mays*	*Triticum astivim*	*Zingiber officinale*
13	*Lathyrus sativus*	*Vigna radiate*	*Triticum astivim*
14	*Saccharun officinarum*	*Daucus carota*	*Vigna radiate*
15	*Lens culinaris*	*Lathyrus sativus*	*Lathyrus sativus*

Source: Field survey, 2016.

People's observation on the disappearance of agricultural crops, are presented in Table 4.5. The respondents opinion shows that these crops are disappearing due to salinity.

Table: 4.5 People's observation on the disappearance of agricultural crops

Species	Reduction in last 40 years (%)
Citrullus vulgaris	87
Saccharun officinarum	80
Vigna mungo	76
Zea mays	73
Cicer arietinum	72
Curcuma domestica	71
Lathyrus sativus	70
Capsicum annuum	68
Cucumis sativus	67
Vigna radiate	65
Triticum astivim	63
Daucus carota	60
Pisum sativum	59
Lens culinaris	57
Corchorus capsularis	56
Oryza sativa	54
Carica papaya	48
Allium cepa	45
Brassica campestris	43
Zingiber officinale	42
Allium sativum	40

Source: Field survey, 2016.

According to people's observation the most ten disappearing agricultural crops are *Citrullus vulgaris*, *Saccharun officinarum*, *Vigna mungo*, *Zea mays*, *Cicer arietinum*, *Curcuma domestica*, *Lathyrus sativus*, *Capsicum annuum*, *Cucumis sativus* and *Vigna radiate*. People's observation shows about 41% of *rabi* (winter) vegetables have affected badly due to salinity.

Due to strong to very strong soil and water salinity, prolonged artificial water logging with saline water for aquaculture, presence of toxic potential acid sulphate soil in some areas and cyclone and tidal bore the land area for agricultural production have greatly decreased. In Paikgacha, between 1983 to 1984 the total agricultural lands were 68242 acre. But now it is only 55462 acre (Agriculture Extension Office, Paikgacha, 2016). 64% respondents think that the agricultural crops have been reduced in their locality. But a considerable portion of the respondents (25%) thinks that the agricultural crops have increased in their locality/village where very few people (11%) think that the contemporary and previous production are unchanged (Figure 4.5).

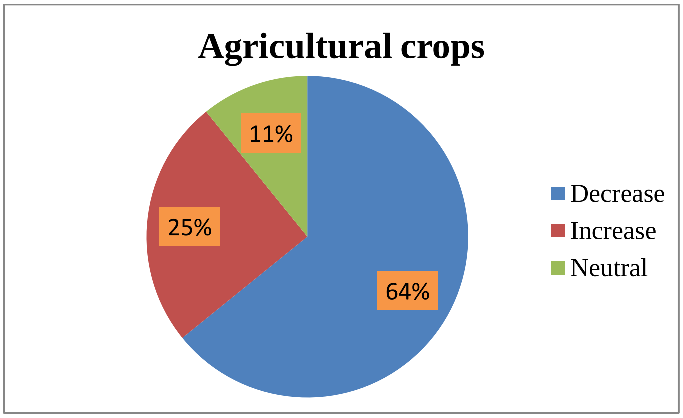


Figure: 4.5 People's opinion on agricultural crops

Increase in salinity intrusion and increase in soil and water salinity will have serious negative impacts on agriculture (Hossain, 2009). It has been also described that in Bangladesh, rice production may fall by 10% and wheat by 30% by 2050 (Synthesis Report, IPCC, 2007).

4.4 Shrimp Culture

Clay to loamy soils is suitable for the construction of ponds for shrimp culture. Before 40 years, most of the lands of Paikgacha upazila were used for agricultural purposes. The shrimp culture was started mainly after 1983. When people started to pick up saline water from outer river, the shrimp culture was established to give them more economic benefit. Hard working is not needed for shrimp cultivation but for agricultural production there is no alternative to hard working.

Besides, it needs less capital and so people are interested on it. But now a days, it is affected by outbreak of virus infection. On the other hand, the aristocrat's people possess most of the lands. So, it is less benefited for the middle class and the lower class people. The study shows 72% respondents are not interested for shrimp culture. Only 11% respondents are interested for shrimp culture and 17% respondents give their opinion for both shrimp culture and agricultural crops.

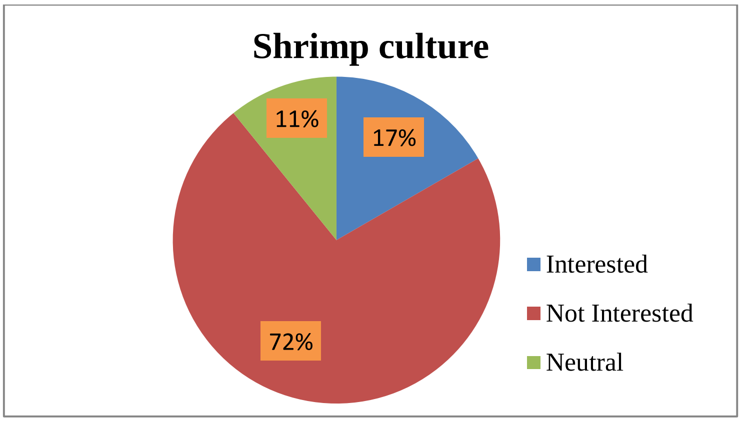
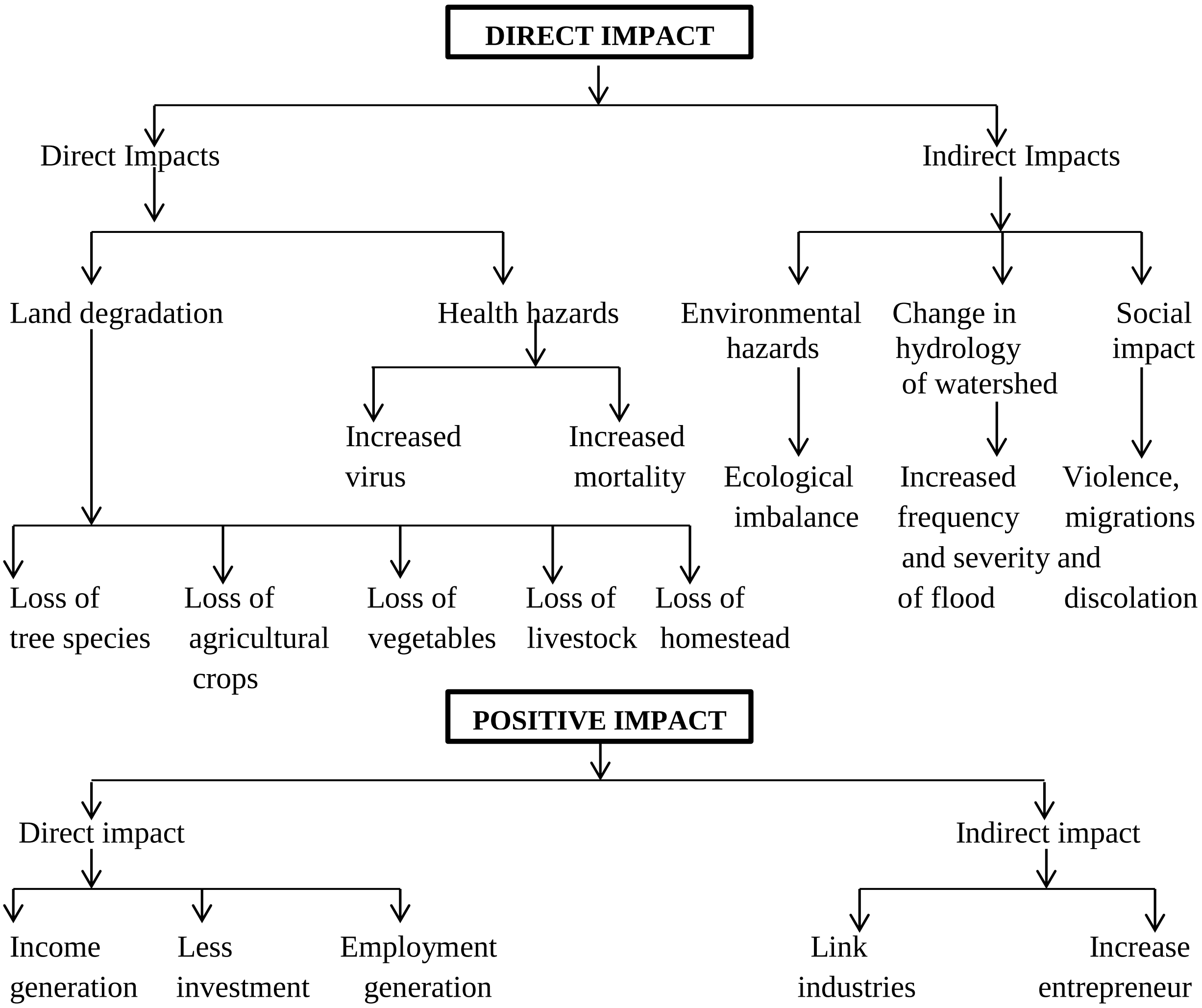


Figure: 4.6 People's opinion on shrimp culture

Soil erosion is the major problem in the study area. Most of the people are greatly concerned due to shrimp culture and they are interested for freshwater cultivation. But for the presence of saltwater in the outer area, they have nothing to do. There is no sufficient land which is not affected by saline water where they usually produce agricultural products. Not only in their agricultural land but also their dwelling place is affected by saltwater. They think the freshwater can provide them both fish and agricultural crops as well as it will also provide them healthy environment. Some people have taken shrimp culture as traditional system. The rearing of cattle, dug, chicken and others domestic animals are decreased severely due to enlarge their land for shrimp culture. They think due to salinity the environment of region is greatly affected as it reduces land stability. They also think the land will not be suitable for their future generation.

In the study Garuikhali, Gadaipur and more than half portion of Kapilmuni union are included under freshwater zone. The people of these areas are economically and environmentally stable than other salinity affected region. They have raised their economic condition by the enhancement of agricultural crops, nursery, freshwater fish and domestic animals.

IMPACTS OF SHRIMP CULTURE



Source: Field survey 2016, Land Zoning report (2009-2010)

4.5 Problems of land due to salinity intrusion

Majority of the people (80%) have thought that the decrease in the navigability of river has created siltation problems in Paikgacha upazila. The major portion of the respondents thinks that the production of tree and crop species has greatly decreased due to high soil salinity in their locality. The respondent’s opinion mentioning lack of drinking water supply is a great problem in their locality/village. The provision of arsenic-safe water is essential to safeguard the health of the rural population. The respondent’s opinion shows that about 1.5 feet dirt is created in summer season in the grass less land in their village/locality. They are more concerned about the adverse effects of natural calamities. The summary on the problems of lands due to salinity intrusion in Paikgacha upazila, are presented in Table 4.6.

Table 4.6 Summary on Problems of lands due to salinity intrusion in Paikgacha upazila

Problems /issues	%	Possible impacts	Surveyed areas
Siltation	80	• Increase in high land • Decrease in navigability of river • Flooding and water logging • Negative effect on irrigation process • Loss of fertility of agricultural land	Lata, Soladana, Kapilmuni, Paurashava
Less productivity	80	• Less tree species and agricultural crops • Less fisheries productivity • Less livestock	Lata, Soladana, Kapilmuni, Paurashava
Less fertility	75	• More chemical fertilizer (Urea, TSP, Potash, Earwax, lime etc.) • More insecticide • Less organic fertilizer • Land degradation	Lata, Soladana, Paurashava, Kapilmuni, Gadaipur, Garaikhali
Soil erosion	70	• Loss of organic matter and nutrients • Reduce in soil fertility • About 1.5 feet dirt in summer season	Lata, Soladana, Kapilmuni, Paurashava
Soil and water salinity	60	• High salinity in drought season (March-April) • Decrease in freshwater availability and shortage of irrigation water and more iron in water • Negative effect on crop production and homestead • Injurious to road, homestead and environment	Lata, Soladana, Paurashava, Kapilmuni, Gadaipur, Garaikhali
Arsenic pollution	60	• Injurious to human health • Induce skin disease and damage to internal organs • Long- term exposure to arsenic in drinking water can cause cancer in the skin, lungs, bladder and kidney	Lata, Soladana, Paurashava, Kapilmuni, Gadaipur, Garaikhali
Water logging	50	• Inadequate drainage • Pollution hazards • Water borne disease	Lata, Soladana, Kapilmuni
Desertification	45	• High probability of desertification within few decades • Injured by cyclone, tidal surge, flood etc.	Lata, Soladana, Paurashava

Source: Field survey, 2016.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Salinity intrusion has been proved to be critical both for the productivity of tree species and agricultural crops. Most of the tree species and agricultural crops are sensitive to salinity because of highly presence of salinity both in soil and surface water. However, the salinity level of most of the area has already exceeded the threshold limit and it is an increasing trend. The higher salinity level takes place during March-April. This problem becomes severe in hot and dry season rather than wet season. Although some saline tolerant species are growing well, the major proportion of the tree species are falling down their growth in such condition. Due to salinity agricultural land use of the area is very poor. Higher salinity has created pressure to the farmer by reducing their income source and food security. Although salinity intrusion provides some opportunities but such opportunities are not enough for sustainable development. The study finds that the people of low saline area are in better condition both in economically and environmentally than the high saline area. On the other hand, Bangladesh is a topmost risky country in the world in terms of climate change. Climate change has increased salinity level through the rise of sea level and more evaporation from higher temperature. For this reason, salinity intrusion and situation management is the main issue for Bangladesh. Climate change and the impact of cyclone and tidal surge are increasing salinity problem in the area again. So, after then if people are continuing to pick up saline water, one day the area may turn into desert. Both tree and crop species may be near critical percentage then and the area will be environmentally unsuitable both for human beings and for other living and non-living things. So, it is high time to pay attention to derive such a solution for such effect for long term sustainability.

5.2 Recommendations

Salinity intrusion affects the production of tree species and agricultural crops in Paikgacha upazila. From the study, some of the recommendations should be taken into accounts as follows:

- Taking necessary steps for ensuring fresh water resource by developing regional policy and strategy regarding trans boundary river, regional court of conflict regulation and strategic direction for Joint River Commission (JRC) to monitor river discharge and building the enclosed embankment system to promote reforestation and to ensure sustainable freshwater crop production in the area.
- Creating better condition in their life style by enforcing mixed farming system. People's perception shows that their life style can be changed by homestead and roadside plantation of tree species and improving crops production by cultivating *boro* and cereal from December to April; *aus* and *boro* from May to July and *amon* from August to November. Loan should be given to the farmer to increase agricultural production.
- Stopping the picking-up of saline water from outside rivers, canals and/or others areas both for socioeconomic and environmental consideration. Due to shrimp farming a few people get benefits where most of the people are faced a lot of loss. The poor farmers become poorer and finally they belong to the poverty level.
- Ensuring the planning and maintenance of irrigation system with canals through well-constructed and managed digital dressing of canals as well as reconstructing of previous canals.
- Ensuring the ownership of the land. In some areas the land owners are motivated to lease their land in lieu of agreement. In some cases this shrimp farming is going a position like nil cultivation of past time that is done forcedly by the higher society.
- Creating more employment by the enrichment of social forestry program, livestock farming system (milk farming, poultry farming and rearing of other farm animals) and fresh water fishing.
- Creating awareness among the local people regarding water resource, its use and management.
- More research can be conducted to find out the survival of tree and crop species in high salinity area.

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APPENDIX: 1

Title: Impact of salinity Intrusion on Trees and Agricultural Crops in the Coastal Area of Bangladesh: A Perception Analysis in Paikgacha, Khulna

Questionnaire for Field Survey

Date: …. /….. / 2016

Questionnaire No:

Location: Village: ………………………………… Union: ……………………………………

General information of the Respondent:

Name	Sex		Literacy (specify)	Illiterate	Occupation		Total no. of family member	Total Income (yr.)	Total land
	Male	Female			Primary	Secondary			

Total land holding of the practiced person:

Homestead	Agricultural	Shrimp pond	Fallow	Urban

1. What kinds of tree species were found mainly before 40 years?

2. What kinds of tree species were found mainly before 20 years?

3. What kinds of tree species are present now?

4. What kinds of agricultural crops were found mainly before 40 years?

5. What kinds of agricultural crops were found mainly before 20 years?

6. What kinds of agricultural crops are present now?

7. Is there any decreasing of tree species? Why?
    1. Yes; why? ....
    2. No; why? …………………………………………………………………………
    3. Neutral; why? ……………………………………………………………………..
8. Is there any decreasing of agricultural crops? Why?
    1. Yes; why? ....
    2. No; why? …………………………………………………………………………
    3. Neutral; why? ……………………………………………………………………..
9. Is salinity increasing in the area day by day?
    1. Yes; why? ....
    2. No; why? …………………………………………………………………………
    3. Neutral; why? ……………………………………………………………………..
10. Is there any impact of salinity on tree species? How?

    (a) Yes (b) No If yes; how? …………………………………………………

    ……………………………………………………………………………………………
11. Do you think tree growth is satisfactory?

    (a) Yes (b) No Give reason: ………………………………………………………...
12. Is there any impact of salinity on agricultural crops? How?

    (a) Yes (b) No If yes; how? …………………………………………………

    ……………………………………………………………………………………………
13. Is shrimp culture increasing in the area day by day? Why?
    1. Yes; why? ....
    2. No; why? …………………………………………………………………………
14. Do you think that species composition in the homestead has been changed due to shrimp culture? Why?
    1. Yes; why? ....
    2. No; why? …………………………………………………………………………
15. Is the salinity level is high, medium or low?

1. High
2. Medium
3. Low

16. Are you interested with shrimp culture? Why?
    1. Yes; why? ....
    2. No; why? ………………………………………………………………………………
    3. Neutral; why? ……………………………………………………………………..

17. Is there quick decrease of species composition due to shrimp culture?

18. Are there any problems in your land? If any problems, what kinds of problems?

- Problem related to trees……………….............
  a)
  b)
  c)
- Problem related to agricultural crops……………
  a)
  b)
  c)
- Problem related to fish culture……………………
  a)
  b)
  c)

19. Recommendation from respondent:

APPENDIX: 2

ANALYSIS OF VARIANCE TEST OF TREE SPECIES

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
1976	91	69.32552572	0.761818964	0.271521636
1996	91	53.47251374	0.587610041	0.314517682
2016	91	48.19480082	0.529613196	0.334127115

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.658167681	2	1.3290838	4.3331851	0.0140505	3.0292180
Within Groups	82.81497896	270	0.3067221			
Total	85.47314665	272				

APPENDIX: 3

LEAST SIGNIFICANT DIFFERENCE TEST OF TREE SPECIES

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Per

LSD

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1976	1996	.174209*	.082104	.035	.01256	.33586
	2016	.232206*	.082104	.005	.07056	.39385
1996	1976	-.174209*	.082104	.035	-.33586	-.01256
	2016	.057997	.082104	.481	-.10365	.21964
2016	1976	-.232206*	.082104	.005	-.39385	-.07056
	1996	-.057997	.082104	.481	-.21964	.10365

*. The mean difference is significant at the 0.05 level.

APPENDIX: 4

ANALYSIS OF VARIANCE TEST OF AGRICULRURAL CROPS

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
1976	25	46.79059849	1.871623939	0.058298849
1996	25	31.05737503	1.242295001	0.084674326
2016	25	25.72427395	1.028970958	0.122669265

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9.596884224	2	4.798442112	54.19061176	4.37605E-15	3.123907449
Within Groups	6.375418561	72	0.08854748			
Total	15.97230279	74				

APPENDIX: 5

LEAST SIGNIFICANT DIFFERENCE TEST OF AGRICULRURAL CROPS

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Per

LSD

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1976	1996	.174209*	.082104	.035	.01256	.33586
	2016	.232206*	.082104	.005	.07056	.39385
1996	1976	-.174209*	.082104	.035	-.33586	-.01256
	2016	.057997	.082104	.481	-.10365	.21964
2016	1976	-.232206*	.082104	.005	-.39385	-.07056
	1996	-.057997	.082104	.481	-.21964	.10365

*. The mean difference is significant at the 0.05 level.