The Effect of Salinity in the flora and fauna of the Sundarbans and the impacts on local livelihood

Amreen Jahan
The Effect of Salinity in the flora and fauna of the Sundarbans and the impacts on local livelihood

Amreen Jahan

Supervisor: Torsten Krause
Evaluator: Patrik Rönnbäck
# Content

1. **Introduction** ........................................................................................................1  
   1.1. Geographical Description and Composition of Forest ..................................1  
   1.2. Population ....................................................................................................3  
2. **Problem Formulation** .......................................................................................3  
   2.1. Background of the Problem ........................................................................4  
   2.2. Research Questions ......................................................................................5  
3. **Methods** ..........................................................................................................5  
4. **Results** ............................................................................................................7  
   4.1 Literature Review ..........................................................................................7  
   4.1.1. Flora ........................................................................................................8  
   4.1.2. Fauna ......................................................................................................12  
   4.1.3. Effect on Fisheries .................................................................................13  
   4.1.4. Effect on Livelihood ..............................................................................13  
   4.2. Questionnaire finding ..................................................................................15  
5. **Discussion** ......................................................................................................17  
6. **Conclusion** ......................................................................................................21  
7. **Acknowledgement** ..........................................................................................22  
8. **List of figures and tables** ...............................................................................23  
9. **Reference list** ..................................................................................................24  
Annex 1: Questionnaire ...........................................................................................27
The Effect of Salinity in the flora and fauna of the Sundarbans and the impacts on local livelihood

AMREEN JAHAN


Abstract

The Sundarbans is a great source of lives, ecosystem and livelihood of the people in the southwest part of Bangladesh. Many natural and manmade issues are threatening this area. Salinity is one of such issues, which creates difficulties in the natural ecosystem and livelihood of the people in the Sundarbans. This paper aims to figure out salinity problems and solutions. Forest is a wealth for a country. Especially a rare kind of forest like ‘Sundarbans’ really deserve this concern to protect its flora, fauna and most importantly people associated with it. Therefore, it is important to figure out the reasons of increasing salinity, how it affects the flora and fauna and especially how the salinity issues affect livelihood of the people. To figure out the research questions, some methodologies have been chosen. Literature review and questionnaire are the main ways selected to sort out the problems and solutions. Literatures were sorted upon on the basis of keywords-salinity, flora, fauna and livelihood in the Sundarbans. Some of the literatures contain different surveys that have been examined to get some results. Apart from that, a village in the Sathkhira district named ‘Harinagar’ was selected to carry out a survey to know the effect of salinity in the daily life and livelihood of the people. Some results show direct effect in flora, fauna, fisheries and livelihood in connection to salinity. It was found in the research study that, salinity is increasing in the Sundarbans due to climate change, sea level rise and other anthropocene reasons. Top dying diseases are affecting some major flora species due to salinity. The lower saline prone plants are replacing by saline zone plants. The agricultural lands are losing fertility for the soil salinity. The fishes of fresh water are decreasing. Some fish species cannot breed in the saline water which results loss of diversity in the fishes. Furthermore, from the result of the questionnaire it was found that the people are ultimate victim of the salinity issues as majority of them are dependent on the forest resources. The diversity of their livelihood is somehow diminishing, though direct connection with salinity has not been established from the questionnaire. All the components of the forest such as flora, fauna, fisheries and people are important to complete the biodiversity of the forest. Proper fresh water management, alternative livelihood, awareness of the people can be some solutions. However, salinity is a natural and scientific phenomenon. It seems difficult to get some sustainable solutions when local people have less to do. Government, NGOs and INGOs have to take proper action in collaboration with local people to improve their livelihood.

Keywords: Sundarbans, Forest, Salinity, Flora, Fauna, Sustainable Development

Amreen Jahan, Department of Earth Sciences, Uppsala University, Villa Vågen 16, SE-75236 Uppsala Sweden
The Effect of Salinity in the flora and fauna of the Sundarbans and the impacts on local livelihood


Summary

Sundarbans, one the largest Mangrove forests in the world, provides a rich ecosystem in the south west part of Bangladesh. A good amount of total flora, fish fauna, avifauna, and aquatic fauna of Bangladesh are found there. More than 7 million people live in this part and depend on the forest for livelihood. Therefore, Sundarbans mangrove forest is embedded with an enormous part of biodiversity. Evidence shows that salinity is a big issue in the Sundarbans, which affects the whole biodiversity there. Climate change is one of the responsible factors for increasing salinity along with some man made reasons. However, in this paper, before going to the salinity issue, the geographical location of the Sundarbans, composition of the forest, information about population have been mentioned to familiarize the audience about the situation. Background information of the salinity issues is vividly described. Furthermore, description of the diverse ecosystem, flora, fauna and fisheries are also an attractive part of the study. These studies are done from the literature review, an important methodology of this thesis. The research questions are formulated based on the salinity problems and its effect on flora, fauna and livelihood. By the means of literature review and questionnaire, it has been attempted to find the answers of research questions. The questionnaire was conducted in a village of the Sundarbans that mainly focuses on livelihood parts. In the result section, the findings from the literature review and questionnaire have been discussed. The flora, agricultural lands, habitats of the animal are decreasing due to salinity. Most of the village people depend on the natural resources for their livelihood. Their livelihood mean are decreasing for the decreased agricultural lands and reduced aqua fauna. An analysis of these findings has been made in the discussion part of this research. Some solutions have been come out from the discussion. Therefore, the effect of salinity has been examined thoroughly in the paper.

Keywords: Mangrove, biodiversity, Fisheries, Village, livelihood, Climate change, Sustainable Development

Amreen Jahan, Department of Earth Sciences, Uppsala University, Villa Vägen 16, SE-75236 Uppsala Sweden
List of abbreviations

BSMF-Bangladesh Sundarban Mangrove Forest
NFTP- Non-timber Forest Products
SIZ-Sundarbans Impact Zone
SLR- Sea level rise
SMF-Sundarbans Mangrove Forest
IWM-Institute of Water Management

Glossary of Terms

Micromhos- the unit of electric conductance is siemens. 1 siemen = 1000000 micromhos.

Ppt- stands for parts per thousand, measurement of salinity. For example, 35 ppt means in every kilogram (1000 grams) of seawater, 35 grams are salinity.
1. Introduction

The Sundarbans is considered as the largest remaining area of mangroves forests in the world. It provides one of the most affluent ecosystems in the world. It is extremely rich with large diverse scale of flora and fauna. The Sundarbans is the home of more than 300 species of plants, 400 species of fisheries and 270 species of birds. Other than the home birds, it also provides shelter to the migratory wither birds and gulls. The Sundarban is the prime habitat of the national animal of Bangladesh, the Royal Bengal Tiger, which is a rare animal in the whole world (Ministry of Environment and Forest, Government of Bangladesh, 2005, p. 5). ‘The Sundarbans were declared as Sundarban Reserve Forests in 1876 and as a Natural World Heritage Site by the UNESCO in 1997 to conserve all its unique flora and fauna’ (Aziz & Paul, 2015, p. 260). Salinity is one of the problems in that area that has a great impacts in the ecosystem, its flora and fauna, but ultimately also its people. These salinity rises have many negative impacts on aquatic species especially on their reproduction. Ultimately it affects fish abundance and fish migration that will affect the livelihood of the people who depend on fishing for food and income (Dasgupta, Huq, Mustafa, Sobhan, & Wheeler, 2016, p. 3). Therefore, the overall goal of this research is to study how salinity is affecting the flora and fauna, and as a consequence, how increasing salinity impacts the livelihood of the people. Various literatures have been examined to carry out the results to reach the research goals. Apart this, most importantly, a survey was done among the local people of the Harinagar village of the Sundarbans. The majority of the people are dependent on the natural resources and ecosystem services for their food intake and income. Therefore, it was found fruitful to do the survey on them to carry out the research how the salinity is influencing their livelihood. Furthermore, attempts have been taken to provide insights into the problem and thoughts for a sustainable development on the accounts for increases in the level of salinity.

1.1 Geographical Description and Composition of Forest

The area of the Sundarbans is about 10,000 km2, which is shared by Bangladesh and India. Among the total area, about 6,000 km2 are in the southwest part of Bangladesh and the rest are in India (Fig. 1) (Getzner & Islam, 2013, p. 75). Among the Bangladeshi part of 6,000Km2 (approx.), about 4100 km2 are landmass and remaining 1900 km2 are water bodies (e.g. rivers, canals and creeks) (Rahman & Asaduzzaman, 2010, p. 37). There are three wildlife sanctuaries in the Bangladesh Sundarban Mangrove Forest (BSMF): i) Sundarbans West Wildlife Sanctuary; ii) Sundarbans East Wildlife Sanctuary; and iii) Sundarbans South Wildlife Sanctuary. The areas of these sanctuaries are 71,502ha, 31,226ha and 36,970ha respectively. The sanctuaries are situated in the islands of Sundarban Forest Division, Khulna which are west of the river Ganges, Brahmaputra and Meghna. (Rahman & Asaduzzaman, 2010, p. 37).
In the Sundarbans Impact Zones, the land cover types are barren land, grassland, vegetation and water body. Barren lands are sandy surface, grasslands are formed with small wood plants, vegetation is referred as dense mangrove and non mangrove plantation and water bodies are river channels (Mondal, 2017, p. 9).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area</td>
<td>%</td>
<td>Area</td>
<td>%</td>
<td>Area</td>
</tr>
<tr>
<td>Water body</td>
<td>5488.04</td>
<td>58.79</td>
<td>5456.85</td>
<td>58.49</td>
<td>5341.20</td>
</tr>
<tr>
<td>Barren land</td>
<td>820.12</td>
<td>8.78</td>
<td>308.71</td>
<td>3.31</td>
<td>154.88</td>
</tr>
<tr>
<td>Grass land</td>
<td>526.17</td>
<td>5.64</td>
<td>1132.98</td>
<td>12.15</td>
<td>1513.15</td>
</tr>
<tr>
<td>Vegetated land</td>
<td>2501.05</td>
<td>26.79</td>
<td>2429.86</td>
<td>26.05</td>
<td>2308.36</td>
</tr>
<tr>
<td>Total area</td>
<td>9335.38</td>
<td>100</td>
<td>9328.40</td>
<td>100</td>
<td>9317.59</td>
</tr>
</tbody>
</table>

Table 1. Different land covers in Sundarbans (Mondal, 2017, p. 9)

According to the Landsat images of the Sundarbans, between 1973 to 2010 (Table 1), it is found that area of grasslands increased while area of vegetation lands had decreased.
1.2. Population

As per latest census of 2011, 7.8 million people live in the different districts of Sundarbans impact zone (SIZ) and in the sub districts of SIZ, the population is 2.16 million (Fig. 3). The population from the first census in 1974 had been increased except a slight decrease in 2011 (Mondal, 2017, p. 5).

![Fig. 3. Population size in Sundarbans Impact Zone (SIZ) (Mondal, 2017, p. 5)](image)

The population growth (in %) in the SIZ districts are mostly positive (Table 2).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagerhat</td>
<td>2.62</td>
<td>1.6</td>
<td>1.75</td>
<td>0.79</td>
</tr>
<tr>
<td>Satkhira</td>
<td>3.45</td>
<td>1.7</td>
<td>1.66</td>
<td>1.56</td>
</tr>
<tr>
<td>Khulna</td>
<td>5.12</td>
<td>2.48</td>
<td>1.28</td>
<td>1.7</td>
</tr>
<tr>
<td>Pirojpur</td>
<td>2.35</td>
<td>1.41</td>
<td>1.16</td>
<td>0.44</td>
</tr>
<tr>
<td>Barguna</td>
<td>2.53</td>
<td>1.89</td>
<td>1.36</td>
<td>0.9</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>2.48</td>
<td>2.35</td>
<td>2.01</td>
<td>1.58</td>
</tr>
</tbody>
</table>

*Table 2. Population growth rate in SIZ districts (Mondal, 2017, p. 5)*

Generally, the structure of population in terms of size and composition depends on the allocation of the natural resources as it provides food and means of livelihood to the people. Therefore, where the woods, plants and fresh water are more available, people like to start staying there. It is found in the forest inventory between 1983-1996, with an increase of 20% population in SIZ, the number of trees in the Sundarbans Reserve Forest (SRF) had been decreased by 25%. In the rural part, this percentage is high, because poor people are more dependent on forest resources (Mondal, 2017, p. 10).

2. Problem Formulation

Salinity is an important impediment on the growth of mangrove forest and distribution. The physiographic nature of the soil and water is being changed by the salinity intrusion, which affects supporting services of the flora, fauna and fisheries such as habitat. Therefore, habitat loss of plants and animals are occurring frequently for salinity intrusion. The nursery ground to breed for fisheries is also diminishing. (Haque & Reza, Salinity Intrusion Affecting The Ecological Integrity of Sundarbans Mangrove Forests, Bangladesh, 2017, p. 140).

The agricultural lands are seriously affected by salinity because most crops like rice,
wheat, etc. require fresh water. Salinity in the water will seriously hinder the irrigation process in agricultural lands (Haque & Reza, Salinity Intrusion Affecting The Ecological Integrity of Sundarbans Mangrove Forests, Bangladesh, 2017, pp. 140-141).

The most importantly, the people who are dependent on the agriculture and fisheries for their food and livelihood are more vulnerable due to this salinity intrusion.

2.1. Background of the Problem

Global climate change is affecting the whole country due to the geographic characteristics of Bangladesh being a low-lying coastal country. As a consequence, the sea level is rising and the fresh water resources are becoming more saline. The change or increase in temperature is also leading to greater evapotranspiration water and thus raising salinity levels in the remaining fresh water bodies (rivers) and aquifers (IPCC, 2014). Rainfall and Himalayans river flow are also affecting the salinity balance of the water bodies in the Sundarbans. With this natural reasons, there are some man made reasons of increasing salinity such as building dam, extortion of soil and water, deforestation and so on.

2.1.1. Reasons for increasing Salinity

i. Sea Level Rise (SLR)

Sea level rise is an important reason for salinity intrusion in the fresh water. The fresh water becomes scarce due to salinity. With sea level rise, the ground water also becomes salinized. Along with the water, the soil also absorbs salt, which creates soil salinity. The soil and water salinity effect on the physical characteristics of the soil and water in the coastal parts due to sea level rise (Haque, Reza, Rahim, Abdullah, Elfithri, & Mokhtar, 2015, p. 673).

Institute of Water Management (IWM) in Bangladesh developed a salinity model to track the effect of salinity for the sea level rise. It has been considered that with the sea level rise of 23 cm, the isohaline lines enter into the inland. The penetration into the inland would be significant as per indication where the minimum salinity is 1 ppt or more than that in the rivers of the western and central Sundarbans. If the seal level increases to 44 cm, the penetration would be higher as expected for the isohaline limits of 1, 5 and 10 ppt. However, the model has some limitations as it used a fixed salinity boundary in the downstream of the rivers. The surface flows can be reduced in the low flow period. But it gives an indication that salinity intrusion is extended along with the rivers in the Sundarbans (Agrawala, Ota, Ahmed, Smith, & Aalst, 2003, p. 44).

The SLR rate in the coastal area of Bangladesh seems higher than the average global SLR during last century. The situation will even worse in the future. The future SLR will affect in the habitat of the animal and plants, biophysical structure of the vegetation, spatial distribution of the plants and also the community composition (Sarkar, 2017, p. 31).
Farakka barrage plays an important role for the salinity intrusion in the southwest part of Bangladesh. It was built by India in Murshidabad district, only 11 miles away from Bangladesh border. The aim was to divert the water of Ganges to Bhagirati-Hoogly River in order to improve the navigability in the Calcutta Port, India (Mia, Hossain, Hossain, & Farzana, 2009, p. 89). Through the Farakka barrage, the fresh water is withdrawn in the dry season by India, which results the fresh water scarcity in the Bangladesh part of the Sundarbans (Aziz & Paul, 2015, p. 242). After the Farakka barrage had been built in 1975, the salinity in that part increased tremendously. In the pre-diversion period of Farakka barrage (1974), the salinity level was 380 micromohs and in 1992 it had been reached at 29,500 micromohs. In the pre-diversion period, 7,000 sq. miles had been engulfed by 500 micromohs salinity level, which became 12,000 sq. miles in the post-diversion period (Rahman & Asaduzzaman, 2010, p. 38).

The fresh water flow from the rivers helps to balance the ecosystem in the Sundarbans by modulating salt-water toxicity and generates suitable environment for the mangrove species. Therefore, fresh water supply is very important to grow plants in the Sundarbans. After the construction of the Farakka barrage, the fresh water supply becomes 65% less than previous. As a result, salinity level increases in the water and soil and ultimately disturbs the ecosystem (Sarkar, 2017, p. 31).

2.2. Research Questions/hypothesis

The main aim of this research is to analyze the effect of salinity in the flora, fauna, fisheries and the livelihood of the local people. Connecting the ecological impacts of salinity with the social impacts, this paper aims to find some pathways of sustainable solutions to the problem. While addressing the research questions and solutions, attempts have been made to focus on some new things. The concerned comprehensive connection among flora, fauna, and livelihood of the people in terms of salinity has been addressed in this paper, which seems unique. It gives a broad picture at one frame. Beside this, the disturbed sustainability of the forest due to salinity and sustainable solutions are least discussed in other literary works available as open sources. Therefore, in this research questions sustainability gets importance. This thesis addresses the following research questions:

- To what extent are the flora and fauna of the Sundarbans affected by the increase in salinity?
- How does salinity affect fisheries and local livelihoods?
- What are potential solutions to adapt to or counteract salinity in the Sundarbans?

3. Methods

‘Research methods are the various procedures, schemes and algorithms used in research’ (Rajasekar, Philominathan, & Chinnathambi, 2013, p. 5). Several procedures were carried out to do this research. The research questions have been formulated at first. To formulate research questions three things were under consideration: what, who and how. To elaborate this- ‘What is the problem’ ‘Who are
affected by this’ and ‘How are they affected’. After formulating research questions in section 2.2, the research design was prepared. Literature review has been chosen an important tool to start the research study. Some previously done surveys and scientific methods that expressed in these chosen literatures have been examined and used to show the results of salinity effect.

![Satellite view of survey site](image)

*Fig. 4. Satellite view of survey site (Google, 2018)*

Beside that, to get informed about the livelihood of the people and its relation to salinity in the Sundarbans, a questionnaire was developed. It was carried out in the Harinagar village in Sathkhira District (Fig. 4). Total 18 local people responded the questionnaire. The questionnaire is placed at **Annex A**. The goal of this questionnaire is to find out the basic livelihood of the people there and how these are connected to salinity. However, with the livelihood, the basic activities such as food collection process, dependency on agriculture for food, environmental issues are also considered. The questionnaires were administered at a market where different people from different occupation came to shop. The process of selecting respondents was random and they were explained about the purpose of the questionnaire, and subsequently they were asked about their willingness to take part. The questionnaire focused in three important criteria: i) Effect of salinity in the daily life ii) Livelihood means affected by salinity iii) Environmental Impact and iv) Solution. The answers were formed in yes/no form. However, to make the answers more accurate two other options were set beside yes/no-do not know and do not want to answer. From the literature review and the response from the people, some solutions have been discussed at the last part of the research. The research process has been shown in a flowchart in Fig. 4.

![Research Process in Flow Chart](image)

*Fig. 5. Research Process in Flow Chart (Kothari, 2004, p. 11)*

Literature review has been chosen as a method of the research. Since this is a short thesis, literature review is less time consuming than fieldwork. Without scientific knowledge and tools it is also difficult to know the effect of salinity on flora and fauna through site visit. Moreover, the studies in the literature were done in many parts of the Sundarbans. It also gives the opportunity to justify the general information by comparing each other. In this research, some literatures were selected
to find the answers of research questions. To find out the literature, different key words were used such as ‘salinity intrusion in the Sundarbans’, ‘effect of salinity in flora/fauna’, ‘livelihood and salinity in Sundarbans’. Beside this, to find out the background information about the geographical information, forest composition, basic information about fisheries, flora and fauna, some general literatures were chosen. The questionnaire was also chosen as a method to get the feedback directly from the people about the effect on salinity on their livelihood. It has given a practical outlook of the relation of salinity to their livelihood, which has a great influence in the thesis.

There were some limitations in the methods chosen. In the literature review part, main limitations were data accuracy and timing. Some data seems inaccurate in case of general information such as area of Sundarbans. Also, many statistical data were very old compared to the date of published articles. These literatures are mainly based on the problems rather than solution. Therefore, it was difficult to come out with good solution from the literature review.

4. Results

4.1. Literature Review

There are abundant of scientific literatures available on the Sundarbans which covers a large range of topics such as salinity intrusion, remote sensing, ecology, biodiversity, aquatic species, mammals and so on (Rahman & Asaduzzaman, 2010, p. 38). This research work has been done through studying more than 30 papers. The gest of some key literatures has been provided in Table 3:

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of Climate Change and Acquatic Salinization on Fish Habitats and Poor Communities in Southwest Coastal Bangladesh and Bangladesh Sundarbans, Dasgupta, S., Huq, M., Mustafa, M. G., Sobhan, M. I., &amp; Wheeler, D. (2016).</td>
<td>Survey regarding salinity in the water of rivers, how salinity effects on fisheries, effect of salinity in the livelihood of the people</td>
</tr>
</tbody>
</table>

*Table 3. List of key literatures and contents (adopted by author) from the literature review*
Background information of ecological and social aspects of Sundarbans and knowledge regarding the effects of increasing salinity on local flora and fauna was obtained from the literatures. Results/tables of some scientific survey regarding salinity were taken out to find the answers of research questions.

4.1.1. Flora

The Flora of Sundarbans is mainly composed of mangrove plants. These species are divided into two types, one is ‘true mangrove’ species and another is ‘mangrove associate’ species. In 1992, Duke recognized 69 true mangrove species. These species belonged from 26 genera and 20 families. Again, in 2001, 65 species were recognized by Kathiresan and Bingham belonged from 22 genera and 16 families (Gopal & Chauhan, 2006, p. 343). From the 65 species of flora, 20 are small tree species, 10 are large tree species, 25 are shrubs and 10 are herbs. The 10 large tree species are true mangrove where 7 more species are also may be added as Mangrove trees (Aziz & Paul, 2015, p. 252). In BSMF, members of Sterculiaceae (Heritiera) and Euphorbiaceae (Excoecaria) dominate more (Gopal & Chauhan, 2006, p. 343).

Effects on Salinity on Flora

The salinity level in the rivers and canals are increasing specifically in dry season due to lack of fresh water inflow into the Sundarbans, which is negatively impacting on flora and fauna of the area.

i) Top Dying diseases

The major mangrove species are dying as a consequence of salinity. ‘Top Dying’ is a type of disease, which is prominent in the ‘Sundari’ tree (Heritiera fomes). From a survey conducted by Bangladesh Forest Department, 5-6% of ‘Sundari’ trees are affected by this disease. The disease spread in the high salinity area and already 50% of the ‘Sundari’ trees that are in high salinity zone are affected. From 1980, this disease has spread on a great scale (Rahman, Rahman, & Islam, 2010, p. 82). Especially in dry month, when there is a less supply of fresh water, the salinity increases and as a result the top dying disease increases (Hussain & Acharya, 1994).

A survey was conducted on the top dying diseases by the Forest Department of Bangladesh during 1994 to 1996. It was found in that survey that every year an average of 134,292 m3 of H. fomes have been died from the disease. Therefore, the disease is responsible for the biodiversity loss in the Sundarban. The salinity level in some rivers and canals in one of the Satkhira range of Sundarbans is 27-33%, while the accepted level is 5-10%, found by the Forest Department Research Centre of Bangladesh. This salinity rise in the waterbodies poses big threat for the extinction of the trees. In this investigation, it is found that from 1985 to 2000, within these 15 years, 68% forest resources had reduced. According to the observation of forest department, 17% top dying trees found dead from the registered 85525 top dying trees (Rahman & Asaduzzaman, 2010, p. 38).
ii). Loss of species due to transformation in saline zone

Salt is a barrier for absorbing water for a plant. If there is a high salt concentration in the moist soil, it creates water stress and drought, which ultimately is the reason of death for the mangrove trees. Some parts of salt such as sodium, chlorine might create toxic effect. The soil with salinity may interfere with the nutritional balance, which ultimately negatively affects plants (Rahman M. R., 2014, p. 179).

The soil of the Sundarbans is slightly alkaline to neutral with a range of pH 5 to 6.8, depending on the presence of high organic mater in soil (Rahman & Asaduzzaman, 2010, p. 39). There are two following zones in terms of salinity in Sundarbans:

1. Mesohaline zone: This is moderately saline zone, the salinity level is 6,250 to 12,500 micromhos. In this zone, ‘Gewa’ (scientific name Excoecaria agallocha) is the dominant species.

2. Polyhaline zone: The zone is saline and the salinity level is exceeding 12,500 micromhos. ‘Goran’ (Scientific name Ceriops decandra) is the dominant species here (Participatory Research and Development Initiative).

There is another zone named oligohaline where ‘Sundari’ is the dominant species. The salinity penetration in the soil is the reason of transforming oligohaline to mesholine area and meshohaline to the polyhaline area according to several research report (Participatory Research and Development Initiative). The salinity of oligohaline is less than 5%, mesohaline is 5% to less than 18%, polyhaline is 18% to 30% (Aziz & Paul, 2015, p. 248).

iii. Carbon sink

The mangroves are an important source of carbon sink. University of Calcutta conducted a research and found that 4,150,000,000 tons Carbon dioxide had been soaked by the Sundarbans, that had a value of $79 billion in the international market (Mahadevia & Vikas, 2012, p. 8). If the mangrove species are reduced due to salinity, the amount of carbon will increase resulting the disturbance of ecological balance.
Effects on agricultural land

Bangladesh is an agricultural country. Due to urbanization and other human needs, the agricultural lands are decreasing very quickly. It is found that 100 thousand hectares of arable land in Bangladesh are exhausted and lost annually. In the Sundarbans, people mostly depends on agriculture for their basic need such as food, livelihood. Various level of salinity in the soil and water is responsible for the agricultural land loss along with the human made reason and urbanization. The tidal flooding during monsoon, movement of saline ground water during summer, shrimp farming and several human made causes salinize coastal agricultural lands. The salinity problem becomes severe and affects the agricultural land as the desiccation of soil affects agriculture (Ministry of Environment and Forest, Government of Bangladesh, 2005, p. 5).

Salinity in the agricultural lands is considered as an important factor for reducing yields and limiting crop production. Many agricultural regions in the Sundarbans became less productive for the increased soil salinity in the last couple of years. For example, in the Asasuni upazila, Satkhira district, one of the important rice production regions of Bangladesh, the rice production has been reduced tremendously. It is found in different salinity surveys, various levels of soil salinity affected 70% of cultivated lands (approximately 1.02 million hectares) in the south coastal parts of the country (Haider & Hossain, 2013, p. 417).

i). Positive effect of salinity in the growth

The growth and development of mangrove species is hindered by high salinity. The structural development is also negatively affected by salinity stress. However, in a survey, it was aimed to find the salinity effect on several mangrove species. There, the major dominant species H. fomes showed that increasing soil salinity has a negative effect on their growth. Other species were found to show positive response with the increased salinity. The Mangrove species are not fond of salts, some of them have the adaptation power with the increased salinity (Sarkar, 2017, p. 48). The species that showed positive responses are listed in Table 4:

<table>
<thead>
<tr>
<th>Mangrove Species</th>
<th>E. agallocha</th>
<th>C. decandra</th>
<th>X. mekongensis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics of positive responses</td>
<td>High protein depletion rate</td>
<td>High protein depletion rate</td>
<td>High germination and seedling growth</td>
</tr>
<tr>
<td></td>
<td>Optimal photosynthesis under salt stress</td>
<td>Salt exclusion ability of roots</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salt accumulation ability in leaves</td>
<td>Ability to invade highly saline and degraded habitats</td>
<td></td>
</tr>
</tbody>
</table>

*Table 4. Positive responses of some Mangrove species on high salinity stress (Sarkar, 2017, p. 48).*
Surveys to investigate salinity affect on Plants

Many surveys have been conducted in the referred literatures. Some of these are discussed here. These studies are done by the respective authors as referred. Some of these are scientific. However, attempt has been made to get a summary from these surveys to reach into a conclusion and get answers for the research question.

A survey was done to find the effect of salinity on the tree diversity and also on their abundance in an area of BSMF in March, 2010. Eight mangrove species were recorded that were distributed in the four ranges. Maximum five species were found in low saline zones. It is found that *Ceriops decandra* (goran) had been increased in the north-eastern part replacing the dominant plant *Heritiera fomes* (sundori). *Ceriops decandra* (goran) is a salt tolerant plant while *Heritiera fomes* (sundori) is a fresh water based plant (Ahmed, et al., 2011, p. 197).

The changes in the forest cover from 1989 to 2010 were tracked in the Nalianala and Chandpai ranges. Some salt tolerant species such as *B. sexangula*, *E. agallocha*, *S. apetala* have been increased within these 20 years, while *H. fomes* has been decreased dramatically (Table 5). In the first ten years, the forest area increased form 44,301.33 hectare to 44,327.83 hectare, but in the second ten years, the forest area 42,703.66 hectare. Changes are tremendous in the decrease of the *H. fomes*, a major mangrove species. Changes in salinity is also responsible for the spatial distribution of plant communities (Ahmed, et al., 2011, p. 200)

<table>
<thead>
<tr>
<th>Classes</th>
<th>Forest cover by tree</th>
<th>Changes of forest cover</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>H. fomes</em></td>
<td>23027.77</td>
<td>19308.51</td>
</tr>
<tr>
<td></td>
<td>(16.15)</td>
<td>(15.02)</td>
</tr>
<tr>
<td><em>E. agallocha</em></td>
<td>15184.45</td>
<td>15828.41</td>
</tr>
<tr>
<td></td>
<td>(4.24)</td>
<td>(0.35)</td>
</tr>
<tr>
<td><em>B. sexangula</em></td>
<td>190.55</td>
<td>1906.06</td>
</tr>
<tr>
<td></td>
<td>(90.00)</td>
<td>(58.75)</td>
</tr>
<tr>
<td><em>S. apetala</em></td>
<td>43.78</td>
<td>81.69</td>
</tr>
<tr>
<td></td>
<td>(86.59)</td>
<td>(32.67)</td>
</tr>
<tr>
<td>Marshy</td>
<td>-</td>
<td>386.67</td>
</tr>
<tr>
<td></td>
<td>(100)</td>
<td>(51.35)</td>
</tr>
<tr>
<td>Shrub</td>
<td>569.55</td>
<td>463.27</td>
</tr>
<tr>
<td></td>
<td>(18.66)</td>
<td>(20.78)</td>
</tr>
<tr>
<td>Water</td>
<td>4726.56</td>
<td>5580.98</td>
</tr>
<tr>
<td></td>
<td>(18.08)</td>
<td>(07.67)</td>
</tr>
<tr>
<td>Total areas</td>
<td>44301.33</td>
<td>44327.83</td>
</tr>
<tr>
<td></td>
<td>(0.059)</td>
<td>(03.66)</td>
</tr>
</tbody>
</table>

*Table 5. Changes of forest cover in Nalianala and Chandpai ranges* (Ahmed, et al., 2011, p. 201)

An assessment was carried out in 2009 for the spatial distribution of saline soils using some soil survey technique such as salinity map, soil and landform map, aerial view in a ground survey in the coastal area of the Sundarbans. It was found that almost 1.056 million hectares out of total 1.6 million hectares (around) lands are affected by different levels of soil salinity. Among these, 0.328 million hectares land are very slight, 0.274 million hectares are moderately slight, 0.189 million hectares are strong and 0.161 million hectares are very strong in salinity. Cropping intensity is poor in the
high saline areas while in the slight and moderately slight areas, the intensity can be enhanced through soil adaptation and water management improvement (Rahman M. R., 2014, p. 178).

**4.1.2. Fauna**

A large variety of faunal species including fish fauna are available in the Bangladesh part of Sundarbans. It is estimated that BSMF covers a wide range of 1136 wildlife species. Among these, 315 are bird species along with 84 migratory birds. The common birds are storks, herons, gulls, and terns. The avifauna of the BSMF and the surroundings covers approximately 48% of total avifauna of Bangladesh. Among the faunal species, around 49 species are mammal. Royal Bengal Tiger is one of the familiar mammal species in the Sundarbans. BSMF is enriched with the aquatic species. There are almost 678 aquatic species in this part of Sundarbans. There is a list (Table 6) of important aquatic species of BSMF that represent 35% of total fauna of Bangladesh (Aziz & Paul, 2015, p. 257):

<table>
<thead>
<tr>
<th>Aquatic Species</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishes</td>
<td>210</td>
</tr>
<tr>
<td>Reptiles</td>
<td>59</td>
</tr>
<tr>
<td>Amphibian</td>
<td>8</td>
</tr>
<tr>
<td>Cetaceans</td>
<td>11</td>
</tr>
<tr>
<td>Mollusks</td>
<td>16</td>
</tr>
</tbody>
</table>

*Table 6. Aquatic species of BSMF, adopted from (Aziz & Paul, 2015, p. 257)*

Important faunal species of BSMF are spotted deer, barking deer, various kinds of Dolphins including Ganges River dolphins etc. Fisheries constitute a major part in the fauna, which is also an important means of the livelihood of the people. Among 210 species, more than 120 species are used for commercial catch for livelihood (Gopal & Chauhan, 2006, p. 345).

**Threat to Tiger**

Tigers are an important part of ecosystem in the Sundarbans. Here, tigers are relying on both terrestrial and water food web, which is very unique. The habitats of tigers are shrinking for the creek water salinity and tides, which creates adverse conditions for tigers to live there (Mallick, 2011, p. 63). As the freshwater from the river Ganges has been decreased and salinity increased in the water and soil, many plants are reducing. Tigers’ prime habitat *Heritiera fomes,Phoenix paludosa, Nypa fruticans* are decreasing gradually which results the decreased number of tigers (Mallick, 2011, p. 56). With an increase of 4 cm per decade at a conservative rate, it has been predicted that sea level in the Sundarbans will increase about 28 cm by 2070. Habitats will be lost in the protected area where tiger lives at the same rate as the rest part of the Sundarbans with this increased sea level rise (Haque, Reza, Rahim, Abdullah, Elfithri, & Mokhtar, 2015, p. 675).

**Threat to Dolphins**

The dolphins are a rare species in the Sundarbans. Ganges dolphin, one of the types of Dolphin found in Raimangal river, the eastern side of the Sundarbans increases in the
monsoon when fresh water is available. But it decreases in number in the dry season, when the salinity increases due to lack of fresh water supply. It is correlated with the food web, the fishes of their prey are less in the dry seasons, consequently affects the migration of the dolphins (Mallick, 2011, p. 64).

4.1.3. Effect on Fisheries

The Sundarbans are the nursery grounds for many fish species, which are harvested in Bangladesh and India. The delta of the Sundarbans ensures suitable temperature, salinity and chemical condition, shelter, and environment for the animal living there. The water bodies get sufficient nutrient supply from organic detritus and land drainage. A big part of commercial estuaries are run in the northern Bay of Bengal, where fishes grow and get mature. Also some fishes and prawns of freshwater come here annually for spawning. Therefore, the balance of the nutrient, salinity and overall environment is necessary to complete this basic lifecycle of the freshwater fish from river and prawn (Chandra & Sagar, 2003, p. 2). However, this balance would be disturbed by the salinity increase, which have ultimate effect on aquatic life of the Sundarbans.

Gain and Uddin conducted a study in 2008 about the salinity impact in some coastal region of the Sundarbans. The research areas included high saline and moderate saline area. Data on salinity increase was found from Bangladesh Water Development Board between 1975 to 2004 in Sibsa and Passur rivers in the Sundarbans, that had impact on fish production in the river (Dasgupta, Huq, Mustafa, Sobhan, & Wheeler, 2016, pp. 3-16).

With the number of fish, the diversity is also impacted by the salinity. The prominent fishes of fresh water in the Sundarbans such as Pangasius pangasius, Lates calcarifer or fishes of moderately saline water such as Tenualosa ilisha cannot breed when the salinity increase. The salinity tolerant fishes for instance, Harpodon nehereus, Trichiurus savala can survive only with the increased salinity. Therefore, the diversity of the fishes changes with high salinity in the water (Gopal & Chauhan, 2006, p. 345).

4.1.4. Effect on livelihood

The people of the Sundarbans are dependent on the resources of the Sundarbans. They are basically dependent on agriculture and fishes for food, timber and trees for fuel. However, poverty is very prominent in this coastal region. The natural calamities such as tidal surge, storm and cyclones are common phenomenon there. These natural hazards are responsible to bring the coastal salty water in the soil and fresh water used for agriculture and drinking. Climate change is also responsible for increasing sea level, which will enhance salinity significantly. Due to climate change, the risks of weather hazards will increase in in the future. Therefore, the dependence of the ecosystem for their livelihood, which is threatened by salinity, makes them more vulnerable (Dasgupta, Huq, Mustafa, Sobhan, & Wheeler, 2016, p. 5).

The livelihood of the people in the Sundarbans are mainly divided into four categories; 1) Agriculture 2) Fishing 3) Wood collection 4) Honey and non-timber forest collection (Datta, Chattopadhyay, & Deb, 2011, p. 538).
Fishing is an important livelihood in the BSMF. However, fishing is a season dependent occupation. In the dry season, the fishes are not much available. Fish migration also happens in the dry season, which forces fisherman to switch into a temporary profession like honey collecting, wood collecting, making handicrafts, boat making or netting. Some fishermen also do land cultivation temporarily. Therefore, the diversity of the work gives opportunity to the people to maintain their livelihood. The adaptation power of the people plays important role to cope out with the natural adversity (Mozumder, Shamsuzzaman, Rashed-Un-Nabi, & Karim, 2018, p. 42).

It is found in a survey, that is done with local fisherman, in Paikgacha, 59% and in Rampal, 21% of freshwater fish species have declined, affecting fisherman dependent on fishes for their livelihood. It is threat for their livelihood and also in their protein intake and food supply (Dasgupta, Huq, Mustafa, Sobhan, & Wheeler, 2016, p. 4).

‘The potential impact on poor households will depend on their vulnerability to changes in fish species in areas where salinization will significantly alter habitats’ (Dasgupta, Huq, Mustafa, Sobhan, & Wheeler, 2016, p. 16).

In some places the case is different, especially in case of shrimp cultivation. Shrimp cultivation requires saline water. Therefore, increasing salinity has positive connection with the livelihood of the shrimp cultivators. But shrimp cultivation decreases the soil fertility and viral infections. Therefore, people who were engaged with shrimp cultivation are trying to go back to the agriculture as their livelihood (Abdullah, Livelihood Strategies of People Surrounding the Sundarbans Mangrove Forest, 2014, p. 241). However, salinity causes loss of livelihood for the farmers and fisherman due to loss of plants, timbers, fish habitat and so on.

A survey was done to find out the income of the people in six villages in Khulna. The survey was carried out through 264 households in those six villages. The summary of the survey is placed in Table 7. (Abdullah, Economic dependence on Mangrove forest resources for livelihoods in the Sundarbans, Bangladesh, 2016, pp. 15-24):

<table>
<thead>
<tr>
<th>Forest income (Percent of total household income)</th>
<th>Forest income to household income inequalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower income households</td>
<td>Middle income households</td>
</tr>
<tr>
<td>74%</td>
<td>48%</td>
</tr>
</tbody>
</table>

| Average household income (per year) | USD 1122 |

<table>
<thead>
<tr>
<th>Forest income (Percent of total household income)</th>
<th>Forest income to household income inequalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower income households</td>
<td>Middle income households</td>
</tr>
<tr>
<td>74%</td>
<td>48%</td>
</tr>
</tbody>
</table>

Table 7. Forest Income pictures among villagers in Khulna adopted from (Abdullah, 2016, pp. 15-24)
Another survey was done in four villages of Asasuni upazila in Satkhira district. Two villages represent low saline area and other two villages represent high saline area (Haider & Hossain, 2013, p. 418). One of the findings of the survey was that in the high saline area the mean yearly income is lower than low saline area. Therefore, the income depends on the salinity. The summary of the study is presented in the Table 8 (Haider & Hossain, 2013, p. 424).

<table>
<thead>
<tr>
<th>Area</th>
<th>Observation (N)</th>
<th>Mean income (Thousand Taka/Year)</th>
<th>Std. Err.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Saline <em>(Chapra and Mahessor Kathi Villages under Badhata Union)</em></td>
<td>75</td>
<td>105.84</td>
<td>5.59</td>
</tr>
<tr>
<td>High Saline <em>(Sreeula and Mahesker Villages under Sreeula Union)</em></td>
<td>75</td>
<td>78.45</td>
<td>6.44</td>
</tr>
<tr>
<td>All</td>
<td>150</td>
<td>92.15</td>
<td>4.40</td>
</tr>
</tbody>
</table>

Mean Difference (between Low and High Saline Areas) 27.39* 8.53

*N.B.: * Statistically Significant at 1 percent Level of Significance.

Table 8. Results of yearly income in two villages (Haider & Hossain, 2013, p. 424)

Farmer’s solution to salinity

In some places, to tackle the salinity problems in the soil, in the low saline areas, farmers prefer to increase water supply and apply gypsum. However, these methods are not sustainable. Applying gypsum in the soil has many side affects, which increases pH level, contaminates the water and causes deficiency of minerals. In the high saline area, the farmers prefer to apply lime or urea which is not environment friendly neither economical. Therefore, farmers in higher saline area spend more on tackling salinity problems whether both of the ways are unsustainable (Haider & Hossain, 2013, p. 428).

4.2. Questionnaire Findings

One of the most important parts of the research was the questionnaire finding. Total 18 people participated in the questionnaire from the “Harinagar’ village in the Sundarbans. The village has been chosen in consideration to communication facilities, diversity of the occupation of the people living there, the acquaintance and suggestions of the place from some other known persons. The occupations of respondents are listed in Table 9.

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisherman</td>
<td>5</td>
</tr>
<tr>
<td>Farmer</td>
<td>5</td>
</tr>
<tr>
<td>Honey Collector</td>
<td>2</td>
</tr>
</tbody>
</table>
Almost all people that took part in the questionnaire process told that they are dependent on the plants, trees, agricultural land and fisheries for their food. If we look into the answers regarding effect of salinity in their daily life most of them think salinity has a negative influence in agriculture and fishing for their daily food source. Some people who have their own farms think that yields of agricultural products, for instance rice, have decreased. Especially in case of fisheries, almost everyone agreed that salinity has influence in the fish availability. Regarding drinking water, some of them do not know if the water contains more salt than previous. Also, they do not know the relation with salinity and drinking water.

Farmers and Fishermen were likely to respond about their livelihood relation with salinity. However, though most of them answered that salinity affects their livelihood, they were not very sure of it. For example, when the question came if salinity affects the income directly or indirectly, most of them chose the option do not know. Three of eighteen wanted to switch their occupation. And the reason is not only because of salinity. Verbally they said, for the instability of job and poverty, they hope to change their livelihood. But most of them, especially the people who are farmer, they wish to continue their job as it is their family tradition.

Regarding environment, some respondents mentioned that salinity is responsible for changing soil quality. Here also, the farmers were most likely to answer. But most of them either do not know or do not want to answer. Only some people told that salinity does not affect the environment.

The respondents in Harinagar village were not much optimistic about the solution. But when the question came about Government and NGOs their response was positive. However, verbally they said, they want solution for the betterment of their livelihood. They are struggling a lot with many natural distress if the reason is salinity or not.

The study by the means of literature review and questionnaire has attained some key findings. First of all, the flora, fauna and the livelihood of the people are deeply interconnected. People rely on natural resources for their basic needs and to maintain their livelihood.

However, there were some limitations in the questionnaire process. Majority of the respondents are illiterate. It took some effort to take their answers. But they were very welcoming and friendly. Also, the term ‘sustainability’ is very new to them. Therefore, it seemed that the survey questions should be narrowed down. It was very difficult to get solutions from them.
5. Discussion

Based on the findings in this thesis, both from literature review and questionnaire, we may look into the relation between the increase in salinity with flora, fauna and people in terms of sustainability. A sustainability model (Fig. 6) has been assessed to look the relationship among the aspects of sustainability. The environment is the foundation of all three aspects, then society and economy comes respectively. Environment is the important part in the ecology of the Sundarbans. It gives the platform to grow up all the lives associated to it. The people are an active part of society in the Sundarbans and their livelihood necessity fulfills the economic aspect. In terms of salinity, the environment is suffering more as the salinity intrusion is disturbing ecological balance.

![Sustainability model](image)

*Fig. 7. Sustainability model (Caradonna, 2014, p. 9)*

Society is based on the environment. However, the residents of the Sundarbans live in a close relation with their surrounding environment, largely depending on natural resources. The natural turmoil, disaster makes the people closer as the people fight together against these difficulties. Strong communities such as fishing communities, farmer communities already exist there. There is no direct link of society with salinity here. But, salinity has negative influence on soil, agriculture, fisheries, which obviously affect the society because the society has grown up with the people whose primary occupations are fishing and farming (Chandra & Sagar, 2003; Getzner & Islam, 2013). At last, the economy, the livelihood means of the people are affected by the salinity as known from the answer of the people. Therefore, salinity is affecting every tier of sustainability threat the ecosystem and the livelihood of the people.

Based on the research, a causal loop diagram has been developed to find the positive and negative relationships among many factors and components of biodiversity with the salinity. As illustrated in the causal loop diagram (Fig. 8), Climate change is responsible for sea level rise, so there is positive relationship with climate change and sea level rise, both of these are responsible for increasing salinity. Salinity has positive impact on loss in the agricultural land and decreases of fisheries. It has negative impact on flora, fauna. However, loss of agricultural land, fisheries has negative impact on livelihood of the people. Another way, flora and fauna provides the livelihood means for the fishermen, farmers, honey and wood collectors, NFTP
Collectors. So, all of these has positive feedback on the livelihood of the people. Shrimp farming is responsible to increase salinity in the water. However, many peoples are associated with shrimp farming for their livelihood and have a positive connection.

If we look into the sustainability compass (Fig. 6), to make the livelihood of the people more sustainable, we have to ensure to improve the status of the nature, economy, society and wellbeing at par. These are interconnected. If we look some solution for the alternative livelihood of the people, we also have to make sure that this livelihood is eco-friendly, as sometimes forests are exploited by the people for urbanization and it is found that the increased number of people causes decrease of natural resources especially number of trees; it provides well-being at the same time it gives financial strength. Therefore, some sustainable solutions have been designed in making consideration of this sustainability compass.

Fig. 8. A Causal loop diagram to see the relationship among Flora, Fauna and livelihood of people

Fig. 9. The Sustainability Compass (AtKisson, 1997)

Solutions like alternative livelihood mentioned later has impact on all of these four aspects- nature, economy, society and well being as these alternative livelihood looks
for the well being of the people in the society without degrading nature and creating livelihood opportunities which strengthens the economy. Therefore, balance on these four aspects is really important to make a sustainable life over there.

5. 1. Solution:

5.1.1. Management of fresh water

Salinity is increasing due to sea level rise and the lack of fresh water from the rivers. The barrages and dams are one of the main reasons for lowering fresh water inflow. Bangladesh Government is on the way of negotiation regarding the water sharing of Ganges river with the Indian Government. If Bangladesh gets their equitable share according to Agreement on sharing of the Ganges water, the supply of fresh water will increase significantly (Kawser & Samad, 2016). However, some major rivers are drying out for siltation and increased use of upstream fresh water that results in ecological pattern change of the water such as transporting organic and inorganic resources through water, changing ecosystem functioning of fishes and water animals (Mahadevia & Vikas, 2012, p. 14).

5.1.2. Alternative Livelihood

From the literature review, it has been found that the income is more in the low saline areas and vice versa. Therefore, in the high saline zones, people have to look for new income sources. As a major livelihood sources, the farming and fishing are affected by the salinity and posing threat to the people who are dependent for their livelihood on these. Farmers are using chemicals to reduce the salinity, but affect the soil, which is unsustainable, and in the long run, destroying soil. Therefore, an alternative livelihood means can boost the mangrove ecosystem and at the same time ensures the livelihood of the people. Honey processing is a good opportunity to make livelihood. Though some people are engaged with this, the amount is little. There are many demand of honey from Sundarbans to all over the country. Well-trained honey farm can meet up the demand of honey. Honey candy production by using these honeys will make surplus value. More salinity resilient mangrove species can be used to collect honey. Bottling plants, wax processing can also be some alternative livelihood trend. Another important sector of livelihood source can be Tannin and dye processing. The leather and chemical industries of Bangladesh use dyes and most of them are chemically formed. While, some barks of the mangrove species provide natural colour. For example, Ceriops decandra, are good sources of Tannin. Therefore, it creates a great scope for the people to involve in dye processing. Medicines can be produced form many mangrove species. Some important mangrove plants that has medicinal qualities are as follows: Tamarix dioica, Tamarix gallica, Thesapia Lampus, Derris indica, Ceriops tagal, Acanthus ilicifolius, Rhizophora apiculata, Casuarina equisetifolia, Derris trifoliata etc. Therefore, these plants are a good opportunity for pharmaceutical sector of the country where local people can be involved for their livelihood. (Datta, Chattopadhyay, & Deb, 2011, p. 540).

Mangrove plants such as Dhundhul (Xylocarpus granatum), Kala Bien (Avicennia marina) are familiar to the coastal fishing community for making gums and resins. Therefore, the barks of such mangrove species can be used to produce eco-friendly
gums, which will also ensure the livelihood of the coastal people who earlier depended on the fishing. The leaves of some mangrove species such as Golpata (*Nypa fruticans*), Hental (*Phoenix paludosa*) are very potential to make handicrafts, ropes, roofs of the hut and so on. Therefore, as tourists visit Mangrove forests, small-scale industry of these handicrafts, mats and other products made form the leaves can be great source of livelihood. Therefore, introduction of technology for the production, marketing interventions are necessary to make these attempts successful (Datta, Chattopadhyay, & Deb, 2011, p. 541).

### 5.1.3. Change of fuel for cooking

With the increased population in the Sundarbans, the number of trees is reducing. People use wood as a fuel for cooking. According to a report of Bangladesh Bureau of Statistics (BBS) in 2011, around 57% people in the SIZ districts had used wood as a fuel for cooking (Mondal, 2017, p. 10). The destruction of wood causes habitat loss of flora and fauna. It also destroys the ecological balance. Biomass energy using garbage and crop waste can be an alternative option for cooking.

### 5.1.4. Sustainable Food

Foods form agriculture and plants are an important part for the marginal people in the Sundarbans. Almost all respondents stated that they depend on the natural resources for their food. Fruits, vegetables, leaves are a good source of their meal. With these, salinity problems are affecting the vegetation process. Therefore, sustainable farming is important which also provide eco-friendly diet. Integrated farming is an example of sustainable farming where growing crops with many types of vegetables and a small fishpond together by a group of people. Wild Mushrooms, fungal flora can be good source of protein and less affected by salinity. These types of food can be a smart food choice for the people. (Datta, Chattopadhyay, & Deb, 2011, p. 541).

### 5.1.5. Monitoring the changes

Monitoring is important to make some sustainable effort. Remote sensing, GIS technology should be used to get some accurate picture, which would be helpful to Fig. out the changes and progresses are done in the ecosystem (Participatory Research and Development Initiative).
6. Conclusion

The eco region of the Sundarbans is bountiful with flora, fauna and well recognized for the vast biodiversity. It provides the means to survival of millions of people living there. This mangrove forest is providing people with many ecosystem services such as providing food, material for housing, regulating floods and storm surges, fisheries shelterbelt and so on. Salinity plays an important role to change the structure and composition of the mangrove species. These changes in plants definitely impacts on the ecosystem services that provided by the Sundarbans. Vegetation is affected and total food web of people and animal is getting disturbed. Wildlife are losing their habitat, wildlife behaviour is changing. The mangrove ecosystem integrity is deteriorating. Local people face instability in their livelihood means. Eventually, the existence of flora, fauna and the livelihood of the people are threatened by salinity (Haque & Reza, Salinity Intrusion Affecting The Ecological Integrity of Sundarbans Mangrove Forests, Bangladesh, 2017, p. 132). This paper tries to identify the problems of salinity in regards to certain parts of biodiversity such as flora and fauna, which has ultimate effect of whole ecology of the Sundarbans and humans connected with this ecosystem. Therefore, it seems very important to find sustainable solutions to protect this ecological sensitive yet important area of Bangladesh what this research aims to identify.
7. Acknowledgements

At first I would like to thank Department of Earth Science, Uppsala University to create me the platform to conduct the thesis work. I am grateful to my thesis supervisor Torsten Krause from Lund University. In spite of the distance from Uppsala to Lund, he never let me feel to realize that. I got immediate feedback whenever I need his help. I would like to thank Ripon Ahmed and Saif Hasan to carry out the questionnaire on behalf of me. The weather of the Sundarbans was really tough in the summer and the way from Dhaka to Sathkhira was tiresome. They really worked hard to get the feedback from the people, which is really an important part of this thesis. My heartfelt gratitude to the people of the Sathkhira who participated in the questionnaire process, whom I never seen but I really feel their agony and pain. They are such inspiration for my work. In addition, I would like to thank Malgorzata Blicharska, thesis coordinator who gave me guidance, feedback and mental support to continue the thesis. Though this is my first thesis work through my academic life, I have learnt so many things from the people associated with this work. The work enlightened me with many insights, which will be helpful in my career.
8. List of figures and tables

List of figures

Figure 1: The location of Sundarbans between India and Bangladesh
Figure 2: Bangladesh Part of Sundarbans
Figure 3: Population size in Sundarbans Impact Zone (SIZ)
Figure 4: Satellite view of survey site
Figure 5: Research Process in Flow Chart
Figure 6: “Top dying” disease affecting H. fomes from 1983 to 1995
Figure 7: Sustainability model
Figure 8: A Causal loop diagram to see the relationship among Flora, Fauna and livelihood of people
Figure 9: The Sustainability Compass

List of tables

Table 1. Different land covers in Sundarbans
Table 2. Population growth rate in SIZ districts
Table 3: Name of some key literature and contents
Table 4: Positive responses of some Mangrove species on high salinity stress
Table 5. Changes of forest cover in Nalianala and Chandpai ranges
Table 6: Aquatic species of BSMF
Table 7: Forest Income pictures among villagers in Khulna
Table 8. Results of yearly income in two villages
Table 9: Participants of Questionnaire
9. Reference List


Participatory Research and Development Initiative. *Salinity threatens the World Heritage: The Sundarban of Bangladesh.*


Annex 1

Questionnaire

The questionnaire is conducted for the research purpose as a part of Master thesis by a student of Uppsala University, Sweden. The goal of this questionnaire is to analyse the impact of salinity in the daily life and livelihood of the people and the environment of the Sundarbans. Taking part in this questionnaire is voluntary and all data will be stored and analysed anonymously – without possibility to identify individual respondents. The consent of each interviewees will be taken before the interview to use the data in the research.

Respondent X:

Consent for interview (Yes / No) – signature of interviewer:

A. Identification and location of household:

<table>
<thead>
<tr>
<th>Village name and code</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Household name and code</td>
<td></td>
</tr>
<tr>
<td>Date of Interview</td>
<td></td>
</tr>
</tbody>
</table>

B. Basic Information:

<table>
<thead>
<tr>
<th>Name</th>
<th>Sex</th>
<th>Age</th>
<th>Occupation</th>
<th>Number of Family members</th>
</tr>
</thead>
</table>

C. Effect of salinity in the daily life:

i) Are you dependant on plants/trees for food?
   □yes □no □do not know □do not want to answer

ii) Do you cultivate your own foods from farming?
    □yes □no □do not know □do not want to answer

iii) What do you think about the production of agricultural crops/trees/plants is more or less than earlier?
     □more □less □do not know □do not want to answer

iv) If production is less, do you think salinity has an influence on this?
    □yes □no □do not know □do not want to answer

v) Do you collect fishes from water sources for your meal?
   □yes □no □do not know □do not want to answer
vi) What do you think salinity has influence on fish growth?
☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

vii) What source do you use to collect drinking water?
☐ open source  ☐ supply water  ☐ do not know

viii) Does this water contain more salt than previously?
☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

ix) What fuels are using to cook?
☐ wood/timber  ☐ kerosene/gas  ☐ do not want to answer

x) If you use wood or timber, is the availability of it affected by salinity?
☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

D. Livelihood means affected by salinity:

i) Do you face any problem in your occupation for salinity?
☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

ii) Does salinity problem affects on your income directly or indirectly?
☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

iii) Are you interested to switch your livelihood if possible?
☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

iv) Do you found salinity as a key reason to switch your occupation?
☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

E. Environmental Impact:

i) Do you think salinity is creating impact in the soil?
☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

ii) Do you think salinity is changing the weather?
☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

F. Solution:
i) Do you think you have personal responsibility for mitigating some issues connected with salinity?

☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

ii) Do you think steps from Government and NGOs should be more extended in the salinity issues?

☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer

iii) Do you want to change your livelihood to one that is less affected on salinity?

☐ yes  ☐ no  ☐ do not know  ☐ do not want to answer