GEOSPATIAL WORLD FORUM
Theme
Dimensions and Directions of Geospatial Industry
18 - 21 January 2011, Hyderabad, India

Impact of Coastal Flooding on Land use Pattern Considering Climate Change

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1. Introduction

Storm surge during a cyclone inundates coastal areas and off shore islands, which causes most of the loss of life and properties. During the past 200 years, 2.6 million people may have drowned during surge events (Nicholls 2003). Approximately 19.5% (391,812 km2) of their combined coastal territory of 84 developing countries is vulnerable to inundation from a 1-in-100-year storm surge (by current reference standards). Homogenous 10% future intensification over the next 100 years (Nicholls et al. 2007) increases the potential inundation zone to 25.7% of coastal territory, taking into account sea-level rise. This translates to potential inundation for an additional 52 million people; 29,164 km^2 of agricultural area; 14,991 km^2 of urban area; 9% of coastal GDP and 7% of wetlands. (Dasgupta et al 2009).

About 37 polders and 282 sluice gates have been constructed by Bangladesh Water Development Board (BWDB) under the Coastal Embankment Project (CEP) in early 1960s for maximizing agricultural return. The recent cyclonic disaster AILA have passed over south west coast of Bangladesh and adjacent part of India with likely storm surge height around 9 feet above normal astronomical tide (DMIC & DMB 2009). Sea water over topped, breached the polder at 32 points and flooded a vast region of the study area (figure 1; polder-5). According to information from the food and disaster management ministry, 147 people died, 3,694,874 people were affected, 783,286 families were affected, 545,226 houses were destroyed and 340,660 acre crops were damaged. It is really a unique event as a storm like this has not hit the Sunderbans within the last three decades (Das, 2009). By landfall locations, Khulna coast located to the south-west corner of Bangladesh faced the highest number (36) of tropical cyclones in 1877–2003, which is 31% of the total storms and the rate of land falling tropical storms in this area has increased 1.18 per year for 1950–2000 (Islam & Peterson 2009). So the south west region is extremely vulnerable for future storm surge flooding.

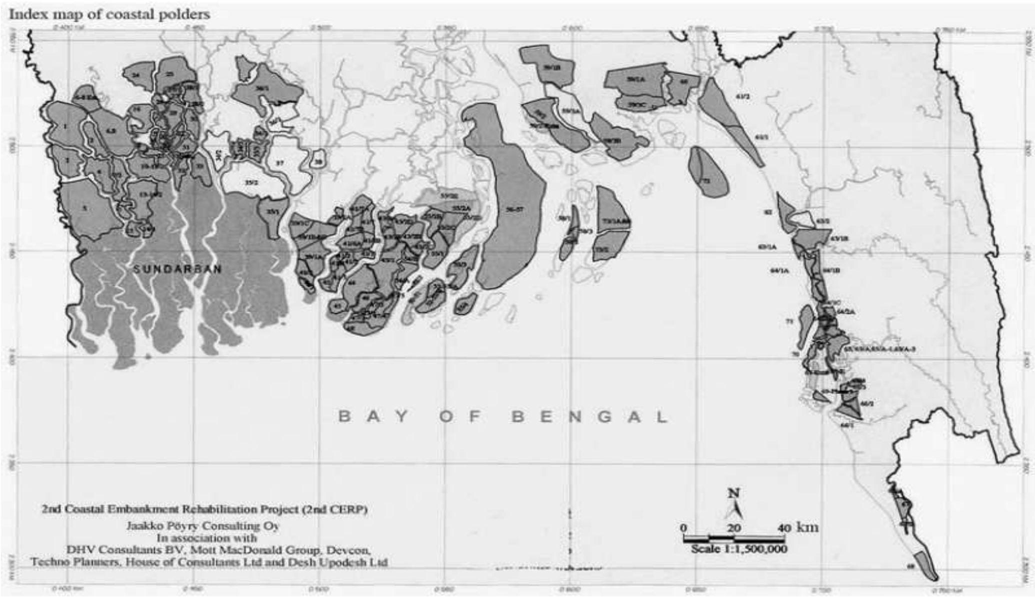


Figure 1: Coastal zone of Bangladesh and polders

2. Study Area

This research has been conducted on the polder number 5 which was severely affected during ‘Aila’. It is situated at 22010’- 22016’N and 89003’- 89012’E. The height of the polder was 4.27 meter PWD that encircled about 55,089 hectares of land from the river or coastal flooding. Total cultivable land is 38552 hectare in the polder where fallow land is 6257.79 hectare. The agricultural land is occupied by 23.8% single crop 55.06% double crop and 21.14%.triple crop. Among the peasants, 19% are landless, 30% are small, 28% are marginal, 16.5% are intermediate and 6.5% rich where cultivable land per head is 0.13 hectare (WARPO 2005).

Polder-5 was constructed in late 1960s to increase agricultural product. After 1990s shrimp culture took over the place of agriculture. Suitable natural condition, infrastructure (e.g. polder) and increasing demand in foreign markets rapidly flourished shrimp farm nearly all over the region. Shrimp farmers weaken the embankments in different ways like frequent cutting, installing worse sluice gate, lacking of management etc. So, shrimp farm increases the exposure of the study area to cyclonic storm surge which induced damage due to ‘Aila’.

3. Methodology of research

This research has been conducted through socio-technical approach where data were collected form different primary and secondary sources. At first the tidal level was determined during ‘Aila’ event on the polder. Field investigation and published literature revealed about the height of storm surge during ‘Aila’. Then, the flood coverage area was determined through spatial analyst of digital elevation model data (DEM, 30m x 30m). The return period for this particular surge height was calculated by using Log normal distribution of the past 50 year (1960-2009) storm surge data. Field investigation was conducted for verifying of flood inundated area, expected change in the land use pattern and trend in production on PRA tools like FGD, resource mapping and trend line analysis.

Surge height of cyclone ‘Aila’ was represented as a base year situation with respect to projected year (e.g. 2030, 2050 and 2100) impact study. SERS – A1B scenarios of the fourth assessment report, IPCC has been considered in sea level rise and population dynamics. To find out future storm surge height (FSSH) of a cyclonic disaster with respect to representative year (e.g. Aila) through use of the equation of Nicholls et al (2007),

FSSH = RCSH+ SLR + (UPLIFT * 100 yr) / 1000 + SUB + RCSH * x
RCSH = Representative cyclone surge height (m);
SLR = sea-level rise for SERS-AIB scenario (m)
UPLIFT = continental uplift/subsidence in mm/yr (Not accounted)
SUB = 0.5 m (applies to deltas only)
x = 0.1 or increase of 10%, applied only in coastal areas currently prone to cyclone

Using spatial analyst, the flood inundated area estimated for the projected years. So, the consequence of climate change to the land coverage would account on the basis of the result of DEM analysis.

4. Result and Discussion

In particular, the current global average temperature is likely higher now than in at least the last 2000 years (Jones and Mann, 2004). Warming temperature increases the sea level and make threatening situation to the coastal community especially during disasters. The effects of sea level rise to the Bangladesh coast are like permanent inundation, drainage congestion in the polders, storm surge inundation and salinity intrusion. As a result, a wide range of impacts on land use pattern and socio-economic is anticipated. According to FAR of IPCC projection was taken into account in case of sea level rise (SLR). The projected SLR would 14cm, 32cm and 48cm for the projected year of 2030, 2050 and 2100.

During ‘Aila’, storm surge raised about 2-3 meter above the highest level of astronomical tide. Cyclonic surge coincided with high tide and created a deadly disaster to the polder areas. Surge from the sea intruded through the mouth of the river and traveled within a short period to the river adjacent to the polder. River water swelled up rapidly and reached near to embankment level at the beginning of ‘Aila’. The height of the surge or duration of the cyclonic event and sea water intrusion period were the predominant determining factors behind devastation of the polder. Climate change and SLR will intensify future storm surge height which was established by different studies. If same type of disaster would occur in future with polder height remaining same, the estimated surge height are shown in the table-1 using of the equation of Nicolls et al (2007)

Table 1: Projected surge height (m)

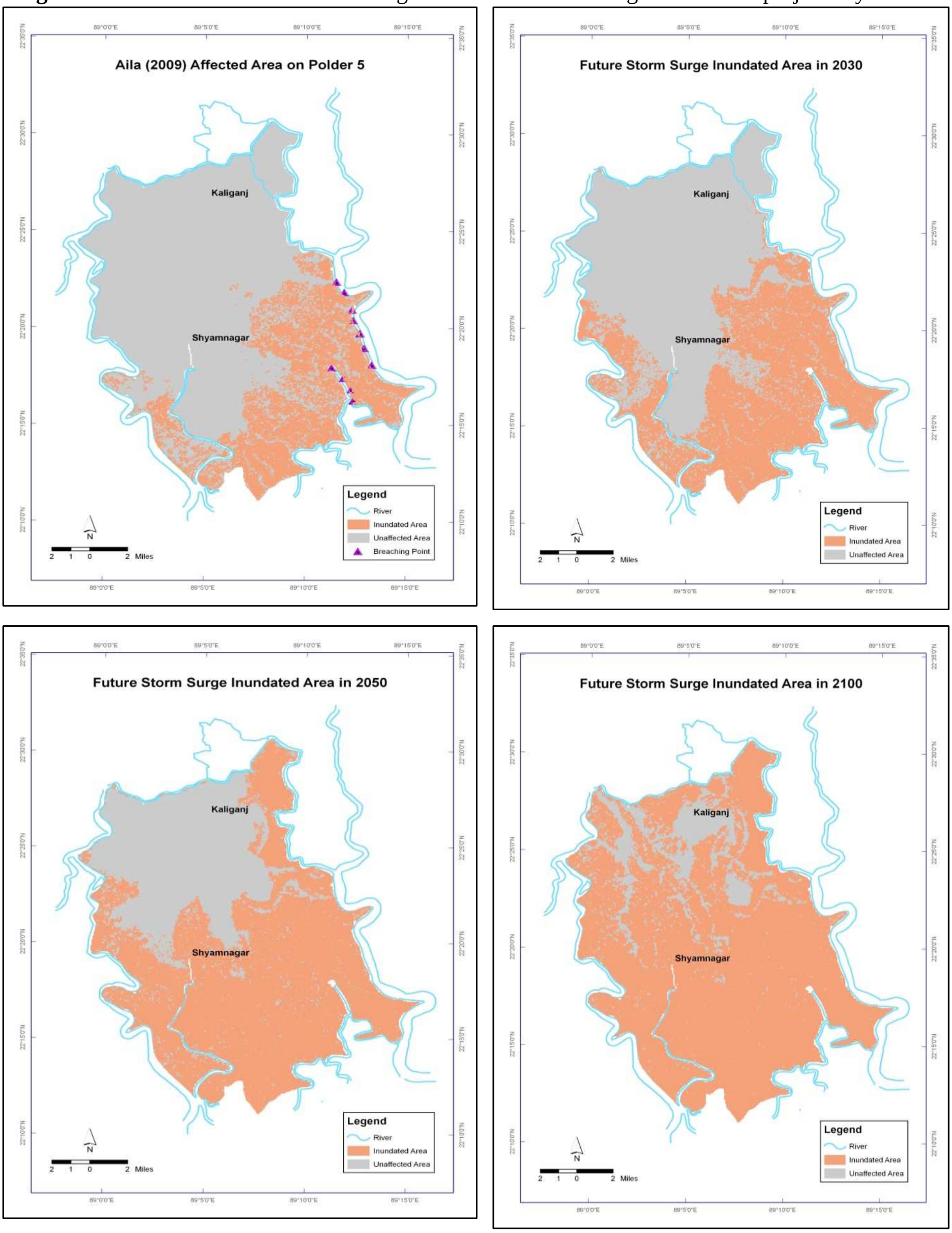
Year	Land elevation	Polder height	High tide level	Aila, Surge	Total Surge Height
2009	1.5	4.27	3.35	2.7	6.1
2030	1.5	4.27	3.35	3.6	6.9
2050	1.5	4.27	3.35	3.9	7.2
2100	1.5	4.27	3.35	4.1	7.5

During ‘Aila 2009’ the total surge height was 6.1m which would become 7.5m in year 2100. The return period for storm surge height of 6.1m was found to be 12.5 years taking 19 maximum surge levels from 1960 – 2009 on the coast of Bangladesh. Before the disaster ‘Aila’ this study area was classified into 69 percent of agricultural land, 14 percent of forests, 9 percent of settlement and 8 percent others like barren, commercial or sacred land. Agricultural lands included paddy cultivation, shrimp culture, fish culture, salt farm and paddy cum fish culture.

Coastal flood coverage area of the cyclone ‘Aila’ was identified by DEM analysis of the study area. Field investigations were conducted to validate the result and evaluate the spatial changes of land use pattern of the affected area. In total about 22.7% (12590 hectare) land was in undated by the cyclone ‘Aila’ in polder no-5.

In future, when the surge level increases, the coastal flood coverage will increase quite proportionally in the polder which is shown in the figure-1.

Figure 1: Estimated coastal flood coverage areas due to storm surge in different projected year



Future flood coverage areas are shown in figure-2. In 2030 about 41.4 % (e.g. 22797 hectares) of the total polder areas would be inundated and in 2050, about additional 64.2% land would be affected by same kind of disaster. In 2100, only 14.3% of terrestrial land area would remain free from storm surge inundation. Forest coverage of the study area would gradually decrease in accordance land inundation. About 14% land was covered by forest in 2009 which would decrease 7% in 2030, 4% in 2050 and only 2% in 2100.

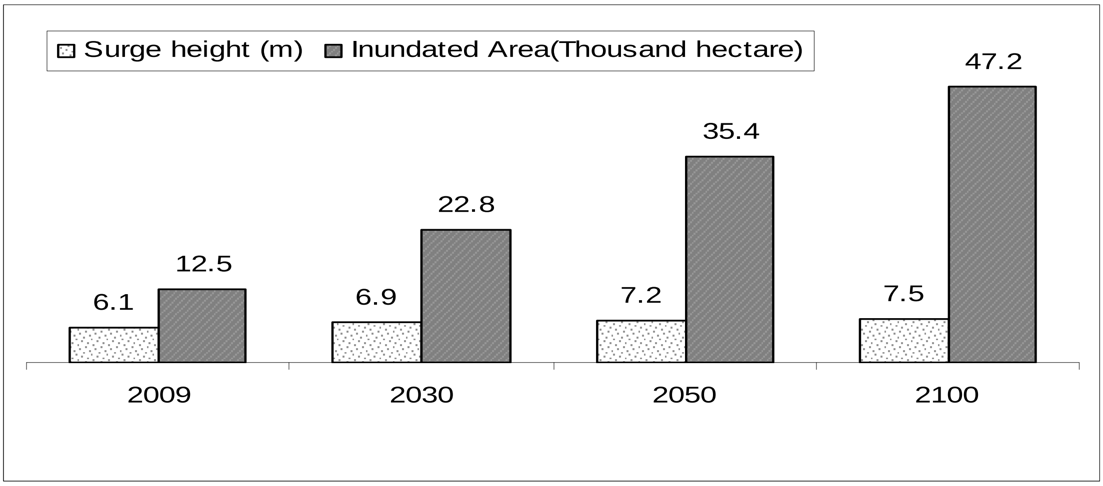


Figure 2: Storm surge inundated area

Change of land use transforms the production process in different sectors of the coastal areas. Analysis of the past data assists to estimate in future production. The expected change in land use would be the prime cause of damage to rice and fish production of the study area which is given in table 2.

Table 2: Impact on different productive sectors in future

Production Sectors	2009	2030	2050	2100
Damage to Rice production	38%	64%	89%	100%
Damage to Fish production	50%	62%	70%	85%

5. Conclusion

The last coastal storm surge flood inundated around 22.7% of land in the studied polder. The predicted coverage area would extend to 41.4% on 2030, 64.2% in 2050 and 86.7% in 2100 due to changing climate in future. This impact would translate to change in land use pattern of the coastal zone in future.

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Paper Reference No.: PN 141

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