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Land Cover Changes of the Coast of Bangladesh in Relation to Cyclones and Storm Surges

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INTRODUCTION

Land cover change analysis using satellite images opened a new window for risk managers, development policy makers and scientists since its inception in 70's. It enables monitoring the temporal changes in relation to many development concerns like natural hazards, land resource management etc. Bangladesh is a developing country and is prone to disaster. Cyclone is one of the deadliest natural hazards in Bangladesh (IEB, 1991). The coast of Bangladesh is characterized by very low elevation ranging from 1-3 meter above m.s.l. within 10 km from the coast line. Almost all of historical cyclones that hit the coast of Bangladesh were associated with tidal surges. The gentle slope and funnel shape of the coast increase the impact of tidal surges in addition to the great loss caused directly by the cyclones.

In the studies related to cyclone and storm surge the aspect of land cover is generally ignored. The pattern of land cover is the result of the activities of the local inhabitants. Land cover may inform about natural resources and human assets exposed to the hazards. Natural disasters also cause people to change the land cover to adapt to the impact of natural hazards. Settlement, forest, agricultural land and landscape of the coastal area changed over time with the regular hit of cyclones and tidal surges along the coast of Bangladesh. There are 202 recorded cyclones in the last 100 years (EM-DAT, 2014) among which 70 cyclones that hit the coastal area causing loss of lives and damage of properties (Quader, 2012). As the coast of Bangladesh experienced a lot of tropical cyclones and associated storm surges the evolution of the coastal land covers might be influenced by repetitive cyclones along with many other factors of course.

This study aims of assessing whether land cover changes can be attributed to natural hazards among other factors. This study aims to check the hypothesis that the land cover is static over the time in the area where cyclone and tidal surge hit in the past and that there is no difference in the proportion of change between the cyclones affected areas and the cyclone free area.

METHODS

Delineation of coastal zone is difficult as it involves a lot of factors including limit of tidal fluctuation, salinity level of surface water, ground water, and soil etc. (PDO-ICZMP, 2003). All of the upazillas (2nd lowest administrative unit of Bangladesh) of interior and exposed coast defined by PDO-ICZMP (2003) are taken as part of coastal area of Bangladesh for this study. Seven scenes are required to study the whole coastal area of Bangladesh with Landsat satellite images. Landsat MSS of 1972-1973 and Landsat TM of 2009-2010 images were

used for classification. All scenes were acquired in the month of February and acquisition time was 3.55- 4.16 GMT. The acquisition month is dry season (characterised by low rainfall) in Bangladesh and acquisition time of Landsat TM scenes were close to low tide time at those dates. The individual scenes were atmospherically corrected, layer stacked, mosaicked, co-registered resulting in RMSE error lower than 0.5 pixels. Thermal bands were excluded during layer stacking.

Images were classified by unsupervised classification with 100 isodata clusters. Seven and nine major land cover classes were identified by clusters merging in the images of 1972 and 2009 respectively (table 1). Classified image of Landsat TM was resampled to 60 meters before comparison with Landsat MSS. The resampling has no effect on spatial details. Post classification comparison was applied to get the changes from 1972-73 to 2009-2010

Table 1. Table showing the description of the land covers classes

CLASSES	DESCRIPTION
Settlement (STLM)	Houses, roads, airport, sea port, harbours and any other built-up areas are included in this class. Some concrete houses are agglomerated in large urban coastal areas and easily identifiable in false colour composition. The kucha and semi-pacca houses near the coast are scattered and located in between trees.
Forest	Mangroves (Sundarban) are termed as forest here. This is located in the south western part of the coast
Home stead vegetation (HMV)	These are long trees, grass lands and other vegetation around the coastal houses.
Hilly vegetation	Vegetation on top of the hills in the eastern belt of the coast.
Agriculture (AGR)	Agriculture crops. These land has nice elongated rectangular shapes in rural area visible on the false colour composition (321 in MSS and 432 in TM).
Barren land (BL)	Salt pan, sand bars, sand dunes, beaches, mud flats, marshy lands, fellow land, agricultural land after harvesting, deforested areas, newly emerged *charlands* (island) are included in this class
Water	Rivers, channels, creeks, closed ponds and open oceans are classified as water
Shrimp cultivation (SC)	Brackish water used for shrimp cultivation.

To reduce classification errors in forest and hilly vegetation class, problematic areas of these two classes were visually identified and recoded with Area of Interest (AOI) in Erdas Imagine.

Accuracy assessment of Landsat MSS image was done by using 80 random points from the false colour composition of 321 as there was no available map or other reference of 1972-73 period of the study area. 80 GCPs were collected from google earth historical image of 2010 to assess the accuracy of the classified image of 2009-2010.

Historical cyclone tracks of GAR 2013 data platform (GAR, 2013) were used for analysis in this study to get the areas that were affected by cyclones in the past. 10 km buffer were generated as areas out of 10 km around the cyclone tracks is considered as hazard free (Poompavai, 2013). Cyclones that hit the coastal area of Bangladesh from 1972 to 2010 were considered only as we have analysed satellite images of this time span. Four Focus group discussions (FGDs) were conducted in two unions (lowest administrative unit of

Bangladesh) in south eastern coast of Bangladesh to get the idea about the land cover classes of the coast and the impact of cyclones on land cover change.

RESULTS

Focus group discussions identified some major livelihood groups in the coastal area of Bangladesh. The main livelihood groups of the coastal area are salt cultivator, agriculture farmers, fishermen, business men, service holders and day labourer. The resources that are vulnerable to natural hazards in that area are settlements, livestock and domestic birds, trees or forest, salt, fish, forestry and homestead trees, agricultural crops, and livestock. Getting ideas from the results of the focus group discussions on livelihoods and coastal resources seven major land cover classes are identified both in the 1972 and 2009 satellite images of the coastal area of Bangladesh. Great change in the amount of homestead vegetation, settlement and agriculture is observed from 1972 to 2009. Settlement and homestead vegetation increased while agriculture decreased remarkably. Hilly vegetation and forest area is almost steady in terms of amount during the period of study. Amount of barren land decreases over the study period. Cloud has negligible impact on change detection (Figure 1).

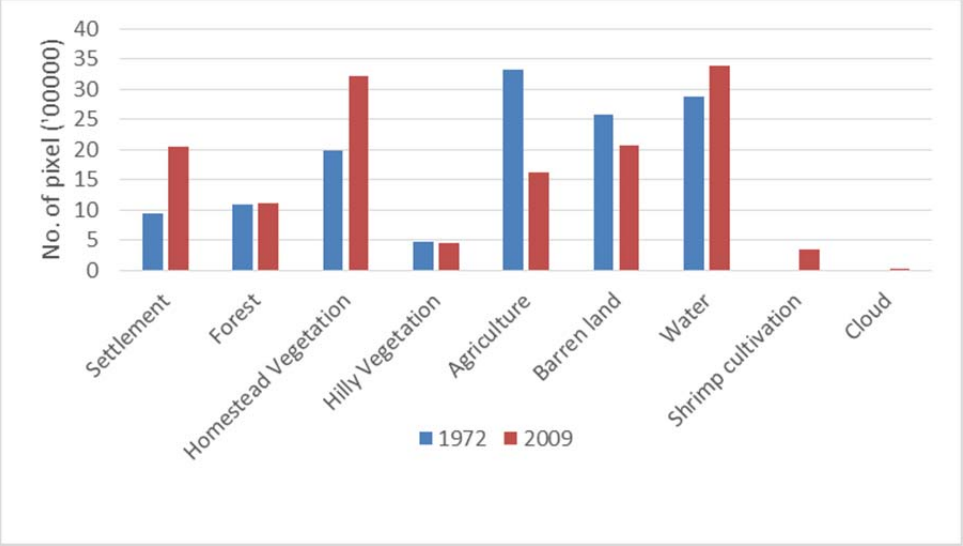

Figure 1. Changes of land covers in terms of pixels. Settlement, homestead vegetation, agriculture and water increased; barren land decreased; forest and hilly vegetation are steady and shrimp cultivation newly appears.

Table 2 shows that settlement, homestead vegetation, agriculture and barren land of 1972 are converted mostly to other land covers in 2009. The great change was observed in the class of barren land and agriculture. Barren land was converted mostly to homestead vegetation and then followed by settlement, water and agriculture. Agriculture was converted mostly to homestead vegetation and then followed by settlement, barren land and water.

Table 2. Table showing the matrix of changes. Percentage of land cover in each cell represent the % changed over the period from 1972 to 2009. The percentage of area occupied by each land cover in 1972 is shown in the leftmost column. The yellow coloured diagonal cells represent the percentage of land cover that is unchanged from 1972 to 2009.

Area (%)	class '72	class 2009								
		STLM	Forest	HMV	HV	AGR	BL	Water	SC	Cloud
6.52	STLM	1.50	0.00	2.04	0.46	0.75	1.06	0.75	0.43	0.01
7.67	Forest	0.02	7.54	0.02	0.00	0.00	0.09	0.55	0.00	0.00
13.92	HMV	2.99	0.00	4.71	0.31	2.23	2.01	2.09	0.58	0.05
3.30	HV	0.47	0.00	0.37	1.35	0.97	0.34	0.02	0.00	0.00
23.33	AGR	4.37	0.00	8.61	0.21	4.33	3.98	2.61	0.92	0.07
18.12	BL	3.51	0.05	5.39	0.75	2.36	3.71	3.31	0.39	0.02
20.20	Water	1.45	0.17	1.44	0.02	0.75	3.34	14.39	0.11	0.01

Conversion of barren land to settlement, homestead vegetation and agriculture suggests rapid growth of population in the coastal area of Bangladesh over the 38 years of study. This growth of population is also supported by the national census statistics of whole country that population was doubled over this time (BBS, 2011). 0.92% out of 23.33% agricultural land and 0.39% out of 18.12% barren land was converted to shrimp cultivation in 2009. This conversion supports the conversion of rice field to shrimp cultivation in the coastal area of Bangladesh. Homestead vegetation is mostly converted to settlement (2.99% out of 13.92%) and agriculture (2.33% out of 13.92%). Settlement is mostly converted to homestead vegetation and barren land (2.04% and 1.06% out of 6.52%). This suggests that settlement are located along with vegetation in the coastal area which is unlike the urban area of mainland. This type of association of settlement might have introduced with the people's indigenous knowledge to live with cyclones. Hilly vegetation was converted mostly to agriculture (0.97% out of 3.30%) that suggest the appearance of human settlement in the hilly regions. People consider hills as safe guard of their settlement to be ruined by strong cyclone wind in the coastal area of Bangladesh (Mahbub, 2003). Forest remains constant in terms of area through the time of study. Conversion of forest to water (0.55% out of 7.67%), homestead vegetation to water (2.09% out of 13.92%) and barren land to water (3.31% out of 18.12%) are caused by erosion.

Figure 2 shows the south-western coast is consistently covered by forest. This forest is the Sundarban, largest mangrove forest of the world. The forest cover did not change a lot in areal extent. Shrimp cultivation appears in 2009-2010 mostly in Sundarban dependent area (where people depend on Sundarban, the mangrove forest for their daily livelihood).

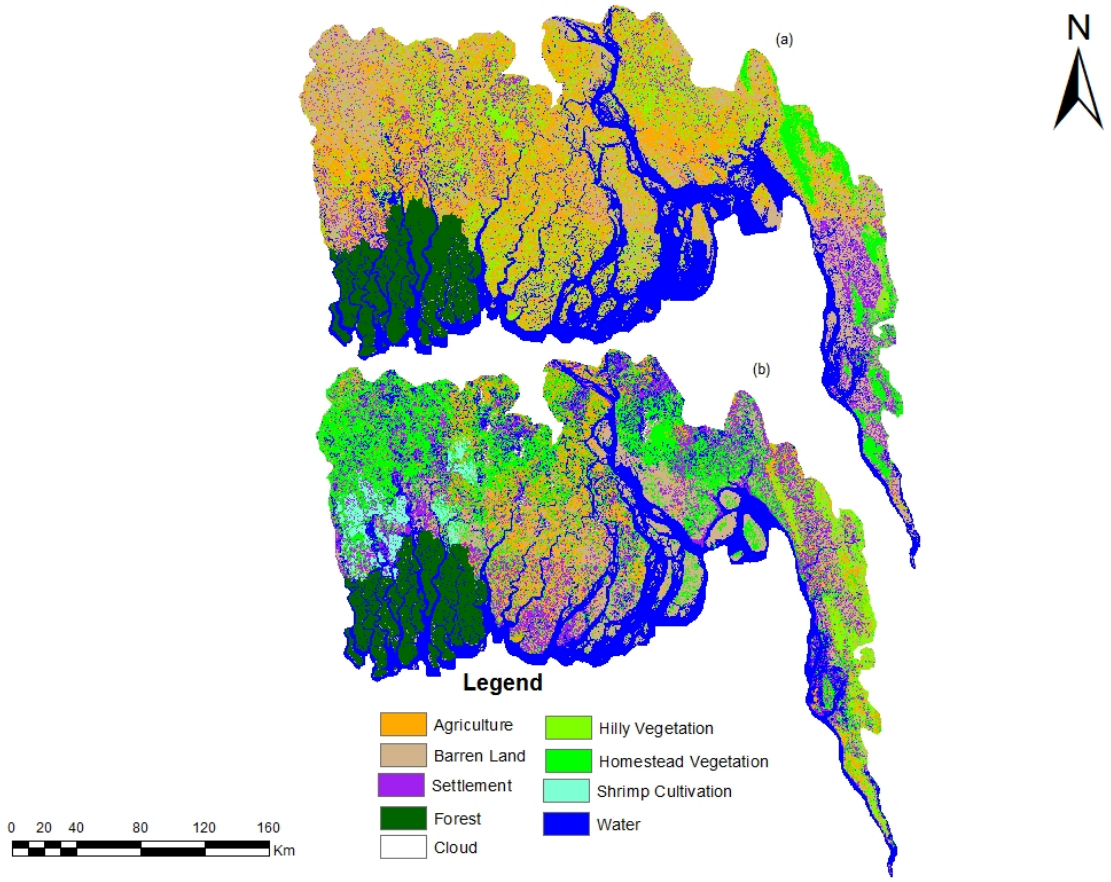

Figure 2. Classified image of (a) Landsat MSS (1972-73) and (b) Landsat TM (2009-2010). Forest in the south-western coast did not change so much and hilly vegetation in the south eastern coast (Hills) is also almost consistent.

Rivers, channels and creeks inside Sundarban are major sources of shrimp fry. Increased salinity of this area made the land unsuitable for irrigation and rice cultivation. Frequent tidal surges along with cyclones play a role to increase salinity in that area. These are the major drivers of locating shrimp cultivation in the coastal area of Bangladesh (Rahman, et al., 2013). South eastern hills covered with vegetation (here classified as hilly vegetation) also changed little compared to barren land and settlement. Expansion of clustered settlement concentrated mostly far away from the coastline as well as near the coast in the central coastal area.

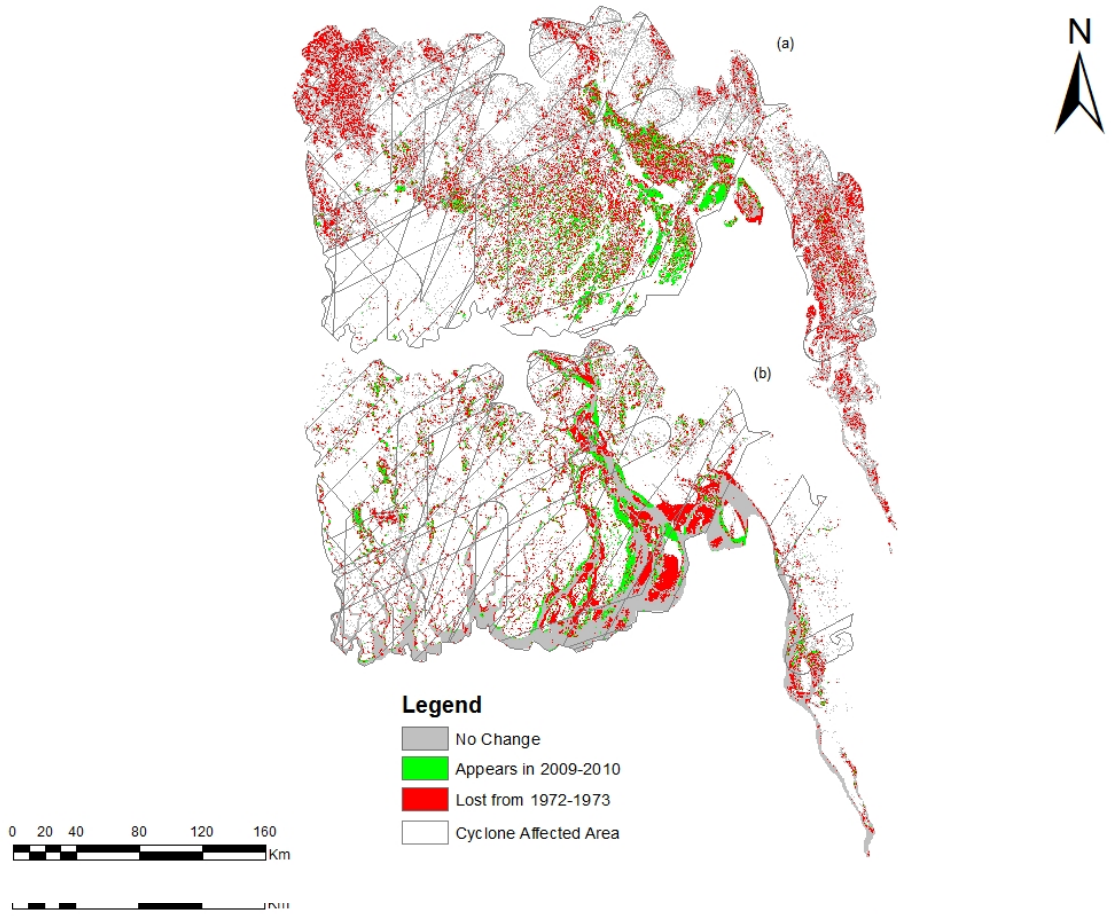

Figure 3. Maps showing changing pattern of (a) homestead vegetation and (b) settlement. Except the urban area of the coast, the scattered settlements are surrounded by homestead vegetation. Buffer of past cyclone tracks are shown on the maps to check the area experienced cyclone during 1972-2010.

Appearance of both homestead vegetation and settlement in 2009 exceeds their lost from 1972 (figure 3 and 5). Appearance of settlement concentrated near the central coast (figure 3b) where the scattered homestead vegetation disappears (figure 3a). This change suggests that the growth of cluster settlements in the central coastal area caused disappearance of scattered homestead large trees.

Figure 4 (a) shows that barren land disappeared equally from the whole area except the Sundarban in the south western part. Barren land appeared inside Sundarban in scattered way and concentrated in and around estuarine islands largely. Appearance and loss of barren land in estuarine central part (figure 4a) and appearance of water in that part (figure 4b) suggests that the central coast of Bangladesh is very active compared to other two parts.

Figure 4. Changing pattern of (a) barren land and (b) water during 38 years of study. Buffer of cyclone tracks are shown on maps to observe the area that was hit by cyclones in the history. Barren land is almost converted from the whole area to other classes. Appearance of water in 2009 and lost of water from 1972 around the sea-land boundary, estuary and river banks suggests accretion and erosion respectively.

Appearance (erosion) and loss of water (accretion) largely concentrated in the estuarine islands, following the large river banks, large riverine islands, offshore islands and around the margin of Sundarban where land meets the water.

Figure 5 shows that the amount of area that did not change throughout the time in case of settlement, agriculture and barren land is not much dependent on cyclone. Even though a lot of other factors play a role in the evolution of land uses in coastal area, cyclone could be one of them in changing settlement, agriculture and homestead vegetation. Although cyclone affected area is large enough in terms of total coastal area under study, three among the cyclones (1971, 1991 and 2007) were deadliest in history. The unchanged area of homestead vegetation and water is cyclone dependent unlike the previous three other classes. Loss of barren land is less dependent on cyclone rather than appearance. Although there are lot of other factors involved in coastal erosion and accretion along with start of shrimp cultivation, loss and appearance of water classes are dependent on cyclone. Tropical cyclones and associated storm surges are responsible in altering the many land covers like succession in new land, deforestation, land degradation and urbanization around the globe (Badarinath, 2012)
Classification of Landsat MSS image of 1972-73 achieved an overall classification accuracy of 79%. Landsat TM image of 2009-2010 classified with an overall accuracy of 84%. The level of accuracy is within the range of classification of coastal area by unsupervised classification of Baris (2013), Prabaharan (2010).

CONCLUSION

The main land cover transitions were found to be forest to barren land, forest to water body (erosion in the transitional zones of land and water), water body to forest, barren land (due to accretion in the transitional zones of land and water), agriculture to water body (appearance of shrimp cultivation) over 38 years of study. The land cover changes of agriculture, forest and water body is the result of the changing mind setup of the local inhabitant towards their primary economic activities, the adaptive techniques to natural hazards adopted by local people and action played by cyclones and tidal surge in the past. The changes of land covers found in this study is needed to be included in any policy making process of managing natural hazards. The role of mangrove forest and hills in protecting land covers from natural and anthropogenic impact is also evident with little changes in these two land covers over 38 years of study. Land cover and land use is not controlled by one factor. Several factors cause the changes of land cover over time. Cyclone and storm surge is one of the causes to change the land covers in the coastal area of Bangladesh. There is scope to work further to check the impact of natural hazards on land cover changes by using images at an interval of 5-10 years. Spatial extent of impact of historical cyclones in the coast of Bangladesh is also needed to be studied to establish the link of cyclones with land cover changes.

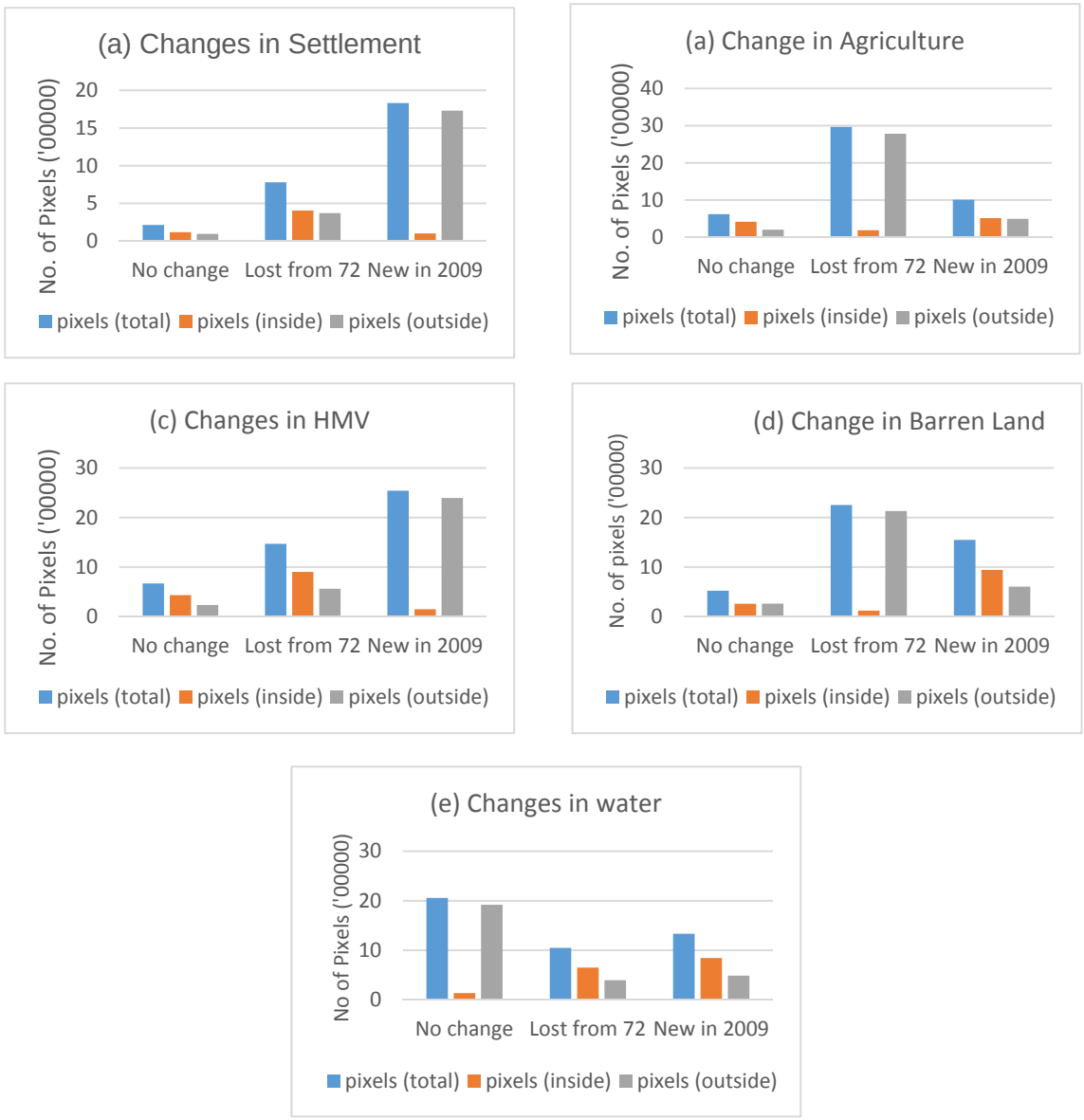

Figure 5. Figures showing the statistics of changes of land cover classes (a) settlement (b) agriculture (c) homestead vegetation (HMV) (d) barren land (e) water. Number of pixels inside the buffer tracks and outside the buffer tracks are the areas of new appearance and loss of particular class in the cyclone experienced area and cyclone free area respectively.

ACKNOWLEDGEMENT
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