

Trend and Impact Assessment of Floods and Cyclones in Coastal Odisha

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Abstract

The state of Odisha situated on the Bay of Bengal periodically experiences loss of life and severe damages from occurrence of various natural hazards such as cyclonic storms, floods, heavy rains, thunderstorms, hail storms, heat wave, droughts etc. The present study aims to find out the degree of impact caused due to the occurrence of flood and cyclone for last five decades along the coastal districts of Odisha. To find out the trend and impact of floods and cyclones on socio-economic variables the UNDPs normalisation method was used to find out the damage index of the taken variables and then the Composite Damage Index (CDI) was obtained by combining all the indices for composite damage assessment of the study area. The district level variation in the impact of flood and cyclone along the Odisha coast shows that the Cuttack district which doesn't shares any coast line in the Bay of Bengal still ranks one in the Composite Damage Index. Many studies have been done before on the occurrence and impact of natural hazards for the coastal districts of Odisha, but none of the authors have tried to make the comparative spatial-temporal analysis of the damages done by the natural hazards along the coastal Odisha. Therefore, the present paper will surely provide additional information to the policy makers on the changing behaviour of the natural hazards over the time and space with regards to its occurrence and impact level.

Keywords: Natural Hazards, Trend, Impact Assessment, Coastal Odisha, Composite Damage Index

1. Introduction

Natural disasters are the outcomes of natural hazards and are characterized as a significant disturbance in the functioning of a community or society, resulting in extensive human, material, economic or environmental damages (Chaudhary & Piracha, 2021). Odisha has a long-standing record of frequent natural calamities. While the coastal regions of Odisha are susceptible to floods and storms, western Odisha is susceptible to severe droughts; a significant portion of the state is also susceptible to earthquakes (Pradhan & Madheswaran, 2023). Furthermore, the state is susceptible to many calamities such as heatwaves, epidemics, forest fires, road accidents, and so on. Historical records confirm that around 80% of the state

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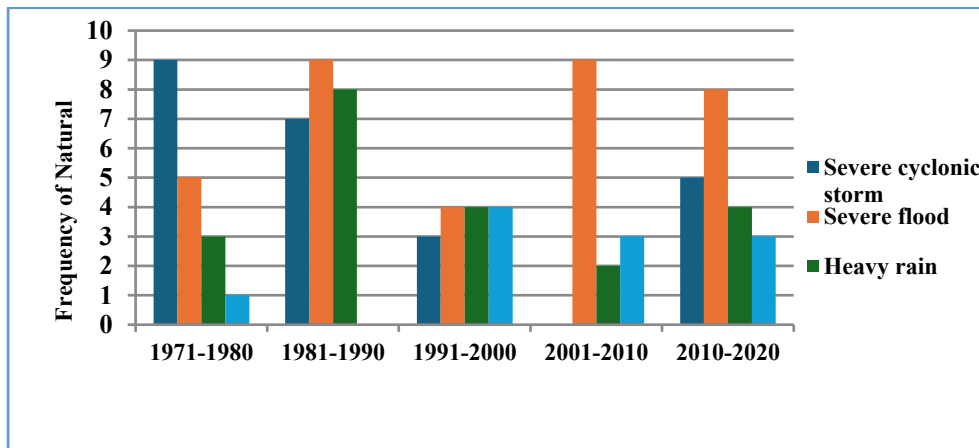
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is susceptible to one or more types of natural disasters (National Institute of Disaster Management Report-2005).

During last 50 years, Odisha has experienced the occurrence of floods for 35 times in 24 years while cyclonic storms have occurred 15 times in 14 years and drought has occurred 11 times in 6 years (Fig. 1). Severe thunderstorm has occurred twice, while extreme heat wave has occurred once. The most destructive natural hazards that have occurred in the coastal Odisha are the floods and cyclones.

Figure 1: Decade wise frequency of natural hazards in coastal Odisha (1971-2020)



Source: OSDMA Annual reports (1999-2020) and IMD Report on Climate of Odisha-2002

Therefore, the present study is focused on the occurrence of flood and cyclone and its trend and impact on the socio-economic variables along the coastal Odisha. Although major studies have been done before on assessment of damages caused by the impact of tropical cyclones on the coastal belt of Odisha (Sarkhel et al., 2019), (Mishra et al., 2023) but this paper presents a detailed analysis of the socio-economic losses and losses to human lives and livestock losses in the last fifty years (1971-2020) over the coastal Odisha.

1.2. Study area

The study area comprises seven districts; i.e. Baleswar, Bhadrak, Kendrapada, Jagatsinghpur, Cuttack, Puri and Ganjam (Fig. 2). These districts are predominantly located in the coastal plains of the state and extend inland ward from the sea for about 100-120 km. the study area extends from 19° 00' to 21° 59' N Latitude and 84° 09' to 87° 30' E Longitude. It is surrounded by West Bengal in the north east, Andhra Pradesh on the south, 10 neighbouring districts of Odisha on the west and Bay of Bengal on the east. The region covers 26240 km², constituting 16.85% of the total area of the state. Except Ganjam district, the elevation of all other six districts is found to be below 100 meters. In some of the western parts of Cuttack and Balasore district, patches of high elevated lands are seen with elevation of above 300 meters. Mahanadi river forms the largest alluvial deltaic plain in coastal Odisha covering almost four districts i.e. Cuttack, Puri, Jagatsinghpur and Kendrapada.

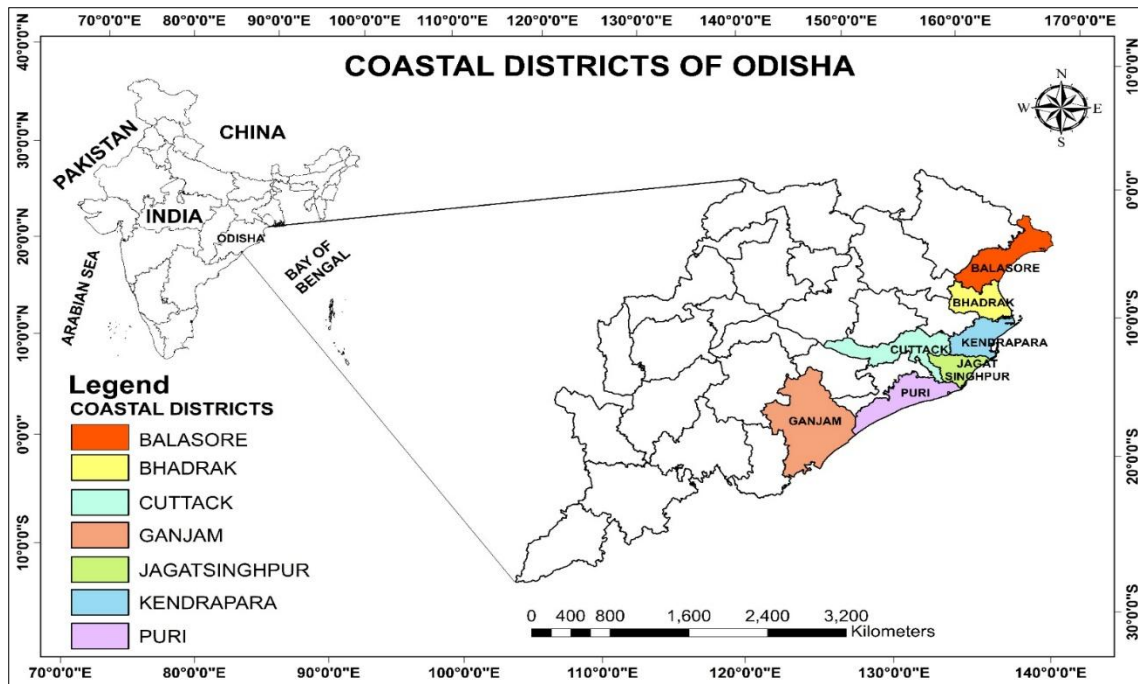


Fig.2: Coastal districts of Odisha

2. Methodology

For the trend in the impact assessment of floods and cyclones, past fifty years data from 1971 to 2020 for the seven coastal districts were collected from the secondary sources such as Odisha State Disaster Management Authority (OSDMA), Indian Meteorological Department (IMD) and Water Resources Department. From the year 1971 to till 1998 the district wise flood and cyclone impact data has been collected from the Indian Meteorological Report published as ‘Climate of Orissa’ in the year 2002. From the year 1999 to the year 2020 the flood and cyclone impact data was collected from the annual reports on natural calamities published by the Revenue & Disaster Management Department with the help of Odisha State Disaster Management Authority, Government of Odisha. Six variables have been implemented for assessment of the impact of both cyclone and flood in these coastal districts (table 1).

Category	Variables
Villages Affected	No of villages affected
Population Affected	Total population affected
Loss of Lives	Number of human lives lost
	Number of livestock dead
Crop Land Affected	Crop Area affected in lakh hectares
Houses Damaged	Number of houses fully damaged/ washed away
	Number of houses severely damaged

	Number of houses partially damaged
Public Infrastructure damaged	Number of school and college buildings damaged
	Number of health centers and hospitals damaged
	Length of roads damaged
	Number of bridges damaged
	Number of culverts damaged
	Number of country boats capsized

Source: OSDMA Annual reports (1999-2020) and IMD Report on Climate of Odisha-2002

The trend of impact of floods and cyclones on human being, livestock, agricultural crop and socio-economic infrastructure was done through various tabular and graphical presentations such as bar graph, line graph, pie chart etc. The district wise variation in the impact level for different districts on different socio-economic variables has been displayed by multiple bar graphs, Pie charts and tables.

For calculating the overall impact level of all the floods and cyclones occurred in the last fifty years among the coastal districts a composite damage map has been prepared for the study area taking the total damage on all the socio-economic variables including the loss of human lives and livestock affected. The absolute values of all the variables shown in table 1 have been normalized using the UNDPs normalization methodology. The formula applied for normalization of the variables in direct relationship is as follows:

$$x_{ij} = \frac{X_{ij} - \text{Min}\{X_{ij}\}}{\text{Max}\{X_{ij}\} - \text{Min}\{X_{ij}\}}$$

Where,

x_{ij} = normalized value of variable j corresponding to district i .

X_{ij} = actual value of variable j corresponding to district i .

$\text{Max}\{X_{ij}\}$ = maximum actual value of variable j corresponding to district i .

$\text{Min}\{X_{ij}\}$ = minimum actual value of variable j corresponding to district i .

After obtaining the normalized values of all the variables the Composite Damage Index (C.D.I) was calculated by employing the following formula:

$$\text{C.D.I} = \frac{\sum_{i=1}^n x_{ij}}{n}$$

Where,

$\sum_{i=1}^n x_{ij}$ = Summation of normalized values

n = number of variables

The normalized values of all the variables lie between 0 and 1. The value 1 represents the region with maximum impact and 0 represents the region with minimum impact. The

Composite Damage Index was classified into five groups using Jenks natural breaks method to represent five categories of the impacts on the study area; namely, very high, high, moderate, low and very low damage zones.

3. Results and Discussion

3.1 Population affected and human casualty

The effect of floods became very much penetrating and intense in view of the fact that the coastal districts are of high population density as compared to the other parts of Odisha. Among the coastal districts large population were affected in the districts of Ganjam, Cuttack and Puri. The average number of populations affected was highest in Ganjam district with around 2.87 lakh population affected per year followed by Cuttack (2.82 lakh) and Puri (2.31 lakh) district (Fig. 3). Jagatsinghpur and Bhadrak district are the least affected districts in terms of population affected per year which is less than 1.5 lakh. But in terms of human causality maximum lives were lost in the districts of Jagatsinghpur (73.5%). Out of the total 11065 human lives lost in these 50 years 8133 lives were lost alone in Jagatsinghpur district. The huge difference in the human causality between Jagatsinghpur district and other coastal districts was due to severe impact of Super Cyclone in 1999 where 8119 lives were lost alone in Jagatsinghpur district (Fig. 4). Maximum lives were lost in Cuttack district due to wall collapse and drowning in the caused by heavy precipitation and flooding. The human casualty was high in Ganjam district after the occurrence of Philine in 2013 while in Puri district maximum human casualty was observed with the impact of Fani in 2019.

Fig. 3: Average population affected per year by floods and cyclones (1971-2020)

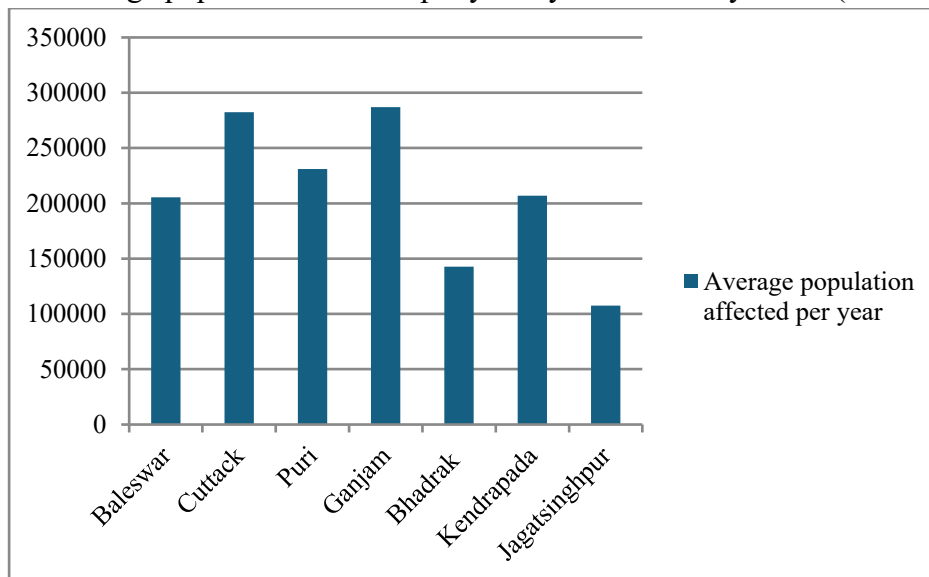
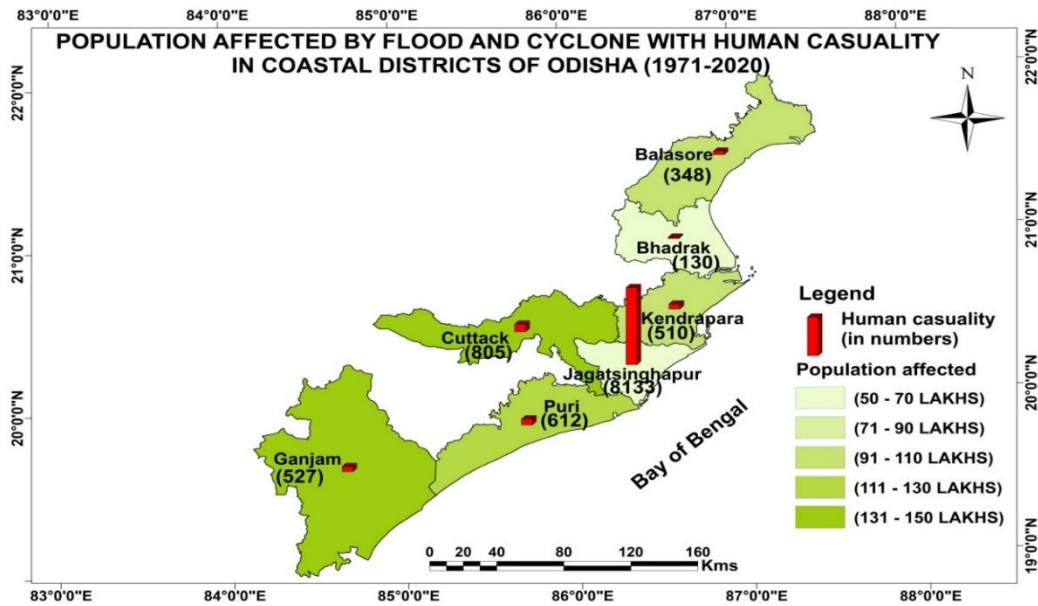


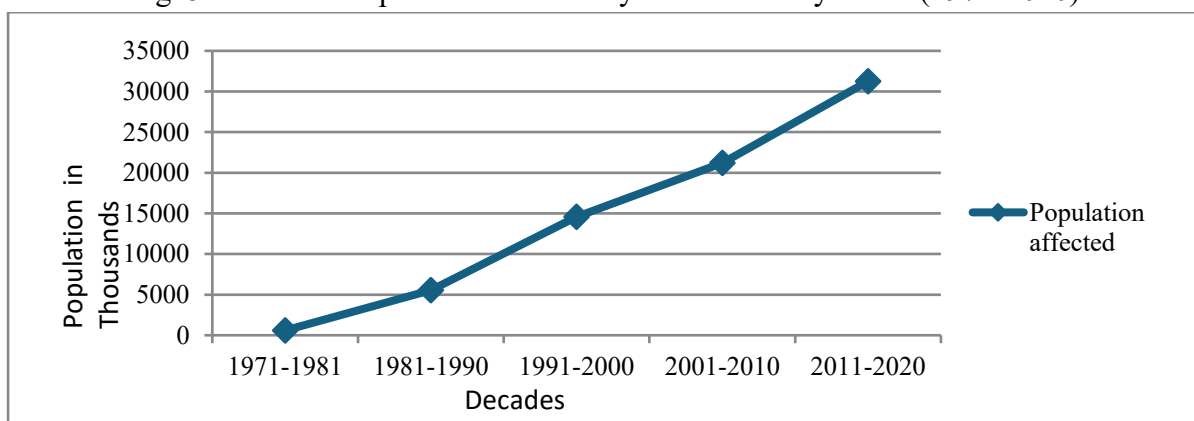
Fig. 4: Map showing total population affected with human causality in coastal Odisha



3.1.1. Trend in population affected

The trend in population affected by flood and cyclones since 1971 shows that there is steep rise in the population affected over the decades (Fig. 5). The rate of increase of population affected since 1971 was around 10 lakhs per decade. This could be due to the increase in the frequency of floods and cyclones over the years in coastal Odisha. Besides, the rivers Subarnarekha, Brahmani, Mahanadi and Rushikulya carrying huge volume of rain water in the upper catchment areas collected from surface run off flows through Baleswar, Kendrapada, Cuttack and Ganjnm districts causing severe floods in these districts affecting maximum population as compared to other flooding areas (Mahapatra, 2005).

Fig. 5.: Trend in Population affected by Floods and Cyclones (1971-2020)



3.2. Livestock affected

Among the natural disasters floods are most hazardous for the livestock animals. As per the report of an NGO called ‘World Animal Protection’ every year nearly one million cattle lost their lives by the floods caused by heavy precipitation (Kumaravel, 2020). Around 55%

of India’s buffaloes, 38% of its cattle, 41% of its goats and 47% of its pigs are vulnerable to floods (Bhatta & Kumar, 2021). The maximum livestock affected was observed in the year 1999 in the Super Cyclone, where it killed more than 11.50 lakh poultry birds and 6.20 lakh milch animals. Among the milch animals’ goat and cow are affected most by the super cyclone (Fig. 6). Except the high impact of super cyclone on Jagatsinghpur district. Overall, the district of Cuttack, Puri and Ganjam are highly affected districts in terms of livestock affected in last five decades (Fig.7).

Fig. 6: Number of milch Animals affected in the Super Cyclone, 1999

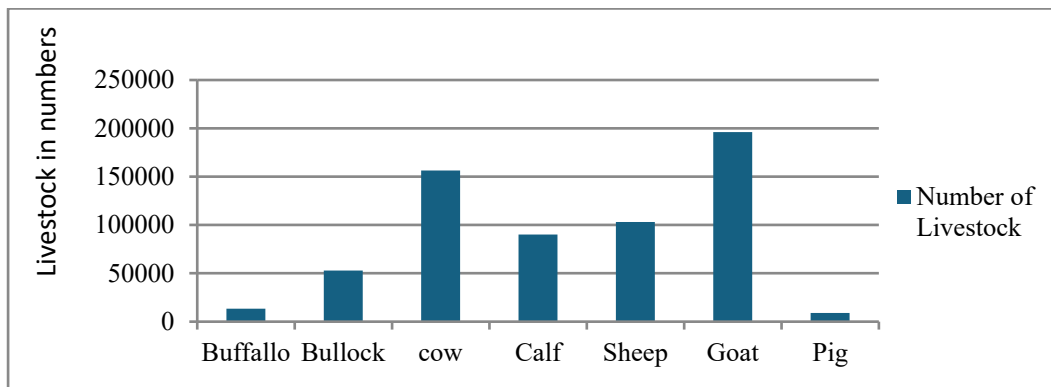
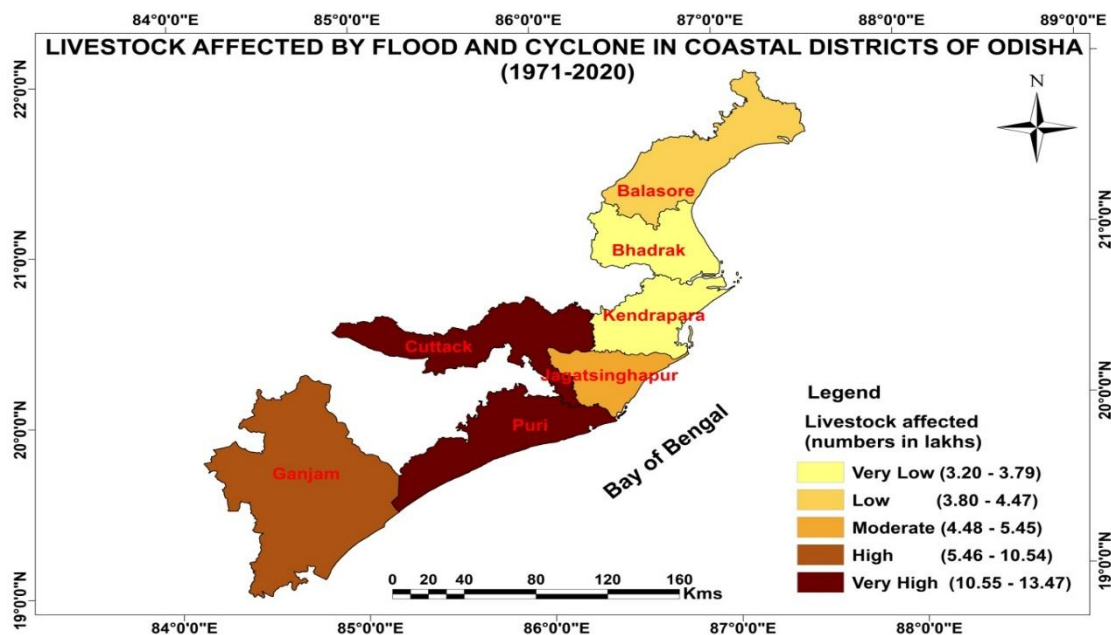


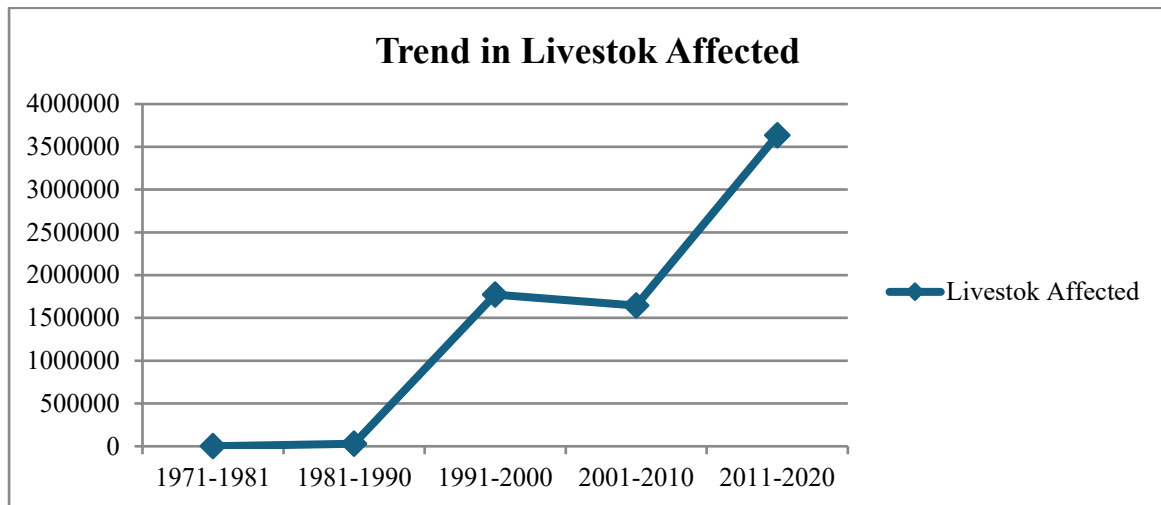
Fig. 7: Map showing livestock affected by flood and cyclone in coastal Odisha



3.2.1. Trend in livestock affected

During the first two decades the livestock affected was very minimal. Then there is sharp rise in livestock affected in the decade 1991-2000 where, 17.50 lakh more livestock lost their lives as compared to the previous decade. But, between the decades of 1999-2000 and 2001-2010, no significant changes observed in the loss of livestock. Further in 2011-2020 the livestock affected was doubled i.e. it was increased from approximately 18 lakhs in 2001-2010 to around 36 lakhs in 2011-2020 (Fig. 8).

Fig. 8: Trend in livestock affected by flood and cyclone (1971-2020)



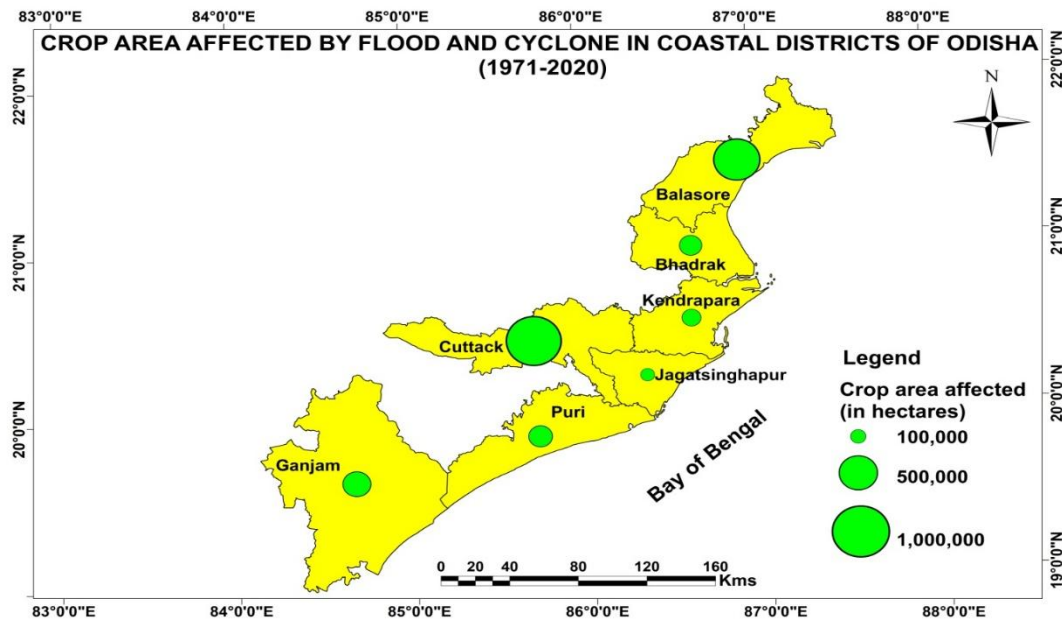
3.3 Crop damaged

108.50 lakh hectares of crop area damaged due to flood and cyclone from 1971 to 2020. It includes both the paddy crops and non-paddy crops affected by the heavy rain fall which were either submerged in the flood water or sand casted by the river flood. The cyclonic wind storms also damaged large areas of standing crops along the coastal belts during the landfall of cyclones (fig. 9). From Table 2 it is found that maximum crop loss of almost 40 lakh hectares was seen in Cuttack districts followed by Balasore district (27.09%) and then Ganjam district (11.27%).

Table. 2: Crop area affected in lakh hectares by flood and cyclone (1971-2020)

DISTRICTS	Crop Area Affected (in Lakh Hacters)	crop loss in %
Baleswar	29.39587	27.09
Cuttack	39.69837	36.59
Puri	9.17907	8.46
Ganjam	12.22961	11.27
Bhadrak	8.28042	7.63
Kendrapada	6.10899	5.63
Jagatsinghpur	3.61175	3.33
TOTAL	108.50408	100.00

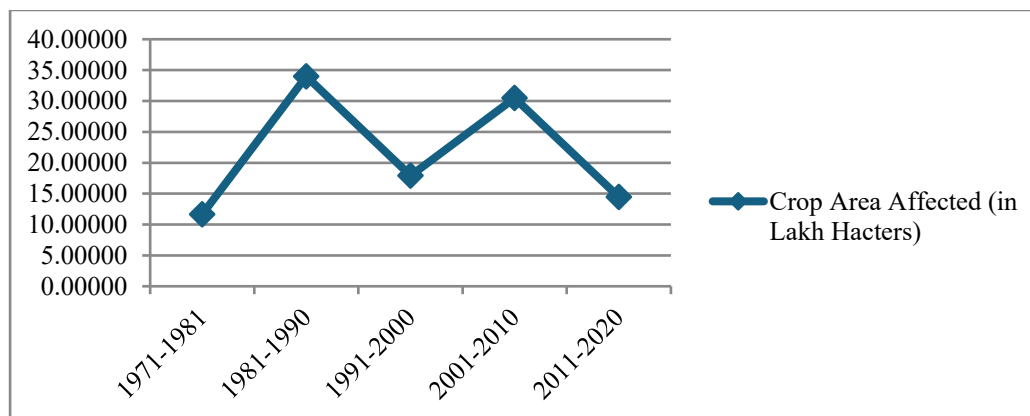
Fig.9: Crop area affected by flood and cyclones in coastal Odisha



3.3.1. Trend in crop damaged

Unlike the other aspects of damage, the trend in crop loss has shown a different trend over the decades. As standing crops are highly vulnerable to flood water (either stagnant water or flow water) (Kaur et al., 2020) hence, the maximum crop loss was observed in the two decades when the frequency of occurrence of floods was maximum i.e. in the decade 1981-1990 and 2001-2010 (Fig. 10). The crop loss was more than 30 lakh hectares in these two decades as compared to the other three decades of occurrence of flood and cyclone where the crop loss was less than 20 lakh hectares.

Fig. 10: Trend in crop area affected by flood and cyclone (1971-2020)



3.4. Houses damaged

Most of the houses in the villages along the coast are made up of earth-based materials which can be easily damaged in heavy rains and floods. The huts made from biomass materials like bamboo, leaves, thatch or light construction using metal sheets are easily destroyed in floods and washed away (Alam et al., 2015). Out of 23.63 lakh houses damaged, more than

half of the total houses damaged were found to be partially damaged. The percentage of severely damaged houses was 36% while the fully damaged houses constitute only 8% of the total houses damaged (Fig. 12).

Among the coastal districts Cuttack, Puri and Kendrapara were highly affected districts where more than 16 lakh houses were damaged out of the total 23.63 lakh houses damaged. Although in terms of total houses damaged were highest in Cuttack district but with respect to fully and severely damaged houses Puri district ranks first. This is because the landfall of Super Cyclone of 1999, near Paradeep coast in Jagatsinghpur district caused heavy damage to the high-density settlement areas in Puri and Cuttack. These three districts are followed by Jagasinghpur and Balasore where, more than 25 lakh houses were damaged either partially or fully (Fig. 11).

Fig. 11: District wise damage of houses with extent of damage in coastal districts of Odisha

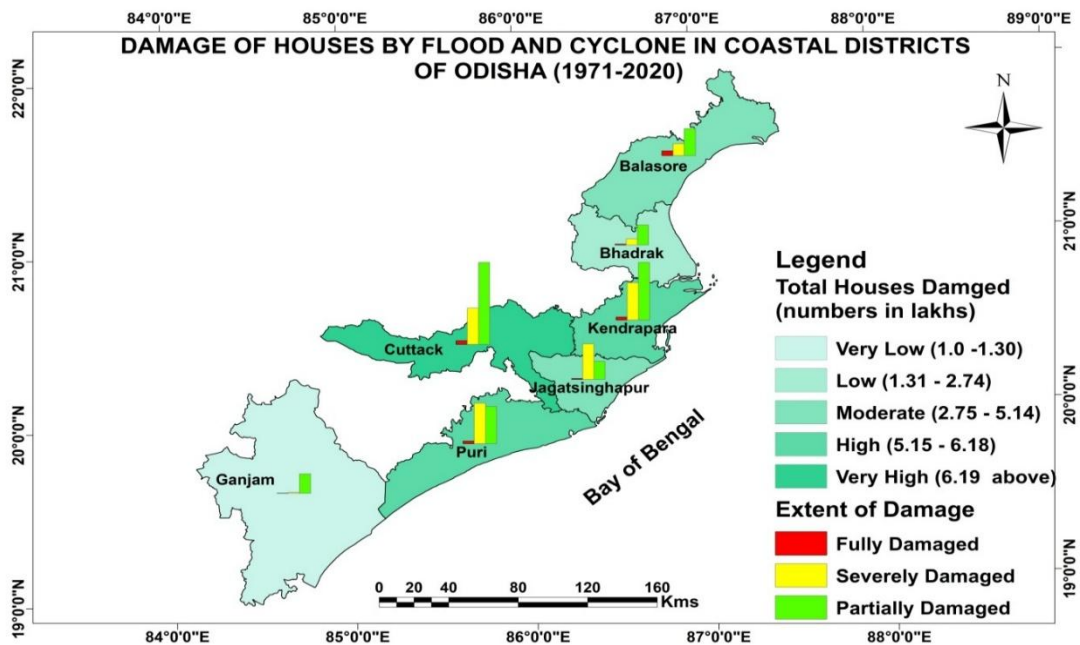
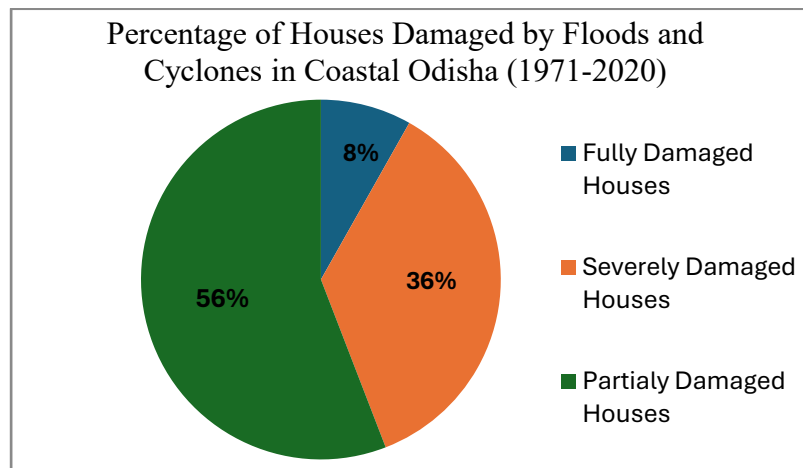


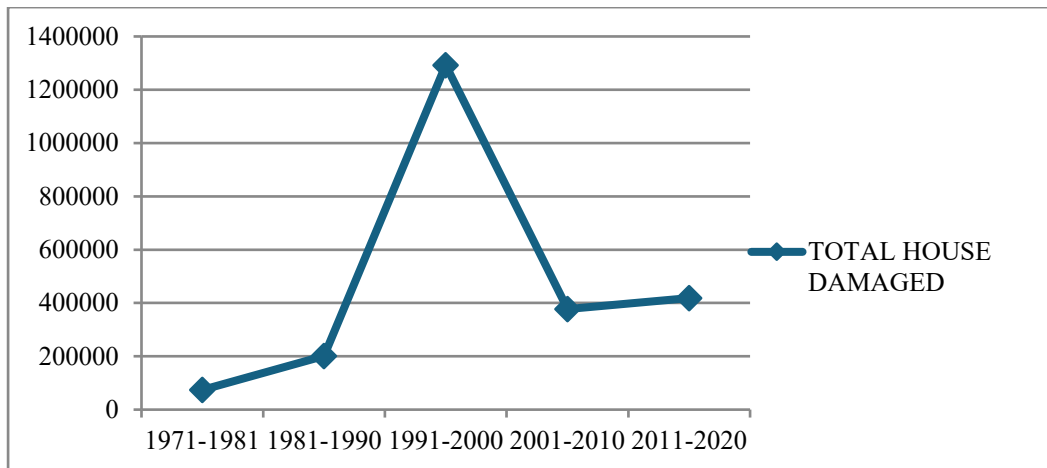
Fig. 12: Percentage of houses damaged basing on extent of damage in coastal Odisha (1971-2020)



3.4.1. Trend in houses damaged

The decadal trend in houses damaged in figure13 shows that, over the years in first two decades there is gradual increase in the total hoses affected. But, with the occurrence of super Cyclone in 1999, there is a drastic change in the total houses damaged in coastal districts of Odisha. The total house damaged which was around 2.01 lakhs in 1981-1990 has suddenly changed to 12.92 lakh in the decade 1991-2000. Again, there is sharp fall in the total houses damaged in the next decade i.e. 2001-2010 and it fallowed the same path with slight increase in the total houses damaged where it remained around 4 lakh houses damaged. Therefore, except the decade of super cyclone the trend in total houses damaged have been gradually increased over the decades. The change in the total houses damaged between last two decades which is minimal among all five decades possibly due to the change in the type of houses from *kutchha* house to *pucca* houses with the increase in the socio-economic standard of the people over the recent decade as *pucca* houses are least vulnerable to floods and cyclones as compared to *kutchha* houses (chhotray & Few, 2012).

Fig. 13: Trend in total houses damaged by flood and cyclone (1971-2020)

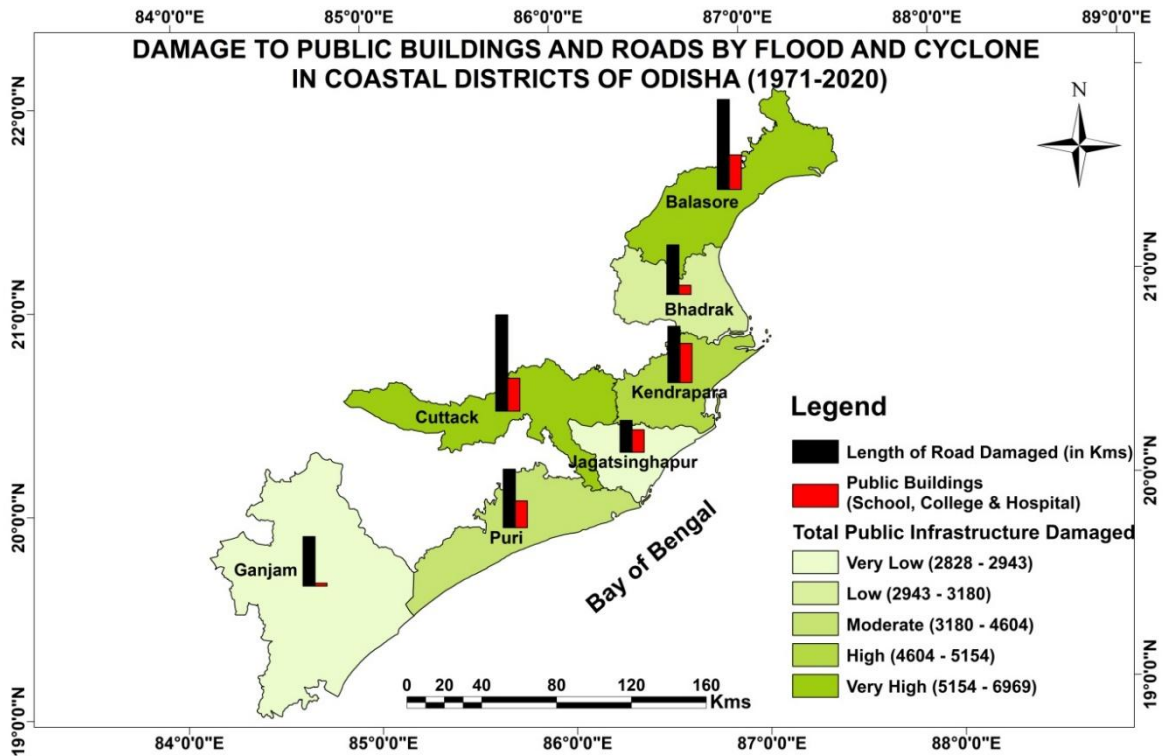


3.5 Damage to transport infrastructure and public buildings

Transport infrastructures such as railways, roads, water ways play vital role in the development of a region or country as it helps in improving the connectivity between regions for movement of either goods or people from one region to other. Although all the coastal districts are connected with the rail services but road ways have major importance in connecting rural areas with the semi-urban and urban areas (Iaquinta & Drescher, 2000). Flood water either stagnant or flow water both are vulnerable to the roads which are mainly made up of asphalts. Asphalts roads can be damaged with continue impact of flood water over longer periods (Mallick et al., 2018). The rural *kutchha* roads which links between rural regions are most vulnerable to rain water which can be easily washed out with heavy rainfall and the resulted flood. In a total 23329.30 km of road length was damaged in the last five decades with an average damage of 466 km per year. Maximum road length was damaged in the districts of Cuttack and Balasore where, both districts together constitute around 10000 km of road length damaged. Except these two districts the road length was evenly damaged in all other coastal district which was around 3000 km of road length (Fig. 14).

Public buildings include schools, colleges, PHCs, CHCs and hospitals. Damage to these public buildings creates both short-run and long-run impacts on the availability of educational services and medical services (Kim & Ahn, 2020). In the past five decades a total of 8476 school buildings and 597 hospitals were damaged by heavy flood in all the seven districts. Maximum school buildings were damaged in the districts of Kendrapara and Baleswar where, more than 1800 school buildings were damaged in each district. Ganjam and Bhadrak are least affected districts in terms of total number of public buildings damaged (Fig. 14).

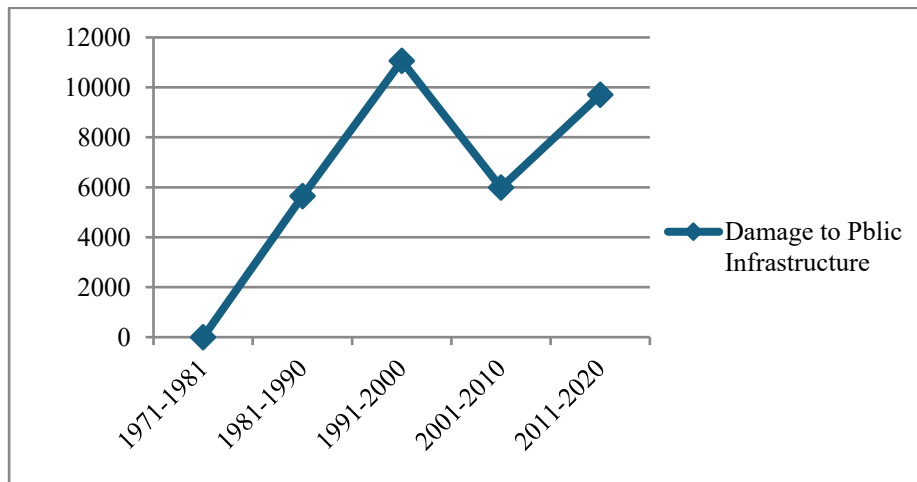
Fig. 14: District-wise damage to public infrastructures by flood and cyclone (1971-2020)



3.5.1. Trend in damage to transport infrastructure and public Buildings

The trend of public infrastructures damages over the last five decades in figure 15 shows that the damage has been increased steadily in first three decades until 1991-2000 where the number of public infrastructures damaged was maximum with the impact of high intensity Super cyclone in 1999. It was fall down in the next decade i.e. in 2001-2010 to the same position with occurrence of only floods. But, with the occurrence of more cyclones along with floods again the damage of public infrastructures increased in the decade 2011-2020.

Fig. 15: Decade-wise damage to public infrastructures by flood and cyclone (1971-2020)

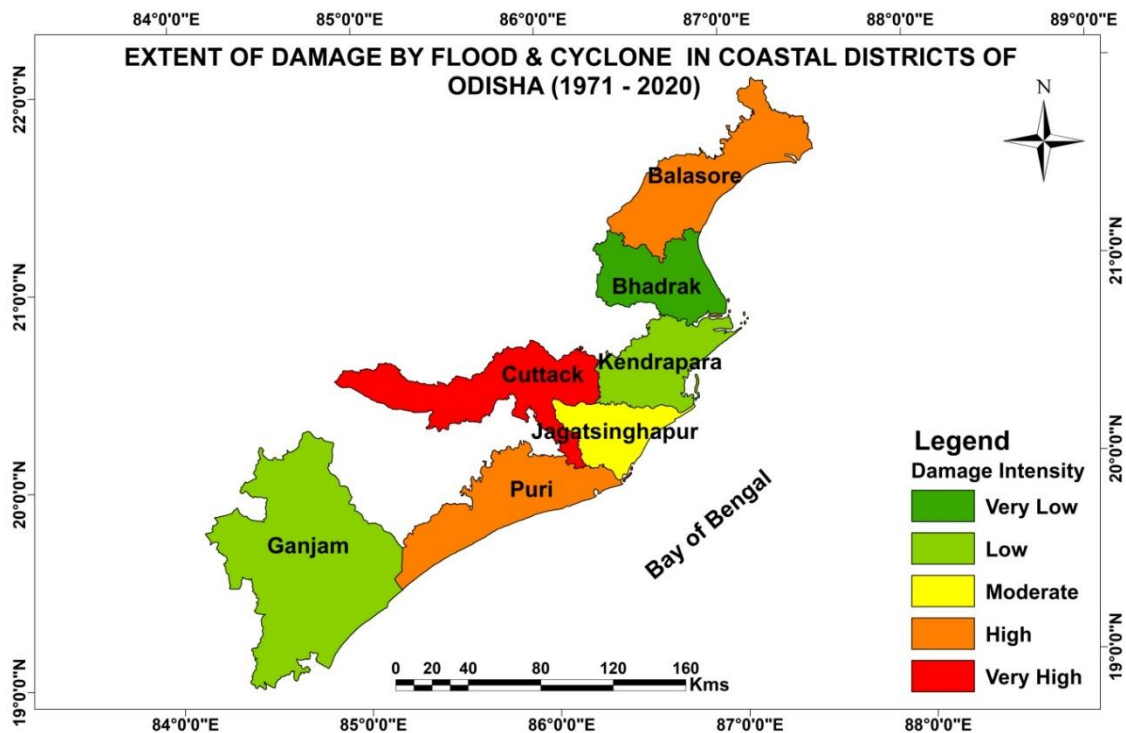


3.6 Composite damage assessment of flood and cyclones in coastal Odisha (1971-2020)

The damage statistics of all the variables such as population affected, number of human lives lost, livestock affected, crop damage, damage to houses, damage to public infrastructure were normalised by the normalisation method and these values were added together to get the Composite Damage Index (CDI). The composite damage index helps in the overall comparison of damage to all the variables irrespective of the difference in their unit values. The calculated damage index has been categorised in to five zones in terms of their extent of damage.

Cuttack district was found to be very highly affected district in the last 50 years among the seven coastal districts. This is certainly due to the damage caused by the frequent floods in Cuttack district. The damage caused by Super Cyclone, of 1999 and the occurrence of the Cyclone ‘Fani’ in 2019, makes Puri the second most affected district after Cuttack. Balasore district has been constant victim of natural hazards particularly the floods. In the last 50 years Balasore has been the second most affected district with respect to floods in coastal Odisha. The location of Bhadrak district with respect to the sea coast makes it least affected to floods and cyclones as compared to the other coastal districts. Although floods have damaged the resources and human population to some extent in Bhadrak district but, it is very less likely to be affected by the cyclones hence, not a single cycle has made the landfall in Bhadrak district. Ganjam and Kendrapara falls in the low affected zones. As the frequency of occurrence of floods and cyclones in Ganjam district is very less therefore the composite damage index is low in Ganjam district (Fig.16).

Fig. 16: Composite Damage Map of floods and cyclones in Coastal Odisha (1971-2020)



4. Conclusion

The state has experienced a rise in the occurrence and strength of floods and cyclones in the past two decades principally due to the increased occupation of flood plains and the production of a greater number of cyclonic disturbances caused by increased human intervention in sea water. Curiously, although the human causality, resulting from flooding and cyclones has declined over the past decade, there has been a substantial increase in the number of people impacted and the economic losses incurred. These trends necessitate enhanced readiness at the national, state, and local levels to ensure that suitable and efficient response measures are implemented during flood emergencies in order to minimise the loss of lives and assets.

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