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A STUDY ON VARIOUS TROPICAL CYCLONE HITS IN INDIA – THROUGH GIS APPROACH

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Abstract: Tropical cyclones are most frequently affecting natural disaster in India. The consequences of the tropical cyclones are Storm surges, flood, high winds, inundation, and erosion etc. along with loss of life, causalities, and damages to the properties causing socio economic loss. Remote sensing & GIS plays a crucial role in early warning, real time monitoring, impact and damage assessment and in the relief operations. Tropical cyclone warning messages provide detailed information about the storm intensity, position, direction and its velocity of movement as well as its future direction, intensity and its landfall positions. In this study basin of origin of various cyclones affected India is identified. India is mostly affected by the cyclones originating from Bay of Bengal. It is found that Frequency of cyclones with various intensities originating in Bay of Bengal is very high and is four times that of originating in the Arabian Sea. It's observed that the frequency of Depressions forming is very high compared to the categories of other cyclone intensities. It is also observed that West Bengal, Orissa and Andhra Pradesh, Andaman and Nicobar Islands are mostly affected states in India by the tropical cyclones from the plots. Gujarat, Lakshadweep are mostly affected with storms that are originating in the Arabian Sea. Tropical cyclones suddenly changes its course of path during its active life span is also observed while plotting the track of cyclones. The main cyclone season in the South Indian Ocean observed is May-July and September-December with major occurrences of storms in April and August from the historical data.

Keywords: tropical cyclones, GIS, basin of origin, cyclone track, Bay of Bengal, Arabian Sea, frequency analysis, ArcGIS

1. INTRODUCTION

Among the coastal disasters tropical cyclones followed by storm surges are one of the catastrophic natural disasters occurring in India. Some of the deadliest tropical cyclone hits in the country are Ockhi (2017), Vardha (2016),Hudhud (2014), Phailin (2013), Nilam (2012), Thane (2011), Jal (2010), Nisha (2008), Fanoos (2005), Sidr (2007), Bhola (1970). All most all the cyclonic storms or storms with higher intensity scale are accompanied by storm surges, heavy precipitation resulting in the inundation of low lying areas later flooding. Tropical cyclones have different names in different places according to the place of its origin. The name "hurricane" is given to systems that develop over the Atlantic or the eastern Pacific Oceans. In the western North Pacific and Philippines, these systems are called "typhoons" while in the Indian and South Pacific Ocean, they are called cyclones. TCs are classified by its form and intensity as they increase its size namely disturbances, depression, storm, hurricanes etc. The disaster potential of a TC is very high when it is making a landfall due to the strong winds along with heavy rainfall and tidal waves. Storm surges causes erosion as well as flooding. Considerable increase in frequency of the most intense cyclones increases the precipitation rate to 20% within 100 km of the storm center [20]. A cyclonic storm loses its intensity as it makes a landfall due to the lack of warm air supply from the ocean. Cyclone affected areas increased with the increase of return periods [10]. Previous studies shows that no certain long term pattern exists in the case of frequency or in the intensity of TCs [14]. However some studies already have proven that there is an increase in the intensity of cyclonic storm activities in the Bay of Bengal during past years compared to that of the Arabian Sea. The intensity of the tropical cyclones during the monsoon period has increased during the recent years. The GIS-based storm surge models can be used in the case of risk modelling to obtain necessary information for different disaster phase including preparedness phase of a Tropical cyclone disaster management. Historical cyclone data and the population data are the crucial data for considering the cyclone risk assessment and it's modelling [10].

The objective of the study is to identify the different cyclone prone areas in India using GIS techniques. This study also aims at the identification of different Basins of origin of the cyclones and depressions in the Bay of Bengal & Arabian Sea and their classification based on the tropical cyclone intensity scale by IMD and their frequency analysis. It also helps in plotting the path of the cyclone followed during its journey. Zoning of the study area can also be done based on the impact of hit and the

frequency of landfalls in the study area using the historical cyclone track data. This study helps in the identification of the different landfall zones in the study area based on the historical trends which in turn helps in the evacuation of the affected people, identification of safe shelter for the people.

2. STUDY AREA

The study area is India which is constantly at risk because of Tropical Cyclones, storm surges, tsunami, floods etc. The study area is located north of the equator with coordinates with 8.085N, 68.192E to 37.09N, 97.40E. India is the seventh largest country in the world with New Delhi as its capital. India is surrounded by Indian Ocean in the south, Bay of Bengal on the southeast and Arabian Sea on the southwest. Tropical cyclones that hit India are originated mainly from the two basins namely Arabian Sea and Bay of Bengal during the spring and fall. The main cyclone season in the South Indian Ocean is May-July and September-December with significant occurrences of storms in April and August. Coastal areas are the most vulnerable to the cyclone hits and are followed by storm surges compared to the inland regions. The coastline of India is about 7516.6 km. There are 9 Districts share the coastline namely Gujarat, Maharashtra, Kerala, Goa, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, 3 Union Territories namely Andaman and Nicobar Islands, Lakshadweep and Puducherry.

Figure 1 Study area

3. DATA USED

This study deals with the analysis of the various historical tropical cyclones and their basin of origin have used the following data:

3.1 Open Series Map

Survey of India (SOI) Open Series Maps (OSM) is used for the digitization of the administrative boundary of the study area. The maps that are used for the digitization of the administrative boundary are mapped to a scale of 1:50,000.

3.2 Cyclone Historical Track Data

Cyclone historical data is issued by the Indian Meteorological Department (IMD) in the form of excel spread sheet. X & Y coordinates are present along with the other details of the cyclone. This data is used to plot the tracks of different cyclones that hit the study area in the past along with their landfall points occurred. Cyclone historical data is having more than 100 years of return period of the cyclones all over the India along with their basin of origin i.e. Arabian Sea or Bay of Bengal over a period of 1842-2016.

3.3 Historical Cyclone Basin of Origin Data

Cyclone historical basin of origin is issued by the IMD. It consolidated data provides the information of the various depressions, CS (Cyclonic Storm) and SCS (Severe Cyclonic Storm) that originated over the Indian Ocean (Arabian Sea and Bay of Bengal) over the period of 1891 – 2016. This data helps to identify various depressions that formed over the land.
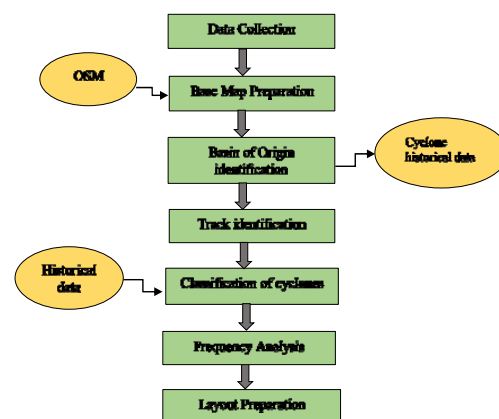
4. METHODOLOGY

Figure 2 Methodology

This study begins with the collection of the data that is required for the achievement of objectives. SOI OSM scaled at 1:50,000 are used for the preparation of the Administrative Boundary. The software used for the study is ArcGIS. The datum used is WGS 84. The cyclone tracks are plotted in the same software using the historical cyclone hits data provided by the IMD (Indian Meteorological Department) using the same datum. For each and every cyclone track attribute table is provided for the further classification and interpretation. Historical data is in the form of X & Y format provided with Latitude and Longitude information of the track followed by the cyclone along with its landfall points during its life span. The consolidated excel spread sheet also provides the details like basin of origin, central pressure, date of occurrence, landfall coordinates, grade of each cyclone. XY data available in the excel spread sheet is converted into a feature class before importing into the ArcGIS. The consolidated tropical cyclone historical data contains all the cyclone hits occurred in India over some decades. Identify the different landfall points of the cyclone according to the track they followed. Maps are properly scaled, labelled Coordinates, title, north arrow, legend, scale bar are provided accordingly. Various cyclone types and depressions are identified by analyzing the intensity of the various storms. The various storms are identified as Depressions (D), Cyclonic Storms (CS) and the Severe Cyclonic storms (SCS) that are formed in the Indian Ocean, Arabian Sea & Bay of Bengal based on the intensity scale provided by IMD (Table 1). Based on the classification the frequency analysis of the different storms that hit the study area over a period of 1981-2016 is carried out.

Table1 Intensity scale for classifying storms issued by IMD

Category	Wind Speed (km/h)
Super Cyclone Storm	≥ 221
Extremely Severe Cyclonic Storm	166-220
Very Severe Cyclonic Storm	118-165
Severe Cyclonic Storm	89-117
Cyclonic Storm	63-88
Deep Depression	51-62
Depression	31-50

5. RESULTS AND DISCUSSIONS

The different map layouts that are prepared during the study are included here. The 9 coastal districts and 3 union territories are prone to the cyclone hits according to the frequency of hits due to its proximity to the sea.

The tropical cyclone tracks clearly depicts that it abruptly changes its course (figure 6).

The intensity and its ferocity are reduced when a cyclone makes a landfall. Identification of the basin of origin, clearly says that the influence of basin of origin is also a factor for the origin as well as the intensity of the tropical cyclones. As most of the cyclones that are originated in the Bay of Bengal basin over the Indian Ocean. The storms formed over Bay of Bengal are four times to the Arabian Sea from the historical dataset (Figure 4).

The storms are classified as Depressions (D), Cyclonic Storms (CS), and the Severe Cyclonic Storms (SCS) (figure 5). In this study, it is identified that some of the Depressions are formed over the land instead of water (Figure 4). Depressions are less disastrous compared to the tropical cyclones formed over the warm water. Depressions are low pressure area and in land it causes erosion in that particular area. Depressions are very common in the ocean with warm air as the supply of the warm air intensified the storm also gets intensified.

Table2 Frequency analysis of different storms

Sl. No	Frequency	Intensity
1	336	CS
2	880	D
3	294	SCS

The frequency analysis results of the storm originating in both the basins are represented in tabular as well as in graphical form. The frequency analysis results show the higher probability of formation of the Depressions in the basins compared to the other storm intensities (Table 2). It is observed that the occurrence of the Severe Cyclonic Storms (SCS) is very less but is the most devastating among the 3 categories. Cyclonic storms are formed less compared to the frequency of Depressions but more frequent than the SCS. As the wind speed increases the intensity of the cyclone also increases along with its disastrous nature. Super cyclone as very rarely occurring but at the same time most devastating type of natural disaster.
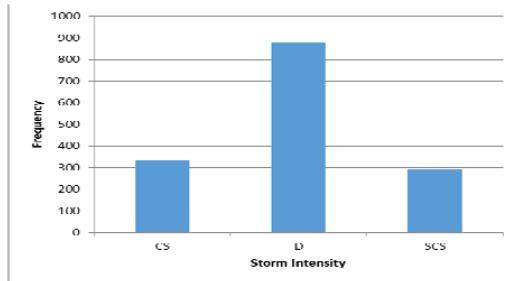
Figure 3 graphical representations of different storms

Figure 7 represents the area prone to the cyclone hits in the study area. The cyclone track density clearly depicts that the West Bengal, Orissa, Andhra Pradesh are the most vulnerable states in India along with Andaman & Nicobar Islands in the east side and Gujarat in the West side along with Lakshadweep Islands. Track density is very heavy over the above mentioned areas is observed during the return period over 100 years. Each and every cyclone track is plotted using the track points (latitude and longitude) of the cyclone. Each and every track points of the cyclone provide details of its intensity, wind direction, wind speed, observed precipitation etc. to predict its future path.
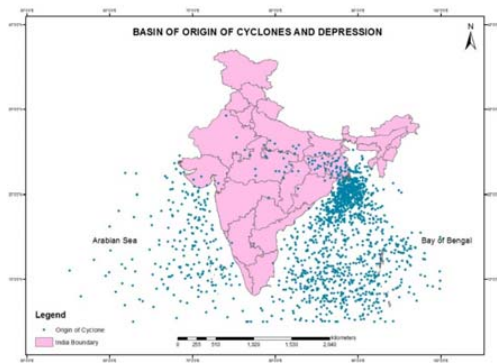

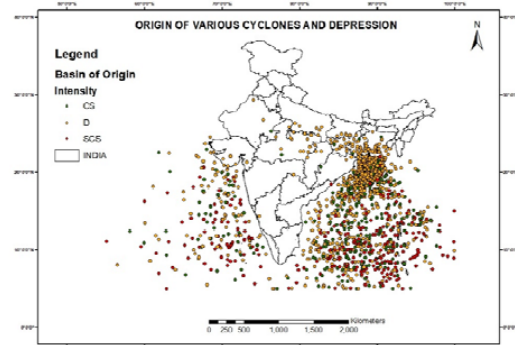Figure 4 Basin of origin of different cyclones & depressions

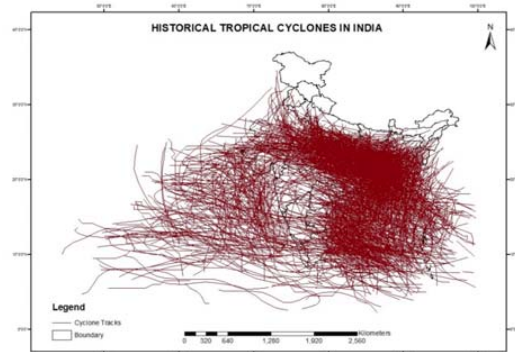**Figure 5** Classified storms based on their intensity

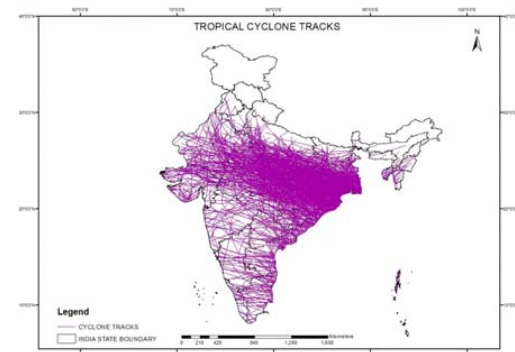**Figure 6** Various historical cyclone tracks in India

Figure 7 Cyclone affected states in India

6. CONCLUSION

The historical cyclone hits show that the Orissa, Andhra Pradesh, West Bengal and Andaman & Nicobar Islands are frequently prone to cyclones and depressions that are formed in the Bay of Bengal basin whereas Gujarat is the most vulnerable state for tropical cyclones

originating in the Arabian Sea is clearly visible from the density of tracks plotted. The deadly cyclones like SCS and CS are mainly originated in the Bay of Bengal basin than in the Arabian Sea basin due to presence of warm air present in the area and are of four times that of originating in the Arabian Sea. Storms are classified as Depressions (D), Cyclonic Storms (CS) and Severe Cyclonic Storms (SCS) based on their intensity using the Intensity scale issued by IMD for the Tropical cyclones originating in Indian Ocean. It's observed that the Depressions are more frequent in number (880) followed by Cyclonic Storms (336) and severe cyclonic storms (294).It is observed that some of the depressions are formed over the land instead of water but they are very weak. It is observed that not all the Depressions develop into cyclonic storms. The sudden deviation of the tropical cyclone path during its active period is also observed while plotting the tracks from the historical data. Most of the historical cyclone hits are observed during the period of October, September, and November. The main cyclone season in the South Indian Ocean observed is May-July and September-December with significant occurrences of storms in April and August from the historical return period data.

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