

Lessons from the Past: Learnings for the Future from the Canacona Disaster

¹Dr. F. M. Nadaf & ²Dr. Joseph S Rauto de Souza

¹Associate Professor of Geography, DPM's Shree Mallikarjun College, Canacona-Goa(India)

²Chief Scientist, Department of Science, Technology and Environment, Government of Goa(India)

ARTICLE DETAILS

Article History

Published Online: 25 May 2019

Keywords

Remote Sensing (RS), Geographical Information System (GIS) Global Positioning System (GPS), Integrated Disaster Management Plan, Predictability, and Mitigation.

Corresponding Author

Email:fmnadaf[at]gmail.com

ABSTRACT

Disasters which are common on the earth are generally caused by a quick release of energy from matter causing a catastrophe. It is moderately acknowledged and accepted that occurrence of disasters cannot be eliminated; however, they can be abridged through earnest efforts towards impact reduction on life; economy, environment, through predictability, forecasting, protectiveness, preparedness, preventiveness, mitigation and ameliorative planning measures. Disaster proofing is also important especially for the weaker sections of the society, wherein efforts must be made to consciously raise the economic status of the people. An effective disaster management program will therefore aim to avoid deaths, reduce casualties, property, damage and minimize disruption of communities, social and economic fabric. Technical innovation is a great instrument, tool and challenge towards mitigating adverse effects of the calamities. Under these circumstances, adaptation efforts can be meaningful and effective through collaboration of various competent actors and players, in an interactive manner, along with the affected community and government machinery, wherein the state administration is a major key player.

A long term planning process is a prerequisite which with an objective at decreasing the level of potential risks, mitigating the consequences and preventing the development of chain of events by localizing and limiting the scope of the catastrophe. Therefore, there is an urgent need for an effective predicting system along with awareness and sensitization drives, supported with sophisticated communication networking. Social, electronic and print media, including capacity building and training, would be an effective approach towards awareness and sensitization generation.

The State of Goa being ecologically fragile, and susceptible to man-made and natural disasters, demands to have at place a disaster management plan at taluka level as a unit and at the State as a block. Thus, there is an urgent need to have an insight into the disaster management plan for the entire State of Goa, and primarily for the flash flood hit Taluka of Canacona. These plans should be people centric, with involvement of the local population and supported with an effective and refined early disaster warning system, coupled with constitution of search and rescue teams.

In this direction, Geo Informatics, a synergy of RS, GIS and GPS tools has been used for rapid appraisal survey of post disaster analysis, data base generation and the generation of an Integrated Disaster Management Plan for the Canacona Taluka. These management plan have been generated through the integration of various thematic layers, viz; land use pattern, slope gradient, elevation and relief, land forms, drainage, lineaments, geology, as also, through a consultative process incorporating traditional knowledge of the local community as also with the interaction with the concerned authorities.

1. Introduction

World over, including the Peninsula of India, the impacts of global warming, are evident from the increasingly erratic anomalies in the climatic pattern, inconsistent rainfall, variations in temperature and so on and so forth, resulting in outrageous disasters. Climate change though a global process, has had serious and devastating impacts at the regional and local level. One such incidence occurred in Canacona the southernmost taluka of Goa on 2nd October 2009, causing enormous apprehension, anxiety and trauma to the affected population. On this fatal day, nature turned sadistic thereby causing an unprecedented precipitation, resulting in catastrophic and devastating flash flooding and landslides in entire Canacona taluka. This resulted in injury and mortality to human life & livestock, disruption of essential services, destruction of households, interruption in communication networks, obstructions to roads, damage to bridges, vehicles and agriculture outcrops, forest plantations, private and government property, landscape, waterscape, displacement of human settlement. Fortunately, prudence prevailed in the

region, and an outsized number of human and livestock injuries and deaths were minimized, as also a sizeable amount of movable property was salvaged as the event occurred at daylight.

In the direction to ascertain the "cause and effect" of the event and suggest plausible measures to combat and mitigate a similar disaster in the future, a meticulous scientific investigation has been attempted through a multi-prone approach coupled with an exhaustive reconnaissance survey. Survey of India topographical maps in conjunction with satellite images integrated in a GIS environment, along with GPS have been used for the said investigations. The comprehensive investigation reveals that the catastrophe at Canacona was due to a synergy of climatic changes, coupled with meteorological, geological [lithology and structure of outcrops], geomorphologic, hydrological and human invasive factors.

Two human deaths due to drowning were reported, with a damage of around 686 households, along with loss of a number of livestock, agriculture and horticultural crops and

innumerable loss to immovable, movable property and house hold assets. The Government of Goa, on 3rd October 2009, declared the event as a State Disaster and pegged the estimate loss to Rs. 130 crores. Government machinery and various NGOs' rushed to the region to provide relief and relieve to the aggrieved families.

This paper is an outcome of the technical report submitted to the Department of Science, Technology and Environment, Government of Goa to synthesize and, as far as possible, conceptualize the approach that can be adopted to address the issue of flash floods and landslides at the taluka scale for the benefit of the community at large and provides an easy reachable guidance on flash flood and landslide management through an Integrated Land Slide Management Plan [ILSMP] and an Integrated Flood Management Plan [IFMP] further synergized into an Integrated Disaster Management Plan, [IDMP] at Canacona Taluka as a block. Viable management prescriptions have been suggested in the areas of hill and hill slopes, water and soil, food and nutrition, livestock, engineering and flood resistant structure, community health and causality, beach, coasts and dune management, economic indicators and viability, institutional mechanism, administrative response and capacity building have been suggested. IEC (Information Education and Communication) has been suggested as it is a major communication tool towards preparing the community for a future disaster.

It is visualized that the prescriptions detailed in this paper towards flash flood and landslide reduction and mitigation at Canacona, may serve as a value addition tool to the concerned authorities, and various emergency services on various administrative scales or broader scales, as it will considerably profit to at least minimize the impact of a disaster, reduce the misery and vulnerability of the affected people in the region. There many lessons to learn from the Canacona Disaster for the safe future of Canacona in particular and Goa in general.

As such, it would be valued if the prescriptions suggested, will facilitate and motivate decision makers in reducing the vulnerability of local communities to the impact of flash floods and landslides, in Canacona region, within the overall disaster management plan and framework of the State and Union of India.

2. Prime Objectives:

The key objectives of the present study are

- To examine the forces and actions those were responsible for Flash Flooding and Landslides on 2nd October 2009.
- To suggest an effective Disaster Management Plan for Canacona in particular and Goa in general.

3. Area of Investigation:

Canacona Taluka covers a geographical area of 352.02 square kilometer, which is 9.50 percent of the total geographical area of the State (Figure 1). According to the 2001 Census, Canacona taluka has a population count of 43,997. Canacona is located in the southernmost part of Goa, between the latitudes of 14° 55' 00" to 15° 10' 00" North and 73° 55' 00" to 74° 15' 00" to the East of Greenwich (Figure

1). In the North, Canacona is bordered by Quepem Taluka, in the East with Sanguem Taluka and in the South it shares its common border with Uttar Kannada district of Karnataka and on the West, Canacona is flanked by the Arabian Sea. The taluka is characterized by hilly topography, high ridges, indented coastline, headlands, beaches, islands and wetlands.

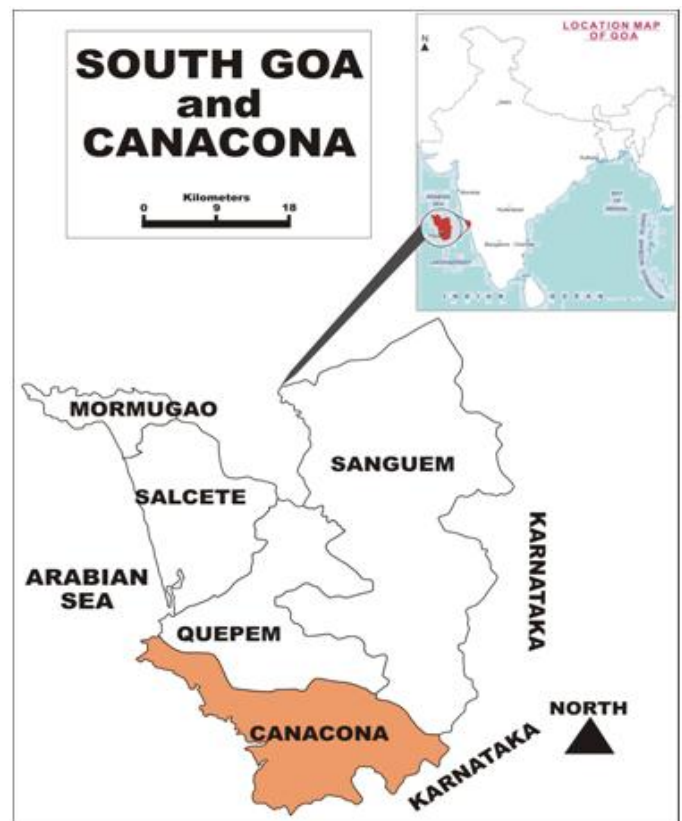


Figure 1

Canacona taluka is gifted by three important estuarine rivers namely Saleri, Talpona and Galgibag. Though these rivers are small but they are vital for Canacona and its identity. A large number of people depend upon these rivers for their livelihood.

The epicenter of Canacona Disaster was between River Talpona and River Galgibag. The region has hilly topography with seven categories of slopes namely A-1, B-2, C-3, D-4, E-5, F-6, and G-7. A large area around Saturli, Kuske, Nadke, and Yedda falls under G-7 category. The region has dendritic drainage with the presence of 1st, 2nd, 3rd, 4th and 5th order streams (Figure 2). An interesting observation is that there are good numbers 1st, 2nd and 3rd order lineaments (Figure 3). As a result drainage at many places is structurally controlled. River Talpona has its source region in the Nadke hills (662 meters above sea level (masl)), Kuske Hills (510 masl) and around Yedda Hills (289 masl). While the source region of River Galgibag on the Karnataka-Goa borders (Dariyya Halla) and Kargal (153 masl) and Maddel (100 masl). Both rivers have systematic network of small tributaries. River Talpona is about 43 kms long and River Galgibag is about 12 kms in length. Both of them drain into Arabian Sea about 2.5 kms apart.

4. Data Utilized:

The data for the investigations consists of primary, secondary and tertiary data sets, comprising of Survey of India Topographical Maps (Index No. 48 E/16, 48 I/4, and 48 J/1), satellite data LISS-III (P6) + PAN (Merged-hybrid) LMX-IV, on 1:50,000 scale, and GPS data, supplemented with detailed ground validation, and ancillary data comprising of reports, maps and available records, including meteorological data. These data sets facilitated to prepare the base map and enabled to navigate a viable access to the region, as also aided in understanding the land use pattern of the region and appreciably extract the spot heights, drainage density, and slope aspect of the region.

5. Methodology and Approach:

- Base Maps and a Road Map for Ground Control Point (GCP) locations and undertaking filed traverses were prepared.
- Detailed and periodic reconnaissance surveys with ground truthing were undertaken in the landslides and flood affected regions in Canacona taluka. The observation stations were plotted on the base map.
- The topographical maps were interpreted for extracting spot heights, slope gradient, cross section profiles, derivation of drainage measurements and water spread area.
- Satellite data was interpreted to generate the particulars of the land use pattern of the region. In addition to refine the aerial perspective of the region, portals like Goggle Earth, ISRO's Bhuvan Earth and NASA's Worlds Wind were accessed.
- GARMAN Map 76 CSX was used to validate the positions at ground.
- The meteorological data facilitated in computing the precipitation and related parameters of the region, whilst, the high tide data indicated the measurements of the tide level.
- On collating, analyzing and integrating the data, in a GIS environment, a report on the cause and affect of the catastrophe was prepared, suggestions various short and long term management prescriptions have been suggested.

6. Results and Discussions:

The chronological progression of the catastrophe at Canacona was attributably caused by the unprecedented and variability in rainfall and allied climatic factors, in the region, where in several landslides were attenuated in the upper catchments due to the unprecedented rainfall causing geometric changes in gradient, which resulted in reduction in the frictional strength of the outcrops, owing to external loading, ensuing an increase in pore water pressure. As the pore pressure of the soils increased, the same could not be relieved by water movement to an unsaturated area, this caused the solid grains to slip incessantly, causing stress within, which eventually lead to slope failure along weak slip surface, and resulted in the down slope movement, causing progressive failure and stress concentrations. The high water ground table also contributed to the landslide catastrophe. This resulted in flushing of unquantifiable volume of land mass,

comprising of rock and mud debris, boulders, pebbles, silt and lateritic outcrops and alike consolidated / unconsolidated material, which silted the low lying regions, including the river basin area.

7. Causes of Flash Flooding:

Unprecedented and Incessant Rainfall:

Canacona Taluka receives around 3000 mm of rainfall annually generally spread from 7th June to 30th September, with an average of 25.86 mm rain daily. The region experiences heaviest rainfall in the month of July of an order of around 900 mm. Following table shows the rainfall recorded from 28/09/2009 to 2/20/2009.

Table 1

Date	Time	Rainfall in mm
28 th September 2009	8:30 AM	-
29 th September 2009	8:30 AM	000.5
30 th September 2009	8:30 AM	086.0
1 st October 2009	8:30 AM	036.0
2 nd October 2009	8:30 AM	162.0
2 nd October 2009	8:30 PM	269.0

Source: AWS, Shree Mallikarjun College, Delem, Canacona

It is evident from the above table that prior to the occurrence of disaster in Canacona, the intensity of rain was very low because normally the Monsoon season ends in Goa on 30th September. But due to Low Pressure development, Goa received heavy to heavy rainfall. From 1st October 2009 to 2nd October 2009 the total rainfall recorded in Canacona was 162 mm i.e., in 24 hours. Further, in the next 12 hours i.e., 8:30 am to 8:30 pm on 2nd October 2009, Canacona received about 269 mm of rain Therefore it is inferred that in 36 hours Canacona received 431 mm of rain, which is equivalent to almost 17 days rainfall of the region. It is but natural that such a situation will invite disasters at any place (Table 1).

On 2nd October 2009, signs of flooding started appearing from 9:30 a.m. From 9:30 a.m. to 2:30 p.m. that is in five hours about 244 mm of rainfall was recorded in Canacona. In an average 244 mm of rain is equivalent to 10 days of rainfall. Rain caused maximum damage from 12:30 p.m. to 2:30 p.m. because the rainfall occurred during these two hours was 132 mm. The rain started subsiding from 3:30 p.m. onwards. By this time enough damage was done.

Tidal Pattern:

The High Tide that occurred on 2nd October 2009 coincided with heavy rainfall which added to the existing problem. It is evident from table 2 and 3 that heavy rainfall and high tide occurred at almost the same time intervals from 09:34 am to 03:52 pm. During this period, the high tide force of water from the Arabian Sea prevented the rain water to drain in to the Sea as both rivers were under high tidal influence (Table 2).

Table 2

Time	Tide Height	Tide Type
3:15 am	0.68 meters	Low Tide
9:34 a.m.	1.98 meters	High Tide

3:52 p.m.	0.56 meters	Low Tide
9:57 p.m.	1.85 meters	High Tide

Source: National Institute of Oceanography

Landslides/Mudfalls/Rockfalls:

The Landslides/Mudfalls/Rockfalls triggered in the source region of River Talpona resulted in flushing of unquantifiable volume of land mass, comprising of rock and mud debris, boulders, pebbles, silt and lateritic outcrops and alike consolidated / unconsolidated material, which silted the low

lying regions, including the river basin area. The flushed material in the streams increased the velocity of water. Hence water from upstream came down heavily in the low lying areas.

Spit and Hook Formation:

It is also interesting to note that at the mouth of River Talpona there is a development of Spit and near the mouth of River Galgibag there is a presence of Hook. Both these coastal features become hurdle in the smooth flow of water (Figure 2).



Figure 2

Decrease in River Carrying Capacity:

Over the years, due to deposition of eroded material, the depth of both the rivers has become shallower. At many places river bed is visible during low tide time. This has resulted into decrease in the water carrying capacity of both the rivers.

Proliferation of Mangroves:

River Talpona and River Galgibag are known for their rich mangrove ecosystems. Mangroves are important in coastal areas as they protect the coast from erosion apart from a host of other advantages. But in case of river Talpona, growth of mangroves has resulted in creation of mini mangrove islands. At many places, river meanders due to presence of thick mangroves. This affects the smooth flow of water.

8. Causes for Landslide/Mudslide/Rockfall:

Landslides pose a great hazard to life and property, in the past, landslides did occur in Canacona taluka, whenever rainfall was heavy to heavy. In 2002; landslides did also occur in Kuske and Yedda and also in 2007 at Char Rasta. Occasionally small mudfall/slides also occur during the monsoon in the region and are prominent at Karmal Ghat. However, the unprecedented rainfall of 2nd October 2009, resulted into large number of landslides/mudfalls/rockfalls of varying dimensions and degree at Saturlim, (510m) Yedda (289m), and Kuske (521m). The landslides between Gaondongrem to Cotigao were numerous. In addition to

landslides, several mudfalls were also observed in Karmalghat, Char Rasta, Gaondongrem, Tudal, and Cotigao (Figure 3).

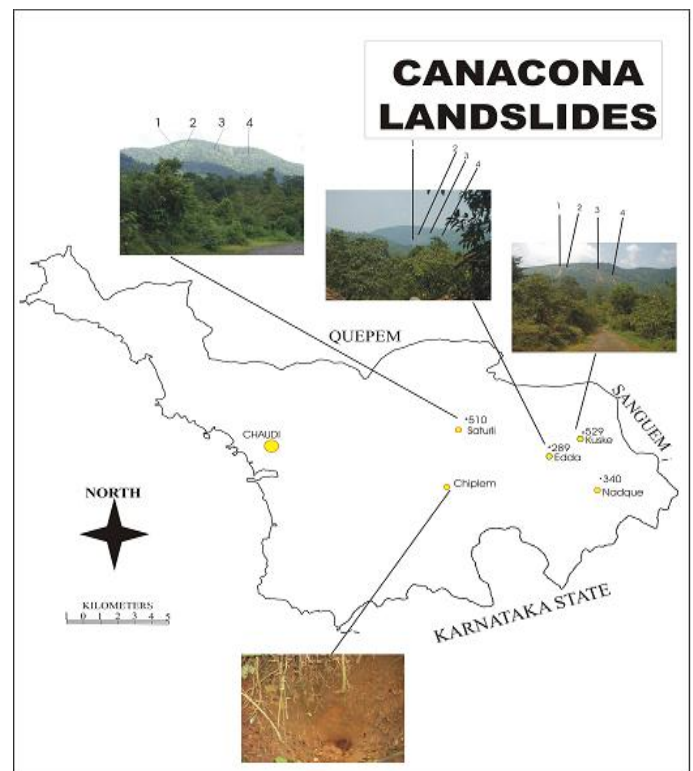


Figure 3

Following are some the factors that led to Landslide/Mudslide/Rockfall:

Heavy Precipitation:

The rain that was responsible for flooding was also the main culprit for Landslides/ Mudfalls/ Rockfalls. The rainfall of that day resulted into the seepage and infiltration of water beyond holding capacity of the soil. The high water ground table also contributed to the landslide catastrophe because the rainfall occurred at the end of Monsoon Season.

Steep Gradient of Hills

It is already mentioned that the Saturli, Kuske, Nadque, Yedda, Gaondongrem, and Cotigao, areas of Canacona fall under very steep sloping category. The percentage of slope is

more than 35. Such areas are highly susceptible for landslides/Mudafalls/Rockfalls.

Presence of Lineaments:

Saturli, Kuske, Nadque, Yedda, Gaondongrem, and Cotigao, areas of Canacona are characterized by the 1st, 2nd and 3rd order lineaments. Lineaments in the region are structurally controlled and had a major impact on water infiltration and retention properties. The lineaments are very important as they help in controlling the hydrology of the region. From the observation it is seen that the region encompasses a density of first, second and third order lineaments. The lineament map infers that the rivers and drainage pattern are controlled by the lineaments and these lineaments along with the hydrology and incessant rainfall were responsible for the landslides, as the lineaments within the landslide region were strongly intersected (Figure 4).

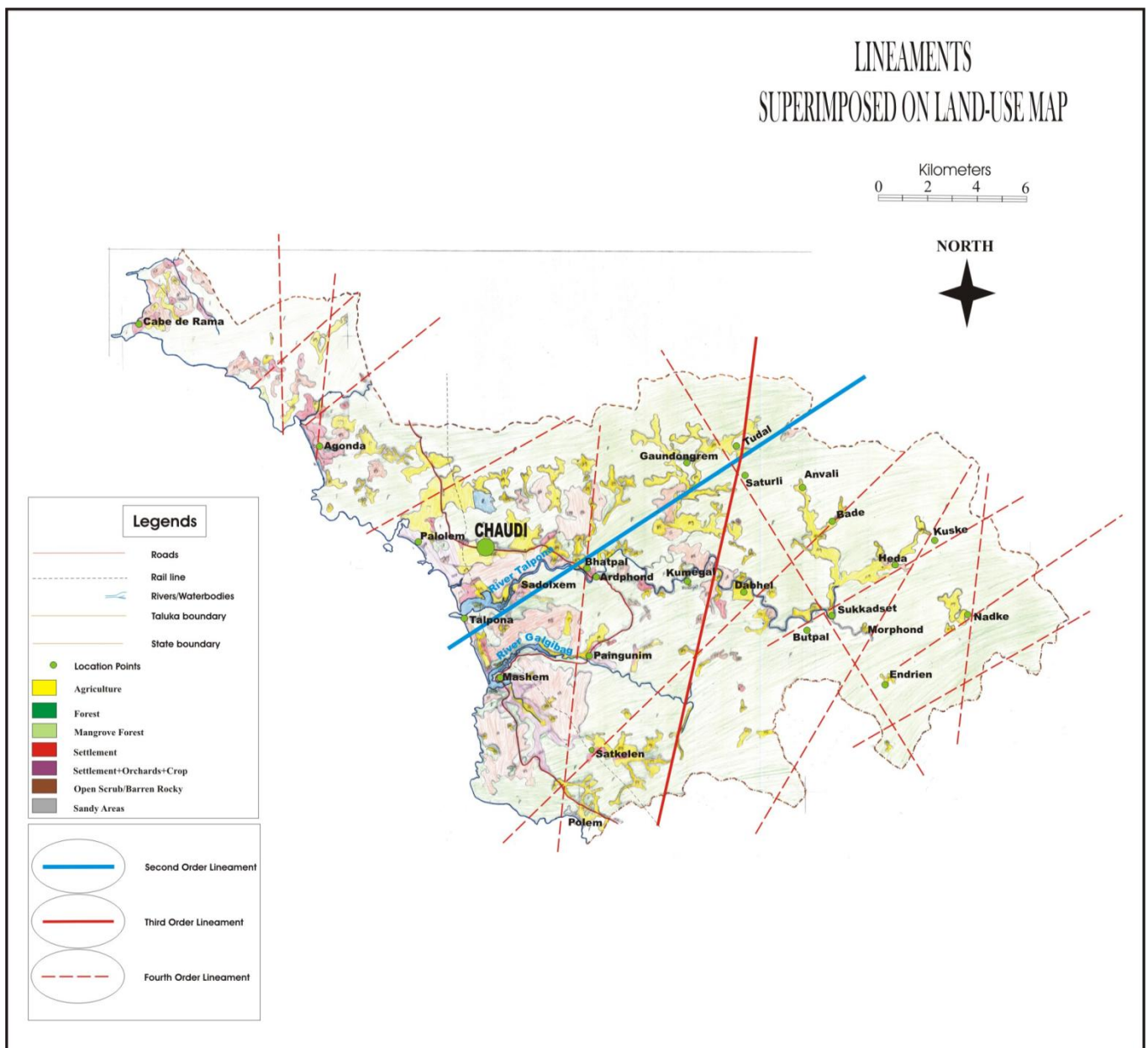


Figure 4

Decomposition of Bed Rocks: HH

The bed rocks of Saturli and Yedda Hill are in a decomposed state with multi joints, fissures, and fractures. Such conditions give rise to landslides (Figure 5).

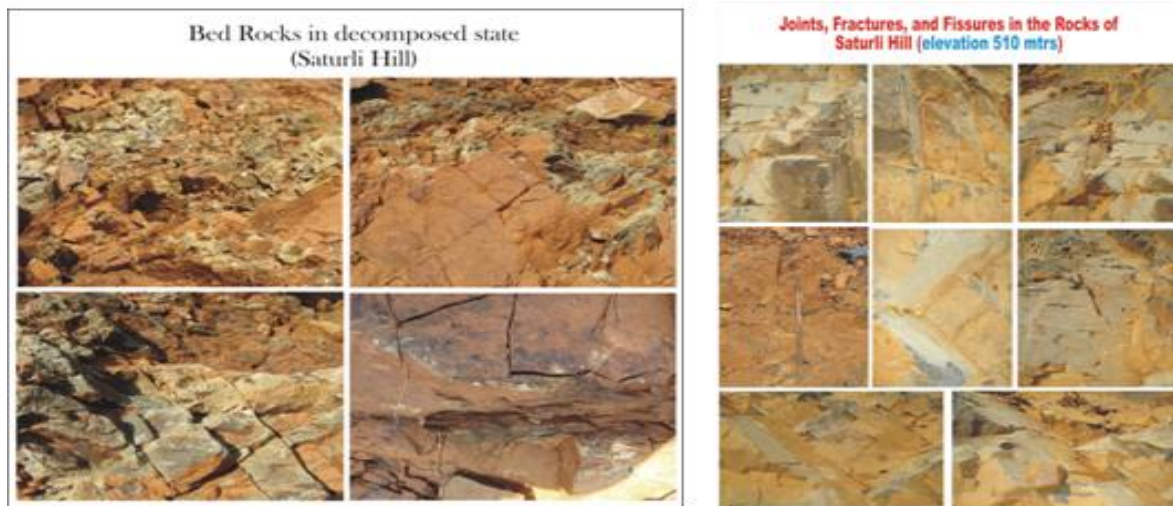


Figure 5

Third Order Hanging Streams:

Canacona taluka is characterized by first, second, third, fourth and fifth order streams. First order indicates small stream and fifth order point to large rivers. Hanging streams are the streams that vanish abruptly on the way. A good number of structurally controlled third order hanging streams are found in the Saturli, Kuske, Avem, Cotigaon, Gaondongrem and Yedda regions. Because of these hanging streams, a large amount of water infiltrates in this region

especially in the lineament zones. Such infiltration and seepage of water creates a platform for landslides.

Human meddling:

Human interference in this region includes kumeri cultivation, grazing, hill cutting, change in landuse from forest to agriculture and deforestation. Such human actions increase the risk of disasters. Landslide occurred at Kuske indicates the same (Figure 6).

Kumeri Cultivation and Landslide at Kuske



Figure 6

9. Recommendations:

It is accepted and acknowledged that it is not possible to do away with disasters; however, a concerted effort can help to minimize the same, through a well established forecasting, warning and alert system, synergized with preventive, preparedness measures on the part of vulnerable community, towards optimum management of a disaster. However, an

effective administrative response framework with integrated machinery system should be recognized, and the approach should be from response to preparedness. Furthermore, supportive policies and policy instruments for sustainable resource and sustainable environment management may be developed. Likewise, a regulatory and strategic framework, including laws to support sustainable land use and judicious

management of resources in the region through application of sound economic instruments is suggested. The existing communication information system should be strengthened and augmented.

Several management prescriptions have been suggested towards resurgence of the affected regions, including the development of an integrated flood and landslide management plan has been developed, as an effective decision support system towards optimum management of the disaster at Canacona. However, the prescriptions suggested herewith may be tested and implemented through scientific interventions and replicated to the rest of the state. This can be attained through an effective and appropriate organizational set up, with an effectual constitutional, legal and tiered organizational framework. .

10. Disaster Prevention, Rehabilitation and Reconstruction

Beach and Dune Management: As the beach morphology and fore dunes play a significant role in combating disaster and as the same have been destroyed due to the disaster, their ecology need to be restored and enhanced. As such, mitigation measures towards trapping and binding the sand through nourishing and replenishing the sediments at Galgibag and other beaches of Canacona, with native pioneer coastal vegetation like sand binders, creepers, may be undertaken. The Forest Department with the support of the community must undertake the reforestation program at the Galgibag beach in particular, in the fore dune, dune and affected region. Salt tolerant plant species may be planted in the near shore region. These dunes should be replenished as they provide vital protection during disasters. Alternatively, towards improvement of the sand replenishment, possibility of promoting artificial dune concept which may help as a natural protection may be examined.

River Management: All the rivers in Canacona need periodic de-silting which is mandatory, maintaining the inherent characteristics of their ecology. Bunds and embankments that are destroyed should be re-stabilized with civil and engineering approaches. Intensive mangrove plantations should be undertaken along the banks of the River Talpona, River Galgibag and River Saleri. The streams, drains and channels clogged and choked should be cleaned up immediately. Mangrove vegetation, [though protected] need be hacked at selected places, if necessary, where the proliferation has affected the stream flow, with due authorization from the concerned authorities. The spit and hook landforms developed at the mouth of Talpona and Galgibag respectively, need to be scientifically treated to minimize their size and shape so as to enable smooth flow and discharge of water up and down stream. The de-silted material should be used to reclaim low lying regions affected by erosion. Periodic excavation of river channels is recommended. The drainage can be filled with debris and rock material to reduce flow, grouting can be used to increase the slope stability.

Hill and Slope Management: Encroachment in the hill areas for undertaking kumeri plantation and hill cutting should be regulated and strictly monitored through effective enforcement. However, if unavoidable and the hill cutting is in

public interest it may be undertaken, only under strict adherence towards maintaining appropriate and technical sound hill slope gradient and also precautionary grouting, to avoid mudfall, rockfalls and landslides. Kumeri plantation along the slopes and toe regions should be controlled, within existing usage area only. Immediate reforestation on hill slopes must be carried on the war footing, with indigenous economically and ecologically species, taking advantage of the current soil moisture content. Social forestry programs should be initiated at Saturli, Gaondongrem, and Kuske. Likewise, stability of the slope can be boosted by consolidating the toe of the hill gradient. Furthermore, and in order to stop further landslides in the region, terracing on the hill slopes is recommended like the one carried out at Char Rasta Landslide by Konkan Railway.

Water, Soil and Land-use Management: Water is the main commodity for human sustenance, as the consequence of the disaster, all open, dug wells may have been infected, as such, it is proposed that all the drinking water sources like wells and tanks should be disinfection. The soil can be enriched with nutrients wherever possible. In order to maintain and enrich the soil and water characteristics in the region, watershed management and rainwater harvesting program may be undertaken. Likewise, the surface and sub surface drainage which has been disrupted or choked with the debris and rock fill material; due to the lands slide need to be opened for smooth water flow.

Environment, Ecology, Forestry, Agriculture and Livestock Management: Reforestation to be undertaken on the slopes of the hills will not only control soil degradation but will also help in flood control in future. Moreover it will also reduce ground water pollution and promote biodiversity, sustainability and help in combating global warming as it would help to reduce the CO₂ in the atmosphere. In order to safeguard the ecological sensitive wetland, any further reclamation to wetlands in the region should be arrested.

Mixed agriculture cropping with due crop rotation practices, may be adopted to enrich the soil fertility. Forest plantations will also help in carbon storage and help to regulate climate changes. The agriculture resources need to be conserved and traditional indigenous practices need to be adopted so as the soil nutrients get enriched as large soil has been eroded due to the landslides. Mangrove forests need to be planted along the banks of the rivers uptill the tides reach.

Flood Resistant Engineering and Structure Management: The disaster in Canacona caused widespread destruction to properties and assets, as such; the damaged houses should be screened to ascertain the nature and type of damage. The flood resistance of buildings potentially at risk should also be secured. No new constructions must be allowed on lower regions and in the flood risk region. However construction should be encouraged in higher elevations and beyond the flood risk zone. The construction should be undertaken adopting foundations, preferably with a plinth upto 1.0 meters. Stilts of concrete pillars / beams can be constructed to provide smooth flow of water, beneath, at time of rise in water due to floods. No structures should be legalized within the NDZ (CRZ-I). However, the structures in the No

Development Zone as per the CRZ Notification should be reallocated towards the landward side and beyond the NDZ. Those structures that are in the river basin should be re-located and shifted beyond the flood risk areas, preferably, at higher altitudes. Houses located on steep hill slopes and terrains need to be relocated to moderately sloping regions. RCC and laterite, masonry with cement-sand mortar is recommended for the super structure.

Integrated Landslide Management Plan [ILSMP] and Integrated Flood Management Plan [IFMP]: In this direction, and in order to identify the strategic points and geographically critical areas prone to landslides, a landslide hazard zonation maps are needed per se an Integrated Land Slide Management Plan [ILSMP] has been suggested towards mitigating the problem. The ILSMP will also be a suitable decision support tool, for the administrators, local community, planners, managers and other stakeholders, in an event of disaster. The zonation maps group the area as zones of moderately susceptible, highly susceptible and low susceptible regions. This criterion has been based on the integration and synthesis of slope morphometry, [greater the high slope - more are the landslides] soil distribution, geology [bearing on soil], drainage, landforms, lineaments and landuse pattern in the region in a GIS environment by overlay analysis. The degree of slope was a very criterion factor, followed by soil and land use pattern. Three regions have been categorized as highly susceptible regions, moderately susceptible regions and low susceptible regions. The region having high slopes (>35%), with very highly erodable soils, hanging streams, barren area as land use, associated with intensive lineaments are categorized as highly susceptible regions.

Likewise, the region having moderate slopes (>15%<35%), with high erodable soils, hanging streams, forest associated with barren area along as land use, associated with intensive lineaments are categorized as moderate susceptible regions. Similarly, the regions having low to moderate slopes (>10% <15%), with moderate erodable soils, hanging streams, kumeri cultivation, associated with intensive lineaments are categorized as low susceptible regions (figure 6)

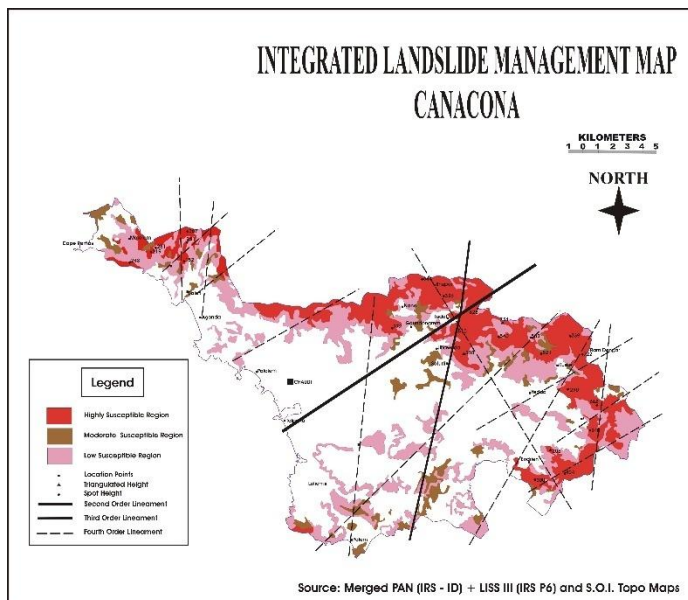
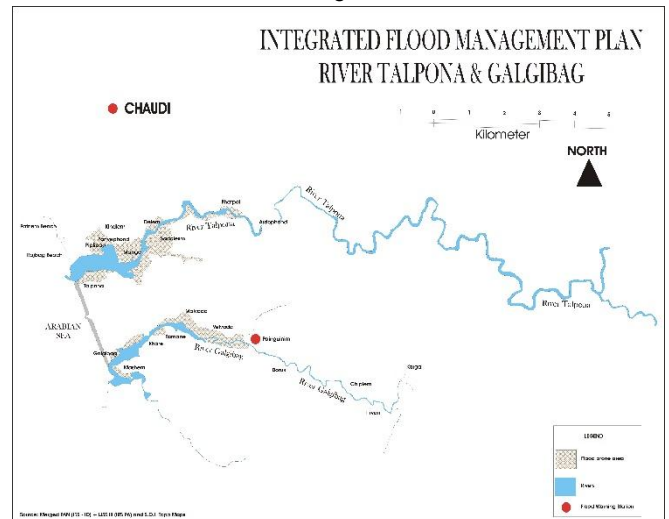


Figure 7

Integrated Flood Management Plan [IFMP]: Flood plains are the integrated part of the river systems and therefore floodplain zoning regulation maps are explicitly important to identify areas at risk of flooding within a given probability, provide the most advanced warnings of likely hazard and help the public to adopt decisions on investments in these areas, as also, for undertaking land use practices and development activities. However, the population pressure is a major constraint in this direction. Flash floods are an outcome of quantity of rainfall and the degree of moisture in the catchment area. Slope terrain, land use pattern, topography, hydrology, landforms soil conditions, drainage, catchment design, hydraulic infrastructure and human influence, which had a decisive influence on the occurrence of flash floods. Therefore, the flash flood at Canacona had been caused by intense rains where the rain water run-off in the region exceeded and flowed beyond the surface spatial area, which then accumulated within the streams and River Talpona and Galgibag at a much accelerated pace. In Canacona 162 mm of rainfall was received in the first 24 hours [on 1st October 8.30 am to 2nd October 8.30] and in the subsequent day [on 2nd October] it recorded 269 mm of rainfall, for 12 hours from 8.30 am to 8.30 pm. Per se, the total quantum of the rain exceeded the carrying capacity of the rivers resulting in large area was coverage by rainwater, thereby submerging the region. Incidentally, being a steeply sloping terrain, the condition aggravated due to the landslides and mudflows that also simultaneously occurred in the upper region.

Figure 8



Towards flood protection in the region, structural and non-structural measures have been proposed. The non-structural measures suggest the establishment of an effective monitoring and flood-warning system, coupled with an education awareness raising and training program and prescribe evacuation routes and sites. It also addresses issue related to safeguarding the infrastructure in the region from being affected by flood, etc, the approach is with an effect in restricting the destruction triggered by the flash floods. Whereas, the structural approach proposes to undertake and adopt repairs and reconstruction of all damaged bunds and embankments along the banks of the Rivers Talpona and Galgibag and restoration of water diversion channels, for facilitating smooth water flow..

However, loss of life and property due to flash floods can be minimized if appropriate disaster response plans supported by reasonably accurate and reliable forecasts are put in place and are well rehearsed. The objective is to identify the risk zones, delay the surface runoff into the catchment area terrain, so as to prevent any erosion of the soil, and facilitate quick diversion of water from built-up areas, so as to assist the soil in absorbing the water, and modify the floods, amend the susceptibility and minimize the burden.

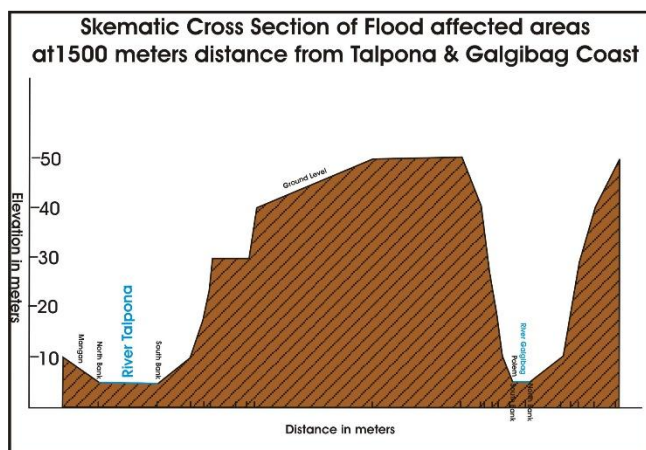
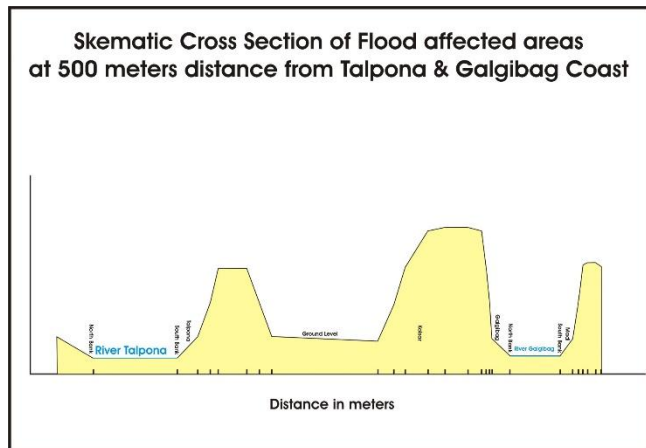


Figure 9

Integrated Disaster Management Plan (IDMP): The elements of water and flood resource, land-use practices, coastal zone component, landslide and demographic aspects have been integrated to develop an Integrated Disaster Management Plan, using components of Parker’s Model for the Canacona Taluka, to this effect. Relief, elevation, land use pattern, river catchment, slope, soil distance from the banks of the river and coasts are the preliminary parameter adopted for the data analysis the schematic profile of river Talpona and Galgibag indicate a unique physiographic setting comprising of denudational hills and slopes, having a relation with landuse.

The tidal pattern, its peak discharge is an added parameter considered. The prescriptions also proposes areas for de-silting and areas to lower the water holding capacity of the land and increase the risk of flooding through the silting of the riverbeds. Discouraging of the land use in high risk zones also formed part of the plan.

However, the success and effectiveness of this approach would largely depend on participatory process of the local authorities, decision makers and community at large.

An effective predicting, forecasting, warning systems, preparedness and mitigation response and recovery system on landslide risks and flash flooding prescribed herewith for Canacona region, is the most important forms of limiting risk to people’s lives and property, through regular forecasts and well informed information systems. In addition, development of evacuation routes and preparation for providing evacuees with food shelter, clothing and shelter on emergency basis is envisaged. These plans advocate that at Chaudi and Poinquinim a 24X7 hour forecasting and warning station should be established forecasting and disseminating effectively the hydro-meteorological situations of the region through a well integrated communication system, either TV, radio, mobile, wireless, or print media. Automatic Weather Stations established across the state and INSAT based disaster warning system, would aid in having a credible data base on the meteorological parameters. Satellite control room as regards to landslides should be established at Chaudi, Cotigao and Gaoundongre with a detailed management directory. The tide table should be displayed at Poinquinim Market and at Chaudi for Talpona River. Furthermore, the roles and responsibilities of various authorities to undertake mitigation measures against flash floods and landslides, should be clearly defined and should be at place, in order to make these recommendations effective.

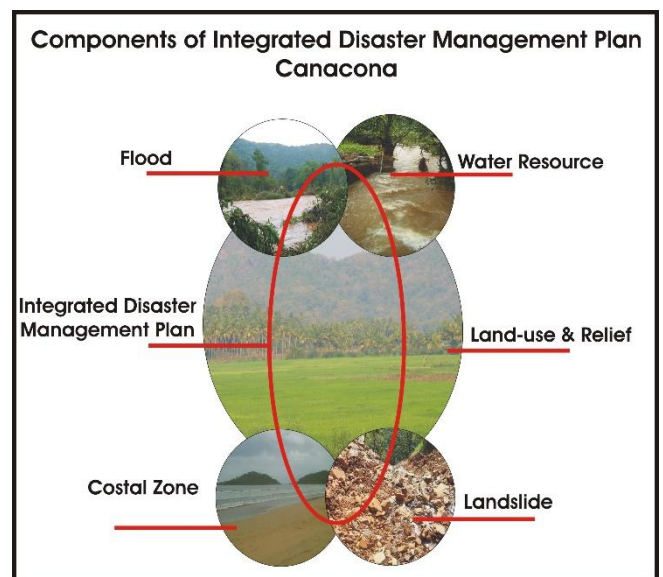


Figure 10

Optimizing or complementing available technological means, in flash flood forecasting in the given socio-economic context of the participating communities. The areas probable prone flooding areas within the Canacona region Taluka, should be accorded top priority to be provided with the most advanced and sophisticated advanced warning system. Committees should be constituted under the Dy. Collector as the Chairman and the respective B.DO, ZAO, A.E, (irrigation, water supply, PWD) and respective CMO, DCF & RFO, police personnel should be constituted for assessment, planning and monitoring. Likewise, an executive cell should be constituted to

execute the plans proposed by the Dy. Collector comprising of JE, Health workers, NCC, NSS, Scouts, Guides and Home Guards. The community being the key player should be actively involved in Participatory Rapid Appraisal (PRA), Action Planning decision making, implementation, evaluation and monitoring.

Likewise, the strengthening of financial instruments and logistics, like insurance schemes, loans for the affected community should also be revitalized along with mobilization of calamity funds in a sustainable manner. The civil repair and retrofitting works need to be executed on priority and the repaired works should be monitored and maintained. The disaster management policies should be promoted and accepted widely with cooperation from the public at large and be integrated in the academic curriculum at School, High Schools and Colleges.

11. Conclusions

A synergy of natural climatic changes coupled with geological and human induced factors were the cause of the catastrophe at Canacona. Based on the detailed reconnaissance survey, data collection and investigations, the permutation, combination and complexity of diverse factors related to meteorological, geology, landuse pattern, slope, structure, hydrology, landforms, soil type, tidal influence, river morphology, drainage density and lineaments setting were contributing factors for the disaster.

The investigations using Geo Informatics reveal that the soaring and incessant 36 hours rainfall, induced due to a low depression in the Arabian Sea caused rapid rain water overflow from the upper catchments, which infiltrated and seeped into the fissure and fracture zones, causing an increase in the pore pressure, which reduced the frictional resistance of the outcrops. Further, due to the hydrology of the region and incessant rainfall, the water table was relatively high, this caused the breaking of the cohesiveness of the soil pores and the shear strength decreased, due to excess moisture. In addition, the denudational slopes and hills, and the structure of the regions, lineaments had a significant factor in the slope failure [along lineament zone], in the upper regions causing translational sliding and toe loss, resulting in the landslides.

The influence of high tide, proliferation & destruction of mangroves & spit and hook landform formation at river mouth, congestion of surface and subsurface drainage, water seepage from beneath, are some of the contributing factors for the disaster. Similarly, responsible are the human induced factors like the alteration in landuse pattern, change in surface and subsurface drainage, siltation of rivers with debris and trees, blockage of bhandarss and damage to embankments, encroachment on river banks, resulted in the flooding over the adjoining areas.

However, the intensity, magnitude and scale of flooding could have been minimized, despite of the unprecedented rainfall, if the depth of the Talpona and Galgibag Rivers could have been deepened, through an organized de silting process, so as to increase their carrying capacity. Likewise, if the spit

and hook formed at the mouth of the River Talpona and Galgibag, respectively, were ecologically dressed, to increase their water in and out flow, the vulnerability would have also been reduced.

Corrective measures to sustain beach and river ecology, forest and agriculture ecology and restoration of livelihood of the affected population, at large need to be undertaken. Medical teams should periodically visit and monitor the area to ascertain any vector borne diseases outbreak, including physiological disorders. Furthermore, earnest efforts need to be made to guarantee that the houses partly damaged are repaired or retrofitted with flood resistant inputs and those houses within the flood risk zone be evicted and reconstructed to higher locations. The silted regions need to be cleaned up and water systems be disinfected. Several prescriptions towards the management of hill and hill slopes, water and soil, food and nutrition, livestock, engineering and flood resistant structure, community health and causality, beach, coasts and dune management, economic viability, institutional mechanism, administrative response and capacity building have been suggested in the recommendations. The concerned authorities should re-consider the norms for release of compensation, considering the steep rise in the economy.

An Integrated Disaster Management Plan, synergizing Flood and Landslide Management approach is proposed for the Canacona Taluka and envisage the same for the entire State of Goa, to avert any disaster or rather to adopt preventive and preparedness measures.

A pro-active approach in handling the disasters to reduce the impacts is the need of the hour. In this direction, disaster prone maps at talukas block wise, need be prepared, in consultation with the local community, rehearsals and mock drills should be demonstrated, human resources need be strengthened through capacity building programs, warning systems need be reinforced, data base on flood and disaster prone zones need to be identified using Remote Sensing coupled with GPS & GIS. However, this approach may not halt a flood at Canacona, or any other parts of the State of Goa, but definitely would minimize the impacts.

It is therefore acknowledged and accepted that occurrence of disasters cannot be eradicated; however, they can be abridged through earnest efforts, towards impact reduction on life, economy, environment, through a well established predictability, forecasting, protectiveness, preparedness, preventive ness, mitigation and ameliorative planning measures. However, an effective administrative response framework with integrated machinery system should be recognized, and the approach should be from response to preparedness.

12. Road Map for Future Improvement

- ❖ Forecasting, warning, trigger mechanism and alert systems need to be improved and strengthened with concerted interface and collaborative efforts from the Central Ministries, State Government and International Agencies. This effort should be established at taluka level, by strengthening

communication link forecasting and control room's facilities by modernizing the existing facilities. There is a vital need to establish concerted and efficient Doppler Radar Systems, as also, improve the tide gauge systems, and strengthen surface observations along with assessment systems, including, high speed recording and warning systems. Taluka level preparedness and response plans should be prepared and made available at all taluka headquarters, through a dedicated helpline, so as to improve strategies to cope up with disasters.

- ❖ In order to facilitate the disaster preparedness and rehabilitation work, a single independent Disaster Management Authority (DMA) need to be constituted both at Taluka and District level, Chaired by the Dy. Collector and Collector respectively. Likewise, the concerned Line Departments, PRI, local NGOS can also be representative members of this authority. The available resources from each department can be diverted to the authority for the execution of the rehabilitation work, draw contingency plans, through an established administrative, financial, technical and legal framework.
- ❖ The Disaster Management Authority (DMA) should identify disaster prone areas related to water and climate anomalies, chemical related, nuclear related, geological and biological related, human induced, accident and industrial related, and other disasters and prepare a blue print, "Disaster Vision Document". Accordingly, appropriate preventive, mitigative measures along with quick response and preparedness strategies need to be adopted to combat any catastrophe in an event of a disaster, in the State of Goa
- ❖ An effective capacity building training, skill development, and awareness generation programme covering the aspects of disaster prevention, mitigation and preparedness is very imperative and should be periodically imparted to the concerned officials of the authority for improving their performance and implementation of disaster related issues.

- ❖ Periodic mock drills should be held, synergizing Block Development Officers, Police, Fire Fighting Department, Health, Defense, Civilians and related Organizations, along with demonstrations on triage and emergency treatment
- ❖ All grants, aids and relief assistance received from various donor agencies need to be channelized to the Disaster Management Authority for proper records and transparent disbursement.
- ❖ Powers and responsibilities should be delegated to each organization like; Power, Health, Fire Services, Police, Civil and Home Guards, Drinking Water, Sanitation, Media, Helpline, Communication, Transport, Town Planning, Revenue Department to handle a disaster. In addition, support from the NCC, NSS, Scouts, and Guides, Youth Movement and Union Ministries like IMD, CRPF, and NGOs, for effective disaster management operations, is obligatory.
- ❖ A repository of credible database on various disaster related parameters, need to be established especially using Geo Informatics and related advance technologies are made available on a common platform, so that the data can be utilized in an effective manner, towards development, resource planning and generation of a sustained disaster mitigation action plan.
- ❖ There is a pressing need for research promotion in climatic, meteorological, geological, geographic and related sciences leading to disasters. Disaster crises and simulation models need to be developed especially related to climate change and human alterations towards augmenting early disaster predictions, warning and resurgence system.
- ❖ The IPCC report [Intergovernmental Panel on Climate Change, 2007] stresses the increase of climate-related hazards (Drought, Floods, Tsunami) across the planet earth, and an indicates a high relationship with geographical localization. This benchmark is very important in the present scenario of inconsistency climatic variation and therefore need to be considered seriously especially in Goa, being a Coastal State.

References

1. Anbalagan, R. (1992). "Landslide hazard evaluation and zonation mapping in mountainous terrain". *Engineering Geology* 01/1992; DOI: 10.1016/0013-7952(92)90053-2. http://www.researchgate.net/publication/222168592_Landslide_hazard_evaluation_and_zonation_mapping_in_mountainous_terrain
2. Anbalagan, R. and Singh, B. (1996). "Landslide hazard and risk assessment mapping of mountainous terrains — a case study from Kumaun Himalaya, India". *Elsevier Engineering Geology* Volume 43, Issue 4, September 1996, Pages 237–246.
3. Avasthy, R. K. and Kumar, H. (2009). "Landslide hazard zonation mapping along Chamba - Bharmaur Road, Chamba District, Himachal Pradesh". *Indian Landslides* Vol.2 No.1. http://www.indianlandslide.info/images/v2_2.pdf
4. www.indianlandslide.info/images/v2_2.pdf
5. Bobade, S. S., Kumthekar, M. B. and Deshpande, P. K. et al. "Study and analysis of causative factors of slumping for designing the preventive measures: A case study in South Konkan, India". *International Conference on Emerging Technology Trends on Advanced Engineering Research*, Proceedings published by International Journal of Computer Applications. <http://research.ijcaonline.org/icett/number2/icett1019.pdf>
6. Bindumadhava, Panigrahi, R. K., Rao, P. J. et al. (1996), *Lateral Movement of the Geogrid Reinforced Soil Retaining Wall*. IGC, Anna Uni., Chennai.
7. Bolleso, Francesco and Enrica De Cian. "Climate Change, Sea Level Rise, and Coastal Disasters. A Review of Modeling Practices." *Energy Economics*, Vol. 46, No. 1 (November 2014): 593-605.
8. Ramanujam, N., Dharanirajan, K., Yuvaraja P. M. et al (2011), *Geophysical imaging of seismically induced coastal landslides and rock slope failures in Port Blair, South Andaman*. *Disaster & Development* Vol. 5, No. 1 & 2, April & November 2011.
9. **Report On Development of Backward Hill Areas (1981)** Planning Commission Government Of India New Delhi

10. Martin & Nadaf (2011) Canacona the Last Frontier, Directorate of Official Language, Government of Goa
11. Nadaf & Pawaskar (2005) Environmental Studies, Intellectual Book Bureau, Bhopal
12. <https://timesofindia.indiatimes.com/city/goa/Synergy-of-climatic-changes-led-to-Canacona-floods-Study/articleshow/5256611.cms>
13. http://planningcommission.gov.in/reports/publications/pub80_dbha.doc
14. <https://www.weather.gov/phi/FlashFloodingDefinition>
15. <https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/rain/flash-floods>
16. <https://earthsky.org/human-world/what-causes-landslides>
17. <https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html>
18. <http://www.conservation.ca.gov/cgs/Pages/Landslides/LandslideTypes.aspx>
19. <https://www.geospatialworld.net/article/application-of-gis-technology-for-coastal-zone-management-a-hydrographer-perspective/>