Management of Cyclone Disaster in Agriculture Sector in Coastal Areas

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PREFACE

Agriculture sector in India faces severe challenges in the form of natural disasters like cyclones resulting in crop damage and poor crop productivity. At the same time, we have to feed the evergrowing human population to ensure food security. This necessitates us to develop a multi-pronged and integrated long term cyclone management. Preventive, mitigation and preparedness measures are equally important as response and rehabilitation measures. This will address the cyclone prone ecosystems in coastal areas which account for 8% of total area in India. Keeping these points in consideration, a one week short course on “Management of cyclone disaster in agriculture sector in coastal areas” is being organized by Directorate of Water Management (NRM division, ICAR) at Bhubaneswar.

Important topics related to cyclone disaster management such as concept of disaster management, integrated approach for cyclone risk mitigation, engineering, soil and crop management interventions for cyclone prone areas, subsurface water harvesting structures for cyclone affected areas and impact of cyclone on socio-economic condition of farming community have been covered during this short course. These topics have been compiled in the form of a training manual. This would be of immense use to various stake holders like researchers, policymakers, government functionaries and academicians in the field of cyclone disaster management. We would like to express our heartfelt thanks to Dr. A.K.Sikka, Hon’ble Deputy Director General (NRM) and Dr. S.K. Chaudhari, Assistant Director General (SWM) for extending their valuable guidance for smooth organization of short course.

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Concept of natural disaster management and integrated cyclone management strategies

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The low productivity in agriculture sector in India will affect the food security negatively. One of the main reasons for poor productivity in agriculture is uncertain weather and its associated natural disasters. Though the average annual rainfall of India is considerably high i.e. about 1200mm, the crop productivity is not satisfactory in several agro-climatic zones. The main reason for this is the uneven distribution of rainfall and extreme climatic events. Most importantly, the natural disasters like cyclones result in heavy rainfall thereby causing flood in the vicinity. Cyclone disaster always accompanies with major storms and heavy wind in addition to flood and it is highly detrimental to agriculture. It is true that the cyclone events cannot be stopped fully, however, we can make ourselves well prepared to reduce the risk reduction. This holds more importance in agriculture sector as the crop establishment and crop productivity is severely influenced by frequency and intensity of natural disasters. This necessitates us to create awareness among the stakeholders about the concept of natural disaster management which in turn aids in development of integrated disaster management strategies.

What is a natural disaster?

A natural disaster can be defined as a major adverse event caused by the natural processes of the Earth. During occurrence of natural disaster, higher level of force will be resulted with in small period causing enormous loss to the crops, animals and human beings. Hence, natural disasters can cause loss of life or property damage, and result in severe economic damage during the process. Some factors like the affected population's resilience, and ability to recover will influence the severity of natural disaster. The common examples of natural disasters are floods, cyclones, earthquakes, drought etc.

Hazard vs Disaster

Several times, hazards may not translate in to disasters. In other words, an adverse event will not rise to the level of a disaster if it occurs in an area without vulnerable population or in an area with sparse population. This may become a severe disaster if vulnerability is very high and social and economic capacity measures have to be implemented for reducing the extent of damage (Fig 1).

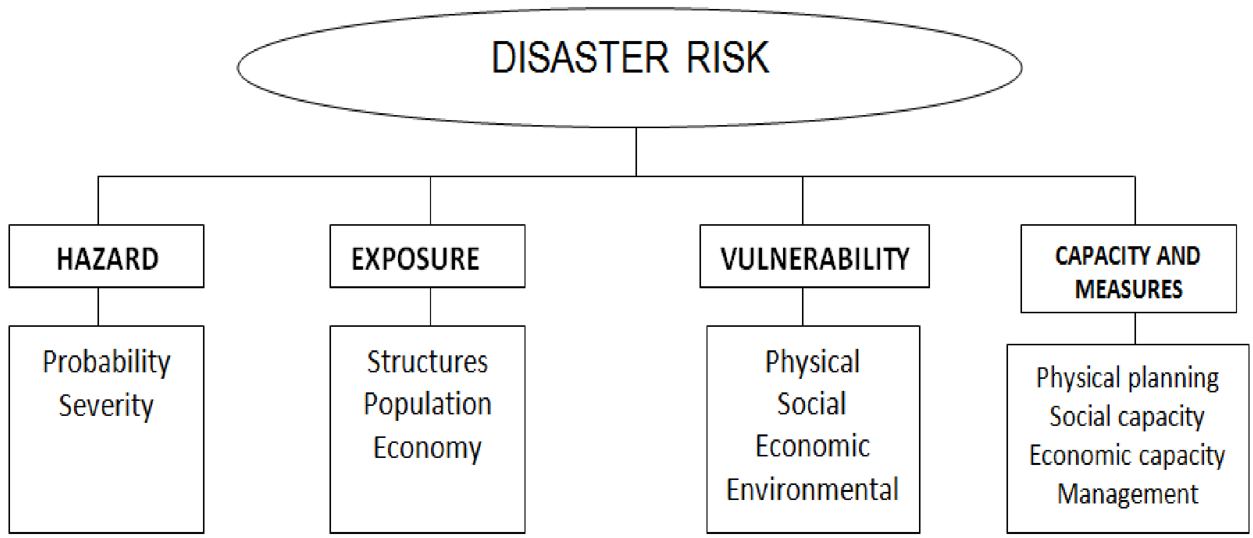

Fig 1: Process of disaster risk

World scenario

There were 905 natural catastrophes experienced by us worldwide in 2012. Out of them, 93% have been identified as weather-related disasters. The economic damage caused by these events was estimated as INR 10,20,000 lakhs and the agriculture sector was the worst affected one. If we look in to the categories of natural disasters experienced during this period, 45% were classified as meteorological in nature (storms), 36% were hydrological (floods), 12% were climatological (heat waves, cold waves, droughts etc.) and 7% were geophysical (earthquakes and volcanic eruptions).

Indian scenario

Food security in India is severely challenged by natural disasters such as floods, cyclones and drought. India is prone to flood in about 49.8 million hectares which accounts for 12.3% of the geographical area (NRAA, 2013). Out of the total geographical area of India, about one-sixth area with 12% of the population is found to be susceptible to drought and 8% of the total area of India is cyclone prone.

Most severely cyclone and flood affected areas

India is quite susceptible to cyclones and floods due to its geographical location surrounded by water on three sides. West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala and Gujarat come under most severely cyclone and flood affected areas of India. In each of these states there is a need to identify the most severely flood affected districts and blocks so that contingency measures can be taken at accurate level. For example, the districts such as Kendrapara, Jagatsinghpur, Balasore, Bhadrak, Puri and Cuttack districts fall under most severely cyclone and flood affected areas in Odisha.

Major consequences of cyclones

Negative impact of cyclone and its associated flood on soil and crop condition

The cyclone and its associated flood incidence causes severe damage to agriculture in several ways. The crops get affected both in terms of establishment and productivity. The stagnation of water inside the crop fields result in crop damage. The pulses and oil seeds and vegetable crops are highly susceptible to flood and the flood will result in their complete crop loss. In case of paddy, the duration of flood will decide the extent of damage to crop. The average annual flood damage was found to be about 3.57 m ha of cultivated area based on the survey of 47 years between 1953 and 1999 (http://www.mapsofindia.com/top-ten/geography/india-flood.html).

Cyclone associated flood water also brings sand and silt along with it to the crop fields and thereby resulting in change in soil physical condition. The top soil was found to be severely altered for a longer period due to deposition of clay which was witnessed in case of flash flood damage in Uttarakhand in 2013. Approximately 30% of the cultivated area in Uttarakhand was severely affected resulting crop loss and several water conservation and harvesting structures were damaged due to this flood event.

Resilient agricultural system as major objective of integrated cyclone management plan

What is resilient agricultural system?

The resilience capacity of the community plays positive role in reducing the vulnerability of the community (UNESCO-IHE, 2009). The role of both Mitigation and adaptation of climate change impacts in minimizing the yield losses is significant (Adger, N., & Kelly, M. (1999). Resilient agricultural system can be defined as a combination of different agricultural practices which aim at providing better resistance and adoptability to the crops to various natural disasters such as floods and drought.

Scope for resilient agricultural systems for management of natural disasters

The natural disasters cannot be stopped, but at the same time, we can improve the level of preparedness to face such disasters. There are some practices which can provide better resistance to cyclones and floods and hence have potential to reduce the extent of crop damage. In this context, there exists a tremendous scope for cyclone and flood resilient agricultural systems.

Important resilient agricultural systems and multi-pronged approach for cyclone/flood management

Sub surface water harvesting structures (SSWHS)

SSWHS were developed by Directorate of Water Management is highly useful for coastal cyclone prone and waterlogged areas where fresh water floats above the saline water below ground could be tapped. The depth of structure should be restricted with in sandy zone below ground up to 5 meter. SSWHS can be created in 0.1 ha with 4 m depth which will create a structure of 4000m^3 and on an average, it has the potential to enhance the water productivity to Rs. 36/m3 by involving pisci-culture and rabi vegetables. This has been well adopted by the farmers in super cyclone affected areas of Erasama block, Jagatsinghpur district, Odisha.

Cyclone and flood resistant / tolerant rice varieties

Flash floods are frequently witnessed due to heavy rains caused by cyclone with in short period resulting in huge crop loss. The flash flood tolerant rice varieties such as Swarna Sub-1 should be used by the farmers to reduce the yield loss under such conditions. Farmers in coastal Odisha which is cyclone and flood prone area have taken the benefit of this variety, but there is a need to generate more awareness among the farmers and to supply adequate quantity of the seed. Waterlogging tolerant varieties of rice such as Durga, Hangseswari, Varshadhan are being suggested for areas of the deep waterlogged and cyclone/flood prone areas which have resulted in additional rice yield and economic returns of the farmers. The agro-economic analysis of improved crop management interventions conducted by Directorate of Water Management, Bhubaneswar revealed that the pod yield of green gram variety SML-668 (0.680 t/ha) was found to be superior compared to that of local green gram variety (0.586 t/ha) under post flood situation in Garadpur block of Kendrapada district. It recorded about 16% higher pod yield compared to traditionally grown green gram variety. As a result, the economic net returns obtained from the cultivation of SML-668 variety of green gram was found to be higher by Rs. 5,600/- per ha compared to the local variety.

Over-aged rice seedlings

The level of submergence at the time of transplanting is found to be higher than the seedling age in cyclone and flood prone waterlogged areas which makes the establishment of seedlings difficult. To overcome this constraint, Directorate of Water Management, Bhubaneswar has developed a cyclone and flood resilient mechanism in the form of over aged seedlings of 60 days old. This has provided an yield advantage of about 32% over the normal seedlings (30 days old) and most importantly this practice has helped successful establishment of seedlings in cyclone and flood prone areas (Roy Chowdhury et al., 2011).

Flood resistant aquatic crops with economic importance

In areas of perennial waterlogging and cyclone prone areas where even rice cultivation is difficult, Directorate of Water Management, Bhubaneswar has standardized a technique for cultivation of aquatic crops with economic importance such as water chestnut. It was revealed that water chestnut either as sole crop or with fish which has potential to provide net income of famers by Rs.33,000/ha. The package of practices for cultivation of other aquatic crops such as Typha sp. And Colocasia sp. were also standardized for flood prone waterlogged areas.

Contingency crop planning and post flood management

Contingency crop planning helps in providing better resilience in post cyclone and flood period resulting in lesser extent of crop damage. The contingent crop plans were prepared for Kendrapara, Puri, Cuttack, Bhadrak, Jagatsinghpur and Balasore districts of Odisha for better cyclone/flood resilience. The practice of zero tillage as crop management intervention helped in better crop establishment and productivity of sunflower, okra and bitter gourd under post flood situation.

Land modification techniques for better cyclone / flood resistance

In medium and lowlands under high rainfall region and cyclone and flood prone areas, land modification such as raised and sunken bed technique would be highly effective in utilization of the available water, higher crop productivity, cropping intensity and economic net returns. The adoption of the technology increased kharif paddy and pointed guard yield from 4.2 t/ha to 5.2 t/ha and 4.24 t/ha to 4.74 t/ha respectively in addition to fish yield of 1 t/ha. Raised and sunken bed system facilitated conservation of available water resources and crop diversification resulting in higher economic net returns to the farmers (Rs. 60,000/- per hectare).

Bio-drainage options for better cyclone and flood resilience

In cyclone and flood prone and waterlogged areas, the practice of bio-drainage using Casuarina and Eucalyptus plantations would act as a viable flood resilient system as they improve soil drainage and operates better micro climate. This allows intercrop cultivation and helps in advanced planting of *rabi* crop resulting in higher water and land productivity. The farmers will get higher economic net returns due to fuel wood, intercrop and *rabi* crop produce.

In addition, water and soil conservation measures in flood catchments in cyclone prone areas are needed to moderate peak flows and water suspended sediments and siltation of water ways. The practice of de-sanding, de-siltation and land shaping will help in bringing desirable shift in soil physical condition under post flood situation.

Conclusion

The frequent occurrence and major area of incidence of cyclones and floods significantly limit agricultural productivity in India which in turn affects the socio-economic prospects of farmers and food security. Cyclone disaster risk cannot be minimized successfully through application of isolated management measures. We have to enhance the accuracy of cyclone preparedness and implement the potential agricultural techniques and structural measures as part of the multipronged and integrated management approach in cyclone prone areas. Immediate attention must be paid to contingency crop planning and integrated cyclone and flood management strategies for reducing the extent of damage. Both structural and non structural measures along with the strong coordination and communication among various stakeholders and community management would provide better cyclone and flood resilience. The identification of agro-climatic zone based resilient agricultural system for different situations of cyclone and flood incidence in would certainly provide necessary relief in this direction. The strong coordination among the Ministry of Home Affairs (nodal agency for natural disaster management in India) and other agencies such as Ministry of Agriculture, Water Resources, Civil Supplies, Heath, Science and Technology, Department of Space, Indian Meteorological Department, Relief commissions of State governments and Non Governmental organizations would help in implementing cyclone and flood resilient agricultural systems.

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Technological Interventions for Rehabilitation of Cyclone Affected Areas

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Introduction

Natural disasters like cyclone, tsunami, typhoons are major natural disasters in coastal areas. The devastation to lives, infrastructure, and agricultural lands and animals leave the people in the region to lose hopes of reviving their lives after such catastrophe. The farming community is worst affected by destruction of standing crops by seawater influx, contamination of wells from salt water, uprooting of coconut trees in coastal areas, loss of productive lands due to salt water ponding, degradation of lands due to sediment deposits or erosion, loss of agricultural tools, loss of small livestock and draft animals, and destruction of fisheries.

After each such disaster in first phase, the people survive on cash grants given by the government and nongovernmental organizations (NGOs) and on their savings, with their self-confidence at very low levels. The government/NGO initiate a work for cash programme that provided immediate relief and incomes around Rs 1500–2000 per month, but the reduction in status from honourable farmers to daily wage labourers badly affect their self-esteem. Surveys of farmers' behavioral changes, using open-ended questionnaires, has suggested that nearly 80% of respondents decide to abandon agriculture and were expecting the government to announce relief packages for their livelihood and alternative employment opportunities.

Thus the challenge is restore farming through interventions aimed towards restoring natural resources and the self-esteem and confidence of farmers. There are very few case studies on level of interventions to rehabilitate agriculture in post disaster situation. Post tsunami of 2004, a study was conducted in the Andaman Islands with the objective of restoring livelihoods through agricultural technologies.

Methodology

A study was conducted by the Central Agricultural Research Institute, Port Blair, during 2005–2008 to evaluate various agricultural technologies for use in tsunami-affected areas of the Andaman Islands to restore the livelihood of farmers. Immediately after the tsunami, damage and losses in terms of crops, land, livestock and fisheries for four selected villages were assessed through the Participatory Rural Appraisal (PRA) technique. On the basis of this assessment, low-lying coastal areas were categorized in different situations, and agricultural technologies were identified for each situation and evaluated in the study area.

Results and Discussion

There were three situations out of which, only two will be prevalent and therefore presented here:

Situation I: Tidal Inundation

Assessment of Spatial and Temporal Variability in Soil

One of the main impacts of the tsunami was salt accumulation, raising fears of strong decreases in soil fertility and productivity.

The texture of typical soils in the study area is sandy clay loam with medium organic carbon content (0.55%) in the upper 25 cm. The soil is acidic (pH 5.9), and its electrical conductivity (ECe) is 0.32 and 0.04 dS m^{-1} at 0–15 and 15–30 cm depths, respectively. Exchangeable calcium and magnesium content are typically 1.8 c mol (p+)/kg soil at 0–12 cm depth and 3.3 c mol (p+)/kg soil at 55 cm depth. After seawater intrusion, the surface soil (0–15 cm) became highly saline, with ECe ranging from 7.6 to 34.4 dS m^{-1} and pH ranging from 5.3 to 6.9. The salinity increased (ranging from ECe 9.7 to 28.4 dS m^{-1}) as soluble salts percolated downward from the surface soil.

After one rainy season, there was appreciable reduction in soluble cation and anion concentrations in all tsunami-affected soils, which in turn resulted in reduced ECe values. The surface-soil ECe of the School line soil series (Guptapara) went from 11.2 to 6.8 dS m^{-1}, and a similar trend was observed in the Dhanikari series. In the Mithakhari, Loha Barrack, and New Manglutan surface soils (Thushnabad series), the ECe decreased from 34.4 to 14.1 dS m^{-1}, from 20.2 to 9.4 dS m^{-1}, and from 7.6 to 4.5 dS m^{-1}, respectively. Similar trends were observed in the subsurface soils. The reason is leaching of soluble salts by high rainfall of the 2005 rainy season (3774 mm, greater than the average rainfall of 3075 mm). These results were in tune to other studies conducted in the region (Ghosal Choudhary, 2009; Ghosal Choudhary et al., 2009; Nayak et al., 2009; Rajat et al., 2009).

After two rainy seasons, there was a drastic reduction in soluble salt concentration of tsunami-affected agricultural lands. The surface soil ECe ranged from 3.9 to 8.3 dS m^{-1}, and the subsurface soil ECe ranged from 3.7 to 7.6 dS m^{-1}. The soil pH was also approaching the pre-tsunami level in most cases. It appears that the construction of low barriers (bunds) along the shore has prevented the entry of seawater into agricultural lands. However, this has also resulted in stagnation in many places, for which interventions are required. Water samples collected immediately after the tsunami showed contamination of both wells and ponds by seawater, with ECe ranging from 2.3 to 11.8 dS m^{-1} from chlorides and sulphates of sodium. However, the level has reduced after one rainy season. The ECe level has further decreased after two rainy seasons, and in most places it is below 2 dS m^{-1}. Methodologies for reclaiming saline and saline-sodic soils after irrigation in arid and semiarid regions may not be suitable for the Andaman and Nicobar Islands. In the Andamans, the analytical results revealed that the $2Na^{+}/Cl^{-} + SO_4^{2-}$ and

CO_3^{2-} + HCO_3^-/Cl^- + SO_4^{2-} ratios were less than one. Thus, application of amendments like gypsum is not required, and leaching through rainwater impoundment alone will be effective in reclamation of the tsunami-affected agricultural lands. Construction of raised embankments along with sluice gates to regulate the ingress of seawater in these areas will improve the productivity of degraded natural resources by restricting the entry of seawater into the field during high tide and allowing drainage of rainwater that may collect during the rainy season during low tide.

Technological Interventions for Managing Degraded Natural Resources

A sea dyke along with a self-operated sluice structure was constructed to arrest intrusion of seawater into agricultural land. Once the ingression was stopped, three interventions were made in the area to enhance productivity.

Raised Beds

Seven farmers' fields were selected and converted into cultivable land by the raised bed method. Raised beds 1 m wide and 0.3 m high were created after field preparation (Figure 9). Chopped coconut husks (Figure 10), followed by soil mixed with compost, were applied before planting crops of high-value vegetables. The raised beds facilitated survival of vegetable crops against heavy rains as well as rising seawater. An average net profit of about Rs 50,000 to 75,000 was recorded from a 1 ha area. This technology also helps in increasing the soil microbial content and pH. The coconut husk serves as a rich source of potash on decomposition, which was aided by a fortnightly spray of glyricidia liquid manure.

Broad Bed and Furrow System

Vegetable and fodder production have been hampered by a shortage of land after the tsunami and excess rainfall during the rainy season (June–December). Other major problems for vegetable production are extensive damage by giant African snails, bacterial wilt, and water shortages. Broad bed and furrow (BBF) is a technique for growing vegetables and fodder in the midst of rice fields while managing salinity and harvesting water in furrows for dry season vegetable production. It involves the use of alternating broad beds (4 m wide, 1 m high) and furrows (6 m wide, 1 m deep) to provide drainage for vegetables and standing water for rice. The BBF system permits fish rearing in the furrows and fodder crops on the beds, both of which help to include animal components in the agricultural system. Net returns of Rs 62,000/ha were obtained in the first year. In the second year, income of Rs 117,000/ha was recorded from sale of vegetables, rice, and fish. Due to the initial cost of BBF, the return in the first year was low. Cropping intensity and cultivated land utilization index (CLUI) were 100% and 0.38, respectively, before the tsunami and almost zero afterward. However, after this intervention, cropping intensity increased to 300% in beds and 200% in furrows, and the CLUI was 0.78. Moreover, the harvested water in the furrows was available for irrigation during the dry season. The income from the intervention was much higher due to the high value of vegetables during the monsoon season.

Brackish-Water Based Integrated Farming System

Affected land was also converted to brackish-water aquaculture ponds using spillways to regulate the entry of seawater. Along the dyke were planted crops such as spinach, amaranth, okra, bitter gourd, bottle gourd, and pumpkin (Figure 12). Sweet potatoes were also planted along the slopes of the dykes. Plantation crops of coconut, banana, and morinda have been planted. Fodder slips of hybrid napier and para grass were planted along the sides of the ponds. Apart from the income from fish, the crops on the embankments yielded an additional initial income of Rs 2000 from fruits and vegetables in one year. The native fodder on the inner and outer slopes of the embankments was identified as a variety of buffalo grass whose palatability and nutrient analysis suited it for feeding to cattle and goats. This intervention produced a considerable increase in income from fields that were almost completely destroyed by the tsunami. Morinda and coconut crops on the embankments will provide long-term income.

Situation II: Temporary Submergence

Assessment of Soil and Water

The pH of surface soil (0–15 cm) under situation III varied between 4.7 and 6.8, and ECe ranged from 7.2 to 22.9 dS m^{-1}, which indicates that the tsunami caused severe changes in pH and soluble salt content. Sampling revealed that in all soil series, the surface soil had become saline while the subsurface soil (15–30 cm) had smaller amounts of soluble salts, clearly indicating that seawater intrusion during the tsunami did not affect the subsurface soil. Distance from the seashore and inherent soil salinity may also account for part of the variation in soluble salt concentration in different locations.

Surface Soils

In the tsunami-affected areas, soil pH (6.93) was slightly higher than in unaffected areas (6.35). Coastal areas were mildly alkaline to slightly acidic and became more strongly acidic away from the coast. Among the three soil series studied, Dhanikhari soils, which are developed on coastal marshes and are strongly acidic, became neutral to alkaline after the tsunami. EC increased in the tsunami-affected areas (17.89 dS m^{-1}), with greater variability (S.D. = 6.31), than unaffected areas (5.27 dS m^{-1}). Dhanikhari series was found to have the greatest variability (6.68–33.2 dS m^{-1}) of the three series studied. ECe was higher in affected areas of Wandoor and Dhanikhari series soils, which might be influenced by the duration of flood, soil texture, drainage, and other factors. The correlation (r = 0.173) between the spatial distribution of ECe and the duration of flood was not significant, but in gently sloping to flat lands toward the coast, ECe increased with duration of flood.

Sodium adsorption ratio (SAR), a measure of the relationship between soluble sodium and divalent cations (calcium + magnesium) in soil, indicates the degree of soil deterioration. SAR was 2.69 in the unaffected areas and 19.14 in the affected areas. Among the three soil series studied, Dhanikhari had the highest SAR values (6.48–48.18), followed by Wandoor and School line. There was no significant pattern in the spatial distribution of SAR in the affected areas. The excessive concentrations of sodium in the soil may create sodicity problems leading to structural deterioration and poor infiltration.

Subsurface soils

Soil samples were collected from different depths (0–25, 25–45, 45–60 cm) and analyzed for pH, ECe, and SAR in affected and unaffected areas. In all the soil series, the soil pH increased from surface (0–25 cm) to subsurface (45–60 cm) levels in both affected and unaffected areas. The soil pH was acidic (0–60 cm) in all three soil series from unaffected areas. However, neutral to slightly alkaline pH was observed in the tsunami-affected areas of School line soils at 45–60 cm depth. In general, surface soils had higher ECe than subsurface soils, except unaffected School line soils, where ECe was higher in the subsurface. The vertical distribution of pH and ECe indicated that the Dhanikhari series is a potential acid saline soil. This has a profound influence on the availability of nutrients at the root zone and the distribution of microflora and microfauna in the soil profile.

Total dissolved solids (TDS) were higher in the surface soils of the Dhanikhari series than in the Wandoor and School line, due to its finer soil texture that affects the rate of infiltration. Sodium toxicity to plants was severe, and the effects of Na on soil pH and structure were significant. In tsunami-affected soils, SAR increased and varied significantly at the surface soils of the three series. Wandoor soils recorded the highest SAR of all, and this higher sodium content might underlie the impeded drainage conditions after the tsunami.

After one rainy season in situation III areas, there was appreciable reduction in soluble cation and anion concentrations in all soil series, which in turn resulted in reduced ECe values.

After two rainy seasons, surface soil ECe ranged from 0.6 to 5.9 dS m^{-1}, and the subsurface soil ECe ranged from 0.4 to 5.3 dS m^{-1}. The soil pH was also approaching the pre-tsunami level in most cases. After two rainy seasons, in most places it was below 2 dS m^{-1}. Hence, agricultural lands in this situation can be easily reclaimed by high annual rainfall that can effectively leach out the accumulated salts.

Technological Interventions for Productivity Enhancement

Natural resources were not damaged significantly temporary submergence; hence, interventions were made to increase productivity to compensate for losses in other situations. These are described in this section.

Impact of Tsunami on Rice Yield

In South Andaman, traditional rice varieties (C 14-8) are very common and high-yield varieties (HYV) (BTS-24; Sumathi; CSR7-1) occupy nearly 20% of the area planted to rice (Balakrishnana et al., 2006). Grains of the variety C 14-8 present at the time of the tsunami were collected and analyzed for various quality parameters. Grains that were submerged in seawater became softer in consistency and had cooking times up to 15 minutes shorter than the control rice. There was no significant difference in yield between traditional varieties and HYV before the tsunami; however, traditional varieties had higher variability and lower yield than HYV in the affected areas. This indicates that HYV adapted better than the traditional varieties in the affected areas. Rice yield was 59% of that in unaffected areas where the tsunami damage was estimated to be severe after one rainy season. Reduction of 37% was observed in areas considered moderately affected. The higher standard deviation (0.44) for moderately affected areas indicates that localized distribution of salts causes a wide variation in rice crop performance in these areas. Hence, the spatial variability of reduction in rice yield seems to be correlated with the spatial pattern of SAR and ECe in the tsunami-affected areas.

Mat Nursery and System of Rice Intensification

The mat nursery technique was demonstrated in the adopted villages (figure 13) for the first time in the Andaman and Nicobar Islands. Various paddy varieties (Taichung-sen-Yu and Quing Livan No. 1 in normal soil, BTS 24, SR 26B, and CST 7-1 in problem soil) were raised in a flat field as a field demonstration for the benefit of the farmers. The System of Rice Intensification (SRI) was applied under this project using Taichung-sen-Yu, Milyang 55, BTS 24, and Nanjing varieties. The critical stage is the first 20 days after transplanting, when seedlings are vulnerable to damage by continuous rainfall. The mat nursery technique yielded a savings of Rs 1600/ha in field preparation and seed costs compared to conventional nursery preparation. The SRI method produced significantly higher yields (3.95 t/ha) than conventional planting methods (2.00 t/ha).

Crop Diversification

Crop diversification with vegetable and fruit crops was the main technological intervention in the affected villages. Vegetables like spinach, coriander, chillies, capsicum, and French beans were introduced in the appropriate seasons using varieties that had already been developed and screened in research farms. These varieties performed well in the farmers’ fields (Figure 14) with the proper management practices and organic substitution of nutrients.

Freshwater Pond Based Integrated Farming System

Existing freshwater ponds were augmented by others constructed by the government for tsunami rehabilitation. An integrated farming system was adopted to fully utilize this resource. Pond embankments were used effectively to grow crops like coconut, arecanut, banana, and papaya along with vegetables like pumpkin, bitter gourd, and others (Figure 15). Fodder crops, whose scarcity was a major constraint in the milk production system, were introduced on the inner and outer slopes, which also protected the ponds against erosion. Poultry was introduced as an additional income source over the ponds, and droppings were utilized as the manure source for crop plants. It is evident from Fig. 4 that income from the land area in situation III increased significantly from Rs 12,860 to Rs 31,280 in one year from a 1500 m^2 pond.

Participatory Water Resource Development

Irrigation facilities are a major constraint in island agriculture. With this in view, water resources were developed using a combination of recharge structures and open dug wells. A series of gabion structures were emplaced across a stream to enhance groundwater recharge, and open dug wells 2 m in diameter were dug along the stream to harvest the recharged water. To involve stakeholders in water resource development and management, a Water Users Association was formed by farmers with active support of the research team. The purpose of the association was to involve farmers in creation and management of the irrigation facilities, inculcating a sense of ownership of the assets created (Srivastava et al., 2009 a). The association was registered with the registrar under the Societies Act. The association performed the following activities:

- Farmers participated in the creation and management of their irrigation facilities, along with other interventions undertaken by the Central Agricultural Research Institute (CARI).
- Members participated in the bidding, and the contract for ring well, gabion construction, and tank construction was won and carried out by the association with community participation.
- Seedlings of vegetables were raised by youth members in the community nursery and distributed to other members and other farmers of nearby villages, generating revenue of Rs 500/month.
- The youth wing of the association volunteered for agricultural activities in the village, for example, sharing of labour charges among themselves.
- The concept of selling produce to a middleman was abolished; one member of the association now sells the association's whole output directly to retailers.
- After three years of persuasion and motivation by the project intervention in the village, the unemployed youths of Manjeri formed a self-help group under the umbrella of the Water Users Association.

Impact of Water Resources Development

Crop diversification was introduced using high-value and nutritious vegetables and fruits and applying scientific methods such as composting technologies, and using pesticides after irrigation facilities were developed. The area under cultivation before the tsunami during the dry season was 5 ha (29%) out of 17 ha available to the association. This area increased to 12.5 ha (71%) after creation of water resources (Srivastava et al., 2007, 2009 b).

Conclusion

The interventions changed the entire socio-economic setting of the village. The technologies introduced have spread. The nutritional status of the adopted village was also improved (Srivastava et al, 2009 c). The experience leads to the following conclusions:

- The soils of the affected land area became saline due to intrusion of seawater; these salts are leached by rain and the soil returned to pre-tsunami status without the need to apply any amendments. However, reclamation can be hastened by strengthening bunds for storing rainwater.
- It was possible to restore agricultural livelihoods with suitable technological interventions compatible with the farming system.
- Where cultivated land was lost (situation I), the farming livelihood could be restored through introduction of livestock based systems. Suitable measures should be taken to introduce quality livestock and improve productivity of existing livestock through better management practices.
- For situation II (partial submergence), the productivity of available natural resources can be restored by arresting seawater intrusion using sea dykes and self-operated sluice gates.
- Interventions and management practices developed for natural resources in situation III (temporary submergence) can lead to enhanced production and productivity that compensate for land lost to permanent inundation.
- The integrated agricultural technological intervention model applied in the Andaman Islands after the 2004 tsunami can be used to manage natural resources and agricultural livelihoods after similar kinds of disasters.

The impact of interventions was recognized by Government of India and it was included in 101 success stories selected from all over India depicted in Coffee Table Book of Ministry of Agriculture & Cooperation of Government of India (Srivastava et al., 2009 d).

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Development of Micro-Water Resources for Enhancing Agricultural Productivity in Cyclone Affected Areas

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Increasing agricultural production, improving agricultural productivity and conserving and managing natural resources through intellectual capital combined with people's effort and appropriate technology, would bring food security, improve standard of living, promote income generation, ensure poverty alleviation and production of market surpluses (Sahoo et al., 2003). These have a very high relevance in the coastal area, recurrently affected by cyclone and flood. The super cyclone, which had hit coastal Odisha, caused considerable damage to agriculture and allied enterprises. Besides, after deluge of water in the monsoon season and a huge wastage of surface water (Sen etal., 2000), the crops suffer from drought during winter. In addition to this, the coastal area very near to sea (0-10 km) faces problem of salinity also, severely limiting the scope of its use for irrigation. Construction of deep tube wells to draw good quality water is feasible, despite certain geo-hydrological constraints, but has not been taken up adequately due to economic reasons.

On an average for Odisha, 663 mm rainfall is in excess during the monsoon and may be utilized for irrigation during second crop, provided it could be properly stored. In this context, there is a good scope of expansion of area under micro water resource development by creating integrated farming system units as well as sub-surface water harvesting structure.

DWM had taken the land modification technology for micro water resource development in Satakabat village of Biswanathpur in Khurda district after the super cyclone. The total waterlogged area was 2212m^2. Two ponds of size 600 m^2 and 1022 m^2 were constructed and the excavated soil was spread around in an area of 590m^2. The height of the raised bed was 1 m above the surrounding field level. The idea of constructing two ponds was to rear fry in small ponds for about two months and then release fish in big pond at fingerling stage. A space of 553 m^2 was provided for cultivation of vegetable crop both in kharif and Rabi. During Rabi season, the performance of different vegetable crops such as ladies finger and tomato was good in low lying areas. The increase in yields in the raised bed cultivation system was 20 to 40 percent more than that in the prevailing low land cultivation system for different crops. This was due to timely plantation of the crops in the raised bed and protective irrigation using pond water which was maintained by pumping from bore well during Rabi and summer season. In the low lying land rabi crop production has a setback due to delayed planting caused by excessive soil wetness for a significant part of post monsoon season and scarcity of irrigation water.

Table 1. Yield and Economics of pond and raised bed system*

Season	Crop	Crop yield (q)	Gross return (Rs)	Cost of cultivation (Rs)	Net return (Rs)
Kharif	Ladies finger	2.08	2496.00	543.00	1953.00
	Brinjal	3.00	3000.00	271.00	2729.00
Rabi	Tomato	1.20	1200	302.00	898.00
	Ladies finger	2.08	2496	543.00	1953.00
Summer	Chilli	2.00	1800	1357.00	443.00
Bund plantation	Pumpkin	0.50	200	50.00	150.00
	Papaya	3.00	900	150	750.00
	Banana	9 bunch	1350	81	1269.00
	Cowpea	0.5	250	15	235.00
	Leafy vegetable	0.05	50	10	40.00
Pond	Bitter gourd	0.62	620	35.00	585.00
	Fingerling	1200 nos.	1200.00	450.00	750.00
	Big fish	0.75	3150.00	950.00	2200.00

**A space of 183 m^2 for vegetable and 224 m^2 for bund vegetables and 90 m^2 for scaffold was earmarked. The study was initiated in 2001.*

The study of comparative economics between pond cum raised bed system and low-lying adjoining land reveals that benefit cost ratio (B: C) in the improved system is 2.45 where as in the low lying system (original condition) it is only 0.7.

The other land modification technology is complete conversion of the low land into pond and dyke system. It was developed in Khentalo village of Nischintakoili block in the district of Cuttack. The total area of the system (2.47 ha) consisted of 1.5 ha swampy area and rest 0.97 ha waterlogged area which was being cultivated with long duration variety of local paddy (yield 1.1 t/ha). Out of 2.47 ha of low productive swampy waterlogged low land, a pond was constructed in 1.64 ha and the dug out earth was put in the bund to raise it for horticultural crops. The bund area was 0.83 ha. The width of bund in north side was 21 meter and 10 meter each in east, south and west side. The pond dimension was 195m x 84 m. The depth of pond was 2 m.

The details of year-wise input and returns from the pond as well as bund system (integrated farming system) are given in Table 2.

Table 2. Economics of integrated farming system

Year	*A: Input cost (Rs)*							*B: Gross return (Rs)*					***Net***	***Net***
	Pond construction & infrastructure	Horticulture/ vegetable seed, fertilizer etc. ***	Fish and prawn seed	Fish feed	Labour	Miscellaneous. *	Total in rupees	Fruits & Vegetable	Fish & prawn	Coconut	Poultry **	Total in rupees	***return in rupees (B-A)***	***return in Rs/ha***
1988	1,23,910 (excavation)	-	-	-	-	20,000	143910	-	-	-	-	-	-	
1989	-	12600	12000	28730	14000	13000	80330	110400	70100	-	-	180500	100170	40,554
1990	-	12000	14700	29750	14000	13500	83950	114000	88000	-	-	202000	118050	47,793
1991	-	12000	16400	31200	14000	14800	88400	98600	96750	-	-	195350	106050	42,935
1992	-	10400	18000	36900	17500	14500	97300	44000	172800	30000	-	246800	149500	60,526
1993	-	8700	23000	42850	17500	16000	108050	42800	199000	45000	-	286800	178750	72,368
1994	-	8900	28300	48700	17500	19000	122400	46000	269200	48500	-	363700	241300	97,692
1995	-	7500	30100	54225	21000	30500	143325	52100	329700	59000	-	440800	297475	1,20435
1996	-	3200	33200	64650	21000	28600	150650	47200	345000	76900	-	469100	318450	1,28,927
1997	-	2850	35500	81000	24500	29000	172850	35450	372400	93250	-	501100	328250	1,32,894
1998	130000 (stone lining)	2900	48900	86800	28000	23000	319600	48300	383900	105000	-	537200	217600	88,097
1999	320000 (poultry shed)	3000	53100	69500	28000	380000	753600	14000	218200	80500	324000	636700	**(-)** 116900	**(-)** 47,327
2000	-	2660	42200	92000	17500	31000	185360	1300	249500	2400	-	253200	67840	27,465
2001	-	2550	58700	106000	17500	34550	219300	12900	541000	6000	-	559900	340600	1,37,894
2002	-	2500	69615	156400	17500	42580	288595	23000	617160	10950	-	651110	362515	1,46,767
Grand Total on 15 year basis							**29,57,620**					**55,24,260**	**25,66,640**	**10,39,125**

**Miscellaneous includes lime, cow dung, pumping, irrigation system, masonry work etc.*

***Poultry was added in the year 1999*

**** Horticulture including banana, papaya, pineapple, mango, areca nut etc.*

Average net return per ha per year on 15 year basis from IFS = Rs. 69,275

The system suffered loss only the year 1999 to the tune of Rs 1,16,900 due to devastation caused by super cyclone (Table 2). Further the impact of cyclone affected the net return in the subsequent year 2000 in which the net return was only Rs. 67.840. The net return was Rs, 1,00,170 in the first year of operation of the system, which has enhanced to the maximum of Rs. 3,62,515 in the year 2002. The comparative net return from the IFS was in the tune of Rs. 70000 and rice cultivation was around 5000 rupees per hectare per year.

Improvement of Capacity of Natural storage of drains

In lowland, there are many localized pockets which are completely unfit and unsuitable for growing rice. Sometimes the water depth reaches more than2 m. In those cases, the storage space should be reconstructed and made further deep during summer season, to receive more water. This will help adjoining lands to moderately suffer from drainage congestion. Such pockets are there in Gobari Doab in Kendrapara and Rajnagar area. Even in the Chilika lake region, the coastal areas are silted up, due to which lowland drainage waters could not be discharged. Tanks in the lowland area should be deepened to store more water as in case of Puri, Ganjam, Balasore districts of Odisha.

Sub-surface Water Harvesting Structures (SSWHS)

In the coastal saline area (0-10 km from sea) there is a large patch near the Hansua creek traversing adjacent to Erasama block of Jagatsinghpur district. This waterlogged patch varies from 10-15 km in length and 5-7 km in width. Huge amount of water is stored in the sandy zone present up to 5-l 0 m below the ground level. Water table in the area rises 0-1.5 m above ground level during monsoon and declines to 1-2 m below ground level during post monsoon season. The depth of saline water table due to ingress of sea water varies from 3-7 m below ground surface and fresh water due to of rainfall floats above it. This fresh water can be harvested for irrigation and fish production (Sahoo et al.,2004).With this background, our institute (DWM) had developed a design for sub-surface water harvesting structure (SSWHS) in the form of excavated tank. Tanks have been constructed in the super cyclone affected area on participatory basis to make the project sustainable. In this system small SSWHS were constructed up to a depth of 3-4 m or less to harvest surface water in the rainy season and to harvest sub-surface seepage water in the rabi season.This structure will provide water for raising paddy nursery in June and will irrigate additional area during rabi as well as in summer. It can also be used for aquaculture and other crops. This system has been found very effective in providing assured irrigation. As, neither the individual resource poor farmers nor the government can bear the full cost, a participatory approach with the involvement of the farmers group under coastal area management programme could be successful to ensure sustainable water resources development.

Selection of Site

This system can be installed at any place nearer to the creek and where a sand zone is found underneath within 10m below ground level. This zone is locally called Bellary in Odisha. In Paradip and Erasama zone, this type of land is available in a vast stretch of areawithin5-l0 km from the sea. There should be arable land and habitation nearby for taking up farming in both kharif and rabi seasons. Seepage rate should be more than 10 mm/day and a clayey zone should exist below the surface till the first 3-4m.

Design and Construction of Sub Surface Water Harvesting Structure.

The design of the SSWHS depends upon the expected rate of inflow/seepage. If the rate of seepage is high, then the area of tank is reduced and vice versa. The recuperation rate by pumping test at different sites in $556m^3$ to $899m^3$ tanks varied from 1.58 m^3/h to 4.07 m^3/h in sandy zone and from 1.01 m^3/h to $3.4m^3/h$ in clayey zone. Capacity of structure may vary from $200m^3$ to $1500m^3$. The depth of structure may also vary from 2-4 m.

Participatory Approach

To make the project sustainable, a participatory approach was adopted. After selection of a site, irrigation user group was formed around the site. Each group member was advised to pay a small percentage of the cost of the project either through labour or cash or material. In the first year it was decided for the irrigation user group to pay40% of the cost of the project. The initial hesitation of the farmers to participate was overcome by seeing the successes of one of the farmer with this participatory approach and several such farmer's groups were formed in different cyclone hit villages of Ambiki Panchayat. At the site, layout of the structure was marked in two parts (60% & 40%) and the group was asked to complete40% work first. For example for a 30m x20mx2m structure layout is given for 30m x 8m x 2m for the farmer group to complete and then project functionary comes forward to complete the remaining 30mx12mx2m earthwork through the same user group by providing wages. By this the group feels their ownership in the project. For subsequent repair and maintenance, they take care of the entire expense. In the 2nd year, seeing the success of the project the subsidy was reduced from 60% to 33%. Still 13 irrigation user groups were formed in 7 different villages. The procedure of construction remained the same.

Performance and Economics of the System

A properly designed and constructed sub-surface water harvesting structure based on the above principle will mitigate the early drought in the kharif season and provide irrigation during the rabi and summer seasons. The evaluation of such a system has shown its effectiveness in dealing with early drought in kharif and an area of 8.8ha was saved. The details of the structures are given in Table 3.

Table3 . Detailsofthefarmers in Erasama block, capacity and cost of the tank (2001).

Name of the Head of the farmers' group and address	capacity (m^3)	vol. of earth work (m^3)	Total cost,A (Rs.)	Farmers' share (40% of A)(Rs.)	Project share (60% of A)(Rs.)	Area saved (kharif, 2002)ha	No. of farmers in the group
Sh. M. Mandal, Baghadi	1287.4	865	17733	7093	10640	2.4	11
Sh. Puspak Nayak, Baghadi	899.0	737	15110	5044	9066	2.2	10
Sh. Subal Behera, Kiyada	1011.5	665	13646	5458	8188	2.2	10
Sh. Sunil Samal, Chaulia	1571.0	793	16255	7541	11313	2.6	17
Sh. Sabyasachi Jena, Kiyada	1152.3	741	15200	6080	9120	2.4	11
Sh. Babaji Pradhan, Ambiki	556.2	365	7490	2996	4494	1.9	6
Sh. Srikanta Rana, Ambiki	779.0	361	7409	2964	4445	3.1	6

In this table it is seen that capacity has increased in different proportions in comparison to volume of earth work (Rs.20.50/m^3 of earth work in 2001) in different groups due to varying nature of soil at different sites.

The irrigation rotation schedule was developed for the group both for kharif (for paddy nursery in case of drought) and for rabi vegetable and pulses. Area irrigated during rabi was 27.9 ha for 71 farmers whereas area irrigated in summer is only 2.3 ha for 11 farmers. The total income from the paddy and rabi crop for each SSWHS was determined from crop harvest. The total amount of fish captured from each SSWHS was determined and the income from fish varied from Rs. 3000toRs. 17,600. Income from fish per cubic meter capacity of SSWHS varied from Rs. 2.96 to Rs. 12.23. Generally, as the capacity increases the income from fish also increases. The total income from SSWHS varied from Rs. 12.93/m^3capacity to Rs. 47.201m^3capacity in the first year itself. Low income from crop is sustained by high income from fish as the SSWHS is being fed continuously by sub-surface seepage water in coastal waterlogged area. The total income from

SSWHS with respect to cost of construction varied from 0.98 to 3.43 in the first year itself. In the 2ndyear 13 irrigation user groups was formed when the farmers participation was up to 67%of the project cost. The performance index is given in the Table 4. Benefit cost ratio for the initial years is calculated on the basis of net benefit and cost of construction of the SSWHS. This would increase in subsequent years when bund plantation would yield benefit.

Table 4. Economics of sub surface water harvesting structure (*)

Name of the Head of the farmers' group	Cost of SSWHS (Rs.)	Kharif	Rabi	From fish	Total	Total expenditure (Rs.)	Net benefit (Rs.)	B.C. Ratio	Crop intensity (%)
Sh. M. Mandal,	17733	9000	37250	14600	60850	20050	40800	2.3	177
Sh. Sunil Samal	16255	8000	24650	17600	50250	16570	33680	2.07	182
Sh. Puspak Nayak	15110	5000	21300	11000	37300	12130	25170	1.66	192
Sh. Subal Behera	13646	9000	19650	3000	31650	10650	21000	1.53	132
Sh. Srikanta Rana	7409	2500	11770	4950	18220	6735	11485	1.55	190
Sh. Babaji Pradhan	7490	3000	8900	4300	16200	5315	10885	1.45	185
Sh. Sabyasachi Jena	15200	5000	61000	3800	14900	4675	10225	0.67	175

**two years after super cyclone (2002-2005)*

IFS in coastal waterlogged area

One experiment was under taken in 1.75 ha of low lying area, which suffered water logging located in Khurda district and susceptible to cyclone. During monsoon the depth of ponding water was more than 50 cm and during driest period (May) of a year the water table was varying between 50-150 cm below ground level. The water quality was good and only paddy was grown in *kharif* in some years with 0.5 t ha^{-1} average yield. The soil was acidic with low available nutrient and iron toxicity was present. The land was only suitable for ploughing during May and early June and high water table restricted growing of any other crop during *rabi* season. The hydrologic data analysis resulted the design dimensions of the three ponds in series which were 27 m x 27 m, 30 m x 30 m, and 34 m x 34 m at the top with 2 m depth and side slope 1:1. The excavated soils were spread around the pond to elevate the surrounding area so as to keep the water table below 2 m from ground surface. Hume pipes of 30 cm diameter and 4 m length were used as inlet and emergency outlet of the pond. Since the objective of the study was to store excess water for reclamation of waterlogged area, the area of the ponds are kept within 20 to 25% of the total area considering the water balance component of the study area.

Design and construction of three micro water resources covering water surface area of 625 (P_1), 785 (P_2) and 1025m^2 (P_3) was completed in March 2006. Treatment implementation and stocking of fish fingerling (*Magur*, 12.2g MBW) was done as the first crop. Population density was maintained at 1200, 2100 and 1700 for P_1, P_2 and P_3 respectively. In this experiment, average growth performance of *Magur* was highest inP_1 (163.5g) followed by P_3 (141.0g) and P_2 (130.5g). In this crop Yield of fish ranged between 1632-1710kg/ha/ 200days, SR%- 61-64.75, FCR- 1.39-1.47, PDI– 0.595-0.623.

Indian major carps (IMC) was taken as second crop and released during 4th week of August 2007. All growth parameters were undertaken regularly. The catla has recorded a maximum growth in comparison to rohu and mrigal. As age of the pond increased the quality of water improved as the sides of the bunds have been stabilized, hence IMC was undertaken in place of magur to reduce the input cost and preference in market.

Under on-dyke horticulture activities, there were 114 papaya, 89 banana, and 16 coconut plants around 1st pond, 69 banana, 9 papaya and 4 coconut plants around 2nd pond and 70 banana plants were planted around the 3rd pond. Besides another 90 banana plants were planted in adjacent area. The different varieties of tissue culture banana planted are G-9, Bantal, and Robosta. Papaya variety was "farm selection".

In the first year under on-dyke horticulture activities vegetable such as bottle gourd in 386 m^2 area (7.8 t/ha), tomato in 252 m^2 area (2 t/ha) and brinjal on 66 m^2 (1.52 t/ha) were taken up. Different varieties of paddy such as *Khandagiri, Swarna, CR-1009 and Surendra* were grown in four different plots showed average yield of 2.72 t/ha.

In 2nd year, 220 bunches of banana were harvested. Different varieties of paddy such as *Khandagiri, Swarna, CR-1009 and Surendra* were grown in four different plots. During *kharif* the yield of Khandagiri was 2.1 t/ha, Surendra gave 3.2 t/ha and Swarna showed average yield of 2.7 t/ha. During *rabi* Khandagiri paddy gave a yield of 2.3 t/ha. Different vegetable were taken as on-dyke horticultural activities as well as intercrops such as brinjal (6.25 t/ha), cowpea (1.5 t/ha), Bean (2 t/ha), ladies finger (4.9 t/ha) and 200 kg of bottle gourd was also obtained.

Conclusion

From the above studies, it is established that micro water resources are to be developed in coastal areas which is experiencing regular cyclones, so that in case crops fail due to cyclone, the aquaculture in the pond and the water stored in the pond would be used for rabi and summer crop cultivation for enhancing the livelihood options of the rural poor. In favourable geo-hydrologic condition where fresh water floats above saline water with an impervious clay interface, sub-surface water harvesting structures are to be undertaken. Also for sustainability of a system, farmer's participation is essential. Farmers' paying capacity must be increased from the system to make it sustainable in the long run. Mere distribution of seed, fertilizer, planting material has not helped much and after the withdrawal of the technology adoption reduced drastically. Participation of farmer by paying 40% of the cost of SSWHS on the 1st year and 67% of the cost in the 2nd year gave them the ownership feeling and they do not take it as government donation or work. Since the system worked with cyclone ravaged poor people successfully this will also work in all coastal areas. This gives a new insight for development of small scale water resources in coastal areas.

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Integrated long term management plan for cyclone risk mitigation

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Indian coasts are highly vulnerable to tropical cyclones and consequent recurrent loss of life and property. As the tropical cyclones are caused by atmospheric disturbances around a low-pressure area distinguished by swift and often destructive air circulation, these are usually accompanied by violent storms and bad weather. The World Meteorological Organisation uses the term 'Tropical Cyclone' to cover weather systems in which winds exceed 'Gale Force' (minimum of 63 kmph). In addition to strong winds and rain, tropical cyclones are capable of generating high waves, damaging storm surge. They typically weaken rapidly over land, where they are cut off from their primary energy source. For this reason, coastal regions are particularly vulnerable to damage from a tropical cyclone as compared to inland regions. Heavy rains can cause significant flooding inland and storm surges can produce extensive coastal flooding up to 40 kms from the coastline. Their effects on human populations are often devastating. The major Tropical cyclones which struck the coastal districts in Odisha during the period 1891-2006 are Balasore (32), Cuttack (32), Puri (19), Ganjam (15) total amounting to 98 numbers. Recognizing this, the Government of India has considered the hazard risk mitigation approach through short term and long term management plan, which lays greater emphasis on prevention, preparedness and mitigation. The high vulnerability coastal states to this calamity are Andhra Pradesh, Gujarat, Odisha, Tamil Nadu and West Bengal.

Strategic mitigation options

Broad risk mitigation strategies available and applicable to all the coastal hazards can be classified into three main types namely; protection, accommodation and retreat. These strategies include both structural and nonstructural measures. Structural measures refer to any physical (natural or artificial) construction to reduce or avoid possible impacts of hazards. Structural measures can range from engineering structures that are added to the landscape to protect from hazards. Non-structural measures refer to policies, regulations and plans that promote good coastal management practices to minimize risks from coastal hazards. Education and outreach campaigns that increase the public's awareness of risks, vulnerability and preparedness responses can be considered as non-structural measures.

"Protection" involves the use of natural or artificial measures to protect landward development. Traditionally, protection against coastal erosion, flooding, storm surge and tsunami inundation has been approached through mitigation by hard structural response. Examples of common protection measures include constructing groynes, seawalls, offshore breakwaters. In some heavily populated areas susceptible to storm surges, dykes, levees, dams, and flood gates have been built to protect coastal communities during extreme sea-level events.

Multi-pronged approach

As no single approach will be able to address the community's vulnerability to hazards, a multi-pronged most effective approach is required to reduce the risks, incorporating protection, accommodation and retreat options to handle the cyclone risk. Once an overall strategy is identified, comprising protection, accommodation, retreat or a combination thereof, specific measures are applied to handle the hazard. Selection of specific measures will depend on a wide variety of factors including: the hazard(s) being addressed; the geographical scope and level of development of the area to be managed; priorities identified through the vulnerability and risk analyses; the timeframe that is being addressed; the existing and potential capacity of the community (e.g., funds, expertise, administrative capacity); and the political, legal and socio-economic context.

Lessons learnt from Phailin

Let us recall the success story of the recent cyclone "Phailin" that hit Odisha and Andhra Pradesh coast of India. The coordination was prompt and organised in case of Phailin in comparison to all major cyclones that hit the east coast - Aila, Thane and Nilam since 2009. In case of phailin have the loss to human life was minimal. Odisha proved that what is required to face natural calamities is perfect coordination between the Centre, State and several Government agencies, and trained personnel, apart from political will. About eight lakh people were evacuated to safer places. Odisha has developed a system of communicating cyclone warnings through mass media, public address systems and religious places. This was made possible because of accurate forecasts from the Indian meteorological department. Not only the Indian prediction on the strength of the cyclone proved right but also the cyclone path was accurately predicted. Within hours of the cyclone striking Odisha, relief workers were in action. Not only did they help contain damage to property and life, they also ensured that the evacuated people were returned to their homes after the cyclone had passed. What is heartening is that the loss of life was minimal against the fury of the terrible storm. Even media played a positive role. Bulletins from the interiors of Odisha kept people informed as reporters went into the remotest areas. The Odisha government did not forget to learn from the 1999 incident when a super cyclone killed 10,000 people. Since then, cyclone shelters have been built in possible cyclone hit locations. A strong lesson emerges from how the cyclone Phailin was handled - when there is a will to do something, India has the competence, capability and resources. The special representative of the UN secretary general for disaster risk reduction said, "Odisha's handling of the very severe cyclone will be a landmark success story in disaster management". The UN highlighted Odisha's efforts in dealing with cyclone Phailin as a successful case study globally.

Long term management plan

The following are the long term plan for extenuating the threat of cyclone.

1. Construction of cyclone shelter
2. Construction / renovation of canals and embankments for improved drainage
3. Shelter belt plantation
4. Construction of missing road links
5. Institutional capacity building and hazard reduction studies
6. Improvement of on-shore warning system
7. Retrofitting of life-line /key /vital installations (roads / culverts / bridges)
8. Awareness generation for cyclone risk mitigation

1. Construction of cyclone shelter

A large number of people in the coastal area do not have access to safe shelters, which could withstand the fury of cyclone. So studies along the entire coastline needs to be conducted to find out villages, where people do not have access to safe shelters within a range of 1.5 km and without having to cross a natural barrier. Cyclone shelters may be constructed in such places to ensure physical safety of people those who have no access to safe shelters. Livestock need to be provided with shelter to ensure their sustenance during a disaster.

Therefore, the cyclone shelters should be designed for multi-purpose use such as school building, community center, or any other public utility buildings so as to ensure that these building are used and maintained during normal times. For proper maintenance of these specially designed buildings in hostile terrains communities should have a sense of ownership of these. Therefore, Cyclone shelter management and maintenance committees may be constituted for upkeep of these shelters. A corpus fund may be placed with the committee for routine maintenance of the buildings. The committees may be encouraged to generate funds by collecting fees from people for using the buildings for social / cultural functions. Designing and building of robust cyclone proof shelters, which have storage and resting areas sufficiently high above the ground using corrosion resistant and durable materials need to be addressed.

Design criteria

If the storm- surge level is more than 1.5 m and less than 4.5 m, then the plinth should be taken as 1.5 meters and the ground floor should be used as stilt with a height varying from 2.5 meters to 4.5 meters. If the storm-surge level is more than 4.5 m, then, the roof of the first floor / terrace could be used as cyclone shelter. To make use of the space provided as stilt on the ground floor the temporary partitions could be erected and concrete benches could be provided, which are easy to maintain and clean after a cyclone. Rain water harvesting technique could be adopted so as to make drinking water available to people in the cyclone shelter at the time of cyclone /

storm-surge. In general the shelters are in RCC frame with non-load bearing, laterally supported filler walls and deeper foundation on elevated ground so as to avoid submergence of the main structure during cyclonic events.

2. Construction / renovation of canals and embankments for improved drainage

In the deltaic areas surface communication is a major handicap for response activities. The widths of the tidal rivers are linked to the sea tide and may not have a stable embankment. This makes it difficult to construct bridges on these. An alternative to road communication could be a coastal canal system. A canal network in the coast would also be an effective tool of water management.

Besides improvement to minor drains in the coastal areas may be considered for effective drainage of water, which may include repair and reconstruction of damaged and other vulnerable flood embankments. Saline embankments protect people, live stocks and agricultural fields from saline water inundation / storm surge. Hence, there is a need to protect vulnerable areas by renovating the existing embankments and creating new ones.

3. Shelter belt plantation

Shelterbelts are barriers of trees that are planted to reduce wind velocities and prevent wind erosion. In coastal areas shelterbelt plantation of Casuarinas is one of the most suitable and effective alternative to minimize the impact of wind velocity and saline ingress. They also provide direct benefits to provide shelter to livestock. Main objective of windbreaks and shelterbelts is to protect the human habitations and agricultural crops. Shelterbelt protects an area over a distance up to its own height on the windward side and up to 20 times its height on the leeward side, depending on the strength of the wind. When designing shelterbelt, the direction of the wind must be considered. A barrier should be established perpendicular to the direction of the prevailing wind for maximum effect. The trees selected for such salt-breaks must have some degree of salt tolerance. Species that has been used successfully tried in India include C*asuarina* e*quisetifolia*. In the selection of tree or shrub species for shelterbelts, the characteristics like rapid growth, straight stems, wind firmness, deep root system which does not spread into nearby field, resistant to drought are considered very important. If there is a Cyclone shelter / building or a construction projects with ≥20,000 sq. m and <150,000 sq. m of built-up area, it will require prior Environmental Clearance as per the EIA notification of 2006.

4. Construction of missing road links

Effective road connectivity ensures fast deployment of men, materials and machinery to affected areas. It helps in ensuring speedy evacuation of people from vulnerable places to safer areas in the face of an impending disaster threat. Thus there is a need for development of a reliable road network in the vulnerable areas so as to ensure coordination of relief and response in the event of a cyclone. The link roads to existing cyclone shelters are also very crucial for evacuation of people. Roads are always associated with culverts and bridges to make them fit throughout the year.

5. Capacity building and hazard reduction studies

While the hazards due to tropical cyclones cannot be reduced, mitigation strategies to reduce their impacts can be devised. Mitigation measures like timely communication of warnings, land use planning, enforcement of cyclone resistant construction etc. go a long way in reducing the vulnerability of structures to cyclonic impacts and the resulting losses. Assessment of risks to physical assets is fundamental before devising any successful mitigation strategies or plans. Thus the institutional capacity building measures need to be emphasized for knowledge updation to handle the unforeseen hazards.

6. Improvement of on-shore warning system

Early reliable warning is one of the important short term mitigation measures that can reduce the severity of the cyclone related disasters if acted upon timely. The degree to which this reduction can be effected will depend upon the accuracy of the warning, the length of time between the warning's being issued and the expected onset of the event and the state of pre-disaster planning and readiness. The public response to warning in the form of correct precautionary action is another important component for the reduction of loses of lives and properties. It is often seen that the fishermen out at sea and unorganized weaker section of the coastal communities are among the first causalities of tropical cyclone disasters. The strengthening of onshore warning communication system is therefore an important intervention that can save many valuable human lives.

7. Retrofitting of vital installations (roads / culverts / bridges)

Roads/culverts/bridges in the cyclone prone areas need to be maintained well. If they are in a bad shape their repair and strengthening works also needs to be given utmost attention. Roads are always associated with culverts and bridges and routine maintenance of these infrastructures is crucial for post disaster response. Bridge foundations in alluvial soils lead to deep scour near some piers when large discharges due to cyclonic storms occur which may result in tilting of foundations. Where the general road condition is found to be bad their restoration work has to be accorded high priority. Repair and retrofitting work is a specialized job and requires the use of special materials and expertise.

8. Awareness generation for cyclone risk mitigation

The public awareness programme is an important component of disaster risk management. Involvement of community under threat is essential for the success of any disaster risk reduction programme. Prior knowledge about the warning system and its limitations, source of warnings makes the community better equipped to fight a disaster. Mechanisms like distribution of circulars, Dos and Don'ts, posters and publicity about precautionary measures through media are in existence but past experience shows that such actions are not sufficient and more need to be done. Man to man contact is essential for the success of awareness programme. Such activities not only to be continued but also these are to be frequent and regular. A well informed awareness programme involving the community is essential.

Thus a multi-pronged approach is needed to mitigate the risk of tropical cyclone, which shall be certainly helpful for minimal loss of life and resources.

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Cyclonic disturbances in the eastern India: implications and predictions

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Introduction

The Orissa state of India is the most climate change-affected region due to frequent occurrence of hydrologic extremes in the recent past (Swiss Re, 2002; Mirza, 2003). The Center of Environmental Studies (CES, 2007) reported that the erratic behavior of climate of Orissa is primarily due to the combination of anthropogenic factors such as deforestation, extensive construction activities, uncontrolled mining, elimination of water bodies and extensive carbon consumption over a period of time. Further, a minor change in the pressure anomaly of the Bay of Bengal can have profound hydrological impact on the land mass of Orissa due to its geographical location at the head of the Bay where the weather forms (CES, 2007). Therefore, it is imperative to explore the long-term changes in rainfall of the study area and also changes in the synoptic disturbances.

Methodology

Test of structural changes

Test of structural change is a general form of the Chow test, commonly used in forecasting (Johnston and Dinardo, 1997). If the parameters of interest in a model differ from one subset of data to another, then structural breaks or change occurs in that time series. The parametric linear regression of response variable i.e. rainfall with time (year) can be defined as

$$y = \alpha + \beta X + u$$

where, y is represents the dependent variable, α is the intercept, β is the slope, X is the independent variable year, and u is the random error. This model can be defined in the matrix form as

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{u}$$

y is a vector of n observation representing the dependent variable, **X** is a matrix of independent variable, $\boldsymbol{\beta}$ is a column vector of parameters i.e. α and β , and **u** is the column vector of errors which is normally distributed with mean 0 and constant variance $\boldsymbol{\sigma}^2$.

In this study, for simplification of the procedure, we investigate the structural change in two subsets of data that form the complete time series, although there is possibility of several subsets with structural breaks. Let the total time series of n observation be divided into two subsets of samples with n_1 and n_2 observation i.e. $n= n_1+n_2$.The structural change may occur between the subset of time series due to the change in intercept or change in slope or combination of both the parameters.

The models representing the subsets of time series can be defined as

$$y_1 = X_1\beta_1 + u_1$$

$$y_2 = X_2\beta_2 + u_2$$

i.e.

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + \mathbf{u}$$

Here, $X_1= [\ i_1 \ \ X_1^*]$ and $X_2=[\ i_2 \ \ X_2^*]$, where, i_1 and i_2 are n_1 and n_2 vectors of ones, and X_1^* and X_2^* are subset vectors of years. Further, the β vectors can be partitioned to a conformable form as

$$\beta`_1=[\ \alpha_1 \ \ \boldsymbol{\beta}_1^*`] \ \ \beta`_2=[\alpha_2 \ \ \boldsymbol{\beta}_2^*`]$$

Null hypothesis of no structural breaks is H_0: $\boldsymbol{\beta}_1 = \boldsymbol{\beta}_2$

Under null hypothesis of common parameters

I. $$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} i_1 & X_1^* \\ i_2 & X_2^* \end{bmatrix} \begin{bmatrix} \alpha \\ \beta^* \end{bmatrix} + \mathbf{u}$$ (common parameters: RSS1)

II. $$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} i_1 & 0 & X_1^* \\ 0 & i_2 & X_2^* \end{bmatrix} \begin{bmatrix} \alpha 1 \\ \alpha 2 \\ \beta^* \end{bmatrix} + \mathbf{u}$$ (different intercept, common slope: RSS2)

III. $$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} i_1 & 0 & X_1^* & 0 \\ 0 & i_2 & 0 & X_2^* \end{bmatrix} \begin{bmatrix} \alpha 1 \\ \alpha 2 \\ \beta_1^* \\ \beta_2^* \end{bmatrix} + \mathbf{u}$$ (different intercept, common slope: RSS3)

The following hypotheses are evaluated for the structural change test.

H$_0$: $\alpha_1 = \alpha_2$ $F = \dfrac{RSS_1 - RSS_2}{RSS_2/(n-k-1)}$

H$_0$: $\beta_1^* = \beta_2^*$ $F = \dfrac{(RSS_2 - RSS_3)/(k-1)}{RSS_3/(n-2k)}$

H$_0$: $\beta_1 = \beta_2$ $F = \dfrac{(RSS_1 - RSS_3)/k}{RSS_3/(n-2k)}$

Results and Discussion

Rainfall distribution during 1901-2000 in Orissa

In last century during 1901-2000, the state Orissa has experienced 99 extreme events that include 49 floods, 30 droughts, 10 cyclones, and 1 super cyclone. The locally weighted regression technique (LOWESS) indicated that the spatially averaged annual rainfall of Orissa experienced three significant regime shifts (Fig. 1). Hence, the climatology is experiencing an erratic distribution in recent years. The detail descriptive statistics of annual rainfall in different regimes of last century are presented in Table 1.

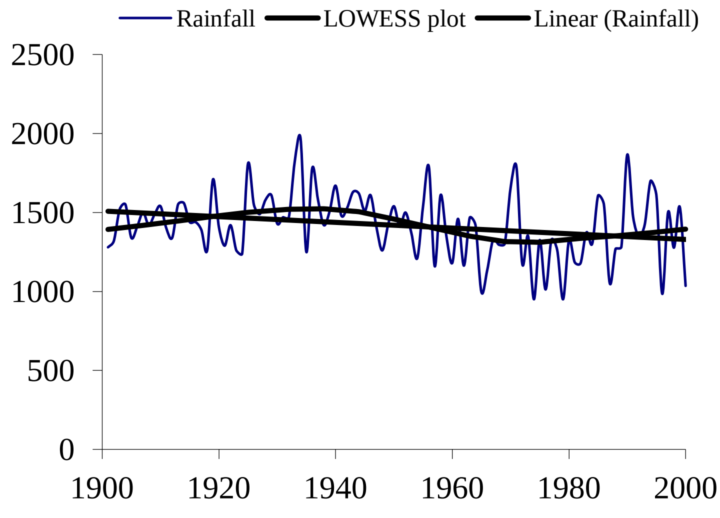

Figure 1. Structural breaks of annual rainfall distribution during 1901-2000

The decadal maximum, minimum and average rainfall of Orissa in last century indicated a decreasing trend as illustrated in Fig. 2. Table 2 shows the decade-wise maximum, minimum and average rainfall amount follow decreasing trend and standard deviations of rainfall follow increasing trend.

Table 1. Descriptive statistics of annual rainfall (mm) in different periods of last century

Period	1901-1940	1941-1969	1970-2000	1901-2000
Observations	40	29	31	100
Mean	1487.25	1403.33	1344.51	1418.67
Standard deviation (SD)	167.59	180.67	244.48	205.18
Skewness	0.84	-0.20	0.22	-0.01
Kurtosis	0.79	-0.20	-0.50	0.17
Minimum	1240	997	950.7	950.7
P10	1270	1160	1012.9	1169.9
Q1	1395	1296	1179.9	1286.6
Median	1470	1417.9	1325.6	1420
Q3	1555	1530	1535.9	1545
P90	1745	1620	1654	1662
Maximum	1970	1790	1865.8	1970
sapiro-wilk	0.942	0.984	0.970	0.989
p<w	0.042	0.922	0.521	0.581

Table 2. Descriptive statistics of decadal annual rainfall (mm) in last century

Decade	Minimum rainfall	Maximum rainfall	Average rainfall	S.D.
1910	1280	1550	1437	97.64
1920	1260	1710	1450	127.28
1930	1240	1810	1468	178.75
1940	1250	1970	1594	215.88
1950	1260	1630	1501	114.74
1960	1160	1790	1412	202.75
1970	997	1654	1322.07	190.37
1980	951	1791	1246.81	249.54
1990	1052	1866	1367.09	242.08
2000	985	1700	1388.69	233.19

Study of structural breaks in different regimes during 1901-2000 in Orissa

The parametric method of structural breaks was studied using the theory presented in theory section. In last century, the annual rainfall of Orissa experienced three significant breaks. The average of annual rainfall during these three regimes were: 1487 mm with standard deviation 167 mm during 1901-1940, 1412 mm with standard deviation 184 mm during 1940-1969, and 1354 mm with standard deviation 241 mm during 1970-2000 respectively. This indicates that the average rainfall is decreasing, but the standard deviation is increasing over rainfall regimes.

Table 3 Test of structural breaks during 1901-1940 and 1941-1969

Id	Parameters	SE	t-cal	P value	F-cal	P
α_1	-8725.99	4128.30	-2.11	0.04	22.05	0.003
α_2	23435.41	6809.50	3.44	0.00		
β_1	5.32	2.15	2.47	0.02		
β_2	-11.27	3.48	-3.24	0.00		

Study of structural breaks/ regime shifts during the period 1901-1940 and 1941-1969 indicated a significant test of structural breaks both in slope as well as the intercepts (Table 3). During the period 1901-1940, the annual rainfall exhibited a significant increasing trend having positive slope (β_1=5.32), whereas during 1941-1969 it experienced a significant decreasing trend with a negative slope (β_2=-11.27). Further, the intercepts are significant in both the regimes of the study period.

Results of structural breaks analysis during the period 1941-1969 and 1970-2000 indicated a non-significant test of structural breaks (Table 4). During the period 1941-1969, the annual rainfall exhibited a significant decreasing trend having slope (β_1=-11), whereas during 1941-1969 it experienced a non-significant increasing trend with a slope (β_2= 2.88). Further, the intercepts are significant in both the regimes of the study period.

Table 4 Test of structural breaks during 1941-1969 and 1970-2000

Id	Parameters	SE	t-cal	P value	F-cal	P
α_1	23435	9036	2.59	0.01	7.89	0.103
α_2	-4381	8300	-0.53	0.60		
β_1	-11	4.62	-2.44	0.02		
β_2	2.88	4.18	0.69	0.49		

Study of structural breaks in annual cyclonic disturbances (depression) over during 1901-2000 in Orissa. The annual cyclonic disturbances (depression) over the Bay of Bengal during 1901-2000 indicated a structural change in 1948 (Fig. 3).

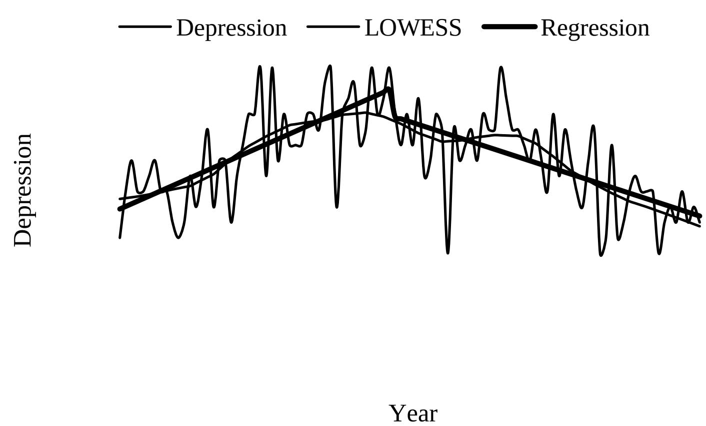

Figure 3. Structural breaks of annual depression over the Bay of Bengal during 1901-2000.

Descriptive statistics indicated that an average of 10.7 depressions occurred during 1901-1948 in comparison to 9.6 during 1949-2000. It is evident that the depression frequency increased significantly during 1901-1948. In contrast, a marked decrease took place from 1949 onwards. This may have decreased the rainfall in recent decades in Orissa and adjacent regions. Since structural change provide enough evidence of climate change, more research need to be carried out to know the reason of these structural breaks in climatic variables.

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Assessment of severity and extent of cyclone damage on crop production and some measures to reduce the impacts

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Cyclone and its Classification

Cyclones arc caused by atmospheric disturbances around a low-pressure are distinguished by swift and often destructive air circulation. They are usually accompanied by violent storms and bad weather. The air circulates inward in an anticlockwise direction in the northern hemisphere and clockwise in the southern hemisphere. Tropical revolving storms (TRS) form in the vast expanses of the warm tropical oceans. They are violent whirls spiralling upward from the ocean surface to great heights, sometimes upto the tropopause and moving across the ocean, generally from east to west. They are characterized by huge pressure deficit at the centre, cyclonic circulation, violent winds and severe weather. TRSs are known as 'cyclones' in the Indian Ocean, 'Typhoons' in the Western Pacific, 'Hurricanes' in the Atlantic and Eastern Pacific, 'Baguios' in the Philippine region and 'Willy Willies' in the Australian waters. More than one cyclone can exist on the chart at a given time. For purposes of identification, names are allotted to the hurricanes in the USA in the alphabetical order in each year eg. Anna, Betty, Clara,Dora, etc. In Japan the number followed by the year is used for identifying the typhoons eg. 1/81, 2/81 etc. Earlier in India the cyclones were referred to by the place of landfall i.e. where they strike coast eg. Midnapur, Puri, Rameswaram etc. Now particular names are given to identify a cyclone in India too like ‘Phailin’.

Cyclones arc classified as: (i) Extra-Tropical cyclones, also known as temperate cyclones); and (a) Tropical cyclones. Extra tropical cyclones occur in temperate zones and high latitude regions, though they are known to originate in the Polar Regions. Cyclones that develop in the regions between the tropics of Capricorn and Cancer arc called Tropical cyclones. Tropical cyclones are weather systems in which winds equal or exceed gale force (minimum of 34 knot, i.e., 62 kmph). These are large-scale weather systems developing over tropical or subtropical waters, where they get organized into surface wind circulation.

A cyclone is originated from a “low pressure area’, followed by ‘depression’ and ‘deep depression’. Cyclones can be classified mainly according to the wind speeds and type of disturbances. Different types of disturbances from origin to final form are given in Table-2.

Table-2: Types of disturbances from origin to final form and associated wind speed.

Sl. No.	Type of Disturbances	Associated Wind Speed in the Circulation
1	**Low pressure Area**	Less than17 knots (<31 kmph)
2	**Depression**	17 to 27 knots (31 to 49 kmph)
3	**Deep Depression**	28 to 33 knots (50 to 61 kmph)
4	**Cyclonic Storm**	34 to 47 knots (62 to 88 kmph)
5	**Severe Cyclonic Storm**	48 to 63 knots (89 to 118 kmph)
6	**Very Severe Cyclonic Storm**	64 to 119 knots (119 to 221 kmph)
7	**Super Cyclonic Storm**	120 knots and above (222 kmph and above

When fully developed, a cyclone is a vast whirlwind of extraordinary violence spiraling around a centre and progressing along the surface of the sea. The speed of wind within 50 to 100 km of the centre in a mature storm can reach 160 km per hour or more. The winds associated with such storms are among the most violent and the rainfall accompanying them is always very heavy. The cyclonic storm transfers its whirling movements to the sea water and, since the storm itself moves comparatively slowly, the winds act for a long time on the water surface producing strong currents of water up to depths of 20 to 25 m. When the storm approaches a coastal belt, the sea level rises, rather suddenly to an overwhelming extent causing dangerous inundations over the coastal areas. The sudden rise in the sea level associated with cyclonic storms also called 'storm tide' strike the coast, causing large scale devastation in a matter of minutes.

Cyclones are also classified into five different levels on the basis of wind speed, and according to their damage capacity (Table-1).

Table -1: Classification of cyclone based on damage capacity

Cyclone Category	Wind Speed, km/h	Damage Capacity
01	120-150	Minimal
02	150-180	Moderate
03	180-210	Extensive
04	210-250	Extreme
05	250 and above	Catastrophic

Formation of Cyclone

Cyclones develop only under favourable conditions when certain pre-requisites are fulfilled. They originate in large sea or ocean areas where the sea surface temperature (SST) is over 26°C. This apparently is the threshold value to maintain a steep vertical lapse rate. This temperature is also required to ensure that the air from the lowest layers which undergoes adiabatic expansion and condensation remains warmer than the surroundings to about 12 km. Tropical cyclones generally form in a preexisting synoptic system such as: wave in the equatorial trough, easterly wave, mid-tropospheric trough or a low pressure area on the surface. This is the starting mechanism.

All disturbances do not develop into cyclones. Only a few grow under a combination of favourable circumstances. A certain minimum value of the Coriolis force is required to provide the initial torque. This means that cyclones do not form near the equator (about 5° latitude on either side). A mechanism is required to remove the rising air in the upper troposphere by rapid divergence in order to facilitate the deepening of the surface low. That is why cyclones intensify when the low level disturbance is situated underneath a high level anticyclone. The vertical wind shear in the basic current must be weak. This condition limits the formation of cyclones to latitudes far equator-ward of the STJ. Cyclones develop near the ITCZ, away from the equator where the SST is over 26°C. That is probably why no cyclones form in the South Atlantic Ocean where the ITCZ remains always north of the equator and the SST is lower than 26°C.

Mechanism of Formation*:* The energy for the development of the intense vertical storms is provided by the coupling and interaction of large scale low level convergence and deep cumulus convection. Thus a weak tropical disturbance amplifies into a tropical revolving storm under favourable moisture conditions. The threshold SST > 26°C enables intense and sustained convection in an oceanic region of radius of nearly 100km. The convection is concentrated along asymmetric spiral bands. Tangential wind speeds reach 100 to 200 kt. The large vertical shears prevent local accumulation of the released latent heat of condensation which gets advected in different directions by the spiral cloud and rain bands. Cyclonic circulation, however, falls off rapidly with height. A temperature maximum occurs at the centre of the storm. When mature, the original cold core of the system becomes warm. The transformation of the cold core system into a warm core system is due to the latent heat released by the many Cb 'hot towers' surrounding the storm centre. This heat provides the energy for the maintenance of the cyclone and also acts as a link in the transport of heat from the tropics to the poles in the general circulation.

A well-developed **cyclone has four distinct phases:**

i. ***Formative Stage***— A tropical disturbance is noticed in a large oceanic area where winds become variable with thunder-squalls. This stage extends from low pressure area to severe cyclonic when an eye and eyewall are formed. Pressure falls slowly and the central pressure deficit is of the order of 10 mb.

ii. ***Immature Stage***— There is rapid fall in the central pressure, reaching the lowest limit. Clouds and rain get organized into spiral bands. Area of strong winds remain small but winds attain the maximum speed. The entire process is very quick.

iii. ***Mature Stage***— Pressure fall and wind increase are arrested. The circulation expands outwards and asymmetry sets in as the area of rain and gales extends much more to the right in the direction of motion of the system. The process lasts a few days.

iv. ***Dissipating Stage***- The decay starts when the system enters land or an oceanic region where SST is lower than 26 C. Over land the moisture supply is drastically curtailed, cutting off the energy input and also there is dissipation due to increased frictional drag. The winds decrease, the cyclone fills up and weakens, though the rainfall may persist for a day or two more.

Horizontal Structure: A full-fledged cyclone has three fell-defined components:

(I) ***Eye:*** The innermost or central portion of the mature cyclone is the 'eye'. It is about 10 to 30 km in diameter, depending upon the size of the storm and is a more or less calm region with little or no clouds and some subsidence. The eye or the calm centre can be described variously as the:

—pressure eye:	where msl pressure is lowest,
— wind eye:	light or calm wind conditions,
— Radar eye:	the eye seen in radar echoes,
— satellite eye:	clear or dark spot seen in the cloud mass in satellite imagery.

The various types of 'eyes' described above may not always coincide. In the warm core systems the temperature inside the eye region can be higher by as much as 10°C than the surroundings. All cyclones do not develop an eye or become warm core systems. Above the warm core is a cold top in the stratosphere.

(II) ***Eye Wall or Inner Ring: Surrounding*** the eye is a tight 'inner ring' of hurricane winds (over 63 kt, attaining 100 to 200 kt in severe cyclones). This core of maximum winds is at the centre of a solid thick wall of towering Cumulonimbus clouds, 30 to 50 km wide round the eye and is referred to **as** the 'eye **wall'.** The Cumulonimbus Cb towers rise from the sea surface to the Tropopause level, nearly 18 km or more high and sometimes extend a km or so into the stratosphere. Incessant lightning keeps the entire eye wall-illumined, making it a fascinating and awesome spectacle. This is a region of violent thundersqualls, torrential rains etc with mountainous waves reaching 20 metres or more in the sea. The eye and eye wall together constitute the core of the cyclone.

(III) ***Outer Ring:*** Beyond the eye wall is an 'outer ring' of cyclonic circulation where the wind speed decreases steeply and clouds, rain etc diminish rapidly outwards. The winds fall off to about 40 kt at a distance of approximately 200 km. In some types of cyclones, however, the decrease of wind outside the wall cloud is gradual. Hurricane speed winds (over 63 kt) may extend to nearly 100 km from the centre and winds of 40 kt spread out to 400 to 600 km. In the periphery of the storm is an outermost field of weak cyclonic circulation and scattered clouds. The cyclones vary in size. The smallest ones are only about 150 km in diameter. These are *'midgate'* cyclones. Big cyclones can have a diameter of 1,500 km.

Vertical Structure: Vertically a cyclone falls into clear-cut layers:

(I) The Inflow Layer*:* Inward radial motion takes place in the lower troposphere roughly up to 3 km in the cyclone with the most pronounced motion in the planetary boundary layer (up to 1 km). Air entering the storm field rises up as spiral rain bands along the '**Eyewall'.** The cyclonic wind vortex has maximum diameter at the surface. This remains nearly the same upto roughly 6 km and then diminishes rapidly aloft.

(II) The Mid-tropospheric Layer: This layer can be taken to be between 3 km and 8 km, Radial motion practically ceases in this layer.

(III) The Outflow Layer*:* The air spiralling up from the inflow layer flows outwards in all directions from the top of the storm. The outflow is found to be maximum above the cyclonic circulation, at about 12 km (200 mb level) where an anticyclone with divergence appears. This outflow serves as the ventilation, so essential for the cyclone to deepen and be sustained. Cirrus cloud streams out in all directions and appears as the cirrus shield. The outflow sinks at the edge of the cirrus shield where it is seen as a cloud-free 'annular zone' (AZ). There is an outer convective band (OCB) on the outside of this annular zone. There is some subsidence in the eye also, which again is cloudless or nearly so.

The three-dimensional picture of tropical revolving has been constructed out of the composite data accumulated over two decades from radar pictures, aircraft raccee probes, satellite imagery etc, mainly over the Atlantic and the Pacific. Data from the Indian Ocean have been meagre. In spite of wide variations and differences in the characteristics of individual storms, a generalized but fairly realistic structure of TRSs has been built up. Horizontally air spirals inwards, speed increasing gradually and then becoming zero at the centre. From the centre, proceeding in any direction, wind speed increases to reach a maximum and then decreases. The locus of the points of maximum speed is the ring of maximum wind. The maximum inflow is found in the eastern semicircle and the maximum winds occur to the right of the direction of movement. The ring of maximum winds is in the middle of the eye wall which is an area of most intense convection.

The heaviest rainfall takes place in this region as spiral bands. Upward motion is concentrated in these bands. The height of the Cb towers is related to the intensity of the storm.

Impacts of tropical cyclone on Indian sub-continent

The Indian subcontinent is one of the worst affected regions in the world. Past records of destructive cyclones (human deaths numbering around 10,000 and above) are given in Table 3. This list does not include Tropical Cyclone which have caused severe loss to properties (such as 'Katrina' in USA in 2005, the severest Tropical Cyclone ever recorded in terms of intensity. In its combination of violence, duration and size of areas affected, the tropical cyclones appears to be unrivalled, amongst all the natural phenomena, for the sum total of destruction it can cause. Though the life span of cyclonic storms passing over the coast of India does not exceed 3 to 6 days, the devastation caused is phenomenally high. Extensive damages are caused on account of the strong winds that blow up to 160 km per hour, heavy rainfall, sometimes, as much as 25 cm in 12 hours and the gigantic tidal waves of 5 to 6 m that roll over the coastal belt of 20 to 30 km. The winds uproot innumerable trees and cause serious damage to hutments, public buildings, engineering works, telephone and power lines and standing crops. The rain causes inundation and drainage congestion that paralyses human activity apart from damaging crop and property in places which are not normally affected by river Hoods. The sea floods engulf all that comes in their way, leaving only mute remnants of pucca buildings and lives that could seek shelter in upper storey's or on high ground. The cumulative effects of these tremendous forces are loss of thousands of human lives, millions of cattle and livestock, washing away of complete villages, damage to standing crops in millions of hectares, flooding and water logging in low lying lands over vast stretches, salinity of soil in thousands of sq. kms, sand casting in extensive areas and damage to private and Government property and public utilities like Railway lines, arterial and feeder roads, power and communication lines, water supply, etc.

Most lives are lost during a cyclone on account of floods and the devastating storm surge that often accompany cyclones. In case of severe cyclonic storms with storm surges, more than 90% of the fatalities occur due to drowning, either during the incoming water phase or during the out surges.

It can be seen that since the year 1737 of the 23 major cyclone disasters (in terms of loss of lives) in the world 21 have occurred over the Indian subcontinent (India and Bangladesh). Tropic cyclones in the Bay of Bengal striking the east coast of India and Bangladesh usually produce higher storm surge as compared to elsewhere in the world because of the special nature of coastline, shallow coastal bathymetry and characteristics of tides. Their coastal impact significant because of the low flat coastal terrain, high density of population, low awareness of the community, inadequate response and preparedness and absence of any hedging mechanism.

Table-3: **Some major Tropical Cyclone Disasters in Terms of Humanloss (With Human Deaths 10,000 or more)**

SI. No.	Year	Country	Deaths
1	1737	Hooghly, West Bengal, India	300,000
2	1779	Manchilipatnam, Andhra Pradesh, India	20,000
3	1782	Coringa, Andhra Pradesh, India	20,000
4	1787	Corings, Andhra Pradesh, India	20,000
5	1788	The Antilles, Carribbean Islands, West Indies	22,000
6	1822	Barisal/Backergunj, Bangladesh	50,000
7	1831	Balasore, Odisha, India	22,000
8	1833	Sagar Island, West Bengal, India	30,000
9	1839	Coringa, Andhra Pradesh, India	20,000
10	1864	Machilipatnum, Andhra Pradesh, India	30,000
11	1867	Contai, West Bengal, India	50,000
12	1876	Backergunj, Bangladesh	20,000-250,000
13	1881	China	300,000
14	I897	Bangladesh	175,000
15	1942	Contai, West Bengal, India	15,000
16	1961	Bangladesh	11,468
17	1963	Bangladesh	11,520
18	1965	Bangladesh	19,229
19	1970	Bangladesh	300,000
20	1971	Paradip, Odisha, India	10,000
21	1977	Divi Seems, Andhra Pradesh, India	10,000
22	1991	Bangladesh	1 38,000
23	1999	Sough of Paradip, Odisha, India	9,893
24	2010	Andhra pradesh	--
25	2013	Phalin, Ganjam, Gajapati	--

Source: Rangachari et al., 2011

The subcontinent with a long coastline of 8041 kilometers is highly prone to tropical cyclones; the majority of them has their initial genesis over the Bay of Bengal and strikes the east coast of India. On an average, five to six tropical cyclones occur every year, of which two or three could be severe. More cyclones occur in the Bay of Bengal than the Arabian Sea and the ratio is approximately 4:1.

Cyclones occur frequently on both the coasts. An analysis of the frequency of cyclones on the east and west coasts of India between 1891 and 1990 shows, that nearly 262 cyclones occurred (92severe) in a 50 km wide strip on the east coast. Less severe cyclonic activity has been noticed on the west coast, with 33 cyclones occurring in the same period, out of which 19 of these were severe.

Tropical cyclones occur in the months of May-June and October-November. The cyclones of severe intensity and frequency in the north Indian Ocean are bi-modal in character, with their primary peak in November and secondary peak in May. The disaster potential is particularly high in the north Indian Ocean (Bay of Bengal and the Arabian Sea) due to the accompanying destructive wind, storm surges and torrential rainfall. Of these, storm surges are the greatest killers of a cyclone, by which sea water inundates low lying areas of coastal regions and causes heavy floods, erodes beaches and embankments, destroys vegetation and reduces soil fertility.

Cyclones vary in diameter from 50 to 320 km but their effects dominate thousands of square kilometers of ocean surface and the lower atmosphere. The perimeter may measure 1,000 km but the powerhouse is located within the 100-km radius. Nearer the eye, winds may hit 320 km/h. Thus tropical cyclones, characterized by destructive winds, torrential rainfall and storm surges disrupt normal life with accompanying the phenomena of floods due to the exceptional level of rainfall and storm surge inundation into Inland areas. Cyclones are characterized by their devastating potential to damage structures, viz. houses; lifeline infrastructure- power and communication towers: hospitals; food storage facilities; roads, bridges and culverts; crops etc.

The most facilities come from storm surges and the torrential rain flooding the low land areas of the coastal territories. The cyclonic disturbances of the monsoon season (June to September) known as "monsoon depressions” are as a rule, of smaller intensity. They form at the head of the Bay and follow a north westerly course and the damages caused by them are mainly due to heavy rain rather than due to strong winds. October and November are the two months to be dreaded most as regards cyclones originating both in the Bay of Bengal and the Arabian Sea, though some exception have been there also. In general, the meteorologists feel that the post and pre-monsoon cyclones usually unleash all their fury on striking the coast and collapse soon after. But the monsoon cyclones possess the unique capacity of travelling without collapsing, on both water and land surfaces. The monsoon depressions, in general, yield copious rain along their tracks, as they move across the country.

Vulnerable areas in India affected by Cyclones

There are 13 coastal states and union territories (UTs) in the country, encompassing 84 coastal districts which are affected by tropical cyclones. Among these, four states (Tamil Nadu, Andhra Pradesh, Odisha and West Bengal) and one UT (Puducherry) on the east coast and one state

(Gujarat) on the west coast are highly vulnerable to cyclone disasters. The details of cyclones which crossed the coastal districts of India during the period 1891-2013, is presented in Table 3.

Table-3: Number of Cyclones crossing various Coastal Districts of (the East and West Coasts of India during the Period 1891-2013

West Coast			**East Coast**		
State	**Coastal Districts**	**No of Cyclones**	**State**	**Coastal Districts**	**No. of Cyclones**
Kerala (3)	Malappuram	1	W. Bengal(69)	24 Parganas (North and South),	35
	Kozikode	1			
	Kannur	1		Midnapur	34
Karnataka (2)	Dakshina Kannada	1	Odisha (99)	Balasore	32
				Cuttack	32
	Uttar Kannada	1		Puri	19
				Ganjam	16
Maharashtra (13)	Sindhudurg	3	Andhra Pradesh (80)	Srikakulam	14
	Ratnagiri	3		Visakhapatnam	9
	Mumbai	3		East Godavari	8
	Thane	4		West Godavari	5
				Krishna	15
				Guntur	5
				Prakasam	7
				Nellore	17
Goa(2)	Goa	2	Tamil Nadu(54)	Chennai	18
				Cuddalore	7
				Southarcot	5
				Tanjavur	12
				Pudukkottai	5
				Ramnathpuram	3
				Tirunelveli	2
				Kanyakumari	2
Gujarat(28)	Surat	1	Puducherry (UT)	Puducherry	8
	Kaira	1			
	Bhavnagar	4			
	Amreli	4			
	Junangarh	7			
	Jamiiagar	6			
	Kachchh	5			

Source: Rangachari et al., 2011

The most vulnerable states to cyclone are given below:

Andhra Pradesh

Andhra Pradesh has a long coastline stretching approximately 1,030 km and equally long history of varying intensity over the past 100 years. More than 500 villages perched along the coastline are within 5 km swathe extending inside from the coast. A good number of coastal villages are within 5-20 km. The flat deltaic plain lands on either side of the Godavari and the Krishna rivers are between 1.5-2 m above mean sea level and are most vulnerable to surges. The coastal districts are primarily agricultural – which have highly productive, network of irrigation canals fed from the Krishna and Godavari rivers. These also face the brunt of floods during the monsoons. The coastline of the state is affected by at least one cyclone every year.

Odisha

In Odisha, the cyclones are usually experienced in the months of October and November. At this time, the *Kharif* paddy is generally in the flowering stage. The flowers being blown off by strong winds, damage the paddy crops seriously. When lashed with severe cyclonic storms as in Andhra Pradesh, the very economic structure gets hit in the coastal district. The affected fertile land of the coastal districts of the state may extend 25 km inland. 75 per cent of the people in this area depend on agriculture and 5 per cent on fishing. About 90 per cent of the populations live in thatched-roof houses. The communication system of the area is extremely poor, weaker sections of the society in these coastal districts have not been able to improve their economic condition on account of frequent floods, saline inundation and severe cyclones. The state has in recent past suffered extensive losses due to "**Super Cyclones**" in 1999 and "**Phailin**" in 2013.This cyclone prone region has a number of inlets into sea which allow the tidal waters to be driven inland for considerable distances causing damage on both the sides of the creeks.

Tamil Nadu

The coast of Tamil Nadu has been hit by cyclonic storms with disastrous effects, almost once in 'two years. In some years, the coast has been hit more than once. The districts affected by cyclones in the State are, Kanyakumari, Thirunelveli, Rama-nathapuram, Thanjavur, South Arcot and Chen-galpattu.

West Bengal

In West Bengal also, the severe cyclones are usually experienced in October and November. The cyclone of October 1942 with a wind speed of 161 km per hour caused a storm surge of 3.5 metres above the normal tide level and caused serious devastation in 24-Parganas and Midnapore districts. Thousands of lives were reported to have been lost apart from tremendous loss of property. Subsequently, the cyclone of September 1976 recorded a wind speed of 160 km and caused widespread devastation in the same districts viz., 24-Parganas and Midnapore.

Tracks of a Cyclone

The life span of a cyclone averages a week. The larger the sea area, the more intense the storm grows. When fully developed, a storm is a violent whirl 200 km (midget) to 1,500 km across, 6 km to 8 km high, spiralling round a centre and progressing like a spinning top on the ocean surface, at a speed of 10 to 30 km/hr, covering a distance of 300 km to 500 km a day. It moves from east to west, steered by the high level zonal easterlies. The movement can be erratic, sometimes with wobbles and even loops. Storms get pulled poleward and hence generally move northwest in the northern hemisphere and southwest in the southern hemisphere. There is a tendency to move into areas of warm waters. They weaken if they enter colder waters (less than 26°C).

Extent of damage by Cyclone and Strom surge

Damage and devastation due to a storm are mainly from hurricane winds, torrential rain and storm surge. Hurricane wind damages houses, uproots plants and trees and torrential rain creates flood and damages to standing crop. Generally cyclones occur at November and December, during that time rice crop is at flowering to grain filling stage and cyclone creates damage and devastation to rice. Storm surge is also greatly responsible for the greatest damage, 90% of the deaths are attributable to the sudden deluge owing to the instantaneous onrush of water and rise in water level with hurricane winds, often covering nearly 25 km inside the coast.

In a cyclonic storm in the open sea, there is a rise in the water level due to the low pressure and this is known by the name 'inverted barometer wave'. Raging winds in the storm whip up mountainous waves over the ocean surface. Waves as high as 20 metres travel long distances affecting i the waters to a depth of nearly 20 metres. Compensating subsurface counter-currents are set up and hence the water does not pile up very high in the open ocean. When the storm approaches the coast, the counter-current gets ratarded, making the water level rise. This rise in level combined with the inverted barometer wave pauses huge piling up of water. This is the 'storm surge’ which hits the coasts as a solid wall of water with the speed of the hurricane winds. This is also known as **'Tidal wave**' and **'Storm wave.**'

The surge height depends on the area of spread if the piled up water. The height is determined by various factors. The shape of the coastline is important. The height gets amplified if:

Water is funnelled into enclosed regions such as Bays and Estuaries, The continental slope is gentle, retarding the counter-current, The angle between the coastline and the right semicircle of the storm track is 90^{O} or less.

The storm surge coincides with the astronomical tide, leading to super-imposition (hence the name tidal wave),

(a) Convergence of wind-driven currents takes place along a line near the coast in shallow waters,

(b) Super-imposition of the short-period waves, breakers or swells takes place.

The inland limit of inundation depends on the topography and the contours. River mouths appear to be the preferred areas of landfall of most cyclones, that too at the high tide epoch. The river mouths are usually flat alluvial plains devoid of trees facilitating rapid and easy inflow of water. The exact time of impact of storm surges is difficult to predict. They are known to occur in advance, during or after the passage of the storm across the coast, depending on the orientation of the coast. Surges can occur with onshore winds even when the storm is passing alongside without actually striking or crossing the coast

Cyclone disaster response mechanism.

The various phases of cyclone disaster response mechanism cover following aspects.

- **Early Warning**

In view of availability of satellite images and remote sensing, cyclone forecasting has become more sophisticated and accurate, but the dissemination of warning percolates down on the low levels rather late, mainly due to inadequate communication network and difficulty in reaching the inaccessible villages.

- **Evacuation**

Forecasting plays a crucial role in facilitating evacuation. Though it is regarded as a costly and difficult method, more often it becomes inevitable. Refusal of people to leave houses, fields and lack of initiative from officials hampers the evacuation process.
Rescue and Relief: This ‘sandwich’ phase usually lasts for 204 weeks, and involves the services of armed forces. Government agencies, NGOs etc. the political and bureaucratic factors influence this phase.

- **Rehabilitation and Development**

Rehabilitation is a long-term slog and it should ideally include restoring life sustenance systems as rebuilding the social fabric of the affected communities. The rehabilitation programme should take care of health, education, special needs of women and children, farmers, agricultural labourers, artisans, marginalized and vulnerable groups. Several factors including the political considerations determine the exgratia payments extended to the affected people.

- **Gender Issues**

By virtue of their lower economic, social and political status and position, women tend to be among the most vulnerable to disasters and as such, need considerate when disbursing relief ignored after the disaster. For house sites for the constructs of houses has invariably been in the name of husband or son. As such women who lose their men in the family or the single women headed households suffer.

- **Health Care**

Health care must take priority over everything else in the aftermath of a "clone, as every aspect of disaster management from food to medication to accommodation is related to health.

Guidelines for management of cyclones

The National Disaster Management Authority (NDMA) which had already prepared and released guidelines for a number of disasters like Earthquake, chemical and industrial disasters etc., released guidelines for management of cyclone in April 2008 aimed at helping various ministries and departments in centre and the state to prepare plans and to minimize loss of life & proper's. NDMA in its guidelines has identified 10 key areas of cyclone management:

- Establishing a state-of-the-art cyclone early warning system involving observations, predictions, warnings and user friendly advisories.

- Commissioning of the 'National Disaster Communication Infrastructure' to provide dedicated and fail-safe communications to the National, State and District Disaster.

- Expanding the warning dissemination outreach by introducing 'Last Mile Connectivity', this will include providing public address system along the entire coast line, using VHP technology. This will be done along with putting in place all other options currently in vogue internationally.

- Implementing the National Cyclone Risk Mitigation Project in all the 13 coastal states and UTs.

- Taking up structural mitigation measures like improving structural lifeline infrastructure; construction of multi-purpose cyclone shelters and cattle mounds, ensuring cyclone resistant design standards in rural and urban housing schemes, building all-weather road links, bridges, culverts and saline embankments etc.

- Management of coastal zones to include mapping and delineation of coastal wetlands, patches of mangroves and shelter belts and identification of potential zones for expanding bio-shield spread based on remote sensing tools.

- Setting up of an exclusive eco-system monitoring network to study the impact of climate change.

- Establishing a comprehensive 'Cyclone Disaster Management Information System' covering all phases of Disaster Management.

- Setting up of a 'National Cyclone Disaster Management Institute' in one of the coastal states to address all issues related to cyclone risks.
- Commissioning of "Aircraft Probing of Cyclone facility" to fill the critical observational data gaps and significantly reduce the margin of error in predicting cyclone track, intensity and landfall.

Conclusion

There has been a paradigm shift in the Government of India's focus from the earlier rescue and relief-centric approach to a holistic approach covering all aspects of cyclone management. However, concerted efforts are required to evolve sound national strategies for the management of cyclones by emphasizing research and development needs in the following aspects. .

- Strengthening of cyclone tracking and monitoring system
- Early warming dissemination
- Storm surge modeling
- Preparation of Disaster Management Plans at different levels
- Conservation and regeneration of mangrove Forests
- Coastal shelterbelt plantation
- Construction of Saline embankments
- Construction of cyclone shelters

- Coastal canal system
- Dredging of river mouths
- Industries in coastal zones
- Use of remote sensing and GIS techniques
- Strengthening of training institutions
- Training of engineers/masons in cyclone resistant construction
- Involvement of prost graduate and research students

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Significance of GIS and remote sensing in cyclone management

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Natural Disasters occur frequently around the world and their incidence and intensity seem to be increasing in recent years. The Disasters such as cyclones and floods often cause significant loss of life, large-scale economic, social impacts and environmental damages. India is one among the disaster prone geographical zones of the world and suffers losses huge money as a result of damages due to different types of disasters annually. Cyclone is a disaster resulting from nature's fury and is beyond human control. It causes damage to agriculture, human lives, livestock, infrastructure and communication facilities. The crucial part here is the information collection, mapping and its dissemination. The real-time operation of satellite remote sensing has demonstrated the translation of information derived from space technology to ground reality. Remote sensing techniques are invaluable for collecting the data rapidly and mapping the affected areas extensively, particularly in developing countries for which conventional resource mapping sources are limited. Mapping the disaster areas would help in the management of rescue and rehabilitation operations. The ancillary information has to be used alongwith remotely sensed data for better assessment. One direct method to estimate the damages is to procure satellite data before, during and after the event and analyze them together for change detection. From the satellite images prior to the cyclone and after cyclone, the situation can be mapped. The satellite images during event reveal the inundation extent. The post-cyclone satellite data shows the residual effects of the damaged area.

Cyclones

Among the coast based natural disasters, storm surges arising during cyclones, abnormal waves during tsunamis are the most prominent ones. The Bay of Bengal being a cyclogenic area, generates cyclones every year. The cyclonic storms, which cross the coastal regions cause sudden abnormal rise of sea water, called surges and this is the primary cause for coastal flooding in the adjoining land. The Bay of Bengal is one of the ocean basins for the transformation of regions of low-pressure in the atmosphere into cyclonic storms. Between the years 1891 and 1977 the Bay of Bengal has generated about 400 cyclonic storms with different degrees of intensity. The effects of these storms are more pronounced in the states located on the East Coast of India, namely West Bengal, Odisha, Andhra Pradesh and Tamil Nadu. Sometimes, the surges along the coast accompanying these storms are abnormally high and form the most destructive component of this coupled ocean-atmosphere phenomenon. A Very Severe Cyclonic Storm (VSCS) PHAILIN originated from a remnant cyclonic circulation from the South China

Sea. The cyclonic circulation lay as a low pressure are over Tenasserim coast on 6th October 2013. It lay over north Andaman Sea as a well-marked low pressure area on 7th October. It concentrated into a depression over the same region on 8thOctober near latitude 12.0^{0}N and longitude 96.0^{0}E. Moving west-northwestwards, it intensified into a deep depression on 9th morning and further into cyclonic storm (CS), 'PHAILIN' in the same day evening. Moving northwestwards, it further intensified into a severe cyclonic storm (SCS) in the morning and into a VSCS in the forenoon of 10th Oct. 2013 over east central Bay of Bengal.

Role of GIS and Remote Sensing in Disaster Management

A Geographic information system (GIS) has a graphic database of geo-referenced information system, which is linked to the descriptive database. It uses high-powered graphic and processing tools that are equipped with procedures and applications for inputting, storing, analyzing and visualizing geo-referenced information. GIS and remote sensing (RS) are very useful and effective tools in disaster management. Various disasters like cyclones, floods, earthquakes, tsunamis and other natural hazards that kill lots of people and destroy property, infrastructures every year. Remotely sensed data can be used very efficiently to assess the severity and impact of damage due to these disasters. In the disaster relief part, GIS, grouped with global positioning system (GPS) is extremely useful in search and rescue operations in areas that have been devastated. Remote sensing is emerging as a popular means of map preparation while GIS can be used for storage, analysis and retrieval. Under remote sensing techniques, maps can be prepared using satellite data or aerial photographs and then digitized and stored on computers using GIS software. GIS and remote sensing technologies have been the object of substantial interest for all countries and bodies concerned with space and in exacting emergency services and disaster management. In disaster management, the objectives of the disaster experts are to monitor the situation, simulate the complicated disaster occurrence as accurately as possible so as to come up with better prediction models, suggest appropriate contingency plans and prepare spatial databases. Remotely sensed data can be used very effectively for quickly assessing severity and impact of damage due to cyclones and other disasters. Disaster maps generally show risk zones as well as disaster impact zones. These are marked areas that would be affected increasingly with the increase in the magnitude of the disaster.

During the disaster prevention stage, GIS is used in managing the huge levels of data required for vulnerability analysis and hazard assessment. It is useful mainly because of its capacity to build models or representations of the real world from information in databases. It is therefore important for aiding hazard prevention and for simulating the damage that would be caused in the event of a natural disaster. GIS can also be used to interpret information by creating thematic maps that show the spatial distribution of the information. These maps show spatial patterns, trends or relationships, making it easier to analyze the information. This is the case in the various successive stages of the process of assessing the damage caused by a disaster. In the disaster preparedness stage, it is a tool for planning evacuation routes, designing emergency operations centres and for the integration of satellite data with other relevant data in the design of disaster warning systems. In the disaster rehabilitation stage, GIS is used to organize the damage information and post-disaster information and in the evaluation of sites for reconstruction. Natural hazard information should be included routinely in developmental planning and investment projects preparation. They should include cost/benefit analysis of investing in hazard mitigation measures and weigh them against the losses that are likely to occur if these measures are not taken. The application of remote sensing and GIS has become a well-developed and successful tool in disaster management. It allows for the combination of the different kinds of spatial data with non-spatial data, attribute data and use them as useful information in the various stages of disaster management.

Disaster mapping

Disaster mapping is a tool for assessing, storing and conveying information on the geographical location and spread of the effects or probable effects of disasters. It is the drawing of areas disturbed through excessive natural or manmade troubles resulting in loss of life, property and national infrastructures. The delineation can occur through the use of ground based observations and also using the remote sensing data. From the information gathered, it is possible to map the affected areas and provide information to the relief supplying groups. The difficulty with traditional manual maps is that they are tedious and time consuming to prepare, difficult to update and inconvenient to maintain.

Cyclone Forecasting - The Early Warning System

Tropical Cyclones are intense low pressure systems which develop over warm sea. They are capable of causing immense damage due to strong winds, heavy rains and storm surges. The frequency of the Tropical Cyclones in the Bay of Bengal is 4 to 5 times more than in the Arabian Sea. Indian Meteorological Department (IMD) is mandated to monitor and give warnings regarding Tropical Cyclone (TC). Data resources are crucial to early forecasting of cyclones. Satellite based observations are being extensively utilized. Satellite integrated automated weather stations have been installed on islands, oilrigs and exposed coastal sites. Buoys for supplementing the surface data network in the tropical ocean have been deployed. The Government has also started a National Data Buoy Programme. A set of 12 moored buoys have been deployed in the northern Indian Ocean to provide meteorological and oceanographic data. Dynamic forecasting of TCs requires knowledge of the vertical structure of both the Cyclone and the surrounding environment.

The goal of any warning system is to maximize the number of people who take appropriate and timely action for the safety of life and property. All warning systems start with detection of the event and with people getting out of harm's way. Such warning systems encompass three equally important elements namely; Detection & Warning; Communication and Response.

The second stage of "Cyclone Alert" is sounded 48 hours in advance of the expected commencement of adverse weather over the coastal areas. Forecasts of commencement of strong winds, heavy precipitation along the coast in association with arrival of cyclone are issued at the alert stage. Landfall point is usually not identified at this stage.

The third stage warning known as "Cyclone Warning" is issued 24 hours in advance. Landfall point is forecast in this stage of cyclone warning. In addition to the forecasts for heavy rains and strong winds, the storm surge forecast is also issued. Since the storm surge is the biggest killer so far as the devastating attributes of a storm are concerned, information in this regard is most critical for taking follow up action for evacuation from the low lying areas likely to be affected by the storm.

Search and rescue operation

Search, rescue and evacuation procedures are carried out immediately after disaster strikes a certain area. These are major operations, usually performed by local volunteers, voluntary organizations and district and state agencies. The basic aim of all such operations is to ensure the survival of the maximum possible number of victims. A plan is worked out with the help of local people through aerial surveys and appropriate steps are then taken by the various teams involved to carry out the operations. Besides bringing material relief, the aim is also to control panic and confusion and to provide moral support.

Assessment of Cyclone Damage (immediately during Cyclone)

During cyclone, Remote sensing data provide timely and detailed information that are required by the authorities to locate and identify the affected areas and to implement corresponding damage mitigation. It is essential that information be accurate and timely, in order to address emergency situations i.e. dealing with diversion of inundated water, evacuation, rescue, resettlement, water pollution, health hazards and handling the interruption of utilities etc. Some important spatial outputs produced and analyzed in real time. The disaster extent maps, real time monitoring by remote sensing data and of damage to buildings and infrastructure maps were prepared. Moreover, meteorological reports based on real-time remote sensing data are required to show intensity/estimates, movement and expected duration of rainfall for the next 3 hours.

Relief (after the Cyclone)

In this stage, re-building of destroyed/damaged facilities and adjustments of the existing infrastructure will occur. The time factor is not as critical as in the last stage. Nevertheless, both medium and high-resolution remote sensing images, together with an operational geographic information system, can help to plan many tasks. The medium resolution data can establish the extent of the damages where as high-resolution data are suitable for pinpointing locations and the degree of damages. They can also be used as reference maps to rebuild bridges, washed-out roads, homes and other facilities.

Conclusion

Disaster Management has to be a multidisciplinary and proactive approach. Besides various measures for putting in place institutional and policy framework, disaster prevention, mitigation and preparedness enunciated and initiatives being taken by the Central and State Governments and other organizations and media also have a key role to play in achieving our goal of moving together, towards a safer country. Remote sensing data and techniques alongwith GIS have proven their usefulness in disaster management plan especially in mapping the new situation after the disaster which help in updating the geographical database. This can be used for the reconstruction of the damaged area. GIS helped to interpret information by creating satellite based thematic maps that show the spatial dimension of the affected areas. It has become easier to carry out the disaster management operations efficiently. Studies have helped in making it possible to forecast and simulate disaster occurrences with regard to specific locations - helping in the initial stages of search and rescue operations. Techniques like satellite imagery and GIS help to identify areas that are disaster prone, zoning them according to risk magnitudes, inventory populations and assets at risk, and simulating damage scenarios. These tools are even useful in managing disasters as they provide instant access to information required in management decisions. Modern communication systems have also proved very useful, particularly in search and rescue operations. They not only help in providing warnings before the disaster, but also help in creating awareness which helps in reducing panic, confusion and mental stress. A communication network system helps in establishing contacts between relief teams which, with better central coordination, can work more efficiently.

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Soil management intervention in cyclone affected coastal areas

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Saline soils in coastal areas occur in river deltas and in narrow strips of land ranging from a few kilometers to about 50 km close to the sea coast along the low lying lands, estuaries and inland depressions (Yadav, 1979). The coastal saline soil has been used by various workers almost synonymously with coastal soil per se which is not correct since all coastal soils are not saline in nature. Velayutham *et al*. (1999) revealed that saline soil resources and their potentials for different Agro-ecological Sub Regions (AESR) of India. It shows total 10.78 million hectare area under this ecosystem (including the islands) in India, which was the first scientific approach for delineation of the coastal soils.

General characteristics of coastal saline soils

In coastal saline soil, the salinity status widely fluctuates from ECe 0.5 dS m^{-1} in monsoon to 50 dS m^{-1} in summer/ dry month. Mostly NaCl followed by Na_2SO_4 are the dominant soluble salts, with abundance of soluble cations in the order of Na>Mg>Ca>K. Chloride is the predominant anion, and bicarbonate is found in traces. In India, the soils are, in general, free of sodicity except in a few pockets in the South and West coast. Saline soil can be classified as the soils having pH less than 8.5, ESP less than 15, and preponderance of chlorides and sulfates of sodium, calcium and magnesium.
Bandyopadhyay et al. (1987) observed that coastal saline soils are characterized by clay loam with varied presence of silt and sand. The electrical conductivity ranges from 0.5 to 9.2 dS m^{-1} with sodium as dominating castion in the salts. Biswas et al. (1990) observed that coastal saline soils generally have highly saline shallow underground water table with gradual upward movement of saline water during summer months and subsequent evaporation of the water that contributes to soil salinity during dry periods. Salinity is one of the major obstacles to crop yield in deltas, estuaries and coastal fringes in the humid tropics. It is a serious impediment to growth of irrigated rice (Ponnamperuma, 1972). The salinity of the soil varies with the season. It reaches the maximum between January and May and decreases thereafter with the onset of monsoon (Bandyopadhyay and Bandyopadhyay, 1984). This cyclic salt accumulation and intermittent flood make these regions predominant in rice cultivation.

A. Salinity build – up

The main obstacle to intensification of crop production in the coastal areas is seasonally high content of salts in the root zone of the soil. The salts enter inland through rivers and channels, especially during the later part of the dry (winter) season, when the downstream flow of fresh water becomes very low. During this period, the salinity of the river water increases. The salts enter the soil by flooding with saline river water or by seepage from the rivers, and the salts become concentrated at the surface through evaporation. The saline river water may also cause an increase in salinity of the ground water and make it unsuitable for irrigation. Agarwal (1983) observed that in coastal saline soils, the problem is further complicated by inundation through backwash from sea, tidal waters, wind borne salts and underground intrusion of sea water in sub soils.

B. Productivity constraints

Coastal soils in a number of situations are constrained by various factors limiting agricultural productivity, which are: (i) Excess accumulation of soluble salts and alkalinity in soil, (ii) Pre-dominance of acid sulphate soils, (iii) Toxicity and deficiency of nutrients in soils,(iv) Intrusion of seawater into underground aquifers, (v) Shallow depth to underground water table rich in salts, (vi) Periodic inundation of soil surface by the tidal water vis-à-vis climatic disaster and their influence on soil properties, (vii) Fine soil texture and poor infiltrability of soil in many areas, (viii) Eutrophication, hypoxia and nutrient imbalance, (ix) Erosion and sedimentation of soil, and (x) High population density.

Nutrient availability and management in cyclone affected coastal areas

A. Nitrogen

Most of the coastal saline soils are deficient in nitrogen. Besides lesser utilization of nitrogeneous fertilizers, especially in coastal areas, the mineralization of soil organic nitrogen, and thus the release of native soil nitrogen to the plant available form, is also slowed down in the salt-affected soils due to decrease in the population as well as activity of microbes with increase in soil salinity. It was revealed from a study at CSSRI, Regional Station Canning that the rates of both mineralization and immobilization of nitrogen in soil were considerably reduced at soil salinity of ECe 10 dSm^{-1} and above. Under salt-stress conditions, the uptake of N by crop plants is generally affected (Alam, 1999). A substantial number of laboratory and greenhouse studies have shown that salinity reduces N nutrition in plants. It has been reported that an increase in Cl^- uptake and accumulation is accompanied by a decrease in shoot nitrate concentration. In their experiment, Aslam et al. (1984) have reported that Cl^- inhibited NO_3^- uptake more than SO_4^{2-} when these anions were present on an equal molarity basis. In contrast to the effect of Cl^- on NO_3^- uptake, reported data indicated that increased NO_3^- in the substrate decreased Cl^- uptake and accumulation. The possible decrease in N uptake by increasing salinity has been partly attributed to a probable substitution of Cl^- for NO_3^-. Both the chloride salts of Na and K inhibited the nitrate uptake similarly, suggesting that the process was more sensitive to anionic salinity than to cationic salinity (Aslam et al.,1984). Although, Cl^- salts were primarily responsible for reduced NO_3^- uptake by plants, NO_3^- reduction in plants was not affected by salinity in studies with barley (Aslam et al.,1984). Salinity also stimulated nitrate reductase activity in peanut plants but decreased the nitrate reductase activity in tomato and cucumber (Cucumis sativus L.) plants. Reduction in NRA may be due to inhibition of NO3-uptake by Cl^- in plant species (Abdul-Kadir and Paulsen, 1982).

In the coastal areas, the excess rainfall during monsoon cause flooding and deep water submergence leading to enormous nutrient losses and low crop yields (Yadav, 1996). Rice is grown as a major crop in most of the coastal areas during the North East monsoon season. The increasing loss of nitrogen through NH_3 volatilization from applied nitrogeneous fertilizer with increase in soil salinity was studied under field condition at Canning in West Bengal. While comparing among different sources at two soil salinity levels, viz. ECe 3-4 and 7-8 dSm^{-1}, the loss was found to be maximum under ammonium sulphate, followed by prilled urea, and minimum under placement of urea (in paper packet) at 5 cm depth, whereas the conventional slow-release sources as lac-coated urea, sulphur-coated urea, and placement of urea briquette occupied the intermediate positions. Reduction in loss when compared with prilled urea broadcast under cropped condition was maximum (73.1%) for placement of urea.

B. Phosphorus

Phosphorus, which plays crucial role in the energy metabolism of cells, is involved in a number of anabolic and catabolic pathways (Alam, 1999). A recent study indicates that salinity may increase the P requirement of certain plants. Awad et al. (1990) found that when NaCl increased in the substrate from 10 to 50 or 100 mM, the P content in the tomato leaf increased from 58 to 70 and 97 mmol kg^{-1} of dry weight. The influence of salinity on P accumulation in crop plants is variable and depends on the plant and experimental conditions. In many cases, salinity decreased the P concentration in plant tissue (Sharpley et al., 1992). It is unlikely that Cl and H_2PO_4 ions are competitive in terms of plant uptake. However, it has also been observed that Cl may have a suppressing effect on P uptake in tomato shoots (Papadopoulos and Rendig, 1983). The presence of Cl as well as SO_4 reduced P uptake in barley and sunflower plants. In other cases, a reduction in plant P concentration by salinity may result from the reduced activity of P in the soil solution due to the high ionic strength of the growth media (Awad et al.,1990). Phosphate solubility and its availability are reduced in saline soils not only because of ionic strength effects that reduce the activity of phosphate but also the P concentration in soil solution is tightly controlled by sorption processes and by the low solubility of Ca-P minerals. It is, therefore, understandable that P concentrations in field-grown agronomic crops decreased as salinity increased in the media. When plants are P-deficient, they may be more sensitive to salinity (Sharpley et al., 1992).

Gibson (1988) observed that adequate phosphorus nutrition was essential for effective ion compartmentation by contributing to efficient carbohydrate utilization in salt-stressed wheat. The level of phosphorus in the coastal saline soils is highly variable, and depends largely on the nature and degree of salinity. The availability of soil phosphorus largely depends on the pH of the soil developed after hydrolysis of salt. An increase in soil pH on hydrolysis reduces the availability of soil phosphorus. Very little work has been done on the transformation and availability of P to crops in coastal saline soils.

C. Potassium

The availability of potassium depends largely on the parent material, clay minerals and weathering conditions. It also depends on the nature and amount of salts in the soil. It was reported from CSSRI, Regional Station Canning that the coastal saline soils are rich in water soluble, exchangeable, non-exchangeable and available K. Thus, with regard to soil fertility, the coastal soils are usually rich in available K and micronutrients (except Zn), low to medium in available N, and are variable in available P status (Bandyopadhyay et al., 1985, Bandyopadhyay, 1990, Maji and Bandyopadhyay, 1991). Major portion of the applied N fertilizer is lost through volatilization (Sen and Bandyopadhyay, 1987).

The higher K/Na ratio in shoots of barley cultivars compared with that in root medium solution indicated selective uptake of K, which seems to be among the processes involved in tolerance of cultivars to salinity stress (Alam, 1999, Niazi et al., 1992). Addition of K suppressed the uptake of other cations by rice and tomato plants in the order of Na>Mg>Ca. The depression of K uptake by Na could be due to the antagonism between the two cations. It is widely recognized that a high Na concentration inhibits K uptake by plants. On the other hand, Na appeared to stimulate the K uptake by plants. Salinity stress has significant inhibitory effects on the concentrations of K, Ca, and Mg as well as stimulatory effects of these nutrient elements on different crop plants (Alam, 1999). With the increasing concentration of NaCl salts, K concentration decreased in the leaves, stems and roots, and was accompanied by a substantial increase of Na in the organs.

In lowland rice, plants adapt to saline conditions and avoid dehydration by reducing the osmotic potential of plant cells. Antagonistic effects on nutrient uptake may occur, causing deficiencies, particularly of K and Ca under conditions of excessive Na content. For example, Na is antagonistic to K uptake in sodic soils with moderate to high available K, resulting in high Na:K ratio in the rice plant and reduced K transport rates. Sodium-induced inhibition of Ca uptake and transport limits shoot growth. Increasing salinity inhibits nitrate reductase activity, decreases chlorophyll content and photosynthetic rate, and increases the respiration rate and N content in the plant. Plant K and Ca contents decrease but the concentrations of NO_3^- –N, Na, S, and Cl in shoot tissue increase.

D. Secondary nutrients

Calcium plays a vital nutritional and physiological role in plant metabolism. Calcium, which like K also is an essential mineral nutrient, helps in maintaining membrane integrity, is important in senescence processes, and is known to counteract the harmful effects of Na on crops (Lahaye and Epstein, 1971). Plant growth is dependent on Ca^{2+}, and both cell division and cell elongation processes are affected by the Ca^{2+} ion concentration.

The presence of Ca^{2+} as the dominant cation in agricultural soils generally ensures that the absolute Ca^{2+} level is not a primary growth-limiting factor. As salinity increases, the requirement of plants for Ca^{2+} increases. The uptake of Ca^{2+} from the soil solution may decrease because of ion interactions, precipitation, and increases in ionic strength that reduce the activity of Ca^{2+}. In citrus, Ca was found to be effective in reducing the transport of both Na and Cl from the roots to leaves. Maintaining an adequate supply of Ca^{2+} in the soil solution is an important factor in controlling the severity of specific ion toxicities.

The magnesium content of the leaves of saline-treated bean plants increased, whereas it decreased in the root. Hodson et al. (1982) found potentially toxic concentrations of Mg in salt-marsh soil solution samples and demonstrated that a salt-marsh clone, *Agrostis stolonifera,* was considerably more tolerant to Mg^{2+} than was an inland clone. Magnesium concentration of avocado leaves was decreased with an increase in the exchangeable Na in the soil. In rice, Mg transport to the tops was suppressed by Na compared with Mg uptake (Song and Fujiwara, 1996). The Mg content in the roots revealed the competition between Mg and Na uptake and transport to the tops (Alam, 1999, Alfocea et al., 1993).

E. Micronutrients

The concentrations of micronutrients in the soil solutions, with the exception of Cl, seem to be low and depend on the physical and chemical characteristics of the soil bodies. The availability of most micronutrients depends on the pH of the soil solution as well as the nature of binding sites on organic and inorganic particle surfaces. In saline soils, the solubility of micronutrients such as Fe, Mn, Zn and Cl is particularly low and plants grown in these soils often experience deficiencies in these elements (Alam, 1999, Page et al., 1990). Nevertheless, the micronutrient concentration in plant shoots may increase, decrease, or have no effect depending on the type of plant tissue, salt tolerance of plant species, salinity, micronutrient concentration, environmental conditions, and/ or abrupt changes in the permeability of the crop cell membranes.

Work done so far on the role of micronutrients in coastal saline soils is meagre. The soils are generally rich in micronutrients, such as Fe, Mn, Zn, Cu, B and Mo. In the coastal sands of Andhra Pradesh in India the soils are deficient in Zn as well as in N, P and K. Iron chlorosis is common to crops like sugarcane (Saccharum officinarum L), jowar (Sorghum bicolor L. Moench), rainfed rice (Oryza sativa L.), etc. In Andhra Pradesh salinity accentuated the zinc deficiency. In coastal saline soils, it was found that the amount of Zn available to the plants decreased with submergence (Maji and Bandyopadhyay, 1990). High amount of $CaCO_3$ (up to 15%) is congenial to Zn and Fe deficiency disorders. High dose of Zn application is recommended in rice as foliar spray. Zn deficiency was noted from various laterite and lateritic soils in other coastal states in India. Besides, Al and Fe toxicities too have been reported from a few acid lateritic soils along the coast. Both Fe and Mn contents were reported to increase in all parts of the salt-treated peanut plants (Chavan and Karadge, 1980). The increase in Fe contents was more prominent than that of Mn. Salinity increased the Fe concentration in the shoots of pea and rice and decreased its concentration in the shoots of barley and corn (Hassan et al., 1970).

Alleviation of nutrient deficiency in cyclone affected coastal areas

Additions of N and P generally increase the growth of plants grown in N- and P-deficient environments, provided that the plant is not experiencing severe salt stress. When both salinity and nutrient deficiency are responsible for limiting growth, relief of the most limiting factor will promote growth more than the relief of the less limiting factor. Therefore, addition of a limiting nutrient can either increase, decrease, or have no effect on relative plant tolerance to salinity, depending on the level of salt stress. Failure to account for the severity of salt stress when interpreting salinity and nutrient interactions has caused considerable confusion among researchers in the past.

Saline soils can successfully be cultivated by removing excessive soluble salts through reclamation techniques. Reclamation of saline soils depends on the local conditions, available resources and the kind of crops that can be grown during reclamation. Reclamation can be accomplished in the long run by continued irrigation and cropping, inclusion of rice in cropping system together with incorporation of large quantities of organic manure (Gupta and Abrol, 1990). Reclamation of saline soils is by reducing the soil salinity to acceptable levels. In saline soils, maintenance of crop productivity at optimum level requires consideration of salt distribution within root zones that is influenced by the water extraction pattern of the crop, the method of water application, soil profile modifications, mulching, rain water leaching and adoption of an appropriate crop rotation involving salt tolerant cultivars (U.S. Salinity Laboratory, 1954).

Long term field experiment in coastal saline soils in India showed that rice and wheat yield could be maintained with 50% NPK used in conjunction with FYM or green manure (DARE, 2003-04). In another detailed long term experiment conducted (CSSRI, 1990) in Sundarbans (India) it was observed that grain yield of crops in a rice-barley rotation increased significantly only due to the application of N. Application of P did not show any significant increase in the yield of crops in the initial 8 years, after which the yield of barley alone increased due to P application. Available K content was high in the soil. The experiments conducted so far showed that a basal dose of 11 kg P ha^{-1} for rice and 5.5 kg P ha^{-1} for barley or for similar upland crops should maintain the fertility status of the soil, whereas the K application may be omitted without any detrimental effect on soil fertility or crop growth. The K removal by the crop was compensated by K added through accumulation and release of non-exchangeable sources. In Sri Lanka addition of Gliricidia muculata in combination with phosphate and a small dose of inorganic fertilizer was effective to secure high rice yields (Deturckl et al., http://www2.alterra.wur.nl/Internet/webdocs/ilri-publicaties/publicaties/Pub53/pub53-h8.pdf). In India, for the coastal acid sulphate soils of Sundarbans, application of lime, superphosphate and rock phosphate have been found beneficial in improving the soil properties and rice growth (Bandyopadhyay, 1989). Application of Ca-rich oystershell, which is available in plenty, was found beneficial, if applied in powdered form, as an inexpensive alternative soil ameliorating agent. In this soil continuous submergence for one year could not improve the soil properties substantially. Effect of salinity on the microbial and biochemical parameters of the salt-affected soils in Sundarbans (India) was studied at nine different sites. The study revealed that the average microbial biomass C (MBC), average basal soil respiration (BSR), and average fluorescein diacetate hydrolyzing activity (FDHA) were lowest during the summer season, indicating the adverse effect of soil salinity (Tripathi et al., 2006). It was suggested that integrated nutrient management should be very effective for increasing its use efficiency for higher and sustainable yield of crops (Bandyopadhyay et al., 2006, Tripathi et al., 2007). Bandyopadhyay and Rao (2001) were of the opinion to introduce systems approach involving organic, inorganic and biofertlizers compatible with the farmers' practice. In coastal soil at Tamil Nadu (India), application of agro-industrial wastes significantly improved soil organic carbon, pH, EC and soil bacteria, fungus and actinomycetes population and enhanced the soil fertility status (macro and micro nutrients) and improved the crop productivity of finger millet. Application of pressmud @12.5 t ha^{-1} recorded better growth and yield of finger millet followed by composted coirpith @ 12.5 t ha^{-1} (Rangaraj et al., 2007).

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Role of Disaster Management Acts and Policies in Cyclone Mitigation Planning in India

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The agriculture sector in India faces severe challenges in the form of natural disasters causing heavy crop loss and poor crop productivity. Several times, these disasters create more havoc as they result in another unfavorable event. For example, cyclone disaster always accompanies with major storms, floods and heavy wind and it is very common to witness significant caused by associated events in addition to the main event itself. Tropical cyclogenesis is very common in the northern reaches of the Indian Ocean in and around the Bay of Bengal which result in cyclones. The frequency of occurrence of cyclone is a major worry in India. In India, the cyclone season runs from April to December, with peak activity between May and November. Low intensity storms with sustained wind speeds greater than 63 km per hour are very frequent and it is observed that a major cyclone (Category 3 or higher) develops every alternate year.

The main cause of the cyclone event in India is intense heating in the Bay of Bengal during summer resulting in humid and unstable air masses. As a result, India witnessed significant number of cyclones including worst ever cyclones like the 1737 Calcutta cyclone, the 1970 Bhola cyclone, the 1991 Bangladesh cyclone and the 1999 Odisha super cyclone. This resulted in severe crop loss affecting food security of the nation. The major states that get affected due to cyclone are Andhra Pradesh, Odisha, Tamil Nadu, and West Bengal located on eastern coast. In western coast, the frequency and extent of damage by cyclones is relatively less and they mainly affect Gujarat and Kerala. Some cyclone events like super cyclone in Odisha (1999) resulted in peak winds of more than 250 kmph (equivalent to category 5 hurricane) causing damage to lakhs of hectares of agricultural land in addition to disruption of 20 million people and death of more than 10000 people.

The natural disasters like cyclone can be predicted before their occurrence though the accuracy varies from event to event. At the same time, we also understand the fact that cyclone affects some coastal states very frequently. This calls for an urgent need to chalk out a strategy to face the cyclone events in an integrated manner. A good forecasting and well prepared multipronged strategy can result in reduction of disruption of human life and it can potentially reduce the damage to agricultural sector (Roy and Kovordanyi, 2012). This can be very much witnessed from the experience of successful management of phailin in 2013. In other words, the balanced combination of science (prediction of cyclone and forecasting) and policy (development of different acts related to pre and post cyclone management) is required for reducing the damage of cyclone on agriculture sector. The role of resilience building among the communities in management of super cyclone affected areas in Odisha is well acknowledged now (Chhotray and Few, 2012).At the same time, we have developed regulations and acts on disaster management in common which includes floods, cyclones, drought, earthquakes etc. and it is really difficult to study them in segregation with respect to individual event like cyclone.

In this context, various stakeholders working in the field of cyclone disaster management must have awareness about various disaster management acts enacted in India.

Disaster Management Act, 2005

The Disaster Management Act, 2005 has 11 chapters and 79 sections and it extends to the whole of India. The Act provides for "the effective management of disasters and for matters connected therewith or incidental thereto. The Act lays down institutional, legal, financial and coordination mechanisms at the National, State, District and Local levels. These institutions are not parallel structures and will work in close harmony. The new institutional framework is expected to usher in a paradigm shift in DM from relief-centric approach to a proactive regime that lays greater emphasis on preparedness, prevention and mitigation.

Institutional Framework under the Act

National Disaster Management Authority (NDMA)

The NDMA, is the apex body for disaster management, headed by the Prime Minister and has the responsibility for laying down policies, plans and guidelines for DM and coordinating their enforcement and implementation for ensuring timely and effective response to disasters. The guidelines will assist the Central Ministries, Departments and States to formulate their respective DM plans. It will approve the National Disaster Management Plans and DM plans of the Central Ministries/Departments. It will take such other measures, as it may consider necessary, for the prevention of disasters, or mitigation, or preparedness and capacity building, for dealing with a threatening disaster situation or disaster. Central Ministries/Departments and State Governments will extend necessary cooperation and assistance to NDMA for carrying out its mandate. It will oversee the provision and application of funds for mitigation and preparedness measures. NDMA has the power to authorize the Departments or authorities concerned, to make emergency procurement of provisions or materials for rescue and relief in a threatening disaster situation or disaster. The general superintendence, direction and control of the National Disaster Response Force (NDRF) is vested in and will be exercised by the NDMA. The National Institute of Disaster Management (NIDM) works within the framework of broad policies and guidelines laid down by the NDMA.

The NDMA is mandated to deal with all types of disasters; natural or man-made. Whereas, such other emergencies including those requiring close involvement of the security forces and/or intelligence agencies such as terrorism (counter-insurgency), law and order situations, serial bomb blasts, hijacking, air accidents, CBRN weapon systems, mine disasters, port and harbor emergencies, forest fires, oilfield fires and oilspills will continue to be handled by the extant mechanism i.e., National Crisis Management Committee (NCMC).

NDMA may, however, formulate guidelines and facilitate training and preparedness activities in respect of CBRN emergencies. Cross-cutting themes like medical preparedness, psycho-social care and trauma, community based disaster preparedness, information and communication technology, training, preparedness, awareness generation etc., for natural and man-made disasters will also engage the attention of NDMA in partnership with the stakeholders concerned. Resources available with the disaster management authorities at all levels, which are capable of discharging emergency support functions, will be made available to the nodal Ministries/Agencies dealing with the emergencies at times of impending disaster(s).

National Executive Committee (NEC)

The NEC comprises the Union Home Secretary as Chairperson, and the Secretaries to the GoI in the Ministries/Departments of Agriculture, Atomic Energy, Defence, Drinking Water Supply, Environment and Forests, Finance (Expenditure),Health, Power, Rural Development, Science &Technology, Space, Telecommunications, Urban Development, Water Resources and the Chief of the Integrated Defence Staff of the Chiefs of Staff Committee as members. Secretaries in the Ministry of External Affairs, Earth Sciences, Human Resource Development, Mines, Shipping, Road Transport & Highways, and the Secretary, NDMA will be special invitees to the meetings of the NEC.

The NEC is the executive committee of the NDMA, and is mandated to assist the NDMA in the discharge of its functions and also ensure compliance of the directions issued by the Central Government. The NEC is to coordinate the response in the event of any threatening disaster situation or disaster. The NEC will prepare the National Plan for Disaster Management based on the National Policy on Disaster Management. The NEC will monitor the implementation of guidelines issued by NDMA. It will also perform such other functions as may be prescribed by the Central Government in consultation with the NDMA. State Disaster Management Authority (SDMA)

At the State level, the SDMA, headed by the Chief Minister, will lay down policies and plans for DM in the State. It will, inter alia approve the State Plan in accordance with the guidelines laid down by the NDMA, coordinate the implementation of the State Plan, recommend provision of funds for mitigation and preparedness measures and review the developmental plans of the different Departments of the State to ensure the integration of prevention, preparedness and mitigation measures.

The State Government shall constitute a State Executive Committee (SEC) to assist the SDMA in the performance of its functions. The SEC will be headed by the Chief Secretary to the State Government and coordinate and monitor the implementation of the National Policy, the National Plan and the State Plan. The SEC will also provide information to the NDMA relating to different aspects of DM.

District Disaster Management Authority (DDMA)

The DDMA will be headed by the District Collector, Deputy Commissioner or District Magistrate as the case may be, with the elected representative of the local authority as the Co-Chairperson. The DDMA will act as the planning, coordinating and implementing body for DM at the District level and take all necessary measures for the purposes of DM in accordance with the guidelines laid down by the NDMA and SDMA. It will, inter alia prepare the District DM plan for the District and monitor the implementation of the National Policy, the State Policy, the National Plan, the State Plan and the District Plan. The DDMA will also ensure that the guidelines for prevention, mitigation, preparedness and response measures laid down by the NDMA and the SDMA are followed by all the Departments of the State Government at the District level and the local authorities in the District.

Local Authorities

For the purpose of this Policy, local authorities would include Panchayati Raj Institutions (PRI), Municipalities, District and Cantonment Boards, and Town Planning Authorities which control and manage civic services. These bodies will ensure capacity building of their officers and employees for managing disasters, carry out relief, rehabilitation and reconstruction activities in the affected areas and will prepare DM Plans in consonance with the guidelines of the NDMA, SDMAs and DDMAs. Specific institutional framework for dealing with disaster management issues in mega cities will be put in place.

National Institute of Disaster Management (NIDM)

The NIDM, in partnership with other research institutions has capacity development as one of its major responsibilities, along with training, research, documentation and development of a national level information base. It will network with other knowledge-based institutions and function within the broad policies and guidelines laid down by the NDMA. It will organize training of trainers, DM officials and other stakeholders. The NIDM will strive to emerge as a 'Centre of Excellence' in the field of Disaster Management.

National Disaster Response Force (NDRF)

For the purpose of specialized response to a threatening disaster situation or disasters/emergencies both natural and man-made such as those of CBRN origin, the Act has mandated the constitution of a National Disaster Response Force (NDRF). The general superintendence, direction and control of this force shall be vested in and exercised by the NDMA and the command and supervision of the Force shall vest in an officer to be appointed by the Central Government as the Director General of Civil Defence and National Disaster Response Force. Presently, the NDRF comprises eight battalions and further expansion may be considered in due course. These battalions will be positioned at different locations as maybe required. NDRF units will maintain close liaison with the designated State Governments and will be available to them in the event of any serious threatening disaster situation. While the handling of natural disasters rests with all the NDRF battalions, four battalions will also be equipped and trained to respond to situations arising out of CBRN emergencies. Training centres will be set up by respective paramilitary forces to train personnel from NDRF battalions of respective Forces and will also meet the training requirements of State/UT Disaster Response Forces. The NDRF units will also impart basic training to all the stakeholders identified by the State Governments in their respective locations. Further, a National Academy will be set up to provide training for trainers in disaster management and to meet related National and International commitments.

Mitigation Reserves

Experience in major disasters in the last decade has clearly established the need for prepositioning of some essential reserves at crucial locations, including some for the high altitude areas. These reserves are intended to augment the resources at the State level. Mitigation reserves will be placed at the disposal of the NDRF for enhancing their emergency response capabilities for assisting the State Governments during a disaster or disaster-like situation.

Existing Institutional Arrangements

Cabinet Committee on Management of Natural Calamities (CCMNC) and the Cabinet Committee on Security (CCS).

CCMNC had been constituted to oversee all aspects relating to the management of natural calamities including assessment of the situation and identification of measures and programmes considered necessary to reduce its impact, monitor and suggest long-term measures for prevention of such calamities, formulate and recommend programmes for public awareness for building up society’s resilience to them. The CCS deals with issues related to defence of the country, law and order and internal security, policy matters concerning foreign affairs that have internal or external security implications, and economic and political issues impinging on National security.

High Level Committee (HLC)

In the case of calamities of severe nature, Inter-Ministerial Central Teams are deputed to the affected States for assessment of damage caused by the calamity and the amount of relief assistance required. The Inter-Ministerial Group (IMG), headed by the Union Home Secretary, scrutinizes the assessment made by the Central Teams and recommends the quantum of assistance to be provided to the States from the National Calamity Contingency Fund (NCCF). However, assessment of damages by IMG in respect of drought, hail storm and pest attack will continue to be headed by the Secretary, Ministry of Agriculture and Cooperation. The HLC comprising the Finance Minister as Chairman and the Home Minister, Agriculture Minister, and Deputy Chairman of the Planning Commission as members approves the Central assistance to be provided to the affected States based on the recommendations of the IMG. The constitution and composition of HLC may vary from time to time. The Vice Chairman, NDMA will be a special invitee to the HLC.

Central Government

In accordance with the provisions of the Act, the Central Government will take all such measures, as it deems necessary or expedient, for the purpose of DM and will coordinate actions of all agencies. The Central Ministries and Departments will take into consideration the recommendations of the State Government Departments while deciding upon the various pre-disaster requirements and for deciding upon the measures for prevention and mitigation of disaster. It will ensure that the Central Ministries and Departments integrate measures for the prevention and mitigation of disasters into their developmental plans and projects, make appropriate allocation of funds for pre-disaster requirements and take necessary measures for preparedness and to effectively respond to any disaster situation or disaster. It will have the power to issue directions to NEC, State Governments/SDMAs, SECs or any of their officers or employees, to facilitate or assist in DM, and these bodies and officials shall be bound to comply with such directions. The Central Government will extend cooperation and assistance to the State Governments as required by them or otherwise deemed appropriate by it. It will take measures for the deployment of the Armed Forces for disaster management. The Central Government will also facilitate coordination with the UN Agencies, International Organisations and Governments of Foreign Countries in the field of disaster management. The Ministry of External Affairs in coordination with the Ministry of Home Affairs (MHA) will facilitate external coordination/cooperation.

Role of Central Ministries and Departments

As disaster management is a multidisciplinary process, all Central Ministries and Departments will have a key role in the field of disaster management. The nodal Ministries and Departments of the GoI (i.e., the Ministries of Agriculture, Atomic Energy, Civil Aviation, Earth Sciences, Environment & Forests, Home Affairs, Health, Mines, Railways, Space, Water Resources etc.) will continue to address specific disasters as assigned to them.

National Crisis Management Committee (NCMC)

The NCMC, comprising high level officials of the GoI headed by the Cabinet Secretary, will continue to deal with major crises which have serious or National ramifications. It will be supported by the Crisis Management Groups (CMG) of the Central nodal Ministries and assisted by NEC as may be necessary. The Secretary, NDMA may be a member of this Committee.

State Governments

The primary responsibility for disaster management rests with the States. The institutional mechanism put in place at the Centre, State and District levels will help the States manage disasters in an effective manner. The Act mandates the State Governments inter alia to take measures for preparation of Disaster Management Plans, integration of measures for prevention of disasters or mitigation into development plans, allocation of funds, establishment of early warning systems, and to assist the Central Government and other agencies in various aspects of Disaster Management.

District Administration

At the District level, DDMAs will act as the District planning, coordinating and implementing body for disaster management and will take all measures for the purposes of disaster management in the District in accordance with the guidelines laid down by NDMA and SDMA.

Management of Disasters Impacting more than one State

At times, the impact of disasters occurring in one State may spread over to the areas of other States. Similarly, preventive measures in respect of certain disasters, such as floods, etc., maybe required to be taken in one State, though the impact of their occurrence may affect another. The administrative hierarchy of the country is organized into National, State and District level administrations. This presents some difficulties in respect of disasters impacting more than one State. Management of such situations calls for a coordinated approach, which can respond to a range of issues quite different from those that normally present themselves, before, during and after the event. NDMA will encourage identification of such situations and promote the establishment of mechanisms on the lines of Mutual Aid Agreement for coordinated strategies for dealing with them by the States, Central Ministries and Departments and other agencies concerned.

Other Institutional arrangements

Armed Forces

Conceptually, the Armed Forces are called upon to assist the civil administration only when the situation is beyond their coping capability. In practice, however, the Armed Forces form an important part of the Government's response capacity and are immediate responders in all serious disaster situations. On account of their vast potential to meet any adverse challenge, speed of operational response and the resources and capabilities at their disposal, the Armed Forces have historically played a major role in emergency support functions. These include communication, search and rescue operations, health and medical facilities, and transportation, especially in the immediate aftermath of a disaster. Airlift, heli-lift and movement of assistance to neighbouring countries primarily fall within the expertise and domain of the Armed Forces. The Armed Forces will participate in imparting training to trainers and DM managers, especially in CBRN aspects, heli-insertion, high-altitude rescue, watermanship and training of paramedics. At the National level, the Chief of the Integrated Defence Staff to the Chairman Chiefs of Staff Committee has already been included in the NEC. Similarly, at the State and District levels, the local representatives of the Armed Forces may be included in their executive committees to ensure closer coordination and cohesion.

Central Paramilitary Forces

The Central Paramilitary Forces (CPMFs), which are also the Armed Forces of the Union, play a key role at the time of immediate response to disasters. Besides contributing to the NDRF, they will develop adequate disaster management capabilities within their own forces and respond to disasters which may occur in the areas where they are posted. The local representatives of the CPMFs may be co-opted/invited in the executive committee at the State level.

State Police Forces and Fire Services

The State Police Forces and the Fire Services are crucial immediate responders to disasters. The Police Forces will be trained and the Fire Services upgraded to acquire multi-hazard rescue capability.

Civil Defence and Home Guards

The mandate of the Civil Defence and the Home Guards will be redefined to assign an effective role in the field of disaster management. They will be deployed for community preparedness and public awareness. A culture of voluntary reporting to duty stations in the event of any disaster will be promoted.

State Disaster Response Force (SDRF)

States will be encouraged to create response capabilities from within their existing resources. To start with, each State may aim at equipping and training one battalion equivalent force. They will also include women members for looking after the needs of women and children. NDRF battalions and their training institutions will assist the States/UTs in this effort. The States/UTs will also be encouraged to include DM training in their respective Police Training Colleges and basic and in-service courses, for gazetted and non-gazetted officers.

Role of National Cadet Corps (NCC), National Service Scheme (NSS) and *Nehru Yuva Kendra Sangathan* (NYKS)

Potential of these youth based organizations will be optimized to support all community based initiatives and DM training would be included in their programmes.

International Cooperation

Disasters do not recognize geographical boundaries. Major disasters may often may often simultaneously affect several countries. It will be the National endeavor to develop close cooperation and coordination with International organizations working in the area of disaster management.

The nature and extent of damage caused by cyclones and their associated floods is well known and at the same time, we also have awareness about most frequent cyclone affected coastal states. This necessitates us to evolve a strategy to face the cyclone events in an effective manner. A well prepared and scientific based multipronged approach is the need of the hour in which the role of various stakeholders working in the line of disaster management play significant role. Hence, the awareness about various acts and policies related to cyclone disaster management in India is highly essential. This will certainly pave the way for developing an integrated cyclone management plan thereby reducing the extent of damage to agriculture sector in India.

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Contingency planning and Crop management interventions for cyclone risk mitigation

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Introduction

Agriculture sector is the backbone of India as it feeds ever growing population and provides employment to about 58% of the population. Several new advanced techniques have been developed to enhance the crop productivity further. However, it is mainly dependent on monsoon and hence faces severe challenge in the form of natural disasters. This trend is clearly visible if we look in to agricultural production in good and bad monsoon years. The natural disasters like floods, drought and cyclone are primarily responsible for crop loss and low crop productivity resulting in poor socio-economic condition of the farmers. Cyclone is one of the natural disasters which occurs very frequently in India (on an average of six per year) and causes severe crop damage. The frequency of severe cyclonic storms is more in months of October, November and May whereas depressions are more common during south west monsoon period (Fig 1). Its frequency in Eastern Coast of India (Bay of Bengal) is about four times higher than that of western coast (Arabian sea). The higher intensity of cyclones occurred in the last four decades is a major worry for agriculture sector (Table 1).

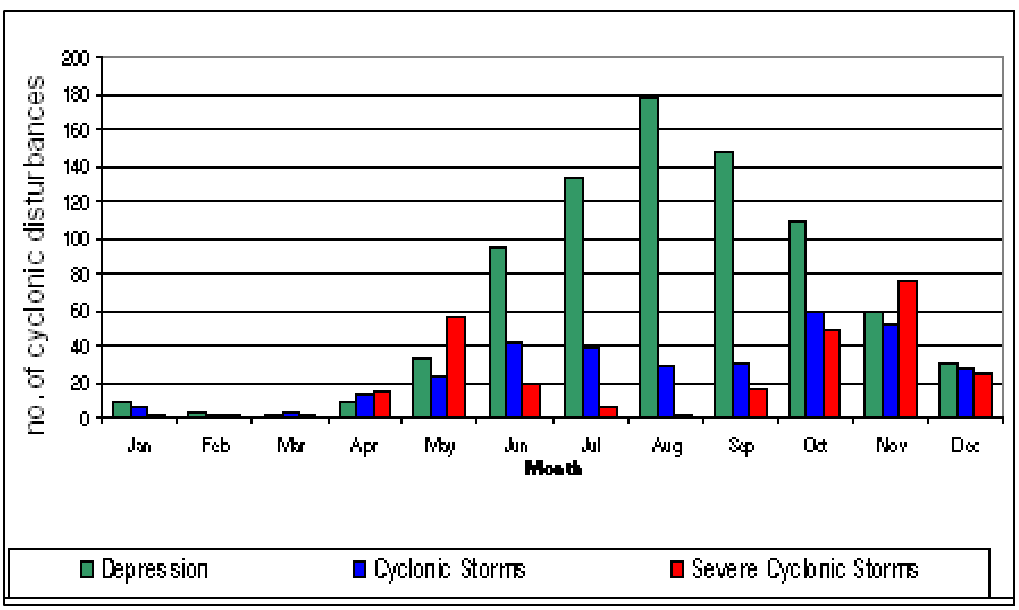

Fig 1: Trend of cyclonic storms in different months in a year

Table 1. The list of very intense Cyclones in the Bay of Bengal since 1970

Place of landfall	Date of landfall	Maximum sustained winds (kmph) - estimated on the basis of satellite imageries
Chittagong	13 November, 1970	224
Chirala, Andhra Pradesh	19 November, 1977	260
Rameshwaram	24 November 1978	204
Sriharikota	14 November, 1984	213
Bangla Desh	30 November, 1988	213
Kavali, Andhra Pradesh	9 November, 1989	235
Machlipatnam, AP	9 May ,1990	235
Chittagong	29 April, 1991	235
Teknaf (Myanmar)	2 May, 1994	204
Teknaf	19 May, 1997	235
Paradip, Orissa	29 October, 1999	260
89.8^0E, Bangladesh	15 November, 2007	220
16.0^0N, Myanmar	02 May, 2008	200

Steps of Cyclone management

The steps for cyclone disaster management includes prevention, mitigation, preparedness, response and rehabilitation (Fig 2). Out of these, preventive measures are important which stress the need for contingency crop planning. Similarly, when the cyclone and its associative flood are already experienced, we need to chalk out the crop management interventions for post cyclone/flood situation.

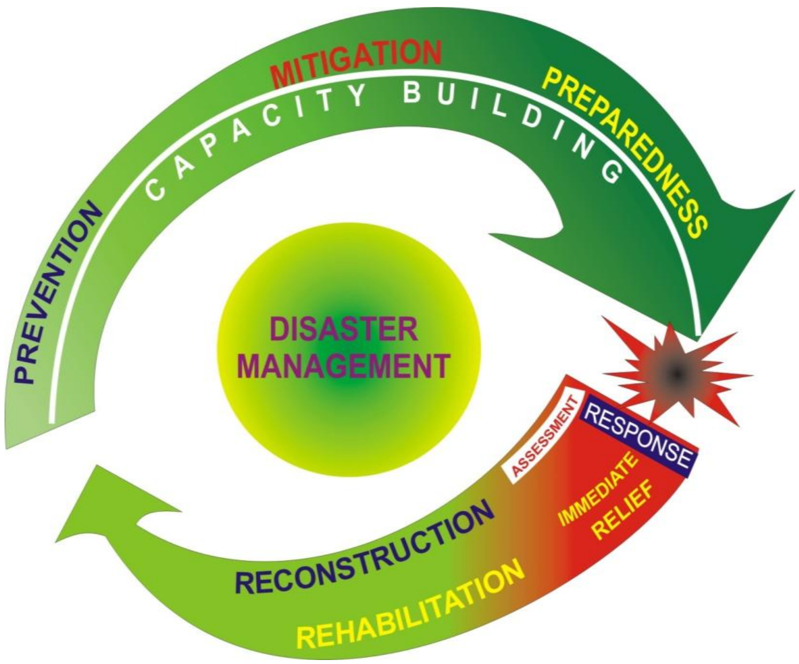

Fig 2 : Different steps of cyclone disaster management

Concept of Contingency crop plan

The changing climate is a major concern for agricultural productivity in general and food security in particular (Brahmanand et al., 2013). This has also resulted in higher frequency of natural disasters like cyclones. Hence, we must be well prepared for sustaining agricultural productivity and this necessitates the concept of contingency crop planning.

Contingency plan can be defined as a plan aimed and executed for an outcome other than in the usual or expected plan. In other words, it is frequently used for risk management when an exceptional risk in future. In general, the change in sowing or planting time of crops, change in seed rate, change in schedule of fertilizer use, use of short duration varieties, improved crop genotypes form the core component of contingency crop planning. In case of cyclone and its associative flood events, we may recommend use of waterlogging tolerant rice varieties such as

Varshadhan, Hanseswari, Durga for better resilience. However, in case of flash floods, the use of swarna sub-1 should form the core component of contingency plan. Similarly, the use of over aged rice seedlings of 45 days and 60 days old are recommended for cyclone and flood prone areas. The development of community nursery and seed bank is critical in supply of seedlings of rice in case of cyclone damage. Atleast seed bank should be developed for 10% of the area under each block which can be utilized for transplanting in post cyclone period.

Crop management interventions for post cyclone / flood situation: Case study

In considerable area in Eastern India, water starts accumulating in the field with onset of monsoon season and water depth rises up to 60 cm or more and continues till maturity of the crop (Jahn *et al.,* 2001 and Biswas *et al.*, 1986). This situation becomes more vulnerable when cyclone and its associated flood occurs. All the engineering and cropping interventions fail in addressing the farming problems during the cyclone/flood season. However, when the flood water recedes gradually, there is an ample scope to implement alternate crop strategies if proper planning is done. Hence, the post cyclone/flood management assumes prime importance for enhancing the crop productivity in India. Eastern India is frequently subjected to cyclone and floods and hence the successful post flood management through contingency crop planning would be of paramount importance in enhancing the crop productivity and thereby ensuring the food security of our nation. Odisha is one of the most important states in Eastern India which is endowed with plenty of natural resources. However, its crop productivity has been found to be quite poor due to waterlogging and cyclone / flood problem. Kendrapada district in Odisha is most susceptible to cyclone associated flood as well as floods due to water inundation from Mahanadi and Paika rivers.

Rice is the major food grain crop grown in Kendrapada district during kharif season and its productivity is very poor due to flood occurrence. The cultivation of flood tolerant long duration rice varieties would certainly boost the crop productivity. However, when flash floods occur, the survival of rice crop becomes difficult leaving the farming community in negative economic situation. After the harvest of rice crop, generally greengram is grown which is harvested in the month of January-February. After the harvest of greengram, the residual moisture left in the soil can be utilized by growing alternate crops that require less amount of water.

Sunflower is an important oilseed crop that is grown under sub tropical climate in wide range of soils. It doesn’t require higher amount of irrigation for its survival and completion of active life cycle. Its water requirement accounts to approximately 500 – 600mm because of which it can be fitted in rice based cropping system in Odisha. The growing demand for the oilseeds in the recent years has brought tremendous scope for the higher profit generation by cultivating sunflower. Sweet potato is an important tuber crop that can be grown well under light texture soils and hence Odisha provides congenial platform for its commercial cultivation. It also requires lesser amount of moisture for its completion of active life cycle and for production of economic yield i.e. tubers. Its water requirement is approximately 400-500mm and hence can be adjusted well under rice based cropping systems in Orissa. Sweet potato can also be grown in marginal lands where people are suffering from malnutrition.

Okra is an important vegetable crop that is suitable for cultivation in summer season. It doesn't require much water and its water requirement is about 600mm and can also be fitted well under rice-pulse-vegetable cropping system in Odisha. Similarly, bittergourd is a cucurbit crop that can be grown in summer season with less water requirement and its potential for getting adjusted under rice based cropping system is enormous.

All these above mentioned crops have to be tested for their resistance to water shortage under post cyclone/flood situation. At the same time provision of conservation agriculture practices might be helpful in successful establishment of crops. The moisture conservation practices like mulching and zero tillage would be instrumental in saving considerable amount of moisture under such situation.

A field experiment was conducted in the farmer's field at Raisar village, kendrapada district, Odisha during post rainy season in 2010 to study and evaluate the impact of zero tillage on crop growth performance, yield attributes and yield of sunflower, sweet potato, okra and bittergourd in post flood situation and to critically analyze the suitable crops under post flood situation along with their associating factors. The experiment was laid out in split plot design with type of tillage as main plot treatments i.e. M1: Conventional tillage and M2: Zero tillage and type of crop as sub plot treatments i.e. C1: Sunflower, C2: Okra, C3: Bittergourd and C4: Sweet potato with three replications. The results revealed that zero tillage influenced the growth parameters and fruit yield of okra, bitter gourd and sunflower positively compared to that of conventional tillage.

Effect on yield attributes

The zero tillage resulted in superior yield attributes of sunflower, bittergourd and okra compared to conventional tillage. In case of sunflower, the head diameter was found to be highest with zero tillage (15.7 cm) compared to conventional tillage (14.8 cm) (Fig 3). The number of seeds per head of sunflower were also found to be highest with zero tillage (236.2) compared to that of conventional tillage (224.5) (Fig 4). In case of okra, the number of fruits were found to be higher with zero tillage (13.2) relative to conventional tillage (11.4) (Fig 5). Similarly, the number of fruits of buttergourd were found to be superior with zero tillage (7.3) compared to conventional tillage (6.8) (Fig 6). However, in case of sweet potato, the reverse trend was observed. The number of tubers per plant in sweet potato were found to be higher with conventional tillage (3.6) compared to that of zero tillage (3.1) (Fig 7).

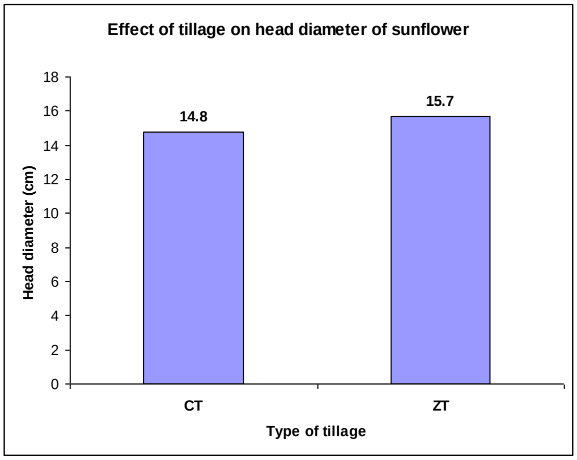

Fig 3 : Effect of tillage on head diameter (cm) of sunflower

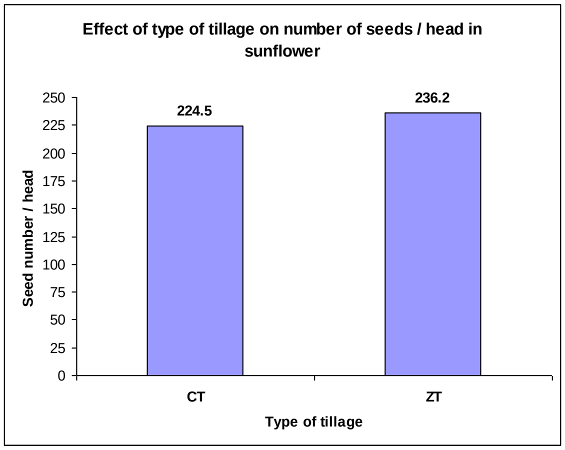

Fig 4: Effect of type of tillage on number of seeds per head in sunflower

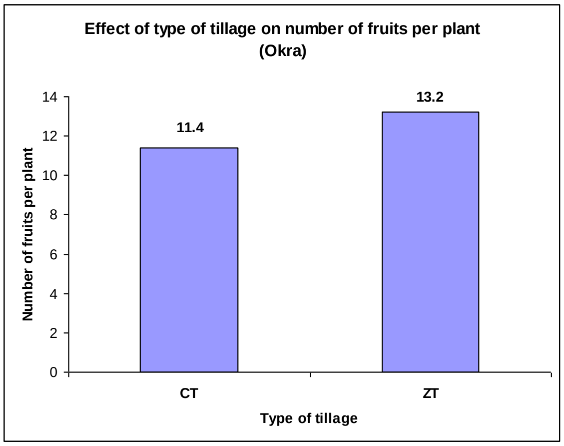

Fig 5 : Effect of type of tillage on number of fruits per plant in Okra

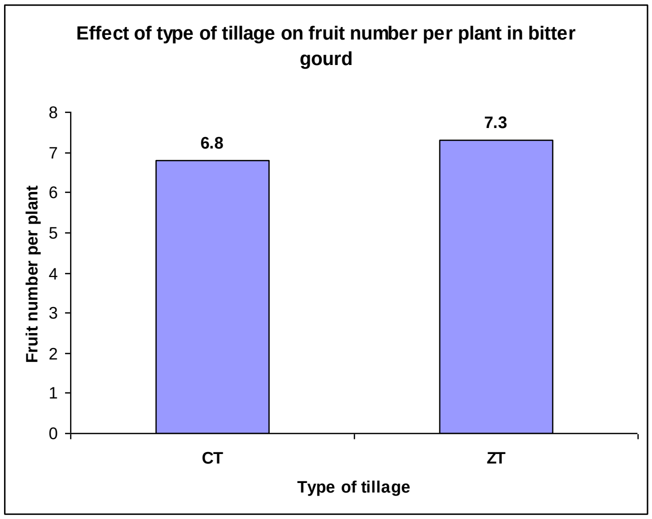

Fig .6 : Effect of type of tillage on fruit number per plant in bittergourd

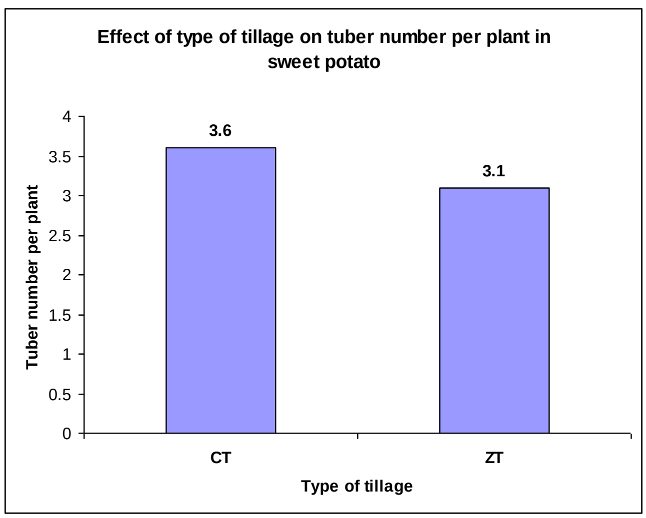

Fig 7 : Effect of type of tillage on tuber number per plant in sweet potato

Effect on Productivity

Conventional tillage resulted in lower crop yield compared to zero tillage in sun flower, okra and bitter gourd. Sun flower resulted in seed yield of 0.91 t/ha under zero tillage compared to 0.82 t/ha under conventional tillage (Table 2). This might be attributed to superior number of seeds per head and larger head diameter under zero tillage. However, the superiority noticed was statistically non significant.

Okra resulted in superior fruit yield of 3.73 t/ha under zero tillage compared to 3.26 t/ha under conventional tillage. Bitter gourd resulted in fruit yield of 4.30 t/ha under zero tillage compared to 4.06 t/ha in conventional tillage. This is due to higher number of fruits per plant and fruit weight under zero tillage. However, the superiority noticed was statistically non significant. Zero tillage resulted in lower tuber yield in sweet potato (5.90 t/ha) compared to conventional tillage (6.63 t/ha). Though the crop establishment was good under zero tillage, the tuber penetration and tuber development was facilitated by better aeration under conventional tillage in case of sweet potato.

Table 2: Productivity of sunflower, okra, bitter gourd and sweet potato (t/ha) as affected by type of tillage

Treatment	Sunflower (Seed yield)	Okra (Fruit yield)	Bitter gourd (Fruit yield)	Sweet potato (Tuber yield)	Mean
Conventional tillage	0.82	3.26	4.06	6.63	3.69
Zero tillage	0.91	3.73	4.30	5.90	3.71
Mean	0.86	3.50	4.18	6.26	
CD (Main)	NS				
CD (Sub)	0.17				
CD (MxS)	0.25				

Case study on impact of phailin

A case study was conducted to assess the impact of phailin on crop situation in Jajpur and Balasore districts of Odisha and farmers were suggested to take up better crop management practices in post cyclone phase. Some farmers responded quickly and implemented the interventions successfully thereby reducing the negative impact on agriculture which is reflected in values of cultivated land utilization index (CLUI).

Impact of crop management interventions on CLUI

The cultivated land utilization index (CLUI) is estimated by summing the products of land area to individual crop component, multiplied by the actual duration of that crop divided by the total cultivated land times 365 days (Chuang, 1973)

$$CLUI = \frac{\sum_{i}^{n} a_i d_i}{A \times 365} \times 100$$

Where, i = 1, 2, 3… n,

n = total number of crops.

ai = area occupied by the ith crop,

di = days that the ith crop occupied and

A = total cultivated land area available for 365 days.

In case of Jajpur district, the CLUI in normal years in the command area studied was found to be 56.5% which has come down to 42.3% in phailin affected year i.e. 2013-14 (Fig 8). However, the CLUI was found to be quite satisfactory (53.9%) even in phailin affected year where the progressive farmers have adopted the advanced crop management interventions. The area under kharif rice was same, however, the jump in area under other crops like groundnut, mustard, vegetables and yam resulted in satisfactory CLUI in progressive village. This is very important finding for formulating the cyclone mitigation and adaptation strategies in the back drop of climate change in future.

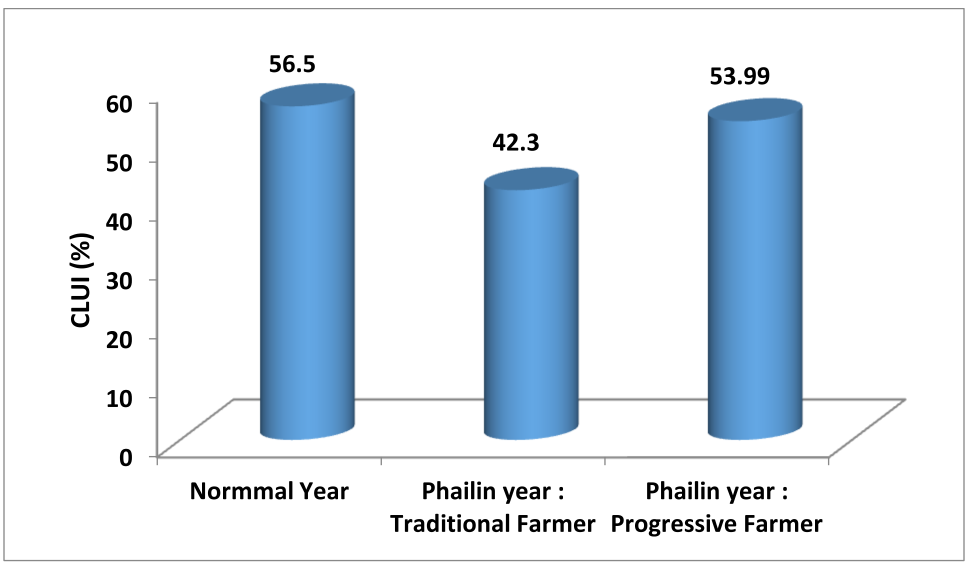

Fig 8: Impact of crop management interventions on cultivated land utilization index (CLUI) due to Phailin in Jajpur district, Odisha.

In case of Balasore district, the CLUI in normal years in the command area studied was found to be 54.1% which has come down to 43.2% in phailin affected year i.e. 2013-14 (Fig 9). However, the negative impact on CLUI was found to be reduced (46.9%) even in phailin affected year where the progressive farmers have adopted the advanced crop management interventions including crop diversification. The area under kharif rice, banana and other vegetables was found to be same, however, the increase in area under crops like groundnut, mustard, chilli, radish, brinjal, cabbage and other vegetables resulted in satisfactory CLUI in progressive village. There is ample scope to improve CLUI from the present level in this village as plenty of ground water is available. Hence, ground water exploitation in cyclone affected areas would provide a better adaptation strategy in the back drop of climate change in future.

In post cyclone affected period, the intercropping of Groundnut + Mustard would be best practice in terms of utilization of available soil moisture and crop yield and economics. The advancement of sowing time by 10 days from 3rd week of November to 1st week of November in green gram is recommended to enhance the pod yield up to 16% under post Phailin cultivation scenario.

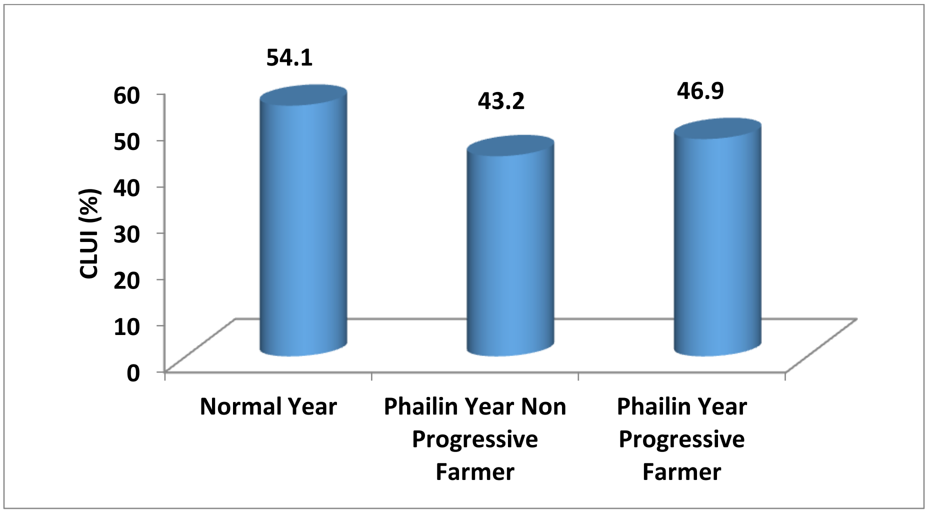

Fig 9: Impact of crop management interventions on cultivated land utilization index (CLUI) due to Phailin in Balasore district, Odisha.

Conclusion

Contingency crop planning would certainly result in reducing the crop loss and productivity in the event of cyclone / flood and it forms the core component of prevention strategy. However, in case of post cyclonic phase, advanced crop management interventions and moisture conservation techniques should form the main component and they should be adopted by the farmers on large scale to sustain the cultivated land utilization index.

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Tropical Cyclone and Crop Management Strategies

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Tropical Cyclone

A tropical cyclone is a rapidly rotating storm system with a low-pressure center, strong winds, and a spiral arrangement of thunderstorms that produce heavy rain. The term "tropical" refers to its origin over tropical seas. The term "cyclone" refers to their cyclonic nature, with wind blowing counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. Warm tropical oceans lead to high evaporation, high humidity and relatively light winds. If these conditions persist long enough, they can combine to produce the violent winds, high waves, torrential rains, and floods. Cyclones typically weaken rapidly over land where they are cut off from their primary energy source. Also, the energy gets weakened after collision with vegetation and infrastructures on land mass. For this reason, coastal regions are particularly vulnerable to damage from a tropical cyclone as compared to inland regions. Heavy rains, however, can cause significant flooding inland, and storm surges can produce extensive coastal flooding up to 40 km from the coastline. Most of the tropical cyclone occurs during six months period from June to November. Tropical cyclone occurs both at sea and/or on land. Worldwide about 1.9 million people have died in the last two centuries due to tropical cyclones. Wide spread flooding after cyclone lead to increased infection and mosquito-borne illnesses. Unsanitary conditions in cyclone shelters increase the risk of disease propagation. Tropical cyclones significantly interrupt infrastructure, leading to power outages, bridge destruction, and the hampering of reconstruction efforts.

Classification of cyclone

Depending on location and strength, a tropical cyclone is referred to by names such as, typhoon, tropical storm, cyclonic storm, tropical depression, and simply cyclone. People use different names for these storms in different places. In the Atlantic and Northeast Pacific, the term “hurricane” is used. The same type of disturbance in the Northwest Pacific is called a “typhoon” and “cyclones” in the South Pacific and Indian Ocean. Based on increased intensity, tropical cyclones are categorized as tropical depressions, tropical storms, and intense storms. A tropical depression is an organized system of clouds and thunderstorms with a defined, closed surface circulation and maximum sustained winds of less than 63 km/h. It has no eye and does not typically have the organization or the spiral shape of more powerful storms. However, it is already a low-pressure system, hence the name "depression". A tropical storm is an organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds between 63 km/h to 119 km/h. At this point, the distinctive cyclonic shape starts to develop, although an eye is not usually present. A tropical cyclone is systems with sustained winds with at least speed of 119 km/h. A cyclone of this intensity tends to develop an eye, an area of relative calm (and lowest atmospheric pressure) at the center of circulation. The eye is often visible in satellite images as a small, circular, cloud-free spot. Surrounding the eye is the eyewall, an area about 16 km to 80 km wide in which the strongest thunderstorms and winds circulate around the storm's center. The maximum sustained wind in the strongest tropical cyclones is reported as 314 km/h. Intensity of cyclone are represented in The Beaufort scale (Table 1).

Table 1. Classification of tropical cyclones in Indian Ocean as per intensity

<table>
<tr><th>The Beaufort scale</th><th>1-minute sustained windspeed (km/h)</th><th>10-minute sustained winds</th><th>North Indian Ocean (IMD)</th><th>SW Indian Ocean (Meteo France)</th></tr>
<tr><td>0–7</td><td>59</td><td>52</td><td>Depression</td><td>Zone of Disturbed Weather</td></tr>
<tr><td>7</td><td>61</td><td>54</td><td rowspan="2">Deep Depression</td><td>Tropical Disturbance</td></tr>
<tr><td>8</td><td>69</td><td>56-61</td><td>Tropical Depression</td></tr>
<tr><td>9-10</td><td>70-100</td><td>63-87</td><td>Cyclonic Storm</td><td>Moderate Tropical Storm</td></tr>
<tr><td>11</td><td>102-117</td><td>89-102</td><td rowspan="2">Severe Cyclonic Storm</td><td rowspan="2">Severe Tropical Storm</td></tr>
<tr><td rowspan="9">12 and more</td><td>119-131</td><td>104-117</td></tr>
<tr><td>133-152</td><td>119-133</td><td rowspan="6">Very Severe Cyclonic Storm</td><td rowspan="3">Tropical Cyclone</td></tr>
<tr><td>154-176</td><td>135-154</td></tr>
<tr><td>178-180</td><td>156-157</td></tr>
<tr><td>181-207</td><td>159-181</td><td rowspan="3">Intense Tropical Cyclone</td></tr>
<tr><td>209-226</td><td>183-198</td></tr>
<tr><td>228-239</td><td>200-209</td></tr>
<tr><td>241-252</td><td>211-220</td><td rowspan="2">Super Cyclonic Storm</td><td rowspan="2">Very Intense Tropical Cyclone</td></tr>
<tr><td>≥254</td><td>≥220</td></tr>
</table>

Effects of Cyclone on Agriculture

The agricultural sector includes field crops, horticultural crops, agro-forestry plants, livestock and fisheries. Cyclones in coastal areas severely affect all these components of agriculture sector through direct damage by high speed wind, torrential rain and extensive flooding. High tide may bring in saline water and sand mass making the fields unsuitable for agriculture. The indirect effects include infection and disease of farm animals, fish and crop plants. Agricultural marketing and trade is adversely affected due to lean season of animal, fish and crop production. Super cyclone in 1999 and phailin in 2013 severely affected crop production and livelihood of farmers in coastal areas in Eastern Coast of India.

Contingent Measures for Agriculture Sector

Direct and indirect effects of cyclone disaster adversely affect the economic back bone of the affected farmers. Government support is required for revival of agriculture. Contingent measures should be adopted to help farmers and farming in the region. Post-cyclone contingent measures may be discussed under different time frame considering the nature of urgency.

(a) Immediate measures(Day 1-7 of cyclone hit)

The most important measure is protecting the livestock of affected farm families. Livestock must be provided shelter and feed immediately. This should be followed by medicines, de-wormers, and vaccinations as per the situation. Arrangements should be made for providing seeds, fertilizers, plant protection chemicals and farm machineries, if the planting season is immediate. Provisions should be made for supplying polythene sheets of appropriate thickness (50 to 100 µ) so that affected farmers can make low cost poly houses for raising vegetable seedlings, advance in the season.

(b) Short-term measures (Week 2-8 of cyclone hit)

Agricultural inputs like seeds, fertilizers, plant protection chemicals and farm machineries must be provided to severely affected farmers if not provided under immediate measures. Provision of agricultural inputs under immediate or short term measure depends on the planting season of the crops in the affected area. Attempts should be made to restore production and livelihoods consisting of crop/horticulture, livestock, and fisheries. Capacity development and training on best utilization of available resources need to be taken care.

(c) Medium term measures (Month 2-6 of cyclone hit)

Within 2 to 6 months of cyclone hit, rehabilitation of damaged agricultural and other rural infrastructure needs to be completed. Farmers should be assisted for resumption of agricultural activities towards a normal agricultural calendar. Technology-based Capacity Development and training for affected farmers, livestock keepers and fishermen is required to prepare for efficient agricultural production. Financial support for crop raising, harvest and post-harvest operations through zero or low interest agricultural credit is needed. Livestock farmers should be helped by arranging feed, fodder and veterinary support. Restocking of birds and arrangement of feeds and medicines are to be arranged for poultry revival. Fish farmers should be provided with fish fingerlings and feed, boats and nets as per need.

(d) Long-term measures (Month 7-18 of cyclone hit)

Rehabilitation of damaged and degraded lands and water courses should be attempted. Restocking of livestock and animal feed/fodder, restocking of fish fingerlings, rehabilitation of damaged orchards, promotion of agro-forestry for firewood and timber, training on crop production and livestock management including disaster preparedness need to be attended. Flood protection dams should be constructed and on-farm water control structures should be developed. Flood tolerant crops and suitable varieties need to be introduced. Threshing floor, drying yard, mechanized farm operations need to be envisaged to avoid harvest and post-harvest losses. Service providers for essential agricultural services are to be promoted in the community.

Crop Management Strategies

1. Provision of wind-brake plantation

Wind-brake help in reducing the wind speed. Promotion of several tiers of wind-brake plants near the sea coast effectively reduce wind speed. Also, it helps reducing the adverse effects of high tides by lowering the amount of saline water and sand mass. Suitable plant species for wind-brake system include casuarina, eucalyptus and acacia. Provision of wind-brake at village level or even at farm level will be added advantage. In lowlying coastal areas, village boundaries are often provided with embankments to prevent flood water. Drainage channels (*Khalasi*) are provided for effective drainage. Provision of wind-brake plantation on such embankments is useful for reducing the wind speed and providing fuel wood and timber.

2. Nursery management technology

Cyclonic rainfall and waterlogging forces the farmer for delaying field preparation and planting of winter season vegetables. Post-cyclone rainfall may damage the vegetable nursery. Vegetable seedlings should be raised under low cost poly houses for getting healthy seedlings, advance in the season. Creeper vegetables like water melon, pumpkin, ridge gourd, cucumber, and bitter gourd are planted at a wider spacing and these crops are not suitable for transplanting. Seedlings of these crops can be raised in disposable plastic cups using fertile soil in poly houses or other protected places. Such seedlings can be planted early the cropping season can be advanced by 3 to 4 weeks.

3. Bio-drainage plants

Waterlogging in coastal region due to high and unusual rainfall during cyclone coupled with insufficient drainage lead to flooding in wider areas. Biological drainage by specific kind of vegetation like casuarina, eucalyptus is a promising tool to improve drainage situation. Cyclones occurring in the months of October and November affect the paddy crop in grain filling to maturity stage. Bio-drainage plants help to reduce the water table at a faster rate and thereby, facilitate in growing the winter season crops like water melon, black gram, ridge gourd, cucumber, cowpea.

4. Rice Production Technology

In several occasions, flood is accompanied by cyclone due to heavy rainfall associated with the process which increases the extent of damage to agriculture. Rice is the most important and best suited crop for waterlogged and cyclone prone coastal areas. Suitable variety for specific situation and appropriate crop management technology can reduce the adverse effects of waterlogging and cyclone.

a) Tolerance to submergence under prolonged waterlogging

Crop submergence at any growth stage limits rice productivity. Tolerance to submergence, in general, is associated with 1) elongation of leaf sheath, culm and leaf or combination of these factors,2) higher oxygen liberation by roots,4) higher amylase and acid phosphatase activity of stem, 5) greater pre-submergence stored carbohydrate ,and 6) high specific leaf weight and maintenance of greater chlorophyll content during submergence. Submergence tolerant rice donors include Fukoku, T 1808, Hatipanjari, CR 383-10, Sarubhujini, T 300,B 24-92, T 535. Recommended rice genotypes for semi deep water situations include Rambha, Tulsi, Kanchan, Durga, Sarla, Kalashree, Panidhan, CR 1014, while for deep water situations Suresh, Biraj, Jalmagna, Jogen, Sabita, Bhudev, Hanseswari are useful.

b) *Tolerance to flash flood*

Flash floods are short staying (10 to 12 days) in nature. Rice variety suitable for this situation should have very little elongation. Thus available carbohydrate is not wasted for elongation; rather it is used for self-sustenance till the flood is receded back. Suitable rice varieties for these situations include Sarala, Piolee, Panikekoa.

c) *Crop management*

i) Management objective should be to get high carbohydrate level before submergence stress. This can be achieved by early sowing/transplanting, using high density grain, sparse seed/seedling density, use of vigorous seedling (0.8-1.0 g as fresh weight/seedling), and optimum plant nutrition.

ii) Community nursery raising, scheduling bushenings, re-transplanting in damaged fields using detached tillers and/or fresh seedlings and transplanting new areas or direct seeding using short duration rice varieties are some crop management strategies.

d) *Salinity tolerance*

Coastal salinity due to intrusion of sea water affects crop productivity. Salinity tolerant varieties like Rambha, and Lunishree should be grown. Soil amelioration using organic manures like FYM, compost and green manure helps in reducing soil salinity.

e) *Lodging tolerance*

Use of tolerant and semi-tolerant rice varieties in waterlogged condition makes the plant susceptible to lodging. Receding water level in post-monsoon season and grain filling stage of the crop are congenial for lodging. Cyclone in this stage results in lodging followed by submergence leading complete damage of grains. Rice variety like CR 1014 has strong stem and it can partially overcome lodging problem.

f) *Selecting rice variety with kneeing ability*

The upward bend of the terminal part called kneeing that keeps the reproductive part of rice plant above water after lodging of plant with the receding of flood water. This helps in keeping rice grain above water level and protects from being damaged. Tiller angle should be more than 45^0 for more than 25% tillers. Rice varieties like Hanseswari, Durga with kneeing ability score less than 3 are desirable.

g) *Escaping peak cyclone period at maturity stage*

Maturity stage coinciding with the peak period of intense cyclone (mid October to mid November) results in severe damage for rice crop. Selection of rice varieties, to escape maturity during this peak period of cyclonic disturbances is one option. Rice varieties like Durga and Varsha Dhan maturing after mid December may be adopted in suitable ecosystem.

h) *Enhancing maturity to escape peak cyclone period*

Spraying diaquat 0.05% or paraquat 0.1% or common salt 10% on the earhead at the rate of 1000 litre/ha at 20 to 25 days after 50% flowering helps in enhancing maturity by 5 to 7 days. This can be done to escape peak period of cyclone occurrence.

i) *Facilitation for quick harvest and post-harvest management*

Quick harvest, threshing and drying the grains before the cyclonic system through early warning is the best option. Covered threshing floor cum drying yard helps in preventing grain damage. Communities drying yards and polythene sheets to cover so that grains do not get moist are possible options to prevent grain damage. Preparing beaten rice from moist grains is also possible to avoid damage.

5. Banana Production technology

Banana is a water loving crop and grows well in humid climate coastal areas. This is a very popular crop in coastal areas. Also, this crop is very susceptible to high speed wind of cyclones. Large scale damage leads to immediate surplus of banana in market followed by a lean period for 10 to 12 months. Crop management strategies listed below may partly overcome this situation.

a) Staggered planting

This helps in planting over a wider window and large scale damage at one time will be avoided. Planting time should be adjusted so that reproductive stage of banana does not coincide with the peak period of cyclone occurrence.

b) Canopy removal

Plant should be subjected partial removal of canopy if it is in reproductive stage. There may be yield reduction, but some check in damage is possible. Partial or complete removal of canopy before cyclone is possible younger suckers or even older plants before reproductive phase.

c) *Crop management*

Provision of support to bunch using stakes made of bamboo often overcomes moderate wind speed. Use of healthy suckers for replanting after cyclone damage is recommended. Survived plants having banana fingers in fruit filling stage may be provided with additional nutrition through bunch tip.

6. Preparation of crop calendar based on tropical monsoon season and peak period

							Tropical Storm / Cyclone Season					
Yearly Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Early) rice *(Sowing)*			√									
Shallow lowland rice *(Transplant)*							√					
Semi-deep and deep water rice *(Sowing)*					√							
Summer rice *(Transplant)*	√											
Mung *(summer)*			√									
Water Melon												√
Seasame *(summer)*			√									

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Concept of Community nurseries and seed banks for climate resilient horticulture

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Agriculture has been facing the wrath of the changing climate in recent years. The climate change in terms of the unpredictability and irregularity of different climatic events especially rains and hailstorms have increased the risk quotient of agriculture profession in India. Since ancient times the farmer has tried to adapt to the changing climate in situations. Farmers have been into selective collection and conservation of seeds with better yields and resistance to biotic and abiotic resistance. However, there has been a drastic change in the agriculture since last century. Whereas earlier agriculture was primarily to cater the food and nutrition requirement of the members of the family and the community, today the agriculture has become a profession or a semi-industry which produces goods in bulk in response to the consumer preference and market demand. The profession now requires better inputs like hybrid seeds, fertilizers and pesticides, and better technologies like mechanized cultivation, protected cultivation, postharvest processing and management. However, agriculture for sustenance is still prevalent in most parts of the developing and underdeveloped nations around the world. The small and marginal farmers practicing agriculture in smaller scale catering own families and disposing off the remainder in local markets. The changing climate has become a curse to such small and marginal farming communities because loss of even a single crop can lead to starvation or malnutrition of the family.

Majority of the sustenance agriculture in India is rainfed. Hence the major reason of crop failure stems from the untimely or insufficient rains at critical growth periods. Loss of standing crop at initial stages could be compensated by re-sowing immediately; however there may not be sufficient seed left with anybody in the community for re-sowing. Moreover it would be difficult for the public and private seed sectors to meet the demand of the cost effective seeds by the rural and tribal farmers residing the far flung and inaccessible areas at that moment. Complete crop failures due to floods and droughts, pest and disease incidence, or fire, can lead to loss of a traditional variety if it is not preserved with other members of the community. Such a situation can be primarily addressed by the community nurseries and seed banks.

Seed banks:

Seed banks serves multiple purposes and largely self sustainable. Traditionally the seed banks are aimed at identifying important local seed varieties, especially that of cereals and vegetables, and orienting the local agricultural community towards conserving and cultivating them, with an broad aim to enhance the livelihood security of small and marginal farmers through conservation of indigenous genetic resources and make the community self sustainable. Seeds of these traditional varieties normally are not available commercially in the market rather the rural people exchange seeds within their village and with people from neighboring villages. These seed exchanges are important for seed supply, diffusion and conservation. The establishment of community seed bank empowers local people to conserve, and multiply seed of crops and varieties of their traditional choice. Such mechanism is likely to make the community more resistant to the devastation of abrupt weather furies. The member of such seed bank can deposit his seed lot with the seed bank for next season. Seed banks equipped with better traditional and modern storage facility can store the seeds while protecting them from damage by any pests. The requisite seed can be loaned from the banks with an obligation to return more than loaned seed lot. The addition seed returned in previous season by the farmers creates a buffer for contingency arising from juvenile crop loss due to natural fury. Further, access to seed banks often encourage and sustain cultivation of traditional varieties for creating community seed security. Local seed banks also protects the traditional varieties from extinctions due to agricultural modernization which promotes farmers to purchase more of commercial hybrids or varieties which in longer run can replace traditional genetic base in many communities. Hence, besides offering the farmers more choice over what they grow, Seed banks also enable rural tribal villages to become less dependent on expensive seeds in the markets. Community seed banks helps in bringing up self sustainability in terms of seed supply and ultimately ensures local food security.

Constitution and formalization of Seed banks

1. Creation of awareness and constitution of management committee: Creation of awareness about the seed banks and its virtues is the foremost requirement for the project to be successful. However with the strong basic concept it won't be difficult. Once the need is understood a management committee can be democratically constituted preferably with participation of regional agriculture and horticultural officers, researchers from KVKs and members of active NGOs. Alternatively a Self help group can be made for the purpose with participation of active farmers. The seed money can be obtained from Village development Committee or any other funding agency. The fund is primarily required to create storage facility for the seeds, office and stationary. If the panchayat office can spare a room for the purpose the venture can be initiated right away. The constituted committee can make the bylaws and charter of rules and regulation for smooth functioning of the bank. The bank can run either on barter system or on payment system. In the barter system the farmer loaning the seeds should agree to return 1.5 times of the loaned seeds of same variety and quality.

2. Eligibility of participating farmers: The participating farmers inclining to avail the facility of the community seed bank should agree to abide by the rules and regulations framed by the committee. The farmers should be cultivating the crop that is included in the schedule of the seed bank. The farmer should allow the committee to monitor the crop at different stages to ascertain the purity and quality of the seeds. The committee should be satisfied with the quality of the seed finally submitted by the participating farmer.

3. Training and capacity building of the participating farmers: The participating farmers would require initial orientation and training on the basic tenets of seed production. They should be made understand the difference between the process of production of seeds and grains. The concept of isolation distance, physical and varietal purity and weed management should also feature in the training. Expert members from State department and other organizations can be contacted for the purpose.

4. Identification and cataloguing of the commercial and tradition varieties: The management committee should survey and find out the available seed and planting materials in the specific geographical region where the seed bank is located. The catalogue should contain the distinct features of the variety, name of the farmer preserving it and its specific agronomic requirements, if any.

5. Field monitoring: It is basic requirement to monitor the seed production plots by technical persons to ascertain that the crop is grown with proper cultivation practices like proper seed rate, spacing, nutrient management, pest and disease management, weeding and rouging, isolation distance, timely harvesting and threshing, etc. The Seed bank management committee may seek the help of experts in the region for the purpose.

6. Seed packaging and disposal: After harvesting the seed lot needs to be cleaned off of debris, weed seeds etc., and packed suitably with proper labeling. This can be done by the famers themselves or the committee may assign this work to some women based groups in the village. Farmers can offload their produce in such seed processing centres and the women groups can process the seed lots. The groups can also be trained to confirm the quality of the seed lot and may report to the VDC or the seed bank committee if they receive substandard seed lots. The procedure and formalities of maintaining, pricing and disposing of the seeds can be formulated by the respective committees. However, proper storage procedures need to be followed to protect the seeds from damage due to moisture, rodents, birds, insects and storage fungi.

Contingency measures in areas prone to natural calamities.

Creation of seed banks in disaster prone areas can be taken up well in advance. The seed banks can be housed in the elevated shelter homes built by the government in such areas. It would be useful measure in remote areas which are cut off from other parts during heavy floods. The farmers can utilize these seeds immediately after receding of flood water without losing any time. The seed banks of flood prone area can have a special repository of rice varieties capable of surviving submerged conditions. Such seed banks should also have supply of seeds of short duration crops especially that of leafy vegetables.

People can create floating structures with light weight planting media to raise small quantities of crops to overcome short supply of vegetables during long spells of floods. Such structures can be created on wood logs, used inflated tubes, thermocol etc. These structures can be prepared before the onset of rains and as the flood water comes these structures would float automatically in a contained area. The vine crops trained over the roof tops also serve as reservoir food source for some period. The tuber crops especially yams can remain safe underground at least in short spells of flooded conditions.

Community nurseries:

Availability of quality planting is highly essential for successful commercial vegetable cultivation. Farmers generally prepare small nurseries in their backyard solely for personal usage. However it is often observed in the villages that crop in early stages is lost due to pest and disease incidence or due to natural calamities like droughts, scanty rains, floods. Under such circumstances the farmer does not have either sufficient time to raise new nursery nor would he get sufficient seedlings from his fellow farmers. In these situations the farmer is prone to lose a complete season. Such situations can be addressed by protected community nurseries managed by resourceful farmer-groups for cultivation of high quality seedlings on commercial basis in protected structures like polyhouses. Such nurseries can serve as regular and contingent source of seedlings of desired quality and quantity.

Constitution and formalization of community nurseries

1. Creation of awareness and constitution of self help groups: Unlike seed banks the community nurseries can have smaller number of subscribers. Creation of awareness about the community nurseries is the prime step towards constitution of community nurseries. Once the farmer groups are ready to take up the venture they should be trained for various activities of nursery management. The resource person or the technology providers have to guide the group on selection of land, source of funding for construction of the polyhouse, technology for construction of low cost polyhouses, potting media, source of quality seeds, pest and disease management, etc.

2. Training and capacity building of the participating farmers: The participating farmers would require initial orientation and training on the basic tenets of quality seedling production under protected conditions. They should also be trained in improved nursery management technologies like soil solarization, grafting, sowing, fertilization, raised beds, pest and disease management activities, etc. They should be made understand the concept of quality planting materials. Experts from State department and other organizations can be contacted for the purpose.

3. Construction of protected structures/ polyhouses: State governments have various schemes with subsidies which facilitate the construction of polyhouses of various sizes. National horticulture board also provides assistances for such ventures. Alternatively the farmers can prepare low cost polyhouses using bamboo poles. The selected site for construction should preferably be elevated to avoid water logging. There should also be provision for regular supply of water to the structure.

4. Seedling production and disposal: The seedling production should follow the preference of seed of the local farmers. The sowing should be done in staggered manner to create regular supply of seedlings during the season. The roots of the seedlings can be treated with bio-agent formulations or pesticides for reducing the field mortality.

Self help groups (SHGs) constituted by CHES in different districts of Odisha for production of quality planting material on commercial basis in protected condition s, are functioning successfully. This initiative to promote a specialized group of farmers to produce the quality planting material based on the demand of the farmers of the region, were able to cater the needs of not only the native village but also the farmers of the neighboring villages. The protection from unseasonal, torrential rains, low

temperatures, insect and airborne pathogens has been a major contributing factor in the success of these protected commercial nurseries. This intervention has given a protection to the farmers of region not only against the accidental loss of planting material in the personal nurseries but also against loss of crop season with the availability of alternate source of ready to plant quality planting material. Introduction of other novel interventions like production of seedlings in potrays and on stall beds were particularly helpful in the avoiding the loss of seedlings during heavy rains and floods. Seedlings raised in potrays could be easily moved to higher places in the event of rising of water level in the nursery. The elevated nursery beds with lighter cocopeat media with have also been proposed to combat the unforeseen flash floods. These innovative interventions were particularly helpful in the avoiding the loss of seedlings during heavy rains and floods.

In the days to come protected production of seedlings would be the helpful in reducing untimely losses of crops due to natural calamities and climate change, besides creating an alternate source of ready to plant quality planting material in a region.

Participation of women in community seed banks and nurseries: Women are the mainstay of any developmental programme in the villages. As mentioned earlier women self help groups have tremendous potential for self engagement in post harvest processing of seed lots in seed bank initiative. Commercial fruit and vegetable nurseries are invoking increasing participation from farm women, due to ease of operations and flexibility of timing. It is seen that in nursery SHGs, family women directly and indirectly contributed in various operations in nurseries like soil solarization, bed preparation, seed treatment, line sowing, polythene preparation, grafting, watering, fertilizer application, pest management, seedling bundle preparation etc.

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Socio Economic Impact of Cyclone and Other Climate Induced Natural Disasters- Some Case Studies

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Introduction

Climate induced natural disasters (CINDs) like drought, flood and cyclone have become serious problems to Orissa. CINDs are of regular occurrence particularly in coastal Orissa and have become the part of normal life. The poor people are the worst affected. In most years, adjustment in household activities combined with relief works provides the minimal succors (employment, food, etc.). However, occasionally the situation gets worsen like the case in coastal Orissa since late 1990s. The farmers and fishermen who are the traditional food producers living in such fragile environments become ecologically, geographically and economically marginalized. However, over time they have evolved certain coping mechanisms and adaptive strategies to reduce drought, flood and cyclone vulnerability.

This communication focuses on coping strategies of the poor to drought, flood and cyclone vulnerability in coastal Orissa. The vulnerability towards all these three extreme events and the rural household's coping strategies are discussed. Rural people's perception and attitudes about natural disasters are also reported. For the study, a simple random sample was adopted and interviews were carried out through questionnaire. From the study a picture of coping responses was built up.

The common perception of rural households in the study area is that climate has changed for the worse with increased **frequency as well as intensity of CIND events in recent years.** Although the warning system was also developed and found to be timely and largely accurate, the rainfall forecasting in drought years were misleading. Further, the cyclone warning was ignored by the rural households which resulted in higher causality than expected. As with most other warning systems, there appears to be a missing link between the warning signals and follow up action.

Discussion

Natural resources are prime mover for a society for sustainable growth and development. The coastal economy is more prone to its control due to enormous contribution it makes to livelihoods of the people. The village Naladiapalda under Mahakalpara block of Kendrapara district in Orissa, a perpetual victim to the climatic turbulences testifies this. The NRM group along with other colleagues carried out focused group discussion with the people of different age groups to ascertain the symbiotic relationship of natural resources within the coastal ecosystem and the livelihoods of the people.

Case Studies

The initial discussion with the villagers revealed that the soil and vegetation of yester years are no more reassuring to make up whatever loss is caused to the people due to floods and droughts in the village. The elderly people recalled their memory that with little or no application of fertilizer, the paddy and groundnut yields were bumper in kharif and post kharif respectively. There were floods, but the duration of floods was less due to large spread area of the Paika river which has been narrowed down on either side with construction of embankments. The river was also flowing almost round the year and severity of salinity was not there till mid April or month of May. The people were mostly using “Janta” for water lifting from the river and the traditional “Chua” or water hole in the riverbeds was a permanent source of fresh water. However, the control of Mahanadi water at different places like Hirakud, Naraj barrage at Munduli and Jobra barrage in Cuttack intensified the woes of villagers due to reduced lean flow of the river and resulting salinity intrusion in as early as month of March. The dug wells use to supply water round the year. The village had a good part of area under forest, which used to supply fuel woods and minor forest produce for daily livelihoods of the people. The land, water resources and vegetation endowment in the village took care of immediate needs of livelihoods that have dwindled with the progress of time.

Dynamics of land resource management

Reacting to our query on quality of land resources, the villagers reacted that the land in the village has become less fertile over the years. Earlier they used to get 30 to 40 quintals of paddy per hectare of land put under kharif, which declined with the passage of time, and presently they used to get hardly 12 to 15 quintals of paddy. Even the productivity of HYV paddy is also declining. The villagers opined that the land resources under private and common property management are low productive due to top soil washout in floods or drought, which are common in the village. The soils have low water holding capacity. The private holdings are fragmented and distributed in 4 to 5 parcels in some cases. The general perception of the villagers towards management of natural resources especially land was that there is little scope for any contingent measures to prevent flood and drought as the problem is so severe that, human endeavor is not strong enough to prevent it. As per the villagers perception, around 70% of land was under low land category in the Tikhiri Gram panchayat. However the villagers opined that upland counts for more than 40% in Naladiapalda village alone. Rest of the land resources come under medium and low land category. The uplands suffer maximum in the event of a drought. The low lands do not get ready for a second crop due to unfavourable edaphic condition. When the fields are ready, irrigation facilities are not available for the crop. Around 10% of land is perpetually in saturated condition in the village, indicating problem of waterlogging. The villagers used to grow local waterlogging varieties of paddy like “Baunsa Gaja”, Rajamalli and Dhuruva Khuda, which were low, productive but water logging resistant. The degradation of land over the years has forced some farmers to penury and out migration as no other sources are available for livelihoods in the village. The villagers are of the opinion that due to application of fertilizer the soil natural productivity decreases.

Scientific land management in the monsoon has little scope except putting some land under paddy and backyard vegetables. The local varieties like Baunsa Gaja, Rajamalli, Dhuruva khuda, Pakhira are popular local varieties practiced in kharif in low and medium lands. The lowland paddy cultivation is called “**Sarada”** in the local area. The average yields vary from 0.5t/ha to as high as 1.5 tons for the local paddy. In the event of waterlogging and flooding Raja Malli and Dhuruba khuda perform better and can give 30-40% of potential yields even if flooded for 15-20 days. In relatively uplands the people take Khandagiri (HYV), which gives a yield of 1.5 to 2.0 t/ha. The short duration pure upland paddy cultivation is called “**Biali**” in local parlance, which is highly susceptible to droughts. Almost all the farmers use broadcasting method of seed sowing in kharif and transplanting for rabi “**Dalua**” crop where ever taken up. Only 10% of land is put under transplanting (medium lands) in kharif. The concept of intercropping or strip cropping, crop diversification, which are considered drought hedging land management practices are not prevalent in the area. The farmers view that yields get affected due to intercropping. Early sowing is also not possible due to hard soil condition in the month of May. Uttam Nayak a progressive farmer has the contingent crop planning in the event of a flood. He goes for early winter vegetable and groundnut as he has control over a tube well installed in his field (50ft deep). He also charges Rs. 50 for one hour pumping if pump is hired out.

Decrease in wetland area

The villagers reported that the wetlands that were around 20-25% of total geographical area decreased over the years due to encroachment for agriculture and habitation**.** The wetlands used to modulate heat waves in the extreme summer and lot of birds and reptiles were seen that was conducive for maintenance of ecosystem. However the wetlands have reduced to less than 10% presently**.**

Impact of climatic hazards on land resources

Uttam Nayak reported a grim picture of natural hazard that has forced him almost to penury. Consecutively he faced crop loss for 3 years out of last 5 years either due to flood or drought. In 2001 there was severe flood. In 2002 there was drought and again in 2003 there was flood. River Paika proved to be sorrow of Naladiapalda village. The embankment has worsened their plight. The 26 households caught outside the flood embankment are worst sufferers. One Shri Surendra Nath Samantray lost 2.5 acres of land to sand casting in the super cyclone. In the 2003 floods he lost 100 % of crop 2.5 acres of land. The floods usually come in the months of July and August and most of the land is put under kharif paddy by then. The flood not only affects the crop but also washes away field bunds and sometimes the topsoil is also affected. However the huge silt load also helps in improving soil quality due to sediment deposit which sometimes prompt the farmers to apply less fertilizer. The duration of flood sometimes last for month that completely destroys any sort land based enterprise. Black gram or groundnut is taken up after flood instead of paddy wherever irrigation is available otherwise the field is left fallow. Black gram is considered as best as the post flood crop as it does not require irrigation and fertilizer application is almost nill due to improved soil condition because of siltations. In the event of flood coming in the maturity of the crops, farmers used to cut top portion of the paddy and leave the rest in water. In the event of drought, the common land management practice is to strengthen bunding to prevent runoff and close rat holes in the fields.

The quality of soil is generally good as perceived by the farmers due to repeated flooding and siltation. However sometimes due to washout of topsoil under high velocity flood current, the yields do not commensurate the potentials of the soil, which is compounded by low fertilizer use.

Land management has little relevance for land less categories of population except some economic activities like grazing in common lands (which is scanty) and digging for mud wall construction. However they are indirectly affected in terms of availability of wage employment that gets affected due to flood or drought. The leasing in system though prevails in the area, the land less people seldom go for it due to high rental fixed for produces. The land less people who constitute around 20% of population in the village migrate in the event of severe drought and flood.

Traditional Water resource management

Some old villagers recall that river Paika had been meeting their water requirements almost in all season and the current salinity problem the month of April to June was not there some fifty years back. The village has no community irrigation pond and the private ponds are scarcely used for irrigation purpose as the ponds are shallow and get dried by February leaving little scope for irrigating a second crop. In total 5 shallow tube wells owned by private individuals are in operation in the village that irrigate around 60 to 80 acres of land in *kharif* and 30 acres in *rabi* through diesel pumps. Around 40-50 people are water users from private tube wells. The common method of irrigation in ayacut under private tubewell is through field channels and mutually decided scheduling among the beneficiaries. Large distance conveyance channel is not economic due to unleveled field conditions. As little common land is available in the villages, community pond system is conspicuous in its absence. As the river Paika is nearby, pond water gets emptied by January due to lower riverbed. The traditional water lifting devices in the area are “Janta” or “Sena” for small and marginal farmers for surface water. **Bund raising** is practiced in the event of an imminent drought. They know the utilization of dew for blacgram and green gram as they term it “Kakar pani” for crops. They traditionally know In-situ water harvesting system through maintenance of bunds. But repair and maintenance of field bunds are costly and get little attention by the farmers. **Mulching,** as a method of soil and water conservation is known to the people and sometimes practiced for vegetable cultivation to reduce ET. The people opine that large investment in river lift system using Paika river could irrigate around 500 acres of land and people are ready to form **Pani Panchayat** for the same. However the river water gets saline by April and hence summer crop is also constrained in the absence of assured irrigation. The drinking water problem is severe due to drying up of existing sources and salinity ingress due to over drafting in tube wells. Most of the hand pumps are defunct or dried due to non-maintenance. The absence of a strong water market prevents private investment on water resources. The water market is at nascent stage.

Recycling of drainage water

The villagers used to **recycle drainage** water for life saving and supplemental irrigation when the crops are stressed especially in kharif. The quality of recycled drainage water is not bad as perceived by the farmers due low fertilizer and pesticide use. In the rabi the fields nearby the surface drainage system used to have vegetables or summer paddy by utilizing drainage water. Sometimes the community uses it for sanitary purpose also.

Dwindling Vegetation

The village had around 10-15% of land under forest cover 50 years back in community as well as private lands. The fuel wood requirement was met from the forest. Though the forest was not dense, the people were meeting the requirement of traditional forest species for religious functions and the bamboo was major species that was contributing to the household requirements. The timber species were not available in the forest. Rampant Cutting of bamboo and other trees denuded the forest cover and exposed them to repeated grazing by cattle. The shrubs also dwindled in the process. The flower species like "Champak" etc are no more available in the area. The private forest plantations are also becoming rare. A species of wood apple that was plenty is hard to get now. The smell of "Kadamba" a traditional forest species are extinct now. Earlier people used to plant these in the common forest land and private lands. The most preferred species now is "Chakunda" in private lands due to speedy growth and log availability. The preference has also shifted to eucalyptus due to economic reasons. But plantation activities are not common in the area. Cashew nut plantation in private lands is seen in backyards of some farm family. Organised orchards are not available in the area.

Common Property Resource Management

Earlier the village used to have small area under village forest, which dwindled with the passage of time. The villagers used to gather minor forest produce and fuel woods from the forest. However the forestlands are no more in existence and encroachments have taken the toll of forestlands. The community pond system is also not prevalent in the village. The publicly provided drinking water tube wells are mostly defunct due to ill maintenance and drying up of source. The use of tube wells for drinking water sometimes has caste biasness where upper castes getting easy assess. Previously the forestland used to be a grazing land for the cattle. With forestland gone, the grazing is a big problem for the cattle. Community Pastureland is not available in the village and the cattle are set free in rabi for open grazing in fallow private lands. The stalk feeding is practiced in kharif only. Around 120 cows and 70 number of bullock population face severe deficit in feed availability and are under nourished. Total goat population is around 300 but sold early due to absence of grazing facility.

Coping Mechanism

Relief anticipation is immediate behavioral pattern in the event of a flood or drought. (It is a bureaucratic joke that Orissa has three cropping season. These are kharif, rabi and relief) The common approach to any imminent flood is to provide higher basement for grain storage and leave the crops to destiny. Some farmers cut down in inputs from the beginning anticipating drought and/or flood. The seed rate is lower than recommended doses and fertilizer use is also minimal. If flood comes in the month of August or September the kharif paddy gets destroyed and people do not go for paddy again. Instead they sow black gram and groundnut after receding of the flood and the field is ready edaphically. However some farmers (10%) go for transplanted paddy by procuring sapling from Marshaghai or Kujanga (Nearest block headquarters) if flood recedes in last week of August. Land draining in the event of excess rainfall is commonly practiced by constructing "**adinallaha'.** No other conservation method is practiced. Varietal choice is not much influenced by calamities. However the preference is always for HYV due to promise higher yields even though risky. The people are of the opinion that due to destruction of plantations and village forest the severity of floods are more. Preparing land for vegetable cultivation after flood or drought are common crop management practices.

Ecosystem Impact –Response Matrix for NRM

Climatic Hazards	Ecosystem Service Impact			Livelihood Impact	Response
	Soil Resource endowment	**Water Resource Endowment**	**Vegetation**		
Cyclone	Salinization if cyclone intensity is more. Private land and common land washout, bund breaches as well as embankment breaches. Damage to standing crops in the private lands and severe littor deposits, water logging due to river surge.	Water bodies both in private and public land gets polluted and saline if sea surge is there River and streams surge and gets muddy. Problem in getting drinking water Crop loss and drinking water problem. Fish harvest from water bodies reduces or totally destroyed	Uprooting of new and old trees, horticultural plant devastation. Coconut plant maximum affected. Old banyan tree uprooted. Banana and other economic species affected most. Shrubs and herbs inundated and get destroyed due to combined effect of winds and river surge. Chakunda, another economic species gets uprooted immediately.	Displacement of livelihoods groups, desertification and overall Insecurity to life and property for a prolonged period. Community need for forest products (MFP) minimized and self-reliance in fuel woods gone Community water use becomes difficult and social conflict for water sharing intensifies especially between different social classes. Upper caste getting easy access than the lower castes.	Repairing breaches in bunds and reestablishing if need be. Vegetative barrior against wash outs, provision of drainage and wait for relief materials from different sources. Out migration for land less in search of work Cut down in food expenditure. Depending on money orders if someone employed outside. Borrowing from relatives and from money lenders Mortgage and Sale of valuables Replantation of fruit trees and sometimes social forestation if encouraged by departments Tube well repairing by agencies and decontamination of existing water bodies. Resource full go for tube well boring
Floods	Crop washout, waterlogging and contamination of land due to littor deposits. Also silt deposit, which is sometimes	Immediate water logging Pond water contamination and well water contaminated. Drainage network silted and free flow	Trees uprooted under severe flood current. If duration is more the shrubs and tree species get decomposed	Cut down in present consumption and govt. food for work programme if implemented does not supply enough	Provision of raised basements for grain storage and earthen made grainstorage "Sangha" used in the flash floods. The community response

	beneficial. Sand casting is severe problem and eats away arable land. Sometimes frees land from toxicity	of water reduces. Drinking water source polluted. Water bodies get extinct if current washes away bunds. Fish resources washed away from ponds.	under silt load. Some species gets completely washed away.	wage employment to all categories of people. Social functions are postponed. Temporary migration to urban areas for employment. Borrowing money from relatives and from moneylenders. Sale of gold if possessed.	build up in the form of joint effort for embankment protection and sharing food and shelter among themselves. Drinking Water transported from unaffected area by boat some times. Wells are drained out after receding of floods. The water hyacinth in the ponds naturally gets washed out making it clean of weeds.
Drought	Parch land devoid of green cover. Speedy wind erosion of topsoil due to drying up of moisture. Soils get hard for plowing. Transplanting not possible and "Gaja marudi" if just after sowing or transplanting drought unsets. Severe rat holes in the fields appear.	Immediate drinking water problem and drying up of water bodies like ponds as well as tube wells. Seasonal streams and perennial streams dry up. Ground water gets saline and river water also unfit for irrigation and drinking. Fish population severely affected due to drying of water bodies.	Vegetations also reduced due to excessive drying of soil and depleting ground water table. Unavailability of fodder for cattle and canopy cover for after noon resting or escape from scorching heat.	Severe crop damage and cut down in consumption expenditure. On farm Investment ability reduced. Low yields create food insecurity and imbalance diet. Non availability of fodder reduces cattle milking.	Social spending reduced. Marriages, religious ceremonies cut down. Preparation for early second crop. Migration for wage employment, Sale of cattle, Sale of valuables, Reduced food consumption. Government and other agencies food for work programme intensified but inadequate for family maintenance
Heat wave	Less land based activities and drying up of water bodies. Summer ploughing suspended causing delay in kharif operation	Water bodies heated and become unfit for human and cattle use. Fish dies. Faster decompose of aquatic weeds.	Trees become less vigor and loose green lusture.	Wage employment is also difficult due to rising temperature. Loss in horticultural crops like less coconut production and less buying and selling activities in agricultural produce.	Thatching intensifies. People do not venture out for land based economic activities

Appendix-I

A checklist of NRM approach in Coping with natural disasters and Village preparedness for the same as responded by the livelihoods groups.

Planning: No planning strategy is adopted in the village and the response is spontaneous and fatalistic.

Capacity building: People have developed inherent strength to face the calamities and little training or awareness camp organized except common Govt. advertisement for use of hygienic methods for drinking water or sanitation.

Insurance and other adapting mechanism: Crop insurance available and subscribed by around 50% of farmers but no compensation due to complicated procedures.

Social Response and adaptability: Group response in terms of sharing of common space and building group pressure on public machineries for relief and rehabilitation

Mitigation: Activities to prevent or reduce impacts of a catastrophic event prior to its occurrence, such as land use planning; retrofitting, building codes and public education are not prevalent in the area.

Disaster risk mitigation Structural approaches are almost nil

Non-structural approaches employ land-use controls, information dissemination, and economic incentives to reduce or prevent disaster vulnerability. No such control is available in the villages

Risk spreading measures: Adopted sometimes through crop management strategies and keeping lands fallow.

Institutions: NGOs, community-based organisations and government agencies. The village committee in position and other agencies step in after event. No coordination among the agencies for common strategies.

Conservation and Adapting to Climate Change: Conservation methods though known not adopted.

Intercropping: Seldom practiced

Soil Management - This approach for increasing the stability and productivity of soil is a general term that involves a range of specific techniques such as fallow cycling, forest buffering, selective planting, managed grazing, etc. Soil management is not systematically carried out due to lack of scientific approach and severity of problem.

Water harvesting: No water harvesting method practiced

Crop management strategy: Sometimes followed

Multiple cropping in waterlogged area: Not carried out

Sequence Cropping: Practiced to some extent (10-15% area)

Drainage Management in Waterlogged area: Field drains provided in excess rainfall situation

Pasture management: Not practiced

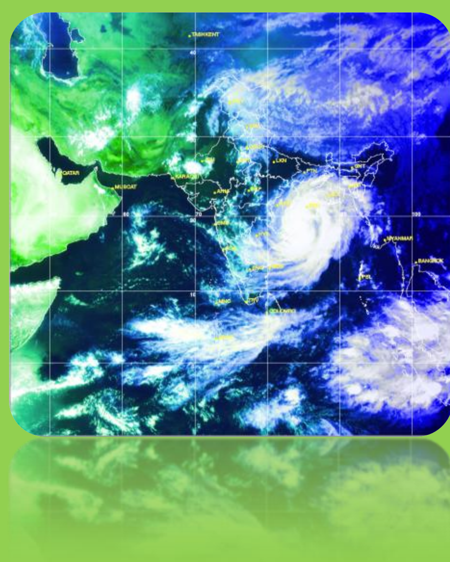
Water management methodology: Sometimes practiced.

Short Course

on

Management of Cyclone Disaster in Agriculture Sector in Coastal Areas

(16th to 22nd July 2014)



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