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Cyclone Proofing of Indian Agriculture:

Contingency Planning and Mitigation Strategies

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Cyclones are regions of low atmospheric pressure surrounded by high atmospheric pressure resulting in swirling winds and incessant rainfall. Rising sea surface temperature amid climate change is leading to higher frequency and intensity of cyclones both along the east and west coast of India. Besides causing widespread damage to property and livelihood, cyclones cause a major setback to agriculture. This in turn affects the socio-economic prospects of farmers and food security of the country. Cyclone proofing of agriculture can be achieved through long-term planning as well as by adopting contingency measures. Land configuration and drainage, improving vegetative cover, windbreaks and shelterbelts, diversified cropping, etc. should be adopted in cyclone-prone coastal areas for better preparedness. During cyclone warning, crop advisory published by various government institutes should be followed for minimizing economic damage. Timely action and implementation of post-cyclone management strategies are imperative for the reestablishment of agricultural systems and stabilizing the livelihood of the farming community.

The agricultural sector is the backbone of India providing direct and indirect employment to about 58% of the population. Amidst the raging pandemic which severely hit India's economy, agriculture was the only sector to return positive GDP growth in 2020. However, agriculture is severely affected by erratic weather conditions occurring due to climate change. Repercussions of climate change-induced temperature rise include dry spells, heat waves, cloud bursts, and cyclonic depressions. Advanced agro-technologies developed to boost crop and animal productivity and sustain food security are often insufficient to mitigate severe climatic anomalies like cyclones, especially in the coastal districts.

Cyclone is a region of low atmospheric pressure surrounded by high atmospheric pressure resulting in swirling atmospheric disturbance accompanied by powerful winds blowing in an anticlockwise direction in the Northern Hemisphere and clockwise direction in the Southern Hemisphere. They occur mainly in the tropical and temperate regions of the world. Cyclones bring strong gusts of winds (~100-200 kmph) accompanied by heavy torrential rains and often cause rise in the sea level and intrusion of saline seawater into farmlands. Incidentally, the farmers of cyclone-prone regions of West Bengal, Odisha, and Bangladesh are socio-economically poor and have lesser risk-bearing ability and resilience power. Cyclones cause a huge loss to life and property, including infrastructural damage (mud houses, older buildings, low-lying settlements), disruption and contamination of ground and pipe water supply, disruption in communication, electrical failures, and much more. Rain and strong winds ruin the standing crop (due to waterlogging) and food stock (lying in low-lying areas), which leads to acute food shortage. Salt from the seawater may get deposited on the agricultural land and increase the salinity.

History suggests that the frequency of severe cyclonic storms is higher in the months of October-November, and April-May and lower during the southwest monsoon period. The frequency of cyclones in the Eastern Coast of India (Bay of Bengal) is about four times higher than that of the western coast (Arabian sea). In the last four decades, increase in sea surface temperature has led to higher frequency and intensity of cyclones per year causing widespread loss to livelihood and agriculture in coastal districts. These regions have witnessed unplanned and fast economic development and destruction of natural shelterbelts without taking into consideration the carrying capacity of the region. Cyclones leads to depletion of vegetation cover, salinity and waterlogging of crop fields, desertification, erosion of biodiversity, power outrages etc., often culminating in a social crisis. The only way to safeguard economic gains and ecological security of the ecosystem is to adopt an integrated coastal environmental planning to reduce the vulnerability of the region.

Stages of cyclone development

The development of a cyclone covers **three** stages:

a) Formation and initial development state/stage: Cyclones develop due to convergence of atmospheric/ oceanic conditions namely warm sea temperature over 28˚C to a depth of 60 meters, high relative humidity of the atmosphere to a height of about 7000 meters, and atmospheric instability (an above-average decrease of temperature with altitude) encouraging considerable vertical cumulus cloud convection. These phenomena provide abundant water vapour in the air by evaporation, followed by condensation of water vapour into droplets and clouds, releasing heat energy and inducing a drop in pressure. A location of at least 4-5 latitude degrees from the Equator allows the Coriolis force to induce cyclonic wind circulation around low-pressure centres.

b) **Fully matured:** A spiral pattern of highly turbulent giant cumulus thundercloud bands forms the chief characteristic of a fully mature tropical cyclone. These bands form a dense highly active central cloud core that wraps around a relatively calm zone, called the **"eye"** of the cyclone.

c) **Weakening or decay:** Weakening of cyclone takes place when the source of warm moist air is abruptly cut off, i.e. when the cyclone hits the land, moves to a higher altitude or there is interference of another low pressure. On average, the life cycle of a cyclone is six days. However, it may last for less than 24 hours to more than 3 weeks.

Cyclone vulnerability of India

India is one of the most disaster-prone countries in the world. The Vulnerability Atlas of India depicts that out of the total geographical area, 54% of the landmass is prone to earthquakes, over 40 million hectares are prone to floods and about 8% of the total area is prone to cyclones. The coastal eco-system sustains a large portion of the population in India with a coastline of about 8041 km (the Arabian Sea on the west and Bay of Bengal on the east). In India, more than 10 million people live in nine coastal states, two union territories, and two groups of islands. 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 (92 severe) in a 50 km wide strip on the East Coast, which shows that the east coast is highly vulnerable. Less severe cyclonic activity has been noticed on the West Coast with 33 cyclones in the same period. In the north Indian Ocean, the average number of cyclones building is usually five in a year. Only one of the five emerges in the Arabian sea. However, in the past three-four years, the Arabian Sea seems to be competing as a cyclone generator with the Bay of Bengal. In 2018, while the Bay of Bengal maintained its average of four cyclones a year, the Arabian Sea generated three cyclonic storms. In 2019, 5 cyclonic storms were generated over the Arabian sea against the normal of 1 per year. In 2020, the Bay of Bengal produced three cyclonic storms while two were formed in the Arabian Sea. The history of cyclones arising in east and west in India has been depicted in Figures 1 a & b respectively.

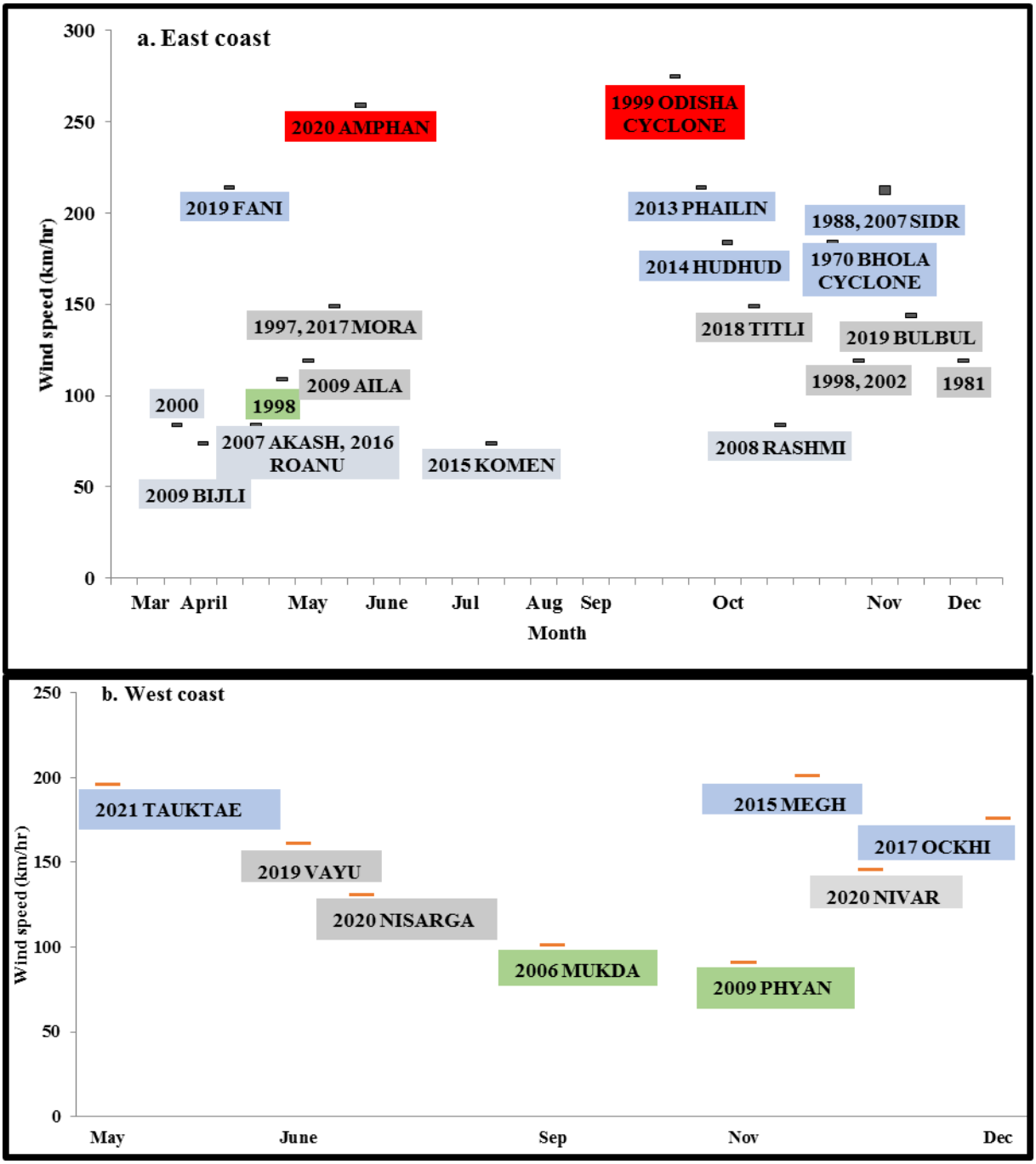

Fig. 1. Intensity and frequency of cyclone during different months in a. Eastern coast and b. West coast of India

CYCLONIC STORM (63-88 km/hr)
SEVERE CYCLONIC STORM (89-117 km/hr)
VERY SEVERE CYCLONIC STORM (118-165 km/hr)
EXTREMELY SEVERE CYCLONIC STORM (166-220 km/hr)
SUPER CYCLONIC STORM (>221 km/hr)

Mitigation strategies and Damage control

The steps for cyclone disaster management include prevention, mitigation, preparedness, response, and rehabilitation. The Disaster Management specialists are redesigning their approach by focusing on risk reduction and mitigation measures rather than only concentrating on post-disaster response (relief and reconstruction). A multi-pronged approach is necessary to combat cyclones and minimise the loss of life.

- ✓ **Warning:** The India Meteorological Department (IMD) is the nodal centre for wind detection, tracking, and forecasting cyclones. Cyclone tracking is done through the INSAT satellite based on which people are evacuated from areas likely to be affected. Accurate landfall predictions can give only a few hours' notice to threatened population. A cyclone warning is disseminated by several means such as satellite-based disaster warning systems, telephone, fax, high priority telegram, radio, television, public announcements, and bulletins in press. These warnings are spread among the general public, the fishing community, port authorities, commercial aviation, and government machinery. Response of the public to the warning in the form of correct precautionary action is vital to save lives and properties.
- ✓ **Hazard mapping:** 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. A hazard map suggests the cyclone vulnerable areas and will be useful to estimate the severity of the cyclone and various damage intensities in the region. The map is prepared with data inputs of past climatological records, history of wind speed, frequency of flooding, etc.
- ✓ **Land use control:** Policies should be in place to regulate land use such that the least critical activities are placed in vulnerable areas and settlements are avoided.
- ✓ **Engineered structures:** All elements holding the structures need to be properly anchored to resist the uplift or flying off of the objects. Also, river embankments should be protected and communication lines should be installed underground.
- ✓ **Coastal belt plantation:** Green belt plantation along the coastal line in a scientific interweaving pattern can reduce the effect of cyclone. Forests act as a wide buffer zone against strong winds and flash floods. The lack of protective forest cover allows water to inundate large areas and cause destruction.
- ✓ **Cyclone shelter development**: Where people do not have access to safe shelters within a range of 1.5 km, multi-purpose cyclone shelters may be constructed to ensure the physical safety of people and livestock.
- ✓ **Public Awareness**: The governments should initiate programs bringing awareness about the natural calamities and making provisions for higher local participation in the mitigation process. Besides, the public should be made aware of upcoming cyclones in advance through mass media.

Contingency crop planning

One of the preventive measures to alleviate the risk of cyclone is the need for contingency crop planning. Contingency planning can be defined as measures aimed at and executed for risk management when an exceptional risk is anticipated in the future. Contingency crop planning would certainly result in reducing crop loss and productivity in the event of cyclone/ flood, and forms the core component of prevention strategy. However, in the post cyclonic phase, advanced crop management interventions should form the main component and they should be adopted by the farmers on large scale to sustain productivity and quality of their crops. Low lying fields adjoining coastal regions may be severely inundated with saline water (up to 60 cm depths) making crop cultivation improbable in near future. All the engineering and cropping interventions fail to address the farming problems during the cyclone/flood season. However, when the flood water recedes

gradually, there is ample scope to implement alternate crop strategies if proper planning is done. Therefore, successful pre and post-flood management through contingency crop planning would be of paramount importance in enhancing crop productivity and ensuring the food security of our nation.

A. Long term crop management strategies for cyclone-prone regions

- **Creation of seed banks and community nurseries**: Cyclonic rainfall and waterlogging forces the farmer to delay field preparation and planting. Incessant rainfall and high wind velocity may damage the crop nursery, especially vegetables. Such situations can be addressed by the creation of seed banks and community nurseries. Seed banks can be housed in elevated shelter homes which can be used by the farmers immediately after receding of floodwater. People can create floating structures with lightweight planting media made of wood or coco-peat to raise small quantities of crops. This can overcome the short supply of vegetables during long spells of floods. High-quality seedlings for commercial basis can be cultivated in protected structures like poly-houses. Provisions should be made for supplying polythene sheets of appropriate thickness (50 to 100 µm) so that affected farmers can make low-cost poly houses for raising vegetable seedlings in advance. Creeper vegetables like watermelon, 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 or jute bags using fertile soil in poly houses.
- **Land modification technique**: Land modification techniques 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. 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. 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.
- **Bio-drainage plants**: Waterlogging in coastal region due to high and unusual rainfall during cyclone coupled with insufficient drainage leads to flooding in wider areas. Biological drainage by specific kinds of vegetation like *Casuarina* and eucalyptus is a promising tool to improve drainage situation. Bio-drainage plants help to reduce the water table at a faster rate and thereby, facilitate in growing the winter season crops like watermelon, black gram, ridge gourd, cucumber and cowpea. This allows intercrop cultivation and helps in the advanced planting of rabi crops resulting in higher water and land productivity.
- **Flood management by improving vegetative cover and developing shelterbelts:** Torrential rains, strong wind, and storm range lead to flooding and landslides in the cyclone-affected areas. The roots of the plants and trees keep the soil intact and prevent erosion. Shelterbelt plantations like *Casuarina*, eucalyptus, and acacia can be developed to break severe wind speeds and protect crops. To protect banana plant, a strong hedge may act as a windbreak. Besides, a strong structure with regular pruning and a strong root system through watering will reduce breakage and toppling. Promotion of natural seaside vegetation like mangroves should be done since their root system checks soil erosion. Species chosen for this purpose should not only be able to withstand the impact of strong cyclonic winds but also check soil erosion and give additional timber.
- **Crop diversification:** Crop characteristics such as lower height, stronger root system, tolerance to waterlogging and/or salinity, and lower pest profile are ideal in cyclone-prone areas. Traditional crops such as jute/sugarcane/maize may be intercropped with short-duration crops such as mungbean, vegetables, etc. for increasing climate resilience.
- **Use of soil ameliorants:** Coastal salinity due to intrusion of seawater as a result of cyclone affects crop productivity. Salinity tolerant varieties should be grown. Soil amelioration using organic manures like FYM, compost, and green manure helps in reducing soil salinity.
- **Participatory Water Resource Development, water harvesting structures, and drainage:** Water resources should be developed using a combination of recharge structures and open dug

wells. Subsurface water harvesting structures (SSWHS) are highly useful for coastal cyclone prone and waterlogged areas where freshwater floats above the saline water below ground. SSWHS has the potential to enhance water productivity by involving pisciculture and vegetables. Drainage system should be improved to reduce waterlogging, especially in standing crops. Ditches may be dug in the field at 10m intervals. To involve stakeholders in water resource development and management, Water Users Association has been formed to involve farmers in the creation and management of the irrigation facilities, inculcating a sense of ownership of the assets created.

- **Pond Based Integrated farming system:** Pond embankments can be used effectively to grow crops like coconut, arecanut, banana, and papaya along with vegetables like pumpkin, bitter gourd. Moringa and coconut crops on the embankments will provide long-term income. Fodder crops should be introduced on the inner and outer slopes to protect the ponds against erosion and to supply food to the livestock. Poultry may be introduced as an additional income source over the ponds, and their droppings may be utilized as the manure source for crop plants and feed for fishes in the pond. Besides, mushroom cultivation and compost preparation may be done with this which will prevent overall crop loss due to natural calamity.
- **Proper storage facility**: Covered threshing floor cum drying yard helps in preventing grain damage. Communities drying yards and polythene sheets to prevent grain from getting moist are possible options to prevent grain damage. Thus, a crop at the maturity stage should be harvested well in advance and kept in a storage area.

B. Crop advisory before a cyclone

- If standing paddy crop is 80% ripe, it should be cut and threshed immediately.
- Harvested paddy should be covered with polythene to prevent moisture.
- Standing sugarcane crop may be tied in a bunch to prevent wind damage.
- For standing crops like jute, proper provision of drainage should be done to prevent waterlogging. One of the corrective measures to be taken for water drainage is by digging a ditch of 25 cm deep and 20 cm wide at 10 m intervals in the field with a downward slope.
- Summer crops like mungbean, black gram, if at maturity stage should be harvested quickly and kept in proper storage areas instead of open yards.
- Irrigation, pesticide, fungicide spray should be temporarily stopped. Watering should be stopped four days ahead for allowing the roots to hold the soil and prevent it from getting uprooted.
- Plucking of ripe fruits like mango and vegetables needs to be done before the onset of inclement weather. Fruits close to getting ripe should be harvested without delay to reduce the tree's weight. For banana, removal of the canopy is best left to the latest practical time possible for a low category and physically small cyclone. Besides, farmers are advised to reduce the top weight of coconut palms by cutting off coconuts, tender coconuts, and old leaves ahead of storms to avoid uprooting the trees.
- Greenhouse and shadow hut cultivation sheds can be protected by fixing them to the ground with metal rods
- In the aftermath of the cyclone, chemicals like metalaxyl+mancozeb, tebuconazole, carbendazim should be kept prepared for preventing bacterial and fungal infestation,
- Livestock should be kept in a proper shed and food should be stocked for 4-5 days. The state government should sensitise fisherfolks about the upcoming cyclones

C. Post cyclone contingency measures:

- Post cyclone, arrangements should be made for providing seeds, fertilizers, plant protection chemicals, and farm machinery, if the planting season is immediate.
- Farmers should be assisted for the resumption of agricultural activities towards a normal agricultural calendar.
- In the case of waterlogging, fungicide spray may be done to reduce pest incidence due to high humidity.

- Weed may proliferate due to heavy rain or due to exposure of soil to sunlight due to canopy loss. Thus, weeding or herbicide application should be done to reduce competition with the recovering crop.
- Within 2 to 6 months of the cyclone hit, rehabilitation of damaged agricultural and other rural infrastructure and water supply, rehabilitation of damaged orchards, promotion of agro-forestry for firewood and timber needs to be completed.
- Flood protection dams should be constructed and on-farm water control structures should be developed. The practice of de-sanding, de-siltation, and land shaping will help in bringing a desirable shift in soil physical condition during post flood situations.
- Technology-based capacity development and training for affected farmers, livestock keepers, and fishermen are required to prepare for efficient agricultural production.
- Financial support for crop raising, harvest, and postharvest operations through zero or low-interest agricultural credit is needed.
- Livestock must be provided shelter and feed immediately. This should be followed by medicines, de-wormers, and vaccinations as per the situation. 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.

Future roadmap

Participatory process is an important requirement for the implementation of contingency plans as it creates awareness, sensitivity and capacity building of all stakeholders, leading to effective planning and implementation at the local level. Since data flows from districts to states and the Government of India regularly, aggregation of inputs requirement at the state and the national level becomes easy for planning and effective delivery. A computer-based Decision Support System could be evolved linking all districts in the country with respective states and at the national level so that the implementation can be monitored at the national level. Convergence of national programs dealing with soil health, water harvesting, watersheds, pressurized irrigation systems, irrigation plans, horticulture systems, tribal sub-plans, water mission, green climate fund, hill ecosystem, farm mechanization, livelihood programs, national mission for sustainable agriculture (NMSA), etc., is essential to manage weather variability. These programs consist of various technological interventions which result in resilient agricultural production systems if implemented coherently and timely. Remote sensing data and techniques along with GIS have proven their usefulness in disaster management plans especially in mapping the new situation after the disaster which helps in updating the geographical database. A communication network system helps in establishing contacts between relief teams which, with better central coordination, can work more efficiently. The strong coordination among the Ministry of Agriculture, Water Resources, Civil Supplies, Heath, Science and Technology, Indian Meteorological Department, Relief commissions of State governments, and Non-Governmental organizations would help in implementing cyclone and flood resilient agricultural systems. Thus, a healthy partnership should be developed between stakeholders at all levels - especially government, private sector, and the community to achieve sustainable mitigation strategies.

Conclusion

Cyclone management needs to be a multidisciplinary and proactive approach. For achieving our goal towards a safer country, we have to enhance the accuracy of disaster prevention, mitigation, and preparedness. We have to implement the potential agricultural and structural mitigation 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 the damage. Contingency measures may be categorized as preventive measures, post-cyclone management, and crop-based advisory. Natural

disasters like cyclones are inevitable and will be a more frequent phenomenon in the future due to climate change. However, a holistic approach employing advanced technologies, timely action, effective communication, and participation of all stakeholders is paramount for minimization of economic loss and swift rejuvenation of the system.