Disasters, Risk Management, Mitigation and Preparedness in Agriculture through Efficient Crop and Water Management

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Abstract

This study analyzed the impacts of natural disasters (particularly typhoons, floods and droughts) on agriculture, food security and the water resources and environment in India. It aimed to propose strategies to how best to respond to the impacts of natural disasters in agriculture. In general, the study found that droughts, floods and cyclones have an insignificant impact on overall agricultural production at the national level. Drought management strategies were emphasized through judicious use of surface and groundwater, selection of crops, cropping sequences and agronomic practices, ensuring availability of quality fodder to animals and proper livestock management, promotion of subsidiary income and employment-generating activities, gainful implementation of government schemes, deployment of information technology for gathering and disseminating information almost on real-time basis. Water management under irrigated and rain-fed ecosystem was also vividly discussed in this paper.

Keywords: Natural Disasters, Cyclones, Floods, Droughts, Agriculture, Water Resources.

Introduction

Disaster is defined as a "catastrophic situation in which the normal pattern of life or ecosystem has been disrupted and extraordinary emergency interventions are required to save and preserve lives and/or the environment".[2] "An event is classified as a disaster if at least 10 people are killed and/or 100 or more are affected and/or an appeal for international assistance is made or a state of emergency declared".[5] As per the United Nations, "a natural disaster is a serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the capacity of the affected society to cope using only its own resources". "A temporary event triggered by natural hazards that overwhelm local response capacity and seriously affect the social and economic development of a region is also a diaster".[1] As per Susman et al.,[7] a natural disaster is the interface between an extreme physical environment and a vulnerable human population.

India is one of the disaster-prone countries in the world. With its vast territory, large population and unique geo-climatic conditions, the sub-continent has experienced many extreme hazardous events that have turned into disasters. Floods, droughts, cyclones, earthquakes and landslides are recurrent phenomena in our country. According to vulnerability atlas of India produced by Building Materials and Technology Promotion Council (BMTPC), New Delhi, India, out of the total geographical area of 32,87,263 sq. km, over 40 million hectares are prone to floods and about 8% of the total area is prone to cyclones. Such extreme conditions and frequent disasters have greatly eroded developmental gains and caused loss of people's lives and properties. In this paper, a natural disaster mitigation plan in terms of drought, floods and cyclones has been discussed.

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Drought Management Plans

Drought is one of major disasters which occur in slow motion and almost every year in some part of the country. It is a temporary aberration unlike aridity, which is a permanent feature of climate and it is a normal, recurrent feature of climate and occurs in all climatic regimes and is usually characterized in terms of deficiency of rainfall, distribution of rainfall, spatial extension, intensity and duration. The frequency of droughts computed based on rainfall departures over the last 200 years indicated that maximum number of droughts was observed in Northwestern India followed by central parts of the country and the least in Northeast regions and in hilly regions.[8]

Many of the districts of the states located in east coast, are prone to drought/dry spells during the main crop growing season *Kharif*. Drought management should not be treated as an isolated problem but as an integral and key factor in sustainable agriculture. Farmers should be encouraged to develop a range of flexible contingency plans that protect the soil, climate and vegetation.

Drought Management Strategies

Drought management strategies largely depend upon the measures which include:

(i) Judicious use of surface and groundwater for drinking and irrigation.
(ii) Selection of crops, cropping sequences and agronomic practices for drought-affected areas.
(iii) Ensuring availability of quality fodder to animals and proper livestock management
(iv) Promotion of subsidiary income and employment-generating activities.
(v) Gainful implementation of government schemes like NREGA, RKVY, NFSM, NHM, RKVY, BRGF and other schemes.
(vi) Deployment of information technology for gathering and disseminating information almost on real-time basis.

Water Management under Irrigated Ecosystem in Case of Deficit Rainfall

Short Term

- **Efficient Irrigation Scheduling and Irrigation System**

i. Irrigation for sowing or transplanting of the crops and saving of the already sown/transplanted crops is the upper most consideration of contingency measures. Canal irrigation scheduling based on reservoir status has many possibilities and flexibilities to adjust or adapt with the rainfall pattern and deficiency.
ii. In case of rice, continuous standing of water is required only in the initial 15–20 days so as to suppress growth of weeds. However, later on, irrigating one day after disappearance of water is the most economical and efficient way of scheduling irrigation.
iii. Sowing of non-rice crops like maize, groundnut, etc., on the ridges and furrows and letting water in alternate furrows can save 20–30% water.
iv. Sprinklers for cereal crops and drip system for widely spaced crops sown in lines like vegetables, sugarcane, cotton, maize, etc., can give an efficiency of 80–90%.

- **Rescheduling of Irrigation Rosters**

Elaborate rosters are generally prepared by assuming normal rainfall and availability of discharge in the canal systems. However, during excessive rainfall deficit, rescheduling is called upon to optimum use of depleted water supplies and high demand. During deficit period, proper enforcement of modified operation system is required so that all farmers of a tail end get their share equitably and this will also result in overall higher production.

- **Renovation Work**

Desilting, repairing, renovation and construction of new conveyance system by utilizing opportunities under NREGA, BRGF, MPLAD funds, etc., may be undertaken.

Efficient Pumping System for Efficient Groundwater Utilization:

i) Efficiency of electric pumps is higher than the diesel pumps. However, because of the subsidized or free supply of electricity, farmers do not care for the efficiency of motors or pump-sets and look for cheaper options in the market. Since supply of power is getting limited year by year, farmers should be advised to go in for more efficient but relatively expensive pumping systems. After all they will be able to irrigate more areas for a given supply of electricity.
ii) Proper maintenance of motors and pumping sets to reduce friction by way of greasing and other maintenance should be advised for efficient pumping.

iii) Sharp bends and excessive height of the delivery pipes also yield less water.

- **Water Harvesting**

Harvested rainwater stored in unlined tanks and ponds should be used for pre-sowing or first irrigation to ensure uniform germination. Storing this water for later period will result into infiltration and evaporation losses.

Use of Poor Quality Water after Proper Treatment

As indicated earlier, about 375 BCM of water will be required for uses other than agriculture, i.e., domestic, industrial, power and others. Considerable proportion of this requirement is non-consumptive and is discharged with varying level of pollution. All these sectors through water use generate large amount of wastewater containing varying levels of contaminants, making them unfit for most of the uses. In the large peri-urban areas, such wastewater is used either without treatment or partial treatment for growing horticultural crops, with potential health hazard to farmers as well as consumers of those products. Similarly, fodder grown (to meet demand of livestock, another prominent activity in peri-urban areas) with wastewater increases the chance of entry of heavy metals and other undesirable substances into the food chain without knowledge of consumers. With water availability shrinking further, these instances are going to increase both in number and magnitude.

Presently, about 350 Class-I and Class-II urban centers having >50,000 population generate around 38,254 million liters per day (mld) wastewater out of which only 11,787 mld, (31%) get treated. It has been projected that wastewater generation will cross 170,000 mld (62 BCM) by 2051 in addition to 30 BCM wastewater generated per year (CSE 2004) from various industries. Recycling and reuse of this huge wastewater resource is a challenge for maintaining food security and restore health of the natural resources vis-à-vis the environment.

This component of operating environment has to be investigated to create a data base on wastewater amount and quality (segregating in four classes: marginally poor, poor, highly degraded, and unusable) to develop technologies for their reuse along with identification of sector where it can be used.

- The conventional treatment of industrial and municipal wastewater and its appropriate recycling can provide an additional source of nutrient-rich irrigation water for improving productivity of vegetable and other crops. This approach should be extensively tested by the soil scientists and agronomists for various soil types and cropping systems and where the potential exists, the policy and implications should be determined and steps taken to implement them.

Long-Term Measures

Canal Irrigated Areas

Assured irrigation in synergy with other technological and policy factors has played a catalytic role in the growth of Indian agriculture over the years. The contribution from irrigated agriculture is more than two-thirds to overall agricultural production. Because of the yield-augmenting impact, irrigation development has always been the priority area of national agricultural development strategy of the government with massive financial support. Consequently, the gross irrigated area in the country has increased and the positive impact of irrigation development was realized in the form of increased food grains production. However, the irrigation sector in the country is suffering from several pitfalls.

(i) The utilization of already-created irrigation potential is only 74% and the gap between irrigation potential created (IPC) and its utilization (IPU) is increasing over the years. For the country as a whole, about 88% of the ultimate irrigation potential (UIP) has already been developed through different major, medium and minor irrigation schemes, which limits further expansion of irrigation infrastructure at large scale. Though there are many factors which influence the utilization of created potential, the prime cause of underutilization is non-completion of field channels, land levelling and shaping, drainage channels, etc. Thus, land leveling and shaping, conservation agriculture will be helpful to utilize the created potential.

(iii) Most of the irrigation projects are operated at an overall efficiency of only about 30 to 35% against the achievable efficiency of 50% or more which might be due to poor maintenance, problems of equity, waterlogging, lag in potential created and utilized, etc., all leading to actual irrigation efficiencies being much less than the achievable values. Excessive losses in conveyance and distribution systems occur due to seepage through main canals, branches, distributaries, minors, water courses and field channels. It is observed that almost half of these losses occur in field channels. Thus, there is enormous scope to improve the

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productivity and efficiency of irrigation systems, which can be achieved both by technological as well as social interventions.

Lining of water courses reduces these losses to bare minimum and has found favor with the farmers of command areas. Lining of main canals may also be considered if losses are excessive or there is a threat of waterlogging and soil salinization. Where the groundwater can be exploited for irrigation, there is hardly any justification for lining as the farmer has better control over groundwater which adds to timeliness of water applications. Where groundwater is unfit for irrigation, seepage from canal network can play havoc with soil productivity.

(iv) Head-tail disparity and mismatch between water demand and canal water supply were found due to excessive upstream development. The cropping pattern may have changed from those for which the system was planned. Provision of auxiliary reservoir and multiple use of water, particularly at tail-end needs to be created to solve the problem. Multiple use of water will ensure higher water productivity.

(v) Most of the irrigation systems are today facing twin issues of sub-optimal sector planning and financial management on the one hand and inadequate maintenance of the system on the other hand. Efficient water management cannot be achieved unless the infrastructure for water conveyance and delivery system is in a reasonably good condition. Maintenance of irrigation system is generally neglected, which leads to weed growth, silting of canal system, breaches, etc. Situation in some cases is seen to be so precarious, that even the headworks and other regulatory structures start showing signs of distress. Infrastructure deterioration from inattentive and absent maintenance regime is one of the main reasons of wastage of water and lower value of irrigation efficiency.

(vi) Optimal allocation of available irrigation water among competing regions and crops is possible with the knowledge of water production functions of crops. At present, precise production functions are lacking and there is an urgent need to develop the same at least for important crops in different regions. Improper allocation of water undermines the equity aspect. For example, in Maharashtra, only 3% of total cropped area occupied by sugarcane is claiming 76% of irrigation water, while other crops are denied even lifesaving irrigation.

(vii) Efficient use of irrigation water requires that water be applied to growing crops at appropriate time and in adequate amount. Where sufficient water is available to fully meet the crop water requirements, irrigation must be applied before yield or quality-reducing stress occurs. Scheduling irrigation with limited water is a big challenge to agricultural scientists and needs rigorous research. Available information on simulation and optimization models can be used to develop optimal irrigation schedules to crops

(viii) The water rates being charged at present are low and the revenues are only a small fraction of the amount required for proper maintenance. This adversely affects the availability of resources with the state governments for proper and regular maintenance of irrigation systems. This consequently leads to deterioration of system and is responsible for the poor quality of services. Low water rates also encourage excess and wasteful use of water.

(ix) Other factors include poor communication facilities in the canal operation system, absence of control structures, etc. Large schemes are usually subject to large variations in water demand. While it may be raining in one part of the scheme, the other part may be dry. Besides, during each season, water requirements increase to reach a peak and then decrease depending on the type of crop grown and the locations. The present provisions in the system do not allow the canal flows to quickly adjust with the variations in water demand; some water, therefore, is lost in the process.

(x) In initial phase of irrigation development, thrust was on creation of irrigation infrastructure and no efforts were made for providing matching drainage facilities in the irrigation commands. This has resulted in problem of water logging and salinity in some of the irrigation commands. Seepage from conveyance system of irrigation projects, excessive application of irrigation water to crops, lack of conjunctive use of surface and ground water, poor on farm water management, deficient maintenance, etc., only added to the problem. Drainage has to be an integral part of the irrigation system, particularly when perennial irrigation is contemplated. Excess water in the root zone causes aeration stress in crops other than rice. This situation develops on fine-textured, low permeability soils after a heavy rain/irrigation or in waterlogged soils. Surface and sub-surface drainage has been shown to improve crop production.

(xi) In spite of the fact that there is an acute shortage of water, no concerted efforts have been made to improve water application techniques in the field and age-old irrigation practices continue to be in vogue. Most of the area in the country is irrigated by surface application

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methods such as basin, check basin, border strip, furrow irrigation, etc. Except for furrow irrigation, adoption of other methods practically means flooding of the irrigation fields resulting in substantial loss of water. This happens as fields are generally not properly levelled or provided with correct slope for quick flow of water from one end to the other. The application efficiency of these methods has been found to be only 30 to 50% as compared to attainable lever of 60 to 80%. Efficiencies are relatively better in furrow irrigation methods. Modern irrigation techniques like sprinkler and drip should be promoted where water is scarce, and the topographic and soil conditions do not permit efficient irrigation by conventional methods. Promotion of such water-saving devices should be an objective of the National Water Policy.

(xii) Consolidation of landholdings is essential to enthuse farmers to invest in irrigation system at the farm level.

(xiii) Another important factor leading to low value of efficiency is lack of involvement of beneficiaries. Farmers are real stake holders of water use. Though the process of formation of Water Users Associations (WUAs) and Participatory Irrigation Management (PIM) started in 1985, the beneficiaries are not involved sufficiently and effectively in the up-keep of the system and water management aspects. These works are considered to be the responsibility of irrigation department and is one of the important reasons of getting low efficiency of irrigation in many states. Water Users' Agency needs to be strengthened **and** farmers should be made partners in management of distribution system and distribution of water.

(xiv) There is a distinct lack of coordination among various agencies involved in development and management of water resources. Though lot of information might have been generated/collected by various agencies, there is no meaningful interaction and linkages between various agencies. The agencies involved in the extension services fail to translate the research findings to actual field. There is lack of mass awareness programs and farmers not realizing the scarcity of water continue to waste water.

(xv) Training and capacity building of irrigation water personnel should be more focused. Water and Land Management Institutions (WALMIs) have done a good job in training different levels of in-service staff of irrigation departments, and this activity should continue. Modern developments in the areas of crop sciences, physical sciences, computer sciences, social sciences, management sciences, operations research, etc., can be advantageously utilized in the teaching and training of professional staff in the areas of water resources management.

(xvi) A task force with multi-disciplinary team should be constituted to evaluate the performance of different irrigation systems to formulate plan for improving the irrigation efficiency by overcoming the existing mismatch between crop water requirement and supply of water because of rigid canal schedules. Procedures to ensure uniform supply to head-end and tail-end farmers by making compensation in time for the reduced tail-end discharge need to be devised. The impact of irrigation projects from the points of view of economic environment and equity needs to be assessed. Such a performance assessment system should be built into irrigation management practices. This will help to initiate timely mid-course corrections, when needed and keep the efficiency of the system high.

Groundwater Irrigated Areas

Presently, groundwater is the largest source of irrigation contributing about 60% of the net irrigated area of the country. Overall, only 58% of the total groundwater resources have been developed indicating scope for its further development. However, there exists wide variability in its development across different geographical regions of the country.

The over-exploitation of groundwater resources (higher withdrawal than recharge) in Northwestern states coexist with its under-utilization of the water abundant Eastern region. The tube well explosion in many pockets of the country has raised sustainability issues on groundwater resources. Most of the groundwater development has taken place through private investment. Further, government policies of providing free/ subsidized electricity and pumps in many states are adding fuel to water crisis. Reduced farm profitability via increasing pumping cost, deceleration in productivity of irrigation water and equity issues in groundwater distribution are also being considered as major challenges in this context. Groundwater pollution is another emerging threat to the sustainability of water resources. Therefore, an understanding of inter-relationship of hydro-geological, agro-climatic, socio, economic and policy factors for sustainable development and equitable distribution of this precious natural resources needs due emphasis.

Strategies

I. Supply Side (Augmentation of Ground Water Reservoir by Groundwater Recharge)

- Maximizing surface water for recharge
- Rejuvenation of traditional surface water bodies
- Exploring possibility for use of partially treated wastewaters for groundwater recharge
- Improving incentives for water conservation and artificial recharge

The artificial recharge of ground water needs to be undertaken in areas: 1. where ground water levels are declining on regular basis; 2. where substantial amount of aquifer has already been desaturated; 3. where availability of ground water is inadequate in lean months; and 4. where salinity ingress is taking place.

The artificial recharge techniques can be broadly categorized as follows:

Direct Surface Techniques

- Percolation tanks
- Flooding
- Stream augmentation
- Ditch and furrow system
- Over irrigation

Direct Sub-surface Techniques

- Recharge pits and shafts
- Injection wells or recharge wells
- Dug well recharge
- Bore hole flooding
- Natural openings, cavity fillings.

Combination Surface-Sub-surface Techniques

- Basin or percolation tanks with pit shaft or wells

Indirect Techniques

- Induced recharge from surface water source
- Aquifer modification

The existing village tanks which are normally silted and damaged can be modified to serve as recharge structure. In alluvial as well as hard rock areas, there are thousands of dug wells which have either gone dry or water levels have declined considerably. These dug wells can be used as structures to recharge. The ground water reservoir, storm water, tank water, canal water, etc., can be diverted into these structures to directly recharge the dried aquifer. By doing so, soil moisture losses during the normal process of artificial recharge, are reduced. In urban areas, the rooftop rainwater can be conserved and used for recharge of ground water. This approach requires connecting the outlet pipe from rooftop to divert the water to either existing wells/tube wells/bore wells or specially designed wells. The urban housing complexes or institutional buildings have large roof area and can be utilized for harvesting rooftop rainwater to recharge aquifer in urban areas.

Demand Side

- Promoting innovative techniques and uses such as; conjunctive use
- Promoting precision irrigation and water-saving crop production technologies
- System of pricing, aligning incentives for ground water use with goal of sustainability
- Need to create appropriate laws/regulatory mechanism
- Governance and prioritization of uses

Conjunctive use provides a greater control on timeliness of irrigation and should be encouraged by making adequate energy available to farmers at a reasonable cost. In order to ensure sustained availability of groundwater, average annual withdrawals should not exceed average annual recharge. Where fresh water is in short supply, groundwater of marginal quality could be advantageously used in combination with good quality water or for alternate irrigations. Recommendations concerning saline and sodic water developed by Indian scientists from field experiments are now available and should be used. Development of conjunctive use system requires knowledge regarding geology of groundwater basin and aquifers, hydrology of surface and groundwater, existing surface and groundwater facilities and storage and transmission characteristics of the basins. Although some efforts have been made in India to predict groundwater behavior using simulation and optimization models, these need to be strengthened.

Strong policy is needed to disseminate water-efficient agricultural practices like laser land leveling, conservation agriculture, short-duration rice varieties and to diversify cropping patterns, bed planting and alternate furrow irrigation, underground pipeline conveyance of irrigation water, appropriate tillage systems including resource conservation technologies and surface retention of crop residues for mulching, etc. Moreover, the practice of flood irrigation should be discouraged and priority incentive be given for micro-irrigation since the latter greatly enhances the water use efficiency. Such practices need to be extended through extension services so that large areas are covered within a reasonable time.

The Punjab Preservation of Sub-soil Water Act 2009 is an effort to conserve ground water resource by mandatory delay in the transplanting paddy beyond 10th June to escape periods of high evapo-transpiration demands. Analysis showed that implementation of the Act saved about 172 m kWh of electricity and about 7.2% of annual ground water draft. State of Haryana also passed a similar Act for the mandatory delay in transplanting rice. Gujarat government adopted another option to regulate the ground water use.

Rainfed Agriculture

Rainfed areas account for 61% of total cultivated area but contributed only 47% to total national food basket. But rainfed farming will remain the main stay for the livelihood support of millions of small and marginal farmers across the country. Under current practices, yield under irrigated agriculture almost reached a plateau and nearly 40% of total cultivated area of the country would remain rainfed even after achieving the ultimate irrigation potential.

Rainfed agriculture is complex, diverse and risk-prone and is mostly affected by climate change and variability of rainfall where productivity is still low. The challenge before Indian agriculture is to transform rainfed farming into more sustainable and productive systems and the potential areas need to be tapped like eastern India through scientific methods of sustainable management of natural resources particularly, water and soil supported by demand driven, appropriate forward-looking policy.

Rainwater management is the most critical component of rainfed farming. The successful production of rainfed crops largely depends on how efficiently soil moisture is conserved in situ or the surplus runoff is harvested, stored and recycled for supplemental irrigation. Different states have initiated special programs on farm ponds/small storage structures in order to ensure the sustainability and to improve the livelihoods of people. Despite these experiences, the adoption of farm ponds at the individual farm level has been very low, particularly for drought proofing through life saving irrigation of *Kharif* crops. A number of technological and socio-economic constraints are cited for this poor adoption and up-scaling. The rainfall extremes and high intensity rain events witnessed in recent years are likely to cause large spatial and temporal variations in the amount of surplus runoff available for harvesting. In some areas, there could be increased runoff and more potential for harvesting, while in other areas it might decrease. The cropped area falling under various ranges of rainfall in India are given in Table 1.

Table 1.Cropped Area Falling under Various Ranges of Rainfall in India

No.	Rainfall Ranges	Classification	Percentage
I	Less than 750 mm	Low rainfall	33
2	750 mm to 1125 mm	Medium rainfall	35
3	1126 mm to 2000 mm	High rainfall	24
4	Above 2000 mm	Very high rainfall	8

Short Term

i) **In-situ Rainwater Conservation:** In-situ methods like deep tillage, contour farming and ridging broad bed and furrow system and agronomic practices (use of farmyard manure, timely weeding and mulching are used to enhance water availability in the soil) would enhance the water storage in the soil profile by improving infiltration of harvested rainwater in the cultivated area.

ii) **Ex-situ Rainwater Conservation:** Runoff water is conserved in farm ponds and check dams outside of crop field which can be used during dry spell period.

iii) **Convergence of Dryland Technologies and Various Government Schemes:** Funds under Prime Minister Krishi Sinchayee Yojna (Watershed Development Component) (WDC-PMKSY) is a modified program of previous Drought Prone Areas Programme (DPAP), Desert Development Programme (DDP), Integrated Wastelands Development Programme (IWDP) of the department of Land Resources and Integrated Water Resources Management (IWRM) may be effectively utilized in drought-prone areas for regeneration of natural vegetation, creating/repairing of rain water harvesting structures, groundwater recharging facilities and to create facilities to prevent soil erosion.[4]

iv) **Improving Water Use Efficiency:** Encouraging farmers through subsidy at larger scale especially in drought-prone areas to go for micro-irrigation methods will be the key component for achieving water use efficiency.

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Contingency Cropping

Contingent Cropping

Selection of crops, cropping sequences and agronomic practices are very important. Relatively more drought tolerant, deep rooted and short duration crops, varieties and cultivars are available for different agro-ecological and rainfall situations. If the rain is excessively delayed or main crop has failed, cultivation or re-sowing with fodder is the best option. Fodders can be harvested at any stage keeping in view sowing of the next *Rabi* season crop.

To overcome these problems and counter the drought conditions in the region, contingency crop planning is needed, which will mitigate drought as well as ensure stable productivity of the region.

Situations	Crop and Water Management Options
Situation-1 Normal onset of southwest monsoon (10th June)	To increase the water productivity of rainfed area, rice in upland can be substituted with vegetable crops like brinjal, cowpea, bean, pumpkin, bitter gourd, ladies finger, cucumber during rainy *(Kharif* season. Intercropping through maize+cowpea, groundnut+pigeonpea can also be adopted by substituting rainfed upland rice. Some of the suitable varieties of vegetables in rainfed condition: Brinjal – Utkal Tarini, BB 49, BB 44, Pusa Kranti, Penthi; Okra – Utkal Gaurav, Baisali Vandhu, Arka Anamika; Sweet Potato – Samrat, Gouri, Sankar; Pumpkin – Guamal, Arka Suryamani, Arka Chandan; Chilli – Agnirekha, Sinduri, NP46A, *G-3* ; Bitter gourd – Pusa Domausumi, Arka Harit; Cowpea – Pusa Kamal, Pusa Dophasali For very traditional rice farmers, those who cannot afford to leave rice even in upland, partial substitution of rice through rice-based intercropping like rice+pigeonpea, rice+blackgram, rice+groundnut (4:1) is recommended. Based on rainfall analysis, 24th standard weeks (14th to 20th June) were found feasible for sowing of direct seeded upland crops of eastern India under normal monsoon. Off-season tillage (summer tillage) with pre-monsoon shower can be done in 19th–20th standard weeks for raising rice nurseries as well as to reduce the effects of pest, disease and weeds. Off-season tillage will recharge the soil profile and land can be prepared immediately on that land after onset of monsoon. Since during the Southwest monsoon months (June–September), 80% of rainfall occurs under normal condition, which may be harvested and recycled for raising second crops after rice specially in medium and lowland rice ecologies. Under normal monsoon condition, some of the suitable rice varieties for up, medium and lowlands are: Upland: Kalinga-II, Kalinga-III, Heera, Vandana, Anjali, Pathara Medium land: Lalat, Swarna, Masoori, Naveen. Low land: Savitri, Gayatri, Padmini, Moti, Mahalaxmi, Rajashree. Some of the suitable varieties of non-rice crop which can be adopted in rainfed upland by substituting rice are: Maize-Hybrids: Ganga-5, Daccan-l03, KH 510, KH-I01, MMH69 Maize Composites : Shakti-l, Novjyot Groundnut : TMV-2, Smruti, *AK-12-24,* JL 24, TAG 26, TAG 26, TAG 24, ICGA II Pigeon pea : UPAS-120, ICPL 151, T21, KPH-8 • Double cropping in upland can be done through maize-horse gram / sesamum rotation.
Situation-II: Delay in onset of monsoon (maximum 3–4 weeks from normal date)	**Crop and water management options** Shifting from traditional crops/varieties to short duration, low water requiring crops in upland, by substituting rice totally. Some of the suitable varieties of low water requiring crops which can be adopted in rainfed upland are: **Black gram** – T-9, PU-30, Sarada, Ujalaprasad

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	Green gram – *K-851,* Dhauli, PDM 54, PDM 11, ML5 **Horse gram** – Urmi, Madhu **Sesame** – Kanak, Kalika, Gujrat-1 The recommended dose of nitrogen application should be reduced by 40% and should be applied as basal and full-recommended dose of P and K should be placed as basal in delayed monsoon situation. The field should be free of weeds for utilization of water and nutrients by the late sown crops. Furrow sowing of *Kharif* crops at closure plant-to-plant distance with wider inter-row spacing is recommended. Frequent intercultural operations should be practiced to facilitate effect of loose soil as dust mulch. Use of bulky organic manures and summer ploughing will facilitate to recharge the soil profile quickly. Major emphasis should be given on in-situ rainwater conservation, harvesting excess runoff for its recycling to make provision for protective irrigation at later stage/crops. Seed treatment and proper plant protection measures should be taken to avoid any germination failure because sowing has already been delayed because of late onset of monsoon. In the event of late arrival of southwest monsoon the pulses like cowpea, blackgram, greengram can be grown upto last week of July in eastern India but pigeonpea, groundnut, maize are not recommended to be sown after 20th July. Castor can be successfully planted up to the last week of August. Planting of maize, cowpea, greengram, blackgram after first week of August can be done only for the purpose of fodder.
Situation-III: Normal onset but dry spell after sowing (Drought at early stage)	When sowing of crops is completed with normal onset of monsoon but dry spell occurs after 1–2 weeks of sowing for 2–3 weeks consecutively, raising community nurseries of rice is recommended for transplanted rice. Direct seeded rice is also damaged because of incidence of 'sprouting drought'. Re-sowing of direct seeded rice should be avoided till sufficient rains have been received. If sufficient good quality seed is not available, locally available seeds from adjoining areas should be used after proper germination check. In upland, non-rice low water requiring crops may be gap filled and re-sowed with subsequent rain rather than allowing sub-optimal poor plant stand to persist. Ridge and furrow land configuration technology may be adopted at 20 days after sowing as in-situ soil moisture conservation practices for non-rice upland crops. By replacing upland rice the legume-based intercropping systems like groundnut+pigeon pea, groundnut+black gram, groundnut+green gram, groundnut+cowpea in the ratio of 4:1 were proved profitable and sustainable in rainfed upland based on findings in farmers' field when drought occurs at early stage.
Situation-IV: Timely onset but early withdrawal by 15 Sept. (late season drought)	In this scenario, farmers will sow crops as per local recommended practices in different land ecologies due to normal onset of southwest monsoon. But early withdrawal of monsoon will affect the crop at reproductive stage. Development of ridge and furrow across the slope will be effective for soil moisture and rainwater conservation for direct seeded crops like maize, groundnut, pigeon pea, upland rice, black gram, green gram etc. to overcome late season drought. Use of locally available organic mulch material to conserve soil moisture is recommended. The practices of intercropping and multiple cropping minimize the risks of aberrant weather in upland. If fertilizers are to be applied, foliar application is recommended. Harvesting of crops like cowpea, maize, green gram, etc. for fodder purpose and harvesting of upland rice at physiological maturity when late season drought is anticipating. Fields should be leveled for uniform water distribution within the sub-plot.

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	Cover cropping like green gram; cowpea can be adopted to restrict the soil moisture loss from the field. Repeated intercultural operations and integrated weed management to make the land weed free is advised to farmers. Lowland rice will be at tillering to dough stage at the time of withdrawal of monsoon, so harvesting of excess runoff water during early monsoon period and utilizing it for protective irrigation will be effective.

Long Term

But with climate change posing a major challenge for rainfed agriculture and the constraints in further expansion of irrigated area in the country, rainwater harvesting and efficient water use are inevitable options to sustain rainfed agriculture in future. A number of technological and socio-economic constraints are cited for this poor adoption and up-scaling. For successful implementation of rainwater harvesting structure/farm ponds, following areas need urgent attention.

- What is the optimum size of farm pond and best design given the catchment area available under different rainfall zones, soil types farming situations?
- How can the capital cost of farm ponds be reduced through convergence of other developmental programs?
- What are the innovations in checking evaporative losses, cost effective sealants, water lifting devices for conveyance?
- What are the best options in terms of crop/farming system choices to realize the best returns from stored water?
- How to resolve the issue of sharing water in case of small holders where catchment and command area belong to different farmers?
- What are the on-site and off-site benefits including environmental pay-offs due to rain water-harvesting
- What are the indigenous techniques of rainwater harvesting which can help farm pond technology become more cost effective?

Besides above measures, renovation of old and silted ponds for water conservation as well as ground water recharge, and monitoring of the effectiveness of WHS (water harvesting structures) constructed under different watershed management programs will also be helpful to strengthen the rainwater conservation program of the country. Crop diversification with low water-requiring crops like pulses, oilseeds along with in situ soil moisture conservation. Several promising soil and water conservation measures for various rainfall zones in India are listed in Table 2.

Table 2.In-situ Soil and Water Conservation Measures for Various Rainfall Zones[8]

Seasonal Rainfall (mm)			
<500	500–700	750–1000	>1000
• Contour cultivation with conservation furrows • Ridging • Sowing across slopes • Mulching • Scoops • Tied ridges • Off-season tillage • Inter-row water harvesting • Small basins • Contour bunds • Field bunds	• Contour cultivation with conservation furrows • Ridging • Sowing across slopes • Scoops • Tide ridges • Mulching • Zingg terrace • Off-season tillage • Broad bed and furrow • Inter-row water harvesting • Small basins • Modified contour bunds • Field bunds	• Broad bed and furrow (Vertisol) • Conservation furrows • Sowing across slopes • Tillage • Lock and spill drains • Small basins • Field bunds • Vegetative bunds • Graded bunds • Zingg terrace	• Broad bed and furrow (Vertisol) • Field bunds • Vegetative bunds • Graded bunds • Level terraces

Some of the conservation practices listed above are temporary in nature and can be implemented by the farmers every year before the onset of monsoon, cost being nominal. Few measures such as contour and graded bunding, continuous, contour or staggered trenches, water harvesting structures and drainage line treatment are already covered under the Mahatma Gandhi National Rural Employment Guaranty Scheme (MGNREGS). Rainfed agriculture is complex, diverse and risk-prone and is mostly affected by climate change and

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variability of rainfall, so each rainfed farmers should be covered under Pradhan Mantri Fasal Bima Yojna. Some soil and water conservation program can also be linked with recently launched Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) where other ongoing schemes of the governments like Accelerated Irrigation Benefit Programme (AIBP) of the Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR), Integrated Watershed Management Programme (IWMP) of Department of Land Resources (DoLR) and the On Farm Water Management (OFWM) of Department of Agriculture and Cooperation (DAC) were merged.

The National Mission for Sustainable Agriculture (NMSA), which is one of the eight missions under the National Action Plan on Climate Change (NAPCC) also seeks to address issues regarding 'Sustainable Agriculture' in the context of risks associated with climate change by devising appropriate adaptation and mitigation strategies for ensuring food security, particularly in dry and rainfed areas, equitable access to food resources, enhancing livelihood opportunities and contributing to economic stability at the national level. The main interventions are in the areas of improved crop seeds, livestock and fish cultures, improving water use efficiency, soil health management, agricultural insurance, credit and market support and access to information.

National Food Security Mission (NFSM), Rainfed Area Development Programme (RADP), National Mission on Micro Irrigation (NMMI), Accelerated Pulses Development Programme (APDP), Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM), Bringing Green Revolution in Eastern India (BGREI) are some of the other important programs of the central government, which can be linked to provide boost to agriculture sector in rainfed areas.

National Mission for Sustainable Agriculture (NMSA) has also four major program components, e.g., rainfed area development, soil health management, on-farm water management and climate change and sustainable agricultural modeling and networking.

Cyclone Management Strategies

The cyclones that occur between the Tropics of Cancer and Capricorn are known as tropical cyclones. Tropical cyclones are weather systems in which winds equal or exceed gale force (minimum of 62 kmph). Indian sub-continent is the worst affected region of the world, having a coastline of 7516 km. (5400 km along the mainland, 132 km in Lakshadweep and 1900 km in Andaman and Nicobar Islands) is exposed to nearly 10% of the world's tropical cyclones. Of these, the majority has their initial genesis over the Bay of Bengal and strike the east coast of India. Cyclones are accompanied with destructive wind, storm surges and torrential rainfall. Four states (Tamil Nadu, Andhra Pradesh, Odisha and West Bengal) and one UT (Puducherry) on the east coast are highly vulnerable to cyclone disasters.

Management Plan before Cyclone

- Keep drainage channels clean in order to drain excess water due to high rainfall.
- Harvesting may be done in field/horticultural crops wherever the crops are in harvestable stage and keeping them in good storage condition/selling them in order to avoid huge loss due to cyclone.
- Getting updated information about cyclone and its associated impacts like high rainfall/wind speed from television/radio/newspaper is very essential.

Management Plan during Cyclone

- Make necessary arrangements to drain the excess rain water standing in the field.
- Get updated information about high rainfall due to cyclone, visit of evacuation/rescue team.

Management Plan after Cyclone

- Cleaning and removing debris from the field and planning for taking up new crop. Farmers may think of utilizing excess water available after cyclone/flood and utilizing them for multiplying income in order to compensate losses incurred by integrated farming systems involving livestock, fisheries and poultry, etc.

Long-Term Management Plan

- **Construction/Renovation of Canals and Embankments for Improved Drainage:** For effective drainage of water in the coastal areas, improving conditions of minor drainages like repair and reconstruction of damaged and other vulnerable flood embankments.

- **Shelter Belt Plantation:** 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.

- **Construction of Dams/ Hydroelectric Projects:** Construction of small/medium-scale dams to

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control and regulate river flow especially in West Bengal and Odisha and minor/check dam in Andhra Pradesh and Tamil Nadu in cyclone/flood-vulnerable sites is one of the long-term management plans for flood-prone areas. It also acts as irrigation source during lean/dry spell period in downstream areas.

Flood management strategies

The term 'flood' is a general or temporary condition of partial or complete inundation of normally dry land areas from overflow of inland or tidal waters or from the unusual and rapid accumulation or runoff of surface waters from any source. Floodwaters claim thousands of lives every year and render millions homeless. One of the more frightening things about flooding is that it can occur nearly anywhere, at any time. Floods may be caused by heavy rain associated with a storm, cyclone, or tropical storm or melt water from ice or snow flowing over ice sheets or snowfields.

Management Plan before Floods

- Keep drainage channels of farm clean and strengthen if any damage/repairs to be done.
- Construction/ restoration of check dams, embankments, field bonds/contour bunding before the onset of monsoon.
- In areas with greater gradient of slope, pucca water/drainage outlets are constructed to protect the farm land from breaking of bonds followed by soil erosion/sand cast during heavy downpours.
- Get updated news/information from newspapers/television/radio about flood situation.
- Promoting weather insurance programs like **Varsha Bima** for financial protection against heavy/excess rainfall-induced flood situation.

Management Plan during Floods

- Making arrangements to drain standing water from field.
- Get updated information about flood situation.

Management plans after floods

- Planning for effective utilizing excess water available after cyclone/flood for multiplying income in order to compensate losses incurred by integrated farming systems involving livestock, fisheries and poultry, etc.
- After receding of standing water from field, gap filling may be done in partially affected field. In fully affected field, farmers may think of re-sowing with short-duration paddy variety/other suitable crops.

Long-Term Management Plans

- Generally, flood prone areas are located nearby rivers and possess fairly high water table and this potential should be utilized to augment irrigation by tapping ground water through wells, shallow tube wells which have to be covered or sealed during the monsoon season when there is high flow in the rivers with consequent submergence.
- In flood-prone areas, strategy should be developed to retain some water in the natural depressions for providing lift irrigation during the *Rabi* season and during hot weather season should be considered.
- Construction of a number of smaller flood-retention reservoirs of suitable capacity near each river is necessary by excavation. This will serve to regulate the ferocity of flash floods down-stream of these reservoirs. The retained flood waters in various reservoirs can provide ample water supply during the dry season.
- Waterlogged and flood-prone areas represent 3.7 mha areas of eastern India. For successful utilization of accumulated flood water in agriculture purpose and to enhance the productivity of coastal belt, ICAR – IIWM has developed innovative technologies of crop and water management. Through pond-based farming system of proper design farmers can cultivate deep water rice, water logging tolerant medicinal plant like Bach (*Calamas*) vegetables on the dyke of the pond and fish inside the ponds during rainy season and salt tolerant vegetables such as ladies finger, water melon, chilly and spinach and boro rice during winter/dry season utilizing harvested water of rainy season inside the pond.

Conclusion

Natural disasters are on the rise and they continue to target the world's poorest and the least developed nations.

There must be greater investment in disaster reduction rather than high-profile response efforts.

Improved data on past disasters would help inform investment and policy decisions and thus help secure more appropriate levels and forms of disaster prevention, mitigation and preparedness.

It is important to develop mechanisms for more efficient assessment and documentation of

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