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Flash drought in Odisha- prediction, impact assessment, coping strategies: Current status and future strategies

R. K. PANDA[1]*, U. C. MOHANTY[1], SUBHAPRADA DASH[2] and CURIE PARHI[1]

[1]Centre for Climate Smart Agriculture, Siksha 'O' Anusandhan, Deemed to be University, Bhubaneswar-751030, Odisha
[2]Department of Agronomy, Faculty of Agricultural Sciences, Siksha 'O' Anusandhan, Deemed to be University, Bhubaneswar-751029, Odisha
**Corresponding author Email ID: rabindrapanda@soa.ac.in*

ABSTRACT

The short-term droughts (flash droughts) occurring due to the prolonged dry spells, heat waves, soil moisture deficits, which are caused due to the climate variability were analyzed for the indian conditions throught investivations of the outcomes of the past studies. Accurate prediction techniques used for flash drought (FD), assessment of its impact on agriculture and farmers' income as well as appropriate coping strategies recommended by different researchers to minimize the losses in crop yield and farmers' income were analyzed. The total loss in crop yield was found to increase with increase in land size; however, per acre loss was higher for smaller holdings. It was observed that the resource crunch small and marginal farmers particularly belonging to SC/ST were worst sufferers due to their inability to adopt appropriate coping strategies such as: crop insurance, short duration climate resilient cultivars, low-interest loans from financial institutions etc. It was inferred that the FD needs special attention particularly for the state of Odisha, where a majority of the population are engaged in agriculture and its allied activities. Agriculture accounts for around 30 per cent of the net state domestic product (NSDP). Investigations of the past studies revealed that the western Odisha regions are most vulnerable to climate change and variability and to the FD caused by the climate variability. The small and marginal tribal farmers of western Odisha whose sole source of income is from agriculture, with low affordability, are worst affected. To cope with these natural calamities, they need to adopt coping strategies namely, going for a variety of sources of income, cultivation of short-duration climate resilient varieties, in-situ rainwater conservation and use for life-saving irrigation, crop insurance, and low interest loans as well as low-cost post-harvest techniques for the perishable crop produce etc.

Key words: Agriculture, climate change, coping strategies, flash drought and impact assessment

Agriculture is the backbone of Indian economy, ensuring food and livelihood securities in a large scale. Drought, cyclone, flood and heat waves are some of the extreme weather events induced by the climate change and variability that have considerable adverse impact on health, agriculture and livelihood. The climate change and variability also have significant impact on field crops, in terms of reduction in yield and input efficiency (Pandey, 2023). These situations are exacerbating due to the ever-increasing population, with escalating demand for food and allied agricultural products. Droughts are natural phenomena having significant impact on agriculture, environment, water resources and socioeconomic systems. Drought is primarily caused by the prolonged deficiency in rainfall and soil moisture as well as high temperature and heat waves. The climate change and variability further trigger the occurrence and severity of drought (Overpeck, 2013; Brodribb *et al*., 2020; Naumann *et al*., 2021; Ault, 2020). Drought is generally perceived as a slow phenomenon. However, recent studies have indicated that droughts can also develop quite rapidly i.e. within a few days or in a week under unusually extreme atmospheric conditions such as: precipitation deficits and heat waves (Trenberth *et al*., 2014; Sheffield *et al*., 2012). The short-term drought may not have the same long-lasting impact as the prolonged drought but can still lead to water stress that affects agriculture, water availability and ecosystem. The short-term drought that develops and intensifies rapidly is termed as flash drought (FD). It is characterized by rapid and extreme soil moisture deficits and high temperatures that can have severe impact on crop growth and yield as well as water availability (Otkin *et al.*, 2018).

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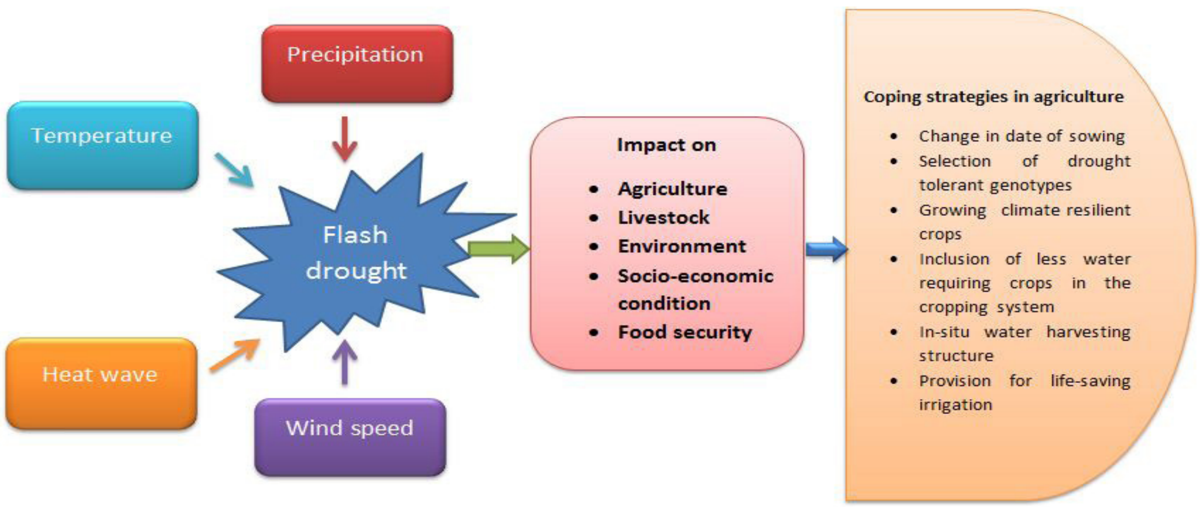

Fig. 1: Flowchart showing climate variables responsible for flash drought, its impact and coping strategies

Indian economy being agriculture based, accurate prediction, impact assessment and coping strategies pertaining to the flash drought and the agricultural drought are of prime importance to minimize the yield loss of major crops. Agricultural drought is the soil moisture deficit over a period of time restricting the normal growth of plants. It can result both from short-term and long-term drought conditions. The major impact of drought is in the form of declined productivity (Ciais *et al*., 2005), decrease in availability of surface water (Lotfirad *et al*., 2021; Radmanesh *et al*., 2022), decline in groundwater availability, reduction in productivity of hydropower (Van Vliet *et al*., 2016).

CLIMATE CHANGE AND VARIABILITY AND THEIR EFFECT ON AGRICULTURE

The global mean annual temperature may increase by 1^0 and 3^0C due to the change in climatic condition by the year 2025 and 2100, respectively (Gupta and Pathak, 2016). Along with the temperature, a significant variation is expected in the intensity and distribution of the rainfall in the coming decades. Moreover, the current estimates of change in climate also indicate an escalation in the concentration of the major greenhouse gases (Dash and Hunt, 2007).

The Indian Summer Monsoon Rainfall (ISMR) has prominent impact on agricultural production, water availability and food security (Wahl and Morrill, 2010). The interannual variability of ISMR has considerable impact on agricultural production, which accounts for about 22% of the Indian gross domestic product (Kumar *et al.*, 2010). Anomalies in the ISMR leads to substantial losses in crop yield and in turn affect the food security of the ever-growing population of India. Analysis of long-term gridded rainfall data (1900-2008) revealed that year to year variability of the average ISMR during the monsoon months of July through September over the entire Indian subcontinent is remarkably low, with a coefficient of variation of only 9%. However, these small variations have significant impact on the food production of the country (Mishra *et al*., 2012). Sampling fluctuations related to the intra-seasonal variability of the ISMR and specifically the cycling back and forth between active and break periods as well as the number and strength of monsoon depressions contribute to the year-to-year variability (Mishra *et al*., 2012)

The productivity and quality of the major cereals, pulses and oilseed crops are likely to be affected due to the rise in temperature (Pandey, 2023). The increase in atmospheric CO_2 concentration may lead to enhancement in the photosynthesis of the crop plants. A reduction in quality is also observed in case of vegetables, fruit crops, ornamental plants, medicinal and plantation crops due to the rise in temperature. The increased crop water demand severely affects the growth and development of the crops grown in rainfed areas without having assured irrigation facilities (Dharbale *et al*., 2019). Even in the irrigated areas, higher rate of evapotranspiration aggravates the situation by lowering the groundwater table. The insects, weed flora and pathogen population are noted to be shifting due to the aberrant weather condition, where minor pests become major ones. Similarly, the organic matter content and crop residues decomposition is also reduced, which affects the availability of nutrient in the soil and uptake by the plants (Malhi *et al*., 2021).

Mallya *et al*., (2016) analyzed the trends and variability of drought for the Indian monsoon region for the three epochs: 1901–1935, 1936– 1971 and 1972–2004. It was observed that the drought severity as well as frequency have an increasing trend during the recent past (1972–2004). It has been found that the regional nature of drought is more dominant and it has a shift towards agricultural belts of coastal south India, central Maharashtra and Indo-Gangetic plains which in turn will have significant impact on food security and socio-economic conditions of the habitats of these regions. A few studies were conducted in India recently to examine whether the trend and uncertainty associated with the summer monsoon rainfall in India is related to global warming or due to the regional changes (Kripalani *et al*., 2003; Mishra *et al*., 2012; Rupa Kumar *et al*., 2006; Chung and Ramanathan, 2006; Kishtawal *et al*., 2010; Niyogi *et al*., 2010). A good number of investigations by the researchers revealed that over the Indian Monsoon region (IMR) there is no change in the long-term mean precipitation. However, the extreme rainfall events have shown significant increasing trends during the last five decades, causing changes in characteristics of drought over the IMR (Rajeevan *et al*., 2008; Stephenson, 2001; Goswami *et al*., 2006; Mishra *et al*., 2012; Lunagaria *et al.,* 2015). Considerable regional variability has been observed in the Indian summer monsoon rainfall (ISMR). Some parts of India had shown an increasing trend of precipitation while some other regions had decreasing trend of precipitation during the summer monsoon season. (Guhathakurta and Rajeevan, 2008; Niyogi *et al*., 2010; Roxy *et al*., 2015). The influence of El Nino Southern Oscillation and global warming caused significant inter-annual, decadal and long-term trends in monsoon time series over the Indian Monsoon Regions (Niranjan Kumar *et al*., 2013)

The eastern India is more vulnerable towards extreme weather events. Odisha as an agrarian state, largely dependent on agriculture and its allied sectors, which are worst affected by the natural calamities like drought, cyclone and flood etc. Most of the farmers being small and marginal, their livelihood along with income is affected by the climate change and variability. Almost 27 districts of Odisha were impacted by drought in the year 2015-16. Due to the unpredictable monsoon, particularly western Odisha districts namely Kalahandi, Sundergarh and Nuapada are also becoming drought prone areas (Patel *et al*., 2019). The farmers of Nuapada district are forced to give up their livelihood due to continuous drought situation (Patel, 2018).

Drought caused by climatic variability

Accurate prediction of the extreme climate events such as: short-term drought and flood is of paramount importance under the recent climatic scenario as well as the associated anomalies in water resources which plays a key role in the planning and decision-making related to agricultural and allied activities (Belayneh *et al*., 2014; Sivakkumar *et al*., 2020).

Sixteen per cent of India's total area is drought prone and approximately, 50 million people are annually affected by droughts (Ray, 2014). Another study revealed that around 60 per cent of the net sown area of India are rainfed, hence significantly affected by extreme climatic events like short-term drought and flood which affects the agro-based economy of the country. This results in drastic decline in yield of major crops due to enhanced biotic and abiotic stress, which in turn reduces the income of the farmers. The climate change and variability further aggravate this situation. These adversities are likely to force the farmers to change their occupation from farming to non-agricultural sectors and may even force them to migrate to other regions in search of opportunities, which is detrimental in the national interest. This study also indicated the Odisha condition, in particular the small and marginal farmers of the state (Arora and Birwal, 2017).

As a consequence of climate change and variability, resulting in frequent occurrence and erratic distribution of high rainfall events and dry spells; short-term as well as long-term drought are being observed frequently. Erratic precipitation as well as water scarcity are the drivers of the meteorological and agricultural droughts, which are more prominent at small regional scales. It has been established that a supervised classification of drought severity using long-term precipitation data mainly depends on the accuracy of the drought indices. The performance of the six commonly used drought indices were critically evaluated for four districts of Tamil Nadu encompassing arid, semi-arid, sub-humid and humid climatic conditions based on 120 years of rainfall data. The study revealed that the Standardized Precipitation Index (SPI) and China Z Index (CZI) provided similar quantification of drought events (about 18% of the total months) irrespective of their climatic considerations while Z-Score Index (ZSI) and Rainfall Anomaly Index (RAI) resulted in overestimation of drought severity (about 30–47%) (Sridhara *et al.,* 2021; Natarajan *et al*., 2023).

ASSESSMENT OF IMPACT OF FLASH DROUGHT ON AGRICULTURE

Flash Drought (FD) is a short-term drought event, characterized by precipitation deficits and rapid progression of heat waves and the resulting soil moisture deficit. Improper understanding of the physical processes of formation of FD is also responsible for the compromise in the accuracy of prediction of FD by different methods. Flash Droughts develop rapidly and have significant impact on agriculture (Tyagi *et al*., 2022). Flash drought (FD) has also severe impacts on water resources availability. Otkin *et al*. (2018) reported that FD results in quick depletion of soil moisture leading to stress in crop. Flash drought is also termed as agricultural drought due to its impact on soil moisture and crop stress. Soil moisture is therefore used as an indicator for FD (Yuan *et al*., 2019, Pendergrass *et al*., 2020).

Deficit precipitation triggers the occurrence and severity of flash drought (FD) (Mo and Lettenmaier, 2016; Yuan *et al*., 2018). FD is also induced by the high temperature and heat wave conditions known as heat wave-FD (Mo and Lettenmaier, 2015). The flash droughts can vary spatially and temporally over the seasons. Subtropical or temperate regions of the world experience flash droughts all through the year.

Flash drought can have significant impact on *Kharif* crops in India due to the fact that flash drought occurs during monsoon season only, thereby having significant impact on crop yield and water availability. The *Kharif* season is an important crop growing season, when rice and maize are grown in major part of India. Deficiency in rainfall and soil moisture during FD results in significant loss in potential yield of rice and maize (Davis *et al*., 2018; Kayatz *et al*., 2019). Analysis of long-term (1951-2018) data revealed that during the monsoon season FD affected on an average 21.5% of the area under rice and maize cultivation in India. It has also been observed that flash droughts can be in a small scale at a local level to a regional level; which may affect significantly the crop production and water management in India. Thus, increased frequency of FD during the monsoon season will affect the crop production and water availability in India considerably, particularly in eastern India including Odisha where the small and marginal farmers mostly depend on the rainfed rice crop (Mahto and Mishra, 2020).

Rice is predominantly grown in Odisha during the *kharif* season. Majority of the rice are grown under rainfed situation, where the uncertainty of monsoon plays a vital role in the growth and development of rice. Abnormality in the south-west monsoon is the primary cause of occurrence of drought in India as well as in Odisha. Late arrival of monsoon in *kharif* season, delay the land preparation for upland crops and the nursery bed preparation, which in turn affects the crop establishment and seedling growth at the initial stage. The high yielding varieties commonly grown in the state are susceptible to extreme weather conditions. Significant yield reduction is observed in rice due to the soil moisture stress and heat stress. The insect pest load along with pathogen and weed infestation are more under the drought situation and the beneficial crop plants are found to be vulnerable to their infestation. In this regard, the shift in weed flora, disease and insect occurrence plays a vital role in controlling the pest. Similarly, flash drought induces various physiological and bio-chemical changes in the plant body, which leads to potential yield reduction in major field crops (Gautam and Bana, 2014).

Drought assessment and monitoring are being done by using different indices and satellite imagery. Based on the assessment, early warning systems are also developed to manage the drought beforehand. The high-resolution data on green vegetation are analyzed for drought assessment on spatio-temporal basis. Among the drought indices, soil moisture index, evapotranspiration index, precipitation and evaporation index are generally used for analyzing the data. However, flash drought intensity index, flash drought stress index, rapid change index and quick drought response index are used to assess the FD. For early detection, the quick drought response index has been used (Rakkasagi *et al*., 2023).

FDs are characterized and identified by two different methodologies i.e. Standardized evaporative stress ratio (Hunt *et al*., 2009) and root zone soil moisture (Yuan, *et al*., 2019; Zhang *et al*., 2019). The standardized evaporative stress ratio is calculated on a 5-day scale by using the concept of evaporative stress ration (actual and potential ET ratio). Whereas, the root zone soil moisture methodology primarily deals with the rapid decline in root zone soil moisture and dry persistency (Mukherjee and Mishra, 2022). Now-a-days artificial intelligence and machine learning are also used to monitor, predict and forecast FD.

COPING STRATEGIES TO MINIMIZE THE LOSS OF YIELD OF MAJOR FIELD CROPS

A study conducted in the north-west Bangladesh revealed that to cope with the adverse effects of droughts on agriculture, additional source of irrigation like shallow and deep tubewells and cultivation of drought tolerant genotypes suitable for the region could be the strategies. The socio-economic and other influential factors also need to be considered while selecting the strategies for coping with the drought. Necessary measures in line with these strategies will therefore enable the farmers to cope with the adverse effect to minimize the losses (Mardy *et al*., 2018).

A study was conducted in the rural areas in the district of Multan, Punjab in Pakistan to assess the impact of extreme weather events on farmers' income and efficacy of coping strategies to minimize the losses. The coping strategies adopted are: cultivating new crop cultivars, low input crops, adopting intercropping system, rearing of animals, use of better-quality seed, appropriate working hours, financial support through low interest loans, support services, migration and change-over to non-agricultural activities. The regression analysis indicated that family size, drought and frequency of high rainfall has detrimental effect on farm income. Whereas income from non-farm activities, mechanization, information on forecasted weather, farm size, and education has conducive impact on the farm income. Adoption of appropriate rainwater water management, conservation and use of natural resources are quite useful to adapt with the adversity of extreme weather events. Other technological interventions like updated early-warning-systems can enhance the preparedness and reduce the risk to some extent (Hussain *et al*., 2020).

A detailed study was conducted in Odisha using primary survey data collected from 400 households from a large number of drought and flood affected villages in Odisha. The study assessed the adverse impact of droughts in terms of crop loss for different land sizes and social status of farmers. The total loss was found to increase with increase in land size; however, per acre loss was higher for smaller holdings. The farmers having large farms were able to cope with these disasters adopting appropriate strategies like crop insurance, short duration cultivars, availing loans from financial institutions etc. On the other hand, due to lack of affordability, the farmers with small holdings, particularly belonging to SC/ST were unable to adopt these coping strategies and were compelled either to leave farming occupation for other activities, sell arable land or migrate to other locations in search of opportunities. Government intervention may be desirable to find additional source of income and handholding for the farmers to compensate their economic loss (Arora and Birwal, 2017).

A majority of the population of Odisha are engaged in agriculture and its allied activities. Agriculture accounts for around 30 per cent of the net state domestic product (NSDP). The climatic conditions of Odisha are favourable for cultivation of a large variety of crops such as: rice, oil seeds, pulses, coconut, sugarcane, and turmeric etc. Rice is the major food crop of Odisha which accounts for about 53 per cent of cropped area (Arora and Birwal, 2017). An intensive study was taken up with multi-stage sampling approach used to design a large number of household survey samples. In the first stage, three drought prone districts in Odisha, namely, Dhenkanal, Cuttack and Jagatsinghpur were considered. The Drought Prone Area Programme (DPAP) of the Govt. of India has been adopted in 8 districts of Odisha including Dhenkanal (Arora and Birwal, 2017). It was revealed that farmers having large land holding are able to mitigate drought through different coping strategies such as: use of groundwater for irrigation of crops, and switching over to short duration varieties incurring relatively high investment to save the loss in crop yield. On the other hand, the small and marginal farmers with limited affordability are unable to prevent major crop failures. Odisha faces natural calamities like droughts and floods quite frequently. A majority of population of the state being below the poverty line, are more vulnerable to natural disasters. This is due to low affordability of small, resource-poor farmers to invest on coping strategies like crop insurance and short-duration cultivars. It was also observed that rate of loss per acre by farmers belonging to the scheduled caste and tribe (SC/ST) community there is much higher than the farmers having large landholding. To cope with these natural calamities, the tribal farmers in particular have adopted certain coping strategies, namely going for a variety of sources of income, cultivation of short-duration genotypes, strategies to minimize the risk of crop failure like crop insurance, and low interest loans and adoption of low-cost post-harvest techniques for the perishable crop produce etc. (Arora and Birwal, 2017).

CONCLUSIONS AND RECOMMENDATIONS

A detailed review of the available literature was done on the studies conducted by various researchers on climate change and variability particularly for the Indian sub-continent having a typical monsoon climate and the consequent short-term droughts (flash droughts) caused due to the extreme weather events were also investigated. Accurate prediction techniques used for flash drought (FD), assessment of its impact on agriculture and farmers' income as well as appropriate coping strategies recommended by different researchers to minimize the losses in crop yield and farmers' income were analyzed. The total loss was found to increase with increase in land size; however, per acre loss was higher for smaller holdings. The farmers having large farms were able to cope with these disasters adopting appropriate strategies like crop insurance, short duration climate resilient cultivars, availing loans from financial institutions etc. On the other hand, due to lack of affordability, the farmers with small holdings, particularly belonging to SC/ST were unable to adopt these coping strategies and were compelled either to leave farming for other activities, sell arable land or migrate to other locations in search of opportunities. Government intervention may be desirable to find additional source of income and handholding for the farmers to compensate for their economic loss.

The FD needs special attention particularly for the state of Odisha. A majority of the population of Odisha are engaged in agriculture and its allied activities. Agriculture accounts for around 30 per cent of the net state domestic product (NSDP). Rice is the major food crop of Odisha which accounts for about 53 per cent of cropped area. Investigations of the past studies revealed that the western Odisha regions are most vulnerable to climate change and variability and the FD caused due to the climate variability. The resources crunch small and marginal tribal farmers of western Odisha whose sole source of income is from agriculture and its allied activities are worst affected. To cope with these natural calamities, they need to adopt certain coping strategies, namely going for a variety of sources of income, cultivation of short-duration climate resilient varieties, in-situ rainwater conservation and use for life-saving irrigation, crop insurance, and low interest loans as well as low-cost post-harvest techniques for the perishable crop produce etc.

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