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Impact of Extreme Weather and Climate Events on Farmers: A review

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Abstract
This paper discusses extreme weather and climate events in two dimensions----first, extremes of atmospheric weather and climate factors (temperature, precipitation, and wind); Second, it impacts the natural physical environment (droughts, floods) on farms. In the systematic review, 162 papers from the years January 2000 to December 2023 were included. Africa and Asia had the most studies conducted, respectively. There has been a notable rise in the frequency of heavy precipitation events globally and more prolonged and intense droughts in West Africa. Many farmers reported that these changes are significant enough to stress crop plants, resulting in decreased growth and production, especially in highly weather-sensitive crops. Studies in Africa concluded that large reservoirs are the only reliable water source in drought. A negligible number of studies in Asia and Africa identified that the local population of farmers was unaware of institutional efforts to address waterlogging.

Keywords: Weather; climate change; temperature; precipitation

1. Introduction:

The variation in weather is a challenge for agriculture. As per the agriculture census 2015-16, marginal and small farmers account for 86 percent of total farmers in India. The increasing extreme weather events and financial loss have dampened farmers' optimism. The sudden increase in temperature, especially when crops are maturing, led to a drop in production, especially wheat and rice, which are the main cash crops. Heavy or incessant rainfall when a crop such as a paddy is ready to harvest incurred losses among farmers and increases the input cost of anti-pesticide sprays, which further causes loss of income (Singh et al., 2019). There is an increase in rainfall in Haryana and Punjab (82 percent and 30 percent, respectively) after 1945. Annual average crop losses due to extreme weather events are estimated to result in losses of approximately 0.25 percent of total GDP (Singh et al., 2019). The debt burden is instigating farmers to commit suicide (Carleton, 2017). Farmers are the primary practitioners of adaptation action to mitigate the adverse impact of climate on a production system.

The government has conducted field- trials of 177 varieties for climate extremes like floods and droughts, heat waves, etc, which the Indian Council of Agriculture Research and State agriculture universities develops. A district contingency plan (DACP) was also formulated for 650 districts to mitigate the impact of weather-related challenges. Despite these efforts, there are limited measures to absorb the shocks of extreme weather events. It needs improvement in different fields, such as rural infrastructure, crop diversification, and sustainable farming. An intensive study to prevent financial loss in agriculture caused by extreme weather events and to protect marginal and small farmers is essential.

Most of the studies across the globe focus on climate change and variability (Shaffril et al., 2018; Karki et al., 2020;

Aryal et al., 2020; Shaffril et al., 2020), but the extreme weather events and losses incurred due to these events are not documented much. Adaptation actions are significant in tackling the impact of climate change (Bahinipati et al., 2021). Still, the change in agricultural practices due to extreme weather events is not the prime focus of the study. The present study attempts to fill the gap by exploring farmers' understanding of extreme weather events and adaptation based on their perception.

2. **Literature Review**

There are three subsections of the literature review. The first subsection discusses the past literature on extreme weather events and how they are conceptualized in the context of agriculture. The following subsection revisits various conceptualizations of adaptive capacity. The last subsection describes the objective of the present study.

(1) Extreme Weather Events

According to the World Meteorological Organization, "An extreme weather event is rare at a particular place and time of year, with unusual characteristics in magnitude, location, timing, or extent. The characteristics of extreme weather may vary from place to place in an absolute sense."

The Intergovernmental Panel on Climate Change (IPCC) defines extreme weather events (EWE) as "as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations" (IPCC, 2012). IPCC also confirmed that climate change affects extreme weather events' intensity and frequency (Smith, 2011).

(2) Farmers' perception of extreme weather events

The literature has contrasting views regarding farmers' perceptions of climate change. Studies focus on understanding farmers' awareness and experience of climate change and variability, such as increases in temperature and precipitation (Dang et al., 2019). Studies also highlighted the adverse consequences, such as climate change's impact on income and agricultural production (Harvey et al., 2018; Skoufias et al., 2011). Several literatures estimate the effects of flood and drought (Wang et al., 2020; Powell & Reinhard, 2016). Studies on the perception of risk have identified several factors that shape farmers' perception of climate change, such as socio-demographic characteristics (Huda et al., 2016; Ameztegui et al., 2018; van der Linden, 2015); socio-cultural factors (McCarthy et al., 2014; Schneider et al., 2017); personal experience with extreme weather events (Akerlof et al., 2013; Spence et al., 2011); and cognitive dimension on climate change such as person's knowledge (Kabir et al., 2016); perceptions of their peers and other people like access to extension services (Gbetibouo 2009; Silvestri et al., 2012); proximity (adversity like disaster or climate change occurring in distant areas rather than local events) (Silvestri et al., 2012). Although all the factors are significant predictors of risk perception in climate change, previous experience of climate change is mainly the focus of study in many studies (Bubeck et al., 2013; Tekeli-Yeşil., 2010; Lawrence et al., 2014). Several studies have indicated that personal experience significantly predicts climate change risk perceptions. For example, in Sweden, previous experience has a strong influence on risk perception (Ohman et al., 2017); the residents have a lesser level of risk perception and preparedness in the absence of their direct experience of earthquakes and tsunamis in Bangladesh (Alam, 2016); the emergency experiences increase perceived risk in Germany (Knuth et al., 2014). The negative consequence of climate change and its impact has an impression on the memory of farmers and strongly influences their perception of risk (Weber, 2006). Farmers observe climatic parameter changes, which sustains their perceptual experience (Joireman et al., 2010; Akerlof et al., 2013). However, the locus of understanding is farmers' opinions on climate change and its impact. With this holistic and integrative approach, it is difficult to understand how farmers view extreme weather events and change their agricultural practices.

III. Extreme weather events and adaptation

To reduce the impact of changing climatic conditions, farmers prepare and adopt measures based on their experience, which has a positive effect (Becker et al., 2018; Lindell et al., 2009), while other studies show there is no significant adaptation and change despite experience and perception (Osberghaus, 2015; Hwang, 2008). There is a disaggregating view in the literature regarding farmers' perceptions based on experience, which will lead to adaptation. To protect crops and stabilize agricultural productivity, adaptation is crucial to climate change (Asfaw et al., 2016). Thus, farmer's adaptation to climate change is not based on changes in temperature and precipitation but on the onset of rainfall, rainfall cessation, windstorm, rainy season, drought/dry spells, and oscillations (Ayanlade et al., 2017); air temperature, precipitation, tropical cyclones, and sea level rise (Dubey et al., 2017); the prevalence of droughts, floods, increased temperature and changes in growing season (Kemausuor et al., 2011) is also significant. Farmers' perception is also based on observations regarding changes in rainfall, frequency, intensity, and duration of droughts (Mamba, 2016) and changes in extreme heat and rainfall trends and wind (Mertz et al., 2009). However, most studies interviewed how farmers perceived climate trends through the impacts on their activities and farm productivity. Therefore, through a thorough review of previous literature, the study's objectives are (1) to understand farmers' perception of extreme weather events, (2) to identify changes in agricultural practices due to these extreme weather events, and (3) to recommend measures that can help the policymakers to tackle extreme weather-related issues. With the help of a systematic review, this study provides an overview of farmers' perceptions of extreme weather events. It identifies the area in the current literature to recommend further study for the practitioner.

3. Method.

In this study, we use a systematic review method to find the published research to date on the impact of on farmers perception of extreme weather and its impact in the agriculture sector (Fig. 2) using PRISMA (preferred reporting items for systematic reviews and meta-analyses) criteria.). Using the search string TITLE ("Extreme weather events" * or "climate variability" and "farmers perception *" or "adaptation" and "agriculture" or "farm" *) and Abstract ("Extreme weather events" * or "climate variability" and "farmers perception *" or "adaptation" and "agriculture" or "farm" *), we searched the Scopus and EBSCO discovery service from 2010 to 2023. Table 1 contains inclusion and exclusion criteria for document selection and personalised search tactics for every database.

Table 1: **Inclusion and exclusion criteria for document selection**

Inclusion criteria	**Exclusion criteria**
Phase 1: Keyword search	
English	Non-English
1 January 2010- 31 December 2023	Pre-2010 or after 31 December 2023
Indexed in the EBSCO Discovery Service and Clarivate Web of Science	Not available via EBSCO Discovery Service and Clarivate Web of Science
Peer-reviewed articles published in journals	Books, book chapters, Conference papers, dissertation/thesis, and others (e.g., Editorials, Meetings, Abstracts)
Online available journals	Articles available in print
Phase 2: Title & abstract review *(full-text review)*	
Studies based on ground reality and empirical findings	Conceptual/Theoretical focus
Environmental and Social sciences	Meteorology atmospheric sciences, public environmental, occupational health, Green sustainable science technology, multidisciplinary science
Selection of documents that focus on farmers' perception and awareness. The terms 'perception,' 'awareness, and 'extreme weather events' must be present or implied in the article's title, topic, or abstract.	Perception related to aquaculture/scales of governance /dairy and livestock farmers/ adaptation decision, food security and pest/disease/gender/ mitigation/ tourism/health/water management/climate education/conservation agriculture, resilience, and vulnerability to climate change is not included in the list.
Climate variability and extreme weather events	Climate modeling and impacts of climate change

Through the Scopus search, we derived 914 articles using the Scopus search (Abstract and Title) under the "Title" category, 729 papers from the EBSCO discovery service, and, under the "Abstract" category, 282 documents. 605 articles in the Title and 215 papers in the Abstract were kept after the paper was repeatedly searched on the EBSCO Discovery Service and removed. In Scopus, 710 were found, with an additional 46 in the Abstract. The articles overlapping in Scopus and EBSCO Discovery Service were removed. The remaining articles have 141 titles and 10 abstracts in the EBSCO Discovery Service and 298 in Scopus. Those articles (Fig.1) that fulfilled the above criteria were included and downloaded for 113 papers (61 papers from Scopus), 42 (Title), and 10 (abstract) from EBSCO Discovery Service)

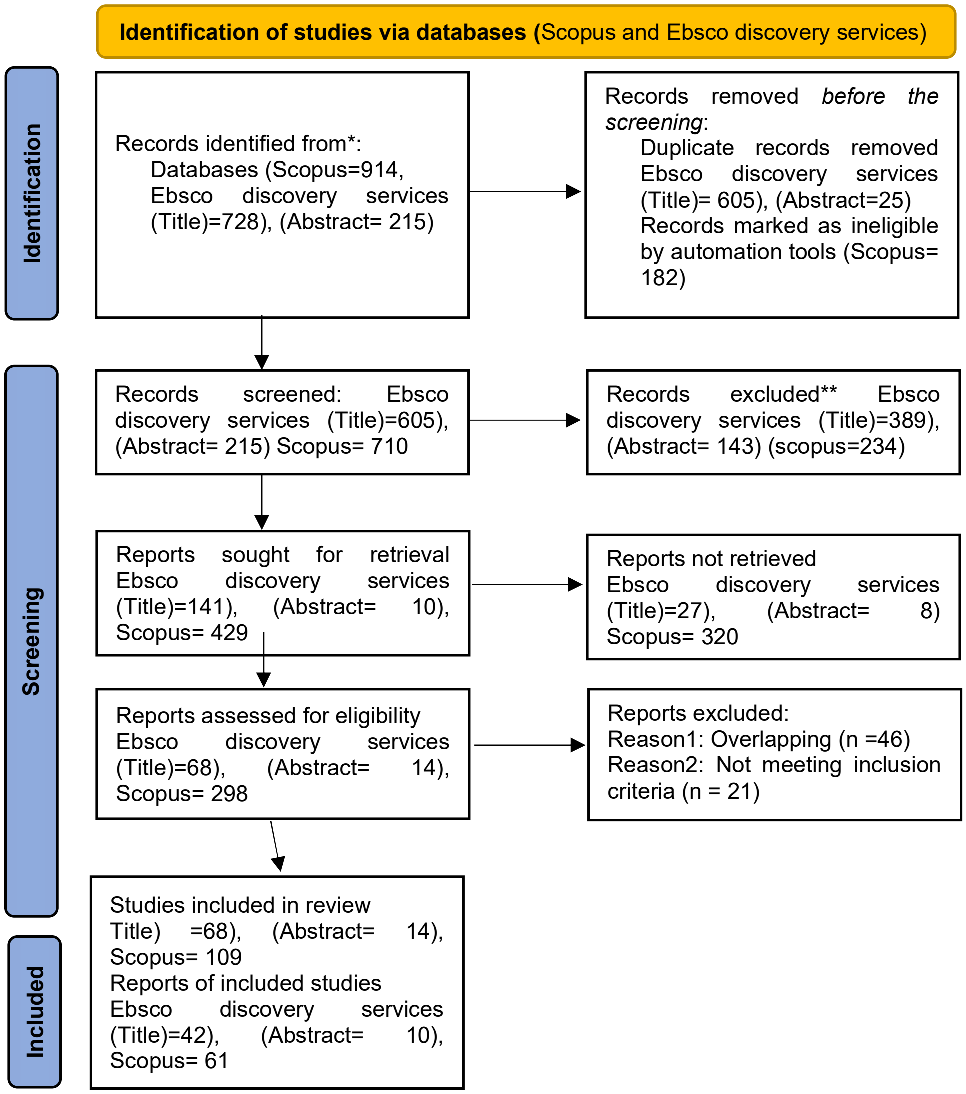


Fig. 2. **Screening and selection process, adapted from PRISMA flowchart** (Page et al., 2021)

4. Results

4.1. General information on the reviewed papers

The search period was fixed from January 2000 to December 2023. Secondly, only peer-reviewed and electronically available journal articles published in English are selected. This means that articles in other languages, such as books, book chapters, conference papers, dissertations/theses, and magazines, were not included. A list of documents enlisted in excluded articles is provided in the Supplemental Materials.

4.2. Farmers' perception of Extreme weather events –

This section analyzes the farmer's perception of an increase or decrease in temperature and precipitation, flood, drought, frost and freezes, storm, heatwaves, and speed (Fig. 2).

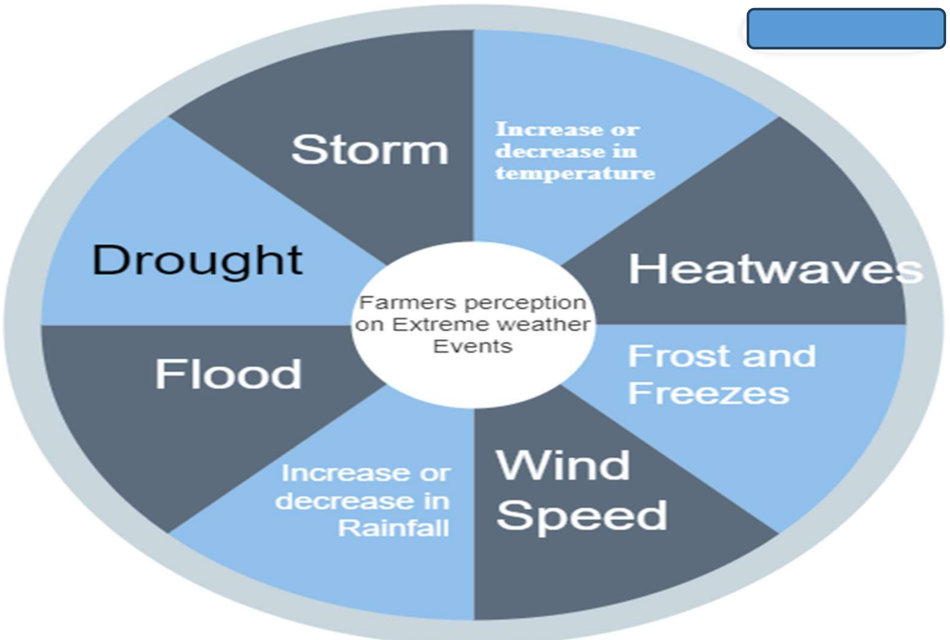


Fig 2: Farmers perception regarding different extreme weather events identified in literature

The majority of farmers reported a temperature rise (29.65 percent). Farmers perceived increased summer (10.26 percent) and hot days (5.2 percent). However, a few farmers also reported an increase in winter temperature (4.5 percent). Farmers were also concerned about a decrease in winter duration. Few studies reported no change or reduction in winter temperature (3.2 percent)

In most studies (73.5 percent), farmers reported a decrease in rainfall, and few studies (12.4 percent) reported farmers' perception of change in the onset and cessation of rains (Nyadzi et al., 2019). This might be due to the misconception that climate change leads to increased rainfall and decreased temperature. The late start of the monsoon is elicited by a few studies, mainly from India (6.5 percent). Besides increase, decrease, or no change in precipitation, other parameters are significantly less highlighted in studies (4.2 percent): erratic rainfall and irregular rain and a reduction of the number of rainy days (2.1 percent). Studies also analyzed the increase in annual rainfall in quantity and distribution during the rainy season. Farmers realize more information is required on the occurrence of extreme weather events in terms of onset and cessation of the rain season, number of rain days, and rainfall intensity (Kalanda-Joshua et al., 2011).

Flood or flooding means covering by water of land that is not usually covered by water (European Commission, 2007). The review highlights a recent increase in flood risk (52.3 percent). The floods affect countries like Germany, France, India, Bangladesh, China, and Vietnam. Farmers stressed the importance of extreme weather events like floods (Breuer et al., 2008; Cliffe et al., 2016). Few studies (6.1 percent) have also highlighted that farmers receive incorrect information about extreme flooding (Ebhuoma, 2020).

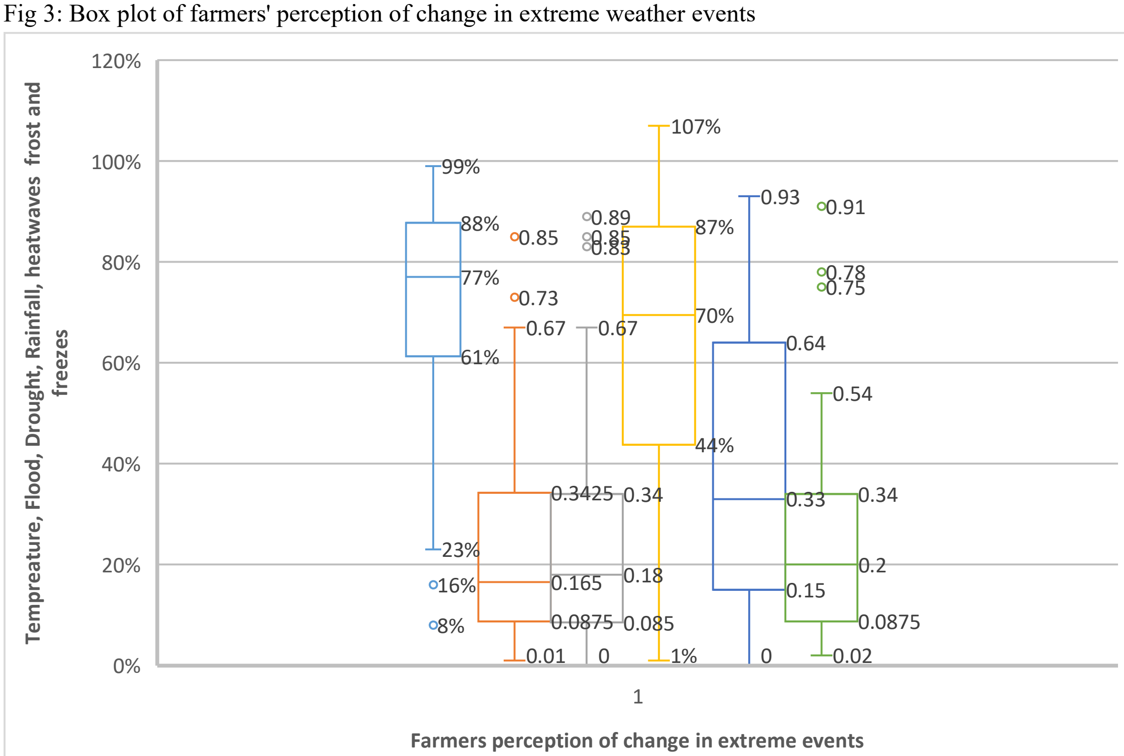
In the majority of studies (86.7 percent), farmers judged drought as an important extreme event that majorly led to a loss in productivity (Letson et al., 2001; Guido et al., 2019; Ewbank et al., 2019; Furman et al., 2015). A substantial number of studies (43.8 percent) also emphasized that drought meant complete crop failure, which is not intended by the government as a forecast predictor (Pennesi et al., 2013). Farmers are more considerate in using drought-tolerant varieties instead of growing high-yielding crops (Crane et al., 2010). Famers experience losses in extreme drought years if the underlying year is an El Nino (drought) year (Makaudze et al., 2015). In Australia, extreme wet or dry weather forecasts delivered economic gains of up to AUD 150 and 260 ha^{-1} per annum, respectively. In the study of

An-Vo D.-A (2019), interviewees stressed the importance of extreme weather events such as storms, dry weather, frosts, freezes, and hail in Florida, USA (Breuer et al., 2008). Similarly, in the study of Choi et al. (2015), farmers consider adverse climate as extreme climate, e.g., dry weather and heat waves, favorable climate as optimal weather conditions for the growing season, and the rest as average climate. In the study, Furman et al. (2015) emphasized that tailored and credible climate services can empower farmers, equipping them to safeguard their operations from the adverse effects of dry weather.

A substantial number of studies (54.2 percent) also highlighted that the varied characteristics of prolonged dry weather influenced different stages of a crop's growth cycle and corresponding field management practices (Ford et al., 2015; Yamamoto et al., 2014; Sugiyama et al., 2014). Besides drought, another primary concern elicited in the studies is estimating the impact of heat waves and dry weather. For example, Kuwayama et al. (2018) found that dry weather negatively affects corn and soybean yield. The projected increase in the frequency of extreme weather events and associated economic losses necessitate adaptive responses that enable farmers to prevent and mitigate the losses (Walsh et al., 2014; Wang et al., 2020). However, studies do not clarify how farmers perceive a change in heat waves over the years and on what scale (frequency, intensity, and duration) it has impacted crop yield.

Limited studies (12.2 percent) analyze farmers' perceptions of frost and freeze (Meldrum et al., 2018; Breuer et al., 2008; Camacho & Conover, 2019). A limited number of studies (0.93 percent) have shown that farmers are concerned about information that affects their long-term decisions, like late frost, which can negatively affect crop growth. Farmers, especially wheat producers, emphasized getting the freeze and frost information in advance (Klopper et al., 2006). Very few studies (0.64 percent) stressed the impact of the strong winds. Farmers perceived strong winds destroy small and large plants (Jagtap et al., 2002). Studies mainly in India focussed on wind speed and direction and how it led to agricultural losses (Kaur & Singh, 2022). A few studies (0.34 percent) analyze farmers' perception of storms and cyclones and the necessary operations to overcome the impact of these barely discussed extreme weather events (Vedeld et al., 2020; Singh Rana et al., 2013; Maini & Rathor, 2011).

Fig 3: Box plot of farmers' perception of change in extreme weather events



4.3. Adaptation from extreme weather events

The following section deals with the change in agricultural practices due to extreme weather events—different conceptualizations of adaptation in agriculture to tackle the impact and loss related to climate change. Most studies (8.1 percent) have specified adaptations such as changes in crop timing, crop diversification, soil conservation, and irrigation. Studies have highlighted that farmers change the planting time (91.2 percent) due to changes in the onset of monsoon. Studies also elicit that the most likely used strategies would be a change of planting date (88.2 percent), change of crop acreage (71 percent), no-tillage/reduced tillage (62 percent), 21 percent for cover crops, change of crop variety (62.9 percent), change of crops planted (42.8 percent), and increase of fertilizer (31.9 percent), and crop allocation. It is common for farmers to modify their management strategies tactically based on information they deem pertinent to the future crop's prospects (Ouedraogo et al., 2018). A limited number of studies (11.7 percent) analyzed those farmers, conserved soil moisture, started to build bunds, mulching, water-storing, and management for irrigation due to an increase in temperature (Negi et al., 2018; Funk et al., 2023).

A few studies (19.5 percent) also highlighted that increased drought incidence enhanced no-tillage/reduced tillage and crop diversification (Etumnu et al., 2023). To combat the impact of drought, farmers are shifting towards conservation practices. Studies elicit that to decrease loss in crop yield due to less rainfall, farmers opt for conservation tillage and crop rotation (Ding et al., 2009; Saak et al., 2021; Wang et al., 2021).

There are contrasting views in the literature. Few studies have shown that crop cover is essential for water management. At the same time, other studies also consider that farmers judge crop cover as a less critical measure to cope with drought (Kaspar & Singer, 2011). The lowest number of studies identify that although cash crops are favorable to face the impact of extreme weather events, they are not cost-effective (Herzberger, 2019). In more than 42 percent of studies, farmers modified their crops. They preferred it above expanding the area for drought-resistant farming, altering planting dates, planting later than usual, modifying pest control techniques, and adding more fertilizer. Decision-making was aided by greater availability of early warning systems, predictions, and guidance on drought resilience. In the study of Ewbank et al. (2019) over 70 percent of farmers made decisions sooner than usual. However, these adaptation methods may not be beneficial in dealing with flooding. Researchers have different opinions on using tillage and conservation practices in case of a flood. This might be due to location change. Studies found that adopting a tillage system and conservation practices is not beneficial (Ding et al., 2009; Antolini et al., 2020; Murtada, 2019) and claimed crop cover could be more important in controlling flood losses than another method. Other studies consider that conservation practices can effectively tackle flood-related loss (Tyler et al., 2021; Antolini et al., 2020; Schilling et al., 2014; Dakhlalla).

A considerable number of studies (42.3 percent) attempt to estimate the impact of heat waves on crop production (Elahi et al., 2022 Chung et al., 2014; Zampieri et al., 2017; Frimpong et al., 2015) and the magnitude and spatial patterns of the growing heat exposure (Tigchelaar et al., 2020). Studies also elicit changes in agricultural practices due to increased heatwaves (Changnon et al., 2003) and farmer views and decisions related to heatwaves (Lane et al., 2018; Dhanya & Ramachandran, 2016).

The effects of rising temperatures and changing rainfall patterns brought on by climate change can be lessened by irrigation. According to farmers, accurate and timely weather-based agro-advisory communications assisted them in making well-informed decisions regarding the usage of inputs, which resulted in savings on irrigation and lower costs for other inputs like fertilizer and pesticides (Mittal, 2016). Most of the research under this theme focused on regions where rice, wheat, maize fruits, and vegetables are farmed.

1.1 5. Conclusions

This study examined how farmers perceived extreme weather events, such as changes in temperature and precipitation patterns, drought, flood, heatwaves, wind speed, storms, frost, and freezes. From the review, it is clear that the maximum number of studies reported changes in temperature, decrease in rainfall, on-set and cessation of rainfall, and rainfall patterns. Several studies that focussed on disasters mentioned floods and droughts. Limited studies focus on heatwaves and storms, while few studies highlight the farmer's concerns regarding frost freezes and wind speed.

Studies have not clarified how they have posed questions regarding extreme weather events to farmers or how farmers, based on their perception, ranked extreme weather events based on their impact.

Most studies highlight that farmers adopt different adaptation methods to tackle extreme weather events. Besides a few studies, in most studies, researchers are not clear which adaptation method applies to which condition. Studies confirm that farmers change their planting dates and crop diversification to deal with the uncertainty of rainfall and temperature. No-tillage or reduction in tillage is applicable in drought conditions, but few studies have identified that this method is not essential for flooding.

Farmers' perception and adaptation to rapidly changing climatic conditions are considered crucial policy measures to address the challenges of heatwaves in agriculture. Farmers' awareness and knowledge are essential policy interventions to adapt climate action and measures to cope with the effect of extreme weather events on agriculture. Instead of assessing the impact of extreme weather events, events-specific studies can inform choices about assessing and managing the risk and guide adaptation strategies. This information is crucial for multiple decision-makers focussed on disaster risk reduction.

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