

Orange Grower's Perception of Drought Impacts and Strategies for Mitigation and Adaptation: A Study of the Vidarbha Region in India

Abstract

Vidarbha, a region in Maharashtra, India, is famous for its sweet-sour-flavoured Nagpur Orange. Vidarbha is witnessing droughts after every alternate year resulting in crop failure and causing distress to orange growers. The present study attempts to – 1) identify critical challenges Vidarbha orange growers face during drought impact and 2) examine the farmers' perception and awareness about drought impacts, and different adaptation and mitigation strategies in practice at the farmer's level. This research used a field study approach in the drought-prone Vidarbha region to acquire orange farmers' perceptions of the drought impact. We have used a three-stage method to carry out this study. In the first stage, a Delphi method is adopted to identify and validate orange growers' challenges due to drought impact. The second stage comprises utilising multi-criteria decision-making (MCDM)-based best-worst method to prioritise and determine the most critical challenges. This is followed by descriptive statistical analysis in the third stage to determine the overall perception of orange growers about drought and its adaptation and mitigation strategies. It is observed through findings that – *"inadequate water bodies*, *lack of availability of capital*, and *high cost of drip irrigation"* are critical challenges orange growers witness during drought. While *"installing an efficient irrigation system* and *pest control"* are the adaptation strategies, and *"seeking guidance from the agriculture department"* and *"reliance on weather forecast"* are the mitigation strategies widely adopted by Nagpur orange growers to alleviate drought stress.

Keywords – Drought; Vidarbha; Orange Growers; Delphi; Best-Worst Method; Adaptation and Mitigation strategies

Orange Grower's Perception of Drought Impacts and the Mitigation and Adaptation Strategies: A Study of the Vidarbha Region in India

1 Introduction

Drought is a complex climatic phenomenon that occurs due to insufficient rainfall over an extended period of time [1]. It results in a water shortage for living, farming, and other essential activities, directly impacting livelihoods and creating drought stress in society [2]. It reduces farmers' income from agricultural production and livestock (due to livestock mortality) and adversely affects livestock health, fertility and productivity [1,3,4]. Further, it creates food insecurity, drinking water shortages, mental and physical health issues, migration for work, accumulation of debt, etc. [5]. Climate change, including its impact on drought, is one of the key reasons for reduced levels of global agricultural production, which, in turn, causes food security concerns [6].

India is considered the global powerhouse of the agriculture sector [7], contributing 20.2% to the country's GDP [8], with around 54.6% of the population engaged in agriculture and allied activities [9]. The excessive rise in the temperature and unanticipated rainfall have reduced crop yields and agricultural production in India [10]. India is vulnerable to climate change risks because of its population, diversified culture, and per capita demand for food [11,12]. According to the *India Meteorological Department*, when the rainfall drops below 75% of the normal climatological level (i.e., 25% reduction in rainfall), it is termed a meteorological drought [13]. India has witnessed a prolonged drought with increasing frequency every year since the 1990s [14,15]. Indeed, it has faced droughts at least once every three years and is considered one of the most susceptible and drought-prone countries globally. Drought impacts and their severity vary from region to region. As a result, the farmers' perceptions of droughts, their impact, and adaption and mitigation vary across regions. Our study is on orange growers' perception of drought impacts, and the setting is the Vidarbha Region in the eastern part of Maharashtra in India.

The Vidarbha region comprises eleven districts with an overall area of around 97,950 km^2. The temperature ranges from a maximum of 48°C in summer to a minimum of 12°C in winter. It falls under the semi-arid climatic zone, and around 93% of the net cultivable agricultural land primarily depends on rain-fed water [16]; over 65% of the population depends on this rain-fed agriculture and its allied activities [17]. The average rainfall of this region was 705.1mm, while

India received about 1180 mm annually [13]. However, in the last 15 years, the conditions have been devastating. Vidarbha region observed unprecedented El-Niño years due to drought episodes in 2002, 2004, and 2009. Since 2012, the conditions have deteriorated to the most vulnerable drought status [18]. After this event, drought is observed every alternate year, making the situation even worse [15,18]. In 2021, Vidarbha received 631 mm of rain compared to the normal index of 705.1 mm, implying an 11% deficit in the normal rainfall level. The worst-hit areas are Amravati (25% deficit), Gadchiroli (22% deficit), Gondiya (21% deficit), Bhandara and Buldhana (15% deficit) each [19]. Figure 1 highlights the overall % rainfall deficit in Vidarbha region. These conditions directly impact and reduce Vidarbha's agricultural production, making the region *"the worst place in the nation to be a farmer"* [15].

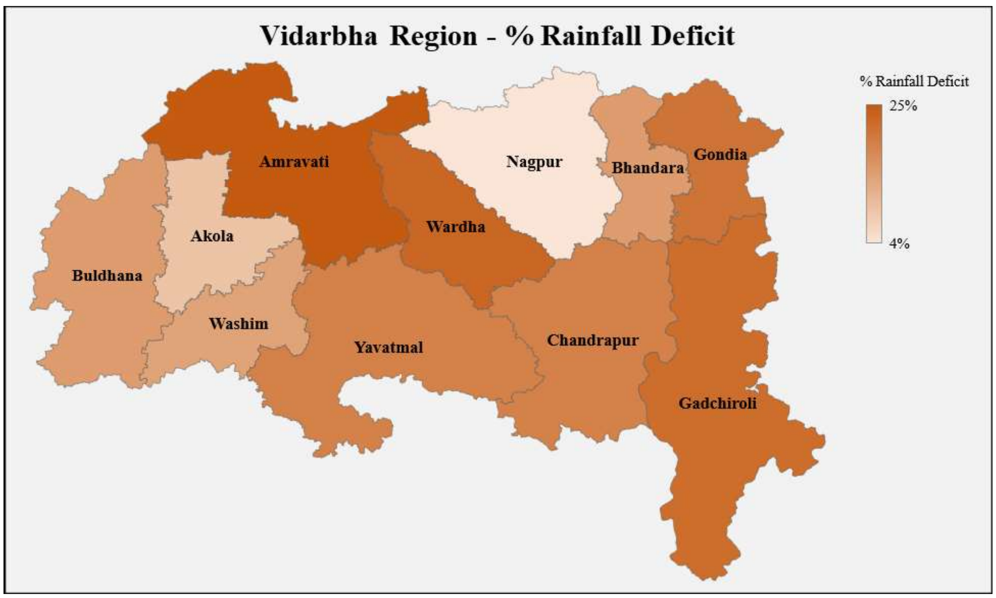

Figure 1. % Rainfall deficit in Vidarbha region [19].

The Vidarbha region is popularly known for its sweet-sour-flavoured *Nagpur Orange.* Orange is a perennial crop with a long orchard life. However, drought conditions restrict the growth, yield of oranges and lead to significant financial loss to the growers. The importance of this region in India's orange cultivation ecosystem can be appreciated from the following facts and figures. Mandarin orange (*Citrus reticulata*), known as *Santra*, is India's most popular citrus fruit, with nearly 40% of the citrus-cultivated area occupied by oranges. India ranks 9th among the top orange-producing countries in the world and contributes 3% to the total orange production globally. It is among the 15 largest exporters of oranges, exporting to over 30 countries, resulting in foreign exchange earnings of USD 17.34 million [20]. Maharashtra is the largest producer of oranges in India. The major growing belts in Maharashtra are – Nagpur, Amaravati, Wardha, Buldhana, and Akola, which fall under the Vidarbha region. Nagpur

Santara has received a GI (geographical indication) tag [21] and it's cultivation covers about 45,226 ha area in Vidarbha [22]. The allocation of the GI tag to Nagpur Santra was expected to benefit growers in terms of profitability and return on investment (ROI). However, due to the uncertainties, including – climate change effects, such as – excessive temperature increases over the years, ever-happening droughts, and heavy and untimely rainfall (in some locations of Vidarbha) [17,22], the orange growers are facing difficulties in gaining the ROI for their produce. Hence, it is crucial to study the supply chain (farm to market) of perishable goods like mandarins in the context of climate change threats in Maharashtra and the Vidarbha region in particular.

The Vidarbha region has predominantly observed drought conditions over the years due to the continuously increasing temperature [15]. Due to the lack of water, it is becoming difficult for the Vidarbha's orange growers to manage their yields, resulting in distressed situations. Due to these drought conditions, the production of oranges in the Vidarbha region has declined by approximately 50% – 70% between 2017 and 2019, which has resulted in substantial economic loss to the orange growers [22–25]. In 2019, the never-seen-before drought in Vidarbha resulted in the failure of around 60% of the orange orchards that cost over ₹ 15 million [25]. The orange growers try to cope with these climatic droughts and maintain their orchards. Some growers expect financial aid from the Government. However, from the trend of orange production in Vidarbha, it is evident that the efforts are not producing the desired results.

We carried out a literature review and analysis of the existing studies to extract the challenges that citrus/orange growers face due to droughts and the adaptation and mitigation strategies orange growers adopt to alleviate these challenges. Table 1 lists existing studies, their main objective and the methodology employed. Table 2 presents the list of mitigation and adaptation strategies adopted by orange growers which are synthesised from the literature. We further identified 11 significant challenges from the literature (included in Appendix 1 of the supplementary file).

Table 1. List of existing studies highlighting the problems faced by orange growers

Study Objective	**Methodology**	**References**
To determine the suitable climate change adaptation strategies (CCAS) and evaluate the impact of CCAS on the production efficiency of citrus farmers.	Mathematical model - Data Envelope Analysis and the Stochastic Frontier Model	(Joseph et al., 2021) [26]
Identify the critical problems faced by orange growers of Madhya Pradesh (India) in the production, processing, and marketing activities.	Descriptive Statistics	(Saryam and Jirli, 2020) [27]

Study Objective	Methodology	References
Evaluate the impact of drought and heat stress-sequence, intensity, and duration over *Cleopatra mandarin*.	Statistical - ANOVA	(Zandalinas et al., 2018) [28]
Provide policy recommendations to make food production systems resilient and less vulnerable.	Conceptual	(Keppen and Dutcher, 2015) [29]
Assess crop water stress index of *mandarin orange* and *navel orange* grown in Southern Spain, considering canopy temperature.	Statistical – Correlation and Regression	(Gonzalez-Dugo et al., 2014) [30]
Provide an overview of the history of citrus production and different constraints in yielding citrus.	Conceptual	(Habermann and Souza, 2014) [31]
To determine the impact of climate change on the agricultural sector of the Mediterranean region by evaluating risk level and impact on the risk index.	Quantitative - Monte Carlo Simulation and Regression	(Iglesias et al., 2010) [32]
Evaluate the impact of a deficit-irrigation strategy in mature 'Lane late' sweet orange.	Quantitative – ANOVA and Schwartz's Bayesian criterion index (SBC)	(Pérez-Pérez et al., 2008) [33]

Table 2. List of Adaptation and Mitigation Strategies Adopted by Orange Growers

Adaptation Strategies		References
1	Rainwater Harvesting	(Gautam and Bana, 2014; Habiba et al., 2012; Joseph et al., 2021; Ojo and Baiyegunhi, 2020; Omerkhil et al., 2020; Udmale et al., 2014) [5,26,34–37]
2	Mulching the Soil	
3	Pest Control During Droughts	
4	Water Recycling	
5	Installing an Efficient Irrigation System	
Mitigation Strategies		
1	Diversify Income through Other Sources	
2	Guidance from Agriculture Department	
3	Weather Forecast	
4	Buy Insurance	

The studies reported in Table 1 primarily focus on determining the constraints for orange farming. The literature is sparse in the following two aspects: (a) identifying critical challenges faced by orange growers at the farm-level due to droughts; (b) investigating the mitigation and adaptation strategies adopted by orange growers for addressing the drought impact. The article by Saryam and Jirli [27] is the only study that reports the concerns of Nagpur orange growers. The vulnerability to drought impact varies even within the same region depending on access to alternative water and irrigation sources. Further, the perception of drought impact by orange growers and, in response to that, the strategies that are adopted are missing from the extant body of knowledge. Thus, to the best of authors' knowledge, the literature is shallow in discussing the critical challenges faced by orange growers at the farm level due to droughts and different mitigation and adaptation strategies orange growers adopt to address the drought impact. This research tries to bridge these gaps in the literature. Given these lacunae in existing literature and the predictions of ever-happening droughts and their impact on orange farming, the study aims to examine farmers' perception and awareness of drought and its impact, and different adaptation and mitigation strategies in practice. Adaptation strategies deal with *"adjusting to actual or expected future climatic changes"*, while mitigation strategies are *"the measures to reduce the impact of climate change"* [38]. The aim of the present study lay a strong foundation to build the following research questions (RQs).

RQ 1. How do orange growers in Vidarbha perceive the impact of droughts and their allied challenges?

RQ 2. What different adaptation and mitigation strategies do orange growers in Vidarbha consider for alleviating the impact of droughts?

This work adopted a field study research approach conducted in the drought-prone Vidarbha region to acquire orange farmers' perceptions of drought challenges and adaptation and mitigation strategies. Initially, through literature, the challenges posed by droughts over orange growers are identified. The identified challenges are then validated through experts' (orange growers) opinions to determine challenges relevant to Vidarbha orange growers using the Delphi method. Further, using a best-worst method (BWM), the challenges are prioritised to understand the critical ones. Finally, a descriptive analysis of the orange growers' opinions provides meaningful insights into their perception of adaptation and mitigation measures.

The remainder of the manuscript is structured as follows – Section 2 describes the research methods used and data collection for the study. In Section 3, the results are thoroughly discussed. The contribution of the study to the literature and the implications to policymakers are briefly narrated in Section 4. The concluding remarks and future research avenues are offered in Section 5.

2 Research Method and Data Collection

This study utilised a three-stage method comprising – 1) Delphi method to validate the challenges orange growers face due to droughts in the Vidarbha region; 2) Multi-criteria decision-making (MCDM) based Best-Worst method (BWM) to evaluate the critical challenges faced by orange growers of Vidarbha due to drought; and 3) Descriptive analysis to assess orange growers' perception about droughts and the adaptation and mitigation strategies. The research design is presented in Figure 2.

2.1 The Delphi Method

The Delphi method is one of the most popular, organised, systematic, and recursive procedures for evaluating participants' opinions anonymously to validate different aspects, like – critical success factors, enablers, challenges, barriers, and criteria [39–41]. Delphi offers each participant/expert an equal opportunity to involve in the analysis and avoid any conflict of opinions due to group pressures that make judgments precise [42–45]. A sample of 5-20 context-specific participants is necessary to conduct Delphi [40,46,47]. Since the context of the study is to determine the relevant challenges faced by Vidarbha's orange growers due to droughts and their overall perception of mitigation and adaptation strategies, we contacted suitable participants based on the following criteria: 1) orange growers in the regions of Vidarbha; 2) orange growers with over 15 years of experience; 3) orange growers that have experienced/encountered at least three droughts. Following the criteria, we identified 18 orange growers for the Delphi phase of the study. The detailed profile of the 18 respondents is provided in Table 3.

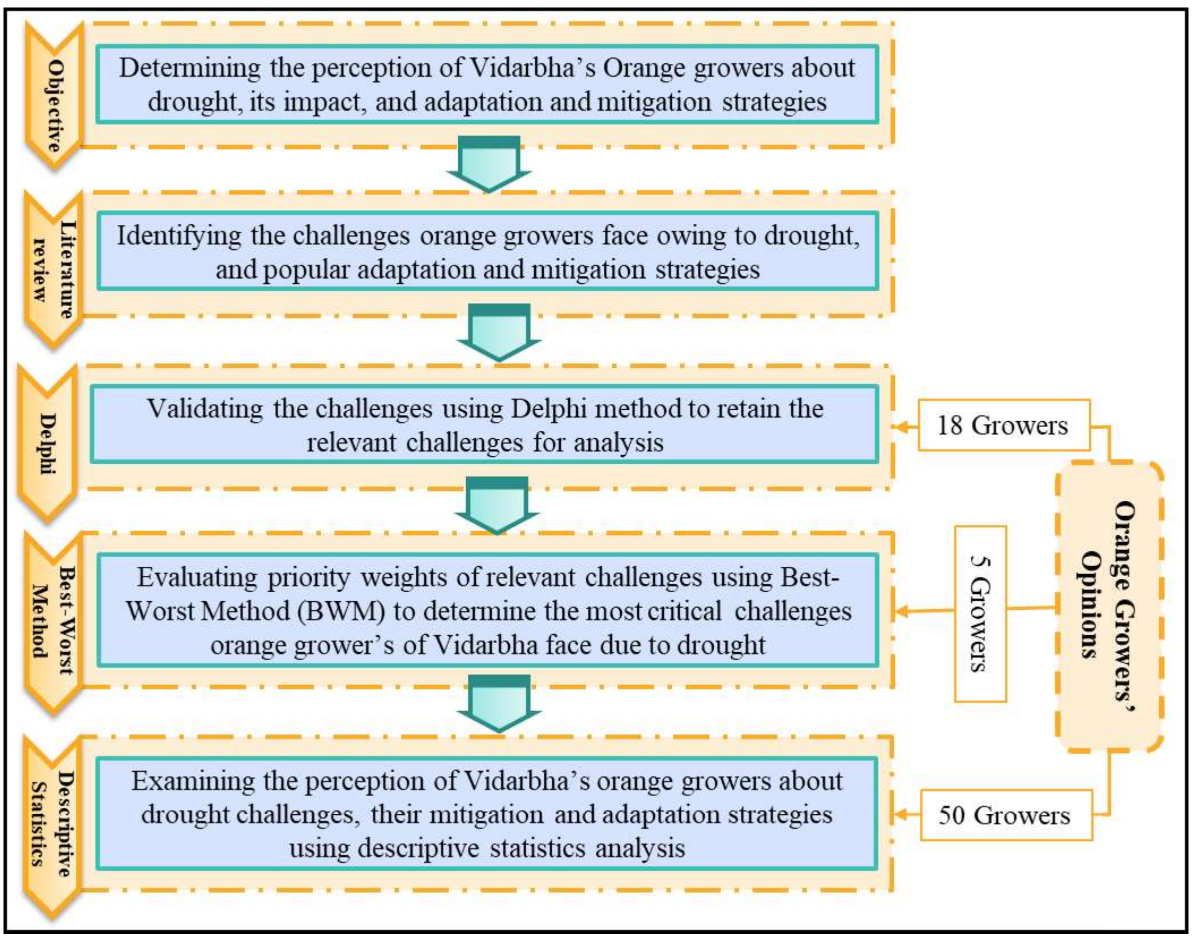

Figure 2. Research Design

Delphi validates the aspects under study through experts' opinions by arriving at a consensus [46]. Delphi utilises different techniques for consensus measurement, such as - cut-off rate, interquartile range, average percent of majority opinions, subjective analysis, etc. [48]. Amongst all, the content validity ratio (CVR) is one of the most powerful techniques [40,49] used in this study to validate the challenges. Consensus is measured in the CVR technique using a balanced three-point scale: essential, helpful but not essential, and not necessary [40]. The CVR is expressed as:

$$CVR = \left. \frac{N_{PE} - \left(\frac{N}{2}\right)}{\frac{N}{2}} \right\} \ldots\ldots\ldots\ldots\ldots (1)$$

N_{PE} = Number of participants suggesting the aspect is essential

N = Total number of participants

The CVR is calculated for the opinions of orange growers on each challenge using equation 1. In the literature, the threshold value for CVR is suggested as 0.29 [46,50,51]. Thus, challenges retaining a CVR value ≥ 0.29 are considered for further analysis. The results are provided in Section 4.1.

Table 3. Respondents' Profile for Conducting Delphi

Sr. No.	Age	Annual Income (₹)*	Education Level#
Expert 1	37	10-30 Lacs	Graduation
Expert 2	61	30-60 Lacs	Above Matriculation
Expert 3	54	Below 10 Lacs	Post Graduation
Expert 4	63	60 Lacs -1 Crore	Graduation
Expert 5	40	10-30 Lacs	Graduation
Expert 6	62	10-30 Lacs	Above Matriculation
Expert 7	44	10-30 Lacs	Graduation
Expert 8	36	10-30 Lacs	Graduation
Expert 9	49	60 Lacs -1 Crore	Post Graduation
Expert 10	48	30-60 Lacs	Graduation
Expert 11	57	30-60 Lacs	Graduation
Expert 12	42	Below 10 Lacs	Post Graduation
Expert 13	65	60 Lacs-1 Crore	Above Matriculation
Expert 14	43	30-60 Lacs	Graduation
Expert 15	47	10-30 Lacs	Post Graduation
Expert 16	41	Below 10 Lacs	Post Graduation
Expert 17	67	Above 1 Crore	Above Matriculation
Expert 18	43	60 Lacs-1 Crore	Post Graduation

Note:
****Income:** 1 Lacs = 100,000; 1 Crore = 10,000,000 (10 Million)*
*#**Education:** Above Matriculation - Upper Secondary School, Graduation – Bachelor's Degree, Post Graduation – Master's Degree*

2.2 Best-Worst Method

The Best-Worst Method (BWM) is one of the popular multi-criteria decision-making (MCDM) methods [41,52] for evaluating the relative priority weights of attributes by comparing the best attribute over others and others over the worst attribute [53–55]. Using limited information, BWM conducts consistent comparisons. BWM comprises mathematical modelling with an objective function to gain the optimal weights and consistency ratio (CR). The rationale for choosing BWM is due to its additive advantage over the other MCDM methods highlighted in the literature [52,56,57], such as –

- As BWM is a vector-based method, it requires lesser attribute comparisons, making it easier for experts to interpret,
- BWM comprises an integer scale, unlike other MCDM methods – AHP, ANP, etc. which consists of fractional scales (1/9, 1/4), making judgment complex,
- BWM effectively handles equalising biases to calculate the weights of attributes and rank them efficiently.

Typically, BWM has two types, namely – nonlinear and linear. A nonlinear BWM model produces multiple optimal solutions [52]. However, in certain applications, one optimal solution is preferred. Rezaei [58] developed a linear BWM method to compute the single optimal value of an objective function to overcome the issue in a nonlinear BWM. As our study aims to prioritise the challenges faced by orange growers due to droughts, it is essential to have single optimality within the solution. Thus, we have used a linear BWM model. The detailed procedure to conduct linear BWM is explained next.

2.2.1 BWM Procedure

BWM comprises five steps to compute the weights of attributes as follows [52,54,58].

Step 1: Identify the relevant decision attributes.
In this step, we identify the relevant n attributes $(c_1, c_2, \ldots, c_n)$ that are crucial for the problem under study. In our study, the attributes to be evaluated are challenges faced by orange growers due to droughts. A total of eight challenges $(c_1, c_2, \ldots, c_8)$ are identified from the literature and listed in Table 2.

Step 2: Determine the best and the worst attribute.
In this step, the "best attribute" (most critical or most desired) and "worst attribute" (least critical or least desired) are identified.

Step 3: Develop the Best-to-Others vector by determining the preference of the best attribute over other attributes using a 1-9 scale.

$$A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$$

Where, a_{Bj} denotes the preference of the "best" attribute " B " over attribute " j "

Step 4: Develop the Others-to-Worst vector by determining preference for all other attributes over the worst attribute, using a 1-9 scale.

$$A_W = (a_{1W}, a_{2W}, \dots, a_{nW})^T$$

Where, a_{jW} signifies the preference of attribute "j" with the "W" worst attribute.

Step 5: Compute the optimal weights of attributes.

To find the criteria's optimal weight, we minimise the maximum among the set of $\{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$. The problem can be represented as -

$$\left.\begin{array}{c} \min \max_j \{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\} \\ s.t. \\ \sum_j w_j = 1 \\ w_j \geq 0, for\ all\ j \end{array}\right\} \quad (2)$$

Model 2 can be transferred as:

$$\left.\begin{array}{c} \min \xi^L \\ s.t. \\ |w_B - a_{Bj}w_j| \leq \xi^L, \ \ for\ all\ j \\ |w_j - a_{jW}w_W| \leq \xi^L, \ \ for\ all\ j \\ \sum_j w_j = 1 \\ w_j \geq 0, for\ all\ j \end{array}\right\} \quad (3)$$

ξ^{L*} represents the consistency ratio (CR) for the comparison vectors under study. Solving model 3, the optimal weights $(w_1^*, w_2^*, \dots, w_n^*)$ and optimal ξ^{L*}value are computed. $\xi^{L*}(CR) \in [0,1]$. The value of ξ^{L*} closer to 0 shows a high consistency [52]. The optimal weights for the challenges enlisted in Table 2 are computed using BWM.

2.2.2 Experts for Performing BWM

The output from the analysis is based on the judgment of the selected experts in BWM. Hence, care should be given to determining appropriate experts [58,59]. To retain the right experts, three essential criteria are provided in the literature – 1) experience in the area of study; 2) working within the study area; and 3) interest in providing opinion and participating in the study [47]. Typically, 3 to 10 experts are required to conduct MCDM analysis, as *"the quality of the information or observations are more important than the quantity"* [60,61]. Since this study utilises MCDM-based BWM for prioritising challenges faced by orange growers due to drought, five orange growers from a drought-prone Vidarbha region who have been into orange farming for over 20 years and have witnessed at least three droughts are selected. Further, the 5-step BWM procedure is followed to evaluate the priority weights of challenges provided in Table 2. These challenges are prioritised based on the relative weights to determine the critical ones.

Table 4. Respondents for BWM

Sr. No.	Age	Annual Income (₹)*	Education Level#
Expert 1	54	10-30 Lacs	Graduation
Expert 2	66	30-60 Lacs	Above Matriculation
Expert 3	63	10-30 Lacs	Graduation
Expert 4	48	60 Lacs-1 Crore	Post Graduation
Expert 5	49	10-30 Lacs	Post Graduation

Note:
**** Income:*** *1 Lacs = 100,000; 1 Crore = 10,000,000 (10 Million)*
#Education: *Above Matriculation - Upper Secondary School, Graduation – Bachelor's Degree, Post Graduation – Master's Degree*

2.2.3 Consistency Ratio Measurement

Comparison vectors are considered to be consistent if $a_{Bj} \times a_{jW} = a_{BW}$, for all j, where a_{Bj}, a_{jW} and a_{BW} are the preference of the best attribute over the j^{th} attribute, the preference of attribute j over the worst attribute, and the preference of the best over the worst attribute [54,62]. However, in some instances, due to the vagueness in judgment, it is observed that j may not be fully consistent with best and worst attribute. Thus, a consistency ratio (CR) is calculated to determine how much a comparison is consistent.

In this study, the input-based consistency ratio CR^I method proposed by Liang et al. [62] is used. The Input-based Consistency Ratio CR^I is given as –

$$CR^I = \max_j CR_j^I$$

where,

$$CR_j^I = \begin{cases} \dfrac{|a_{Bj} \times (a_{jW} - a_{BW})|}{a_{BW} \times a_{BW} - a_{BW}}, & a_{BW} > 1 \\ 0, & a_{BW} = 1 \end{cases} \quad (4)$$

The local consistency level corresponds to a specific criterion C_j is given as CR_j^I. While CR^I is the global or overall input-based consistency ratio for all the criteria under study, which can be the maximum value of CR_j^I. Input-based consistency measurement offers significant advantages, such as – 1) quick feedback on the consistency within input preference; 2) easily interpretable; 3) can be used for different BWM approaches (linear or nonlinear) for consistency measurement; 4) the most inconsistent comparison vector can be detected in the early stage [59,62]. Liang et al. (2020) [62] further provided threshold values, as given in Table 5, for the input-based consistency ratio to check whether the judgments are consistent or not.

Table 5. Threshold values for input-based consistency ratio [62]

Scales	**Criteria**						
	3	**4**	**5**	**6**	**7**	**8**	**9**
3	0.1667	0.1667	0.1667	0.1667	0.1667	0.1667	0.1667
4	0.1121	0.1529	0.1898	0.2206	0.2527	0.2577	0.2683
5	0.1354	0.1994	0.2306	0.2546	0.2716	0.2844	0.2960
6	0.1330	0.1990	0.2643	0.3044	0.3144	0.3221	0.3262
7	0.1294	0.2457	0.2819	0.3029	0.3144	0.3251	0.3403
8	0.1309	0.2521	0.2958	0.3154	0.3408	0.3620	0.3657
9	0.1359	0.2681	0.3062	0.3337	0.3517	0.3620	0.3662

2.3 Descriptive Statistics

In the final stage of the study, we performed descriptive statistics to understand how orange growers perceive the impact of droughts and different adaptive and mitigation strategies. A questionnaire is designed to gain the feedback of orange growers from the Vidarbha region. The details of the questionnaire, sampling, and pilot testing are provided next.

2.3.1 Questionnaire Design

The questionnaire is an effective instrument for collecting data in an exploratory study that explores a phenomenon [63]. It helps to interview the participants via face-to-face, telephonic, and mail modes. Selecting a suitable survey mode is crucial and depends on the topic, local feasibility, goal, and the overall budget of the study [5]. The questionnaire must be designed carefully to obtain unbiased opinions and retain the most accurate data. The involvement of an unanticipated communication gap between the researcher and respondents caused due to the improper questionnaire yields inaccurate results [5,63,64]. Different guidelines have been suggested in the literature to avoid these issues, namely – 1) the use of simple and familiar words to the respondents; 2) the length of a questionnaire should be kept short to avoid response fatigue; 3) the flow of the questions to maintain the focus of the respondents; and 4) group the same type of questions together to maintain the readability [5,37,65,66].

In this study, the questionnaire is designed to gather information on the level of orange growers' awareness of droughts and their impacts, different mitigation and adaptation strategies, and their expectations and suggestions from the Government. Following the aforementioned guidelines, a structured questionnaire comprising closed-ended and open-ended questions was designed. As the first language of the farmers is Marathi, the survey was translated into the local language *(Marathi)*. The questionnaire is subjected to the pilot test to understand whether further improvement is needed.

2.3.2 Pilot Testing of Questionnaire

An initially developed questionnaire (provided in Appendix 2 of the supplementary file) is used for the pilot test. A pilot testing of the questionnaire is carried out over a sub-set of the targeted population (i.e., few orange growers from villages in the Vidarbha region) to remove any redundancy, missing information and validate the relevance of the questions with the research topic. A total of 10 farmers from nearer villages of Nagpur, namely – Katol, Mohadi, and Gondi Digras were interviewed. The interactions with the farmers offered novel insights into the problem under study. The questionnaire was modified based on the responses and suggestions of orange growers acquired during pilot testing. The respondents from the pilot test were omitted further for data collection. The revised (final) questionnaire is included in Appendix 3 of the supplementary file.

2.3.3 Sampling Method

The final questionnaire is developed based on the responses from pilot testing and comprises closed-ended questions, including – multiple choice questions, multiple option questions, dichotomous questions (Yes/No), and open-ended questions. We have utilised a purposive sampling method to finalise the sample size for the present study. Purposive sampling is – *"…a judgmental sampling method in which individuals are selected to be part of the sample based on the researcher's judgment as to which individuals would be the most useful such that the quality of the collected survey data can be controlled…"* [67]. The participants in this study are selected based on the two critical criteria – 1) The participants should fall under the category of orange growers, especially from the districts within Vidarbha region; 2) They should be actively doing orange farming and have faced drought instances during their orange farming tenure. Since the respondents required are very distinct and purpose-specific, as prescribed in the aforementioned criteria, purposive sampling is most suitable. In purposive sampling, the number of respondents is less due to purpose-driven criteria for selecting experts [68]. The major focus of purposive sampling is obtaining relevant information in a precise manner and not just the quantity of information [63]. Hence, in the present study, the final sample includes 50 orange growers from the villages within the Nagpur, Amaravati, and Buldhana districts of the Vidarbha region who have witnessed at least 3 drought encounters and fulfilled the abovementioned criteria.

We interviewed a head or representative (orange grower) within each household, which were males within the family. Interviewing a single person from each family helped in avoiding redundant information and since the interviewees were head of the family (i.e., main orange grower), we received the apt information. Most of the data (41 respondents) was collected through telephonic communication to adhere to the COVID-19 rules and regulations. While to get a natural feel of the farmers' perceptions, nine respondents were interviewed face-to-face at their orange orchards through a field visit. This not only helped in gaining the opportunity to meet these growers and understand their issues but also to learn the procedure of growing the oranges. These learnings help us in gathering suggestions for policy implications and orange growers' perspectives on how to adopt or mitigate the drought. During both face-to-face and telephonic interviews, the respondents were actively engaged because of their interest in the topic and the opportunity to share their experience and expertise.

2.3.4 Data Analysis

The primary data collected through telephonic and face-to-face interviews were statistically analysed using the IBM SPSS Statistics V26. As the responses to open-ended questions were collected to understand the views of orange growers and their suggestions to the Government, these were skipped from the statistical analysis and coded separately for the latent understandings. A five-point Likert scale (1 for strongly disagree to 5 for strongly agree) was used to code responses to the close-ended questions. This study adopted the data analysis procedure utilised by Udmale et al. [5].

Orange growers' perceptions of droughts, their allied impacts, and various adaptation and mitigation strategies are assessed using descriptive statistics. Data was analysed to determine the adaptability of orange growers' different adaptation and mitigation strategies. For this, the orange growers are categorised according to their landholding size, namely – Marginal (below 2.47 acres), Small (2.48-4.94 acres), Semi-Medium (4.95-9.88 acres), Medium (9.89-24.71 acres), and Large (>=24.72 acres) land holding [69]. The average landholding for Maharashtra is 1.35 hectares [70], which is equivalent to 3.33 acres. Since for orange cultivation acres unit is used to measure the land size, we converted the categories from hectares to acres.

2.3.5 Profile of the Respondents

As discussed earlier, 50 orange growers were interviewed from three major districts of the Vidarbha region, namely - Amaravati, Nagpur, and Buldhana. The detailed profile of the respondents is presented in Table 6. Most respondents (82%) are relatively young farmers and fall in the 25 - 44 age group. The average household size of the sampled population was 7.28, and the average dependents on orange farming were 6.08, which is larger than the average size of 5 persons per household in Maharashtra State [5].

The overall landholding for orange cultivation size ranges from 1.5 to 125 acres, with an average landholding of 10.775 acres. Out of 50 orange growers, it is observed that around half of the respondents have no interest in buying crop insurance. The majority of the respondents (28) do not own the insurance, while others (22) have purchased the insurance from the Government. Ten respondents cultivate both the harvest of the orange, namely - *Ambiya* and *Mrig*. While 40 opted to take a single harvest a year. Considering the marital status of the respondents, only five are single, while the others (45) are married and are responsible for their family members.

Table 6. Profile of Respondents for Statistical Analysis

Particulars	Overall Landholding Category				
	Marginal	**Small**	**Semi Medium**	**Medium**	**Large**
Age Group					
25-44	1	6	15	16	3
45-64	-	-	7	1	1
Average Annual Income (in ₹)					
Below 10 Lacs	1	3	2	-	-
10-30 Lacs	-	2	7	3	-
30-60 Lacs	-	1	10	2	-
60 Lacs -1 Crore	-	-	3	11	2
Above 1 Crore	-	-	0	1	2
Education Level					
Above Matriculation (Upper Secondary School)	-	5	9	6	1
Graduation (Bachelor's Degree)	1	1	10	9	2
Post Graduation (Master's Degree)	-	-	3	2	1
Family Details					
Average Family Size	8.00	6.89	7.12	7.26	7.11
Average Dependents	5.00	4.32	4.51	4.56	12.00
Crop Insurance					
None	1	4	11	10	2
Only Government	-	2	11	7	2
Loans					
No	1	1	5	9	-
Yes	-	5	17	8	4
Number of Harvest					
Only One	1	5	17	15	2
Two Harvest	-	1	5	2	2
Marital Status					
Married with Dependent Adults	-	3	-	-	-
Married with Young Children	-	2	11	4	-
Married with Young Children and Dependent Adults	1	1	11	8	4
Single	-	-	-	5	-

3 Results and Discussion

This section offers the results achieved through the three-stage method deployed in this study and the critical discussion of the findings.

3.1 Delphi

Initially, 11 challenges faced by orange growers due to droughts are identified through literature[1]. Further, 18 orange growers from different parts of Vidarbha were approached to gather their opinions on the criticality of each challenge specific to drought conditions in the Vidarbha region. We then compute the CVR values of all challenges. As mentioned earlier,

[1] The list of 11 challenges is provided in Appendix 1 of the supplementary file.

challenges having a CVR score ≥ 0.29 are retained for the study. This results in the retention of eight relevant challenges (C1 to C8) for the analysis, as listed in Table 7. These eight challenges are subjected to the BWM method in the next stage.

Table 7. Relevant Challenges Orange Growers face due to Droughts

#	Challenges	Description	CVR Score
C1	Unavailability of prescribed fertilisers	Oranges are affected by diseases as a result of droughts. Thus, a list of suitable fertilisers should be prepared for orange growers. However, no prevailing document is available that helps orange growers understand suitable fertilisers to overcome disease due to droughts [71].	0.67
C2	Uncertainty of electric supply	The frequent occurrence of load shedding (power-cut) results in the interruption of regular activities of the orange orchards [22].	0.78
C3	High cost of drip irrigation	Since drip irrigation is very effective in drought conditions, orange growers are expected to have drip irrigation. However, the high cost of drip irrigation makes it difficult for orange growers to install drip irrigation [22,72].	1.00
C4	Unavailability of appropriate pesticides	Orange farmers have no prescribed pesticides to avoid pest attacks during drought conditions [22,71].	0.78
C5	Lack of availability of capital	Insufficient capital, lack of availability of loans, and inadequate insurance make farmers insecure about their losses due to droughts. So, farmers fear investing more capital in the orange orchard after droughts [71].	0.89
C6	Lack of availability of required information within acceptable time frames	There is often a delay in passing information to orange growers in remote locations of Vidarbha on forecasted droughts, climate change, and untimely rainfall. This results in delayed awareness and preparedness [22,71].	0.56
C7	Inadequate water bodies	An inadequate number of water bodies makes orange growers rely on their borewells, which is a cost-intensive and uncertain option due to insecurity related to groundwater availability [4,22].	1.00
C8	Lack of availability of technical guidance	Many technology-oriented solutions (plastic mulching, drip fertigation, disaster mapping system, etc.) are available for orange growers. However, such technical guidance for orange growers is unavailable, resulting in unawareness of technological solutions [72–74].	0.67

3.2 Best-Worst Method

The five steps of BWM are followed to compute the priority weights of the challenges (listed in Table 5) orange growers face during droughts. As mentioned in steps 3 and 4, using a 1-9 scale, the responses are received, which are later on used for formulating best-to-others and others-to-worst vectors. Five orange growers provided their opinions on the best (most critical) and the worst (least critical) challenges based on individuals' perceptions. Table 8 and 9 provides orange growers' opinions on the best and worst challenges. Once the judgments from the five experts (orange growers) are collected (See Table 8 and Table 9), the input-based consistency ratio (IBCR) is evaluated.

Table 8. Best to Other Vector

# Experts	Best Attribute (most critical)	Best to Others							
		C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
Expert 1	**C7**	7	3	2	6	3	5	1	4
Expert 2	**C7**	6	7	3	4	2	5	1	5
Expert 3	**C5**	6	4	3	9	1	6	3	5
Expert 4	**C7**	8	3	1	5	2	4	1	3
Expert 5	**C5**	7	3	4	8	1	5	2	6

Table 9. Others to Worst Vector

Others to Worst					
Other Criteria	**Worst Attribute (least critical)**				
	Expert 1	**Expert 2**	**Expert 3**	**Expert 4**	**Expert 5**
	C1	**C2**	**C4**	**C1**	**C4**
C1	1	2	2	1	2
C2	6	1	5	6	6
C3	5	6	6	7	4
C4	3	3	1	4	1
C5	5	5	9	6	8
C6	4	4	3	5	2
C7	7	7	6	8	7
C8	5	3	5	4	4

To elaborate on IBCR, consider the opinions of Expert 4. The best attribute is C7 and the worst is C1 (refer to Tables 8 and 9). It is seen that the value of a_{BW} is 8 for Expert 4. Further, the value for CR_j^I is computed using equation 4 and provided in Table 10. The global or overall CR^I is 0.2143. As given in Table 6, the threshold value for 8 attributes (8 challenges) and the 8-scale (a_{BW}) is found as 0.3620. Thus the CR^I = 0.2143 < 0.3620. This portrays that the judgments received from Expert 4 are consistent. A similar procedure of IBCR is conducted to check the consistency within the opinions of other experts. The judgments from every expert are found to be consistent.

Table 10. Input-based consistency ratio – Expert 4.

Expert 4	C1	C2	C3	C4	C5	C6	C7	C8
Best – C7	8	3	1	5	2	4	1	3
Worst - C1	1	6	7	4	6	5	8	4
CR_j^I	0.0000	0.1786	0.0179	0.2143	0.0714	0.2143	0.0000	0.0714

Once the consistency check for each expert is completed, the priority weights are computed using a BWM model. The computation results in obtaining five weight vectors. The five weight vectors are aggregated using a geometric mean method followed by normalisation. The five respondents' weight vectors and the aggregated weight of each challenge are presented in Table 11. The challenges are prioritised based on the aggregated weights, as shown in Table 11. It has been observed from the analysis that *inadequate water bodies* (C7), *lack of availability of capital* (C5), and *high cost of drip irrigation* (C3) emerged as the critical challenges Vidarbha's orange growers are facing during drought situations.

Table 11. Weights of Challenges Orange Growers Faced

Challenges	Weights Computed from Experts' Opinions					Geometric Mean	Priority Weight	Rank
	1	2	3	4	5			
C1	0.0328	0.0655	0.0708	0.0258	0.0569	0.0467	0.0494	8
C2	0.1245	0.0345	0.1061	0.0979	0.1328	0.0900	0.0953	4
C3	0.1867	0.1310	0.1415	0.2369	0.0996	0.1522	0.1610	3
C4	0.0622	0.0982	0.0313	0.0587	0.0332	0.0518	0.0548	7
C5	0.1245	0.1965	0.3531	0.1468	0.3321	0.2113	0.2235	2
C6	0.0747	0.0786	0.0708	0.0734	0.0797	0.0754	0.0797	6
C7	0.3013	0.3171	0.1415	0.2627	0.1992	0.2344	0.2480	1
C8	0.0934	0.0786	0.0849	0.0979	0.0664	0.0835	0.0883	5

3.3 Descriptive Statistical Analysis of Orange Growers' Perceptions

We evaluated the perception of Vidarbha's orange growers about drought challenges and their mitigation and adaptation strategies. A critical discussion of these findings is presented in this section.

3.3.1 Orange Grower's Perception of Drought

The overall perception of orange growers of the drought's impact on orange cultivation is reported in this section and shown in Figure 3. Orange growers were asked about their perception of droughts and their impacts on livelihoods. The orange growers believe that droughts are a natural phenomenon happen due to weather changes, insufficient rainfall, lack of water availability for farming, and excessive temperature increase. Apart from the large growers and growers situated in the outskirt villages of Nagpur (where rainfall is adequate), others (26) believe that droughts are the primary reason for reducing their household income, as shown in Figure 3(a).

A five-point Likert scale was used to measure awareness of the forthcoming weather changes and droughts on their orange cultivation, 35 orange growers out of 50 agree that they are aware, as seen from Figure 3(b). Despite the awareness, the orange growers are unprepared to manage their effects. This is because the impacts of droughts at a farmer-level can be different, for example – fungi attack, rotting of oranges, crop failure, or yield and income loss. Thus, as evident from Figure 3(c), most of the farmers (30) are not fully prepared to control the drought stress.

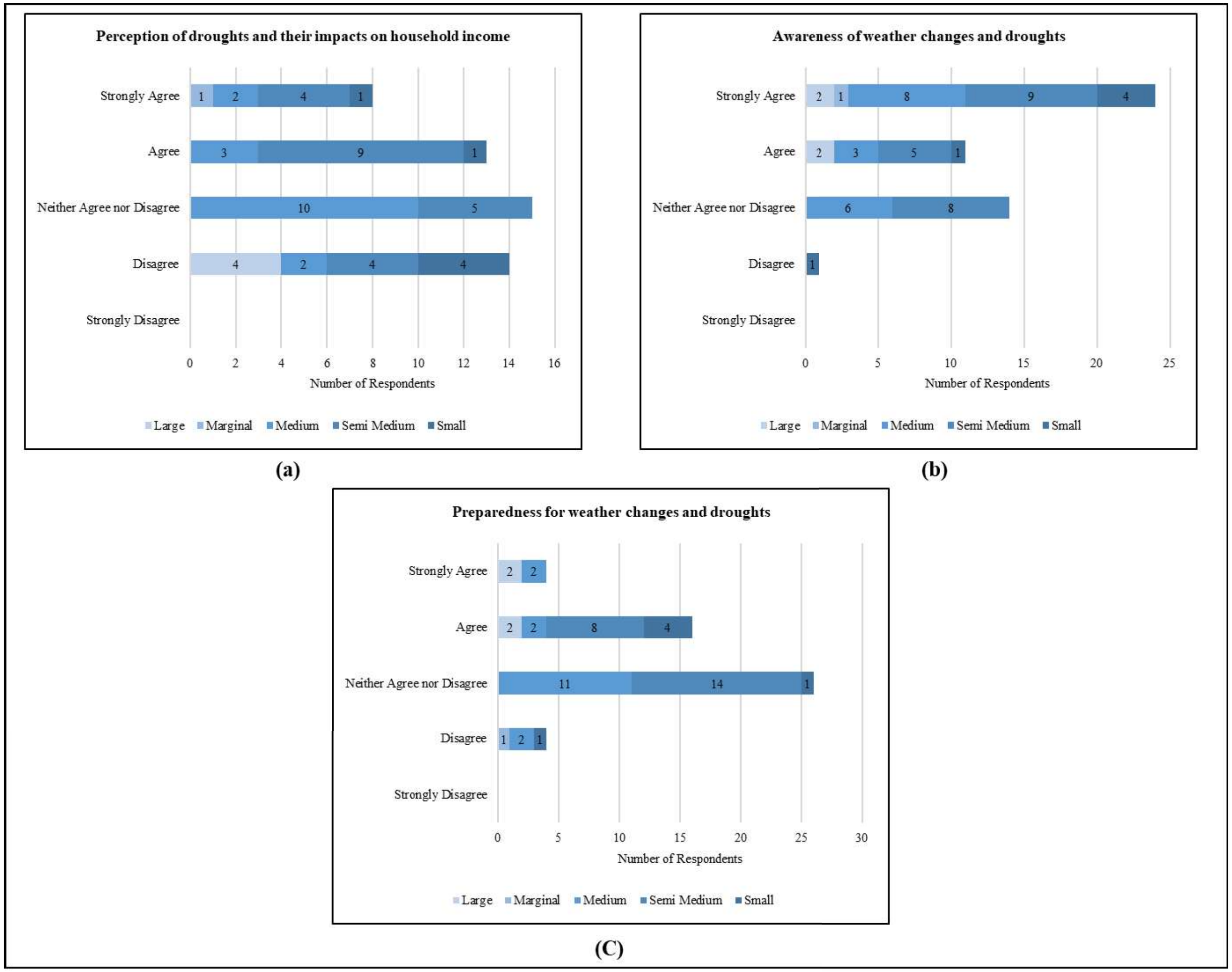

Figure 3. Orange Growers' Perceptions of Drought

3.3.2 Analysis of the Adaptation Strategies

Adaptation strategies deal with adjusting to actual or expected future weather and climatic change. This section analyses the applicability of adaptation strategies based on orange growers' category of landholdings and is illustrated in Figure 4.

3.3.2.1 Rainwater Harvesting

The pattern of the rains is abnormal in the different parts of the Vidarbha region. The respondents stated that even though rainfall may be at an average level, but the number of rainy days might be erratic. Sometimes untimely rains and hailstorms affect the oranges and lead to failure of yields. Such instances were previously reported in the Vidarbha region [23]. The discussion with the farmers during the data collection revealed that investing in rainwater harvesting systems would not be an efficient solution due to the sporadic rainfall. As shown in Figure 4(a), 41 farmers either "disagreed" (11) or "strongly disagreed" (30) with rainwater harvesting as an adaptation strategy. Thus, most of the farmers have not installed any rainwater harvesting system.

3.3.2.2 Soil Mulching

Typically soil mulching is not required for orange cultivation. The major reason is the plunging that is required for orange orchards. Also, in some cases, it can reduce the critical oxygen exchange to feeder roots and stress an orange tree which may result in the failure of yield [75]. In our study, the respondents growing other crops along with orange are observed to mulch the soil for the other crops. The response of farmers to the soil mulching adaptation strategy is shown in Figure 4(b).

3.3.2.3 Pest Control Measure

The crops suffer pest and insect attacks due to the lack of water. During drought, pest and fungi attacks, namely - *Acaulospora*, *Entrophospora*, *Gigaspora*, *Glomus*, and *Pacispora*, are more common on oranges [76]. Thus, as safety precautions, the orange growers always spray pesticides on orange crops. Figure 4(c) illustrates the response of farmers to the pest control adaptation strategy, where all 50 farmers either "agreed" (4) or "strongly agreed" (46).

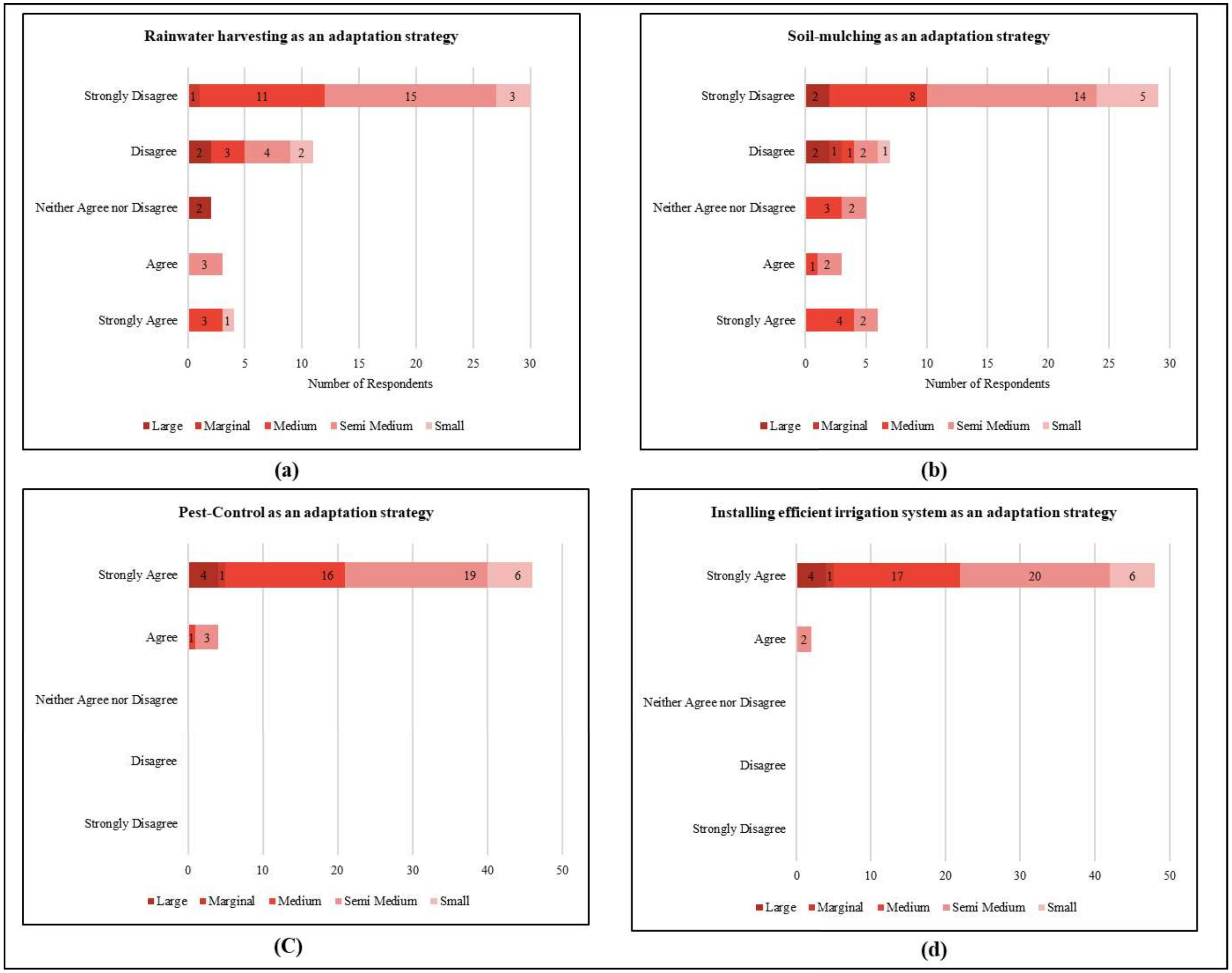

Figure 4. Orange Growers' Perception about Adaptation Strategies

3.3.2.4 Installing an Efficient Irrigation System

The Vidarbha's orange growers mentioned that the most efficient way to manage the impact of drought on orange production is the availability of an efficient irrigation system, typically drip irrigation. Orange growers in Vidarbha have constructed borewells at their orchards to facilitate adequate water supply to the plants. All the farmers in this study are observed to have at least a single borewell. Some farmers have four borewells in their fields, particularly large farmers. Figure 4(d) highlights the farmers' responses to installing an irrigation system as an adaptation strategy.

3.3.3 Analysis of Mitigation Strategies

Mitigation strategies are the measures to reduce the impact of climate change. This section analyses the applicability of mitigation strategies for tackling drought situations corresponding to the orange growers' landholding categories. The results are shown in Figure 5. Following are the key observations.

3.3.3.1 Diversify Income Through Other Sources

Most farmers under drought stress choose to generate income through other sources or allied agriculture activities [5]. Income diversification as a mitigation strategy works if farmers have the skillsets for another income source [5,35]. However, in our survey, most farmers strongly disagree with this mitigation strategy, as they believe an efficient irrigation system can help them generate the required production level (refer Figure 5(a)).

3.3.3.2 Weather Forecast

Although uncertainty is associated with weather predictions, the orange growers mostly follow the forecasts. It helps them understand the weather conditions in the coming period. Drought conditions are predicted well in advance, and a suitable awareness campaign is delivered to provide information about the forthcoming droughts. Figure 5(b) shows the response of orange growers to the weather forecast as a mitigation strategy.

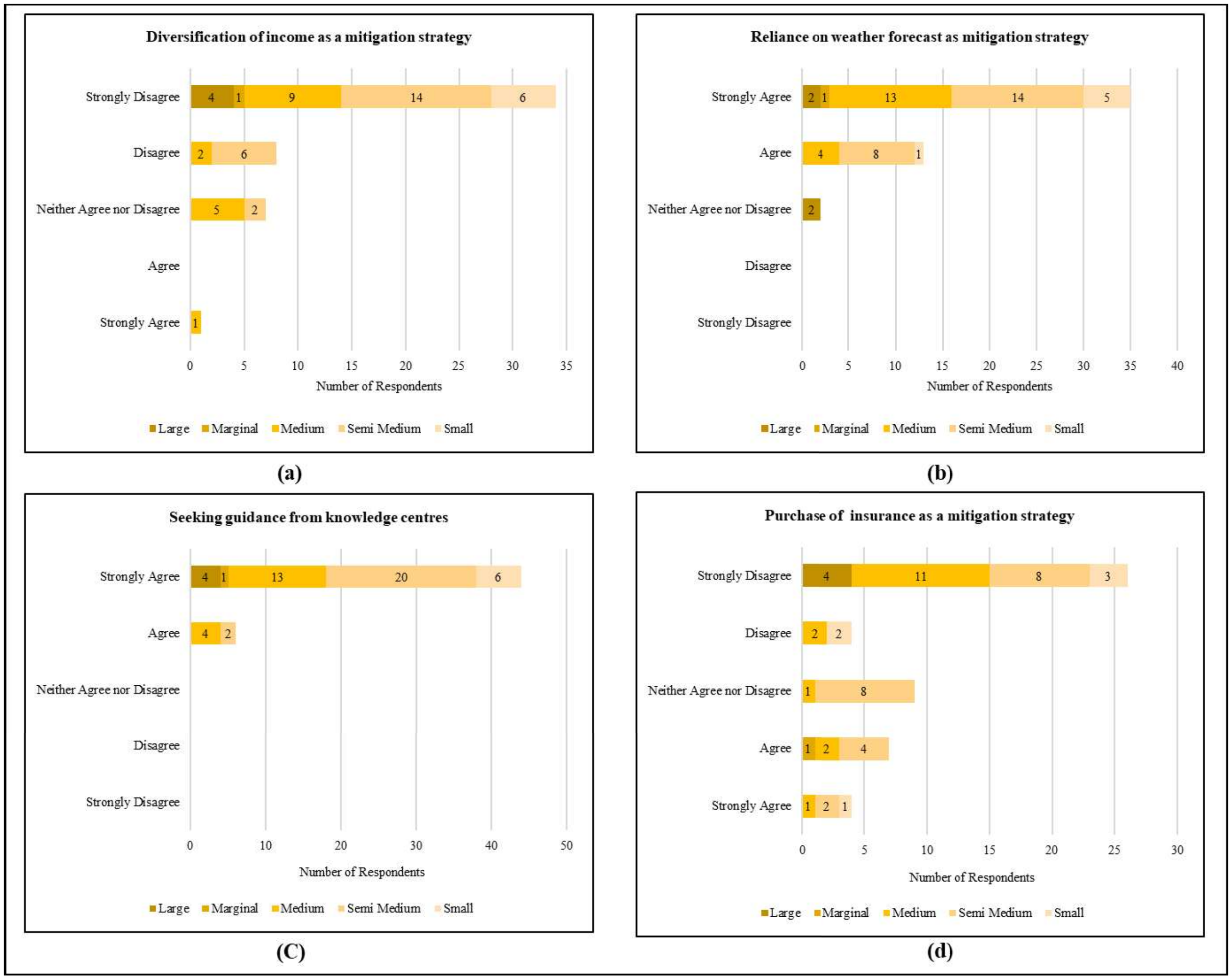

Figure 5. Orange Growers' Perception about Mitigation Strategies

3.3.3.3 Seeking Guidance from Agriculture Department

Figure 5(c) depicts the overall response of orange growers to seeking guidance from the agriculture department as a mitigation strategy. This is the most common mitigation strategy practised by Vidarbha's orange growers. Once the drought arises, orange growers approach the nearest agriculture help and knowledge centres in India, known as *Krishi Vigyan Kendra (KVK)*. Orange growers discuss their problems, and the representatives of KVK escalate their query to the Government if the centres cannot resolve them.

3.3.3.4 Purchasing Insurance

As discussed earlier, despite purchasing insurance for drought distress, very few orange growers have received insurance for their losses. This was because most of the orange growers did not fit into the rules and regulations around insurance claims. On the other hand, the orange farmers who benefited from insurance payout also commented that the insured value was not sufficient for the loss of yield. This is the major reason for the hesitance of orange growers to purchase insurance. Figure 5(d) illustrates the responses of orange growers to buy insurance for mitigating drought impacts.

4 Contributions

This section offers the contributions made by the present study in literature. Further, we also provided the major policy implications through the analysis.

4.1 Theoretical Implications

The present work provides promising theoretical contributions to the literature on climatic changes, drought adaptation and mitigation strategies, and perishable food supply chains particularly Vidarbha's oranges. It is well documented that the challenges of horticulture crops grown in orchards like Oranges, having a long life span of plantation, impacts severely due to droughts [35,77]. This study is an early attempt in the literature to understand and analyse the field-level challenges Vidarbha's orange growers experience due to droughts. The study utilised a three-stage approach for identifying and analysing the challenges and mitigation and adaptation strategies as a bottom-up approach to support policymakers. This study also offers a comprehensive list of eight challenges of Vidarbha's orange growers during drought situations. Among the eight challenges, lack of water bodies, lack of capital and high cost of drip irrigation are found to be critical ones using BWM.

Apart from this, the present research also consolidated the list of the most sought-after risk mitigation and adaptation strategies perceived by orange growers' of Vidarbha. The prospective researchers can benefit from the results of the study to build upon new avenues using the critical mitigation and adaptation strategies identified.

One of the noteworthy contributions of the present study to the literature on mixed methods is the illustration of the application of judiciously chosen mixed methods. The mixed method approach utilised in this study comprises Delphi, BWM, and descriptive analysis methods. The proposed integrated three-stage approach can be further extended in different research domains where the nature of the study is exploratory.

4.2 Implication for policymakers

This study offers significant implications for policymakers to develop a strategic road map for Vidarbha's orange growers through the orange growers' interviews gathered from field visits and results obtained through a proposed three-stage method. The suggestions through these policy implications are expected to alleviate the burden of orange growers posed due to crop failure loss owing to ever-happening droughts.

While Vidarbha's high risk of drought has been established through climatological studies and field observations, policymakers often need empirical inputs (such as results from BWM) to design and support crop-specific disaster risk reduction and mitigation interventions. With predominant rain-fed orchards, the Vidarbha region has a higher vulnerability to rainfall variability and droughts. The findings from this study show that increasing land under irrigation can reduce vulnerability through the development of water bodies and canal irrigation systems. Policymakers could support the capital cost of installing suitable drip irrigation.

Most of the orange growers during the interviews collected while field visits showed their hesitance in insuring their orange orchards to secure their orange orchards from crop failure. Most of the orange growers complained that not succeed in getting the claim for crop failure from the insurer. After discussing the issues around crop insurance, we learned that the insurance providers have stringent terms and conditions pertaining to landholding size, the overall financial condition of orange growers, and the type of crop failure. Thus, policymakers could come up with affordable insurance schemes with lenient terms and appropriate communication strategies to generate awareness about these products. It will help orange growers to receive aid in terms of some types of crop insurance, which will be provided based on the losses of growers and is not based on their income since “a loss is a loss” no matter who (in terms of the financial status of farmers) is affected by it.

While the former policy intervention reduces the vulnerability of rain-fed farmers, the latter policy could help in building the resilience of impacted farmers with economic support and social impact. Apart from this, even though GI registration of Nagpur *Santra* has been over 9 years, during the interviews it has been noticed that Vidarbha’s orange growers have not benefitted and are unable to obtain business advantage. Policymakers, retailers and stakeholders in the supply chain need to provide a price advantage for this GI product, i.e. Nagpur *Santra* and it should reach Vidarbha’s orange farmers.

5 Conclusion

Vidarbha, a region where the *“sun beats down mercilessly”*, is becoming an unfavourable place for farming in Maharashtra, India [78,79]. Despite this, it is known for its orange cultivation, and Nagpur (a famous city in Vidarbha) is recognised as the Orange City of India. In recent years, the region has experienced droughts every alternate year. This represents a tremendous challenge for the orange growers. Due to hot summers and droughts, the water level in the Vidarbha region is declining, and this results in reducing the overall agri-production of the region, including oranges, also known as Nagpur *Santra*. The declining orange production creates a massive financial burden on the orange growers. Thus, it is of interest to know what critical challenges Vidarbha orange growers face during drought and how they tackle these issues and manage their earnings through orange cultivation. This research work is developed to determine the orange growers’ perception of drought conditions and weather changes and different adaptation and mitigation strategies adopted by them to relieve the impact of drought. This research considers two major research questions – 1) How do orange growers in Vidarbha perceive the impact of droughts? 2) What different adaptation and mitigation strategies do orange growers in Vidarbha consider for alleviating the impact of droughts?

We analysed the literature and identified 11 challenges that orange growers face during drought and the different adaptation and mitigation strategies adopted by orange growers to manage drought impact. Following this and supporting our empirical study of orange growers in the Vidarbha region, a three-stage research design consisting of the Delphi method, multi-criteria decision-making (MCDM)-based best-worst method (BWM), and descriptive data analysis is adopted. In the first stage, using the Delphi method, the most relevant drought-related challenges faced by the orange growers from Vidarbha are identified. This results in retaining

8 out of 11 originally identified challenges from the literature (refer Table 5). The relative weight of each challenge is evaluated through BWM in the second stage to prioritise them for understanding the critical ones using the expertise of five orange growers. The findings suggest that inadequate water bodies, lack of availability of capital, and high cost of drip irrigation are the critical challenges Vidarbha's orange growers face during drought conditions.

Next, descriptive analysis is used to assess orange growers' perceptions of drought, its allied impacts, and various adaptation and mitigation strategies. Data collected from 50 respondents (orange growers) were analysed to determine the adaptability of different adaptation and mitigation strategies by orange growers. The orange growers are categorised according to their landholding, namely – Marginal, Small, Semi-Medium, Medium, and Large. All the strategies are assessed based on these categories to know how orange growers with different landholding sizes deal with drought effects. It is evident from the analysis that the installation of an efficient irrigation system is the most utilised adaptation strategy. While seeking guidance from the agriculture department and knowledge centres are popular mitigation strategies orange growers adopt during drought conditions.

This study is the first attempt to understand Vidarbha region's orange growers' perceptions of drought and its allied impact and also learn the different adaptation and mitigation strategies that are considered suitable by the orange farmers. One interesting finding of the research is that despite purchasing insurance for securing orange orchards, many farmers in Vidarbha did not receive a claim for crop failure due to stringent rules of insurance providers. Our study also offers major contributions to the literature and significant implications for policymakers. Also, this study can help orange growers for different regions not considered in this study; for example, they may utilise the most commonly adopted strategies reported from the Vidarbha region as they have proven to help reduce the impact of drought.

Despite its implications, this study comprises certain limitations that offer the directions to conduct future research. This study relies on the opinions of 5 orange growers for BWM and 50 orange growers for the questionnaire/face-to-face interviews and the descriptive analysis of their responses. Although the sample size is adequate as per the suggestions provided in the literature, future research could consider a larger sample size to generate more insightful findings. Future studies may use advanced statistical methods such as regression, structural equation modelling, ANOVA, non-parametric significance test, Kruskal–Wallis H-test, etc., to analyse the impact of drought on orange growers.

Further, future studies can deploy agent-based simulation modelling to understand the aspects of different agents, such as – farmers, middlemen, merchants, etc., and their interactions to learn the impact of deploying different mitigation and adaptation strategies on farmers' income. This study can further be extended to evaluate the impact of drought on orange growers from different regions.

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Title Page

Orange Grower's Perception of Drought Impacts and Strategies for Mitigation and Adaptation: A Study of the Vidarbha Region in India

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