Assessing Farmer Vulnerability to Climate Change in Karnataka: A Focus on Index Development

ABSTRACT

Agriculture represents a core part of the Indian economy and provides food and livelihood to much of the Indian population. Climate change can affect crop yields both positively and negatively, by impacting agricultural inputs such as water for irrigation, amounts of solar radiation that affect crop growth, as well as the prevalence of pests and diseases. It is widely accepted that developing countries are generally more vulnerable to the effects of climate change than the more developed countries. Among the developing countries, India may be most vulnerable to climate change due to its high reliance on natural resources mainly agriculture, inability to adapt financially and institutionally, low per capita GDP, extreme poverty and huge population. Temperature and rainfall are the most important crucial factors which affect plant development, growth and yield. So, any changes in the climate will adversely affect the productivity of the major crops through changes in the phenological process of the crop. So, Vulnerability assessment is a practical tool to identify the systems that are susceptible to be harmed, Knowing the systems' level of vulnerability is helpful to identify and develop reduction actions like increasing the adaptive capacity and decreasing the sensitivity and understand the dynamics between the different sectors and dimensions. In this study, a vulnerability index of the farmers to climate change was developed using the standardized procedures with three dimensions: exposure, sensitivity and adaptive capacity. Consisting a total of 56 items. The validity of vulnerability index was validated using face and content validity. Consequently, reliability of the vulnerability index was also verified using Cronbach's Alpha. Thus, the study found that the vulnerability index reliability was 0.846(α).

Keywords: Climate Change, Agriculture, Farmers and Vulnerability index

1. INTRODUCTION

Nine billion people must be fed by 2050, which will require an additional 70.00 per cent more food production (FAO, 2009; Godfray *et al.*, 2010;). Global food security is increasingly threatened by climate change Climate change has several consequences, including rising temperatures, more frequent and intense extreme weather events, water shortages, rising sea levels, ocean acidification, land degradation, altered ecosystems, and a decline in biodiversity.

Climate variability plays a crucial role in shaping food production and farmers' income in Indian agriculture. Nearly 60 per cent of yield variability can be attributed to climatic fluctuations. The impacts of climate change are evident in the sowing and crop duration as well as the intensity and duration of heat and water stress experienced by agricultural systems. Higher average temperatures lead to reduced radiation interception and biomass production, hampering crop growth (Zhao et al., 2017). Additionally, aboveoptimal temperatures directly impact the crop physiological processes.

India is the seventh-most vulnerable country with respect to climate extremes. Climate action needs to be scaled up both at the sub-national and district levels to mitigate the impact of extreme events. An analysis by the Council on Energy, Environment and Water (CEEW) suggests that three out of four districts in India are extreme event hotspots, with 40 per cent of the districts exhibiting a swapping trend, *i.e.*, traditionally flood-prone areas are witnessing more frequent and intense droughts and *vice-versa*. Further, the IPCC states with high confidence that every degree rise in temperature will lead to a three per cent increase in precipitation, causing increased intensification of cyclones and floods.

Agriculture is the prime occupation of about 50.00 percent of the Indian population, and along with its allied activities, agriculture contributes to around 18.30 percent of the national GDP. Farming is completely reliant on many co-activities like resource availability, soil type, and climatic suitability and agribusiness is majorly dependent on the level of productive farming. Climatic disruptions like changes and variations in precipitation, temperature, and solar radiation pose a serious threat to the overall agricultural ecosystem encompassing arable lands, livestock, and hydrology sections thereby posing a negative influence on the existing models of agribusiness. Climate variability plays a crucial role in shaping food production and farmers' income in Indian agriculture (Khatri-Chhetri *et al.,* 2016). Nearly 60.00 per cent of yield variability can be attributed to climatic fluctuations. Climate change is a global phenomenon; however, its manifestations and impacts vary locally, so do the adaptation capacities, preferences, and strategies. Effective planning for climate change adaptation programming requires an assessment of local vulnerabilities so as to bridge the gap between community needs and priorities at the local level and policy processes at the higher level. Micro-level studies should form the inputs for formulating relevant policies at the macro level. Researches done at the national and regional level data fail to capture the location specificity of smaller areas. This calls for the need of detailed explorations at the finer spatial level/local level. Keeping in view the above facts, as there is a need of an in-depth analysis of the local level vulnerabilities by integrating quantitative analysis with qualitative information obtained from primary field survey. So in this regard the vulnerability index was developed to asses vulnerability of dryland farmers in Karnataka region. So which assists the agricultural scientists and policy makers to support the crop yield sectors which will help safeguard national and food security, especially for most affected people like small and marginal farmers.

Vulnerability assessment is a practical tool to identify the systems that are susceptible to be harmed, which are water, food security, human welfare, natural resources, among others. Knowing the systems' level of vulnerability is helpful to identify and develop reduction actions like increasing the adaptive capacity and decreasing the sensitivity and understand the dynamics between the different sectors and dimensions.

2. METHODOLOGY

The methodology section deals with the systematic procedure followed in achieving the part of the research objective, that is the development of Vulnerability Index to Study the vulnerability of farmers to climate change in Karnataka.

An "index" refers to a composite measure or indicator that is used to represent a complex concept, construct, or phenomenon. It is a quantitative tool designed to simplify and summarize multiple variables or items into a single score or value, making it easier to analyse and interpret data. As vulnerability is a complex phenomenon involving various indicators viz. exposure, sensitivity and adaptive capacity. Index construction involves a systematic process of selecting, weighting, and combining individual variables or items to create a more manageable and meaningful measure. Thus, index construction is suitable tool to study the climate change vulnerability.

The study was conducted in the Yadgiri and Kalaburagi districts of Karnataka. The top two talukas having the greater variability of climate change in each selected districts of Karnataka were purposively selected for the study. Based on the same criteria The top six villages from each taluk was selected. From each village, 10 farmers were randomly selected. Thus, from each selected district, 120 farmers were selected by using simple random sampling. The total sample constituted from two districts were 240.The vulnerability of the farmers is measured using the composite index procedure, as discussed in the sections below. Personal interviews and focus group discussions are employed for gathering data.

2.1 Construct of the Research

A concept is a term that expresses an abstract idea generalizing from particulars and summarizing related observations. The term "construct" is a concept with additional meaning evolved for scientific purposes, in other words a construct is a combination of concepts (Ray and Mondal, 1999).

Vulnerability assessment is a useful adaptation planning tool for mitigating climate risks (IPCC 2014). To mitigate the loss of lives and livelihoods, India should devise a climate risk strategy based on a robust vulnerability assessment. While India has conducted such assessments for specific sectors and geographies, there is still no unified framework for a micro-level assessment, making comparisons difficult. Numerous studies have assessed the aggregate effects of climate change along with societal and political factors on farming in different countries but studies on the impact of climate change on crop productivity as well as vulnerability in the case of India, are very less. Hence, the present study aims to examine the impact of changes in climatic parameters on crop productivity, primarily the pulses and explore the relationship between Vulnerability and climate-smart agriculture technologies. The study also reviews the trend in variability of different selected climatic indicators over the decades.

NASA's definition of climate change says it is "a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass changes such as sea-level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events."

In the present study "Climate change" is operationally defined as any change in climatic parameters (rainfall and temperature) over time due to natural variability or as a result of human activity. To address the research issue vulnerability of famers to climate change was taken as the major construct. vulnerability is defined as "the propensity or predisposition to be adversely affected. It encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2021). In the present study, Vulnerability of farmers to climate change is operationally defined as the degree to which a farmer is susceptible to, or unable to cope up with adverse effects of climate change on agriculture. It depends on extent of farmers expose to climate change (rainfall & temperature), their level of sensitivity to climate change and their adaptive capacity.

2.2 Dimensions to Measure the Construct

In general vulnerability is a function of major three components *viz.*, Exposure, Sensitivity and Adaptive capacity. Exposure refers to the degree and the characteristics as a system exposed to significant variability; sensitivity refers to the degree of influence as a system stimulated by climate-related factors, including the adverse and beneficial effects; adaptive capacity refers to ability of making protection and avoiding loss as the natural and man-made system affected by actual or expected climatic stimuli and their impacts. Vulnerability is defined as the degree to which a system is susceptible or unable to cope up with adverse effects of climate change and it is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and adaptive capacity. Hence, several items were framed under these concepts to design the vulnerability index.

2.3 Operationalization of the concepts

2.3.1 Exposure of farmers to climate variability is operationally defined as degree of climate variability and change (rainfall & temperature) that farmers experiences over a period of time.

2.3.2 Sensitivity of farmers to climate change is operationally defined as the degree in which withstanding capacity of farmers is adversely affected due to changes in rainfall and temperature.

2.3.3 Adaptive capacity of farmers to climate change (rainfall & temperature) is operationally defined as the ability of farmers to adjust themselves to climate change and its potential damages caused on agriculture or to take up advantage of opportunities created or to cope up with its consequences.

2.4 Collection and structuring of index items

After, identifying different concepts or dimensions relevant to the measuring construct, the next step is the collection and creation of number of items under each concept. The items were collected from various sources *viz.*, research articles, review articles, various national and international conference proceedings, working papers, and also from several web sources. Discussion with field workers and focus group discussion with farmers were also done for the structuring of items relevant to measure the vulnerability of farmers. A total of 118 items were collected and structured initially and after critical evaluation and discussion with the advisory committee, only 89 items were retained under three dimensions stated earlier. These edited items were then sent to 110 extension specialists through post and Google forms into their inboxes working in various institutions like, Indian Council of Agriculture Research (ICAR), State Agriculture Universities, NAARM, CRIDA, IIHR, KVKs, MANAGE, IIMR, Experts in various Resource institutes, Agricultural Officers and experts in other national institutions throughout India. for the critical evaluation of statements to determine their relevancy on a three-point continuum viz Most Relevant (MR), Relevant (R) and Irrelevant (IR) with the score of 3, 2 and 1 respectively. The judges were also requested to make necessary modifications or suggestions and addition or deletion of items. The responses received from 58 experts out of 110 experts in time. The relevancy score for each statement was found out by adding the scores based on the rating of all the judges. The relevancy weightage of each item was worked out to get the mean relevancy score using the following formulas.

2.4.1 Relevancy Weightage

Relevancy weightage was worked out by the following standard formula

$$\textit{Relevancy weightage} = \frac{MR*3+R*2+IR*1}{Maximum\ \ possible\ \ score}$$

2.4.2 Mean relevancy score

Mean relevancy score was worked out by the following standard formula

$$Mean\ relevancy\ score = \frac{MR*3+R*2+IR*1}{Total\ number\ \ of\ judges\ \ responded}$$

3. RESULTS AND DISCUSSION

3.1 Selection of index items

Using the relevancy weightage formulae, the relevancy weightage of each dimension was calculated and all the dimensions had the relevancy weightage of more than 0.75. So, all the three dimensions are found as valid to be included in the composite Index and it was presented in Table.1.

Table 1. Relevancy weightage for selection of dimensions for Vulnerability Index

Sl. No.	Indicators	Relevancy Weightage
1.	**Exposure**	0.818
1.1	Rainfall	0.826
1.2	Temperature	0.811
2.	**Sensitivity**	0.822
3.	**Adaptive Capacity**	0.812
3.1	Proactive Adaptation	0.820
3.2	Proactive Adaptation	0.800

Using the mean relevancy score formulae, the mean relevancy score was calculated for verifying the validity of each item for the **Vulnerability Index of farmers.** The values of relevancy score of each item were given in Table. 2.

Table:2. Mean Relevancy score for selection of items for Vulnerability Index of farmers.

Sl. No.	Dimensions and Items	Mean Relevancy Score
I	**Exposure**	
I.A	**Rainfall**	
1	Observed decrease in total number of rainy days in a year (>2.5mm/Day)	2.45*
2	Experienced reduction in amount of annual average rainfall	2.41
3	Observed variation in onset of monsoon in recent years	2.60*
4	Experienced changes in annual rainfall pattern	2.58*
5	Observed greater shift in the seasonal rainfall pattern	2.45*
6	Exposed to prolonged dry spell	2.41
7	Greater uneven distribution of rainfall throughout the cropping seasons	2.56*
8	Experienced intense rains during harvesting stage in recent years	2.32
9	Deforestation leads to reduction in rainfall	2.47*
10	Change in wind speed causes uneven distribution of rains	2.23
I.B	**Temperature**	

11	Experienced greater increase in average annual temperature	2.45*
12	Exposed to higher variations in day-night temperature	2.34
13	High incidence of extreme hot days	2.50*
14	High incidence of extreme cold days	2.52*
15	Experienced summer was getting hotter	2.45*
16	Exposed to prolonged of summer season	2.34
17	Experienced variation in temperature during crop growth period	2.50*
II	**Sensitivity**	
18	Heavy rainfall leads to water logging in the fields	2.60*
19	High rainfall causes soil and water erosion	2.72*
20	Excess water erosion leads to reduction in soil fertility	2.50*
21	Heavy rains during initial stage of crop causes seed rot and damping off of seedlings	2.50*
22	Leaching of applied fertilizers due to heavy rains	2.52*
23	Excess moisture availability leads to high weed infestation during vegetative stage of crop	2.61*
24	Heavy rains cause reduced branching and nodulation in the crop	2.49*
25	Intense rainfall leads to flower and fruit drop	2.56*
26	High and continuous rain causes outbreak of pests and diseases	2.54*
27	Continuous rains at maturity causes in-suit germination of seed	2.49*
28	High and continuous rains during post- harvest and marketing stages leads to improper drying of produce which fetches low price in the market	2.52*
29	Crusting and cracking of soil surface takes place due to low/no rainfall	2.32
30	No rainfall during initial stage of crop causes improper germination of seeds	2.38
31	Low soil moisture availability leads to lower fertilizer use efficiency	2.58*
32	No rainfall during vegetative stage causes drying and dropping of leaves	2.47*
33	No rainfall during flowering stage causes effect on flower setting and crop faces water stress	2.32
34	Low/no rainfall during pod development stage affects seed filling in pods	2.23
35	Volatilization of applied fertilizers takes place due to high temperature	2.12
36	Greater crop evapotranspiration due to high temperature	2.40
37	High temperature affects on crop nodulation	2.32
38	Greater temperature causes pollen abortion, flower drop and	2.45*

	pollination	
39	Higher temperature during pod development leads to poor pod setting	2.45*
40	High temperature during harvesting stage causes pod shattering	2.30
41	Low temperature during vegetative stage helps in occurrence of aphids' infestation	2.20
42	Low temperature during post-harvesting and marketing stage leads to improper drying of produce and infestation of storage pests	2.32
43	Greater variation of temperature leads to prolongment of cropping period	2.54*
44	Farming in dry land and rainfed areas are more drought prone	2.38
45	Small and marginal farmers are more likely to be adversely affected due to climate change	2.47*
46	Single farming system without subsidiary occupation have to face more economic crisis during adverse climatic conditions	2.56*
47	Poor access to weather information adversely effects to planning and carrying timely crop production activities	2.49*
III.	**Adaptive Capacity**	
A.	**Proactive adaptation**	
48	Adapted by following proper drainage (natural drainage) system to remove excess water and prevent water logging	2.56*
49	Adapted contour farming to check soil and water erosion	2.58*
50	Adapted by application of FYM to avoid soil erosion and water erosion	2.41
51	Conservation of moisture through ridges and furrows to increase water use efficiency	2.56*
52	Construction of farm ponds to provide irrigation during crop critical growth stages and prolonged dry spills	2.61*
53	Adapted rain water harvesting (surface runoff harvesting) technology to collect and conserve rain water for crop production	2.50*
54	Adapted in-situ water harvesting methods (Broad bed furrows, ridges and furrows)	2.50*
55	Treating seeds with calcium chloride and biofertilizers (Rhizobium, PSB, PGPR etc.…) to withstand moisture stress and helps in fixing atmospheric nitrogen	2.60*
56	Adapted early maturing and drought tolerant varieties	2.54*
57	Practicing of seed treatment with fungicide to reduce damping off of seedlings and Trichoderma viride (bio fungicide) to control occurrence of fusarium wilt	2.60*
58	Carrying of nipping operation to increase lateral branching and high pod setting	2.49*
59	Taking up of timely agronomic management practices to avoid pest	2.52*

	and disease incidence	
60	Practice of mixing of grains with neem leaves, neem oil and ash to manage storage pests and diseases	2.50*
61	Adapted crop diversifications to overcome ill effects of climate change	2.54*
62	Adapted Integrated Farming System for sustainable farming	2.60*
63	Adapted subsidiary activities – poultry/ animal husbandry/fishery/sericulture/ apiculture/piggery to overcome ill effects of climate shock	2.61*
64	Received credit from commercial banks and cooperative banks (Gramin banks)	2.18
65	Availed crop insurance from different sources like PMFBY, WBIS and MNAIS etc..	2.29
66	Maintaining extension contact with AO/AAO/AHO, KVKs and UAS scientists for agriculture and allied sector information	2.41
67	Actively participated in different organizations like GP, SHGs, co-operative society and milk cooperatives for socio-economic benefits.	2.41
68	Received assistance from external agency like GP, ADO and BLDO for agriculture and allied sectors	2.32
69	Maintaining farmer to farmer extension for exchange of knowledge regarding farming and climate smart agriculture	2.49*
70	Well connected to transportation and markets	2.21
71	Adopted access to communication channels like newspaper, television, radio, mobile and internet for agriculture and allied sector information	2.27
72	Adopted access to agriculture input centres for purchasing seed/ seedlings, fertilizers, PPCs, biofertilizers…	2.45*
73	Adopted access to technologies like agriculture machinery and harvesters etc..	2.18
74	Receiving climate related information like weather forecasting, weather-based agriculture information, adaptation and mitigation strategies to climate change	2.56*
B.	**Reactive adaptation**	
75	Practicing of gap filling operation in case of seed rot and damping of seedlings due to heavy rainfall in the initial stage of crop	2.46*
76	Practicing transplanting of seedlings to make sure pooper germination of seeds in moisture stress condition	2.46*
77	Adapted early/delay sowing in adverse climatic conditions	2.47*
78	Application of fertilizers in a band placement to increase its use efficiency	2.48*
79	Application of fertilizers by mixing with soil to manage volatilization	2.38

	of fertilizers	
80	Practicing of foliar application of macro and micro nutrients during water stress conditions	2.58*
81	Practicing of mulching (sand, organic and inorganic) to conserve soil moisture and control weed infestation	2.69*
82	Application of anti-transpirants on plants to minimize moisture loss thorough transpiration	2.32
83	Applying of herbicides (pre and post emergent) to check weed infestation	2.32
84	Spraying of IAA/NAA (growth hormones) for regulating growth and development in plants	2.34
85	Spraying of pulse magic to reduce flower drop and enhance the productivity	2.21
86	Management of pest and diseases by application of chemical and biological control (Integrated pest management)	2.47*
87	Application of growth retardant (PGRs) spray/ salt solution spray to control germination of seeds in the pods of standing crop	2.30
88	Proper sun drying and drying of produce in hot chambers to reduce the moisture level of the produce and improve its quality	2.36
89	Storing of produce in dry and cool godowns to control storage pests and diseases	2.45*
	Total score	**218.07**
	Mean Relevancy Score	**2.45**

Accordingly, the items having the relevancy score equal to and more than 2.45 were retained for the final Vulnerability Index of farmers. Since the mean relevancy score of the overall items were calculated as 2.45. The items that were retained for constructing the final index was given in Table. 3.

Table:3. List of items for Vulnerability Index of farmers.

Sl. No	Dimensions & Items
I	**Exposure**
A	**Rainfall**
1	Observed decrease in total number of rainy days in a year (>2.5mm/Day)
2	Observed variation in onset of monsoon in recent years
3	Experienced changes in annual rainfall pattern
4	Observed greater shift in the seasonal rainfall pattern
5	Greater uneven distribution of rainfall throughout the cropping seasons
6	Deforestation leads to reduction in rainfall
B	**Temperature**
7	Experienced greater increase in average annual temperature
8	High incidence of extreme hot days
9	High incidence of extreme cold days

10	Experienced summer was getting hotter
11	Experienced variation in temperature during crop growth period
II	**Sensitivity**
12	Heavy rainfall leads to water logging in the fields
13	High rainfall causes soil and water erosion
14	Excess water erosion leads to reduction in soil fertility
15	Heavy rains during initial stage of crop causes seed rot and damping off of seedlings
16	Leaching of applied fertilizers due to heavy rains
17	Excess moisture availability leads to high weed infestation during vegetative stage of crop
18	Heavy rains cause reduced branching and nodulation in the crop
19	Intense rainfall leads to flower and fruit drop
20	High and continuous rain causes outbreak of pests and diseases
21	Continuous rains at maturity causes in-suit germination of seed
22	High and continuous rains during post- harvest and marketing stages leads to improper drying of produce which fetches low price in the market
23	Low soil moisture availability leads to lower fertilizer use efficiency
24	No rainfall during vegetative stage causes drying and dropping of leaves
25	Greater temperature causes pollen abortion, flower drop and pollination
26	Higher temperature during pod development leads to poor pod setting
27	Greater variation of temperature leads to prolongment of cropping period
28	Small and marginal farmers are more likely to be adversely affected due to climate change
29	Single farming system without subsidiary occupation have to face more economic crisis during adverse climatic conditions
30	Poor access to weather information adversely effects to planning and carrying timely crop production activities
III	**Adaptive Capacity**
A	**Proactive Adaptation**
31	Adapted by following proper drainage (natural drainage) system to remove excess water and prevent water logging
32	Adapted contour farming to check soil and water erosion
33	Conservation of moisture through ridges and furrows to increase water use efficiency
34	Construction of farm ponds to provide irrigation during crop critical growth stages and prolonged dry spills
35	Adapted rain water harvesting (surface runoff harvesting) technology to collect and conserve rain water for crop production
36	Adapted in-situ water harvesting methods (Broad bed furrows, ridges and furrows)
37	Treating seeds with calcium chloride and biofertilizers (Rhizobium, PSB, PGPR etc.…) to withstand moisture stress and helps in fixing atmospheric nitrogen
38	Adapted early maturing and drought tolerant varieties
39	Practicing of seed treatment with fungicide to reduce damping off of seedlings and Trichoderma viride (bio fungicide) to control occurrence of fusarium wilt
40	Carrying of nipping operation to increase lateral branching and high pod setting
41	Taking up of timely agronomic management practices to avoid pest and disease incidence

42	Practice of mixing of grains with neem leaves, neem oil and ash to manage storage pests and diseases
43	Adapted crop diversifications to overcome ill effects of climate change
44	Adapted Integrated Farming System for sustainable farming
45	Adapted subsidiary activities – poultry/ animal husbandry/fishery/sericulture/ apiculture/piggery to overcome ill effects of climate shock
46	Maintaining farmer to farmer extension for exchange of knowledge regarding farming and climate smart agriculture
47	Adopted access to agriculture input centers for purchasing seed/ seedlings, fertilizers, PPCs, biofertilizers…
48	Receiving climate related information like weather forecasting, weather-based agriculture information, adaptation and mitigation strategies to climate change
B	**Reactive Adaptation**
49	Practicing of gap filling operation in case of seed rot and damping of seedlings due to heavy rainfall in the initial stage of crop
50	Practicing transplanting of seedlings to make sure proper germination of seeds in moisture stress condition
51	Adapted early/delay sowing during adverse climatic conditions
52	Application of fertilizers in a band placement to increase its use efficiency
53	Practicing foliar application of macro and micro nutrients during water stress conditions
54	Practicing of mulching (sand, organic and inorganic) to conserve soil moisture and control weed infestation
55	Management of pest and diseases by means of chemical and biological control (Integrated pest management)
56	Storing of produce in dry and cool godowns to control storage pests and diseases

3.2 Quantification of dimensions and items for the index

After the selection of the dimensions and the items/statements for the index, to complete the composite vulnerability index there must follow suitable scoring procedure. A separate index was developed for each dimension. For each item in the exposure dimension the respondents were asked to give their responses on a three-point continuum *viz.*, Exposed, Somewhat Exposed and Not Exposed and for sensitivity i. e Affected, Somewhat Affected and Not Affected and for Adaptive Capacity it is Adapted, Somewhat Adapted and Not Adapted with scores of 3, 2 and 1, respectively. For each of the dimension, separate index was a calculated using the following formulae.

$$\textit{Component index} = \frac{\textit{Individual score obtained on the indicator}}{\textit{Maximum possible score of that indicator}}$$

For example, Exposure index of farmers was computed as below

$$\textit{Exposure Index} = \frac{Item1 + Item2 + Item3 + \cdots + Item\ 11}{11 \times 3}$$

Where, the exposure indicator has eleven items and the maximum possible score of each item is three. Similar procedure was followed for all the remaining two dimensions to get the individual index scores.

The Climate Vulnerability index (CVI) for each of the selected respondent was calculated as follows.

CVI= {EI-ACI} X SI

Where,

EI is the index of Exposure,
ACI is the index of Adaptive capacity, and
SI is the index of Sensitivity

The climate vulnerability index value is between 0.00 and 1.00 As index value less than 0.05 indicates least vulnerability and values between 0.05 and 0.20 indicates Moderate Vulnerability. While, CVI of more than 0.20 indicates high vulnerability.

Table 4. Vulnerability Index of farmers

CVI Classification	CVI Value
Least Vulnerable	<0.05
Moderate Vulnerable	0.05 - 0.20
Most Vulnerable	>0.20

Here the total number of items in each indicator of the Vulnerability Index of farmers is the weightage of items in the index and its value is 56.

3.3 Standardization of the tool

3.3.1 Reliability

It is more important to test the reliability of the instrument for sound measurement. If the quality of reliability is satisfied by an instrument, then while using it we can be confident that the transient and situational factors are not interfering (Kothari and Garg, 2014).

In the present study the reliability of the index was determined using 'Cornbach's alpha'. Cronbach's alpha is a measure used to assess the reliability, or internal consistency, of a set of scale or test items. It is computed by correlating the score for each scale item with the total score for each observation, and then comparing that to the variance for all individual item scores. The formula for Cronbach's alpha is

$$\propto = \frac{\mathbf{N}\,.\,\bar{\mathbf{c}}}{\bar{\mathbf{v}} + (\mathbf{N}-\mathbf{1}).\,\bar{\mathbf{c}}}$$

Where, N = the number of items.
$\bar{c}$ *= average covariance between item-pairs.*
$\bar{v}$ *= average variance.*

Table 5. **Reliability statistics index**

Index	Reliability Statistics		
	Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**No. of Items**
CVI	0.839	0.846	56
Even Items	0.829	0.842	28
Odd Items	0.776	0.798	28
Even Items: *I2, I4, I6, I8, I10, I12, I14, I16, I18, I20, I22, I24, I26, I28, I30, I32, I34, I36, I38, I40, I42. I44,*			

I46, I48, I50, I52, I54 & I56
Odd Items: *I1, I3, I5, I7, I9, I11, I13, I15, I17, I19, I21, I23, I25, I27, I29, I31, I33, I35, I37, I39, I41, I43, I45, I47, I49, I51, I53 & I55.*
I: Item

In the present study, the structured items are employed to 30 respondents in the non-sample area. The resulting α coefficient of reliability for the vulnerability index of farmers is 0.846, which made evident that the internal consistency of Vulnerability index is 'Better'. Hence, it is clear from the above results that the constructed index is reliable as the value of reliability coefficient (α coefficient) is greater than 0.6.

3.3.2 Validity

Validity of a research instrument assesses the extent to which the instrument measures what it is designed or intended to measure (Robson, 2011). The face and content validity were chosen to validate the tool. The face validity of the tool is established through the statement of each item and it was clearly self-evident. The content validity of the tool is established through the experts' judgement. From the calculations done for carrying out the relevancy test, the content validity of the tool is established. So, the instrument was said to be valid for measuring the Vulnerability of farmers to climate change.

4. CONCLUSION

Climate change is having catastrophic impacts on communities and geographies around the world. India's state of vulnerability is a grim reality that will only worsen without immediate intervention. In its Sixth Assessment Report, the IPCC confirms that breaching the 1.5°C mark is inevitable and that it will likely happen by 2030 (IPCC 2021). Given that India, the seventh most vulnerable country in the world, has aspirations of becoming a five-trillion economy, it needs a climate approach that focuses on realising a just transition and on climate proofing. While Indian districts become ever more vulnerable, the country's leadership has been globally acknowledged for its climate vision. India is a signatory to and an active member of many regional and international disaster risk reduction treaties like the Delhi Declaration, Emergency Preparedness in South-east Asia Region (EPSEAR), the Sendai Framework for Disaster Risk Reduction (SFDRR), and the South Asian Annual Disaster Management Exercise (SAADMEX). The India–led Coalition for Disaster Resilient Infrastructure (CDRI) counts 27 countries as members; its mission is to build climate-/ disaster-proof infrastructures with a special focus on extremely vulnerable countries and small island developing states (SIDS) (CDRI 2021).

Climate change is a global phenomenon; however, its manifestations and impacts vary locally, so do the adaptation capacities, preferences, and strategies. Effective planning for climate change adaptation programming requires an assessment of local vulnerabilities so as to bridge the gap between community needs and priorities at the local level, and policy processes at the higher level. Micro-level studies should form the inputs for formulating relevant policies at the macro level. Researches done at the national and regional level data fail to capture the location specificity of smaller areas. This calls for the need of detailed explorations at the finer spatial level/local level. Keeping in view the above facts, as there is a need of an in-depth analysis of the local level vulnerabilities by integrating quantitative analysis with qualitative information obtained from primary field survey. With the above said information the The index findings would be useful for finding the overall Vulnerability of farmers to climate change, which in turn helps to address the issues particularly in crop productivity, growth, quality, and several other adverse impacts that have ultimately worsened nutritional food security. Certain policy and research initiatives like modified and improved agronomic practices synchronized with precautionary measures can mitigate the impact of adverse climate change. Adopting climate-smart practices would include measures such as encouraging the cultivation of climate-smart crops, the use of heat tolerant varieties, modifying rearing livestock practices and agricultural farming techniques in a way that is less expensive but more precise, an adjustment in planting time for coping with climate exposure risk, and improving early warning and early response systems in the event of the extreme climatic incidents.

ABBREVIATIONS

FAO - Food and Agricultural Organization, NABARD - National Bank for Agriculture and Rural Development, NAARM - National Academy of Agricultural Research Management, CRIDA - Central Research Institute for Dryland Agriculture, IIHR - Indian Institute of Horticultural Research, MANAGE - National Institute of Agricultural Extension Management & IIMR - Indian Institute of Millets Research, NASA -National Aeronautics and Space Administration

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