Original Research Article

Developmentand Standardization of a Climate Vulnerability Index to Measure the Vulnerability Indices of Paddy Growers

ABSTRACT

India is prominently recognized as the foremost producer of paddy, cultivating this crop over 47.83 million hectares and generating 135.75 million tonnes of paddy, thus playing a substantial role in the worldwide paddy output. However, there is an anticipated decline in paddy production yields due to the projected effects of climate change, estimated to range from 10% to 30% by 2030. The assessment of vulnerability will give a comprehensive picture of current and future climate change risks with more stress factors to be anticipated. It will help identify opportunities arising from climate change, and provide information on how to assess adaptive capacity and cope with uncertainty. Adaptation cannot be planned based on the climate projections; information on risk and vulnerabilities is also needed to determine how the climate interacts with socio-economic issues. Against this backdrop, the proposed research seeks to fill this crucial knowledge gap by developing and constructing vulnerability indices tailored specifically for paddy growers in India. Based on review of literature and discussion with experts, three dimensions along with indicators and sub-indicators by adopting the indicator approach method under the vulnerability indices of paddy growers due to climate change were identified. The relevancy rating score was obtained from 50 judges in the concerned area. Based on the relevancy score, 17 indicators and 65 sub-indicators of 0.80 and above were considered for inclusion in the vulnerability index. To compute the index values for each of the identified dimensions, their relative importance in the vulnerability was worked out by assignment of weights to indicators and sub-indicators under each dimension through Principal component analysis (PCA) and the findings revealed that sensitivity was observed to be in the top position (8.36), followed by exposure (8.28) and adaptive capacity (5.61) in assessing the climate vulnerability of paddy growers.

Keywords: Climate change; exposure; sensitivity; adaptive capacity; vulnerability index; paddy growers; principal component analysis.

INTRODUCTION

India is prominently recognized as the foremost producer of paddy, cultivating this crop over 47.83 million hectares and generating 135.75 million tonnes of paddy, thus playing a substantial role in the worldwide paddy output (MoA&FW, 2023). However, there is an anticipated decline in paddy production yields due to the projected effects of climate change, estimated to range from 10% to 30% by 2030 (IPCC, 2023). Natural disasters are a common occurrence worldwide, with Asia experiencing the most frequent occurrences compared to other regions and there is a risk to food and water security due to increased temperature extremes, rainfall variability and drought (IPCC, 2022). As the impacts of climate change intensify agricultural production, a cornerstone of global economies is increasingly vulnerable to the evolving climatic patterns. Paddy cultivation faces unique challenges amidst changing environmental conditions.

The onset of human-induced global warming, signified by a rise of 1.1 degrees Celsius, has ushered in unprecedented changes in Earth's climate (IPCC, 2023). These changes, from altered precipitation patterns to rising temperatures, have direct and profound implications for agricultural systems worldwide. Despite concerted global efforts over the last three decades to combat climate change, progress has been slow, and vulnerabilities in the agricultural sector persist.

Climate change has become an important area of concern for India to ensure food and nutritional security for growing population. In India, significant negative impact has been implied with medium-term (2010-2039) climate change, predicted to reduce yields by 4.5-9%, depending on the magnitude and distribution of warming. Since agriculture makes up roughly 16% of India's GDP, a 4.5-9% negative impact on production implies a cost of climate change to be roughly up to 1.5% of GDP per year (Venkateswarlu et al., 2013). Furthermore, India's rank as the 7th most exposed and vulnerable nation in the Global Climate Risk Index Report-2021 underscores the urgency of understanding and mitigating the specific challenges faced by its agricultural sector.

The maximum temperature and low rainfall conditions have been identified as key factors impacting Indian rice yields, subsequently affecting the nation's economy (Ashkra et al., 2023). Climate change compounds these challenges, posing a significant threat to Indian agriculture in general, influencing food security, and hindering efforts to meet Sustainable Development Goals (IPCC, 2023).

In terms of vulnerability to extreme weather events, India stands as the seventh most vulnerable nation globally. A temperature increases of just one degree Celsius may result in a 3-7% reduction in yields of major food crops, with rice production anticipated to decrease significantly under higher temperature scenarios. Paddy farmers, already contending with heavy rainfall, low temperatures, and other climate-induced stressors, face a multitude of challenges, leading to reduced yields and variations in crop prices.

The assessment of vulnerability will give a comprehensive picture of current and future climate change risks with more stress factors to be anticipated. It will help identify opportunities arising from climate change, and provide information on how to assess adaptive capacity and cope with uncertainty. Adaptation cannot be planned based on the climate projections; information on risk and vulnerabilities is also needed to determine how the climate interacts with socio-economic issues.

The ongoing El Niño year in India, coupled with expected disruptions in monsoons, further heightens the vulnerability of paddy growers, presenting potential threats to food security and exacerbating existing challenges. Despite the critical importance of understanding and mitigating these vulnerabilities, the estimation of climate change vulnerability in the specific context of paddy cultivation is still a relatively nascent field of study.

Against this backdrop, the proposed research seeks to fill this crucial knowledge gap by developing and constructing vulnerability indices tailored specifically for paddy growers in India. These indices will encompass a comprehensive set of parameters, considering factors such as temperature variations, precipitation patterns, and the overall climatic conditions impacting rice production. By adopting a multidimensional approach, this research aims to provide nuanced insights into the vulnerabilities faced by paddy growers, facilitating targeted policy interventions, sustainable agricultural practices, and enhanced climate resilience in this vital sector. The resulting indices will not only contribute to academic scholarship but also serve as practical tools for policymakers, researchers, and stakeholders striving to address the complex challenges posed by climate change in Indian agriculture.

Theoretical Background of the study

Vulnerability is a multidimensional concept which varies across temporal and spatial scales and depends on economic, social, geographic, demographic, cultural, institutional, governance and environmental factors (Thornton et al., 2006; Piya et al., 2012). Vulnerability is defined as the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2022). Vulnerability to climate change is defined as the degree to which a system issusceptible toand unable to cope up with the adverse effects of climate changeincluding climate variability and extremes. Vulnerability is a function or magnitude andrate of climate change and variation to which a system is exposed, its sensitivity, and itsadaptive capacity(IPCC, 2007).

Exposure is “the degree to which a system is exposed tosignificant climatic variations”. Sensitivity to climate change is defined as “the degreeto which a system is affected, either adversely or beneficially, by climate variability”.Adaptive capacity is “the ability of a system to adjust to climate change to moderatepotential damages or to take advantage of opportunities, or to cope with theconsequences”(IPCC, 2007).

Operationalization of Vulnerability indices of paddy growers:

Vulnerability indices of paddy growers due to climate change is operationally defined as the degree to which paddy growers are susceptible to or unable to cope with adverse effects of climate change. It takes into account the exposure of paddy growers to climate-related hazards, their sensitivity to these hazards, and their adaptive capacity.

(a) **Exposure of paddy growers to climate variability** is operationally defined as degree ofclimate variability that farmers experiences over a period of time in cultivation of paddy.

(b) Sensitivity of paddy growersto climate change is operationally defined as the degree to which paddy growers and their farming practices are adversely affected due to the changes in climate. It takes into account how various climatic factors such as precipitation, temperature and extreme weather events can influence farming practices, yield, income and overall agricultural productivity.

(c) Adaptive Capacity of paddy growersto climate change is operationally defined as 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.

METHODOLOGY

Vulnerability index was developed by following the procedure as given below:

Step1: Identification of Dimensions

The vulnerability indicesof paddy growers due to climate change was identified as adependent variable. Based on a thorough review of literature related to vulnerability toclimate change, three dimensions were identified viz.,

- Exposure of paddy growers,
- Sensitivity of paddy growers and
- Adaptive capacity of paddy growers.

Further the different indicators and sub-indicators were framed under each dimension by adopting the ‘indicator approach method’ and those sub-indicators are the variables for the research study.

Step 2: Collection of indicators and sub-indicators

A large number of draft indicators and sub-indicators on each dimension of vulnerability indices of paddy growers due to climatechange were collected based on review of literature, discussion with concerned specialists.These indicators and sub-indicators were carefully edited, revised and restructured in google forms.

The Google forms were mailed to 100 experts in the agricultural extension and otherrelated fields of ICAR Institutes and SAUs to critically evaluate the relevancy of each indicator and sub-indicators in the three-pointcontinuum viz., Relevant (R), Somewhat Relevant (SWR) and NotRelevant (NR) with the score of 3, 2 and 1 respectively. They were also requested to add other indicators that they find relevant to measure vulnerability indices of paddy growers. A total of 56 judges returned thequestionnaires duly completed and 50 were considered for further processing. From thedata gathered, Relevancy Rating Scorewas worked out for all the indicators and sub-indicators by using the formula

$$\textbf{Relevancy Rating Score} = \frac{\mathbf{R \times 3 \ + \ SWR \times 2 \ + \ NR \times 1}}{\textbf{No. of judges responded } \times \textbf{Maximum score}}$$

Taking into consideration the overall values which was given by thejudges, the items having relevancy rating score of equal and more than 0.80 were considered for the inclusion infurther analysis. Thus, indicators andsub-indicators were considered for further processing and suitablymodified as per the comments of experts wherever applicable. The indicators that have passed the criteria arepresented in Table 2.

Step 4:Operationalization and Functional relationship of indicators and sub-indicators to climate vulnerability

The indicators and sub-indicators are operationalized in this step as given below:

Table 1.Functional Relationship of the indicators to the climate vulnerability

Dimensions	Indicators	Sub-indicators	FR[a]	Description of the sub-indicator
Exposure of paddy growers to climate variability	Monsoon Variability	Changes in pre-monsoon rainfall	↑	Farmers who perceived alterations in rainfall patterns occurring before the onset of the monsoon season
		Changes in the onset and duration of South-West Monsoon	↑	Farmers who had a perspective on shifts in the timing and length of the primary monsoon season.
		Changes in post-monsoon rains	↑	Farmers who viewed variations in rainfall patterns following the

				monsoon season
		Changes in Winter season	↑	Farmers who observed alterations in temperature and weather conditions during the winter months
	Precipitation Variability	Delay in onset of rainfall	↑	Farmers who experienced delays in the arrival of seasonal rainfall.
		More number of rainy days	↑	Farmers who encountered an increased number of rainy days
		More dry spells during crop season	↑	Farmers who experienced prolonged periods of limited rainfall within the crop growing season
		Rainfall aberrations during crop growth period	↑	Farmers who observed irregular or unexpected rainfall patterns occurring during critical stages of crop growth
		Erratic rainfall throughout the season	↑	Farmers who perceived unpredictable fluctuations in rainfall amounts and distribution over the entire cropping season
		Low number of rainy days/Untimely winter rainfall	↑	Farmers who reported a decrease in the frequency of rainy days or rainfall occurring at inappropriate times during the winter season
	Climate Hazard	Occurrence of floods	↑	Farmers who experienced sudden inundation of land areas due to excessive rainfall or river overflow.
		Occurrence of cyclones	↑	Farmers who reported an increase in frequency and incidence of Cyclones
		Heavy rains	↑	Farmers who encountered heavy rainfall events over a period of time
		Unseasonal rains	↑	Farmers who experienced rainfall occurring outside the typical monsoon season or at irregular intervals.
		Extended dry spells	↑	Farmers who experienced prolonged periods of limited rainfall
		Hailstorms/Thunderstorms and Lightning	↑	Farmers who faced hailstorms, thunderstorms, and lightning perceived significant impacts on their crop damage and yield loss.
	Temperature	Rising Temperatures	↑	Farmers who observed maximum temperatures over time
		Heat waves during crop season	↑	Farmers who experienced heat waves during the crop season
		Low Temperature	↑	Farmers who encountered low temperatures
Sensitivity of paddy growers to climate	Crop phenology	Delay in planting nursery/sowing	↑	Farmers who experienced delays in planting nursery or sowing due to unfavourable weather conditions
		Change in timing of	↑	Farmers who observed alterations in

variability		planting		the usual timing of planting activities influenced by climate variations.
		Change in scheduling irrigation	↑	Farmers who noted modifications in the timing and frequency of irrigation
		Change in scheduling pesticide inputs	↑	Farmers who reported adjustments in the timing of pesticide applications to manage pest due to climate-related factors
		Change in scheduling of post-harvest activities	↑	Farmers who experienced alterations in the timing of post-harvest activities such as harvesting, drying, and storage influenced by climate variations
	Pest and Disease Dynamics	Susceptibility to pests-BPH, yellow stem borer, leaf folder, rodents due to climate change	↑	Farmers who reported an increase in the incidence of pest/insect attack due to climate change
		Susceptibility to diseases- Blast, sheath blight, bacterial blight due to climate change	↑	Farmers who reported an increase in the incidence of diseases attack due to climate change
		Inability to take plant protection activities	↑	Farmers who faced challenges in implementing plant protection activities against pest/disease attack due to climate-related factors
	Economic vulnerability	Augmented climate-induced cultivation costs	↑	Farmers who believed climate-led risk had increased the cost of rice cultivation
		Climate-induced market challenges	↑	Farmers who encountered disruptions or difficulties in accessing markets and selling their produce due to climate change impacts.
		Hefty labour costs	↑	Farmers who faced an increased expenses associated with labour for agricultural activities
		Price fluctuations	↑	Farmers who observed unpredictable changes in commodity prices influenced by climate variations
		Income instability	↑	Farmers who experienced fluctuations or uncertainty in income levels over time due to climate change
		Debt vulnerability	↑	Farmers who reported susceptibility to financial indebtedness or an inability to repay loans.
		Weather triggered input expenses	↑	Farmers who believed additional input expenses incurred in response to weather-related risks or uncertainties.

	Water sensitivity	Delayed/Limited release of canal water for irrigation	↑	Farmers who experienced delays or limited release of canal water for irrigation due to climate-related factors
		Low yields due to non-availability of irrigation	↑	Farmers who believed low yields due to non-availability of irrigation water influenced by climate variability
		Non-availability of water during planting	↑	Farmers who encountered non-availability of water during planting seasons due to climate-related factors
		Non-availability of water during grain formation	↑	Farmers who experienced non-availability of water during grain formation stages influenced by climate variability
	Extreme weather sensitivity	Crop failure due to floods/cyclones	↑	Farmers who faced crop failure due to floods or cyclones driven by climate variability.
		Affecting fodder production	↑	Farmers who observed adverse impacts on fodder production influenced by climate variability
		Low quality of harvested rice grain	↑	Farmers who encountered low quality of harvested rice grain due to climate change
		Reduction in crop yield	↑	Farmers who experienced reductions in crop yield influenced by climate variability.
Adaptive capacity of paddy growers to climate variability	Socio-Demographic	Education	↓	Farmers' average years of schooling
		Farming Experience	↓	Number of years
		Membership in community level organisations/farmer-based organisation	↓	Farmers who were members of community-level organizations or farmer-based organizations
	Knowledge Acquisition	Awareness of climate information and early warning system	↓	Farmers who were aware of climate information and early warning systems shared their perceptions.
		Awareness of climate change impacts on paddy farming	↓	Farmers who were aware of climate change impacts on paddy farming
		Understanding of climate resilient practices and climate-informed inputs	↓	Farmers who had an understanding of climate resilient practices and climate-informed inputs
	Preparedness	Access to early warning system/climate information	↓	Farmers who had access to early warning systems or climate information services

		Utilization of mobile apps and online portals for monitoring weather and pest conditions	↓	Farmers who utilized mobile apps and online portals for monitoring weather and pest conditions
	Weather-Responsive Planning	Flexibility in farming schedules based on weather changes	↓	Farmers who demonstrated flexibility in farming schedules based on weather changes
		Rescheduling planting and harvesting dates based on weather forecast	↓	Farmers who rescheduled planting and harvesting dates based on weather forecasts
		Utilization of climate forecasts to anticipate and manage yield variability	↓	Farmers who utilized climate forecasts to anticipate and manage yield variability
	Social Networking	Participation in farmer groups, cooperatives and networks	↓	Farmers who participated in farmer groups, cooperatives, and networks shared their experiences
		Exchange of climate related information and best practices	↓	Farmers who exchanged climate-related information and best practices expressed varied opinions
	Capacity Building	Participation in workshops/training sessions on climate resilient practices	↓	Farmers who participated in workshops or training sessions on climate-resilient practices shared their perspectives.
		Access to Agricultural Extension services	↓	Farmers who had access to Agricultural Extension services
	Financial resilience	Access to agricultural credit and loans	↓	Farmers who had access to agricultural credit and loans
		Access to non-formal credit	↓	Farmers who had access to non-formal credit
		Access to crop insurance	↓	Farmers who had access to crop insurance
		Access to market	↓	Farmers who had access to markets
	Infrastructural Preparedness	Rainwater harvesting	↓	Farmers who practiced collection and storage of rainwater for agricultural use
		Elevated pathways for drainage of water	↓	Farmers who utilized and construction of raised pathways to facilitate drainage and prevent waterlogging.
		Access to	↓	Farmers who had access to

		mechanized equipment		availability of machinery for agricultural operations.
		Grain storage silos	↓	Farmers who utilized facilities for storing and preserving harvested grains

[a] Functional relationship of the indicators to the vulnerability

Step 5: Normalization of Indicators and sub-indicators

The indicators and sub-indicators that passed the criteria of relevancy rating scores were selected for inclusion in the index. Consequently, the scores of all indicators and sub-indicators were normalized using the provided formula.

$$U_{ij} = \frac{Y_{ij} - Min_{yj}}{Max_{ij} - Min_{yj}}$$

Where,

U_{ij} = Unit score of the ith respondents on thejth component

Y_{ij} = Value of ith respondent on the jth component

Max_{ij} = Maximum score on the jth component

Min_{yj} = Minimum score on the jth component

Step 7: Validity Test:

In the present investigation, KMO and Barlett's Testwas adopted to compute the validity of the Vulnerability Index and it was established by the expert'sjudgement.The variance proportion can be interpreted as per the following table

Table 2.The KMO Value Interpretation Criteria

KMO Value	Interpretation of sampling adequacy
1 to 0.9	Very Good
0.8 to 0.9	Good
0.7 to 0.8	Medium
0.6 to 0.7	Reasonable
0.5 to 0.6	Acceptable
< 0.5	Unacceptable

Prior to assigning weights to indicators and sub-indicators under each dimension via Principal Component Analysis, the normalized data underwent analysis with KMO and Bartlett's Test to assess the validity of items for measuring sampling adequacy, utilizing SPSS software (version 20).

Step 6: Assignment of weights to indicators and sub-indicators under each dimension through Principal component analysis(PCA)

After normalization, factor analysis for each data set of 17 indicators and 65 sub-indicators under each dimension of vulnerability index was runchoosing Principal Component Analysis

(PCA) for extraction and varimax method forrotation of factors using SPSS software (version20).Then, the method followed by Feroz et al.,2010; Maiti et al., 2015 adopted for this study to assign the weight to the indicators sub-indicators under each dimension.

The initial Eigen values above were recognized. Based on the number of Eigen values exceeding 1, an equivalent number of rotated components were extracted for each sub-indicator, as depicted in the rotational component matrix. Subsequently, the extracted rotated component matrix was multiplied by the Eigen values, with the first values being multiplied by the first extracted component column and the second Eigen value being multiplied by the second extracted component column. The resulting values were then aggregated for each indicator to determine their respective weights. Similarly, the same process was carried out to derive weights for other indicators. Convert the obtained values into absolute values and calculate the sum of each row for all the indicators to obtain weightage values.

Step 8: Reliability of the Vulnerability Index:

Internal consistency reliability method via Cronbach alpha was adopted to testthe reliability using SPSS software version 20. The standard Cronbach Alpha coefficient valueof equal or more than 0.70, which indicatesgood internal consistency of items and considered for further inclusion in the index.

RESULTS AND DISCUSSION

Selection of indicators for inclusion in the index: The responses were quantified and presented in the Table 3.

Table 3: Relevant Rating Scoreof Indicators

Indicator	RRS
Monsoon Variability	0.85
Precipitation Variability	0.86
Climate Hazard	0.87
Temperature	0.91
Crop phenology	0.89
Pest and Disease Dynamics	0.91
Financial resilience	0.88
Water sensitivity	0.83
Extreme weather sensitivity	0.84
Socio-Demographic	0.83
Knowledge Acquisition	0.85
Preparedness	0.82
Weather-Responsive Planning	0.87
Social Networking	0.84
Capacity Building	0.92
Economic Vulnerability	0.89
Infrastructural Preparedness	0.84

And it is evident from theTable 3 that the relevancy scores for different indicators ranged from 0.81 to 0.92. Therelevancy rating scores were calculated by dividing theactual score obtained with maximum score obtainablefrom 50 experts. The indicators with relevancy ratingscore more than 0.80 were selected for inclusion inthe index for measuring the vulnerability index.Only 17 indicators satisfied this criterion and they weremonsoon variability, precipitation variability, climate hazard, temperature, crop phenology, pest and disease dynamics, financial resilience, water sensitivity, extreme weather sensitivity, socio-demographic, knowledge acquisition, preparedness, weather-responsive planning, social networking, capacity building, economic vulnerability and infrastructural preparedness

Selection of sub-indicators: Only those items with relevancyrating score more than 0.80 were selected for inclusionin the index. The relevancy scores were calculated bydiving actual score with the maximum score possible.Out of 86 items chosen, 65 items were finally selectedfor inclusion in the index. The responses for items ofthe index were quantified and given in the Table 4.

Table 4. Relevancy Rating Score of Sub-indicators

Indicator	Sub-indicator	RRS
Monsoon Variability	Changes in pre-monsoon rainfall	0.84
	Changes in the onset and duration of South-West Monsoon	0.92
	Changes in post-monsoon rains	0.84
	Changes in Winter season	0.83
Precipitation Variability	Delay in onset of rainfall	0.83
	More number of rainy days	0.85
	More dry spells during crop season	0.87
	Rainfall aberrations during crop growth period	0.89
	Erratic rainfall throughout the season	0.90
	Low number of rainy days/Untimely winter rainfall	0.86
Climate Hazard	Occurrence of floods	0.87
	Occurrence of cyclones	0.89
	Heavy rains	0.85
	Unseasonal rains	0.89
	Extended dry spells	0.90
	Hailstorms/Thunderstorms and Lightning	0.84
Temperature	Rising Temperatures	0.91
	Heat waves during crop season	0.85
	Low Temperature	0.85
Crop phenology	Delay in planting nursery/sowing	0.89
	Change in time of planting	0.87
	Change in scheduling irrigation	0.87
	Change in scheduling pesticide sprays	0.83
	Change in scheduling of post-harvest activities	0.82
Pest and Disease Dynamics	Susceptibility to pests-BPH, yellow stem borer, leaf folder, leaf mite and rodents due to climate change	0.89
	Susceptibility to diseases- Blast, sheath blight, bacterial leaf blight due to climate change	0.92
	Inability to take plant protection activities	0.91
Economic	Augmented climate-induced cultivation costs	0.89

Vulnerability	Climate-induced market challenges	0.92
	Hefty labour costs	0.90
	Price fluctuations	0.88
	Income instability	0.92
	Debt vulnerability	0.89
	Weather triggered input expenses	0.83
Water sensitivity	Delayed/Limited release of canal water for irrigation	0.80
	Low yields due to non-availability of irrigation	0.81
	Non-availability of water during planting	0.82
	Non-availability of water during grain formation	0.90
Extreme weather sensitivity	Crop failure due to floods/cyclones	0.81
	Affecting fodder production	0.81
	Low quality of harvested rice grain	0.89
	Reduction in crop yield	0.85
Socio-Demographic	Education	0.86
	Farming Experience	0.89
	Membership in community level organisations/farmer-based organisation	0.81
Knowledge Acquisition	Awareness of climate information and early warning system	0.80
	Awareness of climate change impacts on paddy farming	0.82
	Understanding of climate resilient practices and climate-informed inputs	0.86
Preparedness	Access to early warning system/climate information	0.82
	Utilization of mobile apps and online portals for monitoring weather and pest conditions	0.85
Weather-Responsive Planning	Flexibility in farming schedules based on weather changes	0.81
	Rescheduling planting and harvesting dates based on weather forecast	0.90
	Utilization of climate forecasts to anticipate and manage yield variability	0.85
Social Network	Participation in farmer groups, cooperatives and networks	0.82
	Exchange of climate related information and best practices	0.86
Capacity Building	Participation in workshops/training sessions on climate resilient practices	0.93
	Access to Agricultural Extension services	0.91
Financial resilience	Access to formal credit	0.85
	Access to non-formal credit	0.80
	Access to crop insurance	0.82
	Access to market	0.83
Infrastructural Preparedness	Rainwater harvesting	0.87
	Elevated pathways for drainage of water	0.81

	Access to mechanized equipment	0.84
	Grain storage silos	0.85

Validity and Computation of assigning weightsto indicators and sub-indicators under each dimension through Principal Component Analysis:

KMO and Bartlett'stest was carried out via principal component analysisto assess the validity of indicators and sub-indicators under each dimension separately and this test analyses whether the responses givenare adequate with the sample or not. The results are presented as following below

The PCA is a variable reduction technique which maximizes the amount ofvariance accounted for in the observed variables by a smaller group of variables calledfactors. It is a process for extracting from a set of variables those few orthogonal linearcombinations of variables that most successfully capture the common information. Itallows reducing the number of variables into their principal components. Factoranalysis attempts to identify underlying variables, or factors, that explain the pattern ofcorrelation within a set of observed variables. PCA was run into selected seventeen indicators and sixty-five sub-indicators under three dimensions of vulnerability indices of paddy growers. The seventeenindicators and sixty-five sub-indicators were entered into a correlation matrixand a Varimax orthogonal rotation with Kaiser normalization was applied to thesolution.Further PCA was carried out with all the indicators under each dimension separately and thefindings were interpreted as following below

Dimension 1: Exposure of paddy growers to climate variability

Table 5: KMO and Bartlett's Test Value for exposure of paddy growers to climate variability

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.567
Bartlett's Test of Sphericity	Approx. Chi-Square	383.706
	Df	171
	Sig.	0.000

Table 5 displayed above presented the output of KMO and Bartlett's test. The Kaiser-Meyer-Olkin (KMO) value obtained was 0.567. Upon comparing this value with those in Table 2, it became evident that 0.567 was an acceptable value. This indicated that the sum of partial correlations was not significant compared to the sum of correlations, amounting to 56.7% of the analysis variables. Consequently, there was no diffusion in the correlation pattern, affirming the appropriateness of factor analysis in this scenario. Thus, reliable and distinct factors could be derived from the factor analysis of this data.

Moreover, Table 5 also provided Bartlett's Test of Sphericity results. The Approx. Chi-Square value obtained was 383.706, with a significance value (p) of 0.000, which was less than 0.001. This implied that the correlation matrix was not an identity matrix, signifying a strength of relationship among the variables. Therefore, factor analysis was deemed applicable for this dataset.

Table 6: Eigen values for exposure of paddy growers to climate variability

Total Variance Explained		
Component	Initial Eigenvalues	Extraction Sums of Squared Loadings

	Total	% of Variance	Cumulative %	Total	% of Variance
1	4.120	21.687	21.687	4.120	21.687
2	3.571	18.797	40.483	3.571	18.797
3	1.476	7.766	48.250	1.476	7.766
4	1.371	7.215	55.465	1.371	7.215
5	1.242	6.538	62.003	1.242	6.538
6	1.048	5.517	67.520	1.048	5.517
7	.994	5.232	72.752		
8	.931	4.902	77.653		
9	.770	4.050	81.703		
10	.692	3.644	85.347		
11	.638	3.359	88.706		
12	.511	2.690	91.396		
13	.408	2.147	93.543		
14	.386	2.032	95.574		
15	.213	1.119	96.694		
16	.200	1.053	97.747		
17	.188	.989	98.736		
18	.154	.813	99.549		
19	.086	.451	100.000		

Extraction Method: Principal Component Analysis.

The table 6 presented the Eigen value specifications and the percentage of variance explained by the components. Components with more than one Eigen value were chosen. Consequently, six factors were extracted from the six components, collectively explaining a total variance of 67.52 percent in exposing paddy growers to climate vulnerability. Hence, it can be concluded that the six factors with more than one Eigen value contributed 67.52 percentof the variation in exposing paddy growers to climate vulnerability.

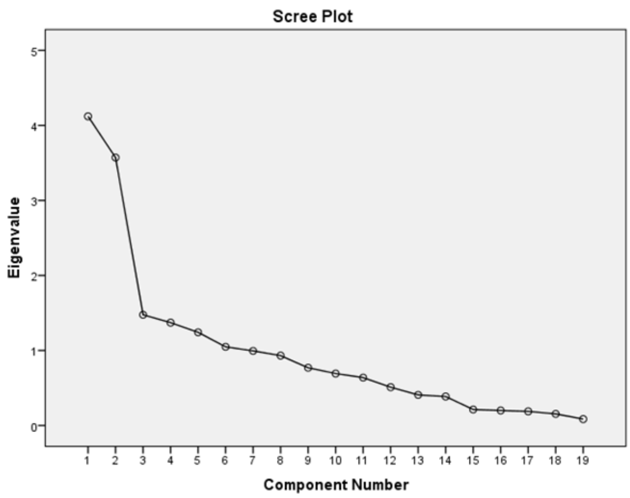

Figure 1: Scree plot for exposure of paddy growers to climate variability

Figure 1, depicted above, illustrated the eigenvalues of all components graphically. This scree plot served as a visual representation of Table 6. The graph was generated utilizing the data from Table 6. On the Y-axis, the graph represented 'Eigenvalues,' ranging from 0 to 6, with the maximum value of 6 derived from the 'Total' column in the 'Initial Eigenvalues' section. These eigenvalues were plotted as points on the curve of the scree plot in Figure 1. The X-axis denoted the 'Component Number,' with values ranging from 1 to 19, obtained from the 'Component' column in Table 6. Upon observation of Figure 1, it was noted that the curve in the scree plot started to level off between component 6 and component 7. Additionally, it was evident that the eigenvalues for components 1 to 6 exceeded 1, while for components 7 to 19, the eigenvalues were less than 1. Therefore, following the extraction process, only 6 factors were retained.

Table 7. Rotated Component Matrix for exposure of paddy growers to climate variability

Rotated Component Matrix[a]						
	Component					
	1	2	3	4	5	6
Changes in Winter season	.781					
Changes in post-monsoon rains	.749					
Changes in pre-monsoon rainfall	.742					
Delay in onset of rainfall	.673					
Extended dry spells		.737				
Unseasonal rains		.718				
Low number of rainy days/Untimely winter rainfall		.697				
Occurrence of cyclones		.514				
Rainfall aberrations during crop growth period			.853			
Changes in the onset and duration of South-West Monsoon			.694			
More dry spells during crop season			.593	.501		
Low Temperature			.553			
Erratic rainfall throughout the season			.550			
More number of rainy days				.733		
Heat waves during crop season				.628		
Rising Temperatures				.620		
Heavy rains					.817	

Hailstorms/Thunderstorms and Lightning						.869
Occurrence of floods				.532		-.583
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.[a]						
a. Rotation converged in 8 iterations.						

In thetable 7, each factor column was scanned to identify the sub-indicators that were more significantly correlated with the particular factor. Consequently, sub-indicators with a factor loading of more than 0.50 were selected for further analysis

Dimension 2: Sensitivity of paddy growers

Table 8: KMO and Bartlett's Test Value for sensitivity of paddy growers to climate change

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.581
Bartlett's Test of Sphericity	Approx. Chi-Square	443.672
	Df	253
	Sig.	.000

Table 8 displayed above presented the output of KMO and Bartlett's test. The Kaiser-Meyer-Olkin (KMO) value obtained was 0.581. Upon comparing this value with those in Table 2, it became evident that 0.567 was an acceptable value. This indicated that the sum of partial correlations was not significant compared to the sum of correlations, amounting to 58.1% of the analysis variables. Consequently, there was no diffusion in the correlation pattern, affirming the appropriateness of factor analysis in this scenario. Thus, reliable and distinct factors could be derived from the factor analysis of this data.

Moreover, Table 8 also provided Bartlett's Test of Sphericity results. The Approx. Chi-Square value obtained was 443.672, with a significance value (p) of 0.000, which was less than 0.001. This implied that the correlation matrix was not an identity matrix, signifying a strength of relationship among the variables. Therefore, factor analysis was deemed applicable for this dataset.

Table 9:Eigen values for sensitivity of paddy growers to climate change

Total Variance Explained					
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	4.480	19.476	19.476	4.480	19.476
2	3.700	16.089	35.565	3.700	16.089
3	1.812	7.879	43.444	1.812	7.879
4	1.589	6.908	50.352	1.589	6.908
5	1.301	5.654	56.006	1.301	5.654
6	1.235	5.369	61.375	1.235	5.369
7	1.105	4.806	66.181	1.105	4.806
8	1.029	4.473	70.654	1.029	4.473
9	.967	4.204	74.858		

10	.851	3.702	78.560		
11	.762	3.312	81.872		
12	.671	2.918	84.790		
13	.640	2.783	87.573		
14	.519	2.257	89.830		
15	.487	2.118	91.947		
16	.432	1.877	93.824		
17	.350	1.520	95.345		
18	.310	1.348	96.693		
19	.202	.877	97.570		
20	.185	.805	98.375		
21	.163	.709	99.084		
22	.133	.579	99.663		
23	.078	.337	100.000		
Extraction Method: Principal Component Analysis.					

The table 9 presented the Eigen value specifications and the percentage of variance explained by the components. Components with more than one Eigen value were chosen. Consequently, eight factors were extracted from the eight components, collectively explaining a total variance of 70.65 percent in sensitivity of paddy growers to climate change. Hence, it can be concluded that the eight factors with more than one Eigen value contributed 70.65 percent in sensitivity of paddy growers to climate change.

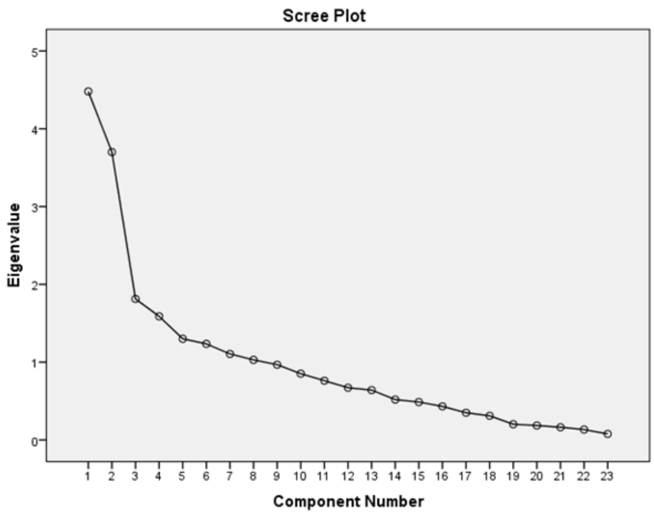

Figure 2: Scree plot for sensitivity of paddy growers to climate change

Figure 2, depicted above, illustrated the eigenvalues of all components graphically. This scree plot served as a visual representation of Table 9. The graph was generated utilizing the data from Table 9. On the Y-axis, the graph represented 'Eigenvalues,' ranging from 0 to 8, with the maximum value of 8 derived from the 'Total' column in the 'Initial Eigenvalues' section. These eigenvalues were plotted as points on the curve of the scree plot in Figure 2. The X-axis denoted the 'Component Number,' with values ranging from 1 to 23, obtained from the 'Component' column in Table 9. Upon observation of Figure 2, it was noted that the curve in the scree plot started to level off between component 8 and component 9. Additionally, it was evident that the eigenvalues for components 1 to 8 exceeded 1, while for components 9 to 23, the eigenvalues were less than 1. Therefore, following the extraction process, only 8 factors were retained.

Table 10. Rotated Component Matrix for sensitivity of paddy growers to climate change

Rotated Component Matrix[a]								
	Component							
	1	2	3	4	5	6	7	8
Reduction in crop yield	.759							
Crop failure due to floods/cyclones	.754							
Low quality of harvested rice grain	.736							
Delayed/Limited release of canal water for irrigation	.686							.548
Non-availability of water during grain formation		.807						
Non-availability of water during planting		.710						
Affecting fodder production		.694						
Change in scheduling pesticide inputs		.581						
Augmented climate-induced cultivation costs		.557				.512		
Weather triggered input expenses			.780					
Debt vulnerability			.664					
Price fluctuations			.610					
Low yields due to non-availability of irrigation				.703				
Hefty labour costs				.608			-.507	
Change in scheduling irrigation				.594				
Change in timing of planting				.590				
Inability to take plant protection activities					.776			
Susceptibility to pests-BPH, yellow stem borer, leaf folder, rodents due to climate change					.724			

Susceptibility to diseases- Blast, sheath blight, bacterial blight due to climate change					-.613			
Income instability						.788		
Delay in planting nursery/sowing							.808	
Change in scheduling of post-harvest activities			.781					
Climate-induced market challenges								.775

In thetable 10, each factor column was scanned to identify the sub-indicators that were more significantly correlated with the particular factor. Consequently, sub-indicators with a factor loading of more than 0.50 were selected for further analysis

Dimension 3: Adaptive Capacity of paddy growers to climate change

Table 11: KMO and Bartlett's Test Value forAdaptive Capacity of paddy growers to climate change

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.534
Bartlett's Test of Sphericity	Approx. Chi-Square	447.140
	Df	253
	Sig.	.000

Table 8 displayed above presented the output of KMO and Bartlett's test. The Kaiser-Meyer-Olkin (KMO) value obtained was 0.534. Upon comparing this value with those in Table 2, it became evident that 0.534 was an acceptable value. This indicated that the sum of partial correlations was not significant compared to the sum of correlations, amounting to 53.4% of the analysis indicators. Consequently, there was no diffusion in the correlation pattern, affirming the appropriateness of factor analysis in this scenario. Thus, reliable and distinct factors could be derived from the factor analysis of this data.

Moreover, Table 8 also provided Bartlett's Test of Sphericity results. The Approx. Chi-Square value obtained was 447.140, with a significance value (p) of 0.000, which was less than 0.001. This implied that the correlation matrix was not an identity matrix, signifying a strength of relationship among the variables. Therefore, factor analysis was deemed applicable for this dataset.

Table 12:Eigen values for Adaptive capacity of paddy growers to climate change

Total Variance Explained					
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	4.074	17.712	17.712	4.074	17.712
2	3.718	16.165	33.877	3.718	16.165
3	1.840	8.000	41.877	1.840	8.000
4	1.681	7.308	49.185	1.681	7.308
5	1.522	6.616	55.801	1.522	6.616

6	1.352	5.878	61.679	1.352	5.878
7	1.219	5.298	66.977	1.219	5.298
8	.989	4.300	71.278		
9	.945	4.111	75.388		
10	.890	3.870	79.258		
11	.805	3.498	82.756		
12	.623	2.709	85.465		
13	.603	2.623	88.088		
14	.537	2.335	90.423		
15	.411	1.787	92.210		
16	.385	1.672	93.883		
17	.345	1.500	95.382		
18	.290	1.262	96.644		
19	.249	1.082	97.726		
20	.173	.752	98.478		
21	.146	.633	99.111		
22	.118	.514	99.626		
23	.086	.374	100.000		
Extraction Method: Principal Component Analysis.					

The table 12 presented the Eigen value specifications and the percentage of variance explained by the components. Components with more than one Eigen value were chosen. Consequently, seven factors were extracted from the seven components, collectively explaining a total variance of 66.97 percent in adaptive capacity of paddy growers to climate change. Hence, it can be concluded that the seven factors with more than one Eigen value contributed 66.97 percent in adaptive capacity of paddy growers to climate change.

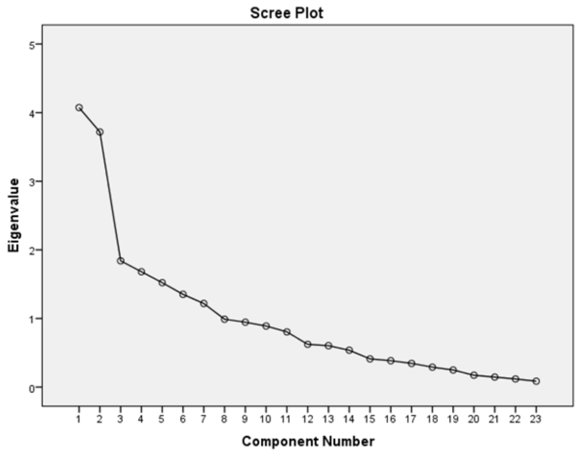

Figure 3: Scree plot for Adaptive capacity of paddy growers to climate change

Figure 3, depicted above, illustrated the eigenvalues of all components graphically. This scree plot served as a visual representation of Table 12. The graph was generated utilizing the data from Table 12. On the Y-axis, the graph represented 'Eigenvalues,' ranging from 0 to 7, with the maximum value of 7 derived from the 'Total' column in the 'Initial Eigenvalues' section. These eigenvalues were plotted as points on the curve of the scree plot in Figure 3. The X-axis denoted the 'Component Number,' with values ranging from 1 to 23, obtained from the 'Component' column in Table 12. Upon observation of Figure 3, it was noted that the curve in the scree plot started to level off between component 7 and component 8. Additionally, it was evident that the eigenvalues for components 1 to 7 exceeded 1, while for components 8 to 23, the eigenvalues were less than 1. Therefore, following the extraction process, only 7 factors were retained.

Table 13. Rotated Component Matrix for Adaptive capacity of paddy growers to climate change

Sub-indicator	Rotated Component Matrix[a]						
		Component					
	1	2	3	4	5	6	7
Participation in farmer groups, cooperatives and networks	.812						
Awareness of climate information and early warning system	.809						
Education	.748						
Membership in community level organisations/farmer-based organisation	.723						
Access to market	.532						
Access to non-formal credit	.513						
Access to mechanized equipment	.500						
Access to Agricultural Extension services		.858					
Access to agricultural credit and loans		.687					
Participation in workshops/training sessions on climate resilient practices		.650	.522				
Utilization of climate forecasts to anticipate and manage yield variability		.633					
Farming Experience		.513					
Exchange of climate related information and best practices			.705				

Flexibility in farming schedules based on weather changes			.549				
Rainwater harvesting			.516				
Utilization of mobile apps and online portals for monitoring weather and pest conditions				-.803			
Grain storage silos					-.787		
Access to crop insurance			.527		.623		
Access to early warning system/climate information					.622	.540	
Rescheduling planting and harvesting dates based on weather forecast						.705	
Understanding of climate resilient practices and climate-informed inputs							.688
Elevated pathways for drainage of water							.606
Awareness of climate change impacts on paddy farming							-.557

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 13 iterations.

In thetable 13, each factor column was scanned to identify the sub-indicators that were more significantly correlated with the particular factor. Consequently, sub-indicators with a factor loading of more than 0.50 were selected for further analysis.

Table 14: Assignment of weights to the indicators

Indicator	Weight obtained through PCA
Monsoon Variability	10.385
Precipitation Variability	9.899
Climate Hazard	10.297
Temperature	2.527
Crop phenology	6.339
Pest and Disease Dynamics	2.749
Financial resilience	9.712
Water sensitivity	10.367
Extreme weather sensitivity	12.643

Socio-Demographic	7.900
Knowledge Acquisition	4.813
Preparedness	3.026
Weather-Responsive Planning	4.316
Social Networking	4.605
Capacity Building	6.567
Economic Vulnerability	8.729
Infrastructural Preparedness	4.922

Table 15. Assignment of weights to the sub-indicators

Indicator	Sub-indicator	Factor Loadings	Weight obtained through PCA
I. Exposure of paddy growers to climate variability			
Monsoon Variability	Changes in pre-monsoon rainfall	0.742	3.057
	Changes in the onset and duration of South-West Monsoon	0.694	1.024
	Changes in post-monsoon rains	0.749	3.086
	Changes in Winter season	0.781	3.218
Precipitation Variability	Delay in onset of rainfall	0.673	2.773
	More number of rainy days	0.733	1.005
	More dry spells during crop season	0.593	1.562
	Rainfall aberrations during crop growth period	0.853	1.259
	Erratic rainfall throughout the season	0.550	0.812
	Low number of rainy days/Untimely winter rainfall	0.697	2.489
Climate Hazard	Occurrence of floods	0.532	1.340
	Occurrence of cyclones	0.514	1.835
	Heavy rains	0.817	1.015
	Unseasonal rains	0.718	2.564
	Extended dry spells	0.737	2.632
	Hailstorms/Thunderstorms and Lightning	0.869	0.910
Temperature	Rising Temperatures	0.620	0.850
	Heat waves during crop season	0.628	0.861
	Low Temperature	0.553	0.816
II. Sensitivity of paddy growers to climate change			
Crop phenology	Delay in planting nursery/sowing	0.808	0.893
	Change in time of planting	0.590	0.938
	Change in scheduling irrigation	0.594	0.944
	Change in scheduling pesticide sprays	0.581	2.149
	Change in scheduling of post-harvest activities	0.781	1.415
Pest and Disease Dynamics	Susceptibility to pests-BPH, yellow stem borer, leaf folder, leaf mite and rodents due to climate change	0.724	0.942
	Susceptibility to diseases- Blast, sheath blight, bacterial leaf blight due to climate	0.613	0.798

	change		
	Inability to take plant protection activities	0.776	1.009
Economic Vulnerability	Augmented climate-induced cultivation costs	0.557	2.693
	Climate-induced market challenges	0.775	0.798
	Hefty labour costs	0.608	1.526
	Price fluctuations	0.610	1.105
	Income instability	0.788	0.973
	Debt vulnerability	0.664	1.203
	Weather triggered input expenses	0.780	1.413
Water sensitivity	Delayed/Limited release of canal water for irrigation	0.686	3.637
	Low yields due to non-availability of irrigation	0.703	1.117
	Non-availability of water during planting	0.710	2.627
	Non-availability of water during grain formation	0.807	2.986
Extreme weather sensitivity	Crop failure due to floods/cyclones	0.754	3.377
	Affecting fodder production	0.694	2.567
	Low quality of harvested rice grain	0.736	3.297
	Reduction in crop yield	0.759	3.400
III. Adaptive capacity of paddy growers to climate change			
Socio-Demographic	Education	0.748	3.047
	Farming Experience	0.513	1.907
	Membership in community level organisations/farmer-based organisation	0.723	2.945
Knowledge Acquisition	Awareness of climate information and early warning system	0.809	3.296
	Awareness of climate change impacts on paddy farming	0.557	0.679
	Understanding of climate resilient practices and climate-informed inputs	0.688	0.839
Preparedness	Access to early warning system/climate information	0.622	1.677
	Utilization of mobile apps and online portals for monitoring weather and pest conditions	0.803	1.349
Weather-Responsive Planning	Flexibility in farming schedules based on weather changes	0.549	1.010
	Rescheduling planting and harvesting dates based on weather forecast	0.705	0.953
	Utilization of climate forecasts to anticipate and manage yield variability	0.633	2.353
Social Network	Participation in farmer groups, cooperatives and networks	0.812	3.308
	Exchange of climate related information and best practices	0.705	1.297
Capacity Building	Participation in workshops/training sessions on climate resilient practices	0.650	3.377
	Access to Agricultural Extension services	0.858	3.190
Financial	Access to formal credit	0.687	2.554

resilience	Access to non-formal credit	0.513	2.089
	Access to crop insurance	0.623	1.918
	Access to market	0.532	2.167
Infrastructural Preparedness	Rainwater harvesting	0.516	0.949
	Elevated pathways for drainage of water	0.606	0.738
	Access to mechanized equipment	0.500	2.037
	Grain storage silos	0.787	1.198

In Table 15, the weights were allocated to the sub-indicators of three dimensions of vulnerability indices for paddy growers. These weights were derived from the PCA interpreted results of the rotated component matrix, where factor loadings exceeding 0.5 were multiplied by eigenvalues exceeding 1 of all the sub-indicators. Specifically, the first set of values was multiplied by the first extracted component column, and the second eigenvalue was multiplied by the second extracted component column, as depicted in earlier tables. Following this multiplication process, the resulting values were converted into absolute values. The sum of each row across all sub-indicators' absolute values was then calculated, ultimately yielding the weighted values for all sub-indicators.

Table 16: Assignment of weights to the indicators

Indicator	Weight obtained through PCA
Monsoon Variability	10.385
Precipitation Variability	9.899
Climate Hazard	10.297
Temperature	2.527
Crop phenology	6.339
Pest and Disease Dynamics	2.749
Financial resilience	9.712
Water sensitivity	10.367
Extreme weather sensitivity	12.643
Socio-Demographic	7.900
Knowledge Acquisition	4.813
Preparedness	3.026
Weather-Responsive Planning	4.316
Social Networking	4.605
Capacity Building	6.567
Economic Vulnerability	8.729
Infrastructural Preparedness	4.922

In Table 16, the weights were assigned for all the indicators (Monsoon Variability, Precipitation Variability, Climate Hazard, Temperature, Crop phenology, Pest and Disease Dynamics, Financial resilience, Water sensitivity, Extreme weather sensitivity, Socio-Demographic, Knowledge Acquisition, Preparedness, Weather-Responsive Planning, social networking, Capacity building, economic vulnerability and Infrastructural Preparedness) by adding the weighted values of sub-indicators of vulnerability indices of paddy growers

Testing for Reliability of vulnerability indices of paddy growers: TheInternal consistency reliability method via Cronbach alpha was adopted to testthe reliability of vulnerability indices using SPSS software version 20.

The reliability coefficient was found to be **0.90,** which is higher than the standard value of 0.70, indicating higher reliability and good internal consistency of the vulnerability index presented in table 17

Table 17: Reliability Statistics of vulnerability indices	
Cronbach's Alpha	N of Items
.903	65

Computation of index values to the dimensions of vulnerability indices of paddy growers

To calculate the index values for each identified dimension, based on the sum of weights acquired through PCA for all indicators as displayed in Table 15, the vulnerability indices of paddy growers were determined and presented in Table 18.

Table 18. Index values of climate vulnerability indices of paddy growers

S.No.	**Dimensions**	**Index values**	**Ranks**
1.	Exposure of paddy growers	8.28	II
2	Sensitivity of paddy growers	8.36	I
3	Adaptive capacity of paddy growers	5.61	III

The table 17, which displayed dimension-wise index values of vulnerability indices for paddy growers, revealed that exposure had an index value of 8.28, followed by sensitivity at 8.36, and adaptive capacity at 5.61. Consequently, sensitivity was observed to be in the top position, followed by exposure and adaptive capacity in assessing the climate vulnerability of paddy growers.

Measurement procedures of indicators

As the index developed was composite in nature, the indicator measures include both quantitative and qualitative procedures. Under each indicator, suitable sub indicatorsand variables were identified and levels of measurement were fixed for variables.

Schedule development

For all the indicators, a schedule was prepared to elicit appropriate variability forvulnerability indices of paddy growers. A pilot study was conducted among 60 respondents in non-sample to test the reliability and validity of index

Calculation of the vulnerability index

The normalized indicators are then multiplied with the assigned weights to construct the indices separately for each component of vulnerability viz. exposure, sensitivity and adaptive capacity separately. Finally, vulnerability index of paddy growers is calculated as:

$$VI = (EI + SI) - AI$$

Where,

VI is the Vulnerability Index,

EI is the Exposure Index,

SI is the sensitivity Index and

AI is the Adaptive Capacity Index

CONCLUSION

In recent years, agriculture has made significant contributions to our nation's growth. However, contemporary challenges such as rising demand, climate change, and environmental pollution highlight the need for more efficient agricultural research. The index developed in this study offers a means to measure the vulnerability indices of paddy growers. Comprising three dimensions, this index serves as a practical tool for evaluating paddy grower vulnerability. It enables researchers to delve into studies on the climate vulnerability indices of paddy growers. Furthermore, administrators and policymakers can utilize this index to assess current vulnerability levels among paddy growers and devise strategies for improvement. The index values will aid in identifying the extent of vulnerability to climate change among paddy growers

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