__Original Research Article__

Developmentand Standardization of an Adaptation Index to assess the Climate Resilient Practices by 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. In recent times, adaptation to climate change has become a major concern to farmers, policy makers and researchers. Climate resilient rice production practices need to be enhanced at the farm level in order to aid rural residents in improving their household food security.Against this backdrop, the proposed research seeks to fill this crucial knowledge gap by developing and constructing adaptation index tailored specifically for paddy growers in India. Based on review of literature and discussion with experts' indicators andsub-indicators by adopting the indicator approach method under the adaptation of climate resilient practices by paddy growers due to climate change were identified. The relevancy rating score was obtained from 30 judges in the concerned area. Based on the relevancy score, 8 indicators and 23 sub-indicators of 0.80 and above were considered for inclusion in the adaptation index. To compute the index values for each of the identified indicators, their relative importance in the adaptation practices was worked out by assignment of index values to indicatorsthrough Principal component analysis (PCA) based on the high factor loadings exceeded 0.5 of sub-indicators were considered and the findings revealed that disease and management had highest index value of 3.461, followed by methods of paddy establishment (2.195), crop rejuvenation techniques (2.10), altered planting dates (2.049), water saving and management techniques (1.987), nursery management (1.562), paddy varieties (1.342) and spacing (1.214).

Keywords: Climate change; climate resilient practices; adaptation 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).

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 have 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). In terms of vulnerability to extreme weather, India is the seventh most vulnerable nation. The development of advanced modelling techniques, mapping the effect of climate change on rice growing regions and providing crop insurance are other examples of managing risks and reducing vulnerability. There will be a projected loss of 10-40% in crop production by 2100 if no adaptation measures are taken. A degree Celsius increase in temperature may reduce yields of major food crops by 3-7% (IPCC, 2012). Rice production is slated to decrease by almost a ton/hectare if the temperature goes up by 20^{o}C.

Rice contributes around 10 per cent of the agricultural GDP and its production generates 3.5-billion-man days of employment in India (Ahmad, *et al*. 2017, Kumar *et al*., 2018). Consumption of rice as a staple food by a large proportion of people, its contribution in agricultural GDP and generation of employment highlights its role in national food security, income and employment generation in India (Ahmad *et al*., 2019). Being a widely adapted plant, rice is cultivated in wide range of ecosystems i.e. from upland to highly submerged areas. Most of the rice in India is grown under rainfed condition during wet season (June-September) with the receipt of monsoon rainfall. The quantum and distribution of monsoon rainfall, which is the major source of water for rice cultivation, has become erratic during recent years due to climate variability (Ishfaq *et al*., 2020; Sattar and Srivastava, 2020). The productivity of the crop depends on a wide range of factors viz. land situations, cultivars, weather, planting window and management practices. One of the major constraints of rice production in India is related to climate (temperature, rainfall and solar radiation) variability in the recent years (Pathak *et al*., 2018). Under such situation, the optimum weather requirement for achieving higher yields need to be quantified. This will help in developing management options for achieving higher rice productivity in the country. Sanchez *et al*. (2014) opined that optimum temperature for vegetative growth of rice is about 28 °C and optimum temperature for grain filling is about 21.7–26.7 °C. Ahmed *et al*. (2015) observed that 1000-grain weight and seed-setting rate decreased beyond temperature of 27.0 °C. Nian-bing*et al*. (2021) studied the effect of solar radiation and temperature on rice in lower reaches of the Huai river basin, China and found temperature being the main limiting factor in realizing higher yields. Change in rainfall pattern, variability in temperature and duration of bright sunshine hours during crop growing season (monsoon/kharif season) affect rice production.

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).It is crucial to manage these vulnerabilities to prevent losses to the farmers. Farmers require awareness on the climate change adaptation measures and they can acquire required information from various sources like news from radio, journals, kisan melas, magazines, T.V, newspapers, etc. Farmers can also get the information from the weather stations about rainfall, floods, cyclones, etc.Climate resilient rice production practices need to be enhanced at the farm level in order to aid rural residents in improving their household food security.

Adaptation to climate change involves changes in agricultural managementpractices in response to changes in climate conditions. It often involves a combination of various individual responses at the farm-level and assumes that farmers have accessto alternative practices and technologies available in the region Successful adaptation to change in climate requires long-term investments in strategic research and new policy initiatives that mainstream climate change adaptation into development planning. Farmers must be aware of the climate resilient agricultural practices and manage the vulnerabilities to assure food security and water security.

Against this backdrop, the proposed research seeks to fill this crucial knowledge gap by developing and constructing adaptation practices tailored specifically for paddy growers in India. These practices will encompass a comprehensive set of parameters, considering factors such as methods of paddy establishment, altered planting dates, paddy varieties and overall climate resilient practices impacting rice production.The resulting practices 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

Adaptation, a complex, multidimensional, and multi–scale process, has been defined as adjustments to behavior or economic structures that reduce vulnerability of society in the face of scarcity or threatening environmental change (Adger et al., 2003). Adaptation is defined as adjustments in natural or human systems in response to real or await climatic stimuli or effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007). It also refers to actions that people, countries and societies take to balance to the change in climate that has occurred. Adaptation has three possible objectives: to reduce exposure to the risk of distraction; to develop the capacity to cope with unavoidable damages; and to take advantage of new opportunities. The purpose of undertaking agricultural adaptation is to effectively manage potential climate risks over the coming decades as climate changes. Adaptation research undertaken now can help inform decisions by farmers, agribusiness, and policy makers with implications over a range of time frames from short-term tactical to long-term strategies.

Operationalization of adaptation of climate resilient practices by paddy growers

Adaptation of climate resilient practices by paddy growers was operationally defined as the adjustments or alterations which are introduced by paddy growers in their farming such as alteration in crop production, soil and water conservation measures, flood management, land use, labour use,financial management and family management in order to reduce the vulnerability of the effects of climate change.

METHODOLOGY

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

Step1: Identification of indicators

The adaptation of climate resilient practices by paddy growers was identified as adependent variable. Based on a thorough review of literature related to adaptation of climate resilient practices by paddy growers, indicatorswere identified.

Step 2: Collection of sub-indicators

A large number of draft sub-indicators on each indicator of adaptation of climate resilient practices by paddy growers were collected based on review of literature, discussion with concerned specialists.These sub-indicators were carefully edited, revised and restructured in google forms.

The Google forms were mailed to 50 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 assess adaptation of climate resilient practices by paddy growers. A total of 36 judges returned thequestionnaires duly completed and 30 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 and sub-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 1

Step 3: 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 4: Validity Test:

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

Table 1.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-indicatorsvia 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 5: Assessment and refinement of indicators and sub-indicatorsthrough Principal component analysis(PCA)

After normalization, factor analysis for each data set of 8 indicators and 23 sub-indicators adaptation index was runchoosing Principal Component Analysis (PCA) for extraction and varimax method forrotation of factors using SPSS software (version20)to assess and refine factor loadings exceeding 0.5 to the sub-indicators and computed the index values to the indicators based on the factor loadings of sub-indicators.

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.

Step 6: Reliability of the Adaptation 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 2

Table 2: Relevant Rating Scoreof Indicators

Indicator	RRS
Methods of paddy establishment	0.90
Altered planting dates	0.87
Paddy varieties	0.94
Nursery Management	0.88
Spacing	0.84
Water saving and management techniques	0.85
Crop rejuvenation techniques	0.82

Disease and pest management	0.87

And it is evident from the Table 2 that the relevancy scores for different indicators ranged from 0.82 to 0.94. The relevancy rating scores were calculated by dividing the actual score obtained with maximum score obtainable from 30 experts. The indicators with relevancy rating score more than 0.80 were selected for inclusion in the index for measuring the adaptation index. Only 8 indicators satisfied this criterion and they were methods of paddy establishment, altered planting dates, paddy varieties, nursery management, spacing, water saving and management techniques, crop rejuvenation techniques and disease and pest management

Selection of sub-indicators: Only those items with relevancy rating score more than 0.80 were selected for inclusion in the index. The relevancy scores were calculated by diving actual score with the maximum score possible. Out of 29 items chosen, 23 items were finally selected for inclusion in the index. The responses for items of the index were quantified and given in the Table 3.

Table 3. Relevancy Rating Score of Sub-indicators

Indicator	Sub-indicator	Relevant Rating score
Methods of paddy establishment	Transplanting	0.93
	Direct seeded	0.90
	Machine planting	0.97
Altered planting dates	Late sowing	0.94
	Early sowing	0.82
	Normal sowing	0.85
Paddy varieties	Early maturity	0.97
	Flood and drought tolerant	0.93
Nursery management	Community nursery	0.85
	Own seed	0.91
Spacing	Narrow	0.84
	Wider	0.85
Water saving and management techniques	Alternate wetting and drying	0.88
	Supplementary irrigation with altered timing	0.84
	Seeking in divine of God for the timely arrival of monsoon rains	0.86
Crop rejuvenation techniques	Tying the paddy crop with rope to keep erect immediately after heavy rains/floods	0.81
	Salt water spray for harvested paddy stalks to avoid discoloration and germination	0.83
	Booster dose of fertilizers	0.82
Disease and pest	Summer ploughing	0.92
	Crop rotation	0.84

management	Nitrogen-fixing cover crops	0.82
	Community adaptation	0.94
	Spraying of pesticides and fungicides	0.85

Validation and Assessment of indicators and sub-indicators through Principal Component Analysis:

KMO and Bartlett'stest was carried out via principal component analysis to assess the validity of indicators and sub-indicators 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 eight indicators and twenty-five sub-indicators under adaptation of climate resilient practices by paddy growers. The eight indicators and twenty-five sub-indicators were entered into a correlation matrixand a Varimax orthogonal rotation with Kaiser normalization was applied to thesolutionand the findings were interpreted as following below

Table 4: KMO and Bartlett's Test Value for adaptation of climate resilient practices by paddy growers

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.541
Bartlett's Test of Sphericity	Approx. Chi-Square	412.836
	Df	253
	Sig.	.000

Table 4 displayed above presented the output of KMO and Bartlett's test. The Kaiser-Meyer-Olkin (KMO) value obtained was 0.541. Upon comparing this value with those in Table 1, it became evident that 0.541 was an acceptable value. This indicated that the sum of partial correlations was not significant compared to the sum of correlations, amounting to 54.1% 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 4 also provided Bartlett's Test of Sphericity results. The Approx. Chi-Square value obtained was 412.836,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 5: Eigen values for adaptation of climate resilient practices by paddy growers

Total Variance Explained					
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	3.798	16.514	16.514	3.798	16.514
2	3.357	14.596	31.110	3.357	14.596
3	2.122	9.226	40.337	2.122	9.226
4	1.842	8.010	48.347	1.842	8.010
5	1.580	6.868	55.215	1.580	6.868
6	1.306	5.679	60.894	1.306	5.679
7	1.166	5.070	65.965	1.166	5.070
8	1.064	4.625	70.589	1.064	4.625
9	.935	4.064	74.654		
10	.852	3.706	78.360		
11	.700	3.043	81.403		
12	.676	2.940	84.342		
13	.629	2.735	87.077		
14	.588	2.557	89.635		
15	.485	2.108	91.743		
16	.407	1.768	93.512		
17	.339	1.475	94.987		
18	.308	1.338	96.325		
19	.254	1.105	97.430		
20	.203	.882	98.313		
21	.172	.749	99.062		
22	.121	.525	99.587		
23	.095	.413	100.000		
Extraction Method: Principal Component Analysis.					

The table 5 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 totalvariance of 70.58 percent in adaptation of climate resilient practices by paddy growers. Hence, it can be concluded that the eight factors with more than one Eigen value contributed 70.58 percent in adaptation of climate resilient practices by paddy growers.

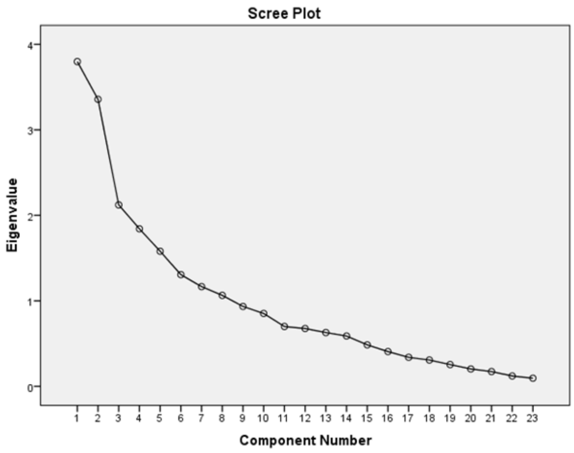

Figure 1: Scree plot for adaptation of climate resilient practices by paddy growers

Figure 1, depicted above, illustrated the eigenvalues of all components graphically. This scree plot served as a visual representation of Table 5. The graph was generated utilizing the data from Table 5. 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 1. The X-axis denoted the 'Component Number,' with values ranging from 1 to 23, obtained from the 'Component' column in Table 5. Upon observation of Figure 1, 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 6. Rotated Component Matrix for adaptation of climate resilient practices by paddy growers

Rotated Component Matrix[a]								
	Component							
	1	2	3	4	5	6	7	8
Own seed	.829							
Community nursery	.733							
Flood and Drought-tolerant	.714							
Narrow	.680							
Direct seeded	.570							.547
Late sowing		.860						
Machine planting		.846						

Supplementary irrigation with altered timing		.693						
Wider		.534						
Spraying of pesticides and fungicides			.872					
Community adaptation			-.827					
Early sowing				.653				
Early maturity				.628				
Summer ploughing				.608				
Seeking in divine of God for the timely arrival of monsoon rains	.511							
Tying the paddy crop with rope to keep erect immediately after heavy rains/floods					.801			
Salt water spray for harvested paddy stalks to avoid discoloration and germination					-.701			
Transplanting						.779		
Nitrogen-fixing cover crops						.564		
Normal sowing						.536		
Crop rotation				.590			-.813	
Alternate wetting and drying								.783
Booster dose of fertilizers			.542					-.598

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 10 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

Table 7: Standardized Factor Loadings of an adaptation index of Paddy Growers

Indicator	Sub-indicators	Standardized Factor Loadings
Methods of paddy establishment	Transplanting	0.779
	Direct seeded	0.570
	Machine planting	0.846
Altered planting dates	Late sowing	0.860
	Early sowing	0.653
	Normal sowing	0.536
Paddy varieties	Early maturity	0.628
	Flood and drought tolerant	0.714
Nursery management	Community nursery	0.733
	Own seed	0.829
Spacing	Narrow	0.680
	Wider	0.534
Water saving and management techniques	Alternate wetting and drying	0.783
	Supplementary irrigation with altered timing	0.693
	Seeking in divine of God for the timely arrival of monsoon rains	0.511
Crop rejuvenation techniques	Tying the paddy crop with rope to keep erect immediately after heavy rains/floods	0.801
	Salt water spray for harvested paddy stalks to avoid discoloration and germination	0.701
	Booster dose of fertilizers	0.598
Disease and pest management	Summer ploughing	0.608
	Crop rotation	0.590
	Nitrogen-fixing cover crops	0.564
	Community adaptation	0.827
	Spraying of pesticides and fungicides	0.872

In Table 8, factor loadings exceeding 0.5 were considered to assess the sub-indicators of adaptation measures obtained through PCA. Higher loadings indicated better representation of the original variables by the latentfactors/components. Conversely, low or non-significant loadings may suggest that the variable does not contribute meaningfully to the factor/component being examined.

Testing for reliability of adaptation of climate resilient practicesbypaddy growers: TheInternal consistency reliability method via Cronbach alpha was adopted to testthe reliability of adaptation of climate resilient practices using SPSS software version 20.

The reliability coefficient was found to be **0.89,** which was higher than the standard value of 0.70, indicating higher reliability and good internal consistency of the vulnerability index presented in table 8

Table 8: Reliability Statistics of an adaptation index	
Cronbach's Alpha	N of Items
.892	23

Computation of index values to the adaptation of climate resilient practicesbypaddy growers

To calculate the index values for each identified indicators, based on the sum of factor loadings acquired through PCA for allsub-indicators as displayed in Table 9, adaptation of climate resilient practices by paddy growers and presented in Table 10.

Table 9 Index values of an adaptation of climate resilient practices by paddy growers

Indicator	**Index value**	**Rank**
Methods of paddy establishment	2.195	II
Altered planting dates	2.049	IV
Paddy varieties	1.342	VII
Nursery Management	1.562	VI
Spacing	1.214	VIII
Water saving and management techniques	1.987	V
Crop rejuvenation techniques	2.100	III
Disease and pest management	3.461	I

The table 10, which displayed indicator-wise index values of an adaptation of climate resilient practices by paddy growers observed that disease and management had highest index value of 3.461, followed by methods of paddy establishment (2.195), crop rejuvenation techniques (2.10), altered planting dates (2.049), water saving and management techniques (1.987), nursery management (1.562), paddy varieties (1.342) and spacing (1.214).

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 indicators as 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 for adaptation of climate resilient practices by paddy growers. A pilot study was conducted among 60 respondents in non- sample to test the reliability and validity of index

Calculation of an adaptation index

Theadaptation index was computed to assess theclimate-resilient practices adapted by paddy growers, using the formula provided below

$$\textbf{Adaptation Index} = \frac{\textbf{obtained adaptation score}}{\textbf{Maximum obtainable score}}\ \textbf{X 100}$$

CONCLUSION

The adaptation index serves as a vital tool for assessing the climate resilient practices adopted by paddy growers. By quantifying the level of adaptation to climate change, this index offers valuable insights into the effectiveness of current agricultural practices in mitigating climate-related risks. Through its comprehensive evaluation, the adaptation index enables researchers and policymakers to identify areas of vulnerability among paddy growers and prioritize interventions accordingly. Moreover, it facilitates the monitoring of progress over time and the development of targeted strategies to enhance resilience in the face of changing environmental conditions. Ultimately, the adaptation index represents a critical step towards building sustainable agricultural systems that can withstand the challenges posed by climate change, ensuring the long-term viability of paddy cultivation.

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