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Development and Standardization of an Adaptation Index to Assess the Climate Resilient Practices by Paddy Growers

Asodi Yaminileela [a++*], M. Rama Devy [a#], G. Nirmala [b†], V. Jyothi [a‡], V. Srinivasa Rao [c^] and K. Nirmal Ravi Kumar [d##]

[a] *Department of Agricultural Extension Education, Agricultural College, Bapatla, Andhra Pradesh, India.*
[b] *Department of Agricultural Extension, ToT, ICAR-CRIDA, Hyderabad. India.*
[c] *Department of Statistics and Computer Applications, Agricultural College, Bapatla, Andhra Pradesh, India.*
[d] *Department of Agricultural Economics, Agricultural College, Bapatla, Andhra Pradesh, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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

++ *Ph.D. Scholar;*
# *Professor;*
† *Principal Scientist;*
‡ *Associate Professor;*
^ *Professor & Univ. Head;*
Professor & Head;
**Corresponding author: E-mail: yaminileela43@gmail.com;*

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. Through a literature review and discussions with experts, we have identified indicators and sub-indicators using the indicator approach method. These indicators will help us understand how paddy growers are adapting to climate change and implementing climate resilient practices. The relevancy rating score was obtained from 30 experts 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 indicators through 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.

1. 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 [1]. 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 [2]. 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% [3]. 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 [4,5]. 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 [6]. 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 [7,8]. 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 [9]. 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. [10] 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. [11] observed that 1000-grain weight and seed-setting rate decreased beyond temperature of 27.0°C. Nian-bing et al. [12] 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 [13]. 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 management practices 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 access to 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.

1.1 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 [14]. Adaptation strategies targeted towards reducing vulnerability is more sustainable and also stated that adaptation to the effects of climate change should incorporate response to climate hazards such as flooding and reducing extent of exposure to and building resilience against further incidence through strengthening the necessary infrastructural capacities [15]. 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 [16]. 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.

1.2 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.

Bello et al. [17] in a study on “Analysis of Adaptation to Climate Change among Rice Farmers in Werstern Zone of Bauchi State, Nigeria” found various adaptation measures practiced by the respondents. These included the practice of migration (45%), off-farm jobs (9.3%), irrigation practices (22%), crop diversification (54%) and no adaptation (5.4%), among others. Islam et al. [18] in a study on “Farm level adaptation to climate change: insight from rice farmers in the coastal region of Bangladesh” revealed that the main adaptation strategies were cultivating flood and salinity tolerant rice varieties (71.00%) direct seeding of rice, (65.00%) supplementary irrigation (43.00%), cultivation of non-rice crops that have shorter growth duration (64.00%), Adjusting planting dates and techniques such as changing harvesting date, using water-saving technology such as alternative wet and dry irrigation method (82.00%) and diversifying income sources (56.00%). Khan et al. [19] in a study on “Rice farmers’ perceptions about temperature and rainfall variations, respective adaptation measures, and determinants: Implications for sustainable farming systems” found that supplementary irrigation (55%), changes in rice cultivation dates (51%), and better fertilizer management (51%) were the major adaptation strategies adopted by the farmers. Further, farmers also reported use of crop diversification (41%), cultivation of climate-smart seeds (40%), cultivation of short-duration rice (39%), farm resizing practice (35%), shift to non-rice crops (32%), and altering irrigation time (29%) as key measures to cope with effects of changing climate. These findings revealed that farmers implement a range of adaptation measures to adapt their rice farming to climate change in the study area.

2. METHODOLOGY

Adaptation, as a multifaceted concept, necessitates a structured approach to capture its various dimensions effectively. The following steps outline the methodological framework utilized in constructing the adaptation index:

Step1: Identification of indicators

The adaptation of climate resilient practices by paddy growers was identified as a dependent variable. Based on a thorough review of literature related to adaptation of climate resilient practices by paddy growers and indicators were identified [14,5,11] and adaptation index was adopted by Ravi shankar et al. [20,21].

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. Drawing insights from relevant literature, such as Bello et al. [17], Islam et al. [18] and Khan et al. [19] These sub-indicators were carefully edited, revised and restructured in google forms for relevancy.

The Google forms were mailed to 50 experts in the agricultural extension and other related fields of ICAR Institutes and SAUs to critically evaluate the relevancy of each indicator and sub-indicators in the three-point continuum viz., Relevant (R), Somewhat Relevant (SWR) and Not Relevant (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 30 experts returned the questionnaires duly completed and considered for further processing. From the data gathered, Relevancy Rating Score was worked out for all the indicators and sub-indicators by using the formula

$$\text{Relevancy Rating Score} = \frac{\text{R×3 + SWR×2 + NR×1}}{\text{No.of judges responded ×Maximum score}} \ldots\ldots\ldots \quad (1)$$

Where as
R- Relevant
SWR- Somewhat Relevant
NR- Not Relevant

Taking into consideration the overall values which was given by the experts, the items having relevancy rating score of equal and more than 0.80 were considered for the inclusion in further analysis. Thus, indicators and sub-indicators were considered for further processing and suitably modified as per the comments of experts wherever applicable. The indicators that have passed the criteria are presented 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.

$$U_{ij} = \frac{Y_{ij} - Min_{yj}}{Max_{ij} - Min_{yj}} \ldots\ldots \quad (2)$$

Where,

U_{ij} = Unit score of the i^th^ respondents on the j^th^ component
Y_{ij} = Value of i^th^ respondent on the j^th^ component
Max_{ij} = Maximum score on the j^th^ component
Min_{yj} = Minimum score on the j^th^ component

Step 4: Validity Test:

In the present investigation, Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's Test of Sphericity was adopted to compute the validity of the Adaptation Index and it was established by the expert's judgement. 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-indicators 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 5: Assessment and refinement of indicators and sub-indicators through Principal component analysis (PCA)

After normalization process which had completed in step 3, factor analysis for each data set of 8 indicators and 23 sub-indicators adaptation index was run choosing Principal Component Analysis (PCA) for extraction and varimax method for rotation 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 test the reliability using SPSS software version 20. The standard Cronbach Alpha coefficient value of equal or more than 0.70, which indicates good internal consistency of items and considered for further inclusion in the index.

3. RESULTS AND DISCUSSION

Selection of indicators for inclusion in the index: The subsequent section presented the findings of the study, focussed on the evaluation of relevant rating scores (RRS) for various indicators related to paddy cultivation practices. These findings were crucial for understanding the effectiveness and significance of different adaptation measures employed by paddy growers in response to climate change challenges.

Table 2. Relevant rating score (RRS) of 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

Given the distribution above (Table 2), it is evident 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. The identified indicators, validated through expert ratings, hold practical significance for paddy growers, policymakers, and agricultural stakeholders. By prioritizing indicators with higher relevancy scores, stakeholders can focus resources and efforts on implementing targeted adaptation measures. Furthermore, these findings underscore the importance of continuous monitoring and evaluation of adaptation strategies to ensure their effectiveness in mitigating climate change impacts on paddy cultivation.

Selection of sub-indicators: The relevancy rating scores for sub-indicators, crucial for inclusion in the index, were calculated and presented in Table 3. These scores were determined by dividing the actual score obtained for each sub-indicator by the maximum score possible. Out of the 29 initially chosen items, 23 were ultimately selected based on their relevancy rating scores exceeding 0.80. Examined Table 3, it is evident that certain sub-indicators received notably high relevancy scores, indicated their importance in the context of paddy cultivation adaptation. For instance, in the "Methods of paddy establishment" category, "Machine planting" received a relevancy rating score of 0.97, signifying its critical role in efficient paddy cultivation. Similarly, "Altered planting dates" exhibited variations in relevancy scores, with "Late sowing" scoring highest at 0.94, followed by "Normal sowing" at 0.85. Moreover, the "Paddy varieties" sub-indicator highlighted the significance of traits such as "Early maturity" and "Flood and drought tolerance," both received high relevancy scores of 0.97 and 0.93, respectively. These findings underscore the importance of selecting appropriate paddy varieties resilient to changing climatic conditions. In terms of management practices, techniques such as "Alternate wetting and drying" and "Spraying of pesticides and fungicides" garnered relatively high relevancy scores, emphasizing their role in effective water management and pest control. However, it was worth noting that not all sub-indicators met the 0.80 relevancy threshold, suggested varying degrees of importance among different adaptation measures. For instance, "Seeking divine intervention for timely rains" received a relevancy score of 0.86, indicated its relatively lower importance compared to other techniques.

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 management	Summer ploughing	0.92
	Crop rotation	0.84
	Nitrogen-fixing cover crops	0.82
	Community adaptation	0.94
	Spraying of pesticides and fungicides	0.85

Overall, the results presented in Table 3 provided valuable insights into the relevancy of different sub-indicators in the context of paddy cultivation adaptation. These findings inform the selection of key indicators for inclusion in the adaptation index, facilitating targeted strategies to enhance paddy growers' resilience to climate change.

Validation and Assessment of indicators and sub-indicators through Principal Component Analysis: The results of the Kaiser-Meyer-Olkin (KMO) and Bartlett's Test, as presented in Table 4, were instrumental in assessing the validity of the indicators and sub-indicators for adaptation of climate resilient practices by paddy growers. The KMO value obtained was 0.541, which indicated an acceptable level of sampling adequacy. This value suggested that the correlations between the variables were sufficiently strong to proceed with factor analysis. Specifically, 54.1% of the variance in the analysis variables could be accounted for by the common factors, underscoring the suitability of the dataset for factor analysis. This implied that reliable and distinct factors could be derived from the factor analysis, facilitating a deeper understanding of the underlying structure of the data. Additionally, Bartlett's Test of Sphericity yielded an Approx. Chi-Square value of 412.836, with a significance value (p) of 0.000, indicating a highly significant relationship among the variables. This implied that the correlation matrix was not an identity matrix, further supporting the suitability of the dataset for factor analysis. The significant relationship among the variables affirmed the presence of underlying factors that could be explored through factor analysis.

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 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	0.935	4.064	74.654		
10	0.852	3.706	78.360		
11	0.700	3.043	81.403		
12	0.676	2.940	84.342		
13	0.629	2.735	87.077		
14	0.588	2.557	89.635		
15	0.485	2.108	91.743		
16	0.407	1.768	93.512		
17	0.339	1.475	94.987		
18	0.308	1.338	96.325		
19	0.254	1.105	97.430		
20	0.203	0.882	98.313		
21	0.172	0.749	99.062		
22	0.121	0.525	99.587		
23	.095	0.413	100.000		
Extraction Method: Principal Component Analysis.					

In summary, the results of the KMO and Bartlett's Test provided strong evidence for the validity of the indicators and sub-indicators selected for the study. These findings justified the application of principal component analysis (PCA) to reduce the dimensionality of the dataset and extract meaningful factors that capture the common information among the variables.

Table 5 provided insights into the Eigen values and the percentage of variance explained by the components in the adaptation of climate resilient practices by paddy growers. The table revealed that eight components had Eigen values greater than one, indicated their significance in explaining the variance within the dataset. These eight components collectively accounted for 70.58% of the total variance in the adaptation of climate resilient practices by paddy growers. This suggested that these factors played a crucial role in influencing the adaptation strategies employed by paddy growers in response to climate challenges. Eigen values serve as indicators of how much variance each component explains in the dataset. Higher Eigen values imply greater explanatory power of the corresponding components. In this case, the first eight components had Eigen values exceeding one, suggested that they were meaningful factors in understanding the adaptation practices of paddy growers.

Overall, the results indicated that the eight factors identified through principal component analysis (PCA) were essential in elucidating the adaptation strategies adapted by paddy growers to mitigate the impacts of climate change. These findings contributed to a better understanding of the factors influencing adaptation in agriculture and can inform the development of targeted interventions to enhance resilience in paddy farming communities.

Fig. 1 provides a visual representation of the eigenvalues of all components, serving as a scree plot derived from Table 5. The plot illustrates the relationship between the number of components and their corresponding eigenvalues. On the Y-axis, eigenvalues are represented, ranging from 0 to 4, with being the maximum components obtained from the 'Total' column in Table 5. Each eigenvalue point is plotted on the curve of the scree plot against the component number, which is depicted on the X-axis, ranging from 1 to 23. Upon examined Fig. 1, it is evident that the curve in the scree plot starts to level off between components 8 and 9. This indicated a point of diminishing returns, suggested that the additional components beyond this point contribute less to the overall variance in the dataset. Furthermore, eigenvalues for components 1 to 8 exceed 1, signifying their significance in explaining the variance within the dataset. Conversely, eigenvalues for components 9 to 23 were less than 1, indicated their relatively lower explanatory power.

Based on these observations, the extraction process retained only 8 factors, as they accounted for a substantial portion of the variance in the adaptation of climate resilient practices by paddy growers. This reduction in the number of factors ensures a more concise representation of the underlying dimensions influencing adaptation strategies among paddy growers, facilitating a clearer understanding of the key drivers of resilience in agricultural systems.

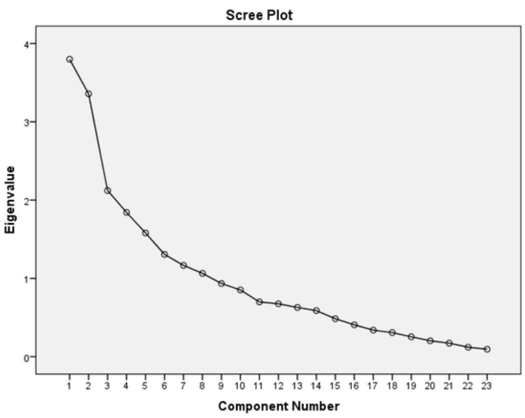

Fig. 1. Scree plot for adaptation of climate resilient practices by paddy growers

Table 6. Rotated component matrix for adaptation of climate resilient practices by paddy growers

Rotated Component Matrix[a]								
Sub-indicators	**Component**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Own seed	0.829							
Community nursery	0.733							
Flood and Drought-tolerant	0.714							
Narrow	0.680							
Direct seeded	0.570							0.547
Late sowing		0.860						
Machine planting		0.846						
Supplementary irrigation with altered timing		0.693						
Wider		0.534						
Spraying of pesticides and fungicides			0.872					
Community adaptation			-0.827					
Early sowing				0.653				
Early maturity				0.628				
Summer ploughing				0.608				
Seeking in divine of God for the timely arrival of monsoon rains	0.511							
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			
Transplanting						0.779		
Nitrogen-fixing cover crops						0.564		
Normal sowing						0.536		
Crop rotation				.590			-0.813	
Alternate wetting and drying								0.783
Booster dose of fertilizers			0.542					-0.598

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]
a. Rotation converged in 10 iterations.

Table 6 presented the rotated component matrix for the adaptation of climate resilient practices by paddy growers, showcasing the correlation between sub-indicators and the extracted factors. Each factor column represents a distinct dimension identified through the principal component analysis. Upon examining the rotated component matrix, sub-indicators with factor loadings greater than 0.50 are deemed to have a strong correlation with the respective factor. These sub-indicators signify the key elements contributing to each dimension of adaptation among paddy growers. For instance, in Factor 1, sub-indicators such as 'Own seed,' 'Community nursery,' 'Flood and Drought-tolerant,' and 'Narrow' exhibited notable factor loadings, indicated their strong association with this particular dimension of adaptation. Similarly, Factor 2 is characterized by sub-indicators like 'Late sowing,' 'Machine planting,' and 'Supplementary irrigation with altered timing,' suggesting that these practices are closely linked to a distinct aspect of adaptation among paddy growers. Factor 3 highlights sub-indicators such as 'Community adaptation,' indicated its importance in addressing specific challenges related to climate resilience within the community context. By analyzing the factor loadings across all eight factors, researchers can discern the underlying dimensions of adaptation strategies adopted by paddy growers. These insights help in understanding the multifaceted nature of adaptation and guide the development of targeted interventions to enhance resilience in agricultural systems.

Given the distribution above (Table 7) presented the standardized factor loadings of the adaptation index of Paddy Growers, showcasing the correlation between each sub-indicator and the identified factors. These standardized factor loadings indicate the strength and direction of the relationship between the sub-indicators and the latent factors extracted through principal component analysis (PCA). In this table, factor loadings exceeding 0.5 were considered significant, indicated a strong association between the sub-indicator and the respective factor. For instance, sub-indicators with factor loadings above 0.5 were deemed to have a notable impact on the corresponding dimensions of adaptation among paddy growers. Conversely, sub-indicators with factor loadings below 0.5 may not significantly contribute to the identified factors. By analyzing these standardized factor loadings, researchers could identify the key sub-indicators that played a crucial role in shaping the adaptation strategies of paddy growers. These findings provided valuable insights into the factors influencing the resilience of agricultural practices to climate change and guide the development of targeted interventions to enhance adaptive capacity within farming communities.

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

Testing for reliability of adaptation of climate resilient practices by paddy growers: The reliability of the adaptation index, which measures the consistency and stability of the assessment tool, was assessed using Cronbach's alpha. This statistical method evaluates the internal consistency of a scale by measuring the extent to which items within the index are correlated with each other. In Table 8, the reliability coefficient, represented by Cronbach's alpha, was calculated to be 0.892. This value exceeds the commonly accepted threshold of 0.70, indicated a high level of internal consistency among the items included in the adaptation index. A Cronbach's alpha of 0.892 suggested that the items comprising the adaptation index were strongly correlated with each other, demonstrating reliability and coherence in measuring the construct of interest. This indicated that the adaptation index is a robust and dependable tool for assessing the climate resilience practices adopted by paddy growers. Therefore, stakeholders had confidence in using this index to evaluate and compare adaptation strategies, leading to more informed decision-making processes aimed at enhancing agricultural resilience to climate change.

Table 8. Reliability Statistics of an adaptation index

Cronbach's Alpha	No. of Items
.892	23

Computation of index values to the adaptation of climate resilient practices by paddy growers: Given the distribution below (Table 9) presented the index values calculated for each identified indicator of adaptation of climate resilient practices by paddy growers. These index values were determined based on the sum of factor loadings obtained through principal component analysis (PCA) for all sub-indicators. In Table 9, each indicator was assigned an index value, represented its relative importance in contributing to the overall adaptation of climate resilient practices among paddy growers. Additionally, the indicators were ranked based on their index values. Table 9 further elucidated the results by displaying the indicator-wise index values of adaptation of climate resilient practices by paddy growers. It revealed that disease and pest management had the highest index value of 3.461, indicated its significant contribution to overall adaptation efforts. Following closely were methods of paddy establishment (2.195) and crop rejuvenation techniques (2.10), emphasizing their importance in climate resilience strategies. Altered planting dates (2.049), water saving and management techniques (1.987), nursery management (1.562), paddy varieties (1.342), and spacing (1.214) also made notable contributions to adaptation efforts, albeit to varying degrees.

These index values provided insights into the relative effectiveness of different adaptation measures employed by paddy growers. By identifying key areas of focus, stakeholders can prioritize interventions and allocate resources more efficiently to enhance the resilience of paddy cultivation in the face of climate change challenges.

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.

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

Calculation of an adaptation index: The adaptation index was computed to assess the climate-resilient practices adapted by paddy growers, using the formula provided below

$$\text{Adaptation Index} = \frac{\text{obtained adaptation score}}{\text{Maximum obtainable score}} \text{ X } 100 \ldots\ldots \qquad (3)$$

4. CONCLUSION

The main aim of this study was to develop an adaptation index to evaluate the climate resilient practices adopted by paddy growers. Through a rigorous process involving the identification of relevant indicators and sub-indicators, followed by factor analysis and reliability testing, the adaptation index was successfully constructed. The index provides a quantitative measure of the level of adaptation among paddy growers, allowing for a systematic assessment of their resilience to climate change impacts.

Key findings from the study indicated that certain adaptation measures, such as disease and pest management, methods of paddy establishment, and crop rejuvenation techniques, have emerged as particularly effective strategies in enhancing climate resilience among paddy growers. These findings highlight the importance of prioritizing investments and interventions in these key areas to further enhance adaptation efforts. Additionally, the study underscores the need for ongoing monitoring and evaluation to track changes in adaptation levels over time and inform adaptive management strategies.

Despite the valuable insights provided by the adaptation index, this study also had limitations. One such limitation is the reliance on self-reported data, which may be subject to biases and inaccuracies. Additionally, the adaptation index may not capture the full complexity of climate resilience among paddy growers, as it focuses primarily on specific indicators and sub-indicators. Future research could explore ways to refine the index and incorporate additional variables to provide a more comprehensive assessment of adaptation efforts.

Nevertheless, the significance of this study lies in its contribution to the development of tools and methodologies for assessing climate resilience in agriculture. By quantifying adaptation levels and identifying effective strategies, the adaptation index offers valuable guidance for policymakers, agricultural practitioners, and other stakeholders involved in climate change adaptation efforts. Ultimately, the insights gained from this study can inform the design and implementation of targeted interventions aimed at building resilient agricultural systems capable of withstanding the challenges posed by climate change.

SUPPLEMENTARY MATERIALS

Supplementary materials available in this link: https://journalijecc.com/media/Supporting-2024_IJECC_115372.zip

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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