Title: **Analysing Adaptive Responses of Smallholder Black Pepper Farmers in Kerala: A Choice Modelling Approach to Climate Change-Relevant Decisions.**

Abstract

This study investigates the complex dynamics of climate resilience strategies among smallholder pepper farmers in Kerala, India. Employing a mixed-methods approach, including Best-Worst Scaling (BWS) analysis, conditional logistic regression, and attribute level preferences, we explore the decision-making processes underlying the adoption of various adaptation practices. Our findings reveals that a combination of practices, characterized by exclusive organic farming practices, diversified cropping systems with cardamom integration, and the preservation of selected landraces, as the most favoured resilience strategy among respondents. Despite concerns over increased maintenance costs, farmers perceive organic farming as conducive to long-term sustainability and autonomy. Conversely, skepticism towards grafted pepper plants and a preference for homestead cultivation over the main field influence decision-making regarding technological adoption. Furthermore, respondents prioritize landrace diversity and diversified cropping systems, reflecting an inclination towards genetic preservation and sustainable farming practices. The study also highlights a strategic shift towards three-tier diversified systems, incorporating cardamom, to mitigate market volatility. However, concerns arise over the potential reduction in black pepper acreage. These findings provide valuable insights for policymakers and agricultural stakeholders aiming to promote climate-resilient practices and enhance the sustainability of smallholder farming systems.

1. Introduction

Black Pepper, revered as "Black Gold" and the most widely used spice in the world, stands as an iconic commodity in global trade. It is cultivated in over 26 countries, collectively producing approximately 315–320,000 tons of pepper annually, including both black and white varieties (Ravindran and Kallupurackal, 2012). Its origins are deeply rooted in the lush landscapes of Kerala, a South Indian state renowned for its rich tradition of spice cultivation. Contributing significantly to India's agricultural landscape, black pepper holds a prominent position, with major cultivation hubs in Karnataka, Kerala, and Tamil Nadu. Despite its historical significance and economic importance, the black pepper industry faces multifaceted challenges stemming from climatic variability, environmental stressors, and economic volatility.

The production dynamics of black pepper in Kerala reflect the intricate interplay between natural phenomena and agricultural practices. Notably, the state experienced a tumultuous period marked by devastating floods in 2018 and 2019, leaving enduring impacts on soil quality and fertility (Figure 1). Studies conducted post-flood underscored a discernible

decrease in essential soil nutrients, complicating the agricultural landscape (GOK, 2018; Varghese and Ray, 2024). Furthermore, climatic anomalies, such as erratic rainfall patterns and rising temperatures, have emerged as pivotal factors influencing black pepper cultivation. The delayed onset of the southeast monsoon disrupts critical phases of the plant's growth cycle, including flower initiation, ultimately hampering yield outcomes. Moreover, the reduction in post-blossom rain adversely affects pollination and berry development, exacerbating production challenges. Beyond local environmental factors, the global black pepper market grapples with pronounced price volatility, aggravated by economic variables like currency fluctuations, labour expenses, and weather-induced crop yield variations (Phiri *et al.*, 2024). Smallholder farmers, constituting a significant proportion of producers, bear the brunt of these fluctuations, particularly in less developed countries across Africa and Asia, where climate change impacts are disproportionately severe.

Against this backdrop, this paper aims to explore the intricate nexus between climatic variability, environmental stressors, and agricultural practices, with a specific focus on black pepper production in Kerala, India, a state renowned for its black pepper production. By elucidating the multifaceted challenges confronting the industry, this study attempts to provide insights that inform resilient agricultural strategies and mitigate the adverse effects of climate change on black pepper cultivation.

In response to the escalating challenges posed by climate change, the imperative for farmers to adapt their practices has never been more pressing. Acknowledging the pivotal role of adaptation in ensuring sustainable agricultural yields, the term "Climate Change-Relevant Decisions" (CCRDs) was coined, which encompass actions contributing to both mitigation and adaptation efforts (Schneider *et al.*, 2021). These decisions are framed within cognitive theories, emphasizing the cognitive processes that underpin farmers' adaptation strategies.

The adaptive responses of individuals to climate change are multifaceted and influenced by a plethora of interdisciplinary theories spanning anthropology, geography, cognitive science, political science, psychology, rural sociology, economics, and data science. Through empirical research, these theories have been extended and refined, providing valuable insights into human decision-making in the context of climate change.

Understanding the decision-making patterns and preferences of farmers is crucial for designing effective interventions and strategies tailored to their specific needs. By aligning adaptation practices with farmers' cognitive frameworks, interventions can enhance their ability to cope with challenges and bolster their resilience. These efforts typically encompass a blend of psychological support, skill-building initiatives, and the creation of supportive environments conducive to adaptation.

In this study, we delve into the adaptation strategies employed by smallholder black pepper farmers in the major cultivation regions of Kerala, India. Specifically, we address two interconnected sub-questions: (1) what adaptation strategies do smallholder farmers in these regions typically employ in response to climate change? (2) Which adaptation practices do farmers prioritize to ensure sustained income from their plantations? (Smith *et al*., 1999). We utilize Best-Worst Scaling (BWS) as a method to analyse the adaptive responses of smallholder black pepper farmers in Kerala to the challenges posed by climate change. BWS is a powerful technique that allows us to explore farmers' preferences by asking them to identify both the best and worst options within a set of adaptation strategies. This approach

offers several advantages, including capturing the relative importance farmers assign to different strategies, reducing response bias by forcing respondents to make trade-offs, and creating a decision context that mirrors real-world scenarios (Ahoudu *et al.*, 2023; Shittu *et al.,* 2021)

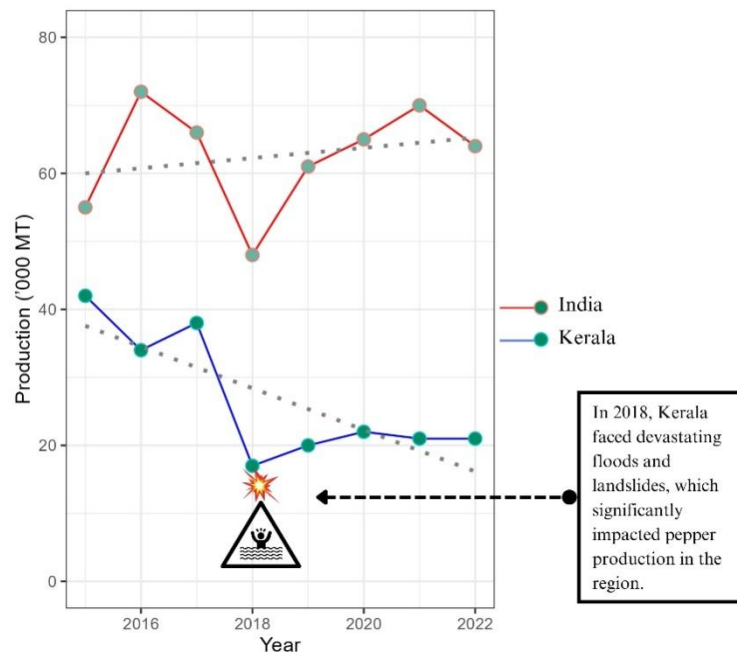Production of black pepper (in '000 MT) from 2015 to 2022 in India and Kerala

Figure 1 Production of black pepper from 2015 to 2022 in India and Kerala

2. Materials and Methods

2.1 Study area

The selection of study areas was based on the consideration of multiple factors, primarily focusing on the significance of districts in Kerala's black pepper production landscape. Among the 14 administrative districts in Kerala, Idukki and Wayanad were identified as focal points due to their exceptional prominence in black pepper cultivation. In the 2019-20 period, Idukki (Southern hills) stood out with a sprawling area of 42,822 hectares dedicated to black pepper cultivation, yielding a production of 20,560 tons, and achieving a productivity rate of 480 kg/ha, where national and state productivity was 235.39 and 239 kg/ha respectively. Similarly, Wayanad (Northern hills) exhibited substantial figures, with 10,307 hectares under black pepper cultivation, resulting in a production of 3,694 tons and a productivity rate of 358 kg/ha. These districts not only lead the state in terms of area, production, and productivity but also contribute significantly to the state's overall black pepper output, with Idukki alone accounting for as much as 59.52% of the total production. Their significant contributions to the overall state production, as well as their diverse geographical and socio-economic characteristics, make them ideal subjects for comprehensive analysis. Moreover, the unique agricultural practices, environmental conditions, and socio-economic factors prevalent in

these districts offer valuable insights into the dynamics of black pepper cultivation in the light of climate resilience, thereby justifying their selection as primary areas of focus in the study.

The Kerala state is divided into 23 agro-ecological units (AEUs) depending upon various factors such as topography, soil types, climate patterns, and vegetation cover. These AEUs acknowledges the heterogeneity of Kerala's terrain and the importance of considering local environmental conditions in agricultural decision-making. The five AEUs having higher area of cultivation under black pepper were purposively selected from the Idukki (3 AEUs) and Wayanad (2 AEUs) districts. Areas from these AEUs were selected purposively depending upon the prevalence of climate change related events as reported by the government agricultural office (*Krishibhavan*), during the preliminary survey. The small holder farmers who possess land holding up to 5 acres were randomly selected from the list obtained from the *Krishibhavans*. Significant contributions of these areas to the overall state production, as well as their diverse geographical and socio-economic characteristics, make them ideal subjects for comprehensive analysis. Moreover, the unique agricultural practices, environmental conditions, and socio-economic factors prevalent in these districts offer valuable insights into the dynamics of black pepper cultivation in the light of climate resilience, thereby justifying their selection as primary areas of focus in the study.

The survey was conducted during the period 2022-23 and 2023-24. The best-worst scaling of climate change adaptation alternatives from 198 smallholder farmers of which 150 farmers provided valid responses. Therefore, the effective sample size became 150.

2.2 Theoretical framework

The theoretical framework guiding this study is rooted in behavioural economics, decision-making theory, and organizational behaviour, providing a lens to understand the complexities of climate-related decision-making processes (CCRDs) within smallholder farming systems in black pepper cultivation in Kerala.

Building upon Simon's concept of bounded rationality (1955), our study recognizes the constraints inherent in decision-making processes, particularly within the context of climate change adaptation among smallholder farmers. These constraints encompass various factors such as emotional influences, social dynamics, incomplete information processing, heuristics, and cognitive biases, as elucidated by seminal works such as those of Tversky and Kahneman (1974). We observe that farmers, faced with the multifaceted challenges of climate change, often grapple with incomplete information and cognitive limitations, leading them to experiment with multiple adaptation practices. In such circumstances, farmers tend to make satisficing choices rather than striving for an optimal rational decision.

Our study employs a choice modelling approach that aligns with the structured information search process inherent in decision-making environments. By employing this approach, we aim to uncover the decision-making patterns followed by black pepper farmers in addressing climate change-related challenges within their field conditions. Through this lens, we seek to gain insights into the preferences and strategies adopted by farmers, shedding light on the dynamics of climate change adaptation at the grassroots level.

In our pilot survey, we observed several adaptation practices among smallholder farmers, including grafting with resistant rootstocks and leveraging traditional knowledge on landraces for commercial nursery businesses. These practices resonate with the theoretical framework outlined by Nelson and Winter (1978) regarding organizational routines and tacit knowledge. The framework also acknowledges the temporal constraints in CCRDs, which necessitate quick adaptive responses. In response to these constraints, decision-makers often rely on simple, fast, and frugal decision-making heuristics, as proposed by Gigerenzer and Todd (1999). Through this, our study seeks to understand how farmers navigate the challenges of climate change by leveraging existing knowledge and adopting adaptive strategies grounded in organizational routines and heuristic decision-making processes.

Our framework also underscores the significance of heuristics and biases in shaping decision-making strategies, echoing March's assertion (1978) that decision-makers often depart from fully conscious preferences, opting instead for established rules, traditions, or external guidance. This acknowledgment of decision-making inconsistency, as emphasized by Fiori (2011), motivates the utilization of Best-Worst Scaling in gathering responses. Furthermore, the framework aligns with the notion that comprehending how and why individuals make specific climate change-related decisions necessitates transcending traditional rational-actor models of human behaviour.

The specific factors that guide individuals in giving varied responses are captured by defining attributes and attribute levels for each adaptation practice. The study refrains from quantifying the costs associated with individual adaptation practices, assuming that these costs are implicitly reflected in the selection of relevant profiles by respondent farmers. Through this theoretical lens, our study aims to provide an understanding of the decision-making dynamics underlying climate resilience strategies in smallholder black pepper farming systems.

2.3 Attribute and level selection

Attributes and attribute level selection for the study involved a collaborative effort between researchers and subject matter experts, aiming to capture the decision-making processes of small holder farmers regarding climate resilience strategies in the southern and northern hills of Kerala. Initially, pilot surveys (explain more details about pilot survey) were conducted to identify relevant attributes that influence farmers' choices in this context. These attributes represent key factors or characteristics that farmers consider when making decisions related to climate resilience.

Following the pilot surveys, subject matter experts from the Indian Institute of Spices Research (IISR) and the Central Marine Fisheries Research Institute (CMFRI), in conjunction with agricultural extension scientists from the Central Research Station (CRS) in Pamapadumpara and regional stations under Kerala Agriculture University, validated the identified attributes. This validation process ensured that the selected attributes accurately reflected the real field conditions and considerations pertinent to smallholder farmers in the region.

Finalized set of attributes which include (A) organic farming practices, (B) grafting for stress tolerance, (C) use of landraces, and (D) cropping systems were selected. Each attribute is further delineated into specific attribute levels. The attribute levels for attribute A are denoted as A_1, A_2, and A_3, while for attribute B, they are denoted as B_1, B_2, B_3, and so forth., which represent different conditions or characteristics within that attribute given in Table 1. These attribute levels were selected based on their relevance to real field conditions in the target regions.

Attribute	Definition	Attribute levels
(A) Organic farming	Compliance with organic agriculture	(A_1) A combination of chemical and organic methods proves more effective for adapting to climate change
		(A_2) Exclusively employing organic inputs in crop cultivation aids in adapting and mitigating climate change-associated management issues.
		(A_3) Certified organic farming serves as an adaptation and mitigation strategy.
(B) Grafting for stress tolerance	Grafting with *Piper colubrinum* as rootstock on black pepper to increase biotic and abiotic stress tolerance	(B_1) Grafting is not effective in the long run
		(B_2) Production and sale of bush pepper plants having ornamental and culinary value grafted on *Piper colubrinum* for home gardens.
		(B_3) Raising grafted plants with irrigation in the main field increases abiotic and biotic stress tolerance.
(C) Landraces	Varietal diversity	(C_1) One or two high-yielding varieties/ landraces
		(C_2) More than two high-yielding varieties/ landraces
		(C_3) More than two high-yielding varieties along with selected landraces known for climate resilience
(D) Cropping system	Number, type, and tiers of crops	(D_1) Sole crop
		(D_2) Two-tiered diversified cropping system with coffee /cocoa /tree spices/areca nut / coconut
		(D_3) Three-tiered diversified cropping

		system with cardamom and tree spices/Arecanut and Coconut

Table 1 Selected Attributes and Attribute Levels for Climate Resilience Strategies in smallholder farmers' decision-making in black pepper cultivation

2.4 Best Worst Scaling

Best Worst Scaling (BWS) is a survey methodology used for evaluating preferences by asking respondents to select the best and worst items from a set of alternatives. It is particularly useful for capturing relative importance and preferences among multiple options. BWS has been described as "a method for capturing preference data in which respondents make a series of choices among subsets of items" (Louviere *et al*., 2015). This approach allows to elicit context-specific insights into decision-making processes.

BWS (Best Worst Scaling) was selected as the methodology in this study due to its unique advantages in evaluating preferences and priorities. BWS allows for the systematic comparison of items within a set, enabling respondents to indicate both the best and worst options, thereby providing richer and more nuanced data than traditional ranking methods. This methodology is particularly well-suited for our study, as it allows us to capture the relative importance and preferences of various factors influencing decision-making in black black pepper cultivation. Its ability to quantify both positive and negative evaluations provides deeper insights into the factors driving decision-making.

In addition to its methodological advantages, we selected Best Worst Scaling (BWS) for its ease of implementation and ability to mitigate respondent confusion when ranking multiple profiles. BWS surveys are relatively straightforward for participants to complete, as they involve simply selecting the best and worst options from a set of alternatives, rather than assigning numerical rankings. This simplicity reduces respondent burden and minimizes the likelihood of survey fatigue or dropout, ensuring higher response rates and more reliable data. Moreover, by focusing respondents' attention on identifying the best and worst options within a given set, BWS reduces cognitive load and avoids the potential for confusion that can arise when attempting to rank multiple profiles according to complex criteria.

2.5 Profile creation

A 3^4 orthogonal array (OA) with four factors generated was utilized to systematically create profiles representing various combinations of factor levels for the attributes (A) organic farming practices, (B) grafting for stress tolerance, (C) use of landraces, and (D) cropping systems. Each profile in the OA corresponds to a unique combination of factor levels for these attributes, enabling structured experimentation and analysis. The utilization of orthogonal arrays (OAs) in profile creation offers several significant advantages. Firstly, by employing OAs, we can explore a diverse range of factor combinations related to attributes. This systematic exploration allows you to efficiently cover a large experimental space while minimizing the number of profiles employed in the study. In addition, OAs ensure a balanced distribution of factor combinations, which is crucial for ensuring that each attribute and its levels are adequately represented. This balance enhances the statistical efficiency to

accurately estimate the effects of different climate resilience strategies on smallholder farmers' decision-making processes.OA was created using the function *oa.design()* in *DoE.base* package (Grömping, 2018) in R (R Core Team, 2021). The nine profile combinations are shown below, the columns of the OA correspond to attributes, while the rows correspond to profiles. A, B, C and D denotes the attributes and numbers 1, 2 and 3 denotes the levels. Detailed attribute level combination can be seen in Table 3 below.

Profile	A	B	C	D
1	1	1	1	1
2	1	2	3	2
3	1	3	2	3
4	2	1	3	3
5	2	2	2	1
6	2	3	1	2
7	3	1	2	2
8	3	2	1	3
9	3	3	3	1

Table 2 Orthogonal Array showing 9 profiles generated through combining levels of attributes

Profile 1	Profile 2	Profile 3
● Chemical and organic inputs ● Grafting is not effective ● One or two high-yielding varieties/ landraces ● Sole crop	● Chemical and organic inputs ● Grafting for the production and sale of bush pepper ● More than two high-yielding varieties along with selected landraces known for climate resilience ● Two-tiered diversified cropping system with coffee /cocoa /tree spices/areca nut / coconut	● Chemical and organic inputs ● Raising grafted plants in the main field ● More than two high-yielding varieties/ landraces ● Three-tiered diversified cropping system with cardamom and tree spices/Arecanut and Coconut
Profile 4	**Profile 5**	**Profile 6**
● Crop grown only with organic inputs ● Grafting is not effective ● More than two high-yielding varieties along with selected landraces	● Crop grown only with organic inputs ● Grafting for the production and sale of bush pepper. ● More than two high-	● Crop grown only with organic inputs. ● Raising grafted plants in the main field ● One or two high-yielding varieties/ landraces

known for climate resilience. ● Three-tiered diversified cropping system with cardamom and tree spices/Arecanut and Coconut	yielding varieties/ landraces ● Sole crop	● Two-tiered diversified cropping system with coffee /cocoa /tree spices/areca nut / coconut
Profile 7	**Profile 8**	**Profile 9**
● Certified organic farming serves as an adaptation and mitigation strategy ● Grafting is not effective ● More than two high-yielding varieties/ landraces ● Two-tiered diversified cropping system with coffee /cocoa /tree spices/areca nut / coconut	● Certified organic farming serves as an adaptation and mitigation strategy ● Grafting for the production and sale of bush pepper ● One or two high-yielding varieties/ landraces. ● Three-tiered diversified cropping system with cardamom and tree spices/Arecanut and Coconut	● Certified organic farming serves as an adaptation and mitigation strategy ● Planting grafted plants in the main field ● More than two high-yielding varieties along with selected landraces known for climate resilience ● Sole crop

Table 3 Nine profiles generated through combining levels of attributes

2.6 Questionnaire

The questionnaire design for this study was based on design method proposed by Louviere et al. (2015), which involved the creation of a Balanced Incomplete Block Design (BIBD). A BIBD was created for 9 profiles (v) with 12 blocks (b) and each blocks having block size (k) of 6. Each profile was repeated (r) 8 times. Where each pair of the profiles was repeated (λ) 5 times. It resulted in a BIBD with parameters (v= 9, b= 12, r = 8, k = 6, λ = 5), which is expressed as a matrix with 12 rows and three columns in Table 4, below. BIBD was created using the *find.BIB()* function in *crossdes* package(Sailer,2022) in R (R Core Team, 2021).

To create the questionnaire, the treatment numbers in the BIBD (1, 2, ..., 9) were replaced with the corresponding profiles (Profile 1, Profile 2, ..., Profile 9) generated earlier. Each block now represented a choice set, consisting of 6 profiles. In total, 12 choice sets were generated, each comprising 6 profiles. Respondents were instructed to evaluate each choice set and select the best and worst options based on their preferences. This design allowed for efficient data collection while ensuring that each profile was evaluated multiple times across different choice sets. For example, the first-choice set consist of the profiles 3,5,6,7,8 and 9 and the 12th choice set consist of the profiles 1,2,4,5,6, and 9. A model choice set is given in Figure 2.

Block	BIBD (9, 12, 8, 6 ,5)

1	3	5	6	7	8	9
2	2	3	4	5	6	7
3	1	2	3	5	8	9
4	1	3	4	5	6	8
5	2	4	5	7	8	9
6	1	2	3	6	7	9
7	1	4	6	7	8	9
8	1	2	5	6	7	8
9	1	3	4	5	7	9
10	1	2	3	4	7	8
11	2	3	4	6	8	9
12	1	2	4	5	6	9

Table 4 Balanced Incomplete Block Design for Questionnaire with 9 Profiles Arranged in Sets of 6 across 12 Choice Sets

Figure 2 A model choice set consisting of profiles 3, 5, 6, 7, 8 and 9

2.7 Statistical Analysis

2.7.1 Counting method

Consider that there are P profiles and N respondents. The counting approach calculates Best Worst Scale scores (BWS scores) based on the number of times (*i.e.*, the frequency or count) profile i is selected as the best (B_{ij}.) or worst (W_{ij}.) profile among all the questions for j[th] respondent, where $i = 1,2,…, P$ and $j=1,2,…, N$. An aggregated Best Worst score of ith profile (BW_i) and mean standardized Best Worst score ($mean\ std.BW_i$) is calculated for each profile using the equations (1) and (2) (Finn and Louviere 1992; Lee, Soutar, and Louviere 2007a; Cohen 2009; Mueller, Francis, and Lockshin 2009).The frequency with which profile

i is selected as the best across all questions for N respondents is defined as B_i. Similarly, the frequency with which profile i is selected as the worst item is defined as W_i. Where $B_i = \sum_{j=1}^{N} B_{ij}$, $W_i = \sum_{j=1}^{N} W_{ij}$. r is the frequency with which profile i appears across all choice sets. A square root of the ratio of B_i and W_i for the ith profile ($sqrt.BW_i$) and standardized score is calculated using equation (3) and (4).

$$BW_i = B_i - W_i$$

(1)

$$mean\ std.BW_i = \frac{B_i - W_i}{Nr}$$

(2)

$$sqrt.BW_i = \sqrt{\frac{B_i}{W_i}}$$

(3)

$$std.sqrt.BW_i = \frac{sqrt.BW_i}{max.sqrt.BW_i}$$

(4)

Where $max.sqrt.BW_i$ is the maximum value of $sqrt.BW_i$. Profiles with higher BW_i scores and $sqrt.BW_i$, accompanied by lower standard deviations $std.BW_i$ and $std.sqrt.BW_i$, exhibit more consistent and widely accepted preferences among respondents. Conversely, profiles with higher standard deviations may indicate greater variability in respondents' perceptions, suggesting diverse or polarized opinions regarding the desirability of those profiles. Hence, while high scores indicate favourable profiles, evaluating their standard deviations offers insights into the consensus or variability in respondents' preferences, aiding in the interpretation of the overall preference landscape. This suggests that profiles with high scores are perceived as particularly favourable or effective in the context of the climate resilience strategies under consideration.

2.7.2 Modelling Approach

In addition to analysing responses at the profile level, it is imperative to gain clarity at the attribute level as well. This involves identifying the most preferred attribute levels to ensure a comprehensive understanding of respondents' preferences. By examining preferences at the attribute level, we can identify the specific attributes and attribute levels that are most favoured by respondents. This process enables us to consider any potential combinations of attributes that may not have been explicitly addressed in the study. Understanding the preferred attribute levels allows for the exploration of alternative combinations that align with respondents' preferences. The modelling approach employs discrete choice models to analyse the responses, with the dataset formatted according to the selected model specifications. Specifically, a maximum difference (maxdiff) model, as outlined by Lancsar *et al*. (2013) and

Marley and Pihlens (2012), is utilized for the analysis. This model assumes that respondents derive utility from each profile within a choice set and select the best and worst profiles based on their subjective utilities. In the maxdiff model, respondents are assumed to select profile i as the best and profile j (where $i \neq j$) as the worst because the difference in utility between these two profiles represents the greatest utility difference among all possible pairings. The number of utility differences in a pair is equal to the number of possible pairs in which profile i is selected as the best and profile j is selected as the worst from P profiles, calculated as $P \times (P\text{-}1)$.

The probability of selecting profiles from a choice set S for each model can be expressed using the conditional logit model. Under assumptions such as a choice set consists of nine profiles S={1,2,3,…,9} respondent k selected Profile i as the first best (FB), Profile j as the first worst (FW). Where $i \neq j = 1,2,…, P$ and $k =1,2,…, N$. then the probability can be expressed using the equation 5

$$\Pr(FB =, WB =) = \frac{\exp(v_i - v_j)}{\sum_{i,j \in S, i \neq j} \exp(v_i - v_j)}$$

(5)

where $v_i = x_i' \beta$; x_i' is a vector of attribute-level variables for profile i; and β is a vector of the coefficients to be estimated.

3. Result and discussion

Best Worst scores were calculated using equations 1, 2, 3, and 4 and the results are presented in Table 5 below. The profiles were ranked accordingly based on the mean BW_i, mean $std.BW_i$ and $sqrt.BW_i$ values.

Profile	B_i	W_i	BW_i	Rank	Mean BW_i	Mean $std.BW_i$	$sqrt.BW_i$	$std.sqrt.BW_i$
1	52	415	-363	9	-2.420	-0.303	0.354	0.104
2	133	202	-69	6	-0.460	-0.058	0.811	0.239
3	167	258	-91	7	-0.607	-0.076	0.805	0.237
4	379	33	346	1	2.307	0.288	3.389	1.000
5	133	192	-59	5	-0.393	-0.049	0.832	0.246
6	78	178	-100	8	-0.667	-0.083	0.662	0.195
7	255	169	86	4	0.573	0.072	1.228	0.362
8	262	143	119	3	0.793	0.099	1.354	0.399
9	333	202	131	2	0.873	0.109	1.284	0.379

Table 5 Best worst score calculated based on counting method for nine profiles

The scatter plot in Figure 3, depicting the mean BWS score (meanBW_i) against the standard deviation of respondents' preferences, offers insights into the variability of preferences for different climate resilience strategies represented by profiles. Profile 4 notably distinguishes itself with a substantially high mean BWS score of 2.307 and a comparatively low standard deviation. This suggests that Profile 4 embodies a climate

resilience strategy that resonates strongly with respondents, eliciting consistently positive evaluations across the board. In contrast, the majority of other profiles received negative or near-zero scores, indicating greater variability and ambiguity in respondents' perceptions regarding their effectiveness in enhancing climate resilience. Therefore, Profile 4 emerges as a standout choice, signifying a robust and widely accepted climate resilience strategy among respondents, characterized by its effectiveness and consensus in addressing climate-related challenges.

In addition to Profile 4, Profiles 7, 8, and 9 also demonstrated positive BWS scores indicating their effectiveness as climate resilience techniques. These profiles are grouped closely together in the plot, following Profile 4, with BWS values of 0.573, 0.793, and 0.873, respectively. This clustering suggests that these profiles share similarities in their perceived efficacy and appeal among respondents. While Profile 4 stands out as the most favoured option with the highest BWS score, Profiles 7, 8, and 9 follow behind, representing viable and promising climate resilience techniques. Profile 9 has high standard deviation indicating a varied response among the respondents. Together, these profiles contribute to a repertoire of strategies that respondents view positively in terms of their potential to enhance resilience to climate-related challenges. Profile 1 is the least preferred. Figure 4 displays the rank order arrangement of the profiles along with their $mean\ std.BW_i$ scores, effectively summarizing the aforementioned findings. From figure 5 it is clear that profile 4 has less negative BW scores and it is noteworthy that Profile 7, 8, 9 has also achieved a maximum BW score value 8 for several respondents but also gained considerable high negative values indicative of mixed responses.
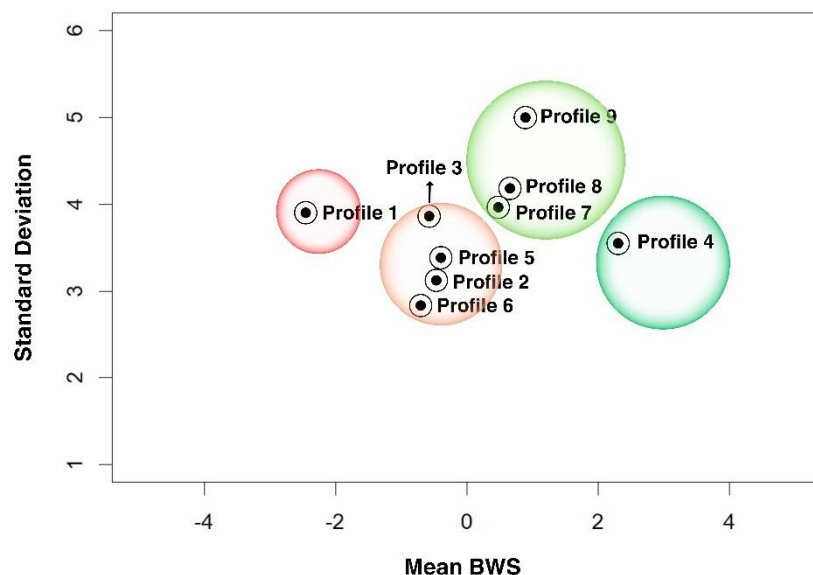

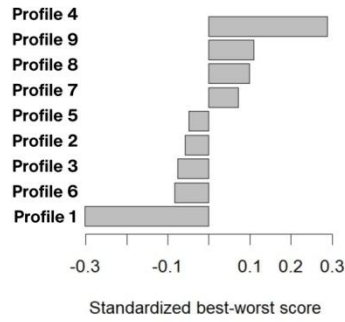Figure 3 Scatter plot based on mean BW_i and its Standard deviation

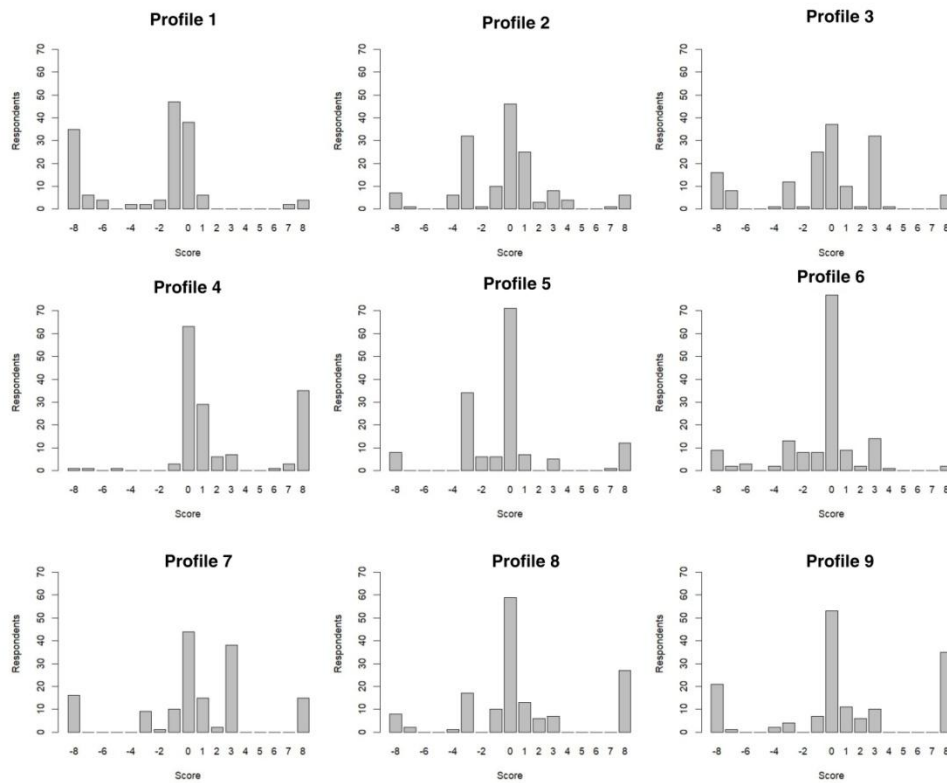Figure 4 Rank order arrangement of profiles along with $mean\ std.BW_i$

Figure 5 Frequency of Individual Best Worst (BW) Scores of Respondents

A utility function is developed for the purpose of fitting a conditional logistic model to the responses on the basis of the maxdiff model to study the attribute level preference. While constructing utility function the attribute levels (Table 1), the following attribute levels were considered as references. (A$_1$) A combination of chemical and organic methods proves more effective for adapting to climate change, (B$_2$) Production and sale of bush pepper plants having ornamental and culinary value grafted on *Piper colubrinum* for home gardens. (C$_1$) One or two high-yielding varieties/ landraces, (D$_1$) Sole crop in corresponding profile are considered as a reference for dummy variables. These attribute levels were considered as reference levels because farm products derived from a hybrid of chemical and organic

management lack the market attribute specificity in asset quality and do not promote long-term climate adaptation. Farmers gave a varied response towards grafting technology in black pepper attributed to its perennial nature, prompts this study to explore the spectrum of adoption, ranging from complete rejection to full integration. The analysis of secondary data on the adoption of black pepper varieties in Kerala revealed the predominance of *Karimunda* and *Panniyur 1* across all pepper-growing districts. However, considering the importance of genetic diversity beyond these two varieties, further exploration was deemed necessary. Hence, C_1 was chosen as the reference level. Given that sole cropping is the least favoured cropping system for climate-resilient farming, this study aims to explore variations beyond this level in the choice analysis.

By designating specific attribute levels (A_1, B_2, C_1, D_1) as reference points, the utility function contrasts the preference for other attribute levels against these references. This comparison enables the identification of how respondents' preferences deviate from or align with the chosen reference levels.

Accordingly, the systematic component of a utility function for the nine profiles (i = 1,2,…, 9) is as follows

$$v_i = \beta_1 A_2 + \beta_2 A_3 + \beta_3 B_1 + \beta_4 B_3 + \beta_5 C_2 + \beta_6 C_3 + \beta_7 D_2 + \beta_8 D_3$$

Where $A_2, A_3, B_1, B_3, C_2, C_3, D_2, D_3$ are dummy variable taking the value of 1 if i^{th} profile has the attribute level A_2, A_3, B_1, B_3, C_2, C_3, D_2, D_3 respectively , 0 otherwise;. βs are coefficients (parameters) for these variables. Conditional logistic model is fitted using *clogit()* function of *survival* package (Therneau,2023) in R (R Core Team, 2021).

Attribute level	β	Odds ratio	se(β)	Pr(>|z|)
A_2	0.793	2.210	0.078	0.000[**]
A_3	0.148	1.160	0.082	0.069[ns]
B_1	-0.654	0.520	0.079	0.000[**]
B_3	-0.407	0.666	0.08	0.000[**]
C_2	1.051	2.86	0.085	0.000[**]
C_3	0.422	1.524	0.081	0.000[**]
D_2	0.414	1.513	0.081	0.000[**]
D_3	0.077	1.080	0.078	0.329[ns]

Table 6: Conditional Logistic Regression Results for Attribute Level Preferences

The results of the conditional logistic regression analysis presented in Table 6 provide insightful implications regarding the influence of different attribute levels on respondents' preferences for climate resilience strategies. The highly significant coefficient (β_1) of 0.793 associated with attribute level A_2, representing the exclusive use of organic inputs in crop cultivation, indicates a substantial positive impact on preference. This suggests that respondents are 2.210 times more likely to favour attribute level A_2 compared to the reference level, emphasizing the perceived effectiveness of organic farming practices in adapting to and mitigating climate change-related challenges. Despite increase in weighted average

maintenance cost (Table 7) as estimated during the study (127% higher than conventional methods), farmers prefer organic farming as they consider it as a long term decision for climate adaptation. Farmers view organic farming as a significant long-term investment due to its promotion of autonomy, economic efficiency, and resilience factors in farm management.

Particulars	Yield increasing phase	Yield stabilising phase	Yield declining phase	Mean (weighted)
Conventional	73034	81340	60679	70311
Organic	90099	91801	75811	89818

Table 7: Average maintenance cost in conventional and organic method of cultivation (INR/acre)

In contrast, attribute levels B_1 and B_3 demonstrate significant negative effects ($\beta_3 = -0.654, \beta_4 = -0.407$) on preference with odds ratio less than one when compared to reference level, indicating that respondents are less inclined to favour these levels compared to the reference level, which involves the production and sale of bush pepper plants grafted on *Piper colubrinum* for home gardens. Farmers prefer this reference level due to the proven effectiveness of the grafting technique in propagating bush pepper in home garden settings, where irrigation costs are manageable. The black pepper crop in Kerala confronts various challenges, including diseases, pests, and climate variability. Foot rot disease, particularly prevalent during the southwest monsoon season, leads to significant crop losses (Anju *et al.*, 2023). In response, farmers seeking to enhance resistance to this disease have turned to grafted plants on the rootstock *Piper colubrinum* in the main field. Farmers have noted that grafted plants display robust growth, establish quickly, and demonstrate resilience to flood and foot rot in field conditions. This decision-making process is shaped by tacit knowledge, aiding farmers in navigating unfamiliar situations within the constraints of bounded rationality. Moreover, farmers proficient in grafting are exploring the option of grafting on *Piper colubrinum* for bush pepper production as a means to enhance their income. The diverse skill sets possessed by farmers influence their decision-making behavior in this regard.

However, attribute level B_3, which pertains to raising grafted plants with irrigation in the main field, experiences a downward trend in preference. This trend may be attributed to limited scientific validation and evidence regarding the efficacy of grafted plants in field conditions. Some studies suggest that grafted plants have limitations, such as a relatively short lifespan of nine to ten years and a lower yield of fruit-bearing spikes. Additionally, the requirement for regular irrigation poses challenges, particularly for smallholder farmers with limited access to resources (Hema *et al.*, 2007). Therefore, the lack of scientific validation and the practical challenges associated with irrigation may contribute to the reduced preference for this adaptation practice among the majority of farmers.

Additionally, attribute level C_2 stands out with a highly significant odds ratio of 2.86, indicating a strong preference among respondents. Most farmers prefer C_2, raising multiple varieties or landraces, with popular choices being Panniyur 1, Panniyur 5, Vijay, and the

landrace Karimunda, alongside others. State and private farms propagate these types for their bold, superior-quality berries, favored by traders based on litre weight. C_3 also is preffered which included selected landraces known for climate resilience, showing its positive impact on preference at the attribute level. Farmers promote climate-resilient landraces and generate income by selling rooted seedlings of these landraces. This underlines the importance of landrace diversity in farmers' CCRDs.

Furthermore, attribute levels D_2 and D_3 representing two and three tiered cropping system demonstrate significant coefficients with odds ratios greater than 1, indicating a heightened preference compared to the reference level which is sole crop. This preference is likely influenced by the traditional agro-forestry landscapes where black pepper cultivation in India occurs. These landscapes often feature intercropping with coffee, arecanut, coconut, and tree spices like clove, nutmeg, allspice, and cinnamon. In regions such as Idukki and parts of Wayanad district, traditional black pepper cultivation has shifted towards three-tier diversified systems centered on cardamom cultivation. This transition is gradual due to challenges such as foot rot-affected black pepper vines struggling to thrive amidst cardamom intercropping. The intensified shading from cardamom ground cover impedes black pepper vine growth, necessitating a gradual shift. This transition has gained momentum recently due to rising cardamom prices. Coffee provides natural shade and mulching, particularly beneficial in inter-row spaces, mitigating soil parching observed after floods in 2018 and 2019. Previous studies have demonstrated that the coffee-black pepper agro-forestry system typically includes shade trees ranging from 77 to 142 per acre, with a Shannon's index measuring 2.37, slightly lower than that of natural forests at 2.50 (Chengappa, & Gracy, 2010). Discussions with experts on best agronomic practices for black pepper, coupled with findings from previous studies like Chengappa *et al*. (2017), emphasize the importance of integrating coffee, cocoa, and tree spices into black pepper-diversified systems to ensure sustainable production. Despite this, the preference for three-tier diversified systems with cardamom suggests a strategic, long-term adaptation to buffer against price volatility in black pepper and cardamom markets. In lowlands where cardamom and coffee are absent, diversified systems comprising black pepper, arecanut, and coconut are prevalent. Additionally, tree spices and cocoa are cultivated within such systems, further enhancing resilience and economic viability.

4. Conclusion

Through a comprehensive analysis of Best-Worst Scaling (BWS) scores, conditional logistic regression, and attribute level preferences, several key observations have emerged on complex dynamics underlying decision-making processes related to climate change resilience strategies among smallholder black pepper farmers in Kerala, India. Profile 4, characterized by its exclusive use of organic inputs in crop cultivation, no affinity for grafted plants in the main field,three-tiered diversified cropping systems with cardamom as the lowest tier, inclination towards preserving selected landraces known for climate resilience, emerged as the most favoured climate resilience strategy among respondents. This profile gives them sustainable benefits in the long run. The attribute level analysis also indicates that farmers perceive organic farming as conducive to promoting autonomy, long-term economic

efficiency, resilience in farm management, and overall sustainability of their farms, even in light of the accompanying increase in maintenance costs. Notably, farmers exhibit reluctance towards raising plantations with grafted black pepper plants on *Piper colubrinum* due to concerns regarding irrigation requirements and skepticism towards the technology. Conversely at the attribute level, corresponding to the choice of grafting with the rootstock *Piper colubrinum,* the production and sale of bush pepper grafts with ornamental and culinary value for home gardens showed preference. This preference is derived from the fewer risks in including the practice in homestead cultivation compared to the main field, farmer routines rooted in their skills in grafting and nursery management, and alternative income boost obtained through the sale of grafts.

Attributes related to landrace diversity and diversified cropping systems demonstrated significant positive effects on preference, indicating respondents' inclination towards preserving genetic diversity and integrating multiple crops into their farming systems. Farmers' awareness of nature-based assets is gradually increasing, albeit at a slow pace, exerting influence on this trend. Most farmers prefer the attribute level, "raising more than two varieties or landraces, however, when farmers selected preferred profiles, they prioritized profile 4, which included a preference for selected landraces known for climate resilience. Also, black pepper as a sole crop is the least preferred choice among smallholder farmers.

The preference revealed in the choice experiment for three-tier diversified systems incorporating cardamom implies a strategic, long-term adaptation to mitigate the effects of price volatility in black pepper and cardamom markets. This preference reflects a strategic, long-term adaptation approach aimed at mitigating the effects of price volatility in agricultural markets and enhancing overall farm resilience. However, a pertinent concern to be addressed is whether this trend will ultimately lead to a reduction in the acreage of standing black pepper crop in the study area. Overall, the findings align with global demands for sustainable agricultural practices and underscore the importance of tailored, resilient strategies in addressing climate change challenges in agricultural landscapes.

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