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

1. **Introduction**

Black Pepper, revered as "Black Gold," stands as an iconic spice in global trade, with its origins deeply rooted in the lush landscapes of Kerala, a South Indian state renowned for its 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. 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. 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. 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?

In this study, 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.

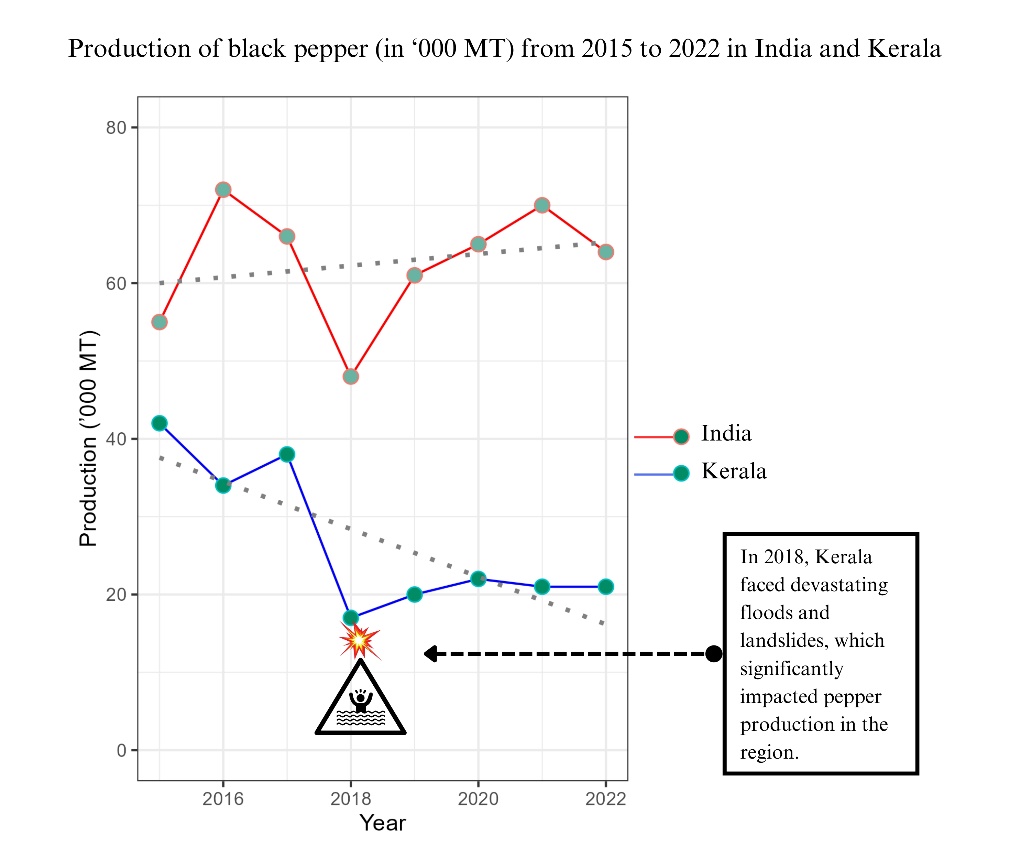


Figure 1 Production of black pepper from 2015 to 2022 in India and Kerala

**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 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 exhibited substantial figures, with 10,307 hectares under 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 pepper output, with Idukki alone accounting for as much as 59.52% of the total production. Write about the number of samples etc here

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.

2.2 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 smallholder 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, 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 |
| 1. Organic farming | Compliance with organic agriculture | A combination of chemical and organic methods proves more effective for adapting to climate change |
| Exclusively employing organic inputs in crop cultivation aids in adapting and mitigating climate change-associated management issues. |
| Certified organic farming serves as an adaptation and mitigation strategy. |
| 1. Grafting for stress tolerance | Grafting with *Piper colubrinum* as rootstock on pepper *to* increase biotic and abiotic stress tolerance | Grafting is not effective in the long run |
| Production and sale of bush pepper plants having ornamental and culinary value grafted on *Piper colubrinum* for home gardens. |
| Raising grafted plants with irrigation in the main field increases abiotic and biotic stress tolerance. |
| 1. Landraces | Varietal diversity | One or two high-yielding varieties/ landraces |
| More than two high-yielding varieties/ landraces |
| More than two high-yielding varieties along with selected landraces known for climate resilience |
| 1. Cropping system | Number, type, and tiers of crops | Sole crop |
| Two-tiered diversified cropping system with tree spices and coffee/areca nut, and coconut |
| Three-tiered diversified cropping system with cardamom, coffee, cocoa, and tree spices |

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

2.3 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 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.

2.4 Profile creation

A 34 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 tree spices, and coffee/areca nut, and 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, coffee, cocoa, and tree spices |
| **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 known for climate resilience. * Three-tiered diversified cropping system with cardamom, coffee, cocoa, and tree spices | * Crop grown only with organic inputs * Grafting for the production and sale of bush pepper. * More than two high-yielding varieties/ landraces * Sole crop | * Crop grown only with organic inputs. * Raising grafted plants in the main field * One or two high-yielding varieties/ landraces * Two-tiered diversified cropping system with tree spices, and coffee/areca nut, and 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 tree spices, and coffee/areca nut, and 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, coffee, cocoa, and tree spices | * 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

2.5 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

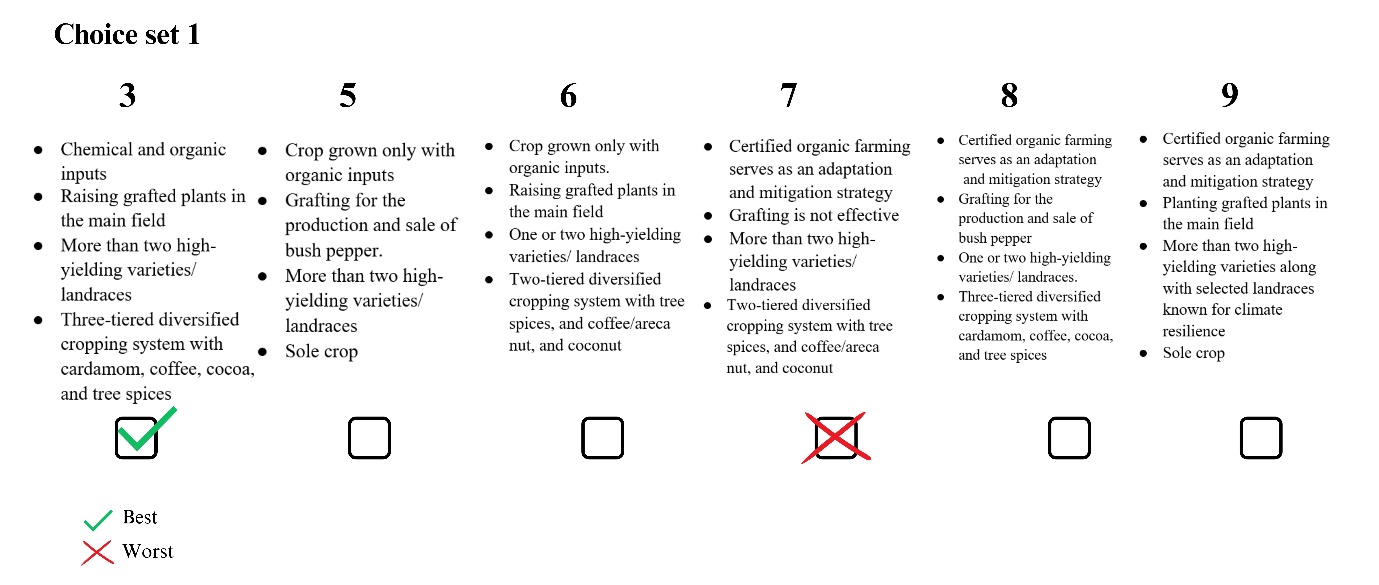


Figure 2 A model choice set consisting of profiles 3,5,6,7,8 and 9

2.6 Statistical Analysis

2.6.1 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 (.) or worst (.) 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 *i*th profile () and standardized Best Worst score () 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 . Similarly, the frequency with which profile *i* is selected as the worst item is defined as . Where . *r* is the frequency with which profile *i* appears across all choice sets. A square root of the ratio of and for the *it*h profile () and standardized score is calculated using equation (3) and (4).

**(1)**

**(2)**

**(3)**

**(4)**

where  is the maximum value of . Profiles with higher scores and , accompanied by lower standard deviations and , 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.

2.6.2 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* ≠ *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* × (*P*-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* ≠ *j* = 1,2, …, *P* and *k* =1,2, …, *N*. then the probability can be expressed using the equation 5

**(5)**

where ;  is a vector of attribute-level variables for profile *i*; and  is a vector of the coefficients to be estimated.

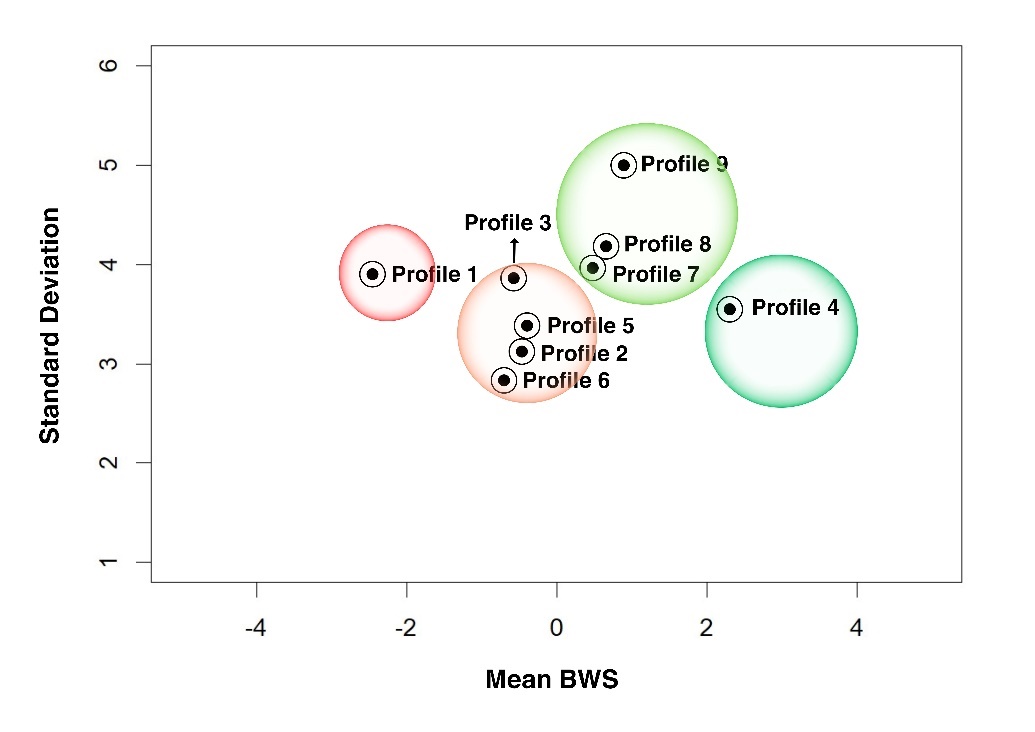
3. Result and discussion

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Profile |  |  |  | Rank | mean | mean |  |  |
| 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 (mean ) 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 favored option with the highest BWS score, Profiles 7, 8, and 9 follow behind, representing viable and promising climate resilience techniques. 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.



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