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Analysis of Farmers' Perceptions on Sealing Techniques for Runoff Harvesting Ponds: A Case Study from Burkina Faso

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Abstract: Water conservation in arid and semi-arid regions faces significant challenges due to low and irregular rainfall, worsened by climate change, which negatively affects rain-fed crop productivity. Various techniques, including supplemental irrigation using runoff harvesting ponds, aim to address these issues but often suffer from water loss due to infiltration, influenced by the pond liner type. This study uses a factorial analysis to assess the farmers' perceptions of four pond sealing techniques. Using the Waso-2 method, a survey conducted in 2022 among 41 rainwater harvesting pond owners across three regions of Burkina Faso revealed that farmers prioritized impermeability and ease of maintenance over cost and availability. Concrete, scoring 16/20, was the most preferred, chosen by over 75% of farmers for its durability and resistance to weathering, despite its high cost. Geomembrane, with a score of 12/20, was valued for its waterproofing properties but had durability concerns. Clay, although cheap and available, scored 8/20 due to poor waterproofing on unstable ground. Bitumen, the least favored with a score of 6/20, was hindered by scarcity and lack of familiarity. To enhance supplemental irrigation in Burkina Faso and similar regions, waterproof concrete or durable geomembrane liners are recommended. Further research into improving bitumen and clay liners is also suggested. These findings provide key insights into farmers' preferences, offering guidance for developing effective water conservation strategies to boost agricultural productivity and address food security challenges in the context of climate change.

Keywords: rainwater harvesting pond; sealing solutions; supplemental irrigation; seepage; Waso

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1. Introduction

The global water crisis, exacerbated by climate change, poses significant challenges to arid and semi-arid regions [1]. These areas are experiencing increased water stress due to unpredictable rainfall, higher temperatures, and prolonged droughts [2], which directly affect crop productivity and water system efficiency [3]. This situation is primarily due to the predominance of rainfed agriculture in these regions [4]. For instance, cereal productivity in arid regions of India could potentially decline by up to 40% by the year 2100 [5]. Similar trends are expected in Australia, with projections indicating a decrease in agricultural yields of up to 35% before 2050 [6].

Between 1900 and 2013, Africa experienced 291 drought events, resulting in approximately 847,143 fatalities and affecting over 362 million individuals, with a total economic impact estimated at USD 2.92 billion [7]. Sub-Saharan Africa, where 50–80% of the population depends on farming, faces severe risks to food security due to these climatic changes [8]. Burkina Faso, as a case in point, relies heavily on rainfed agriculture, which supports the

livelihoods of over 80% of its population [9]. A projected temperature increase of 2.5 °C could result in a dramatic 46% reduction in agricultural production [10].

Addressing the challenges of water scarcity requires innovative solutions for water management and use. One critical strategy is enhancing water retention, which plays a vital role in stabilizing agricultural production and mitigating food deficits [11]. Increasing water retention is essential for three key reasons. First, it mitigates the impact of droughts. The Sahel region frequently experiences prolonged droughts that severely affect crop yields [12]. By enhancing water retention, farmers can ensure a more stable water supply during dry periods, reducing the risk of crop failure [13]. Second, it enhances soil moisture. Improved water retention maintains essential soil moisture levels, supporting root development and nutrient uptake, which leads to healthier and more resilient plants [14]. Third, it reduces water runoff. Techniques such as mulching, terracing, and retention ponds help reduce water runoff, conserving water and preventing soil erosion, which can degrade land and further reduce agricultural productivity [15]. One of the keyways to achieve this is through rainwater harvesting, a traditional practice that captures and stores excess water, preventing it from running off and going to waste.

Rainwater harvesting (RWH) is a traditional practice that has been used for hundreds of years. Archeological evidence attesting the capture of rainwater dating from the Neolithic period have been discovered [16]. In ancient times, rainwater was the main source of supply for drinking and non-drinking water needs, because water supply systems were not yet developed [17,18]. This technology involves collecting, conveying, and storing run-off water on an impermeable surface for later productive use [19,20].

Water harvesting methods, once developed simply for convenience [21,22], are now the subject of renewed attention [23,24]. In fact, water harvesting has become an additional source of water supply in regions facing water shortages, especially in the context of global warming and water scarcity.

Farmers in Burkina Faso have long adapted to water scarcity by employing various strategies to conserve soil moisture and improve crop resilience [25]. These practices include constructing anti-erosion embankments, utilizing traditional planting techniques such as "zaï" and crescent methods, and cultivating drought-resistant crops [26,27]. These methods have not only rehabilitated degraded soils [28] but have also significantly increased agricultural yields and household incomes [29,30].

In the context of prolonged and more frequent drought periods, these local adaptation strategies prove to be increasingly ineffective [31,32]. In response to these challenges, rainwater harvesting ponds (RWHP) for supplemental irrigation have been promoted as a viable solution by NGOs since 2007 [33]. This approach was further popularized in 2012 by the Ministry of Agriculture, in partnership with the Institut International d'Ingénierie de l'Eau et de l'Environnement (2iE), through the "Maïs de Case". The studies [34] clearly demonstrate that the use of this method can increase maize yields by up to 21% annually.

Unfortunately, the labor-intensive process of excavating predominantly iron-rich soil [35], the pond's capacity to retain water for extended periods, and the associated construction costs are critical factors that can either facilitate or hinder the development of supplemental irrigation through rainwater harvesting ponds (RWHP) [36]. These factors are closely linked to the soil state, which refers to the physical and chemical conditions of the soil, including its texture, structure, moisture content, and nutrient levels. The expenses involved in pond construction are also influenced by these conditions [37]. Additionally, the type of liner used to minimize leakage along the pond's edges and bottom plays a significant role in addressing these challenges.

While extensive literature exists on agricultural practices and water management, there is a notable lack of studies on the farmers' perceptions of pond sealing techniques. Understanding these perceptions is crucial for successful implementation and adoption. Following over ten years of expanding the use of supplemental irrigation by RWHP, producers were given the opportunity to share their perspectives through a survey using the Waso-2 tool [38].

The aim of this survey is to gather opinions on different liner options, specifically clay, bitumen, concrete, and geomembrane, underscoring the value of local knowledge in fine-tuning this irrigation system for sustainable farming in Burkina Faso and similar Sub-Saharan zones. The study seeks to identify the most sustainable and efficient liner solutions that can enhance agricultural productivity and water conservation in these regions.

2. Materials and Methods

2.1. Study Area

The study was conducted in the heart of the vast plain of Burkina Faso, between parallels 11.30° and 13.00° N, the rural communes of Koubri, Ziniaré, Tanghin Dassouri, Saponé, Gaongo, Ipelcé, Douloukou, Toécé and Kombissiri. The climate is Sudano-Sahelian, characterized by average annual rainfall of between 600 and 900 mm over a period of four to five months [39]. The soils are predominantly leached tropical ferruginous type, with a low organic matter content that varies from 1% to 5% from the surface to the depths, with low concentrations of mineral elements [40]. Consequently, the lack of rainfall and the poor quality of the soil are the main obstacles to the proper growth of crops. Despite all of this, agriculture is the main livelihood strategy in this area with low productivity: cereal yields are around 30% of the potential [41]. Sixteen villages that exemplify typical rainfed farming systems are the focus of this study (Figure 1).

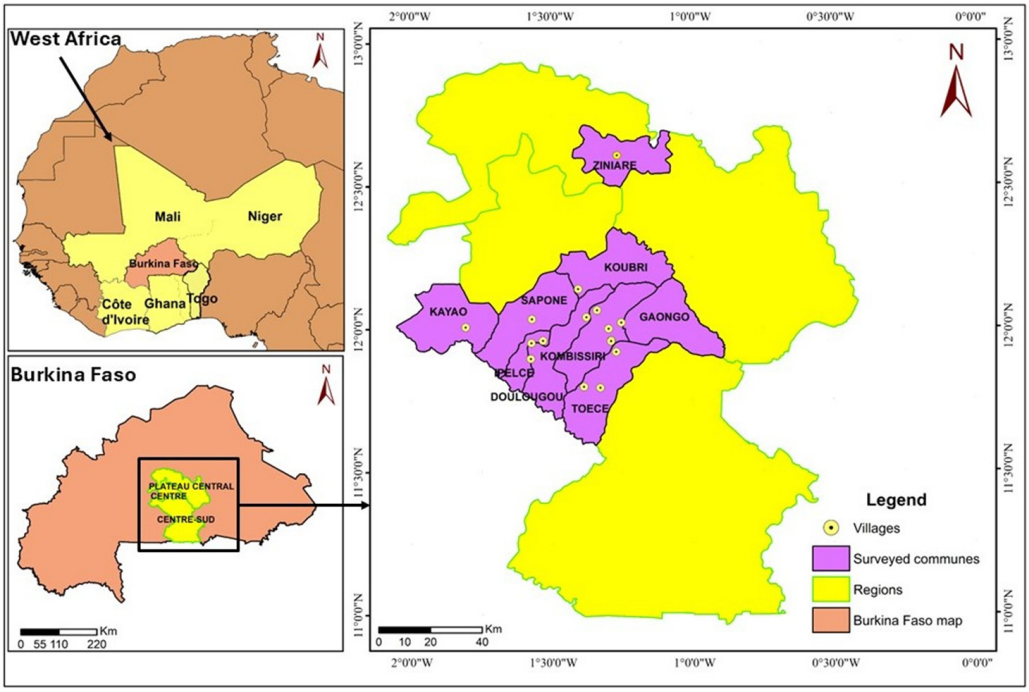

Figure 1. Location of the study area in the Sudano-Sahelian zone of Burkina Faso.

These representative villages were chosen because they reflect the most common land-use systems in the region, characterized by water scarcity, high demographic and land pressure, and soil degradation. Awareness campaigns, training programs, and financial investments have been undertaken by the government and its partners to enhance the farmers' access to adaptive agricultural solutions, thereby improving their livelihoods and resilience to climate change. For the purposes of this study, there is at least one adopter of RWHP supplemental irrigation in each selected village.

2.2. Data Collection on Farmers' Perceptions

This survey was carried out using the Waso-2 tool and a survey questionnaire. These were used to conduct personal interviews (PI) to collect the individual opinions of all the

selected farmers. The PI were conducted in collaboration with the South-Central Regional Department of Agriculture, Burkina Faso. The data collected were then processed for analysis using Stata 16 software.

2.2.1. Waso-2 Survey Tool

Waso-2, a scientific and entertaining device, was created by Dr. Amadou Keïta, the second author. This innovation combines the Awale, an African game, and the Soroban, a Japanese calculating instrument. The name "Waso", which means "pride" in Bambara, the predominant language in Mali, reflects this dual heritage [38]. Waso-2 serves three main purposes: it functions as a computational tool, an entertainment instrument, and an investigative device. Only the investigative function is considered in this study.

The Waso-2 is a locally crafted tool, made from wood by artisans, consisting of 24 compartments arranged in a 6 × 4 matrix, along with 120 sticks (Figure 2). This design enables the collection of accurate numerical data, even from populations with limited formal education. This method was specifically chosen because in Burkina Faso, 73% of farmers have not attended school [42].

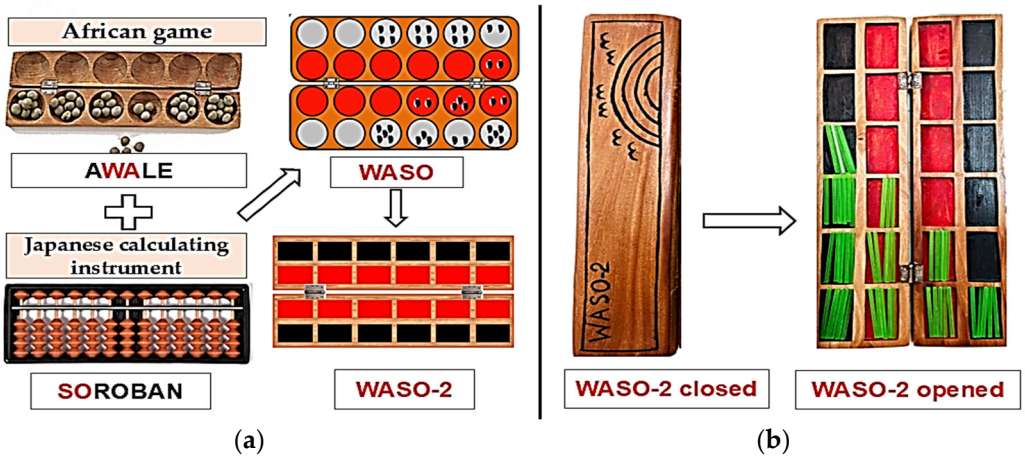

Figure 2. Presentation of the WASO-2 Survey Tool. (**a**) Overview of the creation steps and process for the WASO-2 survey tool. (**b**) Illustration of the WASO-2 survey tool in both closed and opened states, showing stick placements.

What makes the Waso-2 particularly appealing is its resemblance to a traditional board game, as shown in Figure 2a, that is widely recognized in rural communities. This familiar format enhances participant engagement by making the data collection process enjoyable. Moreover, the Waso-2 surveys are conducted individually, which is crucial in highly hierarchical settings, such as rural Sub-Saharan Africa, to ensure the authenticity and sincerity of the responses.

Numerous studies using the Waso-2 method [43–47] have demonstrated its ability to elicit independent and convergent opinions from non-literate farmers in Mali, Côte d'Ivoire, and Burkina Faso. Consequently, the Waso-2 proves to be an excellent tool for conducting surveys in rural Burkina Faso, particularly for assessing perceptions of rainwater harvesting pond (RWHP) waterproofing techniques. This instrument enables the collection of unbiased opinions and information from respondents, free from external influences or environmental pressures [48].

2.2.2. Questionnaire

Identifying the root cause of a problem is crucial once the trial has been established [49]. One effective method for this is the use of a Fishbone Diagram, also known as an Ishikawa Diagram, to develop a questionnaire [50]. The questionnaire design process began with the creation of an Ishikawa diagram, as illustrated in Figure 3. This approach systematically categorizes potential causes, enabling a comprehensive examination of the problem's

underlying factors [51]. This diagram was developed through consensus among the authors, who are experts in the field of water infiltration at RWHP and is based on the process described by [52]. The diagram serves to identify the survey topic (ST), ensuring there is no overlap or redundancy. For each ST, survey topic questions (STQ) are formulated, representing the factors that may influence the results. Ultimately, anticipated responses (AR) are suggested for each specific test question (STQ) to compile the survey form, as detailed in Appendix A. According to [53], these AR correspond to the levels or values of the factors in inferential statistics.

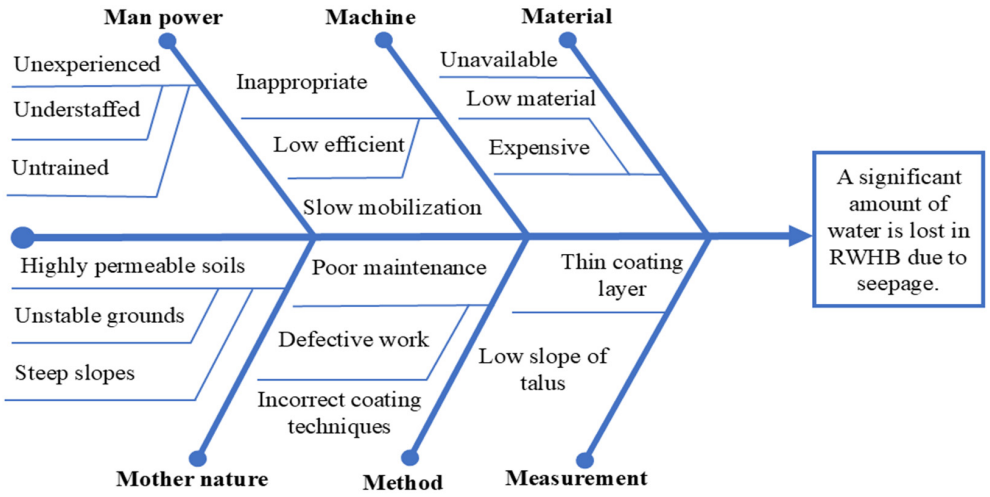

Figure 3. Cause and effect diagram showing factors that increase water seepage in RWHP.

2.2.3. Sampling

One of the most significant challenges faced by researchers is the determination of an appropriate sample size that accurately represents the population. This is essential for ensuring the precision of results, enhancing statistical power, minimizing margins of error, balancing resource constraints, and addressing ethical considerations [54].

The minimum sample size n_i for a Waso-2 survey for multiple independent means is estimated using Formula (1) [55]:

$$n_i \geq (1 + \sqrt{g+1}) \times \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2}{\delta^2} + \frac{Z^2_{1-\alpha/2} \times \sqrt{g+1}}{2(1+\sqrt{g+1})} \quad (1)$$

where α = the probability of committing a false positive; β = the probability of committing a false negative; g = the maximum number of possible responses per question (for the WASO-2, g = 6, corresponding to the six columns per line in the survey tool).; δ = the real difference between the levels of the factor; n_i = sample size or number of replications; and Z = indicates how many standard deviations an element is from the mean.

The total population is estimated by the formula $n_{gi} = \sum_1^g n_i$. The values for the WASO-2 method have been derived by the creator from several relevant experiments conducted using the tool. Given the parameters, α = 0.04; β = 0.20; g = 6; δ = 1. The resulting Commas values are $Z_{0.975} = 1.960$; $Z_{1-\beta} = 0.8416 \leftrightarrow n_i \geq 27$, $Z_{0.975}$ = 1.960; and $Z_{1-\beta}$ = 0.8416 $\leftrightarrow n_i \geq 27$ [38].

Once the minimum sample size was known, stratified random sampling was used. According to [56,57], this technique avoids bias and improves the sample's representativeness.

It is more appropriate when the population is naturally divided into small, distinct groups that do not coincide. Three strata were, therefore, identified within the population studied: 1—owners of impermeable RWHP; 2—owners of permeable RWHP; and 3—owners who had abandoned their RWHP. These three groups were formed on the assumption that opinions would differ depending on whether the innovation worked, failed, or was abandoned altogether. The list of official RWHP adopters from the Bazèga

provincial Department of Agriculture, Animal Resources, and Fisheries was used for this purpose [58]. People living in unsafe areas (red zone) were excluded from the population P, and then the sample sizes per stratum were defined, keeping in mind that the final sample must consist of at least 27 individuals. As a result, a sample of N_{ST} = 16 sample was selected for adopters in accessible areas and a sample of N_{ST} = 25 for adopters in partially accessible areas.

The proportionality coefficient f was then calculated using Formula (2).

$$f = \frac{N_{ST}}{N} \quad (2)$$

where N_{ST} = stratum sample size, and N = stratum size. The sample size for each substratum is given by the formula $N_{SS} = f \times N_{ST}$. The total sample size N_i = 41 according to the algorithm below.

The security status was meticulously considered during the sampling process. Regions classified as red zones [59], due to heightened security risks and frequent insurgent activities, were excluded from the population sample. Consequently, only the 288 RWHP owners situated in the relatively safer orange and green zones were included in the study (Figure 4). This approach ensured the safety of the research team and the reliability of the data collected.

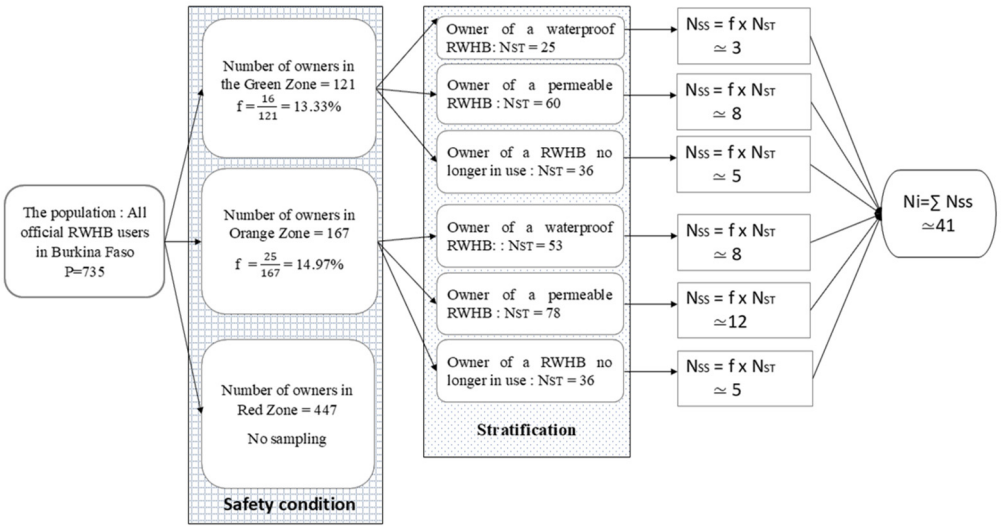

Figure 4. Algorithm for sample size determination.

2.2.4. Ethical Considerations

This study collected personal information, making anonymity crucial. The measures ensured confidentiality, with respondents informed their data were for evaluation only. The questionnaires omitted any identifying personal data. The participants were briefed on the study's purpose, assured of confidentiality, and could consent to voice recordings. Participation was entirely voluntary with no coercion involved. The study adhered to the ethical guidelines of the 2iE Institute's Research Ethics and Deontology Committee (Approval No. 2024/0875/DG/SG/DR/HK/fg), which also approved the study's methodology.

2.2.5. On-Site Survey Process

The survey was conducted in Mooré, the main spoken language in the study area [60]. The Waso-2 tool and questionnaire were used to collect the individual opinions of 41 RWHP owners (Figure 5). Each question was accompanied by a maximum of six anticipated responses. Each respondent was asked to assign a score of between 0 and 20 to each AR. The maximum duration of an interview was one hour.



(**a**) (**b**)

Figure 5. This is the figure of the onsite process. (**a**) Briefing of all RWHP owners in the village of Kombougo on the principle of Waso-2 before the individual surveys. (**b**) Individual survey of a RWHP owner in the village of Gomtoaga using Waso-2.

2.3. Data Treatment and Analysis Tools

Excel 2016 and STATA were used for data processing. The survey results were compiled in excel (see Supplementary Materials: Table S1 for collected data) and exported to STATA, a statistical processing and analysis software package [61,62]. Before processing, the data underwent bootstrapping. This approach was essential for providing robust estimates of statistical measures without relying on strict parametric assumptions. By employing this resampling technique, it was possible to more accurately assess the variability and confidence intervals of the estimates, particularly when dealing with small sample sizes or non-normally distributed data [63]. The generation of numerous simulated samples enhanced the reliability of the findings, ensuring that the conclusions were not overly dependent on the specific characteristics of the original sample [64]. Consequently, this method strengthened the validity of the results, making them more generalizable and trustworthy [65]. Subsequently, the Shapiro–Wilk normality test, Bartlett's test for homoscedasticity, and analysis of variance (ANOVA) were employed to ensure the robustness and validity of the results. The Shapiro–Wilk test was utilized due to its high sensitivity to deviations from normality, while Bartlett's test was applied to verify the assumption of equal variances, a critical requirement for ANOVA. The ANOVA was conducted to compare the means across different strata to detect significant differences. These statistical methods were rigorously selected to validate the data and ensure sound conclusions, with the objective of accurately capturing the producers' perceptions and proposing sustainable solutions to address infiltration issues in the RWHP.

- Shapiro–Wilk normality test hypothesis (H1)

  Null hypothesis (h_0): The sample belongs to a normal distribution
  Alternative hypothesis (h_1): The sample does not belong to a normal distribution
  Level of meaning: *p*-Value > 5%

- Bartlett's homoscedasticity test hypothesis (H2)

  Null hypothesis (h_0): All population variances are equal.
  Alternative hypothesis (h_1): At least one population variance is different from the others.
  Level of meaning: *p*-Value > 5% [66]

- ANOVA test hypothesis (H3)

  Null hypothesis (h_0): There is homogeneity between the variances of the strata
  Alternative hypothesis (h_1): There are at least two strata for which the variances are not homogeneous.
  Level of meaning: *p*-Value > 5% [67]

- Box plot [68]

Symmetry: If the median is centered in the box and the whiskers are of equal length, the data are symmetrically distributed.

Skewness: If the median is closer to one end of the box or the whiskers are of unequal length, the data are skewed.

Outliers: Points outside the whiskers indicate potential outliers that may need further investigation.

- Multiple component analysis [69]

3. Results

3.1. Descriptive Statistics

The statistics in Table 1 provide a description of the population. Approximately 71% of the farmers interviewed were under the age of 60. Several studies have shown that age can be a determining factor in the adoption of an agricultural innovation [70,71]. In sub-Saharan Africa, farmers under 60 are more likely to adopt RWHP [58]. Furthermore, all RWHP adopters own their farms. This shows the decision to adopt supplemental irrigation is positively associated with the holding of a traditional or modern land title. Moreover, this population is predominantly male (95%). This gender disparity is significantly influenced by local land laws in rural West Africa, which prohibit women from inheriting land. These customary laws, deeply rooted in traditional practices, ensure that land is passed down through male lineage, effectively excluding women from land ownership. Consequently, women lack independent access to land titles and can only utilize the land owned by their husbands or male relatives [72]. However, she may have the right to use over fields belonging to her husband's family or lineage for her agricultural activities [73].

Table 1. The characteristics of the respondents.

Variables	Measures	Percentage
Gender	Men	95%
	Women	5%
Age of interviewed farmers	from 18 to 35 years old	5%
	from 36 to 60 years old	66%
	More than 60 years old	29%
Functionality of the RWHP	Functional	27%
	To be repaired	44%
	Abandoned	29%
Owner of the farm	Yes	100%
	No	0%

3.2. Inferential Statistics

The objective of the inferential statistical analysis is to ascertain the opinions of the owners of RWHP regarding four types of liners utilized in Burkina Faso: bitumen, clay, geomembrane, and concrete.

Q1: What is the main problem you have found with the liner you have adopted?

- Shapiro–Wilk normality test for Q2 variables

Shapiro–Wilk's test Hypothesis: (See H1)

The Shapiro–Wilk normality test was employed to assess whether a variable follows a normal distribution. This test was conducted both globally and by strata, with the results presented in Table 2. The *p*-values for all variables (AR1_1, AR1_2, AR1_3, AR1_4, and AR1_5) exceed 0.05. Therefore, the null hypothesis (h_0) is accepted for all variables and

suggests that the data conform to a normal distribution. As the normality tests were conclusive, the ANOVA can be applied [74].

Table 2. Shapiro–Wilk normality test for Q1variables results.

Variables/Anticipated Responses	Code	*p*-Value			
		Stratum 1	Stratum 2	Stratum 3	Overall
Wall gullies/or slumping	AR1_1	0.286	0.887	0.572	0.3715
Erosion of pond inlet:	AR1_2	0.324	0.466	0.188	0.07181
High permeability:	AR1_3	0.0527	0.240	0.0791	0.05781
Filling problem:	AR1_4	0.446	0.613	0.207	0.09566
Cracks:	AR1_5	0.738	0.300	0.580	0.06779
-	Decision at 5% threshold	Normally distributed into stratum 1	Normally distributed into stratum 2	Normally distributed into stratum 3	Normally distributed.

To apply the ANOVA test, the heterogeneity of variances between the strata (1, 2, and 3) was assessed using Bartlett's test at a 5% significance level. In fact, performing Bartlett's test prior to conducting an ANOVA is essential for validating the results of the ANOVA. Bartlett's test evaluates whether the variances across the groups being compared are homogeneous. ANOVA relies on the assumption that the variances of the populations from which the samples are drawn are equal. If this assumption is not met, the ANOVA results may be inaccurate, potentially leading to erroneous conclusions [75].

- Bartlett's test and ANOVA for Q1 variables

  Bartlett's hypothesis (see H2)/ANOVA test hypothesis (See H3)

The *p*-values of Bartlett's test shown above clearly indicate that the variances of the five variables tested are homogeneous. This conclusion of homogeneity allows us to proceed to the ANOVA test, the results of which are presented in the same Table 3. The null hypothesis h_0 is accepted. This assumes that the means of the strata are equal for AR1_1, AR1_2, AR1_3, AR1_4, and AR1_5. The ANOVA test reveals that there is no difference between the strata for all the variables. The following tests are carried out independently of strata.

Table 3. Bartlett's test and ANOVA for Q1 variables summary.

Variables	Bartlett's Homoscedasticity Test			ANOVA Test		
	K-Squared	*p*-Value	df	F Value	Pr (>F)	df
AR1_1	1.5336	0.4645	2	0.619	0.539	2
AR1_2	1.2209	0.5431	2	0.62	0.528	2
AR1_3	0.58195	0.7475	2	0.409	0.664	2
AR1_4	0.13891	0.9329	2	0.57	0.566	2
AR1_5	2.1342	0.344	2	0.448	0.618	2
Decision at 5% threshold	The variances are not significantly heterogeneous across the strata.			The variances do not differ significantly across the strata		

Figure 6, presented in the form of a box plot [68], indicates that the median value of AR1_3 exceeds 14/20. The box plot of AR1_1 show that this variable has a median value greater than 10/20, and the 75th percentiles of AR1_2, AR1_4, and AR1_5 are also noteworthy.

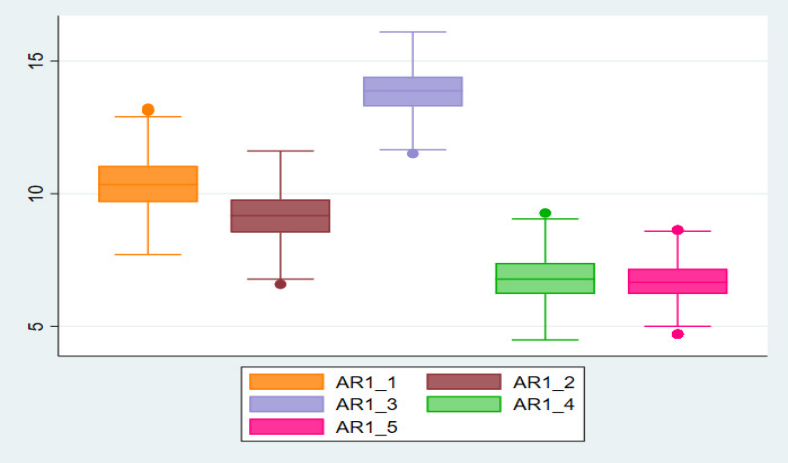

Figure 6. Box plot of Q1 variables.

Based on the test results, it can be concluded that AR1_3, representing 'high permeability,' is the most significant issue for farmers utilizing supplemental irrigation with RWHP, with a median score of 14. This is followed by AR1_1, which pertains to 'wall erosion and/or slumping.' Conversely, problems related to 'filling' and 'cracking' are among the least frequently encountered, as their median scores are approximately 7.

Q2: What do you think is the most effective solution to the problems you have experienced?

- Shapiro–Wilk normality test for Q2 variables

Shapiro–Wilk's test hypothesis: (See H1)

The normality tests performed demonstrate normal distribution in every stratum (Table 4). Bartlett's test is used to assess the homogeneity of variances for all variables before conducting the ANOVA test.

Table 4. Shapiro–Wilk normality test for Q2 variables results.

Variables	Code	*p*-Value			
		Stratum 1	Stratum 2	Stratum 3	Overall
Maintenance work:	AR2_1	0.683	0.400	0.0157	0.1632
Mixed waterproofing solution:	AR2_2	0.172	0.92	0.907	0.05835
Change of geomembrane:	AR2_3	0.404	0.302	0.05977	0.05977
Clay or bitumen resurfacing:	AR2_4	0.431	0.356	0.787	0.05679
Replacing the original coating with a more suitable one:	AR2_5	0.612	0.351	0.387	0.1374
	Decision at 5% threshold	Normally distributed into stratum 1	Normally distributed into stratum 2	Normally distributed into stratum 3	Normally distributed.

- Bartlett's test and ANOVA for Q2 variables

Bartlett's hypothesis (see H2)/ANOVA test hypothesis (See H3)

The *p*-values of Bartlett's (Table 5) test, shown above, clearly indicate that the variances of all variables tested are homogeneous. This conclusion of homogeneity allows us to proceed to the ANOVA test, the results of which are presented in the same table. The null hypothesis h_0 is accepted. This assumes that the means of the strata are equal for AR2_1, AR2_2, AR2_3, AR2_4, and AR2_5. The following tests are carried out independently of strata.

Table 5. Bartlett's test and ANOVA for Q2 variables summery.

Variables	Bartlett's Homoscedasticity Test			ANOVA Test		
	K-Squared	*p*-Value	df	F Value	Pr (>F)	df
AR2_1	1.4246	0.4905	2	0.751	0.472	2
AR2_2	0.81096	0.6667	2	1.315	0.269	2
AR2_3	0.7433	0.6896	2	3.904	0.0205	2
AR2_4	3.2966	0.1924	2	0.092	0.912	2
AR2_5	0.12881	0.9376	2	0.506	0.603	2
Decision at 5% threshold	The variances are not significantly heterogeneous across the strata.			The variances do not differ significantly across the strata		

Figure 7, shown in a box plot form, reveals that the median of AR1_2_2 is greater than 13.5/20 and the 75th quantiles of AR1_2_1, AR1_2_3, and AR1_2_5. AR1_2_5 has a median greater than 11.5/20. To know if there is an association between the problems experienced by farmers (Q1) and the solutions they propose (Q2), a principal component analysis (PCA) was carried out.

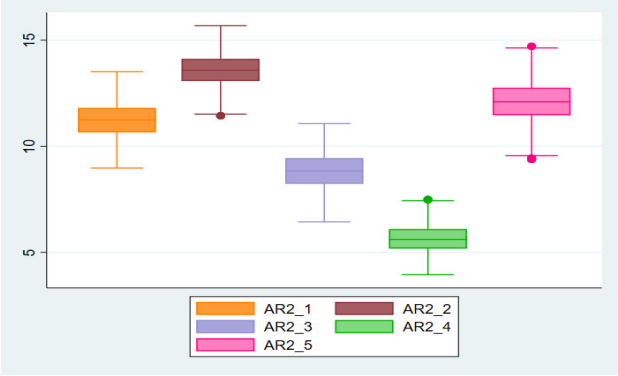

Figure 7. Box plot of Q2 variables.

Figure 8 illustrates the relationship between the challenges faced by farmers and the solutions they have proposed. The analysis shows that AR1_1, AR1_2, and AR2_1 positively influence the formation of axis 2 but negatively affect axis 1 [76]. Conversely, AR2_3 and AR2_5 positively contribute to both axes 1 and 2. However, AR2_3 and AR2_5 also have a positive impact on axis 1 and a negative impact on axis 2. Additionally, AR1_3, AR1_4, and AR2_2 negatively influence both axes 1 and 2.

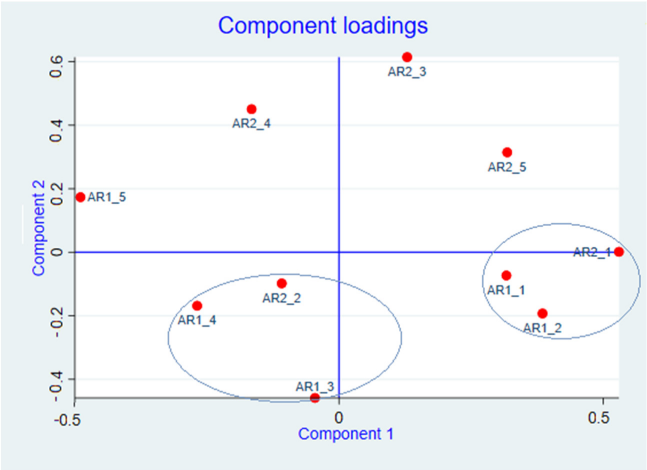

Figure 8. Principal component analysis between Q1 and Q2 variables.

This graph highlights the close relationship between certain problems and their corresponding solutions. For instance, AR1_1, AR1_2, and AR2_1 are closely linked, as are AR1_3, AR1_4, and AR2_2. These insights from the principal component analysis (PCA) can help farmers make more informed decisions by understanding which solutions are most closely associated with specific problems.

Q3: What materials do you find to be the most effective for waterproofing your huts and storehouse?

- Shapiro–Wilk normality test for Q3 variables

Shapiro–Wilk's test hypothesis: (See H1)

Normality tests performed within each stratum show that all variables exhibit a normal distribution (Table 6). Bartlett's test is used to assess the homogeneity of variances for the variables before conducting the ANOVA test.

Table 6. Shapiro–Wilk normality test for Q3 variables results.

Variables	Code	*p*-Value			
		Stratum 1	Stratum 2	Stratum 3	Overall
Clay + used oil:	AR3_1	0.0657	0.203	0.744	0.1144
Banco lump +with straw:	AR3_2	0.238	0.0805	0.316	0.1097
Clay + bitumen:	AR3_3	0.370	0.385	0.109	0.0603
Raw clay + water + cow dung:	AR3_4	0.00394	0.586	0.216	0.05699
Red clay + black clay + cow dung + ash + water:	AR3_5	0.481	0.650	0.190	0.07433
-	Decision at 5% threshold	Normally distributed into stratum 1	Normally distributed into stratum 2	Normally distributed into stratum 3	Normally distributed.

- Bartlett's test and ANOVA for Q3 variables

Bartlett's hypothesis (see H2)/ANOVA test hypothesis (See H3)

The *p*-values of Bartlett's test, shown above, clearly indicate that the variances of all the variables tested are homogeneous (Table 7). This conclusion of homogeneity allows us to proceed to the ANOVA test, the results of which are presented in the same table. As the null hypothesis h_0 is accepted for the five variables tested, there is no significant difference between the strata. In conclusion, the data can be processed for all Q3 variables without considering strata.

Table 7. Bartlett's test and ANOVA for Q3 variables summary.

Variables	Bartlett's Homoscedasticity Test			ANOVA Test		
	K-Squarted	*p*-Value	df	F Value	Pr (>F)	df
AR3_1	0.64007	0.7261	2	0.621	0.538	2
AR3_2	1.803	0.406	2	5.139	0.00602	2
AR3_3	0.87264	0.6464	2	0.523	0.593	2
AR3_4	1.0603	0.5885	2	1.184	0.306	2
AR3_5	1.5934	0.4508	2	0.887	0.412	2
Decision at 5% threshold	The variances are not significantly heterogeneous across the strata.			The variances do not differ significantly across the strata		

Figure 9, shown in a box plot form, reveals that the highest medians are 10.5/20. On the graph, AR3_1 has the best scores with minima and maxima of 8 and 13.5, respectively.

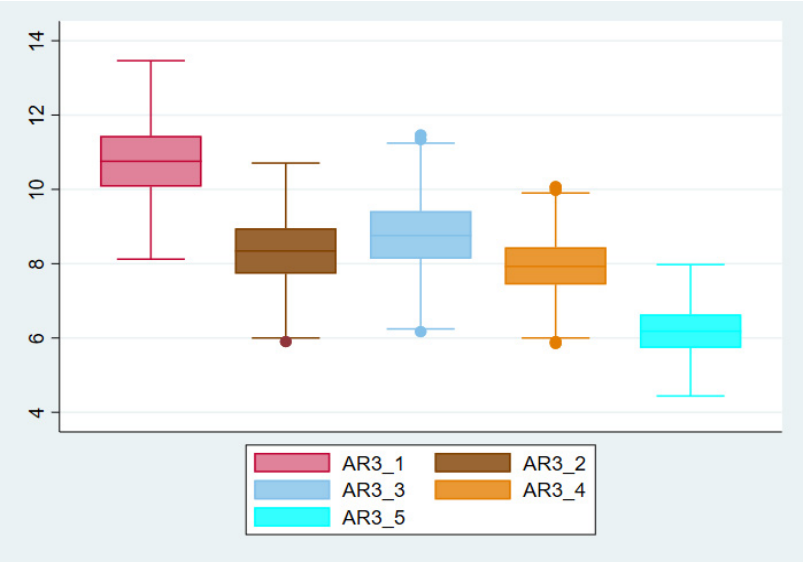

Figure 9. Box Plot of Q3 Variables.

Q4: Where do you think the most effective clay for waterproofing infrastructures (boulis, RWHP. . .) comes from?

- Shapiro–Wilk normality test for Q4 variables

Shapiro–Wilk's test hypothesis: (See H1)

Normality tests performed within each stratum show that all variables exhibit a normal distribution (Table 8). Bartlett's test is used to assess the homogeneity of variances for the variables before conducting the ANOVA test.

Table 8. Shapiro–Wilk normality test for Q4 variables results.

Variables	Code	*p*-Value			
		Stratum 1	Stratum 2	Stratum 3	Overall
Lowlands	AR4_1	0.151	0.419	0.706	0.06531
Termite mounds	AR4_2	0.565	0.315	0.071	0.1193
Stream banks	AR4_3	0.881	0.192	0.248	0.05382
Deep soils	AR4_4	0.468	0.667	0.257	0.1046
	Decision at 5% threshold	Normally distributed into stratum 1	Normally distributed into stratum 2	Normally distributed into stratum 3	Normally distributed.

- Bartlett's test and ANOVA for Q4 variables

Bartlett's hypothesis (see H2)/ANOVA test hypothesis (See H3)

The *p*-values of Bartlett's (Table 9) test, shown above, clearly indicate that the variances of the four variables tested are homogeneous. This conclusion of homogeneity allows us to proceed to the ANOVA test, the results of which are presented in the same table. The null hypothesis h_0 is accepted.

Table 9. Bartlett's test and ANOVA for Q4 variables summary.

Variables	Bartlett's Homoscedasticity Test			ANOVA Test		
	K-Squared	*p*-Value	df	F Value	Pr (>F)	df
AR4_1	3.0454	0.2181	2	1.386	0.251	2
AR4_2	2.8822	0.2367	2	1.63	0.197	2
AR4_3	1.7499	0.4169	2	0.26	0.771	2
AR4_4	0.73059	0.694	2	0.24	0.786	2
Decision at 5% threshold	The variances are not significantly heterogeneous across the strata.			The variances do not differ significantly across the strata		

This assumes that the means of the strata are equal for AR4_1, AR4_2, AR4_3, and AR4_4. In conclusion, the data can be processed for all Q4 variables without considering strata.

The medians presented in Figure 10 do not exceed 10/20. In this graph, AR4_1 and AR4_2 exhibit the highest scores, with minimum and maximum values of approximately 7/20 and 13/20, respectively.

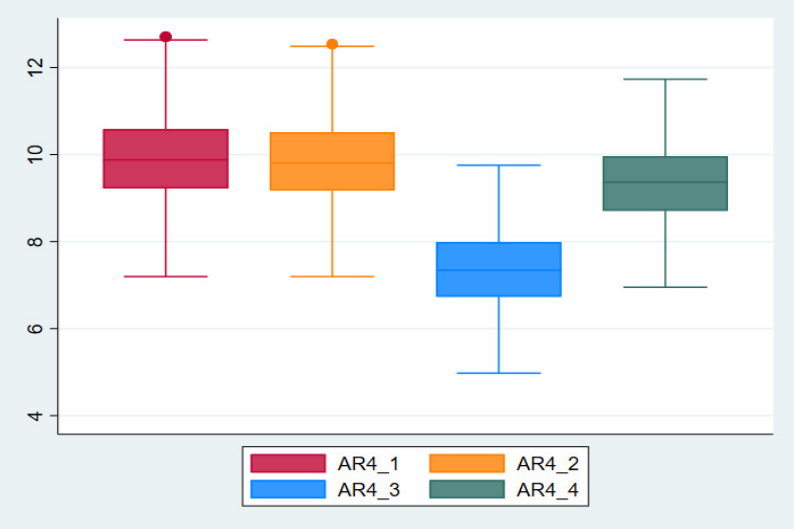

Figure 10. Box plot of Q4 variables.

To determine whether there is an association between the local techniques employed by farmers (Q3) and the origin of the clay use (Q4), a principal component analysis (PCA) was conducted.

Figure 11 shows the principal component analysis (PCA) [77] of clay origin (Q4) and the local solutions (Q3) proposed by farmers. The analysis reveals that AR3_3 and AR4_3 positively influence axis 2 but negatively affect axis 1. On the other hand, AR3_1, AR3_2, AR4_1, and AR4_4 positively contribute to both axes 1 and 2. In contrast, AR3_4, AR3_5, and AR4_2 positively impact axis 1 but negatively affect axis 2.

This graph also highlights the close relationship between certain local solutions and specific types of clay used. The variables form groups based on their proximity. For example, if a farmer rates one variable highly, they are likely to rate another variable within the same group similarly. This is particularly evident for the pairs AR3_4 and AR4_2, as well as AR3_1, AR3_2, and AR4_4.

Q5: What do you know about bitumen?

Q6: What do you know about geomembrane?

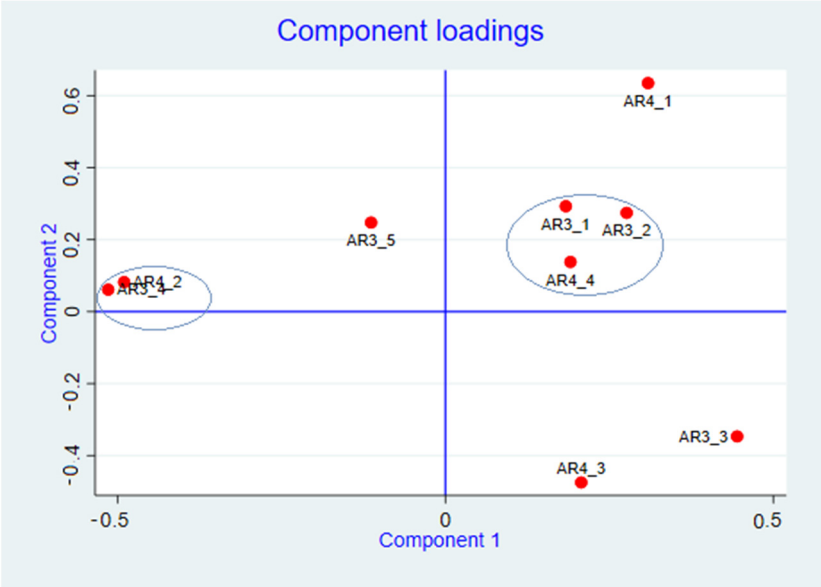

Figure 11. Principal component analysis of local solution combinations (Q3) proposed by farmers and the clay origin (Q4).

- Shapiro–Wilk normality test for Q5 and Q6 variables

Shapiro–Wilk's test hypothesis (See H1)

As the normality tests were conclusive for all the variables of Q5 and Q6 (Table 10), the ANOVA can be applied. Bartlett's test is used to assess the homogeneity of variances for all variables before conducting the ANOVA test.

Table 10. Shapiro–Wilk normality test for Q5 and Q6 variables results.

Variables	Code	*p*-Value			
		Stratum 1	Stratum 2	Stratum 3	Overall
I have seen it before:	AR5_1	0.164	0.127	0.416	0.0697
I know how to install it:	AR5_2	0.0569	0.652	0.163	0.0569
I know a sales outlet here in the village:	AR5_3	0.311	0.271	0.578	0.09771
It is too expensive:	AR5_4	0.092	0.434	0.300	0.09909
I have seen it before:	AR6_1	0.323	0.431	0.494	0.1004
I know how to install it:	AR6_2	0.425	0.287	0.111	0.1013
I know a sales outlet here in the village:	AR6_3	0.365	0.418	0.183	0.1348
It is too expensive:	AR6_4	0.06408	0.0006358	0.002482	0.1797
-	Decision at 5% threshold	Normally distributed into stratum 1	Normally distributed into stratum 2	Normally distributed into stratum 3	Normally distributed.

As h_0 is accepted for all variables tested (Table 11), there is no significant difference between the strata [78]. In conclusion, the data can be processed for all Q5 and Q6 variables without considering strata.

Figure 12 compares the scores of anticipated responses between bitumen and geomembrane using a box plot. The comparison reveals that the median scores of AR5_1, AR5_2, and AR5_3 are significantly less than those of AR6_1, AR6_2, and AR6_3, respectively. Conversely, only the median of AR5_4 is greater than AR6_4.

Table 11. Bartlett's test and ANOVA for Q5 and Q6 variables summary.

TESTS	Codes / Parameters	AR5_1	AR5_2	AR5_3	AR5_4	AR6_1	AR6_2	AR6_3	AR6_4
Bartlett's test	df	2	2	2	2	2	2	2	2
	p-value	0.4611	0.8063	0.3771	0.08552	0.6023	0.5407	0.9669	0.168
	Decision at 5% threshold	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted
ANOVA test	df	2	2	2	2	2	2	2	2
	p-value	0.383	2.319	0.833	0.607	0.282	0.002	0.424	2.505
	Decision at 5% threshold	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted	h_0 accepted

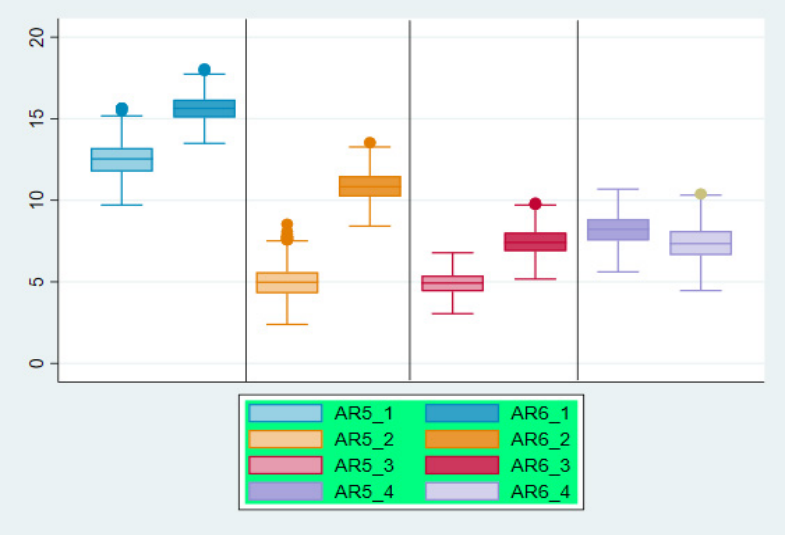

Figure 12. Box plot of variables Q5 and Q6 for comparison between bitumen and geomembrane.

Q7: Which liner do you consider the most effective for waterproofing RWHP?

- Shapiro–Wilk normality test for Q7 variables

Shapiro–Wilk's test hypothesis (See H1)

Normality tests performed within each stratum show that all variables of Q7 exhibit a normal distribution in every stratum (Table 12). Bartlett' test is used to assess the homogeneity of variances for the variables before conducting the ANOVA test.

Table 12. Shapiro–Wilk normality test for Q7 variables results.

Variables	Codes	*p*-Value			
		Stratum 1	Stratum 2	Stratum 3	Overall
Geomembrane	AR7_1	0.363	0.205	0.865	0.06404
Bitumen	AR7_2	0.558	0.073	0.0125	0.1282
Masonry/Concrete	AR7_3	0.593	0.104	0.559	0.05763
Clay	AR7_4	0.167	0.906	0.119	0.06368
-	Decision at 5% threshold	Normally distributed into stratum 1	Normally distributed into stratum 2	Normally distributed into stratum 3	Normally distributed.

- Bartlett's test and ANOVA for Q7 variables

Bartlett's hypothesis (see H2)

ANOVA test hypothesis (See H3)

The *p*-values of Bartlett's test, shown above, clearly indicate that the variance of the variable is homogeneous [79]. This conclusion of homogeneity allows us to proceed to the ANOVA test, the results of which are presented in the same Table 13. The null hypothesis h_0 is accepted. This assumes that the means of the strata are equal for all variables. The data can be processed for variable AR7_1, AR7_2, AR7_3 and AR7_4 without considering strata.

Table 13. Bartlett's test and ANOVA for Q7 variables summary.

Variables	Bartlett's Homoscedasticity Test			ANOVA Test		
	K-Squared	*p*-Value	df	F Value	Pr (>F)	df
AR7_1	1. 8386	0.3988	2	0.864	0.422	2
AR7_2	1.1807	0.5541	2	1.322	0.267	2
AR7_3	3.2225	0.1996	2	0.026	0.974	2
AR7_4	1.4707	0.4793	2	0.071	0.931	2
Decision at 5% threshold	The variances are not significantly heterogeneous across the strata.			The variances do not differ significantly across the strata		

Figure 13 shows that in all strata, the best scores are attributed to AR7_3 with an average score of 16/20, succeeded by AR7_1 with a median of around 10/20.

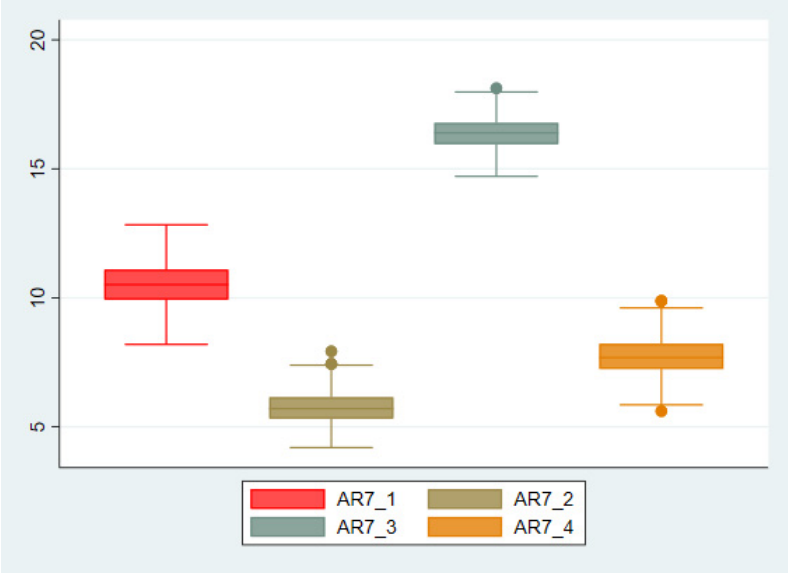

Figure 13. Box plot of Q7 variables for comparison of clay, bitumen, geomembrane, and concrete.

Based on the previous tests, producers prefer AR1_7_3 'Masonry/Masonry slab/Concrete' coating, followed by AR7_1 'geomembrane'.

Q8: What do you estimate to be the optimal price for the completion of 300 cubic meter RWHP coating?

- Shapiro–Wilk normality test for Q8 variables

Shapiro–Wilk's test hypothesis (See H1)

The Shapiro–Wilk normality test was employed to assess whether a variable follows a normal distribution. This test was conducted both globally and by strata, with the results presented in Table 14. The *p*-values for all variables (AR8_1, AR8_2, AR8_3, and AR8_4) exceed 0.05. Therefore, the null hypothesis (h_0) is accepted for all variables and suggests that the data conform to a normal distribution. As the normality tests were conclusive, the ANOVA can be applied.

Table 14. Shapiro–Wilk normality test for Q8 variables results.

Variables	Codes	*p*-Value			
		Stratum 1	Stratum 2	Stratum 3	Overall
0–1000 USD:	AR8_1	0.260	0.261	0.708	0.059
1000–1500 USD:	AR8_2	0.465	0.163	0.429	0.05467
1500–2000 USD:	AR8_3	0.580	0.377	0.804	0.1481
More than 2000 USD:	AR8_4	0.606	0.0501	0.448	0.05935
-	Decision at 5% threshold	Normally distributed into stratum 1	Normally distributed into stratum 2	Normally distributed into stratum 3	Normally distributed.

- Bartlett's test and ANOVA for Q8 variables

Bartlett's hypothesis (see H2)/ANOVA test hypothesis (See H3)

The *p*-values of Bartlett's test, shown above, clearly indicate that the variance of the variable is homogeneous. This conclusion of homogeneity allows us to proceed to the ANOVA test, the results of which are presented in the same Table 15. The null hypothesis h_0 is accepted. This assumes that the means of the strata are equal for all variables. The data can be processed for variable of Q8 without considering strata. The following tests are carried out independently of strata.

Table 15. Bartlett's test and ANOVA for Q8 variables summary.

Variables	Bartlett's Homoscedasticity Test			ANOVA Test		
	K-Squared	*p*-Value	df	F Value	Pr (>F)	df
AR8_1	0.90562	0.6358	2	1.062	0.346	2
AR8_2	1.1162	0.5723	2	0.793	0.453	2
AR8_3	2.2002	0.3328	2	1.294	0.275	2
AR8_4	0.14805	0.9286	2	0.095	0.91	2
Decision at 5% threshold	The variances are not significantly heterogeneous across the strata.			The variances do not differ significantly across the strata		

The medians presented in Figure 14 do not exceed 15/20. In this graph, AR8_4 and AR8_3 exhibit the highest scores, with minimum and maximum values approximately 10/20 and 16/20, respectively.

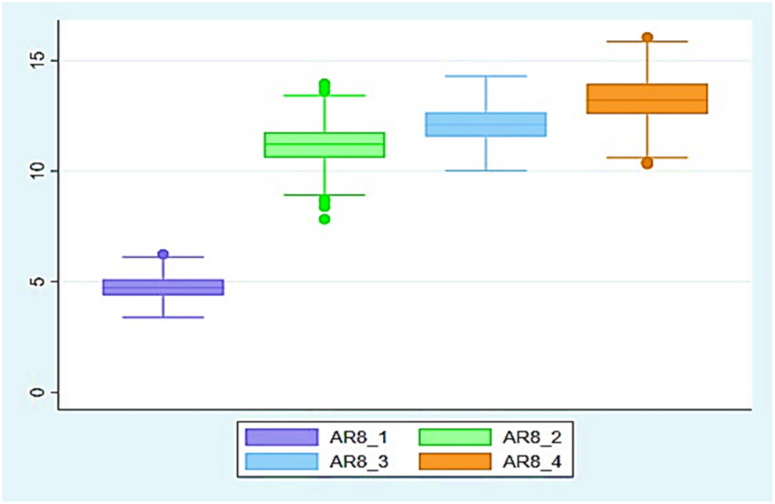

Figure 14. Box plot of Q8 variables for comparison of the liner's prices.

To determine whether there is an association between the sealing techniques employed by farmers (Q7) and the price they suggest (Q8), a principal component analysis (PCA) was conducted.

Figure 15 illustrates the PCA of the sealing solutions (Q7) proposed to farmers and the prices they suggested (Q8). The analysis shows that AR7_1 and AR8_1 positively influence axis 2 but negatively affect axis 1. Conversely, AR7_3 and AR8_3 positively contribute to both axes 1 and 2. In contrast, AR7_2, AR8_2, and AR8_4 positively impact axis 1 but negatively affect axis 2.

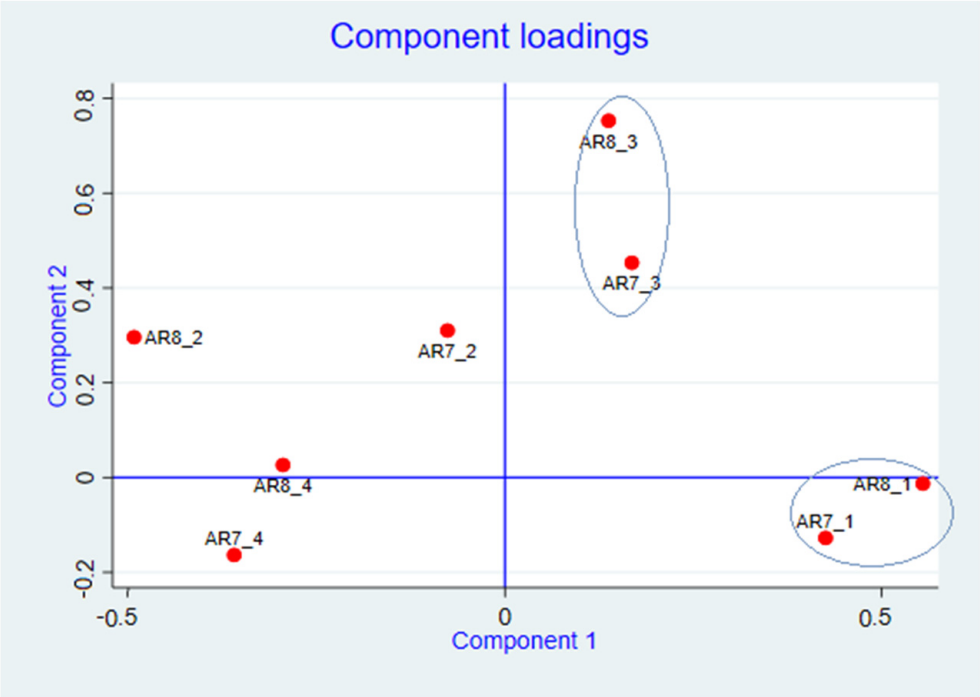

Figure 15. Principal component analysis of sealing solution (Q7) proposed to farmers and the price they suggested (Q8).

This graph also highlights the close relationship between certain sealing solutions and their associated prices. The variables form groups based on their proximity. For example, if a farmer rates one variable highly, they are likely to rate another variable within the same group similarly. This is particularly evident for the pairs AR7_1 and AR8_1, as well as AR7_3 and AR8_3.

4. Discussion

Rainwater harvesting ponds (RWHP) play a crucial role in the areas where the rainfall is insufficient to ensure normal plant growth [80]. The major objective of RWHP is to collect run-off water from remote or unexploited areas, store it [81], and make it available in times of water scarcity.

According to the correlation tests carried out (Tables 2 and 3 and Figure 6), the high permeability of RWHP remains the main problem faced by supplemental irrigation users in Burkina Faso [82]. Several farmers stated that their ponds fill up after the first rains, but all the water seeps into the soil after 3 to 4 days. These results are in line with the work of [83], who state that water loss, particularly in arid areas, is a major problem for optimizing RWHP [84]. A report by [85] also explains that most of the agricultural ponds constructed in Kenya under the government's water harvesting programs have failed to meet the expected water demand due to water loss through seepage. Those losses are primary due to the soil porosity, the water pressure, the saturation, the erosion, and the poor compaction [86].

The farmers argue that facing the high permeability of RWHPs, the best option would be to use mixed sealing solutions (Figure 8). This is a very attractive alternative for producers [87], and it can be seen in Figure 7 where more than 75% of the population gave this solution a score of 14/20. In the studies by [88], it is indicated that 3/4 of the RWHPs in Burkina have a mixed liner (clay and geomembrane, geomembrane and cement, clay and cement).

In addition, gullies and landslides are the second most common problem faced by the farmers. In fact, 50% of the population gave at least a mark of 12/20 to the problems linked to the gullying and crumbling of the RWHP walls (Figure 7). This result is in line with those of [89,90], which showed that controlling gullying and slumping of the walls is a challenge for farmers. Maintenance work is recommended to deal with this problem (Figure 8). It is crucial to understand that sediment buildup in ponds demands considerable additional labor. This ongoing task involves regular and thorough cleaning to prevent excessive silting, which can hinder the ponds' performance and efficiency [91]. The lifetime of a RWHP is estimated at 20 years, assuming proper maintenance [31]. As a result, RWHP beneficiaries are made aware from the outset of projects of the importance of maintenance work for the durability of their structure [92].

Farmers clearly consider maintenance work to be a crucial aspect in guaranteeing the efficacy of the linings. To provide better assistance to producers, questions 3 and 4 focused on the local techniques they use to waterproof their homes or facilities. According to [93], traditional waterproofing techniques are simple in use and economical if materials are locally available. In Burkina Faso rural areas, over 70% of the population is living in traditional earthen construction, and clay is the principal material used in traditional architecture [94,95]. Curiously, Figure 9 shows that the best medians are equal to 10.5/20, which reflects farmers' average confidence in the ability of local clay-based techniques to waterproof structures. This could be explained by the results of [96], who state that traditional waterproofing methods disintegrate easily if weather conditions change, impose an unnecessary deadload, and are almost impossible to dismantle for repairs. Clay mixed with drain oil seems to be the local technique considered by the producers interviewed to be moderately effective for sealing the walls (Figure 9). In addition, the type of clay they use for the combination is lowland clay (Figures 10 and 11), kaolinite [97]. It is important to note that [98] studies recommend the use of bentonite (swelling clay) to waterproof retention ponds.

Furthermore, farmers are more familiar with geomembrane than with bitumen (Tables 10 and 11 and Figure 12). The main advantages of geomembrane are that its thickness is constant and it can be laid by just two people. It offers high insulation, good resistance, and elasticity [99]. Despite its advantages, such as its long service life, the existence of laying standards [100] with known thicknesses and dosages, the fact that it does not require joints, its suitability for rough surfaces, and its easy connection on both vertical and horizontal surfaces [101], bituminous shape is little known for waterproofing RWHPs in Burkina Faso. This could be explained by the fact that during the laying of this surfacing, a large quantity of asphalt fumes containing volatile organic compounds (VOCs) is emitted, causing potential health risks for construction workers [102]. Indeed, epidemiological studies have shown that these gases have a carcinogenic effect in humans, with the lung being the target organ [103,104]. Furthermore, as bitumen is a complex mixture of hydrocarbons and associated metals, relatively high pollution indices for toxic metals (Pb, As and Hg) and total petroleum hydrocarbons (TPH) were detected in the water in contact with this coating [105].

Regarding their preference among the four types of pond coatings proposed, the respondents clearly favored the concrete, with a median score of 16 out of 20, compared to 5.5 out of 20 for asphalt and 7.5 out of 20 for clay (Figure 13). Concrete has four important properties: workability, cohesiveness, strength, and durability [106]. According to [107], waterproofing RWHPs with cement gives a yield of 70% with an estimated lifespan of 20 years. To a lesser extent, adopters choose geomembrane/tarpaulin, which is very effective

but with a short lifespan estimated at 3 years [108]. Clay and bitumen are the last choice for waterproofing RWHPs.

Regarding the cost, respondents are aware that a high-quality coating requires a significant investment. Consequently, the majority confirms that the cost for the optimal coating of a 300 cubic meter pond amounts to approximately 2000 USD (Figure 14). By correlating the cost of coating and the type of liner, which are two closely interdependent parameters, it becomes evident that respondents estimate the expense for constructing the concrete lining to be between USD 1500 and 2000. This estimation aligns with the price studies conducted by [88].

However, for the geomembrane, respondents estimate the cost to be less than USD 1000, which corresponds to the average price for an 80-micron geomembrane. It is important to note that the recommended thickness for lining RWHPs is 750 microns, which exceeds USD 2000. The survey results do not establish any cost estimates for bitumen or clayey linings, likely due to a lack of awareness among the producers.

These findings are consistent with the research conducted by [109], which highlights the cost implications of different pond lining materials. Additionally, the study by [110] provides a comprehensive analysis of the economic feasibility of various pond coatings, further supporting the respondents' cost estimates.

5. Conclusions

This study underscores the farmers' extensive experience with rainwater harvesting ponds (RWHP) over the past decade, highlighting their expertise in construction, usage, and maintenance. The findings reveal that while clay is commonly used in housing, it proves ineffective as a RWHP lining due to practical limitations. Although bitumen is familiar in road construction, it remains largely unrecognized for other applications. Geomembrane is valued for its ability to prevent seepage, but its fragility and the need for frequent replacement limit its long-term viability. Concrete stands out as the preferred material due to its durability and low maintenance requirements, yet its high cost remains a significant barrier, indicating the need for substantial subsidies to facilitate wider adoption. The study emphasizes the importance of balancing material effectiveness with economic feasibility to ensure sustainable agricultural practices. To enhance the sustainability and performance of RWHPs, long-term studies evaluating the performance and maintenance requirements of different materials are essential and will provide critical insights. Additionally, fostering collaboration between the public and private sectors can drive innovation and reduce the cost of high-quality RWHP materials. These actions will support more resilient agricultural practices and promote broader adoption of effective water management solutions.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/resources13100144/s1, Table S1: Collected data.

Author Contributions: Conceptualization, T.V.R.K. and A.K.; methodology, A.K.; software, T.V.R.K.; validation, A.K., A.L.G. and D.N.; formal analysis, T.V.R.K.; investigation, B.B., A.K. and T.V.R.K.; resources, D.N.; data curation, B.B., A.L.G. and T.V.R.K.; writing—original draft preparation, T.V.R.K.; writing—review and editing, A.K. and A.L.G.; visualization, T.V.R.K.; supervision, A.K.; project administration, D.N. and A.L.G.; funding acquisition, D.N. and A.K. All authors have read and agreed to the published version of the manuscript.

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Appendix A. Waso-2 Survey Form

Survey Topic (ST): the ideal RWHP liner/Questionnaire for rainwater harvesting pond owners

Section A—General Information

1. Survey number:
2. Date:
3. Start time:
4. Name of the village:
5. Name of the province:

Simplified respondent consent form
My name is _____ [name of investigator] and I am conducting a survey on behalf of the International Institute for Water and Environmental Engineering (2iE). Our study focuses on the techniques used to seal rainwater harvesting ponds in your province. We aim to understand how these ponds are protected from seepage, the context in which they were obtained or built, the types of liners used, the reasons behind these choices, and the overall durability of the ponds. Your insights are invaluable to us, and we would greatly appreciate your participation in this survey, which will take approximately 30 min. Rest assured, all personal information you provide will remain confidential and anonymous. Participation in this survey is entirely voluntary. You are free to skip any question or stop the survey at any time. While we hope you will share your experiences with us, please note that this survey is purely for academic and scientific purposes. We are not able to offer humanitarian aid, such as donations or financial assistance, based on your participation. Your input will help us better understand the local conditions and improve future research. Whether or not you participate will not affect any potential assistance you may receive in the future. Do you have any questions before we begin?

6. Do you agree to participate in this survey? (if NO, end the survey)

- Yes ☐
- No ☐

7. Would you allow us to record this interview with our dictaphone?

- Yes ☐
- No ☐

Section B: Questions

Survey Topic (ST): THE IDEAL RWHP LINER

Q1: What is the main problem you have found with the liner you have adopted?

Code	Anticipated Responses	Mark Out of 20	Observations
AR1_1	Wall erosion and/or slumping		
AR1_2	Erosion of pond inlet:		
AR1_3	High permeability:		
AR1_4	Filling problem:		
AR1_5	Cracks:		

Q2: What do you think is the most effective solution to the problems you have experienced?

Code	Anticipated Responses	Mark Out of 20	Observations
AR2_1	Maintenance work:		
AR2_2	Mixed waterproofing solution:		
AR2_3	Change in geomembrane:		
AR2_4	Clay or bitumen resurfacing:		
AR2_5	Replacing the original coating with a more suitable one:		

Q3: What materials do you find to be the most effective for waterproofing your huts and storehouse?

Code	Anticipated Responses	Mark Out of 20	Observations
AR3_1	Clay mixed with used oil:		
AR3_2	Banco lump mixed with straw:		
AR3_3	Clay plus bitumen:		
AR3_4	Raw clay + water + cow dung:		
AR3_5	Red clay + black clay + cow dung + ash + water:		

Q4: Where do you think the most effective clay for waterproofing infrastructures (boulis, RWHP) comes from?

Code	Anticipated Responses	Mark Out of 20	Observations
AR4_1	Lowlands:		
AR4_2	Termite mounds:		
AR4_3	Stream banks:		
AR4_4	Deep soils (excavations):		

Q5: What do you know about bitumen?

Code	Anticipated Responses	Mark Out of 20	Observations
AR5_1	I have seen it before:		
AR5_2	I know how to install it:		
AR5_3	I know a sales outlet here in the village:		
AR5_4	It is too expensive:		

Q6: What do you know about geomembrane?

Code	Anticipated Responses	Mark Out of 20	Observations
AR6_1	I have seen it before:		
AR6_2	I know how to install it:		
AR6_3	I know a sales outlet here in the village:		
AR6_4	It is too expensive:		

Q7: Which liner do you consider the most effective for waterproofing RWHP?

Code	Anticipated Responses	Mark Out of 20	Observations
AR7_1	Geomembrane/Tarp:		
AR7_2	Bitumen:		
AR7_3	Masonry/Concrete:		
AR7_4	Clay:		

Q8: What do you estimate to be the optimal price for the completion of 300 cubic meter RWHP coating?

Code	Anticipated Responses	Mark Out of 20	Observations
AR8_1	0–1000 USD:		
AR8_2	1000–1500 USD:		
AR8_3	1500–2000 USD:		
AR8_4	More than 2000 USD:		

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