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How to increase cookstove adoption? Exploring cost-effective dissemination techniques in Central Mozambique

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ABSTRACT

The adoption and usage of improved cookstoves have been promoted in the Global South to mitigate the adverse effects of relying on solid biomass for cooking. However, the uptake and continued use of improved cookstoves remain low. Several behavioral changing techniques have been used to increase the adoption of improved cooking stoves. Still, the monetary costs involved in the dissemination process are generally neglected, and few studies follow an experimental design to evaluate the impact of different stove dissemination approaches. Thus, we conducted an experiment to explore the cost-effectiveness of dissemination approaches and measure their effect on improved cookstoves adoption in Central Mozambique. Forty communities were randomly assigned to receive one of the following treatments: (1) individual video training, (2) on-site group training or (3) a combination of both. In total, 620 households we randomly selected from the 40 communities to participate in the study and 510 were included in the final analysis. The rates of adoption within each treatment were 53 % for individual video training, 21 % for on-site group training and 47 % for the combination of both. The monetary training costs were lower for individual video training, which stimulated the early and sustained adoption of improved cook stoves. Our findings provide strong evidence that the tool used for capacity building affects the adoption of improved cookstoves. Extension agencies should be aware of cost-effectiveness and adjust dissemination approaches to achieve the highest impact per unit of resource expenditure.

1. Introduction

The rural areas in Mozambique, like in most other countries in the Global South, primarily depend on biomass energy. Approximately 95 % of the population relies on solid fuels for cooking [1]. This has been associated with deforestation [2], low energy efficiency [3], adverse health and climate impacts [4,5], as well as women's time poverty [6]. In line with these challenges, the United Nations Sustainable Development Goal 7 calls for universal access to affordable, reliable, sustainable, and modern energy by 2030 [7].

It is argued that as opposed to facilitating a transition to conventional forms of energy, such as electricity, coal and gas, which are not accessible to rural communities [8], the use of improved cookstoves (ICS) can enable households to utilise solid biomass more efficiently [9]. Empirical evidence suggests that ICS can substantially reduce fuel use [10] and time for cooking [9], decrease the time for gathering wood [2], and the exposure to indoor air pollution and respiratory diseases [4,11]. However, despite the profound knowledge of ICS's benefits, its adoption and sustained use remains far from expectations [9], even when financial incentives such as lowering the price of stoves are adopted [12,13]. In many rural areas, there is free access to solid fuel such as tree branches or manure; thus, people may prefer to spend their income on other

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priorities [14]. Moreover, individuals who decide to adopt a stove may later discontinue the adoption [15]. Hanna et al. [16] and Pine et al. [17] further suggest that after adoption, the intensity of use of an ICS may vary or decline over time. This undermines the achievement and sustainability of cookstove benefits. Therefore, facilitating the initial adoption of an ICS is a necessary but insufficient condition to achieve sustained usage [18].

Achieving sustained use of ICS may require more than just the distribution of stoves. It may also be necessary to provide technical information on the stove use and comparative advantages of ICS relative to other stoves [19]. Jürisoo et al. [19] suggest the use of behavior change techniques to support and motivate users to develop new cooking habits. Such techniques can include easily comprehensible manuals, educational initiatives, cooking demonstrations, community meetings, tutorials, and marketing or communication campaigns [20–26]. In Mozambique, several governmental and non-governmental agencies have implemented stove intervention programs in many areas using techniques such as marketing campaigns, demonstrations and training of community-based organisations [4,27]. However, a study by Pailman et al. [9] found that 60 % of ICS adopters still used traditional three-stone or unimproved cookstoves. This highlights the need for more effective methods for promoting sustained ICS adoption. In this study, we follow Troncoso et al. [28] and define the adoption of ICS with regard to the frequency of use. As such, we consider adopters, the households using the ICS at least two times per week.

Multiple limitations of existing capacity-building approaches have been identified in the past, requiring highly context-sensitive solutions. In particular, the effectiveness of ICS promotion efforts can be limited by inadequate training approaches, an insufficient focus on opinion leaders, and budget constraints, favouring rather superficial training approaches [29–31]. Despite the vast body of academic literature testing the effectiveness of training approaches, the costs associated with dissemination are rarely considered in the ICS dissemination research. Moreover, there is a shortage of experimental designs to evaluate the impact of ICS interventions [26].

Budget constraints and cost-effectiveness of stove intervention are important variables for selecting the dissemination approach [32]. For example, compared to individual face-to-face approaches, demonstrations to groups are more effective in reaching out to larger populations at a lower cost. Research has shown that group-based approaches can effectively trigger the purchase of ICS [19]. However, the diversity of attendees can mean that not everyone perceives or understands the content equally. Lewis et al. [23] found that individual and personalised demonstrations are more effective in disseminating clean cooking stoves. They require high financial resources but tend to result in higher uptake outcomes [23]. Thus, given the typical budget limits on dissemination programs [33], locally appropriate and cost-effective approaches are still required to achieve maximum impact per unit of resource expenditure.

We argue that the dissemination tool is also essential to enhance the cost-effectiveness of ICS dissemination programs. Word of mouth has been used to trigger ICS adoption [26,34,35], but other studies have suggested and used short documentaries and videos to promote ICS [32,36–38]. The literature in the field of agricultural extension has also shown that a video can cost-effectively reach the widest – even geographically isolated – populations [39,40]. Unlike on-site demonstration, the video does not require the facilitator to have experience with the promoted skills [40,41]. This may, arguably, minimize the costs required to hire highly qualified specialists and organize training activities.

Thus, we conducted an experiment in Gurue district, Central Mozambique, in which household members were trained to construct, use and maintain an ICS. The aim was to stimulate the adoption of ICS and explore the cost-effectiveness of an in-person demonstration for a group and an individual video-based training. With this, we intend to contribute to informed decision-making and investments by policymakers and development stakeholders promoting ICS in Mozambique.

We distinguish between the groups of adopters since strategically targeting the users with the highest adoption potential can improve ICS dissemination [18]. Rogers [42] categorised adopters into five groups based on when they adopt a technology: innovators, early adopters, early majority, late majority, and laggards. Van den Bulte and Joshi [43] further distinguish between independent adopters and imitators. Latter's decision to adopt is influenced by the former, and both categories can be found during the earlier or later stage of the adoption process [43].

Programs aiming to disseminate new technologies must invest in dissemination techniques that encourage early adoption from the highest number of independent adopters since non-adopters can also play a significant role in the adoption process by acting as opponents, thus, preventing others from adopting [44]. In contrast, independent early adopters are more likely to positively influence those within the social network [17], leading to the highest diffusion outcomes.

The present study adds to the emerging literature that includes the cost-effectiveness of stove interventions (see Afridi et al. [32]). Specifically, we demonstrate that the economic perspective should be considered when analyzing ICS adoption and related promotion programmes rather than merely assessing the effectiveness of the training method.

2. Methods

2.1. Study design and sampling approach

The study was based on a participatory action research methodology [45] and followed an experimental approach since it sought to analyse the causal relationship between variables [46]. This approach is also recommended when the aim is to evaluate the impact of energy-related behavior change programs and initiatives [47]. We tested and introduced an ICS between June and December 2020 in two localities, namely Lioma and Mepuagiua, in Gurué district (Fig. 1). The ICS design – based on an ICS implemented in Idifu village, Tanzania [48] – can be constructed using freely available materials. A detailed description of its features can be found in previous work [49]. The two areas were purposely selected, within Gurué district, based on similarities with regard to household socio-economic characteristics and lack of access to clean cooking fuels. All communities belonging to the two selected localities (29 in Lioma and 11 in Mepuagiua) were included in the study. Therefore, 40 communities were randomly assigned to receive either group-based training, individual training or a combination of both. The description of these approaches is presented in the next subsections. In Lioma, we randomly selected ten households in each community and, in Mepuagiua, 30 households participated in the training. Thus, we selected 620 households (290 in Lioma and 330 in Mepuagiua). The difference in the number of households selected in each community was based on the population size of the localities and the average number of residents per community. Lioma has a population of 29,868 inhabitants, and Mepuagiua has 61,227 inhabitants. Although this sample size was determined due to financial and logistical constraints, it is within the minimum acceptable range for a population size of $<$100,000 people within a precision level of $+/-$ 5 % [46,50]. Before the training sessions, meetings with the local villagers were held to understand the status quo with regard to cooking energy needs and jointly agree on the stove design.

Since the training activities involved both the construction (mainly done by men) and usage of the stove (mainly done by women), for each sampled household, both male and female representatives were trained together whenever possible (dual households). Where that was not possible (mainly due to the unavailability of one of the representatives), only a female or male representative was trained from the household (single households). In Lioma, we trained 98 dual households and 192

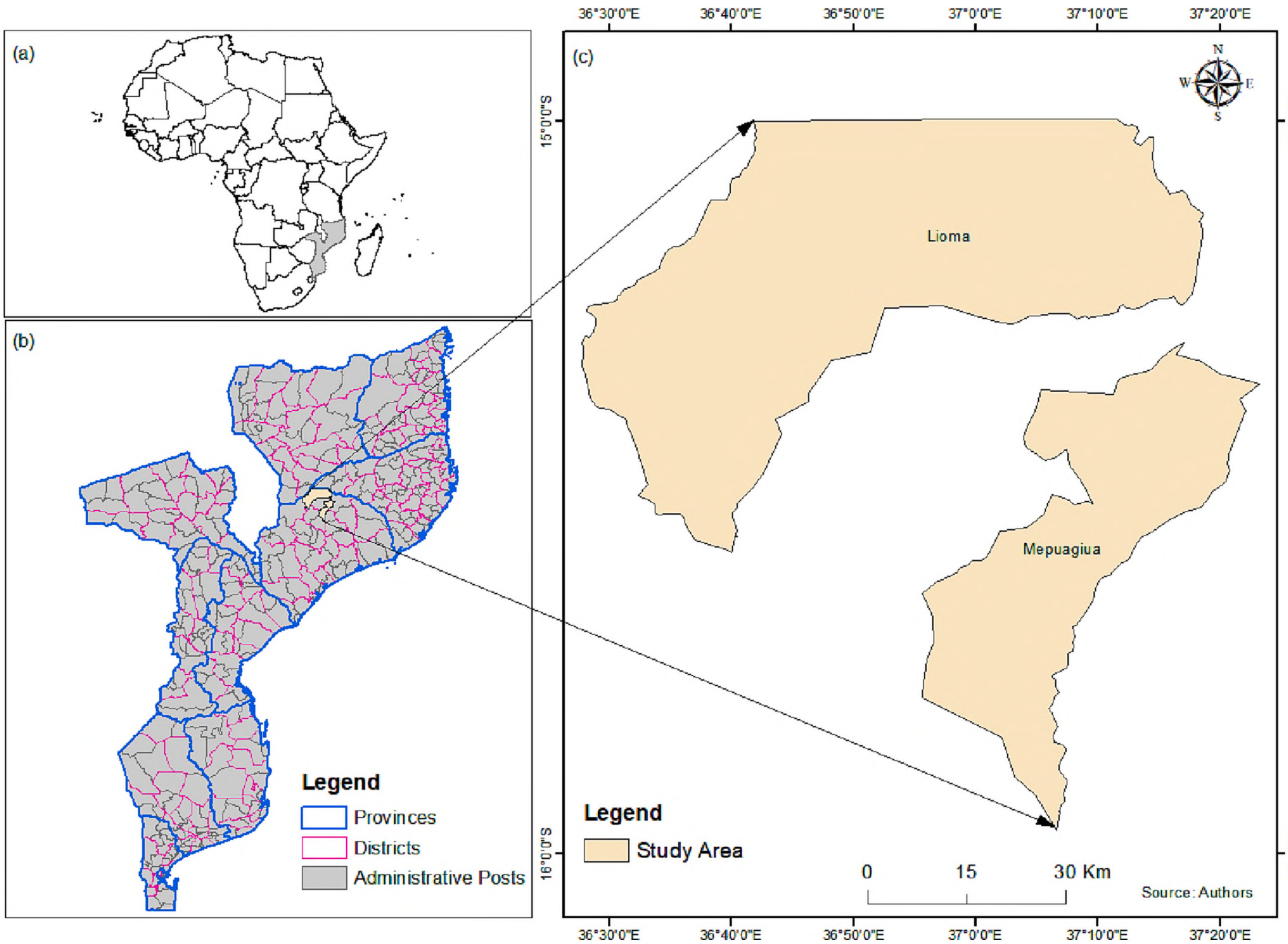

Fig. 1. Study area location. (a): Africa, (b): Mozambique and (c) Study area.

single households. While in Mepuagiua, 149 dual households were trained, and the remaining 181 were single households. From a total of 373 single households, 73 were represented by female residents. Thus, a total of 320 women were trained from both single and dual households, which represents 52 % of the households.

2.1.1. Group training approach

Local farmers were instructed on how to construct, maintain and use the ICS. The training also included information on the advantages of using the ICS. Two hundred and ten heads of selected households attended the workshop in groups of ten people for three days. Two groups were trained per day, and the first day was dedicated to training on theoretical aspects of clean cooking, associated advantages and introduction to the ICS design. The second training section (second day) mainly focused on demonstrations and explanations of constructing the ICS. The third day was dedicated to demonstrations on how to use and maintain the ICS. An experienced trainer conducted training sections, and all explanations were translated into the local language. The training module also involved presentations, group discussions, and exercises. An experienced male trainer performed the demonstrations on construction, and previously trained local female residents hosted the demonstrations on how to use and maintain the ICS. Pamphlets were provided to participants at the end of the training for future reference.

2.1.2. Individual training approach

The individual training consisted of an approximately 10 min video illustration on construction, maintenance and use of ICS. The use of video for this approach was due to the fact that a video is a time-effective tool compared to on-site demonstrations. For instance, it required nearly 4 h to construct the ICS used in the present study. The video was shown to 220 households individually using laptops and android tablets. Local enumerators who have attained at least the 12th grade and with a good comprehension of Portuguese and the local language in the study villages were recruited and trained for at least two days on how to deliver ICS information using the video. The enumerators were instructed to show the video in a quiet place where they were unlikely to be disturbed during the duration of the screening of the videos to maintain optimal concentration. Preferably, the videos were shown in the farmer's home, but there were cases in which the video was shown on the farm. A pre-test was conducted before the video demonstration to ensure that the enumerators followed the instructions shown during the training.

In this video, an example of the ICS during a cooking process with two pots is shown. Subsequently, the trainer introduces himself and explains in Portuguese the advantages of using an ICS, then introduces the materials necessary to construct the ICS, such as clay or anthill soil, sand, sawdust, mud bricks, banana stem, and water. The trainer demonstrates and explains how the sawdust and clay (or anthill soil) are mixed in a volumetric ratio of 1:1 and the addition of water to the mixture to make it mouldable for blending. Next, the trainer explains how to prepare the stove's ground. The location needs to be wet, and the blended mixture of sawdust and clay (or anthill soil) is used to construct a 2 cm high base for the stove. Next, the foundation bricks on the 2 cm high mixture are also laid down. However, if bricks are unavailable, the sawdust-clay mixture should be used. The video continues with demonstrations on how to create the pans' spaces and finish the stove construction. After the stove construction, the trainer explained that the stove takes up to 4 weeks to get completely dry and should be protected from intrusion and unfavourable weather conditions. Subsequently, instructions on how to use and maintain the stove daily were provided. The participant also received pamphlets for future reference.

2.1.3. Combined training approach

The 190 participants selected to receive the combination of training approaches were first exposed to group training. Subsequently, they received a visit to their homes, in which the video was shown as described above.

2.2. Data collection

After the training phase of the ICS, two rounds of face-to-face interviews took place. The households were surveyed to estimate the influence of the training approach, including other factors, on the adoption of ICS. To minimize social desirability bias and validate the reported adoption rates, we explained the confidentiality and anonymity procedures at the beginning of the interview. Whenever possible, observations of the cooking tasks and the stove condition were made [51]. Informed consent was obtained from all individual participants in the study. The first round was conducted during January 2021 (a month after the last training activities), and the follow-up survey was conducted during January–February 2022 (13–14 months after receiving the training). In the first data collection, 277 and 313 trained farmers in Lioma and Mepuagiua agreed to participate in the study. In the follow-up, 80 households (31 in Lioma and 49 in Mepuagiua) were unavailable for the interviews. Thus, the study included 510 observations (246 households in Lioma and 264 in Mepuagiua), of which 40 % were single households with a male representative. It is important to note that most households that did not agree to participate in the data collection phase (83 %) were those represented only by men during the training.

In addition to the training approach, other variables, including those related to the individual participating in the study and the social system or network surrounding the participants, were collected (Table 1 and Fig. 2). These variables were based on previously published work on factors influencing the adoption or rejection of ICS (e.g. Mamuye et al. [52] and Jagger and Jumbe [25]). Age was already found relevant for technology adoption [49] since youth are more enthusiastic about experimenting with new things and technologies. Education levels influence knowledge about ICSs and clean fuels [53]. Social interactions with adopters may stimulate adoption through stronger peer spill-over [54]. Households where women are the decision-makers are expected to be more likely to adopt ICS [55]. The household size can positively influence adoption since more cooking wood is expected to be consumed in larger households. Therefore, the fuel efficiency associated with the use of ICS might stimulate adoption [17]. Previous experience may influence the perception of the potential adopters with regard to the benefits of using ICS. In addition, the geographical location was recorded to understand whether the households residing in Lioma are more likely to adopt ICS than those in Mepuagiua since household location is an important determinant of adoption [56].

We obtained data on the costs associated with stove construction material, ingredients for the cooking demonstrations, and the trainers' visit to the farmers, including salary, food and transportation costs. The total costs for the group training included the trainer's salary and expenses for food (coffee and lunch breaks), construction materials, food ingredients (for cooking demonstrations) and transportation. The individual training had an additional cost for the video making; however, costs associated with the construction materials, ingredients and food for the participants were eliminated. This data was used to derive the cost per farmer for a specific training approach, estimated by dividing the total costs associated with the preparation and implementation of training by the total number of participants. Furthermore, the relative cost per adopter was calculated by dividing the total cost by the number of participants who adopted the ICS.

Table 1
Individual characteristics of the households (continuous variables).

Variable	Mean	SD	Min	Max
Age (Years)	42.90	13.03	19	69
Years of education	5.07	2.85	0	16
Monthly income (MZN)	5075.93	3955.65	1000	43,224
Size of the household	6.48	2.60	1	15

2.3. Data analysis

We cross-tabulated the number of adopters by each adoption category to provide summaries of the adoption rate. Four categories of adopters were created: non-adopters, sustained adopters, late adopters, and discontinued adopters. Non-adopters were defined as households that did not have an ICS in both rounds of data collection. Sustained adopters were defined as early adopters who continued to use the ICS until the end of the follow-up survey period. Late adopters were households that did not build the ICS immediately after the training but used it during the follow-up period. Discontinued adopters were defined as early adopters (those who adopted immediately after the training) who were not using or did not have the ICS during the follow-up period (12 to 13 months after the first data collection). It is noteworthy that ICS stove programs usually fail to completely replace the traditional three-stone fire stove due to a variety of reasons, including the additional effort necessary for ICS maintenance, the mismatch between the technical features and real-world behavior of users and stove interference in local cooking habits [16,57]. Thus, in this study, households were not required to completely replace the three-stone fire stove to be considered ICS adopters. However, only the households who used the ICS at least 2 to 3 times a week to prepare their meals were classified as adopters. These are classified as medium adopters according to the categories proposed by Troncoso et al. [28]. A chi-square test of independence was applied to detect the relationship between the type of ICS adopters and the training approach.

Furthermore, a random effects probit model was applied to examine further the relationships between the adoption of ICS and the training approach while controlling for geographic location, individual and social network characteristics. Probit is a useful model for analyzing panel data in which the dependent variable is a participant's binary choice, and the independent variable is randomly assigned by the experimenter [58]. One of the assumptions of this model is the existence of an unobserved latent variable [59] that can be represented as:

$$Y^{*}_{i,t} = \alpha + \beta X_{i,t} + \varepsilon_{i,t} + u_i \tag{1}$$

Where $Y^{*}_{i,t}$ is the latent variable, $X_{i,t}$ is the vector of independent variables (see Table 1 and Fig. 2), β is the vector of coefficients, $\varepsilon_{i,t}$ and u_i are the idiosyncratic and individual-specific error terms, respectively. The observed binary dependent variable occurs when $Y^{*}_{i,t}$ exceeds a given threshold [60] and can be expressed as:

$$Y_{i,t} = \begin{cases} 1 \; if \; Y^{*}_{i,t} \geq 0 \\ 0 \; if \; Y^{*}_{i,t} < 0 \end{cases} \tag{2}$$

Our interest is to estimate the probability that a randomly chosen individual from the population adopts an ICS conditional on training approach while controlling for the effects of geographic location and individual and social network characteristics. Group training was used as the base (or reference) category. We compared the effect of receiving individual training and the combination with group training. We estimated the marginal effects of receiving a specific training approach on the probability of adopting ICS. The random effect probit prediction of

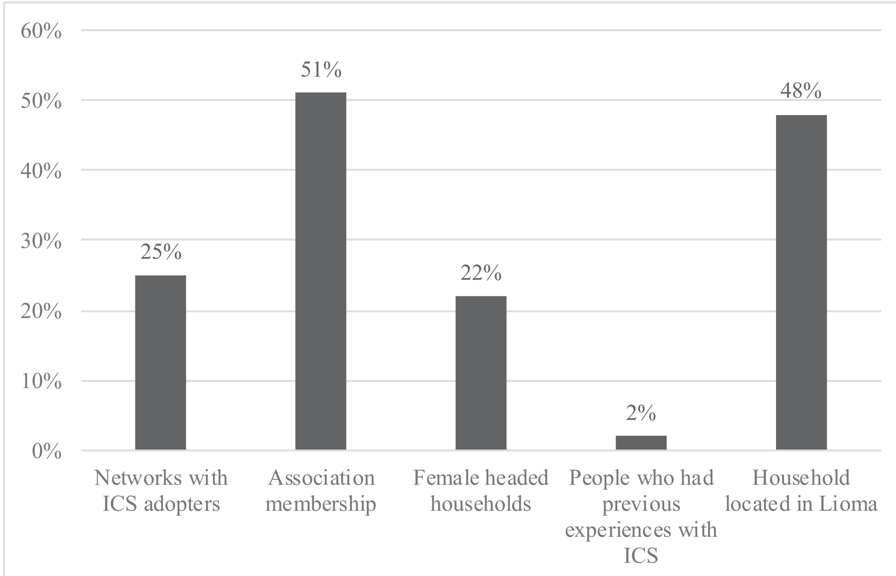

Fig. 2. Individual characteristics of the households (categorical variables).

this probability is:

$$Pr\left[Y_{i,t} = 1 | X_{i,t}\right] = \Phi\left(\frac{\alpha + \beta X_{i,t}}{\sqrt{1+\sigma_u^2}}\right) \quad (3)$$

Where Φ is the standard normal cumulative density function [58]. $Y_{i,t}$ is the dependent variable that equals 1 if the household adopted the ICS and 0 otherwise. Note that this variable is equal to 0 and 1 for non-adopters and sustained adopters, respectively, regardless of the data collection period. However, for late adopters, it equals 0 in the first data collection and 1 in the second. In contrast, for discontinued adopters, it equals 1 in the first data collection and 0 in the second.

3. Results

3.1. Adoption rates

Fig. 3 shows that the training method has a strong influence on adoption as well as on whether farmers sustained the usage of ICS. The chi-square test of independence shows an association between the type of adopters and the training approach (Pearson chi-square = 71.0080, *p*-value < 0.01). The overall adoption rate during the follow-up survey

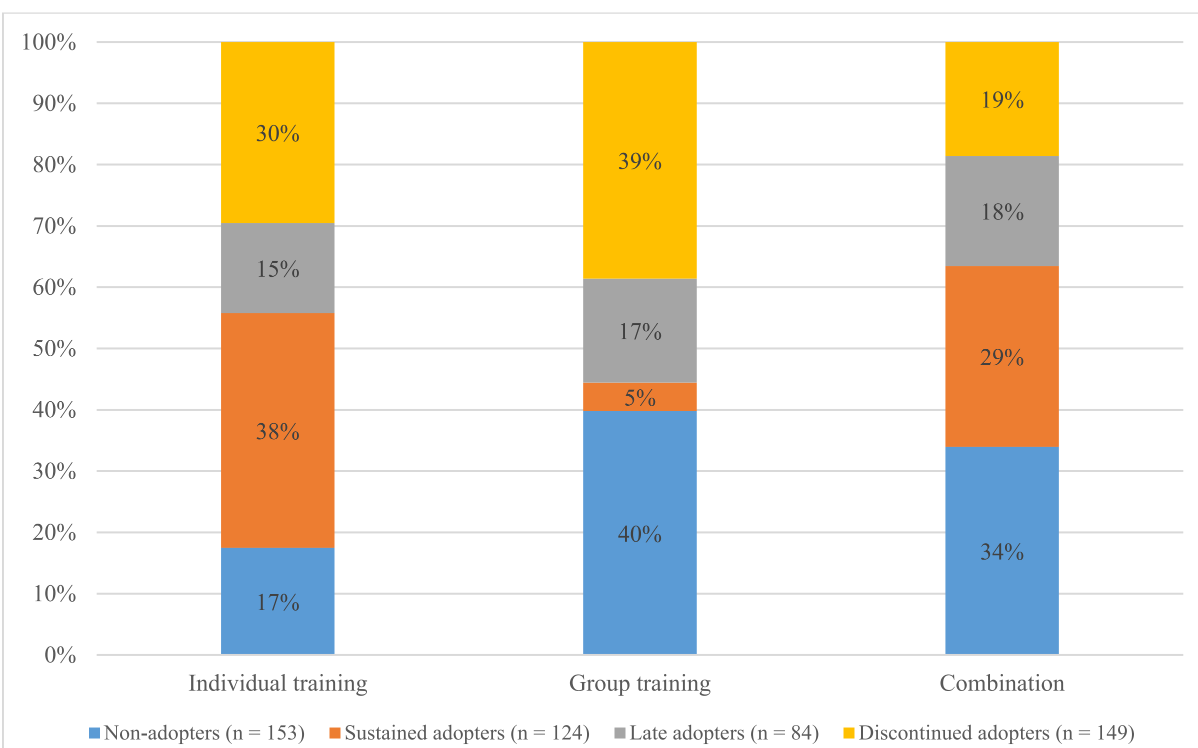

Fig. 3. Adoption rates of ICS.

was nearly 41 %. Generally, the highest rate of early adoption (discontinued and sustained adoption) was observed among those who received individual training and the lowest among group training. However, part of the household who adopted the ICS immediately following the individual and group training discontinued the use within 12 to 13 months of adoption. The level of discontinued adoption was relatively lower among the combination group. About 30 % of the total sampled households never adopted the ICS. Notably, the proportion of late adopters is almost the same for all approaches, which was confirmed by the chi-square independence test, which did not show significant differences (p-value > 0.05). This fosters the hypothesis that the training approach and does not influence the adoption rates in the long run.

3.2. Effect of the training method on adoption

The probit regression model (Table 2) shows that after controlling for geographic location and individual and social network characteristics, the farmers trained by the individual approach are predicted to be more likely to adopt the ICS than those who received group training (on-site demonstrations). Compared to group training, combining both approaches also increases the probability of adoption. The marginal effects suggest that individual training increases the likelihood of adoption by 20 % compared to group training (Table 3). The likelihood of adopting ICS increases by nearly 14 % when the farmer receives the combination of individual and group training approaches. Household individual characteristics that play a role in the adoption process are the household head's age, the household's size and location, and whether the farmer belongs to a network with adopters. Age is negatively related to adoption, whereas the household size, location and having relatives, friends or neighbours who have adopted the ICS increases the likelihood of being an adopter.

3.3. Costs estimation

The cost per participant was estimated at 1047.6 MZN for the group training (1 USD = 63.8776 MZN), 625.0 MZN for individual training and 1757.9 MZN for the combination of both approaches (Table 4). The highest cost for all training approaches was the salary of the trainers. Individual training had the lowest cost, while the combination of approaches had the highest cost for salary. The highest total costs were observed in the combination of the two approaches. The cost per adopter also indicated that individual group training is the most cost-effective. In the group training, each adopter (including both sustained and late adopters) costs 5945.95 MZN (approximately 93 USD) on average, while in the individual training approach, the cost per adopter is 1417.53 MZN (approximately 22 USD).

Table 2
Random effect probit estimates of ICS adoption.

Variables	Coefficients	Standard errors	p-Values
Training method			
Individual	0.595053	0.110587	<0.001
Combination	0.413444	0.114955	<0.001
Household characteristics			
Gender	−0.14574	0.114264	0.202
Age	−0.05521	0.007813	<0.001
Years of education	−0.01582	0.014929	0.289
Previous experiences with ICS	0.250719	0.286366	0.381
Monthly income	4.15E-09	1.76E-05	1.000
Size of the household	0.052344	0.016938	0.002
Networks with adopters	0.67681	0.099549	<0.001
Association membership	0.061947	0.144268	0.668
Household location	1.012329	0.205212	<0.001
Constant (α)	1.106116	0.405616	0.006
$\ln(\sigma_u^2)$	−13.8511	19.10011	
σ_u	0.000982	0.009382	
rho (ρ)	9.65E-07	1.84E-05	

Number of obs = 1020 Number of groups = 510. Wald chi-square = 184.68, Prob > chi2 = 0.0000.

Table 3
Marginal effect of the training approach on the probability of ICS adoption.

Training method	Marginal effect	Standard errors
Individual	0.202019***	0.037128
Combination	0.139545***	0.038436

***, **, * Significant at 1 %, 5 %, 10 %, respectively.

4. Discussion

This study shows that the approach used to deliver information can affect the adoption of clean cooking technology. We used two face-to-face approaches to inform local farmers about the benefits of adopting an ICS and instruct them how to construct, utilise and maintain it. In one approach, we trained the participants in groups; in the other, the participants were trained individually using a video. We also trained one group of participants by combining both approaches. As expected, individual video training resulted in higher adoption rates compared to in-person group training and a combination of the two approaches.

Nevertheless, we observed that the adoption pattern varied over time, and therefore, four categories of adopters were identified in this study: non-adopters, sustained adopters, late adopters and discontinued adopters (Fig. 3). A higher rate of sustained adoption was observed in individual video training. This study is in line with Lewis et al. [23], who argue that individual and personalised approaches are more effective in disseminating clean cooking stoves.

The group-based training took three days per group and was, therefore, more cost-intensive than the individual video training. Moreover, it required people to travel to the training site and could have been regarded as an opportunity for entertainment and social gathering rather than a training activity. Nevertheless, this study supports the idea that the effectiveness of a training approach is context-dependent.

The combination of training approaches also resulted in high rates of adoption when compared to group-based training. The additional use of one-on-one personalised visits might be responsible for this result. The literature suggests that the use of multiple strategies leads to higher rates of adoption [20,23]. In this study, however, we noted that the households who participated in both group-based and individual training had a relatively low adoption rate compared to those who only participated in the individual training. This is probably because in the group training as well as in the combination of both approaches, the households were mostly represented by male decision-makers, who are generally not responsible for cooking activities. On-site demonstrations required both male and female household representatives to move to the training sites, and since it was not mandatory to have both in the training activities, most households preferred to send only one of the representatives (mostly male). This prevented women from participating in the trainings, leading to lower adoption rates. While in the individual training in which there was no need for moving to the training site, we were mostly able to train both female and male representatives together.

As shown in Table 2, geographic location affects the adoption rates. Cultural factors might also play a role [21]. Individual methods are widely used by public extension in Mozambique [61] and may have been regarded as formal and, therefore, more persuasive than the group method. Perhaps farmers feel obliged to adopt the ICS by enumerator visit in case of individual video training. In the present study, the individual training approach was time and cost-effective since every visit took 25 to 30 min and did not require additional costs with construction materials and food provided to participants. The training costs per participant and adopter were lower when compared to the other approaches. Thus, videos might be presented to a much larger number of farmers than on-site training. As shown in Table 2, the combination of

Table 4
Cost per adopter for ICS dissemination approaches.

Training method	Cost items	Unit cost (MZN)	Total cost (MZN)	Number of participants	Cost per participant (MZN)	Number of adopters (sustained and late adopters)	Cost per adopter (MZN)
Individual training	Video Making	25,000	137,500	220	625.0	97	1417.53
	Trainers' Salary	112,500					
Group training	Tools used in Construction	2000	220,000	210	1047.6	37	5945.95
	Food ingredients	3000					
	Trainers' Salary	195,000					
	Trainers' transportation	5000					
	Coffee and lunch breaks	15,000					
combination	Construction material	1500	334,000	190	1757.9	74	4513.51
	Food ingredients	3000					
	Trainers' Salary	315,500					
	Trainer transportation	4000					
	Coffee and lunch breaks	10,000					

video and on-site positively promoted adoption, compared to the single use of group training; however, it is the most cost-intensive approach.

Notably, these results must be interpreted and generalised with caution since this study uses different approaches (individual versus group) and different tools (video versus on-site). We argue that the training tool is also essential in knowledge transfer. As Van Mele et al. [62] suggest, showing a video to farmers to transfer knowledge can eliminate cultural barriers between the trainer and the trainee. It combines visual and verbal communication methods [63] and can more cost-effectively reach the widest – even geographically isolated – populations [39]. Several studies have also used video-based approaches to increase farmers' knowledge and awareness (e.g. [32,36–38]). In addition, due to its visual element, a video can easily be understood by people without formal education, even if not in the local language [64]. Unlike on-site demonstration, the video also does not require the facilitator to have experience with the promoted skills [40,41].

Our analyses further revealed that household characteristics are also crucial for stove adoption. In particular, age, household size, connection to a network with adopters, and geographic location affect the adoption. These characteristics are particularly important for stove promoters since they can use them to target households with characteristics likely to foster early adoption. By strategically targeting households with such characteristics, improved stove programs would better allocate time and resources since early adopters are likely to influence those within the social network positively [18]. This can ensure that the local communities accept the new technology and prevent the negative reputation hindering innovation diffusion [42]. Other factors such as gender, education, monthly income, association membership and experiences with ICS are not significant predictors of adoption.

The fact that connection to a network with adopters positively influences adoption and membership in an association does not, might seem counterintuitive since social interactions across rural households stimulate stronger peer spill-over [54]. However, in our study, participants were only asked if they belonged to any association or cooperative, regardless of its purpose. Therefore, we argue that the non-significance of this variable might be because it did not necessarily mean having contact with adopters or discussing ICS. On the other hand, having a network with adopters is more specific and indicates that the adopter had contact with someone who has already had ICS experience and may have been influenced in some way. Nevertheless, we could not distinguish between independent adopters and imitators, which would allow us to understand further the former's influence on the latter's behavior. Moreover, this study did not capture the reasons for discontinued usage that, among other variables, may also be due to influence by other community members who have negative perceptions about the benefits of the stove.

We expected education to affect adoption significantly since education levels influence the process of capturing knowledge related to ICSs and clean fuels [53]. However, the non-significance of education in this study might imply that rather than formal education, awareness creation is more important since the training method positively affected the adoption. The non-significant association between gender and ICS adoption is also counterintuitive since it was expected that households where women are the decision-makers, would be more likely to adopt ICS [55]. Nevertheless, further understanding of the decision-making process is still necessary since gender differences in preferences within households can also play a role [65].

4.1. Study limitations

The present study has three important limitations, as described below:

1) In our study area, the cooking activities are primarily done by women; however, in 40 % of the households that agreed to participate in this study, only men were trained. This is an important issue to be considered since it might have played a role in the observed adoption rates. Thus, the generalization of this study's findings should be made with caution, and future studies should be more specific on the target audience to avoid introducing biases in the study results.
2) Although we took some precautions, such as explaining the confidentiality and anonymity procedures at the beginning of the interview and making observations of the cooking tasks, the study may not be exempt from social desirability as we were unable to validate the responses on adoption for the entire sample.
3) Furthermore, in this study, we compare individual and group training approaches using different tools (video and on-site demonstrations), which might make these approaches not perfectly comparable. Thus, we suggest that future studies should compare different approaches using the same tool. For example, they could study the effect of using video to train a group of people versus training the participants individually.

5. Conclusions

This study reveals that the training approach plays a significant role in promoting clean cooking technologies. As expected, the individual approach resulted in the highest adoption rates and is cost- and time-effective compared to the group training approach. The training approach had no significant effect on the adoption among late adopters. The study concludes that the capacity-building approach significantly influences the effectiveness of improved cookstoves dissemination programs. For better financial resource efficiency of stove promotion programs, the extension agencies should be aware of cost-effectiveness and adjust dissemination techniques to achieve the highest impact per unit of resource expenditure.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Custodio Efraim Matavel reports financial support was provided by Federal Agency for Agriculture and Food (BLE).

Data availability

Data available as supplementary material.

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Appendix A. Supplementary data

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