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Gender differentiation on the determinants and intensity of adoption of Purdue improved cowpea storage (PICS) bags in Northern Nigeria

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ABSTRACT

Postharvest and storage of agricultural produce such as cowpea remains a significant challenge in sub-Sahara Africa. This study assessed gender differentiation on the determinants and intensity of adoption of Purdue-improved cowpea storage (PICS) bags in northern Nigeria. Primary data was collected via a well-questionnaire from Kano, Kaduna, Gombe, Bauchi, Plateau, and the Niger States. Each State was purposively selected based on the concentration and availability of female PICS bag users. From the sampling frame 2989, 20% of male and female small-scale cowpea farmers were randomly selected, totalling 598 cowpea farmers. Descriptive and double-hurdle regression models were used. The result of the socioeconomic analysis indicated that farmers' mean age was 42 years, with an average of 8 persons per household and a dependency ratio of 1.19. Years of schooling were 10 with a farming experience of 25 years and 2.17 ha as the average farm size. Results of the Logit model in males were significant for (extension contact, PICS information from other farmers and radio sources, and cowpea income, bags non-available) and for females (age, awareness, extension contact, PICS information from other farmers and radio source, bags non-available). The truncated regression model was significant in males (cowpea income) and females (education, output, and bags non-available). Adopting PICS bag technology by cowpea farming households enhanced female farmers' adoption. Therefore, policymakers should implement methods to motivate female farmers to adopt this technology further.

1. Introduction

Nigeria is a sub-Saharan African country with an agrarian economy; seventy per cent (70%) of the population lives in rural areas and depends on agriculture for a living [1]. The livelihoods of most Nigerians depend on their ability to produce and market agricultural products [2]. In Nigeria, cowpea is one of the most important commercial agricultural products and nutritional legumes,

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grown chiefly by Northern Nigerian farmers because of its high protein content, affordable cost, and increasing demand for humans and animals [3]. However, this crucial cereal is prone to spoilage due to poor postharvest handling and storage. The cowpea bruchid weevil has been reported to destroy more than 25% of cowpea poorly stored [4]. To relieve the challenges of cowpea producers, improved hermetic storage technology using triple-layer PICS bags was put in place by Larry Murdock and colleagues [5], and this novel technology was reported cost-effective and scale-neutral and had a social and financial impact on adopters with an average net cash flow from cowpea storage in PICS bags of $10.81/100 kg bag and $39.27 per adopter [6].

Cowpea provides food and fodder and also improves soil fertility [7]. It is the primary source of plant protein, vitamins, and feeds for livestock, and because of this, it is often referred to as the poor man's meat [8]. Cowpea is also an important trade commodity in Nigeria. It is ascertained that cowpea contains 25% protein and 60 % carbohydrate [2]. However, the production of cowpea depends on the cultural behaviour of farmers. In African traditional society and Northern Nigeria especially, men are usually considered breadwinners in households, but it has been noticed that women play a crucial role in sustaining the family [6]. Ref. [9] reported that women provide about 60–80% of the food in most developing countries, which makes them responsible for half of the world's food production. However, their contribution is always overshadowed and attributed to men. Women usually embark on non-remunerated activities such as domestic work, caregiving, daycare, preparation of meals, etc., which undervalue their contribution and impact, thereby overlooking their impact [10]. However, studies on agricultural production and storage of cowpea in West Africa (Burkina-Faso, Niger and Nigeria) are sparse and limited to Ref. [6], who reported an average of 46% of hermetic storage by women. Therefore, the impact of PICS bag adoption by gender will give an insight into women's contribution to adoption.

This paper aims to determine the factors that would encourage the adoption and intensity of hermetic storage technology by gender. The study will enlighten the factors affecting the adoption of PICS by gender.

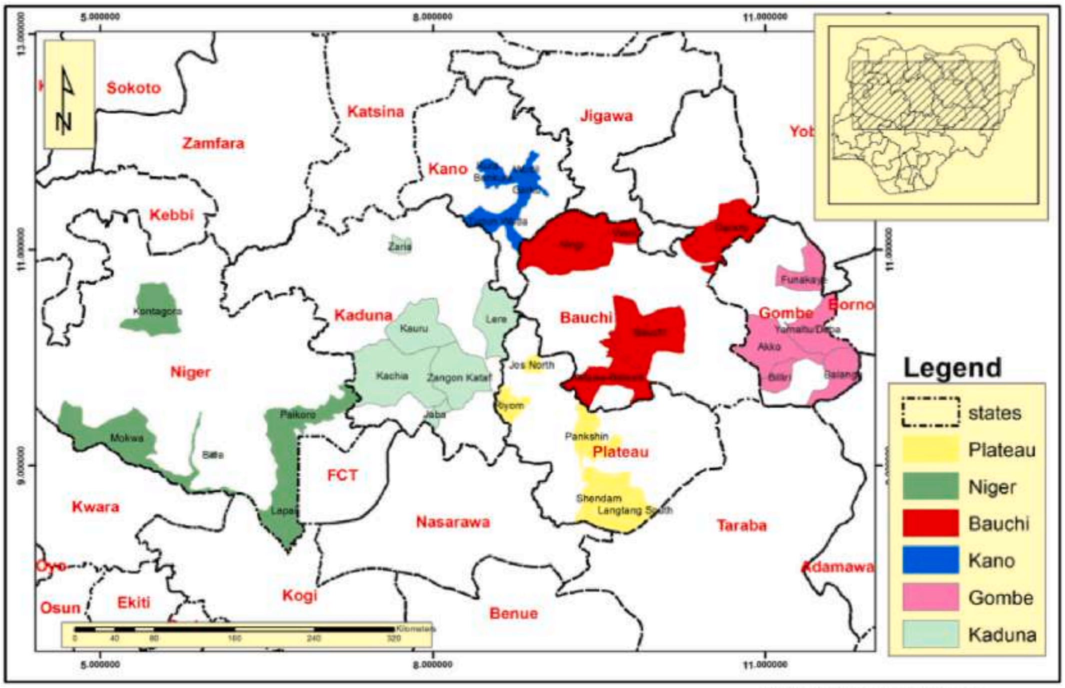
2. Materials and methods

2.1. Description of the study area

This study was conducted in three geopolitical zones of Northern Nigeria: North East, North West, and North Central [11]. In each zone, two States were selected Gombe and Bauchi in the North East zone, Kano and Kaduna in the North West zone, and Plateau and Niger in the North Central zone (Fig. 1). Agro-ecologically, Northern Nigeria is Sudan and Sahel savannah. Cowpea is known to be the staple food in the area.

2.2. Data collection methods

Socioeconomic data (Schooling, age, year of farming experience, household size, farm size, household dependency ratio, access to



Source: Dept. of Geog. BUK (2017)

Fig. 1. Map of the study area.

credit, contact with extension agent, membership of an association, and information on PICS) was obtained from household heads via a semi-questionnaire. Enumerators used the local language (Hausa) to administer the questionnaires. Recruitment and training of ten (10) enumerators were done for two days on data collection methods and related topics. The researcher supervised the enumerators closely during the process. Respondents were told their information would be treated confidentiality, and research objectives were explained before the interview.

2.3. Sampling procedure and sample size

The research was conducted in some selected Northern Nigeria States because of PICS farmers' availability. A combination of purposive and multistage sampling procedures was employed for the study. The first stage in the sampling procedure involved the purposive selection of two states from each of the three agroecological zones of Northern Nigeria based on the concentration and availability of female cowpea farmers and PICS bag users. The states selected were listed above. Stage II involved the purposive selection of at least five (5) Local government areas (LGAs) from each State where PICS bags were widely used. Stage III involved a purposive selection of communities based on the abundance of female cowpea farmers. In the last stage, based on a list provided by the IITA Kano station, 20% of male and female small-scale cowpea farmers were randomly selected using numbers on Microsoft Office Excel. Participants in PICS training who used the bag for at least one year were classified as the treatment group. In contrast, farmers who were non-participants in the PICS demonstration/training and were not using the bag were classified as a control group.

These random selections resulted in 299 PICS bag users, comprising 138 men and 161 women. The control group respondents were selected from non-PICS villages (i.e., villages where PICS demonstration/training was not carried out) from the same LGAs, which are similar in characteristics to the villages where PICS demonstration was carried out. These villages were identified and randomly selected, resulting in 299 respondents, including females (161) and males (138) in the treatment and control groups. Therefore, the total sample size of respondents was 598 cowpea farmers.

2.4. Data analysis methods

Data were analyzed using descriptive statistics (percentage, frequency, mean), binary logistic, and Tobit regression models through Stata 15 software.

2.4.1. Double hurdle model (DHM) specification

The double hurdle model was used to measure factors influencing the probability and intensity of adopting PICS bags. The double-hurdle model is a parametric generalization of the Tobit model, as reported by Refs. [12–15].

The double-hurdle model is applied so that both hurdles (the decision for adoption and intensity of adoption) have associated equations, incorporating the effects of the farmer's characteristics and circumstances.

The double hurdle assumes that households make two sequential decisions about adopting and intensity of use of technology. The household's socioeconomic characteristics condition each hurdle in the model (Table 1). A different latent variable is used to model each decision process. The first decision variable (Z) takes the value 1 for farmers who have adopted PICS bags and takes the value zero for otherwise.

However, the expected utility of adopting a technology (Z_i*) is latent. The first hurdle is the adoption decision equation estimated by using a Logit model given as [12–15]:

$$z_i^* = X_{1I}^I \beta_I + \mu_I \tag{1}$$

Table 1
Description of variables used in the logit regression model.

Variables	Description	Expected Effects
Dependent variable		
Adoption	1 if a respondent adopted PICS and zero if not.	
Quantity of cowpea stored in PICS Bags	Continuous (kg)	
Explanatory variables		
age	Continuous variable indicating the age of the respondent (years),	+
information about PICS bags from other farmers	1 if a respondent received information on PICS from other farmers and zero otherwise	+
household size	Continuous variable indicating the number of people in the household	+
awareness	1 if a respondent aware about PICS bags and zero otherwise	+
information about PICS bags from radio	1 if a respondent received information on PICS from radio and zero otherwise	+
education	Continuous variable indicating the years of schooling	+
contact with extension agent	1 if a respondent have contact with extension agent and zero otherwise	+
cowpea income	Continuous variable indicating the amount of cowpea sold	+
output	Continuous variable indicating the quantity of cowpea harvested	+
membership of association	1 if a respondent is a member of farmers' group and zero otherwise	+
used other methods to store cowpea	1 if a respondent uses other methods and zero otherwise	+
PICS bags available	1 if bags are available and zero otherwise	+

$$Z_i = 1 if Z_i^* > 1$$

$$Z_i = 1 if Z_i^* \leq 1$$

where, Z $_i$* = latent variable that takes the value of 1 if the farmer adopts PICS bag and 0 otherwise, X'_{1i} = vector of explanatory variables (farmers/farm specific characteristics, institutional and technology specific characteristics) that influences adoption choice, β_i = vector of parameters and u_i = independently distributed error term.

The second hurdle of the double-hurdle model involves an outcome equation which uses a truncated model to determine the intensity of adoption measured in terms of the proportion of cowpea stored in PICS bags. Therefore, the second hurdle uses observations only from those cowpea farmers who indicated a positive value on the use of PICS bags. The truncated model is expressed as follows [12–15]

$$Y_i^* = X'_{2i}\beta_2 + v_i \quad (2)$$

$$Y_i = \begin{cases} Y_i^* if Y_i^* > 0 \text{ and } D^* > 0 \\ 0 \text{ otherwise} \end{cases}$$

where, Y_i = observed response on the proportion of cowpea stored in PICS bags, X_i = vector of explanatory variables, β = vector of parameter estimates, v_i = error term.

The observed value of the proportion of cowpea stored in PICS bags is therefore expressed as [12–15]:

$$Y_i = Z_i Y_i^* \quad (3)$$

The error terms of the two decision models (adoption and intensity of adoption models) are distributed as follows [12–15]:

$$\mu_i \sim \mathbb{N}(0, 1)$$

$$V_i \sim \mathbb{N}\left(0, \delta^2\right) \quad (4)$$

Therefore the empirical model used to estimate the level and of intensity of adoption is given below [16]:

$$Y_i = \beta_0 + \beta_1 X'_1 + \beta_2 X'_2 + \beta_3 X'_3 + \beta_4 X'_4 + \beta_5 X'_5 + \beta_6 X'_6 + \beta_7 X'_7 + \beta_8 X'_8 + \beta_9 X'_9 + \beta_{10} X'_{10} + \beta_{11} X'_{11} + \beta_{12} X'_{12} + \mu_i \quad (5)$$

β_0 is constant, $\beta_1 - \beta_{12}$ is logistic regression coefficients and μ_i is the error term that is assumed to be normally distributed with mean zero and constant variance [16].

3. Results and discussion

3.1. Characteristics of farmers

The average age of a farmer was 43 and 41 years for female and male farmers, respectively (Table 2). The average household size was approximately eight (8) persons per household for both female and male farmers. The dependency ratio was 1.08 and 1.19 for female and male responding households. About 70% of female and male responding households have at least primary education. However, the highest mean years of schooling was ten (10) years in female responding households, whereas for males, it was nine (9) years of schooling. This suggests that farmers can read and write comfortably and assimilate a good knowledge of adoption technology.

The average farming experience, however, did not vary widely among the groups, as the variation was between 23 years for female farmers and approximately 25 years for male farmers. The average for all the groups was approximately 24 years, implying that the farmers have many farming experiences.

Table 2
Socio-demographic characteristics of farmers surveyed.

Variables	Female		Male		Pooled	
	Treatment	Control	Treatment	Control	Female	Male
N	161	161	138	138	322	276
Age (years)	44.3	41.4	42.2	39.5	42.8	40.9
Household size (number)	7.9	8	8.3	7.3	8	7.8
Dependency Ratio	1.07	1.08	1.21	1.16	1.08	1.19
Years of schooling	10.5	9.7	9.5	8.6	10.1	9.1
Farming Experience (years)	24.2	21	26.8	23.3	22.8	25
Farm size (hectare)	1.96	1.59	2.19	2.16	1.78	2.17
Extension Contact	75.2	27.3	71.7	33.3	51.2	52.5
Membership of Association	72	70.2	74.6	61.6	71.1	68.1
Information on PICS	88.2	6.8	91.3	8	47.5	49.6
Access to credit	45.3	52.2	13	19.6	48.8	16.3

The average farm size in the surveyed area ranges from 1.78 ha in female households to 2.17 ha in male households, thus showing minimal disparities (0.39) in farm sizes among farming households. This suggests that both sexes have access to farmland.

The percentage of extension visits was greater than 50 for female and male farming households, respectively (Table 2). The average number of years spent in an association was five years for females and three years for males. Table 2 reveals that most (above 88%) of the treatment (both female and male farmers) got information about PICS bags.

The analysis showed that households that obtained credit for farming purposes were higher among female households in the surveyed areas. Overall, very few farm households (32.5%) could obtain credit in that year; this might be due to insecurity in the study area.

3.2. Determinants of farmers decision to adopt PICS bags

The result of the estimated double-hurdle model is presented in Table 3. The double hurdle was justified because some factors that influenced the farmers' decisions to adopt PICS bags were not the same factors that influenced the intensity of adoption of PICS bags by gender. The Logit model was estimated to identify the factors influencing the decision to adopt PICS bags (first hurdle). The results reveal that six and five factors significantly influence farmers' decision to adopt PICS bags by female and male farmers, respectively. These factors are the farmer's age, awareness of the technology, access to extension contact, information about PICS bags, source of information from other farmers and radio, cowpea output, cowpea income, and non-available bags. The Log-Likelihood ratio (LR) of −71.69 and −58.97 of the estimated Logit model for Female and Male farmers, respectively, were significant ($p < 0.01$), and this indicates the joint significance of the explanatory variables included in the model.

The estimated coefficient of farmer's age in explaining the probability of adopting PICS bags technology was positive and significant ($p < 0.050$) for female respondents. This indicates that the age increment of farmers enhances their likelihood of adoption. This result contradicts the findings of [15], who suggested that younger people are more likely to take up new technology than older farmers. The result of this study may be because aged farmers are likely to acquire knowledge and experience over time compared to younger farmers.

The coefficient of awareness was significant and positive for female farmers ($p < 0.10$) and pooled ($p < 0.05$). The result revealed that female households' awareness of PICS bags was higher than males. This indicates that awareness is a tool for PICS bag dissemination. Our study agrees with the findings of [17]; who reported that awareness was an essential factor influencing individual behaviour to adopt PICS technology.

The estimated coefficient of the visit of the extension agent has a positive and significant influence on the adoption of PICS bags for female and male farmers and pooled data at $p < 0.01$, $p < 0.05$, and $p < 0.01$, respectively. This means the likelihood of adoption increases when a farmer has contact with an extension agent. A significant positive effect of extension agents on PICS technology was reported by Refs. [18,19] on improved bread-wheat technologies.

The coefficient sources of information on PICS bags from other farmers and radio were significant ($p < 0.01$) for both female and male farmers. The adoption of the PICS bags by female farmers has increased over time due to continued awareness. This is consistent with the critical role played by farmers in disseminating information to their folks [20]. The radio source was significant ($p < 0.05$) and positive for male farmers only. The radio broadcast was a significant source of information on PICS technology available to the farmers. The availability of reliable information sources will enhance the communication process by adopting improved technologies (PICS bags). This implies that male farmers have a higher and greater chance to listen to the radio broadcast. Radio is a valuable source of

Table 3
Double-hurdle estimates of determinants and intensity of adoption of PICS bags.

Variables	FEMALE		MALE		POOLED	
	Logit model	Truncated model	Logit model	Truncated model	Logit model	Truncated model
Age (years)	0.05 (2.4)**	1.8 (0.95)	0.04 (1.12)	13.6 (0.53)	0.39 (2.52)**	6.8 (0.95)
Education (years)	0.26 (0.49)	87.5 (1.75)**	0.18 (0.29)	414.9 (0.69)	0.28 (0.73)	271.1 (1.36)
Household size (number)	−0.008 (−0.18)	−6.3 (−1.61)	−0.014 (−0.20)	−51.7 (−0.82)	−0.015 (−0.39)	−23.6 (−1.36)
Association (yes, no)	−0.006 (−0.06)	−9.1 (−0.21)	−0.037 (−0.45)	−0.009 (−0.45)	−0.03 (0.42)	−8.1 (−1.68)**
Awareness (yes, no)	1.43 (1.66)*	–	1.03 (1.29)	6.6 (0.62)	1.16 (2.04)**	3.9 (0.61)
Extension contact (yes, no)	1.31 (2.65)***	27.1 (0.49)	1.36 (2.56)**	21.1 (0.36)	1.28 (3.65)***	30.9 (0.58)
Other farmers (yes, no)	3.62 (5.75)***	−14.1 (−0.22)	3.85 (5.74)***	3.1 (−0.77)	3.74 (8.37)***	−5.5 (−0.7)
Radio source (yes, no)	0.63 (0.80)	−11.1 (−0.22)	1.45 (2.03)**	13.1 (0.21)	1.08 (2.10)**	−18.3 (−0.54)
Cowpea Income (amount)	0.29 (0.52)	0.0002 (1.31)	1.45 (2.27)**	0.004 (2.0)**	0.94 (2.33)**	0.001 (3.19)***
Output (yes, no)	0.55 (1.82)*	31.3 (3.56)***	0.03 (0.17)	44.8 (1.27)	0.20 (1.22)	39.8 (2.77)***
Other methods (yes, no)	0.34 (0.57)	19.6 (0.28)	0.68 (0.99)	17.6 (0.99)	0.53 (1.21)	17.9 (0.87)
Bags non-available (yes, no)	−2.67 (−3.67)***	−15.3 (−4.38)***	−3.57 (−3.13)***	−42.1 (−1.04)	−3.02 (−4.97)***	−39.7 (−2.74)***
Constant	6.07 (3.61)***	−123.9 (−0.9)	5.39 (3.21)***	−529.5 (−0.92)	5.40 (4.73)***	−929.4 (−0.99)
N	322	157	276	134	598	291
LR Chi (12)	300.21	54.73	261.91	6.85	555.89	26.52
Prob > Chi^2	0.0000	0.000	0.0000	0.867	0.0000	0.0091
Pseudo R^2	0.6768		0.6895		0.6751	
Log likelihood	−71.69	−1012.9	−58.967	−924.72	−133.78	−1967.79
Sigma		207.7 (11.4)***		969.8 (3.46)***		602.6 (6.86)***

***P < 0.01, **P < 0.05, *P < 0.10, figures in parenthesis are z-values.

information on improved agricultural technologies [21].

The estimated coefficient of cowpea income was significant ($p < 0.05$) and positive for male and pooled data. This implies that as the income of the households increased by 1, the likelihood of using PICS bag technology increased by 0.004 factors. It suggests that as cowpea income increases, the probability of adopting PICS bags increases as income makes it possible to meet the financial obligation in technology used. In this case, male farmers receive more income than female farmers. This corroborates with [17,22].

The estimated coefficient of bags non-available was negatively significant ($p < 0.01$) for female male farmers and pooled data. Everything being equal, it implies that the probability of PICS bags being available increased by 2.67 for female and 3.57 for male farmers; as the availability of PICS bag supply at the harvesting time increased, farmers' use of PICS bags enhanced. The scarcity of PICS bag vendors, disconnection in information flow, and supply chain of PICS bags is the prominent constraint farmers face in the study area. The lack of local availability of the bags was often the reason for not using PICS bags [18].

The estimated coefficient for the output was positive and significantly ($p < 0.10$) influenced the farmer's decision to adopt female farmers. The results revealed that female-headed households were 55% more likely to use PICS bags than male-headed households. Farmers with higher output are likely to adopt the PICS bags, purchasing more bags to store their produce, increasing the probability of adoption. This corroborates with the findings of Refs. [6,17].

Factors determining the extent of adoption of PICS bags were estimated using the truncated regression model, as shown in Table 3. The results revealed some variation in the Logit and truncated regression models, justifying the double hurdle. This implies that the factors that influenced the farmers' decision to adopt PICS bags were not the same factors that influenced the farmers' intensity of adoption. Education was positive and significantly ($p < 0.01$) related to adoption intensity for female farmers; educated female farmers (17.5%) were more likely to use PICS bags than males. This implies that education plays a critical role for farmers by enabling them to identify the problem of postharvest loss and to change into practice the knowledge and skills acquired for the use and adoption of PICS. This is in line with the result by Ref. [23].

The coefficient of the quantity of output store was positive and highly significant ($p < 0.01$) to adoption intensity for female farmers. This implies that female farmers had a 35.6% added advantage in storage over male farmers. That is, the more cowpeas increased by the female farmer, the higher the adoption intensity of PICS bags. This is consistent with [6].

Bags' non-availability was significant ($p < 0.01$) to the adoption intensity of PICS bags for female farmers. This implies that if bags are made available, the intensity of adoption of PICS bags will increase drastically in female-headed households by 43.8% more than in male households. This agrees with [6], who documented that farmers complained of unavailable bags.

The coefficient of cowpea income was found to impact PICS technology adoption for male farmers positively. It indicates that male-headed households had a 20% increase in cowpea income than female-headed households. Households with a high cowpea income are likely to adopt PICS bags. This result corroborates that of [24], who reported a variation in earnings from farming as a ratio of household monthly income.

4. Conclusion

This study assessed gender differentiation on the determinants and intensity of adoption of Purdue-improved cowpea storage (PICS) bags in northern Nigeria. A combination of purposive and multistage sampling procedures was employed for the study. Adopting PICS bag technology by cowpea farming households was instrumental in female farmers. Several significant variables explained the adoption of the PICS technology including age, awareness, extension contact, information sources, radio source, cowpea income and bags unavailable. Thus, there is a need to increase awareness and training of farmers and make the bags available across the study area at an affordable price. Therefore, policymakers should implement methods to motivate female farmers to adopt this technology further.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Ndonkeu Nathanel Ndaghu: Writing - review & editing, Writing - original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tahirou Abdoulaye:** Supervision. **Amina Mustapha:** Supervision. **Djomo Choumbou Raoul Fani:** Writing - review & editing. **Rayner Tabetando:** Writing - review & editing. **Ukpe Udeme Henrietta:** Writing - review & editing. **Sahbong Lucy Kamsang:** Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e23026.

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