



Farmer Awareness and Socio Economic Determinants of PM KUSUM Adoption in Uttar Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Solar irrigation pumps are a major advancement in agricultural technology, offering farmers a sustainable solution to irrigation while reducing dependence on conventional energy sources. In India, small and marginal farmers often face financial and climatic challenges, limiting the adoption of such innovations. Despite government support through the PM-KUSUM Scheme (Component B), uptake remains modest due to financial constraints and low awareness. This study examines

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the socio-economic factors influencing the awareness and adoption of solar pumps. Illiteracy, influenced by factors such as gender, age, caste, and family structure, remains widespread, especially among females, lower castes, and joint families. Primary data were collected through a structured schedule with selected farmers. Analytical tools such as averages, percentages, and means were used to analyze socio-economic factors, while Binary Logistic Regression analysis was performed using SPSS to identify the major factors influencing adoption. Income levels of both illiterate and graduate farmers were similar, suggesting that income is tied more to access to resources than education. Awareness of the scheme was spread mainly through friends and relatives (30.95%), agricultural officers (27.38%), and social media (22.62%). While many farmers understood the procedures, technical knowledge, especially regarding solar panel maintenance, was lacking. Binary logistic regression showed occupation, landholding size, caste, and education as key adoption factors. The study emphasizes the need for targeted outreach to smallholders through mass media, fairs, meetings, and demonstrations.

Keywords: Solar irrigation pump; PM KUSUM scheme; Socio-economics; binary logit model.

1. INTRODUCTION

In the era of technology, agriculture is the backbone of India's economy, which continues to evolve with innovative solutions to improve productivity and sustainability. Agriculture contributes 16% of the country's GDP at current prices and employs nearly 46.1 percent of the country's workforce (Economic Survey 2024-25). As per the Food and Agriculture Organization (FAO), about 60% of India's agriculture depends on rain, making it highly risky to monsoon fluctuations, along with the income and lives of millions of Indian farmers. The traditional methods of irrigation, which use diesel and electricity, are often expensive and environmentally unsustainable. Rising electricity prices, driven by limited market competition and regulatory changes, have significantly increased the cost burden on irrigated agriculture (Langarita et al., 2017). Diesel-powered pumps lead to high fuel costs, while electricity shortages and irregular supply make the already risky agricultural sector worse. These problems have directly impacted the incomes of farmers, making it harder to achieve the government's goal of doubling farmer's income (Gautam et al., 2020). India has about 30 million (21 million electric and 9 million diesel) pump sets, which use 20% and 12% of India's total electricity and diesel consumption, respectively (Srinivas, 2018). The Government of India is spending roughly \$5.85 billion annually on agricultural subsidies, causing a significant financial burden to the distribution companies (DISCOMs) (Bhati et al., 2019). Farmers are using traditional ways of irrigation inputs, suffering from high irrigation input costs, lack of modern irrigation inputs, lack of regular supply, lack of coordination, regional disparities, and lack of finance (Umar, N. 2020). On the

other hand, Uttar Pradesh has vast inter-regional and inter-district disparities. The Eastern, Central, and Bundelkhand regions have been tackling very tough situations since independence. These regions are facing several problems like low productivity, floods, drought, and poor technology. The main crops in the state are wheat, rice, sugarcane, pulses, and vegetables (Nair, S. et al., 2013). Now it's time to switch the source of energy from fossil fuels to renewable sources. These non-conventional energy sources, such as solar, wind, and biofuels, can help provide clean, green, and reliable energy sources for farms and are capable to solve the problem of sustainable development associated with fossil-fuel based power plants as these energy sources are unlimited, eco-friendly and provides energy with negligible emissions of air pollutant and greenhouse gases (Singhal, 2007).

During the presentation of the Union Budget 2018-19, the Central Government announced the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme. This scheme aims to use solar energy for irrigation and reduce the agriculture sector's dependency on conventional power sources. India is the highest off-grid solar photovoltaic producing country (International Renewable Energy Agency, 2024). This scheme is one of the largest initiatives in the world to provide clean energy to more than 35 lakh farmers by solarising their agriculture pump under components B and C (MNRE, 2025). Component B is the only component of the PM KUSUM scheme that provides Solar Irrigation Pumps to the farmers, so we discuss only Component B. This research allows us to assess the real-world impact of the scheme on irrigation, which is vital for improving

crop productivity and ensuring food security (Meena, N. K et al., 2021). Despite significant research and implementation in the field of agricultural technology, there remains uncertainty about the extent to which farmers prefer traditional irrigation methods over non-conventional alternatives, thus the provision of PM-KUSUM scheme in the Union Budget of 2018-19. However, even the scheme offering a 60% subsidy by both central and state governments, the adoption of solar irrigation pumps remains low, indicating limited uptake by farmers. This limited uptake is particularly concerning given the potential benefits of solar pumps for small and marginal farmers and their contribution to India's broader goals of sustainable energy and agricultural development. Therefore, it is essential to analyze their economic status with their education level and the factors contributing to the low popularity and adoption of solar pumps under Component B of the PM KUSUM scheme.

Within this context, our study is focused on two main objectives: i) To assess the socio-economic impact with the relation of educational status of the farmers, and ii) To analyze the factors influencing their awareness of the PM KUSUM scheme. This study contributes to the existing literature by identifying which features of this scheme are most important to farmers and their education status. Additionally, the study identifies factors that hinder farmer's awareness of the PM KUSUM scheme.

2. REVIEW OF LITERATURE

K.M, Dr. et al. (2021) and Diyyala, R. et al. (2023) analyzed the impact of key government schemes like MSP, PM-KISAN, PM-KUSUM, and PMFBY on agriculture. The study found these initiatives effective in improving productivity, income stability, and financial inclusion. It emphasized the importance of integrating modern technology and allied activities like poultry and beekeeping to support rural transformation and economic growth. The study of Guno and Agaton (2022) and Agrawal, D. K. (2022) examined the socio-economic and environmental impacts of solar irrigation for small-scale farmers in the Philippines. The study found significant CO₂ reductions, high returns on investment, and an average payback period of 2.88 years. While 69% of farmers showed interest, high initial costs remained a barrier. The authors recommended policy support to improve accessibility and promote sustainable agriculture.

Kumar et al. (2024), and Sethi and Biswal (2023) studied factors influencing the adoption of solar water-pumping systems in Gujarat. Economic benefits (33.2%) and government policy (26.3%) were key drivers. Affordable costs, subsidies, and energy savings motivated adoption. The study recommended expanding such schemes, promoting farmer awareness, and integrating solar with drip irrigation for higher income and sustainability. It also emphasized reducing grid dependency and carbon emissions through policy support and financial assistance. The study of Aditya and Dagmar (2024), Singh, (2022), and Sow, et al. (2024) analyzed the adoption of solar pumping systems among vegetable farmers in Senegal using a sequential logit model. They found that awareness was shaped by socio-economic factors like age, credit access, and climate change knowledge, while initial and continued use were influenced by plot size, location, gender, and household size. Access to credit was crucial for sustained adoption. The study highlighted the need for targeted institutional and financial support to promote long-term use of solar irrigation systems.

While the above studies highlight the benefits of solar irrigation and the role of policies. They don't fully explore how factors like illiteracy, caste, gender, or family impact awareness and adoption, nor do they address the gap between understanding the process of ordering the solar irrigation pump and their knowledge of different aspects of the scheme. The influence of informal sources like friends and relatives in spreading awareness is also often overlooked. This study focuses on these real-life issues in the Bahraich district, offering a clearer picture of what truly affects adoption among small and marginal farmers.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The survey was conducted in the Bahraich district of Uttar Pradesh. It was purposively selected because this region is known for its challenging educational level and comes under the list of the Aspirational District Programme (launched in 2018), which focuses on various developmental aspects, including agriculture and water resources. The main source of irrigation in the district of Bahraich is tube wells and wells. The source-wise irrigated area in the district during 2021-22, Tube wells and wells, 58.1 and

36.07 percent, respectively, of the total irrigated area in the district. There are two types of tube wells, i.e., state and private tube wells, which cover 2.4 and 55.7 percent, respectively (District Statistical Journal, Bahraich 2021-22). The diesel-powered pumps are high at 72323 all over the district, and the electricity-powered pumps are only 328 over the district. So, we can say that the consumption of diesel in irrigation is higher than electricity (District Statistical Journal, Bahraich 2022-23).

3.2 Data Collection and Sampling

The survey schedule was prepared for the collection of primary data, and sampling techniques were used like- Multistage sampling, Snowball Sampling, and Random Sampling. To accomplish the study objectives, an initial step involved the selection of six blocks, namely Kaisarganj, Fakharpur, Chittaura, Payagpur, Shivpur, and Mihinpurwa, within the Bahraich district. Utilizing a multistage sampling technique, two villages were chosen from each block, followed by the selection of ten farmers from each village. As a result, a total sample size of 120 farmers was obtained. Among them, 84 respondents, who had installed solar irrigation pumps, were selected using the snowball sampling method, while the remaining 36 respondents were selected using random sampling.

3.3 Empirical Methodology

The Binary Logit Model, also known as logistic regression, was employed as a statistical tool to analyze the relationship between a binary dependent variable and a set of independent variables. It was particularly suitable for this study, as the outcome variable had two possible categories, such as "Yes" or "No", representing the awareness status of the respondents. The model utilized a logistic function to transform the linear combination of the independent variables into a probability score ranging between 0 and 1. In this study, the binary logit model was used to examine the influence of various socioeconomic factors on the farmer's level of awareness regarding the PM-KUSUM scheme (Kumar, 2024), (Sathish Kumar, M et al. 2024)

The formula used for binary logit analysis was:

$$P(Y = 1) = \frac{1}{1 + e - (\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k)}$$

Where, $P(Y=1)$ is the probability of the dependent variable Y being 1 (success, positive outcome); e is the base of the natural logarithm; β_0 is the intercept; $\beta_1, \beta_2, \dots, \beta_k$ are the coefficients associated with the predictor variables X_1, X_2, \dots, X_k ; X_1, X_2, \dots, X_k are the predictor variables. The logistic regression equation estimates the log odds (logit) of the event happening. The probability of $Y=0$ (failure, negative outcome) is then $1-P(Y=1)$.

SPSS software (version 16.0) is used to conduct data analysis and run the logit regression model. Definition and explanation of all variables are given in Table 1. The farmers' responses to statements concerning their awareness are methodically recorded on a three-point continuum scale: 'fully aware – 2', 'partially aware – 1', and 'not aware – 0'. Subsequently, the cumulative scores acquired are utilized to categorize the respondents into low and high levels of awareness. Finally, a score of 0 is assigned to respondents exhibiting low awareness, while a score of 1 is attributed to those demonstrating high awareness, for utilization in a logit model. (Gautam, Sandeep et al., 2023)

4. RESULTS AND DISCUSSION

4.1 Socio-economic profile of the respondent

The average age of the sampled farmers is 48 years, with 82.50% of the total respondents being male, as shown in Table 1. The majority of respondents fall within the age group of 46 to 55 years. The major caste in the Surje area is Other Backward Classes (OBC), which is 47.50% of the total selected respondents. The family type of the selected area is joint, which is 60.83%.

Findings show that the maximum respondents are illiterate. Moreover, the distribution of average annual income among the respondents indicated that approximately 50% of them fall into the medium income category, with earnings ranging between Rs. 50,001 and Rs. 75,000.

In Table 2, the majority of respondents, 48 (40%), fall within the age group of 46–55 years, and the highest number being illiterates is 36 (30%). The data also indicate that illiteracy tends to increase with age, as we see in table 17.50, per cent of respondents who are illiterate is more than 56 years old. The older generation has a lower

literacy rate as comparison to the newest generation because of the resources they have access to according there generations. Interestingly, the number of illiterate respondents (36) is nearly equal to the number of

graduates (35). This can be attributed to the fact that, in the survey, a larger proportion of respondents who owned solar pumps were included compared to those who did not.

Table 1. Descriptive statistics of socioeconomic characteristics of the respondents

Particulars	Frequency (n=120)	Percentage (%)	Mean
Gender			0.83
Male	99	82.50	
Female	21	17.50	
Age			47.8
18-25	2	1.67	
26-35	9	7.50	
36-45	32	26.67	
46-55	48	40	
>56	29	24.17	
Caste			1.94
General	35	29.17	
OBC	57	47.50	
SC	28	23.33	
ST	0	0.0	
Family Type			0.61
Joint	73	60.83	
Nuclear	47	39.17	
Education			3.02
Illiterate	36	30	
Primary	20	16.67	
High School	5	4.17	
Intermediate	24	20	
Graduation	35	29.17	
Annual income			67,469
<50,000	13	10.83	
50,001-75,000	60	50	
75,001-1,00,000	31	25.83	
>1,00,000	16	13.33	

Table 2. Age-wise education status of respondents in the study area

Age group	Level of education					Grand Total
	Illiterate	Primary	High School	Intermediate	Graduate	
18-25	0 0%	0 0%	0 0%	0 0%	2 1.67%	2 1.67%
26-35	1 0.83%	0 0%	0 0%	1 0.83%	7 5.83%	9 7.50%
36-45	1 0.83%	8 6.67%	1 0.83%	10 8.33%	12 10%	32 26.67%
46-55	13 10.83%	10 8.33%	3 2.50%	10 8.33%	12 10%	48 40%
>56	21 17.50%	2 1.67%	1 0.83%	3 2.50%	2 1.67%	29 24.17%
Grand Total	36 30%	20 16.67%	5 4.17%	24 20%	35 29.17%	120 100.00%

Table 3. Caste wise education status of the respondents in the study area

Qualification	Caste			Grand Total
	General	OBC	SC	
Illiterate	5 4.17%	20 16.67%	11 9.17%	36 30%
Primary	2 1.67%	9 7.50%	9 7.50%	20 16.67%
High School	2 1.67%	2 1.67%	1 0.83%	5 4.17%
Intermediate	7 5.83%	13 10.83%	4 3.33%	24 20%
Graduate	19 15.83%	13 10.83%	3 2.50%	35 29.17%
Grand Total	35 29.17%	57 47.50%	28 23.33%	120 100.00%

Table 3 shows the relationship between caste and level of education. It reveals that most respondents which are belong to the OBC and Scheduled Cast (SC) categories are illiterate, 16.67% and 9.17% respectively. In contrast, individuals from the General category have the highest proportion of graduates (15.83%). There is some reason that is why they did not get an education, like some level of caste-based discrimination, poor family planning, so children have to work to support their family rather than getting an education.

Table 4 examines the relationship between family type and level of education. It shows that most of the joint families have the highest number of illiterate respondents, 27 (22.50%), while in nuclear families, the maximum number of respondents are graduates, 24 (20%). This is because the income and resources are shared among more members, which can limit the amount available to everyone.

Interestingly, Table 5 shows that both illiterate and graduate respondents fall within the same annual income range of ₹50,001 to ₹75,000. Behind this, the major reason would be fewer job opportunities, and also, this suggests that higher educational qualifications do not necessarily translate to higher income in the context of small-scale farming. It also indicates that factors such as access to resources, type of crops grown, and irrigation facilities like solar pumps may play a more significant role in determining income than education alone.

4.2 Awareness Sources of Respondents for the Scheme

Awareness of the PM-KUSUM scheme is essential for linking farmers to solar irrigation

benefits and government subsidies. In rural areas, effective information sources help bridge the gap between policy and practice, enabling farmers to make informed decisions and access the scheme.

The data elucidated in Table 6 furnishes a comprehensive depiction of the sources contributing to farmers' awareness regarding the diverse PM KUSUM Scheme in the Study area. A detailed look at the scheme shows clear patterns in how people get their information.

The scheme, in the study area Friends and Relatives, emerges as the primary source of awareness at 30.95%, while Agricultural Officers play a notable role, contributing 27.38%, and after that, Social Media plays its role by 22.62% in the Sources of awareness of the PM KUSUM scheme.

4.3 Awareness Level of Respondents Regarding Various Aspects of the Scheme

Table 7 depicts the levels of awareness displayed by respondents with regard to various aspects of the PM KUSUM scheme. Each statement in table is segmented into 3 categories: "Not aware," "Partially aware," and "Fully aware", with corresponding scores of 0, 1, and 2 assigned to each category, respectively. Notably, awareness levels vary across different aspects of PM KUSUM. This table analyzes respondents' awareness of various aspects of the PM-KUSUM scheme, revealing varying levels of understanding. A majority (59.52%) were fully aware of the procedural aspects.

Table 4. Family-wise education status in the study area

Qualification	Family type		Grand Total
	Joint	Nuclear	
Illiterate	27 22.50%	9 7.50%	36 30%
Primary	15 12.50%	5 4.17%	20 16.67%
High School	4 3.33%	1 0.83%	5 4.17%
Intermediate	16 13.33%	8 6.67%	24 20%
Graduate	11 9.17%	24 20%	35 29.17%
Grand Total	73 60.83%	47 39.17%	120 100.00%

Table 5. Education-wise annual income of the respondents in the study area

Qualification	Annual Income				Total
	< - 50000	50001-75000	75001-100000	>- 100001	
Illiterate	7 5.83%	19 15.83%	10 8.33%	0 0%	36 30%
Primary	2 1.67%	10 8.33%	7 5.83%	1 0.83%	20 16.67%
High School	0 0%	1 0.83%	4 3.33%	0 0%	5 4.17%
Intermediate	4 3.33%	11 9.17%	3 2.50%	6 5%	24 20%
Graduate	0 0%	19 15.83%	7 5.83%	9 7.50%	35 29.17%
Grand Total	13 10.83%	60 50%	31 25.83%	16 13.33%	120 100.00%

Table 6. Awareness obtaining sources of respondents pertaining about PM KUSUM Scheme in the study area

Scheme	Sources of Awareness					
	Agricultural Officer	Bank Agent	Panchayat	Friend/Relatives	Organization	Social Midea
PM	23	5	4	26	7	19
KUSUM	27.38%	5.96%	4.76%	30.95%	8.33%	22.62%

Table 7. Awareness of respondents regarding various aspects of the PM KUSUM Scheme in the study area

Aspects	Procedural Knowledge of Scheme	Initial Investment & Subsidies	Pump Capacities	Solar Panel Maintenance	Financial Viability	Energy & Cost Saving	Universal Solar Pump Controller (USPC)
Not Aware	1 (1.19)	12 (14.29)	10 (11.90)	21 (25.00)	3 (3.57)	0 (0.0)	79(94.05)
Partially Aware	33 (39.29)	35 (41.67)	42 (50.00)	46 (54.76)	59(70.24)	6(7.14)	5(5.95)
Fully Aware	50 (59.52)	37 (44.05)	32 (38.10)	17 (20.24)	22 (26.19)	78 (92.86)	0 (0.0)

Table 8. Binary logit regression analysis to assess Awareness of farmers for the PM KUSUM scheme in the study area

Variables	B Coefficient (log odds)	Exp(B)/ Odds ratio	Std. err.	Wald	Sig.	95% cof. Interval	
						Lower	Upper
Age	.305	1.357	.394	.600	.439	.627	2.936
Gender	.128	1.136	.772	.027	.869	.250	5.162
Caste	1.340	3.820	.493	7.392	.007	1.454	10.039
Educational Qualification	.835	2.305	.248	11.348	.001	1.418	3.747
Income	-.569	.566	.726	.614	.433	.136	2.350
Occupation	3.195	24.422	.764	17.509	.000	5.467	109.095
Family type	.412	1.510	.692	.355	.551	.389	5.865
Land	1.710	5.530	.518	10.901	.001	2.004	15.264
Household Expenditure	-.348	.706	.371	.883	.347	.342	1.459
Constant	-4.628	.010	2.291	4.081	.043		
Number of observations	120						
-2 Log likelihood	85.569						
LR chi2 (9)	61.038						
Prob > chi2	0.000						

In terms of financial viability, 70.24% had partial awareness, 26.19% were fully aware, and 3.57% were not aware at all, indicating limited understanding of long-term economic benefits. The highest awareness was observed in the area of energy and cost savings, 92.86% of respondents were fully aware, and 7.14% had partial knowledge, with none completely unaware. The aspect of USPC 94.05% respondents are not aware, and 5.95% are partially aware that there is no one who is fully aware of this aspect of the PM KUSUM scheme.

4.4 Results from the Binary Logit Regression Model

Logistic regression has been used as an important statistical method to analyze farmer's awareness of various components of the PM-KUSUM scheme. Since the outcome variable is binary, indicating whether a respondent is aware or not, logistic regression is well-suited for this type of analysis. The model includes several demographic and socio-economic variables such as age, education, income, and landholding size as independent variables to explore how these factors influence the likelihood of being aware of the scheme.

One of the key strengths of logistic regression in this context is its ability to generate odds ratios, which help interpret how the chances of awareness change with variations in each independent variable. These findings offer meaningful insights for policymakers and development agencies by identifying which

groups are more or less likely to be informed. This, in turn, can help in designing targeted awareness strategies and improving the overall reach and impact of the PM-KUSUM scheme in rural areas.

Upper caste farmers tend to have higher odds of being aware of PM KUSUM (odds ratio = 3.820, $p = 0.007$). The p -value is more significant level of 0.05, indicating higher significance, caste more likely to contribute to higher awareness. Education is a highly significant predictor (odds ratio = 2.305, $p = 0.001$). Farmers with higher education levels are much more likely to be aware of PM KUSUM, emphasizing the importance of education in understanding the scheme. Occupation exhibits highly significant (odds ratio = 24.422, $p = 0.000$). Farmers with different occupations may have stronger odds of being aware of PM KUSUM. Farmers who own larger land tend to have higher odds of being aware of PM KUSUM (odds ratio = 5.530, $p = 0.001$). While the p -value is more likely to be less than the significance level of 0.05, indicating high significance, land ownership might contribute to higher awareness (IRENA, 2024).

5. CONCLUSION AND RECOMMENDATIONS

Solar pumps play a key role in advancing sustainable agriculture in India by enhancing irrigation efficiency and reducing dependence on traditional energy sources. However, adoption under the PM-KUSUM Scheme (Component B) remains limited due to financial constraints and

low awareness. This study explores the socio-economic factors influencing awareness and adoption, revealing that illiteracy among farmers is shaped by gender, age, caste, and family structure. In rural areas, male dominance restricts female education, while lower castes and joint families often face more barriers to schooling. Interestingly, both illiterate and educated farmers fall within a similar income bracket (Rs. 50,001–75,000), suggesting that access to resources and technologies like solar pumps, rather than education alone, plays a more critical role in improving farm income. These findings highlight the need for targeted policies that focus on improving infrastructure and resource access to boost the livelihoods of small-scale farmers. The scheme, in the study area Friends and Relatives, emerges as the primary source of awareness at 30.95 per cent, while Agricultural Officers play a notable role, contributing 27.38 per cent, and after that, Social Media plays its role by 22.62 per cent in the Sources of awareness of the PM KUSUM scheme. The awareness of respondents regarding different aspects of the PM-KUSUM scheme reveals varying levels of understanding across key components. In terms of procedural knowledge of the scheme, a majority of respondents (59.52%) were fully aware, while 39.29 per cent had partial awareness.

Binary logistic regression results in odds ratios and their 95% confidence intervals. The odds ratio tells us how likely it is that a farmer will adopt a solar irrigation pump based on different factors. Occupation (Odds ratio = 24.42), Land (Odds ratio = 5.53), Caste (Odds ratio = 3.82), and Educational Qualification (Odds ratio = 2.31) are important factors. Which means they have a strong and significant effect on the adoption of solar pumps. This means that farmers with more land, better education, or certain occupations and caste backgrounds are more likely to use solar irrigation.

By analyzing the socio-economic conditions and awareness levels related to the scheme, it becomes clear that improving farmer education and expanding outreach are essential. Awareness about the PM-KUSUM scheme should be promoted through multiple channels, including mass media, community meetings, and local demonstrations. Efforts must be made to ensure the scheme is inclusive, particularly targeting small and marginal farmers, and remains free from any caste-based discrimination. Educational initiatives such as training sessions, agricultural fairs, seminars,

and field demonstrations can be key in empowering farmers and increasing participation in the scheme.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of this manuscript.

CONSENT

As per international standards or university standards, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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