ADAPTIVE CAPACITY TO CLIMATE CHANGE AND FOOD SECURITY AMONG FARM HOUSEHOLDS IN SOUTHWEST NIGERIA

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A B S T R A C T

Smallholder farming households represent one of groups most exposed to the vagaries of climate change because their production and livelihood depend on climatic elements. This study assessed the effect of climate change adaptive capacity on smallholder farming households' food security in Oyo State, Nigeria. Data from 246 farming households were analysed using factor analysis to generate the Climate Change Adaptive Capacity Index (CCACI), Foster-Greer-Thorbecke Indices and Logit Regression. The most adopted adaptation strategies were intercropping, fallowing, fertilizer application, and crop rotation. Most of the households had moderate or high adaptive capacity to climate change. Econometric results show that farm households with low climate change adaptive capacity have a greater likelihood of being food insecure relative to farm households with moderate and high climate change adaptive capacity. These findings emphasize the need to enhance smallholder farmers' capacity to mitigate the adverse effect of climate change on national food security.

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Introduction

The climate in Nigeria has been changing. Sustained increases in temperature, variation in rainfall, flooding, sea levels, land degradation, extreme weather events, loss of biodiversity, and the affected freshwater resources over time serve as a clear indication. The temperature has increased significantly since the 1980s and the future climate projections indicate rises in temperature and rainfall variations across all ecological zones in Nigeria (Haider, 2019). Sub-Saharan Africa's (SSA) food production is mainly driven by smallholder farming households, who significantly practice rain-fed agriculture, making them susceptible to the negative consequences of climate change (Joshua et al., 2016; Makate, et al., 2018; Oyawole et al., 2019; Dhakal et al., 2022).

These climatic vagaries could severely impact food production, thereby affecting food consumption and the farm households' food security. This makes adaptation a critical component in minimizing the negative impacts of climate change while ensuring food security, especially among smallholder farming households. In SSA, different adaptation measures are used by agricultural households to combat climate change. Some of these include the adoption of drought tolerant varieties, changing planting dates, adoption of irrigation and water harvesting schemes among others (Wossen et al., 2014; Adeagbo, Ojo and Adetoro, 2021; Zakari et al., 2022). The adoption of these strategies by smallholder farm households could indicate potential climate change adaptation which improves their odds of being food secure. However, as Chepkoech et al. (2020) argue, the adaptive capacity of the individual households (i.e., 'their control over tangible and intangible resources') directly influences their decision on whether or not to implement these adaptation measures.

The Intergovernmental Panel on Climate Change (2014) defines climate change adaptive capacity "as the ability of systems, institutions, humans and other organisms to adjust to climate change (including climate variability and extremes), to moderate potential and actual damages, to take advantage of opportunities, and to cope with consequences". Climate change adaptation capabilities is intricately connected to food security. Individual or household access to information, physical (assets), financial, human resources and basic infrastructure may either limit or enhance their climate change adaptive capacity, which will in turn influence their climate change adaptation behavior and thereby impact their "physical and economic abilities to access sufficient, safe and nutritious food required for their dietary needs" (Perez-Escamilla and Segall-Correa, 2008). However, while there have been various studies examining the adoption of adaptation strategies as well as climate change adaptive capacity among farm households, there are limited studies that empirically investigate the relationship between climate change adaptive capacity and food security in SSA.

For instance, while Connolly-Boutin and Smit (2016) provided an important framework for understanding the linkage between climate change adaptation and food security, others examined climate change adaptive capacity at the city-level in Kenya and Nigeria among others (Leal Filho et al., 2019). Other studies focused on describing the various adaptation measures deployed by farming households to mitigate climate change effects and what factors influenced such adoption decisions (Ojo and Baiyeghuni, 2020; Adeagbo, Ojo and Adetoro, 2021). Based on the Sustainable Livelihood Framework, Abdul-Razak and Kruse (2017) and Chepkoech et al (2020) conceptualized and estimated a climate change adaptive capacity index using household-level data from Ghana and Kenya respectively. This study adds to the body of knowledge by identifying various climate change adaptation measures utilized by farming households, estimating their level of adaptive capacity to climate change, and modelling its effect on their food security status among other covariates in Oyo State, Nigeria. This will provide empirical basis for designing effective policies and interventions needed to strengthen smallholder farmers' climate change adaptive capacities for improved food security and overall wellbeing.

Materials and methods

Study Area

The study was conducted in Oyo State, South-west, Nigeria. The State lies on latitude 8.0°N and longitude 4.0°E. Oyo State's weather is tropical, having dry and wet seasons as well as a comparatively high humidity level. The rainy season runs from April to October, whereas the dry season is from November to March. The typical daily temperature is between 25 °C (77.0 °F) and 35 °C (95.0 °F). (OYSG, 2022). The majority of Oyo State residents work in the agricultural sector (production, processing, marketing etc). Oyo State's climate supports the planting of various staple crops like yam, maize, soyabean, cassava and plantains as well as cash crops like oil palm, cashew and cocoa (Olawale et al., 2021).

Sampling Technique

This study used primary data collected from smallholder agricultural households selected using a multistage sampling procedure. In the first stage, 2 ADP zones (Ibadan/Ibarapa zone and Saki zone) were selected randomly from the 4 ADP zones in Oyo State using the simple random sampling technique. In the second stage, proportionate stratified sampling was used to select 2 blocks in the Saki zone and 3 blocks in the Ibadan/Ibarapa zone, considering the number of blocks in each zone. The third stage involved selecting 2 cells each from each of the blocks to make 10 cells and, finally, a random sampling of 25 respondents per cell to give a total of 250 respondents. It should be noted that data collected from 4 respondents were unusable because of a high incidence of missing responses, thereby led to the data being excluded from data analysis. The main types of data collected for this study include household demographic characteristics, climate change adaptation strategies adopted and household expenditure.

Analytical Techniques

Descriptive Statistics

The respondents' socio-economic characteristics, the adopted climate change adaptation strategies, and the perception of the respondents to climate change impacts were described using descriptive statistical measures such as tables, frequencies, means, and percentages.

Climate Change Adaptive Capacity Measurement: Factor Analysis

The respondents' climate change adaptive capacity index was generated using Factor Analysis. This involved collapsing the variables representing the sub-indicators of adaptive capacity into fewer orthogonal uncorrelated factors that proxy for the climate change adaptive capacity index. Following Eakin and Borjorquez-Tapia (2008), each respondent's climate change adaptive capacity (as highlighted in Table 1) was analysed using five indicators, and twenty-five sub-indicators of adaptive capacity. These were physical resources, human resources, financial resources, information, and livelihood diversity.

Table 1. Description of Climate Change Adaptive Capacity Indicators and Sub-Indicators

Indicators	Sub-Indicators	Description
Human Resources	Knowledge in farming Household head education Percentage of adults having primary education Proportion of adults in the household Sick or Ill members	The respondent's length of time in farming. The number of years the household head spent pursuing formal education. The proportion of adults in the household with some formal elementary education as a percentage of the total adults in the household. The number of adults in the household is expressed as a percentage of the total number of household members Number of sick or ill members the household has
Physical Resources	Farm size Irrigation Ownership of farm implements and machines Farm tenure Access to healthcare Access to transportation network	The farm size cultivated in hectares Irrigation facility source used on the farm The number of productive farm implements and machines possessed by the farming household Farm tenancy type If the respondents have access to formal healthcare facilities in their community If the respondents have access to good road network linking their community to markets and other communities
Financial Resources	Remittances from relatives Value of animal units Gets financial support/subsidy from the government Credit access	The amount of remittances/regular financial help gotten by the household The estimated total worth of animals the household owned and reared. If the respondent often obtains government financial aid or subsidy for farming. If the respondent has access to credit (formal or informal) facilities, or if they have accessed credit to finance farming in the last 5 years

Indicators	Sub-Indicators	Description
Information	Climate change awareness	If the respondent is aware of the causes and effects of climate change on agricultural production
	Training on soil management	If the respondent received training on sustainable soil resource management practices from institutions
	Training on environmental management	If the respondent received training on sustainable environmental management practices from institutions
	Receives extension assistance or education	If the farmer enjoyed agricultural services, has consulted or received agricultural education from agricultural extension agents
	Membership in farmers' organisation	If the respondent belongs to any farmers' organisation
	Sources of climate information	The number of climate data sources that the farmer has access to.
Livelihood Diversity	Number of livelihood or income sources	The number of all sources of livelihood or income available to the household
	Percentage of cultivable crop land not cultivated	The proportion of cultivable land that is not used for growing crops
	Number of crops cultivated	The total quantity of crops grown annually
	Crop diversification	If the respondent practices crop diversification

Factor analysis assumes that variance of the original variables representing the sub-indicators of climate change adaptive capacity is made up of variance accounted for by the unique factors (error terms) as well as variance accounted for by the common factors. The model specification for the Factor Analysis is expressed as:

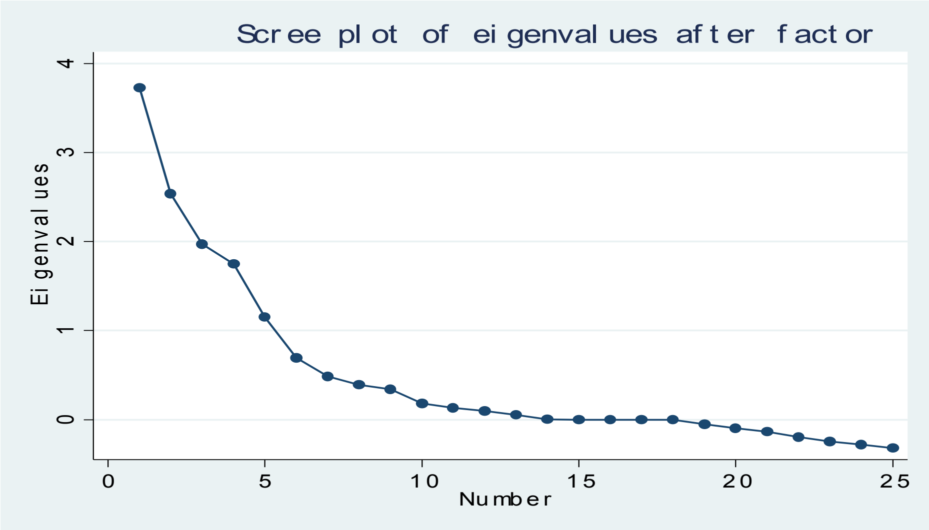
$$
\begin{aligned}
X_1 &= \vartheta_{11}F_1 + \vartheta_{12}F_2 + \cdots + \vartheta_{1n}F_n + \varepsilon_1 \\
X_2 &= \vartheta_{21}F_1 + \vartheta_{22}F_2 + \cdots + \vartheta_{2n}F_n + \varepsilon_2 \\
X_3 &= \vartheta_{31}F_1 + \vartheta_{32}F_2 + \cdots + \vartheta_{3n}F_n + \varepsilon_3 \\
X_{25} &= \vartheta_{251}F_1 + \vartheta_{252}F_2 + \cdots + \vartheta_{25n}F_n + \varepsilon_{25}
\end{aligned} \tag{1}
$$

Where X_1 to X_{25} are the original twenty-five variables representing the sub-indicators of climate change adaptive capacity; ϑ_{i1} to ϑ_{in} are the rotated factor loadings in relation to the twenty-five variables; F_1 to F_n are the standardized uncorrelated common factors; and ε_i represent the independently and identically distributed error terms with zero mean in relation to the twenty-five original variables.

Computation of Composite Index of Climate Change Adaptive Capacity

From the Factor Analysis, five factors were retained following the Kaiser criterion and the scree plot rule (Dunteman, 1989). Based on the Kaiser criterion, we retained factors having eigenvalue of at least one, and the scree plot rule involves retaining factors having sudden drop in their eigenvalues after the first factor. The scree plot is the graphical representation of the factors' eigenvalues. The scree plot is used to indicate points of significant drop and levelling off of the factors' eigenvalues. The five retained factors cumulatively explain about 91.4 percent of the total variation in the twenty-five variables representing the sub-indicators of climate change adaptive capacity.

Figure 1. Scree plot of eigenvalues on Sub-indicators of Climate Change Adaptive Capacity



The five retained factors were rotated orthogonally to reduce the number of sub-indicator variables with high factor loadings[7], thereby making each factor distinct and uncorrelated with other factors and for easy interpretation of the factors. Thereafter, the scores of each retained factor for each respondent was predicted as a weighted[8] sum of the standardized sum of the sub-indicator variables representing climate change adaptive capacity. In order to obtain each respondent's composite index of climate change adaptive capacity, the predicted factor scores were aggregated by estimating the average predicted score across the five retained factors. Similarly, for easy interpretation of the aggregated index of climate change adaptive capacity in terms of percentage, the minimum-maximum normalization method was applied.

$$CCACI_{i,normalised} = \frac{CCACI_i - CCACI_{MIN}}{CCACI_{MAX} - CCACI_{MIN}} \quad (2)$$

Where $CCACI_{i,normalised}$ is the normalised overall index of climate change adaptive capacity for each respondent, ranges between zero and one; $CCACI_i$ is each respondent's climate change adaptive capacity index to be normalized; $CCACI_{MIN}$ denotes the minimum value of the climate change adaptive capacity index; $CCACI_{MAX}$ is the maximum value of the climate change adaptive capacity index.

7 Factor loadings are the correlation between the factors and the original indicator variables.

8 The weights were the predicted scoring coefficients

Table 2. Categorization of the Adaptive Capacity Levels

Adaptive Capacity Level	Ranges of Climate Change Adaptive Capacity Indices
Low Adaptive Capacity	0 – 0.33
Moderate Adaptive Capacity	0.34 – 0.66
High Adaptive Capacity	0.67 – 1.00

Food Insecurity: Foster, Greer and Thorbecke (FGT) Indices

The Foster, Greer, and Thorbecke indices were used to determine the incidence, depth and severity of food insecurity among the respondents. These indices have been widely applied in empirical studies because they are reliable and additively decomposable (Oyinbo and Olaleye, 2016). Following Ibrahim et al. (2019) and Ogunniyi et al. (2021), this study used the two-thirds of the mean monthly per capita household food expenditure (MPCHFE) as the household food security line.

The FGT index can be expressed generally as follows:

$$P_{\alpha} = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{Z - Y_i}{Z}\right)^{\alpha} \qquad (3)$$

Where:

P_{α} = Foster, Greer and Thorbecke index ($0 \leq P \leq 1$)

N = total number of respondents i.e. the total farming households sampled

q = number of respondents below the food security line i.e. the number of food insecure people

z = the food security line [defined as 2/3 of mean Per-capita daily food expenditure of the ith sampled household]

Y_i= Per-capita monthly food expenditure of the ith household

α = non-negative food security aversion parameter (0, 1 or 2); where P0 = food insecurity headcount; P1 = food insecurity depth and P2 = food insecurity severity respectively

Logit Regression Model

The logistic model was employed to determine the effect of adaptive capacity to climate change and other socioeconomic characteristics on the farming households' food security status in the study area. Logit regression is applicable because the dependent variable is dichotomous (binary) and not continuous (Greene, 2008), which indicates whether or not the farming household is food secured. The model is explicitly stated thus;

$$Y^* = X\beta + \varepsilon$$

$$Y_i = \begin{cases} 1 & if\ Y_i^* > 0 \\ 0 & otherwise \end{cases} \quad (4)$$

Where:

Y* is the underlying response variable in which $Y_i = 1$ if household is food insecure, and 0 if food secure

x_1= Sex of household head (1 if male, 0 female)

x_2= Age of household head (in years)

x_3= Household size (number of persons in the household)

x_4= Household head's years of formal education (number)

x_5= Cultivated land area (in hectares)

x_6= Extension contacts (1 if household had access to government extension, 0 otherwise)

x_7= Credit access (1 if access, 0 if otherwise)

x_8= Farmers' association membership (1 if the farmer is a member, 0 if otherwise)

x_9= Moderate Climate Change Adaptive Capacity (1 if household has moderate adaptive capacity, 0 otherwise)

x_{10}= High Climate Change Adaptive Capacity (1 if household has high adaptive capacity, 0 otherwise)

Results and Discussion

Descriptive Statistics of Respondents' Socioeconomics Characteristics

Table 3 presents the socioeconomic characteristics of the sampled households. Most farming households are male headed, with an average age of 48 years and a household size of 7 persons. This indicates that most household heads are still economically active, more receptive to innovation, and can withstand the stress involved in agricultural production as well as adapt to climate change, given their access to and willingness to utilise modern information and technology (Gbetibouo, 2009; Jiri, Mafongoya and Chivenge, 2017). About two-thirds (64.6%) of the household heads completed at least primary education, while 34.1% had no formal education. Ali and Erenstein (2017) explained that educated farming households are more likely to be aware of and adopt agricultural methods and innovations to cope with climate risk. The mean farm size is 3.2 ha. About 47.2% of the farming household heads belong to a farmers' association, and 53.7% of them had contacts with extension agents, while credit was accessible by just 29.7% of the farming households.

Table 3. Descriptive Statistics of the Respondents

Variables	Frequency	Percentage	Mean
Age			
20 to 30	38	15.4	
31 to 40	56	22.8	
41 to 50	49	19.9	48.1
51 to 60	51	20.7	
Above 60	52	21.1	
Sex			
Male	184	74.8	
Female	62	25.2	
Marital Status			
Single	19	7.7	
Divorced	3	1.2	
Married	210	85.4	
Widowed	14	5.7	
Education			
No Education	84	34.1	
Primary	76	30.9	
Secondary	67	27.2	6.01
Diploma/NCE	7	2.8	
HND/BSc	9	3.7	
Adult Literacy	3	1.2	
Household Size			
≤ 3	36	14.6	
4-6	104	42.3	
7-9	55	22.4	6.87
10-12	34	13.8	
> 12	17	6.9	
Farm Size (Ha)			
≤ 1	73	29.7	
1.01 – 3.00	100	40.7	
3.01 – 5.00	43	17.5	3.2
5.01 – 7.00	5	2.0	
> 7.00	25	10.2	
Extension Contact			
Yes	132	53.7	
No	114	46.3	
Access to Credit			
Yes	73	29.7	
No	173	70.3	
Membership in Farmers' Association			
Yes	116	47.2	
No	130	52.8	
Off-Farm Income			
Yes	124	50.4	
No	122	49.6	

Descriptive statistics of adaptation strategies adopted by Respondents

Table 4 presents the several adaptation strategies chosen by the respondents. The result shows that among other strategies, intercropping (83.3%), field fallowing (74.4%), fertiliser application (70.3%), crop rotation (67.9%), changes in planting period (67.1%) and mulching (64.2%) are the major adaptation strategies practised by the respondents. It was observed that most farmers intercropped cassava with maise (two major staple crops that constitute a major percentage of household diet) and with vegetables, probably to ensure household food availability. However, integrated pest and disease management (41.5%), erosion control (33.3%) and integrated water management (15.0%) were less adopted. These strategies are consistent with those reported by other studies (Ojo and Baiyeghuni, 2020; Adeagbo, Ojo and Adetoro, 2021) in Southwest Nigeria.

Table 4. Distribution of Adaptation Strategies Employed by Respondents

Adaptation Strategies	Frequency	Percentage (%)
Change in planting period	165	67.1
Erosion Control	82	33.3
Crop Rotation	172	69.9
Fertiliser Application	173	70.3
Mulching	158	64.2
Intercropping	205	83.3
Integrated pest & disease mgmt.	102	41.5
Integrated water management	37	15
Field Fallowing	183	74.4

Distribution of Respondents' Level of Climate Change Adaptive Capacity

Results shown in Table 5 indicate that most (61.0%) of the households are in the high adaptive capacity category with an average adaptive capacity score of 0.67, which falls within the high adaptive capacity level ($0.66 \leq CCACI \leq 1$). This result is in line with Chepkoech et al. (2020), who reported that about 66% of their respondents had either moderate or high capacity to adapt to climate change. However, 4.1% of the households fall in the low adaptive capacity category, suggesting that they are not well placed to adjust to the changes and uncertainties of climate, which may be detrimental to their wellbeing and livelihood.

Analysis of Farm Households' Food Security Status

Table 6 provides information about households' food security profiles and food expenditure. The mean monthly per capita household food expenditure was ₦4408.50k ($12.3), while the food security line was ₦2939.10k ($8.2). This is similar to the food security line of ₦2643.663 reported by Ogunniyi et al. (2021). Based on these, the food insecurity headcount ratio (P_0) shows that 45.0% of the households are food insecure, with a gap (P_1) and severity index (P_2) of 0.17 and 0.09, respectively. This suggests that an average food-insecure household in this study needs 17.0% (₦499.65k ₦ $1.4) of the food insecurity line to become food secure, while 9.0% of the food insecure farm households are in very severe food poverty.

Table 6. Food Security Status of the Respondents

Food Insecurity Indices	Values
Headcount (P_0)	0.45
Gap (P_1)	0.17
Severity (P_2)	0.09
Average per capita household food expenditure (MPCHFE)	₦4408.50
Food insecurity line (2/3 of MPCHFE)	₦2939.10

Result of Logistic Regression Model

The result of the logit regression model used to determine the effect of households' climate change adaptive capacity on food security is presented in Table 7. The result shows that household size, education and adaptive capacity significantly influence food insecurity at 1%.

The result revealed that households in the low adaptive capacity category are more likely to be food insecure than those in moderate and high adaptive capacity categories. This is critical given that climatic shocks such as erratic and unpredictable rainfall are expected to reoccur in the coming years, especially in sub-Saharan Africa (Intergovernmental Panel on Climate Change IPCC, 2014). In particular, most of these smallholder farmers operate rain-fed agricultural production, which makes their livelihood highly exposed and susceptible to climatic vagaries (Srivastava *et al*., 2017; Oyawole et al., 2019).

Household size is significantly and positively correlated with household food insecurity, indicating that households with additional members are more likely to be food insecure. As Ibrahim et al. (2019) argued, this could be due to the increased total consumption needs associated with larger households, particularly those of children who are still dependents and are unlikely to be economically productive and yet utilise a significant proportion of household income. This is in tandem with Ogunniyi et al. (2018), who reported that households with additional members are likely to have less food expenditure per capita, thus negatively affecting food security.

Furthermore, education negatively influences the probability of household food insecurity. This suggests that additional years of education received by the head of household will likely result in the household being food secure. This may be because knowledgeable farmers tend to adopt modern agricultural technology to increase their productivity and adapt to climate change with climate risk, thus ensuring greater agricultural output for household consumption and market sales (Ali and Erenstein, 2017). In addition, higher educational attainment is largely associated with better job opportunities and, consequently, increased earning potential in off-farm activities, which could provide additional household income for both consumption and farm investment (Mutisya *et al*., 2016; Ogunniyi *et al*., 2021)

Table 8. Logistic Regression Results for the Effect of Climate Change Adaptive Capacity on Household Food Security

Variables	Coefficient	Standard Error	z-value
Sex	0.084	0.397	0.21
Age	0.013	0.013	0.95
Household size	0.385***	0.077	5.02
Education	-0.107***	0.039	-2.72
Farm size (Ha)	0.001	0.062	0.02
Extension contacts	0.487	0.435	1.12
Credit access	-0.613	0.423	-1.45
Farm Association membership	0.342	0.454	0.75
Medium adaptive capacity	-2.596***	0.708	-3.66
High adaptive capacity	-5.644***	1.169	-4.83
Constant	-0.237	0.897	-0.26
LR chi2(10) = 57.84			
Prob > chi2 = 0.0000			
Pseudo R2 = 0.22			
Log likelihood = -100.68			

Note: 1%, 5%, and 10% level of significance are denoted by ***, **, *; represent

Conclusion

This study was designed to identify the various strategies employed by farm households in adapting to climate change, determine their adaptive capacity level, and analyse its effect on household food security in Oyo State, Nigeria. Intercropping, field fallowing, fertiliser application, crop rotation, changes in planting period, and mulching were the dominant strategies adopted by the farmers. More than half of farm households had high adaptive capacity, while few had a low adaptive capacity to climate change. However, about one-third of the households were food insecure, with a food insecurity gap and severity index of 0.17 and 0.09, respectively. The results from the logit regression model show that households with low climate change adaptive capacity have a greater probability of being food insecure relative to households with moderate and high climate change adaptive capacity.

Similarly, large households and those with uneducated heads are also likely to be food insecure. The findings of this study underscore the necessity to enhance smallholder farmers' ability to adapt to the negative impacts of climate change and its adverse effect on national food security. This includes deliberate investment in rural infrastructure (such as rural roads and communal irrigation schemes) and credit access to farming households to purchase farm implements and machinery. Furthermore, public investment in improving access to education (both children and adult literacy) in rural areas should be increased.

Conflict of interests

The authors declare no conflict of interest.

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