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Management and climatic pressure on the efficiency performance of snail farming in Nigeria: A trend stochastic frontier approach from 2019 – 2021

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Abstract

Livestock farming in Nigeria is having its share of climate variability problems which can affect its sustainability, snail is one of the livestock products that are highly susceptible to climate issues because they are subjected to several limitations like a longer period of hibernation and heat stress which increases mortality. Due to the health benefit of snail meat that has made its production very lucrative, it became necessary to conduct this study on the management and climatic pressure on the efficiency performance of snail farmers by adopting a stochastic frontier approach to operationalize the stated objectives using secondary data. The focus of the study was to establish the technical and profit efficiency of the farmers over the time trend of production. However, the study found that snail farming recorded more technical efficiency (0.940) value in 2021, whereas 2019 recorded the least technical efficiency (0.714). With this high TE record in 2021, the study caveat that farmers are producing 6% below optimal production capacity which must be closed up in a short while to stay efficient in the sector. More so, information about the profit efficiency (PE) revealed that before an average farmer attains the level of most profit-efficient snail farming, the farmer would have to up his/her profit by 25.3% (2019), 33.7% (2020), and 11.9% (2021). The study also found that the most profit-inefficient farmer would have to improve their profit by 66.8% (2019), 99.8% (2020), and 72.4% (2021) before they can come up to the most profit-efficient farmer. The study also revealed that educated farmers are more technically efficient. Interestingly, the study revealed that snail farming in the study is stock, fumigant, feed, labour, and capital dependent. The study also observed that humidity and rainfall are the climate variability that negatively affects the TE of the farmers. The study, therefore, recommends that farmers should adopt climate-friendly agriculture as a way to survive the variability that threatens food security.

Keywords: Management; Climatic pressure; Efficiency, Performance; Snail farming

1 Introduction

The snail, botanically known as *Archatina achatina* is of Western, Eastern and South Africa origin and has elongated shells [1]. The fact that snails can lay nearly one million eggs a year makes it prolific to return good output [1, 2]. What makes snails unique is that they are micro-animals that are characterized by their small body size that requires minimal effort. Supportively, Kaine and Ume [3] found that microlivestock are becoming more important in West African homes, where snail meat has traditionally been an important part of the home diet. Snail breeding is not capital intensive and could be obtained by anyone, regardless of economic conditions or livelihood. Snail production is an affordable, low-cost enterprise for poor families, regardless of the size of the enclosure or the area or location of available land. Snails

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can be fed with garbage and leaves such as papaya, cassava, okra, watermelon skin, and pineapple, resulting in very low feeding costs [1, 4].

Nutritionally, Aderounmu *et al.* [5]; Engmann *et al.* [6] divulge that snail meat contains 37-51% protein; highest in poultry (18.3%), sheep (16.4%), guinea pigs (20.3%), cattle (17.5%), and pigs (14.5%). Snail is low in cholesterol and fat (0.05-0.08%), has an iron content of 45-59 mg / kg, is medically recommended for pregnant women, and is also used to treat diseases such as anemia, hypertension, and vitality in men, stomach, heart diseases, asthma, ulcer, rheumatism, and pile among others. The protein content reported by Engmann *et al.* [6] and Aderounmu *et al.* [5] contradicts the early study by Imevbore and demosun [7] who alleged that the edible part of snail has 88.37% protein. Uboh *et al.* [8]; Adeola *et al.* [9] suggested that snail meat contains calcium, iron, magnesium, zinc, and very low fat which makes it healthy for every age. The results of a proximate analysis by Seedi *et al*. [10] submitted that snail meat nutritionally contains 18.2-20.7% - crude protein, 2.9% carbohydrate, 1.4% Ether extract, 0.1% crude fibre, 1.4% ash, 5% Nitrogen free extract, 12.2mg/100g iron, 1.2% water, and 73.7% water. Despite the economic and health benefit inherent in snail production, this micro livestock is susceptible to adverse weather conditions brought by climate change and its variability.

Due to varying degrees of technical and environmental factors, the world's production of snail meat has not kept pace with demand, which is credited to environmental manipulations like urbanization, deforestation, burning of biomass, the use of harmful chemicals that contributed greatly to climate change impact [11]. Climatic variables are among the determining factors in the survival, growth and sustenance of any organism in its niches. Climate change is already hurting agriculture through the rise in temperature, solar radiation, low or high humidity, inconsistent precipitation, etc. A concerned scholar named Nnodim and Ekpo in their study alluded that the incidence of wildfire, high soil temperature, unpredictable rainfall pattern, water logged soil, low-level humidity, and low soil Ph are the variables that adversely affected snail production in Rivers State [12]. Thus, the seasonal variations in snail physiology are linked to annual cycles of photoperiod, temperature, humidity, and water availability which tend to elongate the period of hibernation, increase stress levels, and increase mortality [11]. If these climate variabilities are not put in check, they can harm the livelihood opportunity of snails which is considered an alternative for rural development and a profitable livestock system [13, 14].

Several studies existed on the technical efficiency of snail production in a different location in Nigeria and around the world. The study by Aminu *et al.* [1]; Kaine and Ume [3]; Aderounmu *et al.* [5]; Onwuchekwa and Nwankwo [15]; Ojo and Zira [16] investigated the technical efficiency of snail production as well as paying attention to the farmer's management profiles that influence the outcome of this efficiency. None paid attention to the climate variabilities acting as external factors that negate the output of frontier efficiencies. Another point that necessitates the novelty of the study is that the profit efficiency of the farmers was also thought to be influenced by climate variabilities. All the works reviewed used cross-sectional data, but this present study used panel data from 2019 to 2021. The choice of these three years gap was to consider an alternative source of livelihood for rural farmers that should be used to cushion the impact of the Covid-19 lockdown that heated countries' economies in 2021.

Because of the abundance of works in the area of technical efficiency (TE), the study adopted the definition used in Surendra which viewed TE as the enterprise's ability to obtain maximum output from a given set of inputs [17], this view was adopted from Battese and Coell's concept [18]. Other studies by Obianefo, Nwagwe *et al.* [19]; Nnamdi *et al.* [20]; Ajayi *et al.* [21] reiterate that TE is the extent to which efforts, time and cost are well managed in the production process to achieve the intended objectives. Considering the inclusion of profit efficiency in this study, we referred to efficiency as the success of producing a large amount of output from a given or fixed set of inputs for profit maximization purposes. A specific definition by Adesina and Djato viewed profit efficiency as the profit gained from operating on the profit frontier by taking into consideration inputs specific prices and factors affecting prices [22]. The study by Okeke-Agulu *et al.* reported that the TE of snail farmers in Imo State is influenced by farming experience and credit access, age and stock size [23]. They also reported that farm size, labour and feed are the most important inputs in snail farming. Aminu *et al.* reported that snail farmers in Ogun State had a TE index of 0.615 [1]. A similar study by Onwuchekwa and Nwankwo in Abia State found that educational attainment, farming experience, extension contact, and cooperative membership have a positive influence on TE. They also summarized that the mean TE index was 0.756 [15]. Based on all the reviewed studies, only Akharume *et al.* reported a profitability ratio of 5.5 for snail production in Southwest Nigeria [24]. The study by Ojo and Zira revealed that education, experience and farm size positively explained 73.8% of the total variation in the profit made by snail farmers in Plateau State [16]. Snail farming in Southeast Nigeria is profitable and its success in production output is dependent on age and level of education [3].

Haven established a scarcity of scholarly works in the area of management and climatic pressure on the efficiency performance of snail farming in Northcentral Nigeria. It is arguably necessary that this study focuses on some specific objectives which are to:

- Execute the maximum likelihood estimation of the production and profit function of the model with the hope to arrive at the technical and profit efficiency of the farmers, and
- Describe the determinants of technical and profit efficiency in the study

2 Material and methods

2.1 Study Area

The study was conducted in Abuja which is part of the States in the North-central geopolitical zone of Nigeria. Created in 1976 from Kaduna, Niger, Kwara and Plateau States, Abuja has a boundary with Kaduna State to the North and Kogi State to the South. Nasarawa State to the East and Niger State to the West [25]. There are six area councils (Abaji, Gwagwalada, Bwari, Kwali, Kuje, and Abuja Municipal Area Councils) in Abuja from which Abuja Municipal Area Council was precisely selected for the study. Abuja is located within Latitude 9° 4' 20.1504'' N and Longitude 7° 29' 28.6872'' E. The average annual temperature and precipitation are 26.0 °C and 1469 mm respectively. The average annual humidity is 34% [25]. Abuja has a total land area of 1,769 km^2 predominantly a grassy savannah region. Apart from crop production, communities in Abuja are good with the rearing of livestock at a subsistence base.

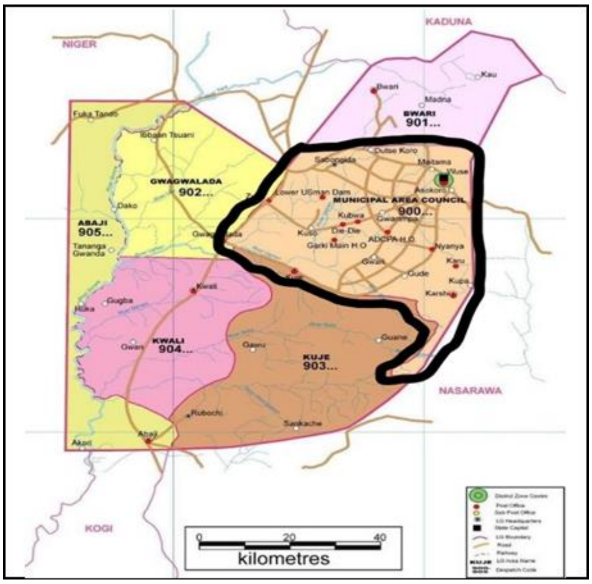

Figure 1 Map of Abuja showing the area council where the study was carried out

2.2 Sampling Technique and Sample Size

The sampling technique used involved a purposive selection of Abuja from all the seven States in the North-central geopolitical zone in Nigeria, this was due to a high number of Gardens and resort centres in Abuja that has potential for snail and other livestock farming. A multi-stage sampling technique was adopted to arrive at the sample size for the study. In stage one, Abuja Municipal Area Council was purposively selected for convenience, from where Karu, Asokoro, and Nyanya were randomly selected. In stage two, a snowball referencing technique was used to locate a snail farmer in each location. In the third stage and last, twenty-three (23) snail farmers were sampled over a three-time period (2019 – 2021). Their record books were sighted and the secondary information necessary to operationalize the study objectives were collected. This brought the sample size to sixty-nine (69), and two hundred and seven (207) total observations for the study.

2.3 Method of Data Collection

Secondary data was used for this study. Data were collected through the use of structured questionnaires. The questionnaire was designed to capture the important variables such as socioeconomic characteristics of the snail farmers, climate variability trends and its challenges to snail farming. In each location, one research assistant who is familiar with the area was engaged, trained and mobilized to collect the data as an enumerator for data collection. Therefore, secondary data were collected through the administration of a structured questionnaire to capture recorded information from the farmers. The fieldwork lasted for three weeks.

3 Stochastic Frontier Model

We applied a stochastic frontier production function using a maximum likelihood estimation approach developed by Aigner *et al.* [26] and was used in Ananthi *et al.* [27]; Obianefo, Ng'Ombe *et al.* [28]; Ng'ombe [29]. The implicit form of the model is defined as:

$$Y_i = f(X_i, \beta_i)\epsilon, i = 1, \ldots, N \qquad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

where: Y_i is all the snails produced by ith snail farmer, X_i is the vector of inputs used in the production process, and β_i is the parameter estimated, ϵ is the stochastic error term which can be decomposed into:

$$\epsilon = v_i - u_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where: v_i is a symmetric error that accounts for random variations in snail output due to some factors beyond the farmer's control; such as measurements errors, climate change impact, pest and disease outbreaks and other exogenous variables not included in the model that are assumed to be independently or identically distributed [26, 30]. v_i follows a normal distribution $N(0, \sigma^2 v)$ which is independent of u_i , and ui is a non-negative truncation that represents technical inefficiency in snail production relative to the stochastic frontier model. u_i is assumed to be normally and independently distributed with mean ui and variance $N(u_i, \sigma^2)$.

On the other hand, the implicit form of profit function used in Idiong and Iko [31] is specified as:

$$\pi_i = f(P_i;\beta_i)\exp\ (v_i\text{-}u_i),\ i=1,2,\ldots n. \qquad \ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where:

π_i is the profit of the *ith* farm, P_i is the price of inputs and β_i remains as defined in equation 1. The v_i's are assumed to be independent and identically distributed random errors; normal $N(0, \sigma^2 v)$ distribution, independent of the u_i's. The u_i's are profit inefficiency effects, which are assumed to be non-negative truncation of the half-normal distribution $N(u_i, \sigma^2)$.

We further expressed the profit efficiency (PE) of snail farmers as the ratio of observed profit to the predicted maximum profit for a best practice. The study also defined the technical efficiency (TE) of the *ith* firm as the ratio of observed output to the corresponding frontier or expected output given the available technology in the area [19]. The *PE* adopted from Idiong and Iko [31] is mathematically expressed as:

$$PE_i = \frac{\pi_i}{\pi^{max}} = \frac{\exp[\pi(P_i;\beta_i)\exp(lnV_i)\exp(lnU_i) - \theta}{\exp[\pi(p_i;\beta_i)\exp(lnV_i) - \theta} = \exp(U_i) \qquad \ldots\ldots\ldots\ldots\ldots\ldots 4$$

$$TE_i = \frac{Y_i}{Y^{max}} = \frac{f(X_i;\beta_i)\exp(v_i - u_i)}{f(X_i;\beta_i)\exp(v_i)} = \exp(u_i) \qquad \ldots\ldots\ldots\ldots\ldots\ldots 5$$

At this stage, the researcher(s) applied the likelihood ratio test adopted by Kumbhakar *et al*. [32]; Obianefo *et al.* [33]; Obianefo *et al.* [28]; Huang *et al*. [34]; Mensah *et al.* [35]; Ng'ombe [29]; O'Donnell *et al.* [30] to test the hypothetical assumption of using a more flexible Trans-log (TL) model over a restrictive Cobb Douglas (CD) model. The rule is that if the LR value calculate is below the table value, Ho should be accepted and the SFA should proceed with CD. The LR test statistic is computed as $\gamma = -2[\ln(L(Ho)) - \ln(L(H_1))]$, where ln(L(Ho)) is the restricted log-likelihood value from CD and $\ln(L(H_1))$ is the unrestricted log-likelihood value from TL. The degrees of freedom for the chi-square distribution was fifteen for the production function, calculated as the difference between the number of parameters estimated under H_0 and H_1. The LR value was 8.93, which is lower than the critical value of 37.697 @ 0.001 probability level. Thus, we failed to reject the null hypothesis that the flexible trans-log function is not the best model; the researcher(s) later proceeded with the CD model. We equally tested the presence of inefficiency components in both production and profit functions. This was achieved by estimating a production/cost function without the inefficiency term and another with the efficiency term. A computed LR value of 587.94 and 297.83 ($p < 0.001$) was obtained for production and profit function respectively, which resulted in the rejection of the null hypothesis of no presence of inefficiency terms. Estimation of all the models was done in Frontier 4.1.

However, the researcher(s) confidently and explicitly defined the production function as follows:

$$LnY_i = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \beta_4 LnX_4 + \beta_5 LnX_5 + (v_i - u_i) \text{ ....6}$$

Where: Y_i = observed snail output (kg), X_1= stock (No), X_2 = fumigant (litre), X_3 = quantity of feed (kg), X_4 = labour (man-day), X_5 = capital (USD).

On the other hand, the profit function of the SFA is explicitly specified as:

$$Ln\pi_i = \beta_0 + \beta_1 LnP_1 + \beta_2 LnP_2 + \beta_3 LnP_3 + \beta_4 LnP_4 + \beta_5 LnP_5 + \beta_6 LnY_{i5} + (v_i - u_i) \text{ .... (7)}$$

where: π_i = normalized profit obtained from the total revenue less the variable cost and divided by the unit price of snail (USD), P_1= average price of the stock (USD), P_2 = average price of fumigant (USD), P_3 = average price of feed (USD), P_4 = average price of labour (USD), P_5 = average price of production tools (USD), and Y_i = observed snail output (kg).

The individual specific technical and profit efficiency is therefore given in equation 8 and 9 as:

$$TE_i = 1 - TE \quad \text{..................} \quad 8$$

$$PE_i = 1 - PE \quad \text{..................} \quad 9$$

To bring an average snail farmer to the point of a technically-efficient farmer or profit-efficient farmer, they will have to minimize the use of inputs and optimize output by $1 - (TE_{mean}/TE_{max})$ or $1 - (PE_{mean}/PE_{max})$. Furthermore, to make the least snail farmer arrive at the point of most technically efficient, they will have to minimize the use of inputs and optimize production by $1 - (TE_{min}/TE_{max})$.

The determinants of technical or profit inefficiency in snail production followed the joint maximum likelihood estimation procedure in a single stage suggested by Coelli [36] which is defined as:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8$$

Where: Z_1 is humidity (%), Z_2 is the temperature (°C), Z_3 is sunshine (days), Z_4 is rainfall (mm), Z_5 is age (year), Z_6 is formal education (years), Z_7 is the household size (No), Z_8 is snail rearing experience (years), δ_0 is a constant term, and δ_1 - δ_8 is the inefficiency parameters.

4 Results and discussion

4.1 Effect of Climate Variability on Snail Production

The information about the effect of climate variability on snail production in Northcentral Nigeria is shown in Figure 1, the study found that the majority (89%) of the farmers accepted that climate variability causes an increase in the stress level of the snail stock. 76% of the farmers also noted that climate variability reduced farmers' access to food for the snail; this is because it may tend to reduce the production of the vegetables to be used as food. Unfavourable climate variability causes hibernation and high mortality as reported by 73% of the farmers. Hülya and Önder [37] noted that hibernation is a technique developed by the snail to adapt to harsh climates or weather conditions, if this hibernation period elongates, it will affect the performance of the small animal some of the variables that may tend towards increasing the hibernation period include those reported by Nnodim and Ekpo [12] as the incidence of wildfire, high soil temperature, unpredictable rainfall pattern, water logged soil, low-level humidity, low soil Ph.

Equally, 63% and 61% responded that climate variability causes a reduction in the size of snails and a reduction in water availability respectively. The remaining farmers reported that climate variability causes exposure to much sunlight (56%), increase disease outbreak (52%), and increase harsh weather condition (50%). To this effect, Surendra and Mohamad [38] submitted that climate variability is among the chief determinants that significantly affect agricultural and livestock production.

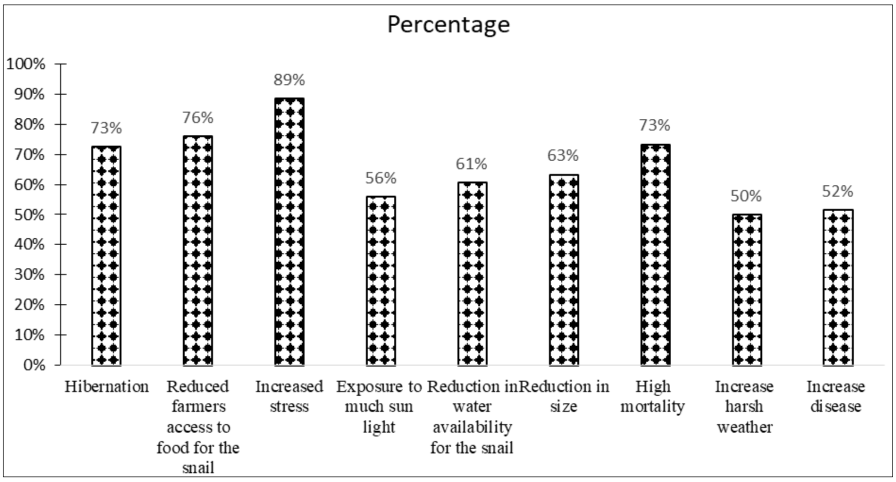

Figure 2 Effect of climate variability on snail production

4.2 Parameter Estimates of Production Function for Snail Farmers

Table 1 Parameter estimates of the production function for snail farmers

Inputs	Parameter	coefficient	standard-error	t-ratio
Constant	β_0	4.091	0.133	30.73
Stock	β_1	0.045	0.008	5.68***
Fumigant	β_2	0.025	0.011	2.23**
Feed	β_3	0.378	0.018	21.32***
Labour	β_4	0.047	0.022	2.13**
Asset depreciation	β_5	0.026	0.011	2.45**
Model diagnostics				
Sigma-squared		0.273	0.036	7.66***
Gamma		1.000	0.000	2339.09***
Log-Likelihood		123.197		
LR test	130.00			

Source: Field Survey, 2022

Table 1 shows the maximum likelihood estimation of the trend of snail production in the study. Breeding stock, fumigant, feed, labour and asset depreciation are the important resources in snail production with the expected positive signs.

The coefficient of stock (β_1 = 0.045 @ 0.01) was positive and significant at a 1% level of probability, this implies that a 1% increase in the quantity of stock introduced to the farm is associated with a 4.5% increase in output. This result is an indication that the quality of the breed used by the farmers is important to increase output in the study area. This result corroborates the work of Okeke-Agulu *et al.* [23] who reported a positive relationship between snail output and breeding stock in their study.

The coefficient of fumigant (β_2 = 0.025 @ 0.05) was positive and significant at a 5% level of probability, this implies that a 5% increase in the quality and quantity of fumigant used to disinfect the space before and after stocking is associated with a 2.5% increase in snail output in the study area. Disinfectants should be used in an appropriate manner as well as the right quantity should be mixed. This dependability on fumigant and other agrochemical inputs should be used in an environmentally friendly manner to ensure sustainability without compromising future interests [28].

The coefficient of feed (β_3 = 0.378 @ 0.01) was positively significant at a 1% level of probability, this implies that a 1% increase in the quantity and quality of feed used for the production is associated with a 37.8% increase in snail output. The body size and weight gained by most livestock and small animals are proportionate to the quality of feed used. This result indicates that feed contributed more to the value of snails produced in the study. This is in agreement with Ahiale *et al.* [39] whose study found that the quantity of feed directly increased carcass yield by 29.6% at a 1% probability level in their study.

The coefficient of labour (β_4 = 0.047 @ 0.05) was positively significant at a 5% level of probability, this implies that snail production is labour dependent in the study, and a 5% increase in labour employment on the farm is associated with a 4.7% increase in snail output in the study area. This result is different from the report of Aminu *et al.* [1] who found a negative relationship between labour use and snail production in Ogun State.

The coefficient of capital (β_5 = 0.026 @ 0.05) was positive and significant at a 5% level of probability, this implies that a 5% increase in the use of productive assets is associated with a 2.6% increase in snail output. This finding on assets is in agreement with Onwuchekwa and Nwankwo [15] who corroborated that assets influenced a 3.8% increment in snail output in their study.

Down the table are the model diagnostic statistics from the estimates. The Gamma value of 1.000 was significant at a 1% level of probability meaning that a 100.0% deviation from frontier output was coming from the inefficiency components (socioeconomic and climate variables) of the model. Again, the Sigma-squared value of 0.273 was significant at a 1% level of probability which confirm a 27.3% variance in expected output. The LR test value of 130.00 is greater than the critical value of 30.58 at 15 degrees of freedom given by Kodde and Palm [40] at a 0.01 probability level. The implication is that the inclusion of the inefficiency components improved the results better.

4.3 Technical efficiency index of snail production

The technical efficiency (TE) index for snail production from 2019 to 2021 is presented in Table 2. The table shows that the majority (70%) of farmers in 2019 had technical efficiency index ranging from 0.600 to 0.800, while the remaining farmers recorded their TE index from 0.401 to 0.600 (25%), and 0.801 and above (6%). Again, the farmers in 2020 had a greater proportion (39%) of their TE index from 0.801 and above, while the remaining 38% and 23% had TE index ranging from 0.601 – 0.800, and 0.401 and 0.600 respectively. Equally, the majority (93%) of the farmers in 2021 recorded a TE index of 0.801 and above, while the remaining 4% and 3% had TE index ranging from 0.601 – 0.800, and 0.401 and 0.600 respectively. Averagely; the farmers had mean TE values of 0.714 (2019), 0.808 (2020), and 0.940 (2021). The study has interestingly revealed that farmers' production ability improves on annual bases. This result indicates that snail farmers are producing 28.6% (2019), 19.2% (2020), and 6.0% (2021) below their optimal or expected value. The minimum and maximum TE values are in agreement with the work of Aminu *et al.* [1], whereas, the mean TE value in 2018 is in agreement with the 0.756 indexes reported by Onwuchekwa and Nwankwo [15]. Since 2021 recorded the least deviation from the optimal output, it could mean that the outbreak of Covid-19 may have encouraged people to develop an interest in agriculture to produce at least their personal food during this recession time. To address the difference in current output and the maximum potential output, it will be necessary to tackle the climate variability problems that negate snail farmers' performance.

Table 2 Technical efficiency index of snail production

Efficiency index	2019	2020	2021	Pooled
0.401 - 0.600	17 (25%)	16 (23.2%)	2 (2.9%)	35 (16.9%)
0.601 - 0.800	48 (70%)	26 (37.7%)	3 (4.3%)	77 (37.2%)
0.801 and above	4 (6%)	27 (39.1%)	64 (92.8%)	95 (45.9%)
Total	69 (100.0)	69 (100.0)	69 (100.0)	207 (100.0)
Min	0.425	0.450	0.420	0.420
Max	0.997	0.997	0.992	0.997
Mean	0.714	0.808	0.940	0.820
Std. Dev.	0.154	0.189	0.095	0.177

Source: Field Survey, 2022. The figures in parentheses are percentages

The pooled data show that snail farmers in the Northcentral region of Nigeria are producing 18.0% below their optimal capacity. This shortfall should encourage the adoption of climate-friendly agriculture to ameliorate the situation in the short run.

For an average farmer to arrive at the level of most technically efficient snail farming, the farmer would have to maximize output to increase production by 28.4% (2019), 19.0% (2020), and 5.2% (2021), which was computed from the method used in Obianefo *et al.* [41] that is mathematically defined as 1 – (mean/max). On the other hand, the most technically inefficient farmer would have to increase output by 57.4% (2019), 54.9% (2020), and 57.7% (2021) before they can arrive at the frontier point. This was also computed from 1 – (min/max). The study revealed that farmers' efficiency increases every year, this is because they gain more experience from more practice.

4.4 Determinants of Technical Efficiency of Snail Production

The climate variability and management profiles of the farmers influencing their technical efficiency were equally investigated in a one-stage stochastic frontier analysis. Thus, the determinants of the technical efficiency of snail farmers in the study are presented in Table 3. Variables with a positive coefficient imply a negative effect on technical efficiency. However, those with negative coefficients indicate a positive effect on technical efficiency. A quick check on these results indicates that humidity and rainfall negatively affected technical efficiency. They are the climate variability that caused the deviation from optimal production over the time trend. Furthermore, sunshine, age and years of formal education positively and significantly affected the technical efficiency of snail frontier output. This finding suggests that education is of greater advantage to snail production in the study area. Uchemba *et al.* [42] noted that education will make the adoption of basic agronomic principles increase the productivity of farmers. The education report is also in agreement with Aminu *et al.* [1] who noted that education positively influenced the technical efficiency of snail farmers in Ogun State, Nigeria.

Table 3 Determinants of technical efficiency of snail production

Management and climate variables	Parameter	Coefficient	standard-error	t-ratio
Constant	α_0	5.559	1.299	4.28
Humidity	α_1	0.003	0.001	2.00**
Temperature	α_2	-0.014	0.010	-1.40
Sunshine	α_3	-0.141	0.026	-5.45***
Rainfall	α_4	0.019	0.003	5.81***
Age	α_5	-0.009	0.005	-1.76*
Years of formal education	α_6	-0.020	0.011	-1.86*
Household size	α_7	-0.011	0.011	-0.95
Snail rearing experience	α_8	-0.001	0.004	-0.16

Source: Field Survey, 2022.

4.5 Estimation of the Profit Efficiency

Table 4 shows the maximum likelihood estimation of the profit function of snail farmers in the study area. The price of stock and labour had the expected negative sign, while capital, feed, and output had the expected positive sign. The diagnostic part of Table 4 showed an LR test value of 297.83 which was greater than the critical value of 34.80 given by Kodde and Palm (1986) at a 0.01 probability level at 18 degrees of freedom. The implication is that the inclusion of the inefficiency components improved the model as justified by a more negative Log-likelihood value of -80.830. The study had a Sigma square value of 4.361 and a Gamma value of 0.997, which implies that a 99.7% deviation from the frontier profit was caused by the inefficient components of the model.

The coefficient of the price of a stock (β_1 = 0.492 @ 0.01) was negatively significant at a 1% level of probability, this implies that an increase in the price of snail stock is associated with a 49.2% reduction in profit in the study area. The price of snail stock represented the most important input to consider during production to maximize profit. Again, the coefficient of the price of feed (β_3 = 0.095 @ 0.05) was positive and significant at a 5% level of probability, this implies that a 5% increase in the price of feed will increase the profit of the enterprise by 9.5%. This result is an indication that farmers in the study are more interested in the quality of feeds and not the price. Another reason could mean that the farmers can mark up their profit on the number of snails sold which makes them pay less attention to the price of feeds.

The coefficient of the price of labour (β_4 = 0.254 @ 0.01) was negative and significant at a 1% level of probability, this implies that a 1% increase in the price of labour will amount to a 25.4% reduction in expected profit from the sales of the snail's is the study area. This result is in agreement with Wongnaa *et al.* [13] who found that an increase in the wage rate will lead to a decline in the profitability of maize farming in Ghana. Expectedly, the coefficient of capital (β_5 = 0.052 @ 0.01) was positively significant at a 1% level of probability, this implies that a 1% increase in capital will increase the profit frontier of the farmers by 5.2%. This result is consistent with Assa *et al.* [43] who found a positive relationship between capital and profit in their study. Furthermore, the coefficient of snail output (β_5 = 0.506 @ 0.01) was positive and significant at a 1% level of probability, this implies that a 1% increase in snail output is associated with a 50.6% increase in profit for the farmers. This study finds it necessary to note that farmers' ability to manage both technical and resource allocation depends to a greater extent the magnitude of frontier output in the study.

Table 4 Estimation of the profit efficiency

Inputs	Parameter	Coefficient	Standard-error	t-ratio
Constant	β_0	6.201	0.792	7.83
Price of stock	β_1	-0.492	0.056	-8.75***
Price of fumigant	β_2	0.015	0.039	0.38
Price of feed	β_3	0.095	0.045	2.11**
Price of labour	β_4	-0.254	0.069	-3.70***
Capital depreciation	β_5	0.052	0.011	4.62***
Output	β_6	0.506	0.126	4.01***
Diagnostic statistics				
Sigma-squared		4.361	0.490	8.89***
Gamma		0.997	0.001	763.05***
Log-Likelihood		-80.830		
LR test				297.83***

Source: Field Survey, 2022.

Based on the profit efficiency index in Table 5, the study revealed that the majority (67%) of the snail farmers in 2019 had a profit efficiency index between 0.602 and above, while the remaining 28% and 6% had a profit efficiency index of 0.402 – 0.601, and 0.202 – 0.401 respectively. In 2020; less than half (36%) of farmer's profit efficiency index was between 0.402 - 0.601, while the remaining 30%, 22%, and 12% had profit efficiency index between 0.602 and above, 0.202 – 0.401, and 0.002 – 0.401 respectively. The farmers in 2021 submitted that the majority (93%) of the farmers had a profit efficiency index between 0.602 and above, while others are between 0.402 – 0.601 (4%), and 0.202 – 0.401 (3%) respectively.

The mean profit efficiency index of the snail farmers is 0.716 (2019), 0.639 (2020) and 0.799 (2021). The pooled sample showed a mean profit efficiency value of 0.718. These imply that in the short run, the farmers are operating at 28.4% (2019), 36.1% (2020), 20.1% (2021), and 28.2% (pooled sample) below their frontier profit. Farmers moved closer to frontier profit in 2021 which could explain the fact that Covid -19 outbreak forced people to pay more attention to agriculture since the need to produce quality foods became sacrosanct. For an average farmer to arrive at the level of most profit efficient, he/she will have to raise their profit by 25.3% (2019), 33.7% (2020), 11.9% (2021), and 25.5% (pooled sample). Equally, for the least farmer to arrive at the point of most profit-efficient farmer, he/she will have to increase or maximize frontier profit by 66.8% (2019), 99.8% (2020), 72.4% (2021), and 99.8% (pooled sample). The result of Table 5 shows an annual improvement in the profit efficiency of farmers.

Table 5 Profit efficiency index

Profit efficiency index	2019	2020	2021	Pooled
0.002 - 0.401	0 (0)	8 (12%)	0 (0)	8 (4%)
0.202 - 0.401	4 (6%)	15 (22%)	2 (3%)	21 (10%)
0.402 - 0.601	19 (28%)	25 (36%)	3 (4%)	47 (23%)
0.602 and above	46 (67%)	21 (30%)	64 (93%)	131 (63%)
Total	69	69	69	207
Min	0.318	0.002	0.250	0.002
Max	0.959	0.964	0.907	0.964
Mean	0.716	0.639	0.799	0.718
Std. Dev.	0.180	0.290	0.124	0.219

Source: Field Survey, 2022.

4.6 Determinants of Profit efficiency

The determinants or inefficiency components of the frontier profit efficiency of the study are presented in Table 6. The study found that humidity and experience had a negative influence on the profit efficiency of the snail farmers in the study area. Again, sunshine, rainfall, age, formal education, and household size positively influenced or increased the frontier profit efficiency of the farmers. Most of the variables that have a positive impact on profit efficiency like age, education, household size, and farming experience are in agreement with the study of Idiong and Iko [31] on profit efficiency and poverty status of farmers in selected rice-growing communities in Cross River State, Nigeria.

Table 6 Determinants of profit efficiency

Management and climate variables	Parameter	coefficient	standard-error	t-ratio
Constant	α_0	19.288	3.298	5.85
Humidity	α_1	0.011	0.005	2.09**
Temperature	α_2	-0.063	0.052	-1.22
Sunshine	α_3	-0.174	0.052	-3.36***
Rainfall	α_4	-0.068	0.014	-4.93***
Age	α_5	-0.085	0.021	-4.07***
Years of formal education	α_6	-0.266	0.040	-6.58***
Household size	α_7	-0.095	0.049	-1.93*
Snail rearing experience	α_8	0.033	0.019	1.75*

Source: Field Survey, 2022

5 Conclusion

This present study used a stochastic frontier model to estimate the technical and profit efficiency of snail production using time series data from North Central Nigeria. The results revealed that snail farming recorded more technical efficiency (0.940) values in 2021, whereas 2019 recorded the least technical efficiency (0.714). Despite the highest TE record in 2021, the farmers are 6% below optimal production which must be closed up in a short while to stay efficient in the sector. More so, information about the profit efficiency submitted that before an average farmer can arrive at the level of most profit efficient, he/she will have to raise their profit by 25.3% (2019), 33.7% (2020), 11.9% (2021), and 25.5% (pooled sample) using the method adopted from Obianefo *et al.* [41]. Equally, for the farmer with the least profit to arrive at the point of the most profit-efficient farmer, he/she will have to increase or maximize frontier profit by

66.8% (2019), 99.8% (2020), 72.4% (2021), and 99.8% (pooled sample) before they can come-up to the most profit-efficient farmer.

The study also revealed that educated farmers are more technically and profit efficient in snail production, this education will help the farmers to properly allocate scarce resources for sustainable snail production especially in the area of labour engagement to reduce idleness or excessive labour supply. Additionally, Ayambila *et al.* [44]; Willybrordus [45] suggested that farmers who gained more experience from their education qualifications tend to have better and improved managerial skills.

The knowledge of technical and profit efficiency will help the farmers to know the time to stop the introduction of particular productive resources. Stakeholders, on the other hand, should sensitize the populace on the health benefit of consuming snails as this will help to broaden the marketability of snails to increase the potential profit from the enterprise.

Recommendations

Due to the novelty of this study, we recommend that farmers should be trained to reduce their short-run production costs and ensure the adoption of recent technologies in production to optimize profit. As would in every empirical study, caveats in this study remain that farmers should adopt climate-friendly production processes as a means to survive the climate variability threatening food security in a world that is already at war with itself due to urbanization.

Compliance with ethical standards

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Disclosure of conflict of interest

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Data Availability Statement

Data are available upon reasonable request from the corresponding author.

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