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Climate Change Adaptation and Efficiencies of Smallholder Mushroom Farmers in Abia State, Nigeria

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Abstract

The study examined climate change adaptation and efficiencies of smallholder mushroom farmers in Abia State, Nigeria. Survey research design was used to sample 120 mushroom farmers using multi-stage random sampling technique. Data for the study were collected from primary sources through the aid of structured questionnaire. Data collected were analyzed using both descriptive statistics such as mean and standard deviation and inferential statistics such as stochastic frontier function. From the result, the study identified farm-level climate change adaptation practices engaged by the mushroom farmers to include: planting early of fast maturing mushroom variety (3.55), mushroom production technologies (3.42), pes and disease resistance varieties (3.40), avoid erosion or flood prone areas (3.39) and intensified mulching (3.35). The mean technical efficiency of the mushroom farmers was 0.731, while their mean allocative efficiency stood a 0.809. Production inputs such as spawn used, farmland, mushroom substrate, labour, chemical and capital significantly influenced both technical and allocative efficiencies while inefficiency factors also expectedly affec the inefficiencies of the mushroom farmers. The study therefore concludes tha smallholder mushroom farmers in Abia State are technically and allocativelly efficient, and they practice notable adaptation strategies to mitigate the impacts climate change in their mushroom production as climate change adaptation practices of the farmers reduces their inefficiencies. Based on the findings and conclusion drawn, the study recommends proactive extension services and agricultural developmen programmes tha will intensify efforts to train farmers on climate change adaptation practices. Hence, through intensified training and technology transfer, mushroom farmers can be helped to build resilience in the face of devastating effects of climate change, and capacity-building programmes focusing on efficien allocation of farm resources to further enhance efficiency levels of the mushroom farmers to optimize inpu use and improve productivity.

Keywords: Climate change, adaptation, efficiencies, mushroom, smallholder, Abia State.

Introduction: Mushroom cultivation is becoming increasingly successful in many regions of the world because of its short growing times, very low inputs requirements for production, easy production technologies, nutritional and economic significane of the production. Mushrooms are macro-fungi tha form visible fruiting bodies and belong to the lower plan kingdom. However, they lack chlorophyll and therefore canno photosynthesize; instead, they rely on a saprophytic mode of nutrition, thriving on decaying organic matter in dark environments (Subhas, Thakur, Bhatta, Pathak, Gautam and Aryal, 2018). Over the years, global mushroom production has expanded rapidly a commercial, medium, and small-scale levels. Presently, global annual production of edible mushrooms is estimated a around 34 million metric tons—representing abou a thirtyfold increase within the pas three decades (Osuafor, Enete, Ewuzie and Elijah, 2023). Edible mushrooms are often described as “white vegetables” or “vegetarian meat” because of their distinc aroma, flavor, and high nutritional content. They are rich in protein, fiber, vitamins, and minerals and possess considerable medicinal value, making them a preferred choice among vegetarians and health-conscious consumers. Mushroom cultivation provides a profitable enterprise, particularly for small-scale or landless farmers, due to its low space requirements and relatively shor production cycle. Mushrooms are broadly categorized as edible, medicinal, or poisonous based on their economic and health significance.Despite the economic potential of mushroom farming, climate change poses a serious challenge to its sustainability. Variations in temperature, humidity, and precipitation directly affec mushroom growth, yield, and quality, while extreme weather conditions can damage infrastructure and disrup production cycles. Globally, climate change has been identified as one of the mos pressing threats to agricultural productivity (IPCC, 2022). In Nigeria, where agriculture remains heavily dependen on rainfall, the impacts of climate-related events such as irregular rainfall, prolonged dry spells, hea stress, and increased pest and disease infestations are severe (National Oceanic and Atmospheric, 2019). These environmental changes reduce farm productivity, threaten food security, and undermine livelihoods, especially among rural households (FAO, 2018).

Studies have shown tha the effects of climate change are more pronounced in low-income and tropical countries due to limited adaptive capacity and dependence on rain-fed agriculture (Ali et al., 2021; Amusa, Igwe & Okoye, 2021). Increased frequency of floods, droughts, and other extreme events negatively influences crop yields, agricultural incomes, and household welfare (Abhishek, Sandeep, Nandini, Avinash, Revanasiddappa, Vinay and Sapana, 2022). Smallholder farmers are particularly vulnerable because of their restricted access to information, finance, and adaptive technologies, which limits their ability to cope effectively with changing climatic conditions. In Nigeria, for instance, unpredictable flooding has damaged over 2.7 million hectares of farmland, significantly affecting smallholder producers (Amusa, Esheya & Efedua, 2022). Climate change thus remains a serious constrain to achieving food security, sustainable development, and poverty reduction goals. Its adverse effects cu across various agricultural subsectors—livestock, crop farming, forestry, fisheries, and agro-processing—causing fluctuations in outpu and incomes. Persisten droughts, off-season rains, and excessive flooding have disrupted planting and harvesting cycles, particularly in rain-dependen regions such as Abia State. According to Adams (2019), climate-induced agricultural disruptions manifes through increased average temperatures, erratic rainfall patterns, pes and disease outbreaks, severe droughts, and rising sea levels, all of which intensify production risks. The ability of mushroom farmers to sustain production and adap to these environmental shifts depends largely on their level of technical and allocative efficiency. Efficiency improvements enhance productivity and resource use, enabling farmers to optimize available inputs for maximum output. Kamai, Omoigui, Kamara and Ekeleme (2020) emphasized tha efficiency growth can be achieved through technological innovation, skill development, and better resource management. Applying these principles to mushroom production implies tha farmers mus combine efficien resource use with adaptive strategies to cope with climatic variations. Despite growing research on the relationship between climate change and agricultural production, there remains a critical gap regarding efficiency analysis in mushroom farming. Mos existing studies, such as Ndem and Oku (2016), Arowosoge (2018), and Adeoye, Idowu, and Alabi (2018), have focused mainly on production systems, profitability, and cost-return analyses withou examining efficiency dimensions. Similarly, studies by Olamo, Martínez-Rodrigo, José, Ágreda, Fernández-Toirán, García-Cervigón, Rodríguez-Puerta and Águeda (2020), Kavavani, De-Cáceres, de-Aragón, Bonet and de-Miguel (2018), Boddy, Büntgen, Egli, Gange, Heegaard, Kirk, Mohammad and Kauserud (2014) investigated climate effects on mushroom yield, ecosystem dynamics, and diversity bu overlooked efficiency factors. Other researchers, including Chikwendu, Ikwunegbo, Ogbonna and Chukwuemeka (2021), Abhishek, et al. (2022), and Oyetundun et al. (2024), have assessed the performance and benefits of mushroom cultivation bu did no link their findings to climate change adaptation. Consequently, this study addresses this gap by examining climate change adaptation and the efficiencies of smallholder mushroom farmers in Abia State, Nigeria. Specifically, the study aims to (i) identify farm-level climate change adaptation practices employed by smallholder mushroom farmers and (ii) determine the levels and determinants of their technical and allocative efficiencies in the study area.

Methods: The study was carried out in Abia State, Nigeria, made up of 17 local government areas (LGAs), broadly divided into three agricultural zones which are; Aba, Ohafia and Umuahia covering a land mass of 700 square km and estimated population of 4,143,100 (National Bureau of Statistics, 2021). The state is agriculturally endowed with a federal university of agriculture and agricultural research institutes making farming of crop and livestock major economic activities in the state. The state is rich in fertile soil that supports the growth of crops such as yam, cassava, cocoyam, melon, maize, oil palm, garden egg, cocoa, and mushroom that is increasingly gaining prominence to mention but a few. poultry, goat, pigs and sheep are the major livestock kept in Abia State. The study adopted multi-stage random sampling procedure for selection of the 120 mushroom farmers (respondents) for the study. In the first stage, the three agricultural zones (Aba, Ohafia and Umuahia) were involved in the study due to wide spread production of mushroom across the state. At the second stage, two Local Government Areas (L.G.As) were selected at random from each agricultural zone, given a total of six LGAs. In stage three, two autonomous communities were randomly selected from each of the LGAs giving a total of 12 autonomous communities. In the fourth stage one village was selected from each of the earlier sampled community given a total of 12 villages. The last stage involves careful random selection of 10 mushroom farmers, giving a sample size of 120 mushroom farmers for the study. Data that were collected were analyzed using both descriptive statistics such as mean and standard deviation and inferential statistics such as stochastic frontier function. To identify farm-level climate change adaptation practices engaged by the smallholder mushroom farmers, descriptive statistics (mean and standard deviation) derived from 4-point rating scale of: Highly Practiced =4, Moderately Practiced = 3, Less Practiced = 2 and Not Practiced = 1. Based on the 4-point response options, the cut-off point of 2.50 was computed. Hence, any adaptation practice with mean value greater than 2.50 was interpreted as “Practiced” while items with mean values less than 2.50 were interpreted as “Not Practiced”. To determine the levels of efficiency and determinants of efficiencies of mushroom production in Abia State, stochastic frontier function was employed;

$$\text{In } Y_i = \beta o + \beta_1 \text{In}K_1 + \beta_2 \text{In}K_2 + \beta_3 \text{In}K_3 + \beta_4 \text{In}K_4 + \beta_5 \text{In}K_5 + \beta_6 \text{In}K_6 + (V_i - U_i) \ldots\ldots\ldots\ldots. (1)$$

Where:

In = natural logarithm,

Y_i = Output of ith mushroom farmer measured in (kg/m^2)

K_1 = Amount of spawn used (kg)

K_2 = Cultivated farmland (ha)

K_3 = Mushroom substrate used (kg),

K_4 = Labour used in mandays

K_5 = Quantity of chemical used (Liters),

K_6= Capital inputs covering depreciation of farm tools and equipment, interest on borrowed capital and rent on land (naira).

$\varepsilon = V_i - U_i$

ε = error term

V_i= Random variability in the production that cannot be influenced by the farmer and

U_i = deviation from maximum potential output attributed to technical inefficiency.

β_0- β_6 = parameters estimated

The corresponding cost frontier (allocative efficiency) of the mushroom farmers was explicitly specified as:

$$\text{In}C_i = \alpha_0 + \alpha_1 \text{In}Y_i^* + \alpha_2 \text{In}P_1 + \alpha_3 \text{In}P_2 + \alpha_4 \text{In}P_3 + \alpha_5 \text{In}P_4 + \alpha_6 \text{In}P_5 + V_i + U_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2)$$

Where:

C_i = Total cost of production of the farmers (naira),

Y_i* = Frontier cost of output (naira)

P_1 = Cost of spawn used (in naira)

P_2 = Cost of mushroom substrate used (in naira),

P_3 = Cost of Labour (in naira),

P_4 = Cost of rent on farmland (in naira)

P_5 = Cost of chemical used (in naira),

P_6= Capital inputs covering depreciation of farm tools and equipment, interest on borrowed capital and rent on land (naira).

Some socio- economic factors influencing technical efficiency of the farmers was determined using the error due to inefficiency as dependent variable and this was estimated by incorporating the socioeconomic variables directly into the frontier model.

$$U_i = \Omega_0 + \Omega_1 Z_1 + \Omega_2 Z_2 + \Omega_3 Z_3 + \Omega_4 Z_4 + \Omega_5 Z_5 + \Omega_6 Z_6 + \Omega_7 Z_7 + \Omega_8 Z_8 + e \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3)$$

Where;

U_i = inefficiency effects

Z_1 = Age of farmer in years;

Z_2 = Household size (number of persons);

Z_3 = Farming experience (years);

Z_4 = Educational level of farmer in years;

Z_5 = Amount of credit (in naira);

Z_6 = Sex of farmer (dummy; 1= male, 0 = female);

Z_7 = Climate change adaptation index

Ω_0 - Ω_8 = parameters estimated.

Results and Discussions

Farm-level Climate Change Adaptation Practices engaged by the Mushroom farmers

The results from Table 1 reveal that smallholder mushroom farmers in the study area are actively engaging in various adaptation practices to combat climate-induced shocks, with some strategies standing out due to their higher adoption levels. Among these, planting early of fast-maturing mushroom varieties (3.55) having the highest mean value, indicating that farmers prioritize this approach as an effective means to reduce the negative impacts of climate variability. Early planting allows mushrooms to complete their growth cycle before the onset of extreme weather events such as excessive heat or unpredictable rainfall patterns. Singh Rajdeep and Singh (2018) found that early planting coupled with fast-maturing varieties helped farmers avoid peak periods of heat stress and moisture scarcity, thereby enhancing productivity. Closely following this is the widespread practice of employing mushroom production technologies with mean value of 3.42 and use of water efficient technology with mean value of 3.41. Siddiqui (2022) highlights the significance of adopting systematic production technologies as these create controlled microenvironments that buffer mushroom crops against erratic weather conditions and help stabilize yields. Oyedele, Adeosun and Koyenikan (2018) demonstrated how low-cost water management systems utilizing agricultural waste materials effectively improve mushroom production resilience in controlled environments. Other farm-level climate change adaptation practices engaged by mushroom farmers include: growing pest and disease resistance varieties (3.40), avoidance of erosion or flood prone areas (3.39), intensified mulching (3.35), making of mounds/ridges/creating of platforms (3.34), practicing multiple cropping to minimized shock (3.17), use of improved mushroom varieties (3.09), use of drought resistant variety of mushroom (3.00), use of intensive fertilizer application for mushroom production (3.00), constructing of drainage around farm to control flooding (2.99) and increased use of agrochemicals (2.96) among others. In agreement with the findings of this study, Singh, Rajdeep and Singh (2018) reported that farmers adopting resistant strains experienced lower incidences of disease and greater economic returns, underscoring the importance of genetic resistance in sustaining productivity. Siddiqui (2022) also advocates for the use of resistant varieties as part of sustainable mushroom cultivation practices, which help reduce reliance on chemical controls and improve farm resilience. By incorporating resistant strains, farmers are better equipped to maintain stable yields despite the growing threat of climate-induced pest outbreaks. Shrestha Huang, Gautam and Johnson (2016) found that small-scale farmers in Nepal who avoided hazard-prone areas enhanced their overall farm efficiency and reduced climate-related losses. Similarly, Singh and Sidhu (2014) observed that micro-site selection considering elevation and drainage plays a critical role in mitigating the adverse effects of heavy rainfall and flooding on crop productivity.

Distribution of Efficiencies of Mushroom Farmers in the Study Area.: Distribution of mushroom farmers based on technical and allocative efficiency level are summarized and presented in Table 2. The results show the distribution of mushroom farmers in terms of technical and allocative efficiency levels. The efficiency scores, which range from 0 to 1, imply that none of the farmers were operating at the absolute efficiency frontier. The mean technical efficiency (TE) was 0.731, while the mean allocative efficiency (AE) stood at 0.809. These values indicate that on average, farmers could potentially increase their technical performance by 26.9% and improve their cost allocation by 19.1% without requiring additional inputs, simply by optimizing the use of current resources and techniques. A closer look at the distribution shows that 35% of the respondents achieved technical efficiency between 0.90 and 1.00, while 18.33% fell within the 0.80–0.89 range. Similarly, allocative efficiency was even higher, with 52.5% of farmers scoring in the 0.90–1.00 range and 17.5% in the 0.80–0.89 range. This suggests that a significant proportion of mushroom farmers are relatively efficient in allocating their resources based on cost considerations, though some remain technically suboptimal in actual production. Despite the relatively high mean scores, the fact that nearly a quarter of farmers (23.5%) scored below 0.60 in technical efficiency reveals gaps in production knowledge and practices. Only 9.17% scored between 0.60 and 0.69, and a further 19.5% fell below 0.50, indicating clear areas for technical improvement. These inefficiencies may stem from a lack of proper training, limited access to quality spawn, poor substrate management, or environmental control deficiencies such as humidity and temperature regulation challenges highlighted by Siddiqui (2022) and Singh and Singh (2018) as key barriers in smallholder mushroom production. The higher allocative efficiency relative to technical efficiency implies that many farmers are adept at responding to market signals and cost structures, even if they are not producing at maximum potential output. Shrestha *et al*. (2016) found that vegetable farmers were more efficient allocatively due to market orientation, but technically constrained due to limited knowledge and support services.

Determinants of Technical Efficiency of the Mushroom Farmers: The maximum likelihood estimates using stochastic frontier parameters for mushroom farming is presented in Table 3. From the result in Table 3, the estimated variance (σ^2), gamma (γ) and Log likelihood function indicate goodness of fit with the stochastic frontier model. For production factors, the coefficient of amount of spawn used, cultivated farmland, mushroom substrate, labor and capital were statistically significant and positively related to total output. This implies that increase in any of these variables will lead to increase in output and vice versa. Chemical used was statistically significant and negatively related to total output. This implies that increase in this variable will lead to decrease in output and vice versa. The coefficient for the amount of spawn used was positive and significant at the 10% level. This finding supports the conclusions of Wanole (2020), who observed that the amount of spawn used significantly influenced output levels. Cultivated farmland was positively related to output and significant at the 10% level. This suggests that an increase in the area dedicated to mushroom farming contributes to improved yields. Although, mushrooms require less land than traditional crops. Sonam and Prabhakar (2021) noted that access to sufficient space was among the key enabling factors for increased production among women mushroom cultivators. The coefficient of mushroom substrate was positive and significant at the 1% level, indicating a strong and direct relationship between substrate use and output among mushroom farmers. Therefore, increased and optimized use of quality substrate directly enhances yield. This finding aligns with Tesfaw, Tadesse and Kiros (2015) who demonstrated that appropriate selection and optimization of locally available substrates significantly improved oyster mushroom cultivation.

Labor was found to be positive and significant at the 1% level, implying that an increase in labor input leads to higher mushroom output. This result corresponds with the findings of Sonam and Hans (2020), who reported that labor involvement, particularly among women mushroom growers played a critical role in achieving better yields and socioeconomic upliftment. The coefficient of chemical use was negative and significant at the 1% level, indicating that higher chemical input reduces mushroom output. This contradicts expectations in crop farming, where chemicals often improve yields by controlling pests and diseases. However, mushrooms are highly sensitive to chemical residues, and misuse can disrupt mycelial growth or cause contamination. The result aligns with that of Tsegaye and Tefera (2017), who highlighted the risks associated with non-organic inputs in mushroom farming and emphasized the importance of organic cultivation practices for both yield and food safety. The coefficient for capital input was positive and significant at the 1% level, suggesting that higher capital investment leads to increased production efficiency. Tahir and Hassan (2023) found that capital availability was crucial for the profitability and feasibility of small-scale button mushroom farming.

Technical inefficiency: The coefficient for age is -1.3386 and statistically significant at the 5% level. The negative sign suggests that as mushroom farmers grow older, their level of technical inefficiency decreases. In other words, technical efficiency improves with age. This may reflect accumulated farming knowledge, skill, and experience that enable older farmers to optimize production better than younger counterparts. This result is consistent with findings from Wanole (2020), who observed that experienced mushroom farmers tend to achieve higher efficiency levels due to their deeper understanding of cultivation practices. Household size has a coefficient of -0.6199 and is highly significant at 1%. The negative sign indicates that larger household size reduces technical inefficiency. This suggests that bigger households provide greater labor availability. The additional labor support could ease workload constraints and increase productive activities. Hence, Sonam and Prabhakar (2021) found that household labor positively impacts efficiency in mushroom cultivation. Formal education has a negative coefficient of -0.0026, significant at the 1% level, indicating that education significantly reduces technical inefficiency and thereby improves technical efficiency. Educated farmers are better equipped to adopt improved technologies, manage resources wisely, and innovate, which enhance production efficiency. This supports the results of Thakur (2020) and Sonam and Hans (2020) emphasizing education as a critical factor in improving mushroom farming productivity. Credit access shows a negative coefficient of -0.0012 with marginal significance at 1%. The negative sign implies that access to credit helps reduce inefficiency, likely by enabling farmers to purchase better inputs, invest in technology, and expand production capacity. However, the weak significance suggests that while credit is helpful, other constraints may limit its full positive impact, consistent with findings by Tesfaw, *et al*. (2015).

The sex of the farmers has a positive coefficient of 2.5719 and highly significant at 1%, indicating that being male is associated with an increase in technical inefficiency in this model. This finding suggests that male farmers, contrary to common assumptions, tend to be less technically efficient than females in this mushroom production. It might reflect better efficiency among female farmers due to their meticulousness or better management in mushroom cultivation submitted by Sonam and Prabhakar (2021). The coefficient of climate change adaptation index was negative (-0.0970) and highly significant at 1%, indicating that increase in rate climate change adaptation capacity significantly reduces technical inefficiency and improves output (efficiency) of the farmers. Farmers who adopt more climate change adaptation practices are likely to gain better control over production processes, leading to higher productivity. This is consistent with the findings of Tahir and Hassan (2023) who emphasize the crucial role of adaptation and adoption of technology boost farm efficiency.

Determinants of Allocative (Cost) Efficiency of the Mushroom Farmers: The maximum likelihood estimates using stochastic cost frontier parameters for mushroom farming is presented in Table 4. The estimated parameters revealed that the sigma squared parameter of 0.90490 implies that about 90.4 percent of the variations in the total cost of production of mushroom were due to differences in their cost efficiencies. The Log likelihood-ratio test shows the estimated value of -93.89 exceeding the chi-square critical value at 1 percent level of probability. Cost of spawn, labour, substrate, cultivated land, chemical and capital significantly influenced allocative efficiency of the mushroom farmers at 1%. The cost of spawn, which is the mushroom seed used to initiate cultivation, was found to be positively and significantly related to the total cost of mushroom production at the 1%. This indicates that any increase in the price of spawn directly raises the overall production cost for mushroom farmers. Efficient sourcing and management of spawn quality and quantity are essential to control costs. Rawat, Negi and Singh (2020) highlight that input prices such as spawn significantly impact the cost-benefit balance in mushroom farming. Labor cost also significantly and positively influenced production costs at 1% level. Labor is indispensable in mushroom farming, as many stages including substrate preparation, spawning, maintenance, and harvesting are labor-intensive. As labour wages rise, the overall production cost escalates, potentially reducing profit margins if not managed carefully. The cost of mushroom substrate is another significant positive determinant of production costs at the 1% significance level. Substrate quality and quantity are critical to successful mushroom cultivation, and its price substantially influences the overall cost structure. Tahir and Hassan (2023) highlighted that the choice and management of substrates directly affect yield and cost efficiency. Higher substrate prices mean increased input costs, emphasizing the need for farmers to identify affordable, high-quality substrate sources and adopt efficient substrate management techniques.

The cost of cultivated land positively and significantly increased total production costs at the 1% level. An increase in land costs directly raises overheads and capital allocation for production. Rawat, *et al*. (2020) discuss how land rental or ownership costs significantly impact the economic viability of mushroom farms, especially in regions where land scarcity drives up prices. Cost of chemical used was found to be significant but negatively related to the total cost of mushroom production at the 1%. This indicates that any increase in the cost chemicals directly reduces the production cost for mushroom farmers. Cost of capital was significant at the 10% level and positively related with production costs, indicating that rising capital costs contribute to higher overall expenses. Capital in mushroom production includes tools, structures like sheds, humidity control devices, and other equipment necessary for cultivation. Ranasingh, Mohanty, and Behera (2010) emphasize that capital investment is a key driver of efficiency but also a considerable cost component in mushroom farming. Proper management of capital assets, including maintenance and investment timing, can help reduce unnecessary expenses.

Allocative inefficiency: From Table 4 the estimated coefficient for age (-0. 0.20063), household size (-0.13667), experience (-0.13667) and credit (-0.32687) were negative. The negative coefficient for age (-0.20063) of the farmers for instance suggests that older mushroom farmers are mor et allocatively efficient, meaning they tend to allocate their resources more optimally to minimize costs. This can be attributed to the wealth of experience and knowledge of the older farmers. Rahman, Hossain, Ali and Afroz (2017) support this, noting that training and accumulated practical knowledge significantly enhance farmers' efficiency. The coefficient of household size was also negative (-0.13667), indicating that larger households reduc et allocative inefficiency, thus improving cost allocation in mushroom farming. A larger household provides readily available labour, which lowers the dependence on hired labor and cuts down labour costs. Raut (2019) observed this phenomenon and submitted that family labour plays a crucial role in cost reduction and efficient input management. Similarly, Rawat, *et al* (2020) reported that households with more members generally exhibit better control over production costs, enhancing income diversification and economic resilience. The negative coefficient of experience (-0.13667) indicates that mushroom farmers with more years of cultivation experience tend to have lower allocative inefficiency. Experienced farmers have learned how to allocate resources efficiently, avoiding wastage and optimizing input use for better output-cost balance. Rahman, *et al*. (2017) argued that experience combined with training improves farmers' ability to select appropriate inputs and apply them at the right levels, enhancing both technical and allocative efficiency. Access to credit shows a significant negative coefficient (-0.32687), implying that access to credit facilities decreases allocative inefficiency, thereby improving the ability of farmers to manage input costs effectively. Access to financial resources allows farmers to purchase quality inputs such as spawn and substrate in adequate amounts and at optimal times, which prevents wastage of resources. Rana, *et al*. (2015) note that financial support is essential for farmers to maintain high production standards and reduce cost inefficiencies. Furthermore, Rawat, *et al*. (2020) reported that credit access enables small-scale mushroom producers to invest properly in inputs and diversify income sources, ultimately improving cost efficiency and farm sustainability.

The coefficient of sex was positive (0.19263) and significantly influenced cost efficiency which suggest that being male is associated with an increase in cost inefficiency. Hence, male farmers, are less cost efficient than females in mushroom production. Sonam *et al* (2021) justified that female farmers are more efficient and meticulous in mushroom farming then their male counterparts. Climate change adaptation index was negative (-0.52077) and highly significant at 1%, indicating that increase in climate change adaptation capacity significantly reduces allocative inefficiency of the farmers. Farmers who adopt more climate change adaptation practices are likely to gain better control over production processes, leading to higher cost efficiency. Tahir and Hassan (2023) links climate change adaptation capacity to increase adoption of technology to boost farm efficiency.

Conclusion: The study concludes that smallholder mushroom farmers in Abia State are technically and allocativelly efficient. The farmers practice notable adaptation strategies to mitigate the impacts climate change in their mushroom production as climate change adaptation practices of the farmers reduces their inefficiencies, hence boost their levels of technical and allocative efficiencies leading to higher productivity. Hence, development of appropriate policies and support systems that focus on inputs, technology dissemination, education, credit access, and infrastructural development can significantly enhance farmers' climate change resilience, efficiency and productivity in the face of climate variability. Based on the findings and conclusion drawn, the study recommends: agricultural development programmes by the state and federal government agencies that will intensify efforts to train mushroom farmers on climate change adaptation practices. Through intensified training and technology transfer, mushroom farmers can be helped to build resilience in the face of devastating effects of climate change. capacity-building programmes focusing on production of inputs and efficient allocation of farm resources to boost efficiency levels of the mushroom farmers to optimize input use and improve productivity.

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Table 1: Mean Ratings of Farm-level Climate Change Adaptation Practices engaged by the Mushroom Farmers

SN	Climate change adaptation practices	$\bar{X}$	SD	Rmks	Ranking
1	Planting early of fast maturing Mushroom variety	3.55	0.69	**P**	**1st**
2	Practicing mushroom production technologies	3.42	0.74	**P**	**2nd**
3	Use of water efficient technology	3.41	0.69	**P**	**3rd**
4	Growing pest and disease resistance varieties	3.40	0.69	**P**	**4th**
5	Avoid erosion or flood prone areas.	3.39	0.72	**P**	**5th**
6	Intensified mulching	3.35	0.68	**P**	**6th**
7	Making of mounds/ridges/creating of platforms	3.34	0.82	**P**	**7th**
8	Practicing multiple cropping to minimized shock	3.17	0.78	**P**	**8th**
9	Use of improved Mushroom varieties	3.09	0.90	**P**	**9th**
10	Using drought resistant variety of Mushroom	3.00	0.71	**P**	**10th**
11	Using intensive fertilizer application for Mushroom production	3.00	0.90	**P**	**10th**
12	Constructing of drainage around farm to control flooding	2.99	0.89	**P**	**11th**

13	Increased use of agrochemicals	2.96	0.63	**P**	**12th**
14	Diversification of livelihoods	2.85	0.72	**P**	**13th**
15	Practicing induced fruiting of mushroom.	2.81	0.74	**P**	**14th**
16	Use of weather forecast	2.81	0.68	**P**	**14th**
17	Practice of indoor cultivation	2.75	0.66	**P**	**15th**
18	Practicing small scale irrigation/watering	2.65	0.76	**P**	**16th**
19	Use of water storage system for farm use	2.63	0.57	**P**	**17th**
20	Processing of mushroom to reduced post-harvest loses	2.48	0.62	**NP**	**18th**
21	Adjusting planting dates	2.47	0.63	**NP**	**19th**
22	Prompt weeding	2.47	0.59	**NP**	**19th**

Source: Field survey; 2025; Decision mean $\bar{X} \geq 2.50$; P = Practiced; NP= Not Practiced

Table 2: Efficiency distribution of respondents

Efficiency	Technical Efficiency		Allocative Efficiency	
	Frequency	%	Frequency	%
0.10-0.19	5	4.17	2	1.67
0.20-0.29	5	4.17	4	3.33
0.30-0.39	7	5.83	3	2.50
0.40-0.49	7	5.83	5	4.17
0.50-0.59	4	3.33	3	2.50
0.60-0.69	11	9.17	5	4.17
0.70-0.79	17	14.17	14	11.67
0.80-0.89	22	18.33	21	17.50
0.90-1.00	42	35.00	63	52.50
Total	**120**	**100**	**120**	**100**
Mean	**0.731**		**0.809**	

Source: Field Survey Data, 2025

Table 3: Maximum likelihood estimate of stochastic production frontier function

Variables	Coefficient	Standard error	t-ratio
Production factors			
Constant	6.055580	0.315184	19.21***
X_1 = Amount of spawn used	0.038372	0.021451	1.79*
X_2 = Cultivated farmland	0.021645	0.011995	1.80*
X_3 = Mushroom substrate	0.639940	0.029042	22.04***
X_4 = Labor	0.184686	0.025057	7.37***
X_5 = Chemical used	-0.067732	0.008779	-7.72***
X_6 = Capital	0.050851	0.011307	4.50***
Return to scale (TRS)	0.867762		
Inefficiency factors			
Z_1 = Age of respondent	-1.338629	0.655012	-2.04**
Z_2 = Household size	-0.619936	0.140917	-4.40***
Z_3 = Experience	-0.003048	0.032297	-0.09
Z_4 = Formal education (years)	-0.002563	0.000781	-3.28***
Z_5 = Amount of credit (naira)	-0.001204	0.000654	-1.84*
Z_6 = Sex	2.571874	0.589235	4.36***
Z_7 = CC Adaptation index	-0.097018	0.019712	-4.92***

Sigma squared(δ)	5.265374	0.108493	-48.53***
Gamma(γ)	0.071885	0.003900	
Log likelihood	91.2966		
Wald chi^2(6)	900.38***		

Source: Field Survey data, 2025*, *; Significant at 1% and 10%, respectively**

CC = Climate change

Table 4: Maximum likelihood estimate of stochastic cost frontier function

Variables	Coefficient	Standard error	t-ratio
Cost factors			
Constant	10.93456	3.41006	3.66***
P_1 = Cost of spawn used	0.40418	0.10876	3.72***
P_2 = Cost of cultivated land	0.37412	0.11404	3.28***
P_3 = Cost of substrate	0.48744	0.10692	4.56***
P_4 = Cost of labor	0.39879	0.11113	3.59***
P_5 = Cost of chemical used	-0.40006	0.10593	-3.78***
P_6 = Capital	0.28261	0.17661	1.60*
Inefficiency factors			
Q_1 = Age of respondent	-0.20063	0.12438	-1.61*
Q_2 = Household size	-0.13667	0.01422	-9.61***
Q_3 = Experience	-0.12733	0.16682	-0.76
Q_4 = Formal education (years)	0.21723	0.42830	0.51
Q_5 = Access to credit (naira)	-0.32687	0.15778	-2.07**
Q_6 = Sex	0.19263	0.08059	2.39**
Q_7 = CC Adaptation index	-0.52077	0.13527	-3.85***
Sigma squared(δ)	0.90490	0.128603	7.04***
Gamma(γ)	0.80325	0.17248	
Log likelihood function	-93.89325		
LR test	128.45775***		

Source: Field Survey data, (2025) *, * Significant at 1% and 10%, respectively**

CC = Climate change