Journal of Agricultural Economics & Development

Homepage: https://jead.um.ac.ir

Research Article
Vol. 38, No. 2, Summer 2024, p. 195-208

Impact of Adopting Strategies to Cope with Climate Change on the Technical Efficiency of Wheat Farmers in Sistan Region-Iran

H. Naruei[1], M. Ahmadpour Borazjani[2]*, M. Salarpour[3], A. Keikha[3], R. Esfanjari Kenari[4]

1, 2, and 3- Ph.D. Student, Associate Profess and Assistant Professor, Department of Agricultural Economics, Agricultural College, University of Zabol, Zabol, Iran, respectively.
(*- Corresponding Author Email: mahmadpour@uoz.ac.ir)
4- Assistant Professor, Agricultural Economics Department, Faculty of Agricultural Sciences, University of Guilan, Guilan, Iran

Received: 18-03-2024 Revised: 03-07-2024 Accepted: 27-07-2024 Available Online: 27-07-2024	**How to cite this article:** Naruei, H., Ahmadpour Borazjani, M., Salarpour, M., Keikha, A., & Esfanjari Kenari, R. (2023). Impact of adopting strategies to Cope with climate change on the technical efficiency of wheat farmers in Sistan region-Iran. *Journal of Agricultural Economics & Development*, *38*(2),. https://doi.org/10.22067/jead.2024.87331.1259

Abstract

The negative and destructive impact of climate change on the efficiency and productivity of agricultural inputs has been demonstrated in many regions of the world, particularly in arid and semi-arid areas. In this context, the adoption of innovative strategies to increase farmers' flexibility and adaptability to climate change has increased. Hence, understanding the impact of climate adaptation strategies on agricultural efficiency and yields is crucial. This study examined the effects of climate change adaptation strategies, input utilization, and external factors beyond farmers' control on technical efficiency using the Endogenous Modified Stochastic Frontier (EMSF) model. Data were collected from 265 questionnaires distributed among wheat farmers during the 2022-2023 cultivation period, using a stratified random sampling approach. The climate adaptation strategy index was formulated using the Principal Component Analysis (PCA) technique. The PCA revealed that changes in farm size (0.812), adaptation of conservation tillage (0.797), and adjustments in planting dates (0.619) were the most influential factors. Conversely, rainwater harvesting (0.219) and biofertilizer application (0.327) emerged as the adaptation strategies with the lowest factor loadings among farmers. In this study, the average technical efficiency of wheat farmers was calculated to be 82%. The model estimation results showed that labor input, chemical pesticides, chemical fertilizers, water, and machinery significantly and positively contribute to wheat production efficiency. Additionally, the implementation of climate adaptation strategies by farmers reduces technical inefficiency. Variables such as education level, farming experience, access to climate information, and access to credit also effectively reduce technical inefficiency.

Keywords: Logit regression, Principal components analysis, Socio-economic characteristics, Stochastic frontier model

Introduction

Climate change is emerging as a significant threat to agriculture, food security, and the livelihoods of millions of people worldwide (IPCC, 2017). Agricultural activities are particularly vulnerable to climate change as they are directly influenced by climatic factors such as temperature and precipitation (Shaffril

https://doi.org/10.22067/jead.2024.87331.1259

et al., 2018). Phenomena like rising temperatures, erratic rainfall patterns, and droughts are manifestations of climate change that lead to fluctuations in crop yields (Zaveri *et al*., 2020). Projections suggest that by 2030, global maize and wheat production, two staple food crops, will decrease by 3.8% and 5.5%, respectively, due to the impacts of climate change (FAO, 2015). However, empirical data reveals that the adverse effects of climate change on agricultural sector in developing countries are even more profound. Consequently, the negative impact of climate change on exacerbating economic issues and increasing the vulnerability of farmers in these regions has been substantiated (Ado *et al*., 2018). Therefore, addressing climate change challenges in agriculture highlights adaptation and mitigation measures (Mirzaei *et al*., 2022).

A review of studies reveals that the strategies employed to adapt to climate change vary widely across different regions of the world. These strategies include limiting the use of nitrogen fertilizers, avoiding conventional ploughing methods in favor of conservation tillage, reducing water consumption through modern irrigation systems, maintaining or enhancing soil fertility, and supporting farm mechanization (Bonzanigo *et al*., 2016; Camarotto *et al*., 2018; Ogundari *et al*., 2018). However, although farmers are exposed to climate change, the decision to change their farming practices has not been pervasive (Pagliacci *et al*., 2020). In this regard, studies on farmers' acceptance and continued voluntary use of climate change adaptation plans show that farmers' choices are influenced by a wide range of factors related to the environment, technology, policy characteristics, institutions, farm structure, farmers' economic characteristics, attitudes, motivations, and social aspects (Deng *et al*., 2016; Luo *et al*., 2016; Page *et al*., 2015).

According to the Seventh Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), climate change has occurred in Iran in recent decades and will continue to intensify in the future (IPCC, 2017). Data indicate that Iran is experiencing frequent droughts, rising temperatures, increasingly erratic rainfall patterns, and declining groundwater resources due to climate change (Yazdanpanah *et al*., 2016; Mardani Najafabadi *et al*., 2022). Consequently, Iranian farmers need to adopt suitable adaptation strategies to cope with climate change and mitigate its effects (Bozorgparvar *et al*., 2018). Despite the adverse impacts of climate change on farmers' livelihoods and water resources in Iran, adaptation strategies have not been widely adopted by farmers, and the development of adaptation approaches has not been prioritized by government agencies (Karimi *et al*., 2018). For example, Mirzaei and Zibaei (2021) concluded that inflexibility in farmers' individual behavior has resulted in practical adaptation to climate change being lower than its potential. They demonstrated that using adaptive strategies, such as improving irrigation efficiency, leads to only a 14% reduction in water consumption. Therefore, it is crucial to assess the effectiveness of climate adaptation strategies on agricultural efficiency and yields.

The Sistan Plain, located in the north of Sistan and Baluchistan province, spans an area of 16.5 thousand square kilometers. It is the floodplain of the Helmand River and one of the most fertile regions in the province. This area ranks first in the province for the cultivation and production of wheat, barley, summer crops, and fodder. Before the recent droughts, the Sistan Plain produced 70% of the province's wheat, 84% of its barley, and 81% of its summer crops, earning it the title of the agricultural center of the province. The location of the study area is shown in Fig. 1.

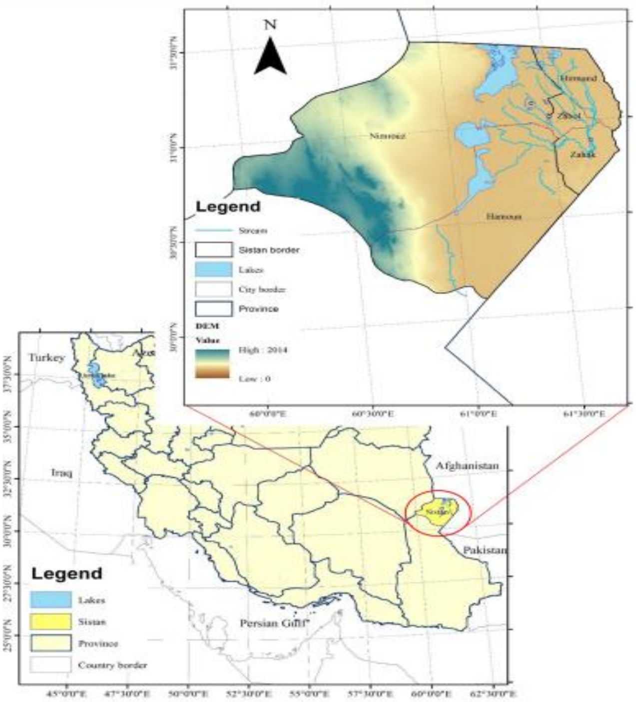

Figure 1- The location of study area
Source: Arranged by the authors

According to the 2018-2019 agricultural statistics, wheat still occupies about 60% of the cultivated area in the Sistan region (Ministry of Agricultural Jihad, 2020). However, this plain is characterized by periods of low water availability and prolonged droughts, with average annual precipitation between 50 and 55 mm and high annual evaporation exceeding 4500 mm (Khakifirouz *et al.*, 2022). Additionally, most wheat farmers in Sistan are smallholders, and one of their main challenges is the inefficient use of agricultural inputs (Sardar Shahraki & Ghaffari Moghdam, 2023). Therefore, it is essential to determine the role of farmers' management practices alongside the influence of uncontrollable factors on their performance. In this context, examining the technical efficiency of wheat production according to the strategies implemented by these farmers is necessary.

In line with this, the present study assessed the impact of climate change adaptation strategies and the inputs used by farmers on technical efficiency. An endogenous modified stochastic frontier (EMSF) model was employed for this purpose. This model not only determined the impact of changes in input consumption under the farmer's control (such as labor, water, farm size, and chemical inputs) on technical efficiency and inefficiency but also estimated the impact of climate change adaptation strategies. A key feature of this study is the consideration of endogenous effects influencing the adoption of climate change adaptation strategies, providing an unbiased and consistent estimate of farmers' technical efficiency. Additionally, the identification of strategies with significant factor loadings to construct the climate adaptation index through the principal component analysis method is another prominent aspect of this study.

Research Methodology

In the present study, we investigated adaptation strategies to climate change and other factors affecting the efficiency and technical inefficiency of wheat producers in the Sistan region. An endogenous modified stochastic frontier (EMSF) model was used for this purpose. It is worth mentioning that the Principal Component Analysis (PCA) method was employed to create an index of climate change adaptation strategies.

The conceptual framework illustrating factors influencing the adoption of climate change adaptation strategies is presented in Fig. 2.

In the following, the methods used to achieve the mentioned goals are described.

Principal Component Analysis

Principal Component Analysis (PCA) identifies the most important components within a dataset. Rather than analyzing all features, it focuses on a subset that holds the most significance. Essentially, PCA extracts the features that contribute the greatest value. The principal components method was first proposed by Pearson (1971) for non-statistical variables. Hotelling (1933) extended the concept to random vectors. The principal components of (X) are standardized linear combinations of (X) components that have special properties in terms of variances. For example, the first component (X) of the standardized linear combination in Equation 1 is:

$$Z_1 = L^{'}X, \qquad L = (l_1, \ldots, l_P)' \in E^P \tag{1}$$

Where L is chosen such that $var(L^{'}X)$ is maximal with respect to L. It is obvious that each weight X_i is a measure of the importance we give to the component l_i. To find a unique solution for the principal components, a specific condition $L^{'}L = 1$ is required. In fact, the components of X are measured with one unit. Otherwise, the necessary condition $L^{'}L = 1$ is not a sensible. The estimates of the principal components are sensitive to the units used in the analysis, resulting in different sets of weights for different units. To avoid this issue, the sample correlation matrix is sometimes used instead of the sample covariance matrix to estimate these weights. This approach ensures that the principal components remain stable despite changes in measurement units. Using the correlation matrix standardizes the variables to the sample variance unit.

The second principal component is the linear combination that has the maximum variance among all the standardized linear combinations uncorrelated with z_1, and continues to the principal component p-th of X. In this way, the initial vector X can be transformed into a vector of principal components with a rotation of the coordinate axis, which has inherent statistical properties. The weights related to the random vector X in the principal components are exactly the standardized Eigenvectors of the covariance matrix (Σ) of X. In addition, the Eigenvalue of Σ are equal to the variances of the principal components, and the largest root is equal to the variance of the first principal component (Giri, 1974).

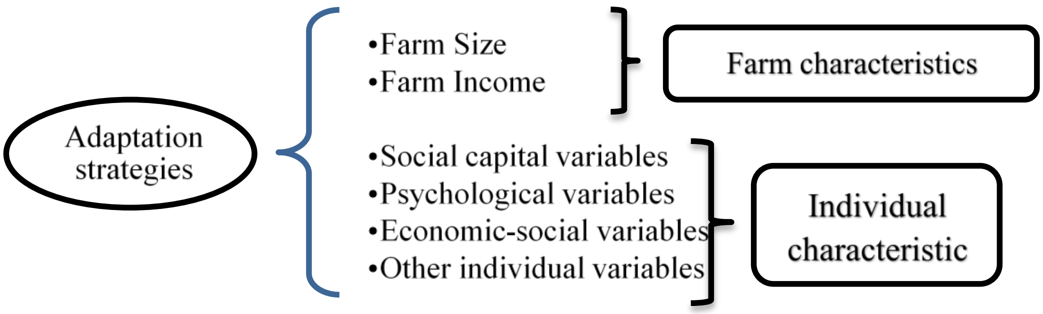

Figure 2- Conceptual framework of factors influencing the adoption of adaptation strategies

Endogenous modified stochastic frontier approach

One important issue in estimating the production function and technical efficiency is the possibility that some production factors are understood by the farmer but not considered by the researcher. In other words, when farmers allocate production factors, these selected inputs may be correlated with other observable components. Stochastic frontier analysis (SFA) models assume that production inputs are independent of the efficiency component. However, in reality, some unobservable characteristics may influence the farmer's choice of inputs, leading to an endogeneity problem in SFA estimation (Ma *et al*., 2018). Since the decision to adopt climate change adaptation strategies is influenced by inherent characteristics such as farmers' management skills and understanding of climate change risk, this issue can lead to an endogeneity problem. Therefore, it is essential to consider the endogeneity problem when estimating the model at the farm level (Ojo & Baiyegunhi, 2020). Concerns about the endogeneity of the production function have been highlighted in several studies. The endogenous modified stochastic frontier model is statistically more efficient than traditional models. If farmers exhibit low technical efficiency, this cannot necessarily be attributed to the lack of adoption or appropriateness of adaptive strategies. Instead, this inefficiency may result from the use of different technologies compared to other production units. Based on this, the stochastic frontier model is presented as Equation 2 (Ackerberg *et al*., 2006).

$$Q_i = X_i\beta + v_i - u_i$$
$$X_i = P_i\alpha + \varepsilon_i$$
$$\begin{bmatrix}\varepsilon_i \\ v_i\end{bmatrix} \equiv \begin{bmatrix}\Omega^{-1/2}\varepsilon_i \\ v_i\end{bmatrix} \approx N\left(\begin{bmatrix}0\\0\end{bmatrix}, \begin{bmatrix} I_p & \theta_v\rho \\ \theta_v\rho' & \theta_v^2\end{bmatrix}\right)$$
$$u_i = l\left(X'_{ui}\prod{}_u\right)u_i^* \quad (2)$$

Where Qi is the logarithm of the farmer's yield and Xi is the combined vector of endogenous and exogenous variables. Xi is the $p \times 1$ vector of all endogenous variables except Qi. This is possible due to statistical noise or when the level of inefficiency is affected by both the inputs and the frontier. $P_i = I_p \otimes P_i'$, where P_i represents the q × 1 vector of explanatory variables. Moreover, v_i and ε_i are two-sided random error terms. On the other hand, u_i it is related to the technical inefficiency of the units and includes management factors. $l_i = l(X'_{ui}\Pi_u) > 0, X_{ui}$ is a vector of exogenous and endogenous auxiliary variables without intercept and u_i^* is a random component independent of v_i and ε_i of producers. Here, Ω is the variance-covariance matrix εi, θ_v^2 is the variance of v_i and ρ is the vector representing the correlation between ε_i and v_i. Therefore, u_i and v_i can be considered correlated with X_i, however, ui and vi are conditionally independent of X_i and P_i. Accordingly, v_i and ε_i are conditionally independent with respect to X_i and P_i.

By using the Cholesky method of decomposition, the variance-covariance matrix $(-\varepsilon_i' v_i)'$ will be converted into the form of Equation 3.

$$\begin{bmatrix}\varepsilon_i \\ v_i\end{bmatrix} = \begin{bmatrix}\bar{\varepsilon}_i \\ \bar{w}_i\end{bmatrix}\begin{bmatrix} I_p & 0 \\ \sigma_v\rho' & \sigma_v\sqrt{1-\rho'\rho}\end{bmatrix} \quad (3)$$

Here, $-\varepsilon_i$ and $-w_i \approx N(\cdot,\cdot)$ are independent. With this operation, the stochastic frontier equation will be changed as Equation 4.

$$Q_i = X_i'\beta + \sigma_v\rho'\varepsilon_i^- + \omega_i - u_i = X_i'\beta + (X_i - P_i\alpha)'\eta + e_i \quad (4)$$

In this regard:

$$e_i = w_i - u_i, \quad w_i = \sigma_v\sqrt{1-\rho'\rho} - w_i = \sigma_w - w_i \quad (5)$$

As well as:

$$\eta = \sigma_w \Omega^- 1/2\rho/\sqrt{1-\rho'\rho} \quad (6)$$

For this approach, e_i is conditionally independent of the given explanatory variables X_i and P_i. As stated in equation 4, the term $(X_i - P_i\alpha)'\eta$ represents a biased correction component. Therefore, it is assumed that:

$$u_i^* \approx N^+(\mathcal{v}, \delta_u^2) \quad (7)$$

$$l_i^2 \approx exp(X'_{ui}\,\pi_u) \tag{8}$$

Finally, the efficiency of farmers $eff_i = exp(-u_i)$ will be estimated from Equation 9.

$$\exp\left(-E\left|u_i / e_i\right|\right) = \exp\left(-l_i\left(\vartheta_{i*} + \frac{\sigma_{i*}\varphi\left(\frac{\vartheta_{i*}}{\sigma_{i*}}\right)}{\Phi\left(\frac{\vartheta_{i*}}{\sigma_{i*}}\right)}\right)\right) \tag{9}$$

Where φ is the standard normal probability density function. Φ also represents the standard normal cumulative distribution function. Therefore, there is heterogeneity in the model if the η component is significant. If η is not significant, efficiency can be estimated using traditional frontier efficiency models. Otherwise, the correction term should be included in the model. The joint significance test was also used to test the significance of the η component.

Data and Sampling Method

The required data were collected through questionnaires and face-to-face interviews with farmers during the summer and fall of 1401. The sample was selected using a multi-stage random sampling method. Initially, sample villages were randomly chosen from various cities in Sistan. Finally, based on Morgan's table, 265 farmers were randomly selected from these villages. SPSS 28 and Stata 17 software were used to estimate the PCA and EMSF models, respectively.

Results and Discussion

The results of the principal component analysis (PCA) were used to calculate the effective dimensions of climate change adaptation strategies are presented in Table 2. The strategies employed by farmers include changing the plot size, adjusting the planting date, using conservation agriculture techniques, applying biofertilizers, utilizing modified crop varieties, and harvesting rainwater. KMO [1] criterion and Bartlett's test were used to ensure the appropriateness of the method and the sample size, with the results shown in Table 1. The null hypothesis in this test is the equality of the unit matrix or the matrix of correlation coefficients. According to these results, the null hypothesis, which indicates the existence of a significant correlation between these variables (a minimum necessary condition for factor analysis), cannot be accepted. Additionally, the KMO statistic value is 0.89, indicating that the data amount was suitable for this method, and the existing correlation between the data is appropriate for factor analysis. Thus, it can be concluded that the adaptation strategies used effectively represent the characteristics and dimensions of farmers' adaptation to climate change and adequately address the issue of adaptation. In other words, PCA is a suitable method for extracting farmers' adaptation strategies to climate change.

As depicted in Table 2, the weights of the factors or strategies were determined through factor analysis. The coefficients obtained emphasize the significance of the strategies utilized by the sample farmers. These coefficients indicate both the ability of the identified factors to elucidate the variance of the studied variables and the appropriateness of the variables for factor analysis. For example, the factor load of the variable farm size is 0.812, indicating a high degree of correlation with the farmers studied. The variables "Conservation tillage" and "change of planting date" have weight loads of 0.797 and 0.619, respectively. In contrast, the adaptation strategies with the lowest factor loads are associated with the use of rainwater and biological fertilizer, with values of 0.219 and 0.327, respectively. According to the study by Ojo and Baiyegunhi (2020), strategies with a load exceeding 0.500 were amalgamated to create a climate adaptation strategy index, which was subsequently utilized to estimate the technical efficiency model.

Table 1- Adequacy criteria of sample size

1- Kaiser-Meyer-Olkin Measure of Sampling Adequacy

Criterion	Statistics	The amount of statistics
KMO		0.89 ***
Bartlett's test of sphericity	Statistical approximation χ^2	304.4***
	Degrees of freedom	15
	The significance level	0.00

Source: Research findings

Table 2- Dimensions of climate change adaptation strategies used by wheat farmers

Adaptation strategies	Weight PC
Use of biological fertilizers	0.327
Change of planting date	0.619
Conservation tillage	0.797
Change the land size	0.812
Use of modified varieties	0.437
Use of rainwater	0.219
Animal husbandry	0.518

Source: Research findings

The estimation results from the maximum likelihood method of the endogenously modified stochastic frontier model are presented in Table 3. The impact of labor input on production is statistically significant and positive at the 1% level (Table 3). The coefficient for this variable suggests that, holding other variables constant, a 10% increase in the labor force results in a 4.9% increase in production. Similarly, Ojo and Baiyegunhi (2020) found that a 10% increase in labor force leads to a 2.9% increase in rice production on Nigerian farms. Mensah and Bromer (Mensah *et al.*, 2016) note that smallholder farmers in Ghana heavily depend on manual labor and that agricultural operations in developing countries often face resource constraints.

The coefficients for the variables of chemical fertilizer and chemical pesticide are statistically significant at the 1% level and both have positive signs. Notably, the input coefficient for chemical fertilizer is numerically higher than that for chemical pesticide, indicating that the contribution of chemical fertilizers to production is more substantial than that of chemical pesticides. The inputs of water consumption and machinery also have a positive and significant effect on wheat production. The coefficient for water consumption in the estimated production function indicates that a 10% increase in water usage, assuming other conditions remain stable, results in a 3.06% increase in production. Consequently, all investigated variables positively impact production as expected. Among the inputs available to farmers, labor input has the highest coefficient, indicating it has the most substantial positive effect on production. Water input ranks next in importance. The exogenous variables used in the inefficiency model were selected to reflect farmers' management capabilities, access to information, and available production resources. Estimating technical efficiency alone is insufficient for determining potential policy interventions. Identifying sources of inefficiency is crucial for making farm-level policy recommendations. Therefore, a positive and significant estimated coefficient indicates a decrease in farmers' technical efficiency, and vice versa.

The results of estimating the factors affecting the technical inefficiency of wheat producers in the Sistan region are presented in Table 3. Analysis of the variables included in the inefficiency model for wheat farmers' production shows that, except for household size and off-farm income, all other variables have a negative and significant effect on inefficiency. Specifically, the effect of the farmer's education level on technical inefficiency is negative and significant at the 1% level. This indicates a direct relationship between education level and wheat production efficiency: as education increases, technical efficiency also increases. The results also reveal that agricultural experience has a significant negative effect on technical inefficiency at the 1% level. This implies that greater agricultural experience enhances the technical efficiency of producers in the study area, resulting in a more optimal use of inputs. Furthermore, access to climate information and credit both exhibit a significant negative effect on technical inefficiency at the 1% level.

This study finding (Table 3) suggests that climate change adaptation strategies effectively address variations in inefficiency. Smallholder farmers who implement these strategies achieve increased yields and improved technical efficiency. Therefore, this research emphasizes that wheat production in Sistan can be enhanced through substantial inputs and technology, provided that smallholder farmers receive support in adopting climate change adaptation strategies. Khanal *et al.* (2018) discovered that adopting climate change adaptation strategies enhanced the technical efficiency of smallholder farmers in Nepal. Similarly, Otitoju *et al.* (2014) confirmed a positive and significant correlation between climate change adaptation strategies and farm-level efficiency in food production in southwestern Nigeria. Roco *et al.* (2017) in Chile and Anser *et al.* (2020) in Pakistan reported similar results. Ojo and Baiyegunhi (2020) also validated the positive causal relationship between the adaptation index and the technical efficiency of rice farmers in various rural areas of Nigeria. The results further indicated that the relationship between education level and inefficiency is negative, indicating that higher education levels result in lower inefficiency. This suggests that smallholders with higher education levels demonstrate greater technical efficiency. This finding is consistent with the studies of Binam *et al.* (2004) and Okonya *et al.* (2013), who identified education as a factor that enhances technical efficiency. However, it contradicts the findings of Danso-Abbeam *et al.* (2017).

The study suggests that long-term experience reduces farmers' technical inefficiency. This can be attributed to the conventional nature of some experienced farmers. Dissatisfaction with basic farming practices often motivates these farmers to adopt new methods, thereby enhancing their production efficiency. This finding aligns with the results of Danso-Abbeam *et al.* (2017) and Baiyegunhi *et al.* (2019), who observed a negative relationship between farming experience and technical inefficiency among Ghanaian farmers. Additionally, Baiyegunhi *et al.* (2019) noted that farming is considered a profession, and as farmers gain more years of experience, they acquire greater knowledge and skills, further improving their efficiency.

The effect of access to climate change information on inefficiency is negative and statistically significant. This indicates that farmers with better access to information are more efficient than those with limited access. Consequently, wheat farmers who have better access to agricultural and climate change information tend to be more innovative and efficient. Table 3 shows the negative and significant effect of access to credit on farmers' inefficiency. Ojo *et al.* (2020) discovered that access to credit significantly enhances the ability of poor households to adopt climate change adaptation strategies. Moreover, reducing potential credit constraints through timely credit provision lowers the opportunity cost of some capital-intensive adaptation strategies. Therefore, overcoming credit constraints is likely to boost the efficiency of smallholder farmers. In other words, the significant coefficient of the credit variable indicates that access to sufficient and timely credit is crucial for improving agricultural efficiency. These findings align with those of Chandio *et al.* (2017). Ojo *et al.* (2019) also found that institutional credit facilitates and increases farmers' productivity.

Finally, the endogeneity test statistic (η) indicates that the adaptation strategy is endogenous. This can be attributed to unobserved characteristics, such as production practices and risk management behavior, that influence farmers' decisions to adopt climate change adaptation strategies.

After estimating the factors affecting

technical inefficiency, the efficiency of each producer was calculated separately. The average technical efficiency, using the endogenous modified stochastic frontier method, was found to be 82%. This indicates that wheat farmers in the study can increase their technical efficiency by an average of 18% by closing the gap with the best producer in the Sistan region. In other words, smallholder wheat farmers lose about 18% of their potential harvest due to technical inefficiency. The minimum technical efficiency observed among the farms was 0.32, while the maximum was 0.98. This 0.66 difference between the most and least efficient farmers highlights the potential for improving efficiency in the region. According to Table 4, 4.5% of the production units have an efficiency between 0.3 and 0.5, 16% between 0.5 and 0.7, and 36.6% between 0.7 and 0.9. Notably, the highest frequency of technical efficiency among wheat farmers is above 90%.

Table 3- Results of Estimated EMSF Model

Variables	Coefficients	Standard error	P-value
Efficiency variables			
Labor	0.494***	0.087	0.000
Chemical pesticide	0.059***	0.023	0.000
Chemical fertilizer	0.100***	0.038	0.010
Water	0.306***	0.050	0.034
machinery	0.201***	0.076	0.000
Intercept	-2.021***	0.488	0.000
Inefficiency model			
Education level	-0.123***	0.047	0.009
household size	-0.078	0.138	0.576
Off-farm income	0.017	0.316	0.956
Agricultural experience	-0.052***	0.012	0.000
Access to climate information	-1.546***	0.407	0.000
Access to credits	-1.630***	0.408	0.000
Climate change adaptation index	-1.143***	0.531	0.031
endogeneity test (η)	Chi2 =133.75	Chi2>Prob=0.000	
Log likelihood	-75.95		

Source: Research findings

Table 4- Frequency distribution and percentage of technical efficiency of wheat producers using the EMSF model

Range of efficiency	Frequency	Percent
0.3≤ TE<0.5	12	4.52
0.5≤ TE<0.7	43	16.22
0.7≤ TE<0.9	97	36.6
0.9≤TE	113	42.64
Average	0.82	
Maximum	0.98	
Minimum	0.32	

Source: Research findings

Conclusion and Suggestions

This study investigated the impact of adopting climate change adaptation strategies on the efficiency of wheat farmers in the Sistan region using an EMSF model. The EMSF method allows for estimating the unbiased and consistent impact of these strategies on technical efficiency among smallholder farmers. This model effectively addresses the endogeneity of frontier variables and inefficiency.

The study results indicate that endogeneity in the model is significant. This issue can be attributed to unobserved characteristics, such as production practices and risk management behavior, which influence farmers' choices of climate change adaptation strategies. Therefore, addressing endogeneity is crucial; otherwise, estimates of efficiency parameters will be inconsistent. In this study, the average technical efficiency, calculated using the endogenous modified stochastic frontier model, was found to be 82%. The results also revealed a substantial difference between the most and least efficient wheat farmers in the Sistan region. This efficiency gap suggests that production can be significantly increased by improving management practices, without altering the level of technology and inputs used. The experimental results of the estimated model show that labor input, chemical pesticides, chemical fertilizers, water, and machinery significantly and positively impact wheat production efficiency in the Sistan region. This study also identified the combined effects of climate change adaptation strategies and socio-economic characteristics such as age, gender, education, agricultural experience, access to credit, and access to information. The results indicate that adaptation strategies adopted by small-scale wheat farmers in Sistan are essential for mitigating the negative impact of climate change and enhancing technical efficiency in wheat production. This study recommends improving technical efficiency by increasing farmers' knowledge through agricultural education, adult education, and timely access to credit to boost productivity. Additionally, technical efficiency can be enhanced by improving farmers' access to timely weather forecasts for the upcoming season. It is also important to encourage farmers to participate in society by forming farmer groups for proper interaction with other farmers. In this context, information on the inefficient use of agricultural production inputs helps smallholder farmers increase their efficiency by optimizing input use. Additionally, farmers' knowledge of local climatic changes and strategies to address them is essential for government, stakeholders, and relevant institutions. Therefore, involving farmers in the planning process to adopt climate-compatible strategies is crucial. However, while adaptation strategies may improve smallholder farmers' productivity, their implementation can be costly and may conflict with other social and environmental objectives. For example, increased use of agrochemicals and pesticides can degrade soils, and changing planting and harvesting dates may not be sustainable in the long term. Therefore, future studies should assess not only the impact of climate change adaptation strategies on the technical efficiency of wheat farmers but also their environmental and social impacts.

Acknowledgment

Authors would like to acknowledge the financial support for this study provided by the University of Zabol using Grant code IR-UOZ-GR-8086.

References

1. Ackerberg, D., Caves, K., & Frazer, G. (2006). *Structural estimation of production functions*. University Library of Munich, Germany. https://mpra.ub.uni-muenchen.de/38349/1/MPRA_paper_38349.pdf.
2. Ado, A.M., Leshan, J., Savadogo, P., Bo, L. & Shah, A.A. (2018) Farmers' awareness and perception of climate change impacts: case study of Aguie district in Niger. *Environment, Development and Sustainability 21*, 2963-2977. https://doi.org/10.1007/s10668-018-0173-4
3. Agriculture Jihad Ministry. (2020). Agricultural Statistics of Crops for the Crop Year 1399-1400, Agriculture Organization of Sistan and Baluchestan. (In Persian)
4. Anser, M. K., Hina, T., Hameed, S., Nasir, M. H., Ahmad, I., & Naseer, M. A. u. R. (2020). Modeling adaptation strategies against climate change impacts in integrated rice-wheat agricultural production system of Pakistan. *International Journal of Environmental Research and Public Health*, *17*(7), 2522. https://doi.org/10.3390/ijerph17072522
5. Azadi, Y., Yazdanpanah, M., & Mahmoudi, H. (2019). Understanding smallholder farmers' adaptation behaviors through climate change beliefs, risk perception, trust, and psychological distance: Evidence from wheat growers in Iran. *Journal of environmental management*, *250*, 109456. https://doi.org/10.1016/j.jenvman.2019.109456
6. Baiyegunhi, L., Hassan, M., Danso-Abbeam, G., & Ortmann, G. (2019). Diffusion and adoption of Integrated Striga Management (ISM) technologies among smallholder maize farmers in rural northern Nigeria. *Technology in Society*, *56*, 109-115. https://doi.org/10.1016/j.techsoc.2018.09.009
7. Binam, J. N., Tonye, J., Nyambi, G., & Akoa, M. (2004). Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. *Food policy*, *29*(5), 531-545. https://doi.org/10.1016/j.foodpol.2004.07.013
8. Bonzanigo, L., Bojovic, D., Maziotis, A., & Giupponi, C. (2016). Agricultural policy informed by farmers' adaptation experience to climate change in Veneto, Italy. *Regional Environmental Change*, *16*, 245-258. https://doi.org/10.1007/s10113-014-0750-5
9. Bozorgparvar, E., Yazdanpanah, M., Forouzani, M., & Khosravipour, B. (2018). Cleaner and greener livestock production: Appraising producers' perceptions regarding renewable energy in Iran. *Journal of Cleaner Production*, *203*, 769-776. https://doi.org/10.1016/j.jclepro.2018.08.280
10. Camarotto, C., Dal Ferro, N., Piccoli, I., Polese, R., Furlan, L., Chiarini, F., & Morari, F. (2018). Conservation agriculture and cover crop practices to regulate water, carbon and nitrogen cycles in the low-lying Venetian plain. *Catena*, *167*, 236-249. https://doi.org/10.1016/j.catena.2018.05.006
11. Chandio, A. A., Magsi, H., Rehman, A., & Sahito, J. G. M. (2017). Types, sources and importance of agricultural credits in Pakistan. *Journal of Applied Environmental and Biological Sciences*, *7*(3), 144-149.
12. Danso-Abbeam, G., Bosiako, J. A., Ehiakpor, D. S., & Mabe, F. N. (2017). Adoption of improved maize variety among farm households in the northern region of Ghana. *Cogent Economics & Finance*, *5*(1), 1416896. https://doi.org/10.1080/23322039.2017.1416896
13. Deng, J., Sun, P., Zhao, F., Han, X., Yang, G., & Feng, Y. (2016). Analysis of the ecological conservation behavior of farmers in payment for ecosystem service programs in eco-environmentally fragile areas using social psychology models. *Science of the Total Environment*, *550*, 382-390. https://doi.org/10.1016/j.scitotenv.2016.01.152
14. FAO. (2015). FAOSTAT. Retrieved 03.12.15 from http://www.fao.org/worldfoodsituation/csdb/en/
15. Giri, N. C. (1974). *Introduction to Probability and Statistics: Statistics* (Vol. 7). M. Dekker.
16. Hotelling, H. (1933). Analysis of a complex of statistical variables into principal components. *Journal of educational psychology*, *24*(6), 417. https://doi.org/10.1037/h0071325
17. IPCC. (2017). *Scoping of the IPCC sixth assessment report (AR6) background, cross cutting issues and the AR6 synthesis report. IPCC-XLVI/Doc. 6. (4.VIII.2017). Agenda Item: 7.4. IPCC Secretariat, Geneva*.
18. Karimi, V., Karami, E., & Keshavarz, M. (2018). Climate change and agriculture: Impacts and adaptive responses in Iran. *Journal of Integrative Agriculture*, *17*(1), 1-15. https://doi.org/10.1016/S2095-3119(17)61794-5
19. Khadka, C., Aryal, K. P., Edwards-Jonášová, M., Upadhyaya, A., Dhungana, N., Cudlin, P., & Vacik, H. (2018). Evaluating participatory techniques for adaptation to climate change: Nepal case study. *Forest Policy and Economics*, *97*, 73-82. https://doi.org/10.1016/j.forpol.2018.08.017

20. Khakifirouz, Z., Niknami, M., Keshavarz, M. & Sabouri, M. S. (2022). Drivers of Farmers' Resilience to Drought: A Case of Sistan Plain. *Iranian Agricultural Extension and Education Journal*, *18*, 161-179. http://www.iaeej.ir/article_156443.html?lang=en (In Persian)
21. Khanal, U., Wilson, C., Lee, B. L., & Hoang, V. N. (2018). Climate Change Adaptation Strategies and Food Productivity in Nepal: A Counterfactual Analysis. *Climatic Change*, *148*(4), 575-590. https://doi.org/10.1007/s10584-018-2214-2
22. Kitole, F. A., Tibamanya, F. Y., & Sesabo, J. K. (2024). Exploring the nexus between health status, technical efficiency, and welfare of small-scale cereal farmers in Tanzania: A stochastic frontier analysis. *Journal of Agriculture and Food Research*, *15*, 100996. https://doi.org/10.1016/j.jafr.2024.100996
23. Luo, L., Qin, L., Wang, Y., & Wang, Q. (2016). Environmentally-friendly agricultural practices and their acceptance by smallholder farmers in China—A case study in Xinxiang County, Henan Province. *Science of the Total Environment*, *571*, 737-743. https://doi.org/10.1016/j.scitotenv.2016.07.045
24. Ma, W., Renwick, A., Yuan, P., & Ratna, N. (2018). Agricultural cooperative membership and technical efficiency of apple farmers in China: An analysis accounting for selectivity bias. *Food policy*, *81*, 122-132. https://doi.org/10.1016/j.foodpol.2018.10.009
25. Mardani Najafabadi, M., Mirzaei, A., Azarm, H., & Nikmehr, S. (2022). Managing Water Supply and Demand to Achieve Economic and Environmental Objectives: Application of Mathematical Programming and ANFIS Models. *Water Resources Management*, *36*(9), 3007-3027. https://doi.org/10.1007/s11269-022-03178-1
26. Mensah, A., & Brummer, B. (2016). Drivers of technical efficiency and technology gaps in Ghana's mango production sector: A stochastic metafrontier approach Amos. *African Journal of Agricultural and Resource Economics*, *11*(2), 101-117. 10.22004/ag.econ.241854
27. Mirzaei, A., & Zibaei, M. (2021). Water conflict management between agriculture and wetland under climate change: Application of economic-hydrological-behavioral modelling. *Water Resources Management*, *35*, 1-21. https://doi.org/10.1007/s11269-020-02703-4
28. Mirzaei, A., Azarm, H., Yazdanpanah, M., & Najafabadi, M.M. (2022). Socio-economic, social-capital, and psychological characteristics and climate change adaptive behavior of farmers in Iran. *Climate Research*, *87*, 1-12. https://doi.org/10.3354/cr01683
29. Ogundari, K., & Bolarinwa, O.D. (2018). Impact of agricultural innovation adoption: a meta-analysis. *Australian Journal of Agricultural and Resource Economics*, *62*(2), 217-236. https://doi.org/10.1111/1467-8489.12247
30. Ojo, T., & Baiyegunhi, L. (2020). Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria. *Land Use Policy*, *95*, 103946. https://doi.org/10.1016/j.landusepol.2019.04.007
31. Ojo, T., Baiyegunhi, L., & Salami, A. (2019). Impact of credit demand on the productivity of rice farmers in South West Nigeria. *Journal of Economics and Behavioral Studies*, *11*(1 (J)), 166-180. https://doi.org/10.22610/jebs.v11i1(J).2757
32. Okonya, J. S., Syndikus, K., & Kroschel, J. (2013). Farmers' perception of and coping strategies to climate change: Evidence from six agro-ecological zones of Uganda. *Journal of Agricultural Science*, *5*(8), 252. https://doi.org/10.5539/jas.v5n8p252
33. Otitoju, M.A., & Enete, A.A. (2014). Climate change adaptation strategies and farm-level efficiency in food crop production in southwestern, Nigeria. *Tropicultura*, (32), 3.
34. Page, G., & Bellotti, B. (2015). Farmers value on-farm ecosystem services as important, but what are the impediments to participation in PES schemes? *Science of the Total Environment*, *515*, 12-19. https://doi.org/10.1016/j.scitotenv.2015.02.029
35. Pagliacci, F., Defrancesco, E., Mozzato, D., Bortolini, L., Pezzuolo, A., Pirotti, F., Pisani, E., & Gatto, P. (2020). Drivers of farmers' adoption and continuation of climate-smart agricultural practices. A study from northeastern Italy. *Science of the Total Environment*, *710*, 136345. https://doi.org/10.1016/j.scitotenv.2019.136345
36. Pearson, K. (1971). LIII. On lines and planes of closest fit to systems of points in space. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, *2*(11), 559-572. https://doi.org/10.1080/14786440109462720

37. Roco, L., Bravo-Ureta, B., Engler, A., & Jara-Rojas, R. (2017). The impact of climatic change adaptation on agricultural productivity in Central Chile: A stochastic production frontier approach. *Sustainability*, *9*(9), 1648. https://doi.org/10.3390/su9091648
38. Sardar Shahraki, A., & Ghaffari Moghdam, Z. (2023). Analysis of types of efficiency with risk of wheat production in Sistan region. *Iranian Journal of Agricultural Sciences*, *54*, 201-220. 10.22059/ijaedr.2022.341903.669143 (In Persian)
39. Shaffril, H. A. M., Krauss, S. E., & Samsuddin, S. F. (2018). A systematic review on Asian's farmers' adaptation practices towards climate change. *Science of the Total Environment*, *644*, 683-695. https://doi.org/10.1016/j.scitotenv.2018.06.349
40. Wahid, U., Ali, S., & Hadi, N. A. (2017). On the estimation of technical efficiency of tomato growers in Malakand, Pakistan. *Sarhad Journal of Agriculture*, *33*(3), 357-365.
41. Yazdanpanah, M., Forouzani, M., Abdeshahi, A., & Jafari, A. (2016). Investigating the effect of moral norm and self-identity on the intention toward water conservation among Iranian young adults. *Water Policy*, *18*(1), 73-90. https://doi.org/10.2166/wp.2015.031
42. Zaveri, E., Russ, J., & Damania, R. (2020). Rainfall anomalies are a significant driver of cropland expansion. *Proceedings of the National Academy of Sciences*, *117*(19), 10225-10233. https://doi.org/10.1073/pnas.1910719117
43. Zhang, B., Fu, Z., Wang, J., & Zhang, L. (2019). Farmers' adoption of water-saving irrigation technology alleviates water scarcity in metropolis suburbs: A case study of Beijing, China. *Agricultural Water Management*, *212*, 349-357. https://doi.org/10.1016/j.agwat.2018.09.021

Journal of Agricultural Economics & Development

Homepage: https://jead.um.ac.ir

مقاله پژوهشی

جلد ۳۸ شماره ۲، تابستان ۱٤۰۳، ص. ۲۰۸-۱۹۵

اثر پذیرش راهبردهای مقابله با تغییر اقلیم بر کارایی فنی گندمکاران منطقه سیستان

هما ناروئی[۱]- محمود احمدپور برازجانی[۲*]- ماشاءالله سالارپور[۳]- علیرضا کیخا[۳]- رضا اسفنجاری کناری[٤]

تاریخ دریافت: ۱۴۰۲/۱۲/۲۸

تاریخ پذیرش: ۱۴۰۳/۰۵/۰۶

چکیده

تأثیر منفی و مخرب پدیده تغییر اقلیم بر عملکرد و بهره‌وری عوامل تولید کشاورزی در بسیاری از مناطق جهان به‌خصوص در مناطق خشک و نیمه‌خشک به اثبات رسیده است. در این راستا، اتخاذ راهبردهای نوآورانه برای افزایش انعطاف‌پذیری و سازگاری کشاورزان به منظور تطبیق با تغییرات اقلیمی گسترش یافته است. بنابراین، آگاهی از میزان اثرگذاری راهبردهای تطبیق با اقلیم بر میزان کارایی و عملکرد زراعین حائز اهمیت است. بر این اساس، در پژوهش حاضر، تأثیر راهبردهای تطبیق با تغییر اقلیم همراه با مصرف نهاده‌ها و عوامل خارج از کنترل کشاورز برکارایی فنی با استفاده از مدل مرزی تصادفی اصلاح‌شده درونزا (EMSF) ارزیابی شد. داده‌ها ازطریق تکمیل ۲۶۵ پرسشنامه درسال زراعی ۱۴۰۱-۱۴۰۰ و به روش نمونه‌گیری تصادفی چندمرحله‌ای برای تولیدکنندگان گندم در منطقه سیستان جمع‌آوری شد. به منظور ساختن شاخص تطبیق از روش تجزیه و تحلیل مؤلفه اصلی (PCA) استفاده شد. نتایج PCA نشان داد تغییر اندازه زمین (۰/۸۱۲) خاکورزی حفاظتی (۰/۷۹۷) و تغییر تاریخ کشت (۰/۶۱۹) بیشترین بار عاملی و استفاده از آب باران (۰/۲۱۹) و استفاده از کودهای زیستی (۰/۳۲۷) کمترین بار عاملی راهبردهای تطبیق در بین کشاورزان را دارند. دراین مطالعه، میانگین کارایی فنی گندمکاران ۸۲ درصد محاسبه شد. نتایج برآورد مدل نشان داد که مساعدت نهاده‌های نیروی کار، سموم شیمیایی، کود شیمیایی، آب و ماشین‌آلات به کارایی تولید گندم از نظر آماری مثبت و معنی‌دار است و با اجرای راهبردهای تطبیق با اقلیم توسط کشاورزان، میزان ناکارایی فنی کاهش می‌یابد. همچنین، متغیرهای سطح تحصیلات، تجربه کشاورزی، دسترسی به اطلاعات اقلیمی و دسترسی به اعتبارات در کاهش ناکارایی فنی مؤثرند.

واژه‌های کلیدی: تحلیل مؤلفه‌های اصلی، رگرسیون لاجیت، مدل مرزی تصادفی، ویژگی‌های اجتماعی-اقتصادی

۱، ۲ و ۳- به‌ترتیب دانشجوی دکتری، دانشیار و استادیار گروه اقتصاد کشاورزی، دانشکده کشاورزی، دانشگاه زابل، زابل، ایران

(*- نویسنده مسئول: Email: mahmadpour@uoz.ac.ir)

۴- استادیار، گروه اقتصاد کشاورزی، دانشکده علوم کشاورزی، دانشگاه گیلان، گیلان، ایران

https://doi.org/10.22067/jead.2024.87331.1259