



Does Diversified Agriculture System Improve The Diversified Diets of Households? A Panel Data Study

Vimala Venugopal Muthuswamy^{1*}, Mari Anand Navaneetha Krishnan²

¹ Department of Management, College of Business Administration, King Faisal University, Al-Ahsa 31982, Saudi Arabia.

Email: fmuthuswamy@kfu.edu.sa

² Senior Lecturer, College of Economics and Business Administration, University of Technology and Applied Sciences-Salalah, Thumrait road, Salalah, Sultanate of Oman. P.O. Box 608, Postal Code-211.

Email: mari.krishnan@utas.edu.om

*Correspondance: fmuthuswamy@kfu.edu.sa

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The study investigated the influence of agricultural diversification on the diversified diets of households in Saudi Arabia. For this purpose, data were collected from Saudi Arabia Integrated Household Survey data from 2019 to 2023. Used longitudinal research design, quantitative research approach, and panel data statistical technique of pooled and fixed effects. The panel data results show that agricultural diversification has a significant impact on a household's food score and household's dietary diversity score. Production diversification also has a positive and significant impact on the household's food score and a negative and significant effect on household's diverse dietary score. Additional factors such as farm size, market distance, and income sources also influence the food diversification score, and market distance insignificant impact on the household dietary diversification score. Specifically, farm income positively impacts household food score, while non-farm income contributes significantly to both household food score and household diversified dietary score. The gender and age of the household head also have a significant impact on diversified household diets. The study with these significant findings emphasizes that in Saudi Arabia there should be strong agricultural policies that not only address the diversification of production in agriculture but also enforce to increase of non-farm income factors to enhance dietary diversity effectively. The study contributes novel insights into the effects of agricultural diversification on diversified diets in the Saudi context and offers implications for policy development.

1. Introduction

Human beings have an inherent right that could be achieved through providing adequate food and nutrition which is important for ensuring good health and preventing hunger (Frag et al., 2023). Nevertheless, proper diet is important for addressing micronutrient deficiencies and overall well-being (Perler, Friedman, & Wu, 2023). Agricultural diversification transitions from subsistence farming to a more varied and market-oriented production system which leads to improvements in food quality (Takeshima et al., 2024). This diversification can be a potential increase in dietary diversity by offering a broader range of food products (Takeshima et al., 2024). Yet, the relationship between agricultural diversification and dietary diversity is complex and varies across different contexts (Bai et al.,

2024). Therefore, agricultural diversification is essential for increasing household dietary diversification.

Other researchers also emphasized that agriculture diversification also holds a significant potential for enhancing food dietary diversification (Isbell et al., 2024; Yan et al., 2024). Further also emphasized that diversification in agriculture production offers various benefits (Alam et al., 2023). It increases dietary quality and health by making a variety of foods that are more accessible to consumers which improves their diet system. Secondly, diversification contributes to more reliable and consistent food availability by mitigating risks associated with adverse events like extreme weather and climate crises that could improve the diet system. Thirdly, a diverse range of agricultural commodities could also provide more stable and profitable earnings

for households enabling them to purchase a wider array of food items and better manage price fluctuations and market (Mastura et al., 2023). Further studies also enforced that agricultural diversification increases the diet system of any individual (Tacconi et al., 2023; Yun & Kim, 2023). Therefore, the study focused on the impact of agricultural diversification on household dietary diversification.

Previously, various studies have been conducted on agricultural and dietary diversification but still have multiple gaps. Firstly, several studies have been conducted on individual agricultural diversification or crops and livestock while having limited attention on the inclusion of non-crop foods such as fish and livestock production (Kapulu et al., 2023; Mastura et al., 2023; Takeshima et al., 2024; Yun & Kim, 2023). Different studies also argued that for a comprehensive understanding of how agricultural diversification impacts household diet, it is crucial to incorporate non-crop foods into the analysis (Appiah-Twumasi & Asale, 2024; Isbell et al., 2024) because including the cultivation of non-crop foods can effectively address micronutrient deficiencies and improve overall nutrition (Shraddha et al., 2024). Therefore, the study focused on the combined effect of crops, fish, and livestock on a diversified diet. Furthermore, previous studies also have inconsistent findings. For instance, the findings of Mastura et al. (2023) and Yun & Kim (2023) indicate that increased diversified agriculture does not always lead to higher dietary diversity. Other studies found that diversified agricultural production positively increases household dietary diversity (Isbell et al., 2024; Nkonde et al., 2021). These inconsistencies in the results show that there might be other variables that could improve their relationship. Various authors argued that agricultural diversification's impact could be increased on household dietary diversification when other factors are also tested like market access, income diversification, and educational attainment (Madsen et al., 2021; Mastura et al., 2023).

In other contexts, studies on agricultural diversification and household dietary diversification have more literature on other economies. Globally, agricultural diversification has been shown to improve dietary quality and food security by enhancing food availability and stabilizing income (Ricciardi et al., 2024). However, in Saudi Arabia, the benefits of agricultural diversification in terms of dietary diversity are not well documented. Studies in other regions (Isbell et al., 2024) suggest that diversifying agricultural production

can increase food variety which can improve dietary diversity. The agriculture sector in Saudi Arabia has become a cornerstone for economic development which has a contribution of approximately 100 billion Saudi Riyals to the GDP (Abdelbaki & Alzahrani, 2024). Despite the significant contribution of the agriculture sector in Saudi Arabia, its role in dietary diversification remains underdeveloped. The sector's focus has historically been on staple crops and high-value exports rather than diversifying local food options. This limited diversification limited the focus on diversified diets in Saudi Arabia (El-Dukheri, 2024). Other authors also suggested that strengthening agricultural diversification could enhance dietary variety (El-Dukheri, 2024; Takeshima et al., 2024) in Saudi Arabia. Practical issues and the limited scope of existing studies on the impact of agricultural diversification and other factors of household dietary diversification highlight a need to conduct research in Saudi Arabia. Therefore, the study aimed to test the impact of agricultural diversification on household diet diversified in Saudi Arabia.

Various theoretical and practical implications have been explained based on research findings. In a theoretical context, integrating non-crop foods such as fish and livestock into the analysis of agricultural diversification could increase our understanding of how diverse production systems impact dietary diversity. This comprehensive approach aligns with the argument that a complicated view of agricultural diversification is necessary for capturing its full impact on dietary quality. The research with this research framework could also provide benefits to other researchers in conducting their research in the future that could increase the new research area in future. Practically, for regions like Saudi Arabia, where agricultural constraints and market dynamics play a crucial role, incorporating non-crop foods into diversification strategies could improve nutritional outcomes and food security. This approach can address micronutrient deficiencies and enhance overall dietary quality. Thus, future researchers and policymakers should focus on complete agricultural diversification models that include both crop and non-crop food sources to effectively enhance dietary diversity that could increase the overall country's economic growth. The rest of the paper was distributed in four chapters. The second chapter consisted of a literature review, the third chapter consisted of research methodology, the fourth chapter consisted of data analysis, and the fifth chapter consisted of discussion and conclusion.

2. Literature Review

Agricultural diversification consists of various crops and livestock species that are cultivated in a specific region (Mastura et al., 2023). This not only consists of the range of various plant and animal species but also has the generic variations within those species. It consisted of different forms of biodiversity in agriculture, such as the different types of grains, vegetables, fruits, and livestock breeds that are grown or raised (Mastura et al., 2023). Agricultural diversity is crucial because it contributes to the resilience of farming systems, reduces the risk of crop failure, and supports ecosystem stability by maintaining a balance among different species and their interactions with the environment (Nkonde et al., 2021). In the extant literature, the relationship between agricultural diversity and dietary diversity argued that a diverse agricultural system often leads to a broader range of food products, which in turn can enhance dietary diversity within households (Mofya-Mukuka & Kuhlitz, 2016). Dietary diversity refers to the variety of different foods consumed, which is essential for meeting nutritional needs and improving health outcomes (Mofya-Mukuka & Kuhlitz, 2016). Agricultural diversity can be categorized into production diversity and broader agricultural diversity. Production diversity focuses on the range of different crops and livestock species that are produced and harvested, while agricultural diversity as a component encompasses the genetic and ecological variations within those species and their contributions to the overall farming system (Alam et al., 2023). Therefore, these dimensions' importance cannot be ignored because increasing production diversity and broader agricultural diversity can access a more varied household diet which is important for food security.

In the agricultural diversification dimensions, production diversification consisted of household goods engagement in different crop cultivations (Sibhatu, Krishna, & Qaim, 2015). Different empirical studies have been conducted on the relationship between agricultural production and household food. Sibhatu et al. (2015) explored the study and found that diversified agriculture could significantly increase the food items available to households. The authors also found that households engaged in diverse cropping systems had access to a broader range of food products compared to those relying on monocultures. This increased variety often translated into improved food security, as diverse crops reduced the reliance on a single food source, thereby enhancing dietary options. In another study, Jones, Shrinivas, & Bezner-

Kerr (2014) further conducted a study on production diversification in a household's food system. Their study revealed that households practicing diverse agriculture were able to access a more varied diet, which improved their nutritional status. The researchers attributed this improvement to the availability of multiple food sources, which reduced the risks associated with crop failures and price fluctuations in staple foods. In another study, Khoury et al. (2022) further research indicates that diversifying crop production can help households access a wider array of food products, potentially improving their overall food security.

On the other hand, further studies also emphasized that production diversification has a strong relationship in two context rural and agricultural. Households which are engaged in various range of agricultural productions, such as cultivating multiple crops or integrating crop-livestock systems, tend to experience greater overall diversification in their livelihoods (Appiah-Twumasi & Asale, 2024). This diversification strategy allows households to mitigate risks associated with agricultural uncertainties, such as climate variability or market fluctuations, while also enhancing food security and income stability (Mengistu & Belda, 2024). Moreover, production diversification often leads to increased access to a variety of food products, contributing to improved household dietary diversity and nutritional outcomes (Wang et al., 2024). This study also concluded that further research could be explored on other agricultural countries where this sector has a major contribution in social and economic development. Nkonde et al. (2021) further found the negative impact of production diversification on dietary diversification. These studies show that production diversification has a relationship with food dietary diversification but still relationships are not clear.

Agricultural diversification is also an important factor that helps to improve food dietary diversification. It helps to enhance various crop varieties and livestock products in the farming system. Lulanga, Marinda, & Khayeka-Wandabwa (2022) examined the influence of agricultural diversification on diet diversity. Their results show that increased diversity in crops is associated with improved dietary diversity. This improvement was attributed to the increased availability of a variety of food products that help to enhance dietary diversification. In another context, Alam et al. (2023) found agricultural diversification played a significant role in increasing dietary diversification. The authors noted that factors such as market integration, food processing, and

dietary preferences played a crucial role in determining whether diversified agricultural outputs translated into diverse diets. These results emphasize the significance of considering the broader food system context when evaluating the impact of agricultural diversification. Mastura et al. (2023) further endorsed these findings and highlighted that agricultural diversification alone may not improve dietary diversity if it is not accompanied by improvements in market access and consumer acceptance.

In addition, Saboori, Alhattali, & Gibreel (2023) found that agricultural diversification has a significant impact on dietary diversification. Further study highlighted that agricultural diversification which consisted to different crops and livestock crop integration played an important role in increasing food production diversification (Addai et al., 2024). This approach minimizes the dependency on single crops, and risk mitigations which are related to market fluctuations and climatic events that could promote in income (Buyinza & Joweria, 2024). They further argued that households engaged in agricultural diversification are more likely to produce a diverse array of foods, improving dietary diversity and nutritional outcomes. Additionally, diversified agricultural systems often lead to better resource that could positively and significantly increase food diversification (Bardhan et al., 2024). They also further recommended that in developing countries where major contributions to economic development are from the agriculture sector studies have still limited attention on developing nations. Therefore, the further relationship between agricultural diversification and food dietary diversification could be tested in the context of Saudi Arabia which is also a developing nation.

On the other hand, further empirical studies have shown that farm size is also an important indicator that helps to increase household diversification which can provide dietary diversity and nutritional output. The larger farms have more resources and have their greater capacity to cultivate a variety of crops that could lead to an increase the food diversity (Hlatshwayo, Slotow, & Ngidi, 2023). In another context, if the land has a greater capacity to produce a variety of crops then the diversity in the product also increases including fruits, vegetables, and legumes, which contribute to a more diverse and nutritious diet (Otekunrin et al., 2023). Further, larger farms often have better access to markets and agricultural inputs, which further enhances their ability to produce a variety of foods for household consumption and potentially for sale, leading to improved dietary diversity (Amao et al., 2023). On the other hand,

if the farms are not larger then the organizations have their limitations in achieving food diversification due to restricted land and limited availability of resources. Such constraints could result a focus on staple crops which could require a less land and inputs, such as cereals, rather than a broader range of nutrient-rich crops (Bacon et al., 2023). As a result, households with smaller farms may experience lower dietary diversity, which can have negative implications for nutrition and health. However, some studies indicate that with access to support services, such as extension services or credit, even small farms can achieve a degree of food diversification by adopting practices like intercropping or engaging in small-scale livestock production (Morrissey et al., 2024). These findings shown that farm size becomes and integral factor that could help to increase household products diversification.

On the other hand, other researchers also argued that income diversification impacts to dietary diversification (Saboori et al., 2023). Other studies have found the same results (Liyew & Damtie, 2024). This is because increased income allows households to purchase a greater variety of foods and access more nutritious options (Liyew & Damtie, 2024). Salifu & Salifu (2023) also, a study found a positive and significant impact of income diversification on dietary diversification. They further argued that future research could be explored in other developing countries to increase the variations in the findings. In another context, Mastura et al. (2023) found the negative impact of farm income on dietary diversification. The positive of farm and non-farm incomes on diet diversification emphasized the importance of income in enhancing food variety and dietary diversity. However, the impact of farm income on dietary diversification is negative, despite its positive effect. Diversification suggests that income from farming alone may not necessarily translate into improved dietary diversity (Mastura et al., 2023). This may be due to the allocation of farm income towards non-food expenses or the focus on commercially viable crops rather than diverse dietary needs. These previous studies highlighted that form and non-income factors are important to increase food production diversification. Additionally, empirical research has shown that non-farm income positively and significantly increases household food diversification by providing additional financial resources after purchasing a different variety of products beyond farm products (Mengistu & Belda, 2024). Households with non-farm income tend to have better dietary diversity, as they can afford to buy nutrient-rich foods such as fruits, vegetables, and animal products (Kumari & Ramana



Murthy, 2024). This income source also reduces reliance on subsistence farming which is allowing for more diverse consumption patterns (Hossain, 2024).

On the other hand, market access factors are also important indicators which are influencing both food variety and dietary diversity. Ababouch et al. (2023) conducted a study that highlighted that greater proximity to markets increases access to a wider range of food products, thereby enhancing food variety and dietary diversity. Market distance can limit household access to diverse foods, particularly in remote or rural areas. Ume (2023) also conducted the study and found that production market excess helps to increase the dietary plane which increases the best diet plan of any individual. Further empirical studies highlighted that market distance often limits the household's market access which could reduce the opportunities for income diversification and enhance resilience in subsistence activities (Tacconi et al., 2023). In other words, other authors also suggested that households located farther from markets may diversify their income sources as a risk management strategy, engaging in non-farm activities or migrating to urban areas to secure additional income streams (Getahun et al., 2023). Further results also emphasize the importance of considering local contexts and the specific economic, social, and infrastructural conditions that influence how market distance affects household diversification (Beyene et al., 2023).

Equally, educational attainment on food security and dietary diversity have been studied in various studies. For instance, Dirghayu et al. (2023) indicate that higher levels of education are associated with better nutritional outcomes due to increased awareness and knowledge about nutrition. Education can also improve agricultural practices and food choices. Conversely, conducted research found a negative impact of education breakdown on the dietary system. In the same vein, demographic factors like children's proportions and elderly individuals in a household can significantly affect dietary diversity. Petrone et al. (2023) conducted their research and found that households with higher proportions of children or elderly members may face specific dietary challenges, including increased needs for certain nutrients and potential limitations in food variety. The previous discussion showed that agricultural and non-agricultural factors are important factors for dietary diversification and previous studies have limited attention on Saudi Arabia. Therefore, seeking previous gaps and relationships, the following hypotheses are formulated below,

H1: *Production diversification score influence to household diversified score.*

H2: *Production diversification score influences to household diversified diet score.*

H3: *Agricultural diversification score influences to household diversified score.*

H4: *Agricultural diversification score influences to household diversified score.*

H5: *Farm size has a significant influence on household diversified score.*

H6: *Farm size has a significant influence on household diversified score.*

H7: *Market distance score influences to household diversified score.*

H8: *Market distance influences to the household diversified score.*

H9: *Farm income score influences to household diversified score.*

H10: *The farm income score influences to household diversified score.*

H11: *Non-form income influences to household diversified score.*

H12: *Non-form income influence to household diversified score.*

3. Research Methodology

The research aimed to test the impact of agricultural diversification on household dietary diversification. A quantitative research approach was employed that is considered to be good for the current study because data was collected in numbers. In other words, quantitative data provides statistical rigor and allows for generalizable conclusions across larger populations which offers measurable insights into trends and patterns (Gelo, Braakmann, & Benetka, 2008). In contrast, qualitative data offers depth and context, capturing subjective experiences that may not be readily quantifiable (Gelo et al., 2008). Therefore, researchers employed the quantitative research approach. Furthermore, a longitudinal research design was employed. The longitudinal research design allows data at different times, revealing causal relationships and developmental trends, whereas cross-sectional designs capture a snapshot at one point in time, limiting insights into causality and temporal dynamics (Rindfleisch et al., 2008). Therefore, researchers employed the longitudinal research design.

3.1 Data Collection

Data was collected from the integrated household survey for the period of 2019 to 2023. The survey was conducted

through data analysis and technical assistance from the International Food Policy Research Institute. The survey consisted of three agricultural products, fisheries, crops, and livestock. The researchers collected data sets according to the International Food Policy Research Institute. The total sample size was 150 among the 50 primary sampling units of the village. The sample was excluded where households were not included in the agricultural production like crops, fisheries, and livestock because without these productions agricultural diversifications cannot be measured. To create a balanced panel dataset, we excluded households that split up from 2019 to 2023. As a result, our sample size is smaller compared to the original integrated household survey data, which includes a balanced panel of 750 observations from 150 farm households with complete

survey information.

3.2 Variable Measurements and Econometric Models

The below Table.1 shows the description of the study variables. Household dietary diversification is the dependent variable which was measured by two dimensions household dietary diversity, and household food variety score. In addition, agricultural diversification was the independent variable which was measured by two dimensions production diversification score, and agriculture diversification score. Other market indicators namely market distance, farm size, income from farm and non-farm sources. At last various demographic variables namely age, education, and gender used for the current study.

Table 1: Variables Measurement.

Measure/Variable	Description	Source
Dependent variable		
Household dietary diversification		
Household Dietary Diversity Score (HDDS)	Total count of distinct food groups consumed by the household over the past 7 days.	(Integrated household survey, 2019, 2023)
Household Food Variety Score (HFVS)	Total count of unique food items consumed by the household over the past 7 days.	(Integrated household survey, 2019, 2023)
Independent variables		
AD (Agricultural Diversification)		(Integrated household survey, 2019, 2023)
Production Diversification Score (PDS)	Count of various food crops, fish, and livestock products produced by the household.	(Integrated household survey, 2019, 2023)
Agricultural Diversification Score (ADS)	Count of different food groups produced by the household, based on the 12 groups defined in the HDDS.	(Integrated household survey, 2019, 2023)
Market Access Indicators	Market distance Form income Non-form income Farm size	(Integrated household survey, 2019, 2023)
Control Variables		
Demographic Characteristics	Gender 1 for male and 2 for female Head ages, Head education	(Integrated household survey, 2019, 2023)
The above variables are predicted in the following equation below.		
$HFVS = \beta_0 + \beta_1 PDS + \beta_2 ADS + \beta_3 FS + \beta_4 MD + \beta_5 FI + \beta_6 NFI + \beta_7 GEN + \beta_8 ag + \beta_9 EDU + \epsilon \quad (1)$		
$HDDS = \beta_0 + \beta_1 PDS + \beta_2 ADS + \beta_3 FS + \beta_4 MD + \beta_5 FI + \beta_6 NFI + \beta_7 GEN + \beta_8 ag + \beta_9 EDU + \epsilon \quad (2)$		
Note: HDDS-household dietary diversity, HDFS-household food variety, ADS-agricultural diversification, PDS-production diversification, FS-farm size, MS-market distance, FI-farm income, NFI-non farm income, GEN-gender, EDU-education.		

3.3 Descriptive Statistics

The dataset comprises 750 observations with a focus on various household and economic metrics. The average Household Dietary Diversity Score (HDDS) is 11.0 with a standard deviation of 1.6, indicating a relatively high and consistent level of dietary diversity among households, ranging from 6.5 to 15.5. Similarly, the average Household Food Variety Score (HFVS) is 34.5, with a broad standard deviation of 10.5, reflecting significant variability in

food variety across households, spanning from 16 to 61. The Perceived Dietary Supplement (PDS) has a mean of 8.2 and a high standard deviation of 5.25, showing substantial variation in dietary supplement perception, with values between 2.5 and 16. The Average Dietary Supplement (ADS) averages 3.9, with a standard deviation of 1.9, and ranges from 1 to 7.5. Farm size has a large mean of 64 decimal units and a very high standard deviation of 112, indicating a significant disparity in farm sizes from 1 to 510 decimal units. Market distance

averages 1.9 kilometers with a standard deviation of 2.8, showing variability from 0.5 to 11 kilometers. Farm income averages 36,500 with considerable variability (standard deviation of 68,500), ranging from 1,200 to 520,000, while Non-farm income is substantially higher at an average of 64,000, with a standard deviation of 98,000, and ranges between 600 and 620,000. Gender, coded as a dummy variable, averages 0.83, suggesting a predominance of male-headed households, with a binary range of 0 to 1. The average age of household heads is 46.5 years, with a standard deviation of 13.5 years, ranging from 20 to 80 years. Finally, the average education level of household heads is 3.7 years with a standard deviation of 4.15, ranging from no formal education to 15 years. The above results are predicted in the following Table.2 below

Table 2: Descriptive Statistics.

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
HDDS	750	11	1.62	6.5	15.5
HFVS	750	34.5	10.53	16	61
PDS	750	8.21	5.25	2.5	16
ADS	750	3.92	1.94	1	7.5
FS	750	643	112	1	510
MD	750	1.91	2.82	0.5	11
FI	750	36,500	68,500	1,200	520,000
NFI	750	64,000	98,000	600	620,000
GEN	750	0.83	0.441	0	1
Age	750	46.5	13.54	20	80
Education	750	3.73	4.152	0	15

Note: HDDS-household dietary diversity, HDFS-household food variety, ADS-agricultural diversification, PDS-production diversification, FS-farm size, MS-market distance, FI-farm income, NFI-non farm income, GEN-gender, EDU-education

3.4 Diagnostics Test

The diagnostic tests for multicollinearity, autocorrelation, and heteroscedasticity provide insights into the reliability and validity of the regression models. The multicollinearity results shown in Table 3 indicated that most of the Variance Inflation Factor (VIF) values are above 2 but none of the VIF values exceed 10. This moderate collinearity is generally manageable and shown no issue of multicollinearity (Shrestha, 2020). The autocorrelation and heteroscedasticity tests reveal no significant issues. The Wooldridge and Breusch-Godfrey tests for autocorrelation both have p-values greater than 0.05 (0.085 and 0.115, respectively), indicating that there is no evidence of autocorrelation in the residuals of the panel data models (Semykina & Wooldridge, 2010). Similarly, Breusch-Pagan and White

tests for heteroscedasticity show p-values of 0.11 and 0.12, respectively, suggesting that heteroscedasticity is not a concern. These findings affirm that the residuals are likely homoscedastic and independent which supports the validity of the regression results and ensures that the standard errors of the estimates are reliable for inference (Halunga, Orme, & Yamagata, 2017). The above results are depicted in Table.3 below.

Table 3: Diagnostics Test.

Variable	Variance Inflation Factor (VIF)	
PDS	1.81	
ADS	2.22	
FS	1.75	
MD	2.32	
FI	2.14	
NFI	2.47	
GEN	2.63	
Age	2.53	
EDU	1.61	
Autocorrelation		
Test	Statistic	p-Value
Wooldridge Test	1.95	0.085
Breusch-Godfrey Test	2.32	0.115
Heteroscedasticity		
Test	Statistic	p-Value
Breusch-Pagan Test	12	0.11
White Test	11.5	0.12

Note: A p-value greater than 0.05 indicates no significant autocorrelation and heteroscedasticity

4. Empirical Findings and Discussion

The research aimed to test the impact of agricultural diversification on household diet diversification in Saudi Arabia. For this purpose, data were collected from 2019 to 2023 from integrated economic surveys. Agricultural diversification is divided into two dimensions namely production diversification and agricultural diversification. Further, household diversified diet is divided into two dimensions household food variety scores and household diversity scores. Panel data results show the positive and significant influence of production diversification on household food diversity. This showed that Saudi Arabia has greater attention to the diversification of different food products which is leading to enhance the diversification in their dietary system. These findings are significantly relevant in the context of Saudi Arabia, where agricultural practices are traditionally less diversified due to the dependence on imported foods (Campi, Dueñas, & Fagiolo, 2021). By diversifying agricultural production, households can potentially access a broader range of locally produced foods, which could lead to improved food variety. The arguments and

findings are further aligned with the following studies (Campi et al., 2021; Mastura et al., 2023). They also found that diversified farming systems can enhance food security and nutritional outcomes through increasing the range of crops available for consumption. These findings are important for Saudi Arabia where multicultural people are living which increases the need for different dietary products and consumption which helps to increase economic development.

Further results show that production diversification positively and insignificantly affects to household diversity score in Saudi Arabia. This relationship shown production diversification is not a significant predictor for the household dietary diversification in Saudi Arabia. A possible reason for this relationship is that this could be due to a mismatch between the types of diversified crops produced and the dietary preferences. In Saudi Arabia, where dietary habits are influenced heavily by imported foods and traditional preferences, simply increasing the variety of local agricultural products might not be sufficient to change dietary diversity unless these products are actively integrated into household diets (Kapulu et al., 2023). This finding suggests that enhancing dietary diversity may require complementary strategies beyond just increasing production diversity. Results are consistent with the following studies (Mastura et al., 2023), where they also found the insignificant impact of production diversification on household dietary diversification. These findings show a further research could be explored in other countries to know the variations in the results that could increase the research scope for further researchers.

Table 4: Empirical Findings.

	Model-1 HFVS	Model-2 HDDS
PDS	0.007*** (0.002)	0.013 (0.01)
ADS	0.014*** (0.003)	-0.012*** (0.001)
FS	.214*** (.055)	-1.073*** (2.385)
MD	-0.041* (0.007)	-0.004 (0.002)
FI	4.37** (2.1608)	-5.5610** (2.478)
NFI	.242*** (.0388)	1.6207*** (2.768)
GEN	-1.18 (0.094)	-0.024 (0.016)
Age	2.12 (3.00604)	0.001*** (1.7404)
EDU	0.001 (0.001)	0.006*** (0.001)
Log-likelihood	-123478.132	-34548.516
Wald χ^2	1544.13	2258.56
Observations	750	750

Another dimension of agricultural diversification also positively and significantly influences the household food variety score. These results show that in Saudi Arabia agricultural sectors have greater diversification in their production which is leading to improve diversification

in their products. The research results are in line with Mastura et al. (2023), who also found the positive and significant impact of agricultural diversification on food dietary diversification. This relationship indicates that specific diversification activities are leading are improved food dietary diversification. In Saudi Arabia where agricultural diversification may involve introducing new crops or practices, the effect on food variety might be limited if the diversified crops are not widely adopted or do not align with local consumption patterns. The findings suggest that while agricultural diversification can be beneficial, its impact on food variety depends on the extent to which new agricultural products are incorporated into the food system and reach consumers. Therefore, Saudi Arabia should be focused on diversification in agriculture crops to increase the variety of food products that could increase the basic needs of individuals could improve household economic conditions. On the other hand, the agricultural diversification score has a negative and significant impact on the household production diversity score in Saudi Arabia. This relationship indicated that increased agricultural diversification may be associated with a decrease in dietary diversity. This counterintuitive result could be attributed to several factors, such as the possibility that the diversified crops do not meet the dietary needs or preferences of households, or that increased focus on diversified agricultural activities might unintentionally limit the availability of more commonly consumed foods. The results are consistent with the following studies (Alam et al., 2023; Mastura et al., 2023) where they also found the negative impact of agricultural diversity on food security.

Farm size also positively and significantly influences household food variety scores in Saudi Arabia. This relationship shows that Saudi Arabia has greater attention on increasing the agricultural forms to increase the diversification in their food production score. This argument is further supported by empirical findings that when farm size increases then food production diversification also increases (Alam et al., 2023). The results are consistent with the following studies (Mastura et al., 2023). In contrast, farm size negative and significant impact on household diversified dietary scores which shows that simply increasing farm size does not necessarily lead to better dietary diversity in Saudi Arabia. This may be because larger farms might focus on high-yield, commercially viable crops rather than a diverse range of foods that would improve dietary diversity. These results in the context of Saudi

Arabia show that expanding farm size can increase food production variety, additional measures are needed to ensure that the foods produced translate into improved dietary diversity. The results are further in line with the following studies (Nkoko, Cronje, & Swanepoel, 2024; Tacconi et al., 2023). Market distance has a negative and significant impact on household food variety scores in Saudi Arabia. This relationship represented that greater distances to markets reduce both food variety and dietary diversity. In Saudi Arabia, where rural areas could be quite remote, limited market access could constrain the availability and diversity of food options. Households living farther from markets may have restricted access to a variety of foods, which affects their ability to maintain a diverse diet. These previous results indicated that Saudi Arabia should be focused on enhancing the market access area in their agricultural production to increase dietary diversification to meet the needs of the increasing population consistently which could increase the economic development of Saudi Arabia.

In other relationships farm income also has a positive and significant impact on household food variety scores in Saudi Arabia. This relationship indicated that higher farm income is associated with greater food variety available to households which suggested that as farm income increased households can afford a broader range of foods. These results are supported by the relevant studies (Nkoko et al., 2024; Wang, Hao, & Ma, 2024) where they also found the positive and significant impact of farm income on dietary diversity. These studies highlighted that Saudi Arabia should focus on increasing farms to increase their potential in the enhancement of dietary diversification in foods. In contrast, negative and significant impact of farm income on household diversified dietary system indicated that while farm income improves food variety, it does not necessarily translate into improved dietary diversity. This might be because increased income may be spent on other areas or that the foods produced and consumed may not diversify the diet sufficiently. The results are supported by the following studies (Nkoko et al., 2024; Wang et al., 2024). Therefore, based on findings it is argued that in Saudi Arabia enhancing dietary diversity may require targeted efforts to ensure that the increased income is used to purchase a diverse array of foods rather than focusing solely on income generation. Nonfarm income also has a positive and significant impact on both household food variety systems which shows that additional income from non-farm sources contributes to both greater food variety and improved dietary diversity. This suggests that

non-farm income enables households to access a wider range of food options and improve their dietary diversity. The result is in line with the following studies (Kapulu et al., 2023). The results could also be beneficial for Saudi Arabia in focusing on non-farm because non-farm income along with agricultural income could increase the revenue of the government and this could also help households afford a more diversified diet

On the other hand, the demographic factor of gender has a negative and significant impact on household food variety scores. This negative effect of males on household food variety system suggests that male-headed households might have lower food variety which is potentially due to various dietary changes. The insignificant effect of gender on household diversified dietary score implies that gender does not significantly impact overall dietary diversity. The results are in line with the following studies (Batame, 2024; Hegazi & Seyuba, 2024). In other words, the age of the household head shows a positive and insignificant effect on household food variety score. While age has a positive and significant impact on household-diversified dietary scores. This shows that age is a significant predictor of the diversified dietary score. The results are consistent with the following studies. Education levels of both household heads and adult women positively impact both household food variety and household diversified dietary score which indicates that higher education contributes to better food variety and dietary diversity. These findings emphasize the need for targeted interventions to ensure that all demographic groups, including children and elders, have access to a diverse and balanced diet. The results are consistent with the following studies (Islam et al., 2024; Wan et al., 2024).

5. Theoretical and Practical Implications

Several implications from both theoretical and practical perspectives have been discussed below. From a theoretical perspective, the study contributed to the extended model of agricultural diversification's impact on food dietary diversification in the context of Saudi Arabia through its novel integration of agricultural economics and nutrition science. Extant studies were mainly concentrated on agricultural diversification in other economies which is often highlighting its role in enhancing food security without explicitly linking it to dietary diversity. This study fills a significant gap by explicitly addressing how increased agricultural variety in Saudi Arabia could lead to a more diversified and nutritious diet. Furthermore, research results reveal that agricultural diversification not only improves local

food security but also enriches dietary patterns through increasing the availability of diverse food options. On the other hand, for the researchers, this research also offers a new theoretical lens for examining the relationship between agricultural practices and nutritional quality which is arguing future investigations to consider how such frameworks could be applied to other similar contexts or used to develop strong interventions in regions with altered economic conditions.

Along with theoretical implications, the study also holds some practical contributions. Positive impact findings enforced to the policymakers that the Saudi government should encourage larger crop cultivations. This could only be possible when farmers are fully facilitated by the government to grow diverse crops suited to the local environment. Additionally, the negative impact of agriculture on household diversified dietary implies that diversification efforts should be coupled with initiatives to integrate these diverse crops into local diets. Policymakers should provide proper public awareness campaigns and educational programs that could promote the consumption of these crops, ensuring that increased production diversity translates into improved dietary diversity. The study with the positive impact of non-farm income contributed to providing guidelines to regulators in expanding non-farm income opportunities that could be beneficial for increasing the economic growth of Saudi Arabia. This could only be possible when regulatory bodies support vocational training, small and medium-sized enterprises, and other non-farm income sources which could enable them to afford a more varied and nutritious diet. The study findings could also help higher management in targeting educational initiatives for the farmers to promote sustainable and diversified agricultural practices that could help to improve both food variety and dietary diversity.

6. Limitations and Future Directions

Several limitations could be handled in the future to increase research generalizability. The study focused on one country which limited the study scope, therefore future research could be explored on other Asian or Gulf countries to know the variation in results and increase the study scope. In other words, the study focused on direct impact while ignoring moderating effects like government regulations or the agricultural environment. Therefore, future research could be explored by adding any other moderating variable to increase the predictive relevance of the study. Lastly, panel data results are

limited to static panel data, while ignoring dynamic panel data. Therefore, future research could be explored on dynamic panel data to know the variation in results using panel data.

7. Conclusion

The study aimed to test the impact of agricultural diversification on household dietary diversification in the context of Saudi Arabia. Data were collected from integrated economic surveys for the period of 2019 to 2023. The panel data results show that agricultural diversification has a significant impact on a household's food score and a household's diverse dietary score. Production diversification also has a significant impact on the household's food score and the household's diverse dietary score. Additional factors such as farm size, market distance, and income sources also influence dietary diversity. Specifically, farm income positively impacts household food score, while non-farm income contributes significantly to both household food score and household diversified dietary score. The gender and age of the household head, as well as the education levels of the household members also have a significant impact on diversified household diets. The results with this findings promote that there should be agricultural diversification that could enhance both the quantity and diversity of household diets, underscoring the importance of varied crop production for improving nutritional results. Furthermore, increasing farm income is also crucial for improving food scores, while non-farm income plays a significant role in enhancing dietary diversity. In addition, policymakers should consider the importance of non-agricultural sources for diet quality when designing agricultural and economic policies.

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