Agribusiness

WILEY

Agribusiness

RESEARCH ARTICLE OPEN ACCESS

Does Contract Farming Improve Diet Quality? The Case of Senegalese Smallholders

Francis E. Ndip[1,2] | Takeshi Sakurai[1]

[1]Graduate School of Agriculture and Life Sciences, The University of Tokyo, Tokyo, Japan | [2]Center for Development Research, University of Bonn, Germany

Correspondence: Francis E. Ndip (ebaifrancis1@gmail.com)

Received: 29 May 2024 | **Revised:** 30 September 2024 | **Accepted:** 3 October 2024

Funding: The authors received no specific funding for this work.

Keywords: contract farming | dietary diversity | nutrition-sensitive | rice | Senegal

ABSTRACT

The institution of contract farming has gained prominence in most developing countries owing to its numerous benefits. While several studies have already highlighted the welfare benefits of contract farming, very few have investigated the effects on diet quality, despite poor quality diets being a serious challenge in most parts of the developing world. Moreover, such existing studies deal with contract farming in speciality crops, although contract farming in staple crops may have different effects on diet quality. Therefore, this study evaluates the role of staple crop contracts on diet quality, proxied by two measures of dietary diversity. Using cross-sectional data from rice-producing households in Senegal, we employ linear models through ordinary least squares to estimate the relationship between contract farming and diet quality. Our results show that participation in contract farming is positively associated with household dietary diversity and hence, diet quality. Our results further show that income is the main pathway through which contracts and diet quality are associated. With increasing calls for agriculture to be nutrition-sensitive, our results suggest that the institution of contract farming can play an important role in this regard by improving diet quality.

JEL Classification: Q16, Q18

1 | Introduction

The institution of contract farming—a pre-planting agreement between a producer and a buyer/processor —has gained importance in many developing countries owing to several factors. On the one hand, in what is dubbed the "supermarket revolution" by Reardon et al. (2009), there has been a proliferation of supermarkets in major urban areas of developing countries whose demands for products of certain quality cannot be met by spot markets. In addition, population growth, globalization, and changes in income of the upper middle class of most developing countries have greatly influenced their dietary patterns and demand for products such as fruits and vegetables (Barrett et al. 2012; Bellemare 2012; Maertens and Swinnen 2009). The quality demands of such products restrict smallholder farmers from producing them out of their own volition. The institution of contract farming is seen as important in supporting farmers to produce such products. Furthermore, by reducing transaction costs (Key and Runsten 1999; Prowse 2012; Ragasa et al. 2018), market risks (Arouna et al. 2021; Key and Runsten 1999; Prowse 2012) and integrating farmers into value chains (Barrett et al. 2012; Key and Runsten 1999), contract farming is argued to lead to rural transformation and poverty reduction (Arouna et al. 2021; Bellemare and Bloem 2018; Meemken and Bellemare 2020, 2020; Otsuka et al. 2016; Swinnen and Kuijpers 2020).

Several studies have already evaluated the effects of contract farming on income (Andersson et al. 2015; Arouna et al. 2021; Bellemare 2012; Maertens and Vande Velde 2017; Meemken

and Bellemare 2020; Ogutu, Ochieng, et al. 2020; Rao and Qaim 2011; Ruml et al. 2022), food security (Bellemare and Novak 2017; Mishra et al. 2018; Ochieng and Ogutu 2022; Soullier and Moustier 2018), profit (Ragasa et al. 2018; Soullier and Moustier 2018) as well as the environmental effects (Dubbert et al. 2023). While most of these studies have already highlighted positive income effects, it is not clear whether such benefits translate to improved diet quality. This is important given that agriculture has been called upon to be more nutrition-sensitive (Qaim 2017; Ruel et al. 2018; Ruel and Alderman 2013). These calls require that agricultural interventions shift from the business-as-usual motive of improving income and the production of certain cereals to encompassing improvement in the quality of diets. Like most agricultural interventions, it is important to understand if contract farming improves diet quality.

Here we ask if contract farming improves diet quality. Poor-quality diets continue to ensnare most parts of the developing world. The quality of diet in many parts of the world has largely remained stagnant or at least not witnessed similar improvements as food availability (Ickowitz et al. 2019; Pinstrup-Andersen 2013). The number of people suffering from poor-quality diets surpasses those suffering from insufficient caloric intake (Pauw et al. 2023; Ickowitz et al. 2019; International Food Policy Research Institute IFPRI, 2019; Willett et al. 2019). According to FAO et al. (2022), about three billion people cannot afford a healthy diet. Such poor-quality diets are a major public health concern serving as a leading cause of non-communicable diseases and one of the leading causes of death (Qaim 2017; International Food Policy Research Institute IFPRI, 2019, Afshin et al. 2019, Hawkes et al. 2020). Consequently, the attention of the food security discourse has recently shifted towards improving the quality of diets especially of smallholder farmers in developing countries who are the most affected (Chege, Andersson, and Qaim 2015; Debela, Ruml, and Qaim 2021; Ogutu, Gödecke et al. 2020; Sibhatu and Qaim 2017).

We study associations between contract farming and diet quality. To the best of our knowledge, just three studies have evaluated the role of contract farming on dietary quality. Providing a detailed analysis, Chege, Andersson and Qaim (2015) show that supermarket contracts improve both caloric and micronutrient consumption. On their part, Ochieng and Ogutu (2022) show that vegetable supermarket contracts increase household dietary diversity. In Ghana, Debela et al. (2021) investigated the effects of two types of contracts on dietary diversity. Their results are mixed, showing both positive and negative impacts, depending on the contract type. Hence, there is a need for more evidence on the dietary effects of contract farming. Moreover, these studies have largely focused on speciality crop contracts whose impacts may differ from those of staple crop contracts since the latter directly affects household food intake. Moreover, staple crop contracts are argued to have broader welfare effects (Meemkem & Bellemare, 2020).

We focus on the associations between a staple crop contract and dietary diversity. Unlike contracts in speciality crops that are mainly destined for the market (mostly international markets), staples can be directly consumed by the household and may have direct impacts on household nutrition. Hence contracting such crops may have differential impacts on household dietary diversity. We contribute to the literature in different respects. Firstly, we provide empirical evidence of the relationship between staple crop contracts and household diet quality, which is proxied by dietary diversity indicators. Although other studies such as Bellemare and Novak (2017) and Soullier and Moustier (2018) have examined the relationship between staple crop contracts and food security, their measures of food security do not reflect diet quality. We therefore open a new strand of literature, which explores the association between staple crop contracts and diet quality. Although dietary diversity is argued to reflect diet quality, some food groups may not really contribute to improved diets (Leroy et al. 2015). In line with Ochieng and Ogutu (2022), we drop such food groups and construct another measure of dietary quality consisting of nine food groups which reflect healthier diets, which we term healthy dietary diversity. We evaluate the association between contract farming and this measure. Secondly, we explore potential pathways through which contract farming affects dietary diversity. Due to the nutritional burden associated with poor-quality diets, which has warranted an interest in nutrition-sensitive agriculture, understanding the mechanisms through which contract farming operates will provide more insights into such interventions. In addition, understanding the mechanisms will be useful for improving contract designs and/or for introducing other kinds of interventions than contract farming.

Thirdly, we perform heterogeneity analysis to gain more insights on the consumption of which food groups are affected by participation in contract farming. Understanding which particular food groups are affected by contract farming sheds light on policies that aim at improving diet quality, particularly amidst the increasing cost of healthy diets (FAO et al. 2023). Lastly, we focus on Senegal where the contract farming arrangements are relatively new but the welfare impacts of such contracts have not been well explored. To our knowledge, only Soullier and Moustier (2018) have investigated the impacts of contract farming in Senegal but they do not focus on diet quality. As argued by Maertens & Van de Velde (2017), the impacts of contract farming may differ with context. Hence, it is important to evaluate such impacts in a different setting.

Our study focuses on Senegal which presents an interesting case to study the dietary implications of contract farming. Like most developing countries, the country faces a major food and nutrition security challenge (Ilboudo Nébié, Ba, and Giannini 2021). Recognizing this problem, the Senegalese government has invested heavily in nutrition (Nene 2018). The results have been very glaring: According to Feed the Future (2018), stunting and wasting rates have reduced to 17% and 7%, from a high of 20% and 9%, respectively. Although recent studies highlight dietary changes wherein fruits and vegetables are major food groups consumed, a substantial fraction of Senegalese's diet is still monotonous, dominated by cereals, especially rice (Marivoet et al. 2021).

At the heart of low dietary diversity is food accessibility. Thus, the poverty of smallholder farmers reduces their purchasing power and consequently affects dietary diversity. Smallholders have generally relied on on-farm diversification for improved

dietary diversity (Gupta, Sunder, and Pingali 2020; Hirvonen and Hoddinott 2017; Koppmair, Kassie, and Qaim 2017; Sibhatu, Krishna, and Qaim 2015). However, recent evidence suggests that on-farm diversification to dietary diversity is at best modest (Koppmair, Kassie, and Qaim 2017; Sibhatu, Krishna, and Qaim 2015). The market has become an important avenue for food sources. Hence, improving farmers' income is likely to improve their purchasing power, market access and consequently, their dietary diversity. In an effort to improve the welfare of smallholder farmers, the government of Senegal introduced a new contract farming scheme in rice production. Such contracts may have boosted farmers' income and improved their food security as reported by Soullier and Moustier (2018), but the impacts on dietary quality are not known. It is thus important to evaluate the impacts on dietary diversity especially as smallholders consume the least diverse diets. According to Tine et al. (2018) over 43% of Senegalese households had a low dietary diversity score.

The remainder of this paper is structured as follows. In section two, we present the conceptual linkages between contract farming and dietary diversity while in section three, the empirical framework and identification strategies are presented. Section four focuses on the data and measurement of key variables. Results are presented in section five and the paper concludes and highlights some policy implications in section six.

2 | Contract Farming and Dietary Diversity: Conceptual Linkages

There are many pathways through which participation in contract farming may affect dietary diversity. Income is the first pathway. There is a large body of literature on positive income effects of contract farming (Arouna, Michler, and Lokossou 2021; Bellemare 2012; Maertens and Vande Velde 2017; Miyata, Minot, and Hu 2009). Such income may translate to improved dietary diversity at the household level by increasing the purchasing power of households. While most rural households largely depend on on-farm diversification (Asfaw, Pallante, and Palma 2018; Ndip et al. 2023), studies have shown that markets play an important role in dietary diversity by granting farmers access to various food types (Ickowitz et al. 2019; Ogutu, Gödecke, and Qaim 2020; Sibhatu and Qaim 2017). This is even truer for food types like dairy products, fish products, and meat products, which are mostly accessed through the market. To the extent that farmers rely on the market for food sources, increased income through contract farming is important for dietary diversity.[1]

The second pathway through which contract farming may affect dietary diversity is by altering production decisions. Most crops produced under contracts usually require quality and grade standards warranting increased labor demand. Ruml and Qaim (2021) show that production under contracts may influence household labor allocation. This usually shifts the attention of the households to the production of contracted crops, neglecting other crops. Hence, contract farming may reduce on-farm crop diversification. The reduction in on-farm diversification may affect the household dietary diversity, especially if the household relies on on-farm diversification for improved dietary diversity. On the other hand, contract farming may release household labor to the cultivation of other crops. In Ghana, Ruml and Qaim (2021) show that while oil palm production contracts required more household labor, marketing contracts on their part freed female farm labor which could be used in the production of other crops. If such labor is allocated to the cultivation of other crops, then it may result in increased on-farm diversification and lead to increased household dietary diversity.

Still in line with production decisions, contract farming may lead to reallocation of land meant to produce other crops. That is, land meant for the production of other crops may be allocated to the production of crops under contracts. This is likely if the contracted crop is a staple crop. Arouna, Michler and Lokossou (2021) show that because of contract farming, rice farmers brought in more land into cultivation. To the extent that such land could be used to produce other crops, such reallocation will eventually reduce the amount of land available for cultivating other crops, and affect the dietary diversity of the household. In the Senegal River Valley (SRV) area, rice is produced using irrigation technologies (van Oort et al. 2016). This same land is used to produce vegetables, creating competition between these crops. Based on the nature of contracts, such competition may reduce the amount of land available for cultivation of other crops than rice and affect the dietary diversity of the household. If less land is available for other crops due to contract farming, it will negatively affect dietary diversity. On the other hand, if more land is available for other crops due to the intensification of rice production under contract farming, positive effects may ensue.

The third pathway involves sales of crops initially meant for consumption. If contract farming schemes offer better prices in addition to other benefits at the farm level or they require farmers to sell the contracted crops to contractors, households will sell crops initially meant for household consumption. This is rarely considered because most contract farming schemes focus on nonstaple crops. However, with recent emergence of contract farming in staple crops, such scenarios are more likely to occur. Rice constitutes a major staple in Senegal, yet serves as a major source of income (Faye et al. 2021). Farmers may therefore sell rice initially meant for household consumption, due, especially to their inability to separate production and consumption decisions. While this will affect dietary diversity, it may affect household food security in general.

From the foregoing, contract farming may affect dietary diversity through various pathways. Whether such impacts are positive or negative may depend on the scenario and interplay of other factors at both the household and farm level. *A priori*, it is difficult to determine the direction of such mechanisms.

3 | Empirical Approach

Our objective is to estimate association between participation in contract farming and household dietary diversity. Since the dependent variable, household dietary diversity is count in nature and takes nonnegative integers, it may warrant the use

of a count data approach (Wooldridge 2010). However, other studies have treated such an outcome variable as continuous due to the restrictive assumptions of count data models such as the Poisson model. In line with such studies, we treat the outcome variable as continuous. We estimate models of the form:

$$D_i = \mathbf{X_i'}\Theta + \beta C_i + e_i \quad (1)$$

where i indexes a household, D_i is the household's dietary diversity measure, $\mathbf{X_i}$ is a vector of household and plot characteristics, which may affect the household dietary diversity, C_i is the contract status of the household, and e_i is the error term. Θ and β are parameters to be estimated. The parameter of interest is β which captures the effect of contract farming on household dietary diversity. *A priori*, we expect the parameter β to appear with a positive sign, indicative of a positive effect of contract farming on dietary diversity.

The contract status in Equation (1) is potentially endogenous because unobserved factors may correlate with a household's decision to participate in contract framing as well as its dietary diversity. For example, some farmers are more caring and hence more concerned about the dietary diversity of their households (Hirvonen and Hoddinott 2017). Such farmers are more likely to engage in contract farming schemes if they are aware that it may increase their household dietary diversity. Other unobserved factors such as motivation also jointly affect the decision to participate in contract farming and household dietary diversity. We cannot control for such unobserved factors by employing household fixed effects because we use cross-sectionally observational data for the empirical analyses, as we will explain in Section 4. Moreover, we cannot find any suitable instrumental variables to deal with such endogeneity. Therefore, we estimate the linear models through ordinary least squares and interpret our results as associations rather than causal.

4 | Data and Outcome Variables

The data used in this study comes from a 2021 survey conducted on the Senegalese side of the SRV, where the total area of irrigated rice fields reached about 110,000 hectares in 2012 (Manikowski and Strapasson 2016). A multistage sampling procedure was employed. In the first stage, 180 farmer organizations were randomly selected from a list of 3304 farmer organizations in the Podor and Dagana departments (Sakurai, 2023). The farmer organizations, usually consisting of 30–40 farmers, have been established to manage irrigation for rice production, and play an important role in collective liability loan from the bank. In the second stage, five-member households were randomly selected from each of the 180 farmer organizations. Data was collected from 331 households that produced rice in either the rainy season or hot dry season in 2020/2021 cropping year. However, upon cleaning the data, 278 households are retained for the analysis.

The outcome variable of interest is the household dietary diversity score (HDDS) which has been used by other studies as a proxy for diet quality (Koppmair, Kassie, and Qaim 2017; Sibhatu, Krishna, and Qaim 2015; Sibhatu and Qaim 2017). It is a count of the food groups consumed in the household (Leroy et al. 2015; Swindale and Bilinsky 2006). The 12 food groups considered are Cereals; Roots/tubers; Vegetables; Fruits; Meat/poultry/offal; Eggs; Fish/seafood; Pulses/legumes/nuts; Milk/milk products; Oils/fats; Sugar/honey; and Miscellaneous which include spices/condiments/beverages (Swindale and Bilinsky 2006). Since some of the food groups do not necessarily promote health (oils/fats; sugar/honey; and spices/condiments/beverages) they may not reflect healthy diets. Hence omitting some of these food groups is argued to reflect healthier diets (Leroy et al. 2015). Following Ochieng and Ogutu (2022), we exclude the three food groups mentioned above and retain nine food groups to reflect healthier diets. Usually, the HDDS is collected over a 24-h recall period. Here we use a recall period of 1 month, which has its pros and cons. On the pro side, 1-month recall period can capture food items that are infrequently consumed. For example, if a household consumes meat only once a month, it is highly unlikely that the household took meat within 24 h before the interview. On the other hand, a long recall period is subject to errors since farmers may not accurately recall all food types consumed. While this may lead to measurement error, it is less likely a problem since measurement error in the outcome variable does not affect estimates (Wooldridge 2010). We acknowledge that using a 1 month recall period may overestimate the HDDS as a longer recall period increases the likelihood of consuming a food group. This may lead to higher HDDS in households. However, this is not the case in our study given that the HDDS are still relatively low and comparable to those reported by other studies such as Debela, Ruml and Qaim (2021) and Ochieng and Ogutu (2022).

For the mechanisms, we consider income and crop diversification as outcomes. Income is the revenue generated by the household from rice sales over a 12-month period and it is measured in FCFA. Crop diversification is measured as the count of different crops produced by the household over a 12-month period.

5 | Results and Discussion

5.1 | Sample Characteristics

Table 1 presents the sample characteristics. First of all, over 23% of our sampled households are engaged in contract farming schemes.[2] Although the participation rate in contract farming among the sample is not low, there are only 3.4 contract farmers in a village on average. As for the outcome of our interest, households consume about nine food groups on average. However, when the unhealthy food groups are excluded, households consume an average of over six food groups. This is similar to other studies from SSA (Debela, Ruml, and Qaim 2021; Ochieng & Ogutu, 2022).

As mentioned above, all the sampled households produced rice in the 2020/2021 cropping year, and they earned 753,705 FCFA as rice income on average. They also diversify their production, cultivating over four crops including rice. There are some households that engage in off-farm activities in addition to farming, but such

TABLE 1 | Descriptive statistics and mean comparison.

Variables	Full sample		Contract farmers		Noncontract farmers		Difference
	mean	sd	mean	sd	mean	sd	
Outcomes							
HDDS (12 food groups)	8.67	1.97	9.22	1.82	8.5	1.99	**
Healthy HDDS (9 food groups)	5.74	1.89	6.27	1.71	5.58	1.91	**
Treatment							
Contract farming (yes=1)	0.23	0.422	1	0	0	0	
Control variables							
Household head level							
Gender of (male=1)	0.97	0.167	62	96.9%	208	97.2%	
Age of (years)	58	13.5	59.0	13.0	58.0	14.0	
Marital status (married=1)	0.924	0.265	57.0	89.10%	200	93.50%	
Education (at least primary=1)	0.709	0.455	42.0	65.60%	155	72.40%	
Household level							
Rice income (10^5 FCFA)	7.54	13.8	10.0	19.0	7.0	12.0	
Crop diversification	4.68	4.42	4.0	4.0	5.0	4.0	
Off-farm income (yes=1)	0.162	0.369	6.0	9.40%	39.0	18.20%	*
Asset value (10^5 FCFA)	7.51	38.2	8.0	18.0	7.0	42.0	
Livestock ownership (TLU)	4.73	9.09	4.0	8.0	5.0	9.0	
Household size	12.2	5.85	11.0	5.0	12.0	6.0	
Number of villages	52						
Number of households	278						

Note: HDDS stands for household dietary diversity score. Healthy HDDS is count of food groups less oils, sweets, and condiments, which are considered unhealthy. TLU stands for tropical livestock unit. We measure TLU units following the approach suggested by (Ahmed and Mesfin 2017), ***, **, and * indicate that the two means are statistically different at the significance level of 1%, 5%, and 10% respectively.

households are only about 16% of the sample. As for asset holdings, households have assets worth over 750,000 FCFA including both agricultural and nonagricultural assets. In addition, households have an average of four tropical livestock units.

Still in Table 1, we do a mean comparison of variables between contract and noncontract farmers. Table 1 shows that contract farming households consume 9.2 food groups compared to 8.5 of households without contracts. The difference is statistically significant. Similarly, contract farmers consume about 6.2 healthier food groups as opposed to 5.6 of noncontract households. Also, fewer contract farmers earn off-farm income compared to noncontract farmers. For the other variables, there are no statistically significant differences between the two groups. Taken at face value, this may pass as suggestive evidence that contract farming increases dietary diversity indicators. However, such comparisons are naïve as both observed and unobserved factors may drive the expected impacts. Therefore, to recoup actual impacts, we resort to the econometric approach.

5.2 | Associations Between Contract Farming and Dietary Diversity Indicators

Table 2 shows the OLS estimates of contract farming on dietary diversity measures. We estimate models with and without controls to gauge the extent to which our results change upon inclusion of controls. Our interpretation focuses on models with controls. The results show that contract farming increases dietary diversity by 0.884 food groups. This finding corroborates those of Ochieng and Ogutu (2022) who found that participation in supermarket contracts increased household dietary diversity. Similar results were obtained by Debela, Ruml and Qaim (2021) who found positive effects of oil palm marketing contracts on dietary diversity. We then turn to healthier dietary diversity where similar results are obtained. Participation in contract farming increases consumption by about 0.867 food groups. This further implies that contract farming increases dietary quality through the consumption of healthier food groups. Ochieng and Ogutu (2022) also found positive effects of participation in supermarket contracts on healthier food groups. Given that dietary diversity is argued to reflect healthier diets, our results show that such can be achieved through contract farming. On a more general note, the results corroborate those which have reported positive food security effects of contract farming (Bellemare and Novak 2017; Mishra et al. 2018; Soullier and Moustier 2018). The results with and without controls suggest that our results are robust to inclusion of controls. The improvement of the R-squared upon inclusion of controls also suggests that we selected the appropriate control variables and further confirm the robustness of our results.

Although striking in simplicity, the results provide novel insights into contract farming and dietary diversity. While the

TABLE 2 | OLS estimates of contract farming on dietary diversity indicators.

VARIABLES	HDDS	HDDS	Healthy HDDS	Healthy HDDS
Contract farming (yes=1)	0.714**	0.884*	0.682**	0.867*
	(0.278)	(0.291)	(0.266)	(0.277)
Gender (male=1)		0.099		0.064
		(0.590)		(0.640)
Age (years)		0.008		0.007
		(0.009)		(0.008)
Marital status (married=1)		0.107		0.083
		−0.485		−0.484
Educational level (atleast primary=1)		0.364		0.400***
		(0.247)		(0.239)
off-farm income (yes=1)		0.844*		0.956*
		(0.306)		(0.297)
Asset value (in 0000FCFA)		0.005*		0.005*
		(0.002)		(0.002)
Livestock ownership (TLU)		0.044*		0.044*
		(0.015)		(0.015)
Household size		0.015		0.02
		(0.020)		(0.017)
Constant	8.505*	6.967*	5.584*	4.062*
	(0.133)	(0.948)	(0.128)	(0.998)
Village fixed effects		YES		YES
R-squared	0.023	0.111	0.023	0.126
Observations	278	278	278	278

Note: HDDS is household dietary diversity score. Healthy HDDS is count of food groups less oils, sweets, and condiments, which are considered unhealthy. Standard error in parentheses.
*$p < 0.01$,; **$p < 0.05$,; ***$p < 0.1$.

literature is replete with benefits of contract farming, there are just two on dietary diversity, which however, record very modest impacts (Debela, Ruml, and Qaim 2021; Ochieng and Ogutu 2022). Our results show that contract farming can grant households access to an additional food group. In the context of nutrition-sensitive agriculture, which has dominated policy circles recently, contract farming can arguably make agriculture more nutrition-sensitive. In addition to providing a plethora of benefits, it can be exploited to improve the nutritional situation of smallholder farmers. Particularly, contracting in staple chains can improve household dietary diversity.

5.3 | Robustness Checks

As a robustness check, we assess the extent to which omitted variables drive our results. To assess the extent to which omitted variables drive our results, we employ the approach proposed by Oster (2019). Assuming that selection on observables is equal to selection on unobservables, we calculate the bias-adjusted estimates of our two indicators of diet quality. These results are presented in Table 3. The bias-adjusted estimates shown in column 5 are higher in magnitude but similar in sign to the unadjusted estimates. This suggests that adjusting for unobserved factors improves the estimates. Moreover, the bias-adjusted estimates still suggest that contract farming is positively associated with dietary diversity indicators, supporting the robustness of our results.

As a further robustness check, we employ the approach by Diegert, Masten and Poirier (2023) to check for the extent to which unobserved factors also drive our results. This approach generates the breakdown point, at which unobserved factors would overturn the results from positive to negative and vice-versa (Diegert, Masten, and Poirier 2023). The higher the breakdown point, the less likely are the results driven by unobservables. While similar to the approach by Oster (2019), Diegert, Masten and Poirier (2023) may provide more robust results by allowing for some of the control variables to be endogenous. The results are presented in column 6 of Table 3. The results show that the breakdown point is large (greater than 75%) suggesting that unobserved factors are less likely to drive the results, further confirming the robustness of the results.

5.4 | Pathways and Mechanisms Result

Here, we further probe the results to understand the pathways through which contract farming and household dietary diversity are

TABLE 3 | OLS and bias-adjusted estimates.

Outcome	Uncontrolled		Controlled		Bias-adjusted estimate	Breakdown point (%)
	(1)	(2)	(3)	(4)	(5)	(6)
	Coeff	R2	Coeff	R2		
HDDS	0.714	0.02	0.884	0.11	2.84	75.6
	(0.278)		(0.291)			
Healthy HDDS	0.682	0.02	0.867	0.13	2.6	76.5
	(0.266)		(0.277)			

Note: HDDS stands for household dietary diversity score. Healthy HDDS is count of food groups less oils, sweets, and condiments, which are considered unhealthy. Standard error in parentheses.
Breakdown points are calculated based on Diegert, Masten and Poirier (2023).
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

TABLE 4 | OLS and Poisson estimates of mechanisms of operation of contract farming.

Variables	Income (OLS)	Crop diversification (Poisson)
Contract farming(1/0)	5.310*	−0.144
	(2.535)	(0.118)
Controls	YES	YES
Village fixed effects	YES	YES
Observations	278	278
R-squared	0.661	

Note: controls include household head's age, gender, educational level, marital status, off-farm income, livestock ownership, household size and asset value. Standard error in parentheses.
*** $p < 0.01$, * $p < 0.1$; *$p < 0.05$.

associated. Although several pathways are hypothesized, we focus on two major pathways; income and crop diversification, due to data limitations. Table 4 contains estimates of contract farming on rice income and crop diversification in columns 1 and 2 respectively. For income, we estimate a linear model through ordinary least squares while we estimate a Poisson model for crop diversification since the outcome is a count. The results in column 1 show that contract farming is positively correlated with income suggesting that income is one of the major pathways through which contract farming affects dietary diversity. As the role of market access in dietary diversity has been highlighted in several studies (Gupta, Sunder, and Pingali 2020; Koppmair, Kassie, and Qaim 2017; Sibhatu, Krishna, and Qaim 2015), it seems income generated from contract farming is used in purchasing food groups. This is expected given that most food groups cannot be produced by farm households. This further confirms the role of market access in dietary diversity. Column 2 shows that contract farming is negatively correlated with crop diversification, although the coefficient is not statistically significant. Thus, participation in staple crop contract farming does not alter household production decisions much.

5.5 | Heterogeneity Effects

In this section, we are interested in which particular food groups are affected as a result of participation in contract farming. We estimate separate linear probability models which are shown in Figure 1. Figure 1 shows that participation in contract farming is positively correlated with legume, roots and tubers, meat, and vegetable consumption. Probably such food groups can be obtained through the market depending on the use of income to access them. In the Senegal River Valley area, rice production under irrigation is the main economic activity (van Oort et al. 2016) suggesting that households may not be able to produce other crops like vegetables, roots and tubers, and legumes. However, as a result of increased income through contract farming, they can access such food groups. Moreover, our pathway analysis shows that contract farming reduces household crop diversification, although not statistically significantly. Households engaged in contract farming may tend to produce only a few crops suggesting that the others can only be accessed through the market. Legumes and vegetables are cheap, yet important sources of vitamins and other micronutrients (Gupta et al. 2021). It seems farmers may choose these cheaper options compared to relatively more expensive options like meats.

6 | Conclusion and Policy Implications

The institution of contract farming has been shown to offer multiple benefits to smallholders, yet little is known about its impacts on diet quality even though poor-quality diets remain a major challenge in developing countries. In this study, we evaluate the role of contract farming in improving dietary quality which we proxy through household dietary diversity. While we consider the traditional 12-food groups measure of dietary diversity, we equally consider a novel nine-food groups measure, which is argued to reflect healthier diets. Additionally, we explore mechanisms through which contract farming operates as well as some heterogeneity effects.

Our results show that contract farming is associated with dietary diversity as well as healthy dietary diversity of smallholder farmers. We further show that income is the main mechanism through which contracts and dietary diversity are associated. This corroborates with a large body of literature, which highlights the role of the market in improving diets through improved income. This is also supported by our heterogeneity analysis, which shows that food groups that can be accessed through the market are likely to be consumed as a result of contract farming participation. Our results suggest that interventions such as contract farming can play an important role in

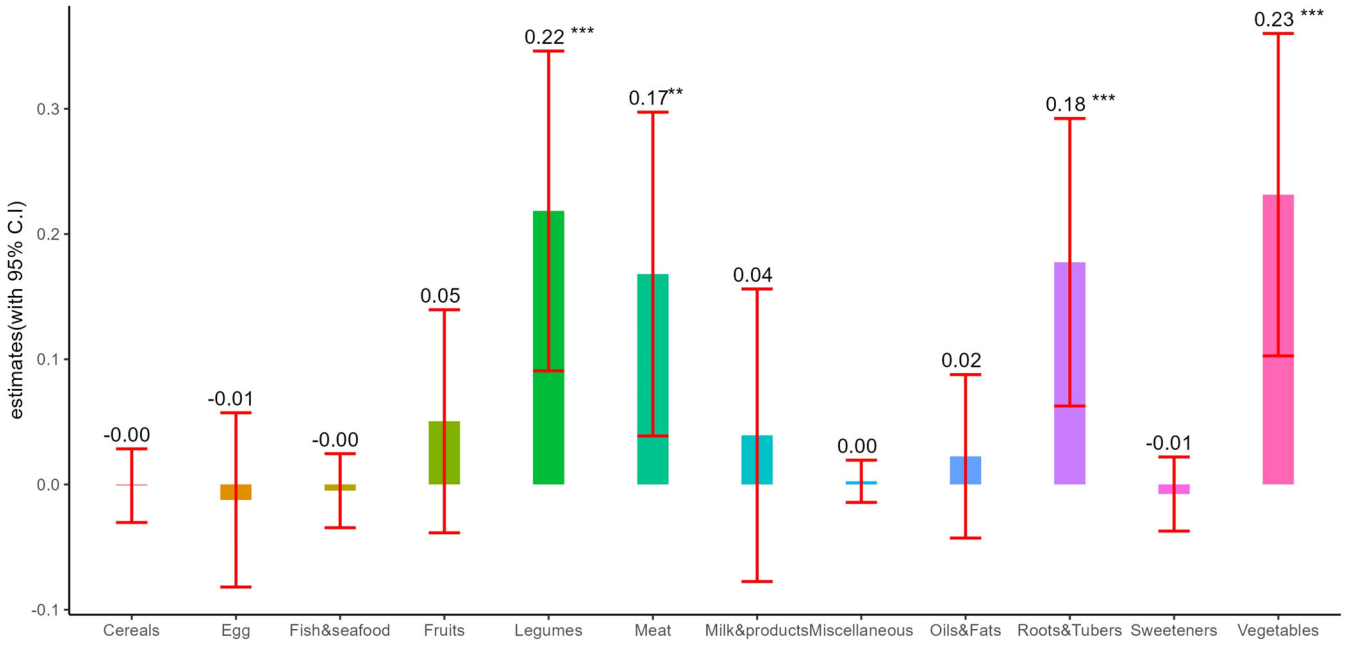

FIGURE 1 | LPM model estimates of different food groups. Controls include households' head age, gender, marital status and educational level, household size, off-farm income, credit access, livestock ownership, and asset value. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

improving diet quality. The full import of contract farming is that it increases farmers' income as shown in our mechanism analysis. An often-cited reason for low dietary diversity is the lack of income to access other food groups not produced by households. With increased income, households can improve access to such food groups. Given that agriculture has been called upon to be more nutrition-sensitive, our results show that interventions such as contract farming which have been generally known for increasing income can also play an important role in achieving such a goal. From a policy perspective, the focus on the benefits of contract farming should transcend income and encompass the dietary benefits associated with it. Owing to these benefits, efforts should be made to design contracts that increase the income benefits of farmers. Attention should also be given to staple crop contracts. Since staple crops are usually produced by many farmers and require simpler technologies, focusing on them may provide even broader dietary impacts.

Our results are limited in some regards. We could not fully explore all potential mechanisms through which contract farming is associated with dietary diversity due to data limitations. Future studies with rich data can explore such mechanisms and hence offer more insights into the relationship. Still in line with data limitations, we could not investigate whether contract types have different effects on dietary diversity. Lastly, our study focuses on a small area in Senegal, limiting the external validity of our findings.

By and large, our results suggest that the institution of contract farming can be used as an intervention to make agriculture more nutrition-sensitive by not just improving the income of farmers, but improving their diet quality. This may ensue in reduced nutrition-related health burdens and spur sustainable development. This may also depend on the general equilibrium effects. For example, if many farmers produce rice under contracts, rice prices will be lower and so will farmers' income from rice. However, such effects have not been studied so far. Further studies could shed more light on the general equilibrium effects of contract farming arrangements to provide a more nuanced view of the institution.

Endnotes

[1]It should be noted that the income pathway may be influenced by gender dynamics at the household level as to who controls the income. Literature suggests that women are more concerned with household welfare (Duflo & Udry, 2004; Fischer & Qaim, 2012; Hoddinott and Alderman 1994; Mehraban et al. 2022; Nikiema and Sakurai 2021). Hence, if income from contract farming is controlled by women it is likely to increase dietary diversity. However, we do not test such pathways in this study. In our regressions, we simply control for the gender of the household head.

[2]Soullier and Moustier (2018) classified contract farming for irrigated rice production in the Senegal River Valley into two types: marketing contract and production contract. Under either contract, farmers receive loans to buy inputs or in-kind loans and repay loans to rice millers with paddy after the harvest. The difference is who supplies the loans. In the marketing contract, a bank (in most cases, the Agricultural Bank) makes loans to farmers and the farmers offer paddy to a rice miller that the bank designates. In the production contract, a rice miller gives loans to farmers and the farmers offer paddy to the rice miller. While the implicit interest rates in the production contracts seem to be higher than those in the marketing contracts, the purpose of both types of contracts remains the same for rice producers. Therefore, this study does not differentiate between the two in the analyses.

Author Contributions

Francis E Ndip: conceptualization; investigation; writing–original draft; writing–review & editing; methodology; software; data curation; formal analysis. **Takeshi Sakurai:** conceptualization; writing–review & editing; validation; supervision; project administration; investigation.

Acknowledgments

Open Access funding enabled and organized by Projekt DEAL.

Ethics Statement

The authors have nothing to report.

DATA AVAILABILITY STATEMENT

The data are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors report that there are no conflicts of interest.

References

Afshin, A., P. J. Sur, K. A. Fay, et al. 2019. "Health Effects of Dietary Risks in 195 Countries, 1990-2017: A Systematic Analysis for the Global Burden of Disease Study 2017." *The Lancet* 393, no. 10184: 1958–1972. https://doi.org/10.1016/S0140-6736(19)30041-8.

Ahmed, M. H., and H. M. Mesfin. 2017. "The Impact of Agricultural Cooperatives Membership on the Wellbeing of Smallholder Farmers: Empirical Evidence from Eastern Ethiopia." *Agricultural and Food Economics* 5, no. 1: 6. https://doi.org/10.1186/s40100-017-0075-z.

Andersson, C. I. M., C. G. K. Chege, E. J. O. Rao, and M. Qaim. 2015. "Following Up on Smallholder Farmers and Supermarkets in Kenya." *American Journal of Agricultural Economics* 97, no. 4: 1247–1266. https://doi.org/10.1093/ajae/aav006.

Arouna, A., J. D. Michler, and J. C. Lokossou. 2021. "Contract Farming and Rural Transformation: Evidence from a Field Experiment in Benin." *Journal of Development Economics* 151: 102626. https://doi.org/10.1016/j.jdeveco.2021.102626.

Asfaw, S., G. Pallante, and A. Palma. 2018. "Diversification Strategies and Adaptation Deficit: Evidence from Rural Communities in Niger." *World Development* 101: 219–234. https://doi.org/10.1016/j.worlddev.2017.09.004.

Barrett, C. B., M. E. Bachke, M. F. Bellemare, H. C. Michelson, S. Narayanan, and T. F. Walker. 2012. "Smallholder Participation in Contract Farming: Comparative Evidence from Five Countries." *World Development* 40, no. 4: 715–730. https://doi.org/10.1016/j.worlddev.2011.09.006.

Bellemare, M. F. 2012. "As You Sow, So Shall You Reap: The Welfare Impacts of Contract Farming." *World Development* 40, no. 7: 1418–1434. https://doi.org/10.1016/j.worlddev.2011.12.008.

Bellemare, M. F., and J. R. Bloem. 2018. "Does Contract Farming Improve Welfare? A Review." *World Development* 112: 259–271. https://doi.org/10.1016/j.worlddev.2018.08.018.

Bellemare, M. F., and L. Novak. 2017. "Contract Farming and Food Security." *American Journal of Agricultural Economics* 99, no. 2: 357–378. https://doi.org/10.1093/ajae/aaw053.

Chege, C. G. K., C. I. M. Andersson, and M. Qaim. 2015. "Impacts of Supermarkets on Farm Household Nutrition in Kenya." *World Development* 72: 394–407. https://doi.org/10.1016/j.worlddev.2015.03.016.

Debela, B. L., A. Ruml, and M. Qaim. 2021. "Effects of Contract Farming on Diets and Nutrition in Ghana." *Applied Economic Perspectives and Policy* 44, no. 2: 911–929. https://doi.org/10.1002/aepp.13204.

Diegert, P., M. A. Masten, and A. Poirier (2023). Assessing Omitted Variable Bias when the Controls are Endogenous (arXiv:2206.02303). arXiv. http://arxiv.org/abs/2206.02303.

Dubbert, C., A. Abdulai, and S. Mohammed. 2023. "Contract Farming and the Adoption of Sustainable Farm Practices: Empirical Evidence from Cashew Farmers in Ghana." *Applied Economic Perspectives and Policy* 45, no. 1: 487–509. https://doi.org/10.1002/aepp.13212.

FAO., IFAD., UNICEF., WFP., & WHO. 2022. "The State of Food Security and Nutrition in the World 2022." In *The State of Food Security and Nutrition in the World 2022*. FAO. https://doi.org/10.4060/cc0639en.

FAO., IFAD., UNICEF., WFP., & WHO. 2023. *The State of Food Security and Nutrition in the World 2023: Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum*. Rome: FAO. https://doi.org/10.4060/cc3017en.

Faye, A., M. Dièye, P. Bilal Diakhaté, A. Bèye, M. Sall, and M. Diop (2021). Working Paper 202 Senegal-Land, Climate, Energy, Agriculture and Development A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.

Feed the Future. (2018) Global Food Security Strategy (GFSS) Senegal Country Plan. Accessed on June 30 at. https://www.feedthefuture.gov/resource/global-food-security-strategy-gfss-senegal-country-plan/.

Gupta, S., N. Sunder, and P. L. Pingali. 2020. "Market Access, Production Diversity, and Diet Diversity: Evidence From India." *Food and Nutrition Bulletin* 41, no. 2: 167–185. https://doi.org/10.1177/0379572120920061.

Gupta, S., V. Vemireddy, D. K. Singh, and P. Pingali. 2021. "Ground Truthing the Cost of Achieving the Eat Lancet Recommended Diets: Evidence from Rural India." *Global Food Security* 28: 100498. https://doi.org/10.1016/j.gfs.2021.100498.

Hawkes, C., M. T. Ruel, L. Salm, B. Sinclair, and F. Branca 2020. "Double-Duty Actions: Seizing Programme and Policy Opportunities to Address Malnutrition in All Its Forms." *The Lancet* 395, no. 10218: 142–155. https://doi.org/10.1016/S0140-6736(19)32506-1.

Hirvonen, K., and J. Hoddinott. 2017. "Agricultural Production and Children's Diets: Evidence from Rural Ethiopia." *Agricultural Economics* 48, no. 4: 469–480. https://doi.org/10.1111/agec.12348.

Hoddinott, J., and H. Alderman (1994). Intrahousehold Resource Allocation: An Overview. https://www.researchgate.net/publication/23721693.

Ickowitz, A., B. Powell, D. Rowland, A. Jones, and T. Sunderland 2019. "Agricultural Intensification, Dietary Diversity, and Markets in the Global Food Security Narrative." *Global Food Security* 20: 9–16. https://doi.org/10.1016/j.gfs.2018.11.002.

Ickowitz, A., B. Powell, D. Rowland, A. Jones, and T. Sunderland. 2019. "Agricultural Intensification, Dietary Diversity, and Markets in the Global Food Security Narrative." *Global Food Security* 20: 9–16. https://doi.org/10.1016/j.gfs.2018.11.002.

Ilboudo Nébié, E. K., D. Ba, and A. Giannini. 2021. "Food Security and Climate Shocks in Senegal: Who and Where Are the Most Vulnerable Households?" *Global Food Security* 29: 100513. https://doi.org/10.1016/j.gfs.2021.100513.

International Food Policy Research Institute (IFPRI). 2019. *2019 Global food policy report* (0 ed.). International Food Policy Research Institute. https://doi.org/10.2499/9780896293502.

Key, N., and D. Runsten (1999). Contract Farming, Smallholders, and Rural Development in Latin America: The Organization of Agroprocessing Firms and the Scale of Outgrower Production.

Koppmair, S., M. Kassie, and M. Qaim. 2017. "Farm Production, Market Access and Dietary Diversity in Malawi." *Public Health Nutrition* 20, no. 2: 325–335. https://doi.org/10.1017/S1368980016002135.

Leroy, J. L., M. Ruel, E. A. Frongillo, J. Harris, and T. J. Ballard. 2015. "Measuring the Food Access Dimension of Food Security: A Critical Review and Mapping of Indicators." *Food and Nutrition Bulletin* 36, no. 2: 167–195. https://doi.org/10.1177/0379572115587274.

Maertens, M., and J. F. M. Swinnen. 2009. "Trade, Standards, and Poverty: Evidence from Senegal." *World Development* 37, no. 1: 161–178. https://doi.org/10.1016/j.worlddev.2008.04.006.

Maertens, M., and K. Van de Velde. 2017. "Contract-Farming in Staple Food Chains: The Case of Rice in Benin." *World Development* 95: 73–87. https://doi.org/10.1016/j.worlddev.2017.02.011.

Manikowski, S., and A. Strapasson 2016. "Sustainability Assessment of Large Irrigation Dams in Senegal: A Cost-Benefit Analysis for the Senegal River Valley." *Frontiers in Environmental Science* 4: 18.

Marivoet, W., J. M. Ulimwengu, L. M. Sall, A. Gueye, K. Savadogo, and K. Dia. 2021. *Hidden hunger: Understanding dietary adequacy in urban and rural food consumption in Senegal* (0 ed. International Food Policy Research Institute. https://doi.org/10.2499/p15738coll2.134483.

Meemken, E.-M., and M. F. Bellemare. 2020. "Smallholder Farmers and Contract Farming in Developing Countries." *Proceedings of the National Academy of Sciences* 117, no. 1: 259–264. https://doi.org/10.1073/pnas.1909501116.

Mishra, A. K., A. Kumar, P. K. Joshi, and A. D'Souza. 2018. "Production Risks, Risk Preference and Contract Farming: Impact on Food Security in India." *Applied Economic Perspectives and Policy* 40, no. 3: 353–378. https://doi.org/10.1093/AEPP/PPY017.

Miyata, S., N. Minot, and D. Hu. 2009. "Impact of Contract Farming on Income: Linking Small Farmers, Packers, and Supermarkets in China." *World Development* 37, no. 11: 1781–1790. https://doi.org/10.1016/j.worlddev.2008.08.025.

Ndip, F. E., E. L. Molua, M.-E. S. Mvodo, et al. 2023. "Farmland Fragmentation, Crop Diversification and Incomes in Cameroon, a Congo Basin Country." *Land Use Policy* 130: 106663. https://doi.org/10.1016/j.landusepol.2023.106663.

Nene, M. 2018. *Nutrition Situation in Senegal*. Washington, DC: World Bank. https://doi.org/10.1596/32469.

Nikiema, R. A., and T. Sakurai. 2021. "Intrahousehold Distribution of Sales Revenue and Household Nutritional Outcomes: What If the Wives Controlled the Farm Revenue?" *Agricultural Economics* 52, no. 6: 1029–1040. https://doi.org/10.1111/agec.12664.

Ochieng, D. O., and S. O. Ogutu. 2022. "Supermarket Contracts, Opportunity Cost and Trade-Offs, and Farm Household Welfare: Panel Data Evidence from Kenya." *World Development* 149: 105697. https://doi.org/10.1016/j.worlddev.2021.105697.

Ogutu, S. O., T. Gödecke, and M. Qaim. 2020. "Agricultural Commercialisation and Nutrition in Smallholder Farm Households." *Journal of Agricultural Economics* 71, no. 2: 534–555. https://doi.org/10.1111/1477-9552.12359.

Ogutu, S. O., D. O. Ochieng, and M. Qaim. 2020. "Supermarket Contracts and Smallholder Farmers: Implications for Income and Multidimensional Poverty." *Food Policy* 95: 101940. https://doi.org/10.1016/j.foodpol.2020.101940.

van Oort, P. A. J., A. Balde, M. Diagne, et al. 2016. "Intensification of an Irrigated Rice System in Senegal: Crop Rotations, Climate Risks, Sowing Dates and Varietal Adaptation Options." *European Journal of Agronomy* 80: 168–181. https://doi.org/10.1016/j.eja.2016.06.012.

Oster, E. 2019. "Unobservable Selection and Coefficient Stability: Theory and Evidence." *Journal of Business & Economic Statistics* 37, no. 2: 187–204.

Otsuka, K., Y. Nakano, and K. Takahashi. 2016. "Contract Farming in Developed and Developing Countries." *Source: Annual Review of Resource Economics* 8: 353–376. https://doi.org/10.2307/26773370.

Pauw, K., O. Ecker, J. Thurlow, and A. R. Comstock. 2023. "Measuring Changes in Diet Deprivation: New Indicators and Methods." *Food Policy* 117: 102471. https://doi.org/10.1016/j.foodpol.2023.102471.

Pinstrup-Andersen, P. 2013. "Can Agriculture Meet Future Nutrition Challenges?" *The European Journal of Development Research* 25, no. 1: 5–12. https://doi.org/10.1057/ejdr.2012.44.

Prowse, M. (2012). Contract Farming in 12 Developing Countries—A Review.

Qaim, M. 2017. "Globalisation of Agrifood Systems and Sustainable Nutrition." *Proceedings of the Nutrition Society* 76, no. 1: 12–21. https://doi.org/10.1017/S0029665116000598.

Ragasa, C., I. Lambrecht, and D. S. Kufoalor. 2018. "Limitations of Contract Farming as a Pro-Poor Strategy: The Case of Maize Outgrower Schemes in Upper West Ghana." *World Development* 102: 30–56. https://doi.org/10.1016/j.worlddev.2017.09.008.

Rao, E. J. O., and M. Qaim. 2011. "Supermarkets, Farm Household Income, and Poverty: Insights from Kenya." *World Development* 39, no. 5: 784–796. https://doi.org/10.1016/j.worlddev.2010.09.005.

Reardon, T., C. B. Barrett, J. A. Berdegué, and J. F. M. Swinnen. 2009. "Agrifood Industry Transformation and Small Farmers in Developing Countries." *World Development* 37, no. 11: 1717–1727. https://doi.org/10.1016/j.worlddev.2008.08.023.

Ruel, M. T., and H. Alderman. 2013. "Nutrition-Sensitive Interventions and Programmes: How Can They Help to Accelerate Progress in Improving Maternal and Child Nutrition?" *The Lancet* 382, no. 9891: 536–551. https://doi.org/10.1016/S0140-6736(13)60843-0.

Ruel, M. T., A. R. Quisumbing, and M. Balagamwala. 2018. "Nutrition-Sensitive Agriculture: What Have We Learned so Far?" *Global Food Security* 17: 128–153. https://doi.org/10.1016/j.gfs.2018.01.002.

Ruml, A., and M. Qaim. 2021. "New Evidence Regarding the Effects of Contract Farming on Agricultural Labor Use." *Agricultural Economics* 52, no. 1: 51–66. https://doi.org/10.1111/agec.12606.

Ruml, A., C. Ragasa, and M. Qaim. 2022. "Contract Farming, Contract Design and Smallholder Livelihoods*." *Australian Journal of Agricultural and Resource Economics* 66, no. 1: 24–43. https://doi.org/10.1111/1467-8489.12462.

Sakurai, T. 2023. "Irrigation Scheme Size and Its Relationship to Investment Return: The Case of Senegal River Valley." In *Rice Green Revolution in Sub-Saharan Africa* (pp. 223–243). Singapore: Springer Nature Singapore.

Sibhatu, K. T., V. V. Krishna, and M. Qaim. 2015. "Production Diversity and Dietary Diversity in Smallholder Farm Households." *Proceedings of the National Academy of Sciences* 112, no. 34: 10657–10662. https://doi.org/10.1073/pnas.1510982112.

Sibhatu, K. T., and M. Qaim. 2017. "Rural Food Security, Subsistence Agriculture, and Seasonality." *PLoS ONE* 12, no. 10: e0186406. https://doi.org/10.1371/journal.pone.0186406.

Soullier, G., and P. Moustier. 2018. "Impacts of Contract Farming in Domestic Grain Chains on Farmer Income and Food Insecurity. Contrasted Evidence from Senegal." *Food Policy* 79: 179–198. https://doi.org/10.1016/j.foodpol.2018.07.004.

Swindale, A., and P. Bilinsky (2006). Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (Version 2). www.fantaproject.org.

Swinnen, J., and R. Kuijpers. 2020. *Inclusive Value Chains to Accelerate Poverty Reduction in Africa*. Washington, DC: World Bank. https://doi.org/10.1596/33397.

Tine, J. A. D., K. Niang, A. Faye, and A. T. Dia. 2018. "Assessment of Women's Dietary Diversity in Southern Senegal." *Food and Nutrition Sciences* 09, no. 10: 1192–1205. https://doi.org/10.4236/fns.2018.910086.

Willett, W., J. Rockström, B. Loken, et al. 2019. "Food in the Anthropocene: The Eat–Lancet Commission on Healthy Diets from Sustainable Food Systems." *The Lancet* 393, no. 10170: 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4.

Wooldridge, J. M. 2010. *Econometric Analysis of Cross Section and Panel Data* (2. ed). MIT Press.