Mixed Farming and its Impact on Food Insecurity and Dietary Quality in the Context of Varying Aridity in Rural Areas of Kenya

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Abstract

Sustainability in agricultural production is key in ensuring food and nutrition security. Mixed farming has been touted as one of the farming systems for enhancing this sustainability. However, there is limited evidence on the effects of mixed farming on different indicators of food insecurity under different biophysical environments. This study investigates the impact of mixed farming on food insecurity and dietary quality in areas with varying degrees of aridity using nationally representative data from 10,817 households extracted from the Kenya Integrated Household Budget Survey 2015/2016. The study uses Food Insecurity Experience Scale (FIES) framework and household dietary diversity score (HDDS) to assess food insecurity and dietary quality, respectively. We applied matching techniques to estimate impacts. Our results show that food insecurity prevails, with mild food insecurity being the most prevalent, followed by moderate and severe levels. Food insecurity differs across the aridity gradient, increasing from the Non-ASAL to the Arid counties. Mixed farming reduced severe food insecurity in all areas, but impact of mixed farming on moderate and mild food insecurity varied with degree of aridity: in the Non-ASAL and Arid areas, all levels of food insecurity reduced for mixed farming adopters, while in Marginally semiarid areas, moderate and severe food insecurity reduced. In Largely semiarid areas, mixed farming reduced only severe food insecurity. The study further found that mixed farming increased overall HDDS, implying improvement in dietary quality, with the largest impact being in the drier areas. Our findings suggest that policymakers should support agro-pastoralists to scale up mixed crop-livestock farming as a strategy to sustainably improve food security and dietary quality.

Key Words*: Mixed farming, Food Insecurity, Dietary quality, FIES, Aridity, Matching techniques.*

1. Introduction

There is increasing food insecurity globally that can be attributed to among others, stagnant agricultural productivity, climate change risk, the rising population, and degraded soil quality (Fraval et al., 2019; Bjornlund et al., 2020; Giller, 2020). Recent projections showed that the number of hungry people would hit 840 million by 2030, and the number of undernourished individuals 132 million by 2020 (FAO et al., 2020). This impedes achievement of the United Nations Sustainable Development Goal 2 (SDG 2) that proposes to end hunger and improve nutrition by 2030, as well as the African Union's Agenda 2063 (72(e)) that aims to eliminate hunger and food insecurity (African Union Commission, 2015; UN General Assembly, 2015).

Sustainable agriculture is essential for reducing hunger and malnutrition since about 70% of households depend on agriculture as their main source of livelihood. A high proportion of food in Africa is produced by smallholders farmers, yet they are the most susceptible to food insecurity, malnutrition and poverty (Fanzo, 2018). In fact, much of the discussion in SDG 2 focuses on Africa, which has the highest prevalence of undernourishment among all regions (19.1%), and twice the world average of 8.9% (FAO et al., 2020). Smallholder farmers provide a critical pathway for agricultural orientated interventions to improve food and nutrition security (Fanzo, 2018; Fraval et al., 2019).

Due to rainfall variability that makes farming unpredictable, and degrading natural resources like soils, smallholder farmers adopt farming systems that minimize risk (Bjornlund et al., 2020) under varying biophysical conditions. The type of farming system is dictated by the amount, timing and rainfall distribution and other agro-ecological conditions. This drives the preference for specialized systems (either crop or livestock systems), agro-pastoral systems based on aridity status and mixed crop-livestock systems in higher rainfall zones. However, due to climate change risk, farmers have adopted diversified agricultural systems as a risk minimizing strategy, to build resilient systems and to improve food security (Thornton & Herrero, 2014; Ngigi et al., 2020).

Mixed farming is one of the systems that can enhance both productivity and sustainability of food and agricultural production (Sneessens et al., 2016). Literature cites numerous benefits of mixed farming as compared to specialized crop or livestock enterprises. For instance, crop residues are used as animal feeds; animal manure could be used to fertilize soils and provide nutrients to crops; water and family labor are used more efficiently; and farm risks are spread over multiple crop and livestock enterprises (Wright et al., 2012; Thornton & Herrero, 2014). These and other benefits confer sustainability and resilience to farming systems especially in the advent of climate change. A study by de Moraes et al. (2014) showed that mixed systems not only led to environmental gains and ecological intensification but also increased yield and income of farmers, as compared to specialized or non-integrated livestock farming in Brazil. Similarly, Bell et al., (2014) showed that crop-livestock integration systems improve farm risk management, increase both crop and livestock productivity and reduce the cost of inputs such as inorganic fertilizers and animal feeds in Australia. Despite the documented advantages of mixed systems, largely crop or livestock farming systems are still widely practised (Ryschawy et al., 2012; Wright et al., 2012; Shahbaz et al., 2017).

Mixed farming is promoted as a key strategy in climate-smart agriculture (FAO, 2013) and is increasingly attracting the attention of researchers. Several studies have assessed the linkages between mixed farming systems and food and nutrition security but the findings are largely mixed. For instance, the study by Parvathi et al (2018) in Lao PDR found that while overall farm production diversity increased dietary quality through dietary diversification, mixed crop-livestock farming resulted in reduced diversity of household diets. Further, Musemwa et al., (2018) investigated the implications of farming and non-farming activities on food consumption and dietary quality in the Eastern Cape Province of South Africa, and found that while household dietary diversity (HDDS) of farmers practising mixed farming was significantly higher than that of non-farmers, it did not differ significantly with that of farm households specializing in crop or livestock farming systems. More recently, Mee et al., (2020) reported from their study in Myanmar's Yamethin District that households practising mixed farming recorded moderate food availability and low food utilization compared to those practising monoculture, which had low food availability and moderate food utilization. There was no difference in food access, with both farming systems reporting high food access.

We complement these studies by investigating the impact of mixed farming on food insecurity and dietary quality in the context of different biophysical environments with varying degrees of aridity using nationally representative data from rural areas of Kenya, where farming is the dominant source of livelihood. Aridity is a key constraint agricultural production (Bannayan et al., 2010; Murray, 2016; Goparaju & Ahmad, 2019), especially where agriculture is largely rain-fed. About 70% of Kenyans live in rural areas where they primarily engage in farming as the main economic activity. Kenya's pursuit of food and nutrition security especially in rural areas is challenged by the biophysical environment under which agricultural production is practised. Over 80% of the country's land area is classified as Arid and Semi-Arid Lands (ASALs), with significant crop and livestock farming activities (ASAL-APRP, 2016). However, low levels of agricultural productivity and high levels of poverty, food insecurity and malnutrition abound in these areas (FAO, 2020). Kenya has embraced climate smart agriculture that promotes mixed farming, but there are no rigorous studies investigating whether and how impacts of mixed farming could be influenced by the biophysical environment. Hence, it remains largely unknown if impacts of this farming system would be beneficial across all environments. The purpose of this study therefore, is to assess impacts of mixed farming on food security and dietary quality among rural households in different biophysical environments characterized by varying degrees of aridity. The study hypothesizes that environmental differences influence food security and dietary quality impacts of mixed farming.

2. Methodology

2.1. Analytical Framework

The study adopts an impact evaluation framework that compares food security and dietary quality outcomes for mixed farming practitioners (adopters) against those of non-practitioners (non-adopters). Under this framework, mixed farming practice is considered to be a *treatment* (T). Consequently, adopters of mixed farming are considered to be treated and therefore referred to as the *treated group* ($T = 1$) while non-adopters are untreated and hence the *control group* ($T = 0$). Impact of mixed farming can be thought of as the difference in the average value of the outcome variable between the treated and control groups (*average treatment effect, ATE*), computed as $ATE = E[Y_i|T_i = 1] - E[Y_i|T_i = 0]$, where $E[Y_i|T_i = 1]$ is the average value of outcome variable for the treated group and $E[Y_i|T_i = 0]$ is the average value of outcome variable for the control group. However, deriving the treatment effect directly in this manner is erroneous because assignment of households into mixed farming adopters and non-adopters was not random, but dependent on socioeconomic factors (Wu et al., 2010). Hence, the treatment effect computed would be under- or over-estimated due to *selection bias* (Angrist & Pischke, 2009).

To correct for potential selection bias, we used a non-parametric method known as propensity score matching (PSM)(Rosenbaum & Rubin, 1983). PSM enabled us to construct a group of households that did not practise mixed farming (control or counterfactual group) which is comparable to households that practised mixed farming (treatment or treated group). PSM was implement by first computing a propensity score, equivalent to the probability that a household practised mixed farming, using a Logit model. Next, we used nearest neighbor matching algorithm (5 neighbors with a caliper of 0.2) to construct the treatment and control groups within the region of common support (Caliendo & Kopeinig, 2008). To assess the quality of matching, we tested for balancing of covariates using Stata's *pstest* command. Finally, impact of mixed farming was computed as the average treatment effect on the treated (*ATT*), by taking the difference in outcome variables (food insecurity variables described in 2.4.2 and dietary quality variable, HDDS, described in 2.4.3) between adopters and nonadopters of mixed farming in the matched sample. Separate PSM models were implemented for the non-ASAL, Marginally Semiarid, Largely Semiarid and Arid regions.

2.2. Study Area

Kenya's land mass is approximately 569,140 square kilometres (FAO, 2015). Of this area, ASALs occupy more that 80% and are residence to about 36% of the country's population, according to the country's Ministry of Devolution and the ASALs (2021). The country is administratively divided into 47 Counties, of which 18 are classified as non-ASALs and 29 as ASALs but with different degrees of aridity (see Figure 1)[1]. Among the ASAL Counties, 8 are arid (85-100% aridity), 8 are marginally semiarid (10-29% aridity) and 13 largely semiarid (30-84% aridity). Agriculture is the mainstay of the country, with different crop and livestock species being raised in each of the biophysical environments according to their adaptability.

[1] From figure 1, the **arid counties** are Garissa, Isiolo, Mandera, Marsabit, Samburu, Tana River, Turkana and Wajir; the **Largely Semiarid Counties** include Baringo, Embu, Kajiado, Kilifi, Kitui, Kwale, Laikipia, Machakos, Makueni, Meru, Taita Taveta, Tharaka Nithi and West Pokot, while the **Marginally semiarid Counties a**re Elgeyo Marakwet, Homa Bay, Kiambu, Lamu, Migori, Nakuru, Narok and Nyeri. The **Non-ASAL Counties comprise of** Bomet, Bungoma, Busia, Kakamega, Kericho, Kirinyaga, Kisii, Kisumu, Mombasa, Murang'a, Nairobi, Nyamira, Nyandarua, Nandi, Siaya, Transnzoia, Uasin Gishu and Vihiga.

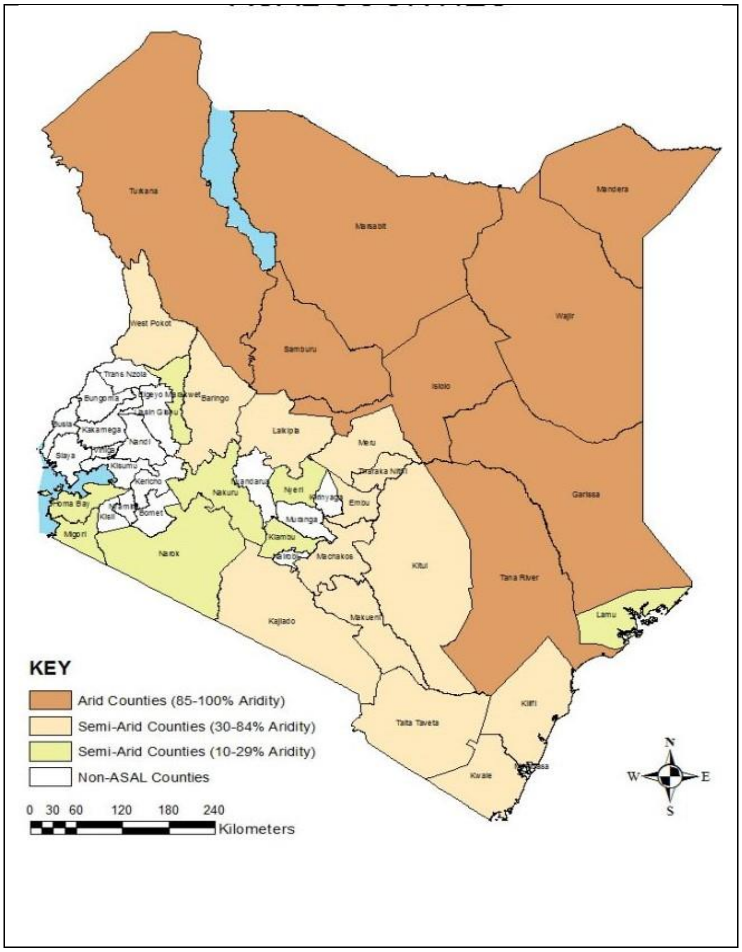


Figure 1: Map of Kenya showing degree of aridity by Counties

2.3. Data

This paper uses data from the Kenya Integrated Household Budget Survey 2015/2016, collected by the Kenya National Bureau of Statistics (Kenya National Bureau of Statistics, 2018). A stratified two-stage cluster sampling was used to select households for the survey from the all the 47 Kenyan counties. Data was collected from rural and urban strata in each county except Nairobi and Mombasa which are entirely urban counties. A total of 2,388 clusters were selected in the first stage of sampling, from which 10 households per cluster were selected in the second stage, making a final sample size of 21,773 households. Data was collected at both household and individual level (where applicable), on variables such as household demographic characteristics, housing conditions, education levels, household income and credit, ownership and use of information and communication technologies, farming activities and food and non-food consumption expenditure, among others. This study considered 10,817 rural households with adults aged 20 years or older, that had been used to analyze overnutrition among Kenyan adults (Muange & Ngigi, 2021). Distribution of the sampled households by ASALs category is shown in Table 1.

Table 1: Distribution of sampled households

Aridity Category	No. of households	% of households
Arid (85%-100% aridity)	1,599	14.8
Semiarid (30-84% aridity) – largely semiarid	3,207	29.6
Semiarid (10-29% aridity) – marginally semiarid	1,744	16.1
Non-ASAL	4,267	39.4
Total	**10,817**	**100.0**

2.4. Measurement of key variables

2.4.1. Mixed farming

Mixed farming, the practice of managing different kinds of crops and/or livestock by the same farmers, exists in different forms as highlighted by (FAO, 2001). In this study, households were asked to state if they practised crop or livestock farming during the 12 months preceding the survey and if so, the main crops grown and type and number of livestock kept. A household that had cultivated at least one crop and raised at least one livestock type was considered to have practised mixed farming.

2.4.2. Food insecurity

Food security is achieved when "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life" (FAO, 2009). Food security is multidimensional, with one vital dimension being steady economic access to sufficient and quality food. Our study focused on this dimension and measured it using Food Insecurity Experience Scale (FIES) approach developed by the Food and Agriculture Organization of the United Nations (Ballard et al., 2013; FAO, 2017; Nord et al., 2016). FIES data is collected either from individual or household levels for a recall period of 30 days or 12 months and the approach is increasingly being applied in SSA (Wambogo et al., 2018). Following the FIES approach, we measured the severity of food insecurity based on economic access using eight questions with binary responses (Yes/

No) to capture self-reported experience of food insecurity and the perceived severity of food insecurity experienced over a 12 months period, as shown in Table 2.

Table 2: Food Insecurity Experience Scale questions and severity of food insecurity measured

S/No	Question	Label	Severity of food insecurity
1.	In the last 12 months, did you worry that your household would not have enough food?	WORRIED	Mild
2.	In the last 12 months were you or any household member not able to eat the kinds of food you preferred because of lack of money?	HEALTHY	
3.	In the last 12 months, did you or any household member eat fewer kinds of food due to lack of money or other resources?	FEWFOODS	
4.	In the last 12 months, did you or any household member miss a meal because of lack of money or other resources to obtain food?	SKIPPED	Moderate
5.	In the last 12 months, did you or any other household member eat less than you thought you should because of lack of money or other resources?	ATELESS	
6.	In the last 12 months, did your household run out of food because of lack of money or other resources?	RUNOUT	
7.	In the last 12 months, were you or any other household member hungry but did not eat because of lack of money or other resources?	HUNGRY	Severe
8.	In the last 12 months, did you or any household member go without food for a whole day because of lack of money or other resources?	WHOLEDAY	

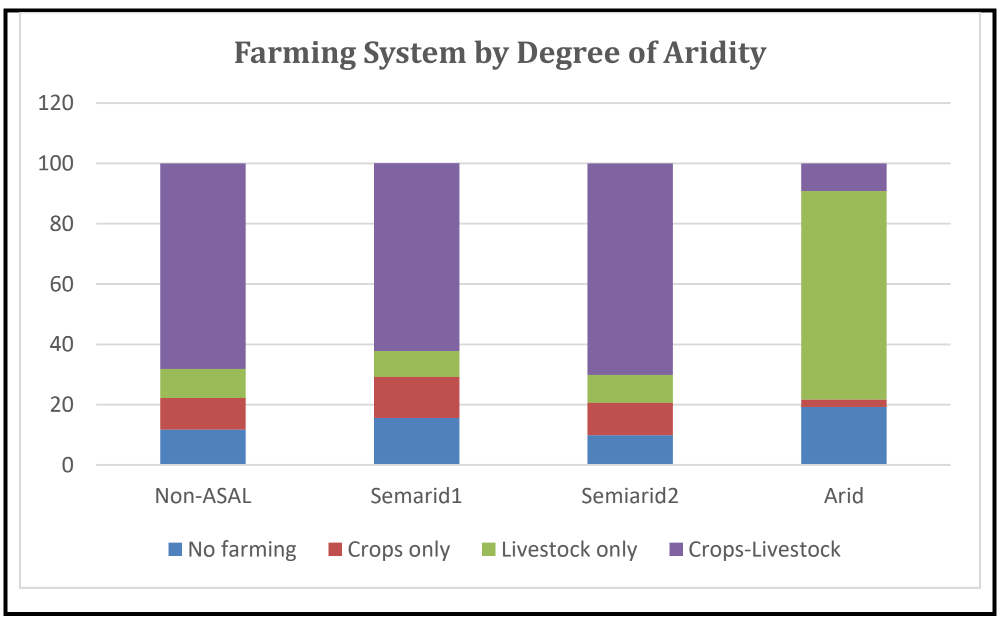
2.4.3. Dietary quality

We measured dietary quality using a household dietary diversity score (HDDS). Dietary diversity is a qualitative measure of access to a variety of foods, a good indicator of nutrient adequacy and extent to which households follow recommend nutritional practices, and a possible remedy to malnutrition (Torheim et al., 2004; FAO et al., 2019). HDDS was computed as a count of food groups consumed by the household during a 7-day recall period preceding the survey. We used the 12 groups of foods recommended by FAO and others to calculate the HDDS (Kennedy et al., 2011). The 12 groups are: cereals; white tubers and roots; vegetables;

fruits; meat; eggs; fish and other seafood; legumes, nuts and seeds; milk and milk products; oils and fats; sweets; and spices, condiments, and beverages.

2.5. Characteristics of the sample

From the 10,817 rural households in our sample, 59.9% practised mixed farming. Further analysis revealed that mixed farming was practised by 9.9% of households in the *Arid* areas 70.8% of households in the *Largely Semiarid* areas, 62.8% of households in the *Marginally Semiarid* areas and 69.3% of the *Non-ASAL* households (Figure 2). The data shows that *Arid* areas of Kenya are least diversified in terms of crop-livestock mixed farming despite being highly risky for agricultural production. This could be explained by lack of adequate rainfall to sustain crop production in these areas. Surprisingly, the *non-ASAL* areas, despite having most conducive physical environment for farming, have high levels of mixed farming just like the *Largely Semiarid* areas that have unreliable rainfall.



Note: Semiarid1 = Marginally Semiarid; Semiarid2 = Largely Semiarid

Figure 2: Farming System by Level of Aridity

Our data also reveals that overall, HDDS averaged at 8.74 out of 12 food groups, representing 72.83%. HDDS was highest in the *Marginally Semiarid* (9.23), followed by *Non-ASAL* (9.17), *Largely Semiarid* (8.90) and *Arid* areas (6.74). As shown in Table 3, HDDS differed across the degree of aridity and significantly between households practising and those not practising mixed farming, at 1% significant levels. This indicates that across the aridity gradient, mixed farming households consumed higher quality diets than those specializing in crop or livestock production.

Table 3: HDDS by mixed farming and degree of aridity

Variable	Mixed farming	Arid	Largely semiarid	Marginally Semiarid	Non_ASAL	All
HDDS						
	Yes	7.86	9.10	9.39	9.35	9.24
	No	6.23	8.42	8.98	8.75	8.01
	Difference	1.23***	0.68***	0.41***	0.60***	1.23***

Other characteristics of the sample (Table 4) show that a large proportion of the households had formal education, with just 25.8% having no formal education. About 70.4% of the respondents were married and 39.5% households were female-headed. Most household heads (96.8%) were religious, subscribing to different religions and denominations. The proportion of households owning mobile phone, television set, computer, and internet connection was 73.9%, 12.8%, 2.1% and 13.6% respectively. Distance from homestead to main road averaged at 57.1 km. Besides, the per capita annual non-food expenditure was KES 34,788 and mean number of rooms in main house (capturing wealth status of the households) was 2.3. As can be seen in Table 4, adopters and non-adopters of mixed farming differed significantly in all but two socioeconomic variables, implying lack of random assignment into adopters and non-adopters of the farming system.

Table 4: Description and characteristics of the sample

Variable	Description	Adopters of mixed farming	Non-adopters of mixed farming	Sample
Education	Level of formal education completed			
None	No formal education (%)	16.48	39.72***	25.79
Primary	Primary school including pre-primary (%)	55.92	37.99***	48.74
Post primary	Secondary school and post primary school vocational training (%)	25.07	23.78***	18.79
College	Post-secondary certificate/diploma (%)	6.12	9.15***	5.22

University	Undergraduate/postgraduate degree (%)	1.78	4.71***	1.45
Married	Household head is married (%)	74.22	64.64***	70.38
Female	Household is female-headed (%)	36.93	43.07***	39.39
Mobile	Household owns mobile phone (%)	78.86	66.51***	73.91
TV	Household owns a television set (%)	15.39	9.04***	12.84
Computer	Household owns a computer (%)	2.02	2.17	2.08
Internet	Household has internet connection of any type (%)	15.45	10.77***	13.58
Religion				
None	Household head has no religious belief (%)	3.01	3.39	3.16
Catholic	Household head subscribes to Catholi faith (%)	23.90	22.12**	23.19
Protestant	Household head belongs to a protestant church (%)	55.66	39.79***	49.30
Other_christ	Household head belongs to another Christian denomination (%)	12.76	9.04***	11.27
Muslim	Household head subscribes to Islamic religion (%)	3.47	23.41***	11.46
Other	Household head subscribes to othe religions (%)	1.20	2.24***	1.62
Age	Age of household head (years)	49.52	44.42***	16.08
Hhsize	Household size (number of members)	4.84	4.14***	2.52
Distance	Distance from homestead to main road (km)	14.54	68.68***	57.07
Expenditure	Per capita annual non-food expenditure (KSh)	35,478	33,756	34,788
Rooms	Number of habitable rooms n main house	2.65	1.78***	1.26

, * Figure differs significantly from that of adopters at 5% and 1% level of significance, respectively

3. Results and discussion

3.1. Descriptive statistics of food insecurity variables

We begin the presentation of study results by describing the severity of food insecurity as captured by the FIES questions (Table 5). The results show that overall, mild food insecurity was experienced by 65% to 72% of households, while moderate and severe food insecurity were experienced by 50%-61% and 28%-44% of households, respectively, depending on the question used to capture food insecurity experience. This implies that mild level of food insecurity was the most prevalent, followed by moderate and severe levels, respectively. Food insecurity experiences differed across the aridity gradient, increasing from the non-ASAL counties to the arid counties. Chi-square tests on all the FIES questions showed significant differences across regions, implying food insecurity experiences differed along the aridity gradient. In the largely semiarid and arid counties, food insecurity of mild, moderate and severe forms was experienced by more than 50% of the sampled households. These results show that there is still a long way to go in achieving zero hunger and food insecurity in Kenya, more so in the drier regions.

Table 5: Descriptive statistics of food insecurity experience by aridity

Variable	All	Non ASAL	Marginally Semiarid	Largely Semiarid	Arid
WORRIED	65.1	61.16	63.30	65.61	76.55
HEALTHY	71.9	69.08	72.08	73.06	77.22
FEWFOODS	68.5	65.07	66.34	70.57	76.11
SKIPPED	52.5	46.87	40.25	57.93	70.00
ATELESS	61.0	57.71	57.05	62.08	71.86
RANOUT	50.1	45.57	41.57	52.47	66.77
HUNGRY	44.1	39.08	35.89	46.54	61.85
WHLDAY	27.6	17.77	19.32	31.93	54.22

3.2. Impacts of mixed farming on food insecurity and dietary quality

Mixed farming impacts were estimated using the propensity score matching approach described in Section 2.1 above. Our analysis confirmed that adoption of mixed farming was indeed not random, but significantly influenced by the covariates described in Table 4, among others. As we show in Table 6, the pseudo-R-squared for the unmatched samples ranged from 0.14 to 0.25 in all models, implying that the variables explained well the probability of that a household paractised mixed farming. After matching, the pseudo-R-squared fell to between 0.01 and 0.02, implying poor explanation of the probability of paractising mixed farming, by the covariates. In addition, the mean bias reduced by between 72.8% and 90.6%, while the median bias also reduced by between 50.5% and 90.2%, implying that matching resulted in significant balancing of the observed covariates between the adopters and non-adopters of mixed farming. For brevity, we omit the results of the models used to compute propensity scores, and of the tests used to check the balancing of individual covariates before and after matching.

Table 6: PSM diagnostics – checking the quality of matching

	All		**Arid**		**Largely semiarid**		**Marginally semiarid**		**Non-ASAL**	
	UM	M	UM	M	UM	M	UM	M	UM	M
Pseudo R^2	0.25	0.01	0.18	0.01	0.25	0.02	0.18	0.02	0.14	0.01
LR chi2	3690.30	94.27	174.87	2.99	972.01	113.57	421.96	56.78	742.63	82.01
Reduction in Mean Bias (%)	90.63		87.35		72.84		68.48		68.52	
Reduction in Median Bias (%)	90.21		87.00		50.52		65.85		62.96	

Note: UM – Unmatched (Before matching); M – Matched (After matching)

Results of PSM, showing impact of mixed farming on food insecurity and dietary quality, are presented in in Table 7. The results show at the national level (model 1), mixed farming reduced food insecurity experience at the mild, moderate and severe levels. The greatest reduction was in the severe level (7.5-8.4 percentage points) followed by moderate (4.4-6.6 percentage points) and mild (3.0-4.1 percentage points) levels. Disaggregated results show that mixed farming had significant negative impact on mild food insecurity experience mostly in the non-ASAL areas. Further, mixed farming reduced moderate food insecurity experience significantly in the Arid, Marginally semiarid and Non-ASAL areas, but not in the Largely semiarid areas, with larger impacts estimated in the Arid and Marginally semiarid areas than in the Non-ASAL areas. Furthermore, mixed farming reduced food insecurity experience at severe levels in all areas across the aridity gradient. Reduction in the proportion of households experiencing hunger ranged from 6.6 percentage points in the Largely semiarid areas to 10.4 percentage points in the Non-ASAL areas, while the decline in the proportion of households going without food for the whole day ranged from 5.5 percentage points in the Arid areas to 10.7 percentage points in the Largely semiarid areas.

These results imply that while adoption of mixed farming by households would reduce severe food insecurity experience in all areas regardless of degree of aridity, impact on moderate and mild food insecurity depends on degree of aridity. The results show that while in the Non-ASAL and Arid areas, mixed farming reduces all levels of food insecurity experience, it only reduces moderate and severe food insecurity experience in Marginally semiarid areas, and severe food insecurity experience in the Largely semiarid areas.

Further results show that, mixed farming increased overall HDDS by 0.374, implying an improvement in dietary quality. Disaggregated analysis reveals that the largest impact was in the Arid areas (0.485), followed by the largely semi-arid areas (0.443), Non-ASALs (0.372) and Marginally semiarid areas (0.248). The results imply that the impact of mixed farming on dietary quality was largest in the drier regions of the country.

Table 7: PSM results – Impact of mixed farming on food insecurity and dietary quality

Variable	All	Arid	Largely semiarid	Marginally semiarid	Non-ASALs
	(1)	(2)	(3)	(4)	(5)
WORRIED	**-3.24****	**-7.77***	**-4.34**	**-4.59**	**-3.43**
HEALTHY	-3.00**	-4.33	-3.30	-2.94	-1.94
FEWFOODS	-4.12***	-5.99	-4.80	-4.99	-4.33**
SKIPPED	-6.62***	-9.94**	-4.38	-10.64***	-6.86***
ATELESS	-4.43***	-9.04**	-2.51	-7.31**	-3.40
RANOUT	-4.40***	-5.61	-4.41	-7.42**	-5.32**
HUNGRY	-7.46***	-8.79*	-6.61**	-9.89***	-10.41***

WHLDAY	-8.35***	-5.48	-10.72***	-9.89***	-8.73***
HDDS	0.374***	0.485**	0.443***	0.248*	0.372***

*, **, *** ATT is significant at 10%, 5% and 1% level, respectively

4. Discussion

This paper investigated the impact of mixed farming on food insecurity and dietary quality in the context of different biophysical environments with varying degrees of aridity. The paper provides novel findings that mixed farming reduced severity of food insecurity as measured by FIES and improved HDDS hence dietary quality. Mild food insecurity was found to be the most prevalent, followed by moderate and severe levels. The severity of food insecurity increased with the degree of aridity and was highest for the Largely semiarid and Arid areas. Mutea et al. (2019) similarly showed that in Kenya the type of agro-ecological zone significantly influences household food security. However, their study indicated that households in non-ASAL areas (humid agro-ecological zone) were less food secure than those in semi-humid and semi-arid zones.

Further, the findings show that mixed farming reduced severe food insecurity in all areas. However, impact of mixed farming on moderate and mild food insecurity depends on degree of aridity. Evidence illustrates that production systems of farms in both developed and developing countries influence food security status, with mixed findings. Mixed farming could support the multidimensionality of food security through various pathways. Mixed farming improves food availability through self-supply of food commodities for household members. For instance, small livestock like goat and chicken could help a household overcome a poor crop harvest. Mixed farming supports household income through the sale of agricultural products, that improve economic access to adequate food. Lastly, mixed farming support farm sustainability that is critical under a changing climate that supports land productivity and income, hence supporting stability in the supply of food products. (Poczta-Wajda et al., 2020) suggest that farms specialized in permanent crops and dairy production were more exposed to food insecurity than crop farms in Poland. The authors argued that mixed farming improves farm sustainability that improves farm incomes which in turn positively impacted food security. A recent study in Myanmar's Yamethin District by (Mee et al., 2020) indicated that mixed farming improved food availability through self-supply and increase food utilization by household member as compared to those practising monoculture.

Lastly, mixed farming increased overall HDDS, implying an improvement in dietary quality. The largest impact was in the drier areas (Arid and largely semiarid areas), followed by Non-ASALs and Marginally semiarid areas. Musemwa et al. (2018) had similar findings that farmers practising mixed farming had a higher HDDS than households specializing in either crop or livestock production systems in the Eastern Cape Province of South Africa. Contrary findings were reported in Lao PDR where mixed crop-livestock farming resulted in reduced diversity of household diets (Parvathi et al 2018).

5. Conclusions and policy implications

Food insecurity is globally rising and this that can be attributed to stagnant agricultural productivity, climate change, the rising population, and degraded soil. This impedes achievement of the United Nations Sustainable Development Goal 2 (SDG 2) as well as the African Union's Agenda 2063 (72(e)) that aim to eliminate hunger and food insecurity and improve nutrition. Sustainable agriculture could reduce hunger and malnutrition. Famers, especially smallholders, adopt farming systems that minimize risk under varying biophysical conditions. Mixed farming is one of the systems with many benefits that can enhance both productivity and sustainability of food and agricultural production, by optimizing resource use. However, studies assessing the association between mixed farming and food and nutrition security produce mixed results, with positive, neutral or negative findings.

This study investigated the impact of mixed farming on food insecurity and dietary quality in the context of different biophysical environments with varying degrees of aridity. The study used nationally representative data comprising of 10,817 households, from rural areas of Kenya. The country promotes mixed farming as a climate-smart agriculture strategy, but rigorous studies investigating how impacts of mixed farming could be influenced by the biophysical environment, are rare. The study adopted an impact evaluation framework that compared food security and dietary quality outcomes for mixed farming adopters against non-adopters. We used propensity score method (nearest neighbor matching, with 5 neighbors and a caliper of 0.2) to remove potential selection bias, and construct treatment and control groups. Food insecurity was measured using the food insecurity experience scale (FIES) approach, while dietary quality was measured using household dietary diversity score (HDDS).

Results show that Kenya still has a long way to go in ending hunger and food insecurity. Food insecurity prevails, with mild food insecurity being the most prevalent, followed by moderate and severe levels. Food insecurity experiences differ across the aridity gradient, increasing from the Non-ASAL counties to the Arid counties. Mixed farming reduced severe food insecurity in all areas. Impact of mixed farming on moderate and mild food insecurity depends on degree of aridity: in the Non-ASAL and Arid areas, all levels of food insecurity reduced for mixed farming adopters, while in Marginally semiarid areas, moderate and severe food insecurity experience reduced. In Largely semiarid areas, mixed farming reduced severe food insecurity. The study further found that mixed farming increased overall HDDS, implying improvement in dietary quality. Largest impact was in the drier areas (Arid and largely semiarid areas), followed by Non-ASALs and Marginally semiarid areas.

Our findings suggest that policymakers should support agro pastoralists to fully adopt mixed crop-livestock farming as a way of improving food security status and dietary quality. Mixed farming can be promoted through awareness creation on different varieties and types of crops and different kind of livestock species suitable for different aridity levels that farmers can adopt to improve food security, livelihoods and build resilient farming systems under changing climate. Besides, the development of agricultural markets in rural areas will support farmers to access to input and output markets essential for sustainable mixed farming systems.

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Availability of data and material

The data is available on request at: http://statistics.knbs.or.ke/nada/index.php. The authors are grateful to KNBS for allowing them access to and use of the datasets.

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