Impact of Agricultural Harvesting on Adolescent Food Security: Evidence from Dietary Diversity Score, Food Consumption Score, Food Insecurity Access Scale and Coping Strategies in Northwest Ethiopia.

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Abstract

Adolescents in Sub-Saharan Africa face significant food security challenges, worsened by socio-economic factors, limited access to nutritious food, and seasonal changes. This longitudinal panel mixed-method study examined dietary diversity, food consumption, food security, and coping strategies among 410 high school students in Machakel district (Woreda), Northwest Ethiopia, during pre-harvest (lean season) and non-fasting post-harvest seasons (season of abundance). Quantitative data were gathered using the dietary diversity score (DDS), food consumption score (FCS), and household food insecurity access scale (HFIAS), and analyzed with descriptive statistics, chi-square, and Wilcoxon tests (STATA 17). Qualitative data on coping strategies collected through interviews and focus group discussions were analyzed using MAX QDA pro-2020. Results showed a significant improvement in food security and dietary diversity after harvest. Before harvest, 26.8% of students were food secure, compared to 61.9% after harvest. Similarly, severe food insecurity dropped from 1.7% to 0.9%. Dietary diversity and food consumption scores also increased significantly after harvest, changing from mostly low scores before harvest to acceptable and high scores afterward. Socioeconomic factors, such as living arrangements, school distance, parental education, and household socioeconomic status, were significantly linked to food security and dietary diversity. During food-insecure times, coping strategies included sharing resources, community support, borrowing, and theft. This study highlighted significant seasonal and socio-economic differences in adolescent food and nutrition security. Year-round, comprehensive interventions are crucial to address these gaps, such as school feeding programs, nutrition education, and social support systems. These efforts should aim to boost adolescent resilience and promote long-term health by providing consistent access to nutritious food and reducing the effects of socio-economic vulnerabilities.

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Introduction

The contemporary definition of food security is the assurance that all individuals have physical, economic, and social access to sufficient, safe, and nutritious food at all times to meet their dietary needs and preferences for an active and healthy life (FAO, 2009). This state requires a supportive environment that encompasses proper care, appropriate feeding practices, adequate healthcare, and education (FAO, 2009, Simelane and Worth, 2020). Despite international commitments, such as the Sustainable Development Goal (SDG) to end hunger and malnutrition, progress remains limited globally in ensuring consistent access to sufficient and safe food (FAO, 2021, UNICEF, 2024).

Adolescents, a substantial global population, are often underserved by nutritional programs despite their high nutritional needs (Baxter *et al.*, 2022). This is particularly true in Sub-Saharan Africa, where they constitute 23% of the population, and in Ethiopia, where they face significant nutritional challenges(Guja *et al.*, 2024). Food security consisted four pillars of availability, accessibility, utilization, and stability, which are crucial for this demographic(NutriSurvey, 2018;Peng and Berry, 2019).

Studies spanning dozens of countries report that roughly one in four adolescents experience food insecurity, which is linked to poorer diet quality, worse mental and physical health outcomes, and educational setbacks, with effects varying by age and gender, underscoring the need for age-sensitive policies and multi-sectoral interventions to support adolescent health and development in both the Global South and North (Fram *et al.*, 2022).

Food security is multidimensional and is best captured through standardized indicators that reflect food availability, access, utilization, and stability. DDS reflects the number of food groups consumed and acts as a proxy for dietary quality, while FCS combines dietary diversity

with frequency of consumption, giving insight into overall household food access. The HFIAS assesses experiential aspects of food insecurity, such as anxiety about food access and compromised food intake. Collectively, these tools provide robust, comparable measures of how agricultural contexts and seasonal changes such as harvest cycles affect food security outcomes (Manikas *et al.*, 2023).

Assessing food security and dietary diversity relies on standardized tools like the DDS and FCS (IDDEX, 2018;NutriSurvey, 2018). Poor dietary diversity is a known contributor to malnutrition (Kennedy *et al.*, 2010;Lopera *et al.*, 2018). Globally, adolescents experience high rates of food insecurity and limited dietary diversification, a trend also prevalent in Ethiopia, where low dietary diversity is common(Mini-EDHS, 2019;Endalifer *et al.*, 2021;Adeyanju *et al.*, 2023). Studies using HFIAS consistently show strong correlations between food insecurity of adolescents and low socioeconomic status of the household (Talleh Nkobou *et al.*, 2022). Furthermore, coping mechanisms, such as reducing meal frequency, worsen malnutrition (Adeleke *et al.*, 2021). Recent Ethiopian research corroborates widespread adolescent food insecurity and the diverse coping strategies employed (Alemayehu and Tesfaye, 2024;Oyato *et al.*, 2024).

Ethiopia's agricultural sector underpins the majority of rural livelihoods and is central to both food availability and economic access to food. Smallholder agricultural production, harvest outcomes, and adoption of improved technologies influence adolescent dietary diversity and food consumption scores across rural communities in Ethiopia. For instance, empirical studies in various Ethiopian regions report that adoption of improved agricultural practices correlates with higher FCS and DDS measures, highlighting the link between agricultural productivity and food security indicators (Aweke *et al.*, 2020).

Within Ethiopia, adolescent food security is shaped by both household food access and broader socio-economic factors. Research in multiple Ethiopian settings shows that adolescent food insecurity is associated with reduced dietary diversity and suboptimal dietary practices, particularly in rural zones where household food access is volatile and dependent on agricultural outcomes. Moreover, coping strategies such as reducing meal frequency or relying on less preferred foods are

commonly reported among adolescents with food insecurity, underlining the lived experience of food insecurity in this age group. These patterns emphasize the need to link agricultural processes like harvesting to measurable outcomes in adolescent food security (Belay *et al.*, 2021).

Across the studies conducted in East Gojjam, food insecurity in rural areas is consistently high reaching 65.3% overall and exceeding 70% in the Abay lowlands and nearly 70% in mountainous highlands while in Machakel district specifically showed severe vulnerability which is evident, with 74% of surveyed households falling into low (31.15%) or severe (43.25%) food insecurity categories and Machakel residents showing more than triple the odds of food insecurity (AOR = 3.28); together, these findings underscore that Machakel district (woreda) is among the most food-insecure localities within an already high-burden (Alemu *et al.*, 2017, Ayele *et al.*, 2020).

Despite existing literature, a critical gap remains in examining adolescent food security in contexts like Ethiopia, especially with the absence of prior longitudinal panel mixed study which investigates the impact of agricultural harvesting on adolescent food security. By integrating concurrently collected quantitative and qualitative data from the same adolescent age cohorts across different time points, this study will provide a nuanced, contextually grounded understanding of adolescent food security. The findings will offer insights to inform targeted school- and community-based interventions, ultimately contributing to efforts to improve adolescent food security and break intergenerational cycles of poverty and malnutrition in Ethiopia. This study aims to comprehensively assess and compare the pre- and post-harvest food security, food consumption, and dietary diversity among Ethiopian adolescents, utilizing HFIAS, FCS, and DDS. in the pre-harvest fasting season (lean season) and non-fasting post-harvest season (season of abundance). It will also explore associated coping strategies and socioeconomic determinants.

Methods

Study Setting

The study was conducted in Machakel district, Amhara region, northwest Ethiopia (Fig. 1). The district is located approximately 328

km northwest of Addis Ababa and 228 km from the regional capital, Bahir Dar. Machakel has a diverse agro-ecological landscape, with 88% classified as Woyina Dega (1,500 -2,300 masl) and Dega (2,300 -3,200 masl). The district is known for its high agricultural productivity, with most farmers practicing mixed agriculture (Nebere *et al.*, 2020).

There are four high schools in the study district. Amanuel High School is located in the main district town, while Dega Segnin, Gira Kidamin, and Shelel are in semi-urban areas. During the 2022/2023 academic year, these schools had a total student enrollment of 7,561, including 3,811 females and 3,750 males.

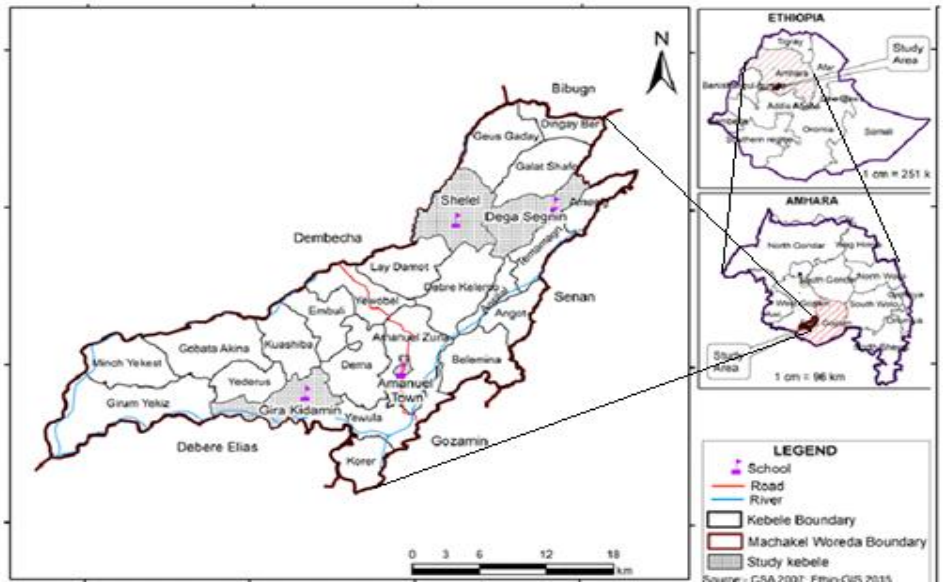

Figure 1: Map of the study area (Machakel District) (Sources: (CSA, 2007;GIS, 2015)

Study Design and Sampling

This study used a longitudinal panel study concurrent mixed-methods design to evaluate diet diversity, food consumption patterns, food security, and coping strategies among high school students in the study district during pre- and post-harvest seasons. The design combined longitudinal data collection (two rounds across seasons) with cross-sectional data from the same student group, alongside simultaneous qualitative and quantitative data collection. This approach provided a

comprehensive understanding of seasonal changes in food security and related coping strategies.

Sample Size Determination and Selection

The sample size was determined using the following formula (Israel, 2013), incorporating finite population correction (FPC) to adjust for the known population (N = 7,561):

$$SS_{kp} = \frac{S}{1+\frac{S-1}{P_k}}$$

This calculation has been validated using Creative Research Systems software (CRS-2012), assuming a 95% confidence level (α=0.05, Z=1.96), a 5% margin of error, and a 50% population proportion (p=0.5) to maximize variability. The resulting sample was then proportionally allocated across the four high schools based on their respective student enrollments (Table 1). The given formula for sample size adjustment when the population is known incorporates finite population correction (FPC) to refine the sample size estimate. It ensures that the sample remains representative while accounting for the limited population size. The formula relies on key statistical assumptions, including a confidence level at 95%, with a significant level of 0.05, a margin of error 5%, and a standard normal Z-score 1.96 based on the chosen confidence level 95%. Since the population proportion is unknown, it is assumed to be 50% (0.5) to account for maximum variability.

The data collection process for the quantitative part utilizes a proportional simple random sampling technique. Classes or sections from all Grades (Grade 9-12) were chosen using simple random sampling. Sections for each grade were assigned proportionally. Initially, data was obtained from each high school regarding their enrollment figures, the number of grades, and sections they had. Subsequently, the number of sample students from each grade was selected through simple random sampling (Lottery method) based on this gathered information. A meticulous and unbiased selection process was undertaken to identify a total of 410 students from four high schools, spanning across Grades 9 to 12. The procedure commenced with a comprehensive listing of all sections within each of the four high

schools, ensuring that every section was properly documented along with its respective school name. This step was crucial in maintaining accuracy and transparency in the selection process.

To ensure fairness and eliminate any potential bias, a lottery-based selection method was employed. Under this approach, sections were randomly drawn from each grade level, ensuring equal representation across different schools and grade levels. This method provided every section with an equal opportunity to be selected, thus upholding the principles of randomness and impartiality. Once the sections were chosen through the lottery process, the corresponding students within those sections were identified as part of the final group of 410 students. This randomized approach guaranteed a diverse and representative sample of students from all four high schools, covering the entire spectrum of grade levels from Grade 9 to Grade 12.

Data Collection

Quantitative data on adolescent food security, food consumption, and diet diversity were collected using DDS, FCS, and HFIAS from students (living with or away from family). To explore context-specific coping strategies for adolescent high schoolers living alone away from family, qualitative data were gathered through 33 in-depth interviews and six focus group discussions with students, school staff, health workers, and community members (room rentees), employing a purposive sampling approach to gain rich insights. Quantitative data were collected during the pre-harvest "lean" season (mid-November/December 2022) and the non-fasting post-harvest season (season of abundance) (April/May 2023) to capture seasonal variations in food security, consumption, and dietary patterns, noting that the main harvest occurs in January. Qualitative data were collected during the pre-harvest season to gain a deeper understanding of the context-specific coping strategies of adolescent high schoolers living alone away from family in the area.

Data was collected from all study participants by trained health professionals who received thorough instruction on study objectives, standardized procedures, ethical considerations (including informed consent), and methods to reduce recall-bias. Survey instruments were pre-tested and piloted to reduce respondent bias. Structured

questionnaires gathered data from sample students on socio-demographic factors, dietary diversity, food consumption patterns, and food insecurity levels.

Dietary Diversity Score (DDS)

Dietary diversity was assessed using the DDS ((Kennedy *et al.*, 2010) (IDDEX, 2018). DDS was calculated based on the consumption of 12 food groups in the past 24 hours, and the scores ranged from 0 to 12. A diet diversity score of less than 3 showed little diversity, indicating the adolescents faced severe food insecurity. A score of 4 to 5 indicated moderate food insecurity and a score of 6 to 12 meant severe food insecurity.

Food Consumption Score (FCS)

FCS was used to measure the variety and frequency of 18 food groups consumed in the previous seven days prior to the survey (WFP, 2015). Adolescents with a scores of 0 to 21 were considered lower dietary diversity indicating they were likely to struggle to consume a diverse and frequent range of food groups, potentially lacking essential nutrients; adolescents with scores 21.5-35 were considered borderline as they experienced some dietary limitations, but their food intake was generally sufficient in terms of diversity and frequency; and adolescents with scores higher than 35 were considered as having an acceptable score as they had a good variety of food groups and consume them frequently, thus, indicating a more secured food consumption pattern.

Food Security Assessment

Food security status of adolescents was assessed following the method of (Coates *et al.*, 2007), which measures behavioral and psychological indicators of food insecurity over the previous 30 days prior to the survey. It uses a standardized questionnaire consisting of nine occurrence questions and nine frequency-of-occurrence questions. Each question is scored from 0 to 3 based on how often the condition was experienced (rarely, sometimes, or often), resulting in a total score ranging from 0 to 27. Higher scores indicate greater food insecurity. Adolescents are then categorized as food secure, mildly food insecure, moderately food insecure, or severely food insecure based on their responses(Coates *et al.*, 2007;Castell *et al.*, 2015).

Coping Strategies

Coping strategies were assessed qualitatively for their context-specific mechanisms in response to food shortages and financial hardship among adolescent students living away from their families. These strategies included both behavioral and psychological adaptations, such as reducing meal portions, seeking alternative income sources, borrowing food or money from relatives, and relying on community support systems. The qualitative approach enabled a deeper understanding of the social, cultural, and economic factors influencing these coping responses (Maxwell and Caldwell, 2008).

Data Analysis

Quantitative data were analyzed using descriptive statistics and the chi-square test The Wilcoxon matched-pairs signed-rank test was used to assess changes in DDS, FCS, and HFIAS scores between pre- and post-harvest seasons. A significant Wilcoxon test indicated a change in food security or dietary diversity indicators over time. STATA 17 was used for quantitative data analysis.

Qualitative data on context-specific coping strategies were analyzed using MAX QDA Pro 2020. The context-specific coping strategy framework (Maxwell and Caldwell, 2008) was adapted to the local context. This framework categorizes coping strategies based on a single question: "*What do you do/what do adolescent students do/ when there is no food to eat and no money to buy food*?" This approach provides insights into context-specific responses to food and financial insecurity, allowing for the identification of both severe and simple coping strategies.

Ethical Considerations

Ethical approval was secured from the Institutional Review Board (IRB) of the College of Development Studies, Addis Ababa University. Permission to carry out the study was granted by the Amhara Regional State Public Health Institute. The Machakel Woreda Health Office assisted in coordinating with local schools. Informed consent was received from school directors, Parent-Teacher Associations, and participating adults. Consent to participate in the study was obtained from adult student participants and parents or guardians for minors. All participants were fully informed about the study's purpose, procedures,

potential risks and benefits, and their right to withdraw at any time. The anonymity of respondents and the confidentiality of the information collected from them were strictly maintained throughout the study.

Results and Discussion

Socio-demographic and Economic Characteristics of Respondents

This demographic data summarizes the socio-demographic characteristics of 410 student respondents, highlighting a population that is equally split by gender (50% each). Approximately 63% of students lived away from their families and rented inexpensive rooms, a common arrangement in the district due to the school's distance from their homes. Over 41% of them came from households more than ten kilometers away from school (Table 1). This could affect food security, as it might limit access to home-cooked meals and increase dependence on affordable, possibly less nutritious options. For students living alone away from family, room rent was the main expense, while purchasing food was the primary cost for about one-third of adolescent high school students, highlighting financial constraints and potential trade-offs.

Table 1: Socio-demographic characteristics of adolescent high school students in Machakel district in 2022/2023 academic year, (n=410)

Variables Description		Frequency (%)
School location	Amanuel	182 (44.4)
	Dega Segnin	95 (23.2)
	Gira Kidamin	90 (21.9)
	Shelel	43 (10.5)
Age of the respondent (years)	15 – 17	155 (37.8)
	18 – 19	255 (62.2)
Grade Level	Grade-9	120 (29.3)
	Grade-10	96 (23.4)
	Grade-11	115 (28.1)
	Grade-12	79 (19.3)
Sex of respondents	Male	205 (50)
	Female	205 (50)
Distance from school	<10 KM	240 (58.6)
	11-20 KM	121 (29.5)
	>20 KM	49 (11.9)
Living arrangement	Living away from family	260 (63.4)
	Living with family	150 (36.6)

Household Characteristics

Majority (60%) of household heads were in their young or middle adulthood, and approximately 65% were married (Table 2). Over half of the mothers could not read or write, whereas 75% of the fathers have an elementary level education. Farming was the dominant occupation for both parents, indicating predominantly agricultural livelihoods.

Table 2: Parental socio-demographic characteristics of adolescent high school students in Machakel district in 2022/2023 academic year, (n=410)

Variables		Frequency (%)
Age of household head	30-50 Years	247 (60)
	>50 Years	163 (40)
Marital status of household head	Single	12 (2.9)
	Married	266 (64.9)
	Divorced	69 (16.8)
	Widowed	63 (15.4)
Father's level of education	Can't read & write	95 (23.2)
	Grade 1-8	311 (74.9)
	Grade 9-12	4 (0.98)
	College/University	4 (0.98)
Mother's level of education	Can't read & write	210 (51.2)
	Grade 1-8	197 (48)
	Grade 9-12	3 (0.73)
Fathers' occupation	Farmer	319 (77.8)
	Merchant	57 (13.9)
	Daily labor or others	34 (8.3)
Mothers' occupation	Housewife	126 (30.7)
	Farmer	207 (50.5)
	Merchant	45 (10.9)
	Daily labor or others	32 (7.8)
Number of Livestock for a household	<2 Livestock	197 (48)
	>=2 Livestock	213 (52)
Dependency ratio	None	157 (38.3)
	1	169 (41.2)
	>1	84 (20.5)
Household farmland size (ha)	None	44 (10.7)
	1 Hectare	188)45.9)
	>1 Hectare	178 (43.4)
Household Wealth	Poor	77 (18.7)
	Middle	245 (59.8)
	Rich	88 (21.5)

Household Resources

Economic indicators such as farmland ownership, livestock holdings, and wealth stratification point to a largely agrarian economy with moderate asset dispersion. Most households own at least one hectare of land and have a modest number of livestock, indicating subsistence-level agricultural productivity. Wealth distribution, skewed toward middle-income groups, conceals underlying vulnerabilities, especially for nearly one-fifth of households classified as poor. The household dependency ratio, with a significant portion supporting more than one dependent, highlights the strain on limited resources. These structural pressures likely affect adolescents' food security, influencing their development and academic performance (Table 2).

Dietary Diversity Score (DDS)

The study evaluated dietary diversity among high school students in the district during both pre- and post-harvest seasons. Before harvest, students mainly consumed carbohydrates, which are good energy sources for the body; however, the amount and frequency of food intake may not meet their daily energy needs. Consumption of other food groups was limited, with low intake of flesh foods (15%) and nuts/seeds (13%). During this season, students depended on only a few food groups (Table 3).

Table 3: Consumption of twelve food groups over 24-hour recall period among adolescent high school students in the pre- and post-harvest seasons, in Machakel district in 2022/2023 academic year, (n=410).

S. N	Type of Food Group	Yes (1) (n (%)		Wilcoxon test
		Pre-harvest	Post-harvest	0.000*
1	All starchy staples	410 (100%)	410 (100%)	
2	Beans and peas	410 (100%)	410 (100%)	
3	Nuts and seeds	54 (13%)	381 (93%)	
4	All dairy	62 (15%)	340 (83%)	
5	Flesh foods and fish	62 (15%)	308 (75%)	
6	Eggs	86 (21%)	254 (62%)	
7	Vitamin A-rich dark vegetables	90 (22%)	131 (32%)	
8	Other Vitamin A-rich vegetables	86 (21%)	213 (52%)	
9	Other fruits	115 (28%)	238 (58%)	
10	Other vegetables	123 (30%)	246 (60%)	
11	Oils and fats	201 (49%)	394 (96%)	
12	Non-alcoholic beverages	197 (48%)	287 (70%)	

Post-harvest (non-fasting abundance season), dietary diversity significantly improved. Consumption of nuts, seeds, and dairy products increased notably (Table 3). Flesh foods, eggs, and Vitamin A-rich foods also showed moderate increases, indicating improved diet quality and micronutrient intake.

Table 4: DDS status of adolescent high school students in the pre-harvest and post-harvest season in Machakel district *in 2022/2023,* (n=410)

DDS status	Pre-harvest	Post-harvest	Wilcoxon
	No. (%)	No. (%)	0.000*
Severely FI (Lower DDS)	151 (37)	0 (0)	
Moderately FI (Acceptable DDS)	136 (33)	97 (24)	
Food secured (Suitable DDS)	123 (30)	313 (76)	

The Wilcoxon signed-rank test confirmed a significant increase in dietary diversity from pre-harvest to post-harvest (p=0.000), reflecting seasonal changes in food availability and access. Increased consumption after harvest likely results from greater availability and affordability following the harvesting season.

Pre-harvest DDS analysis revealed lower dietary diversity, with 37% of students having "Severe food insecurity" (consuming 0-3 food groups), indicating a high risk of micronutrient deficiencies. Another 33% had "moderate food security" (consuming 4-5 food groups), and 30% achieved "food security" (consuming 6-12 food groups)(NutriSurvey, 2018). This highlights the challenges in achieving adequate dietary diversity pre-harvest, reflecting broader food insecurity and aligning with findings from studies in various countries(Roba *et al.*, 2019;Dello Russo *et al.*, 2023).

Post-harvest, dietary diversity improved, with no students consuming less than four food groups. However, 24% still exhibited "moderate food insecurity," indicating persistent challenges. This improvement aligns with increased post-harvest food availability and affordability, consistent with research in Ethiopia (Ayenew *et al.*, 2018). The overall improvement in food security and DDS post-harvest corroborates

findings linking harvest seasons to better dietary diversity (Hjertholm *et al.*, 2019;Seyoum *et al.*, 2024).

The Wilcoxon matched-pairs signed-rank test confirmed a highly significant difference in DDS between pre- and post-harvest ($p < 0.0001$, $r=0.991$), with substantially higher DDS post-harvest. This highlights the strong influence of seasonal food availability on adolescent diets and the risk of micronutrient deficiencies pre-harvest, consistent with other African studies (Roba *et al.*, 2019).

Table 5: Chi-square test result for DDS status of adolescent students in the pre-harvest and post-harvest season (%) in Machakel district in 2022/2023 (n=410)

Variables Descriptions		Low Variety		Acceptable		Suitable		X^2 test
		Pre-	Post-	Pre-	Post-	Pre-	Post-	
School	Amanuel	25.6	3.7	14.9	22.4	3.9	18.3	0.001*
	Dega Segnin	9.8	0.5	12.7	14.9	0.7	7.8	
	Gira Kidamin	13.4	2.2	8.5	12.2	0.0	7.6	
	Shelel	5.4	0.7	3.9	5.1	1.2	4.6	
Age	15-17 Years	23.7	4.9	12.9	17.3	1.2	15.6	0.016*
	18-19 Years	30.5	2.2	27.1	37.3	4.6	22.7	
Sex	Male	30.7	4.9	17.1	26.8	2.2	18.3	0.011*
	Female	23.4	2.2	22.9	27.8	3.7	20.0	
Grade level	Grade 9-10	33.7	7.1	17.3	23.7	1.7	21.9	0.000*
	Grade 11-12	20.5	0.0	22.7	30.9	4.2	16.3	
Living condition	Living alone	35.9	6.8	24.4	48.1	3.2	8.5	0.000*
	With family	18.3	0.24	15.6	6.6	2.7	29.8	
Number of Siblings	None	6.8	0.0	5.1	7.1	0.5	5.4	0.000*
	1-4 Siblings	40.7	5.8	31.9	42.4	4.6	29.0	
	>4 Siblings	6.6	1.2	2.9	5.1	0.7	3.9	
Main Expense of adolescents	Food	17.3	1.5	13.9	14.2	2.2	17.8	0.000*
	Room rent	24.4	5.4	17.1	33.4	2.7	5.4	
	Others	12.4	0.24	9.0	7.1	0.9	15.1	
Distance from high schools	<5 KM	20.5	1.9	16.3	12.9	2.9	24.9	0.000*
	5-10 KM	19.3	2.9	11.7	23.4	1.7	6.3	
	>10 KM	14.4	2.2	11.9	18.3	1.2	7.1	
Mothers' occupation	Housewife	14.6	1.5	12.9	18.1	3.2	11.2	0.000*
	Farming	32.2	5.1	16.6	27.1	1.7	18.3	
	Non-farming	7.3	0.5	10.5	9.5	0.9	8.8	
Fathers, occupation	Farming	45.6	6.6	27.6	43.7	4.6	27.6	0.002*
	Non-farming	8.5	0.5	12.4	11.0	1.2	10.7	
Total		**54.2**	**7.1**	**40.0**	**54.6**	**5.9**	**38.3**	**100**

Chi-square tests showed significant associations between DDS and school location, age of adolescents, gender, grade level, living arrangements, number of siblings, income sources, expenses, and distance from school (table 5). Students living alone had significantly lower DDS (p=0.000), consistent with a systematic review and studies in Sub-Saharan Africa (Admasu *et al.*, 2022), highlighting the importance of family resources and home-cooked meals(El Ansari *et al.*, 2012).

Grade level also associated with DDS (p=0.025), with older students showing more varied diets, possibly due to greater autonomy, nutritional awareness, and economic factors, similar to findings in China (Zhou *et al.*, 2022). Financial constraints, particularly prioritizing non-food expenses like rent, also negatively impacted DDS, consistent with research on food insecurity among students (Trübswasser *et al.*, 2022;Otekunrin and Otekunrin, 2023). Students from poorer households were more likely to prioritize non-food expenses, further limiting their access to diverse, nutritious foods.

Finally, household size significantly affected DDS (p=0.000), with larger families facing resource constraints that limit dietary diversity, consistent with Ethiopian studies (Ayele *et al.*, 2023;Jateno *et al.*, 2023). The study underscores the need for year-round interventions to ensure consistent access to nutritious foods, including promoting food storage and preservation, supporting school feeding programs, and encouraging home gardens.

Food Consumption Score (FCS)

Pre-harvest FCS analysis revealed concerning food and nutrition security (Table 6). A significant proportion (19%) had "poor" FCS (<21), indicating poor dietary diversity and insufficient intake, with risks of malnutrition and micronutrient deficiencies. Over half (54%) were "Borderline" FCS (21.5-35), suggesting food insecurity risk, while only 27% had "Acceptable" FCS (>35). This aligns with Ethiopian studies highlighting pre-harvest food insecurity (Mezgebe *et al.*, 2024).

Table 6: FCS level of adolescent high school students in the pre-harvest and post-harvest season in Machakel district, n=410

FCS status	Pre-harvest season	Post-harvest season	Wilcoxon
	No. (%)	No. (%)	
Poor (0-21)	77 (18.8)	7 (1.7)	0.000*
Borderline (21.5-35)	223 (54.4)	125 (30.5)	
Acceptable (>35)	110 (26.8)	278 (67.8)	

Post-harvest, FCS significantly improved (p=0.000). The seasonal improvement in FCS aligns with increased post-harvest food availability, consistent with Ethiopian studies linking harvests to improved nutrition (Markos *et al.*, 2024). This seasonal shift reflects broader patterns in rural settings(Wiafe *et al.*, 2023), with similar post-harvest improvements observed in other studies (Njura *et al.*, 2020).

Chi-square tests revealed significant associations between FCS and living arrangements, number of siblings, income sources, expenses, school distance, household age, marital status, parental education, farmland size, livestock ownership, wealth index, and dependency ratio (table 7).

Parental occupation, household wealth, farmland size, and livestock ownership are likely to influence food availability and dietary diversity. The dependency ratio and school distance may impact food accessibility and meal frequency. High dependency ratio, where many household members are not income earners, can strain resources, limiting the ability to purchase sufficient or nutritious food, thereby reducing meal frequency. Additionally, long distances to schools may require children to leave home early and return late, disrupting regular mealtimes and reducing access to fresh home prepared food. These findings emphasize the complex interplay of socioeconomic factors in adolescent food security, consistent with a recent study (Wiafe *et al.*, 2023).

Table 7: Chi-square test for FCS status of adolescent high school students in the pre-harvest and post-harvest season (%) in Machakel district in 2022/2023 (n=410).

Variables Description		Poor		Borderline		Acceptable		X^2-test
		Pre	Post	Pre	post	Pre	post	
Sex	Male	9.8	4.9	25.6	26.8	14.6	18.3	0.011*
	Female	9.0	2.2	28.8	27.8	12.2	20.0	
Living arrangement	Living alone	18.3	1.7	31.5	23.2	13.7	38.5	0.000*
	With family	0.5	0.0	22.9	7.3	13.2	29.3	
Number of Siblings	None	0.0	0.0	5.6	1.9	6.8	10.5	0.000*
	1-4 Siblings	15.1	1.7	42.2	23.2	20.0	52.4	
	>4 Siblings	3.7	0.0	6.6	5.4	0.0	4.9	
Main source of money for adolescents	Family only	15.1	1.5	29.3	18.3	0.0	24.6	0.000*
	Part-time only	3.4	0.24	4.9	2.7	1.7	7.1	
	Both	0.0	0.0	18.8	8.5	23.4	33.7	
	Others	0.24	0.0	1.5	0.98	1.7	2.4	
Main expense of adolescents	Food	9.3	0.5	23.7	12.9	0.5	20.0	0.000*
	Room rent	9.0	1.2	23.9	14.9	11.2	28.1	
	Others	0.5	0.0	6.8	2.7	15.1	19.8	
Distance from high schools	<5 KM	0.5	0.0	22.4	9.0	16.8	30.7	0.000*
	5-10 KM	3.7	0.98	19.0	11.5	10.0	20.2	
	>10 KM	14.6	0.7	12.9	10.0	0.0	16.8	
HH Marital status	Single	0.7	0.0	1.9	1.5	0.24	1.5	0.000*
	Married	0.0	0.0	41.5	16.3	23.4	48.5	
	Divorced	7.3	0.5	6.3	5.6	3.2	10.7	
	Widowed	10.7	1.2	4.6	7.1	0.0	7.1	
Mothers' level of education	Can't read & write	13.2	1.5	37.8	23.2	0.24	26.6	0.000*
	Can read & write	4.4	0.24	13.2	5.6	0.24	12.0	
	Formal education	1.2	0.0	3.4	1.7	26.3	29.3	
Fathers' level of education	Can't read & write	7.1	0.7	15.9	12.0	0.24	10.5	0.000*
	Can read & write	9.8	0.98	28.1	12.0	0.24	25.1	
	Formal education	1.9	0.0	10.5	6.6	26.3	32.2	
Mothers' occupation	Housewife	6.8	0.5	20.2	9.0	3.7	21.2	0.000*
	Farming	9.5	1.2	23.4	18.1	17.6	31.2	
	Non-farming	2.4	0.0	10.7	3.4	5.6	15.4	
Fathers' occupation	Farming	15.1	1.7	42.4	26.1	20.2	50.0	0.011*
	Non-farming	3.7	0.0	12.0	4.4	6.6	17.8	
HH farmland size	None	10.7	0.7	0.0	4.2	0.0	5.9	0.000*
	1 hectare	7.8	0.98	25.6	13.7	12.4	31.2	
	> 1 hectare	0.24	0.0	28.8	12.7	14.4	30.7	
Number of Livestock	< 2 livestock	18.5	1.7	29.0	19.3	0.5	27.1	0.000*
	≥ 2 Livestock	0.24	0.0	25.4	11.2	26.3	40.7	
Wealth Status	Poor	8.1	0.7	10.5	7.1	0.24	11.0	0.000*
	Middle	10.5	0.98	21.7	13.4	12.7	30.5	
	Rich	0.24	0.0	22.2	10.0	13.9	26.3	
Total		**18.8**	**1.71**	**54.4**	**30.5**	**26.8**	**67.8**	**100**

Specifically, students living with families had higher FCS, reflecting parental support and home-cooked meals, aligning with Ethiopian findings (Belay *et al.*, 2024). Conversely, students living farther from family had lower FCS, likely due to travel burdens, consistent with a systematic review (Matsuzaki *et al.*, 2020). This highlights the need for school-based interventions like feeding programs. Family socioeconomic status and parental education (p=0.000) were key determinants. Students from wealthier households with more educated parents had higher FCS, consistent with other studies from Ethiopia (Abera *et al.*, 2023;Tegegnework *et al.*, 2023).

Family size had a significant association (p=0.000) with FCS, likely due to resource constraints, consistent with research on family size and food security (Harper *et al.*, 2022). Similarly, livestock and farmland ownership had significant association with FCS, which is, similar to observations in African studies in Kenya and Zambia (Njura *et al.*, 2020;Bwalya *et al.*, 2024). Higher household income and lower dependency ratios also correlated with FCS, highlighting the impact of economic factors, consistent with a study in Ethiopian findings (Trübswasser *et al.*, 2022).

Finally, FCS was significantly higher post-harvest ($p < 0.0001$, $r = -0.99$), as shown by the Wilcoxon test, demonstrating the strong influence of seasonal agricultural cycles, consistent with research in Africa and Ethiopia (Roba *et al.*, 2019;Aweke *et al.*, 2020). These findings underscore the need for multifaceted interventions addressing socioeconomic factors, family structure, and logistical challenges to improve adolescent food security.

Household Food Insecurity Access Scale (HFIAS) Results

Significant seasonal disparities in household food insecurity experiences were observed among the study participants, underscoring heightened vulnerability during the pre-harvest period (Table 8). During the pre-harvest season, anxiety and uncertainty about food access were prevalent among most of the participants. The sharp improvement in worrying and anxiety during the post-harvest period highlights the seasonal dependence on access to food and the psychological relief that accompany food availability. This pattern underscores the emotional toll of food insecurity, with anxiety being a

key early symptom of scarcity before more tangible deprivations emerge.

Significant dietary compromises were made during the pre-harvest season, as most study participants had to consume unpreferred or limited types of foods due to food shortages. Following post-harvest season, the number of individuals struggling with these quality-related dietary constraints decreased dramatically, pointing to a notable improvement in dietary variety and access to preferred foods (Table 8). However, even in the post-harvest season, nearly one in four participants still faced these challenges, suggesting that persistent underlying constraints, such as economic barriers or limited agricultural or food market diversity, persisted despite seasonal improvements in food availability.

The most severe forms of food insecurity, including reductions in food quantity and direct experiences of hunger, were experienced by some study participants during the pre-harvest season. During the post-harvest period, however, a drastic reduction in such experiences was noted, with nearly universal access to at least some food and a complete elimination of full-day hunger episodes. This seasonal disparity highlighted the need for targeted pre-harvest interventions to mitigate nutritional and health risks during critical periods of food shortage for adolescents.

The "lean season" is characterized by reduced food access for adolescents, with only 26.8% of students being food secure (Table 9). This aligns with other studies from Ethiopia that showed heightened food insecurity among adolescents pre-harvest (Belayneh *et al.*, 2021). Reduced food availability during this period can increase psychological stress and negatively impact students' attention and academic performance (Wudil *et al.*, 2022;UNICEF, 2024), as well as potentially leading to nutritional deficiencies (Schneider *et al.*, 2023;Fitawek, 2024).

Table 8. Food insecurity experiences of adolescent high school students during the pre-harvest and post-harvest seasons in Machakel district in 2022/2023 academic year, (n=410).

HFIAS Questions	Occurrence [No (%)]				Frequency of occurrence [N (%)]					
	Never		Yes		Rarely		Sometimes		Often	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Worrying about food	108 (26)	291 (71)	302 (74)	119 29)	72 (18)	86 (21)	204 50)	33 (8)	26 (6)	0 (0)
Unable to eat preferred food	119 (29)	294 (74)	291 (71)	116 (28)	180 (44)	111 (27)	92 (22)	5 (1)	19 (5)	0 (0)
Eat only a few kinds of food	139(34)	303 (74)	271(66)	107(26)	171(42)	105 (26)	81 (20)	2 (0.5)	19(5)	0 (0)
Eat foods they really don't want to eat	220 (54)	337 (82)	190 (46)	73 (18)	126 (31)	72 (18)	47 (11)	1 (.2)	17(4)	0 (0)
Eat a smaller meal	307 (75)	375 (91)	103 (25)	35 (9)	67 (16)	8 (2)	28 (7)	1 (.2)	8(2)	0 (0)
Eat fewer meals in a day	337 (82)	405 (99)	73 (18)	5 (1)	51 (12)	4 (.9)	19 (5)	1 (.2)	3(1)	0 (0)
No food of any kind	363 (89)	405 (99)	47 (11)	5 (1)	44 (10)	5 (1)	3 (1)	0 (0)	0(0)	0 (0)
Go to sleep hungry	368 (90)	410 (100)	42 (10)	0 (0)	39 (10)	0 (0)	3 (1)	0 (0)	0(0)	0 (0)
Go the whole day and night without eating	397 (97)	410 (100)	13 (3)	0 (0)	13 (3)	0 (0)	0 (0)	0 (0)	0(0)	0 (0)

* Rarely (1 or 2 times); sometimes (3 to 10 times); Often (more than 10 times)

* Rarely (1 or 2 times); sometimes (3 to 10 times); Often (more than 10 times)

General food insecurity decreased substantially at post-harvest, indicating the positive impact of harvests (Table 9). However, moderate or severe food security was experienced by less than 5% or 1% of the students, respectively. This suggests that post-harvest improvements are uneven, and structural issues related to food access persist (Abera *et al.*, 2023;Béné and Devereux, 2023).

Table 9: HFIAS status of adolescent high school students in the pre-harvest and post-harvest season in Machakel district, (n=410)

HFIAS category	Pre-harvest	Post-harvest	Wilcoxon
	No (%)	No (%)	
Food secured	110 (26.83)	254 (61.95)	0.000*
Mild food insecurity	223 (54.39)	130 (31.71)	
Moderate food insecurity	70 (17.07)	22 (5.37)	
Severe food insecurity	7 (1.71)	4 (0.98)	

Chi-square tests revealed significant associations ($p<0.05$) between adolescent food security status and school location, living arrangements, number of siblings, and income sources, main expense, parents' education, parents' occupation, and household socio-economic

status (Table 10). Students living alone experienced significantly higher food insecurity (p=0.000), reflecting the importance of familial support (Abaynew *et al.*, 2024). Larger family sizes were also associated (p=0.000) with increased food insecurity, highlighting resource constraints and competition for food (Mekonen *et al.*, 2023).

Furthermore, students relying solely on family income showed higher food insecurity than those with supplementary income (p=0.000), emphasizing the protective role of financial diversification (Beyene *et al.*, 2023). Distance from school has association (p=0.000) with food insecurity, with students living farther from high schools experiencing greater food insecurity due to transportation costs and reduced access to family food provisions(Abizari *et al.*, 2017).

Parental education, occupation, and household composition significantly influence food security. Parental education has association with adolescents' food insecurity, likely due to limited income-generating potential (p=0.000), while educated parents' nutritional knowledge and financial management skills support better food access(Smith *et al.*, 2023). Maternal occupation was associated with food security of adolescents, aligning with studies highlighting the positive impact of maternal income on household food access and child nutrition(Melaku *et al.*, 2024).

Age of household head and number of dependents have an association with food insecurity, reflecting reduced earning capacity and dependency burdens (Bitana *et al.*, 2023). Household wealth was also directly associated with food security (p=0.000), consistent with Ethiopian and Ghanaian studies demonstrating the impact of poverty on food access and educational outcomes (Masa and Chowa, 2021;Delbiso *et al.*, 2024). Finally, farmland and livestock ownership were significant determinants of food security. Larger farm sizes and livestock holdings improved food security, aligning with Ethiopian research showing the benefits of income diversification and livestock ownership(Tesfaye *et al.*, 2023).

Table 10: Chi-square test for HFIAS status of adolescent high school students *(%)* in Machakel district in 2022/2023, (n=410)

Variables Descriptions		FS	Mildly FIS	Moderate FIS	Severe FIS	X^2-test
School	Amanuel	13.2	24.6	6.6	0.0	0.008*
	Dega Segnin	6.1	12.4	3.2	1.5	
	Kira Kidamin	4.9	12.4	4.4	0.24	
	Shelel	2.7	4.9	2.9	0.0	
Age	15-17 Years	10.5	19.8	6.8	0.7	0.918
	18-19 Years	16.3	34.63	10.2	0.98	
Living arrangement	Living alone	13.7	31.5	16.6	1.7	0.000*
	With family	13.2	22.9	0.5	0.0	
Number of Siblings	None	6.8	5.6	0.0	0.0	0.000*
	1-4 Siblings	20.0	42.2	15.1	0.0	
	>4 Siblings	0.0	6.6	1.9	1.7	
Main source of money for adolescents	Family only	0.0	29.3	14.2	0.98	0.000*
	Part-time only	1.7	4.9	2.7	0.7	
	Both	23.4	18.8	0.0	0.0	
	Others	1.7	1.5	0.24	0.0	
Main Expense for adolescents	Food	0.5	23.7	8.5	0.7	0.000*
	Room rent	11.2	23.9	8.1	0.98	
	Others	15.1	6.8	0.5	0.0	
Distance of home from high schools	<5 KM	16.8	22.4	0.5	0.0	0.000*
	5-10 KM	10.0	19.0	3.7	0.0	
	>10 KM	0.0	12.9	12.9	1.7	
HH head Marital status	Single	0.24	1.9	0.5	0.24	0.000*
	Married	23.4	41.5	0.0	0.0	
	Divorced	3.2	6.3	7.3	0.0	
	Widowed	0.0	4.6	9.3	1.5	
Mothers' level of education	Can't read & write	0.24	37.8	11.5	1.7	0.000*
	Can read & write	0.24	13.2	4.4	0.0	
	Formal education	26.3	3.4	1.2	0.0	
Fathers level of education	Can't read & write	0.24	15.9	5.4	1.7	0.000*
	Can read & write	0.24	28.1	9.8	0.0	
	Formal education	26.3	10.5	1.9	0.0	
Mother types of occupation	Housewife	3.7	20.2	6.1	0.7	0.001*
	Farming	17.6	23.4	8.8	0.7	
	Non-farming	5.6	10.7	2.2	0.24	
Size of farmland	None	0.0	0.0	9.0	1.7	0.000*
	1 hectare	12.4	25.6	7.8	0.0	
	>1 hectare	14.4	28.8	0.24	0.0	
Number of Livestock	<2 Livestock	0.5	29.0	16.8	1.7	0.000*
	≥2 Livestock	26.3	25.4	0.24	0.0	
Wealth Index	Poor	0.24	10.5	6.8	1.2	0.000*
	Middle	12.7	21.7	10.0	0.5	
	Rich	13.9	22.2	0.24	0.0	
Dependency Ratio	None	10.7	21.0	5.9	0.7	0.000*
	One	9.5	23.3	8.3	0.24	
	Greater than one	6.6	10.2	2.9	0.7	
Total		**26.8**	**54.4**	**17.1**	**1.7**	**100**

Context Specific Coping Strategies

Qualitative data revealed diverse coping strategies employed by adolescents living alone away from family, ranging from community-based support to risky behaviors. These commonly practiced coping strategies, categorized as simple and severe, could impact students' academic performance and well-being. Reliance on social actions (sharing food) and support from the community and charity organizations was common. However, some students resorted to gambling, theft, and other harmful actions.

The coping strategies listed can be grouped into four main categories. Dietary changes include actions that directly affect food consumption patterns. These strategies include eating nothing for the whole day, reducing portion sizes, decreasing meal frequency, resisting hunger, and drinking water when feeling hungry. These approaches are often immediate responses to food scarcity, aiming to stretch limited food supplies.

Table 11: List of coping strategies practiced by adolescent high school students and their severity in Machakel district, (n=33 KII, 6 FGD)

List of simple coping strategies	**List of Severe coping strategies**
Sharing of resources Engaging in per-time work Seeking social support Borrowing food and money Buying Kochero (small, dried pieces of injera) from church students Temporary discontinuation of education Females engaging in housekeeping jobs	Early marriage Begging Immigration Commercial sex work Permanent discontinuation of education Gambling Eating nothing the whole day Reducing portion size of food Reducing the frequency of meals Resisting hunger Drinking water when feeling hungry

Diversification of food sources involves seeking alternative means to access food or income to support food security. This includes engaging in per-time work, females taking up housekeeping jobs, buying Kochero from church students, borrowing food and money, and seeking social support. These strategies reflect efforts to increase resources or food availability through various social and economic activities. Decreasing the number of people in a household is another coping mechanism, often used to reduce the number of mouths to feed. This includes early marriage and immigration, which may be seen as ways to shift the burden of care or reduce household size during times of crisis.

Rationing strategies focus on managing and sharing limited resources more efficiently. Sharing of resources falls under this category, as it involves distributing available food or money among household or community members. Other strategies that do not fit neatly into these categories, such as temporary or permanent discontinuation of education, begging, theft, commercial sex work, and gambling, are considered other strategies, often reflecting more severe or desperate responses to prolonged hardship.

Sharing food with relatives and owners of rented rooms were a common practice by adolescents in the district, demonstrating community support (Endris *et al.*, 2017). Seeking help from various social networks like relatives was also prevalent in the study area. Community-based support was a key coping mechanism as indicated by other studies(Weldemariam *et al.*, 2023). Many students engaged in part-time work, compromising academic performance which has similarities with previous studies (Islam and Hoque, 2022). Borrowing food or money was most frequently mentioned coping strategies for adolescents in the district, reflecting resilience in resource-limited settings (Weldemariam *et al.*, 2023). Some students bought cheap, low-nutritious food from church students (Yeqolo temari).

Similar to other observations, desperate measures included begging (Nathan and Fratkin, 2018), temporary or permanent discontinuation of education (Tsemato *et al.*, 2024), and early marriage for girls (Raj *et al.*, 2019) were practiced by adolescent high school students in the district. On the other hand, female students sometimes engaged in

housekeeping jobs (Lorato *et al.*, 2023) or, more disturbingly, commercial sex work (Robinson and Usman, 2019) in this district. Male students sometimes engaged in theft and gambling.

Students also coped with enduring hunger as indicated by other literatures(Belew *et al.*, 2024). Reducing food portions and meal frequency (Tsegaye *et al.*, 2018), resisting hunger psychologically (Leung *et al.*, 2020), and drinking water to ease hunger (McKay *et al.*, 2023) were also practiced by the adolescents. Persistent food insecurity can drive students to harmful practices like theft and gambling (Conrad *et al.*, 2022;Sklar *et al.*, 2024), highlighting the need for interventions.

Conclusions and Recommendations

In the district, adolescent food security is affected by seasonal food availability and socioeconomic factors. Pre-harvest shortages worsen dietary diversity and food consumption for low-income students living away from their families. Post-harvest improvements do not eliminate vulnerability from structural inequalities, leading to significant seasonal food security disparities. Adolescents often cope, sometimes severely (through theft, begging, or early marriage), which negatively impacts their education, health, and social stability. Addressing this requires integrated strategies, including awareness, education, agricultural support, school access, community initiatives, and monitoring, as well as expanding school infrastructure to incorporate nutrition education.

Study Limitations

The longitudinal panel study design may not fully capture the continuous nature of food insecurity, as self-reported data may be subject to recall bias, and the sample is limited to high school students in one district, which restricts generalizability. Purposive sampling of qualitative data may also introduce some selection bias. Despite these limitations, the study provides valuable insights into adolescent food and nutrition security in Machakel district, informing interventions and policies.

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