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Rethinking Food Insecurity Assessment Methods: Evidence from Khyber Pakhtunkhwa, Pakistan

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Abstract: This study evaluates three standard food insecurity measures—Household Food Insecurity Access Scale (HFIAS), Food Consumption Score (FCS), and Minimum Dietary Energy Intake Requirement (MDER)—using survey data from 300 individuals in Bannu and Dera Ismail Khan districts in Khyber Pakhtunkhwa, Pakistan. We find a strong correlation ($p < 0.01$) between FCS and MDER ($\rho = 0.93$), indicating alignment in assessing dietary energy sufficiency. In contrast, correlations between FCS and HFIAS ($\rho = 0.087$) and between MDER and HFIAS ($\rho = 0.079$) are weak, suggesting that HFIAS captures different dimensions of food insecurity. Comparative analysis reveals that FCS and MDER often indicate more severe food insecurity than HFIAS. Bannu consistently shows higher severe food insecurity rates than Dera Ismail Khan, with ANOVA results confirming significant district differences ($F = 76.14$ for MDER, $p = 0.000002$; $F = 129.1$ for FCS, $p = 0.00002$; $F = 11.85$ for HFIAS, $p = 0.000658$). Vulnerable groups, including daily wage households, Internally Displaced Persons (IDPs), and female-headed households, exhibit higher rates of food insecurity. These disparities arise from methodological inconsistencies and the subjective nature of self-reported measures, highlighting the need for accurate measurement through comprehensive surveys to effectively understand the full extent of food insecurity.

Keywords: Food insecurity, internally displaced persons, female-headed households, Food Consumption Score (FCS), Household Food Insecurity Access Scale (HFIAS), Minimum Dietary Energy Intake Requirement (MDER).

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1. Introduction

Food insecurity is a complex and urgent issue that impacts populations globally, with far-reaching implications for health, well-being, and economic development (FAO, 2019; UNICEF, 2017). As researchers and policymakers strive to tackle this issue, it has become evident that food security is a multifaceted phenomenon that requires consideration of various interconnected dimensions (Jones et al., 2013; Herwig, 2000). Thus, understanding the complexity of food security involves examining different aspects, including food access, availability, affordability, utilization, stability, and resilience (Berry et al., 2015; Jones et al., 2013; Herwig, 2000). These interconnected dimensions create a web of factors influencing individuals' and communities' overall food security status. The expanded definition of food security emphasizes this intricate relationship and highlights the necessity of considering these dimensions collectively. For instance, food accessibility, which refers to the ability to obtain adequate and nutritious food, is essential to food security (Herwig, 2000). It encompasses factors such as access to food markets, transportation infrastructure, and social and cultural barriers that may prevent individuals from acquiring the food they need (Jones et al., 2013; Grainger, 2010).

On the other hand, availability emphasizes a sufficient food supply by considering both production and distribution systems (United Nations, 1975). Likewise, affordability is crucial for food security, as the ability to purchase food at reasonable prices is essential for individuals and families (Herwig, 2000). Additionally, stability and sustainability—vital aspects of food security—focus on ensuring that food production, distribution, and consumption practices are environmentally sustainable (Devereux et al., 2014; Lang & Barling, 2012) in the face of external shocks. This highlights the importance of long-term strategies, such as developing resilient crop varieties, enhancing seedling preparation, improving storage, and providing nutritional education (e.g., empowering farmers and communities), while also accessing health services to ensure optimal use of food resources (Power, 1999; USAID, 1992; Herwig, 2000; Jones et al., 2013). Similarly, individuals' capacity to meet their dietary needs can be significantly influenced by economic constraints, income inequality, and market dynamics (Jones et al., 2013). Furthermore, effective food usage involves several components, including proper preparation, storage,

nutritional education, and access to health and sanitation services. Optimal food utilization ensures that individuals can obtain food and maximize its nutritional value (Herwig, 2000; USAID, 1992).

While these dimensions provide a framework for understanding food insecurity, questions arise about how effectively existing indicators capture its complexities and the individuals affected. For instance, how do various indicators, such as calorie adequacy, dietary diversity, and experiential measures, enhance our understanding of food insecurity, and how do these measures vary across different socioeconomic strata and geographical regions? What limitations and challenges do traditional metrics, like food consumption (calorie intake, dietary diversity) or behavioral and socio-psychological measures, face when addressing the complexities of food security? Furthermore, how can complementary indicators be integrated to offer a more comprehensive assessment of food insecurity that incorporates both objective and subjective components? (Hedlund et al., 2013; Klasen, 2008; Coates et al., 2007; Smith et al., 2006).

By addressing these questions, we can better understand the interplay among various dimensions and related factors of food insecurity, thus paving the way for targeted interventions and strategies that promote sustainable food systems and alleviate food insecurity on a global scale (Grainger, 2010; Leroy et al., 2015; Stamoulis & Zezza, 2003; Frank et al., 1999; Alinovi et al., 2010; Lovendal et al., 2004). In the following sections, we will explore each dimension and its associated indicators for measuring food insecurity in greater depth. This exploration provides a comprehensive overview of the methodological challenges present in the existing literature and empirical evidence, highlighting their significance and interconnections. By carefully analyzing these dimensions and indicators, we aim to deepen our understanding of food insecurity and gain critical insights into potential pathways for policy development and action.

2. Challenges in Measuring Food Security: What we have Learned?

The measurement of food security has resulted in the development of a new set of indicators designed to capture various aspects of food insecurity (Manikas et al., 2023; D'Souza et al., 2015; Maxwell et al., 2014; Mathiassen, 2014). These metrics include experience-based indicators, dietary diversity indicators, and household-level calorie adequacy (Manikas et al., 2023; De Haen et al., 2011; Mullainathan et al., 2001). While calorie adequacy has historically served as the primary measure of food security, other indicators, such as experience-based and dietary diversity

indicators, play significant roles in assessing food insecurity (Manikas et al., 2023; De Haen et al., 2011). The selection of indicators can shape the outcomes of these indicators, the measurement techniques used, and the dimensions of interest set by researchers (Smith et al., 2006; Hedlund et al., 2013), in addition to the characteristics of specific respondents (D'Souza et al., 2015; De Haen et al., 2011; Deitchler et al., 2010).

Recognizing that these indicators may not always convey the same concept is essential. For instance, experiential measures that fall under self-reported categories enable individuals to define their perception of "adequate" consumption based on personal viewpoints rather than relying on externally defined criteria (Headey & Ecker, 2013; Hedlund et al., 2013; Deitchler et al., 2010). Furthermore, self-reported measures can be influenced by socioeconomic status and gender (Headey & Ecker, 2013; Hedlund et al., 2013). For example, socioeconomic status can shape dietary norms, leading to different views on what constitutes adequate food consumption among households with varying socioeconomic backgrounds. Gender differences further impact perceptions, as individuals' opinions on a satisfactory food package can vary by gender, resulting in differing responses to food insecurity questions from men and women (Aziz et al., 2022; Broussard, 2019; Hedlund et al., 2013; Croson & Gneezy, 2009; Coates et al., 2007). Moreover, global studies consistently show that female-led households experience higher levels of food insecurity compared to their male-led counterparts (Aziz et al., 2022; Broussard, 2019; Jung et al., 2017; Atuoye et al., 2017; Matheson & McIntyre, 2014). The ability to differentiate between varying levels of food security may also be shaped by these differences in interpretation and response (Deitchler et al., 2010; Hedlund et al., 2013).

Indicators such as calorie intake, dietary diversity, and body mass index (BMI) are commonly used to evaluate food security; however, they have inherent limitations in capturing the complexities of this concept (Coates et al., 2007; Smith et al., 2006). While calorie intake provides insight into the quantity of food consumed, it neglects to consider the accessibility and nutritional quality of that food (Smith et al., 2006; Coates et al., 2007). In contrast, dietary diversity highlights the variety of foods consumed but may not sufficiently address nutritional adequacy (Svedberg, 2002). Similarly, BMI reflects an individual's weight status, but it can be influenced by factors beyond diet, such as genetics and physical activity (Klasen, 2008).

To address these limitations, researchers have developed tools like the Household Food Insecurity Access Scale (HFIAS) to evaluate various aspects of food security, including availability, affordability, and personal experiences of hunger (Coates et al., 2007). Funded by the United States Agency for International Development (USAID), the Food and Nutrition Technical Assistance Project (FANTA) has been instrumental in developing the HFIAS, which is widely recognized for its effectiveness in measuring the severity of food insecurity (Piperata et al., 2023; Hedlund et al., 2013; Coates et al., 2007).

Another relevant method is the Food Consumption Score (FCS), which assesses dietary adequacy by analyzing both the quantity and quality of food consumed (Manikas et al., 2023; Mathiassen, 2013; Smith et al., 2006). By examining various aspects of dietary intake, the FCS provides a comprehensive view of the nutritional factors related to food insecurity. Finally, the Minimum Dietary Energy Intake Requirement (MDER) focuses on meeting the energy needs of individuals and households, making it a crucial indicator for assessing food insecurity (Manikas et al., 2023; Piperata et al., 2023; Smith et al., 2006).

Nonetheless, it is crucial to acknowledge the limitations inherent in using these measurement tools. Experience-based assessments, such as the Household Food Insecurity Access Scale (HFIAS), depend on self-reported accounts and perceptions, introducing subjectivity and potential recall bias into the evaluation process (Chrzan & Brett, 2017). Furthermore, specific indicators, like the Food Consumption Score (FCS) and the Minimum Dietary Energy Intake Requirement (MDER), primarily concentrate on food access and dietary sufficiency while overlooking factors such as food utilization and stability within households (Smith et al., 2006). Although instruments like the Core Food Security Measurement/Household Food Security Survey Module (CFSM/HFSSM) have undergone extensive evaluation and show commendable reliability and validity (Chrzan & Brett, 2017; Coates et al., 2007), others may need further scrutiny and validation.

Additionally, focusing solely on household-level assessments may unintentionally overlook disparities and variations in food access and utilization among individuals within a household (Manikas et al., 2023; Piperata et al., 2023; Coates et al., 2007). It is also crucial to recognize that measurement tools developed for specific populations may not be universally applicable or relevant in diverse contexts. This underscores the urgent need for tailored instruments that can effectively capture the unique

complexities of different populations and geographic regions (Manikas et al., 2023; Piperata et al., 2023; Chrzan & Brett, 2017; Hedlund et al., 2013; De Haen et al., 2011; Deitchler et al., 2010).

To fully understand the concept, it is necessary to integrate complementary indicators that represent its various aspects, such as access to food, dietary sufficiency, and the occurrence of hunger (Chrzan & Brett, 2017; FAO, 2012). Coates (2013), Jones et al. (2013), and De Haen et al. (2011) argue that relying on a single metric presents challenges and may not accurately reflect the extent of food insecurity. Therefore, it is essential to utilize indicators that include objective and subjective components (Hedlund et al., 2013; De Haen et al., 2011; Barrett, 2010; Deitchler et al., 2010; Masset, 2011). Furthermore, measurable data on food intake, spending, and health markers aid in assessing the objective elements of food security (Barrett, 2010; Masset, 2011). However, food security is also perceived subjectively and influenced by social factors such as gender, class, and cultural environment (Mallick & Rafi, 2010; The Economist Intelligence Unit, 2012). These subjective elements reflect individuals' perspectives on the adequacy of their food intake, their exposure to risks, and the cultural acceptability of food (Barrett, 2010; Masset, 2011).

Addressing the limitations of current measurement approaches is essential for improving our understanding and assessment of food insecurity. This requires refining existing tools and developing context-specific strategies that account for the unique characteristics of the population being studied (Chrzan & Brett, 2017). Conducting comprehensive household surveys and pursuing additional research in this area are critical steps toward informing policymaking and advocating for enhanced measurement methods that provide a more accurate assessment of food insecurity (Chrzan & Brett, 2017). By continuously refining measurement techniques, policymakers and practitioners can effectively target interventions and confront the complex challenges associated with food insecurity.

Accurately measuring food insecurity is essential in Pakistan, where challenges such as violence, climate change, and food insecurity must be addressed (Aziz et al., 2022; de Cock et al., 2013; Gandure et al., 2010; Faber, 2009). While previous research has explored various household food security indicators, limited attention has been given to comparing food insecurity across groups using multiple indices (Aziz et al., 2022; de Cock et al., 2013; Gandure et al., 2010; Faber, 2009). We can comprehensively understand food insecurity by assessing these factors,

encompassing access and perceptions. However, the limitations of survey-based data collection methods and the exclusive reliance on single measurement techniques at the household level have impeded the study of individual-level food security.

This research addresses these gaps by integrating three commonly used approaches: the Food Consumption Score (FCS), the Minimum Dietary Energy Intake Requirement (MDER), and the Household Food Insecurity Access Scale (HFIAS). Each approach has its own methodology and serves a unique purpose, providing valuable insights into various dimensions of food insecurity. By incorporating dietary and experiential measures, the study captures both consumption patterns and individuals' socio-psychological experiences related to food insecurity across 300 households in the Bannu and DI Khan districts. The research identifies inconsistencies and limitations associated with current measurement techniques, emphasizing the need for methodological and empirical advancements. Improving existing tools and developing tailored strategies is essential for enhancing the accuracy of food insecurity measurement. Comprehensive household surveys and further research in this field are crucial for informing policymaking and advocating for improved measurement methods to accurately assess food insecurity. These advancements will support the creation of more effective interventions and policies to tackle this pressing global challenge.

This study makes several significant contributions to measuring and understanding food insecurity. First, it emphasizes the need for a holistic and multidimensional approach to assessing food security. A more comprehensive understanding of the complex nature of food security is achieved by examining various indicators, including measures of energy adequacy, dietary diversity, and empirical metrics. Second, the study highlights the importance of incorporating individuals' experiences and subjective perceptions into the assessment of food insecurity, as illustrated by the use of HFIAS. Acknowledging the influence of individual perspectives on food security enhances the validity and relevance of measurement methods. Furthermore, the study recognizes the limitations and challenges of current measurement techniques and stresses the need for further testing and evaluation of existing tools to improve their effectiveness.

This study focuses specifically on the context of Pakistan and employs various measurement approaches to assist policymakers and

researchers in enhancing the effectiveness of interventions and policies aimed at addressing food insecurity in Pakistan and similar situations.

3. Methodology

By examining the complex nature of food insecurity and emphasizing the impact of various individual, socio-cultural, economic, institutional, and regulatory factors, our theoretical foundation for selecting dimensions and measures of food security is based on Sen's entitlement and capabilities framework, as well as the concept of food as a human right (Sen, 1981a; Sen, 1981b, 1993, 1999). Sen argued that food insecurity is not just a lack of food availability; it arises from individuals' inability to access food due to poverty, unequal distribution, and social exclusion. These insights align with our research questions regarding the effectiveness of existing indicators in capturing the complexities of food insecurity and understanding how different socioeconomic factors may influence food access and utilization.

Furthermore, from a human rights and social justice perspective, food represents a moral imperative, guaranteeing equitable and fair access to sustenance for all individuals, regardless of their socio-cultural or economic background (Sen, 1981; Power, 1992). Therefore, our theoretical foundation emphasizes addressing food access and affordability and ensuring relative stability and appropriate utilization by recognizing systemic inequalities and advocating for social and economic rights to mitigate food insecurity.

The selection of food insecurity measures, including the Minimum Dietary Energy Requirement (MDER) and the Food Consumption Score (FCS), highlights individuals' need for proper nutrition and access to a range of nutritious food options. Similarly, by incorporating individuals' experiences and subjective perceptions in assessing food insecurity, as shown by the Household Food Insecurity Access Scale (HFIAS)—which is noted for its effectiveness in capturing the lived experience of hunger and the severity of food insecurity (Piperata et al., 2023; Hedlund et al., 2013; Coates et al., 2007)—our approach enables us to address our research questions regarding the effectiveness of existing indicators, the limitations of traditional metrics, and the integration of complementary indicators for a thorough assessment of food insecurity.

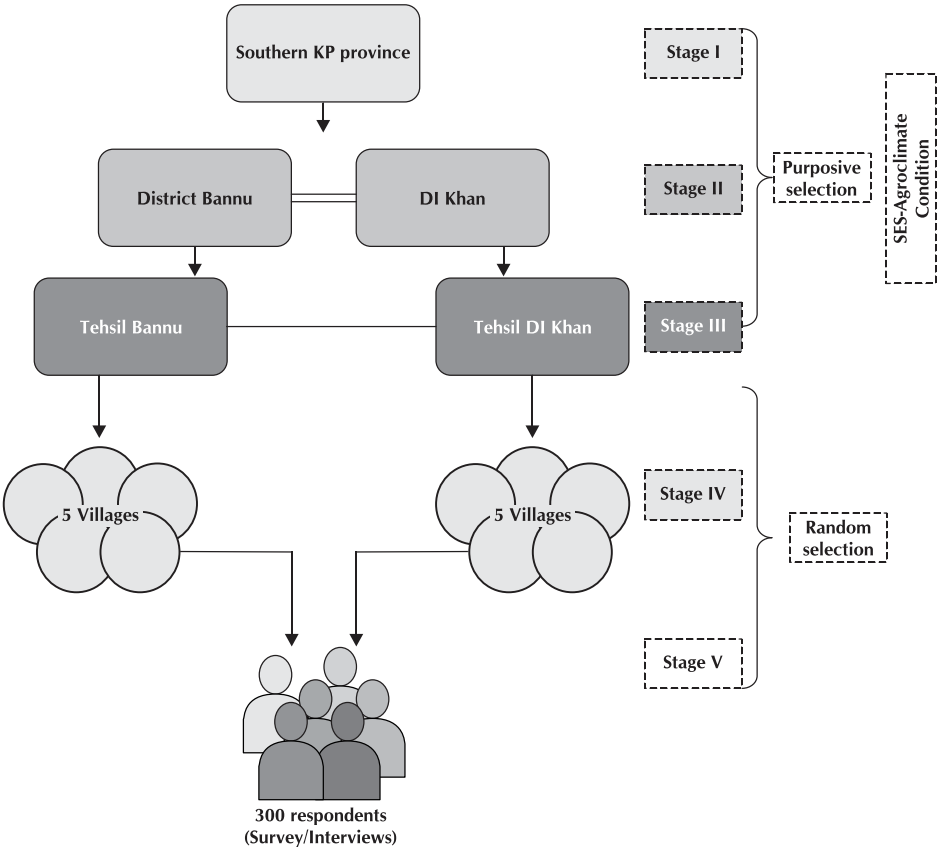
The data used in this article were collected through a survey conducted in southern Khyber Pakhtunkhwa (KP), Pakistan. This region

was selected for its distinct socioeconomic and ecological characteristics, which significantly contribute to the growing issue of food insecurity. It is essential to consider various socioeconomic and cultural factors, such as the impacts of conflict, the existence of internally displaced populations, and gender-related barriers, as these elements may further worsen food insecurity and poverty (Ahmad et al., 2022; Ahmed et al., 2017; Khan et al., 2020). Many districts in this area, including Bannu and DI Khan, are characterized by deprivation that includes limited infrastructure and a lower human development index (UNDP, 2020; Ahmad et al., 2022). Additionally, the presence of internally displaced persons (IDPs) and the ongoing conflicts arising from the war on terror have complicated the food security situation (Ibid).

A multistage sampling approach was used to ensure representative data collection. The first stage involved purposefully selecting the Bannu and Dera Ismail Khan (DI Khan) districts in southern KP province due to their high vulnerability to food insecurity and other disasters. In the second stage, tehsils (sub-districts) were randomly selected within each district to guarantee geographical diversity. This was followed by selecting five villages from each tehsil, totaling ten villages across both districts. Thirty respondents were chosen from households in each village in the final stage. A systematic sampling method was applied to ensure fair representation of individuals within each household and village. The selection interval was determined based on the village size, ensuring that every individual in a household had an equal chance of being included in the study. This method helps reduce bias and provides a more accurate depiction of the overall population.

A total of 300 individuals were interviewed from households selected to balance statistical power and feasibility (Tryfos, 1996). Special attention was given to including vulnerable groups, such as internally displaced persons (IDPs) and smallholder farmers, in the sample to comprehensively understand food security issues (See Figure 1 for a graphical illustration).

Figure 1: Sampling & Data Collection Process



We employed three empirical techniques to assess household food security: the Food Consumption Score (FCS), Minimum Dietary Energy Requirements (MDER), and the Household Food Insecurity Access Scale (HFIAS). These methods offer valuable insights into various aspects of food security, including dietary diversity, energy availability, and food accessibility (Manikas et al., 2023; Maxwell et al., 2014; Mathiassen, 2013). Appendix A of the Supplementary Material provides details on each indicator and computation method. Spearman's rank correlation coefficient (Spearman's rho) and ANOVA were utilized to compare the indices and evaluate their consistency (Maxwell et al., 2014). Spearman's rho is a non-parametric correlation measure suitable for examining relationships between categorical or ordinal variables. Additionally, the scale values of the indices were converted into categorical values using commonly accepted thresholds, enabling a comparative analysis of each

indicator against the others and leading to a comprehensive evaluation of household food security.

4. Results

4.1. Household Characteristics

Table 1 presents households' demographic and socioeconomic characteristics in the two districts. The results show that females head 15% of households in Bannu, while in Dera Ismail Khan, that proportion is higher at 35%. Overall, across both districts, 25% of households are female-headed. The age distribution of household heads is fairly balanced. When looking at the types of households or groups, Bannu has a higher percentage of internally displaced persons (26%) and daily wage earners (72%) compared to Dera Ismail Khan. In Dera Ismail Khan, a larger proportion of households consists of small farmers (21%) and landless tenants (21%) than in Bannu. Approximately 49% of households in both Bannu and Dera Ismail Khan have heads aged between 25 and 40 years. The other age categories—41-50, 51-60, and over 60—show minor variations between the two districts. The educational backgrounds of household heads differ significantly between Bannu and Dera Ismail Khan. In Bannu, 3% of the heads are illiterate, while in Dera Ismail Khan, this percentage is considerably higher at 52%. Across both districts, the majority—72%—are literate. The overall number of family members in households varies between the districts. Households in Bannu generally have larger family sizes, as 88% have six or more family members (46% with six to ten members and 42% with more than ten members). In contrast, only 59% of households in Dera Ismail Khan have six or more family members (51% with six to ten members and 8% with more than ten members). Conversely, Dera Ismail Khan has a larger proportion of smaller households, with 41% having five or fewer members, compared to just 12% in Bannu.

Table 1: Household's Characteristics

Variables	Bannu (%)	Dera Ismail Khan (%)	Total (%)
Vulnerable Groups			
Internally displaced person	26	7	16
Daily Wager	72	51	62
Small Farmer	1	21	11
Landless tenant	1	21	11
Gender of the Head of Household			
Female	15	35	25
Male	85	65	75
Age of Head of Household (years)			
25~40 years	49	49	49
41~ 50	33	19	26
51 ~60	13	17	15
> 60	6	14	10
Head of Household Education			
Illiterate (read and write)	3	52	28
Literate (read and write)	97	48	72
Total family members in the home			
1~2	0	5	3
3 ~5	12	36	24
6 ~10	46	51	48
More than 10	42	8	25
Monthly income PKR of HH Head			
Less than 20,000	25	75	50
21,000 to 40,000	65	19	42
41,000 to 60,000	9	3	6
More than 60,000	1	3	2
Monthly Expenditure			
Less than 20,000	19	25	22
21,000 to 40,000	75	62	68
41,000 to 60,000	5	8	6
More than 60,000	2	5	3
N	150	150	300

Source: Authors' estimates 2023.

In Dera Ismail Khan, the distribution was as follows: 5% had 1 to 2 family members, 36% had 3 to 5 family members, 51% had 6 to 10 family members, and 8% had more than 10 family members. The patterns of monthly income and expenditure varied between the two districts. In both Bannu and Dera Ismail Khan, most households reported a monthly income and expenditure ranging from less than PKR 20,000 to PKR 40,000. These descriptive statistics provide insights into the characteristics of the households included in the study.

5. Assessing the Degree of Association between Food (in)Security Measures

The Spearman's rank correlation coefficients among the three food security measures analyzed demonstrate a degree of association consistent with our initial expectations. All correlations were statistically significant at the $p < 0.01$ level, as indicated in the correlation analysis presented in Table 2.

Table 2: Correlations between Food Security Measures
(Spearman's Rho Estimates)

Metrics	FCS	MDER	HFIAS
FCS	1.00	0.93	0.087
MDER	0.93	1.00	0.079
HFIAS	0.087	0.079	1

Source: Authors' estimates (2023).
Note: At the p 0.01 level, each correlation is significant. The matrix is symmetrical.

The results indicate a strong positive relationship between the Food Consumption Score (FCS) and the Minimum Dietary Energy Requirement (MDER), with a correlation of 0.93. This suggests that FCS and MDER capture similar aspects of food security, particularly in terms of dietary energy sufficiency. However, the correlation between FCS and the Household Food Insecurity Access Scale (HFIAS) is much weaker, at 0.087, implying that FCS may not align closely with HFIAS in assessing food security. The relationship between MDER and HFIAS is also weak, with a correlation of 0.079. These findings indicate that while FCS and MDER are strongly correlated and may effectively capture dietary energy sufficiency, HFIAS provides a different dimension of food security that is not as closely related to the other two measures. This suggests that HFIAS may offer specific insights into food security that the other measures might not fully capture. Our findings support the idea that a comprehensive evaluation should consider the statistical relationships among these metrics, their theoretical foundations, and the aspects of food security they are designed to measure.

Table 3 provides a comparative analysis of the differences in classification among three food security measures used in this research: FCS (Food Consumption Score), MDER (Minimum Dietary Energy Requirement), and HFIAS (Household Food Insecurity Access Scale). The values demonstrate the differences in classifying food insecurity among these measures. For instance, a value of -0.4 between FCS and MDER

indicates that FCS generally classifies households as less food insecure than MDER. Likewise, the comparison between FCS and HFIAS shows a value of -0.4, suggesting that FCS categorizes households as less food insecure than HFIAS.

However, the relationship between MDER and HFIAS, which shows a value of 0.4, indicates a moderate positive correlation. It is important to note that this does not imply that MDER and HFIAS classify households similarly regarding food security status. As Table 4 illustrates, HFIAS classifies a greater proportion of households as food secure (49.30%), while MDER is more conservative, identifying only 12.66% of households as food secure. This discrepancy arises because HFIAS and MDER operate on fundamentally different scales: HFIAS uses a descending scale where lower scores indicate greater food security (0-8 is food secure), whereas MDER employs an ascending scale where higher values represent better food security (>466 is food secure). Therefore, despite the positive correlation, the two measures do not classify food security comparably; instead, they reflect different dimensions and thresholds of food security.

These findings highlight the complexities of utilizing various food security measures, each offering unique insights into different aspects of food security—such as dietary diversity, energy sufficiency, food access, and temporal dimensions. The Food Consumption Score (FCS) emphasizes dietary diversity, while the Minimum Dietary Energy Requirement (MDER) focuses on caloric sufficiency, and the Household Food Insecurity Access Scale (HFIAS) reflects food access and household experiences. Each measure provides valuable yet distinct perspectives, underscoring the need for careful selection based on the specific context and objectives of the study. The following section provides additional details on how these metrics categorize food insecurity across different districts and among vulnerable households, further revealing the diverse and multifaceted nature of food security.

Table 3: The Degree to which Food Insecurity Measures are Classified Differently

FS Indices	FCS	MDER	HFIAS
FCS	0.0	-0.4	-0.4
MDER	0.4	0.0	0.4
HFIAS	0.4	-0.4	0.0

Source: Authors' estimates (2023).

6. Comparative Analysis of District-based Food Insecurity Measures

The varying degrees of difference among the three food insecurity indices underscore the importance of calculating and analyzing the food insecurity status in the study region. Table 4 presents the percentage distribution of households across three categories of food insecurity in two districts, Bannu and Dera Ismail Khan, along with the total number of households surveyed in both districts.

In Bannu, the Food Consumption Score (FCS) indicates that 57.3% of households are severely food insecure, 40% are moderately food insecure, and only 2.7% are classified as food secure. In contrast, Dera Ismail Khan shows significantly lower levels of severe food insecurity, with 7.3% of households categorized as severely insecure, 52% classified as moderately food insecure, and 40.7% deemed food secure.

The Household Food Insecurity Access Scale (HFIAS) in Bannu shows that 2.7% of households are classified as severely food insecure, 12% as moderately food insecure, and a substantial 85.3% as food secure. In comparison, in Dera Ismail Khan, 25.3% of households are severely food insecure, 61.3% are moderately food insecure, and only 13.3% are considered food secure.

The Minimum Dietary Energy Requirement (MDER) findings are particularly striking. In Bannu, 98% of households are severely food insecure, with only 2% classified as food secure. In Dera Ismail Khan, 67.33% of households experience severe food insecurity, 9.3% are moderately food insecure, and 23.3% are classified as food secure.

Table 4: District Comparison of Food Security Status Based on FCS, HFAIS, and MEDR

FS Metric/District	Food Security Status (Percent)		
FCS *Cut-off value*	**Severe food insecure** (FCS<90)	**Moderate FIS** (FCS 91-180)	**Acceptable food secure** (FCS>180)
Bannu	57.30	40.00	2.70
Dera Ismail Khan	7.30	52.00	40.70
Total	32.20	46.00	21.70
HFAIS *Cut-off value*	**Severe food insecure** (HFIAS>16)	**Moderate FIS** (HFAIS 9 to 16)	**Acceptable food secure** (HFIAS 0-8)
Bannu	2.70	12.00	85.30
Dera Ismail Khan	25.30	61.30	13.30
Total	14.00	36.70	49.30

FS Metric/District	Food Security Status (Percent)		
MDER *Cut-off value*	**Severe food insecure** (MDER<426)	**Moderate FIS** (MDER 426-446)	**Acceptable food secure** (MDER>446)
Bannu	98	0	2
Dera Ismail Khan	67.33	9.33	23.33
Total	82.6	4.66	12.66

Source: Authors' calculations, 2023.

Bannu consistently shows higher severe food insecurity levels than Dera Ismail Khan, especially in the MDER measure. In contrast, Dera Ismail Khan exhibits more moderate levels of food insecurity and a larger proportion of food-secure households in the FCS and HFIAS measures. These differences underscore the importance of selecting appropriate food security metrics and considering their implications for policy and intervention strategies.

The ANOVA results in Table 5 indicate significant differences in food security status among districts based on the three food security measures (MDER, FCS, and HFIAS), with all measures showing significant F values. This suggests that food security status varies significantly across districts, indicating disparities in meeting the minimum dietary energy intake and variations in the quantity and quality of food consumed. Additionally, the HFIAS measure reveals variations in experiences of hunger and the accessibility and affordability of food. These results highlight the diversity of food security status among districts, suggesting that customized interventions and policies may be necessary to address their specific food security challenges. The differences identified through these assessment tools emphasize the need for targeted measures to address the specific factors contributing to food insecurity in each district.

Table 5: ANOVA Results: Comparison of Food Security Measures across Districts

Metrics	Df	Sum Sq	Mean Sq	F-value	Pr(>F)
MDER	1	1773005	1773005	76.14	0.000002***
	298	6939517	23287		
FCS	1	566197	566197	129.1	0.00002***
	298	1306625	4385		
HFIAS	1	531	530.7	11.85	0.000658***
	298	13342	44.8		

Source: Source: Authors' calculations, 2023.
Note: Significant level: *** 0, ** 0.001, * 0.01.

7. Household Food Insecurity Based on FCS, HFIAS, and MDER: Vulnerable Groups Comparison

Table 6 presents a comparative analysis of food security status among various household categories, utilizing the Food Consumption Score (FCS), the Household Food Insecurity Access Scale (HFIAS), and the Minimum Dietary Energy Intake Requirement (MDER). The results reveal significant discrepancies among the measures, reflecting the complexities involved in assessing food insecurity. For instance, the Daily Wage households show a stark contrast: while 69% are classified as severely food insecure and 28.6% as moderately food insecure according to the FCS, the HFIAS indicates that 78.6% of these households are food secure, with only 9.5% experiencing severe food insecurity. This discrepancy suggests that the HFIAS may underestimate the severity of food access issues reported by the FCS and MDER. For IDP households, the FCS categorizes 36.9% as severely food insecure and 47.7% as moderately food insecure.

In comparison, the HFIAS presents a more favorable picture, with 56.9% classified as food secure and only 7.7% facing severe food insecurity. This difference may stem from the HFIAS's focus on food access and hunger experiences, which could diverge from the consumption and energy measures of the FCS and MDER. Small Farmers and Landless Tenants show mixed results: the FCS indicates that only 7.5% are severely food insecure, with a higher proportion (37.7%) being food secure. However, the HFIAS reports that 34.0% are severely food insecure and only 5.7% are food secure. MDER results also indicate significant food insecurity (69.8%), suggesting that these households continue to struggle with energy sufficiency despite better food security indicators from the FCS. According to the FCS, female-headed households display varied results: 21.3% are severely food insecure, and 46.7% are moderately food insecure.

In contrast, the HFIAS shows a lower severe food insecurity rate (13.3%) and higher food security (50.7%). However, MDER data highlight that 80% of these households experience food insecurity. These inconsistencies emphasize the need for a multidimensional approach to food security assessments that reflect each measure's distinct aspects, including both subjective and objective elements—dietary diversity, energy sufficiency, and food access. Addressing these discrepancies is crucial for developing targeted interventions and policies that alleviate food insecurity across diverse household categories.

Table 6: Group-wise Comparison of Food Security Status based on FCS, HFAIS, and MEDR (in Percent)

FCS *Cut-off value*	**Severe food insecure** (FCS<90)	**Moderate FIS** (FCS 91-180)	**Acceptable food secure** (FCS>180)
Daily Wager	69.00	28.60	2.40
IDPs	36.90	47.70	15.40
Small Farmer and landless tenants	7.50	54.70	37.70
Female head-HHs	21.30	46.70	32.00
Total	32.30	46.00	21.70
HFIAS *Cut-off value*	**Severe food insecure** (HFIAS>16)	**Moderate FIS** (HFAIS 9 to 16)	**Acceptable food secure** (HFIAS 0-8)
Daily Wager	9.50	11.90	78.60
IDPs	7.70	35.40	56.90
Small Farmer and landless tenants	34.00	60.40	5.70
Female head-HHs	13.30	36.00	50.70
Total	14.00	36.70	49.30
MDER	**Food Insecure**		**Food Secure**
Daily Wager	92.9		7.10
IDPs	86.2		13.80
Small Farmer and landless tenants	69.8		30.20
Female head-HHs	80.0		20.00
Total	82.7		17.30

Source: Authors' calculations, 2023.

Smallholder farmers and landless tenants face significant challenges due to limited access to land and resources, impacting their ability to produce enough food and earn sufficient income to purchase food and other essentials. This is reflected in their higher rates of food insecurity across various measures. Internally Displaced Persons (IDPs), displaced by conflict or natural disasters, also experience notable food insecurity; however, the HFIAS indicates a relatively better situation for them compared to the FCS and MDER measures. This discrepancy highlights the need for more targeted assistance. Previous studies by Munoz-Mora (2016) and D'Souza and Jolliffe (2013) support these findings, demonstrating that IDPs often struggle with food access and remain undernourished. Though female-headed households face gender discrimination and have limited access to education and resources, their results show a mixed picture: they show relatively higher food security levels according to FCS and MDER but still encounter significant challenges. Daily wage laborers, with their inconsistent and often inadequate income, experience severe food insecurity according to FCS and MDER, while appearing more secure in the HFIAS measure. These inconsistencies across measures suggest that

food security assessments must consider multiple dimensions to accurately reflect the varying experiences of different vulnerable groups.

Focusing on the MDER results, we observe that among various household categories, the Daily Wager category has the highest percentage of food insecurity, with 92.9% of households affected. This can be attributed to the nature of their employment, which is often unstable or unreliable, leading to fluctuating income and challenges in accessing food. The IDP category also reveals a significant percentage of food insecurity, with 86.2% of households confronting this issue. This is not surprising, as IDPs are frequently displaced due to conflict or other disasters and may have limited access to resources and support systems.

The ANOVA results in Table 7 reveal significant differences in food security parameters among the four categories (IDP, daily wage earners, smallholder farmers, landless tenants, and female-headed households). This underscores the importance of considering specific socioeconomic or vulnerable groups when evaluating food security. The notable differences in MDER and FCS reflect varying levels of dietary adequacy and food consumption across these categories. Meanwhile, the significance of HFIAS highlights differences in the experiences or stress related to food insecurity. Understanding these variations can aid in developing targeted interventions and policies to address each category's unique food security challenges.

Table 7: ANOVA Results: Comparison of Food Security Measures across vulnerable groups

Metrics	Df	Sum Sq	Mean Sq	F-value	Pr(>F)
MDER	3	672483	224161	8.253	2.73e-05 ***
	296	8040039	27162		
FCS	3	255956	85319	15.62	1.86e-09 ***
	296	1616866	5462		
HFIAS	3	417	139.11	3.06	0.0285 *
	296	13455	45.46		

Source: Authors' calculations, 2023.
Note: Significant level: *** 0.001, ** 0.01, * 0.05.

Overall, Table 7 shows significant levels of food insecurity across all types of households, with the highest rates among small farmers and landless tenants. This data can guide policy interventions and resource allocation targeted at addressing food insecurity in vulnerable populations.

8. Discussion

The comparative analysis of food security metrics highlights the importance of understanding their different classifications. While these metrics may show strong correlations in continuous quantitative analysis, categorical comparisons reveal significant discrepancies. This study's findings confirm that various food security metrics, specifically FCS, HFIAS, and MDER, show variations in their classifications of food insecurity (Maxwell et al., 2014; Alinovi et al., 2010). The FCS, which assesses food consumption patterns, classifies a smaller percentage of households as food secure compared to HFIAS. Specifically, 21.7% of households are identified as food secure by FCS. In contrast, 49.3% of households are considered food secure by HFIAS, and only 12.6% are categorized as food insecure by FCS, indicating that FCS identifies a higher proportion of households as food insecure. This trend is observed in both districts; in Bannu, for example, only 2.7% of households are food secure, according to FCS, compared to 85.3% according to HFIAS.

Similarly, in Dera Ismail Khan, 40.7% of households are classified as food secure according to the Food Consumption Score (FCS), while only 13.3% are deemed secure by the Household Food Insecurity Access Scale (HFIAS). However, the Multidimensional Empowerment and Resilience (MDER) identifies a significantly larger percentage of households as severely food insecure compared to either HFIAS or FCS. In Bannu, 98% of households are classified as severely food insecure by MDER, in contrast to just 2.7% by HFIAS. In Dera Ismail Khan, MDER identifies 67.3% of households as severely food insecure, compared to 25.3% by HFIAS (see Table 4). These discrepancies highlight the methodological differences among the metrics, with FCS focusing on food consumption and MDER evaluating dietary energy intake; both impose a stricter threshold for food insecurity than HFIAS, which considers psychological distress and food preferences.

Significant variations arise when comparing various food security measures across four vulnerable groups—daily wage earners, internally displaced persons (IDPs), small farmers, and female-headed households—based on the metrics used. The Food Consumption Score (FCS) identifies daily wage earners as the most food-insecure group, while small farmers and landless tenants demonstrate the highest level of food security. However, the Household Food Insecurity Access Scale (HFIAS) shows a greater percentage of food-secure households among most groups, particularly among daily wage earners and IDPs. The Minimum Dietary

Energy Requirements (MDER) results reveal severe food insecurity among daily wage earners and IDPs, although small farmers and landless tenants report the highest food security levels. These differences highlight the methodological variations and challenges in accurately assessing food insecurity among diverse populations (see Table 6).

These findings align with observations in the existing literature that emphasize the complexities of accurately measuring food security among various groups (Manikas et al., 2023; FAO/WFP/IFAD, 2013; Coates, 2013; Cafiero, 2012; Mullainathan et al., 2001). The imperfect correlation among these metrics may lead to misclassification and exclusion errors, posing challenges for effective responses and optimal resource allocation (Maxwell et al., 2014; Coates et al., 2007). This underscores the need to carefully consider the selection of measurement tools and their implications for policy and intervention strategies, especially when addressing differing levels of food insecurity among distinct populations.

Several factors may explain discrepancies in categorization. For example, the metrics address various aspects of food security; the Food Consumption Score (FCS) primarily focuses on food consumption, while the Household Food Insecurity Access Scale (HFIAS) includes additional factors such as psychological anxiety and food preferences (Coates, 2013; Headey & Ecker, 2013; De Haen et al., 2011). The Minimum Dietary Energy Requirement (MDER), on the other hand, considers the minimum dietary energy intake, or calorie intake, by examining the quantity of food available to individuals; however, it does not account for nutritional quality or accessibility (Faber et al., 2009; Smith et al., 2006; Coates et al., 2007). The different dimensions assessed by these metrics contribute to their varying prevalence estimates (Maxwell et al., 2014; Manikas et al., 2023). Therefore, relying solely on one metric may overlook significant dimensions of food insecurity and limit the effectiveness of interventions. Operational considerations also play a role in the discrepancies between the metrics (Coates, 2013; Headey & Ecker, 2013). Indicators are often used to identify households in need of immediate intervention or support, typically focusing on moderate to severe levels of food insecurity (Coates, 2013). The HFIAS, for instance, captures only the most severe behaviors, resulting in lower prevalence estimates compared to other metrics (Mullainathan et al., 2001). However, the severity thresholds of these metrics may not cover the full spectrum of food insecurity, especially across different contexts, socioeconomic conditions, and demographics of respondents or households at various times (Leroy et al., 2015; D'Souza et al., 2015; Hedlund et al., 2013; De Haen et al., 2011; Deitchler et al., 2010).

Experiential measures, which fall under self-reported categories, enable individuals to define what they consider to be "adequate" consumption based on their perspectives rather than relying on externally established criteria (Headey & Ecker, 2013; Hedlund et al., 2013; Deitchler et al., 2010). These self-reported measures can be influenced by socioeconomic status and gender (Headey & Ecker, 2013; Hedlund et al., 2013). A household with higher socioeconomic status may have different dietary norms compared to those with lower socioeconomic status. Furthermore, gender differences can affect individuals' perceptions of what constitutes a sufficient food bundle, leading to variations in responses to food insecurity inquiries between men and women (Aziz et al., 2022; Broussard, 2019; Hedlund et al., 2013; Croson & Gneezy, 2009; Coates et al., 2007). Moreover, cross-national investigations consistently show that households led by females experience higher levels of food insecurity than those led by males (Aziz et al., 2022; Broussard, 2019; Jung et al., 2017; Atuoye et al., 2017; Matheson & McIntyre, 2014). These differing interpretations of the measurement scale may also impact its precision in classifying households' food security status (Deitchler et al., 2010; Hedlund et al., 2013).

In Khyber Pakhtunkhwa, many vulnerable groups—including internally displaced persons (IDPs), women, small farmers, and tenants—face significant obstacles in accessing food. These obstacles result from factors such as displacement, limited land ownership, gender discrimination, and economic marginalization. The ongoing conflict and violent events have adverse long-term effects, in addition to short-term impacts, on food security and the health of these individuals (Brown, 2018; Parlow, 2012), leading to decreases in agricultural production (Munoz-Mora, 2016) and shifts in consumption patterns among households, particularly for IDPs and refugees, resulting in varying outcomes across different metrics. IDPs often experience restricted mobility and limited access to markets, which complicates their ability to secure adequate food supplies. Women, who are typically responsible for household food provisioning, face hurdles regarding land ownership and limited participation in decision-making processes, hindering their access to food and essential resources, and potentially increasing their fears and anxieties. Small farmers and landless tenants experience lower food insecurity rates than the aforementioned groups. However, this rate remains relatively high, with 69.8% of households facing food insecurity. Contributing factors include limited access to credit and a lack of technical knowledge, which may impede their ability to produce enough food to meet their needs (Ahmed et al., 2017).

Similarly, the flexibility inherent in metric selection is crucial, particularly when adapting measurements to specific applications and assessing their capacity to address various dimensions of food security. Establishing cut-off thresholds and creating categorical classifications also influence variations in prevalence assessments (Coates et al., 2007; Maxwell et al., 2008). Assigning threshold values to continuous quantitative measures is subjective, and generalized categories may not apply universally (Jones et al., 2013; Coates et al., 2007). Contextualizing metrics and setting location-specific criteria are vital for calibrating cut-off points to ensure accuracy in estimations (Maxwell & Caldwell, 2008). Nonetheless, the need for quick and easily implementable indicators may impede achieving this contextual accuracy.

Although this study does not propose a definitive "best" performance index due to the lack of a gold standard for comparison, the analysis highlights the strengths and weaknesses of each measure in capturing specific aspects of food security. Utilizing multiple indicators can provide a more comprehensive understanding of the food security landscape and reduce the risk of misclassification (World Food Program, 2012). When resources permit, employing a variety of indicators or a complementary approach can help identify the widest range of food security needs. These variations in classification have significant implications for measurement, policy, and practice. Policy decisions and resource allocation based on different metrics can yield contrasting outcomes. The choice of metrics should be context-specific, considering the intervention's timing, purpose, and nature. Incorporating individual experiences and subjective perceptions into the assessment of food insecurity (e.g., HFIAS) allows us to evaluate the effectiveness of current indicators, the limitations of traditional metrics, and the integration of complementary measures for a comprehensive evaluation of food insecurity (Piperata et al., 2023; Hedlund et al., 2013; Coates et al., 2007). Likewise, metrics that provide a more thorough assessment, such as HFIAS, may be more suitable during heightened food insecurity or emergencies.

Conversely, in relief-focused interventions targeting the most severe cases, metrics like the Minimum Dietary Diversity Score (MDER), which evaluates dietary diversity, can offer valuable insights. The varying prevalence estimates also create challenges for analyses that rely on multiple indicators. Researchers and policymakers need to carefully interpret and reconcile these different estimates. Furthermore, selecting a single metric for food security assessments should consider the specific

context's objectives and priorities, along with the characteristics of the respondents.

9. Conclusion and Policy Recommendations

Guided by Sen's entitlement framework and recognizing food as a human right, our study provides valuable insights into the complex nature of food insecurity and the importance of selecting appropriate measures to grasp its nuances fully. Our research uncovers significant disparities in the prevalence of food insecurity among various socioeconomic groups and vulnerable individuals by utilizing three distinct measures. Specifically, our findings indicate that the Food Consumption Score (FCS) tends to classify fewer households as food secure compared to the Household Food Insecurity Access Scale (HFIAS), while HFIAS categorizes more households as food insecure than the Minimum Dietary Energy Requirements (MDER). Moreover, the prevalence estimates derived from each metric differ notably, especially among vulnerable groups such as internally displaced persons (IDPs), women, and small farmers.

Given these findings, it is recommended to address the challenges highlighted by disparities in food security metrics, socioeconomic factors, and gender. Policymakers should consider integrating various food security metrics, such as the Food Consumption Score (FCS), Household Food Insecurity Access Scale (HFIAS), and Minimum Dietary Energy Requirement (MDER), to gain a comprehensive understanding of the prevalence of food insecurity. This approach encompasses the diverse dimensions of food insecurity and ensures more accurate assessments tailored to the specific context. Additionally, acknowledging the contextual variations in food insecurity, policymakers should implement context-specific strategies that reflect the socioeconomic and demographic characteristics of the target population. Furthermore, efforts must be made to strengthen social protection programs to assist vulnerable populations affected by food insecurity, including targeted cash transfer programs, food assistance initiatives, and livelihood support to enhance household food security in these regions.

Furthermore, there is a need for greater policy coherence and coordination across various sectors, including agriculture, health, education, and social welfare, to effectively address the root causes of food insecurity. Collaborative actions between sectors can enhance the implementation of comprehensive strategies that promote food security and improve community well-being. Additionally, both the government

and the non-profit sector should continue their investment in research and data collection efforts to monitor food security trends, identify emerging challenges, and evaluate the effectiveness of interventions over time. In addition to quantitative studies, regular assessments and qualitative research can provide valuable insights into the evolving aspects of food insecurity, intra-group dynamics, and household interactions, which can inform evidence-based policy decision-making.

10. Limitations and Future Research Directions

Although our study contributes to understanding food insecurity among vulnerable groups through a thorough, multidimensional assessment approach, we recognize its limitations. For instance, the geographic focus and limited sample size may restrict the applicability of our conclusions to other areas. While our research offers valuable insights into food insecurity for these vulnerable individuals and groups, it may only partially capture aspects within households (e.g., intra-household dynamics, women, children, etc.). Additionally, given the study's framework and objectives, this research does not establish causal links between variables. Consequently, to address these limitations, further research should conduct both quantitative and qualitative long-term investigations across varying contexts and levels (for example, within households and groups). This would enhance our understanding of the dynamics of food insecurity. It is also essential to explore causality and various factors such as policy, institutional, economic, environmental, and social exclusion that may affect the food insecurity status of these individuals. Improving measurement accuracy and providing guidance for effective policies and practices should prioritize creating and validating comprehensive frameworks that integrate diverse indicators.

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Supplementary Materials

Appendix A

Estimating Food Insecurity

Household Food Insecurity Access Scale (HFIAS)

HFIAS employs the definition of food security according to USAID, which states that food security is achieved when individuals have adequate physical and economic access to food that meets their dietary requirements for a productive and healthy life. In this research, we asked a series of inquiries, to evaluate the level of food insecurity within households, ranging from acceptable food security to severe food insecurity (0-24). This methodology has been validated and implemented in diverse national contexts. The data collected from the survey were used to gauge the prevalence of food insecurity (access) and monitor changes in the food security status of a population over time (Becquey et al. 2010; Knueppel et al., 2010; Coates et al., 2007; Swindale, & Bilinsky, 2006).

Food Consumption Score (FCS)

The FCS was computed by inquiring about the frequency of consumption of various food groups over the past seven days among households. These groups include main staples, pulses, vegetables, fruit, meat and fish, milk, sugar, oil, and condiments. Assigning weights to each consumption frequency based on their nutritional significance, the FCS is obtained by summing up the weighted values i.e. $FCS = \sum w_i x_i$. Here, wi represents the weight of food group i, and xi denotes the frequency of consumption within the household, representing the number of days the food group was consumed in the previous seven days. Subsequently, households were categorized as severe, moderate, or acceptable food consumption level (food secure), utilizing predefined thresholds. However, these thresholds can be adjusted to align with specific consumption patterns observed in the country in question (WFP, 2008; Coates et al., 2007; Swindale & Bilinsky, 2006)

Minimum Dietary Energy Intake Requirement:

To assess the energy intake required by individuals in a household, we also used Minimum Dietary Energy Requirement (MDER). The MDER can be calculated based on the age, sex, and activity level of individuals and is used to determine the prevalence of undernourishment in a population

(FAO, 2017). The steps below are used to determine DEC (tkcal) at the households' level for the categories that have available food supplies available. This analytical framework has been taken from Ishaq, Khalid, and Ahmad (2018)

Step 1: Convert Food Measurements into Gram

To convert food amounts from kilograms to grams, multiply the kilograms by 1000, the gram by 1, and so on. For amounts stated in liters, firstly change them into milliliters, and afterward utilize their densities. Further, these have converted them into grams by using the method below.

$$Q_{ih_s} = Q_{ih_s}\,(mls) * \left(\frac{g_m}{m_l}\right) \tag{1}$$

Where $'i'$ depicts a food item with a reliable density coefficient, $'h_i'$ signifies households and $'g_m'$ stands for grams while $'m_l'$ for milliliters.

Step 2: Modify Food Proportions to Account for Non-Edible or Refutable Portions

Both non-edibles and edibles food quantities purchased by households over the baseline period (fourteen days or thirty days) are mentioned in Survey. For solely edible portions, there are FCT that contains kcal. Therefore, where necessary, the preceding formula is employed to convert quantities to EP.

$$EQ_{ih_s} = Q_{ih_s} * \left(1 - \frac{R_i}{100}\right) \tag{2}$$

Here, $'EQ'_{ih_s}$ denotes edible quantity which includes the amount of each food item that the household purchased or consumed. The $'R_i'$ provides a percentage of the food components for non-edible grams. The edible component of food is displayed by $\left(1 - \frac{R_i}{100}\right)$, which is also known as the edible coefficient.

Step 3: Calculating each Household's Estimated Total Daily Calories (Kcal)

The following method is used to determine how many kcal are contained within food components for which appropriate EP and calorie quantities are available.

$$tkcal_{g_m h_s} = \Sigma_{i=1}^{g_m} \left(\frac{EQ_i * kcal}{t}\right) \tag{3}$$

Where $'g_m'$ is the category of food commodities that households purchase or consume, together with information on their amount and cost. $'EQ_i'$ denotes the amount of edible food, while Kcal denotes the commodity calorie content. In equation (12), any DEC per $'i_{th}'$ food intake is represented by $(E_{Q_i} * \text{kcal})$ that is subsequently multiplied with $'t'$ to get daily average DEC. The reference interval of the food commodity purchased/consumed within a household is shown herein in the letter with $'t'$. Every food category in $'g_m'$ group's everyday calories have been added up to determine total daily DEC (tkcal) intake at household levels.

Considering the Age-Sex Structure of Households

The Survey primarily provides statistics regarding food consumption at household levels. Nutrition energy needs to rely on the age and sex of the person. As a result, they alter between households owing to differences in their structure and age-sex structure. The adult equivalent size of every household gets determined using the Equation below to accommodate for such variations. The adult equivalent factor or size (AE_i) for the individual household person is derived from the equivalency scale found in the Pakistan Poverty Reduction Strategy Paper (PRSP-I, 2003), which is repeated in the Table. The Equation below provides its adult equivalent size as the average of each adult equivalence number for each member of a household. While adjusting the age-sex disparities between families, enables comparability of DEC amongst households.

Additionally, likely, houses with food security will also include people who are food insecure and vice versa if food is never distributed within households according to individual needs. Since mainly household-level records are available in Surveys, the analysis in current research is done at households under the assumption that food is divided fairly amongst family members.

$$AE_{h_S} = \Sigma_{i=1}^{h_s size} AE_i \quad (4)$$

Table 2: Adult Equivalent Scale for MDER

Age Brackets	Daily Energy Requirement Per Person (kcal/day)	Equivalent Factor
Male		
< 1	710	0.275
1-9	1358	0.493
10-17	2952	1.032
18+	2819	1.016
Female		
< 1	708	0.242
1-9	1050	0.834
10-17	2326	0.821
18+	2275	0.864
National Average	2350	1

Source: PRSP-I (2003) & (Ishaq, Khaliq & Ahmad, 2018).

Daily Average Dietary Energy Consumption for each Adult Equivalent Computation

The number of calories acquired from procedures we and up is divided by the adult equivalent size of the household in Equation 8 below to produce the overall every day for each adult equivalent DEC ($\mathrm{DAEtkcal}_{h_s}$) at the household scale.

$$\mathrm{DAEtkcal}_{h_s} = \frac{\mathrm{tkcal}_{h_s}}{\mathrm{AE}_{h_s}} \tag{4}$$

Household levels Food Security Status

Based on the above, the minimum dietary energy demand for each household level is examined by comparing if they have been food secure or not (MDER). The MDER recommended by FAO (2017) for such investigation is employed after being translated into adult equivalents. Here below, it is evident from equation 6, which compares the food security in households that one indicates food security while zero indicates food insecurity.

$$\mathrm{FI}_{h_s} = \begin{cases} 1;\ \text{When } \mathrm{DAEtkcal}_{h_s} > \mathrm{MDER} \\ 0;\ \text{when } \mathrm{DAEtkcal}_{h_s} < \mathrm{MDER} \end{cases} \tag{5}$$

In this equation, FI(hs) is the food insecurity status of the household, which is assigned a value of either 0 or 1. The value of 0 indicates that the household is food insecure because their daily average dietary energy

consumption for each adult equivalent (DAEtkcal(hs)) is less than the Minimum Dietary Energy Requirement (MDER), while the value of 1 indicates that the household is food secure because their DAEtkcal(hs) is greater than or equal to MDER.

Minimum Dietary Energy Requirement (MDER)

The MDER, as defined by FAO (2008), seems to be the bare minimum of energy that a person needs to lead a healthy lifestyle, sustain a weight that seems to be suitable for their height, and engage in moderate physical activity. The weighted mean of the MDERs for the various sex and age categories inside the population constitutes the MDER for the total population. Whenever a household is incapable of satisfying its MDER and unable to maintain health, the body weight needed for mild exercise, or the position of the body when at rest. Therefore, when a person's DEC falls below MDER, health problems arise from calorie deprivation. As a result, this insufficiency also contributes to low productivity levels including mental and physical damage (Bagriansky, 2017).

$$\text{MDER} = \left(\frac{1772*\text{N}}{\text{AE}_{2022}}\right) \tag{6}$$

Hence, "N" stands for the overall sample size and AE_{2022} indicates the sum of the adult equivalent size of households from the sample collected. Therefore, in equation 8, this research utilizes 433.55 kcal/day/adult equivalent for MDER to identify households that are eating fewer calories (food insecure) than MDER.

Table 3: Minimum Dietary Energy Requirement (MDER)

Sn.	Name of Food	Description	Food Energy (Kcal) in 100g
1	Wheat flour (Kg)	NA	357
4	Maize flour (Kg)	NA	276
5	Rice (Kg)	NA	360
6	Butter (Kg)	NA	721
7	Milk (Ltr)	NA	105
8	Paneer (Kg)	NA	35
9	Ghee (Kg)	NA	900
10	Eggs (Num)	Number*17	155
11	Meat (Kg)		123
12	Fish (Kg)		101
13	Chicken (Kg)		187
14	Fruits (Kg)	Apple, Apricot, Banana ripe, Grapes, Guava, Jaman, Lemon, Melon water, Mandarin, Orange Sweet, Peach, Pear, Pomegranate, Phalsa,	57+96+74+73+82+30+64+23 +44+43+47+58+66+43+78= 878/15=58.53
15	Onion (Kg)		44
16	Potato (Kg)		21
17	Vegetables (Kg)	Bottle guard, bitter guard, Bringal, Cauliflower, Cucumber, Cabbage, Ladyfinger, Pepper sweet, Spanish,	15+19+26+27+16+23+35+25 +27+21+37+121+53+44+83+ 23+26=621/17=36.53
18	Sugar (Kg)		390
19	Gur (Kg)		310
20	Any Other		

Sources: Food Composition Table (AIOU, 2001), (GoP, WFP, 2016a) Note: 100g = 0.1 Kg, Calories= quantity*Calories in 100g*10, Liters= Quantity*cal (100g)*10, Grams= Quanity*Cal in 100g

Table 3 presents the Minimum Dietary Energy Requirement (MDER) for different food items, along with their corresponding energy values in kcal per 100g. The table also provides the energy values for different quantities of other food items such as liters of milk, grams of sugar, and kilograms of vegetables. The food energy values presented in Table 3 are used to estimate the energy intake of different households and compare it with the MDER to determine their food security status.

Appendix B: Degree of Difference in Classification of MDER & HFIAS

print(result_table_mder_hfias)

Acceptable food secure	Moderate FIS	Severe food insecure	
Severe food insecure	0.0000000	-0.4000000	4.0000000
Moderate FIS	-0.1538462	0.0000000	7.5384615
Acceptable food secure	-0.9918033	-0.9836066	-0.9098361

Degree of Difference in Classification of FCS & MDER

print(result_table_fcs_mder)

Severe food insecure	Moderate FIS	Acceptable food secure	
Severe food insecure	-0.8790323	-0.9274194	-0.3951613
Moderate FIS	0.5714286	0.8571429	14.8571429
Acceptable food secure	-0.9473684	-0.8947368	-0.4210526

Degree of Difference in Classification of HFIAS & FCS

print(result_table_fcs_hfias)

Acceptable food secure	Moderate FIS	Severe food insecure	
Severe food insecure	0.0000000	-0.4000000	4.0000000
Moderate FIS	-0.1538462	0.0000000	7.5384615
Acceptable food secure	-0.9918033	-0.9836066	-0.9098361