Climate Change and Food Security Across Agro-Ecological Zones

Evidence from Rural Households of Pakistan

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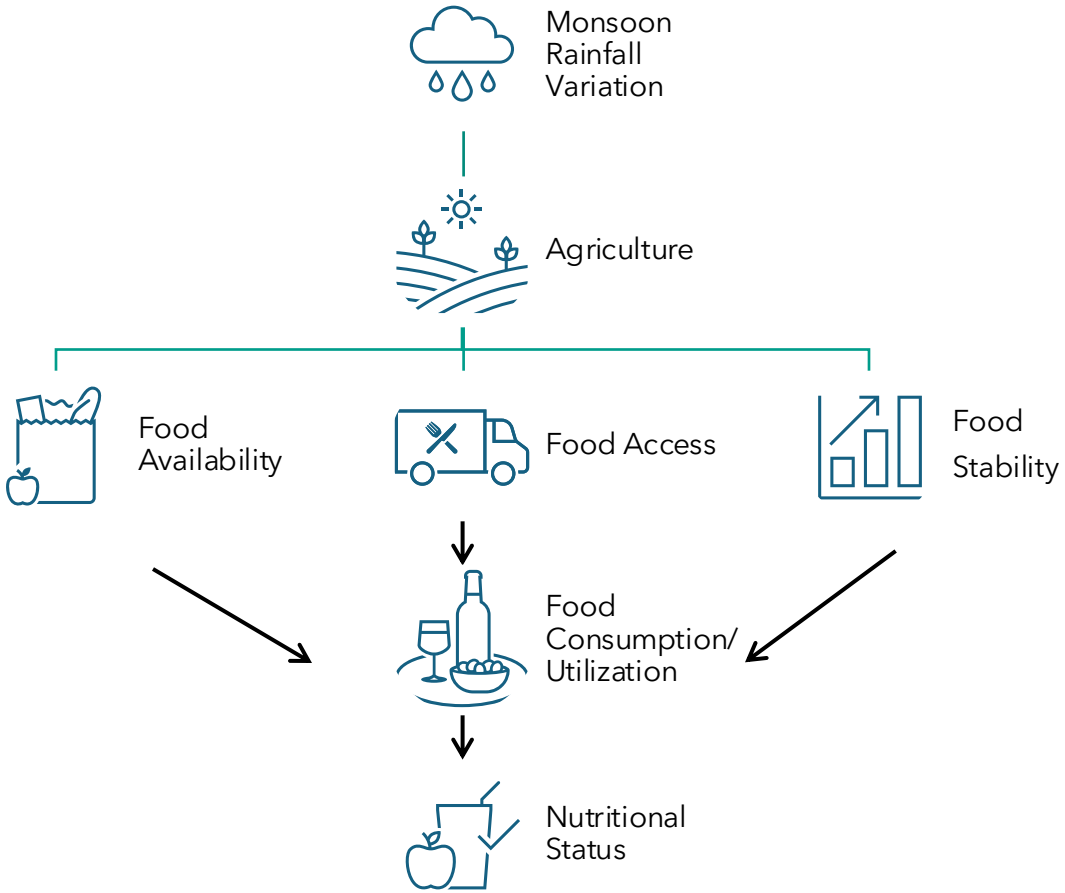
Introduction

Rationale

- Pakistan is 5th most vulnerable nation to the **climate change** (Global Climate Risk Index).
- More than two-third of Pakistan's area lie in semi-arid to arid climate zone (Nabeel & Athar, 2017).
- Pakistan has a diverse landscape and is divided into **10 agro-ecological zones**, each with its own peculiar environment and varied agriculture output (PARC, 2019).
- Pakistan's rain-fed **agriculture** receives more than 60 percent of annual rainfall during monsoon (wet) season (Faisal et al., 2013).
- There is evidence of inadequate nutritional intake and low dietary diversity, especially in rural households – around 37 percent of the population i.e., 13 percent of the households, is facing the menace of **food insecurity** (UNICEF National Nutritional Survey, 2018).

Conceptual Framework



Based on World Food Submit (1996), World Bank Group (2023) and empirical evidence from literature.

- Studies indicate that climate-induced rainfall variability affects **crop patterns and yields** (Kogo et al., 2020; Kurukulasuriya et al., 2006).
- Rainfall variability affects the **nutritional quality** of diets by altering both macronutrient and micronutrient proportions in food (FAO et al., 2022; Guilia et al., 2020).
- At the World Food Submit of 1996, four key dimensions of **food security** were identified: *physical availability of food*, *economic and physical access to food*, *food utilisation*, and *stability* of these three factors over time (World Bank Group, 2023).
- In the absence of these four dimensions, food insecurity prevails resulting in **nutritional deficiencies** (Kinda & Badolo, 2019; Ludwig, 2018; Derbile et al., 2016).

Research Objectives

- To measure monsoon rainfall variability (proxy for climate change) across agro-ecological zones of Pakistan.
- To investigate impact of monsoon rainfall variation on food security status in rural households across agro-ecological zones of Pakistan.
- To analyze the impact of monsoon rainfall variation on food security in agricultural households with livelihood diversification.

Data & Methodology

Data Sources

- Climate Data:
  - *Total Surface Precipitation* (MERRA-2 Reanalysis/ mm/day with a spatial resolution of 0.5x0.625) from **NASA Giovanni Earth Data**. Since this study focuses on the monsoon season in Pakistan, monthly data for *July*, *August*, and *September* from **1981** to **2019** was considered. Eventually, the data was used to calculate monsoon rainfall variability for 2013, 2015, and 2018, relative to 30-year historic averages, respectively.
- Household Data:
  - 3 rounds of Pakistan Social & Living Standard Measurement Survey/Household Integrated Economic Survey (PSLM/HIES) **2013-14**, **2015-16**, and **2018-19**.
    - **HIES 2013-14**: 17,989 households (**11,755** rural households)
    - **HIES 2015-16**: 24,238 households (**8,083** rural households)
    - **HIES 2018-19**: 24,809 households (**15,936** rural households)
    - A *stratified two-stage sample* design is adopted for these surveys.

Climate Variation Indicators

Rainfall Variation (z-score)

$$z = \frac{x - \mu}{\sigma}$$

z = standard score
x = observed value
μ = 30-year historic mean
σ = 30-year historic standard deviation

Lowest: $z < -1.5$
Lower: $-1.5 < z < -1$
Moderate: $-1 < z < 1$
Higher: $1 < z < 1.5$
Highest: $z > 1.5$

Coefficient of Variation

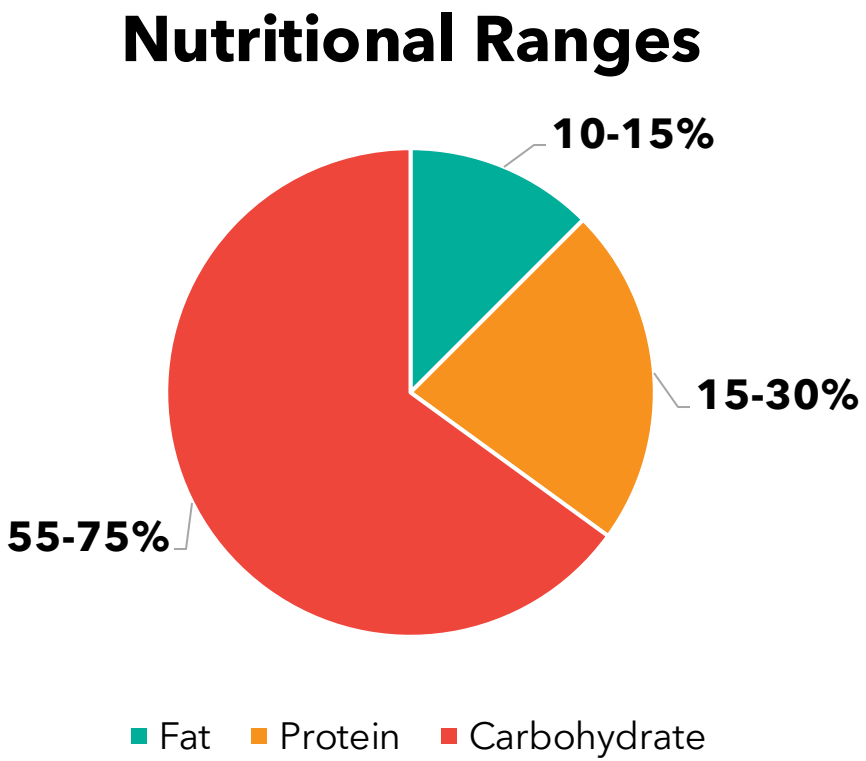
$$\theta = \frac{\sigma}{\mu}$$

θ = coefficient of variation
σ = 30-year historic standard deviation
μ = 30-year historic mean

High CoV: $\theta > 1$
Low CoV: $\theta < 1$

Food Security Indicators

Balanced Diet



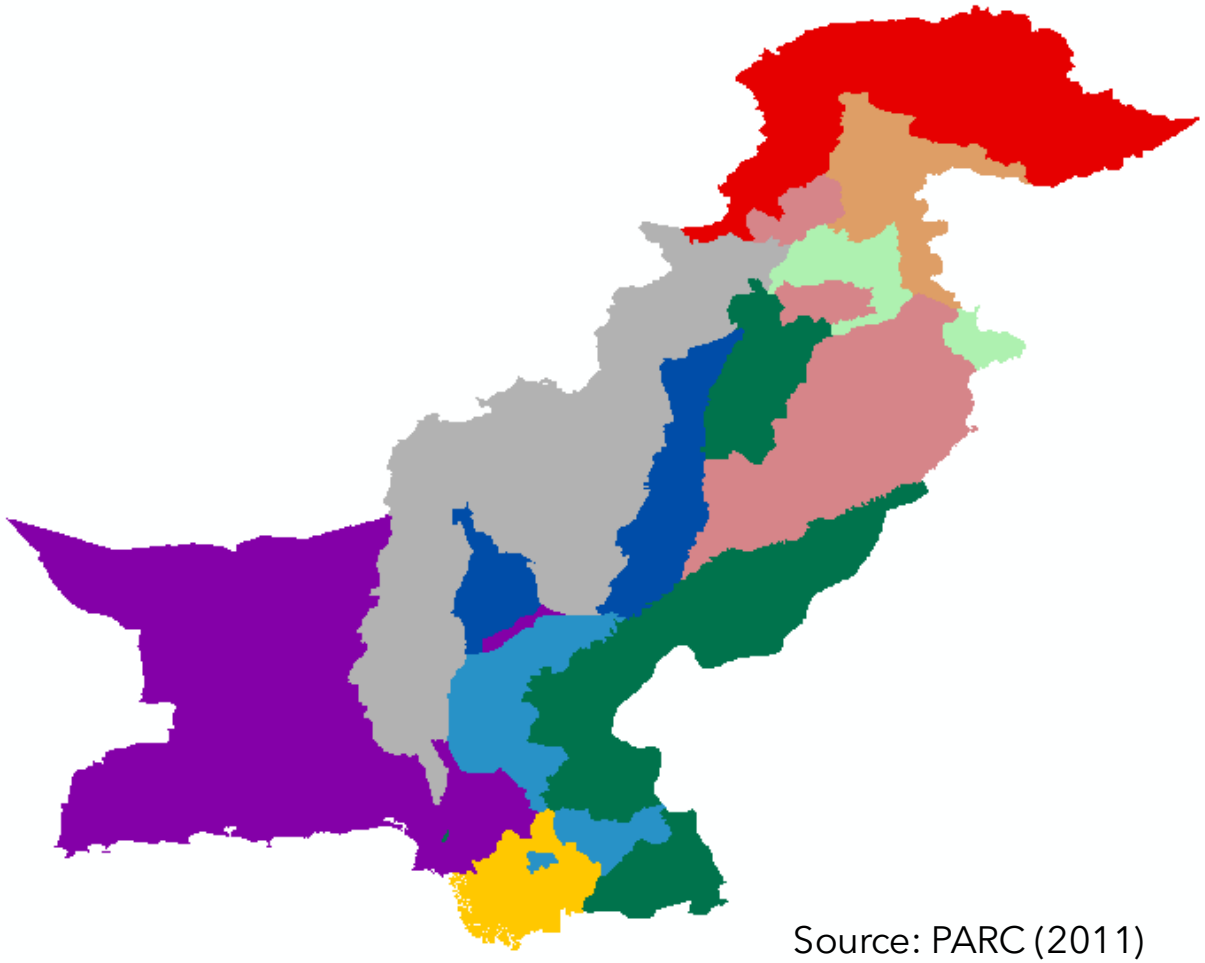
Source: FAO and WHO, (1998)

Household Dietary Diversity Score (HDDS)

- The HDDS is a qualitative indicator that is based on a questionnaire inquiring household members regarding food consumption in the previous 15 days to 1 month.
- Therefore, this study incorporates the food items consumed by households categorised into 16 groups to determine HDDS. However, one group (organ meat) data is unavailable in HIES.
- Each food item weighs 1 point with the maximum HDDS = 15. For ease of computation, all food groups are coded 1 to 15.

Source: FAO (2011) and Kennedy et al. (2011)

Agro-Ecological Zones of Pakistan



Zone 1	Indus Delta
Zone 2	Southern Irrigated Plain
Zone 3	Sandy Desert
Zone 4	Northern Irrigated Plain
Zone 5	Barani (Rainfall) Lands
Zone 6	Wet Mountains
Zone 7	Northern Dry Mountains
Zone 8	Western Dry Mountains
Zone 9	Dry Western Plateau
Zone 10	Sulaiman Piedmont

Source: PARC (2011)

Regression Models

For Rural Households

$$FS_r = \alpha + \beta_1 A_r + \beta_2 MRI_r + \beta_3 H_r + \beta_4 R_r + \beta_5 Y_r + \mu_r$$

where, $\boldsymbol{FS_r}$ is a measure of food security (with balanced diet or household dietary diversity score as proxies) in rural household $\boldsymbol{r}$, $\boldsymbol{A_r}$ is the agricultural household (with non-agricultural household as base), $\boldsymbol{MRI_r}$ is the zonal monsoon rainfall intensity, $\boldsymbol{H_r}$ is a vector of household characteristics (income, dependency ratio, head's education, head's age, and head's gender), $\boldsymbol{R_r}$ is a vector of regional characteristics (zone and district), and $\boldsymbol{Y_r}$ is a vector of time (2013-14, 2015-16, and 2018-19).

For Agricultural Households

$$FS_a = \sigma + \gamma_1 L_a + \gamma_2 MRI_a + \gamma_3 H_a + \gamma_4 R_a + \gamma_5 Y_a + \epsilon_a$$

where, $\boldsymbol{FS_a}$ is a measure of food security (with balanced diet or household dietary diversity score as proxies) in agricultural household $\boldsymbol{a}$, $\boldsymbol{L_a}$ is livelihood source of household, $\boldsymbol{MRI_a}$ is the zonal monsoon rainfall intensity, $\boldsymbol{H_a}$ is a vector of household characteristics (income, dependency ratio, head's education, head's age, and head's gender), $\boldsymbol{R_a}$ is a vector of regional characteristics (zone and district), and $\boldsymbol{Y_a}$ is a vector of time (2013-14, 2015-16, and 2018-19).

Results & Analysis

Summary Statistics

Variable	Percent	Variable	Percent
Monsoon Rainfall		**Household Asset Index**	
Lowest ($z < -1.5$)	**3.8**	Poorest	**26.0**
Lower ($-1.5 < z < -1$)	**7.8**	Poorer	**22.2**
Moderate ($1 < z < -1$)	**61.4**	Middle	**24.1**
Higher ($1 < z < 1.5$)	**6.8**	Richer	**14.6**
Highest ($z > 1.5$)	**20.2**	Richest	**13.1**
Agricultural Household		**Household Income Index**	
Agricultural	**35.4**	Poorest	**22.1**
Non-Agricultural	**64.6**	Poorer	**21.7**
Household Dietary Diversity Score		Middle	**19.5**
(HDDS)			
Low	**20.0**	Richer	**18.8**
Medium	**23.6**	Richest	**17.9**
High	**56.4**	**Household Size**	
Balanced Diet		Less than or equal to 5	**39.8**
Balanced	**36.0**	Greater than 5	**60.2**
Unbalanced	**64.0**		

Source: Author's calculation using HIES and NASA Giovanni Earth Data

Monsoon Rainfall Variability

2013

In 2013, the overall monsoon precipitation was 29.5 % higher than the (30-year) historic average.

2015

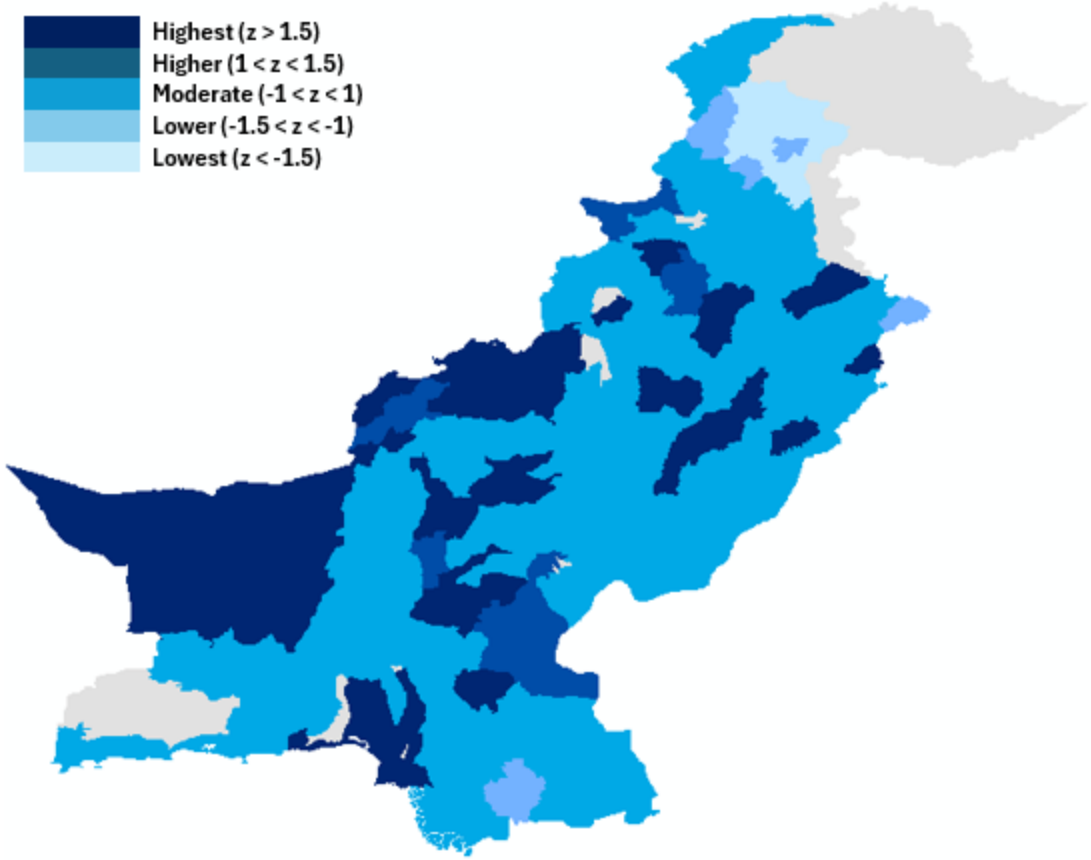
In 2015, the overall monsoon precipitation was 8.7 % higher than the (30-year) historic average.

2018

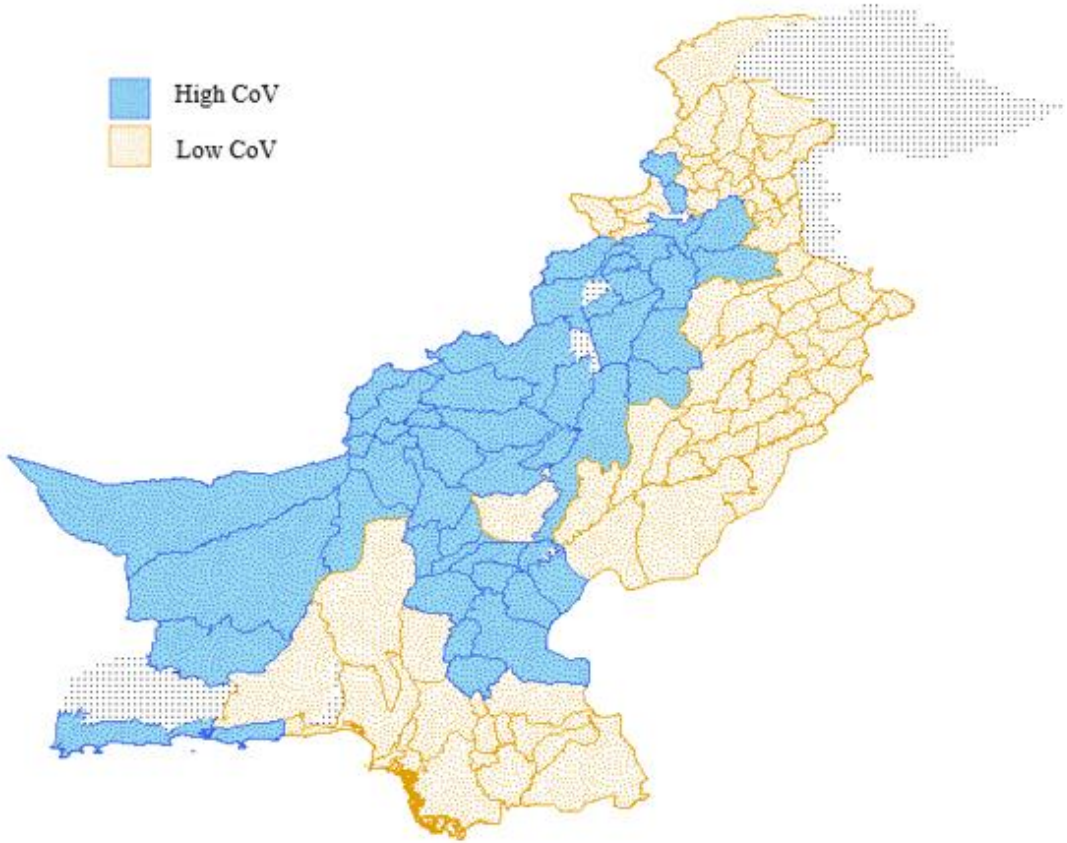
In 2018, the overall monsoon precipitation was 11.7 % lower than the (30-year) historic average.

Geospatial Mapping of Climate Variation

Monsoon Rainfall (z-score)



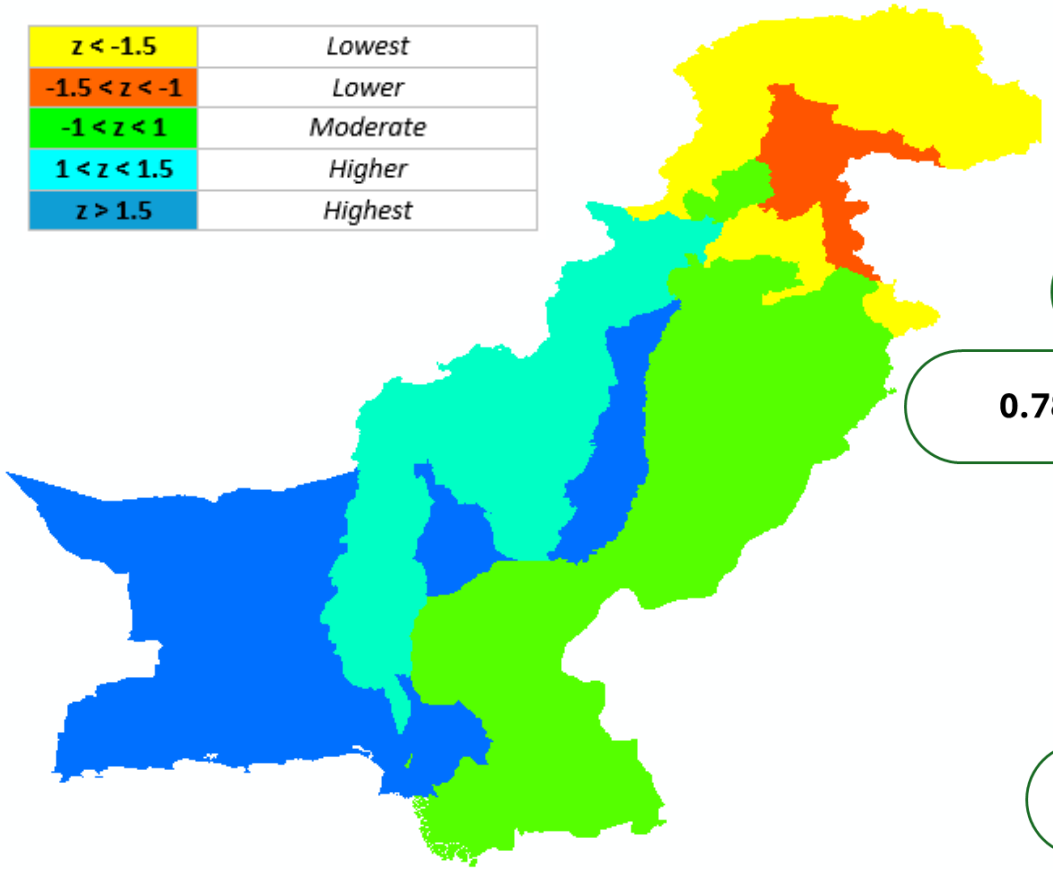
Coefficient of Variation



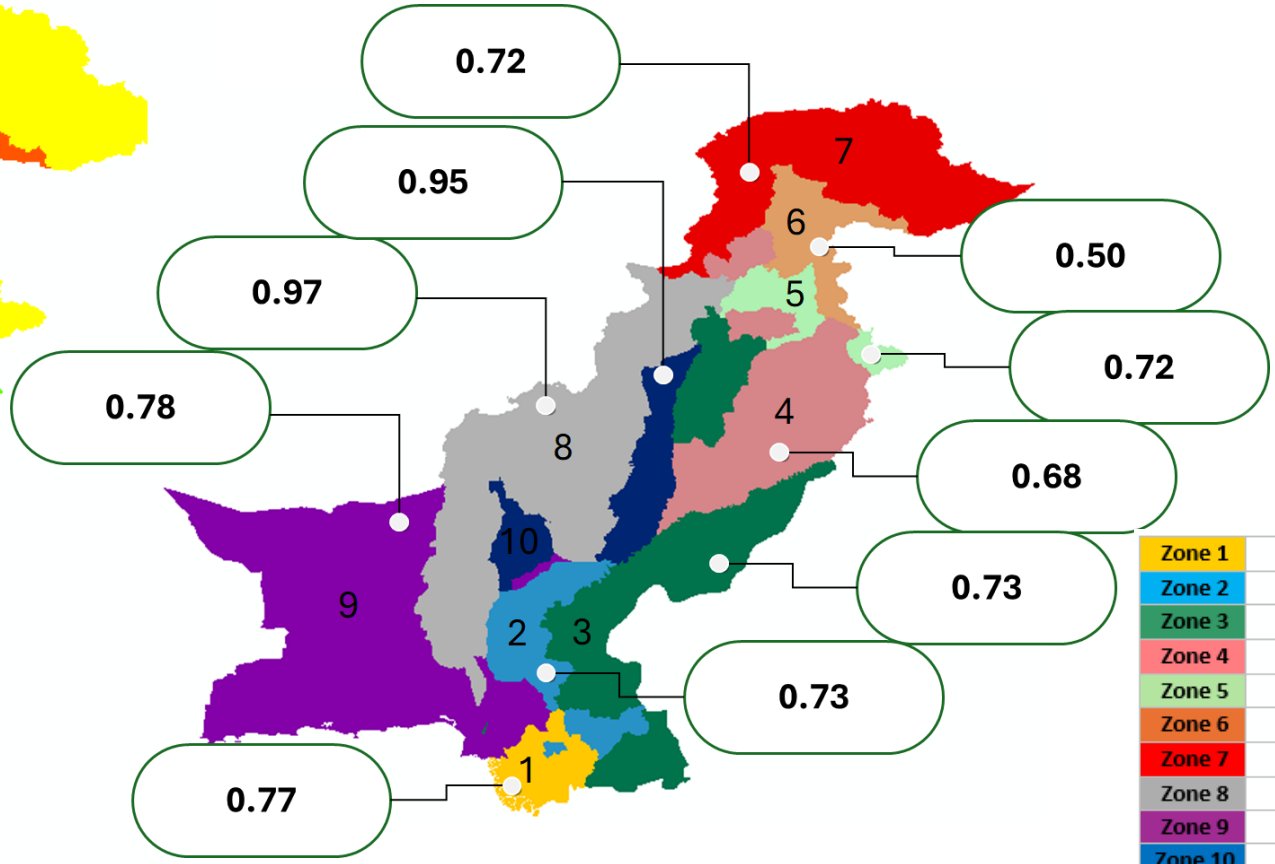
Geospatial Mapping of Climate Variation (Zones)

Monsoon Rainfall (z-score)

z < -1.5	*Lowest*
-1.5 < z < -1	*Lower*
-1 < z < 1	*Moderate*
1 < z < 1.5	*Higher*
z > 1.5	*Highest*



Coefficient of Variation



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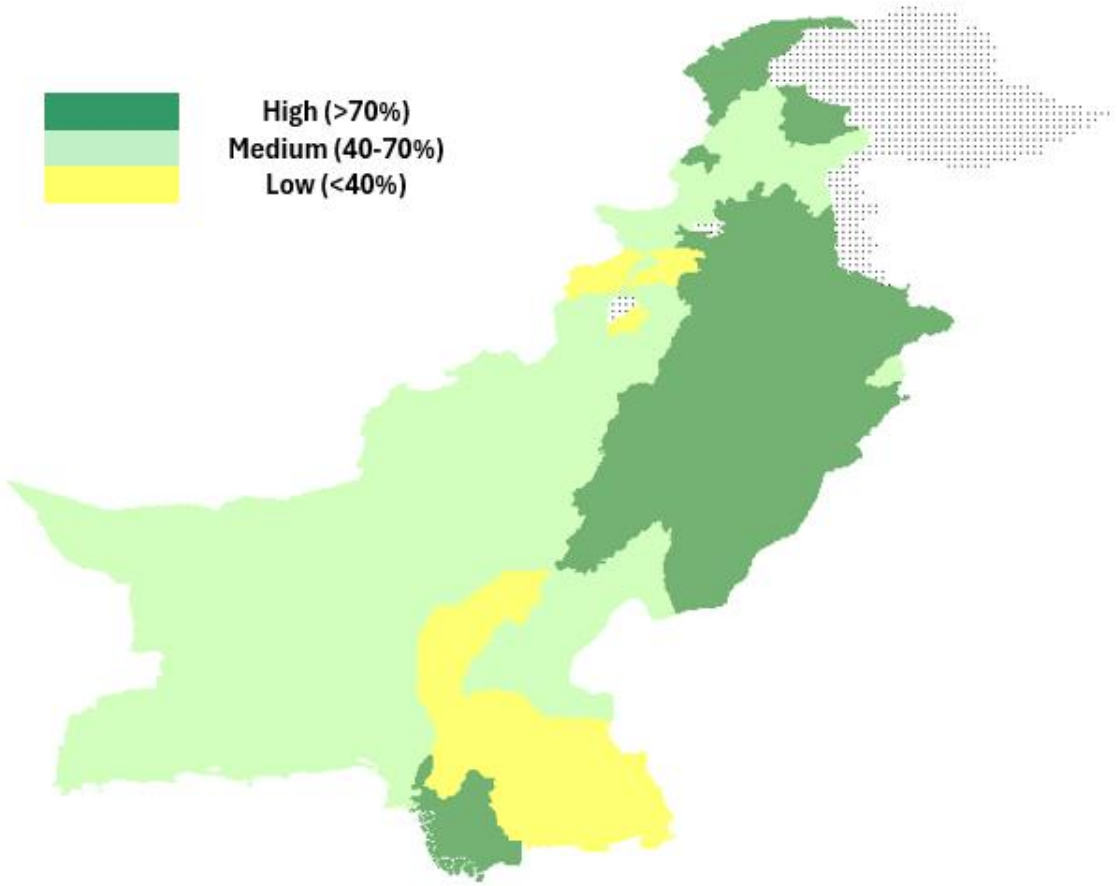
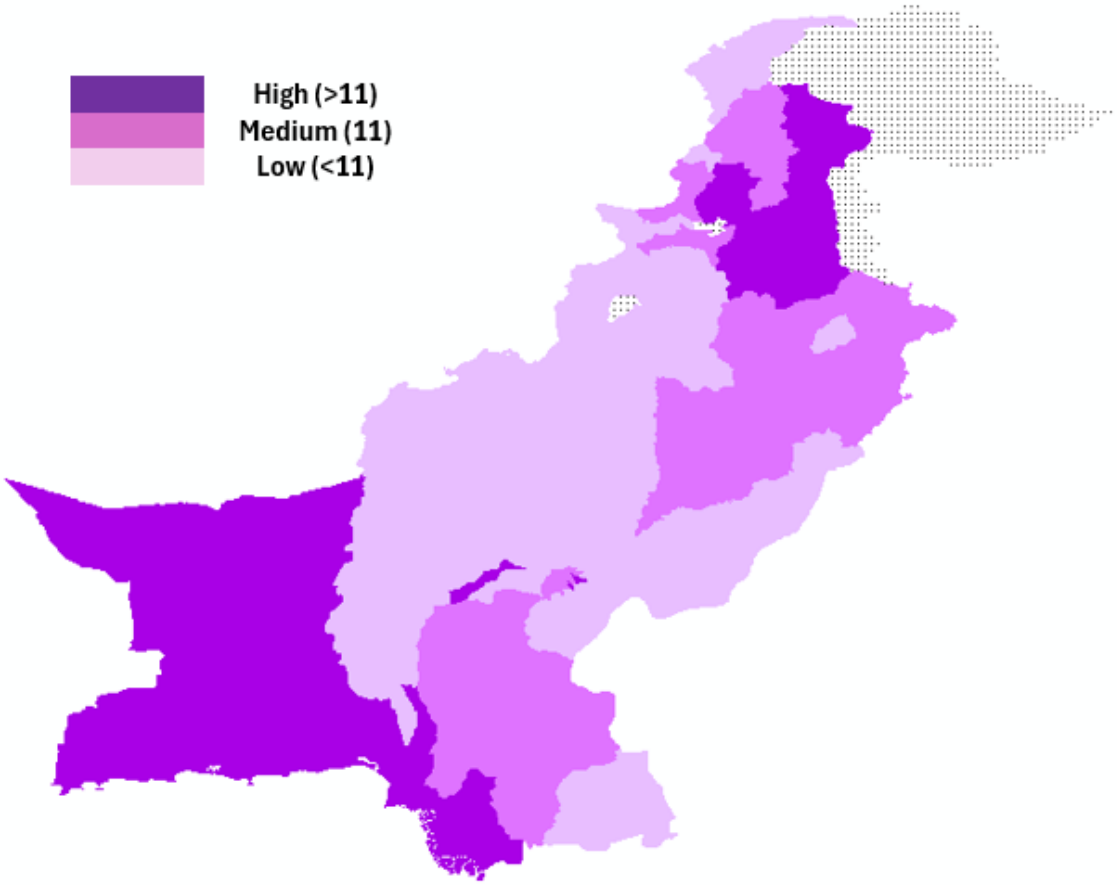
Geospatial Mapping of Food Security

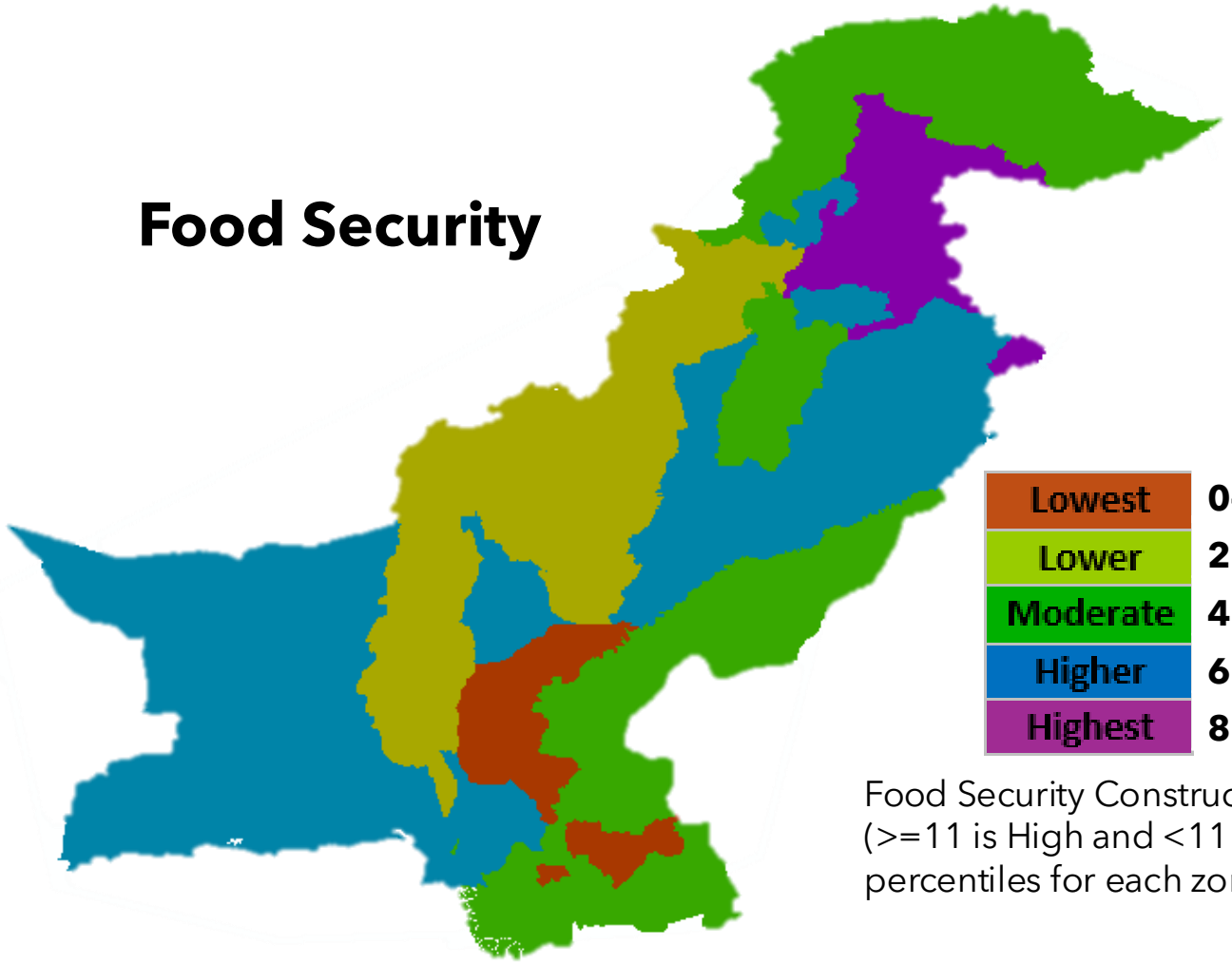
Balanced Diet



HDDS



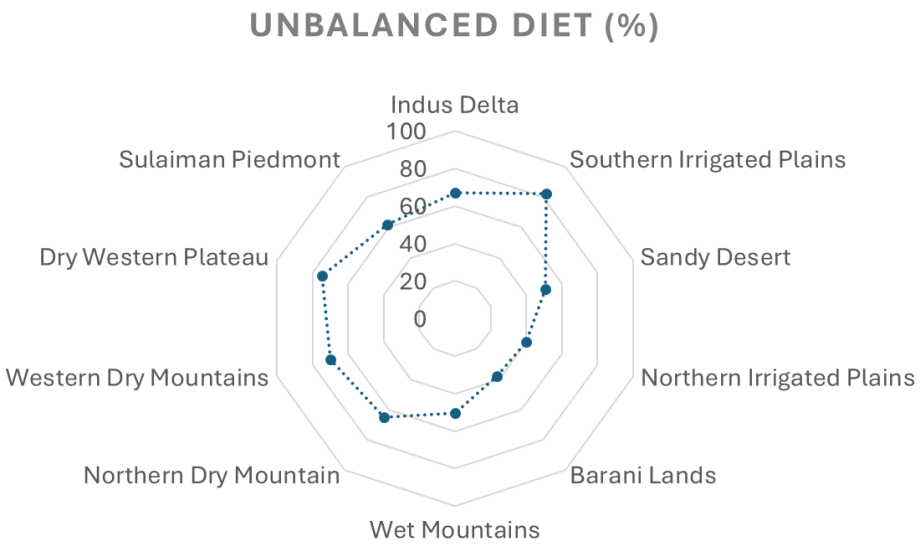
Geospatial Mapping of Food Security (Zones)



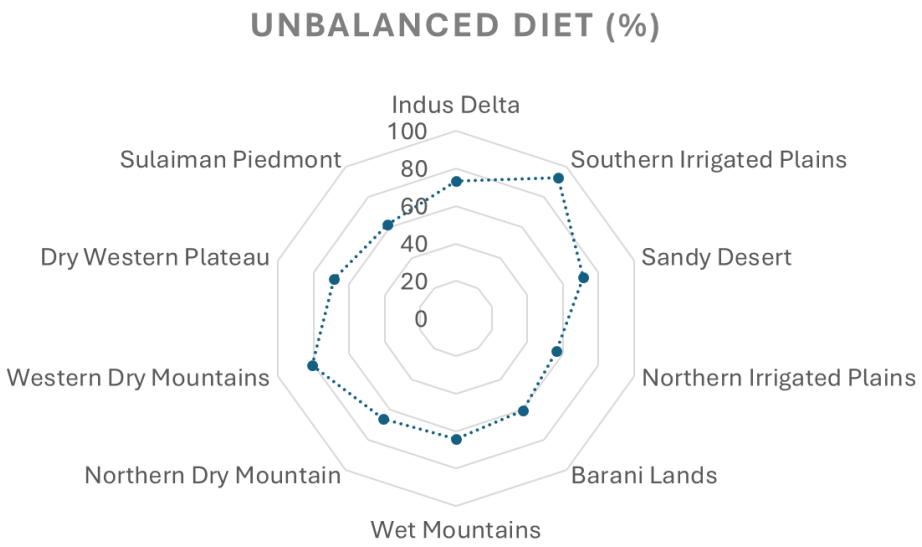
Food Security Construction: Balanced Diet (1=Yes and 0=No) and HDDS (>=11 is High and <11 is Low) are given 50% weigh each to calculate percentiles for each zone.

Balanced Diet

Agricultural Households

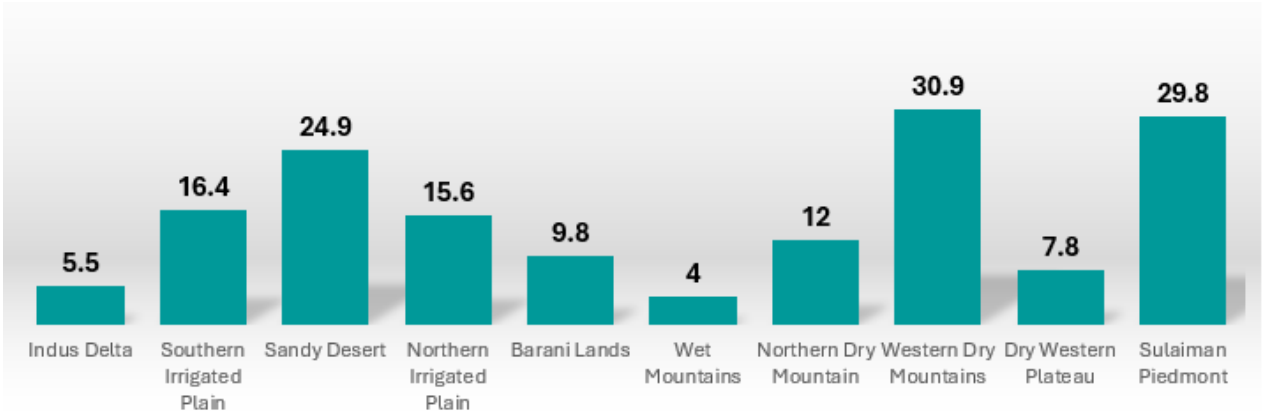


Non-Agricultural Households

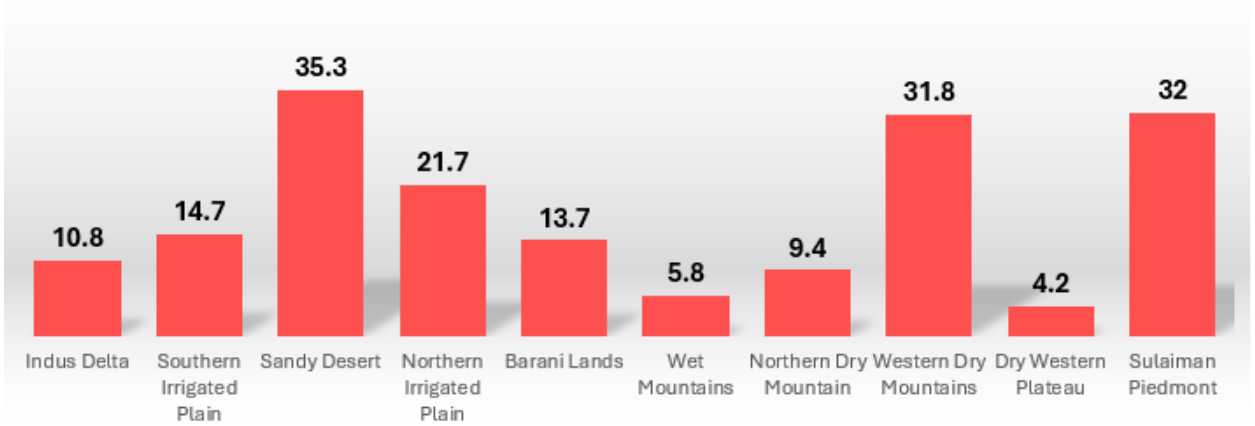


Household Dietary Diversity Score (HDDS)

Low HDDS (%) Agricultural Households



Low HDDS (%) Non-Agricultural Households



Association between Agriculture and Food Security

	Balanced Diet			HDDS [d]		
	No	*Yes*		*Low*	*Medium*	*High*
Land Type			**Land Type**			
(p = 0.000) chi²(1) = 23.48			(p = 0.000) chi²(2) = 94.98			
Barani (Rain-fed)	51.1	48.9	*Barani (Rain-fed)*	13.2	18.4	68.4
Irrigated	56.6	43.4	*Irrigated*	18.7	23.9	57.4
Land Size [a]			**Land Size** [a]			
(p = 0.000) chi²(2) = 20.08			(p = 0.000) chi²(4) = 31.33			
Small	52.9	47.1	*Small*	18.3	22.4	59.3
Medium	47.7	52.3	*Medium*	16.3	21.2	62.5
Large	51.9	48.1	*Large*	13.1	20.0	66.8
Land Share			**Land Share**			
(p = 0.000) chi²(2) = 492.22			(p = 0.000) chi²(4) = 156.16			
No Share	49.7	50.3	*No Share*	16.2	20.9	62.9
< 50%	72.0	28.0	*< 50%*	21.7	27.9	50.4
> 50%	68.5	31.5	*> 50%*	20.4	20.4	59.3
Crop Type [b]			**Crop Type** [b]			
(p = 0.000) chi²(1) = 44.61			(p = 0.398) chi²(2) = 1.84			
Homogenous Crop	57.7	42.3	*Homogenous Crop*	17.5	22.5	60.0
Crop Diversification	51.2	48.8	*Crop Diversification*	16.6	23.1	60.3
Livelihood Type [c]			**Livelihood Type** [c]			
(p = 0.000) chi²(2) = 410.45			(p = 0.000) chi²(4) = 35.28			
Cropping	71.4	28.6	*Cropping*	20.7	23.7	55.6
Diversified Livelihood	50.4	49.6	*Diversified Livelihood*	16.6	22.4	60.9
Livestock	74.1	25.9	*Livestock*	24.1	20.4	55.6

[a] Small < 1 acre, medium > 1 and < 5 acres, and large > 10 acres.
[b] Homogenous crop = food crop and crop diversification = food and cash crop.
[c] Diversified livelihood = cropping and livestock both.
[d] HDDS categorization, low < 11 i.e., mean HDDS, medium = 11, and high > 11.

Regression Results

Logistic Regression: Rural HHs	Balanced Diet (OR)	HDDS (OR)
Zonal Monsoon Rainfall Intensity		
(Ref: Moderate)		
Lowest	0.51***	1.09
Lower	0.64***	2.51***
Higher	0.69***	0.99
Highest	1.23**	1.11
Rural Households		
(Ref: Non-Agri Households)		
Agricultural Households	1.57***	1.34***
Constant	0.24***	0.53***
Household Controls	Yes	Yes
Region FE	Yes	Yes
Time FE	Yes	Yes

Logistic Regression: Agri HHs	Balanced Diet (OR)	HDDS (OR)
Zonal Monsoon Rainfall Intensity		
(Ref: Moderate)		
Lowest	0.33***	1.06
Lower	0.23***	1.49
Higher	0.76	2.90*
Highest	0.89	1.41
Livelihood Source		
(Ref: Cropping only)		
Livestock & Cropping	1.81***	1.21***
Constant	0.08**	1.87**
Household Controls	Yes	Yes
Region FE	Yes	Yes
Time FE	Yes	Yes

(Odds Ratio with 95% Confidence Intervals)

Conclusion

Main Findings

- Climate-induced rainfall variability is prevalent across the agro-ecological zones of Pakistan.
- Within agro-ecological zones, disparity in monsoon rainfall is high –zones with traditionally higher monsoon rainfall experienced reduced rainfall, while barren lands of Balochistan and Sindh witnessed multifold increase in the monsoon rain.
- With monsoon rainfall variability, agricultural households fare better in terms of food security compared to non-agricultural households.
- Agricultural households with diversified livelihood sources are more food secure, relative to ones reliant on cropping only.

Policy Recommendations

- To attain higher food security amid monsoon rainfall variation, agricultural policy should advocate farmers to diversify their livelihood sources use irrigation for their agricultural land instead of relying on rainfall only.
- Small farmers are more vulnerable to food insecurity; therefore, the agricultural policies should be focused on small land holders.
- Relatively food insecure agro-ecological zones are Sandy Desert (Zone 3), Western Dry Mountains (Zone 8), and Sulaiman Piedmont (Zone 10); hence, these climate zones must be focused upon more.

Limitations

- Several items belonging to different food categories are grouped together. (For example, code 11706 includes “tinda, pumpkin, bottle gourd” where pumpkin is “vitamin A rich vegetable” while tinda and bottle gourd are categorized as “other vegetables”).
- For readymade food items, only expenditure values are given; caloric and nutritional value of these food items cannot be calculated.
- Balanced diet does not breakdown into under and over consumption.
- No indicator that captures intra-household consumption pattern

Thank You!