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Climate Change and Education: Evidence from Palestine

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ABSTRACT

This study investigates the impact of climate change on women's education in Palestine, focusing on how climatic factors affect years of schooling. Using pooled data from the Palestinian Labor Force Survey and climate indicators from the Palestinian Meteorological Department, the analysis explores both immediate and lagged effects of climate change on women's years of schooling. Findings reveal gendered disparities in the effects of rainfall and temperature on schooling, with women facing unique vulnerabilities. Mechanism analysis indicates that agricultural households in Palestine are highly vulnerable to climatic shocks which in turn increases the vulnerability of girls in these households; Climatic shocks negatively impact farming productivity and the overall working environment, exacerbating the challenges faced by these families. The study also identifies regional heterogeneities, with southern districts showing greater resilience compared to central and northern regions, while Jericho faces pronounced adverse impacts.

KEYWORDS: Climate Change; Education; Gender Disparities; Palestine; Educational Outcomes

JEL CLASSIFICATION: I25; Q54; J16

1. INTRODUCTION

The phenomenon of climate change has rapidly evolved from a distant environmental concern to a pressing global crisis with far-reaching implications for human society (Singh 2021). Characterized by rising global temperatures, shifting weather patterns, and increasingly frequent and severe extreme weather events, climate change is fundamentally altering ecosystems, economies, and communities around the world (Gaines et al. 2023). While no region is immune to its effects, the impacts of climate change are not distributed evenly; developing countries bear a disproportionate share of the burden (Shan 2023; Parsons et al. 2024). These countries, often with limited resources and infrastructure, face significant challenges in adapting to the changes wrought by a warming planet (Maja and Ayano 2021). Among the myriad consequences of climate change, the impact on education is particularly concerning, especially for vulnerable populations; a recent World Bank report highlighted that the adverse effects of climate change on learning and educational outcomes lead to reduced future earnings and productivity, with the impact being particularly severe for disadvantaged populations—for example, in 2023, over 36 million students in Bangladesh and the Philippines experienced school closures as a result of extreme heatwaves. Projections indicate that a 10-year-old in 2024 is expected to face a substantially higher frequency of extreme weather events throughout their lifetime compared to a 10-year-old in 1970 (World Bank 2024). Globally, the manifestations of climate change are diverse and pervasive. The Earth's average temperature has already risen by about 1.2 degree Celsius since the late nineteenth century, driven primarily by increased concentrations of greenhouse gases in the atmosphere (NASA 2021).

This warming trend has led to melting polar ice caps, rising sea levels, and more frequent heatwaves (Kumar, Ranjan, and Verma 2021). Additionally, climate change is causing shifts in precipitation patterns, leading to longer and more intense droughts in some regions and heavier rainfall and flooding in others (Tabari 2020). The frequency and intensity of extreme weather events—such as hurricanes, typhoons, and wildfires—are also on the rise, causing widespread destruction and displacement (Clarke et al. 2022). These environmental changes have direct and indirect impacts on human health, income, food security, water availability, and livelihoods particularly in developing countries (Shan 2023).

Developing countries are especially vulnerable to the impacts of climate change due to several interrelated factors. First, these countries often rely heavily on agriculture, which is highly sensitive to climate variations (Hallaq and Daas 2024a; Liu, Shamdasani, and Taraz 2023). Changes in rainfall patterns, prolonged droughts, and soil degradation can devastate crop yields, leading to food insecurity and economic instability (Liliane and Charles 2020). Second, the infrastructure in developing countries is typically less robust than that in developed countries, making them more susceptible to damage from extreme weather events (Salimi and Al-Ghamdi 2020; Malpede and Percoco 2024). Limited access to healthcare, education, and financial resources further exacerbates these vulnerabilities, reducing the capacity of communities to recover from climate-related shocks (Iyer-Raniga and Vahanvati 2020). Further, developing countries frequently have less political and economic influence on the global stage, thus limiting their ability to advocate for international climate action and secure the resources needed for adaptation and mitigation efforts; that is not to say, however, that developed countries are immune to the effects of climate change. A recent study by Park (2017) on high school exit exams in New York City found that heat exposure can negatively affect educational performance in both the short and long terms.[1] The study also revealed that cumulative heat exposure throughout the school year could slow the rate of learning, as evidenced by lower exit exam scores, even when controlling for the immediate effects of exam day temperatures. Nonetheless, developing countries remain more vulnerable due to insufficient infrastructure to mitigate these impacts.

In the context of Palestine,[2] a lower middle-income developing country, climate change presents a unique set of challenges, intersecting with the region's ongoing political and socio-economic difficulties. The impacts of climate change in Palestine are complex, affecting water availability, agricultural productivity, and the overall stability of communities (Mason et al. 2012). Water scarcity, exacerbated by both natural and human-induced factors, is a significant concern. Reduced rainfall, combined with the degradation of water resources and the effects of the Israeli occupation, places immense pressure on Palestinian communities (Aish, Ayesh, and Al-Najar et al. 2021). Agriculture, a vital part of the Palestinian economy, is also severely affected by climate variability. Decreased crop yields and the loss of arable

[1] Refer to Section 2 of the appendix, which examines the correlation between climate change indicators and passing rates of the General Certificate of Secondary Education (GCSE) exam, commonly known in Palestine as Tawjihi.

[2] See Section 1 of the appendix for detailed contextual information.

land due to desertification and soil erosion further undermine food security and rural livelihoods (Hallaq and Daas 2024a). These environmental stressors are compounded by the political situation, which restricts access to resources, limits economic opportunities, and hampers efforts to build resilience against climate impacts (Isaac and Hilal 2024).

Despite these challenges, Palestinian girls and women have demonstrated remarkable resilience and success in education. In recent years, girls in Palestine have outperformed boys in academic achievement and have achieved higher enrollment rates in both secondary and tertiary education (OCED 2023; UIS 2023). This success is particularly significant given the constraints imposed by cultural norms, economic hardship, and the ongoing conflict. Girls' educational achievements reflect their determination and the value placed on education by Palestinian families, even in the face of adversity. However, the gains made by girls in education are under threat from the growing impacts of climate change. While girls have made significant strides in academic performance and enrollment, they remain vulnerable to climate-induced shocks that could disrupt their educational trajectories.

In Palestine, most school buildings lack proper heating and cooling systems, and ventilation is often poor, creating uncomfortable and sometimes unhealthy learning conditions (Baba, Shahrour, and Baba 2024; Hallaq 2024). In the summer, classrooms can become stiflingly hot, while in the winter, they are frequently cold and damp. The lack of climate control in schools not only affects students' ability to concentrate and perform academically but also poses potential health risks (Leal Filho et al. 2023; Cho 2017). The vulnerability of girls to climate change is rooted in a complex interplay of other factors as well. Climate change exacerbates existing gender inequalities by increasing the burden of unpaid care work, which often falls disproportionately on girls and women (Marphatia and Moussié 2013; Glazebrook, Noll, and Opoku 2020). During periods of environmental stress, such as droughts or heatwaves, girls may be required to assist with household chores, including fetching water from increasingly distant sources or caring for younger siblings while parents work (Islam 2020). This additional workload can lead to higher absenteeism from school and, in severe cases, could cause girls to drop out entirely (Shahidul and Karim 2015; Bzour, Zuki, and Mispan 2022). This dynamic, coupled with the broader socio-political context, places girls at a distinct disadvantage, making it harder for them to continue their education in times of crisis.

Further, adverse climatic conditions may exacerbate barriers to educational access, including increased economic pressures on households, infrastructure disruptions, and health-related challenges (Randell and Gray 2019; Adejuwon 2018). Consistent with this hypothesis, previous studies have documented a negative relationship between climate change–related data and school attendance. For instance, Mfon (2024) highlighted the detrimental effects of extreme weather events on attendance rates, while Fuller et al. (2018) provided evidence linking climatic variability to reduced educational participation. Furthermore, Kearney et al. (2024) emphasized the importance of examining how climate-related disruptions, specifically, affect school attendance, demonstrating a critical gap in the existing literature.

This paper contributes to the existing body of literature by offering an analysis of how climate change impacts the education of girls and women in a context marked by socioeconomic and political instability. While only a few studies have explored the effects of climate change on education, few have specifically focused on gender disparities within this framework, particularly in regions like Palestine where vulnerabilities are compounded by ongoing conflict and economic challenges. By using pooled data from the Palestinian Labor Force Survey and incorporating climate indicators from the Palestinian Metrological Department, this study provides empirical evidence on the intersection of climate change and education, and women's education, in particular. The findings not only fill a critical gap in the literature but also show the importance of integrating gender and climate perspectives in policy discussions aimed at promoting educational resilience in vulnerable communities. This study reveals the significant and gendered impacts of climate change on education for women in Palestine. While increased rainfall occasionally supports education by alleviating economic pressures, excessive rainfall and extreme temperature variations—especially rising maximum temperatures—tend to disrupt schooling (Kousky 2016). Regional heterogeneities further highlight the complexity of these effects; southern districts demonstrate resilience to climatic stressors, while northern and central districts, as well as Jericho, face heightened vulnerabilities.

The paper is structured as follows: Section 2 outlines the data and variables employed in the study, Section 3 details the estimation models, Section 4 presents and analyzes the results, Section 5 discusses the proposed mechanism to interpret the results, and Section 6 concludes the paper.

2. DATA

The data used in this study is drawn from the Palestinian Labor Force Survey (PLFS), conducted by the Palestinian Central Bureau of Statistics (PCBS) over the period from 1999 to 2018. The PLFS is a quarterly survey, where each participating household is interviewed for two consecutive quarters, followed by a break, and then interviewed again for two additional quarters. This methodological approach ensures the collection of comprehensive longitudinal data on the socioeconomic characteristics of a representative sample of the Palestinian population. For the purposes of this analysis, the study restricts the sample to individuals aged between 10 and 75 years, focusing on educational outcomes across this age range. The final dataset comprises 1,192,295 observations, providing a robust sample for examining the impact of climate change on girls' education in Palestine, see Table 1 below for the descriptive statistics.

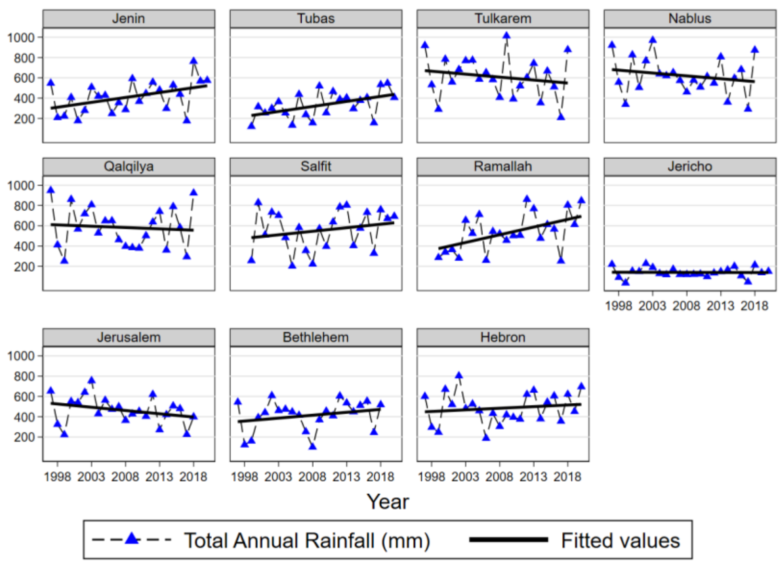
Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Years of schooling	1192295	9.19	4.02	0	31
Gender (1=female)	1192295	.492	.5	0	1
Refugee status (1=refugee)	1192295	.282	.45	0	1
Age	1192295	31.4	15.7	10	75
Age squared	1192295	1235.7	1214.6	100	5625
School attendance	.	.	.	.	.
Currently Attending	1192295	.304	.46	0	1
Attended and left	1192295	.44	.496	0	1
Attended and graduated	1192295	.223	.416	0	1
Never attended	1192295	.034	.18	0	1
LFP (1 = in labor force)	1192295	.394	.489	0	1
Work in agriculture	1192295	.074	.261	0	1
Locality type (1=Rural)	1192295	.411	.492	0	1
Marital status	.	.	.	.	.
Never Married	1192295	.462	.499	0	1
Engaged	1192295	.257	.437	0	1
Married	1192295	.263	.44	0	1
Divorced	1192295	.003	.054	0	1
Widowed	1192295	.014	.118	0	1
Separated	1192295	.001	.028	0	1
Year	1192295	-	-	1999	2018
Climate Change Indicators	.	.	.	.	.
Total annual rainfall (mm)	1192295	472.14	189.7	36.1	1012.8
Average max. temperature (°C)	1118026	23.46	2.6	18.346	33.19
Average min. temperature (°C)	1100758	14.43	1.6	9.7	20.24

Calculated by authors based on PLFS data 1999 - 2018

The primary outcome variable of interest is the number of years of schooling, which measures the total years of formal education completed by each individual. The main independent variables are total annual rainfall, average maximum temperature, and average minimum temperature obtained from the Palestinian meteorological department; due to the lack of available data at a more granular level, such as locality or neighborhood, and given the relatively small geographic scope of Palestine, the data has been aggregated at the district level. Annual rainfall is most abundant in the northern region of the West Bank, where it can reach up to 700 mm, while in the Dead Sea area in the south, it is considerably lower, ranging between 80 and 100 mm (Barghouthi and Gerstetter 2012). Figure 1 illustrates a clear pattern of significant variability in annual rainfall across different districts over the years. This variation includes periods of drought as well as times of more favorable climatic conditions. Particularly, regions where agriculture is a primary economic activity—such as the northern cities of Tubas, Jenin, and Salfit—display more marked fluctuations in rainfall level. Additionally, it is important to highlight that Palestine has witnessed an increase in extreme weather events, particularly droughts, in recent decades, with the southern and eastern slopes being most affected (ARIJ 2012).

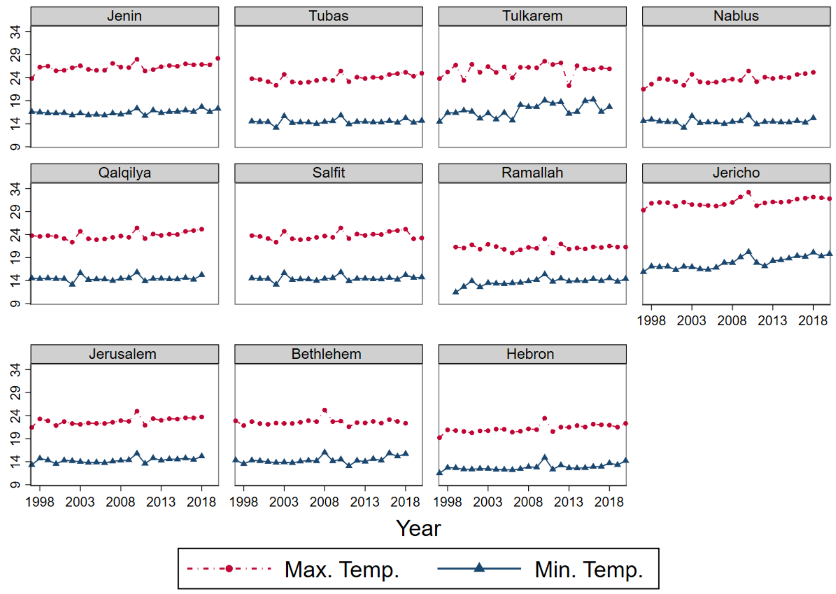
Figure 1. Total Annual Rainfall Per West Bank Districts Over the Period 1999–2018.



Source: Own Calculations Based on Palestinian Meteorological Department Data

Figure 2 demonstrates that the average annual maximum surface temperatures in the West Bank range from 18.3°C to 33.1°C, while the average annual minimum surface temperatures vary between 9.7°C and 20.2°C across different districts.

Figure 2. Average annual maximum/minimum temperature (West Bank districts) covering the period 1999–2018.



Source: Own calculations based on Palestinian Meteorological Department data

To accurately assess the impact of climate change on years of schooling, a range of control variables is included to account for other factors that could influence educational outcomes; gender is controlled for using a binary variable. Gender is a critical factor in educational studies, especially in contexts where cultural and socioeconomic norms may differentially affect the educational opportunities available to boys and girls and their academic achievement (Olitsky 2014). Refugee status is another important control, captured by a binary variable indicating whether an individual is a refugee. Refugee populations often face unique challenges, including economic instability and limited access to services, which can impact educational attainment (Hammoud 2017). By controlling for refugee status, the study accounts for the possibility that educational outcomes may be influenced by these socioeconomic conditions, independent of climate factors. Age and age-squared are included to control for the non-linear relationship between age and education. As individuals age, their educational attainment typically increases, but this relationship may plateau or even decline later in life. The inclusion of age-squared allows the model to capture these diminishing returns to education, ensuring a more accurate estimation of the effects of climate change across different age groups. School attendance status is controlled for using categorical variables that distinguish between those currently attending school, those who have attended but never completed, those who have graduated, and those who have never attended. Labor force participation is included as a binary control variable. Participation in the labor force can influence educational outcomes, particularly if economic pressures lead individuals to leave school prematurely. Female labor force participation also varies in different regions in Palestine (Hallaq and Daas 2024b). By controlling for labor force participation, the study isolates the impact of climate change on education from the effects of economic activity.

District-fixed effects are implemented to control for unobserved regional characteristics that might influence both climate conditions and educational outcomes. Further, this study focuses only on West bank districts (namely, Jenin, Tubas, Tulkarm, Nablus, Qalqilya, Salfit, Ramallah, Jericho, East Jerusalem, Bethlehem, and Hebron). Year-fixed effects are included to control for time-specific factors that might influence educational outcomes across the study period. These could include changes in educational policies, economic conditions, or other macro-level factors that vary over time. Year-fixed effects allow the study to account for these temporal variations, ensuring that the results reflect the impact of climate change rather than broader time-related trends; for instance, the Second Intifada (2000–2005) in Palestine constitutes a significant shock and is accounted for through the inclusion of year-fixed effects in the analysis. Rural residence is controlled for with a binary variable. Rural areas often face distinct challenges, such as limited access to schools, which can affect educational attainment. Controlling for rural residence helps differentiate the impact of climate change on education from the effects of rural–urban disparities. Marital status is included as a categorical control variable, capturing whether an individual has never married or is engaged, married, divorced, widowed, or separated. Marital status is particularly relevant for understanding educational attainment among girls (Omoeva and Hatch 2022), as early marriage might lead to school dropout (Mehra et al. 2018). Including this variable ensures that the study accounts for the potential influence of marriage on education.

3. ESTIMATION MODEL

In this section, we outline the empirical model used to investigate the relationship between climate change indicators and years of schooling. Specifically, we examine how total annual rainfall, average maximum and minimum annual temperatures, and the corresponding lagged effects (one-year and two-year lagged effects) influence years of schooling. The inclusion of current-year and lagged effects in the empirical model is essential for capturing the temporal dynamics of how climate change indicators influence years of schooling. Current-year variables account for the immediate impact of climatic factors, such as extreme weather events disrupting school attendance or academic performance within the same year. The one-year lagged effects reflect delayed consequences, such as economic hardships caused by events like droughts, which may force families to withdraw children from school in the subsequent year. Additionally, these effects capture lingering health or recovery challenges that affect schooling. Extending the analysis to a two-year lag incorporates longer-term impacts that may not manifest immediately, such as prolonged economic difficulties, delayed adjustments in schooling decisions by families, or systemic delays in repairing damaged educational infrastructure.

We, therefore, employ an Ordinary Least Squares (OLS) regression analysis, as it is sufficient given the exogeneity of our main variables. The OLS model, as specified in equation (1), is augmented to incorporate current and lagged effects of climate variables, allowing us to capture the potential delayed impact of these indicators on educational outcomes. This approach ensures that the estimation is both robust and theoretically aligned with the temporal dynamics of the relationships under investigation.

$$\text{Years of Schooling}_{ijtk}=\alpha_0+\beta_1 \text{Rain}_{jt}+\beta_2 \text{Rain}_{jt-1}+\beta_3 \text{Rain}_{jt-2}+\gamma X_{ijtk}+\delta_j+\lambda_t+\epsilon_{ijtk} \quad (1)$$

In this equation, (Years of Schooling) $_{ijtk}$ represents the total number of years of schooling completed by individual i, residing in district j, in year t, within locality type k. The coefficients β_1, β_2, and β_3 capture the effects of total average rainfall for district j in year t and its lagged effects from one year and two years, respectively. We used standardized values for the climate change indicators. Standardization ensures comparability across indicators, allowing the effects of rainfall and temperature to be interpreted on the same scale. Without this adjustment, the coefficients would reflect differences in the units of measurement, such as millimeters for rainfall and degrees Celsius for temperature, making interpretation more challenging (Hallaq and Daas 2024; Marchetta et al. 2019)[3]. By focusing on deviations from historical trends rather than absolute levels, the analysis captures anomalies that are more relevant for understanding the impact of climate variability on years of schooling. Standardization also improves the numerical stability of the regression model and reduces potential issues related to multicollinearity, especially when including lagged variables. Furthermore, this approach makes the findings more interpretable for policymakers, as it emphasizes how deviations from typical climate conditions—such as a one-standard-deviation increase in rainfall—impact educational outcomes. Finally, standardizing variables aligns the methodology with established practices in climate change research (Zarch et al. 2015; Hansen et al. 2012; Hallaq and Daas 2024a), facilitating comparisons with other studies and enhancing the robustness of the analysis.

$$\text{Years of Schooling}_{ijtk}=\alpha_0+\Upsilon_1\text{MaxTemp}_{jt}+\Upsilon_2\text{MaxTemp}_{jt-1}+\Upsilon_3\text{MaxTemp}_{jt-2}+\gamma X_{ijtk}+\delta_j+\lambda_t+\epsilon_{ijtk} \quad (2)$$

Similarly, $\Upsilon 1$, $\Upsilon 2$, and $\Upsilon 3$ in equation (2) represent the effects of the average maximum temperature for district j in year t and its lagged effects from one year and two years, respectively,

$$\text{Years of Schooling}_{ijtk}=\alpha_0+\text{Ɲ}_1\text{MinTemp}_{jt}+\text{Ɲ}_2\text{MinTemp}_{jt-1}+\text{Ɲ}_3\text{MinTemp}_{jt-2}+\gamma X_{ijtk}+\delta_j+\lambda_t+\epsilon_{ijtk} \quad \text{-- Eq (3)}$$

Ɲ1, Ɲ2, Ɲ3 in equation (3) capture the corresponding effects of the average minimum temperature for district j and its lagged effects. The term γX_{ijtk} includes a vector of individual-level control variables such as gender, age, area of residence, school attendance, labor force participation, marital status, and refugee status. Additionally, δ_j represents district-fixed effects, accounting for unobserved time-invariant characteristics specific to each district, while λ_t denotes year-fixed effects, capturing unobserved factors constant across districts but varying over time; Palestine's socio-political situation and the fluctuations

[3] Figures B1, B2, and B3 in the Appendix present the standardized values of our key explanatory variables—rainfall, maximum temperature, and minimum temperature—across West Bank districts over the period 1999–2018.

occurred after the first intifada (2000–2005) make the year-fixed effects an integral part of this analysis in order to control for any consequent impacts. Finally, ϵ_{ijtk} is the error term.

As previously discussed, the West Bank region in Palestine exhibits significant geographic and climatic diversity, with distinct districts experiencing varying levels of rainfall and maximum temperatures (refer to Figures 1 and 2 in the Data Section). To account for this variation, we initially conducted an analysis on the entire sample of households. Subsequently, we disaggregated the analysis by gender with separate evaluations for rainfall indicators (Table 2), maximum and minimum temperature indicators (Table 3). To explore heterogeneous effects, we further segmented the analysis by geographical sub-regions for female residents: females in the Southern Districts (Hebron, Bethlehem), females in the Northern Districts (Tubas, Jenin, Tulkarm, Nablus, Qalqiliya, and Salfit), females in the Central Districts (Ramallah and East Jerusalem), and females in Jericho. Results for rainfall indicators (heterogeneous effects) are presented in Table 4, while Table 5 presents results for maximum and minimum temperature indicators. Finally, the results for the proposed mechanism are presented in Table 6.

Additionally, we assessed the impact on different age groups, with results for individuals younger than 23 years and those 23 years and older detailed in Section 3 in the appendix. Further, Section 4 in the appendix material presents additional results analyzing the effect of climate change indicators on the likelihood of girls completing a year of education.

4. RESULTS and DISCUSSION

The Impact of Total Annual Rainfall on Years of Schooling

The analysis in Table 2 reveals a relationship between total annual rainfall and years of schooling, with distinct patterns emerging for the entire sample, as well as for males and females.

Table 2. The Effect of Total Annual Rainfall on Years of Schooling

Dep Var: Years of Schooling	(1) All sample	(2) Males	(3) Females
Total annual rainfall (mm std)	-0.013**	-0.043***	0.024***
	(0.006)	(0.008)	(0.008)
Total annual rainfall (mm std)_1	-0.011**	-0.030***	0.007
	(0.005)	(0.008)	(0.008)
Total annual rainfall (mm std)_2	0.013**	0.013*	0.014*
	(0.005)	(0.007)	(0.007)
Constant	5.055***	2.781***	6.229***
	(0.025)	(0.037)	(0.034)
Observations	1,192,295	605,228	587,067
R-squared	0.421	0.338	0.519
Individual characteristics	YES	YES	YES
Year Fixed Effects	YES	YES	YES
Locality type	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

For the entire sample, a one-standard-deviation increase in total annual rainfall is associated with a small but statistically significant reduction in years of schooling ($\beta = -0.013$, $p < 0.05$). This negative effect suggests that excessive rainfall may disrupt educational activities, potentially due to infrastructure challenges such as flooding or transportation barriers (Mir et al. 2024); Indeed, Garbero and Muttarak (2013) highlighted that extreme climatic events might negatively disrupt educational processes. The lagged effects provide additional insight: while the one-year lag also shows a negative impact ($\beta = -0.011$, $p < 0.05$), the two-year lag exhibits a positive effect ($\beta = 0.013$, $p < 0.05$). The positive two-year lag may reflect a recovery period during which households adapt to prior disruptions, allowing educational attainment to stabilize or even improve. Hallaq and Daas (2024) argue that increased rainfall in Palestine might positively affect agricultural productivity, especially in regions dependent on rain-fed farming. This could alleviate prior economic constraints, thus, creating a recovery period. This recovery period could restore normalcy in educational activities.

For males, the current-year rainfall effect is more pronounced, with a significant reduction in years of schooling ($\beta = -0.043$, $p < 0.01$). This could indicate that men, often expected to work or assist in agricultural tasks during adverse weather conditions, are more likely to experience schooling disruptions. The negative one-year lagged effect ($\beta = -0.030$, $p < 0.01$) reinforces this finding, suggesting that the economic or logistical challenges posed by heavy rainfall extend into the subsequent year. Interestingly, the two-year lagged effect is positive but marginally significant ($\beta = 0.013$, $p < 0.1$), hinting at potential long-term adaptations or recovery mechanisms.

In contrast, females display a different pattern. For girls, increased rainfall in the current year positively impacts years of schooling ($\beta = 0.024$, $p < 0.01$). This could reflect two factors: first, a redistribution of household labor, where men are tasked with outdoor activities, and second, an increase in agricultural productivity, which boosts household income and further supports girls' education. In traditional Palestinian household settings, men may be more likely than women to engage in outdoor labor tasks, such as agriculture or other economic activities, during periods of increased rainfall. This redistribution could, we argue, reduce women's responsibilities at home and allow them more time for educational activities. In regions where agriculture is the primary activity, increased rainfall is linked to higher agricultural productivity, which in turn boosts household incomes. This could help explain why increased rainfall has positive effects on girls' education. The lagged effects, however, are less consistent. While the one-year lag is insignificant, the two-year lag is positively associated with schooling ($\beta = 0.014$, $p < 0.1$), aligning with the broader trend that increased rainfall raises household income, thereby improving the financial capacity to support girls' education and increasing their chances of attending school.

The Impact of Average Maximum Temperature on Years of Schooling

Panel A in Table 3 below presents the effects of rising maximum temperatures on educational years of schooling.

Table 3 The Effect of Average Maximum/Minimum Temperature on Years of Schooling

Dep Var: Years of Schooling	Panel A (1) All Sample	(2) Males	(3) Females	Panel B (4) All Sample	(5) Males	(6) Females
Average max. temp (°C Std)	-0.070***	0.000	-0.124***			
	(0.018)	(0.025)	(0.025)			
Average max. temp (°C Std)_1	-0.073***	-0.035	-0.104***			
	(0.016)	(0.022)	(0.022)			
Average max. temp (°C Std)_2	-0.018*	0.005	-0.039***			
	(0.010)	(0.014)	(0.014)			
Average min. temp (°C Std)				-0.014	-0.023	-0.012
				(0.010)	(0.014)	(0.014)
Average min. temp (°C Std)_1				-0.018*	-0.029**	-0.013
				(0.010)	(0.014)	(0.014)
Average min. temp (°C Std)_2				-0.018**	-0.010	-0.028***
				(0.007)	(0.010)	(0.010)
Constant	5.243***	2.925***	6.415***	5.178***	2.941***	6.291***
	(0.032)	(0.045)	(0.043)	(0.028)	(0.040)	(0.038)
Observations	1,074,036	544,869	529,167	1,056,768	536,182	520,586
R-squared	0.423	0.339	0.523	0.422	0.338	0.521
Individual characteristics	YES	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES	YES
Locality	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Column (1) shows that a one-standard-deviation increase in the average maximum temperature reduces years of schooling (β = -0.070, p < 0.01) for the entire sample. The lagged effects further show the prolonged nature of these impacts, with a one-year lag (β = -0.073, p < 0.01) and a weaker but still significant two-year lag (β = -0.018, p < 0.1). The results suggest that extreme heat likely exacerbates physical discomfort, particularly in regions lacking adequate infrastructure, such as cooling systems in classrooms. For males, Column (2), results indicate no significant relationship between maximum temperature and years of schooling. This lack of effect might be due to societal expectations, where men's education is less disrupted by heat-related issues compared to women. However, the results for females reveal a stark contrast. A one-standard-deviation increase in maximum temperature significantly reduces years of schooling for girls (β = -0.124, p < 0.01), with similarly negative impacts for the one-year lag (β = -0.104, p < 0.01) and the two-year lag (β

= -0.039, $p < 0.01$). This shows the vulnerability of women to heat stress, which may disproportionately affect their ability to attend and perform in school. The sustained lagged effects indicate that the consequences of extreme heat persist over time, potentially due to prolonged economic- or health-related challenges. Climate change is expected to intensify the disease burden for women in four critical areas: mental health, fertility-related conditions, cardiovascular disease, and bone health (Canelón and Boland 2020). Additionally, it restricts access to clean water, hygiene facilities, and adequate menstrual products, making it more challenging for women and girls to manage menstrual hygiene effectively. These challenges are further aggravated in the aftermath of climate change events, leading to heightened negative experiences (Moore 2022).

The Impact of Average Minimum Temperature on Years of Schooling

As shown in Panel B in Table 3 above, the effects of minimum temperatures on years of schooling are less pronounced than those of maximum temperatures.

For the entire sample, Column (4), no significant effect is observed for the current year, but a marginally significant negative effect emerges for the one-year lag ($\beta = -0.018$, $p < 0.1$). The two-year lag shows a stronger negative effect ($\beta = -0.018$, $p < 0.05$), suggesting that cooler conditions may have delayed consequences, possibly related to health issues or economic strain during colder periods (McMichael, 2012; Sarofim et al., 2016). For males, Column (5), the results align with those for the entire sample, with no significant current-year effect and a negative one-year lag ($\beta = -0.029$, $p < 0.05$). The two-year lag, however, is insignificant, indicating limited long-term impacts. For females, Column (6), the current- and one-year lagged effects are also insignificant, but the two-year lag reveals a significant negative impact ($\beta = -0.028$, $p < 0.01$). This result may point to delayed effects of colder temperatures on girls, possibly due to increased caregiving responsibilities or higher absenteeism during extreme weather (Fruttero et al. 2024).

Heterogeneity Analysis by Region

The heterogeneity analysis in Tables 4 and 5 illustrates how geographic location moderates the effects of climatic variables on women's years of schooling.

Table 4. Heterogeneity Analysis – The Effect of Total Annual Rainfall on Women's Years of Schooling

Dep Var: Years of Schooling	(1) Southern Districts	(2) Northern Districts	(3) Central Districts	(4) Jericho District
Total annual rainfall (std)	0.049***	0.004	0.132***	0.693***
	(0.017)	(0.014)	(0.021)	(0.097)
Total annual rainfall (std)_1	0.070***	-0.005	-0.018	0.196**
	(0.018)	(0.012)	(0.021)	(0.093)
Total annual rainfall (std)_2	0.066***	-0.007	0.097***	0.657***
	(0.019)	(0.012)	(0.020)	(0.108)
Constant	6.676***	5.899***	6.855***	-171.862***
	(0.056)	(0.051)	(0.067)	(7.719)
Observations	232,148	263,340	122,106	28,383
R-squared	0.509	0.530	0.521	0.481
Controls	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

For total annual rainfall (Table 4), southern districts[4] benefit from increased rainfall ($\beta = 0.049$, $p < 0.01$), with even stronger positive effects observed for the one-year ($\beta = 0.070$, $p < 0.01$) and two-year ($\beta = 0.066$, $p < 0.01$) lags. The results suggest that rainfall in these regions might improve agricultural productivity, reducing economic pressures and enabling continued education; rainfall likely enhances agricultural yields in these predominantly agricultural areas, reducing economic pressures (Amare et al. 2018) and enabling families to prioritize education. In contrast, northern districts[5] show negligible effects (these districts already receive more consistent rainfall, meaning additional rainfall has a limited marginal benefit - refer to figure 2 in the data section), while central districts[6] experience significant positive impacts for current year ($\beta = 0.132$, $p < 0.01$), the two-year lag also shows positive effects ($\beta = 0.097$, $p < 0.01$); while these districts are more urbanized, rainfall may improve water availability and reduce costs associated with drought conditions, thus indirectly supporting education (Hallaq and Daas 2024). Jericho, on the other hand, exhibits the strongest positive

[4] Southern Districts: Hebron and Bethlehem.

[5] Northern Districts: Tubas, Jenin, Tulkarm, Nablus, Qalqiliya, and Salfit.

[6] Central Districts: Ramallah and East Jerusalem.

effects for current-year and lagged effects ($\beta = 0.693$, $\beta = 0.196$, $\beta = 0.657$ respectively), likely reflecting the unique climatic and economic conditions in Jericho as it is one of the hottest and driest regions in Palestine, thus rainfall has a disproportionately significant effect compared to other areas (Shadeed and Alawna 2024). Jericho's economy relies heavily on agriculture, particularly for crops like dates and citrus fruits, which are highly sensitive to rainfall (Baker 2012). Increased rainfall directly boosts agricultural productivity and household incomes. Also, increased rainfall may alleviate chronic water scarcity[7] (Judeh and Shahrour 2021), reducing household costs and freeing up resources to support education.

[7] Jericho relies on aquifers for its water, increased rainfall may replenish aquifers and support irrigation-dependent farming, further amplifying its economy (Khayat et al. 2009).

Table 5 Heterogeneity Analysis: Impact of Average Maximum/Minimum Temperature on Women's Years of Schooling

Dep Var: Years of Schooling	(1) Southern Districts	(2) Northern Districts	(3) Central Districts	(4) Jericho District	(5) Southern Districts	(6) Northern Districts	(7) Central Districts	(8) Jericho District
Average max. temp (°C Std)	0.143***	-0.119**	-0.419***	-0.887***				
	(0.044)	(0.056)	(0.095)	(0.081)				
Average max. temp (°C Std)_1	0.135***	-0.159***	-0.357***	-0.099				
	(0.036)	(0.045)	(0.107)	(0.077)				
Average max. temp (°C Std)_2	0.160***	-0.024	-0.178**	-0.177**				
	(0.034)	(0.018)	(0.071)	(0.077)				
Average min. temp (°C Std)					0.027	0.056	0.500***	0.883
					(0.021)	(0.046)	(0.054)	(0.714)
Average min. temp (°C Std)_1					0.035*	-0.002	0.238***	0.978
					(0.020)	(0.037)	(0.044)	(0.735)
Average min. temp (°C Std)_2					0.067***	-0.028*	0.241***	-0.317
					(0.020)	(0.016)	(0.044)	(1.066)
Constant	6.886***	6.227***	6.064***	-219.727***	6.687***	6.000***	7.707***	4.332***
	(0.080)	(0.074)	(0.103)	(9.002)	(0.057)	(0.066)	(0.109)	(1.138)
Observations	199,158	238,430	122,106	28,383	194,671	234,336	122,106	28,383
R-squared	0.520	0.531	0.521	0.482	0.517	0.529	0.521	0.490
Individual characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES
Locality type	YES	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The results in Table 5 above for maximum and minimum temperature effects on women's years of schooling reveal significant regional disparities across the southern, northern, and central districts and Jericho, shaped by each region's unique climatic, economic, and infrastructural characteristics.

For maximum temperatures, the southern districts (Hebron and Bethlehem) exhibit a positive effect on years of schooling; this finding may reflect a higher degree of acclimatization and adaptation among local communities to elevated temperatures. The southern districts, characterized by relatively hot, dry, and arid conditions, have historically developed resilience strategies, including structural adjustments in school buildings, flexible school hours during extreme heat, and cultural norms that prioritize education even in challenging environmental conditions (Appiah-Kusi and Al-Madbouh 2024; Ighbareyeh et al. 2015b). Furthermore, households in these areas rely on agricultural products—such as grapes, citrus and plums (Ighbareyeh and Carmona 2018)—that are less directly disrupted by heatwaves. Additionally, they have diversified economic sources (Salameh 2010) that could insulate educational outcomes from temperature variability.

In contrast, the northern and central districts (Tubas, Jenin, Tulkarm, Nablus, Qalqiliya, Salfit, Ramallah, and East Jerusalem) experience significant negative effects of maximum temperatures on years of schooling, with coefficients ranging from $\beta = -0.119$ to $\beta = -0.419$ ($p < 0.01$). These districts generally have more moderate climatic conditions compared to the southern districts, and thus, sharp increases in temperature are more disruptive and less easily managed. In agricultural areas of the north, higher temperatures could harm crop yields, intensifying economic pressures on households and increasing the likelihood of education discontinuity to contribute to family income. In central districts, where urbanization is often higher, extreme heat may exacerbate poor school infrastructure—such as inadequate cooling systems—and create physically uncomfortable learning environments, reducing attendance and academic performance.

Jericho, however, stands out with the most severe negative impact of maximum temperatures on education ($\beta = -0.887$, $p < 0.01$). Known as one of the lowest-altitude cities on Earth, Jericho faces extreme heat stress, especially during summer months (Trottier et al. 2019). The region's already harsh climate amplifies the effects of rising maximum temperatures, that could make educational institutes hot and learning conditions unbearable. Limited access to adequate infrastructure, including proper cooling systems in classrooms, further intensifies these adverse effects. Additionally, heat stress could impact household economic stability, particularly in agriculture-dependent sectors such as date farming, where extreme heat can damage crops (Allbed, Kumar, and Shabani 2017) and thereby reduce income, limiting a family's ability to support their education.

Regarding minimum temperatures, the southern districts demonstrate a small but statistically significant positive effect on years of schooling for both the one-year and the two-year lag. This result suggests that lower minimum temperatures in these regions may create relatively favorable conditions for education, as cooler weather can improve physical comfort and reduce health risks associated with heat stress (Lundgren et al. 2013). In these arid districts, lower nighttime temperatures might also alleviate daytime heat impacts, enabling better focus on education activities. Conversely, the northern districts show only small negative effects for the two-year lag of minimum temperatures, indicating a delayed impact and seeming to materialize over time, reflecting gradual economic and logistical consequences of prolonged exposure to cold conditions.

In central districts, however, minimum temperatures consistently exhibit positive effects across the current year, one-year lag, and two-year lag. These districts in Palestine frequently experience snowfall during winter (Ward, Learmont, and Ruckstuhl 2021; Issar and Zohar 2019). This pattern suggests that the climatic conditions in these areas might buffer against extreme minimum temperatures, and cooler weather may create optimal learning environments in education institutes, yet the fact that these districts face snowy winters more often, may make them more resilient against changes in minimum temperatures. Interestingly, Jericho reveals no significant effects of minimum temperatures on years of schooling. This result aligns with Jericho's generally stable and consistently high minimum temperatures throughout the year (Ighbareyeh et al. 2015), which likely do not fluctuate enough to create meaningful disruptions or improvements in educational outcomes. The climatic stability in terms of minimum temperatures in Jericho contrasts with the region's pronounced vulnerability to extreme maximum temperatures, emphasizing the unique and location-specific nature of climate impacts on education.

5. MECHANISM

To understand how climate change influences labor allocation in Palestine, particularly participation in the agricultural sector, we examine the mechanisms underlying the relationship between climatic conditions and labor market outcomes using a logit model. Table 6 presents the odds ratios (OR) of working in the agricultural sector in response to variations in climate indicators.

Table 6 Mechanism – The Effect of Climate Change on the Probability of Participation in the Agricultural Sector

Dep. Var. Working in Agriculture sector	(1) OR	(2) OR	(3) OR
Total annual rainfall (mm Std)	0.916***		
	(0.007)		
Total annual rainfall (mm Std)_1	1.029***		
	(0.008)		
Total annual rainfall (mm Std)_2	1.044***		
	(0.008)		
Average max. temp (°C Std)		1.404***	
		(0.041)	
Average max. temp (°C Std)_1		0.947**	
		(0.020)	
Average max. temp (°C Std)_2		0.972**	
		(0.013)	
Average min. temp (°C Std)			1.331***
			(0.022)
Average min. temp (°C Std)_1			0.949***
			(0.014)
Average min. temp (°C Std)_2			0.967***
			(0.010)
Constant	0.023***	0.022***	0.023***
	(0.001)	(0.001)	(0.001)

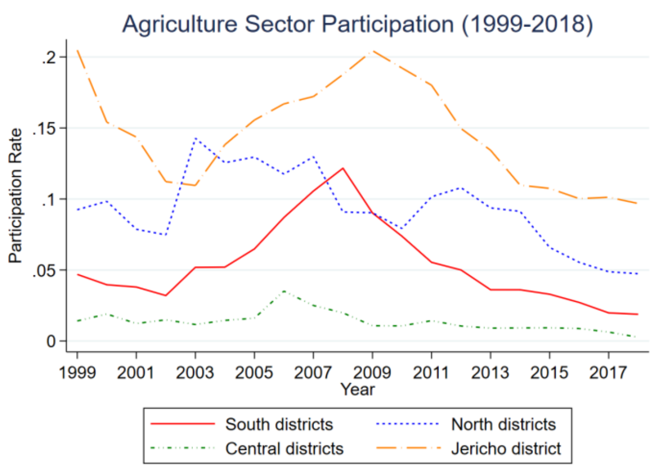
Observations	1,192,295	1,074,036	1,056,768
Pseudo RB2	0.227	0.230	0.230
Individual characteristics	YES	YES	YES
Year Fixed Effects	YES	YES	YES
Locality type	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results show that current total annual rainfall reduces the odds of participation in the agricultural sector in the current year (OR = 0.916, $p < 0.01$). In contrast, the lagged effects of rainfall are positive. A one-year lag (OR = 1.029, $p < 0.01$) and a two-year lag (OR = 1.044, $p < 0.01$) indicate a recovery period following climatic shocks. These results suggest that after periods of excessive rainfall, agricultural systems may stabilize, improving conditions for farming. Increased rainfall in prior years could enhance soil fertility and water availability, thus boosting labor demand and encouraging workforce re-entry into the sector; which in turn, increases agriculture households' income. Current-year maximum temperatures significantly increase the odds of working in the agricultural sector (OR = 1.404, $p < 0.01$). This effect may be attributed to increased agricultural demand due to higher temperatures driving the growing season or requiring more intensive irrigation and labor inputs. However, the lagged effects of maximum temperature are negative. The one-year lag (OR = 0.947, $p < 0.05$) and the two-year lag (OR = 0.972, $p < 0.05$) highlight a delayed adverse impact, potentially due to heat stress reducing crop yields or causing prolonged economic strain on agricultural households. These findings reflect the dual nature of temperature increases—short-term labor demand rises due to operational adjustments, while long-term stress undermines productivity and agricultural employment. Similar to maximum temperature, the current average minimum temperature increases agricultural sector participation (OR = 1.331, $p < 0.01$). Warmer nighttime temperatures may extend the growing season or reduce risks associated with cold stress on crops, thereby encouraging labor-intensive agricultural activities. Lagged effects reveal negative associations for the one-year lag (OR = 0.949, $p < 0.01$) and two-year lag (OR = 0.967, $p < 0.01$). These effects likely stem from cumulative crop stress or economic challenges resulting from prolonged climate variability. The observed relationships suggest that climate change impacts agricultural participation through immediate economic adjustments and longer-term productivity dynamics. In the short term, climatic variability, such as higher temperatures and improved water availability from rainfall, creates demand for agricultural labor. However, prolonged exposure to these conditions introduces economic and ecological stressors, reducing long-term viability and labor absorption capacity in the sector.

Figure 3 below illustrates participation rates in the agriculture sector from 1999 to 2018. The data reveals that Jericho has the highest participation rate in the agriculture sector, followed by the northern districts, then the southern districts, while the central districts show a minimal participation rate of approximately 0.01 percent.

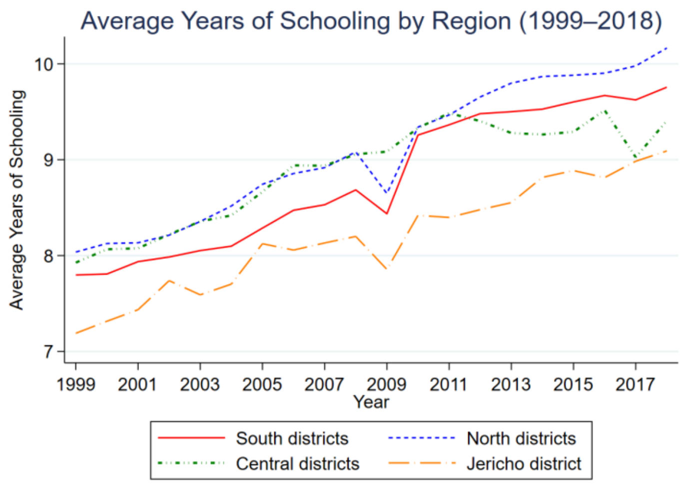
Figure 3. Participation in the Agriculture Sector Over the Period 1999–2018.



Source: Own calculations based on PLFS

In contrast, Figure 4 highlights the average years of schooling in each region of Palestine, with Jericho reporting the lowest average.

Figure 4. Average years of schooling by region over the period 1999–2018.



Source: Own calculations based on PLFS

This further supports our main findings that Jericho is significantly impacted by climate change due to its heavy reliance on agriculture. Thus, we argue that agricultural households in Palestine are highly vulnerable to climatic shocks, which, in turn, increases the vulnerability of girls in these households; climatic shocks negatively impact farming productivity and the overall working environment, exacerbating the challenges faced by these families.

6. CONCLUSION

This study provides empirical evidence on the impact of climate change on women's education in Palestine, revealing complex and region-specific relationships between climatic variables and years of schooling. Results indicate that excessive rainfall, extreme maximum temperatures, and variations in minimum temperatures have significant but heterogeneous effects on women's education across different regions and age groups. While rainfall can sometimes alleviate economic pressures and support education, extreme temperatures—particularly maximum temperatures—pose substantial barriers to school attendance and completion. The findings emphasize the importance of targeted interventions that address both immediate and lagged effects of climatic disruptions. Regional disparities highlight the need for context-specific policies: while southern districts display resilience, northern and central regions, along with

Jericho, require enhanced infrastructural and socio-economic support. Policies should focus on improving school infrastructure, particularly heating and cooling systems, as well as providing financial assistance to families affected by climate-induced economic shocks.

Further, addressing the intersection of gender, education, and climate change is crucial for building educational resilience in Palestine. This study shows the importance of integrating gender-sensitive strategies into climate adaptation and educational planning to ensure that progress in girls' education is not reversed by the growing impacts of climate change.

Competing interests:

The Authors declare none.

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APPENDIX

A1. Contextual Setting

The West Bank, as part of the Palestinian territories, presents a diverse and complex socio-economic and environmental landscape that significantly shapes its education sector and the vulnerabilities faced by different regions under the threat of climate change. This contextual setting explores the regional disparities in agriculture dependency, the structure and conditions of educational institutions, and how these factors interact with climatic and socio-political challenges to impact schooling outcomes.

In the central districts of the West Bank, which include Ramallah and East Jerusalem, the economy is primarily driven by services, administrative functions, and finance (UNDP 2016; Morrar and Gallouj 2016). These districts serve as economic and political hubs, with Ramallah acting as the de facto administrative capital of Palestine (Roy 2016). The presence of governmental institutions, non-governmental organizations, and international agencies provides better access to resources and infrastructure, including relatively well-equipped schools and universities compared to other districts in the West Bank. However, even in these urbanized districts, educational institutions are not immune to climate-related stressors. Schools often lack adequate heating and cooling systems, making them vulnerable to the rising frequency of heatwaves and cold spells[8] (Baba et al. 2024). Moreover, water scarcity—exacerbated by climate change and political restrictions on water resources—imposes additional pressure on school operations (UNICEF 2023; World Vision 2023). Universities, including Birzeit University near Ramallah, represent important centers of higher education and research, but they too face challenges due to the ongoing conflict and unstable socio-economic situation (Asi 2015). Moving northward, the districts of Tubas, Jenin, Tulkarm, Nablus, Qalqilya, and Salfit exhibit a mixed economic profile with moderate reliance on agriculture (UNDP 2017). These regions are often referred to as the agricultural heartland of the West Bank, with fertile lands supporting

[8] In 2023, the Palestinian Ministry of Education suspended schools across the occupied West Bank and Gaza Strip following the Emergency Committee's recommendation due to severe weather conditions. According to the Palestine Meteorological Department, the region experienced a deep depression accompanied by a polar air mass, leading to a significant drop in temperatures, strong winds, and heavy rainfall (MEMO 2023).

olive groves, citrus fruits, and vegetable farming. Agriculture not only serves as a key economic driver but also plays a significant role in the social fabric of these districts. Consequently, any climate-induced disruptions, such as erratic rainfall, prolonged droughts, or sudden heatwaves, have cascading effects on both household incomes and educational outcomes (Mason et al. 2012). In years of poor harvests, families may prioritize agricultural labor over schooling, particularly for boys, while girls are often expected to shoulder increased domestic responsibilities (Quisumbing and Pandolfelli 2010). Educational infrastructure in these districts varies widely, with urban centers like Nablus housing reputable universities, such as An-Najah National University, while rural schools often suffer from underfunding, overcrowding, and inadequate facilities (Hallaq 2024). These disparities highlight the uneven distribution of educational resources and the heightened vulnerability of students in these areas to climate shocks.

In the southern districts of Hebron and Bethlehem, the economic landscape is more diversified. Hebron, the largest city in the West Bank, combines agricultural activities with a robust manufacturing sector, particularly shoe production, glassblowing, and artisanal crafts (Hoja and Yu 2022). Meanwhile, Bethlehem heavily relies on religious tourism, attracting thousands of pilgrims annually (Selwyn and Isaac 2015). While agriculture remains significant in the rural outskirts of these districts, urban centers demonstrate a higher degree of economic resilience to climate-related shocks. However, the reliance on tourism and small-scale industries introduces unique vulnerabilities, as economic downturns caused by political instability or climate disruptions can have immediate and severe impacts on household income and, by extension, children's education. Schools in Hebron and Bethlehem face infrastructural challenges, with many facilities lacking proper insulation, ventilation, and cooling systems (Taqatqa 2023).

Jericho, located in the Jordan Valley, represents a distinct case within the West Bank. The district's economy is almost entirely dependent on agriculture, with date palm cultivation being the primary source of income for many households (Baker 2012; Trottier et al. 2020). The hot and arid climate of Jericho makes it exceptionally vulnerable to climate change, with rising maximum temperatures, prolonged droughts, and decreasing water availability posing existential threats to both agriculture and daily life (FAO 2008). These climatic pressures place immense strain on families, who often resort to pulling children out of school to contribute to agricultural labor or to reduce household costs. Schools in Jericho are among the most vulnerable in the West Bank, with poor infrastructure, limited resources, and inadequate adaptation measures to cope with extreme heat (Baba et al. 2023). Classroom conditions often become unbearable during peak summer months, leading to increased absenteeism and reduced academic performance, particularly among girls.

Across all districts, the education sector in Palestine operates under significant constraints, shaped by both political and environmental challenges. The West Bank is home to a mix of public, private, and UNRWA (United Nations Relief and Works Agency) schools, which together serve thousands of students across urban, semi-urban, and rural areas (Nuseibeh 2024). Public schools, which make up the majority of educational institutions, often face chronic underfunding, leading to overcrowded classrooms, insufficient teaching materials, and poorly maintained facilities (Hallaq 2024). Many schools lack basic amenities, such as adequate water supply, sanitation facilities,[9] and proper ventilation systems. These infrastructural deficiencies are further exacerbated by climate change, as extreme weather events place additional stress on already fragile school environments.

Universities in the West Bank, including Birzeit University, An-Najah National University, and Bethlehem University, play a critical role in higher education and research. These institutions have become important hubs for knowledge production and skill development, contributing significantly to Palestine's human capital (Sharabati-Shahin and Thiruchelvam 2013). However, universities are not insulated from the broader vulnerabilities faced by the region. Funding shortfalls, political restrictions, and infrastructural limitations hinder their ability to provide a stable and conducive learning environment (McGahern, 2024). Climate change introduces an additional layer of complexity, as rising temperatures and erratic weather patterns disrupt campus activities, strain resources, and increase operational costs (Moraci et al. 2020; Camacho 2009). The gendered dimensions of these challenges are particularly pronounced. Girls' education,

[9] At least 178 Palestinian schools face inadequate facilities, including poor infrastructure, insufficient sanitation units, a shortage of drinking water fountains, environmental hazards, and a lack of hygiene supplies. Source: "Improving Access to WASH Facilities and Increasing Hygiene Awareness in West Bank Schools". https://projects.hpc.tools/project/171338/view project number HPSE21-WSH-171338-1

despite significant strides in recent decades (Atef 2019), remains vulnerable to socio-economic shocks exacerbated by climate change (Yadav and Lal 2018). In households facing financial stress due to poor agricultural yields or economic disruptions, girls are more likely to be pulled out of school/university or assigned additional household responsibilities. Furthermore, cultural norms sometimes place a higher value on boys' education during times of crisis, intensifying gender disparities in educational attainment.

A2. General Certificate of Secondary Education (GCSE) Exam & Climate Change Indicators

We investigate the correlation between climate change indicators and passing rates of the General Certificate of Secondary Education (GCSE) exam, known in Palestine as Tawjihi; We utilized data from the Palestinian Ministry of Education, specifically district-level data on passing rates for the GCSE in Palestine. Table A1 presents the descriptive statistics.

Table A1 Descriptive Statistics - GCSE and climate change data

Variable	Obs	Mean	Std. Dev.	Min	Max
Year	182	-	-	2000	2018
District (Categorial)	182	-	-	1	50
Total annual rainfall (mm)	182	477.554	206.486	45.8	1012.8
Average max. temperature (°C)	182	24.184	2.982	18.346	33.19
Average min. temperature (°C)	182	14.863	1.746	9.775	20.245
Male Passing rates (GCSE)	182	.641	.1	.367	.841
Female Passing rates (GCSE)	182	.809	.076	.468	.973

Calculated by authors based on Palestinian Ministry of Education and the Palestinian Meteorological Department data.

This exploration focuses on three primary climate indicators: average annual rainfall, average maximum temperature, and average minimum temperature. In exploring the relationship between climate change and GCSE passing rates, we observe patterns that shed light on potential associations (See Tables A2 & A3 below).

Table A2 Pairwise correlations - Female Passing rates (GCSE)

Variables	(1)	(2)	(3)	(4)
(1) Total Annual rainfall	1.000			
(2) Maximum average temp	-0.432	1.000		
	(0.000)			
(3) Minimum average temp	-0.319	0.897	1.000	
	(0.000)	(0.000)		
(4) Female Passing rates (GCSE)	0.254	-0.183	-0.131	1.000
	(0.000)	(0.013)	(0.078)	

*** p<0.01, ** p<0.05, * p<0.1

Table A3 Pairwise correlations - Male Passing rates (GCSE)

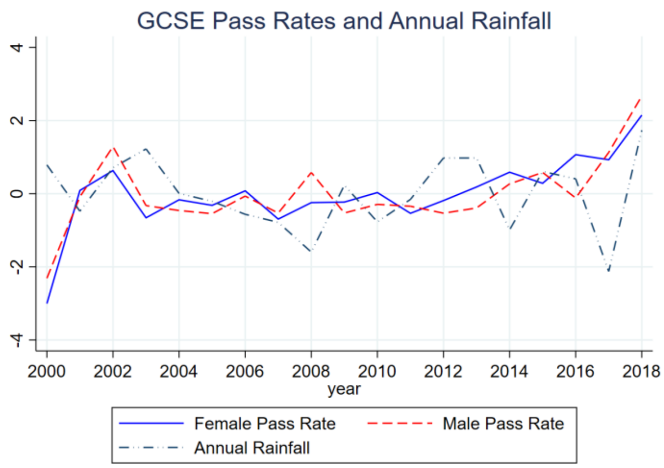
Variables	(1)	(2)	(3)	(4)
(1) Total Annual rainfall	1.000			
(2) Maximum average temp	-0.432	1.000		
	(0.000)			
(3) Minimum average temp	-0.319	0.897	1.000	
	(0.000)	(0.000)		
(4) Male Passing rates (GCSE)	0.208	-0.227	-0.146	1.000
	(0.003)	(0.002)	(0.049)	

*** p<0.01, ** p<0.05, * p<0.1

Total annual rainfall appears to have a modest positive correlation with both female and male passing rates. Conversely, maximum and minimum temperatures exhibit negative correlations with passing rates for both genders, indicating that higher temperatures might be associated with marginally lower success in exams.

The aim is not to draw causal conclusions but to provide descriptive analysis into how fluctuations in these climate variables align with changes in an important educational outcome. This contextual analysis serves as a backdrop for understanding the potential influence of climate variability on education. While these relationships are not the central findings of this study, they provide valuable descriptive support to the broader discussion on how climate change interacts with education

Figure A1 Correlation between GCSE passing rates and average annual rainfall (standardized values).

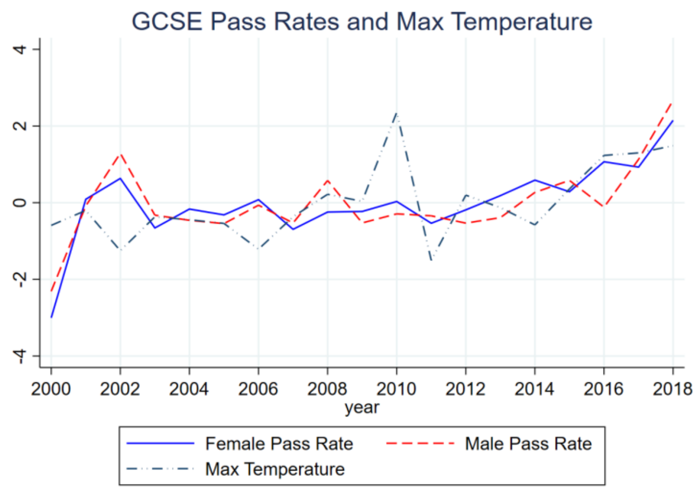


Source: Own calculations based on Ministry of education and Palestinian metrological department data.

Figure A1 above presents the correlation between GCSE passing rates for males and females and average annual rainfall, using standardized values. The trends indicate a dynamic and correlated relationship, where changes in rainfall levels are to some extent associated with shifts in passing the test. As the years progress, the connection between rainfall and passing rates appears to stabilize somewhat, though certain patterns persist. A striking example occurs from 2016 to 2018, where a marked increase in rainfall aligns with a significant rise in both male and female passing rates. Interestingly, the figure shows that male and female passing rates generally follow similar trends, suggesting that rainfall impacts both genders in comparable ways. However, during specific periods, such as 2016–18, male passing rates exhibit a slightly steeper increase compared to female rates, indicating potential differences in how climatic conditions influence academic outcomes.

Figure A2 below presents the relationship between GCSE passing rates and maximum annual temperatures.

Figure A2 Correlation between GCSE passing rates and average maximum temperature (standardized values).

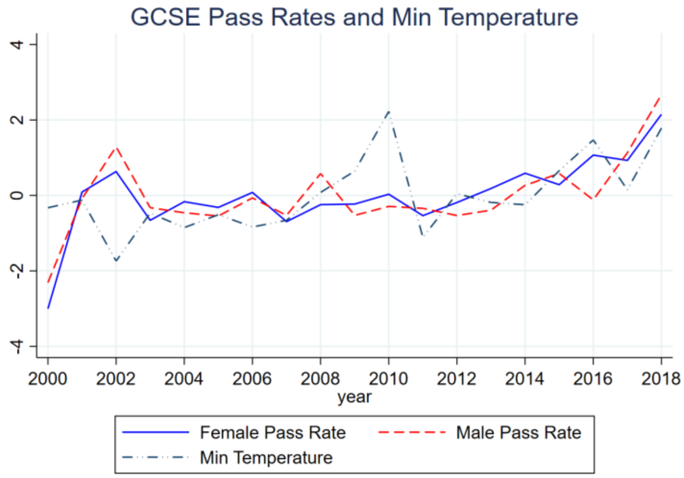


Source: Own calculations based on Ministry of education and Palestinian metrological department data

The trends suggest a complex interplay where fluctuations in maximum temperatures appear to influence the passing rates to some degree. Over the years, there is an apparent pattern where periods of higher maximum temperatures correlate with increases and sometimes decreases in both male and female passing rates.

On the other hand, Figure A3 below illustrates the relationship between GCSE pass rates and minimum annual temperatures.

Figure A3 Correlation between GCSE passing rates and average minimum temperature (standardized values).



Source: Own calculations based on Ministry of education and Palestinian metrological department data

The data presents a view of how these variables have evolved over time. Initially, between 2000 and 2003, both male and female pass rates exhibit a consistent upward trend. However, from 2004 to 2008, pass rates stabilize, despite the continued rise in minimum temperatures, suggesting a decoupling of these variables during this period. Also, from 2012 to 2018, there is a clear upward trajectory in both pass rates and minimum temperatures, indicating a potential correlation. Gender comparisons show that female pass rates generally outperform those of males.

3. Heterogeneity Analysis by Age Groups

Table A4 Heterogeneity Analysis: Impact of Average Maximum/Minimum Temperature on Years of Schooling by Age Groups

Dep Var: Years of Schooling	Age < 23			Age > 23		
	(1)	(2)	(3)	(4)	(5)	(6)
Total annual rainfall (std)	0.003			0.041***		
	(0.007)			(0.011)		
Total annual rainfall (std)_1	0.017***			0.030***		
	(0.006)			(0.010)		
Total annual rainfall (std)_2	0.007			0.028***		
	(0.006)			(0.010)		
Average max. temperature (°C Std)		-0.069***			-0.104***	
		(0.019)			(0.033)	
Average max. temperature (°C Std)_1		-0.046***			-0.082***	
		(0.016)			(0.030)	
Average max. temperature (°C Std)_2		-0.019*			-0.069***	
		(0.011)			(0.018)	
Average min. temperature (°C Std)			-0.039***			-0.011
			(0.011)			(0.019)
Average min. temperature (°C Std)_1			0.002			-0.024
			(0.010)			(0.018)
Average min. temperature (°C Std)_2			-0.020**			-0.048***
			(0.009)			(0.014)
Constant	-14.458***	-14.426***	-14.534***	17.079***	17.204***	17.129***
	(0.111)	(0.117)	(0.117)	(0.069)	(0.079)	(0.074)
Observations	216,254	194,624	191,858	357,474	322,544	316,893
R-squared	0.721	0.724	0.721	0.601	0.606	0.604
Controls	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A4 above provides further insight into the heterogeneity of climatic impacts by age group, specifically comparing women below 23 years of age and those above 23 years of age.

For total annual rainfall, younger women (younger than 23 years) exhibit no significant relationship with current-year and two-year lag rainfall, indicating limited immediate disruptions in their schooling. However, the one-year lagged effects are significant, with a positive impact observed for one-year ($\beta = 0.017$, $p < 0.01$). This suggests that younger women might benefit from recovery efforts or adaptive measures implemented after adverse weather conditions. Women (older than 23 years), on the other hand, show significant positive effects for current-year rainfall ($\beta = 0.041$, $p < 0.01$) and even stronger effects for one-year ($\beta = 0.030$, $p < 0.01$) and two-year ($\beta = 0.028$, $p < 0.01$) lags. This pattern indicates that older women, who might be less directly dependent on parental decision-making, are better positioned to capitalize on favorable conditions following rainfall.

For average maximum temperature, younger women experience significant negative effects in the current year ($\beta = -0.069$, $p < 0.01$), one-year lag ($\beta = -0.046$, $p < 0.01$), and two-year lag ($\beta = -0.019$, $p < 0.1$). These results suggest that extreme heat disrupts their immediate education environment and has prolonged adverse effects. For older women, the negative effects are even more pronounced. Current-year maximum temperature reduces schooling ($\beta = -0.104$, $p < 0.01$), with similar impacts for one-year ($\beta = -0.082$, $p < 0.01$) and two-year ($\beta = -0.069$, $p < 0.01$) lags. This highlights the compounding vulnerability of older women, who might face additional economic or health-related pressures during extreme heat events.

For average minimum temperature, younger women show a significant negative effect for current-year and two-year lagged impacts, while one-year lagged effects are insignificant. While older women exhibit an insignificant effect for both the current year and one-year lag, the two-year lagged effect is negative and significant.

4. Additional Results

To further investigate the effect of climate change on girls' years of schooling, we utilized a logit model to estimate the effect of climate change indicators on the likelihood of girls failing to complete a year of education. This analytical approach allows us to capture the probabilistic relationship between environmental factors and another educational outcome. Therefore, this analysis aims to provide insights into the pathways through which climate change affects educational attainment, with particular attention to gender-specific vulnerabilities. Equation (A1) below presents the model use for the mechanism:

$$Log\left(\frac{P}{1-P}\right) = \alpha_0 + \beta_1 \text{ indicator}_{jt} + \beta_2 \text{ indicator}_{jt-1} + \beta_3 \text{ indicator}_{jt-2} + \gamma X_{ijtk} + \delta_j + \lambda_t + \epsilon_{ijtk} \quad \text{(A1)}$$

Where P represents a binary outcome variable indicating one, if a female attended school but never completed (left) and zero otherwise; the rest of the equation is similar to equation in the main manuscript.

To explore the underlying mechanism, we utilize a similar specification to Equation (4), with the outcome variable replaced by a binary indicator denoting whether an individual is employed in the agriculture sector. This approach enables us to analyze the impact of climate change on the likelihood of employment within the agriculture sector.

The results in Table A5 below present how climate variables affect the likelihood of women failing to complete a year of education.

Table A5 additional results - Impact of Climate Change Indicators on Women's School Completion

Dep. Var. Attended school but never graduated	(1) OR	(2) OR	(3) OR
Total annual rainfall (std)	0.962***		
	(0.006)		
Total annual rainfall (std)_1	0.972***		
	(0.006)		
Total annual rainfall (std)_2	0.979***		
	(0.006)		
Average max. temp (°C Std)		1.137***	
		(0.023)	
Average max. temp (°C Std)_1		1.102***	
		(0.020)	
Average max. temp (°C Std)_2		1.046***	
		(0.012)	
Average min. temp (°C Std)			0.933***
			(0.011)
Average min. temp (°C Std)_1			0.964***
			(0.011)
Average min. temp (°C Std)_2			0.985*

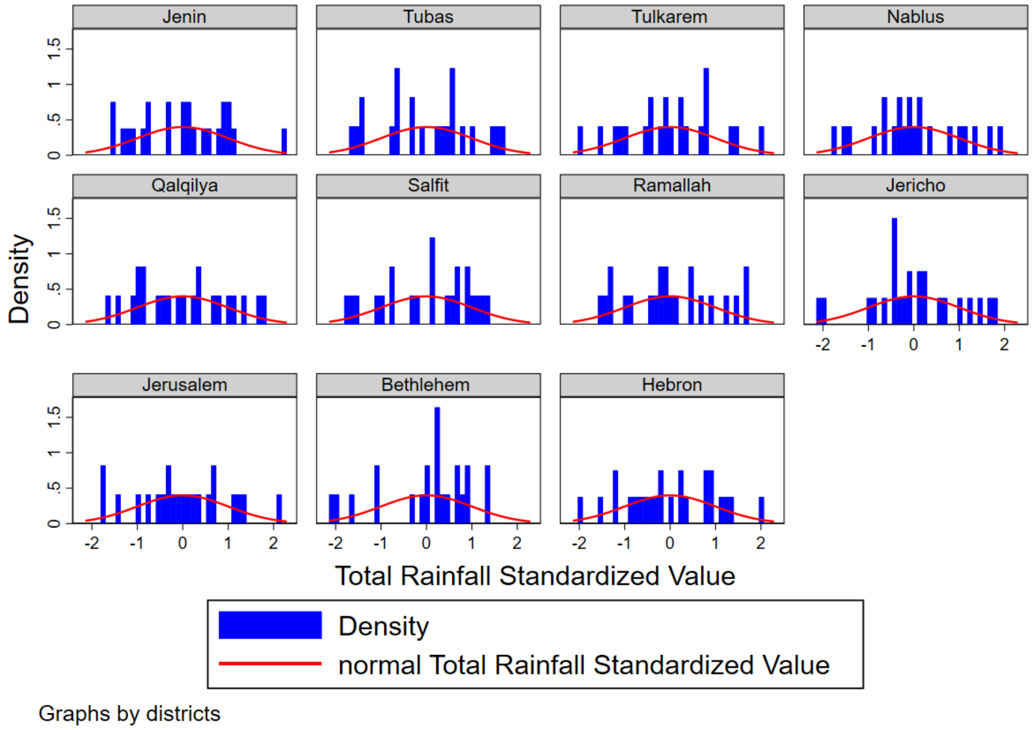
			(0.008)
Constant	0.021***	0.020***	0.026***
	(0.001)	(0.001)	(0.001)
Observations	587,067	529,167	520,586
Pseudo RB2	0.285	0.275	0.276
Individual characteristics	YES	YES	YES
Year Fixed Effects	YES	YES	YES
District Fixed Effects	YES	YES	YES
Locality type	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Column (1) shows that higher total annual rainfall reduces the odds of non-completion, with odds ratios (OR) for the current year (OR = 0.962, $p < 0.01$), one-year lag (OR = 0.972, $p < 0.01$), and two-year lag (OR = 0.979, $p < 0.01$) suggesting that rainfall may mitigate educational disruptions, possibly by alleviating economic pressures on households that depend on agriculture.

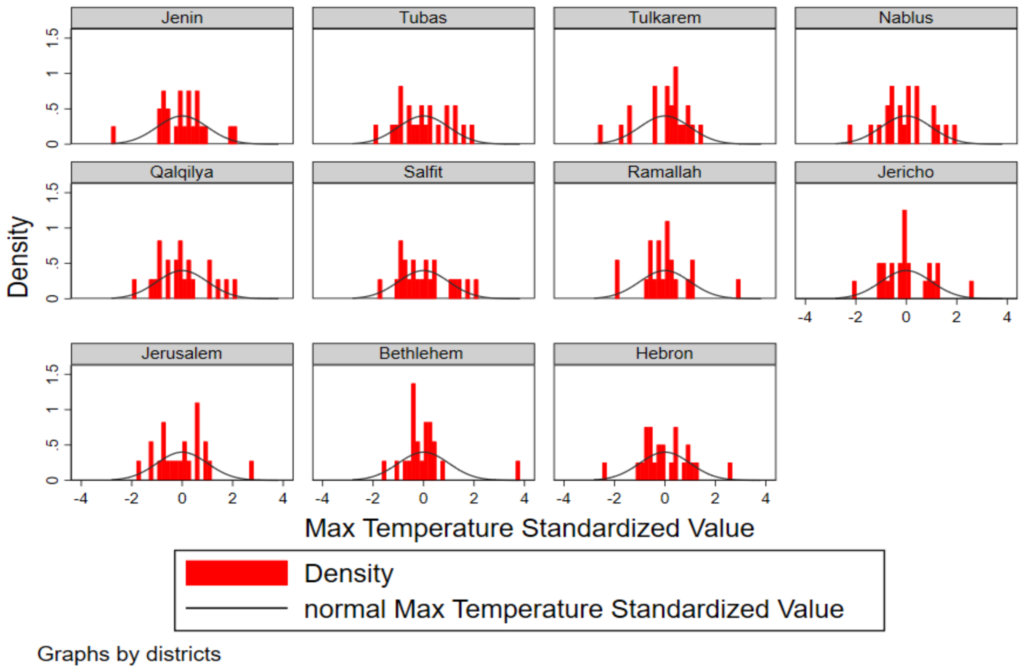
Conversely, maximum temperatures increase the likelihood of school non-completion (OR = 1.137, $p < 0.01$), with sustained impacts in lagged years. These results highlight the adverse effects of heat on educational persistence for women. Minimum temperatures exhibit a protective effect, reducing the likelihood of non-completion (OR = 0.933, $p < 0.01$), though these effects diminish over time. The results linking climate change to women's education operates through a combination of economic, social, and infrastructural pathways. First, economic disruptions caused by extreme weather events—such as reduced agricultural productivity during droughts or crop damage from excessive rainfall—place additional financial strain on households, often resulting in school dropouts for girls who are expected to contribute to household labor or income generation. Second, climate-induced disruptions to school infrastructure, including damaged buildings and lack of proper heating or cooling systems, create uncomfortable and unsafe learning environments. Third, socio-cultural norms in Palestine often prioritize boys' education over girls' during times of economic hardship, intensifying gender disparities in educational attainment. These interconnected pathways demonstrate how climate change exacerbates pre-existing vulnerabilities, showing the need for integrated interventions that address economic stability, infrastructure resilience, and cultural barriers simultaneously.

Appendix Figure B.1: Total Annual Rainfall in (Standardized Value) per West Bank Districts Over the Period 1999–2018



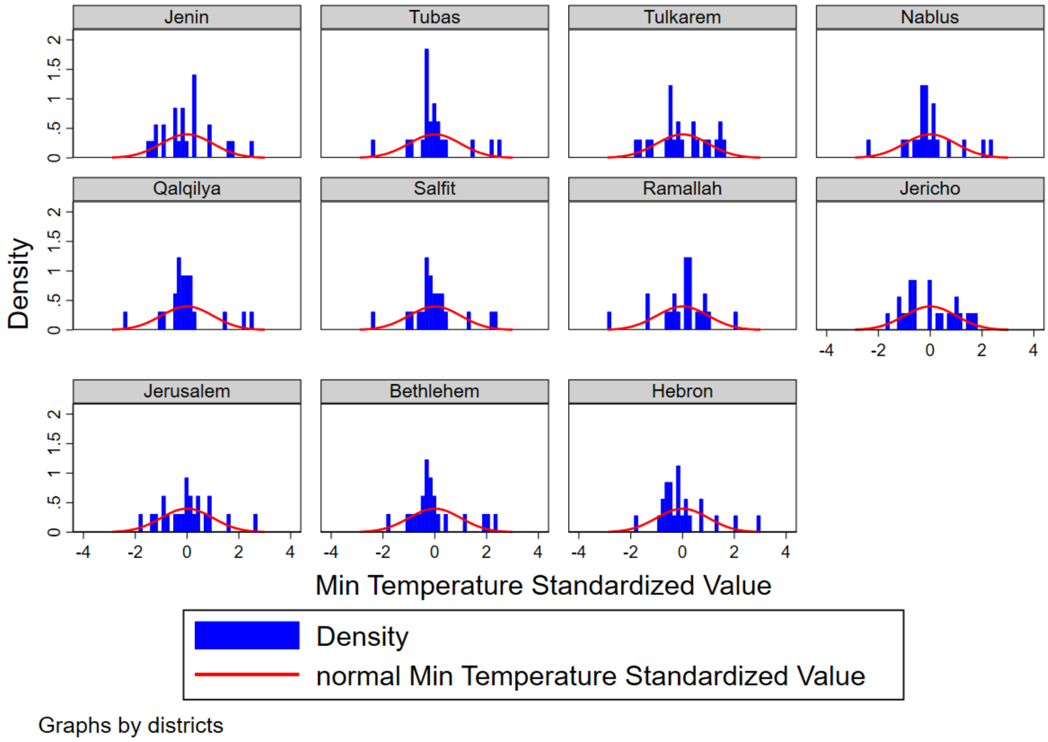
Source: Own calculations based on PCBS data.

Figure B.2: Average Maximum Temperature (Standardized Value) per West Bank Districts Over the Period 1999–2018



Source: Own calculations based on Palestinian Meteorological Department data.

Figure B.3: Average Minimum Temperature (Standardized Value) per West Bank Districts Over the Period 1999–2018



Source: Own calculations based on Palestinian Meteorological Department data.

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