Rain and time use in Bangladesh: does rain reduce gender gaps?

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Abstract

Climate change is intensifying, affecting human lives and activities globally, especially in developing countries. While heavy monsoonal rainfall, leading to flooding, is a widely studied shock the impact of dry-season rainfall remains under-researched. This study examines the effects of dry-season rainfall on time-use patterns across gender and vulnerable groups. Our study draws on data from over 32,000 individual time-use diaries from Bangladesh Time Use Survey 2021, which was merged with high-resolution satellite rainfall data. Using exogenous variation in daily rainfall during January-April 2021, when rainfall is historically minimal and unexpected, we employ Tobit models to estimate its effects on time allocation across five activity domains. The results indicate that an additional millimetre of rain reduces time spent on economic activities by more than 2 hours monthly, representing substantial time losses equivalent to 27 work hours lost annually per person, and an increase in leisure time by about an hour every month. Rainfall also reduces gender gaps in paid work by 2.2 hours/month. However, this reduction occurs because men reduce their own work time rather than women increasing their own. Traditional gender differentials in household activities remain unchanged. Heterogeneity analysis reveals that individuals with no formal education, poor households, and agricultural families experience the largest disruptions, with poor agricultural households losing about 7 hours/month of economic work for an additional millimetre of rain. These findings highlight that climate vulnerability extends beyond extreme events and disasters to reveal that even modest weather variations affect the already vulnerable populations.

Keywords: Time allocation, gender gaps, rainfall shocks, Bangladesh

JEL category: J22, J16, Q54, C24

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1. Introduction

Human-induced climate change has intensified extreme weather events, causing widespread adverse impacts globally. Between 1993 and 2022, these events claimed over 765,000 lives and resulted in nearly USD 4.2 trillion in losses (Germanwatch, 2025). While research has focused on climate change's effects on health and economic output (Paavola 2017; Kolstad & Moore, 2020; Hall & Crosby, 2022; Hernandez & Madeira, 2022), less attention has been paid to how it reshapes the allocation of time across daily activities. Time is an extremely scarce resource an and equal budget of 24 hours is available to all humans. Individuals adapt to climate shocks by reallocating time across activities like work, care, household chores and rest. This can have significant effects on economic status and quality of life. Focusing merely on productivity losses, therefore, overlooks this invisible yet crucial dimension of adaptation. Moreover, time reallocation in response to weather shocks also sheds light on the immediate behavioural responses and underlying gender mechanisms of the society. An investigation of the effect of exogenous weather shocks on time use activities is, therefore, an important yet under-researched area.

Existing literature on the impacts of weather shocks on time allocation has focused primarily on developed countries (Kruger & Neugart,2018, Nguyen et al., 2021). There is a scarcity of such studies for LMICs, despite the knowledge that these regions face disproportionate climate risks (Hallegatte et al., 2016; Germanwatch, 2025). Bangladesh, the focus of our study, is especially vulnerable to extreme weather events such as floods and cyclones (Islam et al., 2014; Dastagir 2015; Ahmed et al., 2021). Moreover, it has a large informal economy and deeply entrenched patriarchal norms with gender biases yet also has a strong micro-credit movement potentially empowering women (Kabeer, 2001; Kapsos, 2008; Chowdhury, 2009; Asian Development Bank, 2010; Hossen, 2020). Therefore, understanding how weather extremes reshape time use under these conditions is crucial for policy formulation.

The relation between weather shocks and time allocation across daily activities is complex and depends on weather conditions of the day (Zivin & Neidell, 2014; Connolly, 2018). On extremely hot days, time spent on paid work reduces, especially for those in climate exposed sectors like agriculture and construction (Zivin & Neidell, 2014; Connolly, 2018; Neidell et al., 2021). Time spent on leisure is also affected, with substitution occurring from outdoor to indoor leisure activities during temperature extremes (Zivin & Neidell, 2014). Though women face substantial reduction in their time on paid work relative to men, the time spent on traditional home- based activities remain the same even on hot days (Jiao et al., 2020; Garg et al., 2020; Torres-Higuera, 2024). This highlights that time allocation in response to a weather extreme is not gender-neutral. Moreover, weather shocks increase the vulnerability of a woman as she has to simultaneously bear climate stress along with the "double-burden" of paid work and house chores.

Rainfall, too, is an important weather shock that disrupts the time use pattern of an individual. Unlike temperature which increases gradually, rainfall may be seen as a sudden shock, especially during the dry season. Excessive rainfall often leads to damage of infrastructure and physical assets, and reduction in economic activity especially in developing countries (Brown et al., 2013; Damania et al., 2020; Frame et al., 2020; Newman & Noy, 2023). It also results in the increase in vector- borne diseases, cognitive under-development, and effects travel and activity scheduling decisions (Chen & Mahamassani, 2015; Carlton et al., 2024; Pazos et al., 2024). Previous research on time use has documented that time spent on work increases on rainy days and time is substituted away from leisure towards work (Connolly, 2008). Studies have also showed that excess rain lowered the time spent on water collection by mothers and reduced the women's time spent attending educational institutes (Boyd, 2023; Maitra & Tagat, 2024). Research has also shown that excess rain causing floods in Bangladesh have increased women's leisure time and reduced their time on domestic work (Vitellozzi & Giannelli, 2024).

Our present work differs from the existing studies in several ways. Firstly, existing research in Bangladesh have studied the effect of excess rainfall shocks causing floods during monsoons (Vitellozzi & Giannelli, 2024), a period, when heavy rain and subsequent flooding is anticipated with households having long adapted behavioural strategy (Azad & Pritchard, 2023; Himel et al., 2025). Our study, on the other hand, focuses on dry season rain (January to April, 2021) when precipitation is unexpected and exogenous. This distinction is important because rain during dry season may generate unexpected disruptions with fewer adaptive responses available. Additionally, our approach of focussing on the effect of rainfall variations during the dry season eliminates anticipation effects, pre-existing seasonal adaptation strategies, and knowledge spill overs from existing coping mechanisms. Secondly, we match daily rainfall satellite data (averaged at the district level) with individual time use diaries. This enables us to capture immediate disruptions and detect short-run substitution patterns across multiple activity domains (paid work, leisure, household production, housework, and childcare). Our identification strategy isolates immediate behavioural responses from longer-term adaptations. Thirdly, our study also reveals that rain reduces gender gaps in time allocation for paid work through direct disruptions. Lastly, we map heterogeneity in time allocation by important socio-economic factors like educational status of the individual, their wealth level and income type of the household. This enables us to identify who are the worst affected in the population.

To bridge the gaps in the literature we investigate the effect of rain during dry season on time reallocation across multiple activity domains. In line with our main research question, we frame the following hypotheses:

H1: Rain reduces time spent on economic activities, with the time 'saved' being reallocated to leisure activities

H2: Rain reduces the gender gap in time allocation across activities

H3: The impact of rain on time spent on economic activities varies across different socio-economic variables (education level, wealth, and income source of the household)

Our study employs individual-level time use data collected from time use diaries of over 32,000 individuals aged 15 years or more covered in the Bangladesh Time Use Survey 2021. This is a nationally representative survey covering all 8 divisions and a first of its kind to be conducted by the Bangladesh Bureau of Statistics and United Nations Women. Using econometric models that account for spikes in the distribution of time use at zero, we find that even a modest amount of rainfall in the dry season can disrupt an individual's time use pattern. With 1 mm increase in daily rainfall individuals reduce 4.5 minutes of their daily time on paid work and reallocate a greater part (2.4 minutes) of the 'saved' time to leisure. Rainfall reduces the gender gap in paid work by 4.4 minutes, not because women increase their time on paid work but because rainfall forces men to reduce their own. We also find that rainfall has an inequitable effect as it aggravates pre-existing vulnerabilities.

The rest of the paper is organized as follows. In Section 2 we present details on the different data sets that we use in our study and describe how we merge our rainfall data with individual time use data. We also describe the methodology of our study including the estimation framework and key regression specifications. Our results are presented in Section 3. In Section 4 we discuss the results and finally Section 5 concludes.

2. Data and methodology

We employ two datasets for our analysis. They are (a) Bangladesh Time Use Survey 2021 and (b) CHIRPS satellite data for recording daily rainfall at the district level.

2.1 Bangladesh time use survey data

The data on time allocation to different activities was taken from the nationally representative Bangladesh Time Use Survey 2021, conducted by the Bangladesh Bureau of Statistics (BBS) and United Nations Women. The survey was conducted during the first four months of the year (January-April 2021). The survey employed a two-stage stratified sampling design covering all eight divisions, with 8,000 households randomly selected. In total, 32,343 individuals were surveyed, providing the first large-scale dataset on daily time allocation in Bangladesh. Two complementary instruments were used: (i) a household questionnaire that collected demographic and socioeconomic characteristics of all respondents, and (ii) individual time diaries for all household members aged 15 years and above. The time diary followed the internationally standardized 24-hour recall method (4:00 AM–4:00 AM) and allowed respondents to report up to three simultaneous activities. Activities were coded using the International Classification of Activities for Time Use Statistics (ICATUS 2016) and were grouped into nine broad categories which are- paid work, unpaid domestic work, unpaid care, volunteer work, learning, socializing, leisure, self-care, and maintenance. Since the data and questionnaire were ethically approved by the respective institutions it eliminated the need for additional ethical clearance for our study.

2.2 Rainfall data

We obtain the daily rainfall data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), a high-resolution (0.05°; ~5.3 km) satellite–gauge blended product. CHIRPS integrates infrared satellite imagery with in-situ station observations to generate bias-corrected rainfall estimates. Using Google Earth Engine, we extracted daily rainfall for all 64 districts of Bangladesh from December 31, 2020 to May 1, 2021, covering the survey reference period. District-level rainfall was computed by spatially averaging CHIRPS grid cells within district boundaries (defined using FAO Global Administrative Unit Layers, GAUL 2015, level 2). This dataset provides exogenous, high-frequency variation in weather shocks that can be directly linked to individuals' daily time diaries. Its fine spatial resolution minimizes measurement error relative to coarse station-based datasets.

2.3 Merged data

To study the effect of rainfall shocks on daily time allocation, we merged the district-level rainfall data with individual time use diaries. Each individual observation in the time use survey contains information on the survey date and district of residence. We matched daily rainfall for the corresponding district for the previous day to each individual's time diary, creating a dataset that links daily rainfall variation with time use reported. This procedure ensures that all individuals in the same district and on the same survey date are assigned the same rainfall value, while maintaining variations across both districts and days provides exogenous rain shocks. The final merged dataset contains 32,149 individuals- their time diaries linked to the contemporaneous daily rainfall in their district. This dataset forms the basis for all our subsequent analyses.

2.4 Variables

2.4.1 Dependent variables

Our analysis examines time allocation across five mutually exclusive activity domains, measured in minutes per day from 24-hour time diaries. These are:

1) ECON: Time spent on paid, economic, market-related activities including employment, business operations, and income-generating tasks
2) HHPROD: Time devoted to household production involving non-market productive tasks that contribute to household welfare, such as food processing, crafts, and subsistence activities
3) HHWORK: Time allocated to household work including general domestic chores including cleaning, cooking, laundry, and home maintenance
4) CHILD: Time spent on care and direct supervision of children, including feeding, teaching, and accompanying them
5) LSC: Time devoted to leisure, rest, social, entertainment, and discretionary activities

2.4.2 Variable of interest

We have two variables of interest which are as follows:

1) RAIN: Daily rainfall measured in millimetres at the district level, derived from CHIRPS satellite data with 5.3 km spatial resolution. Each individual's time diary is matched to the rainfall recorded in their district on the day preceding the survey.

2) FEMALE: Binary indicator to record the gender of respondent where 0 = male and 1 = female

2.4.3 Covariates

The other control variables and their description, taken at the individual level, are provided in Table 1.

Table 1: Details of control variables

Acronym	Nature	Description
AGE	Continuous	Age of the individual
EDU	Categorical	Education level where 0= no formal education, 1= primary, 2= secondary and 3= above secondary
MSTAT	Categorical	Marital status where 0= unmarried and 1= married
HHSIZE	Continuous	Household size
CHILD06	Continuous	No. of children below 6 years in each household
RELIGION	Categorical	Religion where 0= Islam and 1= religious minorities
LWSCORE	Continuous	Logarithm of wealth score
CFUEL	Categorical	Clean fuel where 0= biomass-based cooking fuel and 1= clean cooking fuel
NIGHTLIGHT	Continuous	Nightlight intensity measured by the Visible Infrared Imaging Radiometer Suite (VIIRS)
RAMADAN	Categorical	Whether survey day was Ramadan, 0= normal day, 1= Ramadan observed

2.5 Empirical specification

2.5.1 Rainfall shocks and time allocation across activities

To estimate the effect of rainfall on time allocation across different activities, we employ a Tobit model (with left censoring at zero). This is because there are many respondents who report zero minutes spent on a particular activity. Therefore, the time allocated on a particular activity is specified as:

$$T_{it} = \beta_0 + \beta_1 RAIN_{it} + \beta_2 FEMALE_i + \beta_3 (FEMALE_i \times RAINit) + \beta_4 X_i + \varepsilon_{it} \quad [1]$$

Here, T_{it} is the observed time spent by individual 'i' on a particular activity on date 't.' $RAIN_{it}$ is the average rainfall (mm) in the individual's district, $FEMALE_i$ is the gender dummy, FEMALEi × RAINit captures the gender differentiated responses in time allocation due to rain. The vector Xi includes individual and household covariates. We use robust standard errors clustered at the primary sampling unit level. This was done to address the nested structure of the data as multiple households are sampled within each primary sampling unit, and multiple individuals are observed within each household. Our coefficients of interest are β_1 and β_3. β_1 captures the average effects of rainfall on time allocation across activities and β_3 measures how this gender gap changes due to rainfall.

2.5.2 Identification strategy

A key component of our identification strategy exploits rainfall variation during Bangladesh's dry season (January- April 2021), when precipitation is historically minimal and largely unexpected (Shahid, 2010; Das et al., 2021). Our empirical approach utilizes this random variation in daily rainfall across districts to identify its effects on time allocation. The critical identifying assumption is that daily rainfall variation during the survey period is plausibly exogenous to unobserved individual and household characteristics that independently affect time use patterns. This is because: (i) Conditional on our set of socio-demographic controls and time fixed effect factors (like Ramadan observance), daily rainfall fluctuations during the dry season are unlikely to be systematically correlated with individual time allocation preferences or constraints. (ii) Residential sorting based on short-term weather patterns is also unlikely in our context. This is because migration in Bangladesh is typically driven by seasonal labour opportunities or major environmental stresses (e.g., flooding), not daily weather fluctuations (Bryan et al., 2014; Call et al., 2017; Alam & Mamun, 2022). The dry season timing of our survey further minimizes concerns about weather-induced population movements. (iii) Anticipatory behaviour is unlikely to drive our results as time use decisions are based on weather conditions at the time of the survey rather than forecasts, especially given the digital divide and limited infrastructure and its lower adoption among rural women and poor in Bangladesh (Rashid, 2016; Rahman et al., 2022; Rahman et al., 2025; Sarker et al., 2025).

2.5.3 Heterogeneity analysis

To assess the differential vulnerabilities of rain on time allocation to paid work, we re-estimate the Tobit models separately across three important socio-economic variables which are:

1) Education level: no formal, primary, secondary, and above secondary education
2) Wealth groups: terciles of household wealth distribution (i.e., poor, middle, rich)
3) Income source of household: agricultural, non-agricultural (service and industry), and others (remittances and transfers)

This heterogeneity analysis reveals which socioeconomic groups face the greatest constraints in adapting their daily time use to unexpected rainfall shocks.

2.6 Software

Variable creation, descriptive statistics, and regression analysis were done using STATA BE version 18.

3. Results

3.1 Sample profile

For our analysis, we restrict the sample to working-age adults (18–59 years) who constitute most of the workforce. We did this because older adults typically have limited labour force participation due to retirement and health constraints, while children follow structured school schedules with minimal economic activity and limited autonomy in scheduling decisions. Both groups are therefore less likely to exhibit the labour market responses to unexpected weather shocks that are central to our analysis (Yu et al., 2010; Gracia et al., 2020). This makes them less suitable for examining paid and domestic time allocation responses. Therefore, our final estimation sample consists of 26,257 individuals (10,153 men and 16,104 women) from all 64 districts across Bangladesh's eight administrative divisions. Table 2 presents the demographic and socio-economic characteristics of our sample by gender and total. Highest percentage of the respondents in our sample, about 33%, are in the age group of 30-39. Roughly 38% of the females and 31% of the males have completed their secondary education and 87% of the respondents are currently married. Most of the respondents (30%) belong to a family having four members. 9% men and 8% women belong to religious minority groups. More than half of the respondents (about 53%) belong to households which are engaged in non-agricultural activities (service and industry). 31% of the respondents belong to the poorest wealth tercile whereas 35% to the rich tercile.

Table 2: Demographic characteristics of the sample by gender (male, female) and total

Socio-economic category	Male		Female		Total	
	Total	Percentage	Total	Percentage	Total	Percentage
Age of the respondent (by groups)						
18-29	2,534	24.958	5,491	34.097	8,025	30.563
30-39	3,103	30.562	5,498	34.141	8,601	32.757
40-49	2,774	27.322	3,140	19.498	5,914	22.524
50-59	1,742	17.158	1,975	12.264	3,717	14.156
Education level of the respondent						
No formal education	2,307	22.722	3,516	21.833	5,823	22.176
Primary education	2,894	28.504	4,207	26.124	7,101	27.044
Secondary education	3,105	30.582	6,160	38.251	9,265	35.286
Above secondary	1,847	18.192	2,220	13.785	4,067	15.489
Marital status of the respondent						
Currently unmarried	1,611	15.867	1,786	11.090	3,397	12.938
Currently married	8,542	84.133	14,318	88.910	22,860	87.062
Household size (by groups)						
1–3	1,969	19.393	3,686	22.889	5,655	21.537
4	3,153	31.055	4,817	29.912	7,970	30.354
5	2,410	23.737	3,765	23.379	6,175	23.518
6+	2,621	25.815	3,836	23.820	6,457	24.592
Religion						
Islam	9,237	90.978	14,790	91.841	24,027	91.507
Religious minorities	916	9.022	1,314	8.160	2,230	8.493
Income type of the respondent						
Agriculture	2,989	29.440	3,959	24.584	6,948	26.462
Non-agriculture	5,617	55.324	8,344	51.813	13,961	53.171
Others	1,547	15.237	3,801	23.603	5,348	20.368
Wealth group of the respondent						
Poor	3,151	31.035	4,981	30.930	8,132	30.971
Middle	3,502	34.492	5,453	33.861	8,955	34.105
Rich	3,500	34.473	5,670	35.208	9,170	34.924
Total respondents (N)	10,153		16,104		26,257	

3.2 Descriptive statistics

Summary statistics of time use categories for our study are provided in Table 3. On average, individuals spend 179 minutes (approximately 3 hours) per day on economic activities. There is however a wide variation in time spent on paid work across our sample. Routine domestic work also constitutes a major portion of an individual's time budget- time spent on household work averages 159 minutes, unpaid household production activities average 36 minutes per day and childcare activities average 45 minutes daily. However, leisure and self-care activities constitute the largest time category, averaging 356 minutes (nearly 6 hours) per day. These figures highlight the time use patterns across multiple activity categories.

Table 3: Summary statistics

Variable name	N	Mean	Min	Max
ECON	26257	179.088	0	940
HHPROD	26257	36.105	0	700
HHWORK	26257	159.392	0	810
CHILD	26257	44.839	0	870
LSC	26257	355.529	0	1030

Building on these overall averages, Table 4 breaks down time allocation by gender to highlight the substantial disparities in daily activity patterns between men and women. The results reveal a stark gender division in time use that reflects traditional household roles in Bangladesh. Men devote significantly more time to economic activities, over 6 hours per day, compared to just 61 minutes for women—a gap of over 5 hours daily. In contrast to this, women shoulder the overwhelming burden of unpaid domestic responsibilities: they spend 241 minutes on household work, nearly eight times more than men's 30 minutes, and 67 minutes on childcare compared to just 9 minutes for men. Leisure and self-care also show a gender bias, with men enjoying 12 minutes more than women despite women's heavier unpaid workloads. These pronounced gender differences in time allocation are all statistically significant at the 1% level, indicating systematic rather than random variation. The patterns align with broader evidence of gendered labour division in South Asian contexts, where women's economic participation remains limited as they bear primary responsibilities for domestic and care work (Islam & Sharma, 2021; Afrin & Saifullah, 2024; Sahu, 2024).

Moreover, Table 4 gives us nuances about gendered responses to rainfall. For economic work, we find the presence of rain-sensitive gender differences in the time allocated. On rainy days, men's economic work falls by 19.9 minutes, while that for women remains statistically unchanged. The contrasting weather responses suggest the existence of gendered occupational segregation i.e., men are predominantly in weather-exposed sectors (agriculture, outdoor labour, transport) whereas women are concentrated in weather-protected activities (home-based work, services, indoor manufacturing). We also see that rainfall has little impact on women's time allocation to household production or childcare, though their household work time declines modestly by 8.5 minutes on rainy days. Men, conversely, increase their time on household work by 4.5 minutes, indicating the redistribution of domestic roles when outdoor employment opportunities shrink. For leisure and self-care, both genders show adjustments-while men increase their leisure by 10 minutes, women increase theirs by 13 minutes. This reinforces our first hypothesis that time "saved" from economic work is absorbed into leisure.

Thus, our descriptive statistics highlight two important features: first, men's time on economic work is more sensitive to rainfall than women's, and second, that rainfall-induced shifts are largely absorbed into leisure rather than unpaid domestic work or childcare. These results set the stage for our regression analysis.

Table 4: Average daily time use (minutes) across activity categories by gender and rainfall condition

	Total			Males			Females		
Time use category	**Male**	**Female**	**Difference**	**Non- rainy day**	**Rainy day**	**Difference**	**Non- rainy day**	**Rainy day**	**Difference**
ECON	366.010	61.241	304.769***	370.802	350.869	19.933***	61.460	60.595	0.865
HHPROD	30.624	39.561	-8.937***	31.140	28.995	2.144	39.386	40.078	-0.692
HHWORK	30.063	240.930	-210.866***	28.982	33.477	-4.495***	243.072	234.615	8.456***
CHILD	9.406	67.178	-57.773***	9.469	9.204	0.265	67.686	65.683	2.003
LSC	362.700	351.008	11.692***	360.238	370.476	-10.238***	347.661	360.871	-13.211***

Source: estimated by authors

Note: ***denotes Prob<0.01

3.3 Effect of rain on time use

Now, to answer our first hypothesis (H1) which states that rain reduces the time spent on economic activities and increases time spent in leisure we look at Table 5. We find that with an additional 1 mm of rainfall the time spent on economic activities falls by 4.5 minutes. Time spent on leisure and self-care activities, due to 1 mm increase in rain, rises by 2.3 minutes. This suggests re-allocation of 'saved' time from economic activities to leisure and selfcare which confirms our first hypothesis. For other routine daily activities, like household production, household work and childcare, we find no significant impact of rain on time allocation.

Table 5: Impact of rainfall, gender, and their interaction on time allocation across activity domains

Variable	Coefficient	Std. err.	t	P>t	[95% Conf. Int.]	
RAIN						
ECON	-4.456	2.255	-1.980	0.048	-8.875	-0.037
LSC	2.352	1.096	2.150	0.032	0.203	4.501
LSC (OLS)	2.352	1.097	2.140	0.032	0.197	4.507
HHWORK	-0.088	1.224	-0.070	0.943	-2.487	2.311
HHPROD	-0.166	2.084	-0.080	0.937	-4.251	3.919
CHILD	0.019	1.094	0.020	0.986	-2.125	2.162
FEMALE						
ECON	-501.020	9.847	-50.880	0.000	-520.321	-481.720
LSC	-10.806	3.346	-3.230	0.001	-17.365	-4.248
LSC (OLS)	-10.789	3.347	-3.220	0.001	-17.365	-4.213
HHPROD	88.443	5.432	16.280	0.000	77.796	99.090
HHWORK	296.256	4.090	72.440	0.000	288.240	304.273
CHILD	158.106	4.442	35.590	0.000	149.399	166.813
FEMALE × RAIN						
ECON	4.411	2.625	1.680	0.093	-0.734	9.556
LSC	-0.167	1.066	-0.160	0.876	-2.255	1.922
LSC (OLS)	-0.167	1.066	-0.160	0.876	-2.261	1.927

Variable	Coefficient	Std. err.	t	P>t	[95% Conf. Int.]	
HHPROD	-1.050	2.289	-0.460	0.646	-5.537	3.437
HHWORK	-0.824	1.156	-0.710	0.476	-3.089	1.442
CHILD	-0.702	1.135	-0.620	0.536	-2.926	1.521

Source: Estimated by authors

3.4 Rain and gender gap

From Table 5, we also find that time spent on economic work by women is 501 minutes less vis-à-vis men. Women also spend 10 minutes less on leisure and self-care activities compared to men. However, women spend 88 minutes, 296 minutes and 158 minutes more compared to men on household production, household work and childcare. Our results underscore that gender biases exist even in the daily, routine tasks of the households.

We also find that rain reduces the gender gap in time allocation only in the case of economic work by 4.4 minutes. However, the narrowing of the gender gap is not because women increase their time spent on paid work but because rain forces the men to reduce their time on work. This is evidenced by the negative marginal effect of rainfall on economic activities combined with the positive coefficient of the interaction term. In rest of the activity categories, we find that, rain does not significantly alter the gender gap in time allocation. This suggests that rainfall primarily affects paid work, leaving the gender division of household and care responsibilities unchanged. This answers our second hypothesis (H2).

3.5 Heterogeneity analysis

Having established the average effects of rainfall on time use and gender gaps, we next explore whether these effects vary across important socioeconomic factors (like education level, wealth status, and household's income source) as outlined in our third hypothesis (H3). The results from Table 6 reveal that individuals with no formal education experience the largest reduction in paid work time of 7.2 minutes per mm (95% CI: -15.723, 1.323). Therefore, education appears to buffer the impact of rainfall on time loss, with higher education providing greater adaptive capacity against rain shocks. Across all education levels, women spend less time on economic work compared to men. The rainfall-gender interaction remains statistically insignificant across all education groups, indicating that education does not moderate how gender gaps respond to rainfall.

Table 6: Impact of rain on paid work by education level, wealth group and income source of household and for agricultural households across wealth groups

Variable	RAIN	FEMALE	FEMALE × RAIN	F statistic
EDUCATION LEVEL				
No Formal education	-7.200*	-478.079***	1.820	126.090***
Primary education	-4.784	-526.155***	8.195	210.290***
Secondary education	0.428	-526.155***	-4.215	158.090***
Above secondary	-4.182	-456.693***	1.170	55.760***
WEALTH GROUP				
Poor	-8.634**	-463.520***	5.859	158.340***
Middle	-7.945**	-494.564***	9.064**	117.330***
Rich	2.504	-571.652***	-2.654	178.460***
INCOME TYPE				
Agriculture	-11.779***	-371.302***	13.846***	119.410***
Non-agriculture	-3.595	-554.328***	2.193	228.920***
Others	1.023	-533.041***	-1.454	62.820***
WEALTH GROUP				
Poor	-14.273***	-385.002***	10.269***	60.230***
Middle	-23.238*	-367.232***	27.947*	69.430***
Rich	19.945*	-359.321***	-17.509*	48.740***

Source: Estimated by authors

Note: * denotes Prob<0.1; ** denotes Prob<0.05; *** denotes Prob<0.01

Wealth-based heterogeneity analysis reveals that poor and middle-income households bear the greatest burden from unexpected rainfall. Poor households experience an 8.6-minute reduction in economic work per mm of rainfall, while middle-income households face disruptions of 7.9 minutes. In contrast, wealthy households show resilience as no significant impact of rain was found. Importantly, the rainfall-gender interaction is significant only for middle-income households indicating that rainfall reduces gender gaps specifically among this group by 9 minutes. Moreover, across all wealth groups women continue to spend less time on paid work than men with the magnitude widening from the poor to the rich households.

From Table 6, we also find that, agricultural households face the most disruptions from unexpected dry-season rainfall, losing 11.8 minutes of economic work per mm. The rain-gender interaction effect is strongest and significant among agricultural households only, suggesting that rainfall substantially reduces gender gaps in paid work within farming communities by 13.9 minutes. Non-agricultural and households with other income source show minimal and insignificant effects.

The most vulnerable group occurs at the intersection of agriculture and poverty. Poor agricultural households experience the largest work time loss of 14.3 minutes per mm of rain, while middle-wealth agricultural households face even more severe disruptions of 23.2 minutes (95% CI: -50.218, 3.741). Strikingly, rich agricultural households show a completely different pattern. Their time spent on economic work *rises* by 19.9 minutes per mm (95% CI: -0.616, 40.506). The contrasting pattern may be due to access of better resources to rich households making them resilient to rain. Engagement in different roles in the agricultural sector as landowners, or in agricultural-allied activities may be another contributing factor. The gender effects are concerning as, among poor and middle agricultural households, rain shrinks the gender gaps by 10.3 minutes and 28 minutes respectively. This is because men lose more work time rather than women increasing their paid work time allocation. However, among rich agricultural households, rain widens the gender gap by 17.5 minutes likely because men increase their time spent on economic work while women do not benefit proportionally.

4. Discussion

Our results demonstrate that even modest amounts of dry-season rainfall significantly affect time allocation across activities. Rainfall reduces time spent on economic work and reallocates time towards leisure. That is because rain increases difficulties in performing outdoor tasks, causing disruptions in sectors like agriculture and construction, and influences worker productivity through increased physical discomfort or safety risks (Spencer & Urquhart, 2021; Sun et al., 2022; Larrson & Rudberg, 2023; Tian et al., 2023; Chen et al., 2025). Our results show a loss of 4.5 minutes per person per day, which is equivalent to a loss of 2.25 hours per person per month (as (4.5*30)/60 = 2.25 hours). While a loss of 4.5 minutes may appear modest in daily terms the cumulative effect is large: extrapolation to the national level and for a year reveals that 27 work hours are lost in a year per person (as work hours lost in a year per person is (4.5/60) * 365 which equals 27.375 hours or approximately 27 hours).

We also found that rain reduces the gender gap in time allocation for paid work only. On average, rainfall narrows the gender gap in economic work by 4.4 minutes per mm per day, which is equivalent to 2.2 hours per month (as (4.4*30)/60 = 2.2 hours). However, this reduction occurs not because women increase their work time, but because rainfall forces men to reduce their time allocation to economic activities. This is because in Bangladesh, male labour force participation substantially exceeds female participation with approximately 80% of men employed compared to only 43% of women (World Bank, 2024). This disparity means that rainfall-induced work disruptions disproportionately affect the gender that dominates the employment sector, especially climate exposed industries like agriculture and construction. Moreover, social norms limiting women's mobility, combined with inadequate transportation infrastructure, push many women towards home-based work within the informal sector which are less susceptible to unexpected rainfall shocks (Rahman & Islam, 2003; Rahman, 2005; Anjum & Daly, 2019). In contrast, the gender gaps in housework, household production, childcare, and leisure remain unaffected by rainfall, given by the statistically insignificant interaction term for these activity domains. Women's time allocation to activities like household production, housework and childcare is considered 'sticky' and does not significantly reduce due to rain as these activities are done indoors and are governed by rigid norms which stress on women's domestic roles irrespective of the weather conditions (Ciminelli et al., 2021; Islam & Sharma, 2021; Thakur & Reimeingam, 2022; Sahu, 2024). Thus, gendered social norms and occupational segregation are key drivers of the asymmetric impact of rain between men and women.

Our findings both complement and contrast with existing rain-time use studies. We find gender-differentiated responses to weather shocks, similar to Connolly (2008) in the US, but our results show the opposite pattern— time is allocated from paid work to leisure. This contrast is likely due to structural differences between developed and developing contexts. In developed countries, better infrastructure, and flexible jobs cushion rainfall shocks, whereas Bangladesh's daily wage and informal workers lack such buffers (Dasgupta et al., 2010; Mukherjee et al., 2023).

Unlike Vitellozzi and Giannelli (2023), who studied the impacts of monsoon flooding in Bangladesh, our dry-season identification reveals that even relatively mild rain can disrupt economic activity and reallocate time across activities. Their findings highlighted the large-scale gendered adjustments under extreme flooding. However, our results show that vulnerability is not confined to extreme climatic events like floods but can also emerge from unexpected shocks in routine daily variations. Thus, our results, complement the extreme weather literature by showcasing that climate vulnerability extends beyond major disasters and includes minor weather variations as well.

Our heterogeneity analysis reveals that vulnerability to unexpected rainfall shocks is unevenly distributed across Bangladesh's population. Individuals who are less educated, belong to poor wealth groups and come from agricultural households are the ones who bear disproportionately higher costs of unexpected rain. This pattern, however, aligns with other climate vulnerability research which show that adaptive capacity and resilience of humans is correlated with their socio-economic status (Tan et al., 2015; Levy & Patz, 2015; Murendo et al., 2023; Pinto et al., 2025). Poor agricultural households due to an additional millimetre of rainfall lose 14.5 minutes of their paid work time, equivalent to 7.15 hours of time loss per month (as (14.5 *30)/60 = 7.15 hours). Our results also show that while individuals from the bottom two wealth terciles of agricultural households reduce their time spent on paid work, the rich agricultural households increase their time on paid work. This maybe because rich agricultural households are landowners who manage supply chain managements, storage operations and are engaged in agricultural allied activities which get impacted due to unexpected rain leading them to increase their time on paid work (Akanda, 2014; Ahmed et al., 2024). Unlike them however, the farmers from the poor and middle wealth groups who work as manual labourers do not have access to improved resources and hence unexpected rain disrupts and lowers their time spend on economic activities. Thus, our analysis shows that, education, and wealth buffer the rainfall shocks, while agricultural dependence magnifies it—especially for poorer and middle wealth households. This unequal distribution of impacts underscores that vulnerability is structured by socioeconomic status.

Despite its findings our study has a few limitations. Firstly, as exact geo-location of respondents in Bangladesh Time Use Survey, 2021 was not given, we had to take district average of daily rainfall satellite data. This weakens our identification. However, despite using district-level data our results are statistically significant which suggest a strong and robust relationship. Secondly, the time during which the survey was conducted the second COVID pandemic wave was still ensuing. However, there were no lockdowns enforced so we argue that plausibly there was no systematic distortions in time allocation across activities. Thirdly, in our study we look at the immediate responses to rainfall and do not focus on the long-term adaptation mechanisms or repeated effects of rain shocks. This issue could have been addressed with the help of panel data following households over multiple seasons to reveal whether short term disruptions translate into long term welfare losses. However, no such data was available. Fourthly, our study does not identify seasonal migrants who are significantly affected by weather conditions. Lastly, presence of unobserved heterogeneity like availability of local infrastructure and informal coping networks could not be taken into our study due to unavailability of such a rich dataset.

Addressing such limitations would deepen the understanding of rain-time use relation. Moreover, examining how this relation varies across dry and wet season, analysing the role of social networks, infrastructural investments, and social protection programs as coping strategies could also serve as a promising avenue for future researches.

5. Conclusion

As climate change intensifies variations in weather globally, understanding how households, especially in developing countries, adapt their daily lives to unexpected weather shocks is becoming crucial for development policy formulation. Our study shows that even fairly low amount of unexpected rainfall during dry season can affect welfare and gender equity through time allocation pathways across different daily activities. Rainfall reallocates time from economic activities towards leisure, resulting in work hour losses that aggregate to substantial welfare costs—approximately 27 work hours lost per person annually. While rainfall does reduce gender gaps in paid work, it occurs by forcing men to reduce work time rather than expanding on women's work opportunities. The costs of dry season rain are disproportionately higher for the already vulnerable sections of the population—the less educated, poor and agricultural households. Therefore, climate adaptation policies should be targeted to these people explicitly rather than being universal in nature. Investing in rural infrastructure like building roads, improving drainage systems, providing covered workspaces and resilient transportation systems could help the vulnerable people to sustain their work activities even during unexpected weather disruptions. Governments could introduce social protection mechanisms against weather shocks in the form of cash transfer programs, off-farm work opportunities and employment guarantee especially catered towards women and weather indexed insurances towards this end.

Our research contributes to the growing literature by recognizing that climate impacts extend beyond disaster events like floods and droughts to include disruptions caused by modest and unexpected weather variations on daily economic life. As weather variability increases globally, the time allocation framework we employ in our study offers policymakers a valuable tool to understand and measure climate impacts that traditional approaches often miss, especially with regard to inclusive growth in society. Results, therefore, from weather-time use studies should be integrated into climate policies. Our findings from Bangladesh offer insights that extend beyond national boundaries, contributing to global knowledge on climate vulnerability and inclusive development.

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