ESSAYS ON ELECTRICITY ACCESS, WOMEN'S EMPOWERMENT, AND CLIMATE CHANGE IN SUB-SAHARAN AFRICA

By

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ABSTRACT

My dissertation research explores relationships between expanded electricity access (Sustainable Development Goal (SDG) 7), women's empowerment (SDG 5), and mitigating climate change risk (SDG 13) in two Sub-Saharan African countries, Zambia and Burkina Faso. Most studies quantifying the benefits of electricity access focus on changes in the number of household electricity connections; however, if and how access to electricity improves women's quality of life and reduces their risk is best understood by examining the cultural context, norms, and gender roles in which that access occurs. For instance, time saved from the use of electric appliances may be used for productive engagements, including paid employment, but if gender roles restrict women from leaving the home or engaging in paid work, such benefits are not realized. Developing countries such as Zambia and Burkina Faso are ramping up electrification efforts to achieve clean and accessible energy for all by 2030. Yet in this effort, there is a focus on off-grid renewable technologies like solar to increase access to rural and remote households for which a connection to the grid would be too expensive. Off-grid technologies likely mitigate the effects of climate change; however, their limited capacity and lack of reliability limit the extent to which they can power most of the appliances needed by women hoping to operate small businesses. The additional income from these small businesses may be increasingly important as hazards from climate change such as extreme temperatures and high variability in rainfall adversely affect people's livelihoods, farmers in particular. Adapting to these risks requires first perceiving them, and women may perceive these risks differently from men, while also certainly having different access to resources and electricity. In this dissertation, I examine access, empowerment and climate risk perceptions in Burkina Faso and Zambia where gender disparities are high, and a significant proportion of the population is engaged in agriculture and vulnerable to climate change risks. In my first essay, I examine how different types of electricity access affect time use between men and women and identify the everyday activities where electricity may have the greatest impact on women's quality of life. Using the World Bank's Multi-Tier Framework (MTF) dataset for Zambia, I apply a Tobit model to examine how male and female household members allocate their time among different activities and the impact of different types of electric connections on those allocations. The results show that compared to households without electricity, off-grid connections significantly increase women's time in paid work, more so than grid connections, while grid connections significantly increase the time both men and

women spend listening to the radio and watching television. These activities have been shown to be key to empowering women through exposure to women in emancipated roles, decreased fertility rates, lower acceptance of intimate partner violence, and increased share of divorce and separation. Off-grid connected households showed no difference in television or radio time and increased time in energy-related activities for both men and women compared to households without electricity. These results suggest that efforts to expand grid-connected and off-grid electricity may have different effects on women's quality of life. In my second essay, I delve deeper into the multi-faceted and context-specific concept of empowerment. In this qualitative study, I conducted 28 semi-structured interviews with Zambian women from households with and without electricity to better understand their subjective meaning of empowerment and how access to electricity may (dis) empower them. We analyzed their responses using the *Spaces* approach to empowerment which categorizes an individual's spaces into physical, economic, political, socio-cultural, and mental space and measures the expansion of mental space along with another space as an indicator of empowerment. We find that electricity access empowers women by expanding their economic, physical, and mental space. Expansion of these spaces takes place primarily through generating income opportunities outside the home, made possible by the use of electrical appliances, and women reporting greater economic independence, camaraderie, self-reliance, and agency as a result. In my third essay, I examine how long-term changes in temperature and rainfall are perceived by farmers in Burkina Faso. I also compared the extent to which these perceptions align with actual recorded changes in temperature and rainfall for multiple periods between 1991 and 2014. I used a logistic regression model to analyze the role of resources, such as asset ownership and perceived standards of living, along with household size, age, and gender of the household head to explain differences in perception and ultimately the decision to adapt. The results show that the vast majority of farmers in Burkina Faso perceive changes in temperature and rainfall; however, only about half of those individuals perceive changes in ways that align with recorded long-term trends in their local temperature or rainfall. The extent to which those perceptions align with recorded changes depends on the time frame selected. Older farmers and those with assets were less likely to perceive temperature and rainfall trends in ways that aligned with climate records; however, farmers' perceptions of temperature change aligning with records and their perceived standard of living were both associated with the decision to adapt.

I dedicate this dissertation to my husband, Arjun, son, Keshav, and daughter, Amrita.
- For running this marathon with me.

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1.1.Introduction

Increasing electricity access is one of the United Nations' 17 Sustainable Development Goals (SDG). Increased access to electricity has been shown to improve productivity (Azimoh et al., 2015; Rathi & Vermaak, 2018), increase income (Dasso & Fernandez, 2015; Dinkelman, 2011; Khandker et al., 2013; Mondal & Klein, 2011), and create better opportunities for new and existing businesses (Ahlborg & Sjöstedt, 2015; Azimoh et al., 2015; Bastakoti, 2006; Mondal & Klein, 2011). It has also been shown to lengthen study times for children (Aguirre, 2017; Azimoh et al., 2015; Lenz et al., 2017; Mishra & Behera, 2016), improve health and sanitation conditions for women (Mishra & Behera, 2016), improve communication via cell phone adoption (Ahlborg & Sjöstedt, 2015), and improve access to information (Azimoh et al., 2015). Despite the known benefits of electricity, access remains low in much of the Global South. In Zambia, the focus of this study, only 42 percent of residents have access to electricity, with a large disparity between rural (11 percent have access) and urban (76 percent) residents (Luzi et al., 2019). Zambia also experiences high gender inequality, ranking 138th out of 191 countries in 2021 on the Gender Inequality Index (GII) (UNDP, 2022).

To improve electrification rates, Zambia has in recent years deployed several large-scale grid extensions and promoted many mini and off-grid technologies, such as solar photovoltaic systems and mini-hydroelectric power ranging from 100 to 1000 kW (REA, 2021). The country's Rural Electrification Agency (REA) recently set a goal of increasing electrification in rural areas to 51 percent by the year 2030, arguing that such access contributes to better living standards (REA, 2021).

Any type of electric connection provides modest benefits (e.g., lighting); however, more significant benefits depend on the capacity and reliability of that electricity (Luzi et al., 2019). For instance, higher capacity electricity can power larger appliances such as refrigerators and coolers, which can also be used to store medication at health clinics. While being connected to a central grid typically provides such a connection, rural and remote households are often far from the grid increasing their cost of connection. In such cases, mini-grids and off-grid solutions have shown promise (Peters et al., 2019). However, off-grid solutions are not always as effective, as they may not provide enough energy for productive uses (Aklin et al., 2017).

Electricity access, both grid and off-grid, provides benefits that are often assumed to be equal for men and women; however, the benefits and costs of energy access are rarely disaggregated by gender (Clark, 2021), and energy access and gender equality (along with women's economic empowerment) are intrinsically linked (Orlando et al., 2018). Certainly, women benefit from having access to electricity; studies show improved health and indoor air quality from the use of better cookstoves (Köhlin et al., 2011), a decrease in effort and time spent cooking (Krishnapriya et al., 2021; Matinga et al., 2019), increased productivity and more employment opportunities (Dinkelman, 2011; Grogan & Sadanand, 2013; Peters & Sievert, 2016), as well as a substantial reduction in fertility rates (Grogan & Sadanand, 2013). Yet these benefits depend to a great extent on the type of activities that men and women engage in within the household, how the addition of different electrical appliances reduce time or effort, and whether these benefits can challenge or alter gender norms, the latter of which is essential to achieving women's empowerment.

The goal of this study is to examine how different types of electricity connections affect everyday activities in Zambia, specifically how men and women in households with and without electricity allocate their time among different activities. We use time-use statistics, which provide quantitative summaries of how time is allocated across a 24-hour window. Analyzing individuals' time use among different activities has been shown to provide valuable insight into individuals' lifestyles (Harvey & Pentland, 2002). We thus also examine how these connections and activities contribute to women's quality of life. We do this using energy access data for Zambia from the World Bank's Multi-Tier Framework (MTF) survey.

The remainder of this paper is organized as follows: In the next section, we describe five types of daily activities, and the role electricity plays in each, before discussing specific time use studies focused on electricity access. In Section 2 we describe our methods and how we analyze our data; Section 3 presents our results. Section 4 we discuss their implications followed by conclusions in Section 5.

1.1.1.Household activities and role of electricity

We separate the daily activities of men and women into five categories and highlight studies that note any impact of electricity access in those categories. These categories include cooking, energy-related activities, care work for children and other members of the household, paid work inside and outside the home, and finally, entertainment-related activities such as watching television and/or listening to the radio.

Cooking activity in the MTF survey includes preparing food, tea, or boiling water. Indoor air pollution caused by the use of biomass, coal, or kerosene to cook generates significant negative health impacts, which predominantly impact women. Better technologies may reduce pollution and result in better health for women (Köhlin et al, 2011); however, switching to electric technologies is often not feasible due to financial (Gill-Wiehl et al., 2021) and cultural constraints (Winther, 2007).

Energy-related activities include activities such as chopping or making pellets for preparing fuel or energy source such as firewood and charcoal. Time spent in these activities can limit the extent to which women can seek employment opportunities outside the home (Apps, 2003). Studies show that the time spent in gathering and using these fuels declines when a household gets an electric connection (Pereira et al., 2011), and these connections can improve the work-leisure balance for women (Barnes & Sen, 2004).

Care work includes activities such as caring, attending, or playing with and for younger children, and helping children with schoolwork. These activities are often done by women in both developed and developing countries, and despite the considerable contribution these activities make to family well-being, the work is typically unpaid (OECD, 2011). When households gain access to modern energy services, care work such as helping children with homework may occur at different times of day due to the presence of lighting and improved sleep (Standal & Winther, 2016). Children benefit by being able to study for longer hours (Dutta et al., 2017). Conversely, when electricity access is unreliable, women often must resort to using traditional fuels such as coal, animal dung, and firewood (Kim & Standal, 2019), limiting their ability to participate in care work.

The next category of time use includes paid work inside and outside the home. Compared to men, women report spending at least twice as much time in unpaid work and share a higher work burden when considering both unpaid and paid work (Seymour et al., 2017). Access to electricity has shown to increase women’s participation in paid work (Grogan, 2018), with women benefitting more from greater productivity and greater increases in earnings than men (Rathi & Vermaak, 2018). Energy-related work and care work are related, since women often face trade-offs between domestic chores and working outside the home (Costa et al., 2009).

The final category, entertainment activities, includes time spent watching television or listening to the radio. Households are noted to purchase television and lighting appliances once connected to the grid (Köhlin et al., 2011). Where women have exposure to information via television, significant impacts have been noted in fertility reduction (Grimm et al., 2015; La Ferrara et al., 2012), a lower acceptance of intimate partner violence (Sievert, 2015), and reported increases in autonomy (Jensen & Oster, 2009). The presence of televisions has been noted to create a qualitative shift in social power through the availability of information, and the use of mobile phones allows women to stay connected to the extended family (Standal & Winther, 2016).

Understanding how the type of electric connection affects unpaid domestic work and care-related activities like childrearing is crucial to determining if Zambia can not only achieve its electrification goals, but also improve women's quality of life.

1.1.2. Time Use Studies

Time allocation is impacted by numerous factors including the age and gender of household members, their access to water, fuel, and infrastructure, as well as individuals' proximity to community centers such as schools, health care centers, financial institutions, and markets. We can observe how time use is gendered by analyzing the total amount of time and the type of work in which men and women engage. Rubiano-Matulevich & Viollaz (2019) find that in both developed and developing countries, women spend more time in unpaid work and fewer hours in the market compared to men, regardless of their age or marital status. Picchioni et al (2020) find significant gender differences in time use in Nepal and India, at least among the rural communities. The presence of adult men and large numbers of children within a household are associated with an increase in leisure time for both women and men; however, that leisure time decreases for women only when the elderly is present. Thus, factors such as age, gender roles, and access to resources affect how time within the household is allocated among different activities and can either constrain or increase time available for paid employment outside the home.

Some studies have combined time use and electricity and have even incorporated gender attributes. For example, Picchioni et al., (2020) use energy expenditure and time use to focus on nutrition and well-being outcomes of men and women. Scheurlen (2015) highlights time use impacts from the reduced availability of fuel resources. Similarly, Johnson et al. (2019) focus on the gendered impacts of electricity access at the household level, specifically from a solar mini-grid in Zambia, using a case study. Quantitative studies have focused on specific impacts like economic outcomes (Azimoh et al., 2015; Mishra & Behera, 2016) and outcomes for children (Aguirre, 2017; Barman et al., 2017; Furukawa, 2014); however, they often do not disaggregate by gender (Bensch et al., 2011; Bernard, 2012).

Here we analyze the impact of different types of electricity access on the time spent in different household activities and disaggregate those activities by gender. Our goal is to compare the time use of women and men in households with electricity (both off-grid and grid connection) and without and explain associations between gendered time use and electricity access. We also aim to identify everyday activities in which an electric connection can deliver the largest quality-of-life impacts for women.

1.2. Methods

1.2.1. Dataset and Study Context

Here we use Multi-Tier Framework (MTF) survey data for Zambia provided by the World Bank (ESMAP, 2018)—the most recent deployment of that survey. This global baseline survey, conducted in 2017-2018, contains information on household access to electricity, clean cooking solutions, as well as alternative sources such as solar devices for 3,738 households in rural and urban Zambia. The dataset also contains demographic information, household electricity connection status, whether the household is connected to the grid, and the type of electrical appliances owned and desired.

1.2.2. Time Use Categories

One section of the survey includes responses to how men and women household members allocate their time among different activities (see Table 1). These quantitative summaries include information on the type of activity and the time spent on each by each respondent within the household. For our analysis, we combined activities similar to the categories described above: Energy Time, Cook Time, Care Time, Paid Work Time, and TV-Radio Time. These categories are also noted to take up the largest proportion of time in a 24-hour window. Table 2 lists the average number of minutes spent each day by i) Women aged 15 years and older, and ii) Men aged 15 years and older in each category.

Category in this study	Activities in survey
Cook Time	Cooking (Food, tea, boiling water)
Energy Time	Preparing fuel/energy source (chopping, making pellets)
Care Time	Caring, attending, or playing with and for younger children Helping children with schoolwork
Paid Work Time	Working outside of the house (for pay and/or self-employed) Income-generating activities inside the house
Entertainment Time	Watching TV or listening to the radio for news and information, or entertainment

Table 1: Categories of activities

Within the MTF survey, the household characteristics were available at the individual level, but time-use data was provided as a total time for each gender group within a household. As a result, we calculated the time spent per category per adult in a household by dividing the total time spent per gender group by the number of individuals (aged fifteen or older) within that group. For example, if the aggregate time spent in care work for one household that included three women was 180 minutes, we divided the aggregate by three (i.e., 180/3 = 60 minutes).

We categorized each household's electric connection as either "No connection" (i.e., the household has no access to electricity), "Off-Grid" (i.e., the household relies on a generator, solar lantern, solar lighting product, Solar Home System, rechargeable battery, or Dry-cell battery), or "Grid Connection" (i.e., the household is connected to the grid) Table 3 identifies the number of households with each type of connection.`

1.2.3. Data Analysis

We first calculated the time spent by men and women in each category across households with different types of electricity access. We next use a Tobit model to regress the time spent in each category of activity on the status of electric connection and other household and household-head characteristics. The descriptive statistics of the key variables are provided in Table 4. The Tobit model (Tobin, 1958) is a censored regression model where the dependent variable is bound above or below, or both, by a certain value. In this case, the lower bound on time is 0 minutes and the upper bound is 1440 minutes (the maximum time that can be theoretically allotted to an activity, i.e., 24x60). This model is used in studying time-use data in which there is a large proportion of observations with 0, leading to a right-skewed distribution and for which OLS estimators tend to be biased and inconsistent. By using a Tobit model, the zeros observed in the dataset are treated as if the respondent did not participate in that activity. The model uses the maximum likelihood technique to estimate the linear relationship between the time spent in each activity and explanatory variables such as household income[1], the electric connection status of the household, marital status[2] of the head of the household, the household type (single or multiple households), locality of the household (Rural/Urban), and the number of children in the household.

	No Connection		**Off-Grid**		**Grid**	
CATEGORY	*Men*	*Women*	*Men*	*Women*	*Men*	*Women*
Cooking	16.5	47.6	16.6	57.7	16.2	57.8
	(30.4)	(52.9)	(29.5)	(60.5)	(26.6)	(67.2)
Energy-related	6.5	11.4	12.1	17.4	4.9	7.9
	(19.1)	(25.4)	(33.7)	(41.7)	(19.8)	(20.4)
Care Work	23.9	52.7	38.4	60.3	41.7	80.0
	(56.4)	(107.0)	(75.7)	(110.3)	(80.7)	(136.6)
Paid Work	156.6	79.5	136.9	101.8	159.9	101.4
	(214.5)	(160.7)	(186.1)	(145.3)	(233.3)	(180.1)
Entertainment	26.9	33.1	34.5	35.6	117.9	137.7
	(64.0)	(82.1)	(85.8)	(91.8)	(147.7)	(177.8)

Table 2: Average time (Standard Deviation) spent in each category

Connection Type	**Frequency**
No connection	1513 (43%)
Off-Grid	780 (22%)
Grid	1222 (35%)
Total	**3515**

Table 3: Number of households by electric connection type

[1] The median income for each category was calculated and multiple incomes within a household were combined to obtain the median household income

[2] Marital status for the household head was re-classified as Married (0) if their marital status was either monogamously/polygamously married or cohabitation with a single partner, and Single (1) if their marital status was never married, divorced, or separated.

Variables	Mean
Rural/Urban (0 Rural, 1-Urban)	0.5
Number of Children	1.4
Number of Adults	2.5
Type of Electric Access (0- No connection, 1- Off-Grid, 2-Grid Connection)	0.9
Ownership of electric stove (0-No, 1-Yes)	0.13
Housing Type (1- Single households, 2- Multiple households,)	1.1
Household Median Income[1] (Zambian Kwacha)	2,090
Marital status of household head[2] (0-Single (Never married, divorced, or separated), 1-Married (Monogamous, polygamous, cohabitation with a single partner)	0.3
Gender (0- Male, 1-Female)	0.2
Education level (1- None, 2- Primary, 3- Jr. Secondary, 4- Sr. Secondary, 5- Trade School, 6-College, 7-University)	3.1
Age	41.1

Table 4: Descriptive statistics of key variables

In the *Cook Time* model, we regress the time spent cooking on the explanatory variables mentioned above, and we include a dummy variable representing whether the household uses an electric stove for cooking or not. In the *Energy Time* model, the dependent variable is the time spent in energy-related activities and the independent variables are the same as the time spent in cooking. In the *Care Time* model, we regress the time spent in care activities on the same independent variables as the earlier models excluding the use of the electric stove. In the *Paid Work Time* model, we regress the time spent in paid work, both inside and outside the home on the same independent variables as above, excluding the use of electric stove and median household income. The former variable was excluded since no direct connection between the use of electric stoves and paid work has been identified and the latter was excluded to avoid reverse causality as an increase in paid work time contributes to an increase in income. In the final *TV/Radio Time* model, we regress the time that men and women spend listening to radio or watching television for news and entertainment, excluding electric stove use.

1.3. Results

The average time spent by each gender among different activities in a 24-hour window is provided in Figure 1. With every type of electric connection, women on average spend at least three times as long as men in cooking activities. In energy-related activities, women always spend more time than men, and spend nearly twice as much time as men when there is no electricity and when the household has a grid connection. In care work, across all 3 connection types, women spend more time than men, with the greatest difference between gendered time use in households without electricity. In paid work, the reverse is true. Across connection types, men spend more time than women, and the difference between genders is highest in households without electricity. In entertainment time, both men and women spend nearly the same time across connection types, with women spending slightly more time than men on average.

The results of the Tobit regression are provided in Table 5. We discuss them by activity type and for both men and women. To understand how the connection type and other dependent variables change the time spent in each activity, we provide the marginal results from the model in Table 6. Since the Tobit model uses censored data, i.e., data that ranges between 0 and 1440 minutes (24 hours * 60 minutes), we use the marginal effects explain the effect of each independent variable while holding all other variables constant.

a. *Cook Time*

In all households regardless of electric connection type, the household head being married increases the time spent in cooking for men and women by 21.2 minutes (*s.e =1.9)* and 4.2 minutes (*s.e = 1.0)* respectively. As the number of children increase in the household, the time spent in cooking decreases for men by 3.4 minutes (*s.e =0.4)* and increases by 8.5 minutes (*s.e =3.2)* for women. Compared to a single-family household, women in multi-family household spend 11.0 minutes (*s.e =3.5)* more in cooking. The results are not statistically significant for men. Median household (log transformed) income is not statistically significant for either gender.

Compared to households without electricity, women in households with off-grid connections and grid connections increase their time spent cooking by 17.2 and 8.0 minutes per day, respectively. Time spent cooking by men did not change significantly ($p > 0.05$) with either type of connection. When an electric stove is used in the household, time spent cooking is reduced by 8.4 (*s.e = 0.7*) minutes for women but increased by 3.4 (s.e = *0.4)* minutes for men.

b. *Energy Time*

Similar to the Cook Time model, in all households regardless of electric connection type, household heads being married increases energy time by 3.4 minutes (*s.e=0.8)* for men and 3.9 minutes (*s.e= 0.9)* for women. Having one more child in the family increases energy time for women by 2.8 minutes (*s.e =0.3)*. The result is not statistically significant for men. Similar to the cooking time model, the locality of the household is not statistically significant. Compared to single family households, being in a multi-family household reduces energy time for men by 3.7 minutes (*s.e=1.0)* but not for women. As the income variable increases, the time spent in energy also increases for men by 1.3 minutes (*s.e= 0.4)* and for women by 1.2 minutes (*s.e=0.4).*

Compared to households without electricity, both men and women in households with off-grid electricity spend more time in energy-related activities. For men, energy activities are increased by 8.1 minutes (*s.e =1.6)* in off-grid households compared to 10 minutes (*s.e =1.8)* for women. Neither men nor women spend more or less time in energy-related activities in grid-connected households. Ownership of an electric stove decreases the average energy time for both men and women by 7.9 minutes (*s.e= 1.6)* and 6.9 minutes (*s.e=1.3)* respectively.

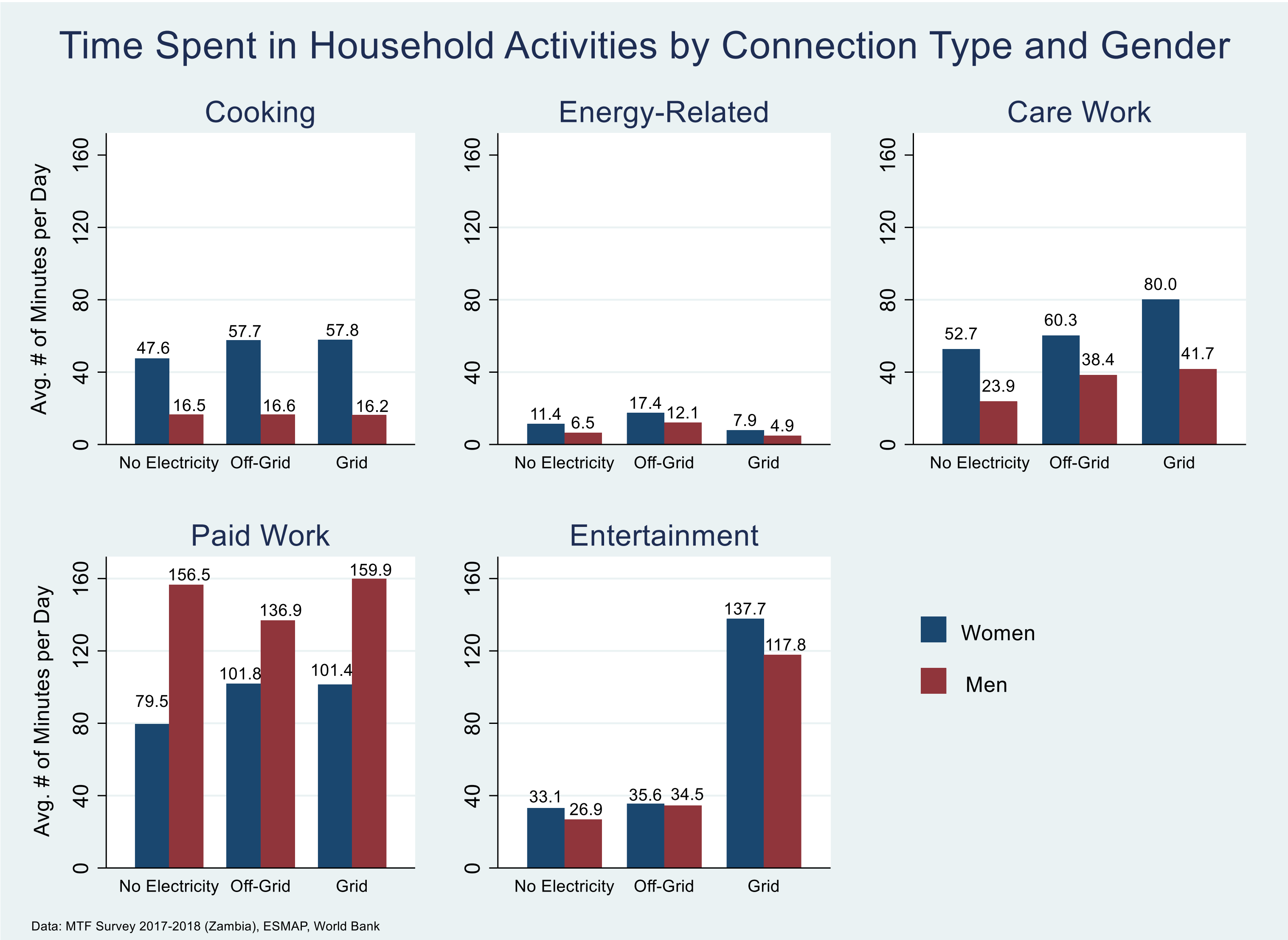

Figure 1: Time spent among different activities disaggregated by gender

Variable	Cook Time (n=2,635) Men	Cook Time (n=2,635) Women	Energy-related (n=2,635) Men	Energy-related (n=2,635) Women	Care Work (n=2,635) Men	Care Work (n=2,635) Women	Paid Work (n=3,515) Men	Paid Work (n=3,515) Women	Entertainment (n=2,635) Men	Entertainment (n=2,635) Women
Connection Type Off-Grid	2.8 (4.0)	25.2*** (4.8)	27.9*** (5.0)	23.9*** (4.0)	46.3*** (11.6)	26.4* (15.0)	5.1 (18.4)	100.5*** (16.2)	21.2 (18.6)	2.4 (21.8)
Grid	-3.9 (3.5)	12.2*** (4.4)	7.1* (4.2)	2.4 (3.0)	34.7*** (10.7)	42.4*** (15.2)	35.4* (20.8)	40.4** (19.2)	214.7*** (14.9)	251.4*** (19.3)
Has Electric Stove?(0-No/1-Yes)	7.6** (3.2)	-12.7*** (4.9)	-31.1*** (5.3)	-19.0*** (3.7)	-31.3*** (11.3)	-42.1*** (16.3)	Not Included		Not Included	
Marital status of Head (0-Single/1-Married)	8.8*** (2.1)	32.0*** (2.9)	13.5*** (3.0)	10.8*** (2.3)	77.3*** (7.9)	112.9*** (10.7)	229.3*** (15.3)	60.5*** (13.8)	56.9*** (10.7)	95.6*** (13.1)
Total # of Children	-7.2*** (1.0)	12.8*** (1.0)	0.2 (0.9)	7.8*** (0.8)	27.0*** (2.4)	55.3*** (3.6)	9.7** (4.4)	32.3*** (3.8)	0.8 (3.5)	21.0*** (3.9)
Urban/Rural Urban	-3.6 (2.9)	2.3 (3.6)	-2.1 (3.3)	-0.9 (2.8)	16.6* (9.0)	31.2** (13.0)	-11.3 (19.0)	12.2 (17.2)	-16.5 (13.3)	-21.9 (16.7)
House Type Multi	-2.6 (3.8)	15.9*** (4.9)	-16.9*** (5.0)	-0.9 (3.1)	23.0** (9.8)	66.3*** (15.5)	1.9 (23.9)	12.2 (22.5)	20.9 (14.2)	63.2*** (17.7)
Log (Median HH Income)	2.3* (1.2)	-0.4 (1.6)	5.1*** (1.4)	3.3*** (1.2)	21.2*** (4.1)	20.5*** (5.5)	Not Included		50.1*** (5.3)	50.1*** (6.2)
Constant	-12.8 (8.9)	-8.7 (11.9)	-83.8*** (11.5)	-61.1*** (9.7)	-348.3*** (36.0)	-411.3*** (42.5)	-168.9*** (17.3)	-238.9*** (16.4)	-560.1*** (42.8)	-662.6*** (49.0)

Table 5: Regression results from the Tobit model. Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

Variable	Cook Time (n=2,635)		Energy-related (n=2,635)		Care Work (n=2,635)		Paid Work (n=3,515)		Entertainment (n=2,635)	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Connection Type										
Off-Grid	1.4 (2.0)	17.2*** (3.4)	8.1*** (1.6)	10.0*** (1.8)	14.2*** (3.8)	9.5 (5.5)	2.4 (8.5)	38.6*** (6.4)	5.4 (4.9)	0.5 (4.8)
Grid	-1.8 (1.6)	8.0** (2.9)	1.7 (1.0)	0.8 (1.0)	10.2** (3.2)	15.8** (5.7)	16.9 (10.0)	14.2* (6.8)	88.2*** (6.2)	96.0*** (7.4)
Has Electric Stove?(0-No/1-Yes)	3.6* (1.5)	-8.4** (3.2)	-7.9*** (1.3)	-6.9*** (1.3)	-9.5** (3.4)	-15.6* (6.1)	Not Included		Not Included	
Marital Status of Head (0-Single/1-Married)	4.2*** (1.0)	21.2*** (1.9)	3.4*** (0.8)	3.9*** (0.9)	23.5*** (2.4)	42.0*** (4.0)	108.8*** (7.4)	22.4*** (5.2)	21.7*** (4.1)	33.6*** (4.6)
Total # of Children	-3.4*** (0.4)	8.5*** (0.7)	0 (0.2)	2.8*** (0.3)	8.2*** (0.7)	20.5*** (1.3)	4.6* (2.1)	12.0*** (1.4)	0.3 (1.3)	7.4*** (1.4)
Urban/Rural										
Urban	-1.7 (1.4)	1.5 (2.4)	-0.5 (0.8)	-0.3 (1.0)	5.0 (2.7)	11.5* (4.8)	-5.4 (9.0)	4.5 (6.4)	-6.3 (5.1)	-7.7 (5.9)
House Type										
Multi Household	-1.2 (1.7)	11.0** (3.5)	-3.7*** (1.0)	-0.3 (1.1)	7.4* (3.3)	27.1*** (6.9)	0.9 (11.4)	4.6 (8.5)	8.2 (5.7)	24.0*** (7.2)
Log (Median HH Income)	1.1 (0.6)	-0.3 (1.0)	1.3*** (0.4)	1.2** (0.4)	6.4*** (1.3)	7.6*** (2.0)	Not Included		19.1*** (2.0)	17.6*** (2.2)

Table 6: Marginal effects from the Tobit model. Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

c. Care Time

In all households regardless of electric connection type, the household head being married increases the time spent in care activities by 23.5 minutes (*s.e=2.4)* for men and 42 minutes (*s.e=4.0)* for women. An increase in the income variable increases time in care work for both men and women by 6.4 minutes (*s.e=1.3)* and 7.6 minutes (*s.e=2.0)* respectively.

Compared to households without electricity, the presence of an electric connection increases the time spent in care activities for both men and women. The increase in time for men in households with an off-grid connection is 14.2 minutes (*s.e = 3.8),* but is not statistically significant for women ($p > 0.05$). Care time for both groups increases in grid connected households by 10.2 minutes (*s.e=3.2)* for men and 15.8 minutes (*s.e=5.7)* for women. Owning an electric stove decreases the time for both men and women by 9.5 minutes (*s.e=3.4)* and 15.6 minutes (*s.e= 6.1)* respectively.

d. Paid Work Time

In all households regardless of electric connection type, the household head being married increases the paid time for men by 108.8 minutes (*s.e=7.4)* and for women by 22.4 minutes (*s.e=5.2)*. With an additional child in the household, men spend 4.6 minutes (*s.e=2.1)* more and women spend 12 minutes (*s.e=1.4)* more in paid work. Neither the urban location or being in a multi-family household are predictors of time spent in paid work.

Compared to households without electricity, women in households with off-grid and grid connections spend 38.6 minutes (*s.e=6.4)* and 14.2 minutes more in paid work, (*s.e=6.8)* respectively. There is no statistically significant change for men in paid time.

e. TV Radio Time

Similar to the paid work model, regardless of the electric connection type, the household head being married increases the time in entertainment by 21.7 minutes (*s.e=4.1)* for men and by 33.6 minutes (*s.e=4.6)* for women. An additional child in the household increases a women's time in entertainment activities by 7.4 minutes (*s.e= 1.4)* but is not significant for men. Median household income is also statistically significant for both men and women. A unit increase in income increases the time spent in entertainment activities by 19.1 minutes (*s.e=2.0)* for men and 17.6 minutes (*s.e=2.2)* for women. Being in a multifamily household is statistically significant for women only and increases their time by 24 minutes (*s.e=7.2)*. Location of the household is not statistically significant for either gender.

Compared to households without electricity, both men and women in grid connected households experience a significant and sizable increase in time spent watching television and listening to the radio: 88.2 minutes (*s.e=6.2)* for men and 96 minutes (*s.e=7.4)* for women. An off-grid connection did not increase TV/Radio time significantly for either men or women.

1.4. Discussion

In this study, we compared how men and women in grid and off-grid-connected households in Zambia spend their time in a day compared to those without electricity. Our results show the type of connection matters. Both off-grid connections and grid connections increase the time women spend cooking, though owning an electric stove, which often necessitates a grid-connection, leads to less time cooking for women. Grid connections have no effect on time spent in energy activities, but off-grid connections increase that time. In care work, both grid and off-grid connections increase men's time in these activities, whereas only grid connections increase women's time in care work. Both off-grid and grid connections increase the time in paid work for women. Finally, having a grid connection increases the time both men and women spend listening to radio or watching television, both of which been shown to empower women (Heywood, 2021; Jensen & Oster, 2009). Off-grid connections led to no such increase. Electricity did not impact men's cooking time, which may be because they rarely cook. Across households, 85 percent of women reported cooking every day compared to only 22 percent of men. However, when a household owns an electric stove, the cooking time increased for men, yet decreased for women. This suggests that owning an electric appliance may encourage more men to assist in cooking; doing so may be easier than using traditional methods (Krishnapriya et al., 2021).

Having an off-grid electric connection increased the time in energy-related activities for both men and women. This counterintuitive result is consistent with the literature on fuel use in Zambia. Mulenga et al. (2019) examined cooking fuel choice in urban households to understand the effect of electricity access, finding that in both households with and without electricity, charcoal remained the most prevalent cooking fuel. Households that use charcoal or other fuels to cook may simply continue to rely on them. It is also important to note that the off-grid systems in our sample consist primarily of batteries and generators; only a few households had solar home systems. The low capacity of the former may simply not allow for the replacement of traditional stoves and fuels. There may be another explanation. In a concurrent study, we found that households prefer using traditional stoves to cook certain types of food like beans (legumes), which require more time to cook. An electricity connection may be ineffectual to households that prefer using these traditional practices and norms (Hooper et al., 2018; Winther, 2007). Regardless of the type of electric connection, women spend more time than do men in energy activities and that time increased as the size of the household increased.

Our results show that while an off-grid connection increases men's time in care work—perhaps because women are more engaged in work outside the home (see below), having a grid connection increases the time for both men and women, and for women more so than men. Larger households led to increased care time, suggesting that electricity connections in large households may have an outsized impact on women's quality of life in those particular homes. Standal & Winther (2016) showed that an electric connection increases the amount of time women spend helping children with their homework. The extent to which this is an improvement in women's quality of life (or not) likely depends on the individual.

Electricity access is strongly associated with time spent in paid work for women, and their paid work increased more with an off-grid connection than it did with a grid connection. This result indicates two things: first, the marginal value of having any type of electric connection is high for women, both in increasing paid work, and likely allowing for additional income to be generated for the family. And second, a grid-connected household may increase women's activities inside the home (i.e., care work), restricting the amount of time available for paid work outside of it. It is important to understand the trade-offs that women make to engage in paid work whether inside or outside the home. Certainly, paid employment impacts household income, and thus consumption, yet the time spent doing household chores, participating in leisure and self-care activities, and doing unpaid work also contribute to an individual's well-being. Women engaging in paid work, thus, could be taking on more work by also doing household chores (Antonopoulos, 2008; Medeiros et al., 2010). Additionally, the disproportionate time spent in unpaid care is known to either contribute to or exacerbate gender gaps in labor markets (Ferrant et al., 2014).

Perhaps our most remarkable result is the significant increase in time spent watching television or radio in households connected to a grid. This is particularly important and impactful for women since watching television exposes them to valuable information about contraception and domestic violence. In seeing other women in emancipated roles, watching television can decrease fertility rates (La Ferrara et al., 2012, Fujii & Shonchoy, 2020; Grimm et al., 2015), lead to lower acceptance of intimate partner violence (Sievert, 2015) and increase the share of divorce and separation (Chong & Ferrara, 2009). Providing grid-connected electricity may be the single greatest contributor to reduced gender inequality simply via increased access to radio and television programs. At the same time, tv and radio time did not increase here for men or women with an off-grid connection. Off-grid systems have been noted to benefit women through the use of mobile phones and home business opportunities (Hossain & Samad, 2021). However, when these systems lack capacity and reliability, they may be less empowering, especially when we consider they also increase women's time spent preparing and collecting fuels. The extent to which mobile phones, television and radio alter women's quality of life differently requires additional work.

1.5.Conclusion

Our study shows that that electricity access impacts households and particularly women in two ways: first, by saving time through the use of appliances that may reduce drudgery and invite men into the kitchen. Time saved here can be spent in other activities such as care work or paid work, though how that time gets reallocated depends on intra-household bargaining, gender relations, and norms (Apps, 2003). For example, women might enjoy cooking or prefer spending more time with their children and family or might prefer to use that additional time to seek paid opportunities outside the home, engage in a home business or in self-care including time spent in entertainment activities. If electricity leads to women spending extra time in those activities, then it improves their quality of life and can be viewed as a benefit. However, should gender roles, norms, and power relations within the house lead to more work and drudgery, such as time spent collecting fuel, then electricity's positive impacts are reduced.

Second, grid connections led to a significant increase in television and radio time, for both men and women. These forms of media have been shown to benefit women in particular by increasing their awareness of issues that reduce their quality of life such as domestic violence and the lack of contraception. From this perspective, grid connections can be considered an essential service to improve quality of life for women. Those advocating for UN SDG 7, i.e., universal access to energy, must be careful to distinguish between off-grid and grid access if women's empowerment is a goal.

Finally, our study did have two limitations that are shared among most time-use surveys in general (Apps, 2003; Seymour et al., 2017). The first is our inability to shed light on how individuals actively reallocate their time among different activities. Doing so requires a comprehensive approach that models intra-household dynamics within and across groups (Pachauri & Rao, 2013). Even though an electric connection in the household may save time for men or women, our model does not explain how that newly saved time is reallocated toward other activities. Additionally, children's contributions to household labor, especially in cooking, energy-related activities, and care work (for younger siblings) affect how adults spend their time. These characteristics are difficult to account for using surveys and often require qualitative work to adequately capture. Nevertheless, our study demonstrates that distinguishing the impacts of grid and off-grid connections to household time use is a crucial step in encouraging women's empowerment and achieving gender equality.

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Chapter 2: Electricity access empowers women through expansion of economic, physical, and mental spaces in Zambia

2.1. Introduction

Access to energy, electricity in particular, and women's empowerment are closely linked. Women are noted to benefit from access to electricity in several ways, such as improved health and indoor air quality from using better cookstoves (Köhlin et al., 2011), increased productivity and employment opportunities (Dinkelman, 2011; Grogan & Sadanand, 2013; Peters & Sievert, 2016) and a substantial reduction in fertility rates (Grogan & Sadanand, 2009). Similarly, at the community level, increased electricity access allows for streetlights and public spaces that create new opportunities for economic and social independence for women (Köhlin et al., 2011). These benefits alone however may not result in women's empowerment as sociocultural norms, power relations within households and hierarchical structures can prevent women from realizing it (Matinga et al., 2019; Rosenberg et al., 2020). For example, electricity access can create employment opportunities for women, but if women are not able to control financial resources, improve their bargaining power within the household, or improve their participation in key decisions, then those opportunities do not necessarily result in empowerment. Furthermore, if access to electricity leads to women allocating greater time to household work, then access may decrease the time for self-care, resulting in disempowerment.

Studies that focus specifically on whether and how electricity access impacts women's empowerment have used different approaches and specific indicators to measure several aspects of empowerment. For example, Matinga et al., (2019) uses McCauley et al.,(2013)'s three tenets of energy justice, including distributive justice (costs/benefits), procedural justice (process) and recognition justice (ownership) to show that while both men and women in Nepal benefit from the use of appliances such as mobile phones, cookers, and televisions, there are several constraints to empowerment. For example, decisions about the placement of lights in the house were not decided by the household members, but rather by the electrician. Such placements might not necessarily benefit women, particularly if it is not in the area of the house where they spend time. Similarly, the use of mobile phones helped women stay connected with their family and friends, but men complained that mobile phones enabled women to have extra-marital affairs. Rosenberg et al., (2020) in their mixed-methods study in India found that when a household gains access, even to appliances that would benefit women, intra-household power dynamics prevented them from appreciating them as men continued to control household affairs, including electricity use by women. Winther et al., (2018) examined individuals' influence over life and everyday decisions as well as gender ideologies, norms and social positions to evaluate how solar powered electricity access affects women's empowerment in Kenya. They concluded that because men tend to own houses and appliances and had decision-making capabilities relating to the placement of appliances and their use access is gendered. They suggested that women's empowerment can only be achieved via their increased participation in energy programs at the operational, management, and ownership level.

Studies also focus on women's economic empowerment, specifically their being able to afford one's own expenses (Burney et al., 2017), have more independence in how they run their businesses (de Groot et al., 2017), and increased employment opportunities and income (Dinkelman, 2011; Grogan, 2018; Rathi & Vermaak, 2018; Standal & Winther, 2016).

The goal of this study is to better understand the concept of women's empowerment within the socio-cultural context and gender norms of Zambia and empowerment's relationship to electricity access. We do this by conducting semi-structured interviews in communities that either do not have access to electricity or were recently electrified. Using the Spaces Approach (Deshmukh-Ranadive, 2005), described below, we examine what empowerment means to women in these communities and how electricity contributes to or erodes empowerment.

The remainder of the paper is organized as follows: In the next sub-sections, we provide the country context, the theoretical framework used in the study, and relate the empirical work in empowerment to the Spaces approach. In Section 2, we describe our methods and how we analyze our data. In section 4, we present the results followed by a discussion.

2.1.1. Positionality Statement

As the first author, I acknowledge my position as an immigrant woman with upbringing in India during a period when electricity was unreliable, similar to that of many countries in Africa currently. Having experienced a lack of freedom of mobility in public spaces that lacked electricity, I am passionate about understanding how women's lives are impacted from electricity access.

2.1.2. Zambia

In Zambia, only 40 percent of the population has access to electricity: 11 percent of the rural population and 77 percent of the urban population (World Bank, 2020). Zambia also experiences high gender inequality, ranking 131st out of 191 countries in Gender Inequality Index (GII) (UNDP, 2022). In recent years, the country has deployed several large-scale grid extensions and many mini and off-grid power technologies. The country's Rural Electrification Agency (REA) has set a goal of increasing electrification in rural areas to 51 percent by the year 2030 and has argued that such access contributes to better living standards. Yet the extent to which these projects and REA's plan will benefit men and women differently (or at all) has not been examined. If access to electricity can indeed empower women, then large-scale electrification efforts should help Zambia progress toward both universal electricity access and gender equality. To understand why and how (dis) empowerment can take place, it is important to examine women's narratives of empowerment, and how their life and bargaining position within the household change because of electricity access.

2.1.3. Measuring Empowerment: The Spaces approach

The concept of empowerment is multidimensional and context-specific. As such, in this study, we use definitions by both Kabeer (1999, 2005) and Narayan-Parker (2005). Kabeer (1999, 2005) describes empowerment as the ability to make strategic life choices through a change, which involves a *process* (means through which the change takes place) and *agency* (the woman being an actor in the process), that moves a woman from a state of disempowerment to empowerment. Narayan-Parker (2005) adds that empowerment also entails the expansion of a woman's freedom of choice and actions that help shape her life, leading to greater control over decisions and resources. Specifically, we use the Spaces Approach (Deshmukh-Ranadive, 2005) to measure (dis) empowerment from electricity access. In this approach, every individual has an allotment of *space*, which influences their capacity to act and their behavior both within the household and outside of it. Space could be physical, economic, socio-cultural, political, or mental. Of these, physical, economic, sociocultural, and mental spaces are relevant to the analysis of impacts at the household and community level. Political space refers to the political situation in the household as well as women's access to, control of, and participation in public offices locally, regionally, and nationally. Political space falls outside the scope of this study.

According to Deshmukh-Ranadive (2005), physical spaces refer to a woman's ownership and control of, and access to, her natal and marital houses, the spaces within them, personal mobility, as well as control over her body and its consumptive, productive, and reproductive functions. This space also includes space and land outside the house such as school or places of work. Within the context of this study, physical space refers to where electric appliances might be placed in the house, whether or not the woman in the household has the freedom to use those appliances, and the freedom a woman has to visit places outside her house.

Economic space in this approach is determined by the ownership of properties, assets, and income. It allows women to have more control over goods and services. Electricity access that creates employment opportunities for women represents an expansion of her economic space. If such employment involves working outside of her house, it indicates an expansion of her physical space as well. Burney et al (2017), in their quantitative study of a distributed photovoltaic irrigation project in Benin, find that the project positively impacted women's empowerment by creating economic independence and thus expanded their economic space. The expansion of both economic and physical space has been possible in cases where women have been part of the electricity project itself. For example, Standal and Winther (2016) find that traditional perspectives of female ability and decision-making were challenged when women engineers were included in the supply of electricity in Afghanistan. Similarly, de Groot et al (2017) note that providing energy services in the informal food sector (where more women were employed) gave women control over how they ran their enterprises, thus affecting their control and agency. Nevertheless, linkages between female entrepreneurship and empowerment are not extensively researched (Osunmuyiwa and Ahlborg, 2019).

Next, Deshmukh-Ranadive (2005) refers to socio-cultural space as a person's position within kin-based hierarchies, which differ from culture to culture. A lack of power in this space can also determine how one benefits from electricity access. For example, Johnson et al. (2019) analyze a solar mini-grid in Zambia and find that electrification benefits were distributed between men and women based on socio-cultural practices and norms both in the household and in the community. Within the households and businesses, the electric appliances, when available and affordable, were used by the male members of the community. Business ownership and economic activities were dominated by male members as they are seen as the primary breadwinners. Thus, the appliances, habits, routines, and norms that contribute to energy culture differ along gender lines and economic status. The expansion of this space through electricity access, and how one's position within the household affects expansion, has not yet been studied.

Finally, mental space is described by Deshmukh-Ranadive (2005) as the feeling of freedom that allows a person to think and act, allowing them to move away from restrictions and lead to a change in perceptions and a feeling of strength. Expansion in mental space takes place in one of two ways. The first is through collective power, where women mobilize their efforts, leading to greater confidence. While there is a lack of studies connecting women's collective action and empowerment to electricity access, all of the studies on empowerment mentioned earlier indicate an expansion in the mental space. The second expansion is through information. For example, information either through media or social groups helps women improve their self-esteem or change their attitude. Studies of empowerment outcomes from watching television are good examples (Jensen & Oster, 2009; La Ferrara et al. 2012). Expansion in mental space is a necessary condition for empowerment, and expansion in mental space and at least one other space indicates empowerment (See Figure 2). Disempowerment happens when existing mental space shrinks due to various factors that reduce an individual's agency. While empowerment cannot take place without the expansion of mental space and another space, disempowerment requires only the contraction of mental space.

While studies cited provide examples of different spaces, community-level expansion of spaces has not been studied widely. Understanding community-level benefits from electrification is particularly important to understand the expansion of physical space. If women view their visit to community spaces and buildings as a way to socialize or explore economic opportunities, it can enhance their self-confidence and boost comradery. Their positive experience and the freedom to access public spaces contributes to a feeling of empowerment. For example, Wamukonya and Davis (2001) note that in Namibia, 87 percent of households that were electrified felt safer at night. Similarly, Chaplin et al. (2017) report that access to electricity and the streetlights it provides leads to increased perceptions of safety in communities including non-connected households in Tanzania. However, Aklin et al (2017) in their assessment of the socioeconomic effects of solar microgrids in India found no effect on women's perceived need for better lighting to improve safety. The reason for differences in these studies could be context-specific and warrant further analysis. Within the context of electricity access, Osunmuviya and Ahlborg (2019) define empowerment as being able to make energy-related decisions and having equal access and control over the resources necessary to access and use electricity. While several impacts or outcomes of electricity access can be considered indicators of empowerment, few studies measure empowerment directly either quantitatively or qualitatively.

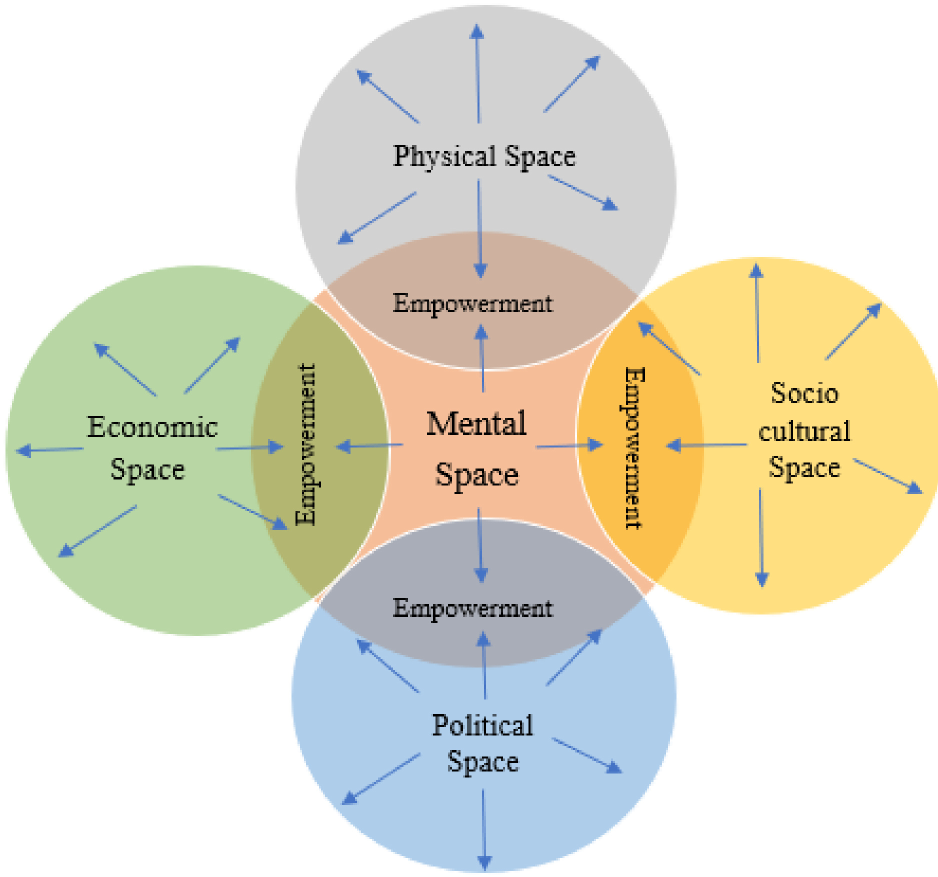

Figure 2: Authors' illustration of the Spaces Approach. As each of these spaces expands, the shared area between mental space and other spaces indicates empowerment

2.1.4. The Spaces approach in electricity access

The Spaces approach can be useful in evaluating if electricity access has resulted in empowerment. We can evaluate how notable impacts from the literature have expanded or contracted each of the spaces. For example, an increase in income for women resulting from access to electricity (Johnson et al, 2019; Grogan, 2018; Rathi & Vermaak, 2018; Dasso & Fernandez, 2015; Khandker et al, 2013; Dinkelman, 2011) may provide an expansion in economic space. Productivity increases resulted from a distributed solar photovoltaic irrigation project in Benin, as has been noted by Burney et al (2017). When work requires venturing outside the home (Dinkelman, 2011; Dasso & Fernandez, 2015), it expands a woman's physical and economic space. If such an opportunity elevates her status within the kinship structure and gives her decision-making power over finances, it indicates expansion of sociocultural space and mental spaces. When electricity in the community gives the perception of safer neighborhoods (Cecelski, 2000; Wamukonya & Davis, 2001; Chaplin et al, 2017), it can allow women to use community spaces, which is an expansion of physical space. Electricity access reducing domestic violence expands mental space. Jensen and Oster (2009) note that the introduction of cable television can alter gender attitudes; they found significant increases in reported autonomy, decreases in the reported acceptability of beating, and decreases in reported son preference. Sievert (2015) find that exposure to information through television led to lower acceptance of intimate partner violence in Sub-Saharan Africa. This literature suggests that women seeing other women in an elevated status on TV leads to increased self-worth.

Outcomes such as decreases in fertility (Peters and Vance, 2011; Ferrara et al, 2012; Fujii and Shonchoy, 2020) and increases in divorce need to be evaluated within the socioeconomic context. La Ferrara et al (2012) note that in Brazil the viewership of television led to significantly lower fertility, with a stronger effect on women of low socioeconomic status and for women in middle and late phases of childbearing life. If this change also implies that women gain reproductive rights, then it could indicate empowerment. Similarly, Chong and Ferrara (2009) find that in Brazil exposure to images of women in emancipated roles on TV was associated with increases in the share of divorce and separation. Divorce and separation could be indicative of freedom from abuse, but could also negatively affects women's socioeconomic status. Since these outcomes of electricity access are evaluated within the context, understanding women's empowerment requires qualitative approaches, such as the interviews described below.

2.2. Methods

2.2.1. Study sites and data collection

For this study, we interviewed women from four provinces in Zambia consisting of households that do not have access to electricity or have been electrified in the past three years. The sample of electrified households included both those with grid access as well as distributed renewable energy sources. A list of study sites, the region, the type of electric connection, and the number of interviews is listed in Table 7. For this fieldwork, we established a partnership with a non-governmental organization (NGO) named LiChi Community Solutions (https://lightupzambia.org/) which has a successful record of providing off-grid solutions to rural villages in Zambia. Due to travel restrictions from COVID-19, some of the sites were chosen based on advice from local authorities. We also hired enumerators who were volunteers at LiChi to conduct interviews in English as well as in the local language. Here we rely exclusively on the English interviews for analysis as recordings in the local language were done in remote areas with ambient disruptions and ultimately proved too difficult to transcribe and analyze.

Province (Town/Village/City)	**Rural/ Urban**	**Percentage of electrified households in the province**[a]	**Number of Interviews**	**Number of Interviewed households with**		
				Grid Electricity	**Off-Grid Electricity**	**No Electricity**
Western Province[b]	Rural	6.7 %	8	5	1	2
Central Province[c]	Rural	25.1 %	6	2	2	2
Lusaka Province[d]	Urban	78 %	8	4	1	3
Copperbelt Province[e]	Urban	74 %	6	3	0	3
		Total	**28**	**14**	**4**	**10**

Table 7: Interview sites

2.2.2. Sample

We used semi-structured interviews that included both quantitative and qualitative questions to analyze the five spaces introduced above (See supplemental table 1 for the interview guide). The quantitative data helped us to understand the use of electricity both in the household and at community buildings and places. The qualitative data allowed us to conceptualize and examine how (dis)empowerment results from the impacts or benefits stated by respondents. The qualitative questions targeted social norms and human behavior, particularly men and women’s perceptions of empowerment and their beliefs regarding the extent to which they feel empowered through electricity access and the expansion of their space.

2.2.3. Research questions

We have three research questions that flowed directly from our literature review and the overarching objectives of this study:

RQ1. What are the impacts of electricity access to women in Zambia?

RQ2. Does electricity access and its impacts empower women?

2.2.4. Data analysis

The qualitative data obtained from questions in Chapters 2-4 of the interview guide were analyzed in MAXQDA software using constant comparison analysis developed by Glaser and

Strauss (1967) which has been used to analyze qualitative data obtained through interviews and focus groups (Onwuegbuzie et al. 2009). There are three stages in this method:

i. Stage 1- Open Coding: In this stage, transcribed interviews were broken down into smaller segments, with a code attached to each segment. In this study, each of the topics within the interview was a segment aligning with different types of everyday activities used in a concurrent study:
    - Segment 1: Cooking (Code Cooking)
    - Segment 2: Energy (Code Energy)
    - Segment 3: Care Work (Code Care)
    - Segment 4: Paid Work (Code Paid Work)
    - Segment 5: Entertainment Time (Code Radio/TV)
    - Segment 6: Decision-making (Code Decision)

ii. Stage 2- Axial Coding: This stage involved grouping the codes into categories. These categories are the impacts/benefits that respondents say resulted from electricity access. For example, if respondents say that they saved time from use of electrical appliances, it was coded as "Time savings".

iii. Stage 3- Selective Coding: The categories we used in this study are the types of spaces described earlier. We categorized the codes from stage 1 into one or more types of space. For example, we categorized decision-making under mental space, physical space, or economic space depending on the type of response. That is, if a woman can decide the amount she spends on self-care, then it is categorized under economic space. If that decision boosts her self-esteem, it is also categorized under mental space.

We then answer our RQs using the themes that emerged from these coding.

2.3. Results and Discussion

2.3.1.RQ1: Impacts of electricity

Women in households with electricity spoke about actual impacts, while women in households without electricity discussed either how they perceived impacts or the impacts they observed in other households. Interviewees identified and highlighted five key benefits. The first was the time and effort saved from the use of appliances in cooking that helped avoid using charcoal, the use of which increased drudgery. A 73-year-old woman who worked selling baby clothes, identified *"…[electricity] will actually help me with this speed because if I have a stove it's better than waking up trying to put up charcoal… that is the whole process and mind you I have children as well so [charcoal] is our last choice…"* Another woman, who was 27 years old, unmarried and unemployed spoke of electricity's benefit, but how power outages impeded the derived benefits, *"…yes [electricity/appliances] has (benefited). It's convenient to just switch on the stove and put my food and cook for the family, it's been very convenient for me (unintelligible). I think it's something that we take for granted, and the power goes off then that's [the] only challenge yeah yes… yes it (cooking) has (changed) significantly…*"

The second benefit included the business opportunities that became possible when households gained access. These opportunities allowed women to purchase larger appliances such as ovens and sewing machines, increasing their earning potential through home businesses. A 31-year-old woman, unemployed, but married with four children identified, *"... I can say it has helped me because where I am it's a stationary and running a stationary you have to use electricity. Without electricity then we are doing nothing.*" Another woman, a 27-year-old social worker, remarked how the lack of electricity increases her cost of food storage, *"…I don't have electricity I don't have a fridge...I always have to ask people to keep for me and then I pay them something. But if I had electricity I would have my own fridge and it would help me, even things like maybe making fritters or scones, or be able to make them faster…*"

The third benefit of access was children being able to study longer due to electric lighting. Not only did they prolong their day, but they were also able to reallocate their daytime to other more productive or enjoyable activities and then study at night. Additionally, the way children study changed with electricity. Here, a 31-year-old, unemployed married woman with four children discussed the importance of electric lighting and television to their children's education: *"…my children are able to even watch from the TV what others are doing. When…we didn't have electricity, they were not able to study, but currently right now as we have electricity in our house they are able to study anytime…"*

Women also perceived increased safety due to lights in the community, especially in the streets. As a result, women felt that their mobility increased during evenings. A 24-year-old self-employed salon owner (unmarried), identified the positive impact of lighting the street. *"…[if] there's security lights …you can't be attacked by people at night…"*

Finally, women felt that electricity access in government offices, health clinics and other public buildings made everyday services such as photocopying, printing, and scanning more accessible. A 27-year-old unmarried woman said, *"…Because in the world of today when you would want a document, if it is in softcopy, they just connect their printers, their computers, they print out and give it to you…"* Additionally, respondents identified the importance of electricity for public health. A 64-year-old woman remarked, *"living in a house with electricity, it's better than living in a candle because for example in the hospital if there is no electricity a lot of patients who die especially those who have who are on oxygen because there is no electricity."*

2.3.2. Meaning of Empowerment

We asked our respondents to define empowerment in their own words and asked them if having electricity helped them achieve empowerment, as per their subjective definitions. Then, analyzing interviews for terms commonly seen in the empowerment literature, such as independence, agency, and freedom, we identified four themes that emerged from women's definition of empowerment. These included economic independence, camaraderie, self-reliance, and agency. The most common theme, economic independence, stemmed from women being able to engage in paid work as a pathway to becoming independent. For instance, a 24-year-old self-employed salon owner (unmarried) identified empowerment as, *"…simply [meaning] women getting involved into money generating activities, so they also become independent…"*. A 27-year-old social worker stated that being empowered is being able *"…to help someone something on their own…you know, independent, able to take care of their needs. So if I am in power, then at least I know that I can do some things for myself without having to ask relatives or neighbors…"*

The second theme, camaraderie, emerged as respondents explained that being part of organized groups such as cooperatives or informal groups with other women made them feel good. A 27-year-old, tertiary degree holder described that being part of women's group helps them to rely on each other's strength, *"…You realize that nowadays people are put in groups that I would say cooperatives or other groups. Women would find themselves in groups where they're involved…"*

The third theme, self-reliance, emerged from women discussing opportunities to do something on their own, particularly without their spouse. A married, employed woman stated that "*it's that women are able to do things on their own and be able to help themselves without really relying on someone or relying on their husband…"*

Finally, respondents discussed how having agency was empowering. Separate from self-reliance, our respondents explained agency emerged from having an additional strength or ability to bring about a change. A 36-year-old woman who was employed at a financial institution and married with two children, argued, *"I would say it's putting a woman in a position where she can, I think, sustain herself,f she can stand like giving her uh capability, able to live this this life like smoothly you know? Empowering…can be in terms of a business…can be financial empowerment and whatnot,…just putting a woman at that level of advantage …"*

2.3.3.RQ3: Electricity access and Women's Empowerment

To answer our final research question, we mapped the four themes onto different spaces to understand how electricity access contributed to women's empowerment. Our respondents were able to identify three main areas (spaces) of their lives that benefited directly from electricity access and how those related to empowerment. The first was the expansion of their economic space. Owning and using electric appliances helped women generate income through businesses inside and outside the home. Our respondents considered small-scale business opportunities such as sewing, hair dressing, selling meat and chickens, all of which required electrical appliances. A 36-year old woman identified that "*we have tailors, we have hairdressers, because of this electricity we have people that are into production, like small-scale farmers…"* Another: *"if there's electricity in the area, women will be able to get their fridges, store their products. If, for example they are into [the] business of selling sausages, chickens, they'll be able to keep their chickens there and able to sell to their customers..."*

Secondly, having access to electricity saves time and allows women to reallocate time for other activities outside the home, be it for paid work, or for gathering or healthcare at government buildings, churches and health clinics. As this creates an opportunity to explore the spaces outside their home, it is also an example of expansion in physical space. A single mother of two children identified the importance of electricity and health clinics, *"…It has changed my experience because for example if someone is sick, is not breathing well, they should be able to use the oxygen and those uses electricity yes"* Another spoke of churches and the power of electricity to literally amplify her voice, *"…In my place of worship there's electricity and I enjoy it because I love singing. When singing we use the microphones that are connected to the PA* *system, of course to the socket, so it has changed my life very much, like I said even when I'm standing in front of people the voice becomes so audible because I am using a microphone."* Singing may also be considered an expansion of women's mental space, which electricity facilitated via improving women's decision-making capabilities. Being able to decide for themselves signaled a feeling of strength in our respondents. The expansion of mental space seemed to occur in two ways. First, electricity enabled women to make direct decisions on important matters such as diet and food expenditure. A 24-year old woman: "*Having electricity would definitely change the way we make decisions. Decisions like diet and food expenses…"* Second, electricity helped women pursue activities that made them feel better about themselves, such as going to the market or church. This space expanded not only because of the time saved, but due to improvements in safety and increased business opportunities in public buildings and spaces. A 32-year-old diploma holder in teaching and food seller remarked*, "[with] electricity in the house you will find that even the activities concerning cooking it would be shortened and most of the time it would be spent to other activities like going to sell in the market"*

Figure 3 represents the results of our mapping exercise. Through coding, we first mapped each area of activity to the impacts (and benefits) that our respondents indicated resulted from gaining access to electricity. We then applied the contextual meaning of these impacts to map them onto the spaces they expanded. For example, having access to electricity saved time in cooking and energy-related activities via use of appliances such as electric stoves and refrigerators. While the ownership of these appliances can indicate an expansion of economic space, the sense of freedom to use the saved time in another activity of their choice can be viewed as an expansion of the mental space. Recalling that the expansion in mental space is a condition for empowerment to take place, our respondents indicated that electricity access results in less drudgery and saves time resulting in their having the choice to use their time as needed. It thus expands their mental space along with economic space (through opportunities to engage in paid work or own appliances), or physical space (creating time for them to explore the spaces outside of their home), resulting in feelings of empowerment.

2.4. Discussion

Women's empowerment is integral to achieving the sustainable development goal of gender equality. In this study, we examined the relationship between women's empowerment and electricity access within the cultural context of Zambia. The unique aspect of this study is that we connect the impacts of electricity access to women's empowerment, while allowing our participants to define what empowerment means to them. We then use the Spaces approach to examine how electricity expands (or decreases) spaces. The interviewees in our study reported expansion in three spaces, namely, economic space, physical space, and mental space. Economic space was expanded via pursuit of paid work opportunities inside and outside the home, made available from saved time in cooking. The additional income also allowed them to make decisions on household expenditures. Expansion in physical space occurred primarily via paid work and travel to government buildings, clinics, and church where the presence of electricity made a remarkable and positive change in their experience.

In each of these instances, women also reported increased economic independence, camaraderie, self-reliance, and agency, each representing an expansion of mental space. Thus, our results show that empowerment is a direct result of electricity access via the use of electrical appliances, which save time, reduce drudgery and create opportunities for paid work inside and outside the home.

To understand these results within the context of Zambia, it is essential to highlight the gender norms that are part of their social structure. There are deep rooted beliefs about girls belonging in the kitchen and these types of discriminatory practices have been identified as challenges to achieving gender equality (Republic of Zambia, 2020). The government of Zambia has responded by prioritizing women's empowerment via the Gender Equity and Equality Act No. 22 of 2015, and creating several programs such as microcredit schemes and girls' education programs. Electricity is likely crucial to both programs. However, the government also acknowledges that rural women might lose out on the benefits from information and communication technologies (ICT) due to a lack of necessary infrastructure (Republic of Zambia, 2020). In the households interviewed here, most of the off-grid technologies used were a small number of solar panels, or inverters (Figure 4), many of which do not have enough capacity to provide the suite of benefits discussed by government officials.

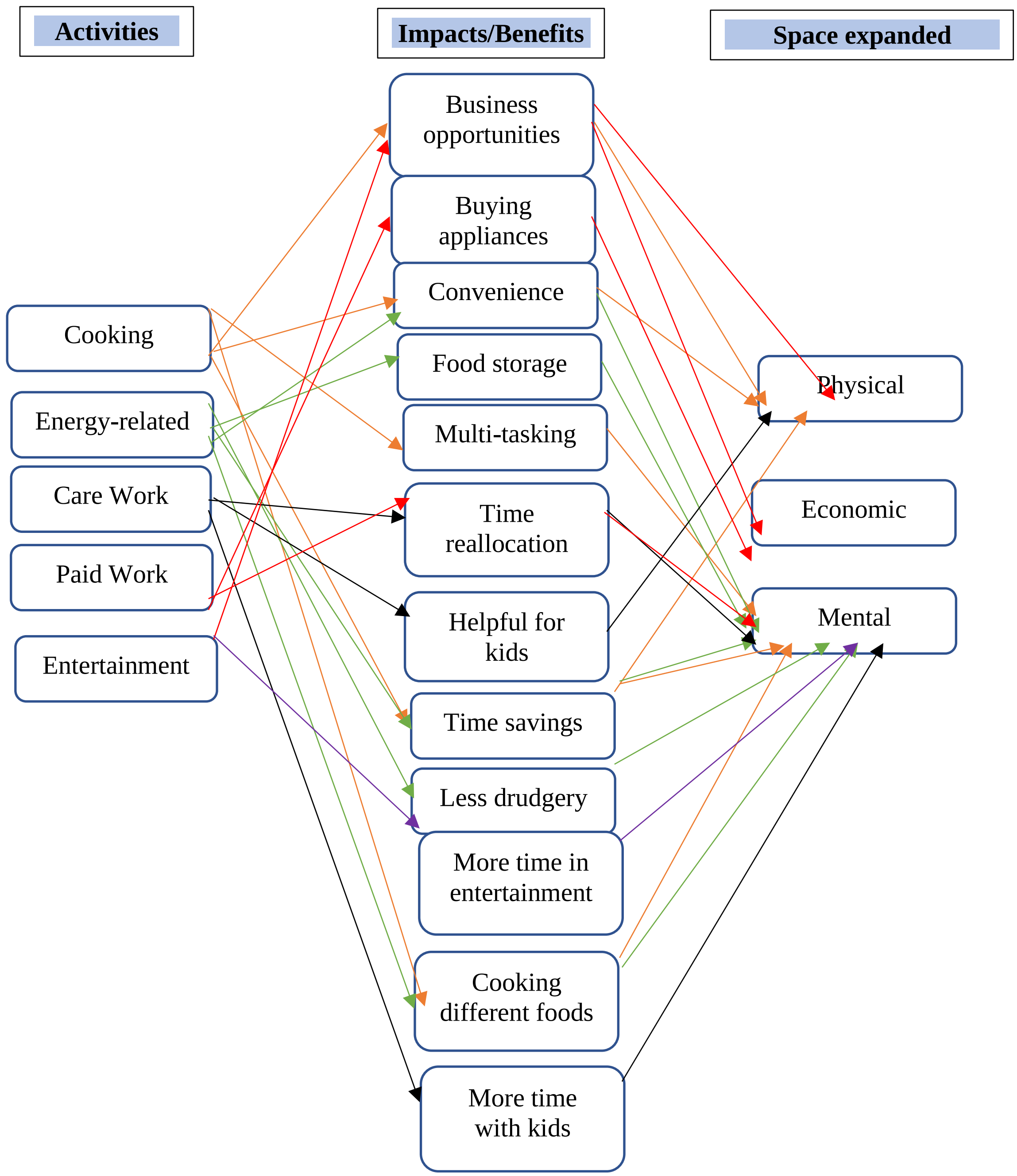

Figure 3: Mapping areas of activity (Column 1) to the spaces they expand (Column 3) through impacts (Column 2)

Evaluating the impacts from electricity access to women using the Spaces approach highlights several opportunities for promoting women's empowerment. The first opportunity is to engage in paid work. Economic empowerment through opportunities outside of home increase a woman's agency, her mobility outside the home, access to resources, and can help her gain economic independence. In other words, an expansion in multiple spaces. As Cohn and

Blumberg (2020) mention, when women are engaged in key production activities, specifically activities that are valued and held important, they cannot be easily replaced. This results in strategic indispensability. Second, women's (non-economic) empowerment can be promoted indirectly by reducing drudgery and saving their time and effort in their daily activities. The ability to decide for themselves as well as having access to important services outside of home boosts morale.

Our study suggests that electrification programs need to be tailored to ensure that women benefit not just from having access within the household but also from viable opportunities to work outside the home. That is, development of complementary infrastructure such as roads or public sanitation might help households view the benefits as a bundle rather than focusing on electricity alone. Building roads in particular can improve access to markets without which alternate income-generating activities may not be possible. Finally, and most importantly, programs must acknowledge the power of information. Sociocultural norms are at the heart of empowerment and evidence from literature (Chong & Ferrara, 2009; Jensen & Oster, 2009; La Ferrara et al., 2012) shows that information through television can bring dramatic changes in mental space. Thus, targeted efforts to disseminate information about issues such as women's rights and domestic violence should be added to development projects perhaps focusing solely on improving electricity access.

Finally, it should be noted that while studies that have shown notable outcomes in education, fertility, and empowerment typically have a large number of households (at least 5000 households) (Chaplin et al., 2017, Burlig & Preonas, 2016) or have been analyzed several years following access (Chong and Ferrara, 2009; Dinkelman, 2011), the women's narratives collected here provide rich cultural context in which to better understand how empowerment and electricity access are related in Zambia. Furthermore, this is one of the few studies to establish a direct connection between subjective definitions of women's empowerment and electricity access.

Figure 4: (Left to right) Rooftop solar panels, solar inverter, solar prepaid system, solar lights

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Chapter 3: Misalignment of perceptions with records and resources for responding to climate risk in Burkina Faso

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3.1. Introduction

Anthropogenic climate change has already resulted in over 1.1◦C of warming (IPCC, 2022), significant increases in the frequency, intensity, and duration of heatwaves and cyclones, and extreme variability in rainfall, flooding, and drought (Eckstein et al., 2021). Projected increases in temperature are expected to result in more frequent and severe extreme events (IPCC, 2022). Such changes are especially impactful in sub-Saharan Africa (SSA), where large numbers of farmers and pastoralists rely on natural resources that are vulnerable to increases in temperature and variability in rainfall (Huq and Reid, 2004). In countries like Burkina Faso, development challenges including rising populations, extreme poverty, and poor institutions and infrastructure, exacerbate these climate risks, weakening locals' adaptive capacity (Alvar-Beltrán et al., 2020). The adaptive capacity of a community depends on how well individuals understand the anticipated impacts (Huq and Reid, 2004) and thus perceive the risk of climate change. People's risk perceptions vary considerably across age, gender, culture, politics, personal experiences, education, income, and wealth (Finucane et al., 2000; Eckel and Grossman, 2008; Akerlof et al., 2013; Booth et al., 2014; Lee et al., 2015). The goal of this study is to better understand the contribution of these factors, particularly those associated with wealth, age, and gender, as well as local long-term climatic trends on farmers' perceptions of climate change and adaptation strategies in Burkina Faso. Different climate risk perceptions mean different adaptation strategies. Alvar-Beltrán et al. (2020) found that farmers in Burkina Faso were aware of the hazards resulting from climate change including increased temperatures, change in rainfall, and delayed and premature rainy seasons, but the number of farmers who adopted conservation strategies depended on their agroclimatic zone and location. Here we examine how farmers' perceptions of climate risk in Burkina Faso align with actual climate data and the extent to which their perceptions inform the actions they take to adapt. We focus on a country that is heavily dependent on agriculture and natural resources. Eighty percent of Burkina Faso's economy is based in agriculture (World Bank, 2021). The country ranks as one of the most vulnerable to climate risks, and it has regional differences in its topography and climatic conditions, as well as climate hazards (World Bank, 2021). With about 40 percent of its population living below the poverty line, the country is ranked 184th of 191 countries in the Human Development Index (HDI) as of 2021–2022 (UNDP, 2022b). The country is expected to experience about a 1.4–1.6◦C increase in temperature from climate change (UNDP, 2021) resulting in increased drought, flash floods, windstorms, and disease outbreaks (World Bank, 2021). Some adaptation efforts have been taken, including creating flood-risk maps to increase flood resilience and for city planning and investments (Conway and Vincent, 2021). As part of The National Adaptation Program of Action (NAPA), Burkina Faso has also prioritized disaster risk reduction among other measures to improve capacities for climate change adaptation (UNDP, 2022a). To better understand the alignment of recorded climatic change, farmers' perceptions, and their adaptation choices, we use empirical studies of climate change perceptions. These studies show both convergence and divergence between perceptions and climate records (e.g., Vedwan and Rhoades, 2001; Meze-Hausken, 2004; Osbahr et al., 2011; Piya et al., 2013; Kabir et al., 2017; Mulenga et al., 2017). Kabir et al. (2017) reported that farmers in Chuadanga, Bangladesh perceived temperature increases and rainfall decreases that aligned with climate records; however, their perceived risk varied considerably across individuals and was rarely aligned with the estimated probability and potential consequences associated with a hazard. Meze-Hausken (2004) found that Ethiopians' perceptions of reduced rainfall were mostly in line with the underlying climate data, but the gap was in part due to people's expectations of actual rainfall needs. Similar conclusions are reported by Osbahr et al. (2011) in southwest Uganda where farmers' perceptions of rainfall were judged against and derived from their actual rainfall needs. Mulenga et al. (2017) explained that such inconsistencies between perceptions and actual data occur when farmers recall and associate unique events with climate change, as opposed to recalling incremental changes over the long run. Farmers also use their personal experiences to perceive climate change, which may not align with actual data (Moyo et al., 2012). Foguesatto et al. (2020) explained such divergences, particularly concerning variability in rainfall, using expected utility theory (Bernoulli, 1738; Von Neumann and Morgenstern, 1947) and the availability heuristic (Tversky and Kahneman, 1973);

farmers recall extreme events, particularly the ones highlighted by the media (Whitmarsh and Capstick, 2018) and thus perceive greater variability in temperature and rainfall than climate records show.

Perceptions about climate change are also influenced by socioeconomic factors (Weber, 2016; Foguesatto and Machado, 2021). Age, education, and personal beliefs about climate change can influence perceptions (Piya et al., 2013; Ansari et al., 2018). In select Amazonian communities, 72 percent of the sampled population perceived changes in climate, and that perception increased with age (Funatsu et al., 2019). Others report the impact of wealth on farmers' perceptions of climate change, measured either, as material assets and farmland owned by farmers (Hou et al.'s, 2015) or as all farm and non-farm assets combined (Singh et al., 2017). In this study, we include asset ownership and farmers' perceived standard of living as proxies for wealth in Burkina Faso. Wealth can have interesting effects; Hou et al.'s (2015) found that wealthier farmers in China were less likely to accurately perceive temperature changes, perhaps because they could afford to protect themselves from high temperatures or because they were involved in management rather than actual farm work. Both perceptions and adaptations likely differ by gender as well. Singh et al. (2017) studied how men and women of the Adi community in Arunachal Pradesh, India perceived climate variability differently and adapted their livelihood activities to it. While both men and women noticed common changes such as fewer rainy days, shorter winters, longer summers, and more variability in rainfall, women and men noted specific changes in their areas of work. Gender continues to be an important factor in climate change adaptation because farmers have been noted to choose adaptation techniques based on agricultural tasks specific to their gender (Darabant et al., 2020). Women are also considered to be more vulnerable than men to climate change impacts since extreme climate events tend to exacerbate existing gender inequality (UNWomen, 2018). Religious and cultural factors also play a role in perceiving risk. Moyo et al. (2012), in a participatory research study of Zimbabwean farmers in two semi-arid areas, showed that farmers perceived climate changes like increased temperatures, more variability, and a decrease in rainfall, but believed the weather changes were caused by cultural and religious factors such as their belief that God was punishing them for ignoring cultural norms or that their ancestors were angry. Bessette et al. (2017, 2019) showed that people often rely on their values to inform their beliefs, and when faced with uncertainty and a complex situation, like long-term temperature and rainfall trends, they use those values to simplify their understanding, leading to inconsistency between their priorities and their choices and likely perceptions and recorded data.

Finally, a lack of information about risk can influence perceptions, and that information need not always be in the form of formal education or expert training. Knowledge and expertise gained by farming are also important (Soubry et al., 2020), and education is often shown to be a strong predictor of climate change awareness and its risks (Lee et al., 2015). Experts and laypeople often perceive risk quite differently (Siegrist et al., 2007). Even when individuals' perceptions of climate change align with trends predicted by climate data, identifying the role that climate change plays alongside other perhaps more pressing concerns like political, economic, and social factors remains difficult (Mertz et al., 2009). Ultimately people's different risk perceptions impact their adaptation strategies. When perceptions align with reality, one would expect such perceptions to lead to stronger intentions to adapt (Abid et al., 2019) and different types of adaptation strategies chosen (Hasan and Kumar, 2019). We examine this supposition below.

The objective of this study is to understand how socioeconomic factors, in particular those related to wealth and resources, such as asset ownership and perceived standard of living, along with the age and gender of the household head, inform the perceptions of climate change risk in farmers of Burkina Faso. To determine the extent to which those perceptions align with actual change, we compare farmers' perceptions with two decades of recorded climate data. We examine whether the factors mentioned above can predict the extent to which those perceptions align with recorded climate data and influence farmers' choices to adapt. This results in four research questions, which we also use to structure our methods and results. First (RQ 1), do farmers in Burkina Faso perceive a long-term change in temperature and rainfall? Next (RQ 2) how do those perceptions align with recorded trends in climate data? Third (RQ 3), what factors explain the alignment of perceptions with recorded climate data? Finally (RQ 4), how do those perceptions impact farmers' choices to adapt?

3.2. Methods

3.2.1. Study population

We relied on two datasets for this study. The first is a quantitative household survey of farmers (and fishers) carried out by the United Nations Development Programme in 2015—2015 being the most recent household survey data we had available. This survey consists of demographic questions and questions about individuals' climate perceptions and adaptations [e.g., perceptions of long-term changes in temperature and precipitation, perceptions on specific temperature changes (warmer or cooler), and rainfall (wetter or drier)], and if and how they adapted [i.e., What type of adaptation choices they use? (see Table 13 for a list of the adaptation choices)]. 1,724 observations exist for Burkina Faso, all of which are male and female household heads (see Table 8). Most of the respondents in the study are smallholder farmers with low incomes who earn an average of USD 52.76 per acre. This is considerably low when compared to the average earnings of USD 187.04 per acre of African farmers from 11 countries noted in a study by Kurukulasuriya and Mendelsohn (2008). Climate data. Our second dataset is sourced from the Climatic Research Unit (CRU) of the University of East Anglia (University of East Anglia, 2021) and accessed through the World Bank's Climate Change Knowledge Portal. It consists of monthly average temperature and rainfall for specific locations in Burkina Faso (amongst other countries) for the years 1991 to 2014. For the geographic location of each respondent in the UNDP survey, we used Python to extract the data from this portal available as a NetCDF file. We obtained the mean monthly temperature and monthly rainfall for every year between 1991 and 2014. Figures 5a, b provide time-series plots of the mean monthly temperature and rainfall, respectively. Note that both temperature and rainfall show an increasing trend over the study-time period (1991–2015), but those trends are not consistent across farmers' specific locations, and rainfall shows considerable variability.

Variables	
Age of household head (Yrs)	48.3
Net revenue per acre (USD)	52.76
Asset ownership (1-Yes/0-No)	0.95
Gender of household head (1-Female/0-Men)	0.02
Percentage of farmers who did not adapt	79.4
Percentage of farmers whose crops are exclusively rainfed	92.8
Percentage of farmers who have less than sufficient income	85.2
LTTemp[i] (1-Yes/0-No)	0.90
TempCoolerWarmer[ii] (1-Warmer/0-Cooler)	0.98
LTRain[iii] (1-Yes/0-No)	0.84
PrecptDrierWetter[iv] (1-Wetter/0-Drier)	0.06

Table 8: Summary statistics of key variables. All statistics are mean values unless otherwise noted (n = 1,724)

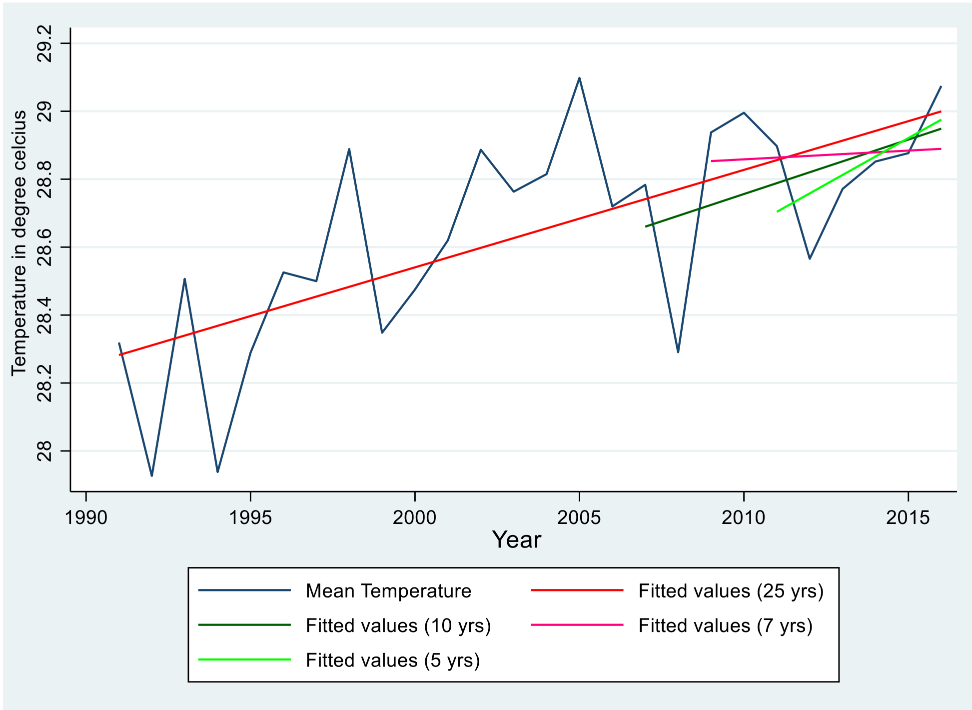

Figure 5a: Mean monthly temperature from 1991-2016

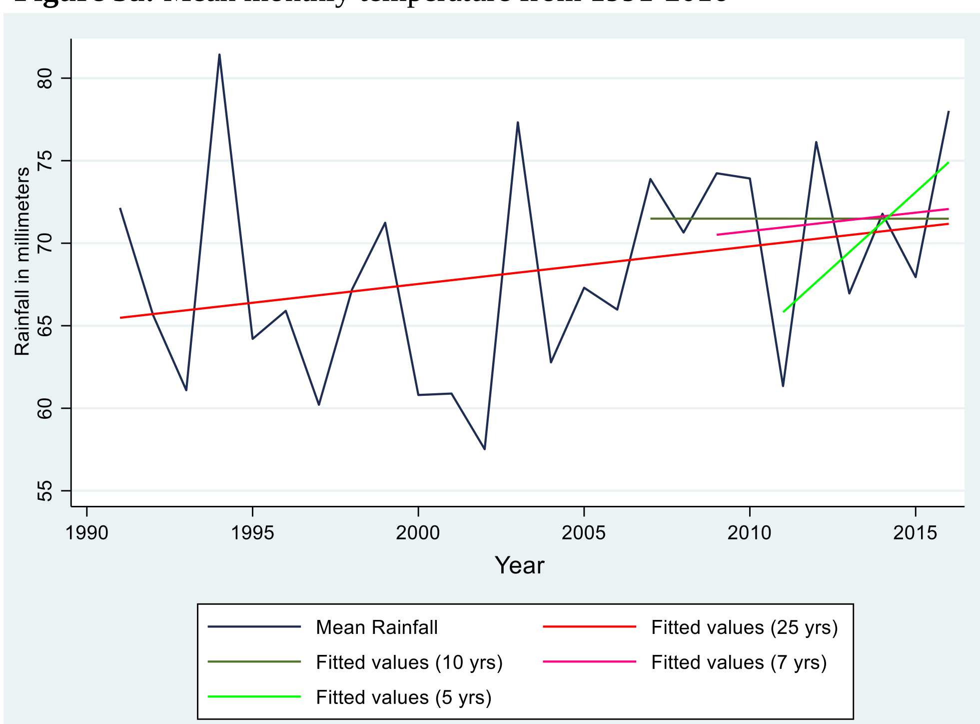

Figure 5b: Mean monthly rainfall from 1991-2016

3.2.2. Data analysis

To answer our first research question (RQ1), we consider the survey question "Have you noticed any long-term shifts in temperature in your area?". We use boxplots to graph the distribution of the slopes of temperature and rainfall change for four timeframes: 5 years (2011–2015), 7 years (2009–2015), 10 years (2006–2015), and 25 years (1991–2015). Our choice of timeframes was guided by existing studies and the availability of data. We chose our shortest timeframe of 5 years as Moyo et al. (2012) find that the farmers in their study were able to recall only up to 5 years. We chose 25 years as the longest timeframe because at the time of data extraction, 25 years was the maximum timeframe for which climate data was available. We then chose 7 and 10 years as reasonable medium-term timeframes to analyze farmers' perceptions. We provide separate boxplots for farmers who report noticing a long-term change in temperature and rainfall, and farmers who did not (Figures 6a,b).

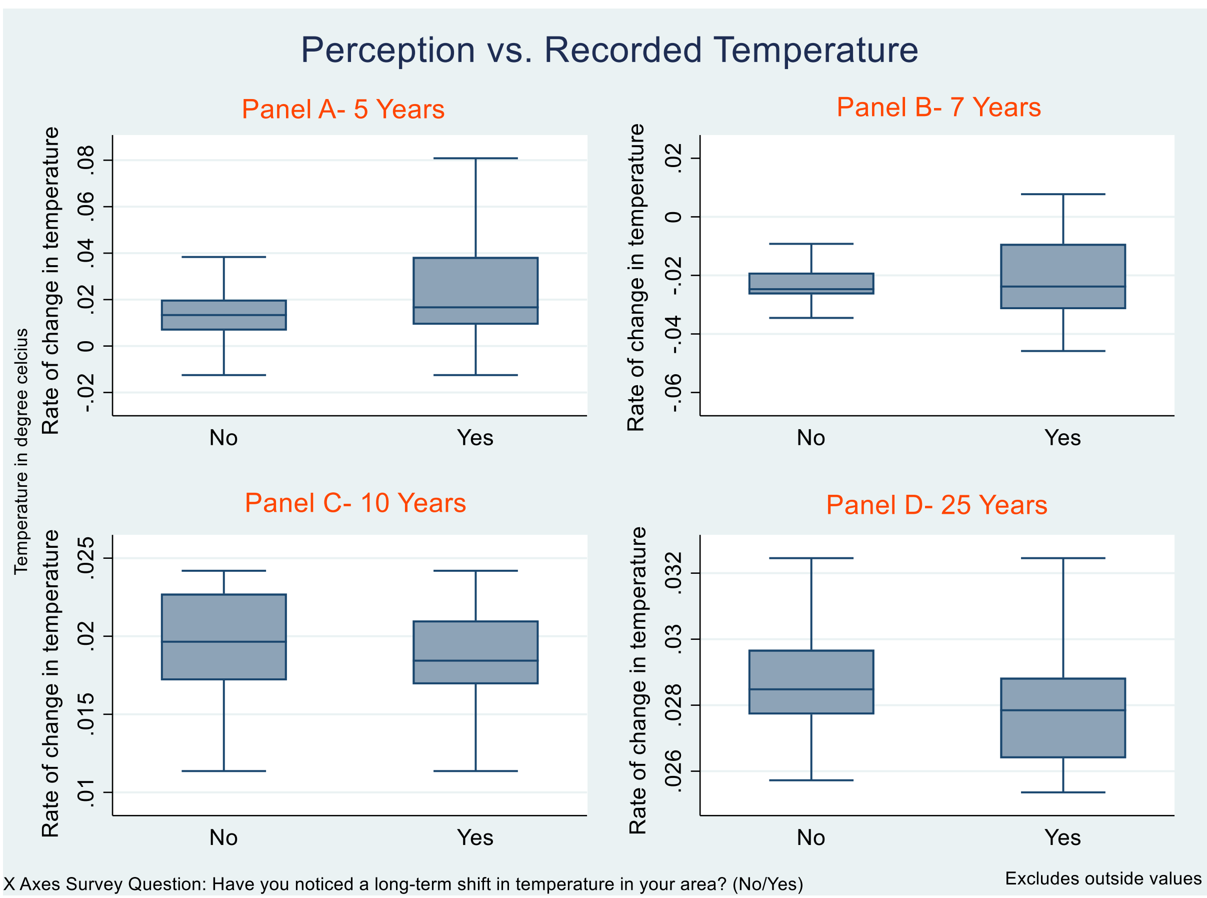

Figure 6a: Comparison of farmers who noticed a long-term shift in temperature (Yes) and those who did not across (No) against the rate of change in temperature

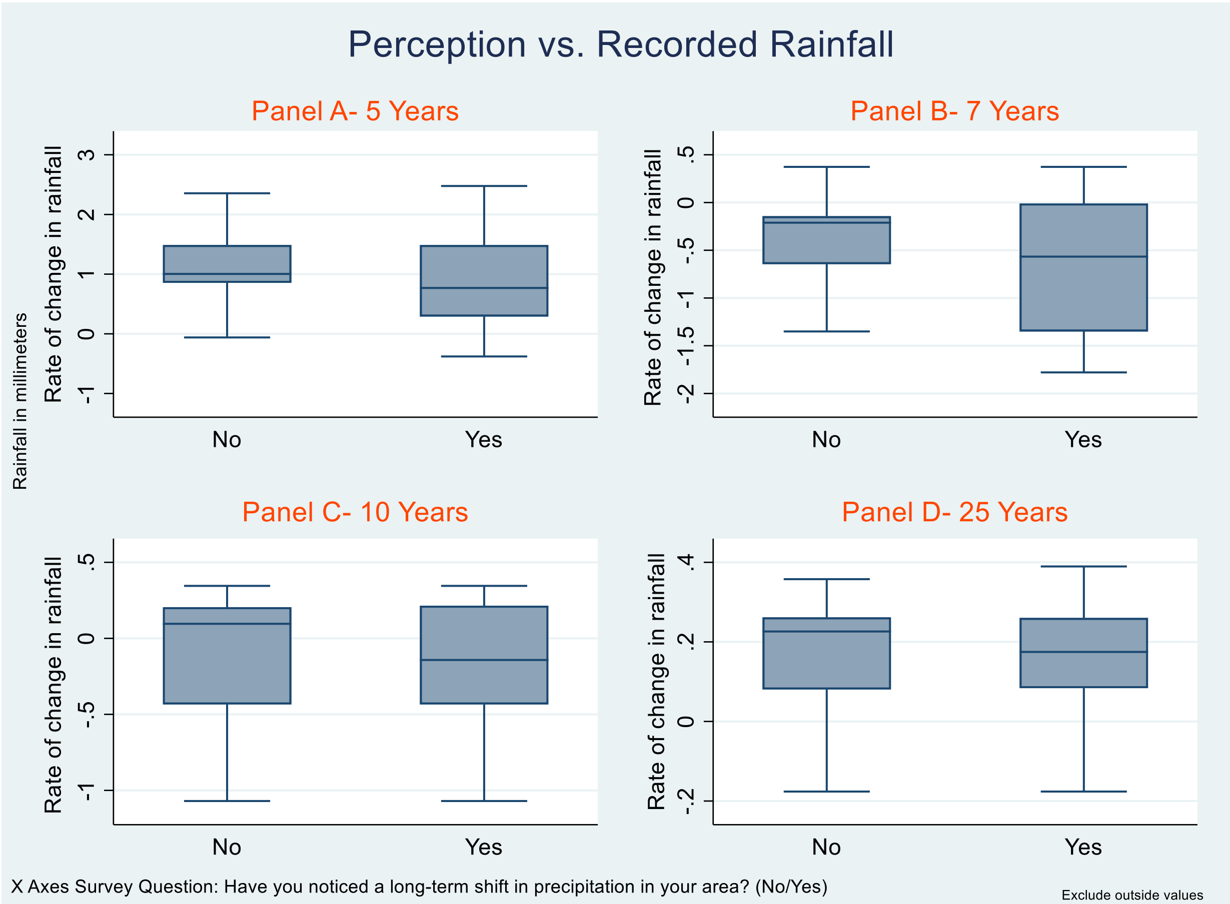

Figure 6b: Comparison of farmers who noticed a long-term shift in rainfall (Yes) and those who did not across (No) against the rate of change in rainfall

To answer RQ 2, we assess the direction of farmers' perceptions (Has it become cooler or warmer? Has it become wetter or drier?) and create a new variable that categorizes whether or not farmers' perceptions align with local recorded temperature and rainfall trends. To do this, we divided the full rage of potential slopes of temperature and rainfall change for each timeframe into quartiles. If a respondent indicated that they perceived that it has become warmer (or wetter, in the case of rainfall) and the slope of the temperature/rainfall change fell in the top two quartiles, then their perception was classified as aligning with recorded data. If a respondent indicated that they perceived that it has become cooler (or drier, in the case of rainfall) and the slope of the temperature/rainfall change fell in the top two quartiles, then their perception was classified as not aligning with recorded data. The four cases of alignment across both temperature and rainfall are shown in Table 9.

Quartile of Recorded Change (Temp or Rain) at Farmer's Location[i]	Farmer's Perception of Temperature Change	Aligned/Not aligned	Farmer's Perception of Rainfall Change	Aligned/Not aligned
1st or 2nd	Cooler	Aligned	Drier	Aligned
3rd or 4th	Warmer	Aligned	Wetter	Aligned
1st or 2nd	Warmer	Not Aligned	Wetter	Not Aligned
3rd or 4th	Cooler	Not Aligned	Drier	Not Aligned

Table 9: Categorization of Alignment variable. i. The quartiles were calculated based on the total range of the recorded rate of change of temperature or rainfall (mean annual rate) for each timeframe and across the entire country

We use boxplots to compare the slope of the temperature and rainfall change and alignment for each of the four timeframes (Figures 7a, b). While examining the medians helps us understand alignment as the slope of temperature and rainfall change varies, we also perform a two-sample *t*-test to determine if the mean estimated slope of temperature and rainfall are statistically different for groups whose perception aligns with recorded data (*Align)* and for groups whose perception does not (*Not Align*). The results are given in Tables 10a, 10b.

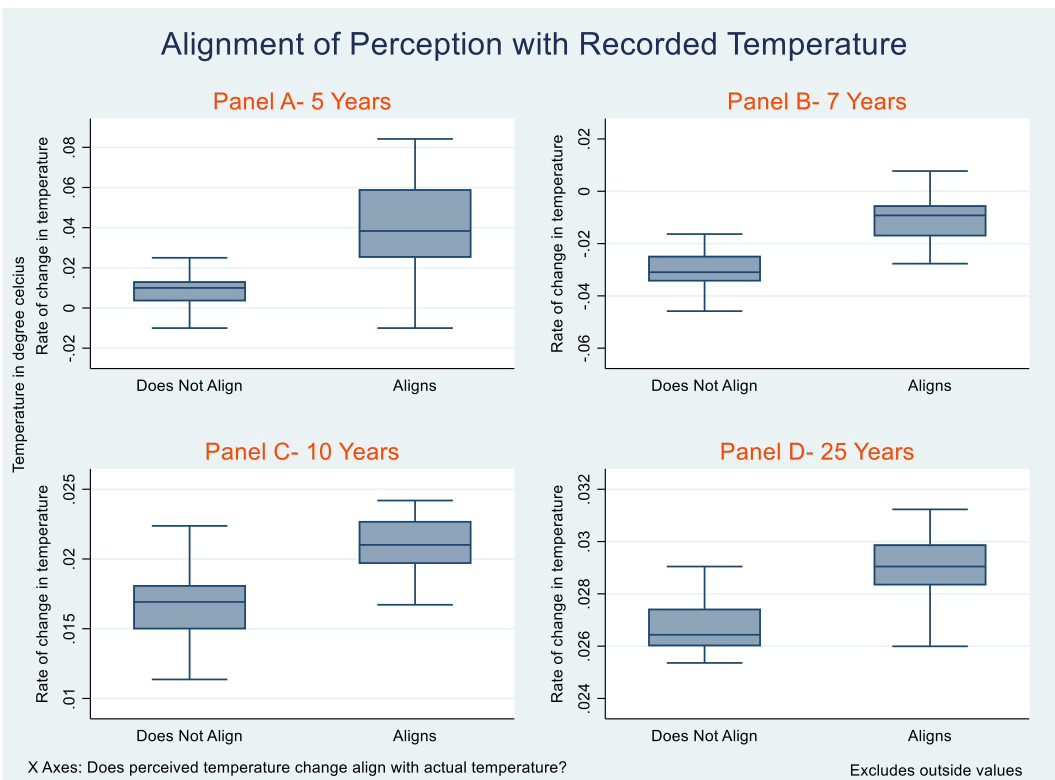

Figure 7a: Alignment of perceived temperature change with recorded rate of change in temperature

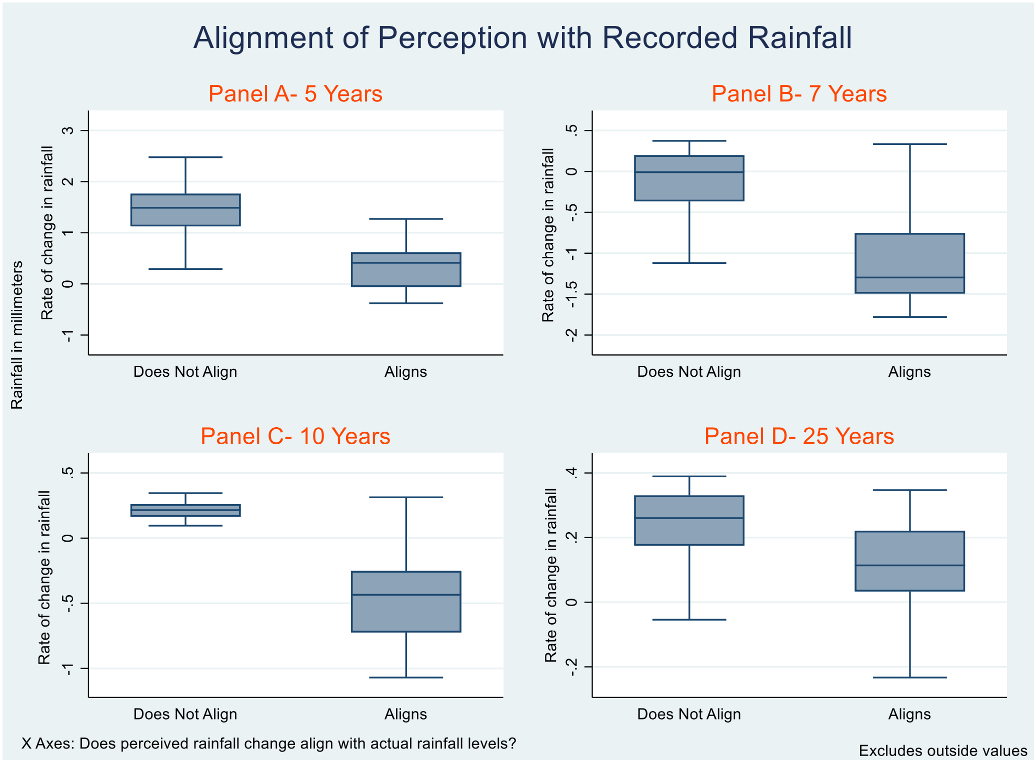

Figure 7b: Alignment of perceived rainfall change with recorded rate of change in rainfall

Timeframe	Group	n	Mean annual rate of temp change	se	t
5-year slope	Not Align	816	0.008	0.01	-39.49***
	Align	735	0.044	0.02	
7-year slope	Not Align	777	-0.031	0.01	-43.97***
	Align	774	-0.011	0.01	
10-year slope	Not Align	806	0.016	0.00	-46.84***
	Align	745	0.021	0.00	
25-year slope	Not Align	794	0.027	0.00	-47.80***
	Align	757	0.029	0.00	

Table 10a: Results of two-sample t-tests with unequal variances- Temperature

Timeframe	Group	n	Mean annual rate of rainfall change	se	t
5-year slope	Not Align	655	1.439	0.39	38.60***
	Align	790	0.371	0.65	
7-year slope	Not Align	630	-0.077	0.33	46.59***
	Align	815	-1.132	0.53	
10-year slope	Not Align	697	0.151	0.19	48.72***
	Align	748	-0.484	0.30	
25-year slope	Not Align	729	0.253	0.13	31.36***
	Align	716	0.037	0.13	

Table 10b: Results of two-sample t-tests with unequal variances- Rainfall

For our third research question (RQ3), we analyze the factors potentially contributing to the alignment of a person's perception with recorded climate data. To do this, we select the timeframe which had the highest proportion of alignment between farmers' perceptions and climate data. These are provided in Table 11.

Timeframe	Temperature	Rainfall
5 years	47.4	54.7
7 years	**50.0**	**56.4**
10 years	48.0	51.8
25 years	48.8	49.5

Table 11: Percentage of respondents whose perception aligns with climate data over each timeframe

We then use logistic regression with the dependent variable being alignment of farmers' perceptions with recorded data. Since the survey responses in our dataset were binary in nature in both farmers perceiving the change (Yes/No) and the direction of that change (Hotter/Colder), this model is well suited to understand probabilities of response variables. Similar studies in climate change perception and adaptation have also used the logistic regression (Fosu-Mensah et al., 2012; Joshi et al., 2017). Our explanatory variables for RQ3 include those examined in the literature review above, i.e., asset ownership, the age and gender of the household head, and household size. The results of the regression are given in Table 12.

Variable	Temperature	Rainfall
Household Size	-0.056*** (0.01)	-0.061*** (0.01)
Age	-0.012*** (0.01)	-0.014*** (0.01)
Gender	-0.057 (0.37)	-0.416 (0.39)
Asset Ownership	-1.162*** (0.29)	-1.291*** (0.32)
Constant	2.321*** (0.35)	2.879*** (0.38)
Observations	1,551	1,445

Table 12: Regression results of factors determining alignment over a 7-year timeframe. Standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

For our final research question (RQ4), we examine how farmers adapt to changes in temperature based on their perceptions. The UNDP survey asked if farmers had deployed an adaptation strategy for changing temperatures or not (Table 13). We use logistic regression to analyze the factors that affect this choice to adapt (or not) including whether they perceived temperature changes in line with recorded data, the size of the household, age, and gender of the household head, and the minimum standard of living as indicated by the farmers. These results are given in Table 14.

3.3. Results

3.3.1.RQ1: Do individuals perceive a long-term change in temperature and rainfall?

The vast majority, i.e., 90 percent, of farmers reported observing a long-term change in temperature, and 83.8 percent of farmers reported observing a long-term change in rainfall.

Adaptation strategies	Percentage of respondents
1. Changed planting dates	8.2
2. Changed irrigation schedule	0.3
3. Changed fertilizer use pattern	0.2
4. Change crop types e.g., maize, sorghum, millet	3.4
5. Use different crop varieties (hybrid or genetically modified	0.2
6. Made irrigation investment (such as sprinkler or groundwater pump	0.2 1.8
7. Others (Please specify)	85.7
8. Did not Adapt	
Total	**100.0**

Table 13: Adaptation strategies for change in temperature. Survey question: Check what kinds of adaptations as a Farmer (Crops only) you have made to the changes in temperature. Select all that apply

Temperature

Figure 5a shows the slope of the temperature change for each of four time periods across respondents who noted a long-term shift in temperature in any direction (*Yes)* and those who did not (*No)*. Note the different scale (y-axis) used in each panel in Figure 5a. The range of temperature change is greater in the 5-year (−0.01◦C to 0.08◦C) and 7-year timeframes (−0.04◦C to 0.01◦C) than it is in the 10-year (0.01◦C to 0.02◦C) and 25-year timeframes (0.025◦C to 0.032◦C). The median values of the slope are higher for the *Yes* group (0.018◦C) than for the *No* group (0.01◦C*)* only in the 5-year timeframe. For the 7-, 10- and 25-year timeframe, the results are not consistent. For example, the median slope for individuals who did and did not perceive a difference is equal in the 10-year (0.02◦C) and 25-year (0.03◦C) timeframes, respectively.

Rainfall

Figure 5b shows the slope of the rainfall change for each of four time periods across respondents who noted a long-term shift in rainfall in any direction (*Yes)* and those who did not (*No)*. The range of slope values are wider in the 5-year (−0.5 to 2.7mm) and 7-year timeframe (−1.75 to 0.5mm) than the 10-year (−1.1 to 0.3) and 25-year timeframe (−0.1 to 0.3mm), similar to that of temperature. However, differences between the median slopes for the *Yes* and *No* groups do not follow similar trends. The median rainfall change for the *No* group (1.0mm) is greater than the *Yes* group (0.77mm) in the 5-year timeframe and all subsequent timeframes.

Variable	**Coefficient**
Perception Aligned	0.957*** (0.21)
Household Size	-0.005 (0.01)
Age	0.002 (0.01)
Gender	0.571 (0.50)
Min. Std.	0.764*** (0.23)
Constant	-3.165*** (0.41)

Table 14: Regression results of the logit model examining household and individual characteristics and the choice to adapt to temperature change (n = 1,494). Standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

3.3.2. RQ2: How do individuals' perceptions of temperature and rainfall compare with recorded data?

Temperature

Using the steps described in Section Data analysis, we plot the distribution of the slope of the temperature change in Figure 6a using boxplots. Similar to Figures 5a and b, we adjusted the values in the y-axis to reflect the range of values specific to each timeframe. The range of slope values for the 5-year timeframe is wider than the rest of the timeframes. In the 5-year timeframe, the values range from −0.01◦C to 0.08◦C. This contrasts the much narrower range of values for the 25-year timeframe—from 0.026◦C to 0.032◦C. Across all four timeframes, the median rate of temperature change for the *Align* group is higher than the median rate of temperature change for the *Not Align* group, signifying individuals were more likely to perceive temperature change in line with recorded data the greater their local temperature change. We next conducted a two-sample *t*-test to ensure the mean slopes (mean annual rate of change) for the *Align* and *Not Align* groups followed a similar pattern for each time frame. The results for temperature are provided in Table 10a. For every timeframe, there is a statistically significant difference in the mean slope of temperature change between the *Align* and *Not align* groups. For example, in the 5-year timeframe, the mean slope of temperature change for the *Not Align* group was 0.008◦C (*se* = 0.01◦C), compared to 0.044◦C (*se* = 0.02◦C) for the *Align* group. Like the median values, the mean values for the *Align* group are significantly higher than that of the *Not Align* group in every timeframe.

Rainfall

Figure 6b shows the distribution of the slope of rainfall changes in each timeframe. For example, in the 5-year timeframe, the slope values range from −1mm to 2mm while in the 25-year timeframe, the values range from −0.4mm to 0.4 mm. The median rate of rainfall change is lower for the *Align* group than it is for the *Not Align* group across all four timeframes. In the 7-year and 10-year time frame, the *Align* groups experienced more rapidly drying conditions than the *Not Align* groups, while in the 5-year and 25-year timeframe, the *Not Align* groups experienced more rapid increases in rainfall. Farmers were thus more likely to perceive rainfall changes in line with recorded data the less rainfall increased over the short and long-run. Our two-sample *t*-test to compare the mean estimated slopes for the *Align* and *Not Align* groups for each time frame are provided in Table 10b. In every timeframe, there is a statistically significant difference in the mean slope of rainfall change between the *Align* and *Not Align* groups. The mean values of the *Not Align* group are higher than that of the *Align* group in every timeframe [the opposite of temperature change (See Section Temperature above)]. For example, the 25-year mean slope value is 0.25mm for the *Not Align* group, which is higher than 0.04mm for the *Align* group.

3.3.3.RQ3: What factors determine perception of temperature and rainfall changes?

Table 11 provides the percentage of respondents whose perception of temperature and rainfall changes align with recorded data over each timeframe (slopes of mean annual temperature and rainfall change, respectively). For our regression model, we selected the 7-year timeframe for temperature and for rainfall because respondents' perceptions aligned most often with the recorded climate data for that timeframe. Table 12 provides the regression results from the logit model examining household and individual characteristics associated with the alignment of individuals' perceptions of temperature and rainfall change with climate records. In the case of temperature, the results from the model show that household size (b = $-0.056***$, *se* = 0.01)1, the age of the household head (b = $-0.012***$, *se* = 0.01), and asset ownership (b= $-1.162***$, *se* = 0.29) are statistically significant and negatively affect the alignment of farmers' perceptions. Gender is not statistically significant. Similarly, when considering rainfall, household size (b = $-0.061***$, *se* = 0.01), the age of the household head (b = $-0.014***$, *se* = 0.01), and asset ownership (b = $-1.291***$, *se* = 0.32) are statistically significant and negatively associated with alignment.

3.3.4.RQ4: How do individuals' adaptation choices differ based on their perceptions?

Seventy-nine percent of farmers in Burkina Faso chose not to adapt to rising temperatures (see Table 13). Table 14 provides the regression results for the logit model examining household and individual characteristics associated with that choice to adapt (or not) to temperature change. Due to the low data quality regarding responses to rainfall adaptation choice questions in the UNDP survey we do not examine them here. Similar to RQ3, the 7-year timeframe was used due to it being best aligned with residents' perceptions. The alignment variable (b = $0.957***$, *se* = 0.21), and whether individuals perceived they had met a minimum standard of living (b = $0.764***$, *se* = 0.23) were statistically significant and positively correlated with the choice to adapt. Household size, age, and gender were not statistically significant.

3.4. Discussion

This study links localized long-term temperature and rainfall data trends in Burkina Faso to UNDP household survey results to examine farmers' perceptions of and adaptation to climate change risk. In doing so, it generates a number of provocative results. The first is that while the vast majority of farmers in Burkina Faso noticed a long-term change in temperature and rainfall, only about half of those who did so perceived change in a way that aligned with recorded local climate data. Second, those who reported not perceiving any climatic change had on average experienced greater temperature increases and greater rainfall change than did their counterparts. Third, those who did perceive climate trends that were in line with recorded data had experienced greater temperature increases across all four timeframes and less rainfall change over the last 5 and 25 years than did those whose perceptions did not align with recorded climate trends. Fourth, older farmers and those who owned assets, and thus were wealthier, were actually less likely to perceive trends that aligned with records (both temperature and rainfall change) than younger farmers without assets. And finally, when it came to the decision to adapt to rising temperatures, the vast majority of farmers had not adapted, perhaps as a result of being without the necessary resources to do so. This last finding is supported by our regression results, which showed that perceiving temperature trends in line with data and perceiving oneself to have met a minimum standard of living (i.e., being wealthier) were positively associated with the decision to adapt.

Many of these counterintuitive results are not wholly dissimilar from previous studies. For example, Mulenga et al. (2017) found that Zambian farmers' perceptions of temperature change overlapped with meteorological data, but they noted inconsistencies with respect to rainy seasons beginning earlier in the past. Similarly, Marin (2010) noted that Mongolian herders had considered only *significant* rains (>5mm) when quantifying rainfall. Abid et al. (2019) in their cross-sectional study of 450 farmers in Pakistan found that while farmers' perceptions of increasing mean temperature aligned with recorded data, their perceptions of rainfall change were inconsistent with recorded data. Niles and Mueller (2016), in their study of farmers' perceptions of climate change in Malborough and Hawke's Bay in New Zealand, find that farmers who had irrigation were more likely to perceive an increase in rainfall compared to rainfed and non-irrigated sheep and beef farmers. They note that inaccurate perceptions about rainfall were likely to have been influenced by the availability of water resources and irrigation infrastructure.

In this study, recorded data for Burkina Faso shows that rainfall has increased over 25 years as well as in every timeframe used in the study. Despite this, 94 percent of the farmers perceive that the climate has been drier. Also, since 93 percent of the farmers indicate that their crops are exclusively rainfed (see Table 8) it is highly likely that the misalignment is due to the actual rainfall falling short of farmer's expectations, similar to that of Meze-Hausken (2004) and Osbahr et al. (2011). Other studies have shown people perceive changes in rainfall more accurately than they do temperature. Piya et al. (2013) found 5 percent more Chepang community residents in Nepal perceived rainfall patterns accurately than did so for temperature. And Vedwan and Rhoades (2001) found similar results in the Western Himalayas of India, arguing that individuals there may perceive changes to rainfall (or snowfall specifically) more accurately compared to temperature because of the former's visual salience, i.e., it is observable.

The time frames used in this study extend backward from the time of the UNDP survey, i.e., 2015. Farmers' perceptions were slightly better aligned with data from shorter timeframes, 5 years and 7 years in particular, and thus likely more dependent on recent experience. This supports earlier work by Moyo et al.(2012), who noted farmers were best able to recall climate from the past 5 years. The extent to which farmers were relying on and recalling unique events to inform their perceptions of temperature and rainfall change however is unclear. Mulenga et al. (2017) argued that farmers were more apt to recall and associate unique events with climate change as opposed to recalling incremental changes over a long run. When we examine the temperature record, we see an unseasonably cool year in 2008 (7 years previous) and the hottest year on record in 2005 (10 years previous), but steadily increasing mean monthly temperatures between 2012 and 2015. For rainfall, we see extremely dry years in 2002 (13 years previous) and 2011 (4 years previous), but relatively steady wetter years on average since 2011. Recent experience suggests on average that it is getting hotter and wetter; yet of those who noticed either a change in temperature or rainfall, 98 percent identified it as getting hotter, while 84 percent identified it as getting drier. Yet temperature increases are also related to soil moisture and therefore can lead to misperceptions (Mulenga et al., 2017). Those authors note that farmers may focus on agricultural drought rather than meteorological drought and thus as temperature increases lead to a decrease in soil moisture, farmers perceive this as a decrease in rainfall. As heatwaves, which have increased in number and severity across the globe, coincide with steadier long-term increases, individuals' recent experiences are simply more likely to coincide with both recorded long and short-term trends. But regarding rainfall, farmers may be intuitively altering their perception based on their rainfall needs, leading to an inconsistency between perceptions and recorded data (Osbahr et al., 2011).

While Funatsu et al. (2019) found in their study that perception of climate change increased with age, here age was negatively associated with farmers' perceptions aligning with recorded data for both temperature and rainfall. While temperatures have steadily increased on average, no matter the timeframe examined—though not necessarily consistently across farmers' locations, rainfall actually declined over a 10-year timeframe, the only timeframe in which rainfall didn't increase. Without further qualitative research, it remains unclear whether older farmers are recalling steady declines in rainfall over the past 10 years or the extremely dry seasons of 2003 and 2011, perhaps relying on the availability heuristic. Younger farmers may not remember 2003 or these steady declines in rainfall, perhaps recalling wetter more recent years. While some studies show gender differences in perception (Singh et al., 2017; Darabant et al., 2020), our study found no differences between gender, at least with regard to perceptions. We posit that men and women in our study potentially engaged in similar farm activities. We also acknowledge that women made up a relatively small proportion of household heads here, and so additional research is necessary.

Our results show that the alignment of farmers' perceptions with recorded data is positively associated with adaptation. Put simply, perceiving climate change is key to adapting. And adaptation is not only necessary but beneficial. Ojo and Baiyegunhi (2020) show that compared to farmers who did not adapt, the ones who adopted at least one strategy had higher farm revenue. Yet we find an intriguing result with respect to the effect of resources on the accuracy of farmers' perceptions; namely, that owning assets led to perceptions less aligned with recorded trends. At the same time, farmers who indicated that they had more than a sufficient standard of living were more likely to adapt to temperature changes. In our study sample, farmers were asked to self-report their standard of living: 88 percent of individuals reported making less than sufficient income. This result is not dissimilar to Hou et al.'s (2015) results and suggests that those individuals engaged in the less affluent aspects of farming may be those most likely to notice it—and yet also find themselves without the means to adapt. While those with enough wealth, which Singh et al. (2017) note helps farmers switch to improved varieties of crops, use costlier inputs, and receive more training and advice than poorer individuals, may be less likely to notice that such decisions are necessary. Other socioeconomic factors such as household size, the age of the head of the household, and gender were not statistically significant with respect to the decision to adapt. Since age and household size were statistically significant for the alignment of perception and recorded data, our results indicate that when it comes to adaptation, here alignment of perceptions and the capacity to adapt were the most important factors.

There are three limitations to this study. First, the study does not consider the extreme events that took place in these timeframes due to non-availability of such data specific to farmers' geographic region. Since extreme events can influence how people perceive if and to what extent climate change has occurred (Whitmarsh and Capstick, 2018), this could potentially help us understand why farmers perceived climate change the way they did. Second, the education level of the farmers, which has been found to influence both perception (Debela et al., 2015) and adaptation (Abid et al., 2019) has not been included in our model due to anomalies in survey responses. For example, the number of years of education were greater than the respondents' age in several cases. This could be from farmers considering their years of experience in farming (practical learning) as opposed to formal schooling. Finally, studies and common sense suggest that adaptation choices depend on more external factors than simply the alignment of people's perceptions with climate data. These decisions depend on credit constraints, information (or the lack of), institutional support, access to extension services, and the availability of stress-tolerant crop varieties (Kabir et al., 2017; Singh et al., 2017; Khanal and Wilson, 2019; Ojo and Baiyegunhi, 2020). Even if the materials and services are available to farmers, individuals may lack the technical knowledge regarding how to use them (Khanal and Wilson, 2019). Yet across SSA, while the urgency of widespread adaptation increases, adaptation policies continue to have a narrow focus, and there remains limited engagement with local expertise or their adaptation responses (Adenle et al., 2017). This gap not only warrants policies to be tailored to conditions that are unique to each country and to the climate risk for which the country is most vulnerable, but adaptation policies that consider variability at the community and *individual* level. This variability exists not just in the ways people experience changing temperature and rainfall, but also, as we examine here, in how they perceive and internalize that change.

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Chapter 4: Conclusion

4.1. Covid challenges

This dissertation required overcoming significant challenges rarely experienced by PhD students in the United States. The three essays in this dissertation were proposed prior to the Covid-19 pandemic, which ultimately led to over 6 million deaths worldwide. Additionally, I sought a specialization in International Development and Gender, Justice, and Environmental Change (GJEC), both of which needed to be substantiated with international fieldwork including primary data collection. Also, before the pandemic, I was awarded a US Fulbright Student Award, which would allow me to live in Zambia for a year and conduct my fieldwork. I was also awarded the Gender, Justice, and Environmental Change (GJEC) Dissertation Fellowship by the Center for Gender (GenCen) at MSU to support my data collection and I had established a great working relationship with a woman-led NGO in Zambia named LiChi Community Solutions, Ltd. This NGO provided off-grid electricity access to several rural and remote households in the country.

The proposed (and approved) studies making up this dissertation were intended to be mixed-methods research with quantitative primary data collection substantiated with qualitative interviews. Thus, my fieldwork as originally planned included participant observations, focus groups, as well as a large sample of interviewees, i.e., at least 150 women. I had also planned to travel to several remote areas in Zambia where new off-grid projects were in construction or being planned. The initial few months after the pandemic-related travel restrictions were in place, both MSU and the Department of State also had travel restrictions following which all Fulbright awards were delayed. With no known start date for my in-country stay, I continued to enroll in required and additional classes to complete my program. There were very brief windows between 2020-2021 when either travel restrictions were loosened by the US State Department or by MSU, but (frustratingly) never simultaneously.

Once vaccines became available in the US, traveling to Zambia became possible. However, vaccine availability was short in Zambia and the number of COVID-related deaths were much higher in the country, particularly during its second and third waves. With the significant risk associated with relocating to Zambia during the pandemic, I declined the Fulbright award. The GJEC award still provided me with the opportunity to collect data remotely however, so consequently, I redesigned my study to allow data collection to be done with the help of the LiChi Community Solutions. This also required modifying the study to include only data collection methods that involved minimal risks to my field staff and I. After consulting with my in-country partners, we proposed a qualitative study with far fewer interviews than originally proposed. The study was then approved by the Institutional Review Board (IRB) at MSU. During the Winter of 2022, international field research restrictions were eased by MSU and, coincidentally, restrictions were lifted by the US Department of State. I traveled to Zambia for two weeks, met with my team, and trained my field staff. I minimized my travel across the country in an effort to reduce risk, and my field staff completed all the interviews.

4.2. Study limitations

Often due to the pandemic restrictions and modifications discussed in the previous section, each of these studies has limitations. The first essay analyzes the time spent by each gender group in each category of household activity. However, intra-household activities are far more intertwined in reality, with adults seeking the help of children, as well as adults multi-tasking, neither of which are explicitly modeled in this study. As an example, children often help parents with household activities such as prepping for cooking or cleaning the house, or adults cook while also watching television. Ideally, these activities would need to be modeled as the sum of all parts within a household, i.e., the total time in 24 hours that is individually and jointly shared in activities. Our study was designed to look at differences between the gender groups, hence the use of a Tobit model as a starting point. Dynamic modeling of intrahousehold activities would also need to account for power relations among the members which can dictate who engages in which particular activity. For example, it is not uncommon for older women in a household to be responsible for decision-making related to food expenditures, and for younger women in the household to be more involved in actual cooking-related activities. Finally, the category of off-grid access in the study combines a wide range of technologies such as solar home systems, batteries, solar panels, and generators each of which have different capacities and thus may impact a household's usage and time allocation in different ways. However, due to the lack of sufficient number of households within this category, they were combined to reflect as one. As such, the impacts from this type of access is to be viewed as a starting point to understand how off-grid access may affect a household's time allocation.

In the second study, which focused on better understanding the subjective meaning of empowerment, and if and how Zambian women related access to electricity to feeling empowered, requires thorough qualitative aspects such as participant observation, focus groups and living in the country. The narrative would benefit from including more perspectives, and more women from unique backgrounds, circumstances, classes, and family structures. However, in order to reduce the risk to my field staff and I, there were fewer sites in which the interviews could be conducted. Having a larger sample, e.g., 150 interviews, would have provided a richer narrative perhaps shedding light on cultural differences within the country. The second limitation is while the results were analyzed using the Spaces approach, political space in the decision-making capabilities was considered as the political space outside of the home even though interactions among household members can be considered political. The focus of the study was to understand the concept of empowerment and including the political space outside the scope of the study. Finally, going from a lack of access to having reliable access to electricity, the women in Zambia spoke of only positive aspects of gaining electricity in their household and not of other unintended consequences such as children and women spending too much time watching television while shirking household work.

The final essay, in which I examined the role of perceptions in how farmers adapt to climate change, had an important limitation. The study included both temperature and precipitation, both of which are indicators of climate change, but as represented in the study are perceived together, rather than in isolation. From the perspective of modeling this aspect, a climate variable and thus the indicator of its variability needs to be included as an interaction between temperature and precipitation. However, doing so also requires a strong understanding of how temperature and precipitation interact in nature. Such a variable was not available for our study. The next limitation is that the choice of timeframes in the study was driven by the availability of climate data for 25 years and previous research on perceptions of climate. However, it is quite possible that our results will be quite different had another timeframe had been used. Thus, the results are very specific to our choice of timeframes. Another limitation is that while the survey relied on a representative sample, Burkina Faso has wide regional differences in climate, differences that cannot be represented simply using monthly temperature and rainfall change. This variability could have been better controlled for by grouping the population and examining locations as separate agroecological zones. Finally, it is important to acknowledge that gender plays a very significant role in climate change adaptation with a growing body of literature particularly in the developing countries. However, in our sample, 98 percent of farmers who were household heads were male and thus, gender effects might not have been discoverable.

4.3. Policy and social implications

The limitation common to all three essays is the lack of in-depth cultural context which would have been possible with in-country travel. All three essays are directly related to and impact the SDGs and the policies needed to achieve them. For example, in the first essay, I establish that there are gender differences in how time is allocated within a household among different activities in the presence (or absence) of electricity. Electrification policies typically do not acknowledge or address gender differences at the household or community level, nor do they examine their gendered impacts post-electrification. Certainly, having access to electricity benefits both genders, but it benefits women in significant ways such as empowering them through information via television and radio. Thus, not only are the types of benefits different, but they can also help women further in improving their lives and closing the gender gap. Thus, policies can mainstream gender and emphasize women's participation in economic activities. To its credit, the government of Zambia has addressed the economic empowerment of women through electrification in its gender equality report. However, the implementation of electrification policies also needs to ensure that there are enough economic opportunities that women can make use of during and post-electrification. This was elaborated in the interviews where women envisioned being entrepreneurs of businesses such as salons and bakery which were not yet available to a few of them. Engaging women specifically from the design and development stage of off-grid projects can ensure that women are direct beneficiaries of electrification. Similarly, being connected to the wider economy through roads and credit facilities will help women to reap the maximum benefits from electrification.

Our second essay highlighted that women experience greater agency when they pursue productive activities using electricity and make their everyday lives easier via the use of appliances. By asking women to define what empowerment means to them, we can not only bolster the claim that electricity access empowers women both economically and socially, but we can also ensure future efforts account for empowerment explicitly in their plans and measures. Finally, we also find that when it comes to climate change, while gender might not be an important factor in understanding how such change is perceived, men and women adapt differently due to various factors including the assets available to them and the role they play in agricultural tasks. Policies need to focus on making more resources available to women giving them the capability to make decisions related to their agricultural tasks.

There are two striking results from all three studies that are overwhelmingly important to policymaking. First, the power of information to effect change is essential and extremely beneficial for women's empowerment (relating to contraception or domestic violence), or the farmers to make agricultural decisions (climate-related information). At the individual level, it is the exposure to essential information that helps women feel empowered and it is the availability of weather information that can help farmers to adopt the necessary adaptation strategies. Second, the availability of resources plays a huge role in how individuals benefit. In the case of electrification, this refers to the availability of economic resources to purchase appliances, or install solar panels, or pay for the connection fees. And in the case of adapting to climate change, these resources help farmers make choices involving the purchase of inputs to ensure sustainable agricultural output. Thus, should a significant portion of a country be caught in a poverty trap, policies are needed to ensure that they receive financial resources to help them out of the trap failing which SDGs will be much harder to achieve.