Hot Take: Cool Roofs

The impact of rising temperatures on women workers living in Bapalaal Kadiyani Chaali – an urban slum in Ahmedabad, India

Milan Escarcega

Photo credit: Milan Escarcega

Abstract

This research study examines how increasing temperatures disproportionately impact informal sector women workers in a slum within Ahmedabad, India, through a variety of pathways. It also captures an understanding of their adaptation methods and makes recommendations to support future innovative solutions to address the heat impacts of climate change.

The study aims to test the hypothesis that rising temperatures have negatively impacted the livelihoods, via a decrease in the productivity of informal sector women workers, through a combination of desk based research and primary findings collected through a focus group discussion (FGD) and key informant interviews (KIIs).

25 female participants were asked about their monthly income during the course of 2022 and temperature data was also collected online for the same time period. A negative correlation between these two variables was significant at the 1% significance level as per the Pearson test ($p = 0.01$, critical value = -0.576, observed value = -0.83, null hypothesis rejected). This suggests that as temperatures increase, productivity of the women decreases, thereby having a negative impact on their livelihoods. Additional qualitative data from the FGDs suggested that the innovative, low cost heat adaptations in place with the support of non-governmental organisations (NGOs) such as Mahila Housing Trust (MHT) are proving to be effective in reducing indoor temperatures.

Whilst these emerging innovations have proven to be effective, they cannot solve the ever worsening heat impacts on vulnerable women workers living in urban slums. The study recommends an urgent call to action by NGOs, community based organisations, philanthropies, the private sector and government agencies to provide support to increase the heat resilience of vulnerable informal sector women workers, so that their livelihoods are protected in light of the long term heat impacts of climate change.

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1. Introduction

The recent increase in the earth's temperature has negatively affected the lives of millions of people across the globe. However, the heat impacts of climate change are disproportionately felt in the Global South, and specifically by those most vulnerable and disadvantaged, namely poor women residing in urban slums. The Intergovernmental Panel on Climate Change (IPCC)'s 6th assessment report on Climate Change Impacts, Adaptation, and Vulnerability highlighted the intensifying heat and humidity in India, which could pose increasing challenges to human survival.[i]

A recent study by Cambridge University estimated that 90% of Indians had been at increased risk from hunger, loss of income or premature death during the record-breaking heat waves in 2022, which are becoming more common due to climate change. [ii]

"During the summers, I often felt like I was going to faint in the heat"

"I believe that the heat is causing more illness in this settlement"

- Ashar ben, resident of the Bapalaal Kadiyani Chaali informal settlement

Ashar ben is just one of over 150 million informal sector, self-employed women workers living in India.[iii] This sector is characterised by a lack of monitoring and regulation by any form of government. Ashar ben lives in an urban slum, also known as an informal settlement. Such settlements have inadequate housing that is often overcrowded, with many people crammed into very small living spaces. They lack basic municipal services such as water, sanitation, waste collection, storm drainage, street lighting, paved sidewalks and roads for emergency access.[iv] Although the specific characteristics vary based on context, this study has adopted the UN Habitat's broad definition of slums which is comprised of what are known as the "five deprivations"; lack of i) access to water, ii) access to improved sanitation, iii) sufficient living area, iv) housing durability and v) security of tenure.[v]

Ashar ben's precariousness, like the majority of poor, self-employed Indian women, is therefore compounded by the poor infrastructure and housing in the urban slum where she lives and works (for most of these women, their home is also their workplace). As a result, they are often hit hardest by the changing climate, grappling with rising temperatures, increased flooding, and the spread of vector-borne diseases. In particular, they bear the brunt of the deadly heat waves which have become an inevitable annual occurrence in many parts of the country, with their devastating physical, social and financial effects.

Higher physical susceptibility to heat effects and the shouldering of additional unpaid care responsibilities linked to heat-related illness, attributes to almost 75% of women's productivity losses in the form of unpaid labour.[vi]

A regional network of home-based women workers found that 43% of women surveyed had reported a loss in income and an increase in caregiving as a direct result of extreme heat.[vii] Another independent study concluded that a heat wave in Ahmedabad city in 2010 caused 53% more female fatalities when temperatures reached 46.8°C.[viii]

Unless addressed, the increasing prevalence of extreme heat events could halt or even reverse India's progress in reducing poverty, gender inequality and income insecurity. Rising heat brings with it the challenge of providing access to climate-friendly cooling solutions. Sustainable Energy for ALL's "Chilling Prospects" report identified India as having the largest number of people- 309.2 million - at high risk due to lack of access to cooling.[ix]

This research builds an interest in the emerging intersection of gender and climate change. It is focused on a case study of the challenges faced and solutions deployed to combat increasing temperatures by self-employed women workers living within a specific informal settlement or slum in Ahmedabad, India. In this case, they are supported by a Non-Governmental Organisation (NGO) called Mahila Housing Trust (MHT). As per their website, the unique nature of MHT's work is to improve urban built environments in poor communities through the collective action of poor, self-employed women residents,[x] with an increasing focus on building climate resilience, in recent years.

The research undertaken aims to shed light on the unique vulnerabilities faced by these women due to extreme heat and explores how MHT is actively supporting them to adapt to the heat impacts of the changing climate. This is a relatively new field of study as the disproportionate impacts of climate change, especially rising temperatures on poor, informal sector women workers and innovative adaptation measures to increase their resilience, are only now becoming more evident. This research case study is an attempt to add to the body of knowledge in this urgent, emerging area of study and suggest recommendations for the future.

Why Ahmedabad

Ahmedabad was specifically chosen to undertake the primary research for this case study as a result of desk-based research. This highlighted the innovative climate resilience activities involving informal sector women workers ongoing in Ahmedabad, facilitated by MHT.[xi] Upon a written request, MHT allowed primary fieldwork to be undertaken in one of its partner informal urban settlements.

The city of Ahmedabad is located in the state of Gujarat, in western India. Bordering the Thar Desert, it has limited vegetational cover due to it being a semi-arid state. The Indian Monsoons also provide little to no relief to the city. Currently it has an estimated population of 8.6 million[xii] with around 40% living in informal settlements or slums.[xiii] This city is an ideal location to assess the impacts of climate induced heating as it lies on the Tropic of Cancer. Therefore, it is constantly bearing the brunt of the latest impacts of global warming, throughout the year. However, the city feels it is perennially stuck in one season, that is the sweltering summer. A recent report by CEPT University and World Bank indicated that Ahmedabad gets a universal

thermal climate index (UTCI) above 46 points on 331 of 365 days- the highest for a South Asian city studied for the survey[xiv]. By 2035, it is projected that 11 million people will be at high risk of living inside an urban heat island within Ahmedabad and its surrounding areas.[xv]

Why Bapalaal Kadiya ni Chaali

MHT has been working since 2018 in partnership with Bapalaal Kadiya ni Chaali, an informal urban settlement which was established in 1940. In line with MHT's ethos, the focus has been on facilitating dialogue with the local government and supporting women-led collective action strategies to improve the infrastructure and services within the settlement. More recently, they have been focused on promoting the climate resilience of the community, in light of increasing demand from the residents to cope with the heat impacts of climate change.

Located in the north east of Ahmedabad, the settlement has a current estimated population of 800 with a total of 160 households. The inhabitants of Bapalaal Kadiya ni Chaali are all employed in the informal sector with many of the men working as street vendors or factory workers. The women predominantly do home-based work, making and packaging traditional paper based crafts for decorations. It is also common for elderly parents to be living with their children, who continue to support them in their old age. The majority of children in the settlement receive education until grade 12, allowing them access to a range of future livelihood options.

By 1981, a drainage system and individual electricity connections had been provided in the settlement by the Ahmedabad Municipal Corporation (AMC). The AMC was instrumental in converting all the houses from mud huts into semi-permanent structures between 1991-95. When MHT began to work in the area in 2018 in partnership with a philanthropic organisation - the Azim Premji Foundation - they focused on identifying the prevalent social and infrastructure issues within the settlement and identified various strategies to solve them. However, due to the Coronavirus pandemic, a comprehensive Slum Development Plan (SDP) was delayed and only completed in February 2023.

Through a participatory exercise to inform the SDP, MHT found that the five main issues faced by the inhabitants in the settlement were:

1) Excessive heat
2) Inadequate access to clean drinking water
3) Drainage problems
4) Limited access to social security
5) Broken roads

In order to combat the key problem of excessive heat within the settlement, MHT is providing innovative, low-cost heat adaptations in the form of white solar reflective paint and bamboo roofing. This special white paint which is applied on the roofs, reflects over 90% of solar radiation, thus cooling the interior temperature of the house, making it possible to live inside, while temperatures soar outside. Currently, 100 roofs have been painted with white paint and one house has a bamboo roof.

While there is more work to be done, this informal settlement provided an ideal case study to investigate how women in poverty are disproportionately affected and how they are adapting to a warming planet.

Role of the Mahila Housing Trust (MHT)

Working exclusively with poor and marginalised women, MHT has been operating in informal settlements across Gujarat to strengthen their collective organisations and improve their housing, living and working environments since 1994[xvi]. It maintains a long-term aim of increasing their overall socio-economic empowerment. MHT's work ranges from organising women to demand for basic amenities, setting up microfinance cooperatives and most recently, championing climate resilience for women in poverty.

MHT helps to build climate resilience by working with scientific experts to design and provide low-cost climate adaptations to the informal settlements, known as cool-roof technologies. Amongst several innovations, these include reflective white paint and bamboo roofs (focus of this research study), which have all been proven to reduce indoor temperatures. Therefore, through this work, MHT is playing a crucial role in improving household living and working conditions by decreasing indoor temperatures of the houses. As this study shows, this has significantly benefited the women consulted, as their home is also used as their work place and a storage area; therefore, these cool-roof technologies also improve the productivity of the women, impacting positively on their livelihoods and general well-being.

Scope of this Study

Impacts of Climate Change

Whilst the impacts of climate change in urban areas can include an increase in severe weather events such as rainfall, resulting in increased flooding; an increase in vector borne diseases such as dengue and other health impacts, this research study is confined to studying the increased heat impacts of climate change on productivity and therefore on livelihoods. This is in order to keep the primary research focused on one variable, to enable an in-depth analysis of the study's key hypothesis.

Definition of Productivity

For the purposes of this study, productivity is defined as the number of work-hours a person is able to complete in a day.

2. Literature Review on the climate change impacts of increasing heat and related adaptation strategies

This literature review examines the impact of climate change, particularly rising temperatures, and heatwaves, on informal settlements, with a specific focus on the disproportionate effects on women living in poverty. It also discusses cost-effective, heat adaptation technologies that are being deployed at the grassroots, to mitigate these impacts.

Climate change, driven by the enhanced greenhouse effect, is a pressing global issue. According to the World Meteorological Organization, there is a 98% chance that at least one of the next five years will be the warmest on record.[xvii] Rising temperatures have led to an alarming increase in heatwaves, particularly in regions like Northwest India, where the UK Met Office found that climate change makes heatwaves during April and May 100 times more likely[xviii]. In order to understand the disproportionate impacts of this phenomenon on poor women, it is first important to consider the shared impacts for everyone living in poverty.

Informal settlements, characterized by limited resources, are particularly vulnerable to the increasing frequency of heatwaves. Residents in these settlements often lack access to or cannot afford expensive heat insulation or cooling methods, resulting in substantial labour productivity losses and higher susceptibility to heat-related illnesses.

However, extreme temperatures during the day are not the only cause of this problem. Heat is also influenced by many factors such as humidity, wind and radiation from the sun. In dense urban areas of poverty, such as Bapalaal Kadiya ni Chaali in Ahmedabad, the urban heat island effect exacerbates the problem. This phenomenon results from a lack of green spaces and high concentrations of roads, and buildings. The urban heat island effect can cause temperature differences of up to 8 degrees between urban and rural areas.[xix] The lack of cooling options within informal settlements means that extreme temperatures persist overnight, posing ongoing health risks and reducing the productivity of residents. According to Dr Siderius from the Wageningen University and Research (WUR), “when the heatwave is over, poor people will be exposed to extremely high night-time temperatures for many more weeks or even months.” This also creates an ongoing health risk as they cannot escape the heat, further reducing the productivity of men and women living in poverty.

While all of the above mentioned impacts equally affect men and women in informal settlements, this research study aims to dig deeper into how informally employed women are disproportionately impacted by rising temperatures. A report commissioned by the Adrienne Arsht-Rockefeller Foundation Resilience Centre (Arsht-Rock) investigates the ‘double burden’ of heat on women in poverty. Kathy Baughman McLeod, director of Arsht-Rock states that "Women are not only more susceptible to physically getting sick from heat, they're also disproportionately expected to care for everyone else who's sick from heat, whether that's paid care or unpaid care."[xx] Therefore, it is clear that even if a woman is not directly impacted by heat, her overall productivity is still likely to reduce as she is expected to spend time

caring for other family members who have fallen ill. Indeed, a report by the Indian Institute of Management Ahmedabad (IIMA) in 2023 found that wage-earning women in India spend “twice the amount of time on unpaid domestic work in comparison to wage-earning men,"[xxi] due to a variety of social and cultural norms.

Furthermore, the majority of women employed in the informal sector use their home as their workplace[xxii]. This means that their productivity is directly impacted by the extreme heat, as they are not able to work as efficiently. In some areas, temperatures are getting so high that it becomes dangerous to work during the day due to an increased likelihood of contracting heat related illnesses. However, this also means that any climate adaptations implemented in the home have a dual purpose of reducing the risk of a heat related illness, as well as increasing a woman’s productivity and therefore having a positive impact on her livelihood.

As heat will cause huge issues for women in informal settlements both now and in the future, MHT has helped to develop a range of innovative, cost effective heat adaptations which are specifically aimed at and accessible to women in poverty to combat these adverse effects, known as cool-roof technologies.

A roof system is the most basic unit of shelter for a home. Although households in urban slums in India (including Ahmedabad) have begun to build homes using brick walls, their roofing systems continue to be constructed poorly.

More than 80% of people living in urban settings in India cannot afford a concrete slab for their roof. The existing methods of building roofing systems are composed of corrugated cement and metal sheets, which crack easily and cause water leakage. They are also a strong conductor of heat, thus becoming overheated and too hot to comfortably live in for more than six months out of the year. These current systems are also toxic to the environment.[xxiii]

The Modroof, made of paper waste and coconut husk is eco-friendly, waterproof and reduces the temperature within the house by 6-7 degrees. It is also easily installed without the need for any technical assistance.[xxiv] Unfortunately it is also relatively expensive, takes 2-3 days to install and due to local production issues, there is very limited supply available.

Thus, MHT in partnership with scientists and researchers, has implemented an innovative and sustainable cooling solution for low-income slum communities. This is a solar reflective white paint which is cheap and also simple to apply onto the roof of a house. The paint has been proven to reduce indoor temperatures by 4-5 degrees Celsius and can be applied to the roofs by the homeowners themselves. According to Ms Bhavna Maheriya, MHT’s programme manager, “this is the most popular adaptation deployed by MHT members to increase their climate resilience, as it is cheap and accessible.”[xxv]

Other forms of adaptation include bamboo roofing which remains durable for 25 years and reduces temperatures by up to 5 degrees. Finally, a “green roof” consists of potted plants being placed on top of a roof in order to create a barrier to prevent the real asbestos or tin roof from overheating. As claimed by Ms Bhavna Maheriya, “The green roof can lower internal temperatures by up to 2.5 degrees.”[xxvi]

However, while the cool roof technologies combat the heat impacts, investing in them adds financial and time burdens on the residents who played no role in enabling climate change, and yet are the worst affected by its impacts. Women often take loans in order to afford them and their productivity may be disrupted while the new roof is being installed. Even to procure and apply the white paint, there can be significant costs. In order to equip 100 households within Bapalaal Kadiya ni chaali with the paint, it cost a total of Rs. 700,000 (around 7,000 GBP), a sum which would have been difficult to collect within the community without any external help.

3. Methodology

Aims and hypotheses

This study has two main aims:

i. To investigate how increasing temperatures affect the productivity of informal women workers on a micro level within one specific, urban settlement

ii. To investigate how effective low cost climate adaptation has been in increasing comfort and productivity at a grassroots level.

In light of the above, the discussion section of this research study recommends ways to support the increased resilience of informal sector women workers living in informal, urban settlements to combat the heat impacts of climate change.

General Hypothesis

The recent, unprecedented rise in global temperatures has caused the productivity of women living in Bapalaal Kadiya ni chaali to decrease due to their prolonged exposure to the heat.

Sub Hypothesis

As temperatures increase over the course of a year, the productivity of women in Bapalaal Kadiya ni chaali significantly decreases due to an increased exposure to heat in the summer months (generally April to September)

Methodology Followed

The methodology followed is a combination of:

i. desktop research of secondary data (via books and peer reviewed articles to inform the literature review and discussion); and
ii. primary data collection (to inform the findings and discussion).
iii.

The research has chosen to collect primary data directly from the field as it is up to date and the researcher can be certain of its accuracy.
While the benefits of peer reviewed articles include the prevention of fraudulent work entering the public domain, a criticism according to Bordens and Abbott (2008) is that they may help to preserve the status quo. Therefore, this research has opted to use a mixture of primary research and secondary, peer reviewed data for this study.

a) Procedure

Accompanied by a translator kindly provided by MHT, the research was undertaken during the first 3 weeks of August 2023 at the MHT office in Ahmedabad, with Wednesday the 10th and Friday the 11th of August 2023 spent physically in Bapalaal Kadiya Ni Chaali, undertaking the primary research in the field. The precise location of the FGD in the informal settlement was at the coordinates: 23°01'57.5"N 72°36'55.9"E.

With the help of a MHT community leader, a focus group discussion (FGD) and two key informant interviews (KIIs) were conducted in the settlement.

The FGD was conducted over a two-hour period in which I asked the group each question from a structured questionnaire and the women's collective responses were recorded. Afterwards, there was a guided walk-through of the settlement facilitated by the MHT community leader to capture photo documentation of the living conditions and the white, painted Cool roofs (see appendix A) which allowed me to gain greater insight into living conditions and the climate adaptations being adopted in the settlement.

On the second day, the two KIIs were conducted separately with individual women residents of the settlement.

b) Design of primary data collection

25 participants were randomly selected from the Bapalaal Kadiyani settlement to take part in the FGD which was structured around a questionnaire (see appendix B) as well as conducting the 2 KIIs using a separate questionnaire (see appendix C). Each question on the questionnaire was discussed in detail with the women.

A structured questionnaire was used for the FGD and KIIs, so that a mixture of qualitative and quantitative data could be collected within an appropriate time frame, due to the short nature of the visit to Ahmedabad, allowing me to collect a wide range of information. Separate structured questionnaires were used for the FGD and the KIIs so that more specific information could be derived during the individual interviews and more targeted questions could be asked, which built on information collected during the FGD.

The main themes of the primary data collected included:

- How heat impacts productivity

- How the various climate adaptations being implemented were impacting the heat effects and therefore productivity
- The impact of heat on increasing the likelihood of illness and therefore impacting productivity.

c) Controls

Bias was minimised via the random selection of the FGD participants from a wide spread of residents living across the various lanes within the settlement.

Researcher bias was minimised by using standardised instructions during the FGD.

A participatory assessment was also conducted after the FGD by having individual conversations with 10 of the participants, chosen opportunistically about their responses. This aimed to make sure that participants had not copied the same answers given by others during the FGD. By individually speaking with 10 participants, it was made sure that a large proportion of the participants' opinions were represented in my data.

d) Participants

25 women living in the informal settlement were randomly selected from 160 households. A random selection method tailored to the settlement's physical layout was agreed with the MHT community leader, to reduce bias. All the selected participants were aged above 20 years old so that everyone involved was mature enough to provide reliable answers.

In addition, two willing residents were selected for separate key informant interviews to inform a more detailed case-study for this report.

e) Strengths and Limitations

As a result of the strong facilitation and involvement by MHT, a strength of this data collection was that all the participants of the FGD were keen and engaged in the research, willing to provide honest accounts of their experiences. Therefore, this increased the reliability of the data. In addition, nobody declined the opportunity to take part and the data collected generally correlated with the desk based research collected in the literature review, as well as previous research done by MHT in other informal settlements around Ahmedabad.

Additionally, a variety of both quantitative and qualitative data was collected, meaning that the limitations of qualitative data being descriptive, yet vague and opinion based were balanced with the accurate, yet context lacking quantitative data. Therefore, this led to a clearer understanding of the issues and adaptations occurring within the settlement.

The small sample size of 25 women was due to an ethical consideration of taking up too many women's time, as they were mainly homebased workers and there was a

negative livelihood impact of diverting them from income earning work to attend the FGD.

One of the main limitations of this study may have been the language barrier as all discussions and interviews were carried out with the help of a translator provided by MHT. This may have resulted in misunderstandings and important information being missed out. Furthermore, as most of the data was collected through the FGD, I was unable to collect individual data such as age or how long each woman had lived in the settlement. This means that women who had recently moved to Bapalaal Kadiya ni chaali would not have been as reliable sources of information as long term residents.

Secondly, the use of random selection in order to choose the FGD participants means that there was not a guaranteed even geographical distribution of participants. This means that some of the participants may have been from the same household or lane within the settlement, potentially decreasing the reliability of the data.

Finally, the data collected about heat impacts on productivity was correlational, thus it cannot support causal relationships. This means that one cannot be certain that rising temperatures can be fully attributed to the clear reduction in womens' productivity during the summer of 2022. Other possible influencing factors may include unrelated illness or a reduced consumer demand for decorations over the summer, which is their main source of income or increased care responsibilities. However, I was unable to further investigate the extent to which these external factors may have impacted my findings due to the time constraints of the research visit.

Even so, there was a very strong correlation between heat and productivity at the 1% significance level, suggesting that the increasing heat was the main contributing factor for this inverse relationship.

f) Ethical considerations

While conducting my primary research, I made sure to take ethical issues into close consideration. Before I began the FGD or any individual interviews, I informed all participants about the aims for conducting this study as well as everything they would be expected to do. Their right to withdraw at any point was also clearly communicated and I warned them about the potentially sensitive topic of heat related illness which may induce psychological stress for any participant who has recently lost a family member to such an illness.

As most of the women were illiterate, it was difficult to provide them with a physical consent form and instead all the instructions and information were communicated verbally, with the help of the translator.

The identity of all women involved in the FGD was kept confidential, however, women who were individually interviewed expressed a wish to be identified so that their own voices were acknowledged. Therefore, these two women have been specifically identified.

When taking any photographs of people or homes, the women were asked individually, as well as during the FGD for consent and informed as to how the research would use the photos.
The research was undertaken without any deception or intention to harm the participants of the research, knowingly or unknowingly.

4. Findings

A quantitative table showing how the respondent's average monthly income changes per month during the year of 2022 is presented below (Figure 1). It was possible to collect a large amount of qualitative data which is presented as quotations or by categorising responses. The questionnaire established a clear relationship between temperature and productivity for the women in the settlement over the course of a year which is shown on figure 3. This can also be backed up by the two line graphs (Figures 1 and 2) which show the changing temperature and productivity respectively during the same year. Additionally, it was evident that electricity bills had been increasing in the area over the last 10 years, although the Coolroof technologies had not had an effect on this.

A pie chart showing the distribution of Coolroof technology within the settlement per household (Figure 4) is also provided below, as well as quotations which provide a testament for the dire impacts of rising heat, as well as the effectiveness of Coolroof technologies in increasing productivity during the hottest months.

Table 1: Table to show the changing monthly temperatures and income of women workers within Bapalaal Kadiya ni chaali during 2022

Month	Maximum daytime temperatures during 2022 (˚C)	Average monthly income (Rs)
January	25	2500
February	31	2500
March	37	2500
April	41	1000
May	42	1000
June	39	1000
July	32	2000
August	31	2500
September	32	2500
October	32	2500

November	30	2500
December	27	2500

The data presented in table 1 has been obtained through a combination of primary (Average monthly income) and secondary (Maximum daytime temperature) research. The daytime temperatures were taken from the World Weather, FORECA website[xxvii]. The average monthly income data refers specifically to the female inhabitants of Bapalaal Kadiyani Chaali settlement, and each data point is based on an average of all the responses collected during the FGD. The data was then rounded to the nearest 100 for ease of calculating a correlation. There seems to be a correlation between the lowest incomes being earnt during the hottest months.

Figure 1: A line graph to show how maximum daytime temperatures in Ahmedabad changed during 2022

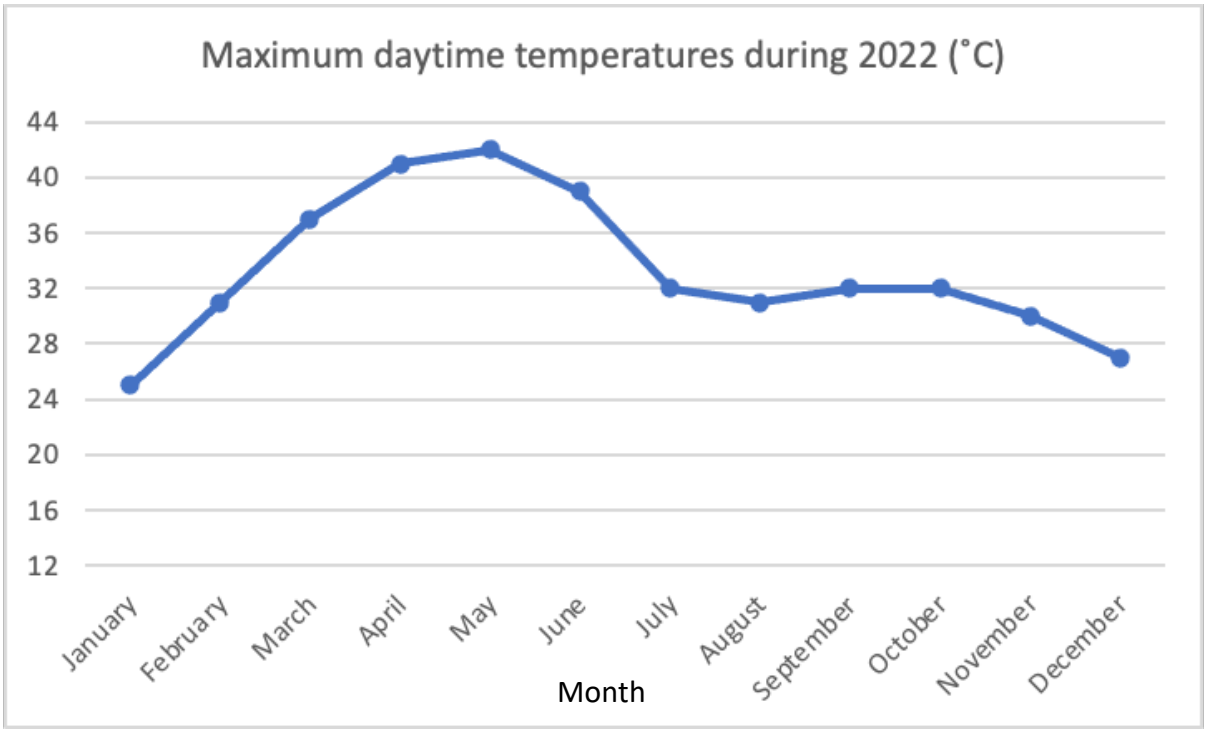
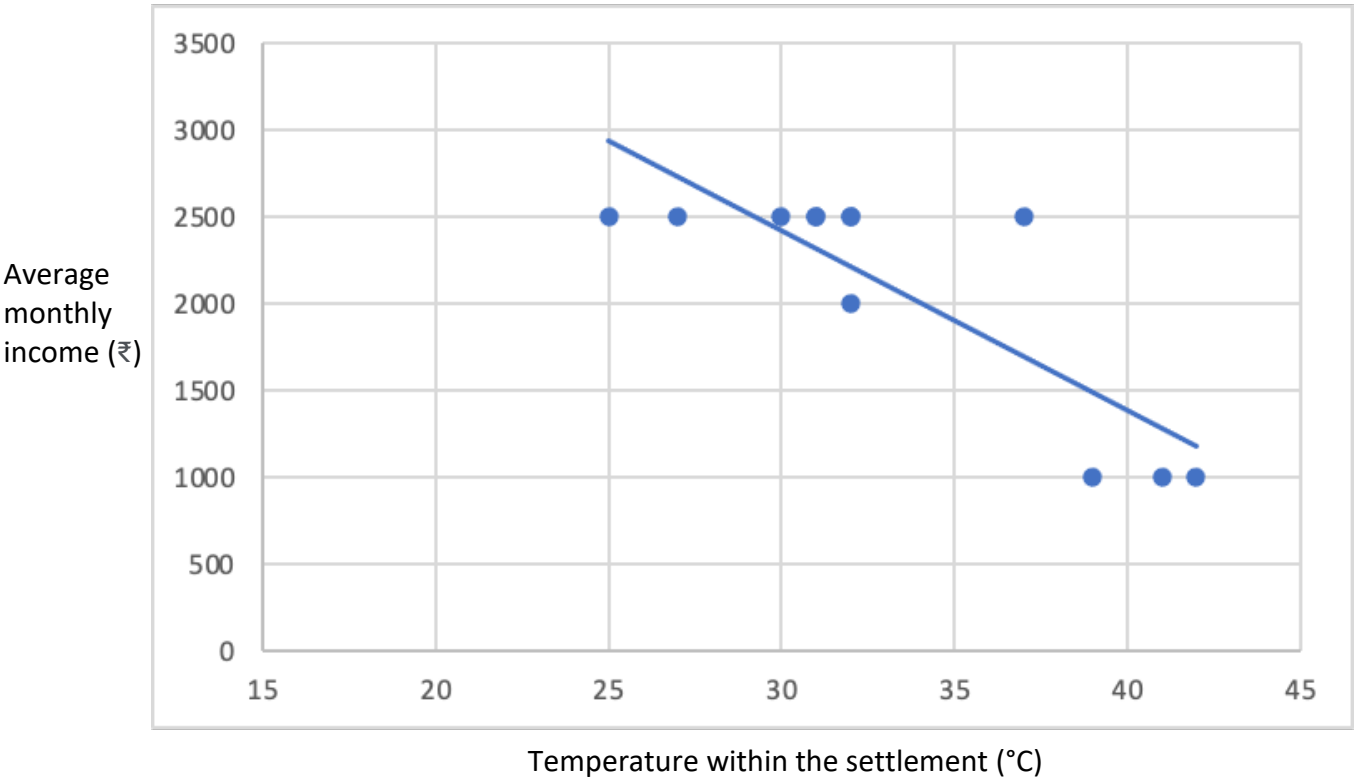


Figure 1 shows that temperatures in Ahmedabad visibly peaked to highs of between 40-44°C during the months of April and May. During the rest of the year, daytime temperatures stayed close to 32°C.

Figure 2: A line graph to show how the women's monthly productivity changes during the course of 2022

Figure 2 shows a clear decline in the productivity of women living in Bapalaal Kadiya ni chaali during the months of April, May and June. During this time, they were only able to earn 1000 Rs compared to an average of 2500 Rs per month during the rest of the year.

Figure 3: A scatter graph to show the relationship between temperature and average monthly income during 2022



From this graph, we can perceive a strong negative correlation between productivity and heat during 2022, as shown by the line of best fit. In order to investigate whether this negative correlation was significant, an inferential statistical test has been used.

Using the data from figure 3, a Pearson product-moment correlation coefficient test was used to determine the extent to which this correlation is significant.

This is the best test to carry out as:

- It directly measures the strength of correlation
- The raw data has a normal distribution

The statistical calculations are shown in the appendix

Level of significance: a 5% significance level was selected, the hypothesis was not directional, therefore a two tailed test is required, n=12

The observed value of rho = -0.83
The critical value of rho = -0.576 (P = 0.05)

As the observed value is greater than the critical value, we can reject the null hypothesis, which is ‘There is no correlation between heat and productivity of informal women workers.’ Therefore, we can accept the alternate hypothesis which is ‘There is a significant, negative correlation between temperature and productivity of informal women workers’

In fact, the observed value of rho was also greater than the critical value of -0.708 at the 1% significance level. Therefore, this correlation is significant even at the 1% level.

Two individual case studies of individual women were also conducted using the Key Informant Interview questionnaire (Appendix C) which brings to life the general findings detailed above.

Ashar ben

Ashar Powar has lived in Ahmedabad since birth and moved to Bapalaal Kadiya ni chaali 4 years ago. She lives with her husband who is a factory labourer and two young children in a one storied house. During the week, both children attend the local school so she spends most of the day packing toran decorations into plastic packets to be collected and sold in bulk. Every day, someone will come to collect the packets and gives her more toran to pack for the next day. Over the course of a day, Ashar ben strives to make 500 identical packs of decorations, earning her between 1500 to 2000 Rs per month.

She recalls how she would feel faint and light headed while working in the extreme heat of summer. Luckily, she did not feel the same level of heat overnight. Every summer, she would visit the free government hospital nearby for medicine and treatment. This would interrupt her work and reduce her overall productivity.

In March 2023, the solar reflective white paint was added to the roof of their house. This summer, she has noticed a reduction in the temperature inside her house and says it has made working conditions “bearable” for her. In turn, her productivity has also slightly increased.

This case study demonstrates that the solar reflective paint has had a clear positive impact on Ashar bens live as she now finds the heat to be bearable and no longer feels ill during the summer.

Nagar ben

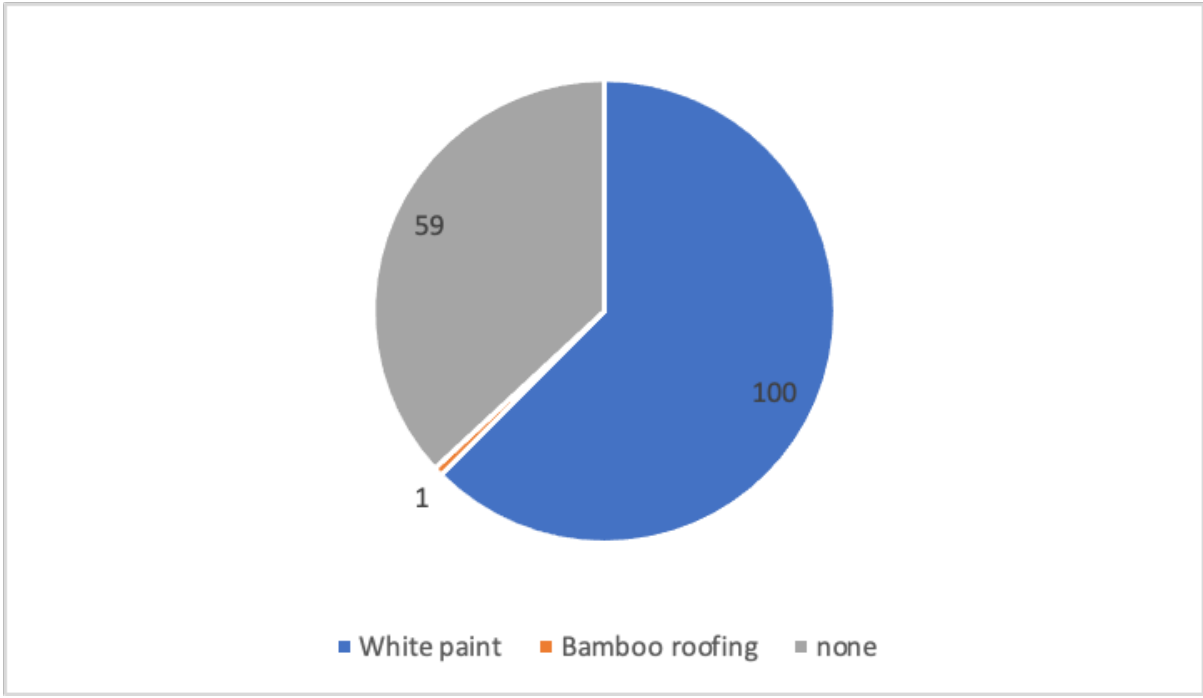
Nagar ben moved to Ahmedabad 60 years ago with her husband from their native town of Dhanara in rural Gujarat. They have been living in Bapalaal Kadiya ni chaali for the last 45 years and currently live with their son, daughter in law and their grandson. Being one of the more well off families in the settlement, they were able to afford to build a second floor to their house last year from personal savings.

Nagar ben also packages toran decorations and consistently makes 2000 Rs per month. She says that before getting a second floor to the house, she did not work over the summer as the temperatures were too high. However, after getting the white paint and a second floor, she is now able to work all year round, increasing her productivity.

Two years ago, she remembers her husband had serious heart pain during the summer and thinks that the heat was one contributing factor for his illness. While he was only in hospital for 15 days, this shows that rising temperatures may be correlated with an increased prevalence of illness.

From this case study, it is evident that the solar reflective paint has helped Nagarben to be productive during summer and has therefore, increased her economic empowerment.

Figure 4: *A pie chart to show the percentage of households using different types of Coolroof technology*



100% of women interviewed as part of the FGD had their houses painted with the solar reflective paint. As shown in figure 4, 101 households within the settlement had made an effort to cool their roofs with the aim of keeping indoor temperatures lower than outdoor temperatures. All the women in the FGD reported an average decrease of between 2-4 degrees inside during summer due to the white paint.

5. Discussion

“Before painting the roof white, I was not able to work at all during the summers because it was too hot.”
Ashar ben, resident of Bapalaal Kadiya ni Chaali

“Next year I am sure that everyone else will choose to paint their roof after seeing the impact it has had for the 100 households who decided to invest in it this year.”
Nagar ben, *resident of Bapalaal Kadiya ni Chaali*

The results from the primary research support the original hypothesis as there was a strong negative correlation between temperature and the productivity of informal sector women living in Bapalaal Kadiya ni chaali. Figure 2 shows that during the warmest three months of April, May and June, average monthly incomes were at their lowest of 1000 Rs compared to 2500 Rs in the cooler months. Figure 3 also shows that the strong negative correlation between temperature and productivity was

significant at the 5% and 1% levels when using the Pearson test, therefore supporting the original hypothesis and sub hypothesis as there was a clear decrease in the productivity of women living in the settlement during prolonged exposure to extreme heat in the summer months. These findings make sense as both the primary and secondary research have found that extreme heat above 40°C for prolonged periods of time is likely to cause fatigue and an increased risk of illness for women workers.

Furthermore, there was additional qualitative evidence to suggest that the Coolroof technology was having a positive impact in reducing indoor temperatures and increasing productivity, fulfilling the second aim of this report and backing up the research conducted by MHT into its effectiveness. In both of the individual interviews that were conducted, Nagar ben and Ashar ben stated that the solar reflective paint was decreasing their indoor temperatures, thus allowing them to be more productive during the summer. All the women in the FGD also agreed that they could feel a decrease in daytime temperatures compared to last year, before the paint was applied.

In agreement with desk based research carried out to inform the literature review, there was also primary, qualitative data collected during the two KIIs which suggested that the extreme daytime temperatures were leading to an increased prevalence of illness across both men and women. Within the focus group, light headedness was also something that 18 out of the 25 women had experienced while working during the summer. Therefore, even if another family member becomes ill, the majority of the duty to care for them falls on the woman, leading to a further reduction in their productivity. This evidence conforms with the previously mentioned report commissioned by Arsht-Rock, and demonstrates there is a clear ‘double burden’ on women at the grassroots level, as a result of rising heat.

However, there was no data collected to support the idea that the daytime and night time temperatures stayed similar throughout a heatwave. In fact, none of the women in the FGD recalled higher or uncomfortable temperatures after the sun had set. This was a departure from previous research presented by Dr Siderius from the Wageningen University and Research (WUR) who thought that temperatures would remain high overnight due to the effect of the urban heat island. One possible reason for this may be due to the brightly coloured houses of Bapalaal Kadiya ni chaali, perhaps leading to less heat being retained by artificial surfaces during the day.

Although it was not possible to exactly measure the temperature change that had been caused by the solar reflective paint, it was clear that there had been a noticeable temperature decrease which somewhat increased productivity. It was also found that MHT charges each household 300 Rs to install the paint, approximately 10% of their monthly income and 10% of the total cost of the paint. This charge is to ensure that the families are accountable and feel that it is something they have actively invested in, increasing the perceived value. The high uptake in residents choosing to pay another 300 Rs in order to reapply the paint every 3 years, suggests that they are experiencing a positive benefit from this technology. From the FGD, we learned that this cost was the main reason why 60 houses in the settlement had not yet got their roof painted. However, 90% of the women shared the opinion that after

experiencing the tangible cooling provided by the paint, the rest of the households within Bapalaal Kadiya ni Chaali planned to get the paint for next summer.

Finally, all 25 of the women in the FGD believed that there was a general trend of annual maximum temperatures increasing over the last 10 years within Ahmedabad. They also said that this has caused their productivity to slightly decrease further, each summer. It is clear that even with Cool roof technology, this cannot combat the ever increasing summer temperatures across India due to global warming. Therefore, grassroots heat solutions may only be effective in the medium term and will not be enough to solve the problem of extreme heat in informal settlements.

Recommendations and areas for future research

This research clearly outlines the ways in which rising temperatures impact informal sector women and especially their ability to work during the summer. It also establishes that Coolroof technologies, specifically solar reflective paint, is supporting their adaptation to climate change and increasing their resilience so that they can maintain their level of productivity over the summer. The active involvement of community based NGOs like MHT that bridge the technological and capacity gap between innovative solutions (for example cool roofs) and informal sector women's collectives, is critical. Therefore, support for NGOs such as MHT and collectives of informal sector women workers via grant funding is crucial for the continuation of such adaptation schemes.

While the white paint is clearly effective, rising annual temperatures mean that these adaptations may not be enough in the long term to ensure heat resilience for poor women. To this end, MHT continues to plan and pilot new strategies which could be used in the future. For example, extreme heat insurance is a new concept, aimed to mitigate against the loss of work hours and income due to heat. This is a risk transfer solution which automatically sends a payment to a member when temperatures exceed a threshold at which it is deemed unsafe to work[xxviii]. Support for the development of innovative, new climate resilience (including heat) insurance schemes aimed at poor communities in slum settlements, are needed.

Another proposed solution which MHT is investigating is the greening of cities. This involves integrating a mixture of green and blue areas into large cities. Parks, streams and recreation zones are all part of this idea with the aim of combatting the Urban Heat Island effect. Previous research has proven that these spaces can regulate microclimate and alleviate temperatures in large cities. MHT currently plans to pilot this project in the city of Amalner, Maharashtra, before expanding to other areas around India if it is a success.

Overall, the demand for cooling technologies in India is projected to grow 8-fold by 2038, and by 2050, it could contribute up to 45% of the country's peak energy demand. While the aforementioned upcoming solutions require extensive further research and piloting to have a large-scale impact, from the evidence gathered today, it is recommended that their potential is explored fully, as well as continuing to

commission research into other forms of climate adaptation in the future. Especially as global warming is an ever-expanding problem around the world today, the pace of finding and implementing appropriate solutions must be able to keep up with this ever-evolving issue.

Finally, the government has an important role to play in investigating and delivering new heat solutions. This is important as they can utilise large economies of scale to effectively distribute the technology across the country on a large scale. The state of Telengana in South India (population of 40 million people) has become the first Indian state to launch a state-wide Cool Roof Policy and commenced a five-year plan for mitigating Urban Heat Island effects in April 2023. This is a very promising development and it is recommended that such state-wide support for Cool roofs is implemented throughout India.

Governments also have a role to play in facilitating access to finance to poor, self-employed women workers so that they can take loans to pay for their contribution to access Cool roof solutions. Governments could also promote the up-take of new solutions through subsidies, in order to financially assist marginalized and low-income communities who may not be in an economic position to be able to invest in such kinds of technology.

Ultimately, the research presented in this report suggests that low-cost climate adaptation is having an immediate, and much needed positive impact on the lives of poor women. However, it is unlikely that this kind of adaptation will ever be able to fully solve this issue.

Therefore, it is important to support ways of increasing women's economic empowerment and earning capacity. It may be the case that providing women with clear pathways to escape from the poverty trap such as education and skills training is the most effective way to mitigate against the impacts of global warming. Gaining access to a greater flow of income provides households with their own disposable income to spend on more efficient cooling technology, increasing their climate resilience for the long term. However, in the short to medium term, the strategic scaling up of energy-efficient and climate-friendly solutions by all players is also crucial to improving lives and decreasing the rate of climate warming through reducing greenhouse gas emissions.

6. Conclusion

The combination of secondary research and this research's own findings conclusively prove that rising temperatures are disproportionately impacting the productivity, health and livelihoods of informal sector women workers and their families. Therefore, their already precarious livelihoods will only become more at risk as the Indian climate continues to heat up. It is imperative to assist them to address and adapt to these impacts through new innovative technologies and greater support to accessing these solutions from NGOs, philanthropies and private sector organisations. Importantly, the government must also step up support in order to increase the long term financial and health security of informal sector women workers, whilst supporting a just transition to a low carbon economy.

In summary, this study issues an urgent call to action, emphasising the ever-increasing impacts of global rising temperatures which is putting informal sector women workers residing in urban slums in particular, at great peril. Failing to do so, could condemn billions of people, particularly in vulnerable regions, to the harrowing consequences of extreme heat and humidity, with limited means. And here, the conviction and activities of MHT remains exemplary and much needed.

Appendix A: Glimpses of the living conditions of the residents of Bapalaal Kadiyani Chaali

The white painted roofs of Bapalaal Kadiyani Chaali

The entrance to Bapalaal Kadiyani Chaali

The white painted roofs of Bapalaal Kadiyani Chaali

The white painted roofs of Bapalaal Kadiyani Chaali

A home based worker of Bapalaal Kadiyani Chaali packaging decorations

A street view of Bapalaal Kadiyani Chaali

A street view of Bapalaal Kadiyani Chaali

Some of the women involved in the FGD and the researcher

Annex B: Focus Group Discussion - Questionnaire

I. General Information

Name of Respondent (R): 20 women

Age (years) All above 20, Sex: female

Address:

_____
_____
_____

Total Members in Household:

Place of work:

Total Monthly Income of respondent:

Source of respondents' income:

II. Dwelling Unit (DU) Information

a) Number of floors: only one house had a second floor
b) Do you use Cool-roofs: Y/ N _____
c) Do you paint the roof white: Y/N
d) Do you use any other material on the roof to reduce heat in the house? Y/ N; If yes, then mention the material(s)

III. Physical Health impacts of Heat:

a) Have you or anyone in your household contracted any physical heat related illnesses in the past 5 years? Y/N
b) How many times?
c) Please specify any symptoms and the period of time when each family member was affected:
d) Did you pay for any remedy for the illness? DD-doctor, medicine, hospitalization
e) If yes please provide a rough estimate as to the total amount spent on remedies:
f) How did you source the money to pay for the remedy? DD- bank loan/personal savings/moneylender loan/family contribution/selling assets/insurance payout/government medicine handouts
g) Please provide a rough estimate as to the number of work days/hours lost due to any heat related illnesses this year:

IV. Adapting to Heat

a) What adaptations has your household used to insulate against heat? DD-white paint/bamboo roof/mod roof/cool roof
b) How much money have you spent on these adaptations?
c) Have the adaptations helped you to be more productive? Y/N
d) Have these adaptations reduced your electricity bill? Y/N
e) Has your electricity bill increased over the last 10 years? Y/N
f) Roughly by how much has your monthly electricity bill been reduced?

V. Heat and productivity

a) Has your overall productivity before you installed white paint been lower compared to ten years ago due to increasing temperatures? Y/N
b) Has your overall productivity before you installed any climate adaptation been lower compared to last year due to increasing temperatures? Y/N
c) Please provide a rough estimate of the number of work day/hours lost due to heat this summer:
d) Please provide a rough estimate of the amount of income you have lost due to heat this year:
e) Has the amount of care work you do increased due to heat over the last 10 years? Y/N
f) Were there power cuts before putting in the coolroof? (Y/N) _____ ii) Frequency:
g) How many power cuts have occurred per day after putting in the coolroof?

VI. General Comments

_____
_____
_____
_____

Annex C: Key Informant Interview – Questionnaire used for individual case studies

I. General Information

Name of Respondent (R): _____

For how long have you been living in Ahmedabad/BKN_____ Sex_____

Address:

_____

_____

_____

Total Members in Household:

Total Monthly Income of Household: _____Code: 1=<8,000;
2=8,000 to 20,000; 3=20,001 to 40,000; 4=40,001 to 80,000; 5=Above 80,000

Total Monthly Income of respondent: _____

Source of respondents' income: _____

II. Dwelling Unit (DU) Information

a) Number of floors: _____
b) Do you use Cool-roofs: Y/ N _____
c) Do you paint the roof white: Y/N _____
d) Do you use any other material on the roof to reduce heat in the house? Y/ N; If yes, then mention the material(s)
   _____

III. Physical Health impacts of Heat:

a) Have you or anyone in your household contracted any physical heat related illnesses in the past 10 years? Y/N
b) How many times in the last 10/ 5 years/year? _____
c) Please specify the age, sex and employment of each affected family member
   _____
d) Please specify any symptoms and the period of time when each family member was affected
   _____
e) Did you pay for any remedy for the illness? DD-doctor, medicine, hospitalization
f) If yes please provide a rough estimate as to the total amount spent on remedies:
   _____
g) How did you source the money to pay for the remedy? DD- bank loan/personal savings/moneylender loan/family contribution/selling assets/insurance payout
h) Please provide a rough estimate as to the number of work days/hours lost due to any heat related illnesses this year: _____

IV. Adapting to Heat

a) What adaptations has your household used to insulate against heat? DD-white paint/bamboo roof/mod roof/cool roof
b) How much money have you spent on these adaptations?
   _____
c) Have the adaptations helped you to be more productive? Y/N_____
d) Have these adaptations reduced your electricity bill? Y/N_____
e) Has your electricity bill increased over the last 10 years? Y/N_____
f) Roughly by how much has your monthly electricity bill been reduced?
   _____
g) Have there been any unintended impacts of the white paint?

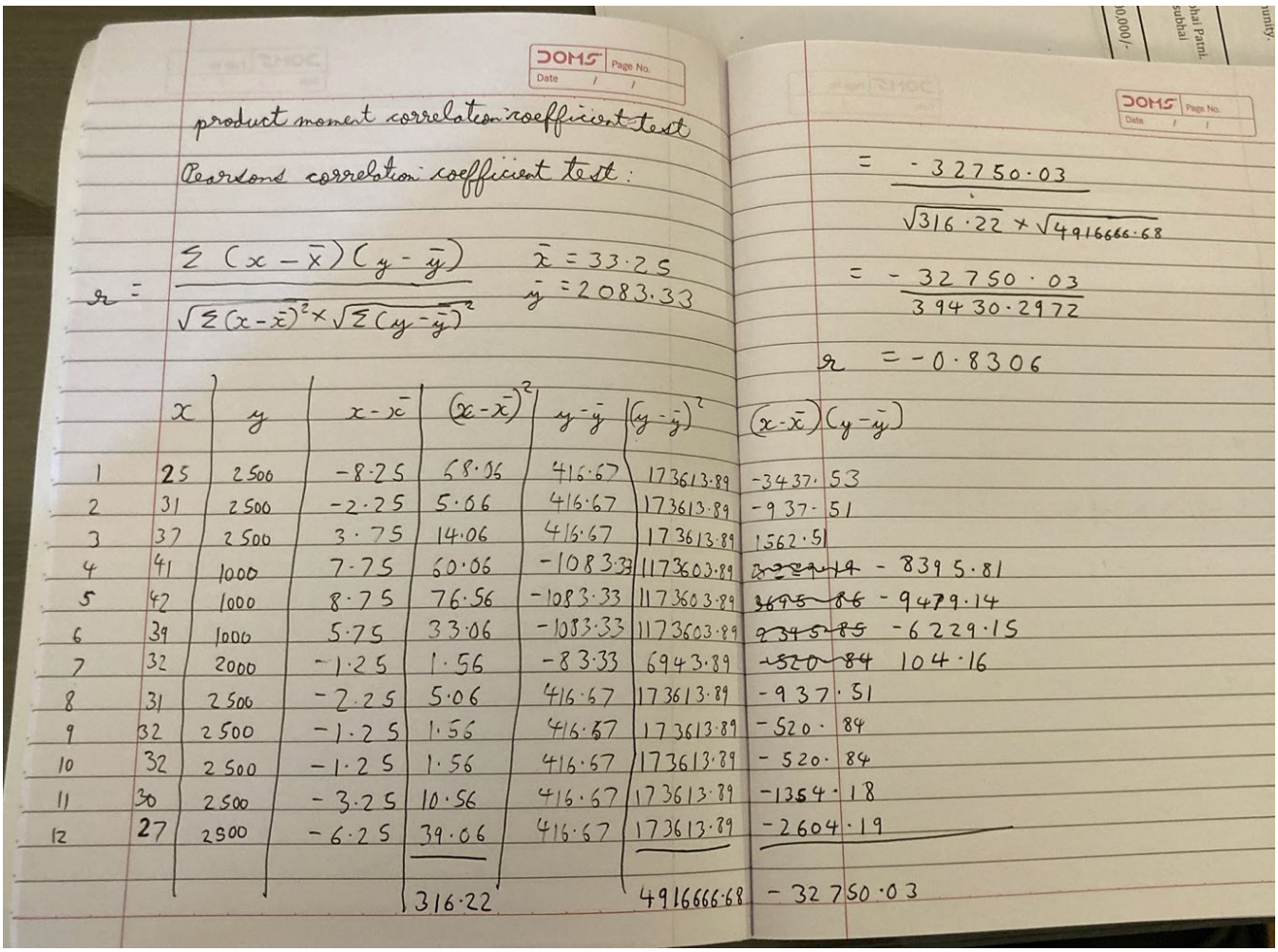
V. Heat and productivity

a) Has your overall productivity before you installed white paint been lower compared to ten years ago due to increasing temperatures? Y/N_____
b) Has your overall productivity before you installed any climate adaptation been lower compared to last year due to increasing temperatures? Y/N_____
c) Please provide a rough estimate of the number of work day/hours lost due to heat this year/has this increased over time: _____
d) Please provide a rough estimate of the amount of income you have lost due to heat this year: _____
e) Has the amount of care work you do increased due to heat over the last 10 years? Y/N_____
f) Were there power cuts before putting in the coolroof? (Y/N) _____; b) Frequency per day: _____
g) How many power cuts have occurred per day after putting in the coolroof? _____

VI. General Comments

_____
_____
_____
_____

Annex D: Pearson Product Moment Correlation Coefficient test calculations



product moment correlation coefficient test

Pearsons correlation coefficient test:

$$r = \frac{\Sigma (x-\bar{x})(y-\bar{y})}{\sqrt{\Sigma (x-\bar{x})^2} \times \sqrt{\Sigma (y-\bar{y})^2}}$$

$\bar{x} = 33.25$

$\bar{y} = 2083.33$

	x	y	$x-\bar{x}$	$(x-\bar{x})^2$	$y-\bar{y}$	$(y-\bar{y})^2$	$(x-\bar{x})(y-\bar{y})$
1	25	2500	-8.25	68.06	416.67	173613.89	-3437.53
2	31	2500	-2.25	5.06	416.67	173613.89	-937.51
3	37	2500	3.75	14.06	416.67	173613.89	1562.51
4	41	1000	7.75	60.06	-1083.33	1173603.89	~~-8395.74~~ -8395.81
5	42	1000	8.75	76.56	-1083.33	1173603.89	~~-9479.86~~ -9479.14
6	39	1000	5.75	33.06	-1083.33	1173603.89	~~-6229.85~~ -6229.15
7	32	2000	-1.25	1.56	-83.33	6943.89	~~-520.84~~ 104.16
8	31	2500	-2.25	5.06	416.67	173613.89	-937.51
9	32	2500	-1.25	1.56	416.67	173613.89	-520.84
10	32	2500	-1.25	1.56	416.67	173613.89	-520.84
11	30	2500	-3.25	10.56	416.67	173613.89	-1354.18
12	27	2500	-6.25	39.06	416.67	173613.89	-2604.19
				316.22		4916666.68	-32750.03

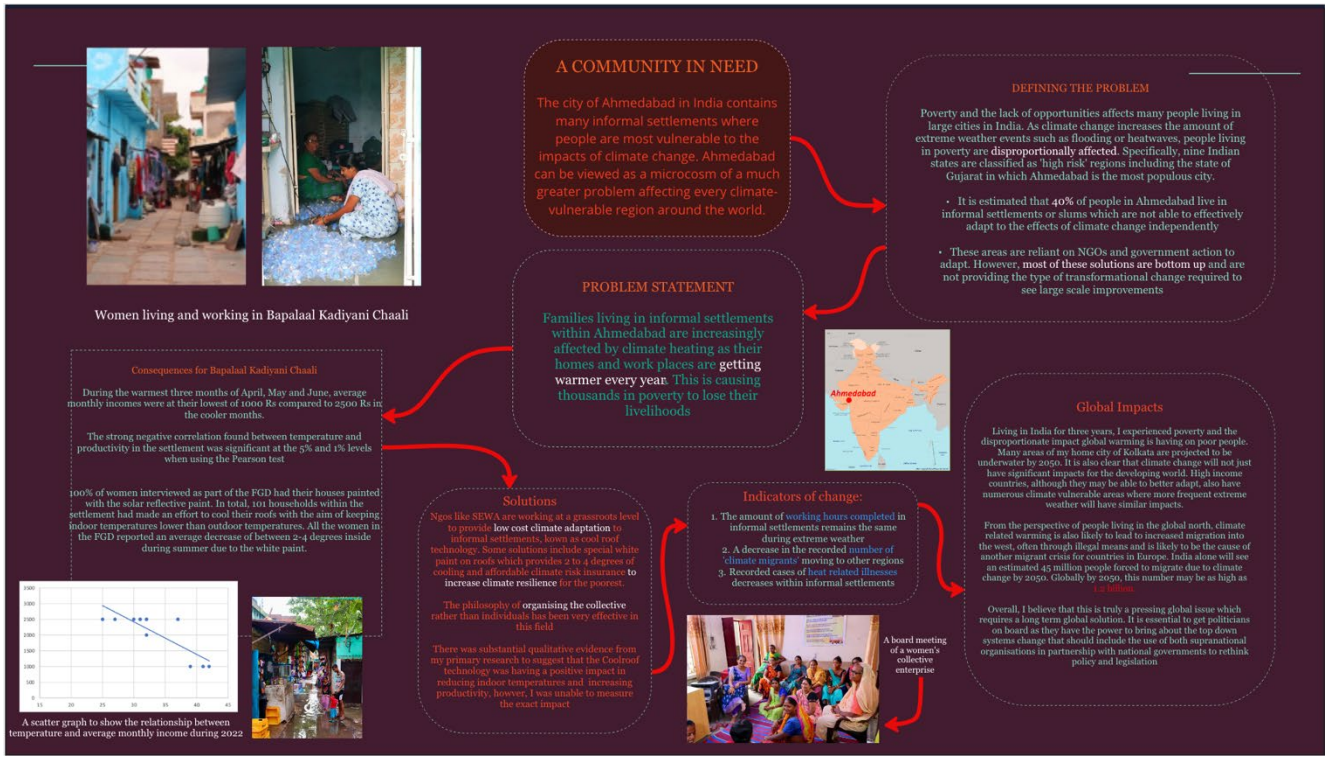
$$= \frac{-32750.03}{\sqrt{316.22} \times \sqrt{4916666.68}}$$

$$= \frac{-32750.03}{3943.2972}$$

$r = -0.8306$

Annex E: A poster made as an initial plan and to collect initial research in one place

It may also be used to raise awareness about this pressing issue in the global north to people who are not yet seriously impacted



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