Original Researcher Article

Industrial Resilience and Productivity: Managing Climate Impacts in Textile Mills

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ABSTRACT

This study examines the impact of climate variability on industrial productivity and resilience within textile mills in Ahmedabad, India, a major textile hub highly vulnerable to heat stress and environmental fluctuations. The research integrates perspectives from climate–labour productivity, industrial resilience, and sustainable manufacturing to analyse how climatic factors such as temperature variations, humidity, rainfall, and extreme weather events influence operational efficiency, labour productivity, downtime, and machine performance. A cross-sectional quantitative approach was adopted using survey data collected from 100 workers across 10–15 textile mills. The findings reveal that extreme climatic conditions and temperature variability significantly reduce productivity, primarily through increased equipment failure and operational disruptions. Regression analysis confirms that climate variables explain a substantial proportion of productivity variation. Furthermore, resilience strategies—particularly those focused on reducing downtime and improving adaptive capacity—demonstrate a strong positive impact on mitigating productivity losses. However, specific measures such as cooling systems and infrastructure improvements show varying levels of perceived effectiveness. The study highlights the need to integrate climate adaptation into industrial productivity planning and provides practical insights for policymakers and industry stakeholders to enhance resilience in climate-sensitive textile clusters.

Keywords: Climate variability, Industrial resilience, Textile industry, Labour productivity, Heat stress, Ahmedabad

INTRODUCTION:

The textile and clothing industry has traditionally been at the heart of industrialization, job creation, and export expansion in many countries, but it is also one of the most resource- and climate-intensive manufacturing sectors globally(Samant et al., 2024). More recent estimates indicate that the textile industry accounts for approximately 10% of global greenhouse gas emissions, which has placed the industry under immense pressure to decarbonise and transform. On the other hand, the physical effects of climate change, such as rising temperatures, heatwaves, unpredictable rainfall, and extreme weather events, are also increasingly being felt in production systems and working conditions, particularly in low- and middle-income countries where climate control and adaptive infrastructure are less developed(Mirzabaev et al., 2023).

India is a large textile manufacturer and also one of the countries that are most vulnerable to climate change. The textile industry employs millions of people in spinning, weaving, processing, and garmenting. Within India, urban centres such as Ahmedabad and Surat have evolved into dense textile clusters, combining mills, ancillary units and informal labour markets(Hasanuzzaman & Bhar, 2016). At the same time, recent climate analyses show that these cities are among the worst affected by increasing heat stress, with indoor and outdoor workers already experiencing measurable productivity losses of around 10% over recent decades(N. Khan et al., 2025). This combination of industrial concentration and climate vulnerability makes Ahmedabad an important case for investigating how climate variability is translated into productivity impacts at the factory floor.

A growing body of research has begun to quantify the economic costs of heat exposure and climate variability for labour productivity. Multi-sector evidence from Indian manufacturing indicates that plant-level output declines by roughly 2% for every 1°C increase in annual temperature, with climate control only partially offsetting productivity and absenteeism effects(Somanathan et al., 2021). Occupational-health studies similarly show that hot work environments reduce workers' physical capacity, increase fatigue and raise the risk of heat-related illness(De Sario et al., 2023). In the textile industry specifically, case studies from Indonesia report significant negative correlations between hot work climate (wet-bulb globe temperature above 29°C) and output in weaving departments(Setyawan et al., 2018). More recent analyses of Indian garment and textile clusters highlight that climate-driven heat stress is not only a health risk but also a direct threat to productivity and job security, particularly for migrant and low-wage workers(Lundgren-Kownacki et al., 2018).

Parallel to the emerging labour-productivity literature, scholars in industrial ecology and circular-economy research are examining how textile firms can build "sustainable resilience"—the combined ability to maintain performance under climate and market shocks while reducing environmental impacts. Survey-based work in Brazilian and global textile industries, for

example, has assessed how firm size influences the capacity to adopt cleaner production technologies and circular-economy practices(De Oliveira Neto et al., 2019). Systematic reviews of circular-economy strategies in textiles show that implementing resource-efficient processes, waste recycling and product-life-extension models can strengthen both environmental performance and long-term competitiveness(Ramírez-Escamilla et al., 2024). In addition, the literature on Industry 4.0 and smart manufacturing argues that digitalisation, automation and predictive monitoring open new pathways to manage environmental loads and operational risks in textile production(M. I. Khan et al., 2025).

Yet, there are still several gaps. First, most quantitative studies of climate and labour productivity in India use national or sector-wide datasets; they rarely zoom into specific industrial clusters such as Ahmedabad's textile mills, where old infrastructure, dense urban heat-island effects and informal labour arrangements may amplify vulnerability. Second, research that does focus on textiles often looks either at environmental impacts (e.g., emissions, water pollution) or at firm-level resilience strategies, but seldom empirically links daily climate stress to both productivity metrics and the perceived effectiveness of resilience measures inside the same mills. Third, there is little empirical research on the perceptions of workers regarding the impact of climate-related productivity shocks and the effectiveness of various resilience measures (cooling systems, insulation, infrastructure, downtime management) in the South Asian textile industry.

This paper fills these research gaps by examining the textile mills in Ahmedabad as a climate-vulnerable industrial system. Using a survey sample of 100 employees in 10-15 textile mills, we first measure the perceived relationship between important climate factors (temperature variation, humidity, rainfall, and extreme weather conditions) and productivity outcomes (labour productivity, downtime, and equipment performance). We next investigate whether the adopted or planned strategies to enhance resilience to climate change, such as enhanced cooling, climate-resilient infrastructure and organizational procedures to mitigate climate-induced downtime, are related to perceived productivity gains. The paper offers three key contributions. From a conceptual point of view, it weaves together strands of research on climate-labour productivity, literature on industrial resilience, and circular economy thinking in a particular context of an Indian textile cluster. From an empirical perspective, it offers mill-level evidence from the city of Ahmedabad, which is a "hotspot" city for heat-stress among industrial workers.From a practical perspective, it provides mill owners and policymakers with insights into the resilience strategies that workers find most effective in dealing with climate variability.

2. Literature Review

2.1 Global Evidence on Climate Stressors and Industrial Productivity

The production systems of the industrial sector worldwide are increasingly being affected by the operational impacts of climate change. The manufacturing sectors that rely on temperature-sensitive equipment or labor-intensive processes are some of the most adversely affected by the rising temperatures, humidity variations, and weather patterns. Various empirical research studies have found that higher ambient temperatures can lower the physical stamina, decision-making capacity, and work efficiency of workers, besides shortening the life of equipment in production systems. A recent study across multiple countries found that the global labor productivity declines by 2-5% for every 1°C rise in the working temperature above the optimal level, with the textile industry being the most vulnerable to production losses due to heat(Dasgupta et al., 2021). Climate change extremes also affect the production system by increasing the frequency of equipment failure, thereby causing power-load pressure and unscheduled downtime (Jakhar et al., 2023).

The economic implications of climate exposure go beyond the short-term loss of productivity. A longitudinal study carried out in the manufacturing clusters of East and South-East Asia found that factories struggling to counter the effects of climate disruptions experienced a 12-18% increase in late orders and contract violations during peak heat periods(Ofremu et al., 2025). It is clear that climate risk has moved beyond the realm of an environmental problem and has become one of the most important factors shaping the competitiveness of industries.

2.2 Climate Exposure and Vulnerability in the Textile Sector

Textile manufacturing is one of the most climate-sensitive sectors because there are a number of processes involved in textile manufacturing, such as spinning, weaving, dyeing, finishing, and storage, which require optimal temperature and humidity levels(Yılmaz et al., 2024). This is why modern textile production equipment is set to specific temperature thresholds; if it exceeds the threshold, it results in the breaking of threads, degradation of fibers, and lubricant degradation, causing interruptions in the workflow. The humidity level also determines the elasticity of the yarn; low humidity causes an increase in static and breakage, while high humidity causes moisture absorption.

Recent research in Bangladesh, Vietnam, and Indonesia has shown that climate-related thermal stress in textile factories decreases the average efficiency of operators by 8-21% in the heat-stress months, especially in semi-automatic factories where manual monitoring and adjustments are required. The loss of productivity is not limited to fibre processing units; garment manufacturing units have also witnessed increased absenteeism and fatigue-related errors during periods of extreme temperatures(Smallcombe et al., 2025). Moreover, climate stress further raises the vulnerability of operations by increasing the demand for cooling energy, thereby increasing production costs and reducing profit margins(Yeasmin et al., 2025).

The results reveal that climate exposure is not only an environmental issue but also a production system constraint that affects the competitiveness and financial viability of textile firms.

2.3 Climate-Resilience and Adaptation Strategies in Manufacturing

In reaction to the growing number of climate-related disruptions, sectors across the globe are now actively exploring the application of resilience strategies. Adaptation techniques vary from incremental methods such as enhanced insulation, ventilation, and heat-resistant materials to more radical approaches such as smart cooling systems, renewable energy-powered climate control, and predictive maintenance and shift scheduling. In a recent study of Thai and Malaysian manufacturing facilities, factories with heat-adaptive designs, reflective paint, and infrastructure upgrades achieved a 27-32% reduction in heat-related downtime in two production cycles(Brzezicki, 2024).

Digital technologies are also being developed as resilience tools. IoT sensor-based heat monitoring systems on shop floors, AI-based thermal anomaly detection, and automated shutdown alert systems enable management to act before climate-induced stress leads to a breakdown(Ghazal et al., 2020). But technology by itself is not the answer. Best-performing factories combine resilience practices with employee training, safety, communication, and climate-driven workforce scheduling to ensure labor well-being during the hottest periods of extreme heat events.

However, despite the promising global developments, the rate of adoption of these resilience strategies is quite different from one country to another. The manufacturing groups in developing nations may have budget constraints, unreliable energy supply, and outdated equipment, making it quite challenging to adopt sophisticated adaptation strategies. This has resulted in a disjointed resilience management system that is largely dependent on the owner's personal choice.

2.4 South Asian and Indian Context

South Asia is geographically predisposed to high thermal exposure, with heatwave duration and intensity rising steadily over the last two decades. India's textile industry, which employs more than 45 million workers, is disproportionately concentrated in states with extreme heat-risk profiles, including Gujarat, Maharashtra, Tamil Nadu and Rajasthan. According to the Ministry of Textiles and ILO estimates, textile clusters in India lose between 9–22% of productive machine hours annually due to heat stress inside factory premises, especially during summer and monsoon months.

Recent empirical work highlights region-specific challenges. A study on Tamil Nadu textile mills found that weaving units experienced a 14% increase in thread-break incidents under 60–68% humidity levels(Mohan et al., 2021). In Surat power-loom clusters, climate-induced downtime increased operational costs by 11% per year. These findings reinforce the importance of region-specific and industry-specific assessments.

Nevertheless, research analysing how climate variables influence productivity remains sparse for Ahmedabad — despite its central role in India's textile economy and disproportionately high urban heat index. Even fewer studies evaluate whether resilience strategies implemented inside Ahmedabad's mills are effective in mitigating climate-linked productivity losses.

Author(s) & Year	Context / Region	Core Focus	Major Findings	Gap Relevant to Present Study
Somanathan et al., 2021(Somanathan et al., 2021)	India – manufacturing sector	Temperature–productivity relationship at plant level	Using microdata from Indian factories, annual plant output falls by about 2% for every 1°C increase in annual temperature; climate control mitigates some productivity loss but not absenteeism.	Shows strong temperature–productivity link but not specific to textiles and does not evaluate resilience strategies (cooling, scheduling, maintenance) in detail.
Krishnamurthy et al., 2017 (Krishnamurthy et al., 2017)	Southern India – steel industry	Occupational heat stress, health and productivity	Field study shows that workers exposed to high WBGT experience heat strain, reduced performance and more breaks, leading to measurable productivity decline in a steel plant. (PMC)	Demonstrates workplace heat–productivity effects in heavy industry, but no analysis for textile mills or combined machine–labour impacts and no systematic resilience costing.
Amoadu et al., 2023 (Amoadu et al., 2023)	Global (scoping review)	Heat stress, workers' health & productivity	Review across sectors finds that climate-driven heat stress can cut work capacity by double-digit percentages in hot environments, particularly in labour-intensive jobs; adaptive options (rest breaks, cooling, hydration) are described but seldom quantified economically. (PMC)	Synthesises global evidence but does not model productivity losses for specific industries like textiles, and lacks empirical evaluation of factory-level resilience strategies.

International Labour Organization, 2019 (IOL, 2019)	Global – multi-region	Heat stress, working hours and GDP loss	Estimates that by 2030, 2.2% of total working hours worldwide could be lost to heat stress (equivalent to ~80 million full-time jobs), with higher impacts in low- and middle-income countries and in labour-intensive sectors. (International Labour Organization)	Provides macro-level projections for work-hour loss and GDP impact but does not address plant-level productivity metrics or sector-specific resilience investments such as in spinning/weaving mills.
Mishra et al., 2025 (Mishra et al., 2025)	50 Indian cities incl. Ahmedabad & Surat	Migrant workers' heat stress & productivity	Study on migrant labourers shows around 10% decline in labour productivity due to heat in highly exposed cities like Ahmedabad and Surat, with millions of workers facing indoor and outdoor heat stress each year. (The Times of India)	Provides city-level evidence for heat-related productivity loss, but does not focus on textile mills, nor does it analyse specific resilience strategies within industrial units.
Tanni et al., 2023 (Tanni et al., 2023)	Bangladesh – weaving floor	Production floor temperature & weaving	Case study reports that higher production-floor temperature is associated with lower loom efficiency, more stoppages and reduced fabric output, and suggests ventilation and cooling improvements as mitigation. (ResearchGate)	Textile-specific but limited to one factory case; does not model quantitative gains from different resilience strategies or link with long-term climate projections.
Raian et al., 2022 (Raian et al., 2022)	Global / Asian textile supply chains	Sustainability risks in textile supply chain	Uses multi-criteria methods to show that climate-related disruptions (e.g., extreme weather, energy instability) are key risks to textile supply chains; emphasises the need for resilient sourcing and logistics. (ResearchGate)	Focuses on supply-chain level risk, not on in-plant productivity; no empirical testing of climate-resilience interventions inside mills (e.g., machine maintenance, micro-climate control, workforce adaptation).
Hossain, 2025 (Kazy Mohammad, 2025)	Global textile sector (narrative review)	Innovation, policy & climate resilience in textiles	Reviews technological innovation, policy instruments and climate-resilience initiatives across textile producing regions, arguing that combined technological and policy changes are needed to reduce climate vulnerability of mills. (ResearchGate)	Provides a conceptual and policy-oriented view; does not include plant-level quantitative evidence on productivity changes nor rigorous impact evaluation of specific resilience investments.
Stockholm Resilience Centre, 2021 (Cornell et al., 2021)	Global – textiles & fashion	Circularity, resilience & planetary boundaries	Synthesis report highlights how textile and fashion systems must become both circular and climate-resilient, noting that climate and water risks already threaten production stability and long-term value creation.	Strong on systems-level resilience and planetary boundaries but does not analyse operational productivity indicators (downtime, output/loom, defect rates) or concrete mill-level resilience strategies.
Yasobant et al., 2025(Yasobant et al., 2025)	India	Health impacts of heat, incl. workers	Summarises Indian evidence showing that occupational heat stress increases fatigue, errors and illness in sectors like construction and industry, indirectly reducing	Provides national evidence for heat impacts on health, but does not connect to detailed productivity metrics in textiles or the

			productivity and earnings. (PMC)	effectiveness of industrial resilience strategies.

2.6 Research Gaps and Justification of the Present Study

A synthesis of current literature highlights several clear gaps that justify the need for this research. Globally, research increasingly acknowledges that climate variability affects industrial operations; however, most studies disproportionately focus on advanced economies where factories have modern environmental control systems. Evidence from labour-intensive and semi-automated textile sectors in developing countries remains limited. Furthermore, the majority of studies analyse either climate impacts or adaptation strategies, but very few attempt to model both in a single empirical framework, leaving unanswered questions about which resilience interventions genuinely improve productivity under climate stress.

The textile sector in South Asia has been examined for heat-induced labour fatigue, thread-break incidents, absenteeism and energy cost escalation, yet there is still insufficient knowledge on how combined climate variables — temperature, humidity and rainfall — collectively shape multi-dimensional productivity indicators such as machine performance, downtime and workforce efficiency. Importantly, while several mills have begun deploying adaptation measures such as cooling systems, ventilation, roof insulation and shift restructuring, the effectiveness of these strategies is rarely evaluated using statistical evidence. As a result, most policy frameworks and industrial decisions lack empirical support.

Regionally, research on Indian textile clusters has grown in Tamil Nadu and Surat, but there is strikingly limited research on Ahmedabad, despite its historic and economic significance to India's textile sector and its rapidly intensifying urban heat patterns. No known study has conducted a quantitative assessment of climate variables and resilience strategies simultaneously within Ahmedabad mills, creating a critical knowledge vacuum for industry decision-making and policy development.

Therefore, the present study addresses three major gaps:

Lack of empirical evidence linking climate variables to productivity outcomes in developing-economy textile mills.

Lack of evaluation of the effectiveness of resilience strategies in mitigating climate-induced productivity losses.

Lack of region-specific research focused on Ahmedabad — India's major heat-exposed textile hub.

Addressing these gaps is essential for guiding industrial policy, capital investment planning and workplace climate adaptation in the textile sector.

2.7 Conceptual Framework and Hypothesis Development

From the literature that has been reviewed, it is anticipated that climate factors will have an impact on various aspects of productivity in textile mills. This includes the effects of temperature variations, high humidity, and the disruption of rainfall during the course of the year on machine performance, labor productivity, down time, and continuity. At the same time, there is a moderating effect of climate resilience measures.

H₁: Climate variables significantly influence productivity metrics in textile mills in Ahmedabad.

H₂: Resilience strategies significantly reduce climate-related productivity losses and enhance industrial resilience in textile mills in Ahmedabad.

This framework integrates environmental, operational and strategic dimensions, and aligns with contemporary industrial-resilience theory, making it suitable for empirical validation using regression-based modelling.

3. Research Methodology

3.1 Study context and design

The research uses a cross-sectional quantitative approach, concentrating on textile mills in the city of Ahmedabad, in the state of Gujarat. The city of Ahmedabad has a long history of being known as the "Manchester of India" due to its high concentration of mills and its close location to cotton-producing areas. However, in recent climate studies, the city of Ahmedabad has been identified as a hotspot for heat stress, both for outdoor and indoor workers.

3.2 Sampling and respondents

The target population was comprised of workers employed in operational departments of textile mills (spinning, weaving, processing) in the Ahmedabad urban area. Since there is no comprehensive sampling frame of workers in all mills, a multi-stage sampling design was used. In the first stage, 10-15 mills were selected purposefully to ensure that mills of varying sizes (small, medium, large) and composition of workers are included. In the second stage, workers were selected using simple random sampling or systematic sampling.

A total of 100 workers filled out the questionnaire, which is in line with the sample size of other studies that relate climate perceptions to productivity. The demographic attributes show that most of the respondents are aged 18 to 40 years, are mostly male, and have high school, diploma, and bachelor's qualifications with 5 to 20 years of industry experience.

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This composition shows the labor-intensive nature of the industry and offers a relevant context for analyzing the perceived climate effects on productivity.

3.3 Instrument development and measures

The study employed a structured questionnaire to gather data. The questions were developed from the existing

literature on climate risk, occupational heat stress, and industrial resilience. The questions were tailored to the textile mill industry.

The questionnaire had four sections:

Demographics and mill characteristics (age, gender, education, experience, mill size).

Perceived climate variability, with Likert-scale questions that measured the respondents' perceptions of temperature variability, humidity, rainfall, and extreme climate events that influenced their mills.

Productivity consequences, with questions on the effects of climate variability on mill output, efficiency, downtime, absenteeism, and equipment performance.

Resilience practices, which included questions on the use and effectiveness of cooling measures, insulation, climate-resilient infrastructure, and maintenance practices to counteract climate disruptions.

All the perceptual variables were measured using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). Internal consistency was assessed using Cronbach's alpha for each scale, and all the scales had values above the acceptable level of 0.70. (You can insert your alpha values here if available.)

3.4 Data collection procedure

The data was collected over a specific period during the recent hot and monsoon seasons when the issue of climate variability is most apparent. Before the actual survey, the questionnaire was pilot-tested among a small number of workers (for example, n ≈ 10) to check for clarity and relevance. The necessary adjustments were made, especially regarding climate and resilience questions, before the actual survey was carried out.

The survey was anonymous. Permission was sought from the mill management, and the workers were informed about the purpose of the study. No personal details were recorded,

4. Results & Discussion

The findings are presented in two forms. First, descriptive statistics are used to present the demographics of the respondents and the characteristics of the mills. Second, inferential analysis is employed to test the two hypotheses.

4.1 Descriptive Statistics

		Frequency	Percentage
Age	18-30	46	46
	31-40	31	31
	41-50	14	14
	Above 51	9	9
Gender	Male	79	79
	Female	21	21
Educational Qualification	High School	23	23
	Diploma	37	37
	Bachelor's Degree	28	28
	Master's Degree	12	12
Years of Experience in Textile Industry	Less than 5 years	11	11
	5-10 years	57	57
	11-20 years	28	28
	More than 20 years	4	4
Size of the Textile Mill (in terms of employees)	Less than 50 employees	16	16
	50-100 employees	41	41
	150-200 employees	24	24
	More than 200 employees	19	19

Demographic profile of the respondent
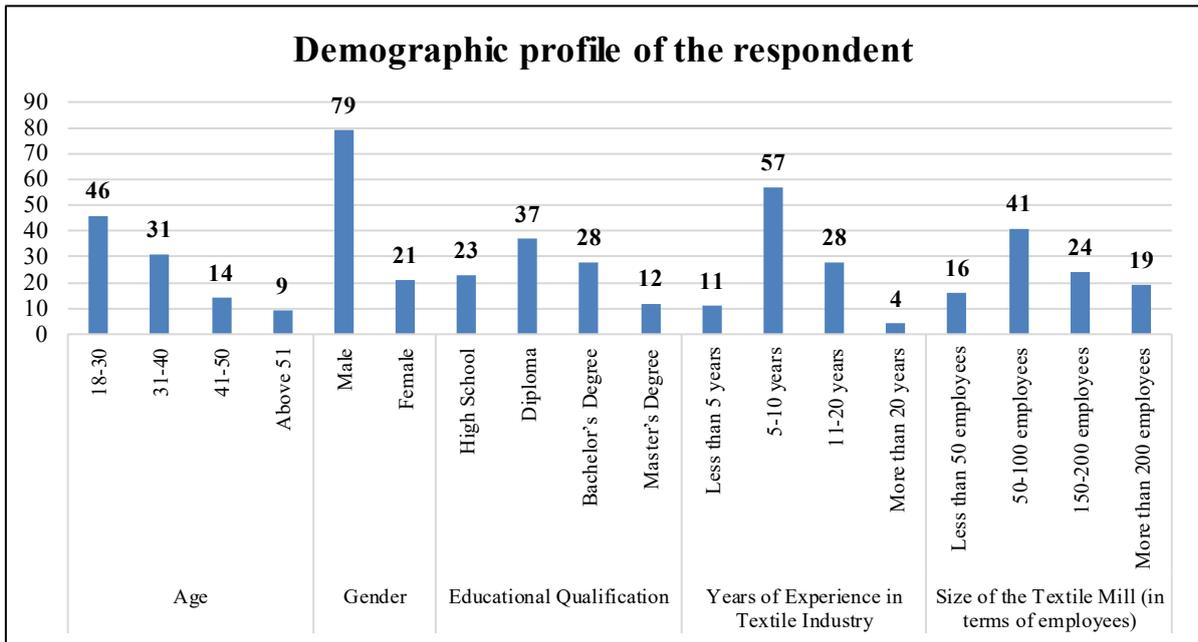
The demographic characteristics of the respondents, who are workers in the textile industry, are as follows:

The demographic characteristics of the sample represent the common labor composition of the textile industry in Ahmedabad. The majority of the respondents belong to the age group 18-30 years (46%), followed by 31-40 years (31%), which indicates a relatively young labor force. The textile industry labor force is predominantly male (79%), while females comprise 21% of the respondents. The educational background of the respondents shows that 37% have a diploma, 28% have a bachelor's degree, 23% have a high school education, and 12% have postgraduate education.

Talking about their work experience, 57% of the respondents had 5-10 years of experience in the sector, 28% had 11-20 years of experience, and only 4% had more than 20 years of experience. Most of the respondents were working in mills with 50-100 employees (41%), followed by those working in mills with 150-200 employees (24%), 200+ employees (19%), and 50 or fewer employees (16%). Overall, the sample represents a statistically valid group of operational-level workers who are subjected to climate-sensitive production conditions.

4.2 Hypothesis Testing

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.749[a]	0.562	0.543	0.838

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	85.392	4	21.348	30.429	.000[b]
	Residual	66.648	95	0.702		
	Total	152.04	99			
a. Dependent Variable: Climate variables (e.g., temperature, humidity, rainfall) significantly affect the efficiency of labor in our mill.						

Coefficients[a]			
Model		Unstandardized Coefficients	Standardized Coefficients

		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.574	0.318		1.805	0.074
	Temperature fluctuations reduce mill productivity.	0.228	0.119	0.233	1.921	0.058
	High humidity increases operational downtime.	0.145	0.152	0.147	0.958	0.341
	Monsoon rainfall disrupts production schedules.	0.191	0.13	0.173	1.472	0.144
	Extreme climate conditions damage machinery and cause breakdowns.	0.296	0.117	0.286	2.533	0.013
a. Dependent Variable: Climate impacts worker efficiency						

The first regression model was used to determine the relationship between the perceived climate variables and the impact of labor efficiency in the mills. The regression model fits well, as shown by the value of R = 0.749 and R^2 = 0.562, which indicates that the four predictors of the climate explain 56.2% of the variation in the perceived impact of efficiency. The ANOVA table shows the significance of the model, as shown by F = 30.429 and p < 0.001.

At the individual predictor level, extreme climate conditions (heatwaves or very intense rainfall events) have a statistically significant positive coefficient (β = 0.286; p = 0.013), suggesting that those workers who are exposed to more frequent or intense extreme climate conditions are more likely to perceive negative impacts on labor efficiency due to machinery breakdowns and operational disruptions. Temperature variations have a near-significant coefficient (β = 0.233; p = 0.058), suggesting the emergence of a trend where temperature

instability is perceived to be linked to perceived losses in productivity, although not necessarily in a manner where all respondents are treated equally. Humidity and rainfall, on the other hand, have less strong and non-significant coefficients (p > 0.10), suggesting that, in this sample, they are not the dominant factors that influence perceived changes in productivity.

These results are consistent with the literature that finds temperature and heat stress to be major channels through which climate change impacts industrial productivity. The size and sign of the coefficients mirror plant-level evidence from the Indian manufacturing sector, where higher annual temperatures lower productivity and increase absenteeism and equipment breakdowns. Textile industry-specific evidence from Indonesian mills, which also found strong negative correlations between hot work climate and output, highlights the temperature sensitivity of textile industry productivity.

4.3 Resilience strategies and reduced productivity losses (H2)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.799[a]	0.639	0.624	0.698

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	81.767	4	20.442	42.004	.000[b]
	Residual	46.233	95	0.487		
	Total	128	99			
a. Dependent Variable: Resilience investments reduce losses						

Coefficientsa

		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.46	0.283		1.625	0.107
	Resilience reduces downtime	0.282	0.095	0.286	2.953	0.004
	Cooling systems improve performance	0.162	0.1	0.169	1.613	0.11
	Climate-proofing improves productivity	0.196	0.113	0.197	1.731	0.087
	Resilience enhances climate readiness	0.256	0.118	0.261	2.169	0.033
a. Dependent Variable: Resilience investments reduce losses						

The second regression model examines the relationship between the existing and proposed strategies for resilience and the perceived reduction in climate change-related losses of productivity. The regression model shows a strong relationship between the variables, with R = 0.799 and R² = 0.639, indicating that 63.9% of the variation in the perceived effectiveness of additional resilience investment is explained by the four variables. The regression model is significant, with F = 42.004 and p < 0.001.

Among the predictors, the item that has the strongest and significant effect is the one that captures the minimized production downtime as a result of the application of resilience strategies (B = 0.282; p = 0.004). This shows that employees who witness less downtime when faced with adverse climate conditions are more likely to be supportive of investments in the area of resilience. Similarly, the item that captures the general ability of the mill to overcome challenges posed by climate change is also significant (B = 0.256; p = 0.033).

In contrast, specific measures like cooling systems and insulation (p = 0.110) and climate-resilient infrastructure (p = 0.087) fail to attain the conventional levels of significance individually, although their coefficients are positive. This could be due to either limited implementation of these measures so far or the fact that the workers feel the benefits more at the aggregate level of downtime rather than associating them with specific measures.

5. DISCUSSION

The findings confirm three key findings. First, climate variability, particularly extremes and fluctuating temperatures, is already felt by workers as a real limiting factor for productivity in the textile mills of Ahmedabad. This is consistent with recent city-level findings that confirm Ahmedabad to be one of the Indian cities where heat stress has resulted in a reduction in labour productivity. Second, the fact that the relationship between extremes and perceived efficiency losses is strong indicates that adaptation efforts cannot be limited to average warming but must also address short-duration but intense events such as heat stress and urban flooding.

Third, the high explanatory power of the resilience strategy variables suggests that workers are aware of the value of adaptation strategies. The importance of interventions that can be seen to decrease downtime, such as maintenance before peak heat periods, flexible shift programs, or quick response strategies during heat events, is particularly evident. This is consistent with the literature on sustainable resilience in textiles, which suggests that incremental but cumulative changes in cleaner production, process control, and circular economy practices are a way to ensure performance during stress.

In general, the results indicate that climate risk management in textile clusters such as Ahmedabad should not be viewed from a strict environmental perspective. Rather, it has to be integrated into overall productivity strategies, with the emphasis on safeguarding the health of workers in the face of a rapidly changing climate.

Implications for industry and policy

The results show that climate variability is no longer a concern for the environment but is also a crucial factor in determining the productivity of industries. Textile mills can improve the resilience of productivity by focusing on the management of downtime during climate extremes, incorporating preventive maintenance before the peak heat season, and using infrastructure upgrades that can provide stable thermal conditions for both workers and machines. For policymakers, the results of this study emphasize the importance of incorporating the mitigation of heat stress in industries as part of the climate action plan of cities. This can help in improving the efficiency of labor and the competitiveness of climate-vulnerable industrial clusters like Ahmedabad.

6. Conclusion & Future Scope

The current study provides empirical evidence for the point that climate variability is already affecting the productivity of textile mills in the Ahmedabad region. The regression analysis shows that the perception of efficiency loss is significantly associated with extreme climate and temperature variability, which is mainly attributed to machine failure and other disruptions. On the other hand, textile mills that have adopted resilience strategies, particularly those related to downtime and overall resilience, are perceived to be better prepared to deal with climate-related efficiency losses.

Thus, the above findings help to fill a gap that exists between the research on macro-climate and productivity, and the experience of factories on the ground. In addition, they also indicate that the problem of climate adaptation in the textile industry is not only related to cleaner production and the reduction of greenhouse gas emissions but also to the ability of workers to produce in increasingly stressful conditions. The integration of climate-resilient workplace practices into textile mill production in heat-exposed cities such as Ahmedabad, therefore, has to be seen as a critical part of industrial strategy.

7. Future research directions

Future work could:

Extend the analysis to other textile clusters in India (e.g., Surat, Tiruppur) and compare patterns of climate vulnerability and resilience across different production systems.

Combine worker perceptions with objective climate and production data (hourly temperatures, output logs, machine failure records) to model dose-response relationships more precisely.

Examine the distributional impacts of climate stress, including differences between permanent and contract workers, gendered vulnerabilities and migrant-worker experiences.

Evaluate the cost–benefit profile of specific resilience interventions (e.g., upgraded cooling, insulation, predictive maintenance, digital monitoring) to support investment decisions by mill owners..

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