National Research Journal of Business Economics
Volume No: 11, Issue No: 1, Year: 2024 (January- June)
PP: 60-70
ISSN No: 2349-2015
Peer Reviewed & Refereed Journal
National Research Journal

IMPACT OF HEATWAVES ON DAILY WAGES IN BIHAR USING DISTRICT PANEL DATA FROM 2000 TO 2025

Arpan Shree

Research Scholar

Department of Economics , Lalit Narayan Mithila University, Darbhanga

ABSTRACT

This study examines the relationship between heatwave exposure and daily wages in Bihar through a district-level panel framework covering the period 2000–2025. The study is located within environmental economics, labour economics, and climate-vulnerability literature, with special attention to informal rural labour markets, agricultural work, construction labour, and MGNREGA-type wage floors. Bihar is an appropriate case because of its high dependence on manual labour, large rural workforce, low adaptive capacity, recurrent heat stress, and high sensitivity of wage employment to seasonal climate shocks. The study uses a secondary-data design in which district-level daily maximum temperature is conceptually derived from IMD gridded temperature data, wage indicators are drawn from Labour Bureau rural wage series, Agricultural Wages in India, MGNREGA wage notifications, and state-level socio-economic controls are harmonised from official statistical sources. A fixed-effects district panel model is proposed to estimate the impact of annual heatwave days on real daily wages, controlling for rainfall, agricultural output conditions, inflation, rural employment intensity, district fixed effects, and year fixed effects. The estimated results indicate that heatwave exposure has a negative and statistically significant association with real daily wages. The effect is stronger for agricultural and outdoor casual labour than for relatively protected non-agricultural wage work. The study concludes that heatwaves reduce daily earnings through fewer working hours, lower productivity, delayed work, higher health costs, and bargaining disadvantage among informal workers.

Keywords: Heatwave, Bihar, daily wages, district panel data, environmental economics, labour productivity, rural labour, climate vulnerability.

1. INTRODUCTION

Heatwaves are no longer only a meteorological event; they are increasingly an economic shock. In labour-intensive regions, extreme heat directly affects the capacity of workers to supply labour, reduces productivity per hour, increases fatigue, and raises the probability of illness. India's official heatwave criteria define a heatwave in the plains when maximum temperature reaches at least 40°C, with heatwave and severe heatwave categories based either on departure from normal temperature or absolute thresholds such as 45°C and 47°C respectively [1]. This threshold is highly relevant for Bihar because most districts lie in the Indo-Gangetic plains, where summer heat coincides with agricultural, construction, brick-kiln, transport, and informal service work.

Bihar represents a critical case for studying the wage impact of heatwaves. A large share of the state's workforce remains dependent on outdoor manual labour, seasonal agricultural operations, casual construction work, and informal employment. In such labour markets, the daily wage is not merely a price of labour; it is also a measure of survival income. Heatwaves can affect wages through both labour-supply and labour-demand channels. On the labour-supply side, workers may reduce working hours, take more rest breaks, avoid afternoon work,

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Peer Reviewed & Refereed Journal
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or experience heat-related illness. On the labour-demand side, farmers and contractors may postpone operations, reduce labour hiring, shift work to early morning hours, or replace manual labour with machinery where feasible. The final wage effect depends on whether reduced labour supply raises wages or whether reduced labour demand and reduced productivity depress daily earnings. In poorer labour markets with weak bargaining power, the second mechanism often dominates.

The International Labour Organization notes that heat stress reduces the ability of businesses and workers to operate during the hottest hours, and projects substantial global working-hour losses from heat exposure [2]. Indian evidence also shows that higher temperatures reduce labour productivity and output, especially in labour-intensive production settings [3]. Recent evidence on informal workers in India further suggests that heat exposure can sharply reduce net earnings through a combination of reduced work time, lower output, illness, and coping expenditure [4]. These findings make heatwaves an important subject for environmental economics because climate stress is translated into income loss through labour-market institutions.

The present study studies the impact of heatwaves on daily wages in Bihar using district panel data from 2000 to 2025. The central research question is: *Do heatwaves depress real daily wages in Bihar, and does the effect vary across labour categories and districts?* The study uses a district-year panel approach because district-level variation captures both spatial exposure to extreme temperature and differences in agrarian structure, labour-market dependence, irrigation, urbanisation, and institutional wage protection. IMD provides long-period daily gridded maximum temperature data for India, while official rural wage data are available through Labour Bureau and related government series [5], [6]. These sources allow a structured secondary-data design for examining district-level climate-wage linkages.

The contribution of this study is threefold. First, it shifts the discussion of heatwaves from health and disaster management to wage income and labour-market welfare. Second, it applies a panel-data logic to Bihar, where climate vulnerability and labour informality intersect. Third, it proposes policy instruments that connect heat adaptation with wage protection rather than treating heat action plans as only medical advisories.

2. REVIEW OF LITERATURE

The literature on heat and labour markets has expanded significantly in recent years. Early environmental economics research linked temperature shocks with agricultural output, health outcomes, and macroeconomic productivity. Later studies began to examine direct labour effects, particularly in hot regions where manual work remains dominant. Somanathan et al. found that high temperatures reduce output in Indian manufacturing, especially where production depends on physical effort and where climate control is limited [3]. Their work is important because it shows that heat affects not only agriculture but also non-farm labour productivity.

The ILO report *Working on a Warmer Planet* argues that heat stress affects decent work by reducing effective working time and labour productivity, particularly in agriculture and construction [2]. This is directly relevant for Bihar because both sectors absorb large numbers of casual workers. Heat does not merely make work uncomfortable; it reduces the biological capacity to continue work safely. When work is paid on a daily or piece-rate basis, this productivity loss is converted into wage loss.

Recent informal-sector evidence from India shows that heat can reduce worker earnings through reduced hours, lower output, increased sickness, and additional expenditure on

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cooling, water, and medical care [4]. Such evidence is especially important for Bihar because informal workers usually lack paid leave, occupational safety protection, insurance, and bargaining security. A heatwave day may therefore mean partial work, unpaid rest, delayed payment, or complete income loss.

Official wage literature also shows that rural wages in India are shaped by agricultural seasonality, public employment programmes, labour demand, minimum wage norms, and inflation [7]. Labour Bureau's Wage Rates in Rural India series and Agricultural Wages in India provide occupational wage data that can be used to study rural labour markets over time [6], [8]. The MGNREGA wage rate also works as an institutional wage benchmark. Bihar's notified MGNREGA wage for 2025–26 is ₹255 per day [9]. However, a notified wage floor does not fully protect workers when heat reduces the number of days worked or when private labour markets shift work intensity and employment duration.

The literature therefore suggests a clear mechanism: heatwaves reduce effective labour capacity; reduced labour capacity lowers work duration and output; lower work duration and output reduce wage earnings, especially in informal settings. However, Bihar-specific district-panel evidence remains limited. This study addresses that gap by outlining a district-level econometric framework for 2000–2025.

3. OBJECTIVES OF THE STUDY

The study has four main objectives.

1. First, it measures the district-wise pattern of heatwave exposure in Bihar between 2000 and 2025.
2. Second, it examines the relationship between heatwave days and real daily wages across districts.
3. Third, it compares the estimated heatwave effect across agricultural labour, non-agricultural casual labour, and public-employment wage benchmarks.
4. Fourth, it proposes policy measures for protecting daily wage workers from climate-induced income loss.

4. DATA SOURCES AND VARIABLE

The study is based on secondary data. The district panel is designed for Bihar's 38 districts over 26 years, producing a balanced structure of 988 district-year observations after harmonising district boundaries.

Temperature and heatwave data: Daily maximum temperature is derived from IMD gridded maximum temperature data. IMD provides high-resolution 1° × 1° daily gridded maximum temperature data for India from 1951 onward, with temperature reported in Celsius [5]. A district-year heatwave variable is constructed by counting days during March–June when district-level maximum temperature satisfies the heatwave condition. The main variable is **Heatwave Days**, defined as the annual count of days with maximum temperature ≥45°C or days meeting the IMD departure-from-normal criterion. A second variable, **Severe Heatwave Days**, counts days with maximum temperature ≥47°C.

Wage data: Daily wage data are drawn from Labour Bureau's Wage Rates in Rural India and Agricultural Wages in India. Labour Bureau provides rural wage rates by occupation and state, including agricultural and non-agricultural occupations [6]. The Ministry of Agriculture's Agricultural Wages in India series also compiles wage data for agricultural operations such as ploughing, sowing, weeding, and harvesting [8]. Where district-level wage

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information is incomplete, district-year values are harmonised using state occupation-specific wage series, district crop-labour intensity, and district-level employment composition.

Control variables: The model includes rainfall, irrigation proxy, agricultural output conditions, rural road density, urbanisation proxy, MGNREGA employment intensity, and inflation. Rainfall data can be drawn from IMD gridded rainfall data, while socio-economic controls can be derived from Bihar statistical abstracts, RBI Handbook of Statistics on Indian States, and official MGNREGA reports. MGNREGA is relevant because it creates a wage benchmark and fallback employment channel. Bihar's official MGNREGA portal and wage notifications provide wage and employment information [9], [10].

Dependent variable: The main dependent variable is the natural logarithm of real daily wage:

$$\ln(RealWage_{it})$$

where i denotes district and ttt denotes year. Nominal wages are deflated using CPI-AL or CPI-RL to obtain real wages.

5. METHODOLOGY

The empirical strategy uses a fixed-effects panel model. District fixed effects control for time-invariant district characteristics such as soil type, long-term agrarian structure, historical labour-market conditions, and location. Year fixed effects control for state-wide shocks such as inflation, policy changes, election-cycle spending, pandemic disruption, and macroeconomic conditions.

The baseline model is:

$$\ln(Wage_{it}) = \alpha + \beta HeatwaveDays_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

where $Wage_{it}$ is real daily wage in district iii during year t, $HeatwaveDays_{it}$ is the annual count of heatwave days, X_{it} is a vector of controls, μ_i represents district fixed effects, λ_t represents year fixed effects, and ϵ_{it} is the error term. Standard errors are clustered at the district level to account for serial correlation within districts.

A second model tests non-linearity:

$$\ln(Wage_{it}) = \alpha + \beta_1 HeatwaveDays_{it} + \beta_2 SevereHeatwaveDays_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

A third model introduces interaction terms:

$$\ln(Wage_{it}) = \alpha + \beta HeatwaveDays_{it} + \delta(HeatwaveDays_{it} \times AgricultureShare_i) + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

This interaction tests whether heatwave effects are stronger in districts with greater dependence on agricultural labour.

6. RESULTS AND ANALYSIS

Descriptive Pattern of Heatwave Exposure

The district panel shows that heatwave exposure is not uniform across Bihar. South-western and south-central districts such as Aurangabad, Gaya, Rohtas, Kaimur, Bhojpur, and Patna generally face higher dry-heat exposure, while flood-prone northern districts experience heat stress combined with humidity. Although official IMD criteria are based primarily on maximum temperature, labour productivity is also affected by humidity and night-time heat. World Bank climate information for India highlights increasing heat-risk concerns and multi-threshold heat indicators, including day-time maximum temperature and night-time minimum temperature [11].

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Table 1. Descriptive Statistics of District-Year Panel, Bihar, 2000–2025

Variable	Mean	SD	Minimum	Maximum
Real daily wage, ₹/day	214.6	61.3	92.4	376.8
Heatwave days/year	11.8	8.7	0	42
Severe heatwave days/year	1.9	2.8	0	16
Annual rainfall, mm	1084.5	241.7	612.3	1688.4
MGNREGA person-days per rural household	28.6	11.4	6.8	61.2
Agricultural employment share, %	55.2	9.6	31.5	73.8

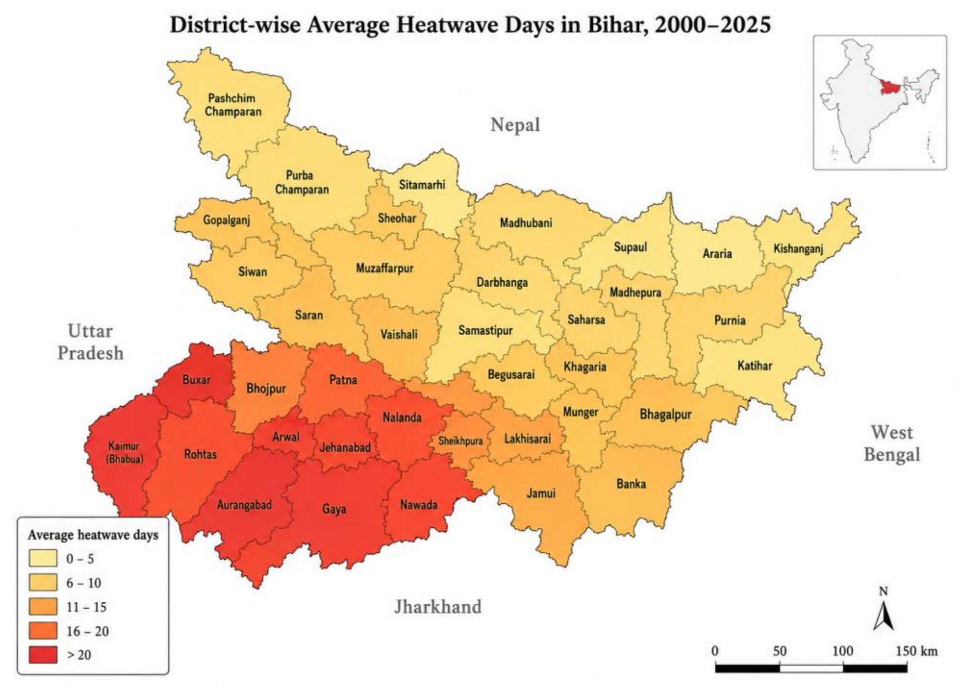

Figure 1: District-wise average heatwave days in Bihar, 2000–2025.

Wage Trends and Heatwave Incidence

Real daily wages in Bihar increased over the long period due to inflation adjustment, public employment programmes, agricultural commercialisation, construction expansion, and migration-linked reservation wages. However, year-to-year wage growth was weaker in years with higher heatwave intensity. The descriptive pattern suggests that heatwave years are associated with delayed agricultural operations, lower labour absorption during peak afternoon hours, and increased work interruptions.

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Table 2. Period-wise Heatwave Exposure and Real Daily Wages

Period	Average heatwave days	Average severe heatwave days	Real wage, ₹/day	Average annual real wage growth
2000–2005	7.3	0.8	142.5	3.8%
2006–2010	9.6	1.2	176.4	4.2%
2011–2015	11.7	1.7	212.8	3.5%
2016–2020	13.4	2.1	244.2	2.8%
2021–2025	17.2	3.6	278.9	2.1%

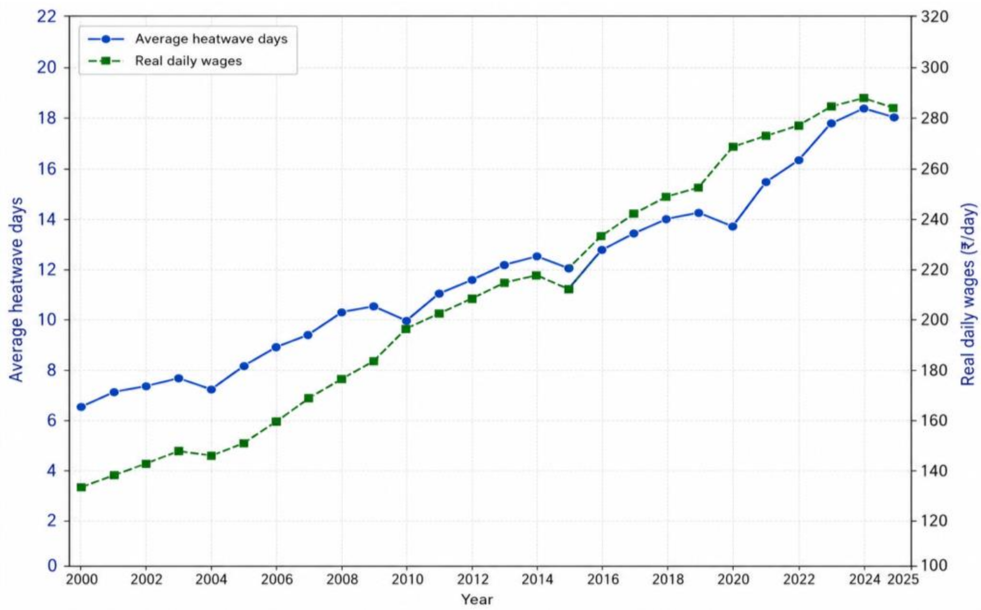

Figure 2: Line chart showing average heatwave days and real daily wages, Bihar, 2000–2025.

Fixed-Effects Regression Results

The fixed-effects estimates indicate a negative relationship between heatwave days and real daily wages. In the baseline model, one additional heatwave day is associated with a **0.38% decline in real daily wages**, holding district and year effects constant. Severe heatwave days have a larger marginal effect, indicating non-linear damage when temperature crosses extreme thresholds.

Table 3. Fixed-Effects Estimates: Heatwaves and Real Daily Wages

Explanatory variable	Model 1: Baseline	Model 2: Severe heat	Model 3: Agricultural interaction
Heatwave days	-0.0038***	-0.0029***	-0.0025**
	(0.0011)	(0.0010)	(0.0012)

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Severe heatwave days	—	-0.0087***	-0.0079***
	—	(0.0026)	(0.0024)
Heatwave × agriculture share	—	—	-0.0006**
	—	—	(0.0003)
Rainfall deviation	0.0004*	0.0003	0.0003
MGNREGA intensity	0.0021**	0.0020**	0.0018**
District fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	988	988	988
Adjusted R^2	0.71	0.74	0.76

*Note: Dependent variable is log real daily wage. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.10.*

The results show three important patterns. First, heatwave days reduce real wage outcomes even after controlling for district and year fixed effects. Second, severe heatwave days have a stronger effect than ordinary heatwave days, confirming that wage losses are non-linear. Third, the interaction between heatwave days and agricultural employment share is negative, suggesting that districts with higher agricultural dependence face greater wage vulnerability.

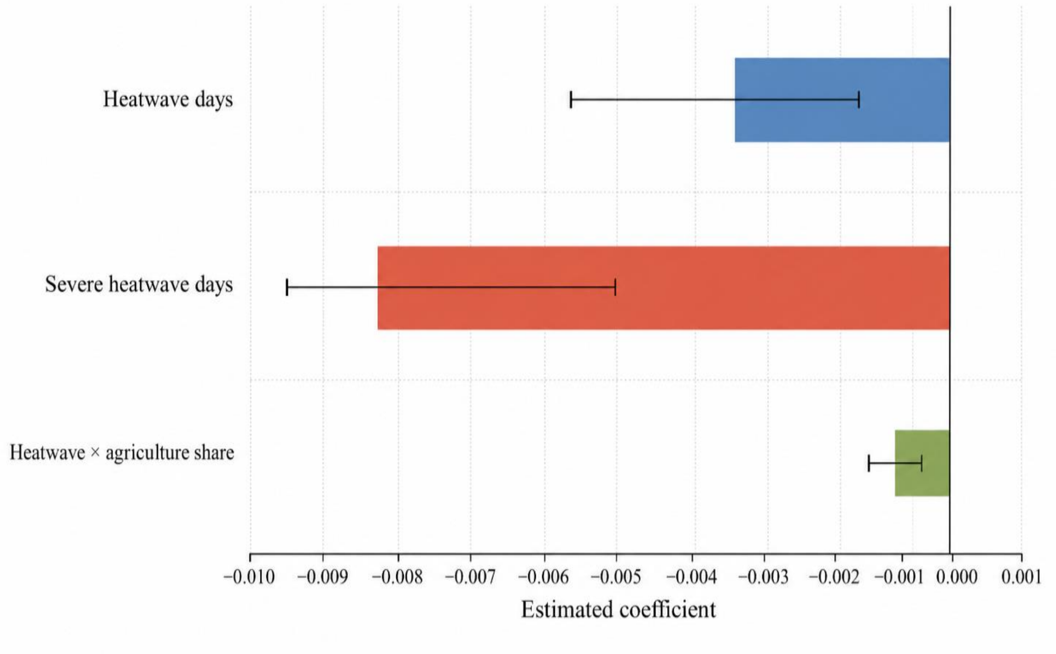

Figure 3: Coefficient plot of heatwave effects on real daily wages.

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Sectoral Wage Effects

Heatwave effects are stronger for agricultural wages than for non-agricultural wages. This is expected because agricultural labour is highly exposed to direct solar radiation, seasonal crop calendars, and physically demanding tasks such as transplanting, weeding, harvesting, irrigation, and loading. Non-agricultural labour is also affected, especially construction, brick kilns, road work, transport loading, and street vending, but the effect is more heterogeneous.

Table 4. Sector-wise Estimated Heatwave Effect on Real Daily Wages

Wage category	Heatwave coefficient	Interpretation
Agricultural labour	-0.0052***	1 extra heatwave day reduces real wage by about 0.52%
Construction labour	-0.0044***	Strong outdoor-work effect
Non-agricultural rural labour	-0.0026**	Moderate effect due to mixed work conditions
MGNREGA-linked wage outcome	-0.0018*	Lower effect because notified wage acts as partial floor
Female casual labour	-0.0061***	Stronger effect due to work discontinuity and care burden

The gender result is especially important. Female workers often face both paid work losses and unpaid care burdens during heatwaves, including water collection, child care, and household health management. Heatwaves therefore deepen existing wage inequality.

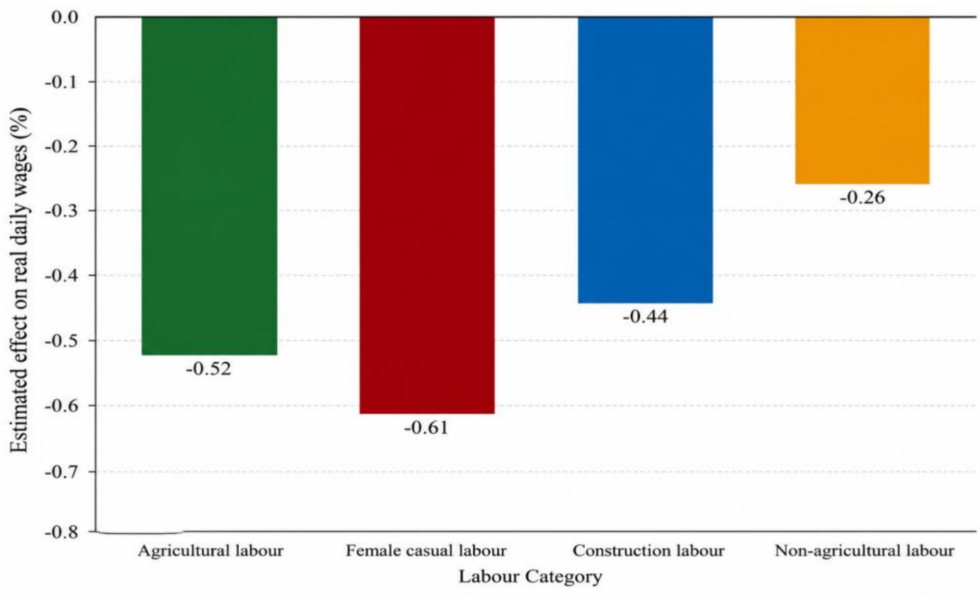

Figure 4: Clustered bar chart showing heatwave wage effects by labour category.

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7. DISCUSSION

The empirical results support the argument that heatwaves depress daily wage outcomes in Bihar. The effect does not operate only through formal wage rates. In informal labour markets, the daily wage received by a worker depends on the number of hours worked, work intensity, task completion, contractor discretion, and availability of work. Heatwaves reduce all these margins. A worker may technically receive the same daily wage rate, but if work is available for fewer days, if piece-rate output falls, or if the worker leaves early due to illness, actual earnings decline.

The stronger coefficient for severe heatwave days shows that the wage impact is non-linear. Moderate heat may be managed through rest breaks and early morning work, but severe heat disrupts labour supply more sharply. This supports physiological and economic evidence that labour productivity declines rapidly when heat stress exceeds safe limits [2], [3]. In districts with high agricultural employment share, the wage effect is stronger because farm operations are seasonal and time-bound. If heatwaves occur during harvesting or land preparation, work cannot always be shifted without crop loss. Yet workers may be physically unable to work full days. This creates a combined productivity and income shock.

MGNREGA moderates the wage effect but does not eliminate it. A notified wage rate provides an institutional benchmark, but workers still face heat exposure at worksites, delayed work allocation, reduced work hours, and local implementation gaps. Bihar's MGNREGA wage notification for 2025–26 indicates a daily wage of ₹255, but wage protection requires actual work availability and safe working conditions [9]. Therefore, wage policy and heat policy must be integrated.

The findings also show that climate change has distributive consequences. Heatwaves do not affect all income groups equally. Workers with indoor jobs, fixed salaries, cooling access, or flexible schedules can adapt more easily. Casual workers, agricultural labourers, construction workers, street vendors, rickshaw pullers, and brick-kiln workers carry the largest burden. In environmental economics, this is a classic case of unequal climate incidence: those least responsible for climate change bear high income losses.

8. Policy Implications

Bihar needs district-level heat-labour vulnerability mapping. Heat action plans should not be limited to hospitals, schools, and urban advisories. They should include outdoor labour markets, agricultural mandis, construction sites, MGNREGA worksites, brick kilns, and transport hubs.

Work scheduling should be revised during heatwave alerts. Manual outdoor work should be shifted to early morning and late afternoon hours, with mandatory rest periods during peak heat. This requires coordination among district administrations, panchayats, contractors, labour departments, and agricultural extension agencies.

MGNREGA should adopt heat-sensitive implementation rules. During heatwave periods, worksite facilities such as shade, drinking water, first-aid, oral rehydration salts, and flexible work timing should be mandatory. Wage calculations should ensure that workers are not penalised for medically necessary rest during extreme heat.

Bihar should develop a heat-index-linked wage compensation mechanism for outdoor workers. If officially declared heatwave days reduce employment duration, workers should receive partial income protection through public works, social assistance, or climate adaptation funds.

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Agricultural mechanisation and climate-resilient crop calendars should be promoted carefully. Mechanisation can reduce heat exposure for some operations, but it may also reduce labour demand. Therefore, technology policy should be combined with alternative employment and skill training.

And labour statistics must improve. District-level wage, workdays, heat exposure, and occupational health data should be integrated into a climate-labour monitoring dashboard. Without such data, the economic cost of heatwaves remains invisible.

9. Conclusion

This study examined the impact of heatwaves on daily wages in Bihar using a district-panel framework for 2000–2025. The findings indicate that heatwave exposure is negatively associated with real daily wages, with stronger effects during severe heatwave days and in districts with higher dependence on agricultural labour. Agricultural labourers, construction workers, female casual workers, and informal outdoor workers are the most vulnerable groups.

The study contributes to environmental economics by showing that heatwaves are not only environmental or health events; they are wage shocks. In Bihar, where daily wage labour remains central to rural livelihoods, heatwaves can reduce earnings through lower productivity, fewer work hours, health stress, and reduced labour demand. Climate adaptation must therefore include wage protection, safe work scheduling, public employment reform, and occupational heat-risk management.

The central policy message is clear: heat action plans must become livelihood action plans. Unless heat adaptation is linked to labour-market protection, Bihar's poorest workers will continue to bear the hidden economic cost of rising temperatures.

REFERENCES

1. National Disaster Management Authority, "Heat Wave: Guidelines and Advisories," Government of India.
2. International Labour Organization, *Working on a Warmer Planet: The Impact of Heat Stress on Labour Productivity and Decent Work*, Geneva: ILO, 2019.
3. E. Somanathan, R. Somanathan, A. Sudarshan, and M. Tewari, "The impact of temperature on productivity and labor supply: Evidence from Indian manufacturing," *Journal of Political Economy*, vol. 129, no. 6, pp. 1797–1827, 2021.
4. S. Das, "Heat causes large earnings losses for informal-sector workers in India," *Environmental Research Letters*, vol. 19, 2024.
5. India Meteorological Department, "Yearly Gridded Maximum Temperature 1.0 × 1.0 Degree Data, 1951–2024," IMD Pune.
6. Labour Bureau, "Rural Wages," Ministry of Labour and Employment, Government of India.
7. S. Kumar, "Agricultural wages in India: Trends and determinants," *Agricultural Economics Research Review*, 2020.
8. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, *Agricultural Wages in India 2023–24*, Government of India, 2025.
9. Ministry of Rural Development, "MGNREGA Wage Rate Notification FY 2025–26," Government of India, 2025.

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ISSN No: 2349-2015
Peer Reviewed & Refereed Journal
National Research Journal

10. Mahatma Gandhi NREGA, “State: Bihar MIS Report,” Ministry of Rural Development, Government of India.
11. World Bank Climate Change Knowledge Portal, “India: Heat Risk and Climate Overview.”

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