The Journal of Climate Change and Health 23 (2025) 100420

Contents lists available at ScienceDirect

The Journal of Climate Change and Health

journal homepage: www.elsevier.com/joclim

Short communication

Early insight on how climate action can benefit health in rural India

Vijay S Limaye[a,*], Sameeha Hossain[b], Ritika Kapoor[c], Dhilsha Jubair[c], Charu Lata[c]

[a] Natural Resources Defense Council, New York, NY, USA
[b] Yale University School of Public Health, New Haven, CT, USA
[c] NRDC India, New Delhi, India

ARTICLE INFO

Article History:
Received 31 July 2024
Accepted 31 January 2025
Available online 3 February 2025

Keywords:
Air pollution
Heat
Climate
Rural
Health
Adaptation
India

ABSTRACT

Introduction: India faces severe health impacts from climate change. While urban-focused initiatives like the National Clean Air Programme and heat action plans aim to address dangerous exposures, rural regions, home to over 60% of India's population, remain underprioritized in mitigation and adaptation measures. To address this gap, the Self Employed Women's Association (SEWA) and Natural Resources Defense Council (NRDC) implemented the *Hariyali Gram* (Green Village) initiative, deploying climate-friendly technologies to support improved lighting, cooling, irrigation, and clean cooking in pilot villages beginning in 2019.
Methods: In March 2024, 90 household surveys were conducted in Nagano Math, a village of 256 households in the state of Gujarat, assessing air quality effects, indoor thermal comfort, and health impacts following the implementation of climate-friendly renewable energy solutions.
Results: Survey responses (n-86) indicated substantial awareness of indoor air pollution from traditional cooking methods, with 88% of respondents acknowledging its impact. Nine households received biogas installations and 78% noted improved indoor air quality, while 66 % observed enhanced outdoor air quality and 56% respondents reported health benefits from adopting cleaner cooking for themselves or other members of the household. Of 19 households that installed cool roofs as part of the program, 37% reported improved thermal comfort indoors.
Discussion: Climate actions in this village are delivering health and environmental gains to this community with benefits are reported in about half of households. Findings of our preliminary survey in a single village suggest scaling up climate interventions across rural India could deliver substantial improvements in living conditions.

1. Introduction

People living in India are increasingly prone to the serious health effects of climate change. While extreme heat and air pollution currently exert a heavy toll on health across the country, exposures to these hazards are expected to worsen in the future [1]. Research and policy action to accelerate efforts to combat climate change across India have largely focused on urban areas where concentrated infrastructure, large population centers, power plants, and transportation networks provide a clear rationale for energy system interventions [2–4]. For example, India's urban centers receive significant attention through government initiatives like the National Clean Air Programme [5] and heat action plans pioneered by municipal governments [6].

While climate change response efforts in cities are urgent, they often overshadow the climate-sensitive health challenges in India's rural regions where residents endure severe heat and air pollution but have far fewer resources to adapt [7,8]. As the country continues to urbanize, city-centric climate change interventions may neglect rural areas where over 60% of the Indian population still resides [9]. Specifically, people living in rural India face significant indoor air pollution burdens from cooking food, lighting, and heating their homes, due to common indoor combustion of solid fuels [10]. Elevated indoor temperatures are another overlooked hazard, particularly in dwellings that lack proper ventilation and insulation. These risks are particularly important in small, low-income villages where the effects of heat are intensified by limited access to cooling technologies [11]. Furthermore, adaptive capacity in rural areas is limited by economic constraints, lower educational attainment, and weak infrastructure [12]. Given these challenges, there is an urgent need to implement and scale up renewable energy interventions tailored for rural villages to reduce these adverse health effects.

Just as climate-sensitive health risks in rural India are poorly characterized and policy intervention lags, available evidence of health benefits from mitigation and adaptation interventions in rural India

* Corresponding author.
E-mail address: vlimaye@nrdc.org (V.S. Limaye).

https://doi.org/10.1016/j.joclim.2025.100420

is sparse. Over the past decade, research has demonstrated the health benefits of climate action in India, but investigations have largely focused on urban areas [4]. Some progress has been reported in rural regions with a clean cookstove intervention resulting in health benefits from cleaner indoor air, including lower blood pressure and reduced eye irritation [13] and studies of landcover interventions such as cool roofs, having demonstrated indoor thermal comfort improvements [14].

As the impacts of climate change on India's rural communities become more intense, efforts to advance mitigation and adaptation can deliver important benefits to human health and environmental quality. Preliminary findings presented here offer insight into these co-benefits of climate action and signal the need for additional action and investigation in other rural settings.

2. Methods

In 2019, the Self Employed Women's Association (SEWA) and Natural Resources Defense Council (NRDC) launched an effort to expand rural access to climate-friendly technologies in the areas of lighting, cooling, irrigation, and cooking. This effort, jointly funded by NRDC and SEWA and termed the *Hariyali Gram* (Green Village), aims to alleviate energy poverty and advance rural climate action through implementation of policy and market-based solutions [15]. Specifically, the program supports installation of energy efficient indoor lighting and fans, village biogas plants for clean cooking, solar-powered water pumps for irrigation, and cool roofs to reduce indoor heat risks. One of the first villages targeted for implementation was Nagano Math, with approximately 256 households in the Arvalli district of the western state of Gujarat [16] (see Figure 1 in Supplemental Material). Agriculture is the primary source of livelihood for Nagano Math residents; most households have small landholdings (fewer than 5 bigha/−2 acres) and rent or share ownership of large farm equipment. Major crops grown in the village include wheat, cotton, corn, castor, pearl millet, peanuts, and vegetables. Most crops are grown for household consumption, other than cotton and peanut crops that are sold in the market.

In March 2024, trained SEWA field staff conducted 90 structured surveys from a random sample of village households to quantitatively assess beneficiary feedback. The overall survey, completed by adults self-identified as heads of each household, assessed energy consumption, fuel usage, health information, perceived effects of technology adoption, and economic impacts; the analysis reported here is restricted to health content only (the full survey instrument is included in Supplemental Material). Household-level data were reviewed for completeness, compiled, and analyzed in Microsoft Excel for this analysis.

3. Results

Complete responses were received from individuals representing 86 of 90 surveyed households. 51% of households overall reported family members with chronic health problems such as heart disease, asthma, and other lung diseases while an additional 21% were unsure if any such problems existed.

Nine households received biogas installations, and five (56%) reported health benefits from adopting cleaner cooking for themselves or other members of the household. In these households there was broad awareness of indoor air pollution risks from traditional cooking methods using solid fuels, with eight of nine (88%) of households identifying this link. Seven of the nine (78%) households reported that shifting from solid fuels to biogas for cooking was beneficial for reducing indoor air pollution levels. Moreover, six of the nine (66%) reported improvements in outdoor air pollution following the adoption of cleaner household cooking fuels in Nagano Math.

Of the 19 households that received cool roof installations, seven (37%) reported improved thermal comfort indoors. Importantly, all of these households also had indoor fans installed (eleven had ceiling fans only, another eight had both ceiling and table fans). Overall, our results suggest switching to biogas from solid fuels helped to improve subjective indoor and outdoor air quality while beneficial health effects were reported by about half of respondents.

4. Discussion

Our results provide early insight into chronic health problems faced by rural households and the perceived health benefits of cleaner energy technologies and built environment modifications. This analysis, while showing some promising results, has a number of limitations. Benefits were not measured prospectively and reported in only about 40−50 % of households. Survey results also represent conditions only in March 2024 for a small sample of households. Related work shows that indoor exposure patterns fluctuate on an hourly basis [17], health effects of adverse exposures can take years to become apparent, and the effectiveness of interventions may also vary over time. As such, sustained evaluation of the local environmental and health effects of *Hariyali Gram* implementation is necessary. Household-level survey responses also limited our ability to discern gender and other individual-specific effects and our cross-sectional data lacked adequate detail to definitively link particular health and environmental findings to specific interventions. The potential for confounding effects, in particular, is a major weakness. Because households that benefitted from cool roof installations also received fans, we cannot attribute improved thermal comfort benefits to any single intervention. Moreover, the small share of households that received biogas installations also installed ceiling fans; more investigation is needed to determine how indoor air quality may have been affected by the presence or absence of fans in these homes utilizing cleaner cooking technologies.

Our preliminary survey was also limited in other areas. We did not differentiate between different types of chronic health conditions (e.g., heart disease, lung ailments). Awareness of the health impacts of indoor air pollution is high in Nagano Math, and respondents were attentive to changes in indoor exposures; however, health benefits from cleaner household air were not as commonly reported. Reporting of cool roof thermal comfort benefits was also not widespread, and somewhat inconsistent with prior studies that have documented indoor temperature reductions in urban and rural settings [18,19]. There is also the potential that respondents were biased in considering health effects and may have been eager to report household benefits from program interventions, regardless of the quality or durability of such gains. Because we lacked a control group, attributing reported changes to the program itself, rather than secular trends in rural development and other factors, is challenging.

In future work, pairing of quantitative and qualitative data collection would provide needed context and detail (e.g., in proving insight to specific self-reported health effects) [20]. Future evaluations would benefit from experimental protocols that facilitate more systematic evaluation of climate actions such as pre- and post-implementation surveys, air and wet bulb globe temperature monitoring at indoor temperature sites, more robust evaluation of indoor and outdoor air quality, and incidence of specific illness exacerbations such as COPD and asthma.

As program implementation scales up to reach additional regions, it is essential to consider the balance between mitigation and adaptation strategies in addressing climate and health challenges in rural India. While mitigation-focused interventions remain paramount to pursue, in order to address inequitable health burdens it will be important to focus on interventions with co-benefits spanning both mitigation and adaptation. Specifically, and there is a compelling case to be made about adaptation-related health, energy, and economic

benefits [21]. Prospective development of analyses while prioritizing implementation in households with at-risk residents due to prior illness, disability or age can inform implementation efforts and help stakeholders to prioritize future projects that maximize positive impacts [22].

5. Conclusion

Preliminary analysis of climate action co-benefits in one Indian village sheds light on the potential for mitigation and adaptation to improve health and environmental conditions in rural settings. This work suggests a path using climate-friendly solutions to enhance thermal comfort, decrease indoor and outdoor air pollution, and improve health outcomes. Our investigation highlights the need for inclusive climate action implementation and health-focused approaches that extend beyond India's urban centers to address the unique challenges of the country's rural residents.

Funding

This work was supported in part with funds from the Natural Resources Defense Council (NRDC).

Author agreement

If accepted, I intend to publish the manuscript as open access, and I intend to license exclusive rights in the article to Elsevier under a CC BY-NC-ND end user license.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Vijay S Limaye: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Sameeha Hossain:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Ritika Kapoor:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Data curation. **Dhilsha Jubair:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Charu Lata:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Acknowledgments

We would like to thank the Self Employed Women's Association (SEWA) team for their support in implementing the *Hariyali Gram* program and conducting household surveys.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.joclim.2025.100420.

References

[1] Joint Global Change Research Institute, Battelle Memorial Institute. Pacific northwest division. India: The impact of climate change to 2030: a commissioned research report. Washington, DC: U.S. National Intelligence Council; 2009 [accessed 31 July 2024].
[2] Khosla R, Bhardwaj A. Urbanization in the time of climate change: examining the response of Indian cities. WIREs Clim Change 2019;10:e560. doi: 10.1002/wcc.560.
[3] Singh C, Madhavan M, Arvind J, Bazaz A. Climate change adaptation in Indian cities: a review of existing actions and spaces for triple wins. Urban Clim 2021;36:100783. doi: 10.1016/j.uclim.2021.100783.
[4] Limaye VS, Magal A, Joshi J, Maji S, Dutta P, Rajput P, et al. Air quality and health co-benefits of climate change mitigation and adaptation actions by 2030: an interdisciplinary modeling study in Ahmedabad, India. Environ Res Health 2023;1:021003. doi: 10.1088/2752-5309/aca7d8.
[5] Ganguly T, Selvaraj KL, Guttikunda SK. National Clean Air Programme (NCAP) for Indian cities: review and outlook of clean air action plans. Atmospheric Environ X 2020;8:100096. doi: 10.1016/j.aeaoa.2020.100096.
[6] Knowlton K, Kulkarni S, Azhar G, Mavalankar D, Jaiswal A, Connolly M, et al. Development and implementation of South Asia's first heat-health action plan in Ahmedabad (Gujarat, India). Int J Environ Res Public Health 2014;11:3473–92. doi: 10.3390/ijerph110403473.
[7] Ravindra K, Agarwal N, Kaur-Sidhu M, Mor S. Appraisal of thermal comfort in rural household kitchens of Punjab, India and adaptation strategies for better health. Environ Int 2019;124:431–40. doi: 10.1016/j.envint.2018.12.059.
[8] Weitz CA, Mukhopadhyay B, Das K. Individually experienced heat stress among elderly residents of an urban slum and rural village in India. Int J Biometeorol 2022;66:1145–62. doi: 10.1007/s00484-022-02264-8.
[9] World Bank. World Bank Open Data (India), https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=IN; 2024 [accessed 6 June 2024].
[10] V Limaye. India's air pollution challenge spans rural and urban areas, https://www.nrdc.org/bio/vijay-limaye/indias-air-pollution-challenge-spans-rural-and-urban-area; 2023 [accessed 31 July 2024].
[11] Goyal MK, Singh S, Jain V. Heat waves characteristics intensification across Indian smart cities. Sci Rep 2023;13:14786. doi: 10.1038/s41598-023-41968-8.
[12] International Fund for Agricultural Development. Rural Development Report 2016: fostering inclusive rural transformation, https://www.ifad.org/en/web/knowledge/-/publication/rural-development-report-2016; 2016 [accessed 31 July 2024].
[13] Aung TW, Baumgartner J, Jain G, Sethuraman K, Reynolds C, Marshall JD, et al. Effect on blood pressure and eye health symptoms in a climate-financed randomized cookstove intervention study in rural India. Environ Res 2018;166:658–67. doi: 10.1016/j.envres.2018.06.044.
[14] Limaye VS. The hidden health costs of climate change: accounting for extreme heat harms to women in the global South. PLOS Clim 2023;2:e0000267. doi: 10.1371/journal.pclm.0000267.
[15] Natural Resources Defense Council. It takes a village: advancing hariyali clean energy solutions in rural India. https://www.nrdc.org/bio/anjali-jaiswal/it-takes-village-hariyali-clean-energy-solutions-india; 2021 [accessed 31 July 2024].
[16] Natural Resources Defense Council. Hariyali green villages: women-led climate and clean energy solutions for prosperity in rural India, https://www.nrdc.org/bio/charlotte-steiner/hariyali-green-villages-women-lead-climate-solutions; 2022 [accessed 31 July 2024].
[17] Mukhopadhyay R, Sambandam S, Pillarisetti A, Jack D, Mukhopadhyay K, Balakrishnan K, et al. Cooking practices, air quality, and the acceptability of advanced cookstoves in Haryana, India: an exploratory study to inform large-scale interventions. Glob Health Action 2012;5:19016. doi: 10.3402/gha.v5i0.19016.
[18] Garg V, Kotharkar R, Sathaye J, Rallapalli H, Kulkarni N, Reddy N, et al. Assessment of the impact of cool roofs in rural buildings in India. Energy Build 2016;114:156–63. doi: 10.1016/j.enbuild.2015.06.043.
[19] Vellingiri S, Dutta P, Singh S, Sathish L, Pingle S, Brahmbhatt B. Combatting climate change-induced heat stress: assessing cool roofs and its impact on the indoor ambient temperature of the households in the urban slums of Ahmedabad. Indian J Occup Environ Med 2020;24:25–9. doi: 10.4103/ijoem.IJOEM_120_19.
[20] Zahno M, Michaelowa K, Dasgupta P, Sachdeva I. Health awareness and the transition towards clean cooking fuels: evidence from Rajasthan. PLOS ONE 2020;15:e0231931. doi: 10.1371/journal.pone.0231931.
[21] Joshi J, Magal A, Limaye VS, Madan P, Jaiswal A, Mavalankar D, et al. Climate change and 2030 cooling demand in Ahmedabad, India: opportunities for expansion of renewable energy and cool roofs. Mitig Adapt Strateg Glob Change 2022;27:44. doi: 10.1007/s11027-022-10019-4.
[22] Limaye VS, Max W, Constible J, Knowlton K. Estimating the costs of inaction and the economic benefits of addressing the health harms of climate change. Health Aff (Millwood) 2020;39:2098–104. doi: 10.1377/hlthaff.2020.01109.