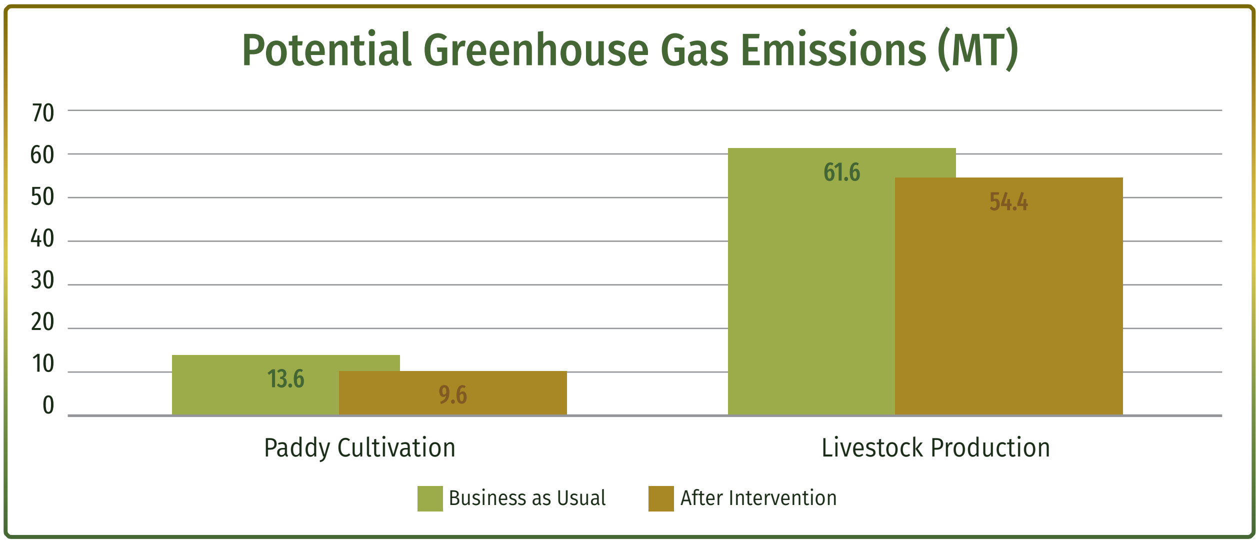
Pathways for Achieving Zero-Hunger, (Net) Zero-Carbon Food Systems in Bihar

Bihar is on the cusp of a transformative opportunity for sustainable growth

With a growing population in a warming world, India faces twin challenges in its agricultural sector—producing more food while also generating less greenhouse gas (GHG) emissions. The country is actively pursuing sustainable growth models, with the aim of transitioning to a net-zero economy to meet its pledge of net-zero emissions by 2070. Agriculture, however, accounts for 18% of emissions and uses significant amounts of land and water. The feedback loop between agricultural production and GHG emissions underscores the need for proactive measures to achieve a balance between meeting food demands and mitigating climate change.

Research conducted by the Tata–Cornell Institute for Agriculture and Nutrition (TCI), in collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), assesses the potential benefits and associated trade-offs, with the adoption of select transformative technologies in Bihar's crop and livestock sectors, for achieving Sustainable Development Goals 2 and 13—zero hunger and climate action, respectively.

By adopting alternate wetting and drying (AWD) for irrigation, Bihar could reduce emissions from paddy cultivation by 4 MT. In the livestock sector, a reduction of 5.4–7.2 MT could be achieved through the adoption of advanced artificial insemination for cattle breeding and the use of anti-methanogenic feed supplements.



Foresight and ex ante impact assessments are valuable support tools for guiding decisions regarding medium-to long-term technologies. Assessments of the sectoral contributions to food systems emissions are essential, in this case, for the design of effective mitigation actions.

By accurately quantifying emissions, policymakers can make informed decisions and implement targeted strategies to reduce carbon footprints. Such a data-driven approach helps in planning and also ensures that policies are directed toward achieving tangible and measurable results.

Agriculture, Climate, and Nutrition in Bihar

Emissions from the agriculture, food, and other land use (AFOLU) sector in Bihar have increased from 15.87 MT in 2005 to 23.05 MT in 2018. About 70% of Bihar's rural workforce is employed in agriculture, contributing over a quarter of the state's gross domestic product.

Bihar's livestock subsector is the highest contributor to emissions from the AFOLU sector. Compared to India's 3.41% growth rate in per capita emissions, Bihar's per capita emissions have increased 4.28% between 2005 and 2018.

Bihar has shown foresight and recognized the need to transition to a sustainable growth paradigm. In 2021, Bihar sought assistance from the United Nations Environment Programme (UNEP) to chart a low-carbon development pathway for the state. Additionally, the state has rolled out several initiatives, such as Jal-Jeevan-Hariyali Abhiyan, the Renewable Energy Policy, and the Clean Fuel Policy, signaling and reinforcing its commitment to progress toward a low-emissions economy.

At the same time, Bihar has one of the highest rates of undernutrition in India, with nearly half of the state's children under the age of 5 years stunted and underweight. In this context, future policy instruments should be designed so that efforts to reduce GHG emissions do not adversely affect hunger reduction, and vice versa.

Sources of GHG Emissions

Approximately 50% of GHG emissions from global croplands come from flooded rice cultivation. India produces 22% of the global rice and is the leading emitter of rice-related methane.

Similarly, in the livestock sector, methane from enteric fermentation is estimated to be the largest source of GHG emissions. Estimates suggest that cattle account for the majority of these emissions.

Transformational Technologies for Climate Mitigation

Implementing transformational technologies contributes to the sustainability of food systems by improving resource-use efficiency, resilience to climate change, and environmental stewardship.

Although there are several technologies that are evolving in response to the global call for a shift toward sustainability, any policy formulation needs to be backed by robust ex ante assessments of likely impacts to ensure the optimal utilization of resources.

Using the CGIAR Research Program on Climate Change, Agriculture, and Food Security's Mitigation Options Tool for Agriculture (CCAFS–MOT), TCI and ICRISAT performed ex ante assessments of three transformational technologies for rice and livestock production in Bihar:

1. **Alternate wetting and drying**: A controlled irrigation technology, AWD could be used in paddy cultivation instead of continuous flooding. It substantially reduces water consumption and the total GHG emissions from paddy cultivation by 20%, while maintaining or even increasing yields.
2. **Advanced artificial insemination**: The use of sex-sorted semen helps control the sex of cattle offspring before insemination, which has economic implications. For example, dairy producers may prefer female calves for replacement heifers, while beef producers may prioritize male calves for meat production.
3. **Anti-methanogenic feed supplements**: Harit Dhara is an anti-methanogenic feed supplement used in livestock production, which was patented by the International Committee for Animal Recording (ICAR) and commercialized in the early 2020s. The supplement has the potential to reduce methane emissions from enteric fermentation by up to 20%.

The successful adoption of these technologies depends on balancing their benefits with the associated costs and challenges.

Accounting for Spatial Diversity

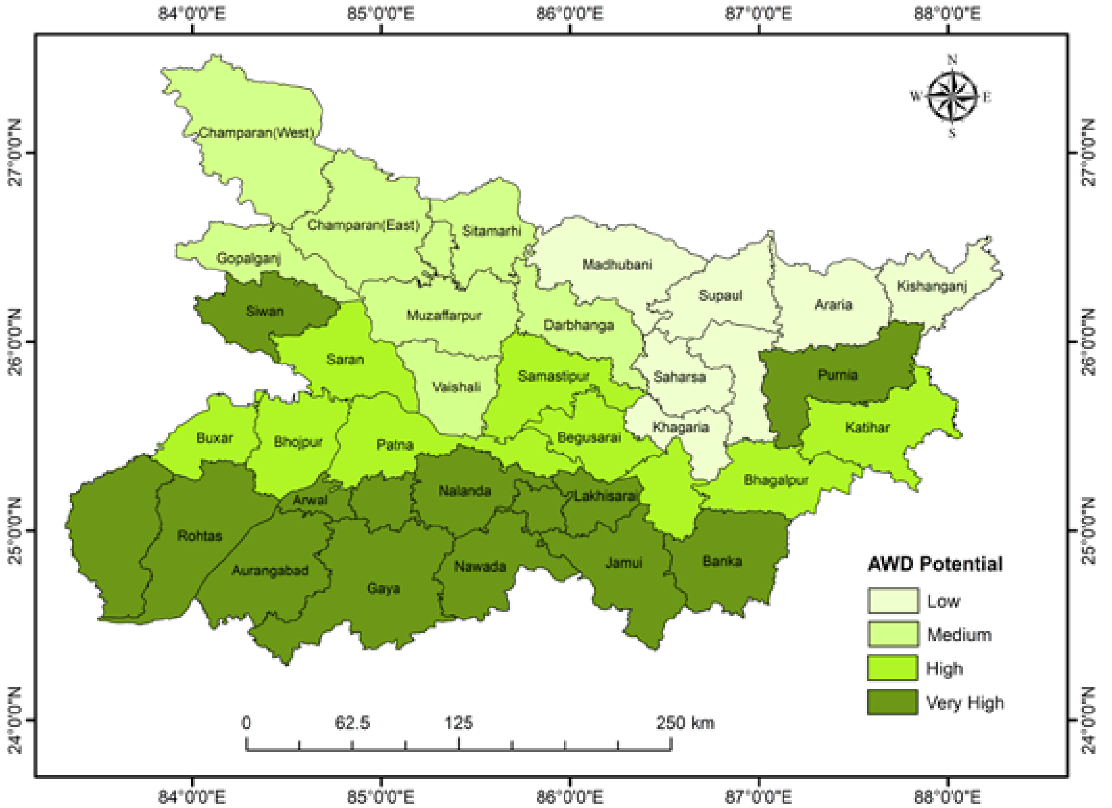
The four broad agroclimatic zones of Bihar are diverse and require different contextualized interventions based on their unique characteristics. The analysis below shows the potential impacts of three interventions in each of the state's agroclimatic zones.

This can help policymakers to prioritize resource allocation for investments in targeted interventions, based on their suitability and context-specific requirements to enhance productivity, resilience, and sustainability.

Alternate Wetting and Drying

The total area under paddy in Bihar is estimated to remain stagnant at around 3 million ha until 2050. Based on current management practices, estimated emissions from paddy cultivation in the state will be 13.57 MT of CO_2 in 2050, as compared to current emissions of 14.4 MT, despite the stagnation in area under cultivation.

Potential Districts for Alternate Wetting and Drying

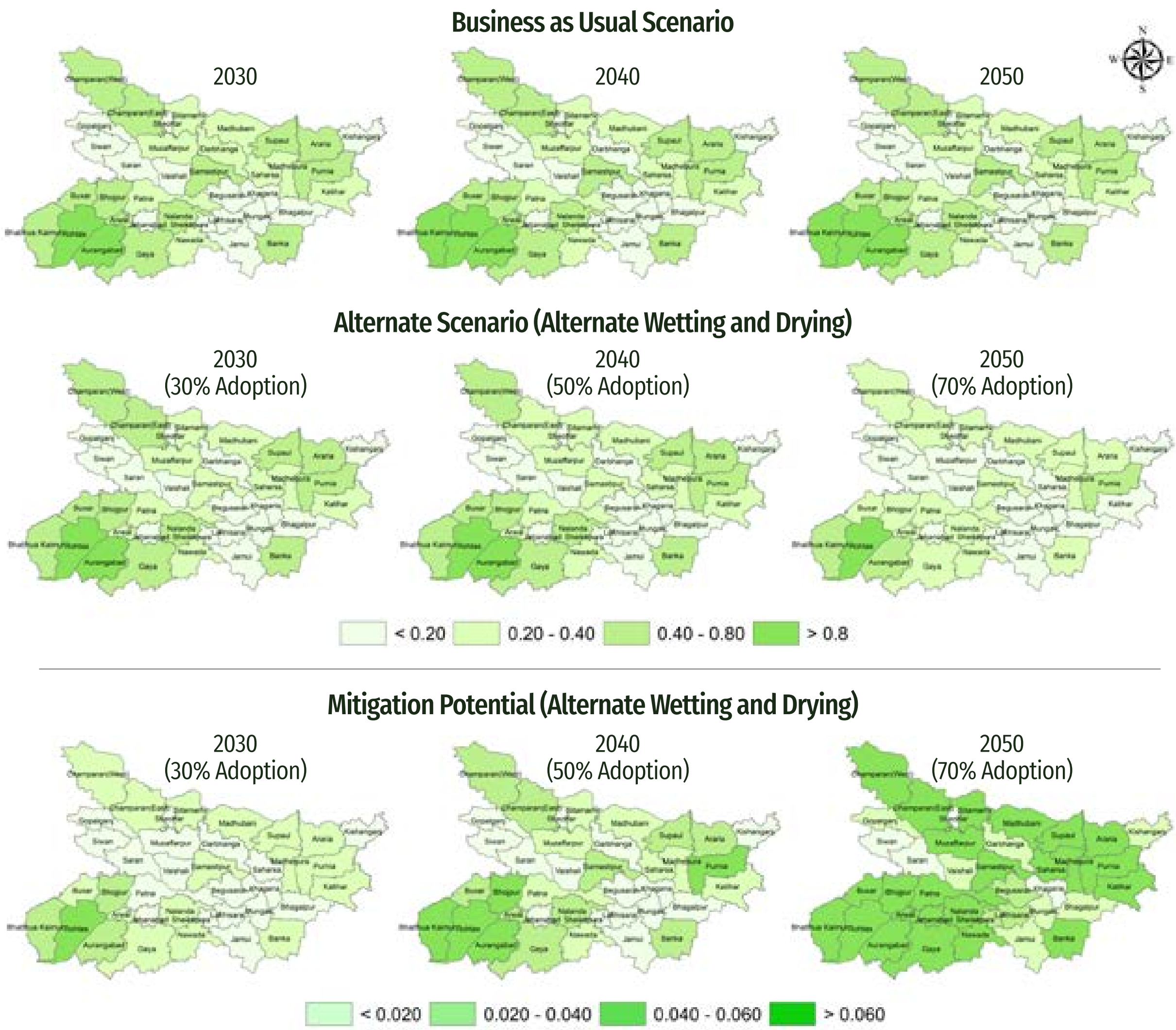


Emissions and Mitigation Potential (MT) from Paddy Cultivation

	Business as usual			Alternate scenario (AWD)			Potential reduction in emissions		
Adoption level (%)				30	50	70	30	50	70
	2030	2040	2050	2030	2040	2050	2030	2040	2050
State	14.4	14	13.57	13.65	12.77	9.61	0.75	1.23	3.96
Northeast	3.3	3.2	3.1	3.13	2.93	2.24	0.17	0.27	0.86
Northwest	4.7	4.51	4.33	4.51	4.22	3.4	0.19	0.29	0.93
Southeast	1.25	1.25	1.25	1.17	1.12	0.84	0.08	0.13	0.41
Southwest	5.16	5.04	4.89	4.84	4.5	3.13	0.32	0.54	1.76

The southwest and northwest agroecological zones account for the majority of emissions from paddy cultivation in Bihar. Consequently, they have the highest mitigation potential.

District-Level GHG Emissions from Rice Production at Different Adoption Rates (MT)



With a 70% adoption rate by 2050, AWD in paddy cultivation in Bihar has an annual mitigation potential of 3.96 MT of CO_2e relative to continuous flooding—currently, the dominant water management practice in paddy production.

Advanced Artificial Insemination and Anti-methanogenic Feed Supplements

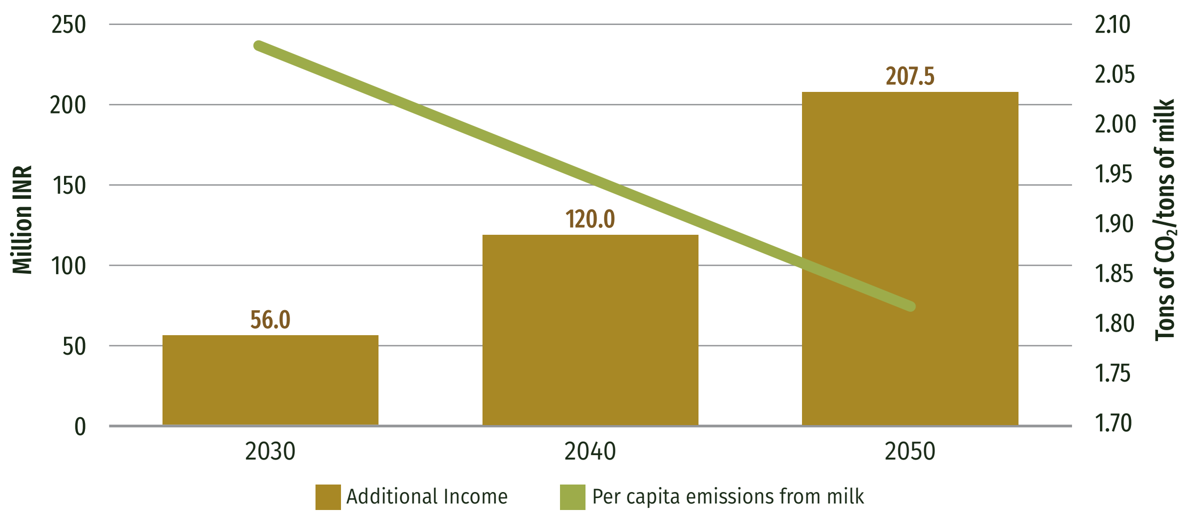
Bihar is projected to have a cattle population of 46 million by 2050, doubling its population of 23 million of 2019. Emissions from cattle in the state are projected to reach 52–61 MT of CO_2e by 2050.

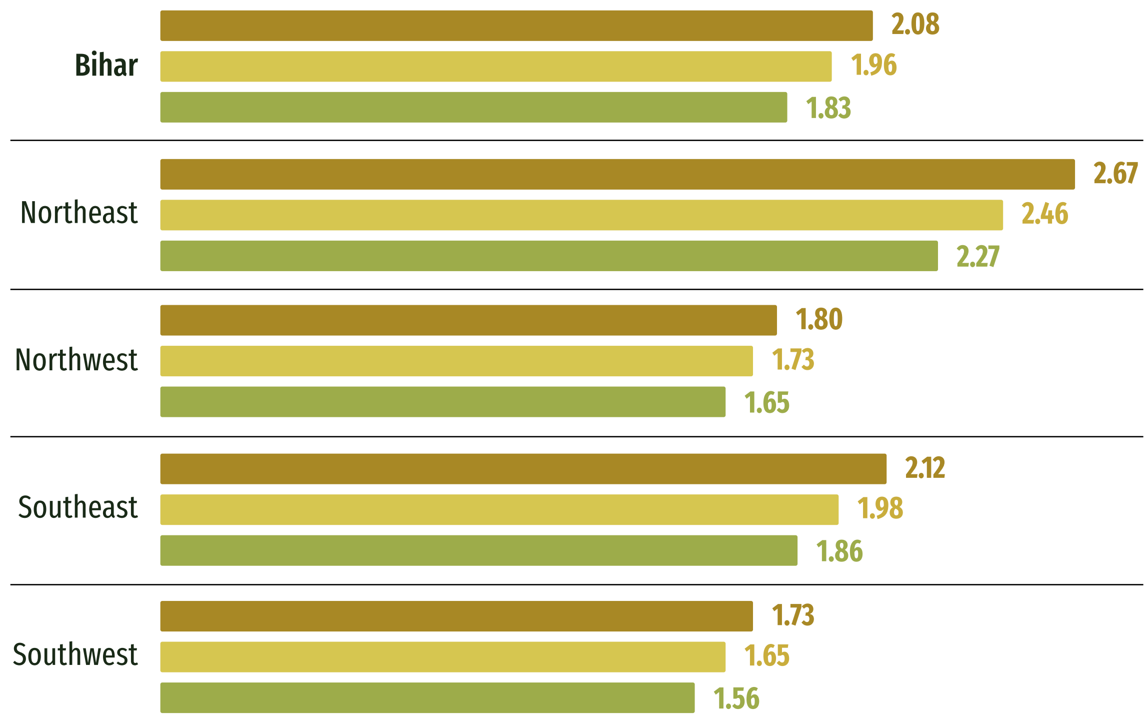
Emissions and Mitigation Potential (MT) from Livestock Sector

	Business as usual			Feed supplement			Advanced artificial insemination			Combined		
	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
State level	32.3–38.1	41.9–49.5	52.5–61.6	31.3–36.9	39.9–47.0	48.5–57.0	31.8–37.7	39.5–46.4	46.8–54.9	29.2–34.2	37.9–44.1	47.0–54.4
North-east	8.5–10.1	11.1–13.2	14.1–16.6	8.2–9.8	10.6–12.6	13.5–15.4	8.5–10.1	10.8–12.7	13.0–15.3	7.6–8.9	10.0–11.7	12.6–14.6
North-west	10.8–12.6	14.2–16.5	17.6–20.4	10.7–12.5	13.5–15.7	16.3–18.9	10.5–12.2	13.0–15.1	15.0–17.4	10.0–11.6	11.9–14.8	15.8–18.1
South-east	4.2–5.0	5.3–6.3	6.6–7.8	4.0–4.7	5.1–5.9	6.1–7.2	4.1–4.8	5.0–5.9	5.5–6.5	3.6–4.2	4.8–5.6	5.9–6.9
South-west	8.8-10.4	11.3-13.4	14.2-16.8	8.4-9.9	10.7-12.7	13.1-15.5	8.7-10.2	10.8-12.7	12.9-15.3	7.9-9.3	10.2-12.0	12.7-14.9
				Potential Emission Reductions								
Adoption Level (%)				10	30	50	10	30	50	10	30	50
State level				1.0–1.2	2.0–2.5	4.0–4.6	0.6–0.9	2.5–3.1	5.6–6.7	3.0–3.9	4.0–5.4	5.4–7.2
North-east				0.3–0.4	0.5–0.6	1.0–1.2	0.0–0.1	0.4–0.6	1.0–1.4	0.9–1.2	1.1–1.5	1.5–2.0
North-west				0.1–0.3	0.7–0.8	1.3–1.5	0.3–0.4	1.2–1.5	2.6–2.9	0.8–1.0	1.3–1.7	1.8–2.3
South-east				0.2–0.3	0.2–0.4	0.5–0.6	0.1–0.2	0.3–0.4	0.7–0.9	0.4–0.5	0.5–0.7	0.7–0.9
South-west				0.4–0.5	0.6–0.7	1.1–1.3	0.1–0.2	0.5–0.7	1.3–1.5	0.9–1.1	1.1–1.5	1.5–2.0

Note: The values indicate the range (Lower–Upper Limit) estimated based on the individual animal's weight.

Income and Emissions from Milk Production Using Advanced Artificial Insemination





Per Capita Emissions from Milk (Tons of CO_2/Tons of Milk)

By adopting breeding through advanced artificial insemination in the livestock sector and improvements in feed management through the introduction of feed supplements like Harit Dhara, annual emissions can potentially be reduced by 5.4–7.2 MT.

With the incremental adoption of these interventions, emissions from milk production should decrease gradually. Income from milk production should increase with the use of sex-sorted semen, due to improved productivity, relative to conventional breeding, all while maintaining a lower herd size.

This analysis suggests that the proposed interventions can help Bihar realize its potential to achieve low-carbon development and inclusive food security in the future while minimizing the trade-offs between pursuing zero hunger and climate action.

TCI's future work will build on the results of this study by assessing multisectoral innovations, such as agrivoltaics and harnessing their synergies to ensure hunger-free prosperity in Bihar. In this context, TCI will integrate the findings of this study to conduct an economy-wide analysis of Bihar's GHG commitments and provide further evidence-based policy recommendations for its climate action plans that ensure there is no reduction in agricultural productivity.

Zero-Hunger, Zero-Carbon Food Systems

This policy brief was produced as a part of TCI's project on Zero-Hunger, Zero-Carbon Food Systems. The project aims to support the reduction of GHG emissions associated with agriculture while improving productivity and benefiting farmer livelihoods.

Learn More

To learn more about the Zero-Huger, Zero-Carbon Food Systems project, visit:

tci.cornell.edu/?projects=zero-hunger-zero-carbon-food-systems

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