

AGRIFRONTLINE

The Voice of Agriculture

Greenhouse Gas Emissions from Indian Agriculture: Challenges, Mitigation Options, and Trade-offs

Deepika Yadav^{1}, Mukesh Kumar Yadav²*

Introduction

India's economy depends heavily on agriculture since it promotes national development, rural livelihoods, and food security. Nearly 40% of Earth's surface is agricultural land, most of which is used for crop production, with the rest for livestock grazing. The world's population has grown rapidly in recent decades, while the amount of arable land available per person has progressively decreased. Despite this restriction, technological advances and improved management techniques have increased agricultural productivity. India is home to roughly 17% of the world's population, despite covering only 2.4% of the planet's territory and accounting for 4% of its freshwater resources. This imbalance severely strains water and land resources. Rising concentrations of greenhouse gases (GHGs) like carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) have caused global warming, altered rainfall patterns, accelerated glacier melting, and driven sea level rise, all of

which have worsened the impacts of climate change. Agriculture is a vital sector for mitigation and adaptation efforts because it both influences and is affected by climate change.

Indian Agriculture in a Changing Climate

Approximately 141 million hectares of India's 328 million hectares of land are used for agriculture. Over 85% of farmers operate on tiny or marginal landholdings, indicating that farm holdings are extremely fragmented. Since a large amount of farmed land is rainfed, crops are vulnerable to pests, droughts, floods, and high temperatures. Due to rising incomes, dietary diversification, and population growth, demand for food grains is likely to increase significantly. India may need to produce far more food than it does now by 2050. Agriculture will need to be intensified to meet this demand, given the scarcity of land and water resources, which could lead to increased greenhouse gas emissions if not managed appropriately.

¹Ph.D. Scholar, Division of Agronomy, Sri Karan Narendra Agriculture University, Jobner

² Ph.D. Scholar, Division of Soil Science, ICAR-Indian Agricultural Research Institute, New Delhi

Drivers of Greenhouse Gas Emissions in Agriculture

Numerous economic, social, and environmental factors affect agricultural emissions. Production systems have changed as a result of population increase, urbanisation, globalisation, shifting dietary habits, and rising per capita income. Specialised, input-intensive systems that mostly rely on irrigation, fertilisers, mechanisation, and electricity are gradually

replacing traditional mixed agricultural methods. Deforestation results from agricultural expansion into forested areas, and emissions of CH₄ and N₂O are increased by the overuse of water and fertilisers. Because of enteric fermentation, livestock intensification has also increased methane emissions. All of these elements have combined to make agriculture a major source of India's overall greenhouse gas emissions.

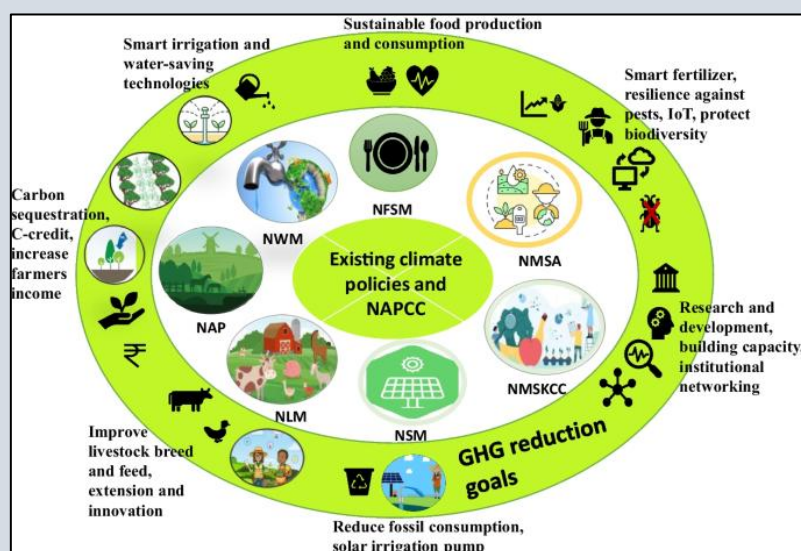


Fig 1: Sources and Contribution of Greenhouse Gas Emissions from Indian Agriculture

Emission Profile of Indian Agriculture

Over 10% of global greenhouse gas emissions are attributed to agriculture. India contributes about 5% of the world's emissions, with agriculture accounting for the largest share of the country's emissions after the energy sector. The largest source of agricultural emissions comes from livestock, primarily from the methane ruminant animals emit during digestion. Nitrous oxide emissions from fertiliser

application are a major factor in agricultural soils. Another significant source of methane is flooded rice fields; residue burning and manure management make smaller but significant contributions. Because of variations in farming practices, soil types, climate, and management techniques, emissions vary widely across locations. States that utilise a lot of fertilisers and cultivate a lot of rice under irrigation

typically have greater potential for global warming.

Mitigation Strategies in Agriculture

There are opportunities in agriculture to reduce greenhouse gas emissions without sacrificing productivity. Supply-side actions that enhance production efficiency and management techniques can be broadly classified as mitigation solutions.

Sustainable Intensification

The goal of sustainable intensification is to increase production on existing farms without harming the environment. Precision farming, improved crop varieties, effective input use, and integrated pest and nutrient management can all improve soil health and farm profitability while reducing emissions per unit of production.

Improved Fertiliser Management

Nitrogen fertilisers are a major source of nitrous oxide emissions; techniques such as soil testing, site-specific nutrient application, slow-release fertilisers, neem-coated urea, and nitrification inhibitors can significantly reduce nitrogen losses, improve nutrient-use efficiency, and reduce production costs.

Mitigation of Methane from Livestock

Better fodder varieties, balanced feeds, improved feed quality, and dietary supplements can all help lower methane emissions from enteric fermentation. Improvements in animal health and genetics boost output, thereby lowering the

emissions intensity per unit of milk or meat produced.

Methane Mitigation from Livestock

Better fodder varieties, balanced feeds, improved feed quality, and dietary supplements can all help lower methane emissions from enteric fermentation. Improvements in animal health and genetics boost output, thereby lowering the emissions intensity per unit of milk or meat produced.

Cutting Down on Rice Cultivation Emissions

Methane production is facilitated by the anaerobic conditions created by flooded rice fields. Methane production and flooding duration are decreased by direct-seeded rice, system of rice intensification (SRI), and alternate wetting and drying (AWD). The potential for mitigation is further increased by balanced fertiliser use and improved residue management.

Trade-offs and Difficulties

Although mitigation measures have many advantages, they also have drawbacks. Growing food often requires more fertiliser and irrigation, which can increase greenhouse gas emissions. Higher water and nitrogen supplies, for instance, may boost crop yields but also increase the risk of global warming.

According to simulation studies, improved resource management can increase productivity in wheat and rice, though in

some cases these increases may be accompanied by higher emissions. Finding "win-win" solutions that increase output while reducing emissions is crucial.

Policy Consequences and Future Directions
Strong institutional coordination and policy support are necessary for effective agricultural mitigation. Farmers can embrace low-emission practices by receiving payments for ecosystem services, accessing carbon markets, and receiving incentives for climate-friendly technologies. For widespread implementation, funding for extension services, location-specific technologies, and research is essential.

Climate-smart agriculture offers a workable strategy to improve resilience and lower emissions by combining mitigation, adaptation, and productivity objectives. Achieving lasting results will depend on

raising farmer awareness, expanding access to technology, and coordinating agriculture and climate policies.

Conclusion

There are opportunities and challenges in reducing greenhouse gas emissions from Indian agriculture. Efficiency and sustainability must take precedence over output restrictions in mitigation measures, given the sector's significance for food security and livelihoods. Climate-smart livestock systems, sustainable intensification, improved water and fertiliser management, and supportive policies can all dramatically reduce emissions without sacrificing productivity. Indian agriculture can make a significant contribution to mitigating climate change while maintaining long-term food and economic security through coordinated effort and farmer-centric policies.

References

1. Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. and Tempio, G., 2013. Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities (pp. xxi+-115).
2. Hristov, A.N., Oh, J., Firkins, J.L., Dijkstra, J., Kebreab, E., Waghorn, G., Makkar, H.P.S., Adesogan, A.T., Yang, W., Lee, C. and Gerber, P.J., 2013. Special topics—Mitigation of methane and nitrous oxide emissions from animal operations: I. A review of enteric methane mitigation options. *Journal of animal science*, 91(11), pp.5045-5069. <https://doi.org/10.1017/S1751731113000876>
3. Jayanegara, A., Leiber, F. and Kreuzer, M., 2012. Meta-analysis of the relationship between dietary tannin level and methane formation in ruminants from in vivo and in vitro experiments. *Journal of animal physiology and animal nutrition*, 96(3), pp.365-375.
4. Makkar, H.P., 2016. Smart livestock feeding strategies for harvesting triple gain—the desired outcomes in planet, people and profit dimensions: a developing country perspective. *Animal Production Science*, 56(3), pp.519-534.

5. Mottet, A., De Haan, C., Falcucci, A., Tempio, G., Opio, C. and Gerber, P., 2017. Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security*, 14, pp. 1-8.
6. Ouda, S. and Zohry, A.E.H., 2022. *Climate-smart agriculture*. Springer International Publishing.
7. Patra, A.K., 2012. Enteric methane mitigation technologies for ruminant livestock: a synthesis of current research and future directions. *Environmental Monitoring and Assessment*, 184(4), pp. 1929-1952.
8. Thornton, P.K. and Herrero, M., 2010. Potential for reduced methane and carbon dioxide emissions from livestock and pasture management in the tropics. *Proceedings of the National Academy of Sciences*, 107(46), pp.19667-19672.
9. Van Zijderveld, S.M., Gerrits, W.J.J., Apajalahti, J.A., Newbold, J.R., Dijkstra, J., Leng, R.A. and Perdok, H.B., 2010. Nitrate and sulfate: Effective alternative hydrogen sinks for mitigation of ruminal methane production in sheep. *Journal of Dairy Science*, 93(12), pp.5856-5866.
10. Zhou, M., Hernandez-Sanabria, E. and Guan, L.L., 2010. Characterisation of variation in rumen methanogenic communities under different dietary and host feed efficiency conditions, as determined by PCR-denaturing gradient gel electrophoresis. *Applied and environmental microbiology*, 76(12), pp.3776-3786.