India’s Biofuel Policy: Implications on GHG emissions and the agrifood system

FABLE Policy Brief
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Headlines

- The transportation sector in India has witnessed unprecedented growth, increasing more than seven-fold over the past two decades. While India has set ambitious biofuel blending targets, it has faced challenges in achieving them.
- Between 2014 to 2022, India’s ethanol blending grew fast from 1.3% to 10.2%, but it is still far from the 2018 National Biofuel Policy ethanol blending target of 20% by 2025: with an even larger gap for biodiesel.
- Here we assess the impacts of the Indian National Biofuel Policy for ethanol on key food and environmental indicators up to 2050 using the MAgPIE global land use partial equilibrium model.
- We compare three potential pathways for achieving India’s ethanol blending mandate by 2050 with different mixes of sugarcane-based feedstocks.
- Diversifying ethanol sourcing from molasses to sugarcane juice has significant benefits, including reduced strain on land, water, fertilizer use, and emissions. These benefits are particularly evident when the production system is more intensive.
- However, due to high water and nitrogen fertilizer use associated with sugarcane cultivation, sustainable potential for ethanol production is limited in the long-term.

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About FABLE

The Food, Agriculture, Biodiversity, Land-Use, and Energy (FABLE) Consortium is a collaborative initiative to support the development of globally consistent mid-century national food and land-use pathways that could inform policies towards greater sustainability. FABLE is convened as part of the Food and Land Use Coalition (FOLU). The Consortium brings together teams of researchers from 24 countries and international partners from Sustainable Development Solutions Network (SDSN), the International Institute for Applied Systems Analysis (IIASA), the Alliance of Bioversity International and CIAT, and the Potsdam Institute for Climate Impact Research (PIK).

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1. Introduction

The transportation sector in India has witnessed unprecedented growth, increasing more than seven-fold over the past two decades. In 2020, it contributed to nearly 19% of the final energy consumed while consuming nearly 50% of the country's total oil.[1] India's substantial size and dynamic growth ensure its pivotal role in the global energy landscape. With its expanding economy, burgeoning population, rapid urbanization, and industrialization, India anticipates the most significant surge in energy demand among all countries up to 2040.[2] Consequently, the transportation sector accounted for 12.9% of India's total greenhouse gas emissions from the energy sector in 2016 and 9.7% of the country's overall emissions, excluding land use, land-use change, and forestry (LULUCF).[3]

In light of India's commitment to achieve net-zero emissions by 2070 and reduce emissions intensity of GDP by 45% by 2030, the need to decarbonize the energy-intensive transportation sector looms large. India's updated climate pledge to the United Nations Framework Convention on Climate Change (UNFCCC) underscores this commitment.[4] In response to these challenges, policymakers are intensifying efforts to transition towards cleaner fuels, with a particular emphasis on liquid biofuels. Despite global renewable energy use in the transport sector remaining relatively low, biofuels, primarily ethanol and biodiesel, accounted for approximately 3.5% of global transport energy in 2020.[5]

In 2009, India launched its biofuel program with the enactment of the National Policy on Biofuels (NPB), mandating a 20% blending requirement for both ethanol and biodiesel, targeted to be achieved by 2017.[6] However, feedstock shortages and limited options to diversify feedstock options have significantly impacted the growth of the sector.[7]

Despite their role in decarbonization efforts, crop-based biofuels have faced criticism for potentially harming food security[8,9] and for uncertain greenhouse gas (GHG) emissions reduction benefits when considering indirect land use changes driven by increased biofuel demand.[10]

To avoid food security concerns associated with biofuels, the 2009 policy only permitted the use of non-edible feedstock and non-arable land, i.e., molasses (a by-product of sugar) for ethanol and jatropha on degraded wasteland for biodiesel. However, to overcome the feedstock shortages, the National Policy on Biofuels (NPB) of 2018 diversifies feedstock options, stipulating a blending target of 20% for both bioethanol and biodiesel, initially targeted to be achieved by 2030 but later amended to be achieved by 2025.[11,12] The expanded feedstock options are i) sugarcane juice, sugar-containing materials (sugar beet, sweet sorghum), starch-containing materials (corn, cassava), and damaged food grains (unfit for human consumption) such as wheat and broken rice for 1st generation ethanol; ii) lignocellulose biomass, woody crops, agricultural residues, and municipal waste for 2nd generation ethanol. For biodiesel, feedstock options include non-edible oilseeds grown on wastelands and repurposing Used Cooking Oil (UCO).

Ethanol production and consumption in India have witnessed an upward trend only from 2014 onwards, with more remunerative supportive policies for ethanol producers.[13] Between 2014 to 2022, India's biofuel blending grew from 1.3% to 10.2% for ethanol and 0.06% to 0.07% for biodiesel (Figure 1). While new alternative ethanol production routes are now available for India, sugarcane is expected to remain the primary source, until advanced biofuel technologies are commercially available.[14]

This policy brief examines the implications of alternative mixes of sugarcane-based feedstocks to achieve India's ethanol blending mandate on critical food and environmental indicators up to 2050. The Model of Agricultural Production and its Impact on the Environment (MAgPIE) - a global partial equilibrium model[15,16] - is used to explore the effects on land use, production and prices, agricultural water usage, fertilizer use, and GHG emissions.

2. Current situation

India, a key player in the global sugar market, is the largest consumer and the second-largest producer, contributing 18.8% of the world's sugar production and 16.2% of consumption in 2021.17 The sugar industry plays a vital role in the nation's agro-based sector, significantly impacting the livelihoods of nearly 50 million farmers and providing direct employment to 0.5 million workers through the sugar mills.18 Sugarcane cultivation occupies 3% of the total cultivated area and contributes about 7.5% (equivalent to US$ 8.61 billion) to the gross value of agricultural production. Nationally, sugarcane cultivation has stabilized around 5 Mha, with an average yield of 70.25 tons/ha and an annual production of 355 million tonnes.

India's sugarcane cultivation is broadly divided into two agro-climatic regions: tropical and sub-tropical. The tropical region, including states like Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, and Madhya Pradesh, represents approximately 42% of the total sugarcane area, contributing 47% to the national production, with an average productivity of 76 tons/ha. In contrast, the sub-tropical regions, comprising Uttar Pradesh, Uttarakhand, Bihar, Haryana, and Punjab, account for about 55% of the total area and contribute 51% to production, with an average productivity of 66 tons/ha. Notably, more than 80% of India's sugarcane production is concentrated in just three states, i.e., Uttar Pradesh, Maharashtra, and Karnataka. The differences in agro-climatic conditions contribute to higher yield levels in tropical states like Tamil Nadu and Karnataka compared to sub-tropical regions like Uttar Pradesh. Sugarcane, a perennial and water-intensive crop, requires 1500–3500 mm of rainfall per year. About 95% of sugarcane crops are irrigated, and its water demand competes for scarce water resources.[19,20]

Historically, sustained government support for the industry and inefficient policies have led to the shifting of sugarcane cultivation belts to water-stressed areas including Maharashtra, Karnataka, and Tamil Nadu.[21] Such inefficiencies have also led to over-production of sugarcane and sugar relative to domestic demand. Moreover, better market access coupled with guaranteed prices set by the government, Fixed Remunerative Prices (FRP), have boosted returns on sugarcane cultivation by 60%–70% compared to other crops,[18] making it the most preferred crop among farmers.

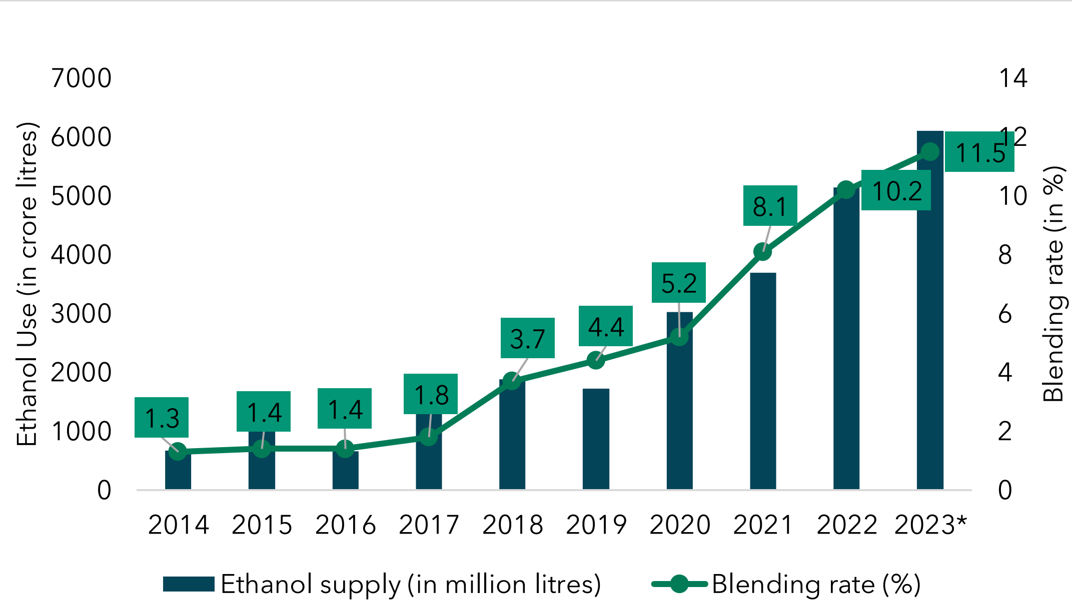
Approximately 75% of India's sugarcane production is used by sugar mills to produce sugar and by-products. Over the past two decades, annual sugar production in India has grown by 6.1%, outpacing the 2.6% growth in sugar consumption. With an annual sugar production of 30 million tonnes, domestic consumption stands at 26 million tonnes, 35% of which is used for household consumption and 65% for industrial purposes.[18]

Considering the domestic sugar surplus, product diversification of the Indian sugar industry has been identified as a crucial strategy for the long-term financial viability and sustainability of the sector. To promote diversification, the Indian government has initiated various measures, including the production of ethanol directly from sugarcane juice,[22] molasses, and cogeneration of electricity.

More recently, with the implementation of the NPB (2018), diverse feedstocks including sugarcane juice, damaged foodgrains, and corn are being diverted for ethanol. In 2023, about 18.4 million tonnes of sugarcane juice was used for ethanol, in addition to 12 million tonnes of molasses (Figure 2). Assured and remunerative prices of ethanol have significantly boosted ethanol supply, rising from 1505 million liters in 2017 to 3695 million liters in 2021, increasing ethanol blending to 8.1% (Figure 1).[23]

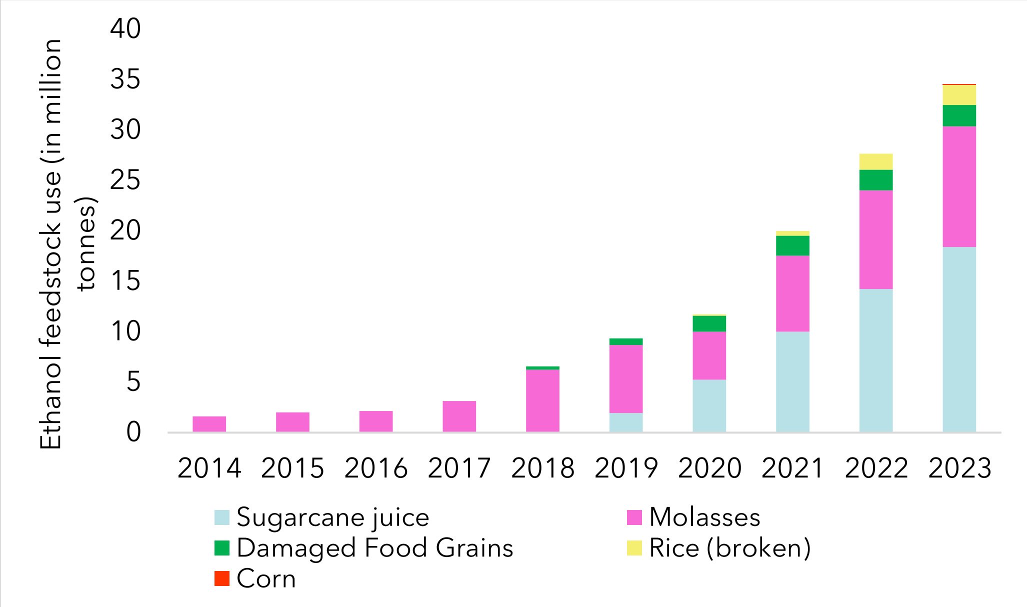
While producing ethanol directly from sugarcane juice can help maintain stability in sugar market prices,[22] environmental sustainability risks over land use change and adverse water security concerns are high.[24] Limited evidence on water-food-energy interactions of the sugar sector complicates long-term policy decisions, endangering overall sustainability.[25]

Figure 1: Evolution of ethanol supply and blending 2009-2023



Source: Biofuels Annual, India, 2023. *Provisional values

Figure 2: Evolution of ethanol feedstock use by type 2014-2023



Source: Biofuels Annual, India, 2023

3. Methodology

To assess the potential impacts of India's ethanol blending mandate with sugarcane-based feedstocks, we use the MAgPIE model.[15,16] The model combines land availability, crop potential, and water resources into economic decision-making factoring in population growth, economic trends, and climate change as drivers. MAgPIE operates on a global scale, with India as a distinct region within the model. It uses biophysical data at 0.5° × 0.5° spatial resolution, which is then organized into spatial clusters based on similar agricultural conditions for efficient decision-making.

The model incorporates trade among 12 global regions, with India treated as a separate entity. The modelled trade system remains rigid, following historical flows of agricultural commodities, though it allows for limited free trade in a small portion of the global market. In India, sugarcane and related processed products are assumed to be import-restricted in alignment with biofuel mandate policy recommendations. Domestic production is sustained through cropland expansion, and particularly in India's case, due to resource limitations, through endogenous investments in yield-enhancing technological advancements. Therefore, the additional demand for sugar cane is met primarily by domestic production intensification (Figure A2). Agricultural commodity prices in the model respond to shifts in both domestic demand and trade, determined through cost minimization calculations, and they serve as indicative prices.[26] Bioenergy includes both 1st and 2nd generation sources where 1st generation bioenergy is based on food crops including sugarcane and 2nd generation includes dedicated herbaceous bioenergy crops and residues which are also fully substitutable based on their energy content.[27] The model estimates region and crop-specific bioenergy quantities, minimizing the costs associated with the production of all included primary and secondary crop commodities subject to socio-economic and biophysical constraints. It operates recursively in 5-year time steps, projecting outcomes up to 2050.

Specific to India, we include ethanol from two alternate sources i.e., molasses and sugarcane juice. Ethanol processing from feedstocks was modelled using India-specific conversion factors. Ethanol demand is based on projected petrol demand in 2050 and we compare four alternate ethanol pathways for the period 2020-2050.

The Business as Usual (BAU): this scenario is based on the SSP2 'middle-of-the-road' pathway representing a continuation of current socio-economic and technological trends, including food demand in the future with no specific policy action specific to biofuels. The population is expected to increase to 1.59 billion in 2030 and 1.63 billion by 2050. The per capita income is assumed to increase to 9,235 $USD_{05MERPPP}$ in 2030 and 16,789 $USD_{05MERPPP}$ by 2050.[28,29]

All Molasses: All the underlying assumptions under this scenario are in line with BAU, except for the demand for first-generation bioenergy and its sources. This scenario is designed to achieve 20% blending following India's NPB 2018. Under this scenario, it is assumed that all ethanol is produced from molasses, a by-product of sugar processing.

Mix 3070 assumes 30% of ethanol is sourced from molasses and the remaining 70% directly from sugarcane juice through distillation. All other fundamental assumptions and the specified demand for first-generation bioenergy align with the BAU and AllMolasses scenario.

Mix1090 assumes a 10% and 90% ethanol composition from molasses and sugarcane juice respectively. All other assumptions align with the other scenarios.

4. Results

Land use

In the BAU scenario, with no specific ethanol targets in place, cropland area is projected to decrease by a modest 1% by 2050. Forestland increases by 42% in all four scenarios, due to the implemented NDC targets requiring additional forest area by 2030 and restricting the conversion of forest areas to cropland. Pastureland, on the other hand, is expected to increase by 102%. Land for forests and pasture expansion is withdrawn from other land, experiencing a 90% decline.

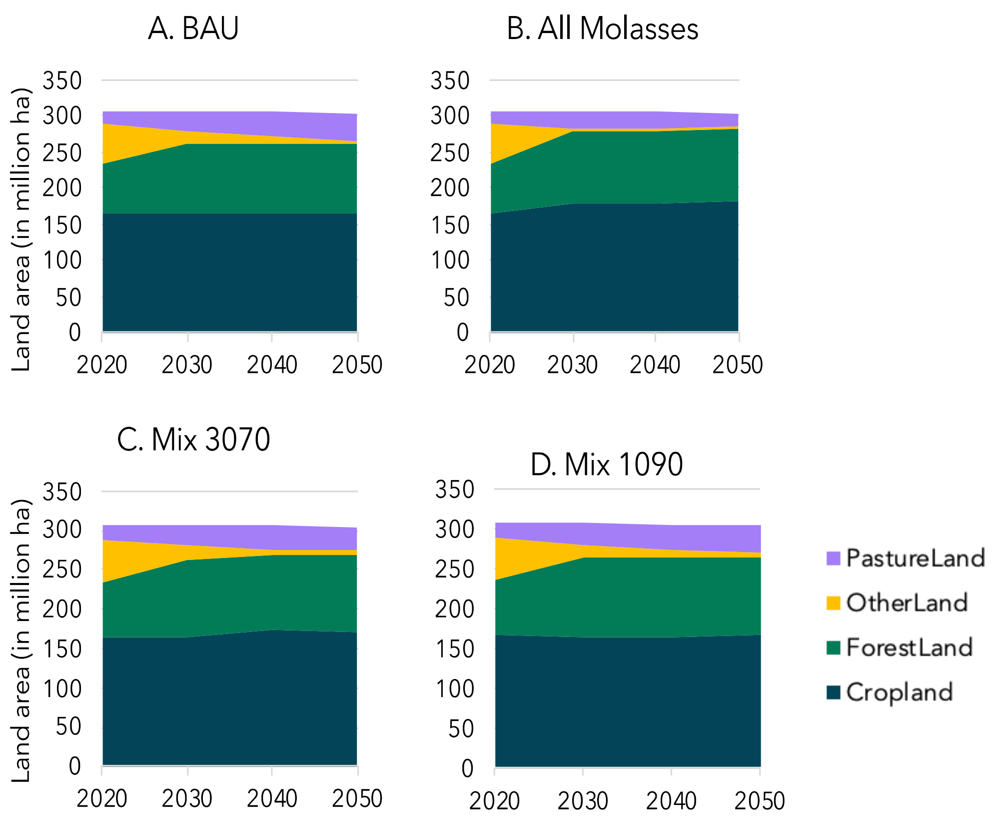
In the 'All Molasses' scenario, to meet the molasses requirement for fulfilling the ethanol mandate by 2050, sugarcane acreage expands from 4 Mha in 2020 to 101 Mha in 2050 leading to an 11% increase in cropland area, rising from 165 Mha in 2020 to 184 Mha by 2050. In contrast, the 'Mix 3070' and 'Mix 1090' scenarios cropland area moderately increases by 4% and 1% by 2050 compared to 2020, respectively. Diversifying feedstock options to include sugarcane juice for ethanol reduces sugarcane area expansion by 47% and 80% by 2050 respectively in the 'Mix3070' and 'Mix1090' scenarios compared to the 'AllMolasses' scenarios (Figure 3). Increased cropland area requirement in both scenarios is met through reduced other land which is reduced by 90% compared to 2020, probably using all the arable other land.

On the other hand, pastureland in the 'AllMolasses' scenario will decrease by 52% in 2050 compared to BAU as area expansion for sugarcane exerts high land pressure. By 2050, pastureland in Mix3070 and Mix1090 will be 69% and 94% higher than the 'AllMolasses' scenario as high income drives increased consumption of livestock products, requiring more pasture areas to meet feed requirements.

Although sugarcane acreage expansion is comparatively lower in the two blended pathways than in the molasses-only route, the sugarcane area needed to meet the blend mandate in 2050 is nearly 5-12 times higher than the BAU case (Figure A1), raising the possibility of large-scale sugarcane monocultures. Crop productivity growth driven by technological change and investment in irrigation infrastructure contributes towards mitigating the high land pressure. By 2050, required technological change to increase the regional supply of sugarcane in the 'All Molasses' scenario is likely to be 133% higher, while required productivity growth in Mix3070 and Mix1090 is 29% and 9% higher than the BAU case.

Technological change requirement in the two mixed sugarcane-based routes is 45% and 53% lower than the 'All Molasses' scenario (Figure A2). Altogether, this indicates that a biofuel pathway for India favoring a higher proportion of sugarcane juice minimizes land use changes, even without significant improvements in productivity.

Figure 3: Land use change

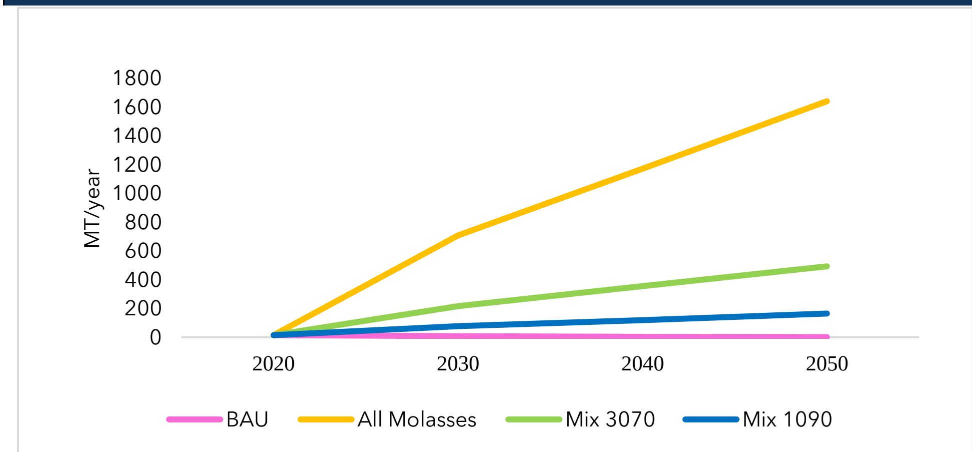


Production and prices

Under the Business as Usual (BAU) scenario, the model effectively manages the flows, resulting in market equilibrium and consequently, a reduction in sugar surplus. The 'All Molasses' pathway leads to domestic sugar overproduction, with annual domestic excess amounting to 710 Mt yr-1 in 2030 and 1640 Mt yr-1 in 2050. Alternative pathways diverting sugarcane juice for ethanol to sugar with a 30-70 (Mix 3070) and 10-90 (Mix 1090) ratio of molasses and sugarcane juice significantly contribute towards reducing domestic sugar overproduction (Figure 4). In the 'Mix 3070' scenario, annual domestic sugar overproduction decreases to 218 million tonnes by 2030 and 492 million tonnes by 2050. A higher proportion of sugarcane ethanol in the total ethanol mix, as illustrated by the 'Mix 1090' scenario, further lowers domestic annual overproduction to 77 million tonnes in 2030 and 164 million tonnes by 2050.

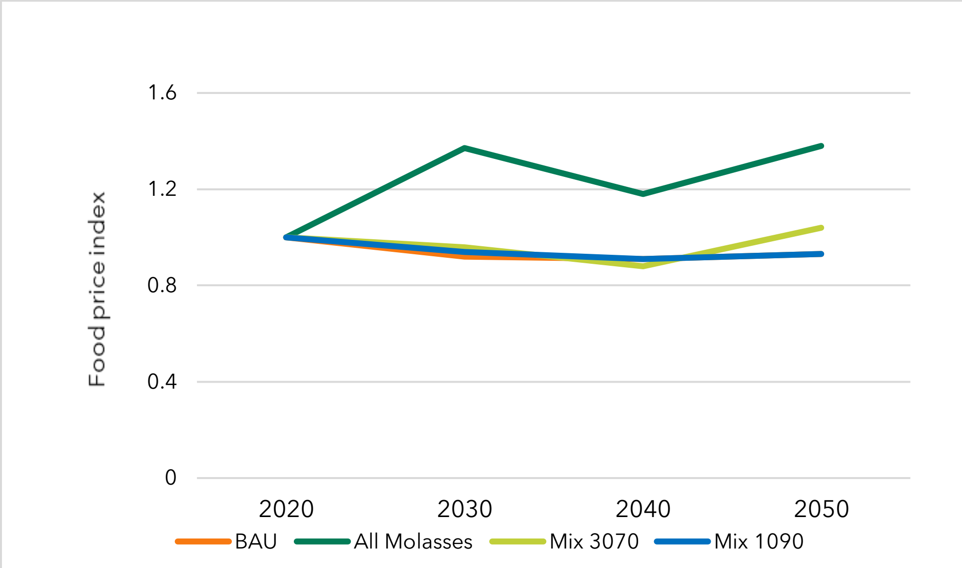
Price impacts of domestic sugar oversupply are evident. Under the 'All Molasses' scenario, there is a substantial increase in the food price index. By 2030, it will rise by 49% compared to the BAU scenario, and by 2050, it will increase by 48%. Land competition with other food crops like cereals, oilseed crops, fruits, vegetables, and nuts, and pulses, due to additional cropland required to accommodate the increased sugarcane acreage in addition to costs of land conversion and technological changes, contribute to the overall increase in food prices. However, as the share of the molasses decreases and sugarcane juice increases in the ethanol mix, the impact on food prices becomes less pronounced. In the 'Mix 3070' and 'Mix 1090' scenarios, which require less sugarcane, the additional land requirements are reduced, keeping food prices close to the baseline (Figure 5).

Figure 4 Domestic sugar surplus



Note: Domestic sugar surplus indicates the excess domestic production over domestic consumption needs (food, feed, processing, etc.).

Figure 5. Food price effects across scenarios



Note: The food price index (index 2020=1) follows the Laspayers price index by weighing current prices based on food baskets in the same period.

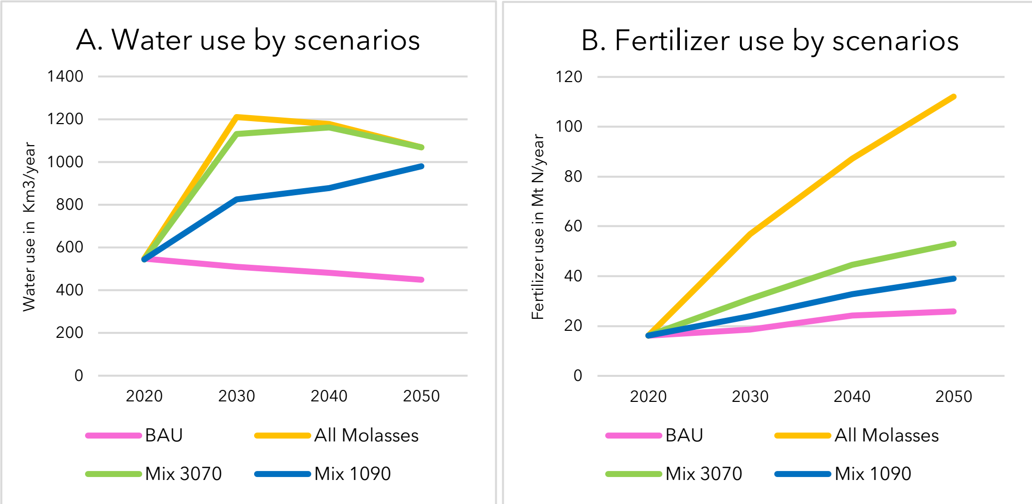
Water and Fertilizer Use

Although sugarcane-based ethanol can potentially be a better alternative than molasses, adverse environmental impacts can imperil the long-term sustainability of the ethanol and sugar sector.

In the BAU scenario, water use decreases by 7% in 2030 and 18% in 2050 in comparison to 2020, mainly due to the climate change impact assumed in the line of RCP 7.0. For all other scenarios, significant adverse water use impacts are evident. Compared to BAU, water usage surges by 118-138% across alternate pathways (Figure 6A). In comparison to the 'All Molasses' scenario, water use in Mix3070 is 0.1% higher while for Mix 1090 it is 8.35 lower, indicating reduced water stress through a mixed sugarcane-based feedstock strategy. However, compared to 2020, agricultural water use in all scenarios is significantly high, suggesting accentuating water stress than the current levels. High water use requirements for all sugarcane-based scenarios draw significant sustainability concerns for biofuels. Given the water-intensive nature of sugarcane cultivation in India, requiring approximately 20 ML/ha, 80% of the needs are met through groundwater extraction. Research indicates a higher blue water footprint than green water footprint for sugarcane grown in water-stressed tropical regions[30]. While using sugarcane juice for ethanol can be a more viable alternative in terms of less land requirements than the exclusive molasses-based ethanol production strategy, concerns about water usage may exacerbate challenges, further compromising water availability for other crops and overall water use.

In the BAU scenario, fertilizer use is expected to increase by 60% by 2050 due to the growing demand for food, increasing fertilizer application. Under the 'All Molasses' scenario, annual fertilizer use will surge from 16 Mt N in 2020 to 112 Mt N by 2050. In the 'Mix 3070' scenario, where there is a higher proportion of sugar juice, annual fertilizer use is anticipated to decrease, reaching 53 Mt N by 2050 which further reduces to 39 Mt N in the 'Mix1090' scenario. Compared to the BAU case, fertilizer use is 333%, 105%, and 51% higher in 2050 for the All Molasses, Mix 3070, and the Mix 1090 scenario respectively (Figure 6B). High fertilizer use significantly contributes towards increased nitrogen surplus in cropland which increases by 278%, 90%, and 43% across the three scenarios compared to BAU. While blended ethanol can potentially be a good alternative to pure molasses, negative environmental impacts can imperil the long-term sustainability of the ethanol and sugar sector.

Figure 6. Water and Fertilizer Use by scenarios

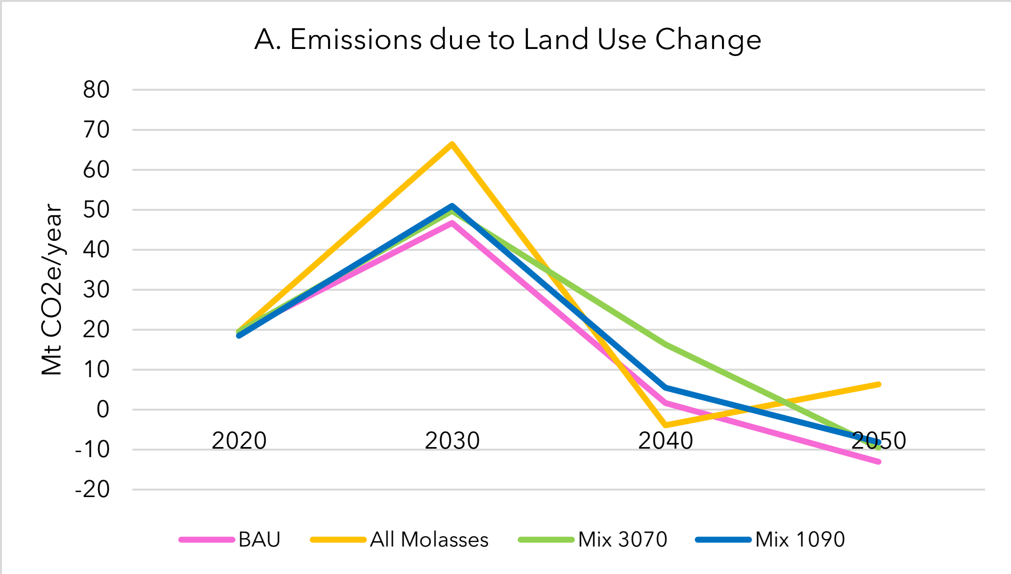


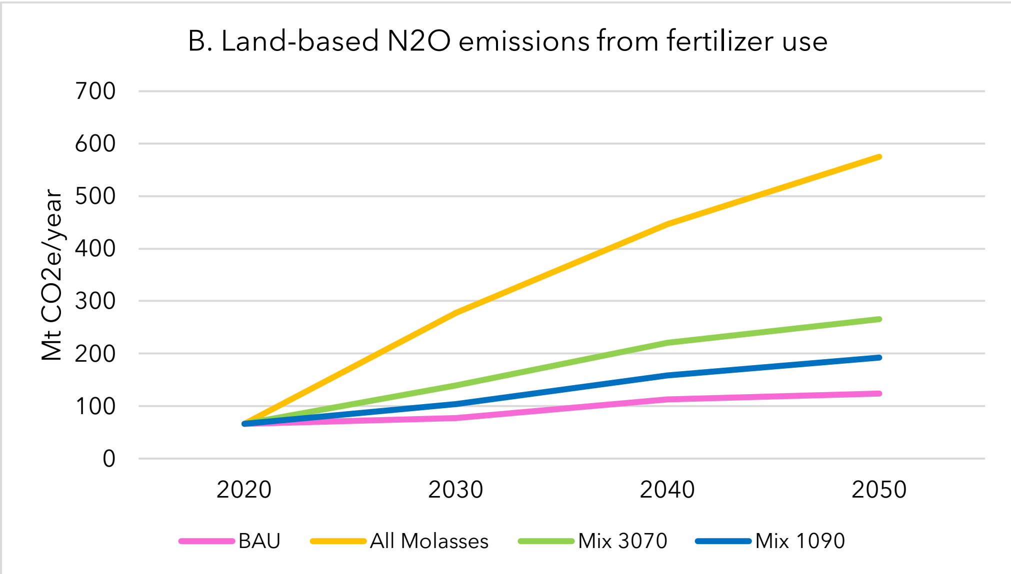
GHG emissions

In the BAU scenario, emissions from land use change initially rise to 47 Mt CO_2e yr-1 by 2030, then drop to -13 Mt CO_2e yr-1 by 2050 due to increased cropland conversion until 2030, due to afforestation efforts. Emissions from nitrogen use show an increasing trend under the BAU scenario due to increased fertilizer use contributes significantly to these emissions, reaching 77 Mt CO_2e yr-1 in 2030 and further rising to 124 Mt CO_2e yr-1 by 2050. Annual CO_2 emissions from land use change will increase to 6 MT CO_2e by 2050 in the 'All Molasses' scenario, a 148% increase compared to the BAU case which is primarily attributed to the conversion of land suitable for natural vegetation into agricultural use. Increasing sugarcane use in the ethanol mix, as indicated by the 'Mix 3070' and the Mix 1090 scenarios contributes towards annual carbon removals by 9 MT CO_2e and 8 MT CO_2e respectively (Figure 7 A).

Annual N_2O emissions from fertilizer use in the expanded sugarcane areas increase to 575 MT CO_2e in the 'All Molasses' scenario while in the 'Mix 3070' and 'Mix 1090' scenarios N_2O emissions are 266 MT CO_2e and 192 MT CO_2e respectively in 2050 (Figure 7B). Although increasing the proportion of sugarcane juice in the ethanol mix reduces nitrogen pollution, these are still 114% and 55% higher than the BAU case. N-application rates are considerably higher in India (150–400 kg N ha−1 y−1) than in Brazil.[31,32]

Figure 7 Emissions due to land use change and nitrogen use.





Note: The result shows that high sugarcane acreage expansion required to meet the molasses supply for ethanol conversion results in higher emissions from land use change. Whereas, diversifying feedstock options to include sugarcane can contribute towards reduced CO_2 emissions from avoided land use change and N_2O emissions from use of chemical fertilizers. Emissions from land use change in Mix 3070 and Mix 1090 are likely to remain 27% and 38% lower than BAU in 2050. However, N_2O emissions from fertilizer application is around 114% and 55% higher than BAU in Mix 3070 and Mix 1090 respectively, indicating high nitrogen pollution.

5. Policy implications

In this brief, we examine the food and environmental implications associated with India's biofuel development. Using the global land use partial equilibrium model MAgPIE, we quantify the food and environmental impacts. Our findings highlight the hidden trade-offs associated with alternate sugarcane-based feedstock pathways.

An ethanol production pathway relying exclusively on molasses can cause significant land use pressures, increase food prices, and cause water and fertilizer overuse due to requirement of large additional sugarcane acreage when compared to a pathway relying more on sugarcane juice. While efforts to increase yield on existing lands can mitigate some of these challenges, these elevate emissions. **In contrast, using sugarcane juice as blended feedstock for ethanol seems to be more advantageous** bringing multiple benefits in terms of curbing overproduction of sugar and stabilizing sugar and food prices, and reducing the burden on land and water resources.

However, balancing the need of food and fuel, along with the interests of farmers, sugar mills, and ethanol producers along with maintaining environmental sustainability remains a key challenge. Although the sugarcane juice blending route offers more potential benefits compared to molasses only, prolonged use of sugarcane for fuel can potentially turn sugarcane into an energy crop, making it more lucrative than other crops for farmers to grow. This can potentially lead to large areas coming under monocropping which can lead to adverse soil conditions and excess exploitation of groundwater resources. Our findings suggest that the sugarcane area needed to meet the blending mandate in 2050 is nearly 5-12 times higher than in the BAU case, indicating the likelihood of converting large land areas for sugarcane. Although productivity improvement can cater to the additional sugarcane requirement to some extent, stagnating sugarcane productivity over the past few decades[33] raises concerns for promoting sugarcane-based biofuels in India. Additionally, high nitrogen uses for achieving productivity growth can aggravate India's nitrogen pollution.

Our study indeed stresses the importance of a holistic approach when it comes to implementing biofuel policies, especially given their potential impacts on land and water use, as well as their potential to increase fertilizer usage and consequently greenhouse gas emissions. The findings of our study clearly underline the need for future policy frameworks to thoughtfully consider these environmental implications, ensuring that ambitious targets and the associated push towards biofuel production does not come at the expense of environmental sustainability. This balance is crucial for ensuring the transition towards a net-zero economy.

Our study also indicates that despite diversifying feedstock options to include sugarcane juice, uncertainty surrounding ethanol feedstocks is likely to remain critical for scaling biofuel blending in India. A critical issue associated with the molasses route is the significant overproduction of sugar and land use pressures. Overproduction and a surplus in the sugar market can drive down prices and potentially destabilize the sector. This can hurt farmers who rely on stable sugar prices for their livelihoods. Countries that export sugar could face challenges due to the global oversupply of sugar, which can decrease international sugar prices and impact the profitability of their sugar industry. To address this, the Government of India has permitted the direct conversion of sugar into ethanol to help mitigate this surplus. This policy adjustment benefits both farmers and sugar mills by enabling them to secure fair market prices. Excessive sugar production can flood the market, leading to price reductions and potential instability within the sector. Cheaper sugar can find its way into diets which may impact public health. Therefore, India should prioritize exploring 2nd generation multi-feedstock pathways, engaging more agricultural biomass-based resources. Sustainably maintaining E20 blend over the years and beyond 2030 would become challenging without the 2G route and therefore, the government may need to revisit the policy in future. While the target of E20 is ambitious, the biodiesel blend target is still far from being achieved. Alternative ethanol feedstock options, such as maize, may fail to present a sustainable solution. This is particularly due to the increasing reliance of the livestock sector on maize as feed, driven by growing demand for animal-based foods.

With rising incomes and urbanization leading to more diversified diets, particularly an increased demand for poultry as a protein source, the sustainability of maize as an ethanol feedstock becomes questionable. In the face of global fossil fuel market uncertainty and evolving climate policies, the shift from fossil fuels to biofuels hinges on supportive policy environments. India's biofuel integration is likely to depend on automotive industry readiness for flex-fuel and electric vehicles as national fleets evolve.[13]

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References

1. Kamboj, P., Malyan, A., Kaur, H., Jain, H. & Chaturvedi, V. India Transport Energy Outlook. *Council on Energy, Environment and Water. New Delhi. Available online at https://www. ceew. in/sites/default/files/ceew-research-transport-energy-use-carbon-emissions-decarbonisation. pdf* (2022).
2. IEA. *India Energy Outlook 2021*. *India Energy Outlook 2021* (2021) doi:10.1787/ec2fd78d-en.
3. CSE. *Greenhouse Gas Emissions by Indian Transportation Sector on the Road to COP26*. https://cdn.cseindia.org/userfiles/India-climate-change-2-Greenhouse-gas-emissions.pdf (2021).
4. Ministry of Environment, Forest and Climate Change, G. of I. *Submission to the United Nations Framework Convention on Climate Change India's Long-Term Low-Carbon Development Strategy Ministry of Environment, Forest and Climate Change Government of India*. https://unfccc.int/sites/default/files/resource/India_LTLEDS.pdf (2022).
5. REN21. *Renewables 2022 Global Status*. *Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector* (2022).
6. Government of India, M. of N. & R. E. *National Policy on Biofuels, India*. (2009).
7. Das, S. The National Policy of biofuels of India – A perspective. *Energy Policy* **143**, 111595 (2020).
8. Rosegrant, M. W., Zhu, T., Msangi, S. & Sulser, T. Global Scenarios for Biofuels: Impacts and Implications. *Source: Review of Agricultural Economics* **30**, 495–505 (2008).
9. Zhang, W., Yu, E. A., Rozelle, S., Yang, J. & Msangi, S. The impact of biofuel growth on agriculture: Why is the range of estimates so wide? *Food Policy* **38**, 227–239 (2013).
10. Searchinger, T. *et al.* Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science (1979)* **319**, 1238–1240 (2008).
11. MoPNG. *National Policy on Biofuels, India*. (2018).
12. MoPNG. *National Policy on Biofuels-2018 Amendment, 2022*. https://mopng.gov.in/files/article/articlefiles/Notification-15-06-2022-Amendments-in-NPB-2018.pdf (2022).
13. Das, P. & Gundimeda, H. Is biofuel expansion in developing countries reasonable? A review of empirical evidence of food and land use impacts. *J Clean Prod* **372**, 133501 (2022).
14. Devi, R. Viewpoint: India risks missing ethanol blending target | Latest Market News. https://www.argusmedia.com/en/news-and-insights/latest-market-news/2527641-viewpoint-india-risks-missing-ethanol-blending-target (2024).
15. Philipp Dietrich, J. *et al.* MAgPIE 4-a modular open-source framework for modeling global land systems. *Geosci. Model Dev* **12**, 1299–1317 (2019).
16. Jha, C. K. *et al.* The role of food and land use systems in achieving India's sustainability targets. *Environmental Research Letters* **17**, 074022 (2022).

17. CACP, M. of A. and F. W. *Price Policy for Sugarcane*. (2023).

18. NITI Ayog. *Report of the Taskforce on Sugarcane and Sugar Industry*. https://www.niti.gov.in/sites/default/files/2021-08/10_Report_of_the_Task_Force_on_Sugarcan_ and_Sugar_Industry_0.pdf (2020).

19. Sharma, B. R. *et al. WATER PRODUCTIVITY MAPPING Of MAJOR INDIAN CROPS*. https://gadm.org/ (2018).

20. Shrivastava, A. K., Srivastava, A. K. & Solomon, S. Sustaining sugarcane productivity under depleting water resources. **101**, 748–754 (2011).

21. Vikas, A. *Sustainability Concerns on Sugarcane Production in Maharashtra, India: A Decomposition and Instability Analysis*. https://www.isec.ac.in/wp-content/uploads/2023/07/WP-441-Abnave-Vikas-Final.pdf (2019).

22. Lee, J. Y. & , Rosamond L Naylor, A. J. F. and S. M. G. Water-food-energy challenges in India: political economy of the sugar industry. *Environmental Research Letters* **15**, (2020).

23. Shilpita Das and Mark Rosmann. *Biofuels Annual India- 2023*. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels Annual_New Delhi_India_IN2023-0039.pdf (2023).

24. Schaldach, R., Priess, J. A. & Alcamo, J. Simulating the impact of biofuel development on country-wide land-use change in India. *Biomass Bioenergy* **35**, 2401–2410 (2011).

25. Das, P., Jha, C. K., Saxena, S. & Ghosh, R. K. Can biofuels help achieve sustainable development goals in India? A systematic review. *Renewable and Sustainable Energy Reviews* **192**, 114246 (2024).

26. Wang, X. *et al.* Taking account of governance: Implications for land-use dynamics, food prices, and trade patterns. *Ecological Economics* **122**, 12–24 (2016).

27. Lotze-Campen, H. *et al.* Impacts of increased bioenergy demand on global food markets: an AgMIP economic model intercomparison. *Agricultural Economics* **45**, 103–116 (2014).

28. O'Neill, B. C. *et al.* The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change* **42**, 169–180 (2017).

29. Popp, A. *et al.* Land-use futures in the shared socio-economic pathways. *Global Environmental Change* **42**, 331–345 (2017).

30. Tayade, A. S. *et al.* Water-efficient genotypes along with conservation measures significantly reduce the green and blue water footprints in sugarcane (Saccharum spp.). *Scientific Reports 2023 13:1* **13**, 1–16 (2023).

31. Otto, R. *et al.* Nitrogen Use Efficiency for Sugarcane-Biofuel Production: What Is Next? *BioEnergy Research 2016 9:4* **9**, 1272–1289 (2016).

32. Yang, L. *et al.* Global direct nitrous oxide emissions from the bioenergy crop sugarcane (Saccharum spp. inter-specific hybrids). *Science of The Total Environment* **752**, 141795 (2021).

33. Sundara, B. Agrotechnologies to Enhance Sugarcane Productivity in India. *Sugar Tech* **13**, 281–298 (2011).

Annex

Figure A1. Area under sugarcane across scenarios in million ha

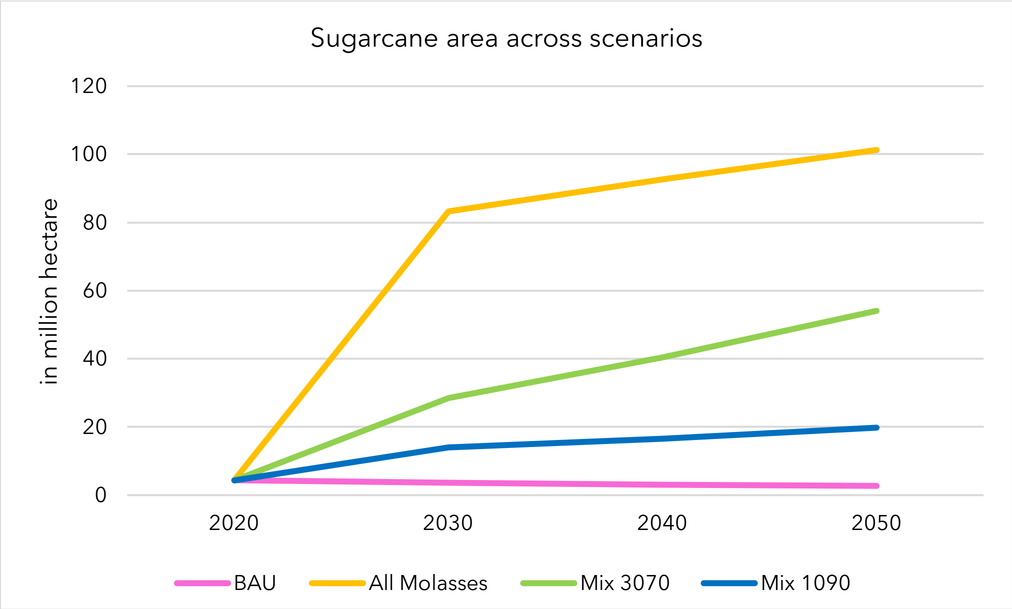

Figure A2. Crop Productivity

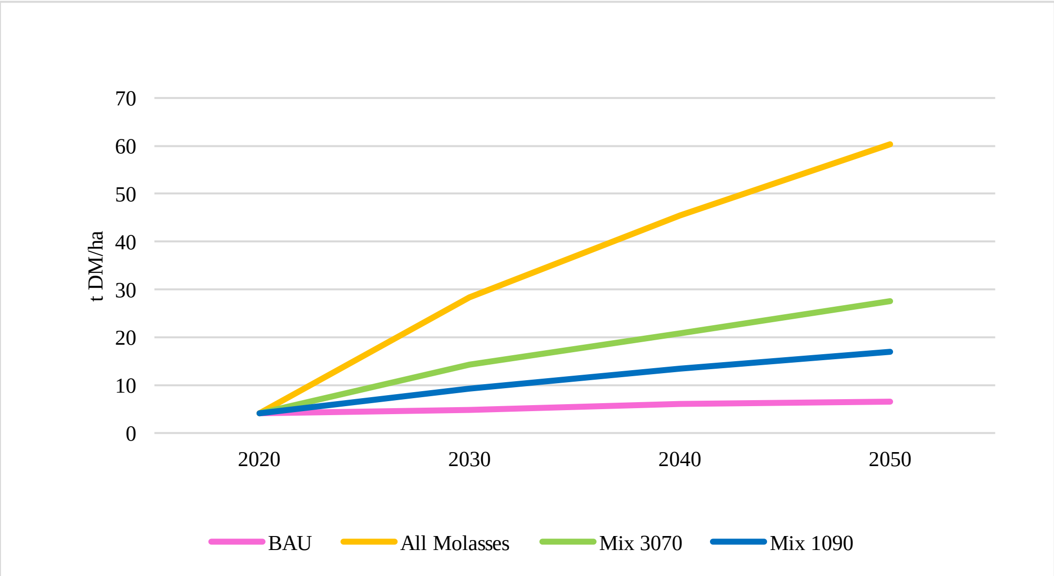

Figure A2. Projected intensification required in the whole crop production system due to the demand side pressure within the model. The figure shows the required aggregated cropland productivity increase across all crop types across scenarios till 2050