Mitigating Methane from Food and Agriculture

a Global Health Strategy

Produced by Abt Associates on behalf of the Global Climate and Health Alliance

August 2023

Abt Associates

THE GLOBAL CLIMATE & HEALTH ALLIANCE

About GCHA

The Global Climate and Health Alliance (GCHA) is the leading global convenor of health professional and health civil society organizations addressing climate change. We are a consortium of health and development organizations from around the world united by a shared vision of an equitable, sustainable future, in which the health impacts of climate change are minimized, and the health benefits of climate solutions are maximized. GCHA works to elevate the influential voice of the health community in policymaking to address the climate crisis.

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All interviewees were informed of the purpose of the interview and how the information from the interview would be used. Oral consent was given and no interviewees received compensation for their engagement with the research.

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1 Introduction

While the advances to global food production — such as the introduction of chemical fertilizers and pesticides, mechanization, large-scale irrigation, and selective breeding and genetic modification — vastly increased agricultural productivity, these processes had unintended consequences. Industrialization and agricultural intensification contribute to deforestation, loss of biodiversity, reduced soil health, and water contamination. Additionally, food and agriculture systems (including forestry and other land use) contribute between 18.4 and 33 percent of total global greenhouse gas (GHG) emissions[1,2].

Methane is a powerful GHG that is accelerating global warming, and worsening air quality by contributing to the formation of ground-level ozone, a toxic air pollutant [see **Overview Report** for how methane impacts human health]. Recognizing the importance of a rapid and deep reduction in methane emissions as a key component of limiting global warming, 150 countries have now signed the Global Methane Pledge, launched in 2021. Signatories to the Pledge have committed to collectively reduce methane emissions by 30 percent by 2030 relative to 2020 levels.[3]

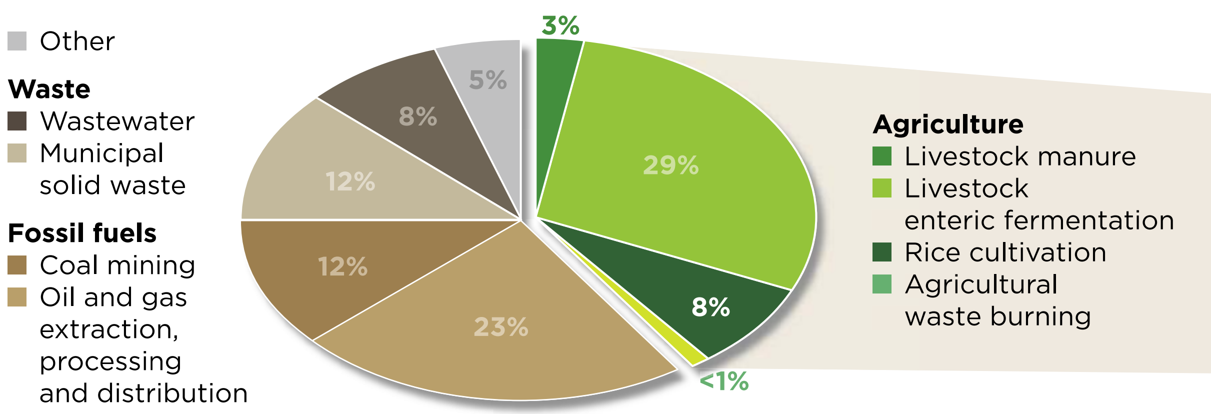
This report examines methane emissions sources from food and agriculture systems; the associated human health benefits of methane reduction solutions; and suggested methane reduction solutions at international, national, and local levels. This report is part of the Global Climate and Health Alliance's *Mitigating Methane, A Global Health Strategy* report series, which aims to bridge the knowledge gap on the intersection of methane mitigation and human health.

2 Methane Sources from the Food and Agriculture Sector

Livestock Production

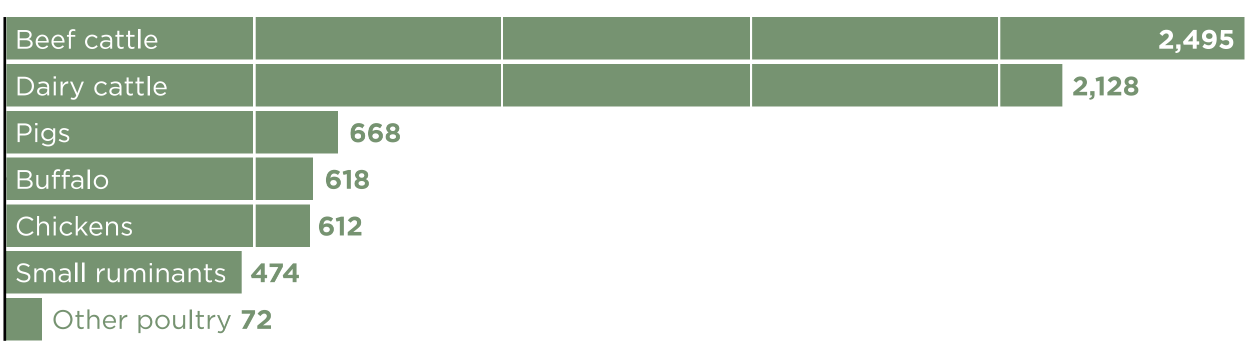
The agriculture sector accounts for approximately 42 percent of anthropogenic methane emissions, of which 29 percent is from livestock enteric fermentation[4]. Enteric fermentation refers to production of methane gas through fermentation of organic materials[5] in the primary stomach (rumen) of ruminant animals such as cattle, sheep, and goats. The process of enteric fermentation in the rumen readily produces methane, which is then released as livestock emit methane and other gases[6]. Additionally, livestock manure produces methane via anaerobic decomposition when manure is stored in low-oxygen environments such as manure lagoons and pits, which accounts for 3 percent of total methane emissions.[4]

Figure 1: Global Anthropogenic Methane Emissions from the Agriculture Sector



Source: United Nations Environment Programme and Climate and Clean Air Coalition (2021). Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions. Nairobi: United Nations Environment Programme

Figure 2: Global Estimates of Greenhouse Gas Emissions by Species, Millions Tonnes CO_2-equivalent



Source: Food and Agriculture Organization of the United Nations (FAO), 2013

Rice Cultivation

Rice cultivation contributes approximately 8-10 percent of total methane emissions globally as flooded rice paddies commonly used for cultivation create conditions (organic material in a low oxygen environment) where methanogenic organisms can thrive and produce methane [7]. Rice is a key food source which feeds an estimated one third of the world population, especially in primary rice producing countries in Southern Asia[8]. Despite the methane emissions associated with current cultivation practices, rice is one the most efficient crops per calorie in regards to land use, as it uses an estimated 0.76m^2 per 1000 kilocalories, compared to 119.49m^2 for beef — more than 100 times less land than beef cattle production[9].

Land Use

Land use emissions from expansion of crop lands, slash and burn techniques, and decomposing biomass represent an additional challenge. The impacts of agricultural land clearing are especially pronounced in the Global South, where vast carbon sinks — rainforests, marshes, and peat bogs, for example — are razed for livestock, food crops, and palm oil production, thus increasing emissions from biomass burning and decomposition, removing existing sources of CO2 gas exchange, and by releasing ancient sources of carbon and methane storage into the atmosphere.

As one example, several studies have demonstrated that net greenhouse gas (GHG) emissions increase when forested regions are cleared for palm oil plantations[10,11,12]. While palm oil constitutes a third of the world's vegetable oil, the carbon and methane sinks destroyed in its production have enormous climate consequences — one study of Indonesian palm oil development estimates that a single plantation expansion contributed 18-22 percent of the entire country's annual GHG emissions in 2020.[13]

Food Waste

Nearly one third of food produced is lost or wasted.[14] Food waste produces methane when such waste decomposes in poorly managed landfills or informal dumpsites. In this report series, methane emissions from food waste, and the mitigation strategies, are addressed in the Waste Sector report.

3 Methane and Health: Food and Agricultural Sector

Targeted solutions to reducing methane emissions from, and improving efficiency of, food and agriculture systems can deliver multiple health benefits, including:

- Reducing the localized health impacts of methane exposure from agricultural activities, which occur primarily via low-level tropospheric ozone and high concentrations of methane. Such health impacts may include asthma attacks, headaches, and discomfort[15].
- Reducing inhalation of air pollutants in smoke, generated from crop debris burning and land clearing activities, that contains black carbon particulate matter, volatile organic compounds (VOCs) such as benzene and formaldehyde[16], and many other gases and aerosols—all of which exacerbate respiratory conditions and affect children's lung health in particular[17].
- Reducing combustion of biomass for land clearing and disposal of crop residues, which contribute to air pollution, including tropospheric ozone, especially via increases in particulate matter, carbon monoxide, VOCs and nitrogen oxides which are present in biomass smoke[18]. In addition to increased rates of respiratory stress and lung inflammation for adults, studies demonstrate that exposure to air pollution in utero and during early childhood influence lung development and may lead to chronic obstructive lung disease and altered lung function[19].
- Improving manure management for agricultural livestock reduces pollution and zoonotic disease pathways which currently impact human health through surface and groundwater intrusion, air pollution from emissions, and air pollution via aerosolized application of liquified manure. Livestock fecal matter contains harmful components (ammonia, hydrogen sulfide, methane, small particulate matter) which can cause respiratory issues and, along with undesirable odors, can decrease quality of life[20].

Figure 3: Typical air pollutants from CAFOs

CAFO Emissions	Source	Traits	Health Risks
Ammonia	Formed when microbes decompose undigested organic nitrogen compounds in nature	Colorless, sharp pungent odor	Respiratory irritant, chemical burns to the respiratory tract, skin, and eyes, severe cough, chronic lung disease
Hydrogen Sulfide	Anaerobic bacterial decomposition of protein and other sulfur-containing organic matter	Odor of rotten eggs	Inflammation of the moist membranes of the eye and respiratory tract, olfactory neuron loss, death
Methane	Microbial degradation of organic matter under anaerobic conditions	Colorless, odorless, highly flammable	No health risks.* Is a greenhouse gas and contributes to climate change.
Particulate Matter	Feed, bedding materials, dry manure, unpaved soil surfaces, animal dander, poultry feathers	Comprised of fecal matter, feed materials, pollen, bacteria, fungi, skin cells, silicates	Chronic bronchitis, chronic respiratory symptoms, declines in lung function, organic dust toxic syndrome

Source: Carrie Hribar, NALBOH, 2010

**Note:* *While breathing methane itself does not pose a direct health risk at low levels, methane is a precursor for tropospheric ozone, a health harming air pollutant.*

Methane emissions are one challenge in and symptom of a larger system of global climate change. Climate change impacts around the world are expected to reduce the quality, quantity, and affordability of food, especially in the Global South[21].

- Agriculture, forestry, and other land use has rapidly expanded alongside industrialization, population growth, and global increases in consumption. Agriculture, forestry, and other land use now affects an estimated 70 percent of global ice-free land, leading to methane and GHG emissions as well as ecosystem losses, net soil loss due to erosion, and a decline in biodiversity[22].

- 25-30 percent of global food produce is lost or wasted[23], and the existing food system fails to effectively nourish and feed global populations in a sustainable and healthy manner. The current global burden of malnutrition, in all its forms, includes undernutrition (wasting, stunting, underweight), inadequate vitamins or minerals, overweight, obesity, and diet-related noncommunicable diseases[24]. An estimated quarter (2 billion) of the world currently lacks access to nutritious and healthy food, and 828 million people globally face food insecurity and inadequate nutrition[25].

- Studies have shown that low reproductive efficiency[26], low-quality feed sources, and overgrazed or degraded environments can all significantly increase the enteric fermentation emissions of livestock[27]. East and Sub-Saharan African cattle, for example, have an estimated greenhouse gas emissions intensity (emissions per unit of livestock product) that is four times greater than the global average[28]. This increases the burden of emissions, land degradation, and biodiversity loss that smallholder farmers and pastoral grazing countries produce relative to the protein output.

Solutions to these large-scale challenges require significant, systemic changes to the way communities, countries, and the world structure food systems. Solutions must consider what food sources and methods of production are incentivized or discouraged at each level of policy making, production, distribution, consumption, and disposal. Producing and delivering enough nutritious food to support healthy people around the world must be an ongoing goal.

The solutions and tables below summarize the health co-benefits of methane reduction from technical solutions for agriculture sector leaders and local and regional governments with the expertise, funding, and mandate to implement suggested changes. Not all solutions will be applicable for every context or setting.

Improved **livestock** operations measures taken to mitigate agricultural methane and improve livestock and manure management also provide associated co-benefits to health and methane mitigation:

Topic	Solutions	Climate and Human Health Co-Benefits
Livestock manure management	Effective manure management for improved health and safety, resource recovery, and methane mitigation via: • Aerated composting • Anaerobic digestion, potentially with: o Biogas for energy use o Anaerobic digestion sludge reuse for fertilizer and compost	Reduced odor exposure, reduced infection and disease, and reduced pollution pathways in surface and groundwater.
Livestock: Food supplementation and animal health	Reduce enteric fermentation methane production from existing livestock via: • Silvopastoral systems (integration of forestry and grazing) • Breeding and phenotype selection for animal health, disease and drought resistance, and reproductive success[lii] • Improvements in feed quality and reduction in indigestible contents	Nutritional benefits due to greater productivity of healthier animals.

"North Carolina has two of the leading counties in the world in terms of density of hogs … many folks consider that part of the state to be the hog capitol of the world, and hogs outnumber people about 35 to 1. The other thing to note about North Carolina is that most of the communities that are severely impacted by the industry are lower income communities and communities of color, which constitutes an environmental justice issue in terms of who's most impacted. If there's a [hurricane] or even a heavy rain event, those [manure] holding ponds can overflow … and if those breach, all of that [liquid hog manure] waste can enter into the surrounding environment, and many of the hog facilities are bordering natural bodies of water, so it can enter into surface water, bodies of water which serve as the source of folks' drinking water, [which impacts] water quality and the potential for [exposure] to infectious and other hazardous agents." –Dr. Courtney Woods, University of North Carolina at Chapel Hill, Interview

Livestock is an inefficient way to produce protein and food in relation to its environmental impacts at a global/industrial scale. Reduction of animal products and promotion of plant-rich diets offers a viable and necessary solution for many high-income countries facing challenges with obesity and heart disease. However in some settings, livestock plays an important role in nutrition, and animal products remain an important source of adequate nutrition and household income[29] for many in the Global South and low-income countries, as well as those in isolated rural or nonarable environments, such as parts of Saharan Africa and Arctic regions around the world[30]. Country context, health status, nutritional status, and cultural needs must be considered when mitigation solutions are suggested for a specific individual or group.

Case Study: Solutions for Mitigating Emissions from Brazilian Beef

Brazil is among the world's top five producers of livestock methane emissions, is the leading global exporter of beef[31], and has significant economic investments in the livestock sector.

Industry perceptions of solutions to reduce enteric fermentation in livestock (and thus methane emissions) often cite concerns of decreases in cattle weight so they are not included in government plans for the industry, Sectoral Plan for Climate Change Adaptation and Low Carbon Emissions in Agriculture Seeking Sustainable Development (ABC+). Policies that support dietary changes that would reduce demand for beef and dairy are unpopular with the agricultural industry.

In the short term, successful implementation of improvements in cattle genetics, quality of feed, and grazing quality would provide large benefits to animal health, increase milk production and efficiency, increase farmer revenues, and reduce methane emissions from enteric fermentation[32]. Longer term, even modest reductions in cattle production and consumption would have large global emissions benefits, as Brazil accounts for an estimated 14 percent of the global cattle population (220 million head)[33]. As a complementary measure, successful implementation of Brazil's new Zero Methane Program[34] would utilize manure biogas as an alternative energy source for agriculture.

Case Study: Sustainable Economic Development in Ethiopia

Ethiopia's dairy cattle sector contributes 12-16 percent of national GDP and is primarily operated by small farmers, who are responsible for 98 percent of milk production in the country[35]. The government's Climate-Resilient Green Economy (CRGE) plan aims to improve economic development while reducing GHG emissions and mitigating local climate impacts[36].

Poor quality feed and degraded grazing environments often lead to increased methane emissions from cattle, while the nutritional and economic wellbeing of a growing population in an arid and pastoral environment currently demands continued dairy and beef production for food security until economic and dietary diversification is achieved. Of low-income rural Ethiopians, it is estimated that 80 percent rely on livestock as their primary food and income source[37].

Continued implementation of the national plan described in Ethiopia's NDC to shift from beef to alternative food sources and for improved feeding methods as a methane reduction solution for livestock could improve the situation.

International funding for improvements in grazing environments and sustainable livestock practices could aid emissions reductions and increase yields. Ethiopia and the World Bank's BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL) signed a $40 million emissions reductions purchase agreement (ERPA) in 2023 which will preserve forests for carbon sequestration and improve livestock management in the country's Oromia region[38]. Reductions in slash and burn land clearing and deforestation caused by livestock farming would support national goals as Oromia contains 52 percent of Ethiopia's forests.

Case Study: America's Livestock Methane Challenge

The United States is a major livestock methane emitter and one of the top five nations in the world for livestock methane contributions[39]. While development of new emissions regulations is under way for the oil and gas sector, the US is falling behind peers such as the EU and New Zealand when it comes to agricultural methane regulations.

No mandatory emissions reductions, livestock production limits, or inclusion of agricultural emissions in greenhouse gas emissions pricing policies (schemes to charge emitters for climate pollutants) are currently in place[40], and technology-based reductions (such as improving feed quality to reduce enteric fermentation) undertaken on a voluntary basis alone cannot be sufficiently scaled to address methane as quickly or extensively as needed. Incentives for voluntary reduction are currently limited, and it is estimated that only a mere 2 percent of livestock methane emissions can be abated at zero net cost to producers[41].

In tandem with national and local efforts to improve dietary guidelines and agricultural subsidies in line with healthy, nutritious, and sustainable diets, federal and state governments should consider commitments towards mandatory emissions regulations, including monitoring, reporting, and verification (MRV) and enforcement.

Adoption of all technically feasible mitigation measures (not including dietary change) could reduce the country's livestock emissions by 30% - representing an estimated 56 MtCO2e emissions savings annually compared to baseline[42]. Population-level dietary changes would reduce emissions even further, while also providing enormous health benefits for Americans, such as reduced risk of heart disease, diabetes, and obesity.

Rice production methods which reduce methane emissions also provide co-benefits via reductions in crop residue burning and reduced water usage for cultivation:

Topic	Solutions	Climate and Human Health Co-Benefits
Low-methane rice production techniques	Reduced and/ or interrupted flooding of rice fields can be achieved through either: • One drawdown of water levels during mid-season growth, or via alternating wetting and drying (AWD) techniques, which interrupt soil inundation periodically[43] • Dry seeding and "aerobic rice" solutions, using well-drained soil for growing • Use of phosphogypsum and sulphate additives to inhibit methanogenesis	Reduced flooding solutions minimize freshwater usage for rice production, allowing households, medical facilities, and wastewater facilities to use this water for sanitation, cleaning, cooking, and drinking, resulting in health co-benefits from increased access to safe drinking and sanitation water.
Rice production waste	Reduced field clearing via burning, and use of composting for rice straw crop residues	Reduced crop incineration fires and open burning of waste materials minimizes exposure to fire smoke, which contains black carbon and particulate matter.

Co-benefits of improved **land use** include:

Topic	Solutions	Climate and Human Health Co-Benefits
Agricultural development and land clearing activities	Reduce the climate and health impacts of agriculture, forestry, and other land use and land development via: • Conserving existing natural sources of carbon storage and accelerating the transition to zero deforestation in these environments • Ending land burning and destruction in biomes with existing natural sources of methane to limit exposure of ancient methane to the atmosphere (e.g. peat bogs, wetlands, permafrost) • Implementing alternative grazing methods and silvopastoral techniques to limit land use requirements as a complementary measure during the transition to zero deforestation	• Reduced climate impact of carbon sink loss and overall climate impacts from land use could result in reductions in climate-induced drought events and heat waves[44] and the associated adverse health outcomes of elevated heat and dust (especially on vulnerable populations) such as heat stress and respiratory illnesses._ • Improved growing conditions as a result of better soil health and availability will increase crop yields and nutrition. (Agricultural activities contribute to soil erosion, which is estimated to be 10 to more than 100 times higher than the current soil formation rate[45].)

Reductions in land and crop residue burning will improve health outcomes by reducing air pollution and tropospheric ozone, both locally and globally. This is especially the case for populations that live in areas of high smoke concentrations, such as valleys and basins which see atmospheric inversions that create chronic air quality challenges. Reductions in clearing also offer some level of abatement for wildlife habitat destruction and localized biodiversity loss.

The land needed to raise livestock for food production requires an estimated 77 percent of global farmland — however that land produces just 18 percent of all food calories and 37 percent of all proteins globally[46]. Inefficiencies in land use at a global scale are key factors in global warming, habitat and biodiversity loss, and desertification and drought events.

Currently, the largest one percent of farms globally utilize 70 percent of active farmland[47]. Land use in a re-imagined food system would increase participation of smallholder farmers, Indigenous Peoples, female farmers, and minority groups and enhance their ability to compete and survive in an increasingly globalized agricultural industry. More than 80 percent of all farms are smallholder (less than two hectares), and they produce 35 percent of global food using just 12 percent of all active farmland[48].

Agriculture, Soil Health, and Nutrition

Soil is an important factor to consider, in terms of food production. In addition to its role in habitat formation, water retention, erosion mitigation[49], and carbon sequestration[50], soil is the basis for an estimated 95 percent of all food production globally, and healthy soils are fundamental to food security, human nutrition, and climate[51]. Plants require similar elements for healthy growth as humans do, and by providing a nutrient-rich growing medium, crops grown in healthy soil will contain essential nutrients and minerals required for human health[52].

Regenerative agricultural practices, such as low-till, no-till, and silvopastoral systems, in conjunction with organic resource recovery and soil amendment via composting and digestate (from anaerobic digestion processes) provide opportunity to limit erosion and soil degradation.

According to the UN Food and Agriculture Organization (FAO), sustainable soil management practices alone could increase nutrient rich soils needed for global food production by 58 percent. This is increasingly vital to food security — it is estimated that agricultural production will need to increase by 60 percent by 2050 to feed growing populations[53].

"Soil is one of the most scarce resources in the world right now. We don't realize it, but...it takes hundreds of years [to make], so bringing good organic material back to soils will help with so many issues — soil degradation, deforestation, and desertification." –Aditi Ramola, International Solid Waste Association (ISWA), Interview

Food systems improvement measures taken to reduce methane emissions also provide associated human and environmental health co-benefits:

Topic	Solutions	Climate and Human Health Co-Benefits
Food systems improvements	Reduced emissions from high-methane food sources and production methods by: • Ending subsidies that lower the cost of processed food that is high in sugar, fat, and salt; and promoting plant-rich diets grown in regenerative and equitable systems. • Improvements in solutions to reduce food loss and food waste and promote reuse and recovery of organic resources.	These solutions would result in reduced emissions, abatement of deforestation and land degradation, and improved health outcomes. Currently, global subsidies and trade policies for the food and agricultural sector average almost $630 billion annually, the majority of which support production of rice, sugar, and meats, while simultaneously creating disincentives for fruit and vegetable production[54]. Food loss and waste reductions would reduce overall food systems emissions by virtue of increasing the efficiency of production and consumption. Additionally, initiatives to decrease food waste may provide intrinsic benefits such as improvements in soil health, quantity, and nutrition as a result of composting, and decreased malnutrition among populations receiving food donations as part of food waste reduction initiatives.

Nutritional and dietary guidelines that include plant-rich and low-emissions recommendations offer health benefits such as:

Topic	Solutions	Climate and Human Health Co-Benefits
Nutritional and dietary guidelines adaptations	A nutritious diet is essential for human health and development and can result in improved infant, child, and maternal health outcomes[55]. Adaptations to dietary guidelines should include: • Reduced consumption of meat and dairy diets in high consumption geographies • Policies to increase availability and accessibility of whole food, plant-rich foods for populations without access to nutritious and healthy foods ("food deserts")	Diets lower in animal products can improve human health and nutrition, especially in populations with high cholesterol, obesity, diabetes, and heart conditions associated with high meat and dairy consumption. Plant-rich, whole food diets would improve nutrition and consumption of magnesium, potassium, iron, thiamin, riboflavin, folate, and vitamins[56]. There is evidence that this can improve insulin sensitivity and decrease the need for diabetes medication, improve blood pressure, decrease cardiovascular-related mortality risk, and lead to increased longevity[57]. Decreased consumption and exposure to antibiotics commonly used in meat production may provide benefits to those with digestive or immune system conditions and can reduce antibiotic resistance.

A meta-analysis comparison of cardiovascular disease mortality among vegetarians and non-vegetarians in the United Kingdom, Germany, United States, the Netherlands and Japan found a 29 percent reduction in ischemic heart disease mortality versus non-vegetarians[58].

In concentrated animal feeding operations (CAFOs), liquid manure is often held in unreinforced lagoons and then sprayed back onto fields as an aerosol. This aerosolized fecal matter contains harmful pollutants and odors[59] (ammonia, hydrogen sulfide, methane, and small particulate matter), which can lead to chronic respiratory symptoms and decreased quality of life. Decreased consumption of meat and dairy products improves co-benefits of community and environmental health via reduced exposure pathways for harmful air pollutants present in manure and other animal by-products (Figure 3[60]).

“The single most effective action to reduce emissions is actually through food systems and the consumption of a healthy, sustainable, local diet…A [specific] diet does not apply to every country and every continent, but needs to be further translated to the national context, local culture, and heritage. Analysis [of the Planetary Health Diet] has proven that it would prevent the premature deaths of 11 million adults.”–Dr. Lujain Alqodmani, EAT Forum, Interview

4 Ways Forward: Methane Mitigation Solutions and Health Benefits

To achieve meaningful methane emissions reductions, systemic changes must be made to the food system including agricultural production. For example, many existing dietary guidelines and agricultural subsidies currently promote caloric production over nutrition and good health outcomes, and often prioritize subsidies for meat and dairy production to achieve low consumer prices. In doing so, societies may have access to low prices for subsidized products, but also bear the burden of increased emissions, environmental harms, and health impacts. The industrialization of global food production contributes to such harms, with marginalized and vulnerable communities around the world inequitably burdened. Changes to dietary guidelines that increase access to healthy, nutritional, plant-rich, and low-emission diets must be pursued, for high-income groups to improve health while reducing disproportionate emissions, and for low-income and climate-vulnerable groups to increase food security and food sovereignty[61].

Fortunately, most solutions for methane reduction are simple and cost-effective and can result in land conservation benefits, emissions reductions, and improved health outcomes.

A recent study found that no-cost solutions for livestock methane emissions reduction, such as improved feeding and manure management, could reduce emissions by 2 percent compared to baseline by 2030 and that implementation of all technically feasible solutions, such as selective breeding, could decrease emissions to 30 percent of baseline levels[62]. The same study found that no-cost solutions for rice production, such as improved irrigation methods, could reduce emissions 6 percent from baseline, and that implementation of all technically feasible solutions, including use of hybrid varieties, could decrease emissions to 50 percent of baseline levels. These solutions do not include dietary change; the estimated potential of emissions reductions is even higher when behavioral and societal shifts such as consumption levels and patterns, and dietary access and incentives are considered as part of a holistic mitigation strategy.

In addition to broader changes to the agricultural sector and its priorities, continued complementary measures which offer methane emissions reductions must be pursued. Chief among these is pursuing an aggressive reduction in food waste, in the production and processing steps, as well as at the stage of consumption [refer to the **Waste Sector** report for additional information]. In addition to ensuring proper organic waste management for emissions reductions from food waste, increased efficiency of production and distribution offers massive mitigation potential by making it unnecessary to produce excess food that goes uneaten, thus avoiding all associated emissions.

There is no panacea that offers a single solution to our current crisis, yet there are many options which in conjunction can offer a holistic methane mitigation solution for the sector, while offering important health benefits that would increase health resilience in the context of climate change.

International actions provide opportunity to increase global awareness, financing mechanisms for technical solutions, and policy support from multinational organizations.

- Galvanize existing international action on agricultural methane mitigation and improved food systems by:
  - Include plant-rich diets and agricultural methane abatement goals in country nationally determined contributions (NDC) updates submitted under the Paris Agreement.
  - Build from existing international frameworks, such as the UN Food and Agriculture Organization's (UN FAO) Strategy on Climate Change[63], to include waste reduction, health and nutrition impacts, land use considerations, and other climate and health perspectives.
- Promote sector-specific solutions:
  - Work towards the creation of international policy task forces that support revised and enhanced nutritional polices that promote diets and markets that are: low-emissions, nutritious and healthy, and affordable and accessible.
  - Increase integration of methane emissions reductions, nutrition, and health in the United Nations Framework Convention on Climate Change (UNFCCC) Sharm el-Sheikh Joint Work on Implementation of Climate Action on Agriculture and Food Security[64].

National actions for improved agriculture and food systems offer solutions for national environmental and health agencies, as well as topics to bring to policy makers at the national level.

- Target key data gaps and prioritize mitigation actions:
  - Address the information gap in methane emissions data at the site-level (voluntary or mandated).
  - Prioritize methane reductions in agricultural facilities and concentrated animal feeding operations located near population centers.
  - Develop solutions for investigating and addressing complaints to elevate community health concerns related to food systems and agricultural practices.
  - Elevate information sharing and public awareness of land clearing for agricultural development, especially in areas of high biodiversity, cultural significance for communities, and ecosystems which provide existing carbon storage.
  - Fully implement the Escazu Agreement[65] and similar policies which promote conservation, restoration, and sustainable use of natural resources and secure access to environmental information, community participation, and the human right to a healthy environment.

- Institute policies which improve food systems and agricultural practices:
  - Revise national-level producer and consumer-level subsidies and taxes to improve access to and affordability of nutritious, plant-rich, low-emissions diets.
  - Promote Zero Deforestation measures and legal protections for land, particularly in areas inhabited by Indigenous communities and those under threat from agricultural development.
  - As a complementary measure to dietary change, increase clinical research and raise awareness of existing and suggested livestock health interventions which improve consumer health, farmer livelihoods, and animal wellbeing.
  - Review existing and suggested national food and agricultural policy and action plans (e.g. the U.S. Farm Bill), for opportunities to support climate mitigation, reduced deforestation and land development, and increased access to nutritionally beneficial diets.
  - Exclude food industry and corporate actors from taking part in policy development to set standards for health and nutrition. For example, see the development of Canada's 2019 food guidelines[66]. Regulations to achieve this separation of health policy and business could take inspiration from Article 5.3 of the World Health Organization Framework Convention of Tobacco Control[67].

Case Study: Low-Methane Rice Cultivation Solutions for Vietnam

Vietnam is the fifth largest global emitter of rice cultivation methane emissions, which contribute nearly 60 percent of the country's total greenhouse gas emissions[68], and currently uses 82 percent of arable land and 70 percent of national water resources[69].

Low-methane cultivation solutions, such as alternate wetting and drying (AWD; see **technical solutions** table), have proven potential, but must be implemented at scale to achieve the desired results. Smallholder rice farming is an essential mode of employment for rural populations in South Asia[70], which must be considered in any intervention.

Vietnam could consider building off government commitments to create national-level funding for farmer trainings. Vietnam's National Methane Action Plan aims to end open incineration of agricultural waste and sets a 2030 limit of 30.7 MMTCO2e for rice cultivation and 15.2 MMTCO2e for livestock production. Increased promotion of low-methane solutions via rural organizations and small farmers groups, alongside government policies which provide funding for training may aid in adoption of low-emissions techniques.

Improvements in emissions, reduced crop residue burning after harvests, and reduced water usage can be expected if feasible alternative cultivation measures are introduced. While the current system of inundation uses an estimated 5,000 liters of water for each kilogram of rice yielded[71], adoption of AWD techniques is projected to cut up to 48 percent of methane emissions from rice and reduce irrigation water by 30 percent without sacrificing the crop yield[72].

Local and community actions to address community concerns, reduce health hazards, and improve nutrition and nutritious food access. For example:

- Increase community and patient engagement around nutrition, food access, and the health impacts and benefits of agricultural activity:
  - Promote local policies and actions which provide communities with food sovereignty[73], or the ability to make independent decisions which increase sustainable agroecological practices and soil health, diversify crops, create or improve access to local markets, and support environmental health and justice.
  - Communicate to decision-makers and media outlets about the climate and health impacts of food production sites and concentrated animal feeding operations (CAFOs).
  - Inform patients about the health impacts of agricultural air pollutants and methods to reduce or prevent harm (e.g., solutions to limit exposure).
  - Conduct health screenings in those nearby or working in CAFOs, large-scale manure sites, and land clearing operations.
  - Increase participation of smallholder farmer businesses and of food producers which practice sustainable and regenerative practices. Over 600 million smallholder farmers around the world, including many women and Indigenous Peoples, are excluded from decision making and food policy spaces[74], which narrows policy perspectives and disenfranchises their ability to participate and contribute to all levels of agricultural bills and regulations.
- Advocate for improved agricultural systems with actions such as:
  - Frequent review and consideration of agricultural policies (such as right-to-farm laws), which can limit the ability of communities and health officials to investigate and potentially limit agricultural development or CAFO siting.
  - Assessment of quality of life/ health issues associated with CAFOs.
  - Improve livestock and manure management and health impact mitigation, including measures which support safe and effective collection and use of biogas as an alternative energy source.

"The [community] has been very focused on health and safety and a lot of the [successful] efforts have come as a result of legal action [Title 6 Civil Rights complaints]. So those efforts were to have the EPA get the state to regulate the industry a little more, but also to put in place mechanisms that would ensure that residents who live near there, as well as the state regulatory agency understood what levels of contaminants the facilities are releasing. Up until the Title 6 complaint, there had really been no [air quality or water quality impacts] monitoring requirements. I would not say it has been a success, but having the EPA come down to North Carolina [to investigate Title 6 complaints] has at least elevated the issue to a level which puts a little more pressure on our state agencies and the industry to do better, and has shown the conditions in which residents are being forced to live." –Dr. Courtney Woods, University of North Carolina at Chapel Hill, Interview

"We found out that most subsidies and public finance in certain countries are funding these non-climate-friendly foods. $528 billion is invested in products such as rice, beef, and sugar, instead of fruits and vegetabls. Governments need to integrate food systems into climate plans; as well, they need to integrate climate action into nutrition and food system plans. Right now, food-based dietary guidelines for several countries hardly mention anything about climate...it has to go both ways." –Vivian Maduekeh, Global Alliance for the Future of Food, Interview

5 References

1 GHG emissions by sector, 2020. Climate Watch, the World Resources Institute. Online, accessed July 19, 2023.

2 Tubiello, F. et al 2021. Greenhouse gas emissions from food systems: building the evidence base. *Environ. Res. Lett.* 16 065007. Online, accessed 21 August 2023.

3 Global Methane Pledge, n.d. About the Global Methane Pledge. Online, accessed 1 May 2023.

4 United Nations Environment Programme and Climate and Clean Air Coalition, 2021. The Global Methane Assessment. Online, accessed 1 May 2023.

5 Kanika Khanna, 2022. How Methanogenic Archaea Contribute to Climate Change, American Society for Microbiology. Online, accessed May 1, 2023.

6 Sarah E. Hook, André-Denis G. Wright, Brian W. McBride, 2010. "Methanogens: Methane Producers of the Rumen and Mitigation Strategies", *Archaea*, vol. 2010, Article ID 945785, 11 pages. Online, accessed 1 May, 2023.

7 Searchinger, Tim and Adhya, Tapan K., 2014. World Resources Institute. Wetting and Drying: Reducing Greenhouse Gas Emissions and Saving Water from Rice Production. Online, accessed May 1, 2023.

8 Mbow, Cheikh et al, 2019. IPCC Special Report on Land and Climate Change. Chapter 5: Food Security. Online, accessed 1 May , 2023.

9 Poore, J., & Nemecek, T., 2018. Reducing food's environmental impacts through producers and consumers. Science, 360(6392), 987-992. Online, accessed 1 May 2023.

10 Germer, J., and Sauerborn, J., 2007. Estimation of the impact of oil palm plantation establishment on greenhouse gas balance. *Environ. Dev. Sustain.* 10, 697–716. Online, accessed May 1 2023.

11 Croezen, H. J., Bergsma, G. C., Otten, M. B. J., and Valkengoed, M. P. J. V., 2010. Biofuels: indirect land use change and climate impact. Online, accessed 1 May 2023.

12 de Souza, S. P., Pacca, S., de Ávila, M. T., and Borges, J. L. B., 2010. Greenhouse gas emissions and energy balance of palm oil biofuel. *Renew. Energy.* 35, 2552–2561. Online, accessed 1 May 2023.

13 Carlson, K. M., Curran, L. M., Asner, G. P., Pittman, A. M. D., Trigg, S. N., & Marion Adeney, J., 2013. Carbon emissions from forest conversion by Kalimantan oil palm plantations. *Nature Climate Change*, *3*(3), 283-287. Online, accessed 1 May 2023.

14 UN FAO, 2011. Global Food Losses and Food Waste. Online, accessed 22 Aug 2023.

15 Public Health England, 2019. Compendium of Chemical Hazards: Methane. Online, accessed 1 May 2023.

16 Voulgarakis, A., Field, R.D., 2015. Fire Influences on Atmospheric Composition, Air Quality and Climate. Online, accessed 1 May 2023.

17 Holm, S.M., Miller, M.D. & Balmes, J.R., 2021. Health effects of wildfire smoke in children and public health tools: a narrative review. *J Expo Sci Environ Epidemiol* **31**, 1–20 (2021). Online, accessed 7 June 2023.

18 Holm, S.M., Miller, M.D. & Balmes, J.R., 2021. Health effects of wildfire smoke in children and public health tools: a narrative review. *J Expo Sci Environ Epidemiol* **31**, 1–20 (2021). Online, accessed 7 June 2023., Voulgarakis et al, 2015.

19 Miller MD, Marty MA., 2010. Impact of environmental chemicals on lung development. Environ Health Perspect. 2010 Aug;118(8):1155-64. Online, accessed 7 June 2023.
20 Carrie Hribar,2010. National Association of Local Boards of Health. Understanding Concentrated Animal Feeding Operations and Their Impact on Communities. Online, accessed 1 May 2023.
21 Marco Springmann, Daniel Mason-D'Croz, Sherman Robinson, Tara Garnett, H Charles J Godfray, Douglas Gollin, Mike Rayner, Paola Ballon, Peter Scarborough,2016. Global and regional health effects of future food production under climate change: a modelling study. The Lancet, Volume 387, Issue 10031,2016. Online, accessed 12 July, 2023.
22 Mbow, Cheikh et al, 2019. IPCC Special Report on Land and Climate Change. Chapter 5: Food Security. Online, accessed 1 May, 2023.
23 Mbow, Cheikh et al, 2019. IPCC Special Report on Land and Climate Change. Chapter 5: Food Security. Online, accessed 1 May, 2023.
24 World Obesity Atlas 2023, 2023. World Obesity Federation. Online, accessed 1 May, 2023.
25 UN FAO, 2022. The State of Food Security and Nutrition in the World, 2022. Online, accessed 1 May, 2023.
26 UN FAO & New Zealand Agricultural Greenhouse Gas Research Centre, 2017. Supporting low emissions development in the Ethiopian dairy cattle sector — reducing enteric methane for food security and livelihoods. Online, accessed 1 May, 2023.
27 Balehegn M, Kebreab E, Tolera A, Hunt S, Erickson P, Crane TA, Adesogan AT., 2021. Livestock sustainability research in Africa with a focus on the environment. Anim Front. 2021 Sep 6;11(4):47-56. Online, accessed 1 May, 2023.
28 Pressman et al, 2018. Mitigation of Enteric Methane Emissions from Dairy Cattle in East Africa through Urea Treatment of Crop Residue Feeds. American Geophysical Union Annual Meeting, 2018. Online, accessed 1 May, 2023.
29 T. F. Randolph et al, 2007. Invited Review: Role of livestock in human nutrition and health for poverty reduction in developing countries. Journal of Animal Science, Volume 85, Issue 11. Online, accessed 12 July, 2023.
30 Reynolds LP, Wulster-Radcliffe MC, Aaron DK, Davis TA, 2015. Importance of Animals in Agricultural Sustainability and Food Security. The Journal of Nutrition, Volume 145, July 2015. Online, accessed 12 July, 2023.
31 EMBRAPA, 2021. Brazil is the world's fourth largest grain producer and top beef exporter, study shows. Online, accessed 1 May 2023.
32 Project Drawdown, Undated. Climate Solutions: Improved Cattle Feed. Online, accessed 12 July, 2023.
33 Charles River Associates, 2022. The impact of the global methane pledge on the Brazilian beef industry. Online, accessed 1 May 2023.
34 Government of Brazil, 2022. The National Zero Methane Program, Online, accessed 1 May 2023.
35 FAO & New Zealand Agricultural Greenhouse Gas Research Centre, 2017. Supporting low emissions development in the Ethiopian dairy cattle sector — reducing enteric methane for food security and livelihoods. Online, accessed 1 May 2023.
36 Federal Democratic Republic of Ethiopia, 2021. Updated Nationally Determined Contribution. Online, accessed 1 May 2023.
37 Mihret, T., Mitku, F., Guadu, T., 2017. Dairy Farming and its Economic Importance in Ethiopia: A Review. World Journal of Dairy & Food Sciences, Issue 12, 2017. Online, accessed 12 July, 2023.

38 The World Bank, 2023. World Bank and Ethiopia Sign $40 Million Agreement to Cut Carbon Emissions Through Sustainable Landscape Management. Online, accessed 1 May 2023.
39 U.S. EPA, 2019. Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation Potential: 2015-2050. Online, accessed 1 May 2023.
40 Patricia Fisher, 2022. The 'Dark Horse' of Climate Change: Agricultural Methane Governance in the United States and Canada. Online, accessed 1 May 2023.
41 Ilissa B. Ocko et al., 2021. Acting Rapidly to Deploy Readily Available Methane Mitigation Measures by Sector Can Immediately Slow Global Warming. Environmental Research Letters 16 (5): 054042, 2021. Online, accessed 1 May, 2023.
42 U.S. EPA, 2019. Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation Potential: 2015-2050. Online, accessed 1 May 2023.
43 Searchinger, Tim and Adhya, Tapan K., 2014. World Resources Institute. Wetting and Drying: Reducing Greenhouse Gas Emissions and Saving Water from Rice Production. Online, accessed 1 May, 2023.
44 Mbow, Cheikh et al, 2019. IPCC Special Report on Land and Climate Change. Chapter 5: Food Security. Online, accessed 1 May 2023.
45 Mbow, Cheikh et al, 2019. IPCC Special Report on Land and Climate Change. Chapter 5: Food Security. Online, accessed May 1, 2023.
46 Health and Climate Network, 2023. Diverse, healthy diets for all: How a focus on healthy diets can transform food systems and climate action. Online, accessed 1 May 2023.
47 Sarah K. Lowder, Marco V. Sánchez, Raffaele Bertini, 2021. Which farms feed the world and has farmland become more concentrated?, World Development, Volume 142, 2021. Online, accessed 1 May 2023.
48 Sarah K. Lowder, Marco V. Sánchez, Raffaele Bertini, 2021. Which farms feed the world and has farmland become more concentrated?, World Development, Volume 142, 2021. Online, accessed May 1 2023.
49 Brevik, E. C., 2013. The potential impact of climate change on soil properties and processes and corresponding influence on food security. *Agriculture* 3. Online, accessed June 7, 2023.
50 Silver WL, Perez T, Mayer A, Jones AR., 2021. The role of soil in the contribution of food and feed. Philos Trans R Soc Lond B Biol Sci. 2021. Online, accessed June 7, 2023. Silver WL, Perez T, Mayer A, Jones AR., 2021. The role of soil in the contribution of food and feed. Philos Trans R Soc Lond B Biol Sci. 2021. Online, accessed 7 June 2023.
51 UN FAO, 2015. Healthy soils are the basis for healthy food production. Online, accessed 1 May 2023.
52 Combs Jr, G. F., 2005. Geological impacts on nutrition. Essentials of Medical Geology, 2005. Online, accessed 7 June 2023.
53 UN FAO, 2015. Healthy soils are the basis for healthy food production. Online, accessed 1 May 2023.
54 FAO, IFAD, UNICEF, WFP and WHO, 2022. The State of Food Security and Nutrition in the World 2022: Repurposing food and agricultural policies to make healthy diets more affordable. Online, accessed 12 July 2023.
55 Willett, W., Rockstrom, J., et al, 2019. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. The Lancet Commissions, Volume 393, Issue 10170, February 2019. Online, accessed July 12, 2023.
56 Farmer B, Larson BT, Fulgoni VL, 3rd, Rainville AJ, Liepa GU., 2011. A vegetarian dietary pattern as a nutrient-dense approach to weight management: an analysis of the national health and nutrition examination survey 1999–2004. *J Am Diet Assoc.* 2011 Jun;111(6):819–27. Online, accessed 1 May 2023.

57 Tuso PJ, Ismail MH, Ha BP, Bartolotto C., 2013. Nutritional update for physicians: plant-based diets. Perm J. 2013 Spring;17(2):61-6. Online, accessed 1 May 2023.
58 Huang T, Yang B, Zheng J, Li G, Wahlqvist ML, Li D., 2012. Cardiovascular disease mortality and cancer incidence in vegetarians: a meta-analysis and systematic review. *Ann Nutr Metab*. 2012;60(4):233–40. Online, accessed 1 May 2023.
59 Heederik, D., Sigsgaard, P., Thorne, P., et al, 2007. Health Effects of Airborne Exposures from Concentrated Animal Feeding Operations. Environmental Health Perspectives, Volume 115, February 2007. Online, accessed 12 July 2023.
60 Carrie Hribar,2010. National Association of Local Boards of Health. Understanding Concentrated Animal Feeding Operations and Their Impact on Communities. Online, accessed 1 May 2023.
61 Health and Climate Network, 2023. Diverse, healthy diets for all: How a focus on healthy diets can transform food systems and climate action. Online, accessed 1 May 2023.
62 Ilissa B. Ocko et al., 2021. Acting Rapidly to Deploy Readily Available Methane Mitigation Measures by Sector Can Immediately Slow Global Warming. Environmental Research Letters 16 (5): 054042, 2021. Online, accessed May 1, 2023.
63 Food and Agriculture Organization of the United Nations, 2022. FAO Strategy on Climate Change: 2022-2031. Online, accessed 1 May 2023.
64 UNFCCC, 2023. Sharm El Sheikh Joint Work on Implementation of Climate Action on Agriculture and Food Security. Informal note by the cofacilitators on the elements of the Joint Work. Online, accessed 12 July 2023.
65 United Nations Economic Commission for Latin America and the Caribbean, Undated. Regional Agreement on Access to Information, Public Participation, and Justice in Environmental Matters in Latin America and the Caribbean. Online, accessed 12 July 2023.
66 CBC News, 2019. New food guide unveiled without food groups or recommended servings. Online, accessed 23 May 2023.
67 Health and Climate Network, 2023. Diverse, healthy diets for all: How a focus on healthy diets can transform food systems and climate action. Online, accessed 1 May 2023.
68 International Rice Research Institute (IRRI), Undated. GHG Mitigation in Rice, Online, Accessed 1 May 2023.
69 International Rice Research Institute (IRRI), Undated. GHG Mitigation in Rice, Online, Accessed 1 May 2023.
70 Sazzadul Hassan, 2022. The Daily Star. The rice economy. Online, accessed 1 May 2023.
71 Climate and Clean Air Coalition (CCAC), Undated. Reducing methane emissions from paddy rice in Bangladesh. Online, accessed 1 May 2023.
72 International Rice Research Institute (IRRI), Undated. GHG Mitigation in Rice, Online, Accessed 1 May 2023.
73 SeedChange, 2023. Food sovereignty. Online, accessed 12 July 2023.
74 SeedChange, 2023. Food sovereignty. Online, accessed 12 July 2023.

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