Practical strategies to mitigate ruminant greenhouse gas emissions

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Abstract

Livestock contributes to 14.5 percent of global greenhouse gas emissions, with ruminants being the largest contributor through enteric methane emissions. Although several mitigation strategies are available to reduce livestock methane, no consensus exists on which methods are the most effective. Here, the mitigation impact of the most pragmatic strategies to reduce enteric methane has been projected to 2050, using cattle emissions as a model. The projection shows that supplementing ruminant feed with anti-methanogenic seaweed and converting grassland into silvopasture offer the greatest potential to reduce emissions. With a synergic combination of strategies, the livestock sector in Europe and most of Asia can reach carbon neutrality by 2035 and 2038, respectively. However, global cattle CO_2-eq emissions will be reduced by no more than 34 percent by 2050, remaining far above the carbon neutrality target.

Mitigation strategies alone are insufficient to lower emissions, and reducing the demand for ruminant products is also necessary – particularly in Africa and Western Asia.

Main

A key target to minimise the impact of the climate crisis on global ecosystems and human economies is to reach carbon neutrality by 2050[1]. For this, reductions to near-zero emissions of carbon dioxide (CO_2) and non-CO_2 greenhouse gas (GHG) are necessary[1]. The livestock sector, which accounts for 14.5 percent of total anthropogenic emissions, generates methane – one of the most potent GHGs and a significant driver of climate change[2,3]. Archaea communities in the rumen of cattle, sheep, goats, and other ruminants produce methane during enteric fermentation, in an amount equivalent to 4.6 gigatonnes of CO_2 emissions annually[2,4]. Livestock husbandry additionally impacts natural resources during animal feed production, grassland use and the life-cycle of animal products[5-7].

With the human population projected to increase from its current 7.8 to 9.7 billion by 2050, and the global demand for animal products expected to double over the same period, reductions of livestock GHG emissions remain defiant to mitigation goals[8-10]. If GHG emission rates continue their rapid growth, the current climate crisis will be exacerbated[2]. Execution of strategies to reduce GHG emissions is needed now to balance demands on food security and environmental preservation[7,11-13].

Several GHG mitigation strategies are available for ruminant enteric methane, and their feasibility varies with the geographical distribution of natural and economic resources[2,7,11]. Although some strategies are already in place, implementation of others lags behind despite their strong data-backed mitigation potential[14-16]. This delay is due in part to the economic inequality that impedes widespread research on ruminants. Such research requires long experimental timescales and a holistic understanding of their implications on ruminant subjects, the environment and human health.

Here, we use cattle to model ruminant CO_2-eq emissions and project the mitigation effect of existing strategies to improve animal productivity and grassland-management. Among the available mechanisms to reduce ruminant GHG emissions, we focus on replacing regular animals with low-methane genotypes, grassland conversion to silvopasture, and methods to inhibit methane production in the rumen. Our projection indicates that global suppression of enteric methane emissions is not possible between by 2050, but mitigation can drastically reduce emission intensity (Figure 1). The projection is based on historical data from 1990 to 2017 from global cattle stocks, enteric methane CO_2-equivalent (CO_2-eq) emissions, and CO_2 emission from ruminant grasslands by area. Data come from the Statistical Database of the Food and Agriculture Organization of the United Nations (FAOSTAT), and exclude GHG emissions from other livestock life-cycle steps.

Breeding genetically advantageous ruminants

Microbial communities ferment plant biomass in the rumen[17]. In this process, hydrogen and CO_2 can be converted into nutrients by beneficial bacteria, or into methane by methanogenic archaea[18]. Methane production uses 2-12 percent of the gross dietary energy and represents a substantial metabolic lost to the ruminant[19,20]. Some animals have genetic traits that can reduce enteric methane emissions by favouring beneficial microbial communities[21] or increasing animal productivity per feed unit[20,22]. Replacing regular with more efficient ruminants (low-methane genotypes) is a strategy that benefits both the environment and the ruminant economy[19,20].

Programs to gather ruminant genetic resources and promote selective breeding are already in place worldwide, from single-country programs in Australia and Latin America to multinational programs in Africa and Europe[23-28]. Nevertheless, ruminant breeding is a slow and expensive process that can take decades before establishing a particular genotype[29-32]. Moreover, breeding must consider region-specific factors, as breeding developments suitable for one region will likely not be implementable worldwide[22,33]. Capital-intensive husbandry systems have been successfully breeding beneficial genetic traits. For instance, in the Australian Northern Territory, replacing foreign English Shorthorn cattle with a locally adapted breed improved animal productivity, mitigating 43 percent of methane emission per tonne liveweight[30,34]. Similar capital-intensive breeding projects funded by national initiatives are in place in other regions such as Europe and South America[29,35-37].

In labour-intensive and less economically successful systems, as are found in Eastern Africa, ruminant breeds are selected for their adaptation to the environment (sparse grassland, heat, local diseases) rather than for their productivity[34,38-41]. While efforts have been made to increase productivity by crossbreeding local with foreign breeds, most attempts lack scientific rigour and ignore the limitations of the foreign animals to adapt in the new environments[38,41,42]. Community or farm-based breeding is a rapid alternative to centralised national or regional breeding strategies, nevertheless few farms – often located in developed countries, can afford comprehensive research facilities for selection of low-methane ruminants[32,41,43,44]. Although individual farms or independent funding sources (e.g. African Dairy Genetics Gain Program[45]) can finance local breeding, extensive ruminant replacement with efficient breeds requires long-term commitments from governments[46].

Complex genetic interactions limit extrapolation from local breeding advances as a global mitigation strategy of enteric methane emissions[22,33,47]. For cattle, the available breeding mitigation potential reduces only 11 percent methane per efficient animal[22]. Taking an optimistic projection of current cattle breeding developments, we estimate that Europe, Oceania and the Americas can successfully introduce locally selected breeds by 2030. Most of Asia will reach this goal by 2035, and Western Asia and Africa by 2040 (Figure 2). As the execution of such measures will take at least a decade, current research efforts to select low-methane breeds could mitigate only 6.6 percent of global enteric methane emissions between 2020 and 2050 (Table 1 and Figure 2).

Improving feeding practices

Improvements in production practices and favouring quality feed can substantially reduce GHG emissions from ruminant feed production[6,48-53]. Ruminant diets range from free-grazing on low-nutritional pasture to stall-feeding on horticulture produce of higher nutritional quality[5,48-50,54]. The preference of one feeding practice over another depends on environmental and economic feasibility and the physiological state of the animal[55]. For instance, beef cattle farming in temperate climates synchronises animal reproduction to pasture seasonality, allowing calves to feed on grass; in contrast, intermediate and mature animals are fed on high-quality fodder to gain weight before slaughter[55-57].

Quality feed has a higher protein content and requires minimal fermentation, resulting in higher animal productivity and lower intensity of methane emissions[49,50,54]. Nevertheless, ruminant feed production strongly impacts the environment, promoting degradation of natural carbon sinks[2,6,58]. A common practice to overcome feed production limitations is recycling molasses, straws and grains otherwise discarded[59-61]. However, such agricultural by-products are highly fibrous, require longer fermentation and foment methane production[54,59,61]. The nutritional content can improve by degrading by-products cellulose before feeding ruminants; however, this process increases feeding costs[62-66].

Conversion to silvopasture

Adoption of more efficient land-use practices by converting pasture into silvopasture is another strategy to overcome ruminant feed production limitations and mitigate GHG emissions[51,67,68]. Silvopasture introduces trees and shrubs within the pasture grassland, securing quality feed all year round in tropical and subtropical latitudes[53,67]. Leguminous, high-quality grasses and other silvopastoral plants are rich in tannins and saponins – metabolites that inhibit methanogenic populations in the rumen, improve nutrient absorption and reduce methane emissions[69-72]. Although these metabolites can induce toxicity from an overdose, *ad libitum* foraging does not pose a risk of excessive dosing, as ruminants occasionally feed on tannin-rich plants to reduce or prevent parasites [70,73-76]. Finally, silvopasture provides additional environmental benefits such as atmospheric CO_2 capture from increased plant biomass production, soil recovery, water retention and increases in biodiversity[51-53,67].

The potential benefits of conversion to silvopasture vary among regions due to differences in climate, humidity, and soil type (Supplementary Table 1). Tropical latitudes hold a potential transformation of 45 to 85 percent of current ruminant grassland area, while 29 percent of the global ruminant grassland could be converted into silvopasture. No conversion is effective in arid regions in North Africa and the Middle East due to their climatic limitations. According to our modelling of soil carbon stock changes using the FAO Ex-Ante Carbon-balance Tool (EX-ACT), silvopasture systems can cut the GHG emissions related to ruminant grazing grassland after the first year of conversion. Over a 30-year projection, silvopasture can capture globally 3.8 times more CO_2 -eq than grassland without conversion (Table 1).

Although silvopasture has a higher return rate and net value than pasture, conversion requires a large capital investment with a payback period of around four years[77]. Government support and incentive payments can motivate farmers to adopt silvopasture systems[68,78,79]. Silvopasture establishment and maintenance cost US$3,129 ha^{-1} over 30 years but generates revenue of US$7,165 ha^{-1} (United States estimation from 2012; includes property taxes, forage and timber revenue)[80]. Besides, successful silvopasture conversion reduces husbandry labour costs, increases animal productivity by introducing high-protein plants and shade value, diversifies farm income sources, and provides invaluable ecosystem benefits[51,68,81].

Inhibition of methanogenic communities in the rumen

Removal of methanogenic communities in the rumen using antibiotics has been a common strategy to reduce enteric methane emissions[54]. However, this strategy is falling out of favour due to significant concerns over antibiotic resistance, antibiotic contamination in the environment, and the potential transfer of bioaccumulated compounds from animal products to humans[54,70,82-85]. Legislations worldwide ban antibiotics of importance for human health to promote animal growth, restricting their use exclusively for veterinary purposes[70,86-94]. In the search for alternatives to inhibit enteric methanogens, vaccines could trigger ruminant immune responses against certain strains of methanogens[95-100]. Since the core microbiome is inheritable and methanogens seem highly conserved across ruminants, vaccines targeting dominant methanogens could facilitate broad immunisation and potentially reduce enteric methane emissions[21,101-103].

Methanogens attached to the cilia of enteric protozoa can be indirectly removed if protozoa are removed from the rumen[104]. Although protozoa removal can reduce up to 42 percent of methane emissions in cattle[105], defaunation also disturbs beneficial microorganisms, impairing digestion and animal performance[106-110]. Despite being among the oldest proposed enteric methane mitigation strategies, defaunation requires complex experimental procedures (i.e. isolation of newborns, or fistulating adults) and no practical and sustainable method is available[104,107,108,111].

Other strategies focus on inhibiting methane production rather than eliminating the methanogens. Examples include probiotics, digestibility enhancers and chemical or natural supplements that alter methanogenesis[18,66,70,87]. Probiotics are a promising method for methane reduction where beneficial fungi and bacteria compete against methanogens for hydrogen sources to form propionate[18,112]. Contrary to methane released to the environment, propionate is metabolised, favouring glucogenesis and increasing animal production[18,113,114].

Available studies analysing the effect of probiotics on enteric methane production show contradictory results, and further research on probiotic strains is needed[63,112,115-117].

Plant oils are natural additives that facilitate digestion, inhibit feed protein degradation, reduce enteric microbial populations, and dehydrogenate ruminal fermentation pathways[54,70,74,118-121]. The capacity for enteric methane reduction depends on the type of plant oil, the ratio of oil to feed, the diet, and the animal species[54,74,119,122]. For instance, seven percent of coconut oil added to a diet of hay and concentrate reduces up to 63 percent of sheep methane emissions[74,123]. Practical methane reductions by plant oil additives range between 10-32 percent, as higher oil proportions affect feed intake, digestibility and animal productivity[65,74,119,124]. However, the extraction of plant oils is expensive, and other additives can offer similar methane mitigation levels for a lower cost[70,74].

Widely used chemical additives (urea, nitrate, sulfate, halogenated compounds) can act as high-potential electron acceptors, redirecting hydrogen to propionic fermentation and disrupting methanogenesis[54,114,125-128]. Halogenated compounds have strong anti-methanogenic potential. Bromochloromethane (BCM) used as a feed additive interferes with cobalamin (vitamin B12) – a hydrogen donor, disrupting with methane production[129]. BMC exhibits low toxicity risk, no bioaccumulation in animal tissue, and reduced up to 91 percent of ruminant methane production[125,128,130-132]. However, the Montreal Protocol restricts industrial production of BCM due to a significant ozone-depletion potential[133].

Naturally occurring halogenated compounds present a lower environmental risk to reduce rumen emissions[130]. Plankton and seaweed produce BMC and bromoform to protect against predators and harmful hydrogen peroxides in the cells[134,135]. Bromoform does not bioaccumulate in the food chain and is not classifiable as a human carcinogen[136-138]. It has been shown, for example, that after two years of daily gavage ingestion (<200 mg/kg), bromoform displayed little carcinogenicity in rats (0.5-4%; n=50)[139]. Supplementing ruminant feed with bromoform-rich seaweed inhibits methanogen growth, consequently promoting propionate production[140]. Seaweed of the genus *Asparagopsis* added in 0.2 to 3 percent to a grass diet can reduce methane emissions up to 98 percent in cattle and sheep[55,141,142]. The use of bromoform-rich seaweed as an anti-methanogenic strategy also increases animal productivity in weight gain without affecting animal health or meat quality[141]. *Asparagopsis* is traditionally used in the Hawaiian cuisine without affecting human health[143].

Before slaughter, intermediate and mature cattle feed on high-quality fodder supplemented with nutrients to increase final animal product[56]. Based on an average lifespan of 420 days for beef cattle[56], we estimate that 11 kg of anti-methanogenic *Asparagopsis* can be supplemented on fodder during 36 percent of the animal lifespan (see Methods). Considering a mitigation effect of 98 percent reduction of enteric methane per animal[141], seaweed at 2 percent feed supplement can reduce 320 Tg of CO_2 -eq emissions from cattle – almost half of the current global enteric methane emissions. Overall, 35.6 percent fewer emissions will be generated compared to a business-as-usual scenario (Figure 2). Widespread commercialisation of seaweed as a feed supplement can be available as early as 2022[55].

Feasibility and mitigation impact

There is no single solution to reduce GHG emissions, and a synergic combination of mitigation methods is required to slow rates of ruminant enteric methane emissions (Figure 3). Although mitigation feasibility depends on economic and environmental resources by region, the focus should be on the strategies with immediate implementation potential. Due to differential research and technological maturity of the strategies described above, heterogeneous implementation could yield immediate benefits, as some of the most effective mitigation strategies already exist, but are not yet deployed at scale.

Regional genetic research and breeding programs are necessary to select highly-productive animals with lower methane-emission intensity[20,47]. However, we show that in comparison to feeding supplements and silvopasture conversion, breeding as a global strategy to mitigate ruminant enteric methane emissions is not feasible in the short term and will not lead to a significant mitigation impact. Based on existing developments, a global replacement of regular cattle with low-methane animals will mitigate 1,943 Tg CO_2-eq emissions by 2050, representing only a 6.6 percent reduction of the current rate of cattle emissions (Table 1 and Figure 2).

Our analyses indicate that using anti-methanogenic seaweed as a feed supplement and silvopasture conversion hold the greatest impact on emissions reduction, providing benefits that no other strategies permit. Seaweed and silvopasture plants not only disrupt enteric methane production and convert atmospheric CO_2 into biomass, but offer sustainable production pathways with much lower life-cycle emissions. Favouring seaweed and silvopasture eases pressure on land and water resources, in addition to holding a carbon farming potential to offset the emissions from ruminant husbandry (Figure 3)[144].

Worldwide conversion of 1.2 million hectares of grassland into silvopasture would have a net carbon sequestration balance of 0.34 Tg CO_2 captured after the first year of conversion. From 2045 onward, silvopasture carbon storage potential would reach a plateau, capturing 102.3 Tg

CO_2 annually (Supplementary Table 2). Such carbon capture is equivalent to 13 percent of current global cattle CO_2-eq emission. Immediate conversion to silvopasture, and supplementation of anti-methanogenic seaweed in feed, could mitigate up to 46 percent of the annual cattle CO_2-eq emissions – avoiding 9,082 Tg CO_2-eq emissions between 2020 to 2050.

A reduction in cattle demand is also necessary

Our analysis assumes no trend changes in the increasing demand for cattle consumption. Modelling mitigation strategies for enteric methane emissions shows that carbon neutrality by 2050 is possible only if there is a slowdown of the growth rate of cattle consumption. Changes in per capita meat consumption in Europe and Central to Eastern Asia, combined with policy mitigation efforts, lower current ruminant GHG emissions[10]. Mitigation strategies in those regions can sharpen this trend, potentially reaching carbon neutrality by 2035 and 2038, respectively (Figure 2). Nevertheless, the demand for ruminant products in developing countries will rise continuously due to population growth and increasing per capita meat purchasing power[9]. Without mitigation, global enteric methane emissions will increase steadily – particularly in Africa, Southern and Western Asia (Figure 2). Implementation of mitigation strategies can reduce emissions intensity, returning to pre-1990 levels of ruminant methane emissions, but this is only a 34% reduction over 2017 emissions level (Figure 2). However, our results indicate that mitigation strategies alone are insufficient to achieve low enteric methane emissions, and a reduction of the demand for animal products is also necessary. *Sustainable* production of livestock cattle at a global scale does not seem possible, and further strategies such as alternative meat production (for example, cultured meat) are necessary.

Methods

Data source

Historical data by country from 1990 to 2017 come from the FAOSTAT database of the Food and Agriculture Organization of the United Nations (FAO, http://www.fao.org/faostat/en/#data, accessed in June 2020). Data included carbon equivalent (CO_2-eq) emissions from cattle enteric methane, cattle stocks (head and tonnes of production), and carbon balance of ruminant grazing grassland by area. To facilitate carbon balance analyses of silvopasture conversion, FAO data were grouped into nine regions based on similarities in soil type and climate regime, following the global distribution of climate zones from the Intergovernmental Panel on Climate Change (IPCC, Supplementary Table 1).

Carbon balance from silvopasture conversion

We used the Grassland Livestock module of the FAO EX-Ante Carbon-balance Tool (EX-ACT version 8.5.6)[145] to analyse soil carbon stock balance. We estimated the potential global area to be converted from pasture to silvopasture using the 2017 FAO data for grazing grassland with organic soil area. We considered the rough regional percentage of area with a suitable IPCC climate for growing silvopasture trees and shrubs. Proper conversion can be possible in regions either with areas holding a tropical to warm temperate climate, moist to wet humidity and with any soil type; or in areas holding a cool temperate and moist regime with a low activity clay soil type (Supplementary Table 1). Using the area percentage and regional environmental descriptors (Supplementary Table 1), we analysed the soil carbon stock balance for a 30-year silvopasture projection allowing an implementation phase of five years. EX-ACT estimates, among others, the carbon stock changes (Tg CO_2-eq) from land-based projects using IPCC Tier 1 methodology for GHG inventories[145]. Projected soil carbon balance reflects the net emissions differences between a business-as-usual scenario versus converting grassland into silvopasture. *Moderately Degraded* and *Improved with inputs improvement* were selected as the initial and final state of the project, respectively. Supplementary Table 1 reports descriptors of climate, moisture regime and dominant soil type input in EX-ACT.

Supplement potential on cattle fodder

Environmental factors influence decision-making on whether to feed cattle by free-grazing on pasture or in feedlots. We estimated that cattle feed on fodder during 36 percent of their lifespan, for approximately 420 days[56]. During the cow-calves operation, young animals graze freely on pasture for nine months without supplement options; for the remaining five months (150 days) before slaughtering, animals are intensively fattened up with a high-quality feed that can be supplemented with bromoform-rich seaweed[56,57]. Assuming that seaweed supplements reduce 98 percent of enteric methane per animal[141], the mitigation effect would account for an annual reduction of 35.6% enteric emissions in the cattle sector.

Data analyses

The historical data from cattle enteric methane CO_2-eq and grassland CO_2 emissions were used to project 2018-2050 emissions data in a business-as-usual scenario. First, we calculated the historical trend averaging the moving trends from 1991-2017. Moving trends were obtained with the formula $Trend_n = Year_n * 100/\ Year_{n-1}$, where $Year_n$ indicates emissions in 1991. Then, we projected annual emissions using the formula $Year_{n+1} =\ Year_n * (Historical\ trend/100)$, with $Year_{n+1}$ indicating emissions for 2018.

Based on the business-as-usual projections, we projected the mitigation effect for each strategy. Using seaweed supplements, we mitigated 35.64 percent emissions starting in 2022. Using efficient animals, we mitigated 11 percent beginning in 2030 in Europe, Oceania and the Americas; in 2035 in Asia (excluding Western Asia); and in 2040 in Western Asia and Africa. Emissions using a synergic combination of all the strategies were calculated summing up the annual silvopasture carbon stock changes with the yearly mitigation of 35.64 or 46.64 percent emissions, according to the year of implementation. All data are expressed in Tg CO_2-eq.

Data availability

All data used in this study are publicly available in the FAOSTAT database (http://www.fao.org/faostat/en/#data). Projection of enteric methane emissions and silvopasture carbon balance using EX-ACT estimations are available in the Supplementary Table 2.

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Figures and Table

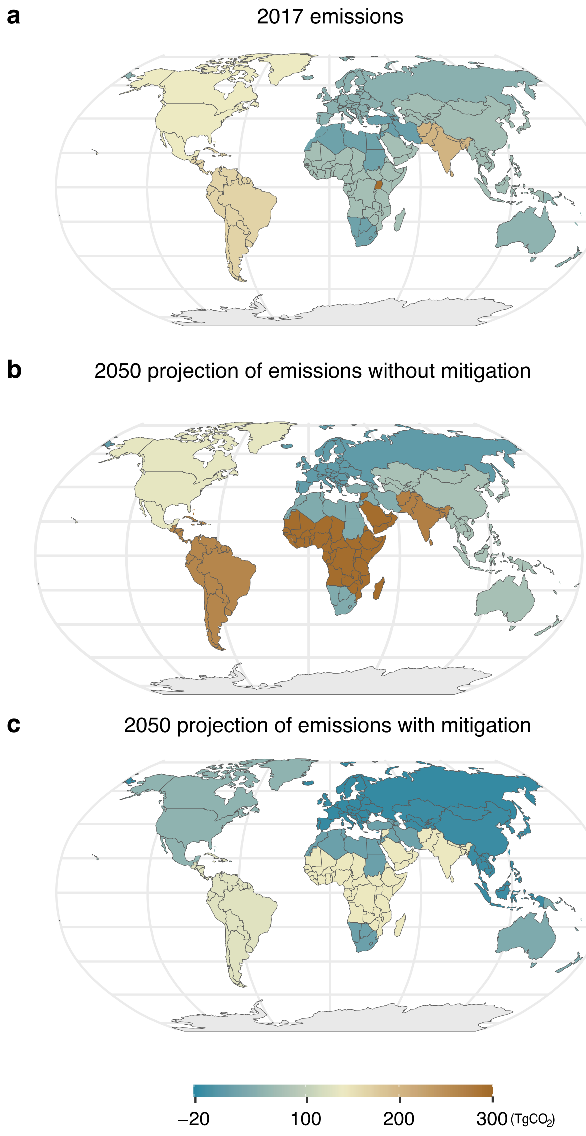

Figure 1 | Cattle-related enteric methane and CO_2 emissions from grassland grazing by country. **a**, Current emissions. **b**, emission by 2050 in a business-as-usual scenario. **c**, 2050 projection of emissions with a synergistic combination of the most practical mitigation strategies available: replacing regular breeds with genotypes for low-methane emissions, use of anti-methanogenic seaweed as feed supplement, and grassland transition to silvopasture. Under a mitigation scenario, Europe and most of Asia would reach carbon neutrality, in addition to offering carbon sequestration in soil and plant biomass from silvopasture systems (negative values in the carbon stock balance; Tg CO_2 equivalent).

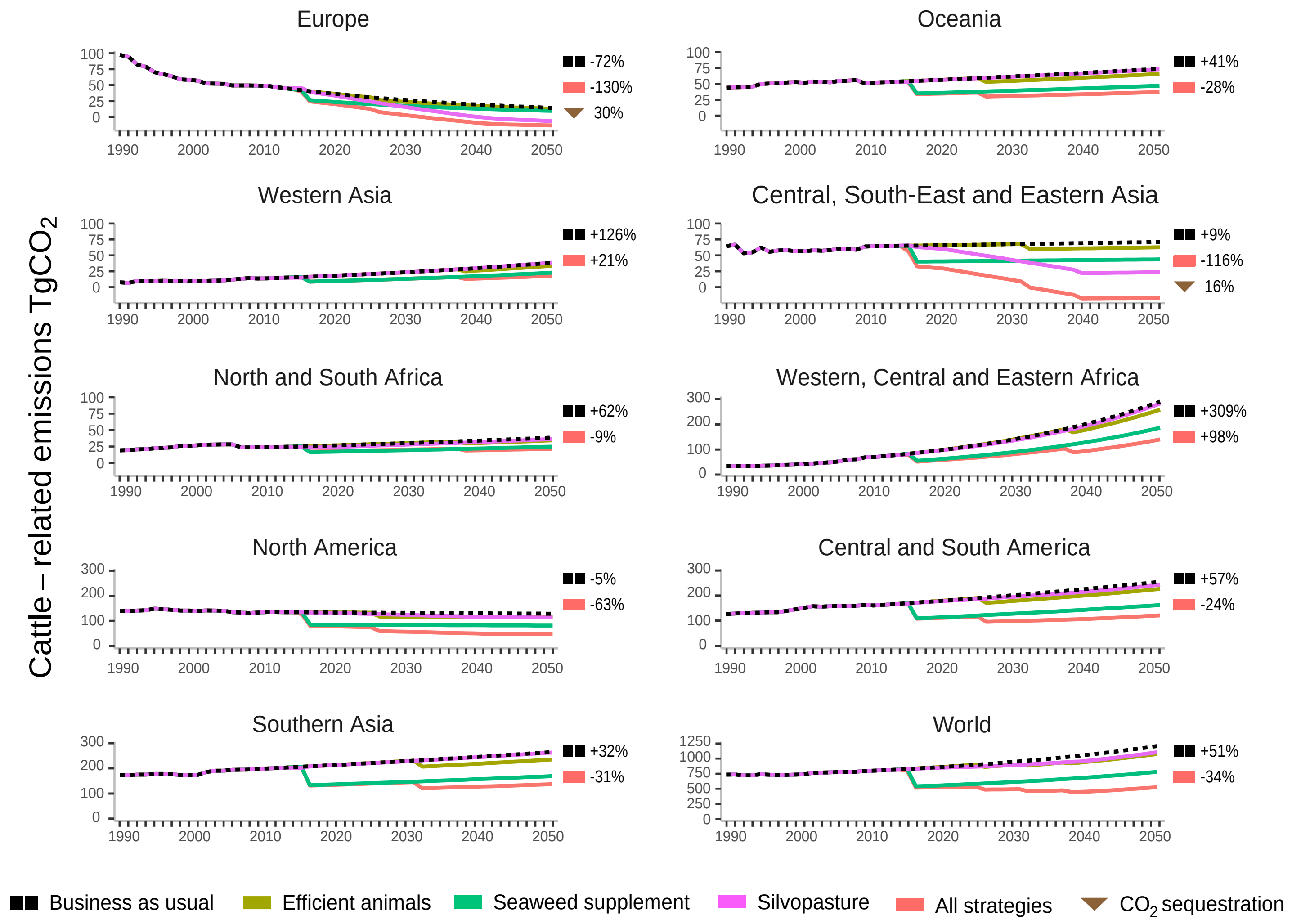

Figure 2 | Global projection of 2020-2050 GHG emissions under a business-as-usual scenario and by implementing mitigation strategies, based on 1990-2017 data from enteric and grassland-use CO_2 equivalent emissions. Trendlines dip between 2017 and 2020 after silvopasture conversion, supplementing anti-methanogenic seaweed, replacing regular cattle with genetically efficient animals, and using a synergistic implementation of all these strategies. Differences between 2050 and 2017 emissions are shown for each region, under scenarios of business-as-usual and execution of all strategies. *Europe* and *Central, South-East and Eastern Asia* additionally project carbon sequestration potential (brown arrows). Note the difference of scale in the emission axes.

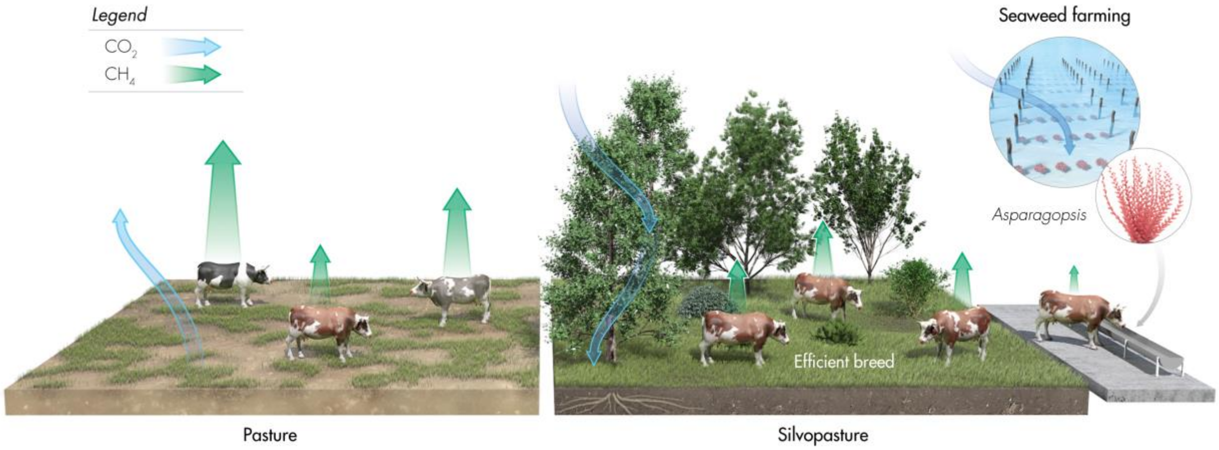

Figure 3 | Plausible mitigation effects of available strategies to reduce GHG emissions directly related to cattle. Planting silvopasture plants reduces the environmental impact of fodder production while increasing soil and biomass carbon sequestration. Additionally, replacing regular breeds with low-methane animals and feeding anti-methanogenic seaweed (Asparagopsis) to ruminants, can increase animal productivity and reduce methane emission intensity. Seaweed production via photosynthetic carbon capture offers significant potential for transforming atmospheric carbon dioxide into ruminant biomass.

Table 1 | Sum of projected cattle-related emissions from 2020 to 2050, following a business-as-usual (BAS) and mitigation scenarios (TgCO$_2$ equivalent). Percentages indicate emissions reduced by the strategy. %*shows the reduction of emissions excluding the breeding strategy. N, North; S, South; C, Central; E, Eastern; W, Western; SE, South-East.

Region	Enteric emissions			Grassland emissions		Enteric + grassland emissions	
	BAS	Seaweed (%)	Breeding (%)	BAS	Silvopasture (%)	BAS	Synergic mitigation (%/%*)
Africa N/S	919	609 (33.8)	878 (4.5)	71	71 (0)	991	991 (35.6/31.4)
Africa C/E/W	4,929	3,230 (34.5)	4,651 (5.6)	238	-139 (158.6)	5,167	5,167 (45.6/40.2
America N	4,026	2,687 (33.3)	3728 (7.4)	210	-271 (228.7)	4,236	4,236 (50/43)
America C/S	6,620	4,387 (33.7)	6,094 (7.9)	35	-210 (707.5)	6,655	6,655 (45.2/37.2)
Asia C/SE/E	1,991	1,326 (33.4)	1,876 (5.8)	265	-847 (419.8)	2,256	2,256 (83.9/78.8)
Asia W	953	629 (34)	907 (4.9)	0	0 (0)	954	954 (38.9/34)
Asia S	7,352	4,883 (33.6)	6,908 (6)	56	-26 (146.2)	7,407	7,407 (40.4/34.4)
Europe	736	502 (31.7)	692 (5.9)	41	-371 (1006.3)	777	777 (88.7/83.1)
Oceania	1,922	1,275 (33.6)	1,771 (7.8)	52	-12 (123.5)	1,974	1,974 (43.7/36)
World	29,448	19,529 (33.7)	27,505 (6.6)	968	-1,804 (286.4)	30,415	30,415 (48.1/41.7)