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Impacts of medications for obesity on global health and the environment

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A new generation of medications for obesity could transform the global food system. While research has explored their health impacts, their implications for global food demand and land use remain unquantified. We apply a global food system model to project the impact of glucagon-like peptide-1 receptor agonist (GLP-1) uptake to 2050 among people with obesity under two scenarios: reduced calorie intake while maintaining dietary composition, and reduced calorie intake combined with shifts towards the EAT–Lancet diet. Compared with the Reference scenario, GLP-1-mediated calorie reduction alone results in up to 6.6 million avoided deaths globally in 2050 and 32 Mha more natural land area, reflecting reductions in cropland, pasture and managed forest. Combining GLP-1 use with EAT–Lancet dietary shifts increases these estimates to 7.7 million avoided deaths and 46 Mha more natural land. Lower food prices increase food consumption among untreated populations, including unhealthy foods, partially offsetting these gains.

Obesity is a non-communicable disease requiring management strategies at both societal and individual levels[1]. Despite existing efforts, rates of obesity, defined as body mass index (BMI) exceeding 30 kg/m^2, continue to rise globally. According to the WHO, global obesity prevalence has nearly tripled since 1975. Today, approximately 1 in 5 adults around the world are living with obesity[2]. Excess body weight contributes to the development of type 2 diabetes, cardiovascular diseases, and various cancers[3], making efforts to address obesity a global health priority.

Recent advancements have vastly improved the effectiveness of available weight loss drugs[4]. Glucagon-like peptide-1 receptor agonists (GLP-1) have received considerable attention in the past few years for the treatment of obesity, type 2 diabetes, and cardiovascular disease. In December 2025, the WHO issued its first recommendation supporting GLP-1 therapies for the treatment of obesity[5], describing them as a 'new chapter' in obesity treatment with potential improvements for other health conditions such as type 2 diabetes and cardiovascular disease[5]. These recommendations reflect the evidence available at the time and are likely to evolve as further evidence on long-term effectiveness, safety, and accessibility becomes available. Medications for obesity currently have limited global uptake, largely because the drugs are not yet accessible in all countries[6], but the recent endorsement by the WHO indicates that this may change over the coming decades. Uptake has already risen in high-income countries, with approximately 12% of the US adult population reporting using them as of November 2025[7], and approximately 2.9% of adults in the UK reporting using medication for obesity to support weight loss in 2025[8]. Given that approximately 42% and 26% of the US and UK adult populations, respectively, experience obesity, this implies that current uptake represents a minority of those potentially eligible for treatment, although not all users necessarily have obesity and access is shaped by cost, insurance coverage, and clinical eligibility criteria[7,9]. The supply and cost of GLP-1 drugs currently limit their accessibility, particularly in low-income countries[6]. However, the core patent for semaglutide, is set to expire in several countries in 2026, potentially lowering costs with the production of generic forms of the drug[6]. Off-patent semaglutide drugs are likely to become rapidly available in India, Canada, China, Brazil, and Turkey. Together, these countries

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account for approximately 40% of the global population and an estimated 33% of adults living with obesity worldwide[10]. GLP-1 therapies are also being explored for a broader range of conditions, such as Parkinson's disease and Alzheimer's disease[11–13]. Global GLP-1 uptake may therefore increase substantially, with projections of the global medications for obesity market reaching $120 billion by 2035[14].

These medications reduce appetite, potentially cutting calorie consumption by 20–30%[15]. At scale, such reductions in calorie intake could alter aggregate food demand, with impacts on food prices, agricultural production, trade, land use, and broader environmental pressures. Food production is a major driver of environmental change, with agriculture occupying nearly 40% of the Earth's ice-free land surface. At the global scale, land conversion for pasture and cropland is a leading contributor to biodiversity loss and accounts for a substantial share of anthropogenic greenhouse gas emissions [16,17]. Transforming the global food system is therefore essential to mitigate these impacts, protect human health, and stabilize the environment[18]. Much of the literature on sustainable diets has focused on shifts in dietary composition, such as reduced consumption of animal-sourced foods and increased intake of fruits and vegetables, however fewer studies have examined how reductions in total calorie intake may influence food-system outcomes and environmental pressures[19,20]. While previous studies have quantified food-system and environmental effects of calorie reductions and dietary shifts in other contexts, the implications of GLP-1-mediated changes for food demand, food prices, and environmental pressures have not yet been quantified. Importantly, any food-system effects of GLP-1 uptake arising through changes in food demand among treated individuals, could have potentially indirect effects on untreated populations through changes in food prices, trade, and agricultural production.

We examine six GLP-1 scenarios: three (GLP-1 calorie-only) in which GLP-1 uptake is modelled among adults aged ≥18 years with obesity (BMI ≥ 30 kg/m^2). These scenarios vary according to whether uptake occurs in high-income countries only (HICs), high- and upper-middle-income countries (HICs and UMICs), or all countries. Three parallel scenarios (GLP-1 calorie+diet) apply the same uptake assumptions but additionally assume that GLP-1 users adopt diets consistent with the EAT–Lancet-2 diet[21]. The EAT–Lancet diet was selected as a widely used benchmark for healthy and environmentally sustainable dietary patterns and provides a representation of the dietary support that may accompany pharmacological obesity treatment, consistent with WHO guidance[5]. All scenarios are evaluated against a common Reference scenario and under the same background socioeconomic and climate conditions, with recent trends in climate, population, and diets assumed to continue [22]. For each scenario we run 30 simulation runs to account for parameter uncertainty. Using the integrated global land and food system model LandSyMM[23], we assess the implications of these scenarios for food demand, mortality, food prices, trade, and land use and other environmental pressures to 2050 (Fig. 1).

Results

Simulations in LandSyMM of the seven scenarios produce estimates of national food prices, diets, international trade, and maps of land use type and intensity to 2050. Across all six GLP-1 scenarios, calorie demand reduces with access to GLP-1. For both GLP-1 calorie-only (Supplementary Fig. 1) and GLP-1 calorie+diet scenarios (Fig. 2), the largest reductions in calorie demand occur when all countries have access to GLP-1 (Fig. 2a and Supplementary Fig. 1a). Average global calorie supply reduction is 11.6 ± 0.02% (SE) under the all countries GLP-1 calorie-only scenarios and 11.4 ± 0.02% (SE) under the all countries GLP-1 calorie+diet scenario.

The greatest reductions in projected calorie consumption across all scenarios, when compared to the Reference scenario, occur in North America, reflecting high projected levels of obesity. For example, in the US, the fraction of the population with obesity is projected to rise from 46% in 2025 to 57% in 2050[24]. Calorie supply in North America is reduced by 26 ± 0.01% (SE) across all six GLP-1 scenarios compared to the Reference scenario.

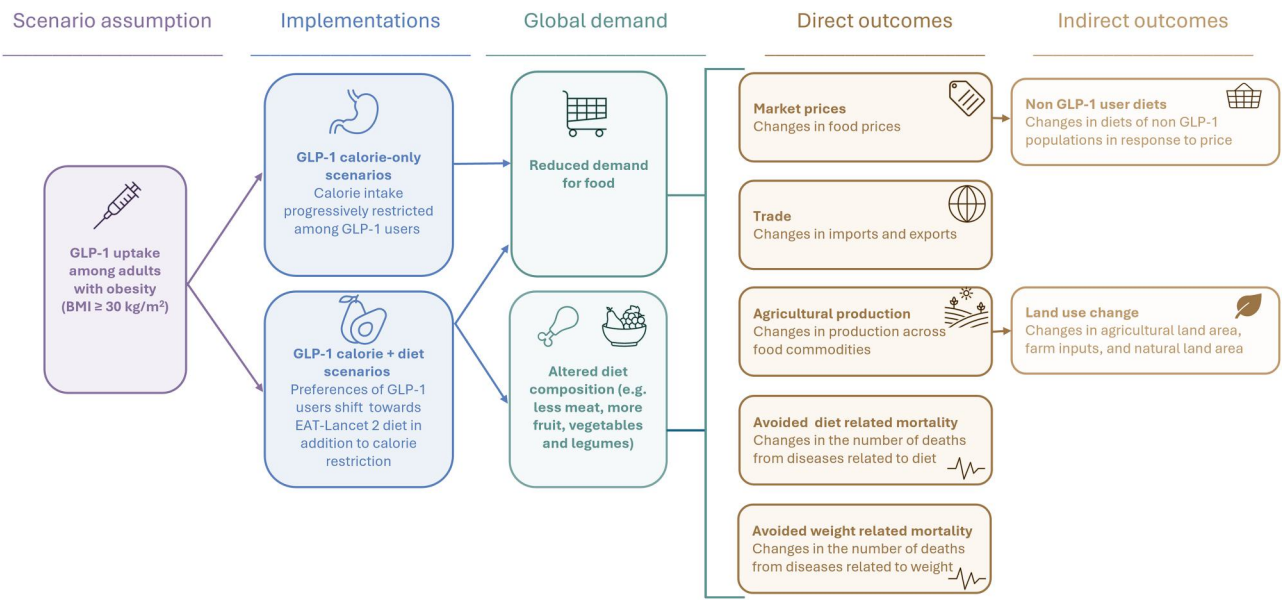


Fig. 1 | Conceptual framework linking GLP-1 uptake to the different endpoints considered. From left to right, the panels illustrate the pathways through which GLP-1 uptake is represented in the modelling framework. GLP-1 uptake alters food consumption among treated populations through reductions in calorie intake, with scenarios additionally considering changes in dietary composition. These changes in food demand affect the global food system, including agricultural production, food prices and international trade. Changes in diets and body mass index (BMI) affect health outcomes through dietary and BMI-related risk factors. Changes in agricultural production alter agricultural land requirements and consequently the area of non-agricultural land. Finally, changes in food prices can affect food consumption among populations not receiving GLP-1 therapies, with associated effects on health outcomes. Together, the framework captures both the direct effects of altered food consumption among GLP-1 users and indirect effects mediated through the wider food system.

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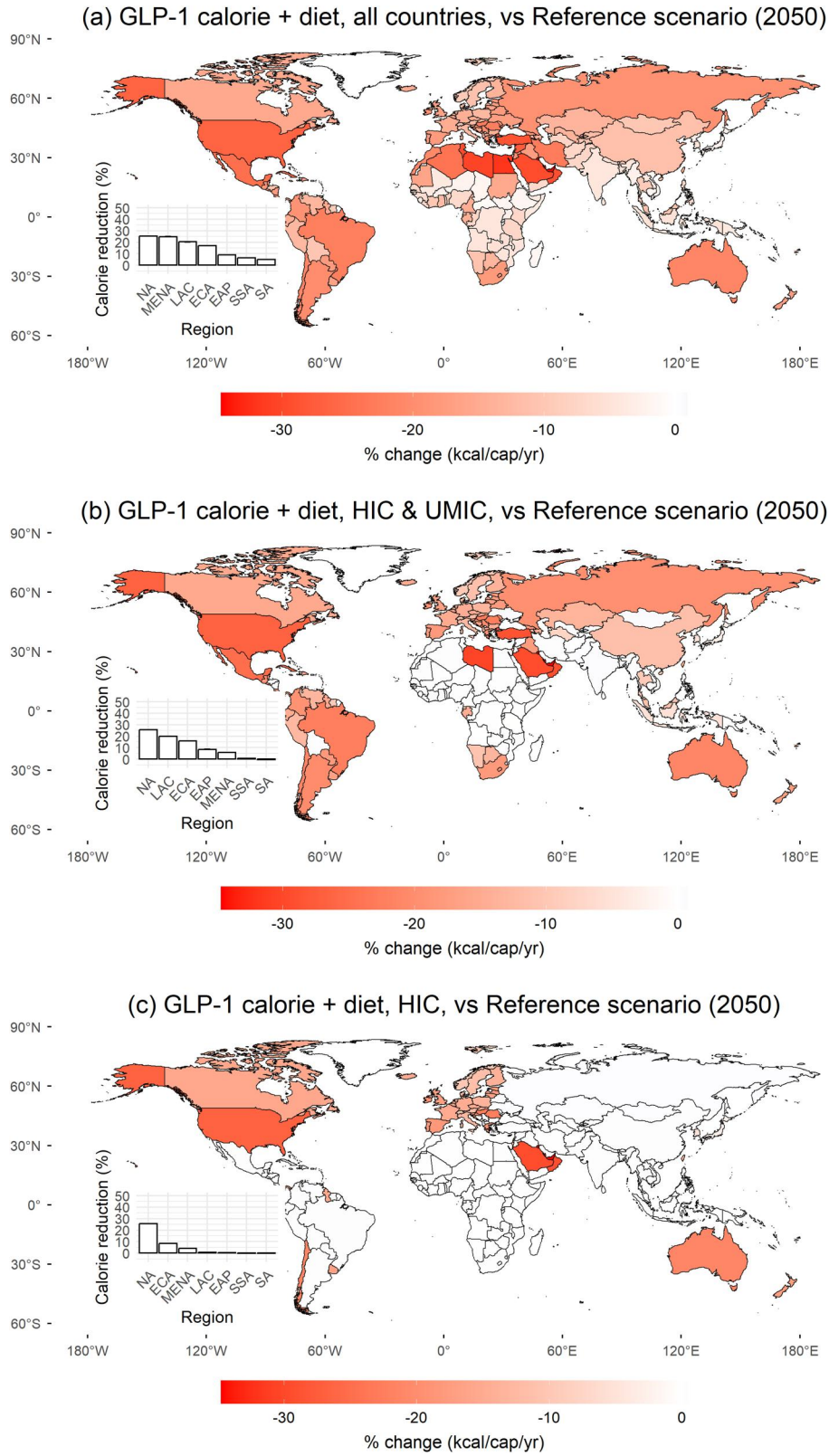


Fig. 2 | Maps of changes in calorie supply by country. Panels show the mean difference in calorie supply between the Reference scenario and GLP-1 calorie+diet scenarios in **a** all countries, **b** high-income (HIC) and upper-middle-income countries (UMIC), and **c** high-income countries. Values represent the mean across 30 simulation runs. Inset panels show the mean total percentage reduction in calorie supply in 2050 in the GLP-1 calorie+diet scenarios compared with the Reference scenario across world regions ($N = 30$). Error bars on the inset plots represent ±1 SE and are smaller than the symbols where not visible. Regions are ordered according to the World Bank regional classification. NA North America, ECA Europe and Central Asia, EAP East Asia and Pacific, LAC Latin America and Caribbean, MENA Middle East and North Africa, SA South Asia, SSA Sub-Saharan Africa. Country boundaries are from the maps R package (v4.3.2).

Within our results, changes observed in untreated populations arise indirectly through food-system feedback, particularly changes in food prices (Supplementary Fig. 2), trade, and production following reduced food demand among GLP-1 users. Reduced food demand in countries adopting GLP-1 therapies lowers global food prices, improving food affordability in countries without widespread uptake (Fig. 3). As a result, lower-income regions experience small increases in consumption despite no prescribed change in dietary preferences in these regions under modelled scenarios. For example, in scenarios where uptake is restricted to higher-income regions, some lower-income and lower-middle-income countries, such as Ukraine, show marginal increases in per capita calorie intake (up to 0.7 ± 0.08% SE).

This effect is somewhat amplified in the GLP-1 calorie+diet scenarios, where dietary preferences towards the EAT–Lancet diet further reduce demand for relatively resource-intensive and higher-cost food groups, particularly meat, as well as discretionary foods such as sugar. Projected food price indices are generally slightly lower in the GLP-1 calorie+diet scenario than in the GLP-1 calorie-only scenario, though their standard deviation ranges overlap (Fig. 3).

Reduced food consumption with GLP-1 uptake increases the number of avoided deaths relative to the Reference scenario (Fig. 4), with most avoided mortality arising from reductions in obesity-related mortality across regions (Fig. 5). Mortality estimates incorporate both dietary and BMI-related risk factors, with the latter represented by changes in the proportions of adults in healthy-weight, overweight, and obese categories. The GLP-1 calorie-only scenario is associated with approximately 6.6 million avoided deaths globally, equivalent to 845 ± 0.6 (SE) avoided deaths per million adults. In the six GLP-1 scenarios, calorie intake is reduced while maintaining the relative proportions of each food group in the diet. As a result, GLP-1-induced calorie restriction leads to reductions in the consumption of all food groups, including fruits, vegetables, and legumes, which contributes to a small increase in diet-related additional deaths (Fig. 5). However, these adverse effects are more than offset by the avoided mortality associated with reduced obesity prevalence and lower consumption of red and processed meat, resulting in an overall increase in deaths avoided.

In contrast to the GLP-1 calorie-only scenarios, where dietary preferences and composition are preserved, in the GLP-1 calorie+diet scenarios, dietary preferences are adjusted and this in turn results in changes in dietary composition. Specifically, these shifts reduce the consumption of red and processed meat while increasing the intake of fruits, vegetables, nuts, and legumes. Consequently, the avoided mortality arises not only from lower overall calorie intake and reductions in obesity, but also from improvements in dietary quality. These dietary changes lead to further reductions in diet-related mortality by increasing the number of deaths avoided through lower red and processed meat consumption, while reducing the additional mortality associated with lower fruit and vegetable intake observed under calorie restriction alone (Fig. 5). This effect is particularly evident for nuts and legumes. In the GLP-1 calorie-only scenarios, calorie intake is reduced while maintaining the same relative proportions of each food group as the untreated population. However, in the GLP-1 calorie+diet scenarios, calorie intake is reduced while the relative

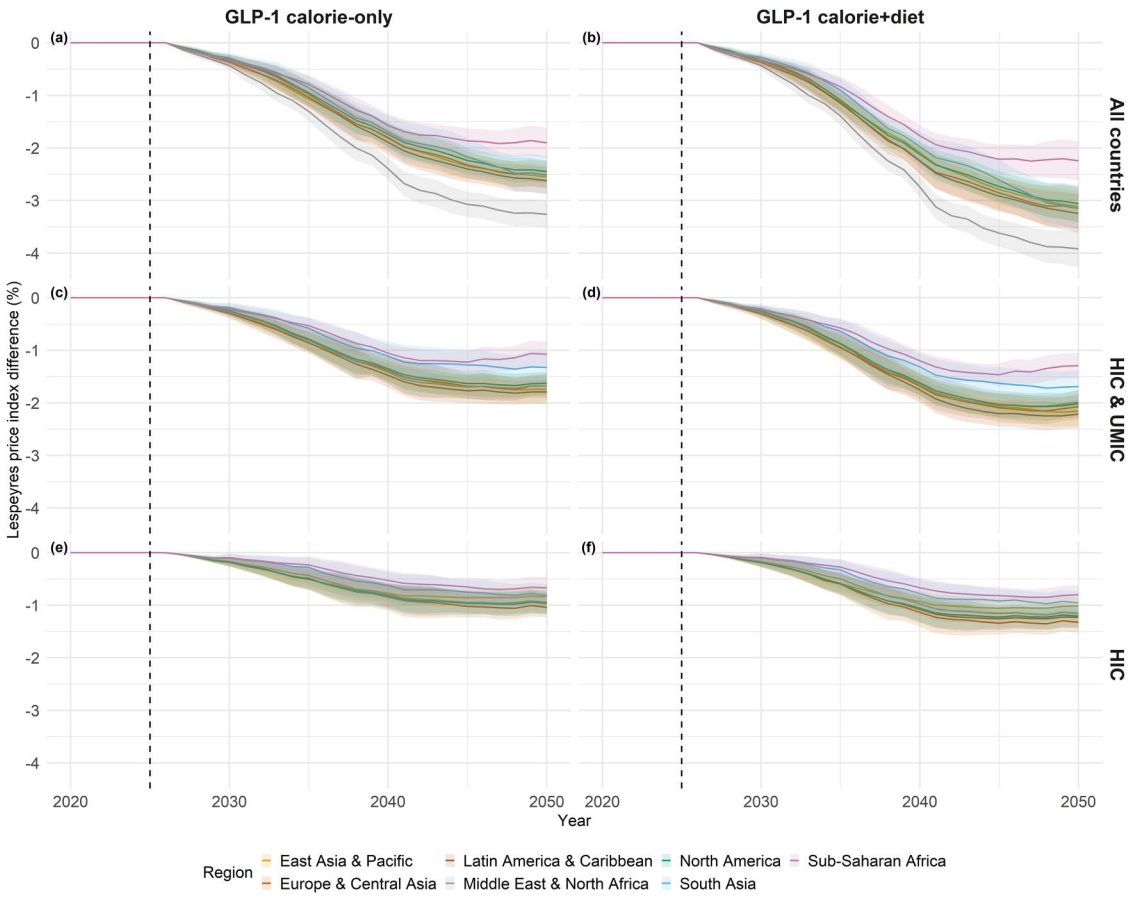


Fig. 3 | Differences in the food price index between the Reference scenario and the GLP-1 calorie-only scenarios (a,c,e) and GLP-1 calorie+diet scenarios (b,d,f), respectively, from 2020 to 2050 by world region. Regions are ordered according to the World Bank regional classification. In all panels, the solid line represents the mean and the shaded ribbons indicate ±1 standard deviation across simulation runs ($N = 30$). The vertical dotted line represents the start of the GLP-1 transition period (2025). HIC high income countries, UMIC upper middle income countries.

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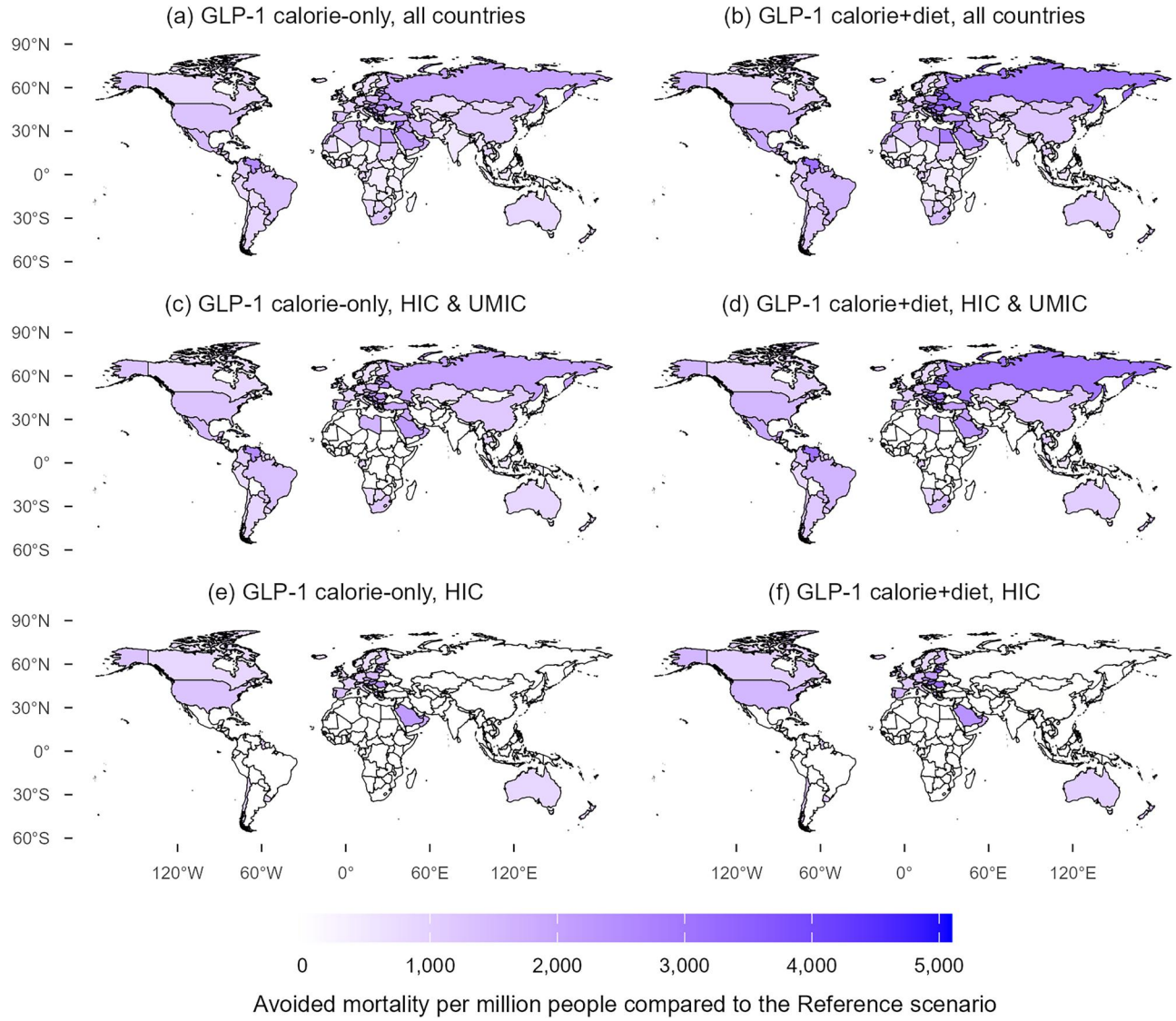


Fig. 4 | Mean total avoided mortality in 2050 in adult populations across the six GLP-1 scenarios compared to the Reference scenario. Total avoided mortality includes changes in mortality associated with dietary risk factors (red meat, processed meat, fruit, vegetables, legumes and nuts) and BMI-related risk associated with changes in the proportions of adults in healthy-weight, overweight and obese categories. Values represent the mean of 30 simulation runs. The left column shows the GLP-1 calorie-only scenarios (**a**,**c**,**e**), and the right column shows the GLP-1 calorie+diet scenarios (**b**,**d**,**f**). HIC high-income countries, UMIC upper-middle-income countries. Country boundaries are from the maps R package (v4.3.2).

proportions of food groups are progressively adjusted towards those of the EAT–Lancet-2 diet. Thus, the shift in dietary preferences increases their consumption sufficiently to reverse this effect, resulting in avoided mortality rather than additional mortality (Fig. 5). Combining GLP-1 uptake with dietary change (GLP-1 calorie+diet) results in around 7.7 million avoided deaths globally (984 ± 0.9 (SE) per million adults), representing a substantial incremental benefit beyond pharmacological intervention alone.

The magnitude of the avoided mortality varies across countries and is driven by both obesity prevalence and baseline dietary patterns. Countries with high levels of obesity and diets rich in red and processed meat, but low in fruits, vegetables, and pulses, experience the largest reductions in projected mortality. For example, the Russian Federation and the United Kingdom have similar projected obesity prevalence in 2050 (45% and 41%, respectively[24]), yet the Russian Federation achieves 1992 ± 1.7 (SE) avoided deaths per million people compared with 937 ± 0.4 (SE) in the United Kingdom in the GLP-1 calorie-only scenarios. This difference is primarily associated with differences in dietary composition: diets in the Russian Federation are more heavily weighted towards meat, with relatively lower intake of fruits, vegetables, and nuts, compared to the United Kingdom. These differences are even more pronounced when comparing GLP-1 calorie-only and GLP-1 calorie+diet scenarios. In the Russian Federation, GLP-1 calorie-only avoids an average of 237,367 ± 2362 (SE) deaths relative to the Reference scenario, while the addition of dietary change increases this to 353,080 ± 3580 (SE) avoided deaths. This corresponds to a 48% increase in avoided deaths beyond the effect of GLP-1 calorie-only. In contrast, in the United Kingdom, GLP-1 calorie-only avoids an average of 58,250 ± 603 (SE) deaths, rising to 67,303 ± 695 (SE) when combined with dietary change. This represents a 15% increase in avoided deaths. Overall, these results highlight that the relative impact of GLP-1 treatment and dietary change is strongly dependent on baseline dietary patterns, with greater avoided mortality from dietary change in countries where diets are further from EAT–Lancet recommendations.

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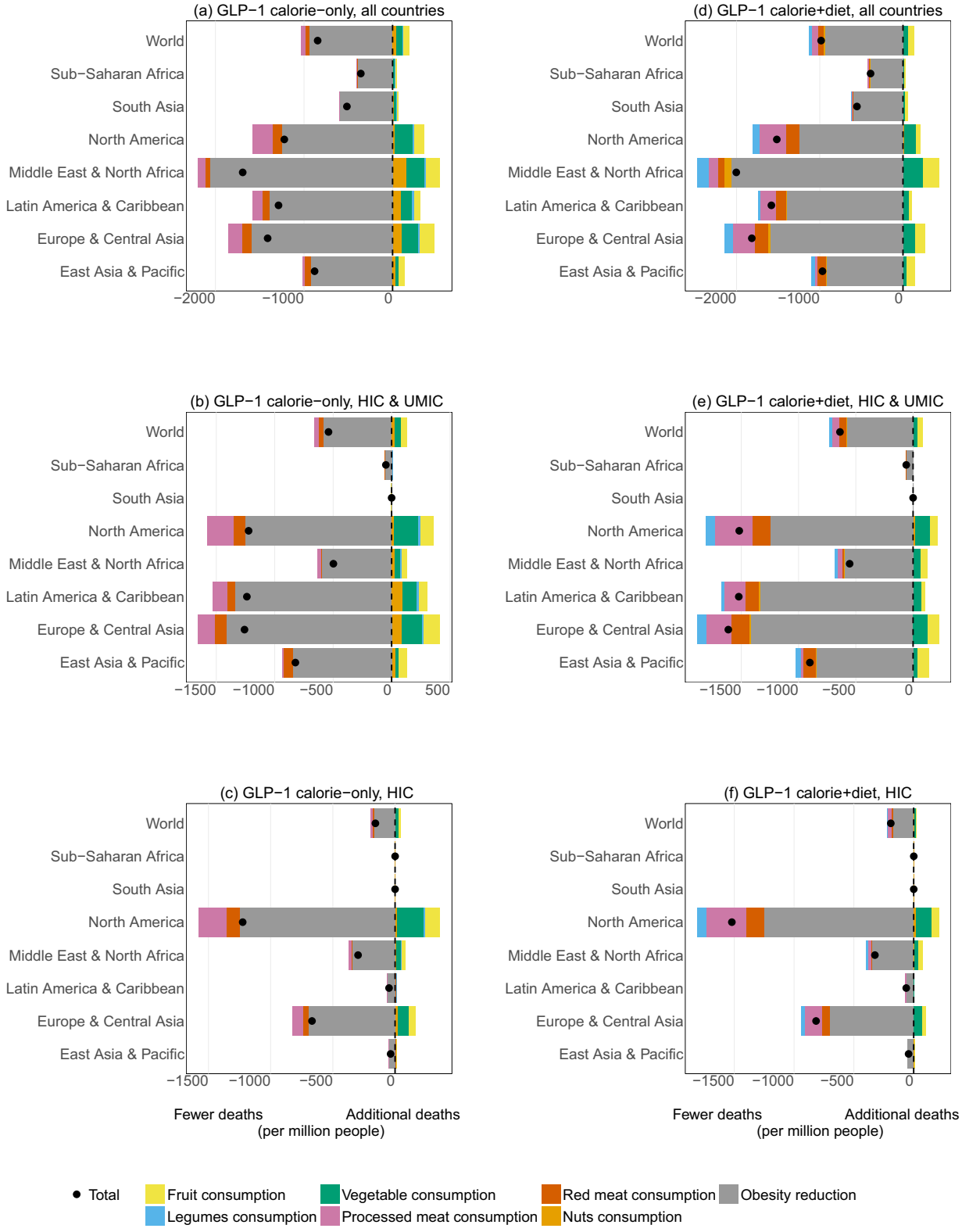


Fig. 5 | Additional and avoided deaths across the six GLP-1 scenarios. The results show the difference in deaths in 2050 between the GLP-1 calorie-only (**a**–**c**) and GLP-1 calorie+diet (**d**–**f**) scenarios compared to the Reference scenario. Additional and avoided deaths per million people are shown for each world region. Regions are ordered according to the World Bank regional classification. Colours represent the different risk factors. Colours and points represent the mean total change in deaths ($N = 30$). The sum of the individual risk factors for a region can be lower than the total change in deaths, as individual risks can be attenuated and/or compensated when combined with other risk factors. Decreasing consumption of fruits, vegetables, nuts and legumes increases mortality risk while decreasing consumption of processed meat and red meat decreases mortality risk. Changes in weight category also contribute to mortality differences, with movement from the obese to overweight category reducing mortality risk. HIC high income countries, UMIC upper middle income countries.

The uptake of GLP-1 medications and associated dietary changes among individuals with obesity is associated with small changes in mortality among individuals not receiving treatment (Fig. 6). Lower food prices for the untreated population are associated with increased consumption of red and processed meat, resulting in a slight rise in mortality (Supplementary Table 5 & Supplementary Table 6). However, this increase is very small, equivalent to 10 ± 0.3 (SE) and 6 ± 0.2 (SE) additional deaths per million adults in the GLP-1 calorie-only and GLP-1 calorie+diet, all countries scenarios, respectively. This is two and three orders of magnitude lower than the mortality reductions observed in treated populations (Fig. 6).

Across all six GLP-1 scenarios, reductions in food demand associated with GLP-1 uptake result in lower agricultural land requirements and a corresponding increase in natural land area, defined here as land not used for cropland, pasture, or managed forest, relative to the Reference scenario. These changes are greatest when GLP-1 access is expanded to all countries (Fig. 7). In the Reference scenario, cropland expands to 1634.2 million hectares (Mha) ± 6.3 Mha (SE) by 2050 (an increase of 54.1 ± 5.4 Mha (SE)), alongside increases of 10.7 ± 1.4 Mha (SE), in pasture and 3.9 ± 0.9 Mha (SE) in forest area. These changes collectively result in a loss of 68.8 ± 0.07 Mha (SE) of natural land. In contrast, scenarios combining GLP-1 uptake with dietary shifts towards the EAT–Lancet diet (GLP-1 calorie+diet) increase natural land area relative to the Reference scenario. By 2050, the area of natural land is greater by an average of 8.0 ± 1.3 Mha (SE), 33.1 ± 1.9 Mha (SE), and 46.3 ± 2.1 Mha (SE) under GLP-1 calorie+diet scenarios in HIC, HIC & UMIC, and all countries, compared to the Reference scenario, respectively. Without dietary change, in the GLP-1 calorie-only scenarios these gains are smaller, with increases of 7.0 ± 0.9 Mha (SE), 21.7 ± 1.2 Mha (SE), and 31.7 ± 1.5 Mha (SE) in natural land area for HIC, HIC & UMIC, and all countries, respectively (Supplementary Fig. 3). GLP-1 calorie+diet also reduces fertiliser and irrigation inputs (Fig. 7). By 2050, fertiliser application drops by 7.6 million tonnes (Mt) ± 0.2 Mt (SE), 22 ± 0.4 Mt (SE) and 30.4 ± 0.6 Mt (SE) in HIC, HIC & UMIC,

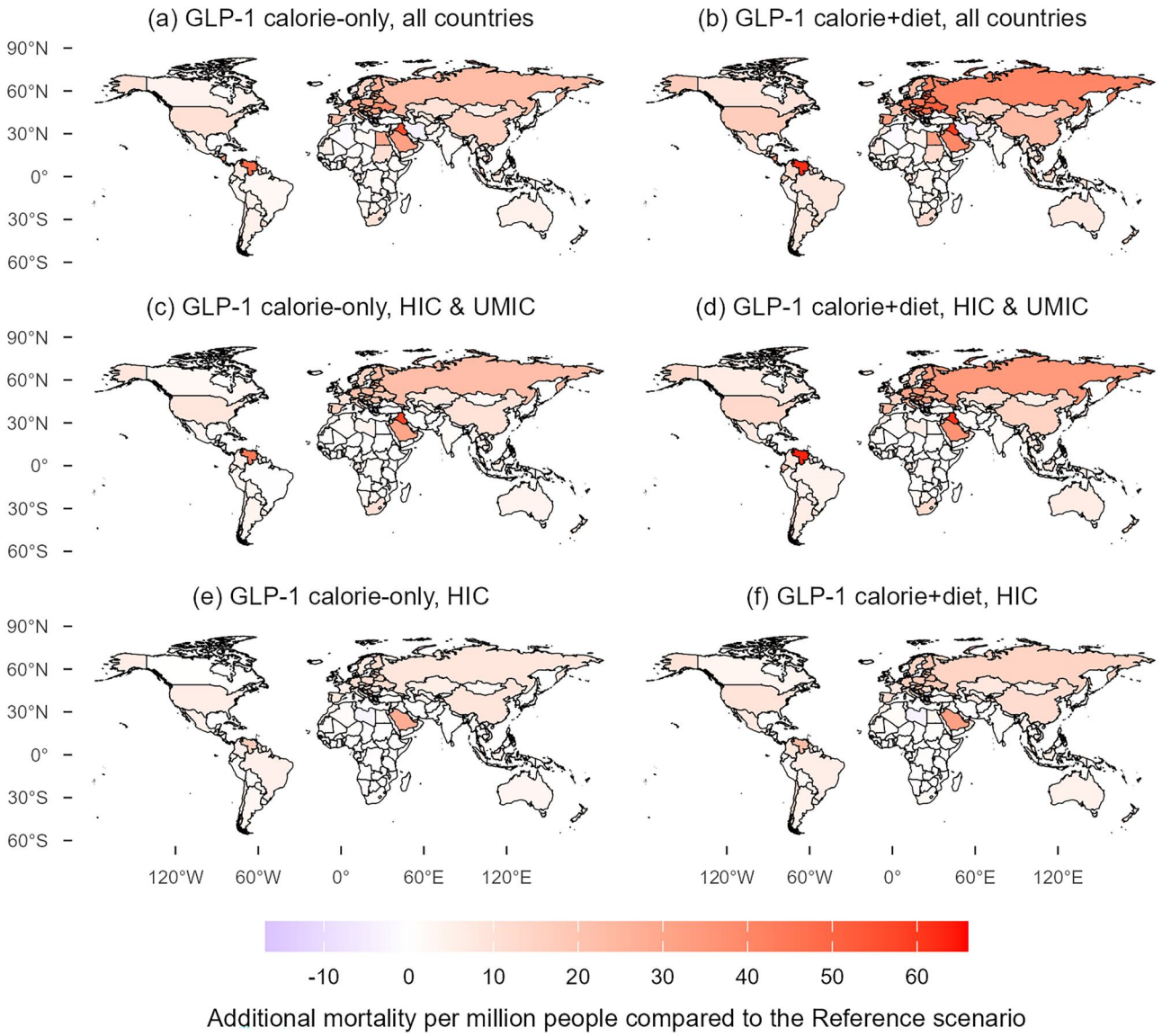


Fig. 6 | Mean additional mortality in 2050 in the untreated adult populations (no GLP-1 uptake or dietary change) due to dietary change. Average total additional mortality under each of the six GLP-1 scenarios is calculated as the additional mortality arising from coronary heart disease, stroke, cancer, respiratory disease, and diabetes due to dietary change in red meat, processed meat, fruit, vegetable, legume and nut consumption, compared to the Reference scenario. Values represent the mean of 30 simulation runs. The left column displays the GLP-1 calorie-only scenarios (**a**,**c**,**e**) while the right column displays the GLP-1+diet scenarios (**b**,**d**,**f**). HIC = high income countries, UMIC = upper middle income countries. Country boundaries are from the maps R package (v4.3.2).

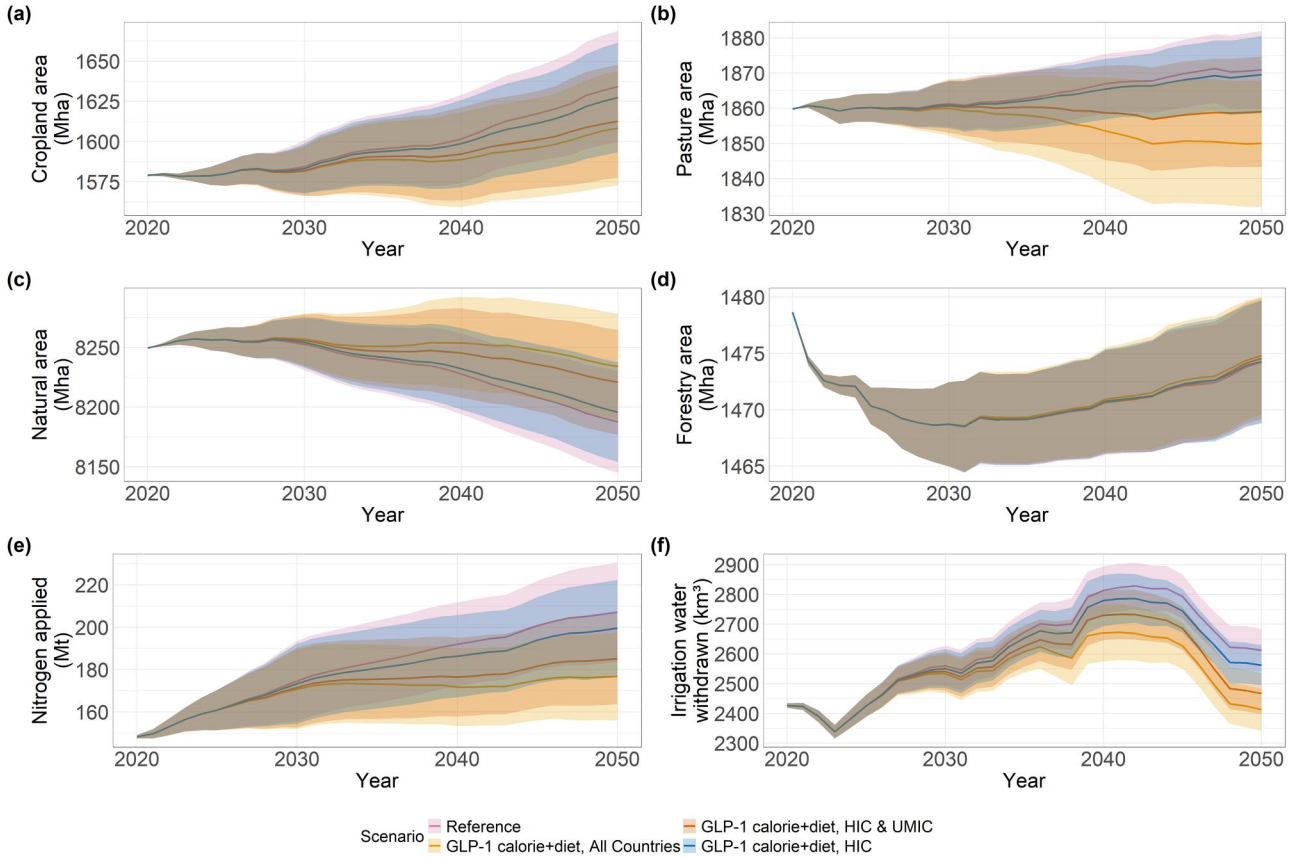


Fig. 7 | Global land use and land management intensity results from 2020 to 2050 in the GLP-1 calorie+diet scenarios. Changes through time are presented for **a** cropland area (million hectare, Mha), **b** pasture area (Mha), **c** natural land area as defined as non-agricultural primary and/or secondary vegetation (Mha), **d** forestry area (Mha) **e** nitrogen fertiliser application (million tonnes, Mt) **f** irrigation water application (cubic kilometres, km³). In all panels, the solid line represents the mean and the shaded ribbons indicate ±1 standard deviation across simulation runs ($N = 30$). HIC high income countries, UMIC upper middle income countries.

and all countries scenarios compared to the Reference scenario, respectively. Irrigation drops by 49.6 ± 0.9 km³ (SE), 145 ± 5.3 km³ (SE) and 185.8 ± 4.7 km³ (SE) in HIC, HIC & UMIC, and all countries scenarios compared to the Reference scenario, respectively. The reductions in both fertiliser and irrigation are more modest in the GLP-1 calorie-only scenarios (Supplementary Fig. 3).

The increase in natural land cover in the six GLP-1 scenarios compared with the Reference scenario is primarily driven by reductions in cropland and pasture area. However, the spatial distribution of this increase does not necessarily correspond to regions experiencing the largest declines in calorie supply (Fig. 8). For example, North America exhibits the greatest reduction in calorie consumption but the second smallest increase in natural land under the GLP-1 calorie+diet, all countries, scenario compared to the Reference scenario, accounting for just 1.7 ± 0.2 Mha (SE) of the total increase of 46.2 Mha in natural land area (3.7%).

In contrast, South Asia and Sub-Saharan Africa, despite accounting for a relatively small share of the global reduction in calorie supply, together account for around 11.5 ± 0.6 Mha (SE), 25%, of the difference in natural land between this scenario and the Reference scenario. A similar pattern is observed in scenarios where GLP-1 uptake and dietary change are limited to high-income countries (GLP-1 calorie+diet, HIC). In this case, North America contributes 0.7 ± 0.6 Mha (SE) to the total increase of 8 Mha in natural land area (0.9%), whereas Latin America accounts for 3.5 ± 0.8 Mha (SE), equivalent to 43% of the difference in natural land between GLP-1 calorie+diet, HIC and the Reference scenario, despite only a small reduction in calorie consumption in this region.

In regions such as Latin America and East Asia and the Pacific, declines in agricultural area and intensity are driven by reductions in exports relative to the Reference scenario, despite limited GLP-1 uptake in these regions (Fig. 9). For example, by 2050 the Latin America and Caribbean region is exporting 592.5 ± 19.1 Mt (SE) of food and feed products in the Reference scenario. However, in the GLP-1 calorie+diet, HIC scenario, the Latin America and Caribbean region export 506.7 ± 21.1 Mt (SE) of food and feed products. Conversely, regions such as North America and Europe and Central Asia see increases of 166.7 ± 3.8 Mt (SE) and 50 ± 4.9 Mt (SE) in exports compared to the Reference scenario, respectively. Exports increase in these regions because by 2050, with domestic demand reduced, they produce more than is required domestically.

Discussion

In this study, we simulate the effects of projected uptake of GLP-1 medications, which, by design, lowers calorie demand, particularly in high-income regions with high obesity prevalence. The added value of our analysis is to quantify potential reductions in mortality and agricultural land use across the world and how this demand shock propagates through the global food system under assumptions on supply, demand, trade, prices, and elasticities. Within this framework, we find that reduced calorie demand translates into substantial avoided mortality globally, with millions of avoided deaths driven primarily by declines in obesity-related mortality, and additional gains where dietary shifts reduce consumption of red and processed meat and increase intake of plant-based foods.

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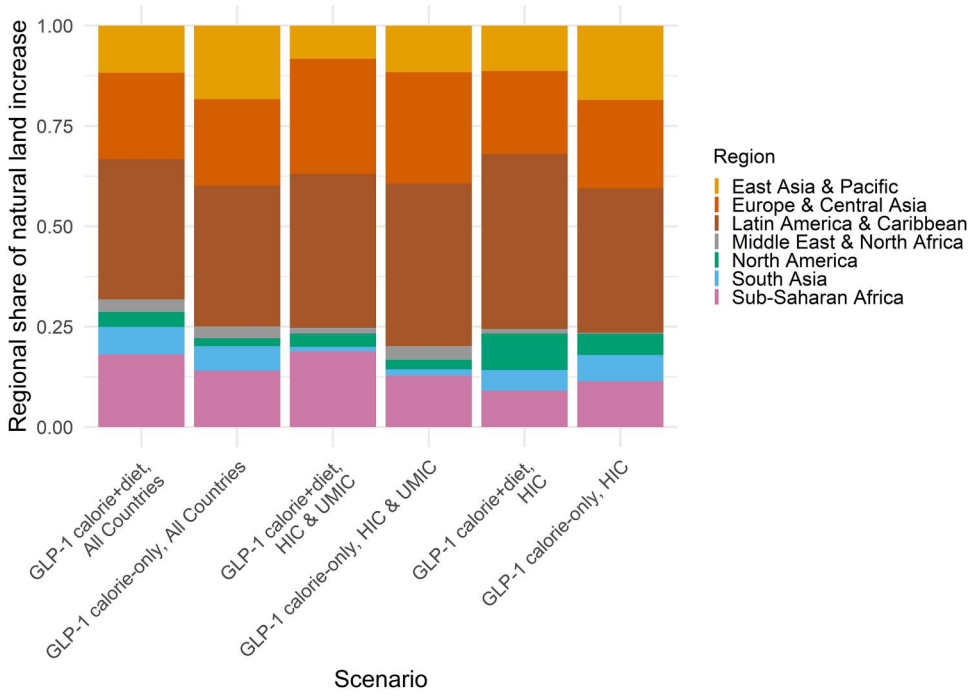


Fig. 8 | Regional contributions to the global increase in natural land area under the GLP-1 scenarios. Stacked bars show the mean share of the total global increase in natural land area in 2050 attributable to each region under each scenario, relative to the Reference scenario ($N = 30$ simulation runs). Regional shares within each scenario sum to 1 (100%). GLP-1 calorie-only scenarios represent reductions in calorie intake associated with GLP-1 therapy while maintaining dietary composition, whereas GLP-1 calorie+diet scenarios additionally incorporate shifts in dietary composition. All Countries, HIC & UMIC and HIC indicate the country income groups in which GLP-1 uptake is assumed to occur. HIC high-income countries, UMIC upper-middle-income countries.

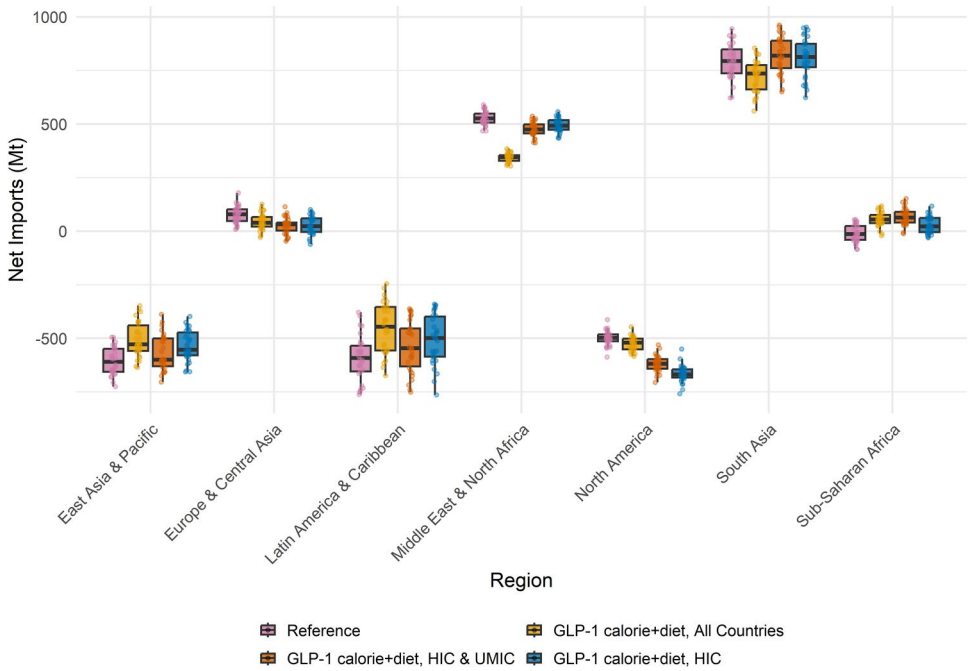


Fig. 9 | Regional net imports (Mt) in 2050 under the Reference scenario and the six GLP-1 scenarios. Boxplots show the distribution of model outputs across simulation runs ($N = 30$) for each region and scenario, with the central line indicating the median, boxes representing the interquartile range (IQR), and whiskers extending to 1.5 × IQR. Individual points represent the results of each simulation replicate. Regions are ordered according to the World Bank regional classification. HIC high income countries, UMIC upper middle income countries.

The model further indicates that these demand-side changes lead to lower global food prices, improving food affordability, while simultaneously reducing pressure on agricultural production systems. This results in increases in natural land area and reductions in inputs such as fertiliser and irrigation, with greater changes observed when GLP-1 uptake is combined with dietary change. Importantly, these environmental and production responses are emergent outcomes of the model rather than imposed assumptions. We also find that the spatial distribution of these effects is shaped by international trade. Although reductions in calorie consumption are concentrated in high-income regions, the associated decreases in agricultural production occur disproportionately in major exporting regions such as Latin America and the Caribbean and East Asia and the Pacific. Thus, reductions in agricultural production and associated changes in land and resource use are not necessarily co-located with reductions in food consumption.

Our results can be interpreted in the context of a growing body of literature that models the health, land-use, climate, and food security implications of large-scale dietary change. Previous studies have examined the environmental and health consequences of shifts towards healthier or more sustainable diets, including reductions in animal-source foods, alignment with dietary guidelines, or global adoption of plant-rich dietary patterns[20,21,25–27]. These analyses often represent health- or sustainability-motivated dietary transitions or policy-driven shifts in food composition. Our study models a pharmacologically mediated reduction in calorie intake, linked to projected obesity prevalence and treatment uptake, alongside dietary adjustments among the medicated population in line with WHO guidance for GLP-1 patients. In this sense, our work complements existing diet-shift modelling by examining a different driver of demand-side change: medical innovation affecting appetite and food intake. Our results indicate that combining appetite-suppressing treatments with dietary change among treated individuals produces larger reductions in agricultural land use and mortality than calories alone[18]. However, these changes remain smaller than those projected under population-wide adoption of sustainable diets[21,25–27]. This study focuses exclusively on land-use and food system changes associated with altered food consumption and does not quantify greenhouse gas emissions, either from land-use or pharmaceutical production, distribution, or disposal. Future research could extend this work by conducting a more comprehensive life cycle or systems assessment that integrates both agricultural emissions reductions and the environmental footprint of large-scale pharmaceutical manufacturing. The reduction in food demand, agricultural land conversion and lower projected global fertiliser requirements identified in our scenarios could be associated with lower global emissions[28], but these potential gains would need to be quantified alongside emissions associated with medication production, given evidence that the pharmaceutical sector contributes to global greenhouse gas emissions[29]. Similarly, although reduced fertiliser use could reduce nutrient runoff, broader environmental assessments would also need to consider the potential ecological implications of increased active pharmaceutical ingredients entering ecosystems [29]. Such effects are not modelled here but represent an important avenue for future research.

The lower agricultural land requirements we find could help support global biodiversity conservation goals. While our analysis does not explicitly model biodiversity outcomes such as species richness, ecosystem integrity, or habitat quality, our results are still indicative of land-use pressures. Natural land increases in the tropics under GLP-1 scenarios, especially in regions such as Latin America and Sub-Saharan Africa, despite their relatively small per capita calorie reductions compared to other world regions. This indicates potentially important implications for biodiversity, as the tropics are hotspots of species richness[30].

Our implementation of GLP-1 uptake rests on several key assumptions. First, relative food consumption across adult and child populations is assumed to be proportional to physiological energy requirements, such that age-specific differences in calorie intake reflect differences in metabolic needs rather than behavioural or cultural variation in diets. Second, GLP-1 treatment is assumed to affect total calorie intake and, in the GLP-1 calorie+diet scenarios, is combined with an assumed transition towards healthier diets among individuals taking medications. This scenario design reflects WHO guidance recommending that GLP-1 therapies are accompanied by behavioural interventions that support healthy dietary practices. The empirical evidence that GLP-1 treatment itself leads to such changes in dietary composition is currently limited[31], with some studies indicating greater protein intake in GLP-1 users and other studies finding a shift towards proportionally greater intake of fat, rather than protein[32,33]. Furthermore, any changes in dietary composition among non-GLP-1 populations arise through market-mediated responses to changes in food prices. Our scenarios do not prescribe behavioural changes, preference shifts, or other medication-related responses among untreated individuals. Therefore, the effects observed in these populations reflect indirect food-system feedbacks rather than direct responses to GLP-1 therapies. Such rebound effects from lower prices could include higher consumption of animal products, increased waste, and the reallocation of savings to other goods and services, all of which could raise greenhouse gas emissions and partially offset the environmental benefits of reduced food consumption[27,34]. Furthermore, dietary change could offset potential avoided mortality from obesity reductions. Further research is needed to better understand these dynamics and to assess the broader environmental and health impacts of changes in food consumption patterns that could be driven by medications for obesity.

Third, the scenarios prescribe changes in calorie intake and dietary composition only for individuals receiving GLP-1 treatment; no direct behavioural response to these changes is prescribed for untreated populations. Untreated populations can nevertheless experience indirect changes in food consumption through the food-system feedbacks represented in the model, including changes in food prices, trade, and production. In addition, GLP-1 treatment access and uptake are fixed within each country and do not respond dynamically to changes in BMI arising from market-mediated dietary feedbacks. Although such effects are small in our simulations, larger consumption changes could, in principle, alter obesity prevalence and therefore the population eligible for treatment. By design, the scenarios also exclude GLP-1 use among individuals with a BMI below 30 kg/m^2. Our scenarios operate at the national level and therefore abstract from income-stratified access, differential obesity prevalence across socio-economic groups, behavioural persistence, and long-term adherence. Moreover, our study does not explicitly model pharmaceutical markets, prescribing dynamics, or individual-level clinical trajectories. While we estimate changes in mortality using a comparative risk assessment framework, consistent with approaches such as the Global Burden of Disease Study, these are derived from changes in risk factor exposure rather than simulated clinical outcomes. Instead, the analysis focuses on estimating the impact of GLP-1–mediated reductions in calorie intake on land-use and the food-system under epidemiologically bounded uptake scenarios. The contribution of this work is therefore not pharmaceutical modelling per se, but the integration of treatment-driven dietary change into a global land–food system model. Incorporating income-stratified uptake and behavioural dynamics would require a substantially more detailed micro-simulation framework and richer data than are currently available at the global scale. Accordingly, our results should be interpreted as a transparent, first-order system-level assessment.

Though the rapid rate of adoption of medications for obesity in high-income countries has been remarkable[7], the assumption that

global calorie intake will be dramatically reduced by 2040 may be overly optimistic. Underlying this is the assumption that individuals will continue to experience appetite suppression, but preliminary evidence suggests that once stopping medications for obesity (UK NICE guidelines indicate individuals should not be on these medications for more than 2 years[35]), individuals regain weight within a couple of years[36,37]. However, the new WHO guidelines (2025) recommend long-term use of GLP-1 therapies for adults living with obesity and emphasise combining pharmacotherapy with intensive behavioural therapy. This combination may help sustain appetite suppression and extend both health and potential environmental benefits[5]. Nevertheless, long-term adherence, treatment discontinuation, access, affordability, and future clinical guidance remain important sources of uncertainty. As a result, the magnitude and persistence of the avoided mortality and increases in natural land estimated here depend on sustained treatment uptake and associated dietary changes over time.

The scenarios presented here should consequently be interpreted as exploratory assessments of the potential impact on the food-system of sustained GLP-1-mediated calorie reduction, rather than forecasts of future treatment trajectories. Alternative assumptions regarding adherence, treatment duration, and weight regain could be explored, but would require additional assumptions regarding re-initiation of treatment, eligibility, healthcare access, and future prescribing practices. Sustained dietary change, may also depend on a food environment that supports the adoption of healthy and sustainable diets, such as through restrictions on the promotion of foods high in fat, salt, and sugar[38]. Although the assumption of a substantial and sustained reduction in overconsumption may represent an upper-bound scenario, it provides a useful framework for quantifying the potential scale and direction of food-system responses. Lower adherence or greater weight regain could reduce the magnitude of the projected effects, while the extent to which these assumptions alter the direction of changes in food demand, prices, and land use remains to be established.. Exploring the sensitivity of these outcomes to alternative assumptions regarding treatment adherence, duration, and weight regain represents an important area for future research.

The widespread use of medications for obesity, combined with targeted dietary change among treated individuals, has the potential to alter global food demand and land use. Our findings suggest that medications for obesity could reduce obesity- and diet-related mortality while also reducing agricultural land demand, resource use and food prices. However, these effects are not uniform across populations. Lower prices and shifting demand may drive increased consumption of meat and sugar among non-medicated populations, partially offsetting reductions in diet-related mortality in some regions. Maximising both health and environmental outcomes will depend on coupling pharmacological interventions with broader dietary change. This will require not only targeted guidance for GLP-1 users, but also population-wide policies that shape food environments and influence consumption across the entire population. Measures that promote healthier diets, alongside appetite-suppressing treatments, could amplify these effects, enabling more profound and sustained transformations of the food system.

Methods

Model and scenario framework

We use LandSyMM (https://landsymm.earth) to explore how reductions in overconsumption between 2025 and 2040 impact the land and food system, and to quantify the associated health implications (Fig. 1). LandSyMM is a global food system and land use model that integrates a dynamic global vegetation model, LPJ-GUESS, with a land system model, PLUM, and a food demand system, MAIDADS[39]. The model combines spatially explicit yield responses with socio-economic scenario data to project future demand, land use, and management inputs, using climate data from CMIP5[40]. It has previously been used to explore future scenarios, including the effects of dietary change, climate change, and global shocks on the land and food system[41,42].

LandSyMM models crop yield responses in detail at fine spatial scales and dynamically links commodity demand to price changes. The MAIDADS [39] system accounts for income, food prices, and elasticities to estimate consumption patterns, showing shifts from staples to discretionary foods with rising incomes and the reverse with price increases. Diets are modelled through the MAIDADS demand system[39], so realised consumption emerges endogenously in response to income, prices, and preference parameters rather than being imposed exogenously. Commodity demand is met through domestic agriculture intensification, expansion, or imports. Excess production is exported, while global market dynamics adjust prices annually based on supply-demand imbalances, with stocks buffering oversupply or undersupply. Countries are either net importers or net exporters of individual commodities each year.

We compare a Reference scenario with six alternative GLP-1 scenarios. In the GLP-1 scenarios, changes in food consumption are implemented between 2025 and 2040. Outcomes are then evaluated in 2050, allowing sufficient time for food-system responses and associated market, land-use, and environmental effects to fully propagate through the model. Three scenarios assume that GLP-1 uptake affects calorie intake only among adults with obesity in: (i) high-income countries, (ii) high- and upper-middle-income countries, and (iii) all countries. We call these scenarios, GLP-1 calorie-only scenarios. Three parallel scenarios apply the same GLP-1 uptake assumptions but with treated individuals also transitioning towards healthier dietary preferences, consistent with the EAT–Lancet-2 diet[21]. We call these scenarios, GLP-1 calorie+diet. The scenarios are intended as exploratory assessments of the impact of sustained GLP-1-mediated calorie reduction on the food-system and are not forecasts of future treatment uptake, adherence, or duration. All scenarios use country GDP and population projections for SSP2, the 'Middle of the Road' Shared Socioeconomic Pathway[22,43] and climate change projections based on Representative Concentration Pathway (RCP) 4.5[44]. Parameter uncertainty is explored using 30 ensemble members per scenario, representing a balance between uncertainty exploration and the computational cost. For each ensemble member, key behavioural, agronomic, and economic parameters are sampled from predefined probability distributions using a Sobol sampling method. Supplementary Table 4 lists the parameter values and distributions consistent with SSP2 assumptions. The uncertainty presented in this paper therefore represents the distribution of outcomes across these 30 ensemble members, capturing uncertainty in model parameters rather than structural uncertainty across socioeconomic pathways. Parameter descriptions can be found in Alexander et al[45].

Baseline calorie demand

Baseline per capita calorie demand is derived from the MAIDADS demand system, which endogenously projects national average daily calorie availability ($\bar{c}_{c,t}$, kcal per capita per day) for each country c and year *t*. This measure represents a blended population average across all age groups.

To introduce demographic structure, we decomposed the MAIDADS average per capita calorie intake into age-specific intake levels. This approach allows GLP-1 assumptions to be applied exclusively to the adult population (aged ≥18 years) across uptake scenarios. We define children and adolescents as individuals aged <18 years. $s_{c,t}^{(18}$ denotes the share of the population aged under 18 in country *c* and year *t*. Country- and year-specific population age fractions are adopted from projected demographics from the Global Burden of Disease

Study to 2050[46]. $r_{c,t}$ denotes the ratio of average calorie intake of individuals aged <18 relative to adults (≥18).

Age- and sex-specific daily energy requirements are assigned as the pooled central estimates of the recommended ranges (Table 1), reflecting moderate physical activity levels and growth-stage requirements.

Within each country-year, the weighted mean energy requirement for the population aged <18 ($\bar{E}_{c,t}^{<18}$) is calculated as the demographic-share-weighted average of the relevant child and adolescent age classes, accounting for sex-specific requirements.

$$\bar{E}_{c,t}^{<18} = \sum_{a,s} \omega_{c,t}^{a,s} \cdot E^{a,s} \tag{1}$$

where $\omega_{c,t}^{a,s}$ is the population share of age group a and sex s among individuals aged <18, and $E^{a,s}$ is the corresponding reference requirement from Table 1. The mean adult requirement $\bar{E}_{c,t}^{\geq 18}$ is calculated analogously for the ≥18 population. The relative intake ratio is therefore defined as:

$$r_{c,t} = \frac{\bar{E}_{c,t}^{<18}}{\bar{E}_{c,t}^{\geq 18}} \tag{2}$$

This procedure ensures that the child-to-adult intake ratio varies across countries and over time in line with demographic structure and sex-specific energy requirements, while remaining consistent with the MAIDADS aggregate per capita calorie projections. In countries with younger age distributions or larger adolescent cohorts, the relative intake ratio will be higher, reflecting greater average caloric requirements among older children. Conversely, countries with a larger share of younger children will exhibit lower relative intake ratios.

Average calorie intake for adults ($A_{c,t}$) is calculated from population-level MAIDADS projections as:

$$A_{c,t} = \frac{\bar{c}_{c,t}}{1-(1-r_{c,t})s_{c,t}^{<18}} \tag{3}$$

Average intake for children and adolescents is then given by:

$$C_{c,t} = r_{c,t} \cdot A_{c,t} \tag{4}$$

This ensures that the weighted average across children and adults reproduces the MAIDADS blended projection:

$$\bar{c}_{c,t} = s_{c,t}^{<18} \cdot C_{c,t} + (1-s_{c,t}^{<18}) \cdot A_{c,t} \tag{5}$$

GLP-1 treatment scenarios

We adopt a country-level tiered approach to modelling GLP-1 uptake by income group to reflect uncertainty around future supply, affordability, and access. Although the cost of GLP-1 drugs is expected to decline and uptake to increase over time, the scale and speed of these changes remain uncertain. We therefore model three access scenarios: (i) high-income countries (HICs) only; (ii) high-income and upper-middle-income countries (HICs and UMICs); and (iii) universal access across all countries. We use the World Bank income group classifications[48]. While the scenarios are designed to reflect the assumption that accessibility to medication for obesity is likely to vary according to wealth, access to medication will also differ between income groups within countries, which we do not capture here. For example, higher obesity levels are often found in lower-income groups in high-income countries, which are also less likely to have access to medications for obesity[49].

Table 1 | Age- and sex-specific energy requirement values used to calculate the relative intake ratio for each country and year, based on the FAO/WHO/UNU Human Energy Requirements joint report (2004)[47]

Age group	Male (kcal/day)	Female (kcal/day)
5–9	1750	1650
10–14	2100	1900
15–17	2600	2200
18+	2650	2100

In the GLP-1 uptake scenarios, from 2025–2040, calorie intake is progressively reduced among adults with obesity (i.e. BMI ≥ 30 kg/m²) in countries with access to GLP-1. For this subgroup, daily food supply is gradually decreased to 1850 kcal per person.

The 1850 kcal per person per day limit (L) reflects an estimated intake of 1500 kcal combined with an assumption that 19% of food is wasted at the consumer level[50]. The 1500 kcal value represents a conservative estimate of intake for adults using GLP-1 medications. Typical guidance suggests daily intakes of 1200–1500 kcal for adult females and 1500–1800 kcal for adult males[51]. Untreated adults (aged ≥18 years; BMI < 30 kg/m²) and children (< 18 yrs) retain their baseline intake levels. This design should be interpreted as a stylised scenario assumption representing sustained appetite suppression among treated adults, rather than a prediction of realised intake in clinical practice.

The adjusted mean calorie intake for country c in year t ($c_{c,t}^{new}$) is therefore calculated as:

$$c_{c,t}^{new} = s_{c,t}^{<18} \cdot C_{c,t} + (1-s_{c,t}^{<18}) \cdot (1-s_{c,t}^{T}) \cdot A_{c,t} + (1-s_{c,t}^{<18}) \cdot s_{c,t}^{T} \cdot L \tag{6}$$

where $s_{c,t}^{T}$ denotes the fraction of the adult population receiving treatment in country c and year t. $s_{c,t}^{T}$ which corresponds to adults with BMI ≥ 30 kg/m². Country- and year-specific values of $s_{c,t}^{T}$ are derived from projected adult obesity prevalence from the Global Burden of Disease Study to 2050[24].

Importantly, this approach assumes average calorie consumption for adults with and without obesity is equal at baseline, in line with evidence from dietary surveys that individuals with obesity do not report higher calorie intake than individuals at a healthy weight[52]. Unfortunately, these survey results are likely affected by under-reporting by individuals with obesity[53]. Thus, the current design likely represents a conservative estimate of calorie reductions in individuals with obesity.

Commodity-level adjustment

For each country, total food supply is adjusted so that overall calorie availability does not exceed $c_{c,t}^{new}$, while preserving the relative proportions of each food commodity group. In other words, projected dietary composition for each year remains unchanged, but total intake is proportionally scaled. To implement this, projected consumption of each commodity f is multiplied by a consumption adjustment factor (CAF). The CAF is defined as the ratio of the adjusted mean total calorie intake to the mean total calorie intake across all commodities as projected by the MAIDADS demand system ($\bar{c}_{c,t}$):

When $c_{c,t}^{new} < \bar{c}_{c,t}$, an over-consumption adjustment factor is calculated as:

$$CAF_{c,t} = \frac{c_{c,t}^{new}}{\bar{c}_{c,t}} \tag{7}$$

Calorie intake for each commodity f is then calculated as:

$$Intake(f) = \bar{c}_{c,t} \cdot CAF_{c,t} \tag{8}$$

This approach ensures that total calorie intake is capped at $c_{c,t}^{new}$ while maintaining the modelled dietary structure. Reductions in calorie intake are phased in linearly over a 15-year period, allowing time for gradual adjustment in purchasing patterns, supply chains, and production decisions through the model's supply and demand mechanisms. As such, the results reflect medium- to long-run structural responses rather than immediate shocks. However, the model does not capture short-term rigidities in consumer behaviours, portion sizes, packaging, or food service practices, nor potential transitional increases in food waste if intake falls faster than supply chains adjust. To the extent that such mismatches occur, early-stage supply responses could be smaller than estimated here.

Dietary change in GLP-1 population

In addition to assessing the effects of GLP-1 through reductions in calorie intake, we examine three scenarios in which GLP-1 treatment is accompanied by shifts in dietary preferences among users towards healthier consumption patterns. We adopt the EAT–Lancet-2 diet[21] as the target diet, characterised by higher intakes of fruit, vegetables, and pulses, and lower consumption of meat and sugar. Dietary preferences are assumed to transition gradually from baseline patterns towards the EAT–Lancet-2 diet in parallel with GLP-1 uptake, such that by 2040 the dietary preferences of GLP-1 users have fully shifted towards a healthier dietary profile. This shift in preferences was implemented by gradually adjusting the α and τ parameters of the MAIDADS food demand system. The combined scenarios also apply the same calorie-capping procedure for the GLP-1 treated population.

Food price index calculation

We use changes in a Laspeyres food price index as an indicator of price-based food affordability at the population level. For each country *(c)*, we calculate the index by pricing the base-year (2020) basket of demanded food groups (*f*) using country-specific prices (*p*) in the current period (*t*). Regional Laspeyres indices are calculated as population-weighted averages of the country-level indices.

$$food\ price\ index_{c,t} = \frac{\sum_f demand_{f,c,t=2020} \cdot p_{f,c,t}}{\sum_f demand_{f,c,t=2020} \cdot p_{f,c,t=2020}} \quad (9)$$

Mortality analysis

Our comparative risk assessment closely follows the framework developed by Springmann and colleagues[20,25,54,55]. We use a country-level risk–disease model that links changes in diet- and BMI-related risk factors to cause-specific mortality to estimate differences in mortality between the Reference scenario and each of the GLP-1 scenarios. To isolate the effects of changes in dietary and BMI-related risk factors between 2025 and 2050, we compare the year 2050 in the scenarios against a baseline with death rates and population structures of 2050 but diets and BMI proportions from 2025. We then compare the differences in calculated mortality between the Reference scenario and the GLP-1 scenarios to isolate the impact of the GLP-1 scenarios in 2050. Mortality data are taken from the Global Burden of Disease project (2021)[56].

The analysis captures key dietary risks (e.g., red meat, fruits, vegetables, nuts and legumes) alongside changes in the adult population fraction with obesity and quantifies impacts on the adult population (age ≥ 20) across major diseases, including cardiovascular diseases, type 2 diabetes, cancers, and respiratory diseases. The number of deaths avoided in country (*c*) in year (*t*) for disease (d), risk factor (*f*), and age group (*a*) is calculated as:

$$\Delta deaths_{c,t,d,f,a} = DR_{c,d,a} \cdot P_{c,t,a} \cdot PIF_{c,t,d,f} \quad (10)$$

where DR is the death rate taken from the Global Burden of Disease Project for the year 2021[56]. P is the population size of the age group; country- and year-specific population age fractions are taken from projected demographics from the Global Burden of Disease Study to 2050[46]. The population impact fractions (PIFs) represent the proportions of disease-specific mortality that would be avoided if exposure to a given risk factor changed from the baseline scenario (*ref*) to the counterfactual scenario (*cfl*), while all other risk factors remain unchanged. For the dietary risk factors, the PIFs are calculated as follows:

$$PIF_{c,t,d,f} = 1 - \frac{RR_{d,f}^{cm_{c,t,cfl}/s_f}}{RR_{d,f}^{cm_{c,t,ref}/s_f}}, f = (red\ meat, processedmeat, fruit, veg, nuts, legumes) \quad (11)$$

where *RR* is the relative risk of disease/mortality cause for the risk factor. Consistent with the original studies [20,25,54,55], parameterisation relies on relative risks derived from meta-analyses of prospective cohort studies. We include non-linear dose-response relationships for fruits, vegetables, and nuts, and processed meat and diabetes, and assume linear dose-response relationships for the remaining risk factors (Supplementary Table 2, adopted from Springmann et al[54].). Because dietary intake differs between GLP-1 populations and non-GLP-1 adult populations, for the dietary risk factors, we perform separate analyses on the adult GLP-1 treated and untreated populations of a country. Modelled consumption levels (*cm*) for both groups are measured in g/capita/day and serving sizes (*s*) are given in Supplementary Table 2. To get consumption estimates, we adjust modelled food supply (*fs*), which represents food available for consumption rather than intake, to account for waste. We follow Springmann et al., who implemented an approach based on the FAO's waste-accounting methodology[6], which adjusts food availability data to account for losses. For each food commodity and country, consumption is calculated by multiplying modelled food supply by conversion factors representing the edible portion (e.g., after peeling) and by the proportion of food actually consumed, accounting for household waste. For fruits and vegetables, we further distinguish between wastage in items consumed fresh and those used in processed forms, applying separate waste fractions to each. Consumption (*cm*) for each commodity and country is calculated as the sum of the edible, non-wasted portions of fresh and processed products:

$$cm = fs \cdot cf_{fresh} \cdot \left(\frac{pct_{fresh}}{100}\right) \cdot \left(1 - \frac{wp_{fresh}}{100}\right) + fs \cdot cf_{proc} \cdot \left(\frac{pct_{proc}}{100}\right) \cdot \left(1 - \frac{wp_{processed}}{100}\right) \quad (12)$$

Values for processed food wasted during consumption ($wp_{processed}$), fresh food wasted during consumption (wp_{fresh}), processed food utilised (pct_{proc}), fresh food utilisation (pct_{fresh}), and conversion factors (*cf*) representing the edible portion (e.g. after peeling), are given in Supplementary Table 1.

Consumption levels are denoted by the subscripts *glp* and *ref*, referring to the GLP-1 and Reference scenarios, respectively. Following Springmann[54] to estimate processed meat, we use the global dietary database estimates for each country for red and processed meat to estimate the ratio of processed meat to the sum of red and processed meat, and apply that ratio to our LandSyMM estimates of total red meat intake for each country. For the BMI-related risk factors

the PIFs were calculated as follows:

$$PIF_{c,t,d,f} = 1 - \frac{\sum_w P^{pr}_{c,t,w} \cdot RR_{d,w}}{\sum_w P^{ref}_{c,t,w} \cdot RR_{d,w}}, w = \begin{pmatrix} healthy\,weight, \\ overweight, obese \end{pmatrix} \quad (13)$$

where the relative risks *RR* are differentiated by disease *d* and weight category *w*. The proportions of the population (*P*) in the different weight categories vary by country and year. Country- and year-specific projections of adult overweight and obesity prevalence are sourced from the Global Burden of Disease Study (to 2050)[24]. We assume that, by 2050, individuals with obesity who adopt GLP-1 medications shift into the overweight category, reflecting conservative assumptions regarding BMI reductions associated with GLP-1 use.

We calculate the combined disease and mortality burden of changes in dietary risk factors and weight risk factors using the following equation:

$$PIFtot_d = 1 - \prod_f \left(1 - PIF_{d,f}\right), f = (weight,\ diet) \quad (14)$$

where PIF_{TOT} is the final PIF for a given disease after all PIFs for risk factors (*f*) have been combined.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

The simulated LandSyMM output data used in this study are available in the Zenodo database under accession code https://doi.org/10.5281/zenodo.21822657 (https://zenodo.org/records/21822657). Food consumption data were accessed through FAOSTAT;. BMI data were accessed through the global health data exchange (https://ghdx.healthdata.org/record/ihme-data/gbd-2021-adult-obesity-overweight-prevalence-1990-2050). Demographic data, disease and mortality data were accessed through the global health data exchange (http://ghdx.healthdata.org/gbd-results-tool).

Code availability

Source code and instructions for the PLUMv2 module of LandSyMM used in this study can be found at https://git.ecdf.ed.ac.uk/lul/plumv2/-/tree/overconsumption?ref_type=heads, and in the documentation folder. LandSyMM does not currently have a general user interface (GUI) however assistance can be given by the authors should others wish to run LandSyMM. Input files and a README file is available at https://doi.org/10.5281/zenodo.21822657 (https://zenodo.org/records/21822657).

References

1. Chong, B. et al. Trends and predictions of malnutrition and obesity in 204 countries and territories: an analysis of the Global Burden of Disease Study 2019. *EClinicalMedicine* **57**, 101850 (2023).
2. World Obesity Federation. *World Obesity Atlas 2025*. (World Obesity Federation, 2025).
3. Stanaway, J. D. et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **392**, 1923–1994 (2018).
4. Moiz, A. et al. Long-term efficacy and safety of once-weekly semaglutide for weight loss in patients without diabetes: a systematic review and meta-analysis of randomized controlled trials. *Am. J. Cardiol.* **222**, 121–130 (2024).
5. Celletti, F., Farrar, J. & De Regil, L. World Health Organization guideline on the use and indications of glucagon-like peptide-1 therapies for the treatment of obesity in adults. *JAMA* **335**, 434 (2026).
6. Taylor, L. WHO: Ramp up production of weight loss injections to combat global obesity. *BMJ* **391**, r2540 (2025).
7. Alex Montero, Grace Sparks, Marley Presiado & Liz Hamel. *KFF Health Tracking Poll May 2024: The Public's Use and Views of GLP-1 Drugs*. (KFF, 2024).
8. Jackson, S. E., Brown, J., Llewellyn, C., Mytton, O. & Shahab, L. Prevalence of use and interest in using glucagon-like peptide-1 receptor agonists for weight loss: a population study in Great Britain. *BMC Med.* **24**, 1 (2026).
9. Yoo, S. G. K. et al. GLP-1 receptor agonists for obesity: eligibility across 99 countries. *Lancet Diab. Endocrinol.* **14**, 105–108 (2026).
10. Arias, A. & Rickwood, S. Off-patent semaglutide in 2026: the next revolution in anti-obesity medications. *IQVIA EMEA* https://www.iqvia.com/locations/emea/blogs/2025/07/off-patent-semaglutide#1 (IQVIA, 2025).
11. Meissner, W. G. et al. Trial of Lixisenatide in Early Parkinson's Disease. *N. Engl. J. Med.* **390**, 1176–1185 (2024).
12. Cummings, J. L. et al. Evoke+e+: design of two large-scale, double-blind, placebo-controlled, phase 3 studies evaluating efficacy, safety, and tolerability of semaglutide in early-stage symptomatic Alzheimer's disease. *Alzheimers Res. Ther.* **17**, 14 (2025).
13. Edison, P. et al. Evaluation of liraglutide in the treatment of Alzheimer's disease. *Alzheimer's & Dementia* **17**, e057848 (2021).
14. Goldman Sachs Research. The anti-obesity drug market may prove smaller than expected. *Goldman Sachs* https://www.goldmansachs.com/insights/articles/the-anti-obesity-drug-market-may-prove-smaller-than-expected (Goldman Sachs Research, 2025).
15. Morgan Stanley. *Downsizing Demand: Obesity Medications' Impact on the Food Ecosystem*. (Morgan Stanley, 2023).
16. Díaz, S. et al. Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science* **366**, eaax3100 (2019).
17. Hong, C. et al. Global and regional drivers of land-use emissions in 1961–2017. *Nature* **589**, 554–561 (2021).
18. *Global Environment Outlook 7: A Future We Choose – Why Investing in Earth Now Can Lead to a Trillion-Dollar Benefit for All*. https://doi.org/10.59117/20.500.11822/49014.(United Nations Environment Programme, 2025).
19. Alexander, P. et al. Losses, inefficiencies and waste in the global food system. *Agric. Syst.* **153**, 190–200 (2017).
20. Bodirsky, B. L. et al. A food system transformation pathway reconciles 1.5 °C global warming with improved health, environment and social inclusion. *Nat. Food* **6**, 1133–1152 (2025).
21. Rockström, J. et al. The EAT–Lancet Commission on healthy, sustainable, and just food systems. *Lancet* **406**, 1625–1700 (2025).
22. O'Neill, B. C. et al. A new scenario framework for climate change research: the concept of shared socioeconomic pathways. *Clim. Change* **122**, 387–400 (2014).
23. Rabin, S. S. et al. Impacts of future agricultural change on ecosystem service indicators. *Earth Syst. Dynam. Discuss.* **2019**, 1–27 (2019).
24. Institute for Health Metrics and Evaluation (IHME). Global Burden of Disease Study 2021 (GBD 2021) Adult Overweight and Obesity Prevalence Estimates and Forecasts 1990-2050. *Institute for Health Metrics and Evaluation (IHME),*2025.
25. Clark, M. A., Springmann, M., Hill, J. & Tilman, D. Multiple health and environmental impacts of foods. *Proc. Natl. Acad. Sci. USA.* **116**, 23357 LP–23323362 (2019).
26. Springmann, M. et al. Options for keeping the food system within environmental limits. *Nature* **562**, 519–525 (2018).

27. Willett, W. et al. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet* **393**, 447–492 (2019).
28. Hendrie, G., Baird, D., Ridoutt, B., Hadjikakou, M. & Noakes, M. Overconsumption of energy and excessive discretionary food intake inflates dietary greenhouse gas emissions in Australia. *Nutrients* **8**, 690 (2016).
29. Sammut Bartolo, N., Azzopardi, L. M. & Serracino-Inglott, A. Pharmaceuticals and the environment. *Early Hum. Dev.* **155**, 105218 (2021).
30. Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A. B. & Kent, J. Biodiversity hotspots for conservation priorities. *Nature* **403**, 853 (2000).
31. Christensen, S., Robinson, K., Thomas, S. & Williams, D. R. Dietary intake by patients taking GLP-1 and dual GIP/GLP-1 receptor agonists: A narrative review and discussion of research needs. *Obes. Pillars* **11**, 100121 (2024).
32. Ponzo, V. et al. Exploring dietary intake in adults with type 2 diabetes using GLP-1 receptor agonists: a cross-sectional analysis. *Nutrients* **17**, 3318 (2025).
33. Johnson, B. V. B., Milstead, M., Green, L., Kreider, R. & Jones, R. Diet quality and nutrient distribution while using glucagon-like-peptide-1 receptor agonist: a secondary cross-sectional analysis. *Obes. Pillars* **16**, 100195 (2025).
34. Regmi, A. & Seale, J. L. Cross-price elasticities of demand across 114 countries. *USDA-ERS Technical Bulletin* (USDA-ERS, 2010).
35. National Institute for Health and Care Excellence. *Semaglutide for Managing Overweight and Obesity*. (NIHCE, 2023).
36. Bawden, A. People who stop weight loss drugs return to original weight within year, analysis finds. (The Guardian, 2025).
37. Prillaman, M. Obesity drugs aren't always forever. What happens when you quit? *Nature* **628**, 488–490 (2024).
38. Luick, M. et al. The impact of price promotions on confectionery and snacks on the energy content of shopping baskets: a randomised controlled trial in an experimental online supermarket. *Appetite* **186**, 106539 (2023).
39. Gouel, C. & Guimbard, H. Nutrition transition and the structure of global food demand. *Am. J. Agric. Econ.* **101**, 383–403 (2019).
40. Dufresne, J.-L. et al. Climate change projections using the IPSL-CM5 Earth System Model: from CMIP3 to CMIP5. *Clim. Dyn.* **40**, 2123–2165 (2013).
41. Henry, R. C. et al. Global and regional health and food security under strict conservation scenarios. *Nat. Sustain.* **5**, 303–310 (2022).
42. Alexander, P. et al. High energy and fertilizer prices are more damaging than food export curtailment from Ukraine and Russia for food prices, health and the environment. *Nat. Food* **4**, 84–95 (2023).
43. O'Neill, B. C. et al. The roads ahead: narratives for shared socioeconomic pathways describing world futures in the 21st century. *Glob. Environ. Change* **42**, 169–180 (2015).
44. van Vuuren, D. P. et al. The representative concentration pathways: An overview. *Clim. Change* **109**, 5–31 (2011).
45. Alexander, P. et al. Adaptation of global land use and management intensity to changes in climate and atmospheric carbon dioxide. *Glob. Chang. Biol.* **24**, 2791–2809 (2018).
46. Vollset, S. E. et al. Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: a forecasting analysis for the Global Burden of Disease Study. *Lancet* **396**, 1285–1306 (2020).
47. FAO/WHO/UNU. *Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation, Rome, 17–24 October 2001. Food and Nutrition Technical Report Series No. 1* (FAO, 2004).
48. World Bank. World Bank country and lending groups. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups (World Bank, 2026).
49. Roser, P., Bajaj, S. S. & Stanford, F. C. International lack of equity in modern obesity therapy: the critical need for change in health policy. *Int. J. Obes.* **46**, 1571–1572 (2022).
50. United Nations Environment Programme. *Food Waste Index Report 2024. Think Eat Save: Tracking Progress to Halve Global Food Waste*. (United Nations Environment Programme, 2024).
51. Almandoz, J. P. et al. Nutritional considerations with antiobesity medications. *Obesity* **32**, 1613–1631 (2024).
52. Gu, W. et al. Trends and disparities in diet quality and nutrient intake among US adults by bodyweight status. *Nutrients* **16**, 2793 (2024).
53. Archer, E., Hand, G. A. & Blair, S. N. Validity of U.S. nutritional surveillance: national health and nutrition examination survey caloric energy intake data, 1971–2010. *PLoS One* **8**, e76632 (2013).
54. Springmann, M. et al. The healthiness and sustainability of national and global food based dietary guidelines: modelling study. *BMJ* **370**, m2322 (2020).
55. Springmann, M. et al. Global and regional health effects of future food production under climate change: a modelling study. *Lancet* **387**, 1937–1946 (2016).
56. Institute for Health Metrics and Evaluation (IHME). GBD Results. https://vizhub.healthdata.org/gbd-results/. (IHME, 2025).

Author contributions

R.C.H., P.A., K.W. and L.M.J. conceptualized the project. R.C.H. carried out the data preparation, simulations and analysis. R.C.H. wrote the manuscript with support from P.A., K.W. and L.M.J. All authors reviewed and edited the manuscript.

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Competing interests

The authors declare no competing interests.

Additional information

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