


# Potential impacts of post-Brexit agricultural policy on fruit and vegetable intake and cardiovascular disease in England: a modelling study

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## ABSTRACT

**Background** Current proposals for post-Brexit agricultural policy do not explicitly incorporate public health goals. The revised agricultural policy may be an opportunity to improve population health by supporting domestic production and consumption of fruits and vegetables (F&V). This study aims to quantify the potential impacts of a post-Brexit agricultural policy that increases land allocated to F&V on cardiovascular disease (CVD) mortality and inequalities in England, between 2021 to 2030.

**Methods** We used the previously validated IMPACT Food Policy model and probabilistic sensitivity analysis to translate changes in land allocated to F&V into changes in F&V intake and associated CVD deaths, stratified by age, sex and Index of Multiple Deprivation. The model combined data on F&V agriculture, waste, purchases and intake, CVD mortality projections and appropriate relative risks. We modelled two scenarios, assuming that land allocated to F&V would gradually increase to 10% and 20% of land suitable for F&V production.

**Results** We found that increasing land use for F&V production to 10% and 20% of suitable land would increase fruit intake by approximately 3.7% (95% uncertainty interval: 1.6% to 8.6%) and 17.4% (9.1% to 36.9%), and vegetable intake by approximately 7.8% (4.2% to 13.7%) and 37% (24.3% to 55.7%), respectively, in 2030. This would prevent or postpone approximately 3890 (1950 to 7080) and 18 010 (9840 to 28 870) CVD deaths between 2021 and 2030, under the first and second scenario, respectively. Both scenarios would reduce inequalities, with 16% of prevented or postponed deaths occurring among the least deprived compared with 22% among the most deprived.

**Conclusion** Post-Brexit agricultural policy presents an important opportunity to improve dietary intake and associated cardiovascular mortality by supporting domestic production of F&V as part of a comprehensive strategy that intervenes across the supply chain.

## INTRODUCTION

Brexit, the planned exit of the UK from the European Union (EU), will impact UK agricultural policy. While part of the EU, the UK abides by the European Common Agricultural

## What this paper adds

- Following Brexit, the UK has signalled its intention to shift towards a new agricultural policy. However, current proposals for post-Brexit agricultural policy do not explicitly incorporate public health goals.
- Post-Brexit agricultural policy presents an opportunity to improve domestic production and dietary intake of fruits and vegetables in England, with beneficial impacts on CVD mortality and inequalities.
- To achieve this, support for British-grown fruits and vegetables should be part of a comprehensive agricultural strategy that intervenes across the whole supply chain.

Policy (CAP), which regulates agriculture across EU Member States under a common regime. Post-Brexit, the UK has signalled its intention to shift towards a new agricultural policy, currently outlined in a draft Agriculture Bill introduced in September 2018.<sup>1</sup> The Agriculture Bill recommends the gradual removal of current CAP payments during a 7-year transition period, between 2021 to 2027. It proposes a new financial assistance system to replace CAP payments, which will be based on the provision of 'public money for public goods'. These public goods would mainly involve environmental goals (box 1).

The omission of explicit health goals in the Agriculture Bill would appear to be a missed opportunity. Leading public health and farming think tanks in the UK have recommended the consideration of public health as a public good in the new Agriculture Bill,<sup>2,3</sup> to capture the dual purpose – a sustainable and healthy agricultural policy. The food supply chain begins at the farm; thus, agriculture is a determinant of the food system and shapes diet through supply-side interventions to the food environment.<sup>4</sup> Therefore, post-Brexit

## Box 1 Public goods outlined in the Agriculture Bill

1. Managing land or water in a way that protects or improves the environment.
2. Supporting public access to and enjoyment of the countryside, farmland or woodland and better understanding of the environment.
3. Managing land or water in a way that maintains, restores or enhances cultural heritage or natural heritage.
4. Mitigating or adapting to climate change.
5. Preventing, reducing or protecting from environmental hazards.
6. Protecting or improving the health or welfare of livestock.
7. Protecting or improving the health of plants.

Source: Agriculture Bill<sup>1</sup>

agricultural policy is an opportunity to improve UK diets by shaping the availability, affordability, diversity, quality and marketing of British-grown fruits and vegetables (F&V).<sup>23</sup>

F&V intake in the UK is suboptimal – currently only 31% of adults meet the governmental recommendations of five F&V per day.<sup>5</sup> Low F&V intake is associated with a substantial burden of disease, including cardiovascular disease (CVD).<sup>67</sup> F&V account only for a small proportion of overall agricultural production in the UK, with only 2.7% of total croppable land used for horticultural crops<sup>8</sup> and domestic production accounting for 16% of fruit and 52% of vegetable total supply in 2018.<sup>8</sup> Thus, Brexit is planned during a period when there is an urgent need to boost domestic F&V production and consumption in the UK to improve health and reduce inequalities. This research aims to quantify the potential impacts of a post-Brexit agricultural policy that increases domestic production of F&V on CVD mortality and inequalities in England, between 2021 to 2030.

## METHODS

We extended the previously validated IMPACT Food Policy model<sup>9 10</sup> to estimate the potential effect of increasing land allocated to F&V as part of the post-Brexit

agricultural regime on production and intake of F&V. Changes in F&V intake were then translated into changes in mortality of coronary heart disease (CHD), ischaemic stroke and haemorrhagic stroke by age group (25 to 34 until 85+ years), sex and quintile of Index of Multiple Deprivation (IMD) 2010, between 2021 to 2030 in England. Stratification by level of deprivation allowed us to quantify the potential impact of modelled scenarios on CVD inequalities. A schematic representation of the model is presented in online supplementary appendix figure A1.

## Data sources

Model inputs and their sources are presented in table 1.

We integrated a number of data inputs from the Department of Environment and Rural Affairs. Data on land used for F&V production (% total agricultural land) were obtained from the June Survey of Agriculture,<sup>11</sup> which collects information from farmers on their agricultural activities on 1<sup>st</sup> June every year. Data from Horticulture Statistics<sup>12</sup> provided information on F&V supply (tonnes), estimated as the sum of F&V production and supply excluding exports, whereas data from the annual Agriculture in the UK report<sup>13</sup> provided an estimate of F&V yield (tonnes/hectare), estimated using data on agricultural area and production.

Modelled scenarios were informed by data on Agricultural Land Classification (ALC) in England.<sup>14</sup> ALC categorises agricultural land in England into grades of land quality based on three criteria: climate, site and soil.<sup>15</sup> Grades 1 and 2 are of the highest quality, allowing to grow a wide range of horticultural crops, including F&V. Grades 3 to 5, which are not appropriate for F&V cultivation, are of lower quality and are mainly used to grow arable crops, such as cereals, grass and other pasture for animal grazing. In this model, we used an estimate of Grade 1–2 land (% total agricultural land).

**Table 1** Model inputs and data sources

Model input	Data source
Total and F&V agricultural land, 2010–2018 (England)	DEFRA, June Survey of Agriculture <sup>11</sup>
Provisional Agricultural Land Classification (England)	Natural England <sup>14</sup>
F&V yield, estimated using area and production data, 2010–2018 (UK)	DEFRA, Agriculture in the UK <sup>13</sup>
F&V supply, estimated using production, import and export data, 2010–2018 (UK)	DEFRA, Horticulture Statistics <sup>12</sup>
F&V purchases, 2008–2016/2017 (UK)	Family Food module of the Living Costs and Food Survey <sup>16</sup>
F&V waste at household level, 2012 (UK)	Waste & Resources Action Programme <sup>17</sup>
Population projections, England, 2021–2030 (2016-based and mid-year)	O <sup>27</sup> NS
F&V intake by age, sex and IMD, England	National Diet and Nutrition Survey Rolling Programme Years 1–4 and 7–8 <sup>28</sup>
RR for CHD/ ischaemic stroke/ haemorrhagic stroke by serving of fruit/vegetable intake by age	Micha <i>et al</i> , 2017 <sup>19</sup>
CHD and stroke mortality projections for England by age, sex and IMD, 2021–2030	Own estimations using data from the ONS
Impact of No Deal Brexit on F&V intake in England in 2021	Seferidi <i>et al</i> , 2019 <sup>23</sup>

CHD, coronary heart disease; DEFRA, Department of Environment and Rural Affairs; F&V, fruit and vegetable; IMD, Index of Multiple Deprivation; ONS, Office for National Statistics; RR, relative risk.

F&V purchases were obtained from the Family Food module of the Living Costs and Food Survey (LCFS),<sup>16</sup> which is an annual representative survey of UK households that collects information on food expenditure and purchasing using 2-week diaries. Data on F&V household waste were obtained from the Waste & Resources Action Programme (WRAP).<sup>17</sup> WRAP used a combination of waste composition data to estimate waste collected by local authorities, composted at home, fed to animals and disposed of down the drain for different food groups, including F&V. We used data from 2012 due to the high granularity in food groups examined that year. National F&V waste was translated into F&V waste per capita measured as a percentage of F&V purchases, using information on UK population size from the Office for National Statistics (ONS) and F&V purchases from the LCFS 2012. Finally, we used F&V intake data for three age groups (25 to 44, 45 to 64, 65+), sex and IMD quintiles in England from the National Diet and Nutrition Survey Rolling Programme (NDNS) Years 1 to 4 and 7 to 8. Years 5 to 6 were not employed due to lack of data on IMD. The IMD is a relative measure of deprivation that assigns a deprivation score to small areas in England based on different socioeconomic criteria. The NDNS uses 4-day food diaries to estimate dietary intake in a nationally representative population sample in the UK. The definition of F&V across the different data sources is described in online supplementary appendix table A1.

We used projections of CHD and stroke mortality, stratified by age (25 to 34 until 85+ years), sex and quintiles of IMD using a Bayesian Age-Period-Cohort model (BAPC). The methodology of the BAPC is described in more detail elsewhere<sup>18</sup> and in online supplementary appendix 1. We used relative risks (RRs) between F&V intake and CVD from meta-analyses of longitudinal studies.<sup>19</sup> Specifically, RRs for CHD, ischaemic stroke and haemorrhagic stroke by serving of fruit intake and vegetable intake were used (see online supplementary appendix table A2). These RRs were chosen because they are age-specific, being adjusted for effect-modification by age, although they were assumed to not vary by sex or IMD quintiles.

### Modelled scenarios

We modelled two potential scenarios of agricultural land change. Agricultural land suitable for F&V (Grade 1–2 land) accounts for approximately 19% of total agricultural

land in England, based on ALC data. However, only 1.4% of agricultural land on average was used to grow F&V in England between 2010 to 2018 with almost no variation across years (see online supplementary appendix table A3). The modelled scenarios assumed that land allocated to F&V in England would gradually increase in equal annual increments throughout the agricultural transition period, defined by the Agriculture Bill as the period between 2021 to 2027. The assumed changes in agricultural land used for F&V production under the two modelled scenarios is shown in table 2. These are plausible in terms of historical data.<sup>11</sup> Overall, the scenarios assumed that by the end of the agricultural transition period (2027), land allocated to F&V would reach:

Scenario 1: 10% of Grade 1–2 land (land suitable for F&V production) in England.

Scenario 2: 20% of Grade 1–2 land (land suitable for F&V production) in England.

We translated increases in agricultural land into increases in F&V production, assuming that F&V yield and the relative difference between F&V agricultural land would not change over time. Extra agricultural production of F&V was then translated into extra F&V purchases using a purchases-to-supply ratio and assuming that all extra production would be mirrored by increased consumer demand. The ratio, estimated using data on F&V purchases and supply in the UK, adjusted for potential losses between the farm and the consumer, including losses at the packaging, distribution and retailing stages, as well as F&V used towards production of processed foods. In a one-way sensitivity analysis, we further investigated the impact of this ratio by assuming that only 50% of F&V production would be translated into F&V purchases, based on estimates on F&V production losses from the Food and Agriculture Organization.<sup>20</sup> We observed no persistent trend of the ratio over time, although annual variations were taken into account in a probabilistic sensitivity analysis. We also assumed a time lag between the decision to shift agricultural land towards F&V and F&V reaching consumer baskets. This was set at 2.5 years on average for all F&V and was allowed to vary between 0 and 5 years in a probabilistic sensitivity analysis. This reflected variation in the production cycle of different crops, with some entering the market at the same year of their production, whereas others, such as apple orchards,

**Table 2** Changes in fruit and vegetable land in the first year of the modelling period (2021), at the end of the agricultural transition period (2027) and at the end of the modelling period (2030) under each modelled scenario

	F&V land (% Grade 1–2 land)			F&V land (% of total agricultural land)		
	2021	2027	2030	2021	2027	2030
Baseline scenario	–	–	–	1.4	1.4	1.4
Scenario 1	–	10	10	1.5	1.9	1.9
Scenario 2	–	20	20	1.8	3.9	3.9

–, represents unknown numbers that are not needed to investigate modelled scenarios.  
F&V, fruits and vegetables.



taking at least 5 years to go through a complete production cycle.<sup>21</sup>

Finally, changes in F&V purchases were translated into changes in F&V intake after accounting for F&V waste at household level. Changes in F&V intake were estimated at national level and translated into changes per person per day using population projections between 2021 to 2030 from the ONS.<sup>22</sup> We assumed that extra F&V intake will be distributed equally among all age, sex and IMD groups. Relevant model inputs are presented in online supplementary appendix table A3.

### The IMPACT Food Policy model

The IMPACT Food Policy model has been previously used to estimate impacts of food policies on CVD outcomes through changes in dietary intake.<sup>9 10</sup> The estimated changes in dietary intake of F&V under the two modelled scenarios were translated into changes in CHD, ischaemic stroke and haemorrhagic stroke mortality, measured in Deaths Prevented or Postponed (DPPs), using mortality projections and appropriate RRs (see online supplementary appendix 2). The combined impact of changes in F&V intake was estimated using a cumulative risk-reduction approach (see online supplementary appendix 2). The cumulative number of CVD DPPs under each modelled scenario was estimated as the sum of CHD, ischaemic stroke and haemorrhagic stroke DPPs, between 2021 to 2030.

### Deterministic sensitivity analysis

We performed a sensitivity analysis to investigate the potential impact of modelled scenarios under a No Deal Brexit. In the main analysis, we assumed that Brexit would not substantially change F&V trade in England. However, depending on the agreed deal, Brexit might drastically change the UK's trade regime with potential implications on F&V intake. A previous analysis has estimated that post-Brexit trade policy might reduce F&V intake, with the worst-case scenario being a No Deal Brexit, reducing fruit intake by -11.4% (-14.2% to -9.5%) and vegetable intake by -9.1% (-11.0% to -7.8%) in 2021.<sup>23</sup> In a sensitivity analysis, we estimated the potential impact of modelled scenarios on CVD mortality between 2021 to 2030, after assuming a reduction in F&V intake in 2021 due to a No Deal Brexit.

### Probabilistic sensitivity analysis

We tested the impact of uncertainty of modelled input parameters on modelled outcomes using Monte Carlo simulation. Statistical distributions were assigned to different model inputs (see online supplementary appendix table A4). Then, the model was run across multiple iterations, using random values of model inputs derived from their respective statistical distributions. The median and 2.5<sup>th</sup> and 97.5<sup>th</sup> percentiles of 1000 iterations were used to estimate model outputs and their 95% uncertainty intervals (95% UI).

**Table 3** Estimated impact of modelled scenarios on production of fruits and vegetables in the beginning, the end and throughout the modelling period

Scenario	Change in production in thousand tonnes (95% UI)	
	Fruits	Vegetables
2021		
Scenario 1	31 (15 to 45)	115 (59 to 181)
Scenario 2	145 (97 to 190)	535 (419 to 723)
2030		
Scenario 1	222 (108 to 368)	803 (452 to 1261)
Scenario 2	1037 (677 to 1457)	3823 (2773 to 4997)
2021–2030		
Scenario 1	1097 (497 to 2062)	4037 (2003 to 7237)
Scenario 2	5177 (2946 to 8435)	19 1888 (11 576 to 29 204)

95% UI, 95% uncertainty interval.

## RESULTS

### Impact of modelled scenarios on F&V production

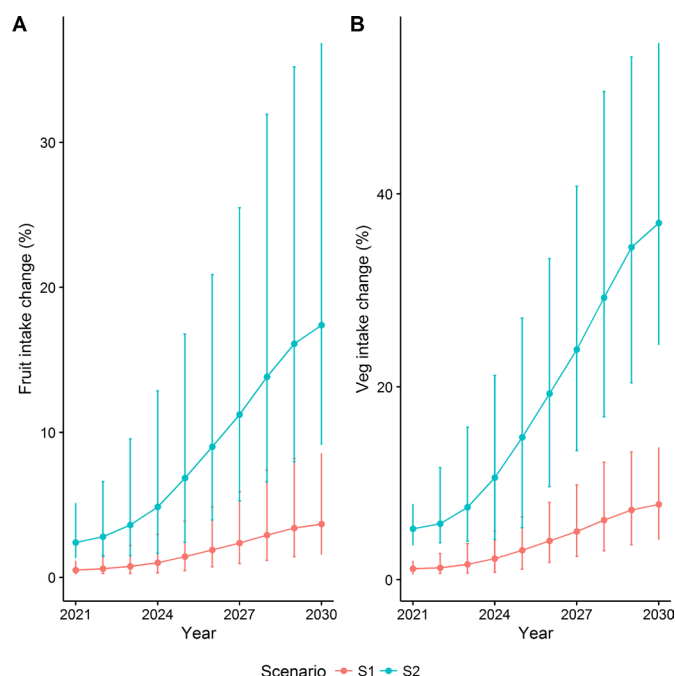
We estimated that F&V production would increase every year between 2021 to 2030, under both scenarios. Increasing F&V land until it reaches 10% of Grade 1–2 land would contribute approximately 1.1 (95% UI: 0.5 to 2.1) million tonnes of extra fruit and 4.0 (2.0 to 7.2) million tonnes of extra vegetable production between 2021 to 2030 (table 3). Under the more ambitious scenario of F&V land reaching 20% of Grade 1–2 land, we estimated that F&V production would increase by approximately 5.2 (2.9 to 8.4) million and 19.2 (11.6 to 29.2) million tonnes, respectively, between 2021 to 2030 (table 3).

### Impact of modelled scenarios on F&V intake

At baseline, dietary intake among English adults aged 25 years and above was approximately 111 (SE: 3) g/day for fruits and 199 (SE: 5) g/day for vegetables, with F&V intake reducing with increasing deprivation (see online supplementary appendix table A5). We estimated that, between 2021 to 2030, F&V intake would gradually increase under both modelled scenarios (figure 1). Increasing land allocated to F&V until it reached 10% of Grade 1–2 land could increase F&V intake by approximately 3.7% (1.6% to 8.6%) and 7.8% (4.2% to 13.7%), respectively, in 2030. Similarly, if land allocated to F&V reaches 20% of Grade 1–2 land compared with maintaining current allocations, we estimated that F&V intake would be approximately 17.4% (9.1% to 36.9%) and 37% (24.3% to 55.7%) higher by 2030 (see online supplementary appendix table A6).

### Impact of modelled scenarios on CVD mortality

We projected that, between 2021 to 2030, CHD and stroke would generate approximately 435 200 (330 500 to 584 500) and 258 500 (148 400 to 532 500) cumulative deaths, respectively, in England, under a baseline business-as-usual scenario. Estimated CHD deaths were increasing with deprivation, with approximately 23% of CHD deaths in 2030 in the most deprived group compared with 15%



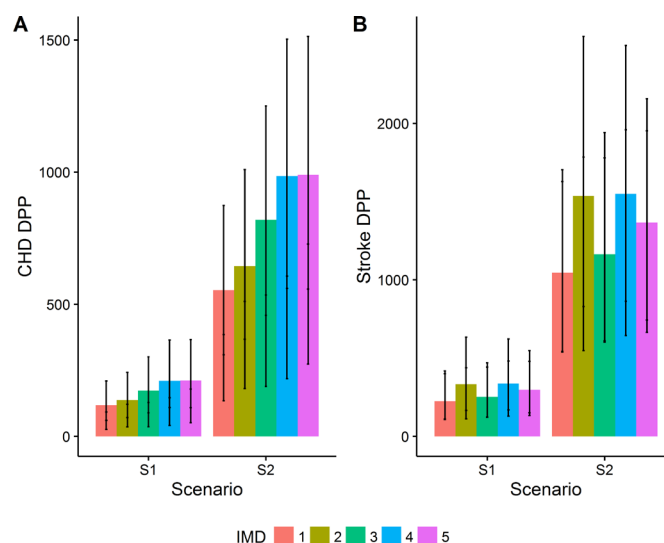
**Figure 1** Estimated impact of modelled scenarios on intake of (A) fruits and (B) vegetables, over the modelling period.

in the least deprived group. Number of stroke deaths was projected to be more equitable, with smaller differences across IMD quintiles.

We estimated that increasing land allocated to F&V until it reaches 10% of Grade 1–2 land was associated with approximately 1230 (630 to 2150) fewer CHD and 2660 (1320 to 4930) fewer stroke deaths between 2021 to 2030. Under the scenario that land allocated to F&V would reach 20% of Grade 1–2 land, we estimated 5750 (3250 to 8910) fewer CHD and 12260 (6590 to 19 960) fewer stroke deaths between 2021 to 2030 (see online supplementary appendix table A7). In 2030, the two scenarios reduced CVD mortality by 1.3% and 6.0%, respectively (see online supplementary appendix table A8).

### Impact of modelled scenarios on inequalities

Across both scenarios, F&V intake was estimated to increase more in the most deprived groups compared with the least deprived (see online supplementary appendix table A6). We estimated that the most deprived group would yield the highest number of CHD DPPs, under both scenarios (figure 2). For example, increasing land allocated to F&V until it reaches 20% of Grade 1–2 land could save approximately 1470 (830 to 2240) CHD deaths in the most deprived group compared with 790 (440 to 1260) in the least deprived, between 2021 to 2030 (see online supplementary appendix table A7). We also estimated that the second and fourth most deprived quintile groups would be the most benefited in terms of stroke outcomes under both scenarios (figure 2). The smallest impact occurred in the least deprived group, which accounted for 17% of stroke DPPs, whereas 43% of stroke DPPs occurred in the two most deprived groups combined.



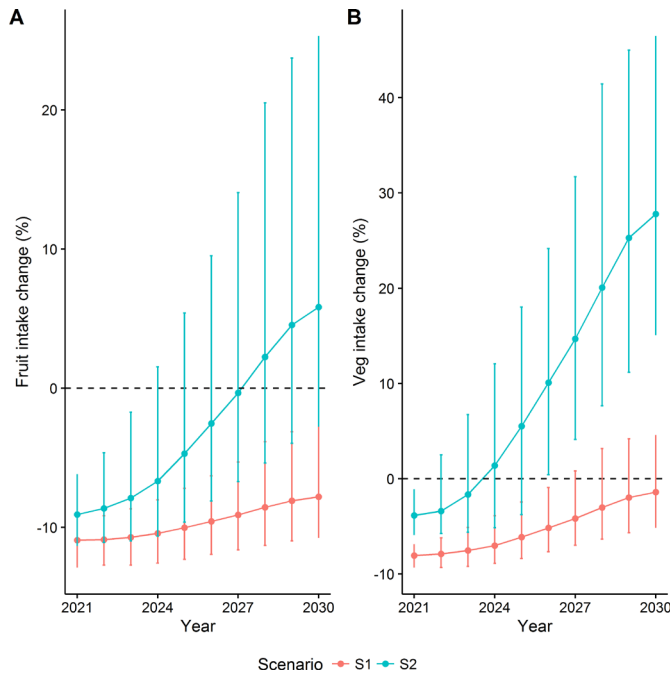
**Figure 2** Estimated impact of modelled scenarios on (A) cumulative coronary heart disease mortality and (B) stroke mortality, by Index of Multiple Deprivation (IMD), 2021 to 2030. CHD, coronary heart disease; DPP, Deaths Prevented or Postponed. IMD 5 is the most deprived group

### Sensitivity analyses

In a sensitivity analysis, we considered the potential impact of a No Deal Brexit on F&V intake in 2021. We estimated that the impact of increasing land allocated to F&V until it reaches 10% of Grade 1–2 land would fail to offset the negative impacts of a No Deal Brexit on F&V intake (figure 3), increasing CVD mortality by approximately 6900 (4290 to 10 190) additional deaths between 2021 to 2030 (table 4). In contrast, increasing F&V land until it reaches 20% of Grade 1–2 land would increase intake of F&V even in a case of a No Deal Brexit (see online supplementary appendix table A9), preventing or postponing approximately 7300 (1520 to 16 080) CVD deaths between 2021 to 2030. These would mostly occur in the most deprived group, which accounted for 28% of CVD DPPs, compared with 13% CVD DPPs in the least deprived group. In a second sensitivity analysis, assuming only 50% of F&V production to be translated into F&V purchases would still largely benefit CVD outcomes in England under both scenarios, although effects were moderately lower (see online supplementary appendix tables A10–11).

### DISCUSSION

This, to our knowledge, is the first study to estimate the potential effects on health and health inequalities via changes in F&V intake of proposed changes in the Agriculture Bill in post-Brexit Britain. We found that the post-Brexit agricultural policy has the potential to increase intake of F&V and reduce health inequalities by increasing agricultural land allocated to F&V in England. We estimated that gradually increasing F&V land throughout the agricultural transition period (2021 to 2027) until it reaches 10% and 20% of land suitable



**Figure 3** Estimated impact of modelled scenarios on intake of (A) fruits and (B) vegetables, under a No Deal Brexit, over the modelling period. Results from sensitivity analysis.

for F&V production (Grade 1–2 land) could prevent or postpone approximately 3890 CVD deaths (0.6% lower CVD mortality) and 18 010 CVD deaths (2.6% lower CVD mortality), respectively, between 2021 to 2030, when compared with a baseline scenario. Importantly, we found that under both modelled scenarios, 45% of deaths averted would occur in the two most deprived groups, thus reducing CVD inequalities.

This study builds substantially on previous work in this field, which is however largely focussed on estimating the impact of changes in diet on land use. A modelling study suggested that following the Eatwell Plate guidelines in the UK would require an increase in UK and non-UK horticultural land of 10 000 and 20 000 hectares, respectively.<sup>24</sup> Similarly, complying with UK dietary guidelines, including an increase in F&V consumption to reach 400 g/day, was estimated to increase land use in England and Wales by 47.7% for vegetables, 55.4% for fruit grown on trees and 103.5% for fruit grown on bushes.<sup>25</sup> Our study found that gradually increasing F&V land throughout the agricultural transition period by approximately 36% (from 1.4% to 1.9% of total agricultural land) or 179% (from 1.4% to 3.9% of total agricultural land) would increase F&V intake by approximately 20 g/day or 86 g/day, respectively, in 2030. While these increases would produce beneficial improvements for CVD outcomes, average F&V consumption would remain below recommended levels of 400 g/day. Our modelled increases in F&V land is comparable with historical data, which show that horticultural land in England between 1983 to 1990 accounted for 1.9% of total agricultural land on average, not exceeding the modelled increases under our first, least ambitious scenario.<sup>11</sup> Thus, we believe that the potential changes we have modelled are plausible.

The current proposal for the post-Brexit agricultural policy is focussing on the protection and improvement of the environment. However, without explicitly having the additional aim of improving the public's health through addressing poor diet represents a significant missed opportunity. Incorporating supply-side interventions that promote F&V production in the Agriculture Bill can

**Table 4** Estimated impact of modelled scenarios on cumulative coronary heart disease, stroke and cardiovascular disease mortality, stratified by Index of Multiple Deprivation (IMD), under a No Deal Brexit, 2021 to 2030. Results from sensitivity analysis

Scenario	Coronary heart disease	Stroke	Cardiovascular disease
Scenario 1			
First IMD quintile	–390 (–580 to –260)	–930 (–1350 to –610)	–1330 (–1920 to –870)
Second IMD quintile	–490 (–710 to –330)	–1150 (–1650 to –740)	–1640 (–2360 to –1070)
Third IMD quintile	–550 (–810 to –370)	–970 (–1430 to –620)	–1520 (–2240 to –980)
Fourth IMD quintile	–460 (–690 to –290)	–850 (–1270 to –490)	–1310 (–1960 to –780)
Fifth IMD quintile	–430 (–650 to –250)	–670 (–1060 to –340)	–1100 (–1710 to –580)
Total	–2330 (–3430 to –1500)	–4570 (–6760 to –2780)	–6900 (–10 190 to –4290)
Scenario 2			
First IMD quintile	220 (–10 to 580)	700 (50 to 1710)	920 (40 to 2280)
Second IMD quintile	260 (–30 to 680)	940 (80 to 2290)	1200 (60 to 2970)
Third IMD quintile	330 (–10 to 850)	830 (110 to 1980)	1160 (110 to 2830)
Fourth IMD quintile	610 (170 to 1230)	1340 (420 to 2750)	1950 (590 to 3980)
Fifth IMD quintile	710 (240 to 1360)	1360 (490 to 2660)	2070 (730 to 4020)
Total	2130 (360 to 4710)	5160 (1160 to 11 380)	7300 (1520 to 16 080)

The fifth IMD quintile is the most deprived



improve CVD outcomes and reduce associated inequalities, highlighting England's capacity to support healthy eating through British-grown F&V. F&V production can be promoted through various strategies, including agricultural subsidies linked to F&V production, improving access to F&V land, support horticulture seasonal workers and invest in relevant research and development. Increasing F&V production, however, is clearly just one part of the multifaceted approach required to radically tackle the growing diet-related burden of ill-health. Our analysis assumed that all extra F&V production would be met by consumer demand. To achieve this, the post-Brexit agricultural policy should be part of an integrated 'farm-to-fork' food strategy that promotes the healthy choice as the easy, accessible and affordable choice across the supply chain. The recently launched UK Food Strategy has the potential to do this. However, this will require sustained leadership and commitment to achieve an agricultural policy that aligns a sustainable food system with public health goals.

This study is topical, offering a timely investigation of the potential post-Brexit agricultural policy at the time of its development, using a previously validated model<sup>9 10</sup> and high quality data inputs. Model scenarios have been informed using data on ALC in England, taking into account the capacity of agricultural land to increase F&V production, while the scope of the post-Brexit agricultural policy to offset the potential negative implications of a No Deal Brexit on F&V intake was investigated in a sensitivity analysis. However, this study also has some limitations. Data inputs were not always available for England, thus they were approximated using UK data (table 1). Scenarios were informed using the only available national data on ALC, which were developed using information on land quality between 1967 to 1974. Although these cannot be used for current evaluation of agricultural land of specific sites, they are appropriate for general agricultural planning at national level.<sup>26</sup> Moreover, the model used an estimate for F&V waste that does not incorporate F&V disposed as part of cooked dishes or out-of-home, while it does not correct for potential changes in F&V weight due to cooking.<sup>17</sup> However, waste estimates include a wide range of waste disposal channels at household level and provide information on disaggregated food groups. The model also assumed that no changes would occur in model inputs throughout the modelling period. Wherever possible, mean estimates of data from the latest available years were used to consider annual variations. In this model, the change in agricultural supply was translated into change in purchases using a purchases-to-supply ratio, which might not accurately represent losses between the farm and the consumer. We further tested the strength of this estimate through a sensitivity analysis that assumed only half of F&V supply reaching consumer baskets, which provided comparable results. As the mechanism through which changes in production would increase intake is not specified in our analysis, changes in prices or purchasing power post-Brexit

were not explicitly modelled. This analysis did not investigate potential changes in consumer behaviour due to different preferences in imported and British-grown F&V. Finally, this model relied on some necessary assumptions (see online supplementary appendix table A12).

Post-Brexit agricultural policy presents an opportunity to improve dietary intake in the UK, with beneficial impacts on CVD mortality and inequalities. However, this is not inevitable and the production of British-grown F&V as part of a comprehensive agricultural strategy that intervenes across the whole supply chain must be supported. A failure to integrate public health aims in the new UK agricultural policy would mean a missed opportunity to be a global leader in orientating the food system towards health and planetary goals.

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Supplementary Appendix

Supplementary Appendix 1: Cardiovascular mortality projections

We used a Bayesian Age-Period-Cohort (BAPC) model to estimate CHD and stroke mortality projections between 2021 and 2030, by age, sex, and IMD. The BAPC model assumes that historic changes in mortality due to population’s age of death, calendar period of death, and cohort of birth will continue in the future. We fitted the model using the BAMP (Bayesian Age-Period-Cohort Modeling and Prediction) software, which employs Markov Chain Monte Carlo simulations for mortality predictions and their 95% Credible Intervals. We used historic population and CHD and stroke mortality data between 1981 and 2016 from the ONS, and ONS population projections between 2017 and 2030. As the ONS does not provide population estimates and projections by IMD for all years used in this model, we assumed that the relative differences in population estimates across IMD quintiles by age and sex group between 1981 and 2030 were equal to the relative differences in 2015. CHD and stroke were defined using ICD-9 and ICD-10 codes as described in Table 1.1. Overall stroke projections were further adjusted to represent ischaemic and haemorrhagic stroke projections, using an ischaemic-to-haemorrhagic stroke mortality ratio from 2016 (Table 1.2) and assuming that no changes will occur in stroke clinical care.

Table 1.1. ICD codes for CVD outcomes

Type of CVD outcomes	ICD-9 codes (1981-2000)	ICD-10 codes (2001-2016)
Coronary heart disease	410-414	I20-I25
Overall stroke	430-438	I60-I69
Ischaemic stroke		I63, I65-I67 (except I67.4)
Haemorrhagic stroke		I60-I62, I69.0-I69.2, I67.4
Other (not specified) stroke		I64, I69.4, I69.8

ICD, International Statistical Classification of Diseases and Related Health Problems; CVD, cardiovascular disease

Table 1.2. Percentage of stroke deaths attributed to ischaemic, haemorrhagic, and other (not specified) stroke and ischaemic-to-haemorrhagic stroke ratio

Population group	Ischaemic stroke	Haemorrhagic stroke	Other (not specified) stroke	Ischaemic-to-haemorrhagic stroke ratio*
Men 25-34	14%	82%	5%	0.22
Men 35-44	12%	79%	9%	0.26
Men 45-54	17%	67%	16%	0.50
Men 55-64	18%	53%	30%	0.90
Men 65-74	23%	37%	40%	1.71
Men 75-84	24%	28%	48%	2.57
Men 85+	30%	19%	51%	4.25
Women 25-34	23%	69%	9%	0.46
Women 35-44	14%	81%	5%	0.23
Women 45-54	14%	73%	13%	0.38
Women 55-64	15%	63%	23%	0.59
Women 65-74	18%	46%	36%	1.16
Women 75-84	23%	32%	46%	2.13
Women 85+	30%	17%	53%	4.98
<i>Overall</i>	<i>26%</i>	<i>28%</i>	<i>46%</i>	<i>2.58</i>

\*Other (not specified) stroke was combined with ischaemic stroke.

\*Estimated using ONS mortality data from 2016

## Supplementary Appendix 2: Deaths prevented or postponed calculations

We used the IMPACT Food Policy model to translate changes in F&V intake into deaths prevented or postponed (DPPs) for each age, sex, and IMD group, every year between 2021 and 2030. DPPs are estimated as shown in the equation below:

$$DPPs = (1 - e^{\beta \times \text{IntakeChange}}) * \text{Mortality},$$

Where  $\beta$  is the natural logarithm of the relative risk between fruit or vegetable intake and coronary heart disease, ischaemic stroke or haemorrhagic stroke, IntakeChange is the estimated change in fruit or vegetable intake under each modelled scenario, and Mortality is the projected number of deaths under a baseline business-as-usual scenario. Where relevant, parameters of this equation were specific for each age, sex, IMD group, and year of the modelling period.

Fruit intake and vegetable intake are independently associated with CVD outcomes. At the same time, fruit intake and vegetable intake might be correlated due to common drivers of dietary behaviour. Thus, we expressed the combined impact of fruit intake and vegetable intake on CVD using a cumulative risk-reduction approach, as previously implemented by Bajekal et al<sup>1</sup>. First, we estimated an adjustment factor, as shown in the equation below:

$$AF = CR/AR$$

where

$$CR = 1 - (1 - \text{abs}(\text{MortalityChange}_{\text{fruit}})) * (1 - \text{abs}(\text{MortalityChange}_{\text{veg}}))$$

and

$$AR = \text{abs}(\text{MortalityChange}_{\text{fruit}}) + \text{abs}(\text{MortalityChange}_{\text{veg}})$$

with  $\text{MortalityChange}_{\text{fruit}}$  and  $\text{MortalityChange}_{\text{veg}}$  being the change in mortality change attributed to fruit and vegetable intake respectively and estimated as  $(1 - e^{\beta \times \text{IntakeChange}})$  similar to the equation above.

The estimated of overall DPPs were then estimated

$$DPPs_{\text{overall}} = (DPPs_{\text{fruit}} + DPPs_{\text{veg}}) * AF$$

where  $DPPs_{\text{fruit}}$  and  $DPPs_{\text{veg}}$  being the DPPs attributed to changes in fruit and vegetable intake, respectively.

## Supplementary Tables

Table A1. Classification of fruit and vegetables across different data sources

Data Source	Fruit	Vegetables
June Survey of Agriculture (land data)	Orchards, Small fruit, Area under glass or plastic covered structure used for 'vegetables, salad, and fruit'*	Vegetables for human consumption (Excludes potatoes, peas for harvesting dry, which are mainly used for stock feeding, and mushrooms), Area under glass or plastic covered structure used for 'vegetables, salad, and fruit'* and mushrooms
Horticulture Statistics (production data)	Total fruit (includes Orchard fruit and Soft fruit)	Field vegetables (includes Roots and Onions, Brassicas, Legumes, Others) Protected vegetables
Horticulture Statistics (import and export data)	Total fruit (includes Orchard fruit and Soft fruit). Exports includes re-exported fruit	Total vegetables, excluding potatoes and sweetcorn
Waste and Resources Action Programme (waste data)	Banana; Orange; Apple; Melon; Pineapple; Other citrus; Stone fruit; Soft / berry fruit; Pear; All other fresh fruit	Carrot; Onion; Other root vegetables; Cabbage; Lettuce; Cauliflower; Tomato; Broccoli; Cucumber; Pepper; Mixed vegetables; Leafy salad; Mushroom; Leek; Bean (all varieties); Spring onion; All other fresh vegetables and salads
Living Costs and Food Survey 2016/7 (purchase data)	Home purchases (includes Fresh fruit; Frozen strawberries, apple slices, peach halves, oranges and other frozen fruits) Eating out (includes Fresh fruit)	Home purchases (includes Fresh green vegetables; Other fresh vegetables; Peas, frozen; Beans, frozen; Other frozen vegetables) Eating out (includes Green vegetables; Other fresh vegetables, excluding peas and sweetcorn and baked beans; Root vegetables; Mushrooms; Mixed vegetables or unspecified 'vegetable'; Other vegetables; Green salads without dressing)
National Diet and Nutrition Survey Rolling Programme, Years 1-4 & 7-8 (intake data)	Fruit, including fresh and dried fruit and smoothies but not including juice	Vegetables, including legumes

Where possible, starchy vegetables such as potatoes and corn were excluded to stay consistent with the definition of fruits and vegetables in Micha et al, 2017<sup>1</sup> that provided the relative risks used in the model.  
 \*50% of Area under glass or plastic covered structure used for 'vegetables, salad, and fruit' was allocated to



fruits and 50% to vegetables, as more granular data were not available. This area covers approximately 0.5% of total horticultural land. Types of crops in glasshouse area in England were estimated as their mean between 2015 and 2017<sup>2</sup>.

Table A2. Relative risks for CHD, ischaemic stroke, and haemorrhagic stroke per serving of fruit or vegetable consumption

Age group	RR per serving of fruit consumption			RR per serving of vegetable consumption		
	CHD	Ischaemic stroke	Haemorrhagic stroke	CHD	Ischaemic stroke	Haemorrhagic stroke
25-34	0.92 (0.87, 0.97)	0.83 (0.76, 0.9)	0.63 (0.49, 0.81)	0.93 (0.89, 0.97)	0.76 (0.64, 0.9)	0.76 (0.61, 0.95)
35-44	0.92 (0.87, 0.97)	0.83 (0.77, 0.9)	0.64 (0.5, 0.82)	0.93 (0.9, 0.97)	0.77 (0.66, 0.9)	0.77 (0.62, 0.95)
45-54	0.93 (0.89, 0.97)	0.86 (0.8, 0.92)	0.69 (0.56, 0.84)	0.94 (0.91, 0.97)	0.80 (0.7, 0.92)	0.80 (0.67, 0.96)
55-64	0.94 (0.91, 0.98)	0.88 (0.83, 0.93)	0.73 (0.61, 0.87)	0.95 (0.93, 0.98)	0.83 (0.74, 0.93)	0.83 (0.72, 0.96)
65-74	0.95 (0.92, 0.98)	0.90 (0.86, 0.94)	0.77 (0.67, 0.89)	0.96 (0.94, 0.98)	0.86 (0.78, 0.94)	0.86 (0.76, 0.97)
75+	0.97 (0.96, 0.99)	0.94 (0.92, 0.96)	0.86 (0.8, 0.92)	0.98 (0.97, 0.99)	0.92 (0.87, 0.96)	0.92 (0.86, 0.97)

One serving of fruits or vegetables equals to 100 g per day.

CHD, coronary heart disease; RR, relative risk

Source: Micha et al, 2017<sup>3</sup>

Table A3. Fruit and vegetable related inputs of the model

	<b>Fruit</b>	<b>Vegetables</b>
Land (% total agricultural land) (mean 2010-2018, SD)	0.3% (0.0%)	1.1% (0.1%)
Land (% total fruit and vegetable agricultural land) (mean 2010-2018, SD)	24% (1.4%)	76% (1.4%)
Yield (tonnes/hectare) (mean 2010-2018, SD)	19.5 (2.8)	22.0 (1.2)
Supply (thousand tonnes) (mean 2008-2017, SD)*	4,166 (417)	4,599 (152)
Purchases at home and eating out (thousand tonnes per year) (mean 2008-2016/7, SD)*	2,612 (102)	2,820 (84)
Household waste 2012 (g/p/w) (point estimate, 95% CI)**	274 (238, 311)	268 (230, 305)
Purchases at home 2012 (g/p/w)**	744	734

\*inputs used to estimate purchases-to-supply ratio

\*\*inputs used to estimate F&V waste as a percentage of fruit and vegetable purchases

SD, standard deviation; 95% CI, 95% confidence interval; g/p/w, grams per person per week

Table A4. Statistical distributions and parameters for model inputs used in the probabilistic sensitivity analysis

Inputs	Distribution	Parameters	Source
F&V land	Normal	Mean and SD of 2010-2018 average land	DEFRA <sup>4</sup>
F&V yield	Normal	Mean and SD of 2010-2018 average yield	DEFRA <sup>5</sup>
F&V supply	Normal	Mean and SD of 2010-2018 average supply	DEFRA <sup>6</sup>
F&V purchases	Normal	Mean and SD of 2008-2016/7 average purchases	LCFS <sup>7</sup>
Waste at household level	Normal	Mean: F&V waste estimates in 2012 SD: estimated from 95% CI of F&V waste estimates	WRAP <sup>8</sup>
F&V consumption	Normal	Mean: mean consumption by age, sex, and IMD SD: SE of the mean	NDNS RP Years 1-4 & 7-8 <sup>9</sup>
RR for CHD/ischaemic stroke/haemorrhagic stroke per fruit or vegetable serving	Log normal	RR and SE(lnRR) estimated from 95% CI, by age	Micha, 2017 <sup>3</sup> Parameters based on Barendregt, 2010 <sup>10</sup>
CHD/ischaemic stroke/haemorrhagic stroke deaths, 2021-2030	Pert	mode: death projections, best estimate min: death projections, lower 95% confidence limit max: death projections, upper 95% confidence limit by age, sex, and IMD	Own estimations
Effect of no deal Brexit on F&V consumption by IMD	Pert	mode: best estimate; min: lower 95% uncertainty limit; max: upper 95% uncertainty limit	Seferidi, 2019 <sup>11</sup>

F&V, fruit and vegetables; SD, standard deviation; DEFRA, Department for Environment, Food & Rural Affairs; LCFS, Living Costs and Food Survey; WRAP, Waste & Resources Action Programme; NDNS RP, National Diet and Nutrition Survey Rolling Programme; IMD, Index of Multiple Deprivation; RR, relative risk; SE, standard error, CHD, coronary heart disease; 95% CI, 95% confidence interval

Table A5. Baseline intake of fruits and vegetables in England by age, sex, and IMD. Means (grams/day) and standard errors and % of the overall sample meeting the 5-a-day targets.

Age/Sex group	Overall	IMD 1	IMD 2	IMD 3	IMD 4	IMD 5
<i>Fruit</i>						
Men 25-44	86.8 (7.6)	111 (33.5)	88.2 (9.8)	80.9 (12.2)	70.1 (11.5)	84.3 (10.2)
Men 45-64	120.1 (6.5)	119.6 (9)	144.8 (15.1)	120.1 (13.1)	109.5 (15)	106.9 (22.8)
Men 65+	117.1 (7.5)	136.6 (15.1)	137.7 (17)	138.6 (24.7)	92.9 (12.4)	76.6 (12.7)
Women 25-44	93.4 (4.5)	119.6 (12.3)	91.3 (8)	95.1 (10.8)	79.8 (7.5)	85.8 (10.7)
Women 45-64	127.1 (5)	146.3 (11.2)	146.3 (10.9)	122.8 (11.9)	107.2 (10.2)	109.2 (11.1)
Women 65+	128.7 (7.7)	154.2 (13.5)	149.2 (18.8)	121.2 (17.2)	114.8 (17.2)	67.2 (15.6)
<i>Total</i>	110.6 (2.7)	132.2 (6.7)	123.8 (5.4)	109 (5.7)	93.9 (4.9)	91.1 (6.3)
<i>Vegetables</i>						
Men 25-44	193.6 (6.9)	223.1 (23.9)	190.5 (10.8)	204.2 (13.3)	165.8 (14.9)	184.6 (11.9)
Men 45-64	200.2 (5.9)	228.8 (13.2)	204.7 (10.2)	197.1 (15.8)	179.8 (13.6)	180.3 (12.2)
Men 65+	188.7 (7.8)	167.5 (11.8)	202.6 (15.7)	232.7 (25.3)	171 (13.3)	174.7 (19.3)
Women 25-44	188.5 (5.3)	194.8 (11.3)	180 (8.9)	208.8 (15.6)	181.2 (9)	179 (12)
Women 45-64	199.1 (5.1)	210.1 (7.8)	217.2 (13.3)	207.9 (13)	170.2 (11.3)	183.4 (12.9)
Women 65+	173.9 (5.4)	201.5 (9.9)	174.2 (10.2)	158.2 (9.4)	155.6 (11.4)	147.1 (16.6)
<i>Total</i>	191.7 (2.7)	206.7 (5.8)	195.4 (5)	199.9 (6.6)	172.6 (5.2)	178.2 (5.7)
<i>Meeting 5-a-day targets</i>	32%	38%	37%	31%	24%	25%

IMD 1 is the least deprived group and IMD 5 the most deprived.

IMD, Index of Multiple Deprivation

Data from the National Diet and Nutrition Survey Rolling Programme Years 1-4 and 7-8



Table A6. Estimated impact of modelled scenarios on fruit and vegetable intake overall and by IMD, in 2030

Scenario	Change in consumption (95% UI)	
	Fruits	Vegetables
Scenario 1		
1 <sup>st</sup> IMD quintile	3% (1.4%, 6.3%)	7.3% (3.9%, 12.7%)
2 <sup>nd</sup> IMD quintile	3.2% (1.4%, 7%)	7.5% (4.1%, 12.7%)
3 <sup>rd</sup> IMD quintile	3.5% (1.6%, 7.4%)	7.3% (3.9%, 13%)
4 <sup>th</sup> IMD quintile	4.2% (1.9%, 8.8%)	8.6% (4.7%, 14.4%)
5 <sup>th</sup> IMD quintile	4.8% (2.1%, 10.5%)	8.4% (4.6%, 14.8%)
<i>Total</i>	3.7% (1.6%, 8.6%)	7.8% (4.2%, 13.7%)
Scenario 2		
1 <sup>st</sup> IMD quintile	14.3% (8.3%, 27%)	34.3% (23.1%, 51.2%)
2 <sup>nd</sup> IMD quintile	14.9% (8.3%, 29.8%)	35.7% (24.6%, 50.6%)
3 <sup>rd</sup> IMD quintile	16.7% (9.2%, 31.8%)	34.5% (22.7%, 53.5%)
4 <sup>th</sup> IMD quintile	20% (11%, 37.7%)	40.8% (28.3%, 57.8%)
5 <sup>th</sup> IMD quintile	22.7% (12.1%, 45.4%)	39.8% (27.2%, 60.4%)
<i>Total</i>	17.4% (9.1%, 36.9%)	37% (24.3%, 55.7%)

Table A7. Estimated impact of modelled scenarios on cumulative CHD, stroke, and CVD mortality, stratified by IMD, 2021-2030

Scenario	Coronary heart disease	Stroke	Cardiovascular disease
Scenario 1			
1 <sup>st</sup> IMD quintile	170 (90, 300)	440 (220, 820)	610 (300, 1120)
2 <sup>nd</sup> IMD quintile	210 (110, 360)	570 (280, 1070)	770 (380, 1440)
3 <sup>rd</sup> IMD quintile	240 (130, 430)	500 (250, 910)	740 (370, 1340)
4 <sup>th</sup> IMD quintile	290 (150, 510)	600 (300, 1100)	890 (450, 1610)
5 <sup>th</sup> IMD quintile	310 (160, 540)	560 (280, 1030)	870 (440, 1570)
<i>Total</i>	1230 (630, 2150)	2660 (1320, 4930)	3890 (1950, 7080)
Scenario 2			
1 <sup>st</sup> IMD quintile	790 (440, 1260)	2060 (1080, 3330)	2850 (1520, 4590)
2 <sup>nd</sup> IMD quintile	970 (550, 1520)	2610 (1380, 4340)	3570 (1930, 5860)
3 <sup>rd</sup> IMD quintile	1150 (650, 1790)	2280 (1210, 3720)	3430 (1860, 5510)
4 <sup>th</sup> IMD quintile	1380 (780, 2110)	2760 (1510, 4460)	4130 (2290, 6570)
5 <sup>th</sup> IMD quintile	1470 (830, 2240)	2560 (1410, 4110)	4030 (2240, 6350)
<i>Total</i>	5750 (3250, 8910)	12260 (6590, 19960)	18010 (9840, 28870)

Table A8. Estimated absolute and relative impact of modelled scenarios on CHD, stroke, and CVD mortality, in 2030

		Scenario 1	Scenario 2
CVD	Deaths at baseline	65020 (35750, 141940)	65020 (35750, 141940)
	Attributable deaths	850 (1360, 500)	3900 (5430, 2640)
	Mortality increase (%)	1.3%	6.0%
CHD	Deaths at baseline	40250 (25830, 64140)	40250 (25830, 64140)
	Attributable deaths	250 (380, 160)	1170 (1570, 840)
	Mortality increase (%)	0.6%	2.9%
Stroke	Deaths at baseline	24770 (9920, 77800)	24770 (9920, 77800)
	Attributable deaths	600 (980, 340)	2720 (3860, 1790)
	Mortality increase (%)	2.4%	11.0%

Table A9. Estimated impact of modelled scenarios on fruit and vegetable intake overall and by IMD, under a no deal Brexit, in 2030. Results from sensitivity analysis.

Scenario	Change in consumption (95% UI)	
	Fruits	Vegetables
Scenario 1		
1 <sup>st</sup> IMD quintile	-8.5% (-11.1%, -4.8%)	-1.9% (-5.4%, 3.6%)
2 <sup>nd</sup> IMD quintile	-8.3% (-11%, -4.2%)	-1.7% (-5.2%, 3.6%)
3 <sup>rd</sup> IMD quintile	-8% (-10.8%, -3.8%)	-1.9% (-5.5%, 3.9%)
4 <sup>th</sup> IMD quintile	-7.3% (-10.4%, -2.4%)	-0.6% (-4.6%, 5.3%)
5 <sup>th</sup> IMD quintile	-6.7% (-10.1%, -0.8%)	-0.8% (-4.7%, 5.7%)
<i>Total</i>	-7.8% (-10.8%, -2.8%)	-1.4% (-5.2%, 4.6%)
Scenario 2		
1 <sup>st</sup> IMD quintile	2.7% (-3.6%, 15.6%)	25.2% (13.8%, 42%)
2 <sup>nd</sup> IMD quintile	3.3% (-3.6%, 18.5%)	26.4% (15.3%, 41.4%)
3 <sup>rd</sup> IMD quintile	5.2% (-2.7%, 20.4%)	25.3% (13.5%, 44.3%)
4 <sup>th</sup> IMD quintile	8.4% (-0.8%, 26.2%)	31.6% (19%, 48.7%)
5 <sup>th</sup> IMD quintile	11.1% (0.2%, 33.8%)	30.6% (17.9%, 51.2%)
<i>Total</i>	5.8% (-2.8%, 25.3%)	27.8% (15.1%, 46.5%)

Table A10. Estimated impact of modelled scenarios on fruit and vegetable intake overall and by IMD, 2030, with purchases-to-supply ratio=50%. Results from sensitivity analysis.

Scenario	Change in consumption (95% UI)	
	Fruits	Vegetables
Scenario 1		
1 <sup>st</sup> IMD quintile	2.4% (1.1%, 5.1%)	5.9% (3.1%, 10.6%)
2 <sup>nd</sup> IMD quintile	2.5% (1.1%, 5.5%)	6.1% (3.3%, 10.7%)
3 <sup>rd</sup> IMD quintile	2.8% (1.2%, 6%)	5.9% (3.1%, 10.9%)
4 <sup>th</sup> IMD quintile	3.3% (1.5%, 7.1%)	7% (3.8%, 12.2%)
5 <sup>th</sup> IMD quintile	3.8% (1.6%, 8.4%)	6.8% (3.7%, 12.3%)
<i>Total</i>	<i>2.9% (1.2%, 6.8%)</i>	<i>6.3% (3.3%, 11.5%)</i>
Scenario 2		
1 <sup>st</sup> IMD quintile	11.3% (6.6%, 21.6%)	27.9% (17.9%, 43.2%)
2 <sup>nd</sup> IMD quintile	11.7% (6.5%, 23.4%)	29% (18.9%, 42.7%)
3 <sup>rd</sup> IMD quintile	13.2% (7.2%, 25.5%)	28.1% (17.6%, 44.9%)
4 <sup>th</sup> IMD quintile	15.7% (8.6%, 30%)	33.2% (21.9%, 49%)
5 <sup>th</sup> IMD quintile	17.9% (9.5%, 35.5%)	32.4% (21.1%, 50.6%)
<i>Total</i>	<i>13.7% (7.1%, 29%)</i>	<i>30.1% (18.9%, 46.7%)</i>

Table A11. Estimated impact of modelled scenarios on cumulative CHD, stroke, and CVD mortality, stratified by IMD, with purchases-to-supply ratio=50%, 2021-2030. Results from sensitivity analysis

Scenario	Coronary heart disease	Stroke	Cardiovascular disease
Scenario 1			
1 <sup>st</sup> IMD quintile	140 (70, 240)	360 (170, 680)	500 (240, 920)
2 <sup>nd</sup> IMD quintile	170 (80, 300)	460 (220, 870)	620 (300, 1170)
3 <sup>rd</sup> IMD quintile	200 (100, 350)	400 (190, 740)	590 (290, 1090)
4 <sup>th</sup> IMD quintile	230 (120, 410)	490 (240, 890)	720 (360, 1310)
5 <sup>th</sup> IMD quintile	250 (120, 450)	450 (230, 840)	700 (350, 1280)
<i>Total</i>	<i>980 (490, 1760)</i>	<i>2150 (1050, 4020)</i>	<i>3130 (1540, 5770)</i>
Scenario 2			
1 <sup>st</sup> IMD quintile	630 (360, 1040)	1660 (890, 2840)	2290 (1240, 3880)
2 <sup>nd</sup> IMD quintile	770 (430, 1260)	2110 (1120, 3600)	2880 (1550, 4850)
3 <sup>rd</sup> IMD quintile	910 (520, 1480)	1830 (990, 3090)	2740 (1510, 4570)
4 <sup>th</sup> IMD quintile	1100 (600, 1750)	2220 (1210, 3710)	3320 (1810, 5460)
5 <sup>th</sup> IMD quintile	1170 (640, 1880)	2060 (1140, 3450)	3230 (1780, 5330)
<i>Total</i>	<i>4590 (2540, 7410)</i>	<i>9880 (5350, 16680)</i>	<i>14470 (7890, 24090)</i>



Table A12. Model assumptions

**Policy scenarios**

All F&V in England are grown in Grade 1 and 2 land

Relative difference between fruit and vegetable agricultural land would not change

All extra F&V production would be used for domestic consumption

All extra F&V consumption would be equally distributed across age, sex, and IMD groups

F&V demand will increase until it meets extra supply

Labour demand to increase F&V production will be met

**Effects of F&V intake on CVD mortality**

There is an immediate effect of increasing F&V intake on CVD mortality.

There is a linear association between CVD risk and CVD mortality, with RRs for CVD morbidity being equal to RRs for CVD mortality.

Relative differences in population estimates across IMD quintiles by age and sex group between 1981 and 2030 were equal to relative differences in 2015

Relative differences between ischaemic and haemorrhagic stroke deaths between 2017-2030 were equal to relative differences in 2016

CVD mortality projections using the Bayesian Age-Period-Cohort model assumed that observed age, period, and cohort effects remain the same throughout the modelling period.

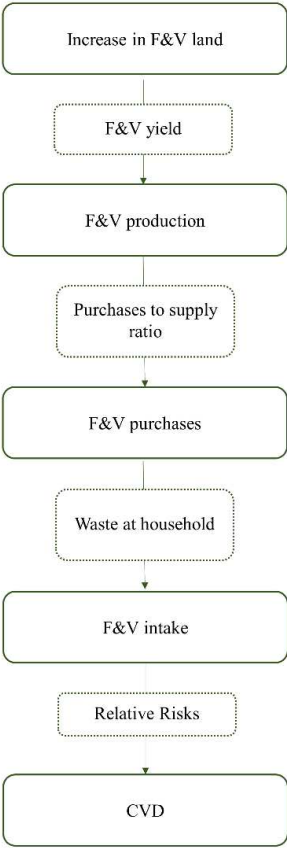


Figure A1. Schematic representation of the model.

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