SUPPLEMENTARY INFORMATION

Distributional issues in natural capital accounting: An application to land ownership and ecosystem services in Scotland

S.1 Land cover by broad habitats in Scotland

Scotland covers about 8 million hectares of land. Heather and heather grassland, enclosed farm, woodland, and semi-natural grassland are, in that order, the main broad habitats characterizing land *cover* in Scotland (Table S.1).

Table S1: Land cover by broad habitat in Scotland

Broad habitat	**Closing stock 2015**	
	(000 ha)	**%**
Woodland	1,340	17.0
Enclosed farm	2,043	25.9
Semi-natural grassland	1,213	15.4
Dwarf shrub heath (heather and heather grassland)	2,080	26.3
Bogs	647	8.2
Inland rock	150	1.9
Freshwater and wetland	158	2.0
Coastal margins	87	1.1
Others	174	2.2

Source: *Own elaboration* based on LCM 2015 aggregated data (CEH, 2017).

S.2 Landownership mapping

We use Andy Wightman s *Who owns Scotland* (2015) database to analyze spatial aspects of landownership distribution in Scotland. This map was developed using a range of methods and information sources, including the raw title deeds held in the National Archives of Scotland, and recordings by the Registers of Scotland in the Register of Sasines[1] and Land Register.

The *Who owns Scotland* map has been updated in order to include some additional public properties belonging to the Scotland's Nature Agency (previously called Scottish Natural Heritage) and Crown Estate properties. This data base has been further reviewed to identify different type of private ownership, including private companies, individual owners, trusts, and charities.[2] The former two ownership categories each account for about one third of

[1] The Sasine Register is the older type of register in Scotland involving a chronological list of land deeds based on written descriptions of properties (unlike the modern Land Register, which is map-based).

[2] A Trust is a legal entity created by a party (the trustor) through which a second party (the trustee) holds the right to manage the trustee's assets or property for the benefit of a third party (the beneficiary). A charity is an organisation with specific purposes defined in law to be charitable – and is exclusively for public benefit. Some

private landownership, while Trust accounts for about 29 percent and charities slightly more than 3 percent. Table S.2 shows the share of total land mass mapped by the *Who owns Scotland* map by type of landowner and local authority.

Table S.2: Distribution of mapped land properties in Scotland by type of landowner and local authority (partial cover)

Local Authority	Land area (ha)		Share of total land covered (%)	Share of land by type of private ownership (%)			
	Total land mass	Mapped (private land)		Private company	Individual owner	Trust	Charity
1. Aberdeen City	18,830	16	0.1	1.7	97.7	0.6	0.0
2. Aberdeenshire	633,994	243,352	38.4	9.5	32.4	57.8	0.3
3. Angus	220,385	77,539	35.2	23.5	21.4	55.1	0.0
4. Argyll and Bute	716,145	438,873	61.3	34.3	38.8	24.8	2.1
5. City of Edinburgh	27,303	0	0.0				
6. Clackmannanshire	16,392	101	0.6	99.3	0.0	0.7	0.0
7. Dumfries & Galloway	645,710	158,793	24.6	51.5	22.7	25.2	0.6
8. Dundee City	6,029	0	0.0				
9. East Ayrshire	127,033	31,819	25.0	46.6	53.4	0.0	0.0
10. East Dunbartonshire	17,449	1,473	8.4	20.8	79.0	0.2	0.0
11. East Lothian	68,315	43,993	64.4	27.6	53.1	19.3	0.0
12. East Renfrewshire	17,423	0	0.0				
13. Falkirk	29,839	689	2.3	0.0	100.0	0.0	0.0
14. Fife	135,718	0	0.0				
15. Glasgow City	17,645	0	0.0				
16. Highland	2,624,818	2,016,993	76.8	34.9	35.3	26.7	3.0
17. Inverclyde	17,363	1	0.0	39.9	60.1	0.0	0.0
18. Midlothian	35,527	12,828	36.1	0.2	23.4	76.5	0.0
19. Moray	225,663	71,154	31.5	54.5	13.2	29.3	3.0
20. Na h-Eileanan an Iar	297,721	47,991	16.1	0.0	0.0	40.8	59.2
21. North Ayrshire	89,561	31,835	35.5	12.5	33.0	47.2	7.3
22. North Lanarkshire	47,222	2,702	5.7	60.3	39.7	0.0	0.0
23. Orkney Islands	106,957	0	0.0				
24. Perth and Kinross	541,970	310,928	57.4	26.7	34.4	37.1	1.9
25. Renfrewshire	26,922	0	0.0	100.0	0.0	0.0	0.0
26. Scottish Borders	474,265	194,784	41.1	48.1	34.2	17.6	0.0
27. Shetland Islands	149,202	0	0.0				
28. South Ayrshire	123,467	21,174	17.1	49.7	16.6	32.7	1.1
29. South Lanarkshire	177,404	67,445	38.0	27.5	70.9	1.6	0.0
30. Stirling	225,472	114,675	50.9	34.1	42.9	14.6	8.4
31. West Dunbartonshire	18,276	1,062	5.8	0.1	99.9	0.0	0.0
32. West Lothian	43,145	3,679	8.5	87.6	12.4	0.0	0.0
(not identified)	0	3,321		100.0	0.0	0.0	0.0
Total	**7,923,165**	**3,897,219**	**49.2**	**33.4**	**34.8**	**28.7**	**3.1**

Source: *Own elaboration* based on Andy Wightman's *Who owns Scotland* map (2015), and the Ordnance Survey (OS) Local Authority boundaries map.

The share of land mapped is higher in areas used for grassland-based farming, rough grazing and woodlands used mainly for livestock breading, forestry, and sporting (Figs. 1 and 2 in the main text).

Trusts such as The Woodland Trust or the Scottish Wildlife Trust are registered as charities, and for the purposes of this study considered under the charity category.

S.3 Spatial distribution of air pollution removal monetary values

Estimations are based on the UK Office for National Statistics (ONS) maps for air pollution removed by vegetation in 2015 and avoided health damage costs (in £/person over the same year). Air pollution removal is estimated with a one square km resolution for six pollutants ($PM_{2.5}$, PM_{10}, NO_2, NH_3, SO_2 and O_3) across the UK by seven land cover classes relevant for the UK (broad habitats). Those include coniferous woodland, deciduous woodland, crops. moorland, grassland, water and bare soil.

Physical and economic estimates for air pollution removal services are based on a report by Jones *et al*. (2017) report (commissioned by the ONS and undertaken by the UK Centre of Ecology and Hydrology, CEH). That study estimates avoided health damage costs on the basis of changes in pollutant exposure from the EMEP4UK[3] model scenario comparisons: i.e. the change in pollutant concentration to which people are exposed.

The Jones *et al*. use exposure-response functions relating ambient pollution to mortality and morbidity derived from epidemiological studies in the UK, USA, Europe and elsewhere. These data are combined with further data on underlying incidence of health outcomes from UK national statistics on mortality and hospital admissions. More precisely, the avoided health damage costs in the UK reflect changes in (i) respiratory hospital admissions; (ii) cardiovascular hospital admissions; (iii) loss of life years (long-term exposure effects from $PM_{2.5}$ and NO_2), and acute mortality (short-term exposure effects from O_3).

Air pollution removal by vegetation is of particular interest for $PM_{2.5}$, which tends to dominate the health impacts of air pollution, and for O_3, which causes health impacts in particular in polluted and warmer regions (Nemitz *et al*. 2020). Jones *et al*. (2017) study estimates an avoided burden on mortality of 1900 fewer deaths from short term exposure to O_3, 27,000 avoided life years lost from exposure to $PM_{2.5}$ and NO_2 combined, 5,800 fewer respiratory hospital admissions and 1,300 fewer cardiovascular hospital admissions from exposure to $PM_{2.5}$, SO_2, NO_2 and O_3.

$PM_{2.5}$ removal accounts for most of avoided life years lost, while O_3 removal for reducing the health burden of respiratory and cardiovascular hospital admissions and deaths due to pollutants exposure (Jones *et al*. 2017). For instance, the $PM_{2.5}$ removal of a single mature tree would then equate to 1.7 life hours/year saved (Nemitz *et al*. 2020).

An important feature of the EMEP4UK model current vegetation scenarios, is that it includes the cumulative effect of pollutant removal during transport from source to receptor. For example, the pollution concentration in London is lowered also by the uptake of some of the pollutants transported long range from continental Europe by vegetation encountered on the way (Nemitz *et al*. 2020). This may also be relevant in larger Scottish cities such as Glasgow, benefitting from e.g. PM_{10} deposition in the English Midlands (*ibid*).

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[3] EMEP4UK is an atmospheric chemistry and transport model which generates pollutant concentrations directly from emissions, and dynamically calculates pollutant transport and deposition, taking into account meteorology and pollutant interactions. For more detail on the EMEP4UK model see Nemitz *et al*. (2020).

The estimated unit values describe a monetary equivalent of health damage costs avoided per unit of exposure. These unit values are then applied to the beneficiary population at the local authority or akin administrative division level. The monetary value associated to air pollution removal (in £ per person) was estimated for year 2012 (ONS, 2018) (Table S.3) which we updated to 2016 prices using the GDP deflator for the figures presented in the main paper. Those unit values are provided by wider areas (mainly based on local authority areas) in Scotland.

Table S.3 Avoided health damage cost by wider areas in Scotland (2012 prices)

Code	Name of the wider area	Value (£ per person)
S1	Aberdeen and Aberdeenshire	9.08
S2	Inverness & Nairn and Moray, Badenoch & Strathspey	8.73
S3	Lochaber, Skye & Lochalsh, Arran & Cumbrae and Argyll & Bute	10.63
S4	Caithness & Sutherland and Ross & Cromarty	7.59
S5	Angus and Dundee City	9.54
S6	Perth & Kinross and Stirling	10.28
S7	Clackmannanshire and Fife	10.52
S8	Edinburgh, City of	10.35
S9	West Lothian	12.68
S10	East Lothian and Midlothian	10.1
S11	Scottish Borders	13.14
S12	South Lanarkshire	12.92
S13	East Ayrshire and North Ayrshire mainland	12.84
S14	South Ayrshire	11.46
S15	Inverclyde, East Renfrewshire and Renfrewshire	11.26
S16	East Dunbartonshire, West Dunbartonshire and Helensburgh & Lomond	12.58
S17	Glasgow City	11.95
S18	North Lanarkshire	13.28
S19	Falkirk	11.69
S20	Na h-Eileanan Siar (Western Isles)	3.01
S21	Orkney Islands	3.96
S22	Shetland Islands	0
S23	Dumfries & Galloway	14.55

Source: *Own elaborations* based on ONS (2018).

The estimation of economic benefits associated with air pollution removal follows Jones *et al*. (2017). This valuation is based on the damage cost per unit of population exposure to polutants. These costs are directly assessed by Jones *et al*. (2017) study as the avoided health damage of reducing air pollutants considering (official UK) unit values describing the monetary equivalent of health impacts of three elements: (i) healthcare costs due to respiratory and cardiovascular hospital admissions, (ii) loss of life years (long term exposure effect from $PM_{2.5}$ and NO_2), and (iii) deaths (short term exposure effects from O_3). The short term impacts of air pollution exposure on mortality and on hospital admissions is estimated by multiplying population weighted air pollution concentrations, population, the rate of illness and response functions.[4] The long term impact on mortality uses a life table approach, which describes the

[4] Response functions relating air pollutant exposure to death and illness used in Jones et al. (2017) are derived from literature review considering epidemiological studies carried out in the UK, Europe, the USA and other locations. Information on the underlying incidence or prevalence of illness and death, derived from national statistics on death and hospital admissions.

structure of the population. Estimations of changes in the risk of mortality combine pollution data and response functions and expected chnages in population structure. The response function in terms of changes in mortality and hospital admissions risks, and the economic values associated to health care costs and loss of life years are taken from literature (see Jones et al. (2017: 34-41) for more details).

For the purpose of our study, we have estimated the avoided health damage cost by local authority, using ONS (2018) data when the wider areas correspond directly to a single local authority. When these values are referred to an administrative division comprising more than one local authority or district within different local authorities, we use 2011 population Census data (last vailable census data in Scotland) to estimate the share of total local area population living in these specific districts or areas. In the event that there is more than one monetary data-point per local authority, we estimate the weighted average avoided health cost data 2011 census population data as a weighting factor (Table S.4).

Total air pollution removal (in kg of total pollutants) by 2015 is estimated for each mapped property, accounting for mid-year population data in 2015 (Table S5). We assigned Table S5 values according to the local authority each mapped property is located. When a property is located in more than one local authority, we assigned weighted average values considering the share of the property area located at each local authority.

Table S.4 Estimation of air pollution removal avoided health damage costs for the Highlands, North Ayshire and Argyll and Bute (2012 values)

Area and local authority	Population Census 2011 [(1)]		Share	Code APR	Value (£/person)	Weighted average (£/person)
	Locality	Council	(%)			
Inverness and Nairn	86191	233,508	37%	S2	8.73	3.22
Skye, Lochabel	70,149	233,508	30%	S3	10.63	3.19
Badenoch and Strathspey [(2)]	3,910	233,508	2%	S2	8.73	0.15
Lochalsh (Kyle of)	650	233,508	0%	S3	10.63	0.03
Caithness, Sutherland and Ross	71,882	233,508	31%	S4	7.59	2.34
Cromarty	726	233,508	0%	S5	9.54	0.03
Highland	**233,508**	**233,508**	**100%**			**8.96**
Arran[(3)]	4,629	138,146	3%	S3	10.63	0.36
Great Cumbrae [(4)]	1,376	138,146	1%	S3	10.63	0.11
Rest of North Ayshire	132,141	138,146	96%	S13	12.84	12.28
North Ayshire	**138,146**	**138,146**	**100%**			**12.74**
Helensburgh	14220	88,166	16%	S16	12.58	2.03
Rest of North Argyll and Bute	73,946	88,166	84%	S3	10.63	8.92
Argyll and Bute	**88,166**	**88,166**	**100%**			**10.94**

Notes: [(1)] Census data obtained online: https://www.scotlandscensus.gov.uk/ods-web/area.html (April 2020), [(2)] Estimated considering the localities included in the district of Badenoch and Strathspey (https://en.wikipedia.org/wiki/Badenoch_and_Strathspey), which are subtracted from the Parliamentary Constituency of Skye, Lochabel and Badenoch; [(3)] Estimated population of Arran: https://en.wikipedia.org/wiki/Isle_of_Arran
[(4)] Estimated population of Great Cumbrae: https://en.wikipedia.org/wiki/Great_Cumbrae,

Table S.5 Estimation of air pollution removal avoided health damage costs by local authority (2016 values)

Local Authority	Mid-year population (2015)	Estimated number of households[(1)]	Value (£/person)	Total value (£)	Total pollutants removal (kg)	Value per air pollutant removed (£/kg)
Aberdeen City	230,350	108,546	9.67	2,226,699	725,482	2.10
Aberdeenshire	261,960	108,849	9.67	2,532,260	34,261,042	0.07
Angus	116,900	52,307	10.16	1,187,272	11,511,431	0.10
Argyll and Bute	86,890	41,499	11.65	1,012,403	37,898,970	0.04
City of Edinburgh	498,810	231,069	11.02	5,496,206	991,578	4.90
Clackmannanshire	51,360	23,418	11.20	575,212	722,533	0.61
Dumfries &Galloway	149,670	69,447	15.49	2,318,383	39,377,663	0.06
Dundee City	148,210	70,343	10.16	1,505,266	132,952	4.61
East Ayrshire	122,060	55,389	13.67	1,668,499	6,880,045	0.23
East Dunbartonshire	106,960	44,516	13.39	1,432,483	806,834	0.07
East Lothian	103,050	44,516	10.75	1,108,044	4,303,211	0.25
East Renfrewshire	92,940	37,265	11.99	1,114,111	778,396	1.39
Falkirk	158,460	70,324	12.45	1,972,067	1,309,662	1.32
Fife	368,080	164,926	11.20	4,122,355	7,160,595	0.52
Glasgow City	606,340	291,262	12.72	7,713,857	341,262	18.52
Highland	234,110	107,321	9.54	2,232,554	122,514,958	0.02
Inverclyde	79,500	36,790	11.99	953,000	712,071	1.20
Midlothian	87,390	37,247	10.75	939,660	2,057,698	0.40
Moray	95,510	41,061	9.29	887,668	12,667,201	0.07
Na h-Eileanan Siar	27,070	12,847	3.20	86,745	12,064,495	0.01
North Ayrshire	136,130	63,314	13.57	1,846,906	4,639,452	0.36
North Lanarkshire	338,260	149,115	14.14	4,782,293	2,006,913	2.14
Orkney Islands	21,670	9,706	4.22	91,357	3,890,732	0.02
Perth and Kinross	149,930	66,289	10.94	1,640,851	25,769,347	0.06
Renfrewshire	174,560	81,333	11.99	2,092,525	1,114,888	1.69
Scottish Borders	114,030	53,330	13.99	1,595,152	29,222,904	0.05
Shetland Islands	23,200	10,108	0.00	0	6,101,292	0.00
South Ayrshire	112,400	52,841	12.20	1,371,319	7,498,495	0.17
South Lanarkshire	316,230	143,606	13.75	4,349,637	9,358,030	0.44
Stirling	92,830	38,368	10.94	1,015,942	11,048,706	0.09
West Dunbartonshire	89,590	43,271	13.39	1,199,852	741,900	0.05
West Lothian	178,550	75,179	13.50	2,410,275	2,286,879	0.95
Scotland	**5,373,000**	**2,435,402**	**11.81**	**63,480,855**	**400,897,617**	2.10

Notes: Estimated number of households as the number of occupied dwelling in 2014 by 2011 Census Data Zone (Scottish Government, 2017).
Source: *Own elaboration* based on Tables S.3 and S.4.

S.4 Spatial distribution of carbon sequestration

Forest carbon uptake, in the UK, is reported by Clilverd *et al*. (2019). We utilize that study to estimate carbon sequestration in forestland by local authority, is assessed using National

Forest Inventory data, and the Forest Research CARBINE carbon accounting model.[5] This latter model accounts for gains and losses of carbon in standing trees, litter, and soils, and due to harvesting of wood products. Net changes in carbon stock at any one time depend on the balance between carbon accumulation rates in tree biomass and soils, woodland planting, and wood harvesting.

The rate of carbon dioxide removal estimated by the CARBINE considers forest planting in the previous decades, as forest management cycles operate over long-time scales of 40 years or more. The specific inputs then required in this model are the areas of newly planted forest in each past year, the stem wood growth rate and the management and harvesting pattern. The model use combined data of new private and state planting from 1920 to 2017, and estimated planting areas pre-1920 for Scotland (and the other UK home nations), which differentiate between conifer and broadleaf woodlands (Clilverd *et al*. 2019). The results of CARABINE are disaggregated in the Clilverd *et al*. study, to 20 km x 20 km grid squares across the UK, and these data are used to estimate carbon balance figures at the local authority level. Clilverd *et al.* then take the 20 km grid square data and disaggregate these further to every 1 km square in the UK. Up to 400 1 km grid squares make up one cell in the 20 km resolution map. These smaller units can then be combined according to the local authority boundaries.

We use the estimated carbon removals due to forest land across Scotland, which are expressed as tonnes per square kilometre (tC/ km^2). Clilverd *et al*. (2019) provides data on carbon removals and emissions related to forest that is remaining as 'forest' and removals/ emissions which due to land use changes (from forest to other land uses) considering a range of values.[6] We use the central point of these values range to approximate the carbon removal and emission values per local authority in Scotland (see Table S6). Net carbon removal from the atmosphere by forest land is then estimated by subtracting the carbon emissions from deforestation from gross forest land carbon removal. The latter includes emissions from the conversion of forest land to grassland, settlement, and crop. Net carbon removal is then converted to tonnes of carbon dioxide per hectare of land (tCO_2/ha) considering that one square kilometre has 100 hectares and the ratio of the molecular weight of carbon dioxide to that of carbon (44/12).

The distribution of forest carbon removals is directly linked to the location and extent of forests at each local authority (see Fig. 2 in the main text). Nonetheless the aggregated level of total carbon removal and emission estimates by local authority ignores the to the wide range of forest areas across authorities. This suggests higher spatial variability than considered in that study. More research is needed to refine the carbon sequestration and removal estimated to (as in case of air pollution) removal given a more accurate understanding of the spatial distribution of climate change regulating services through net woodland carbon removal due to woodland expansion and growth.

[5] More information available online: https://www.forestresearch.gov.uk/research/forestry-and-climate-change-mitigation/carbon-accounting/forest-carbon-dynamics-the-carbine-carbon-accounting-model/ (last accessed 07.06.2021)

[6] Land Use, Land Use Change and Forestry sector following the Greenhouse Gas (GHG) Emissions reportimg requirements (and sectors) of the United Nations Framework Convention on Climate Change (UNFCCC).

Table S.6 Carbon balance from forest land carbon removal (through sequestration) and emissions

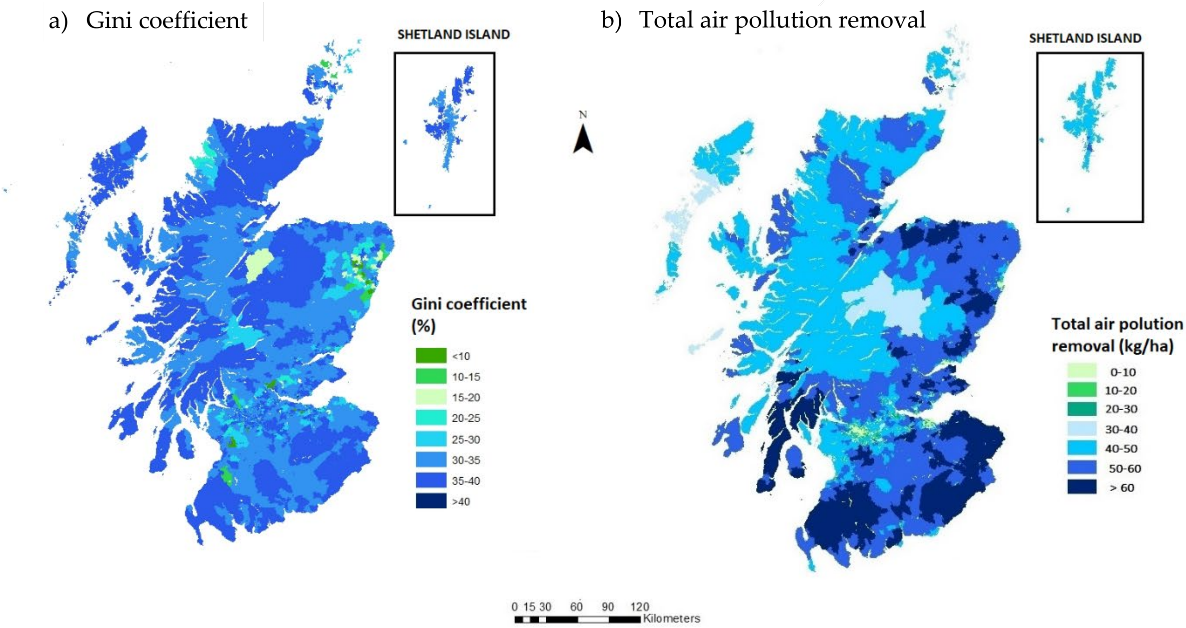
Local authority	Carbon removal			Carbon emissions									Net CO_2 uptake ($t\ CO_2/ha$)
	Sector 4A (forest land) tC Km^2			Sector 4C2 (deforestation to grassland) tC km^2			Sector 4C2 (deforestation to settlement) tC km^2			Sector 4A (Forest land, Wildfires) tC km^2			
	Min	*Max*	*Central*	*Min*	*Max*	*Central*	*Min*	*Max*	*Central*	*Min*	*Max*	*Central*	
Aberdeen City	-30	-20	-25	0.25	0.5	0.375	0.2	0.3	0.25	0.0	0.0	0.0	-0.89
Aberdeenshire	-30	-20	-25	0.5	1.0	0.75	0.5	0.6	0.55	0.0	0.0	0.0	-0.87
Angus	-20	-10	-15	0.5	1.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.51
Argyll and Bute	-40	-30	-35	1.0	1.5	1.25	0.5	0.6	0.55	0.0	0.0	0.0	-1.22
Clackmannanshire	-20	-10	-15	0.5	1.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.51
Dumfries and Galloway	-70	-60	-65	1.5	2.0	1.75	>1	1.0	1.1*	0.0	0.0	0.0	-2.28
Dundee City	-20	-10	-15	0.5	1.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.51
East Ayrshire	-50	-40	-45	1.0	1.5	1.25	0.5	0.6	0.55	0.0	0.0	0.0	-1.58
East Dunbartonshire	-20	-10	-15	0.5	1.0	0.75	0.3	0.4	0.35	0.0	0.0	0.0	-0.51
East Lothian	-20	-10	-15	0.5	1.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.51
East Renfrewshire	-20	-10	-15	0.5	1.0	0.75	0.5	0.6	0.55	0.0	0.0	0.0	-0.50
City of Edinburgh	-20	-10	-15	0.25	0.5	0.375	0.2	0.3	0.25	0.0	0.0	0.0	-0.53
Eilean Siar	-10	0	-5	0.0	0.5	0.25	0.0	0.1	0.05	0.0	0.0	0.0	-0.17
Falkirk	-20	-10	-15	0.5	1.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.51
Fife	-20	-10	-15	0.5	1.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.51
Glasgow City	-20	-10	-15	0.5	1.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.51
Highland	-30	-20	-25	0.5	1.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.87
Inverclyde	-20	-10	-15	0.25	0.5	0.375	0.2	0.3	0.25	0.0	0.0	0.0	-0.53
Midlothian	-30	-20	-25	0.5	1.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.87
Moray	-50	-40	-45	1.5	2	1.75	0.5	0.6	0.55	0.0	0.0	0.0	-1.57
North Ayrshire	-20	-10	-15	0.5	11.0	0.75	0.5	0.6	0.55	0.0	0.0	0.0	-0.50
North Lanarkshire	-30	-20	-25	0.5	11.0	0.75	0.4	0.5	0.45	0.0	0.0	0.0	-0.87
Orkney Islands	-10	0	-5	0.0	0.5	0.25	0	0.1	0.05	0.0	0.0	0.0	-0.17
Perth and Kinross	-30	-20	-25	0.5	1.0	0.75	0.5	0.6	0.55	0.0	0.0	0.0	-0.87
Renfrewshire	-20	-10	-15	0.25	0.5	0.375	0.2	0.3	0.25	0.0	0.0	0.0	-0.53
Scottish Borders	-50	-40	-45	1.0	1.5	1.25	0.5	0.6	0.55	0.0	0.0	0.0	-1.58
Shetland Islands	-10	0	-5	0.0	0.5	0.25	0	0.1	0.05	0.0	0.0	0.0	-0.17
South Ayrshire	-70	-60	-65	1.5	2.0	1.75	>1	1.0	1.1*	0.0	0.0	0.0	-2.28
South Lanarkshire	-30	-20	-25	0.5	1.0	0.75	0.5	0.6	0.55	0.0	0.0	0.0	-0.87
Stirling	-40	-30	-35	0.5	1.0	0.75	0.5	0.6	0.55	0.0	0.0	0.0	-1.24
West Dunbartonshire	-20	-10	-15	0.5	1.0	0.75	0.5	0.6	0.55	0.0	0.0	0.0	-0.50
West Lothian	-20	-10	-15	1.5	2.0	1.75	0.4	0.5	0.45	10	20	15	0.08

Notes: * Assumed value as Clilverd et al. (2019) study only specifies higher than 1. We use a conservative value in that case that is slightly higher than 1.

Source: *Own elaboration* based on Clilverd et al. (2019)

S.5 Income distribution and inequality in Scotland

Income distribution in Scotland was estimated using information on weekly gross (total) income levels in 2015 by the 2011 Data Zone also referred to as *small zones*[7] (Scottish Government, 2017). This data base provides information for 6,970 small zones. These local income estimates are available for years 2014, 2015, 2017 and 2018, and have been produced for the purposes of updating the Scottish Government Housing Need and Demand Assessment (HNDA) Tool,[8] which aims to estimate future additional housing needs. In our paper we use the estimates for 2015, as this is one of the years for which Jones *et al*. (2017) model provides spatially distributed physical estimates for air pollution removal, as well as the year monetary data on the avoided health damage cost by wider areas in Scotland are also available (Table S.3)



Source: *Own elaboration* based on (a) Own estimated Gini coefficient; and (b) ONS (2018) air pollution removal data set by 2011 Data zone, (c) Gross weekly income by household and Data zone (Scottish Government, 2020b) and, (d) total population by Data zone (Scottish Government, 2016). Reproduced with permission under the Open Government Licence v 2.0.

Figure S.1: Spatial distribution of the Gini coefficient (in percentage) **compared to the total air pollution removal in Scotland** (in kg per hectare), year 2015

The income data cover total income received by all adult members of a household, including welfare benefits, tax credits and housing benefits. The estimates reflect gross income before any deductions are taken off for income tax, national insurance contributions and council tax

[7] Data zones are the small area geography used by the Scottish Government to allow statistics to be available across a number of policy areas. Data zones have a population of between 500 and 1,000 household residents.

[8] More information available online at: http://www.gov.scot/Topics/Built-Environment/Housing/supply-demand/chma.

etc[9]. These gross income levels range from £50 per week to £2,000 per week, accounting for 18 gross income categories in total.

Using these gross weekly household income data, we have further estimated the Gini coefficient (Fig. S.1) considering the total number of households and total population by Data Zone and income category defined in the data accompanying the HNDA report (Scottish Government, 2020b) and Scottish Index of Multiple Deprivation (SIMD) report (Scottish Government, 2016), respectively. The steps taken for estimating the Gini coefficient are detailed as follows.

HNDA information has been rearranged by quintiles of population), and for each population quintile we have estimated the total aggregated income. Total income by quintile is estimated as the weighted median income for each population quintile accounting for the share of households represented by each population quintile. Note that this median income is estimated for each of the 18 HNDA gross income categories as the number that occupies the central position over each income category range, and this value is then multiplied by the share of houses within each population quintile.

Income distribution information by quintiles of population was used to estimate the Lorenz curve and Gini coefficients for each one of the 6,970 small zones. The Lorenz curve is a graphical representation of income or wealth distribution in a population. Basically, this curve shows the cumulative proportion of income against the cumulative proportion of the population. The Gini coefficient (in percentage) is estimated as the ratio of the area that lies between the line of equality (a 45°-degree line) and the Lorenz curve over the total area under the line of equality.

In order to understand the relation between economic inequality and air pollution removal, we have estimated simple statistical correlations between median gross income, Gini coefficient, total air pollution removal by pollutant and air pollution removal monetary value, using 2011 Data zone values for each one of the variables referred to above (Table S.7).

The results of this simple correlation analysis show that there is a relatively strong negative linear relationship between the Gini coefficient and gross income. This indicates that at higher income levels a lower Gini coefficient is observed, which indicates a better income distribution in, on average, richer areas for example in Aberdeen and Aberdeenshire in North-East Scotland (Fig. S.1(a)). We also find a relatively weak positive relationship between gross income and total air pollution removed. Possibly this indicates a higher air quality control services in areas of higher incomes, which in Scotland corresponds to more densely populated areas. There appears to be no relationship between the monetary value associated with air pollution removal, gross income, and income distribution (Table S.7).

[9] Net income (after taxes and contributions) adjusted by household size would be a more appropriate measure analysing income distribution and inequalities. This data is not available at the spatial granularity requiered.

Table S.7 Correlation matrix income and air pollution removal indicators

Class	Gini coefficient	Median Household gross income	Air Pollution Removal (APR)							Monetary value APR
			$PM_{2.5}$	PM_{10}	NH_3	NO_2	O_3	SO_2	Total	
Gini coefficient	1.00									
Median household gross income (£/week)	**-0.49**	1.00								
$PM_{2.5}$ (kg/ha)	-0.07	0.19	1.00							
PM_{10} (kg/ha)	-0.05	0.17	0.99	1.00						
NH_3 (kg/ha)	-0.08	0.29	0.63	0.63	1.00					
NO_2 (kg/ha)	-0.08	0.24	0.66	0.60	0.72	1.00				
O_3 (kg/ha)	-0.10	0.19	0.40	0.33	0.35	0.55	1.00			
SO_2 (kg/ha)	-0.08	0.21	0.62	0.57	0.61	0.74	0.77	1.00		
Total APR (kg/ha)	-0.08	**0.29**	0.68	0.68	1.00	0.76	0.41	0.66	1.00	
Monetary value APR (£/ha)	0.01	-0.07	0.12	0.08	-0.05	0.08	**0.41**	0.21	-0.02	1.00

Notes: Household income refers to gross median weekly income.

The HNDA information has been further rearranged in five – roughly even – weekly gross household income intervals, (<£400, £401 - £800, £801 - £1200, £1201 -£1600 and > £1600) by small zone, and considering the total aggregated population (households) by income interval. In this case we aim to estimate the share (in percentage) of air pollution value (in monetary terms) attributed to households by local authority and income interval (see Table S.8).

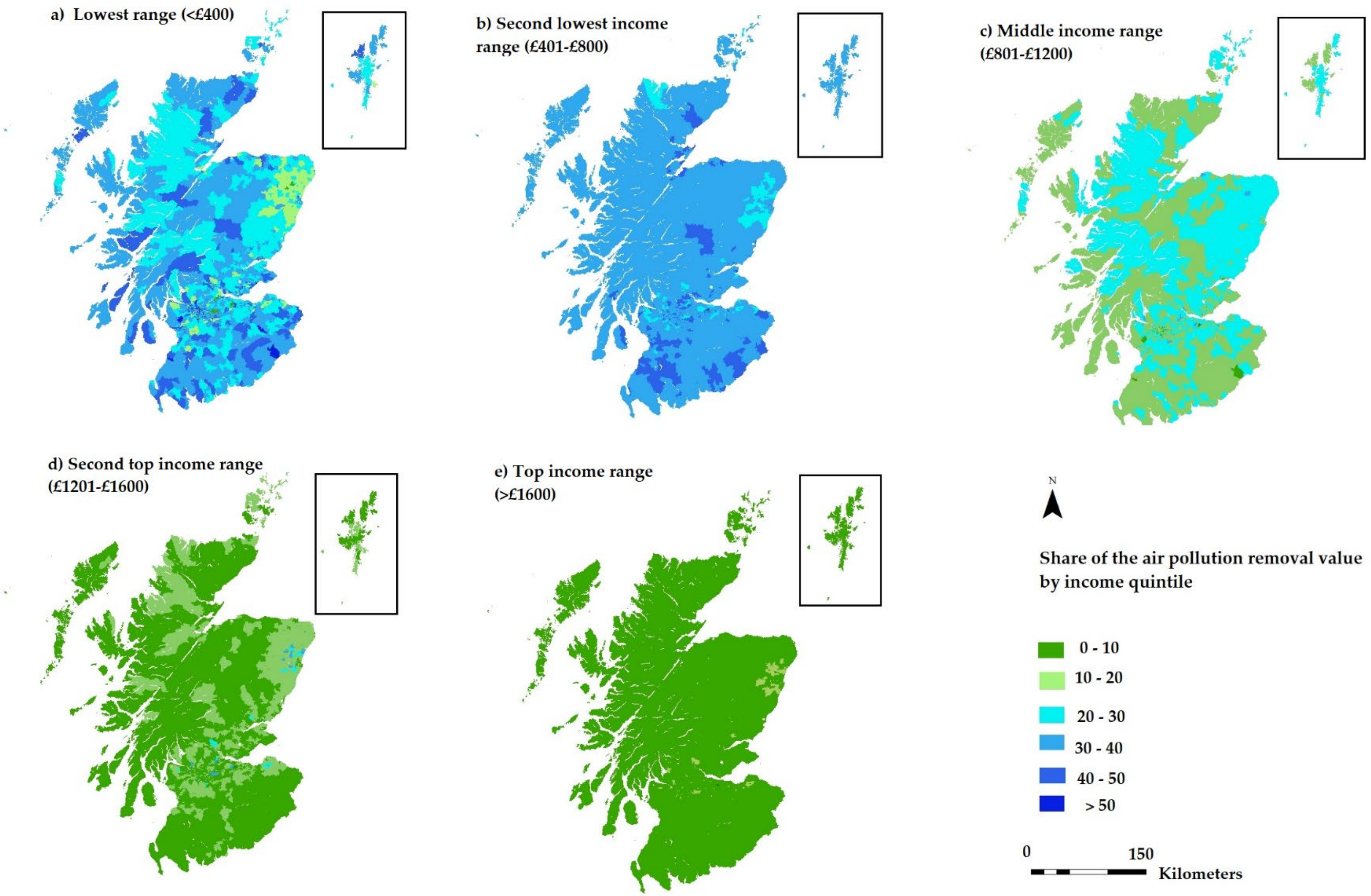
Local authority total air pollution removal data were estimated by aggregating the small zones' total pollutants removal. The economic value of air pollution removal in turn depends on the aggregated population at the local authority level. The monetary value of total air pollution removal by local authority is further divided by the total air pollution removal by local authority (Table S.5). The resulting unit value per kilogram of pollutant removed is then multiplied by the units of pollutants removed by each small zone, and this value distributed by the five income intervals considering the share of households per income interval and small zone.

At the aggregated level almost two thirds of the air pollution removal services are consumed by that population within the lowest to second lowest income intervals. Only 15 percent of the air pollution removal services are in turn consumed by population in the two highest household income interval levels. Finally, Figure S.2 shows the spatial distribution across Scotland of the share of air pollution removal value by income interval across Scotland.

Table S.8 Share of air pollution removal value attributed to households by household income interval

Local authority	Gross income (mean) £/week (year 2015)	Household gross income interval (£/week)				
		Lowest	Second lowest	Middle	Second highest	Top
		≤400	401-800	801-1200	1201-1600	>1600
		Share of total air pollution removal monetary value (%)				
Aberdeen City	752.01	21.7	32.6	24.7	14.2	6.9
Aberdeenshire	894.20	21.7	34.0	25.0	13.3	6.0
Angus	677.52	26.0	37.5	22.9	10.0	3.7
Argyll and Bute	650.99	34.6	38.8	18.2	6.4	2.1
City of Edinburgh	750.49	25.5	35.4	22.6	11.5	5.0
Clackmannanshire	676.99	26.4	36.3	22.5	10.5	4.3
Dumfries and Galloway	619.18	33.4	40.5	18.2	6.0	1.9
Dundee City	607.84	22.6	34.6	24.7	12.6	5.4
East Ayrshire	667.90	24.3	39.5	23.3	9.5	3.4
East Dunbartonshire	898.61	21.5	33.7	25.0	13.7	6.2
East Lothian	764.98	22.6	34.9	24.1	12.8	5.7
East Renfrewshire	899.07	23.8	33.5	23.6	13.0	6.0
Falkirk	695.45	28.5	37.5	21.5	9.1	3.3
Fife	689.80	29.5	36.9	21.0	9.1	3.4
Glasgow City	584.47	36.0	36.8	17.6	7.0	2.6
Highland	690.77	32.2	39.6	19.1	6.9	2.2
Inverclyde	637.29	22.2	34.8	24.3	12.9	5.8
Midlothian	732.56	20.0	34.9	26.0	13.4	5.7
Moray	697.04	26.9	39.4	22.1	8.7	3.0
Na h-Eileanan an Iar	635.37	38.8	37.7	16.4	5.4	1.6
North Ayrshire	617.57	35.1	37.8	18.0	6.8	2.4
North Lanarkshire	675.52	28.1	38.5	21.6	8.7	3.1
Orkney Islands	645.26	36.5	37.7	17.6	6.2	2.0
Perth and Kinross	711.79	27.6	38.0	21.6	9.3	3.5
Renfrewshire	660.39	20.3	34.5	25.8	13.6	5.8
Scottish Borders	647.86	28.1	38.1	21.6	8.9	3.2
Shetland Islands(1)	658.13	0.0	0.0	0.0	0.0	0.0
South Ayrshire	675.49	32.9	39.9	18.6	6.5	2.1
South Lanarkshire	705.38	25.3	37.6	23.1	10.1	3.8
Stirling	776.84	26.8	36.1	22.1	10.6	4.4
West Dunbartonshire	578.23	31.6	37.6	19.8	8.1	2.9
West Lothian	738.97	22.5	34.9	24.7	12.6	5.4
Scotland	**553.77**	**27.8**	**36.8**	**21.7**	**9.8**	**3.9**

Note: (1) The Shetland Islands have a zero value, as no avoided health cost are provided for this area in the ONS (2018) data base.
Source: *Own elaboration* based on ONS (2018) and Scottish Government (2020a) data.



Source: *Own elaboration* based on ONS (2018) air pollution removal and Scottish Government (2020b) gross income distribution data by 2011 Data Zone. Reproduced with permission under the Open Government Licence v 2.0.

Figure S.2: Spatial distribution of the estimated share of air pollution removal value by household income intervals (ranges) in Scotland (in percentage) (income data for 2015)

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