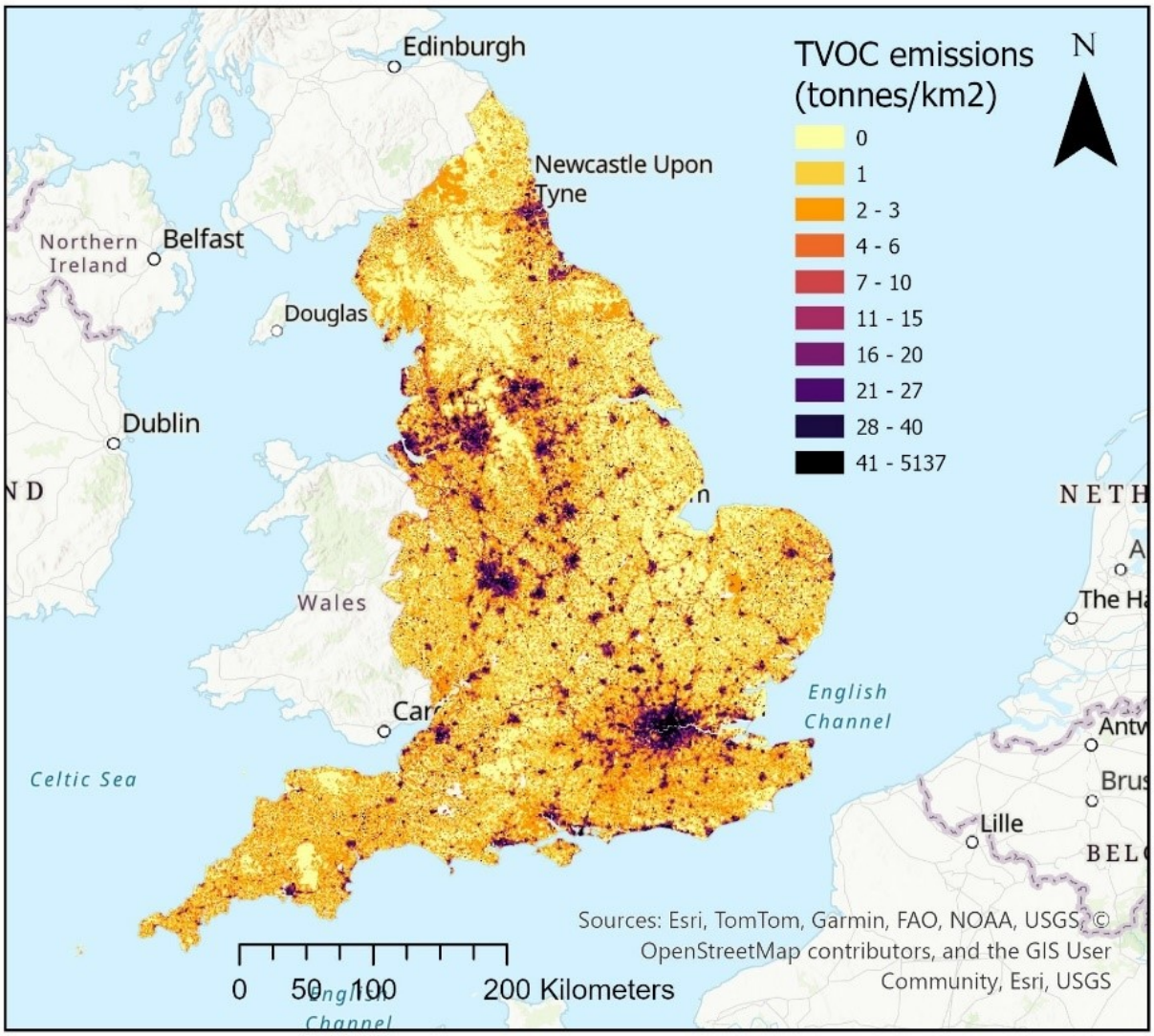
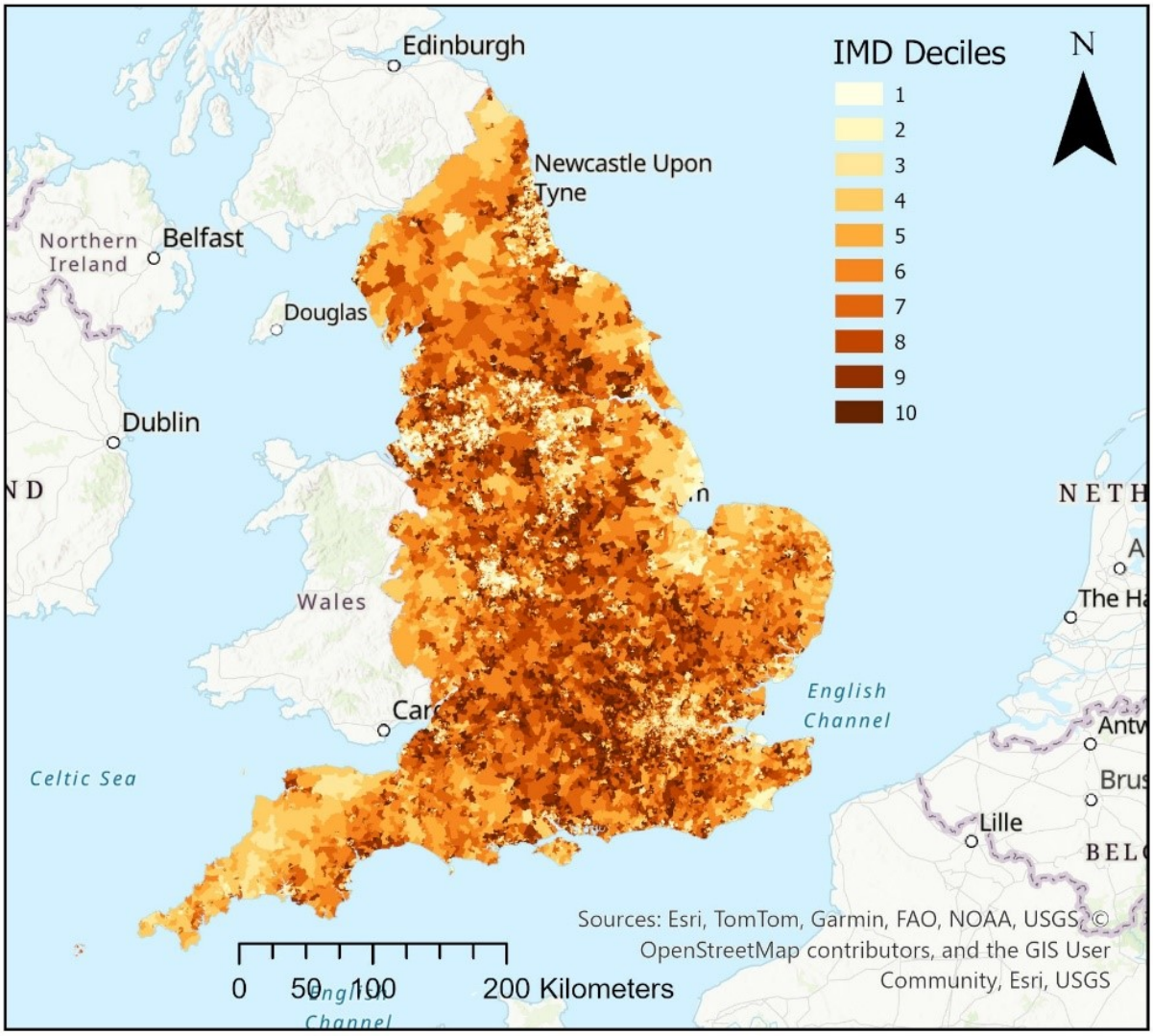
Supplementary Information (SI) for Environmental Science: Advances.

Supplementary Material

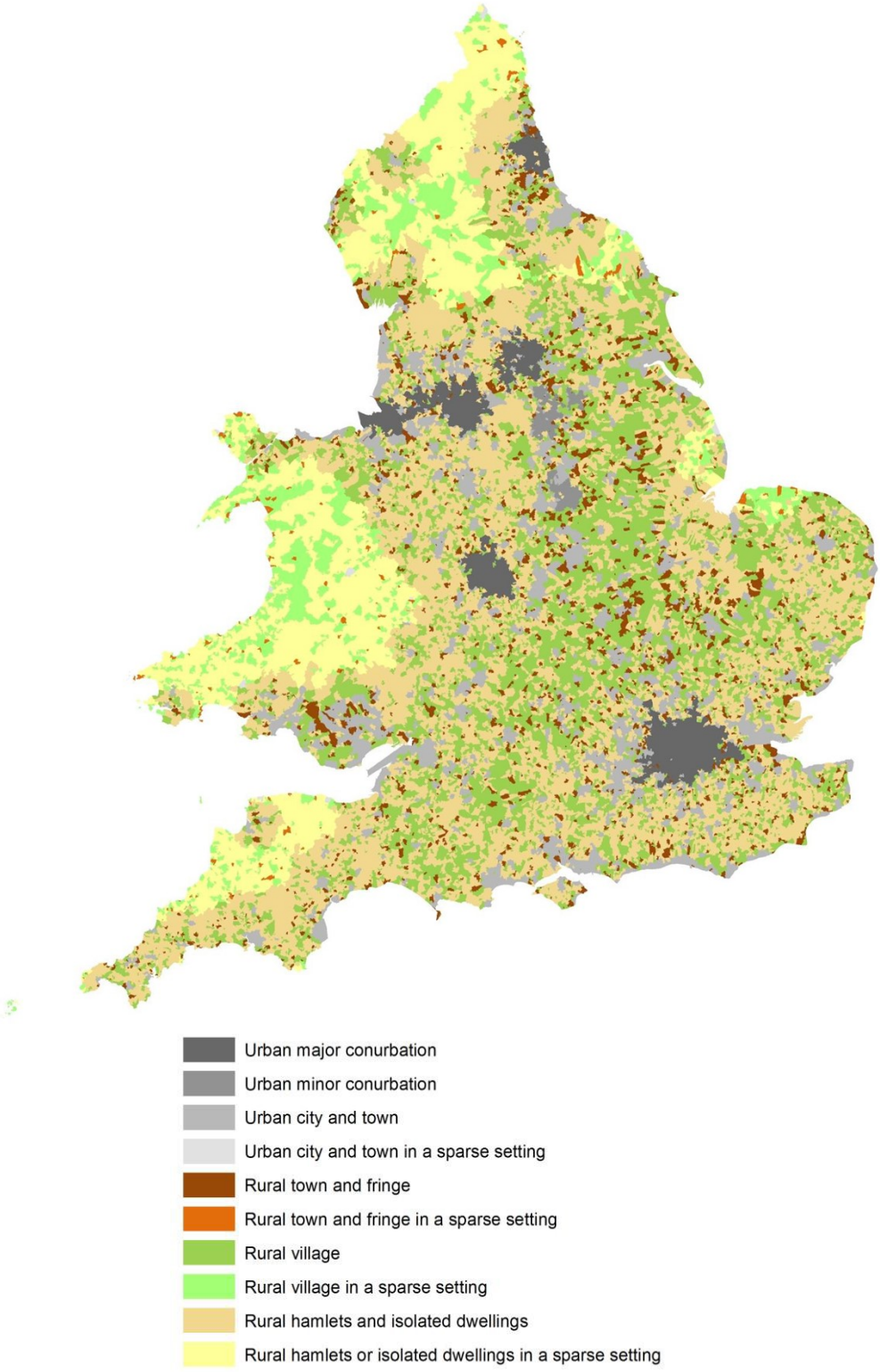
Supplementary Figure, S1: Annual 2019 non-methane Total Volatile Organic Compound (TVOC) emissions (tonnes/km^2) by 1km^2 gridded surface.



Supplementary Figure, S2: 2019 Indices of Multiple Deprivation Deciles in England at lower super output area level (LSOA). 1 is the 10% most deprived LSOAs, whilst 10 is the 10% least deprived LSOAs in England.



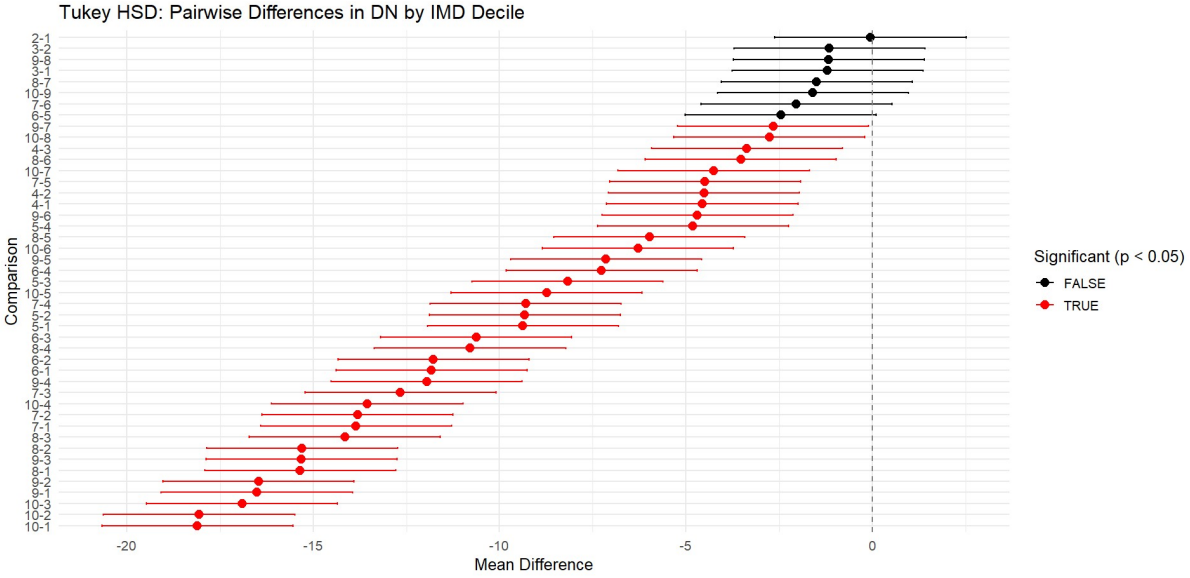
Supplementary Figure, S3: 2011 Rural Urban Classification for England at lower super output area level.



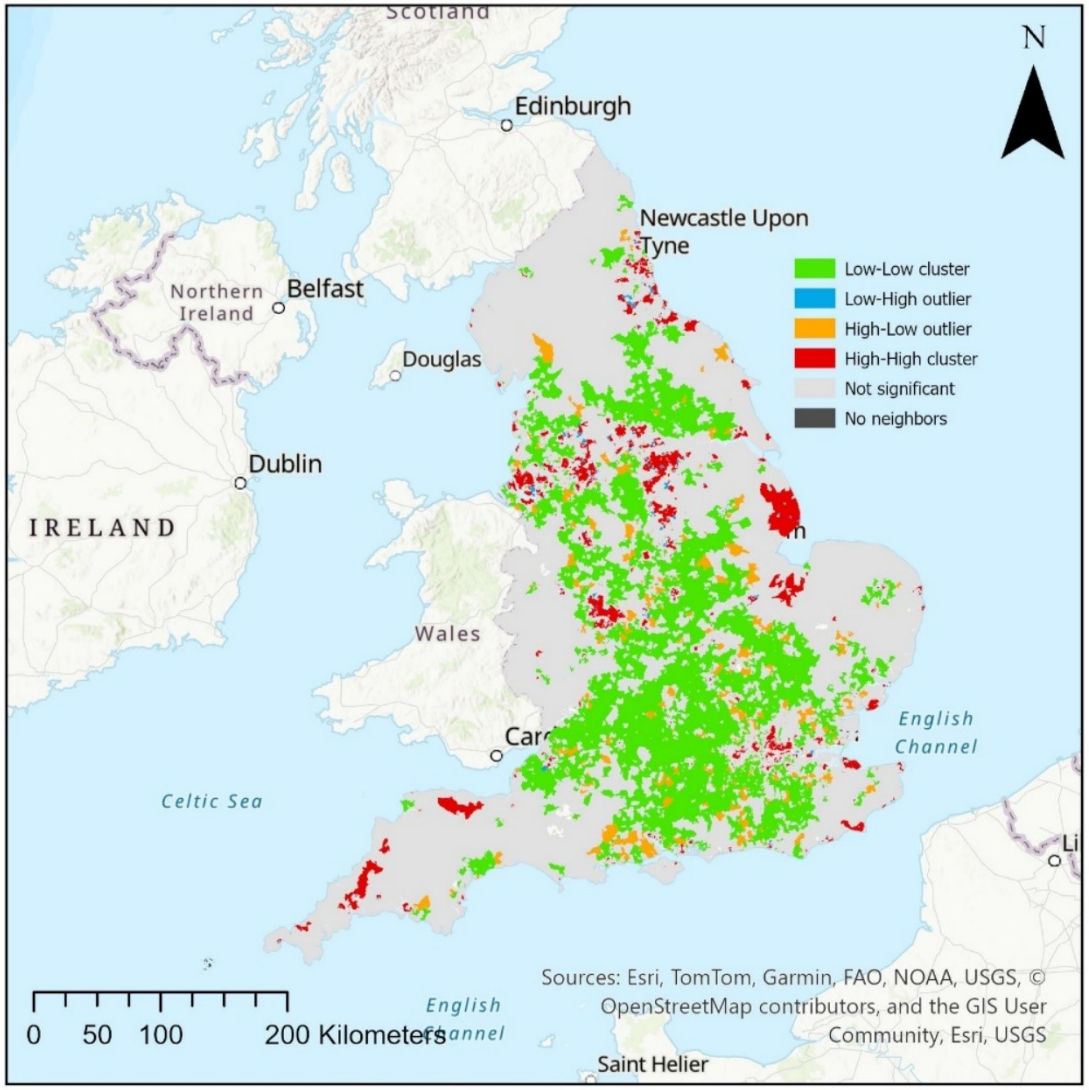
Supplementary Table, S1: Model outputs for one-way analysis of variance (ANOVA) statistical testing of TVOC emissions within deprivation deciles. Table includes degrees of freedom (Df), sum of squares (Sum sq), mean square (Mean Sq), variance between groups (F value), and P-value (Pr (>F)).

		Df	Sum sq	Mean Sq	F value	Pr (>F)
TVOC (England)	IMD_Decile	9	1484039	164893	153.2	<2e-16
	Residuals	32744	35231710	1076		
TVOC (London)	IMD_Decile	9	274652	30517	43.34	<2e-16
	Residuals	4624	3255947	704		
TVOC (Major Urban)	IMD_Decile	9	519378	57709	37.9	<2e-16
	Residuals	11433	17406826	1523		
TVOC (Minor Urban)	IMD_Decile	9	9596	1066.3	3.254	0.000643
	Residuals	1198	392507	327.6		
TVOC (Urban Cities)	IMD_Decile	9	617164	68574	85.31	<2e-16
	Residuals	14438	11605451	804		
TVOC (Rural Towns)	IMD_Decile	9	66878	7431	8.508	1.16E-12
	Residuals	2927	2556451	873		
TVOC (Rural Villages)	IMD_Decile	9	45771	5086	14.09	<2e-16
	Residuals	2351	848796	361		
TVOC (Rural Dispersed)	IMD_Decile	9	3111	345.7	2.369	0.0151
	Residuals	171	24951	145.9		
Solvent	IMD_Decile	9	659283	73254	372.8	<2e-16
	Residuals	32744	6434509	197		
Industrial Processes	IMD_Decile	9	4327	480.8	1.357	0.202
	Residuals	32744	11600613	354.3		
Agricultural	IMD_Decile	9	2722	302.4	19.55	<2e-16
	Residuals	32744	506373	15.46		
Road	IMD_Decile	9	2530	281.13	295.8	<2e-16
	Residuals	32744	31125	0.95		
Population density	LSOA_Size	9	4048670	449852	1313	<2e-16
	Residuals	32833	11253232	343		
White British	population	9	3440108	382234	379.7	<2e-16
	Residuals	32744	32962799	1007		
Asian	population	9	1815774	201753	191	<2e-16
	Residuals	32744	34587133	1056		
Black	population	6	1289527	214921	200.4	<2e-16
	Residuals	32747	35113380	1072		
White other	population	5	1884476	376895	357.5	<2e-16
	Residuals	32739	34515751	1054		

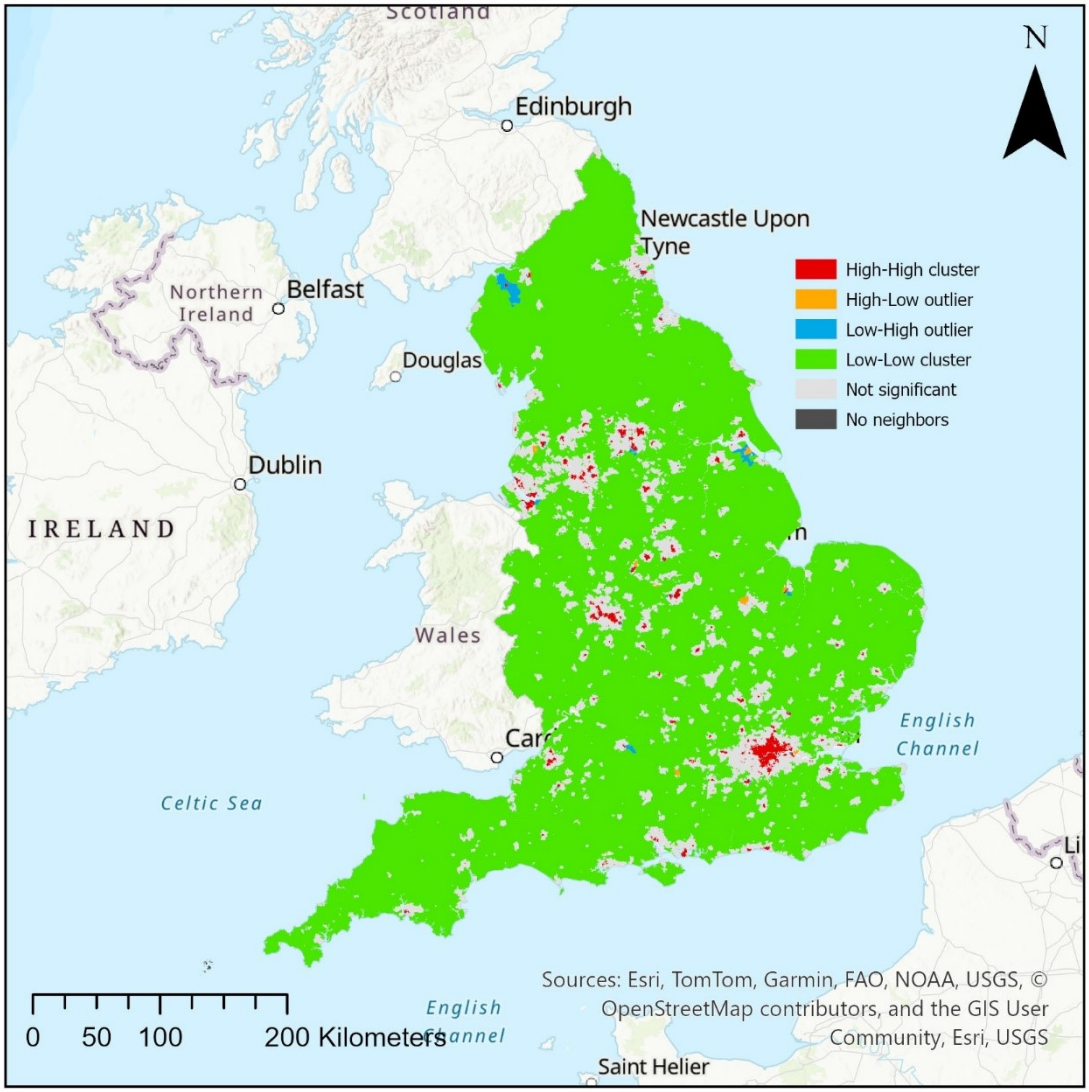
Supplementary Figure, S4: Tukey's Honestly Significant Difference (HSD) analysis of significant difference between TVOC emissions in deprivation deciles within England. Plot shows mean difference in TVOC emissions by deprivation deciles.



Supplementary Figure, S5: Global Moran's I cluster analysis of Indices of Multiple Deprivation (IMD) deciles in 2019. For example, "High-High clusters" are areas of where high deprivations LSOAs are clustered together, "High-Low outliers" are areas where high deprivation deciles are neighboured by low deprivation areas, "Not significant" are areas of no spatial pattern.



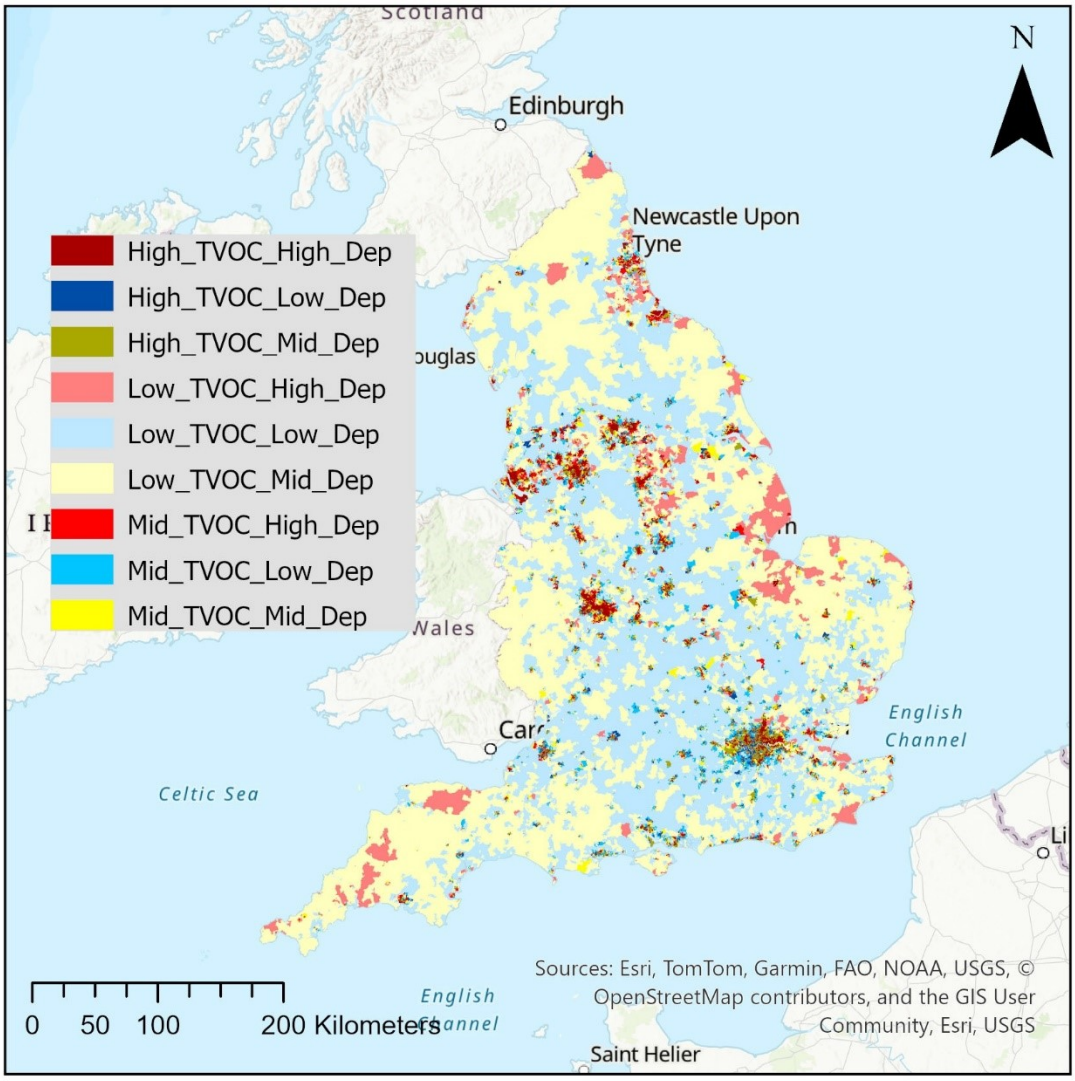
Supplementary Figure, S6: Global Moran's I cluster analysis of Total Volatile Organic Compounds (TVOC) emissions in 2019 across England. For example, "High-High clusters" are areas of where high TVOC emissions LSOAs are clustered together, "High-Low outliers" are areas where high TVOC emissions LSOAs are neighboured by low TVOC emissions LSOAs, "Not significant" are areas of no spatial pattern.



Supplementary Table, S2: Cross-tabulation of TVOC emissions and deprivation levels (LSOA, England). Values represent a count of LSOAs with their percentage representative to the total in brackets (e.g., 6525 LSOAs are low deprivation and low TVOC, which accounts for 58.1% of total "Low TVOC" LSOAs. Pearson χ^2 value shows the statistical significance of the association between deprivation and TVOC emissions, whilst Cramer's V is the strength of the association.

	Low deprivation	**Mid deprivation**	**High deprivation**
Low TVOC	6,525 (58.1%)	3,355 (29.9%)	1,345 (12.0%)
Mid TVOC	4,355 (40.8%)	2,959 (27.7%)	3,363 (31.5%)
High TVOC	2,258 (20.6%)	3,539 (32.3%)	5,145 (47.0%)
Pearson χ^2 (df = 4) = 4,267.7, $p < 0.001$			
Cramér's V = 0.255			

Supplementary Figure, S7: Bivariate spatial analysis of TVOC emissions and deprivation scores across England in 2019.



Supplementary Table, S3: Cross-tabulation of TVOC emissions and land classification types (LSOA, England). Values represent a count of LSOAs with their percentage representative to the total in brackets (e.g., 143 LSOAs are rural dispersed and low TVOC, which accounts for 1.3% of total "Low TVOC" LSOAs. Pearson χ^2 value shows the statistical significance of the association between land classification and TVOC emissions, whilst Cramer's V is the strength of the association.

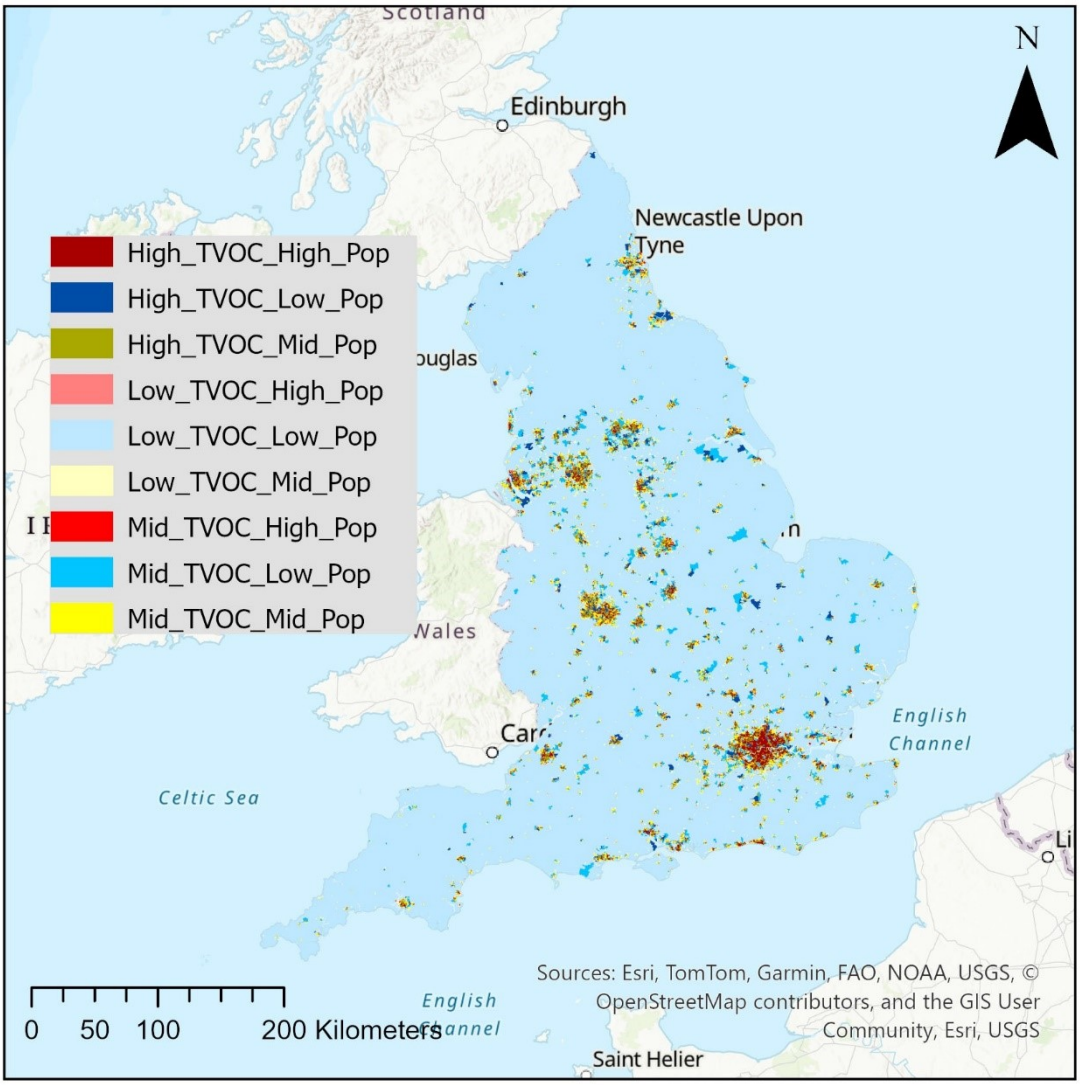
	Rural dispersed	**Rural town**	**Rural village**	**Urban city & town**	**Urban major conurbation**	**Urban minor conurbation**
Low TVOC	143 (1.3%)	181 (1.6%)	2,746 (24.5%)	2,326 (20.7%)	1,259 (11.2%)	306 (2.7%)
Mid TVOC	25 (0.2%)	0 (0.0%)	152 (1.4%)	30 (0.3%)	3,836 (35.9%)	537 (5.0%)
High TVOC	10 (0.1%)	0 (0.0%)	39 (0.4%)	5 (0.0%)	6,428 (58.7%)	365 (3.3%)

Pearson χ^2 (df = 12) = 13,737, p < 0.001
Cramér's V = 0.457

Supplementary Table, S4: Cross-tabulation of TVOC emissions and population density (LSOA, England). Values represent a count of LSOAs with their percentage representative to the total in brackets (e.g., 470 LSOAs have high population density and low TVOC, which accounts for 4.2% of total "Low TVOC" LSOAs. Pearson χ^2 value shows the statistical significance of the association between population density and TVOC emissions, whilst Cramer's V is the strength of the association.

	High population density	**Mid population density**	**Low population density**
Low TVOC	470 (4.2%)	2,432 (21.7%)	8,323 (74.1%)
Mid TVOC	3,476 (32.6%)	5,352 (50.1%)	1,849 (17.3%)
High TVOC	7,002 (64.0%)	3,164 (28.9%)	776 (7.1%)
Pearson χ^2 (df = 4) = 16,065, p < 0.001			
Cramér's V = 0.495			

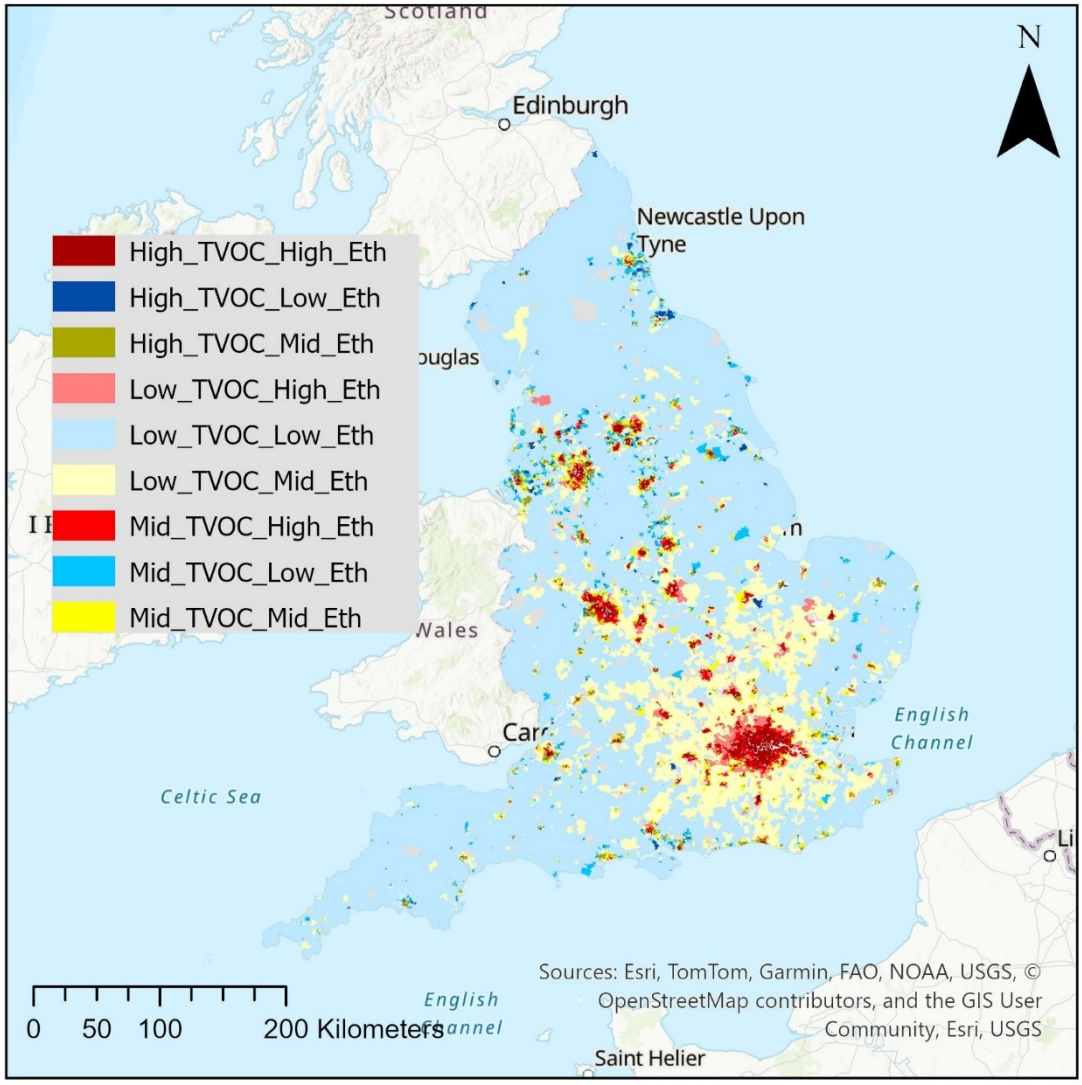
Supplementary Figure, S8: Bivariate spatial analysis of TVOC emissions and population density in England in 2019



Supplementary Table, S5: Cross-tabulation of TVOC emissions and population of ethnic minorities (LSOA, England). Values represent a count of LSOAs with their percentage representative to the total in brackets (e.g., 6704 LSOAs have a low ethnic minority population and low TVOC, which accounts for 61.9% of total "Low TVOC" LSOAs. Pearson χ^2 value shows the statistical significance of the association between land ethnic minority population and TVOC emissions, whilst Cramer's V is the strength of the association.

	Low ethnic minority	**Mid ethnic minority**	**High ethnic minority**
Low TVOC	6,704 (61.9%)	3,449 (31.8%)	676 (6.2%)
Mid TVOC	2,941 (28.2%)	4,522 (43.3%)	2,982 (28.5%)
High TVOC	959 (9.1%)	2,632 (25.0%)	6,945 (65.9%)
Pearson χ^2 (df = 4) = 10,943, p < 0.001			
Cramér's V = 0.415			

Supplementary Figure, S9: Bivariate spatial analysis of TVOC emissions and population of ethnic minorities in England in 2019



Supplementary Table, S6: Model outputs for spatial autoregressive (SAR) model for associations of deprivation, population density, and land-use with TVOC emissions in England in 2019. Land classification categories statistics are in reference to rural dispersed. The estimate gives the direction and magnitude of the effect, the standard error quantifies uncertainty, the z-value measures how far the estimate is from zero relative to that uncertainty, and the p-value indicates whether the effect is statistically distinguishable from zero after accounting for spatial dependence.

Predictor	Estimate	Std. Error	z-value	p-value
Intercept	0.7630	0.0203	37.55	<0.001
Deprivation (IMD_rev)	0.0100	0.00064	15.77	<0.001
Density index (dens_idx)	0.1262	0.00202	62.49	<0.001
% Ethnic minority (per 1%)	0.00148	0.000094	15.81	<0.001
Land-use (RUC11)				
Rural dispersed (ref)	—	—	—	—
Rural town	–0.136	0.0194	–6.99	<0.001
Rural village	–0.179	0.0204	–8.77	<0.001
Urban city & town	–0.056	0.0186	–3.02	0.003
Urban major conurbation	–0.086	0.0188	–4.56	<0.001
Urban minor conurbation	–0.086	0.0203	–4.25	<0.001
Spatial lag parameter (ρ)	0.7163	0.00385	186.23	<0.001

Supplementary Table, S7: Annual Average VOC concentrations (µg/m³) and relative contribution to TVOC (%) at Chilbolton Observatory (CHBO) and London Marylebone (MY1) in 2019.

	CHBO (µg/m³)	MY1 (µg/m³)	CHBO(%)	MY1(%)
ethane	2.922909	9.697112	25.49442	24.15349
propane	2.214836	5.922022	19.31842	14.75052
n-butane	0.995309	4.65574	8.681362	11.59648
iso-butane	0.608731	2.670108	5.30952	6.650684
toluene	0.526715	2.435018	4.594157	6.065123
iso-pentane	0.497662	2.400903	4.340745	5.980148
ethene	0.581925	2.395054	5.075707	5.965581
m+p-xylene	0.275546	1.643273	2.40339	4.09305
ethyne	0.762291	1.01574	6.648913	2.529997
n-pentane	0.263618	1.012383	2.299351	2.521635
propene	0.138807	0.860217	1.210716	2.142621
benzene	0.570582	0.834771	4.976775	2.079241
o-xylene	0.119615	0.646655	1.043319	1.610682
1,2,4-trimethylbenzene	0.086462	0.597482	0.75415	1.488203
ethylbenzene	0.117963	0.488	1.028909	1.215506
2-methylpentane	0.077139	0.471242	0.672829	1.173765
n-heptane	0.095809	0.411864	0.835671	1.025867
iso-octane	0.065147	0.367491	0.56823	0.915343
n-hexane	0.09344	0.326661	0.81501	0.813644
1,3,5-trimethylbenzene	0.036318	0.224353	0.316773	0.558817
1-butene	0.098218	0.211718	0.856688	0.527346
n-octane	0.063398	0.200033	0.552972	0.49824
trans-2-butene	0.0387	0.135877	0.337548	0.33844
trans-2-pentene	0.021386	0.105045	0.186534	0.261645
1,2,3-trimethylbenzene		0.103867	0	0.25871
isoprene	0.037448	0.091353	0.32663	0.227543
cis-2-butene	0.039773	0.090055	0.346909	0.224307
1-pentene	0.026446	0.082598	0.230669	0.205734
1,3-butadiene	0.088702	0.051243	0.773682	0.127636
Total	11.4649	40.14788	100	100

Supplementary Figure, S10: 3D surface plot showing percentage of LSOAs for each deprivation decile within each area size group (%)