**Supplementary Table 1. Geographical correlations of concentrations between 14 mineral elements at the county level of USA**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Al | As | Ca | Cu | Fe | Hg | Mg | Mn | Na | P | Pb | Se | Ti |
| As | r=0.4015,p < 0.0001 |  |  |  |  |  |  |  |  |  |  |  |  |
| Ca | r=0.4864,p < 0.0001 | r=0.2897,p < 0.0001 | - | - | - | - | - | - | - | - | - | - | - |
| Cu | r=0.7450,p < 0.0001 | r=0.5840,p < 0.0001 | r=0.5209,p < 0.0001 | - | - | - | - | - | - | - | - | - | - |
| Fe | r=0.7288,p < 0.0001 | r=0.4457,p < 0.0001 | r=0.3642,p < 0.0001 | r=0.6923,p < 0.0001 | - | - | - | - | - | - | - | - | - |
| Hg | r=0.2877,p < 0.0001 | r=0.1594,p < 0.0001 | r=-0.0329,p < 0.0001 | r=0.3617,p < 0.0001 | r=0.4612,p < 0.0001 | - | - | - | - | - | - | - | - |
| Mg | r=0.7047,p < 0.0001 | r=0.4163,p < 0.0001 | r=0.8257,p < 0.0001 | r=0.7052,p < 0.0001 | r=0.5698,p < 0.0001 | r=0.1362,p < 0.0001 | - | - | - | - | - | - | - |
| Mn | r=0.4335,p < 0.0001 | r=0.4834,p < 0.0001 | r=0.2990,p < 0.0001 | r=0.5178,p < 0.0001 | r=0.7153,p < 0.0001 | r=0.3820,p < 0.0001 | r=0.40,p < 0.0001 | - | - | - | - | - | - |
| Na | r=0.8235,p < 0.0001 | r=0.2238,p < 0.0001 | r=0.5667,p < 0.0001 | r=0.5466,p < 0.0001 | r=0.5305,p < 0.0001 | r=0.1085,p < 0.0001 | r=0.7116,p < 0.0001 | r=0.3682,p < 0.0001 | - | - | - | - | - |
| P | r=0.6975,p < 0.0001 | r=0.5683,p < 0.0001 | r=0.5930,p < 0.0001 | r=0.7098,p < 0.0001 | r=0.6131,p < 0.0001 | r=0.2508,p < 0.0001 | r=0.6907,p < 0.0001 | r=0.5383,p < 0.0001 | r=0.6308, p < 0.0001 | - | - | - | - |
| Pb | r=0.3288,p < 0.0001 | r=0.2937,p < 0.0001 | r=0.0999,p < 0.0001 | r=0.3237,p < 0.0001 | r=0.4657,p < 0.0001 | r=0.4345,p < 0.0001 | r=0.1515,p < 0.0001 | r=0.4592,p < 0.0001 | r=0.1553, p < 0.0001 | r=0.3412, p < 0.0001 | - | - | - |
| Se | r=0.3577,p < 0.0001 | r=0.6194,p < 0.0001 | r=0.2416,p < 0.0001 | r=0.4833,p < 0.0001 | r=0.2773,p < 0.0001 | r=0.3028,p < 0.0001 | r=0.3390,p < 0.0001 | r=0.2781,p < 0.0001 | r=0.2040, p < 0.0001 | r=0.5222, p < 0.0001 | r=0.2447,p < 0.0001 | - | - |
| Ti | r=0.2705,p < 0.0001 | r=-0.2081,p < 0.0001 | r=-0.1860,p < 0.0001 | r=0.117,p < 0.0001 | r=0.4493,p < 0.0001 | r=0.4053,p < 0.0001 | r=-0.0431,p < 0.0001 | r=0.2051,p < 0.0001 | r=0.1891, p < 0.0001 | r=0.0594, p < 0.0001 | r=0.3188,p < 0.0001 | r=-0.1607,p < 0.0001 | - |
| Zn | r=0.7128,p < 0.0001 | r=0.6059,p < 0.0001 | r=0.4133,p < 0.0001 | r=0.7922,p < 0.0001 | r=0.7789,p < 0.0001 | r=0.4701,p < 0.0001 | r=0.6298,p < 0.0001 | r=0.6131,p < 0.0001 | r=0.4979, p < 0.0001 | r=0.7113, p < 0.0001 | r=0.4634,p < 0.0001 | r=0.4972,p < 0.0001 | r=0.1541,p < 0.0001 |

*r, correlation coefficient; p, p value.*

**Supplementary Table 2. Statistical assessment of the optimal number of clusters from latent class analysis models**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model | LL statistics | % Reduction in LL from H0 | BICLL |  CAICLL | The smallest size of the clusters |
| 1 cluster (H0) | -21886.4 | - | 43853.1 | 43863.1 | 100% |
| 2 cluster | -17815.0 | 18.60 | 35798.8 |  35819.8 | 12.74% |
| 3 cluster † | -15439.2 | 29.46 | 31135.5 | 31167.5 | 9.34% |
| 4 cluster | -14878.9 | 32.02 | 30103.3 | 30146.3 | 4.86% |
| 5 cluster | -14026.7 | 35.91 | 28487.2 | 28541.2 | 4.57% |
| 6 cluster | -13446.2 | 38.56 | 27414.6 | 27479.6 | 4.44% |
| 7 cluster | -12962.2 | 40.78 | 26535.0 | 26611.0 | 4.93% |
| 8 cluster | -12539.0 | 42.71 | 25777.1 | 25864.1 | 4.76% |

*BICLL, Bayes Information Criterion based on* *Log-likelihood Statistics; CAICLL, Consistent Akaike’s Information Criterion based on Log-likelihood Statistics. †The optimal model.*

**Supplementary Table 3. County level statistics of mineral concentrations, health measurements and socio-demographics, stratified by LCA derived clusters**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Characteristics | Number (%), or mean (Standard deviation) | Number (%), or mean (Standard deviation) | Number (%), or mean (Standard deviation) | *p* value |
|  | Common cluster *n*=2056 | Infertile cluster*n*=739 | Plentiful cluster*n*=285 |  |
| Mineral concentrations (mg/kg) |  |  |  |  |
|  Aluminum (Al) | 48066.67 (13898.44) | 21328.1(11264.44) | 45948.17 (13169.78) | < 0.0001 |
|  Arsenic (As) | 6.914 (3.237) | 3.303 (1.716) | 13.0 (12.992) | < 0.0001 |
|  Calcium (Ca) | 17787.26 (12492.62) | 2669.935 (2435.214) | 50290.75 (42709.36) | < 0.0001 |
|  Copper (Cu) | 15.887 (10.164) | 6.544 (4.069) | 24.046 (30.665) | < 0.0001 |
|  Iron (Fe) | 25979.85 (10639.52) | 13475.57 (8239.227) | 31264.79 (18719.65) | < 0.0001 |
|  Lead (Pb) | 23.858 (22.817) | 17.958 (8.885) | 52.615 (110.518) | < 0.0001 |
|  Magnesium (Mg) | 7094.261 (4535.02) | 1370.524 (1123.532) | 10489.74 (8295.604) | < 0.0001 |
|  Manganese (Mn) | 712.876 (365.008) | 366.905 (253.895) | 1031.516 (863.908) | < 0.0001 |
|  Mercury (Hg) | 0.06 (0.186) | 0.059 (0.17) | 0.075 (0.193) | 0.4240 |
|  Phosphorus (P) | 611.747 (618.977) | 226.546 (120.913) | 1313.871 (2525.605) | < 0.0001 |
|  Selenium (Se) | 0.338 (0.169) | 0.202 (0.07) | 0.684 (0.573) | < 0.0001 |
|  Sodium (Na) | 7972.077 (4403.465) | 1716.393 (1564.566) | 6320.125 (3985.59) | < 0.0001 |
|  Titanium (Ti) | 3571.401 (1861.872) | 4014.439 (2121.807) | 3016.016 (1796.204) | < 0.0001 |
|  Zinc (Zn) | 63.154 (22.568) | 28.237 (14.546) | 115.754 (122.962) | < 0.0001 |
| Health measurements |  |  |  |  |
|  Life expectancy, year  |  |  |  |  |
|  Life expectancy (2014) | 78.291 (2.183) | 75.951 (2.011) | 78.507 (2.179) | < 0.0001 |
|  Difference in life expectancy between 1980 and 2014 | 5.426 (1.804) | 4.899 (2.377) | 5.876 (2.001) | < 0.0001 |
|  Age-specific mortality risk, % |  |  |  |  |
|  0 – 5 years | 0.655 (0.189) | 0.883 (0.196) | 0.634 (0.165) | < 0.0001 |
|  5 – 25 years | 0.896 (0.266) | 1.157 (0.268) | 0.873 (0.234) | < 0.0001 |
|  25 – 45 years | 2.878 (0.817) | 3.767 (0.831) | 2.797 (0.718) | < 0.0001 |
|  45 – 65 years  | 12.502 (2.774) | 15.607 (2.725) | 12.235 (2.687) | < 0.0001 |
|  65 – 85 years  | 51.156 (5.644) | 56.21 (5.063) | 50.701 (6.253) | < 0.0001 |
|  Cause-specific mortality rate, number of deaths/ 100 000 Population |  |  |  |  |
|  Communicable, maternal, neonatal, and nutritional diseases |  |  |  |  |
|  HIV/AIDS and tuberculosis | 1.09 (1.215) | 2.92 (3.153) | 1.29 (1.814) | < 0.0001 |
|  Diarrhea, lower respiratory and other common infectious diseases | 31.669 (9.85) | 39.308 (10.926) | 30.835 (8.417) | < 0.0001 |
|  Neglected tropical diseases and malaria | 0.077 (0.06) | 0.064 (0.034) | 0.077 (0.061) | < 0.0001 |
|  Maternal disorders | 0.329 (0.127) | 0.457 (0.166) | 0.328 (0.121) | < 0.0001 |
|  Neonatal disorders | 3.035 (1.055) | 4.449 (1.367) | 2.907 (0.892) | < 0.0001 |
|  Nutritional deficiencies | 1.512 (0.679) | 1.886 (0.683) | 1.438 (0.527) | < 0.0001 |
|  Other communicable, maternal, neonatal, and nutritional diseases | 1.201 (0.297) | 1.42 (0.333) | 1.196 (0.262) | < 0.0001 |
|  Noncommunicable diseases  |  |  |  |  |
|  Neoplasms | 200.647 (29.215) | 226.352 (29.957) | 197.649 (32.396) | < 0.0001 |
|  Cardiovascular diseases | 267.531 (55.52) | 314.062 (55.359) | 263.378 (53.481) | < 0.0001 |
|  Chronic respiratory diseases | 61.765 (15.792) | 71.223 (17.547) | 60.475 (17.165) | < 0.0001 |
|  Cirrhosis and other chronic liver diseases | 17.793 (8.28) | 20.265 (5.621) | 17.695 (8.432) | < 0.0001 |
|  Digestive diseases | 16.161 (2.36) | 16.445 (2.508) | 15.409 (2.69) | < 0.0001 |
|  Neurological disorders | 93.904 (21.148) | 101.952 (21.42) | 94.508 (23.961) | < 0.0001 |
|  Mental and substance use disorders | 12.743 (6.85) | 14.292 (6.583) | 12.972 (6.507) | < 0.0001 |
|  Diabetes, urogenital, blood and endocrine diseases | 60.792 (17.012) | 72.127 (17.784) | 58.348 (16.594) | < 0.0001 |
|  Musculoskeletal disorders | 3.257 (0.764) | 3.097 (0.646) | 3.283 (0.878) | < 0.0001 |
|  Other non-communicable diseases | 6.483 (1.356) | 7.814 (1.454) | 6.261 (1.307) | < 0.0001 |
|  Injuries  |  |  |  | < 0.0001 |
|  Transport injuries | 21.737 (8.809) | 27.621 (9.072) | 20.712 (8.747) | < 0.0001 |
|  Unintentional injuries | 23.957 (5.091) | 24.389 (4.234) | 22.811 (5.678) | < 0.0001 |
|  Self-harm and interpersonal violence | 21.165 (7.045) | 24.201 (5.063) | 20.798 (6.877) | < 0.0001 |
|  Forces of nature, war and legal intervention | 0.08 (0.056) | 0.117 (0.243) | 0.084 (0.092) | < 0.0001 |
| Socio-demographics  |  |  |  |  |
|  Population characteristics |  |  |  |  |
|  Size, *n* | 95968 (320031.3) | 79131.76 (211914.9) | 197354 (521857.4) | < 0.0001 |
|  Gender, male % | 50.092 (1.967) | 49.796 (2.682) | 50.268 (2.598) | 0.0015 |
|  Ethnicity, white alone % | 89.005 (13.152) | 74.428 (18.42) | 89.257 (11.992) | < 0.0001 |
|  Age, % |  |  |  |  |
|  0 – 9 years | 12.215 (2.193) | 12.181 (1.772) | 12.318 (2.103) | 0.6423 |
|  10 – 19 years | 12.911 (1.678) | 12.787 (1.576) | 13.019 (1.867) | 0.0904 |
|  20 – 29 years | 12.018 (3.087) | 12.688 (2.965) | 12.132 (2.861) | < 0.0001 |
|  30 – 39 years | 11.397 (1.584) | 11.769 (1.613) | 11.883 (1.956) | < 0.0001 |
|  40 – 49 years | 12.004 (1.429) | 12.632 (1.339) | 12.491 (1.683) | < 0.0001 |
|  50 – 59 years | 14.738 (1.69) | 14.243 (1.43) | 14.636 (1.744) | < 0.0001 |
|  60 – 69 years | 12.384 (2.508) | 12.057 (2.207) | 12.087 (2.54) | 0.0029 |
|  70 – 79 years | 7.497 (1.971) | 7.41 (2.059) | 7.053 (1.885) | 0.0018 |
|  ≥ 80 years | 4.755 (1.531) | 3.988 (1.184) | 4.308 (1.616) | < 0.0001 |
|  Socio-economics |  |  |  |  |
|  Educational level (25 years and over), % |  |  |  |  |
|  Less than a high school diploma | 12.421 (6.269) | 16.73 (5.516) | 11.997 (5.611) | < 0.0001 |
|  A high school diploma only | 34.0 (7.279) | 35.72 (6.415) | 32.985 (7.758) | < 0.0001 |
|  Completing some college or associate's degree | 31.388 (5.413) | 28.927 (4.202) | 30.555 (4.749) | < 0.0001 |
|  A bachelor's degree or higher | 22.191 (9.215) | 18.62 (8.634) | 24.462 (10.836) | < 0.0001 |
|  Median household income (annual), US dollar | 48207.46 (11663.56) | 41724.81 (10910.38) | 51572.92 (12874.3) | < 0.0001 |
|  Unemployment rate, % | 5.911 (2.26) | 7.335 (1.875) | 5.506 (1.679) | < 0.0001 |
|  Poverty rate, % | 15.78 (5.949) | 20.743 (6.517) | 14.692 (5.423) | < 0.0001 |
|  Healthcare service |  |  |  |  |
|  Medical insured population (age<65), %  | 86.639 (5.043) | 83.247 (3.963) | 85.512 (5.386) | < 0.0001 |
|  Physicians (per 1000 population), *n* | 1.235 (1.75) | 1.036 (1.146) | 1.482 (1.665) | 0.0002 |
| Residential environment and location  |  |  |  |  |
|  Rural-Urban Continuum Code |  |  |  |  |
|  1 (Metro areas, 1 million population or more) | 242 (11.77) | 102 (13.8) | 84 (29.47) | < 0.0001 |
|  2 (Metro areas, 250 thousand to 1 million population) | 248 (12.06) | 104 (14.07) | 23 (8.07) |
|  3 (Metro areas, population fewer than 250 thousand) | 234 (11.38) | 102 (13.8) | 14 (4.91) |
|  4 (Urban population of 20 thousand or more, adjacent to a metro area) | 152 (7.39) | 43 (5.82) | 18 (6.32) |
|  5 (Urban population of 20 thousand or more, not adjacent to a metro area) | 61 (2.97) | 17 (2.3) | 10 (3.51) |
|  6 (Urban population of 2,500 to 19,999, adjacent to a metro area) | 362 (17.61) | 174 (23.55) | 51 (17.89) |
|  7 (Urban population of 2,500 to 19,999, not adjacent to a metro area) | 306 (14.88) | 78 (10.55) | 34 (11.93) |
|  8 (Completely rural or less than 2,500 urban population, adjacent to a metro area) | 145 (7.05) | 57 (7.71) | 15 (5.26) |
|  9 (Completely rural or less than 2,500 urban population, not adjacent to a metro area) | 306 (14.88) | 62 (8.39) | 36 (12.63) |
|  Latitude | 39.794 (4.434) | 34.018 (3.044) | 38.751 (4.873) | < 0.0001 |
|  Longitude | -93.161 (12.373) | -86.092 (5.953) | -93.777 (10.61) | < 0.0001 |

*p values are from ANOVA or Chi-squared tests.*

**Supplementary Table 4. Association of clusters with life expectancy (2014) and change in life expectancy (1980-2014) in metro areas with confounding adjustment**

|  |  |  |
| --- | --- | --- |
| Variables in multivariate regression analysis | Life expectancy (metro area), 2014Model *R2*(adjusted), 0.702 | Change in life expectancy (metro area), 1980-2014Model *R2*(adjusted), 0.466 |
|  | Regression coefficient | 99.5% Confidence intervals | *p* value | Regression coefficient | 99.5% Confidence intervals | *p* value |
| Pattern of minerals |  |  |  |  |  |  |
|  The ‘Common’ cluster | 0 (referent) | - | - | 0 (referent) | - | - |
|  The ‘Infertile’ cluster | -0.308 | (-0.596, -0.020) | 0.003 | -0.120 | (-0.477, 0.238) | 0.346 |
|  The ‘plentiful’ cluster | -0.250 | (-0.589, 0.088) | 0.038 | 0.027 | (-0.393, 0.447) | 0.855 |
| Population size, *n* (per 10 000 population) | 0.004 | (0.002, 0.006) | <0.0001 | 0.005 | (0.002, 0.008) | <0.0001 |
| Gender, male %  | 0.104 | (0.039, 0.170) | <0.0001 | 0.093 | (0.012, 0.175) | 0.001 |
| Ethnicity, white alone % | 0.032 | (0.023, 0.042) | <0.0001 | -0.029 | (-0.040, -0.017) | <0.0001 |
| Education level, bachelor’s degree % | 0.109 | (0.091, 0.126) | <0.0001 | 0.070 | (0.048, 0.091) | <0.0001 |
| Median household income, *n* (per 10 000 dollars) | 0.267 | (0.090, 0.444) | <0.0001 | 0.466 | (0.246, 0.685) | <0.0001 |
| Unemployment rate, % | 0.081 | (0.007, 0.155) | 0.002 | 0.282 | (0.191, 0.374) | <0.0001 |
| Poverty rate, % | -0.082 | (-0.124, -0.040) | <0.0001 | -0.052 | (-0.104, 0.0) | 0.005 |
| Insured population, % | -0.085 | (-0.122, -0.048) | <0.0001 | -0.124 | (-0.171, -0.078) | <0.0001 |
| Physicians, *n* (per 1000 population) | -0.038 | (-0.094, 0.018) | 0.056 | 0.027 | (-0.042, 0.097) | 0.271 |
| Latitude | 0.10 | (0.065, 0.135) | <0.0001 | 0.081 | (0.037, 0.124) | <0.0001 |
| Longitude | -0.01 | (-0.019, -0.001) | 0.002 | 0.029 | (0.017, 0.040) | <0.0001 |

**Supplementary Table 5. Association of clusters with life expectancy (2014) and change in life expectancy (1980-2014) in non-metro areas with confounding adjustment**

|  |  |  |
| --- | --- | --- |
| Variables in multivariate regression analysis | Life expectancy (non-metro area), 2014Model *R2*(adjusted), 0.710 | Change in life expectancy (non-metro area), 1980-2014Model *R2* (adjusted), 0.334 |
|  | Regression coefficient | 99.5% Confidence intervals | *p* value | Regression coefficient | 99.5% Confidence intervals | *p* value |
| Pattern of minerals |  |  |  |  |  |  |
|  The ‘Common’ cluster | 0 (referent) | - |  | 0 (referent) | - | - |
|  The ‘Infertile’ cluster | -0.497 | (-0.746, -0.248) | <0.0001 | -0.390 | (-0.680, -0.10) | <0.0001 |
|  The ‘plentiful’ cluster | -0.146 | (-0.456, 0.164) | 0.186 | 0.113 | (-0.248, 0.473) | 0.380 |
| Population size, *n* (per 10 000 population) | -0.042 | (-0.088, 0.003) | 0.009 | -0.047 | (-0.10, 0.006) | 0.013 |
| Gender, male %  | 0.124 | (0.086, 0.161) | <0.0001 | 0.143 | (0.10, 0.187) | <0.0001 |
| Ethnicity, white alone % | 0.019 | (0.012, 0.026) | <0.0001 | -0.034 | (-0.043, -0.026) | <0.0001 |
| Education level, bachelor’s degree % | 0.122 | (0.105, 0.139) | <0.0001 | 0.085 | (0.065, 0.105) | <0.0001 |
| Median household income, n (per 10 000 dollars) | 0.134 | (-0.067, 0.334) | 0.061 | 0.217 | (-0.017, 0.450) | 0.009 |
| Unemployment rate, % | -0.034 | (-0.084, 0.017) | 0.062 | 0.160 | (0.101, 0.218) | <0.0001 |
| Poverty rate, % | -0.116 | (-0.147, -0.086) | <0.0001 | -0.097 | (-0.133, -0.061) | <0.0001 |
| Insured population, % | -0.026 | (-0.049, -0.003) | 0.002 | -0.103 | (-0.130, -0.077) | <0.0001 |
| Physicians, *n* (per 1000 population) | -0.117 | (-0.258, 0.024) | 0.020 | 0.030 | (-0.135, 0.194) | 0.612 |
| Latitude | 0.102 | (0.077, 0.127) | <0.0001 | 0.120 | (0.091, 0.149) | <0.0001 |
| Longitude | 0.001 | (-0.009, 0.010) | 0.877 | 0.030 | (0.018, 0.041) | <0.0001 |

**Supplementary Figure 1. Flowchart of the process of analysis**

