Supplemental Materials

# Long-term exposure to $PM_{2.5}$ and mortality for the older population: Effect modification by residential greenness

Table of Contents

eTable 1. Correlations between selected variables in NC

| | NDVI | Temperature | Humidity | % Black | % Hispanic | Median household income | Population density | Below poverty | Education |
|---|---|---|---|---|---|---|---|---|---|
| $PM_{2.5}$ | -0.17 | 0.33 | -0.37 | 0.25 | 0.16 | 0.08 | 0.25 | 0.04 | 0.23 |
| NDVI | | -0.19 | 0.05 | -0.14 | -0.05 | -0.14 | -0.43 | 0.07 | 0.18 |
| Temperature | | | -0.05 | 0.29 | 0.14 | 0.14 | 0.17 | 0.02 | 0.01 |
| Humidity | | | | -0.14 | -0.24 | -0.10 | -0.33 | 0.01 | -0.01 |
| % Black | | | | | 0.23 | -0.34 | 0.19 | 0.44 | 0.32 |
| % Hispanic | | | | | | -0.11 | 0.24 | 0.08 | 0.04 |
| Median household income | | | | | | | 0.35 | -0.57 | -0.62 |
| Population density | | | | | | | | -0.15 | -0.36 |
| Below poverty | | | | | | | | | 0.64 |

eTable 2. Correlations between selected variables in MI

| | NDVI | Temperature | Humidity | % Black | % Hispanic | Median household income | Population density | Below poverty | Education |
|---|---|---|---|---|---|---|---|---|---|
| $PM_{2.5}$ | -0.33 | 0.39 | -0.43 | 0.22 | 0.11 | 0.07 | 0.32 | 0.04 | 0.33 |
| NDVI | | -0.13 | 0.49 | -0.46 | -0.22 | 0.32 | -0.69 | -0.48 | -0.48 |
| Temperature | | | -0.49 | 0.22 | 0.13 | 0.15 | 0.34 | 0.01 | 0.10 |
| Humidity | | | | -0.43 | -0.04 | -0.09 | -0.61 | -0.22 | -0.19 |
| % Black | | | | | -0.05 | -0.40 | 0.61 | 0.59 | 0.43 |
| % Hispanic | | | | | | -0.15 | 0.08 | 0.13 | 0.21 |
| Median household income | | | | | | | -0.12 | -0.57 | -0.57 |
| Population density | | | | | | | | 0.40 | 0.34 |
| Below poverty | | | | | | | | | 0.55 |

eTable 3. Associations between long-term exposure to $PM_{2.5}$ and total mortality across greenness groups in urbanized areas (UAs) in NC and MI

| | HR (95% CI) | |
|---|---|---|
| | NC | MI |
| Total | 1.059 (1.049-1.068) | 0.968 (0.957-0.978) |
| Greenness | | |
| Low | 1.094 (1.077-1.111) | 1.022 (1.006-1.038) |
| Medium | 1.022 (1.006-1.040) | 0.949 (0.932-0.967) |
| High | 1.024 (1.006-1.043) | 0.997 (0.958-1.037) |

HR calculated per 1 $\mu g/m^3$ for $PM_{2.5}$; Models were stratified by greenness groups.

State-specific cutoffs for greenness group: low (<0.60), medium (0.60-0.64), and high (≥0.64) for NC; low (<0.42), medium (0.42-0.49), and high (≥0.49) for MI

N for NC 753,466 persons and MI 890,104 persons

N for urbanized areas: low greenness group 246,298 persons, medium greenness group 253,033 persons, and high greenness group 254,135 persons for NC; low greenness group 297,613 persons, medium greenness group 296,951 persons, and high greenness group 295,540 persons for MI

eTable 4. Associations between long-term exposure to $PM_{2.5}$ and total mortality across greenness groups in urban clusters (UCs) in NC and MI

| | | HR (95% CI) | |
|---|---|---|---|
| | | NC | MI |
| Total | | 1.161 (1.148-1.174) | 1.067 (1.053-1.082) |
| Greenness Low | | 1.134 (1.111-1.158) | 1.056 (1.036-1.076) |
| | Medium | 1.279 (1.250-1.309) | 0.978 (0.944-1.014) |
| | High | 0.999 (0.975-1.023) | 0.964 (0.935-0.995) |

HR calculated per 1 $\mu g/m^3$ for $PM_{2.5}$; Models were stratified by greenness groups.

State-specific cutoffs for greenness group: low (<0.62), medium (0.62-0.66), and high (≥0.66) for NC; low (<0.48), medium (0.48-0.51), and high (≥0.51) for MI

N for NC 335,626 persons and MI 228,528 persons

N for urban clusters: low greenness group 110,732 persons, medium greenness group 111,905 persons, and high greenness group 112,989 persons for NC; low greenness group 77,401 persons, medium greenness group 77,344 persons, and high greenness group 73,783 persons for MI

eTable 5. Associations between long-term exposure to $PM_{2.5}$ and total mortality across greenness groups in rural areas in NC and MI

| | | HR (95% CI) | |
|---|---|---|---|
| | | NC | MI |
| Total | | 1.155 (1.139-1.172) | 1.035 (1.022-1.048) |
| Greenness | | 1.117 (1.093-1.140) | 1.053 (1.035-1.072) |
| Low | | | |
| | Medium | 1.166 (1.131-1.202) | 0.895 (0.863-0.929) |
| | High | 1.040 (1.006-1.076) | 0.971 (0.941-1.001) |

HR calculated per 1 $\mu g/m^3$ for $PM_{2.5}$; Models were stratified by greenness groups.

State-specific cutoffs for greenness group: low (<0.65), medium (0.65-0.67), and high (≥0.67) for NC; low (<0.48), medium (0.48-0.51), and high (≥0.51) for MI

N for NC 174,597 persons and MI 199,926 persons

N for rural areas: low greenness group 59,014 persons, medium greenness group 57,096 persons, and high greenness group 58,487 persons for NC; low greenness group 66,788 persons, medium greenness group 66,375 persons, and high greenness group 66,763 persons for MI

eTable 6. Associations between long-term exposure to $PM_{2.5}$ and total mortality across greenness groups in each urbanicity areas (urbanized, urban clusters, and rural areas) based on state-specific cutoff for tertiles for greenness group in NC and MI

| | HR for mortality for 1 μg/m$^3$ $PM_{2.5}$ (95% CI) | |
|---|---|---|
| | NC | MI |
| ***Urbanized areas*** | | |
| Total | 1.059 (1.049-1.068) | 0.968 (0.957-0.978) |
| Greenness | | |
| Low | 1.092 (1.077-1.107) | 1.025 (1.011-1.038) |
| Medium | 1.035 (1.018-1.053) | 0.788 (0.769-0.807) |
| High | 0.869 (0.847-0.891) | 0.913 (0.873-0.955) |
| ***Urban clusters*** | | |
| Total | 1.161 (1.148-1.174) | 1.067 (1.053-1.082) |
| Greenness | | |
| Low | 1.165 (1.137-1.194) | 1.092 (1.060-1.124) |
| Medium | 1.286 (1.260-1.312) | 1.036 (1.012-1.060) |
| High | 1.023 (1.001-1.044) | 0.875 (0.852-0.899) |
| ***Rural areas*** | | |
| Total | 1.155 (1.139-1.172) | 1.035 (1.022-1.048) |
| Greenness | | |
| Low | 1.104 (1.067-1.144) | 1.055 (1.026-1.085) |
| Medium | 1.175 (1.142-1.208) | 0.991 (0.967-1.015) |
| High | 1.106 (1.082-1.130) | 0.925 (0.904-0.948) |

Models were stratified by greenness groups.

State-specific cutoffs for greenness group: low (<0.61), medium (0.61-0.65), and high (≥0.65) for NC; low (<0.45), medium (0.45-0.49), and high (≥0.49) for MI

N for urbanized areas: low greenness group 316,191 persons, medium greenness group 272,721 persons, and high greenness group 164,554 persons for NC

N for urban clusters: low greenness group 78,923 persons, medium greenness group 114,540 persons, and high greenness group 142,163 persons for NC

N for rural areas: low greenness group 23,587 persons, medium greenness group 35,877 persons, and high greenness group 115,133 persons for NC

N for urbanized areas: low greenness group 396,259 persons, medium greenness group 271,921 persons, and high greenness group 221,924 persons for MI

N for urban clusters: low greenness group 19,203 persons, medium greenness group 96,218 persons, and high greenness group 113,107 persons for MI

N for rural areas: low greenness group 23,443 persons, medium greenness group 69,347 persons, and high greenness group 107,136 persons for MI

eTable 7. Associations between long-term exposure to $PM_{2.5}$ and total mortality by combined disparities of greenness and SES in NC and MI

| | | | Greenness | |
|---|---|---|---|---|
| | | | Low | High |
| *NC* | | | | |
| | SES | Lowest | 1.149 (1.129-1.170) | 1.023 (1.004-1.043) |
| | | Highest | 1.051 (1.024-1.079) | 0.918 (0.862-0.978) |
| *MI* | | | | |
| | SES | Lowest | 1.014 (0.999-1.029) | 0.965 (0.943-0.987) |
| | | Highest | 0.984 (0.934-1.036) | 0.817 (0.758-0.879) |

HR calculated per 1 $\mu g/m^3$ for $PM_{2.5}$; SES group was based on the lowest and highest quartiles of median household income.

eTable 8. Distribution of $PM_{2.5}$ concentration by greenness using the subset of areas with $PM_{2.5}$ monitors based on state-specific cutoff for tertiles for greenness group

| $PM_{2.5}$ | Greenness Levels | Mean | SD | Min | 25% | 50% | 75% | Max | IQR |
|---|---|---|---|---|---|---|---|---|---|
| *NC* | | | | | | | | | |
| $PM_{2.5}$ Estimates | Total | 9.57 | 1.94 | 4.24 | 8.55 | 9.23 | 10.24 | 15.73 | 1.69 |
| | Low | 10.20 | 1.94 | 5.41 | 8.75 | 9.44 | 11.28 | 15.73 | 2.53 |
| | Medium | 9.72 | 1.77 | 4.53 | 8.55 | 9.22 | 10.29 | 15.31 | 1.74 |
| | High | 8.81 | 1.85 | 4.24 | 8.11 | 9.07 | 9.49 | 15.12 | 1.37 |
| $PM_{2.5}$ Monitor values | Total | 9.67 | 2.09 | 4.22 | 8.53 | 8.95 | 10.53 | 16.00 | 2.00 |
| | Low | 10.00 | 2.28 | 5.32 | 8.40 | 9.22 | 11.45 | 15.90 | 3.05 |
| | Medium | 9.80 | 2.01 | 4.28 | 8.55 | 9.12 | 10.63 | 15.90 | 2.08 |
| | High | 9.23 | 1.89 | 4.22 | 8.53 | 8.90 | 9.40 | 16.00 | 0.87 |
| *MI* | | | | | | | | | |
| $PM_{2.5}$ Estimates | Total | 9.61 | 1.63 | 3.49 | 8.50 | 9.37 | 10.02 | 17.33 | 1.52 |
| | Low | 10.11 | 2.06 | 4.40 | 8.84 | 9.70 | 11.14 | 17.33 | 2.30 |
| | Medium | 9.47 | 1.44 | 5.31 | 8.45 | 9.27 | 9.94 | 16.48 | 1.50 |
| | High | 9.22 | 1.09 | 3.49 | 8.49 | 9.24 | 9.64 | 16.03 | 1.14 |
| $PM_{2.5}$ Monitor values | Total | 9.64 | 1.76 | 3.48 | 8.65 | 9.53 | 9.90 | 19.85 | 1.25 |
| | Low | 10.24 | 2.21 | 3.48 | 8.84 | 9.87 | 11.33 | 19.85 | 2.49 |
| | Medium | 9.40 | 1.53 | 5.92 | 8.51 | 9.35 | 9.64 | 19.85 | 1.13 |
| | High | 9.26 | 1.19 | 4.63 | 8.65 | 9.37 | 9.61 | 16.24 | 0.96 |

State-specific cutoffs for greenness group: low (<0.61), medium (0.61-0.65), and high (≥0.65) for NC; low (<0.44), medium (0.44-0.49), and high (≥0.49) for MI

N for low greenness group 86,956 persons, medium greenness group 93,385 persons, and high greenness group 90,378 persons for NC

N for low greenness group 114,000 persons, medium greenness group 109,678 persons, and high greenness group 112,027 persons for MI

eTable 9. Sensitivity analysis results (HR for mortality for 1 μg/$m^3$ $PM_{2.5}$) using the subset of areas with both $PM_{2.5}$ monitor values and $PM_{2.5}$ estimates based on the state-specific cutoff for tertiles for greenness group

| | HR (95% CI) | |
|---|---|---|
| | NC | MI |
| $PM_{2.5}$ estimates | | |
| Total | 1.124 (1.115-1.134) | 1.045 (1.035-1.056) |
| Greenness | | |
| Low | 1.052 (1.036-1.069) | 0.958 (0.943-0.973) |
| Medium | 1.133 (1.117-1.150) | 1.001 (0.981-1.022) |
| High | 1.024 (1.006-1.043) | 1.151 (1.119-1.185) |
| $PM_{2.5}$ monitor values | | |
| Total | 1.120 (1.111-1.129) | 1.042 (1.034-1.051) |
| Greenness | | |
| Low | 1.035 (1.021-1.049) | 0.996 (0.986-1.007) |
| Medium | 1.144 (1.129-1.159) | 1.036 (1.018-1.054) |
| High | 1.133 (1.115-1.151) | 1.131 (1.105-1.158) |

Models were stratified by greenness groups.

State-specific cutoffs for greenness group: low (<0.61), medium (0.61-0.65), and high (≥0.65) for NC; low (<0.44), medium (0.44-0.49), and high (≥0.49) for MI

N for low greenness group 86,956 persons, medium greenness group 93,385 persons, and high greenness group 90,378 persons for NC

N for low greenness group 114,000 persons, medium greenness group 109,678 persons, and high greenness group 112,027 persons for MI

eTable 10. Sensitivity analysis results (HR for mortality for 1 μg/$m^3$ $PM_{2.5}$) using the same cutoffs for tertiles of greenness across states

| | HR (95% CI) | |
|---|---|---|
| | NC | MI |
| Original findings using state-specific cutoffs | | |
| Total | 1.124 (1.117-1.130) | 1.007 (1.001-1.013) |
| Greenness | | |
| Low | 1.104 (1.093-1.116) | 1.063 (1.053-1.074) |
| Medium | 1.183 (1.171-1.196) | 0.929 (0.918-0.940) |
| High | 0.978 (0.966-0.991) | 0.957 (0.944-0.971) |
| Sensitivity analysis using same cutoffs across states | | |
| Total | 1.124 (1.117-1.130) | 1.007 (1.001-1.013) |
| Greenness | | |
| Low | 1.006 (0.975-1.039) | 1.033 (1.026-1.041) |
| Medium | 1.129 (1.116-1.141) | 0.957 (0.944-0.969) |
| High | 1.130 (1.122-1.139) | 0.076 (0.000-21.072) |

Models were stratified by greenness groups.

State-specific cutoff for greenness group: low (<0.61), medium (0.61-0.65), and high (≥0.65) for NC; low (<0.45), medium (0.45-0.49), and high (≥0.49) for MI

Same cutoffs across states: low (<0.49), medium (0.49-0.61), and high (≥0.61) for both states

State-specific: N for low 418,701 persons, medium 423,138 persons, and high greenness 421,850 persons for NC; low 438,905 persons, medium 437,486 persons, and high greenness 442,167 persons for MI

Same cutoffs: N for low 54,110 persons, medium 350,389 persons, and high greenness 859,190 persons for NC; low 802,784 persons, medium 515,717 persons, and high greenness 57 persons for MI

eTable 11. Associations between long-term exposure to $PM_{2.5}$ and total mortality across greenness groups in each urbanicity areas (urbanized, urban clusters, and rural areas) based on same cutoffs for tertiles of greenness across states

| | HR for mortality for 1 μg/m$^3$ $PM_{2.5}$ (95% CI) | |
|---|---|---|
| | NC | MI |
| ***Urbanized areas*** | | |
| Total | 1.059 (1.049-1.068) | 0.968 (0.957-0.978) |
| Greenness | | |
| Low | 0.974 (0.929-1.022) | 1.016 (1.005-1.028) |
| Medium | 1.118 (1.102-1.135) | 0.971 (0.931-1.012) |
| High | 1.034 (1.021-1.047) | - |
| ***Urban clusters*** | | |
| Total | 1.161 (1.148-1.174) | 1.067 (1.053-1.082) |
| Greenness | | |
| Low | 0.958 (0.862-1.064) | 1.098 (1.079-1.118) |
| Medium | 1.212 (1.177-1.247) | 0.897 (0.874-0.919) |
| High | 1.159 (1.143-1.174) | 0.670 (0.049-9.189) |
| ***Rural areas*** | | |
| Total | 1.155 (1.139-1.172) | 1.035 (1.022-1.048) |
| Greenness | | |
| Low | 0.943 (0.826-1.075) | 1.058 (1.040-1.076) |
| Medium | 1.175 (1.125-1.227) | 0.892 (0.872-0.913) |
| High | 1.170 (1.151-1.189) | 0.123 (0.000-63.014) |

Models were stratified by greenness groups.

Cutoff for greenness group: low (<0.49), medium (0.49-0.61), and high (≥0.61) for both states and all urbanicity groups

N for urbanized areas: low greenness 34,560 persons, medium greenness 271,546 persons, and high greenness 447,360 persons for NC

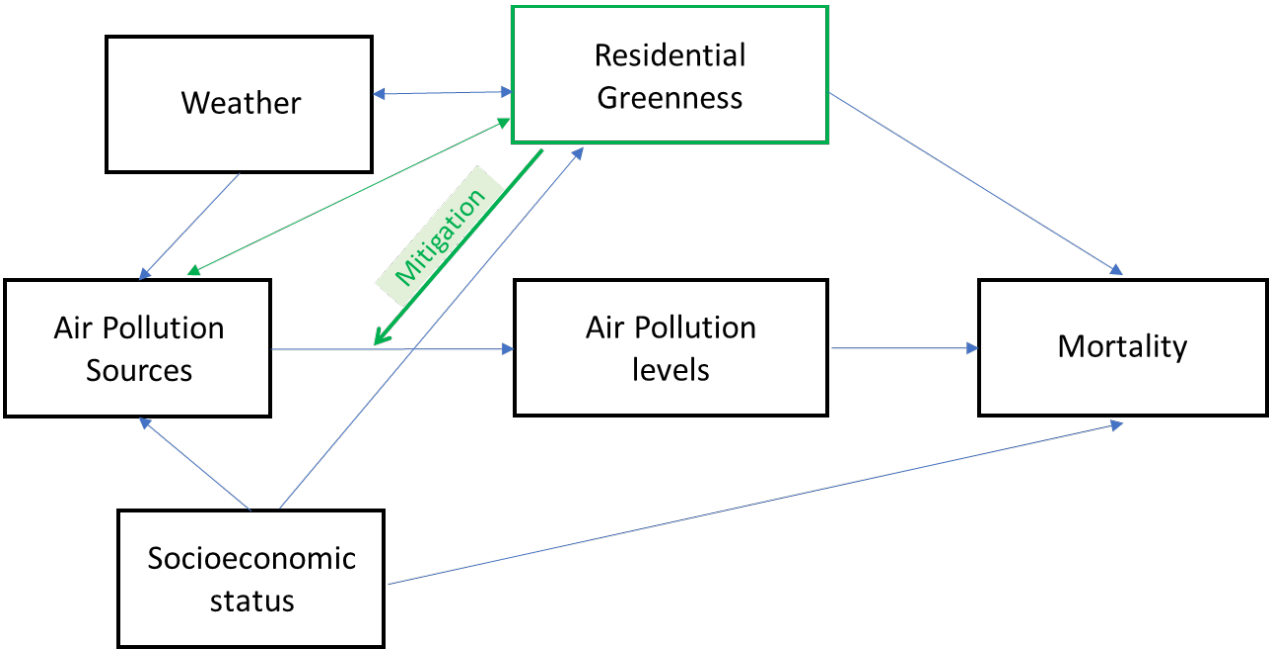
N for urban clusters: low greenness 15,049 persons, medium greenness 61,435 persons, and high greenness 259,142 persons for NC

N for rural areas: low greenness 4,501 persons, medium greenness 17,408 persons, and high greenness 152,688 persons for NC

N for urbanized areas: low greenness 624,143 persons, medium greenness 265,961 persons, and high greenness 0 person for MI

N for urban clusters: low greenness 103,166 persons, medium greenness 125,335 persons, and high greenness 27 persons for MI

N for rural areas: low greenness 75,475 persons, medium greenness 124,421 persons, and high greenness 30 persons for MI




eFigure 1. Causal diagram of relationships between air pollution, greenness, socioeconomic status, and mortality