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de Satgé, J., Strubbe, D., Elst, J., De Laet, J., Adriaensen, F. and Matthysen, E. 2019. Urbanisation lowers great tit *Parus major* breeding success at multiple spatial scales. – J. Avian Biol. 2019: e02108

## Supplementary material

# Appendix 1.

**Table A1.** Overview of the main study plots (with 10 or more nestboxes) with characterization of their urbanization levels at Plot (3 x 3 km) and Subplot (200 x 200m) levels (Green = low, Yellow = intermediate, Red = high) and a general description at both spatial scales.

| Plot name | Plot | Subplot | Subplot description | Plot description |
|---|---|---|---|---|
| Makegem | Green | Green | forest | medium-sized forest (ca 200ha) in largely agricultural landscape |
| Herenthout | Green | Green | linear strips of wooded area | largely forest and agriculture |
| Sint-Joris-Weert | Green | Green | forest | large forest (> 1000 ha) |
| Kalken | Green | Yellow | gardens | agriculture and residential areas |
| Bornem | Green | Yellow | forest edge | Managed riverine forest adjacent to a large town (> 10000 people) |
| Geraardsbergen | Green | Red | gardens | largely agriculture with some residential areas |
| Tielt-Winge | Green | Red | gardens | largely forest and agriculture |
| Peerdsbos | Yellow | Green | forest | forest, wooded parks and residential areas |
| Aalter | Yellow | Green | small forest remnant bordering large pond | residential areas mixed with agriculture |
| Overijse | Yellow | Yellow | public park with mostly ornamental trees | large town (> 10000 people) surrounded by agriculture and small woodlots |
| Ruisbroek | Yellow | Yellow | secondary forest on former industrial land | mostly residential and (former) industrial areas |
| Boshoek | Yellow | Red | public park with mostly ornamental trees | small town (< 1000 people) surrounded by agriculture, small woodlots and more residential areas |
| Zottegem | Yellow | Red | scattered gardens | residential areas mixed with agriculture |
| Aalst | Red | Green | open woodland on marshy ground | bordering on small city (> 50000 people) |
| Oudenaarde | Red | Green | public park with mostly ornamental trees | large town (> 10000 people) surrounded mostly by agriculture |
| Antwerpen | Red | Yellow | public park with mostly ornamental trees | large city (> 100000 people) |
| Brussel | Red | Yellow | university campus with mostly ornamental trees | large city (> 100000 people) |
| Gent | Red | Red | gardens and small greenspaces | large city (> 100000 people) |
| Leuven | Red | Red | public park with mostly ornamental trees | small city (> 50000 people) |
| Sint-Niklaas | Red | Red | gardens and small greenspaces | small city (> 50000 people) |

**Table A2.** Model summaries for 'no-covariate' generalised linear mixed-effects models (i.e. models without individual-level covariates) regarding the significance of urbanisation (at plot and subplot scale) for great tit laying dates, clutch sizes, mean nestling mass, fledglings per egg and fledglings per nest.

| Explanatory variables | Response variables (n) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Laying date (430) | | | Clutch size (308) | | | Mean nestling mass (340) | | | Fledglings per egg (395) | | | Fledglings per nest (395) | | |
| | *df*, den-*df* | F-value | *p* | *df*, den-*df* | F-value | *p* | *df*, den-*df* | F-value | *p* | *df* | $\chi^2$ | *p* | *df*, den-*df* | F-value | *p* |
| Subplot | 2,407 | 2.10 | 0.124 | 2,146 | 4.41 | **0.014** | 2,199 | 6.95 | **0.001** | 2 | 86.02 | **<0.001** | 2,336 | 14.53 | **<0.001** |
| Plot | 2,22 | 4.40 | **0.025** | 2,12 | 6.50 | **0.012** | 2,20 | 4.52 | **0.024** | 2 | 0.08 | 0.961 | 2,22 | 0.51 | 0.609 |
| Plot × Subplot | 4,405 | 2.53 | **0.040** | 4,144 | 0.87 | 0.483 | 4,192 | 3.85 | **0.005** | 4 | 7.42 | 0.115 | 4,337 | 0.20 | 0.937 |
| Year | 1,414 | 507.03 | **<0.001** | 1,384 | 38.65 | **<0.001** | 1,330 | 0.05 | 0.820 | 1 | 48.04 | **<0.001** | 1,381 | 36.82 | **<0.001** |
| | (12.16 ± 0.54) | | | (-1.04 ± 0.17) | | | | | | (-1.05 ± 0.27) | | | | | |

Parameter estimates and their standard errors indicated in parentheses, parameter estimates not shown for non-significant and urban scale terms (for best-fit model estimates of urbanisation effects see figures 3-6). Significant values ($p<0.05$) shown in bold. Degrees of freedom (*df*) and denominator degrees of freedom (den-*df*) reported

**Table A3.** Comparison of GLMM fixed effects for top-ranked 'equivalent' models (ΔAICC < 2) for great tit mean nestling mass (MNM) and fledglings per egg (FPE) models respectively, with Akaike's information criterion corrected for small sample size (AICC), delta values (ΔAICC), Akaike weights (WAICc) and degrees of freedom of each model (df)

| Model rank | INT | BS | LD | $LD^2$ | P | S | WA | Y | P × S | *df* | $AIC_C$ | $\Delta AIC_C$ | $W_{AICc}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MNM | | | | | | | | | | | | | |
| 1 | 17.411 | -0.386 | -0.315 | *NA* | + | + | 0.204 | *NA* | + | 14 | 1273.7 | 0.00 | 0.256 |
| 2 | 17.222 | -0.384 | -0.473 | *NA* | + | + | 0.195 | + | + | 15 | 1274.3 | 0.60 | 0.190 |
| 3 | 17.441 | -0.394 | -0.339 | *NA* | + | + | *NA* | *NA* | + | 13 | 1274.3 | 0.60 | 0.189 |
| 4 | 17.232 | -0.391 | -0.511 | *NA* | + | + | *NA* | + | + | 14 | 1274.4 | 0.69 | 0.181 |
| FPE | | | | | | | | | | | | | |
| 1 | 2.018 | | *NA* | | *NA* | + | | + | *NA* | 5 | 2015.9 | 0.00 | 0.440 |
| 2 | 1.950 | | -0.090 | | *NA* | + | | + | *NA* | 6 | 2016.2 | 0.31 | 0.356 |

Random effect of location specified for all model combinations. + indicates fixed effect included in model, *NA* indicates a fixed effect excluded from the model, and blank cells indicate terms not included in the full model. Further model combinations with $\Delta AIC_C > 2$ not shown. *INT* intercept, *BS* brood size, *LD* laying date, $LD^2$ quadratic polynomial of LD, *P* plot-scale urbanisation, *S* subplot-scale urbanisation, *WA* weighing age, *Y* year, *P × S* two-way interaction of urban scale effects

The following figures provide illustrations of plots (3×3km) categorized as rural (top row; 'green'), suburban (middle row; 'yellow') and urban (bottom row; 'red') (Figure A1). The superimposed grid shows subplots (200×200m) categorized as urban (red overlay), suburban (yellow overlay) and rural (green overlay). Cells with light grey overlay were intermediate, and not considered for placing nestboxes. In each plot, locations were chosen for placing nestboxes in each of the three subplot types, as explained in the Methods section. The final two images (Figure A2) are magnifications illustrating the juxtaposition of 'urban', 'suburban' and 'rural' subplots at a smaller scale.

For both figures, the underlying land-cover map shows tall vegetation (> 3m; dark green), low vegetation (< 3m; in agricultural use: yellow; non-agricultural: light green), buildings (built-up area; bright red), roads and other transport infrastructure (dark red), all other surfaces without vegetation (grey) and surface water (blue).

Correlations (Pearson's correlation coefficients) between the percentage built-up area (used to discriminate between the three categories) and other land-cover types were as follows at plot level (N = 27 plots): -0.52 (tall vegetation), -0.56 (all low vegetation), 0.77 (other surface without vegetation), 0.82 (transport infrastructure), and -0.05 (surface water). This led us to conclude that % built-up area is a highly suitable proxy for representing the land-cover transition from urban to rural.

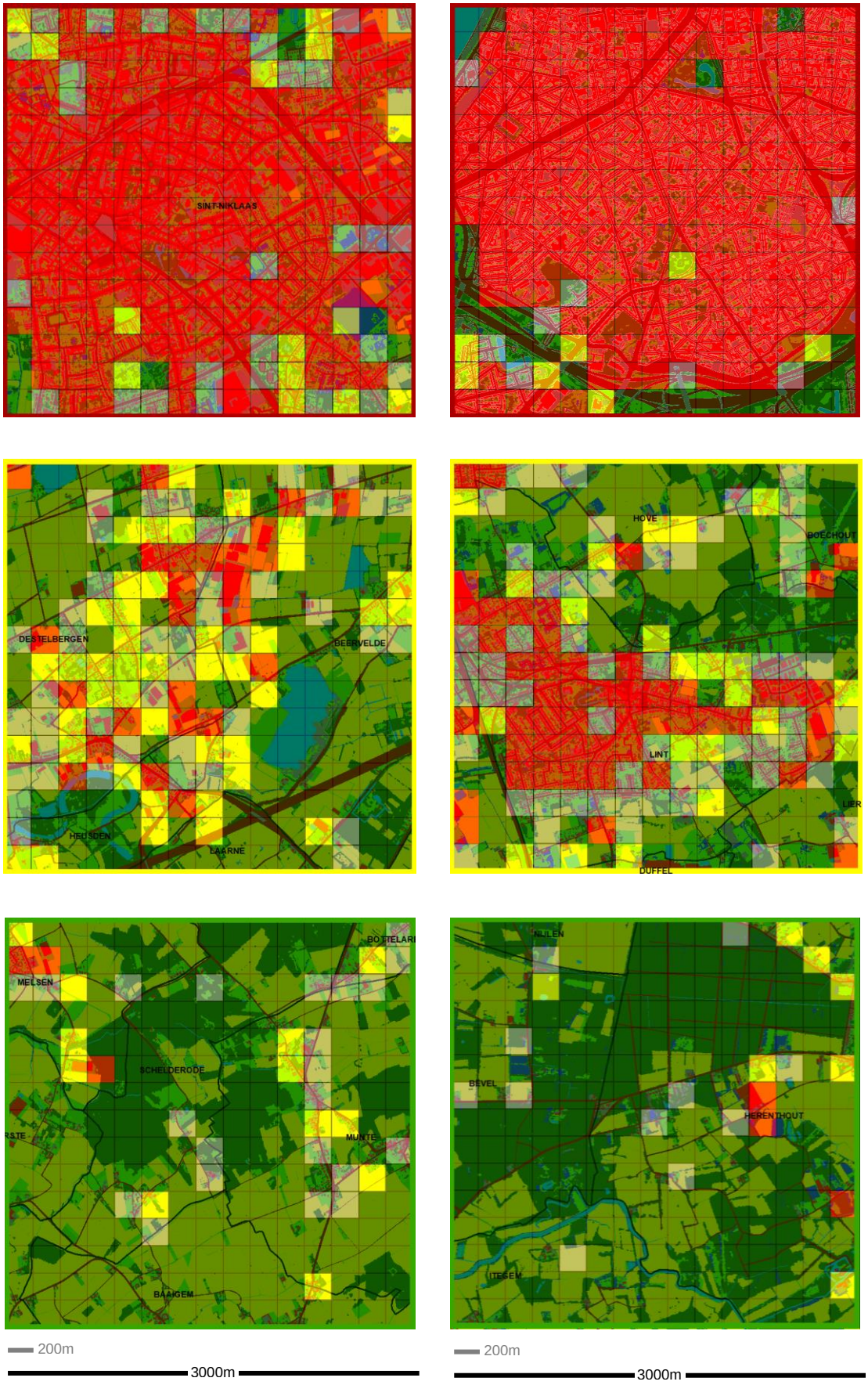


**Figure A1.** Illustrations of plots (3×3km) categorised as rural (top row; 'green'), suburban (middle row; 'yellow') and urban (bottom row; 'red') based on percentage built-up area.

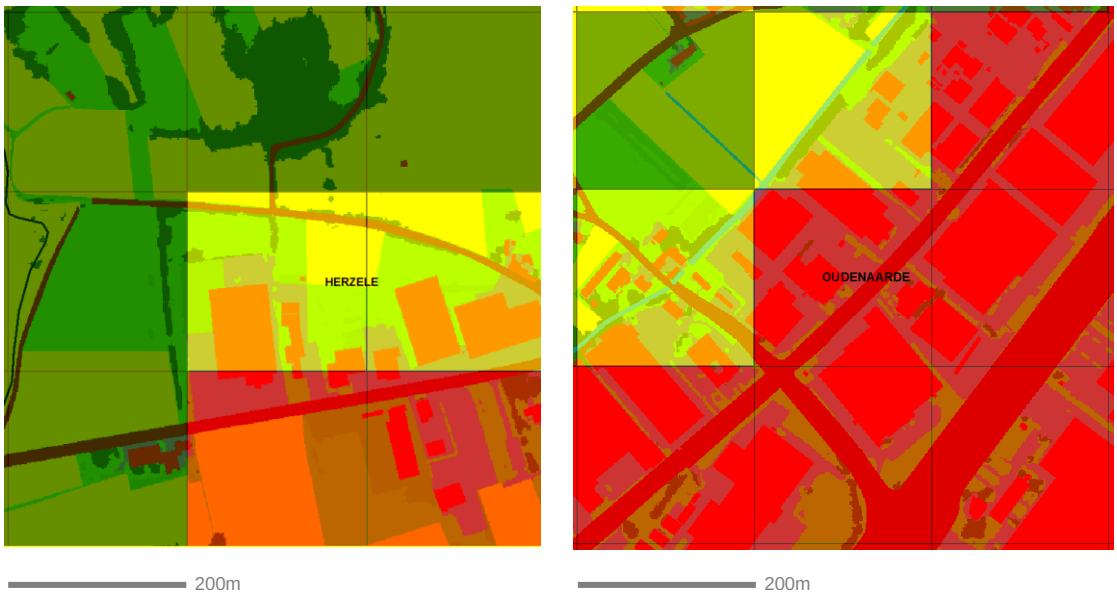


**Figure A2.** Illustrations of multiple neighbouring subplots (200×200m) juxtaposing 'urban' (red), 'suburban' (yellow), and 'rural' (green) subplots at the local scale.