Nitrogen Dioxide and Nitrogen Oxides Trends in the UK 2005 to 2018

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Experts in air quality
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Executive Summary

Determining trends in nitrogen dioxide (NO_2) and nitrogen oxides (NOx) concentrations is an important component of understanding the success or otherwise of policies to reduce exposure of people and ecosystems to these pollutants.

Air Quality Consultants Ltd. (AQC) has now updated a previous study that examined trends across the UK covering the period 2005 to 2016. The present report extends that work, presenting trends for the 14-year period 2005 to 2018 and for the shorter 9-year period 2010 to 2018.

Results are presented for 112 monitoring sites for the period 2005 to 2018 and 183 sites for 2010 to 2018, using sites for which data are present for the whole of each period, to ensure robust results. Significant downward trends are seen at most sites. Overall downward trends across all sites are -3.1% per year for NO_2 and -3.0% per year for NOx over the 9 years 2010 to 2018. The downward trends are steeper at rural sites, at -3.4% per year for NO_2 and -4.1% per year for NOx, than at road and urban sites, at -3.0 to -3.1% per year for both NO_2 and NOx.

The downward trends in NOx concentrations (2005 to 2018) are smaller than those for estimated UK NOx emissions (2005 to 2017), which suggests that emission reductions presented in the National Atmospheric Emission Inventory (NAEI) are overly optimistic. It is recommended that the validity of the NOx emissions estimates used in the NAEI, especially those for road vehicles, is reviewed in light of these observations.

AQC's previous report showed that sites across central and northern England and north Wales showed no significant trend over the period 2005 to 2016. This area of the UK has now caught up, with slightly steeper downward trends than the rest of the UK over the period 2010 to 2018.

Defra publishes projections of roadside and background concentrations. Recent projections of NO_2 concentrations, from a base year of 2017, now match the overall trends in measured roadside and rural NO_2 concentrations for the years 2017 and 2018.

The pattern of trends over time, which for NO_2 is of little change between 2005 to 2010 and then a steeper downward trend from 2010 to 2018, is consistent with evidence of an increasing ratio of NO_2:NOx in vehicle emissions in the period to 2010 and then a decline from 2010. There is now evidence of the NO_2:NOx ratio increasing for Euro 6 light duty vehicles, which is likely to limit the current declines in NO_2 concentrations to be less than those of NOx.

While the observed reductions in NOx and NO_2 concentrations are encouraging, additional measures and actions will be required in order for the reducing trend to continue into the future. It is thus considered important to regularly monitor trends in ambient concentrations.

Contents

1 Introduction

1.1 There is considerable current interest in exposure to nitrogen dioxide (NO_2) in the UK. An important feature of this interest is that NO_2 concentrations have not fallen in line with official projections. This is driven largely by the failure of vehicle emission controls imposed through Euro standards to deliver the improvements expected for diesel vehicles. This was initially brought to light by the analysis of trends in concentrations, which did not fall as expected from the introduction of 'tighter' emission standards[1] during the 2000s (Carslaw, Beevers, Westmoreland, & Williams, 2011) (Carslaw & Rhys-Tyler, 2013). There is evidence from real-world testing that the introduction of the Euro 6 standards for light duty vehicles (LDVs) and Euro VI standards for heavy duty vehicles has resulted in emissions reductions, thus from around the mid-2010s reductions in concentrations would be expected. A report was produced by Air Quality Consultants in January 2018 that provided an analysis of NO_2 and nitrogen oxides (NOx) trends over the period 2005 to 2016 (Laxen, Zygmunt, & Laxen, 2018). This was too early to detect the influence of the Euro 6 and Euro VI standards, so the exercise is being repeated using data extending to the end of 2018. The analysis covers two periods: 2005 to 2018, to essentially extend the previous analysis, and 2010 to 2018, to identify more recent trends using as many available monitoring sites as possible.

1.2 The UK has an extensive national network of automatic monitoring sites measuring NO_2 and NOx, including the Automatic Urban and Rural Network (AURN) and some affiliated sites, mainly owned and operated by local authorities. In addition, there are numerous other sites operated by local authorities, many of which are linked into networks for data reporting. This report draws together data from as many of these networks as was practicable.

1.3 The *openair* software package (Carslaw & Ropkins, 2012) has been used to analyse the data. The analysis has covered both NOx and NO_2. The focus has been on trends across sites, rather than at specific sites, with trends presented for all sites and separately for road, urban and rural sites. Consideration has also been given to the geographic distribution of the trends at individual sites.

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[1] Dates of first introduction of Euro standards most relevant to the current study: Light Duty Vehicles: Euro 3 in 2000, Euro 4 in 2005, Euro 5 in 2009/11, Euro 6 in 2014. Heavy Duty Vehicles: Euro III in 2000, Euro IV 2005, Euro V in 2008, Euro VI in 2013. Euro 6 standards for diesel cars and vans have effectively been introduced in stages from 2014 to 2019, reflecting the introduction of revised test requirements covering real world emissions. The year of first introduction does not represent the cessation of sales of earlier models.

2 Methodology

2.1 The approach can be described according to the following three steps:

- data compilation;
- data processing; and
- data analysis.

Data compilation

2.2 Hourly-mean NO_2 and NOx concentrations from 2005 to 2018 (inclusive) have been collated from the following air quality networks:

- Automatic Urban and Rural Network (https://uk-air.defra.gov.uk/networks/find-sites)
- London Air Quality Network (Kings College London) (http://www.londonair.org.uk/)
- Scottish Air Quality Network (http://www.scottishairquality.scot//)
- Kent Air (http://www.kentair.org.uk/)
- Welsh Air Quality (http://www.welshairquality.co.uk/)
- Heathrow Air Watch (http://www.heathrowairwatch.org.uk)

2.3 Various criteria have been applied to define an appropriate data set of 112 monitoring sites for the period 2005 to 2018, and 183 sites for the period 2010 to 2018 for further analysis of the trends, as set out below.

Data processing

2.4 To help ensure a robust outcome of the analyses, sites have been **excluded** from the analysis based on the following criteria[2]:

- sites with data capture for the full period of less than 75%;
- sites with data capture in the first two years of less than 50%;
- sites with data capture in the last two years of less than 50%;
- sites with data capture in at least one of the first two years of less than 75%; and
- sites with data capture in at least one of the last two years of less than 75%.

2 Data capture criteria have been applied to the published 1-hour mean data.

The focus on the first two and last two years in each period is because these years are more likely to influence the combined trends. In practice, data capture was generally high throughout the periods, as is apparent in the appended data for each of the included sites.

2.5 For some sites, data are available from more than one source. This applies in particular to Defra's AURN sites, which in London are also included on the London Air website operated by King's College London (KCL). Where duplicate sites have been identified, the approach has been to retain the results available from Defra.

2.6 Sites are usually categorised as: Industrial, Kerbside, Roadside, Urban Background, Suburban and Rural Background. For the purpose of this analysis, Industrial sites have been excluded from the datasets, as they are designed to reflect the influence of local industrial sources and will therefore not be representative of more general exposure. In one case, the 'urban background' AURN site 'London Hillingdon' has been reclassified as a roadside site, as it is around 30 m from the busy M4 motorway. In addition, the Lambeth - Bondway Interchange site in the Vauxhall area of central London, which is classified as Industrial, has been reclassified as a roadside site, as it is close to a busy road. Further grouping of site types has been carried out as described in paragraph 2.16.

2.7 The sites included in the analyses and their features are set out in Table A1.1 in Appendix A1 for the period 2005 to 2018 and in Table A2.1 in Appendix A2 for the period 2010 to 2018.

Data analysis

2.8 The *openair* package used in this report is open-source software based on R (Carslaw & Ropkins, 2012)[3]. *Openair* provides a consistent set of tools for analysing and understanding air pollution data. Two particular components of *openair* have been used, a smooth-trend fit to the data and a statistical Theil-Sen linear fit. In each case, the analyses calculate monthly mean data, with monthly means only calculated when the 1-hour mean data capture for the month exceeds 75%.

smoothTrend Function

2.9 The smoothTrend function in *openair* helps check the linearity of a trend. Monthly averages are calculated from the hourly concentrations and the Generalized Additive Model finds the most appropriate level of smoothing. The plots show the smoothed trend line fitted to the monthly data, along with the 95% confidence interval, which is shown by the shading around the trend line.

TheilSen Function

2.10 The TheilSen function in *openair* provides an analysis of the statistical significance of trends in air pollution data and yields accurate confidence intervals, that are resistant to outliers. The trends in % per year are derived from the concentration change from the start date to the end date as a % of

[3] Further information at: http://www.openair-project.org/Default.aspx

the start concentration, divided by the number of years (where the period of 2005 to 2018 is treated as 13 years). The plots show the best-fit linear trend line, together with the lines representing the 95% confidence interval. The plots also give the numerical trend and associated confidence interval values. Trends are considered to be not significant (NS) when the p value is greater than 5% ($p>0.05$). The significance of the trend is also shown on the plots, as follows:

******* **for p≤0.001;**

****** **for p=0.001 to p=0.01;**

***** **for p=0.01 to p=0.05;** and

$^{+}$ **for p=0.05 to p=0.1.**

Spatial Analysis

2.11 The geographical analysis has been carried out using GIS mapping.

Categorisation of Trends

2.12 The trends, in % per yr, for each site, from the Theil-Sen analysis, have been categorised into:

- **significant positive trend** (a significant increase in concentrations over the period);
- **no significant trend** (no significant change concentrations over the period); and
- **significant negative trend** (a significant decrease in concentrations over the period).

2.13 In addition, the significant trends have been categorised into:

- **positive trend >+2%/yr;**
- **positive trend <+2%/yr;**
- **negative trend <-2%/yr;**
- **negative trend -2 to -4 %/yr;** and
- **negative trend >-4%/yr**,

to reflect the magnitudes of the changes, as well as their significance.

Presentation of Trends

2.14 The focus is on presenting trends in percent per year (%/yr) rather than microgrammes per cubic metre per year (µg/m^3/yr). This is to make comparisons between sites with very different concentrations more meaningful. For the sake of completeness, trends in µg/m^3/yr are included for some tabulations.

2.15 The focus of the analysis is on grouped sites, to strengthen the confidence in the findings. This will help overcome unusual results due to specific features of some of the monitoring sites, e.g. sites may be affected by local measures that have changed traffic flows or changed the proportion of buses on the road(s) near to the site. Specific features near to a site are more likely to affect roadside/kerbside sites than urban background or rural sites.

2.16 The analysis covers:

1. comparison of **trends by site type**, based on three groupings:
   - **Road**: which groups together kerbside and roadside sites;
   - **Urban**: which groups together urban centre, urban background suburban sites; and
   - **Rural**: i.e. all sites away from urban and road traffic sources;
2. the pattern of **geographic trends** across the UK; and
3. a comparison of trends over the 14-year period **2005 to 2018** with those for the more recent 9-year period **2010 to 2018**, as well as with the results for the 12-year period 2005 to 2016 presented in the previous report.

3 Results for 2005 to 2018 and 2010 to 2018

3.1 Trend analyses have been carried out using results for 112 monitoring sites for the period 2005 to 2018 and 183 sites for the period 2010 to 2018, for both NO_2 and NOx concentrations. The results are summarised in a series of Tables in Section 4 and in Figures in Section 5 and are described and discussed below. The results for the individual sites are set out as Theil-Sen plots for 2005 to 2018 in Appendix A3 and in for 2010 to 2018 in Appendix A4.

Overall Trends Across the UK

3.2 The overall trends in NO_2 and NOx for all sites in the UK and by site type are summarised in Table 1 for 2005 to 2018 and in Table 2 for 2010 to 2018. A significant overall downward trend is seen for both NO_2 and NOx over the period 2005 to 2018, with the magnitudes of the reductions being essentially the same for both pollutants, at -1.82% per year for NO_2 and -1.86% per year for NOx (Table 1). The rates of reduction are slightly greater with the extended time period than they were for 2005 to 2016, for which the trends were -1.50% per year for NO_2 and -1.48% per year for NOx (Laxen, Zygmunt, & Laxen, 2018), suggesting a greater reduction in the last two years. The downward trends for the more recent period, 2010 to 2018, are significantly greater, at -3.11% per year for NO_2 and -3.04% per year for NOx. This is consistent with the shape of the smooth-trend fit to the data for NO_2 (Figure 1), which shows a steepening trend with time over the period 2005 to 2018. However, the smooth-trend fit to the data for NOx (Figure 2) does not show this steepening trend, having an essentially linear trend over the period 2005 to 2018. The fact that the smooth-trend fit to the NOx results does not reflect the greater rate of reduction since 2010 is likely to be a limitation of fitting a smooth trend to data with considerable seasonal variation from year to year. Visual inspection of the summer minima in each year shows a steady slow decline from 2005 to 2015 then a steeper decline from 2015 to 2018; the winter maxima are much more variable from year to year. The differences between the NO_2 and NOx smooth-trend patterns are also likely to be influenced by changes in emissions of primary NO_2 and the consequent impact on NO_2:NOx ratios, as is examined further in the section starting at paragraph 3.16. For completeness, the Theil-Sen plots for 2005 to 2018 are presented in Figure 3 for NO_2 and Figure 4 for NOx.

3.3 The smooth trends fits to the all sites data for the shorter period 2010 to 2018 are essentially linear for both NO_2 (Figure 5) and NOx (Figure 6). The linear Theil-Sen trends for these two periods are shown in Figure 7 and Figure 8.

3.4 The magnitudes of the trends at individual sites over the period 2010 to 2018 are summarised in Figure 9 for NO_2 and Figure 10 for NOx. They show that when significant trends are identified, they are mostly in the range -2 to -4 % per year. For this period there are no sites with a significant upward trend, unlike the results for the 2005 to 2016 period (Laxen, Zygmunt, & Laxen, 2018). There are, though, still a number of sites with no significant trend: 21% of sites for NO_2 and 29% of sites for NOx. These sites are set out in Table 3 for NO_2 and Table 4 for NOx. It is noted that, even though the trends are not significant, they are almost entirely negative (i.e. downward).

Trends by Site Type

3.5 For both time periods the rates of reduction in concentrations are broadly similar at the road and urban sites, -3.1% per year for NO_2 and -3.0 and -3.1% per year for NOx, but they are greater at the rural sites, -3.4% per year for NO_2 and -4.1% per year for NOx (Table 1 and Table 2). The trends at rural sites will reflect changes in total emissions across the UK, while those at roadside sites will be dominated by road traffic emissions. The magnitudes of the trends for both NO_2 and NOx at individual roadside and urban sites show similar distributions, with most sites having reductions of between -2 and -4 % per year for the period 2010 to 2018 (Figure 11 and Figure 12), however, the trends are greater at rural sites, with more sites having downward trends greater than -4% per year (Figure 13). The same information is presented separately for NO_2 in Figure 14 and for NOx in Figure 15.

3.6 The overall smooth trends at road, urban and rural sites for the period 2005 to 2018 are shown for NO_2 in Figure 16, Figure 17 and Figure 18 and for NOx in Figure 19, Figure 20 and Figure 21, while the equivalent Theil-Sen trends are shown in Figure 22, Figure 23 and Figure 24 for NO_2 and Figure 25, Figure 26 and Figure 27 for NOx. The smooth-trend fits for NO_2 show a curved pattern, with an increasing rate of reduction over time, that is prominent at roadside sites (Figure 16), but absent at rural sites (Figure 18) and intermediate at urban sites (Figure 17). In the case of NOx, there is only a slight curved trend for road sites (Figure 19) that is also evident for rural sites (Figure 21), but absent from urban sites (Figure 20). For the road sites, these patterns suggest a changing role for primary NO_2; this is examined further in the section starting at paragraph 3.16.

3.7 The overall smooth trends for NO_2 at road, urban and rural sites for the shorter period 2010 to 2018 are shown in Figure 28, Figure 29 and Figure 30 and for NOx in Figure 31, Figure 32 and Figure 33, while the equivalent Theil-Sen trends are shown in Figure 34, Figure 35 and Figure 36 for NO_2 and Figure 37, Figure 38 and Figure 39 for NOx. The smooth-trend fits for both NO_2 and NOx are essentially linear over this shorter period, with the exception of NOx at rural sites (Figure 33). For rural NOx the trend is flat at the beginning of the period, becomes increasingly downward during the middle years, and then flattens out in the last two years. These features are not apparent in the longer data run 2005-2018 (Figure 21), so not much significance should be attached to them.

Comparisons of Trends with Other Studies

3.8 Carslaw *et al* (2011) set out trends over the period 2004 to 2009 as being *"best described as having been weakly downward".* The trends in NO_2 over this period were reported as being *"decreases in the range 0.5 to 1% per year, although rural sites* (showed) *a greater decrease ~1.4% per year".* In contrast to the present study, the NOx trends reported by Carslaw *et al* (2011) were higher than those of NO_2, being reported as decreases of -1 to -2% per year, compared with the -0.5 to -1% per year for NO_2, although subsequent work by Font & Fuller (2015) examining trends in London showed that *"Between 2010 and 2014, sites that exhibited decreasing* (trends in NOx and NO_2) *showed an approximate 1:1 ratio* (for the NOx and NO_2 trends)", which is consistent with the current study. Carslaw and Rhys-Tyler (2013) reported the trends for 23 roadside sites in London as being downward at -1.07% per year for NOx and -0.59% per year for NO_2 over the period 2003 to 2012. A recent analysis of trends at long-term roadside sites in London over the period 2000 to 2017 presents graphs of trends that equate to -2.5% per year for NO_2 (10 sites) and -2.0% per year over the period 2010 to 2017 for NOx (9 sites) (Lang, Carslaw, & Moller, 2019a), while the urban background NOx trend is -1.8% per year (11 sites) (Lang, Carslaw, & Moller, 2019b)[4]. The higher rates of reduction found by Lang, Carslaw and Moller (2019a) and (2019b), as compared with those for the earlier studies, are consistent with the findings of the present study. The rates of decline in London over the period 2010 to 2017 are, however, somewhat lower than the overall rates of decline for the whole of the UK found in the present study for the slightly longer period 2010 to 2018 (Table 2), which were -3.1% per year (both NO_2 and NOx) at road sites and -3.0% per year (NOx) at urban sites,.

Comparisons of Measured Trends with Emissions Trends

3.9 The trends in emissions from the UK as a whole over the period 2005 to 2017 (as reported to the European Commission) are shown in Figure 40, together with the trends for four individual subcategories. Reported emissions from the road traffic sector (the sum of the heavy duty vehicles and passenger cars categories) are shown in detail in Figure 41[5]. Changes in total emissions are likely to have the greatest effect on concentrations at rural sites, while concentrations at the road sites would be expected to more closely reflect changes in emissions from road vehicles. The trends in NOx concentrations at the roadside and rural sites over the 2005 to 2018 period (Figure 19 and Figure 21) follow a broadly linear reduction, as do the NOx emissions over the 2005 to 2017 period (Figure 40 and Figure 41)[6]. While the patterns of changes in emissions and concentration are broadly similar, the rates of reduction are not. The rate of reduction of reported NOx emissions from all UK sources over the period 2005 to 2017 is -4.3% per year (calculated from the best fit linear regression and expressed as the reduction from the concentration in the first year), while that for road vehicle emissions is -5.6% per year. The reported rate of reduction in NOx emissions of -4.3% per year is higher than the rate of reduction in measured NOx concentrations at rural sites over the period 2005 to 2018 (-2.5% per year, Table 1). In turn, the rate of reduction in reported emissions from road vehicles of -5.6 % per year

4 The trends are approximate as they have been derived from Figure 5 in (Lang, Carslaw, & Moller, 2019a) and Figure 6 in (Lang, Carslaw, & Moller, 2019b).

5 Taken from the National Atmospheric Emission Inventory (accessed September 2019) at: https://naei.beis.gov.uk/overview/pollutants?view=summary-data&pollutant_id=6

6 In detail, the concentrations follow a slightly convex pattern, while the emissions follow a slightly concave pattern.

is considerably higher than that the rate of reduction in measured NOx concentrations at road sites (-1.7% per year, Table 1). This would suggest that the reductions in emissions over the period 2005 to 2017, as reported to the European Commission and presented in the NAEI, are over optimistic, and that this is especially so for road vehicles (which will play a large part in the trend for total NOx emissions)[7]. It is recommended that the validity of the NOx emissions estimates used in the NAEI, especially those for road vehicles, is reviewed in light of these observations.

Trends by Geographic Area

3.10 The previous report for the period 2005 to 2016 (Laxen, Zygmunt, & Laxen, 2018) identified a geographic variation in the trends across the UK. Significant downward overall trends were seen for both NO_2 and NOx for sites across much of the UK but no significant overall trends were found for sites in central and northern England (the mapped results for the 2005 to 2016 study are reproduced in Figure 42 for NO_2 and Figure 43 for NOx).

3.11 The mapped results for the current study, for the more recent period 2010 to 2018, are provided for NO_2 in Figure 44 and NOx in Figure 45. To avoid overlapping sites, the results are shown separately for sites with no significant trend, and those with downward trends of <-2% per year, -2-4% per year and >-4% per year. It is evident that there are few sites in the central and northern England area that now show no significant trend, none with a <-2% year trend, with most sites having a -2-4% per year or >-4% per year trend. The overall trends in the three areas for 2010 to 2018 are summarised in Table 5, with the previous results for the period 2005 to 2016 included. It is evident that significant downward trends are now apparent in all three areas, and are, if anything, slightly higher in the central and northern England area. This is consistent with this area of the UK catching up with the other areas, which may be down to different patterns of traffic growth and/or vehicle mix in terms of Euro standards.

3.12 For completeness, the patterns of trends across London and the South East of England are shown in greater detail in Figure 46 for NO_2 and Figure 47 for NOx. There are no clear spatial patterns evident.

Comparison with Predicted Trends

Roadside

3.13 The technical guidance provided to local authorities in 2009 (LAQM.TG(09)) included a table that projected roadside concentrations of NO_2 (Box 2.1 of LAQM.TG(09)). The predicted annual reductions of -3.5% to -4.5% per year over the period 2006 to 2016 were much higher than the

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[7] It is recognised that concentrations at rural sites will be affected by emissions from Europe, however, the contribution will be minimal. In turn, concentrations at road sites will be affected to a very limited extent by rural concentrations (rural concentrations are a small fraction of road concentrations, around 10% in this study, Table 2) thus hardly at all by emissions from Europe.

measured reductions (Laxen, Zygmunt, & Laxen, 2018). With the publication of the updated guidance in 2016, Defra changed from a fixed table to one published on the Defra website that could be updated from time to time. The previous version, made available towards the end of 2017[8], predicted annual reductions of NO_2 at roadside sites of -3.9% per year from 2015 to 2016 and -4.3% per year from 2016 to 2017, again above the measured reductions identified in this study. The latest version of the projections for NO_2 at roadside sites predicts a reduction of -3.4% from 2017 to 2018 and -3.5% from 2018 to 2019 (for rest of the UK <10% HDV). The projections have been added to the NO_2 smooth-trend graph for roadside sites and now appear, visually, to be in agreement with measurements (Figure 48).

Rural and Urban

3.14 Trends in concentrations can also be derived from the Defra background maps[9]. The percentage changes in NO_2 and NOx for the years 2017 to 2018 and 2018 to 2019 have been calculated for the whole of the UK (based on averaging all 1x1km grid squares). The results are:

- 2017 to 2018: a -3.8% per year reduction in NO_2 and a -4.2% reduction for NOx;
- 2018 to 2019: a -4.0% per year reduction in NO_2 and a -4.4% reduction for NOx;

3.15 Averaging across all grid squares gives results that reflect rural concentrations, as reflected in the low average concentrations of around 5-6 $\mu g/m^3$. The projections have therefore been added to the NO_2 smooth-trend graph for rural sites and now seem to be in agreement with measurements (Figure 49).

Influence of NO_2:NOx Emission Ratios on Trends

3.16 There is a non-linear relationship between NO_2 and NOx, which is most evident at higher NOx concentrations (Air Quality Expert Group, 2004). This is illustrated in Figure 50, which shows various fits to annual mean concentrations at background and roadside sites (Laxen & Wilson, 2002). Applying an approximate fit to the data in Figure 50, in the range 30-50 $\mu g/m^3$ NO_2, shows that a reduction in NOx of -3.1% per year would equate to a reduction of around -2.3 to -2.6% per year for NO_2. The rates of reduction will tend towards a 1:1 relationship at lower concentrations such as will arise at rural sites. In practice, the rates of reduction over all three periods, 2005 to 2016, 2005 to 2018 and 2010 to 2018, and all three site types, are essentially the same for both NO_2 and NOx (see Table 1 and Table 2). They are thus contrary to expectation at the road and urban sites.

3.17 The departure from expectation is likely to reflect the role of the changing fraction of primary NO_2 emissions, which will have the greatest effect on road concentrations and no effect on rural

[8] https://laqm.defra.gov.uk/tools-monitoring-data/roadside-no2-projection-factor.html

[9] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

concentrations. It is known that the fraction of NO_2 in NOx emissions from motor vehicles increased during the period to roughly 2010 and has since decreased. This is evident from a recent analysis that has shown NO_2:NOx ratios for emissions from diesel passenger cars and light commercial vehicles increasing over the period 2000 to around 2007/09 as a function of the date of manufacture of the vehicle, before decreasing during the next few years (see Figure 51) (Carslaw, et al., 2019c). This is not a direct reflection of the fleet ratios, as vehicles of a particular year of manufacture will only make up a proportion of the vehicles on the road in a given year, however, it provides a good indication of the pattern. The pattern of increasing then decreasing ratios (Carslaw, et al., 2019c), is consistent with the smooth-trend pattern for NO_2 concentrations seen at road sites over the period 2005 to 2018, namely a convex curve (Figure 16), compared with a more linear trend for NOx (Figure 19). There is evidence of the NO_2:NOx ratio increasing for vehicles manufactured in recent years (Figure 51). Once these vehicles make up a significant proportion of the fleet it would be expected that the rate of NO_2 decline at roadside sites would be reduced to less than that for NOx (contrasting with a greater reduction over recent years).

Future Predictions

3.18 A large proportion of the reported reduction in total UK NOx emissions over recent years has been associated with closure of coal-fired power stations. Whilst there are further improvements that can be made regarding emissions from power generation, this particular action cannot be repeated. Similarly, over the next few years, Euro VI and 6 vehicles will start to dominate the fleet, and once this happens, additional actions will be required in order for there to be continued reductions in NO_2 and NOx at the roadside. This might include a movement away from diesel vehicles, electrification of the fleet, or more stringent type-approval standards. Without additional changes over and above those delivered by the Euro VI and 6 emissions standards, it is to be expected that the current downward trends in NO_2 and NOx concentrations will start to flatten out over the next 5 to 10 years. Regular updating of trends in measured concentrations will reveal whether, and to what extent, this arises in practice.

4 Tables

Tables

Table 1: Summary Results for All UK and by Site Type, 2005-2018

Name	Number of Sites	NO_2			NOx		
		Mean Conc (mg/m^3) [a]	Mean Trend (%/yr)	Mean Trend (mg/m^3/yr)	Mean Conc (mg/m^3) [a]	Mean Trend (%/yr)	Mean Trend (mg/m^3/yr)
All UK							
All UK	112	33.9	-1.82***	-0.70	73.8	-1.86***	-1.48
By Site Type							
Road all UK	52	46.9	-1.80***	-0.96	116.2	-1.74***	-2.16
Urban all UK	45	26.7	-1.65***	-050	44.3	-1.99***	-0.93
Rural all UK	15	9.9	-2.46***	-0.29	13.5	-2.54***	-0.38

[a] Mean of all years and all sites

Table 2: Summary Results for All UK and by Site Type, 2010-2018

Name	Number of Sites	NO_2			NOx		
		Mean Conc (mg/m^3) [a]	Mean Trend (%/yr)	Mean Trend (mg/m^3/yr)	Mean Conc (mg/m^3) [a]	Mean Trend (%/yr)	Mean Trend (mg/m^3/yr)
All UK							
All UK	182	33.6	-3.13***	-1.19	75.4	-3.07***	-2.53
By Site Type							
Road all UK	109	41.5	-3.10***	-1.46	102.4	-3.02***	-3.37
Urban all UK	57	25.4	-3.09**	-0.89	41.6	-3.08*	-1.37
Rural all UK	16	9.2	-3.41***	-0.36	12.3	-4.09***	-0.57

[a] Mean of all years and all sites

Table 3: Sites with No-Significant NO_2 Trend, 2010-2018

Site Type	Site	Non-signficant trends (%/yr)
Road	Chichester – A27 Chichester Bypass	-0.1
	Dartford Roadside - 3 Bean Interchange	-0.55
	Dumbarton Roadside	-2.02
	Dundee Whitehall Street	-0.89
	East Dunbartonshire Bishopbriggs	-1.94
	Falkirk West Bridge Street	-1.8
	Fife Cupar	-1.92
	Haringey Roadside	-1.46
	Horsham – Cowfold	-0.03
	Horsham – Park Way	-1.27
	Hounslow Brentford	-0.62
	Newcastle Cradlewell Roadside	-0.21
	North Lanarkshire Chapelhall	-1.46
	Paisley Gordon Street	-2.45
	Sevenoaks – Bat and Ball	-0.66
	Sutton – Worcester Park	-0.8
	Swansea Morriston Roadside	-1.35
	West Dunbartonshire Clydebank	-1.86
Urban	Aberdeen	-1.02
	Barking and Dagenham – Rush Green	-2.24
	Belfast Centre	-1.83
	Bexley – Belvedere	+0.10
	Bexley – Belvedere West	-2.23
	Brighton Preston Park	-1.91
	Bristol St Paul’s	-2.51
	Cwmbran	-1.88
	Hounslow 2 - Cranford	-1.40
	Leaminton Spa	-2.12
	London Harlington	-1.63
	Newcastle Centre	-1.20
	Norwich Lakenfields	-1.40
	Portsmouth	-1.47
	Reading New Town	+0.41
	Sunderland Silksworth	-1.85
	Thurrock	-1.21
Rural	Glazebury	-2.72
	St Osyth	-1.93
	Yarner Wood	-2.44

Table 4: Sites with No-Significant NOx Trend, 2010-2018

Site Type	Site	Non-signficant trends (%/yr)
Road	Armagh Roadside	-1.41
	Chichester – A27 Chichester Bypass	-0.92
	Dartford Roadside 3 – Bean Interchange	-0.25
	Dumbarton Roadside	-2.06
	Dumfries	-0.28
	Dundee Whitehall Street	-0.61
	Ealing – Western Avenue	-1.96
	East Dunbartonshire Bearsden	-1.71
	East Dunbartonshire Bishopbriggs	-1.64
	Edinburgh Salamander Street	-2.32
	Enfield – Bowes Primary School	-1.72
	Enfield Derby Road	-2.51
	Falkirk Hope Street	-2.76
	Haringey Roadside	-1.69
	Havering – Rainham	-1.72
	Horsham – Cowfold	-0.99
	Hounslow Brentford	-1.05
	Inverness	-2.06
	London Marylebone Road	-1.24
	N Lanarkshire Chapelhall	-1.00
	Newcastle Cradlewell Roadside	-1.51
	Paisley Gordon Street	-2.22
	Perth Crieff	-2.30
	Sevenoaks – Bat and Ball	-0.53
	Slough Town Centre A4	-1.83
	Storrington Roadside	-0.56
	Sutton – Worcester Park	-0.51
	Swansea Hafod DOAS	-1.38
	Swansea Morriston Roadside	-1.42
	West Dunbartonshire Clydebank	-2.66

Site Type	Site	Non-signficant trends (%/yr)
Urban	Aberdeen	-1.96
	Barking and Dagenham – Rush Green	-1.57
	Bexley – Belvedere	-0.25
	Bexley – Belvedere West	-2.89
	Bristol St Paul's	-2.17
	Crawley – Gatwick Airport	-1.96
	Cwmbran	-1.31
	Falkirk Grangemouth MC	-3.39
	Hillingdon Sipson	-2.03
	Hounslow 2 – Cranford	-0.15
	Leamington Spa	-1.65
	London Harlington	-1.62
	Middlesbrough	-2.94
	Newcastle Centre	-1.86
	Portsmouth	-0.90
	Reading New Town	+0.25
	Richmond Upon Thames – Barnes Wetlands	-2.91
	Sunderland Silksworth	-1.76
	Thurrock	-0.27
Rural	Glazebury	-3.09
	High Muffles	-2.65
	Maidstone Rural	-1.83
	Yarner Wood	-2.06

Table 5: Summary Results for All Sites for 3 Areas: 1) Scotland and Northern Ireland, 2) Central & Northern England + North Wales, 3) Southern England and Southern Wales, 2005-2016 and 2010-2018

Name	NO_2		NOx	
	Mean Trend 2005 to 2016 (%/yr) [a]	Mean Trend 2010 to 2018 (%/yr)	Mean Trend 2005 to 2016 (%/yr)	Mean Trend 2010 to 2018 (%/yr)
Area 1 - Scotland and Northern Ireland	-1.56***	-3.02***	-1.51***	-3.15**
Area 2 - Central & Northern England + North Wales	-0.11 (n/s)	-3.17**	-0.04 (n/s)	-3.72***
Area 3 Southern England and Southern Wales	-1.66***	-3.07***	-1.61**	-2.96***

[a] Taken from previous report (Laxen, Zygmunt, & Laxen, 2018)

Table 6: Summary Results for All Sites for 3 Periods, 2005-2016, 2005-2018 and 2010-2018

Period	Mean Trend (%/yr)	
	NO_2	NOx
2005 to 2016 [a]	-1.50	-1.48
2005 to 2018	-1.82	-1.86
2010 to 2018	-3.13	-3.07

[a] Taken from previous report (Laxen, Zygmunt, & Laxen, 2018)

5 Figures

Figures

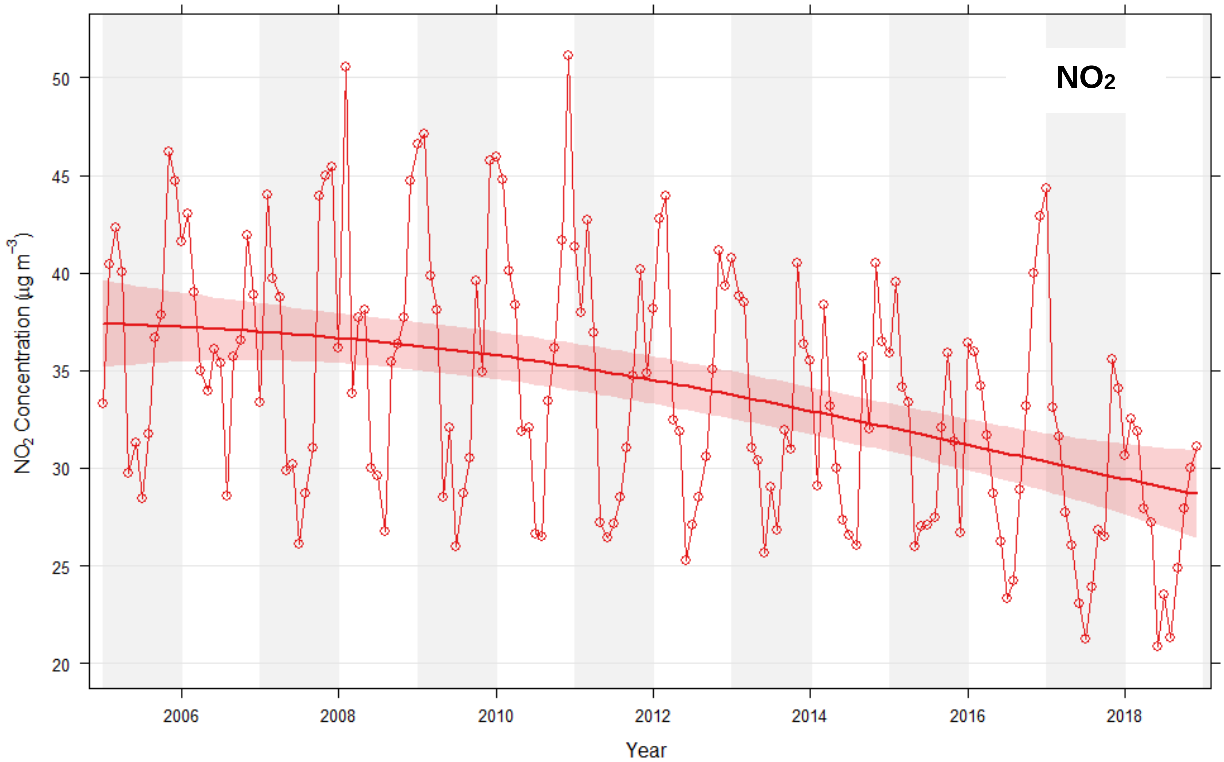

Figure 1: Overall NO_2 Trend across All UK Sites and SmoothTrend Fit, 2005-2018

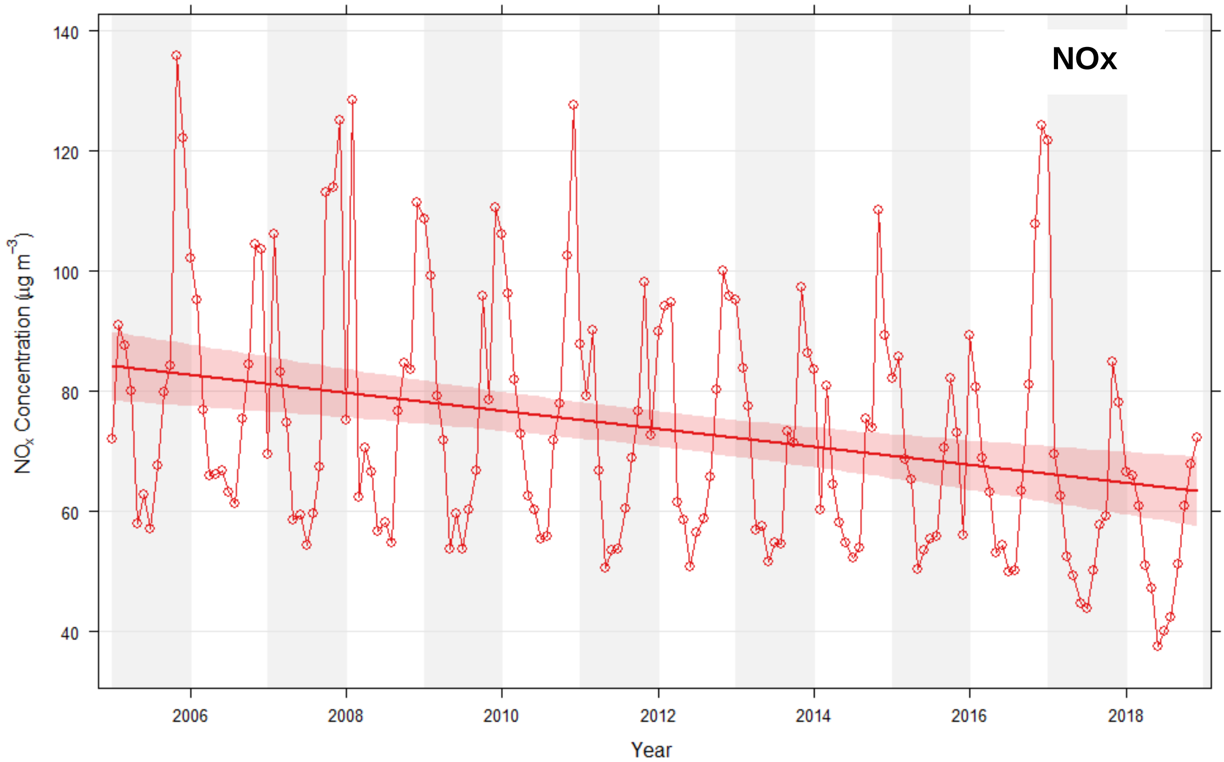

Figure 2: Overall NOx Trend across All UK Sites and SmoothTrend Fit, 2005-2018

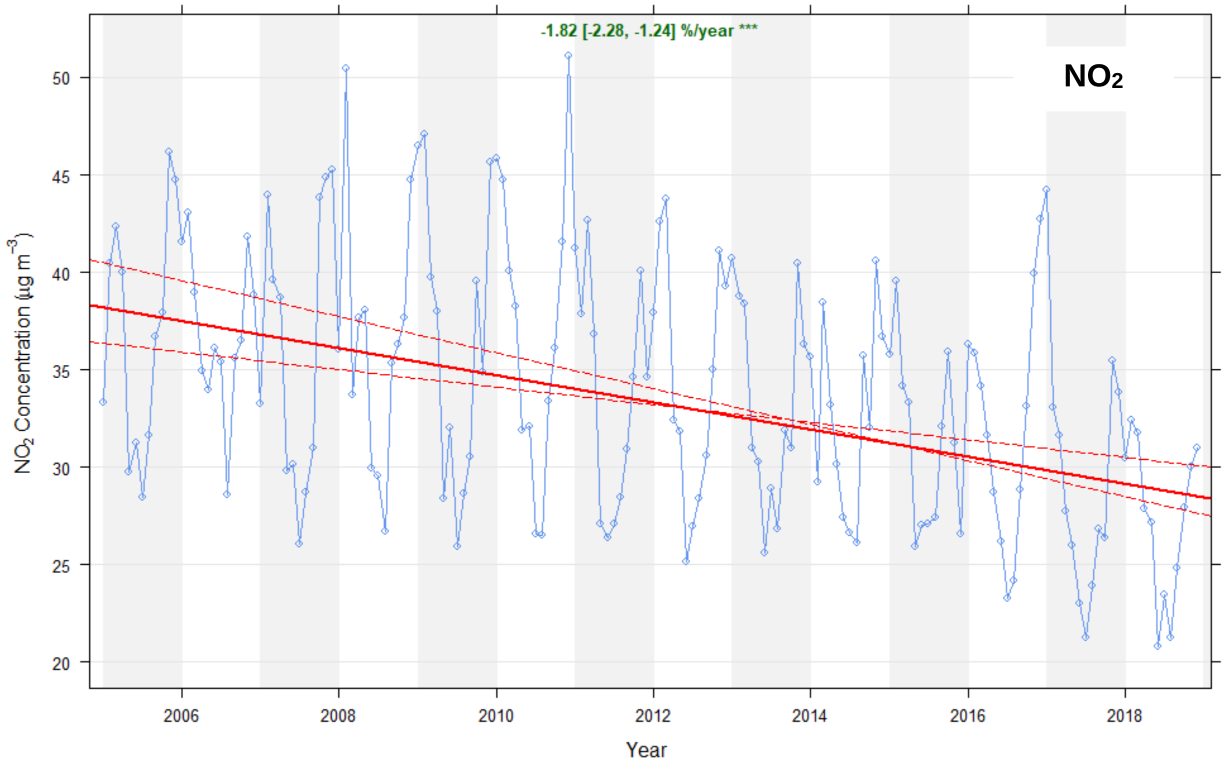

Figure 3: Overall NO_2 Trend across All UK Sites and Theil-Sen Fit (% per yr), 2005-2018

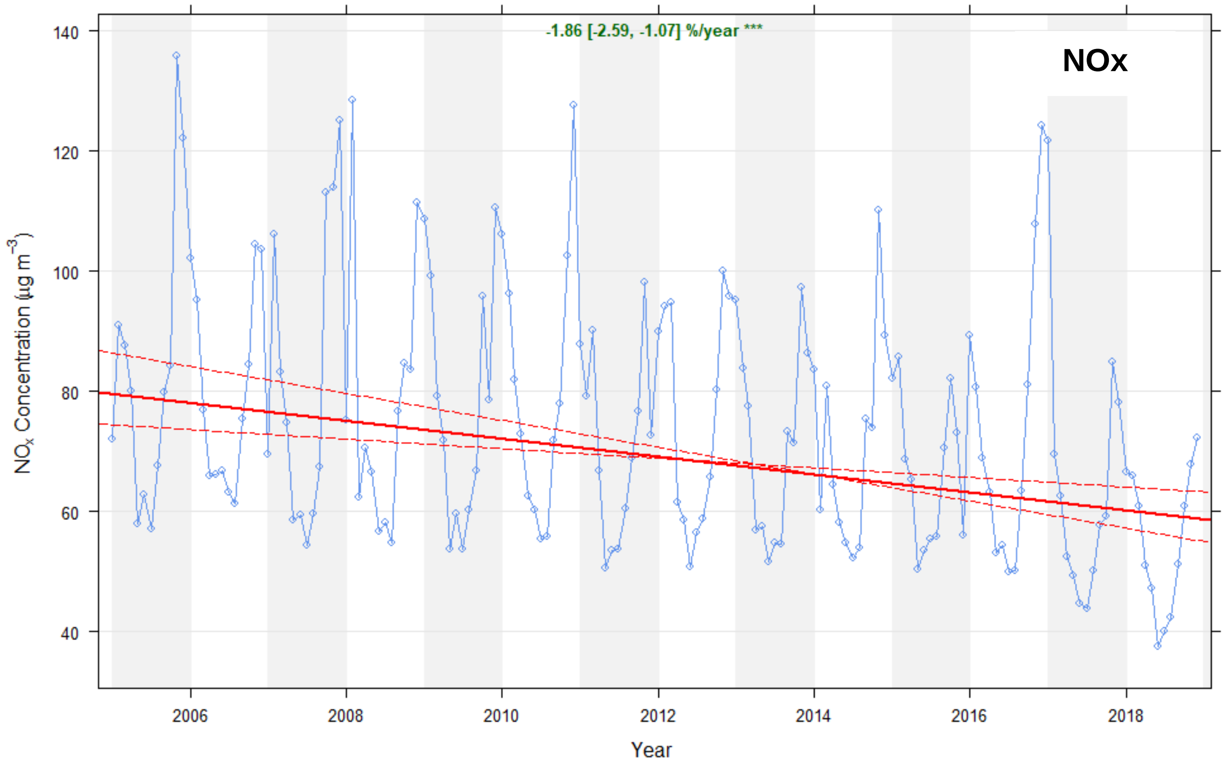

Figure 4: Overall NOx Trend across All UK Sites and Theil-Sen Fit (% per yr), 2005-2018

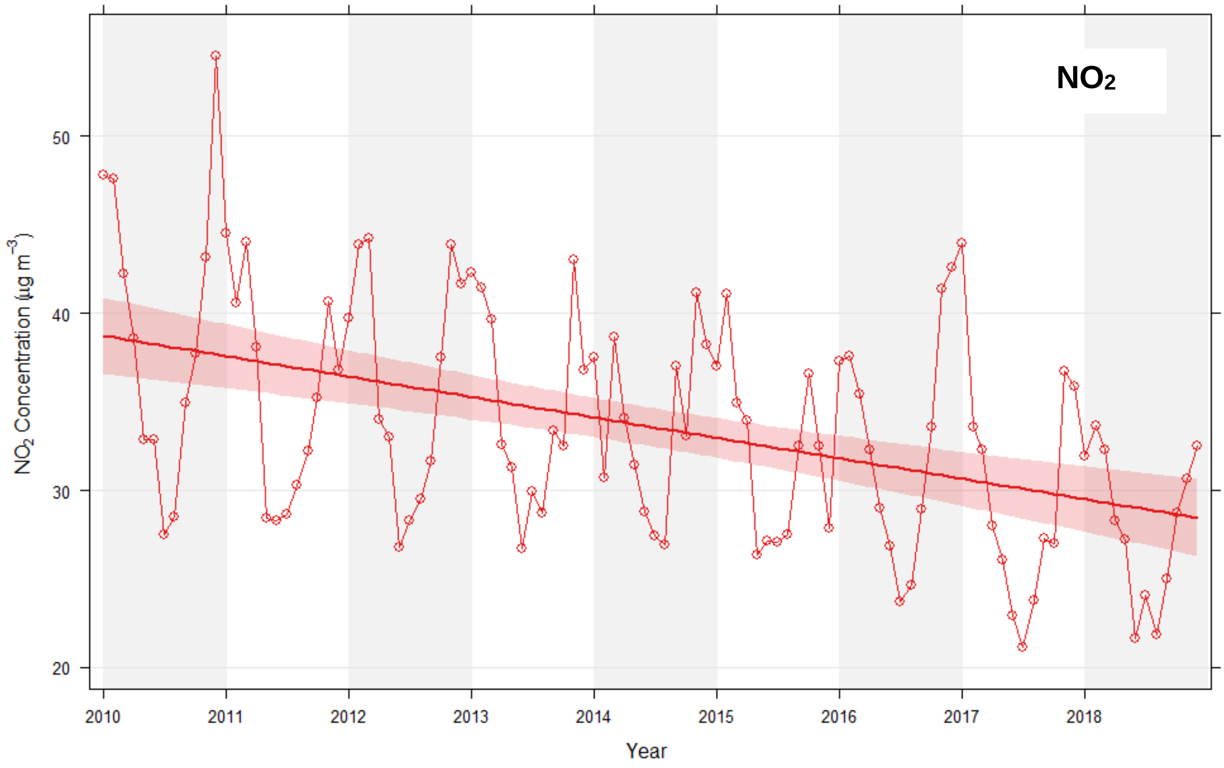

Figure 5: Overall NO_2 Trend across All UK Sites and SmoothTrend Fit, 2010-2018

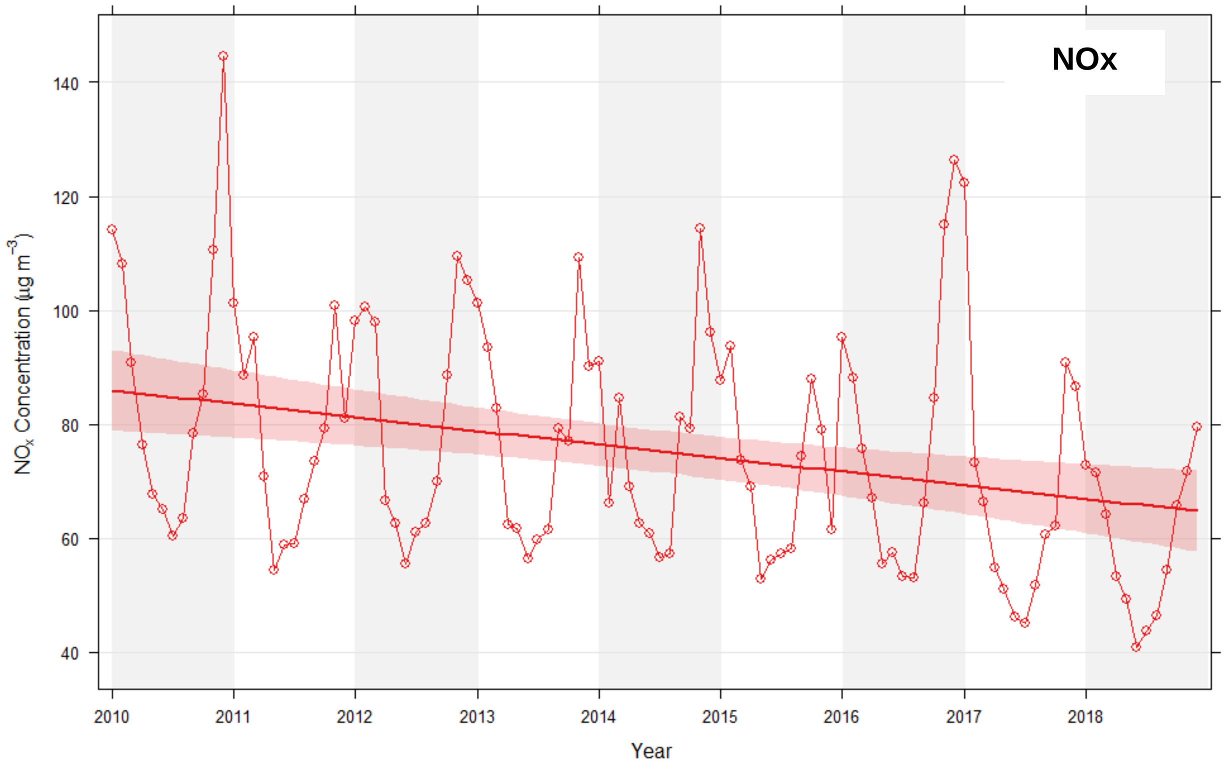

Figure 6: Overall NOx Trend across All UK Sites and SmoothTrend Fit, 2010-2018

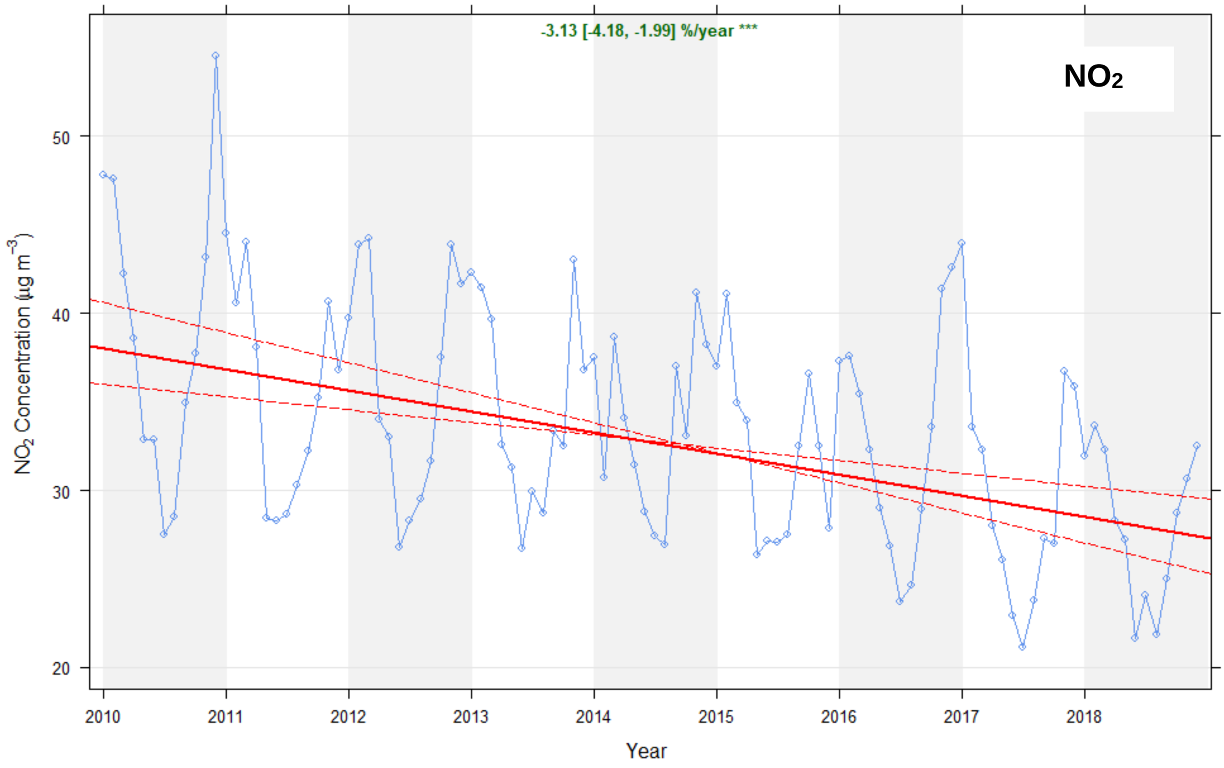

Figure 7: Overall NO_2 Trend across All UK Sites and Theil-Sen Fit (% per yr), 2010-2018

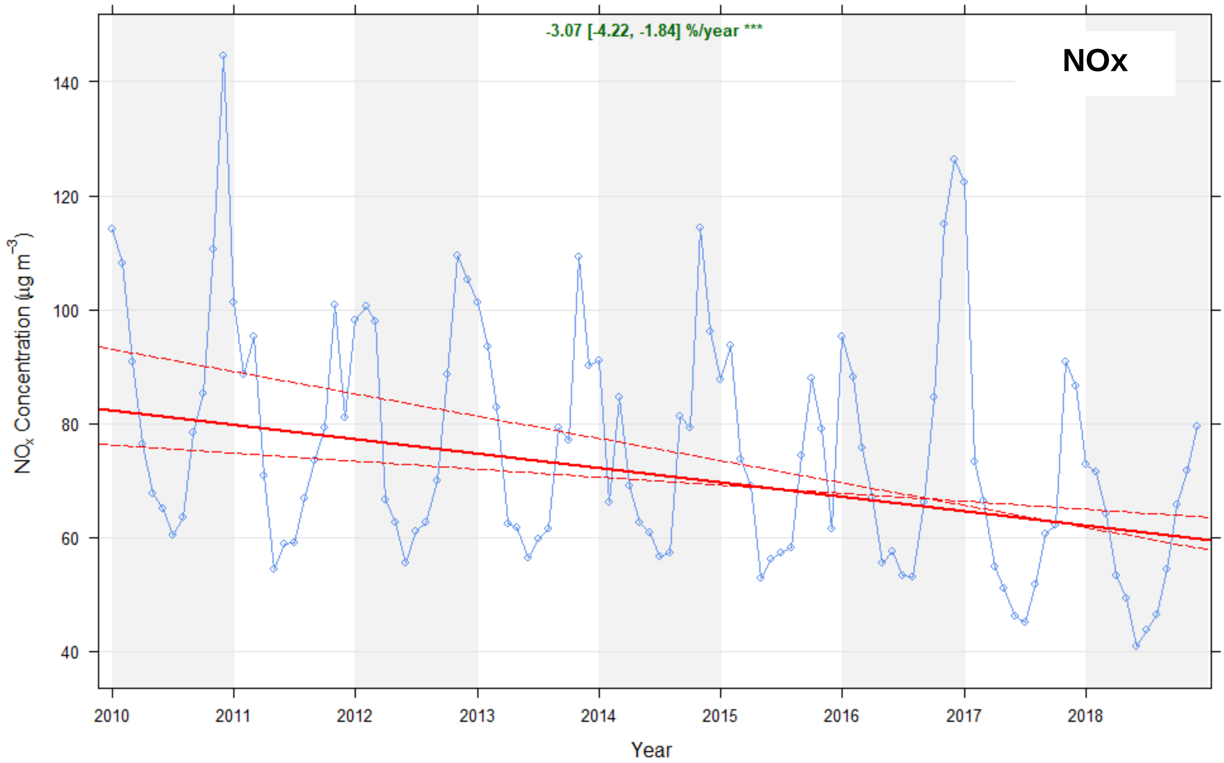

Figure 8: Overall NOx Trend across All UK Sites and Theil-Sen Fit (% per yr), 2010-2018

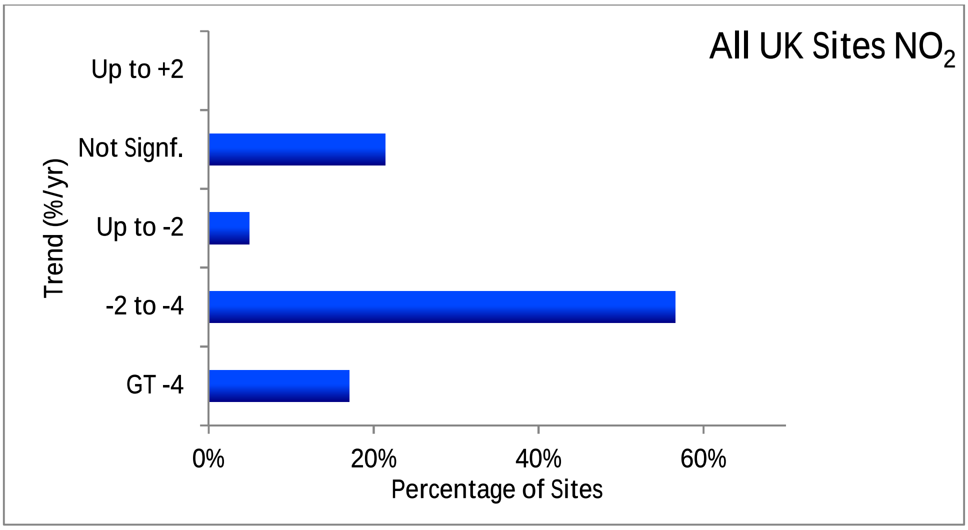

Figure 9: Significance and Magnitude of NO_2 Trends at All UK Sites, 2010 to 2018

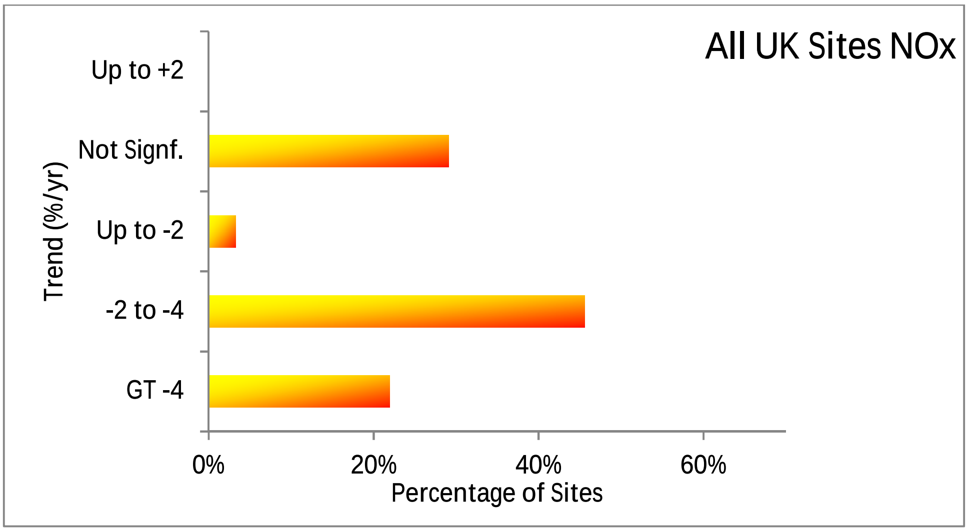

Figure 10: Significance and Magnitude of NOx Trends at All UK Sites, 2010 to 2018

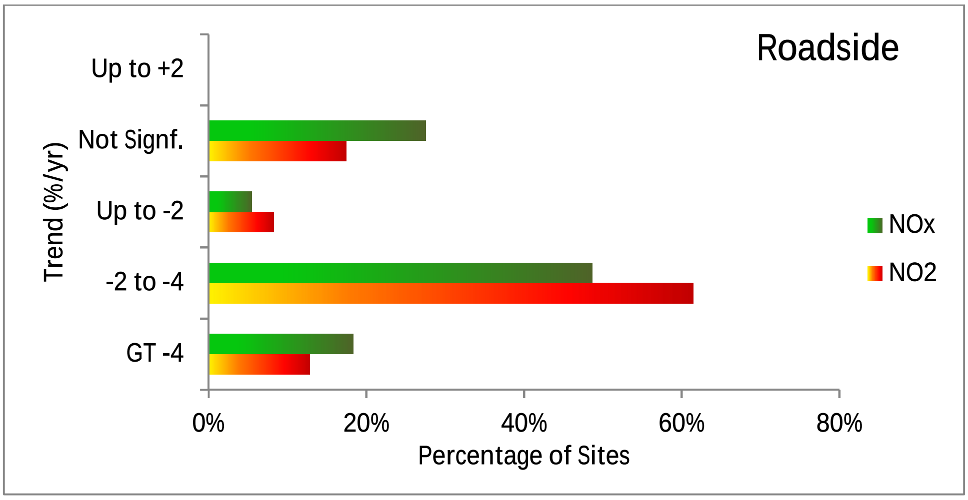

Figure 11: Significance and Magnitude of NO_2 and NO_x Trends at All UK Roadside Sites, 2010 to 2018

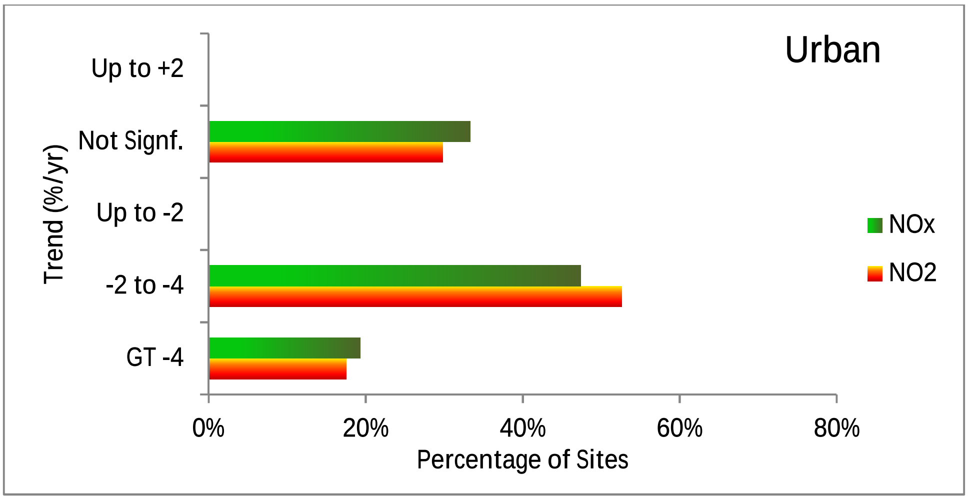

Figure 12: Significance and Magnitude of NO_2 and NO_x Trends at All UK Urban Sites, 2010 to 2018

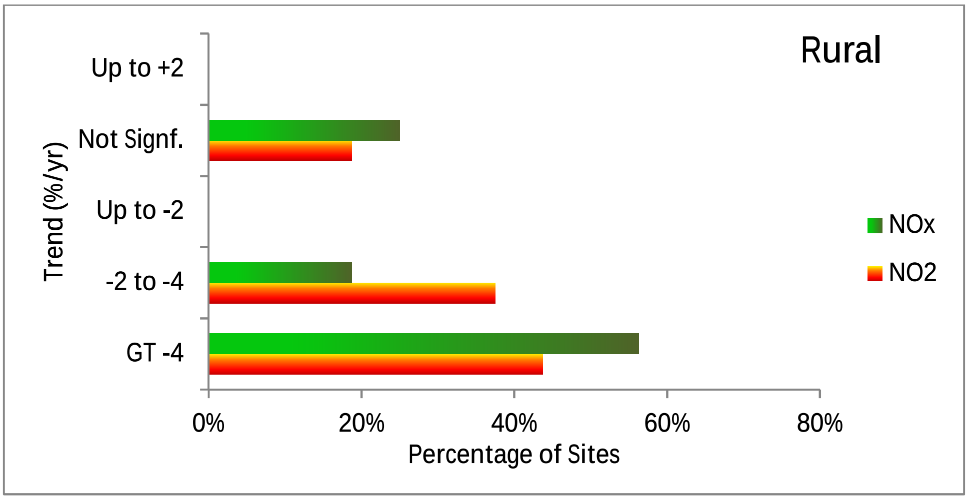

Figure 13: Significance and Magnitude of NO_2 and NOx Trends at All UK Rural Sites, 2010 to 2018

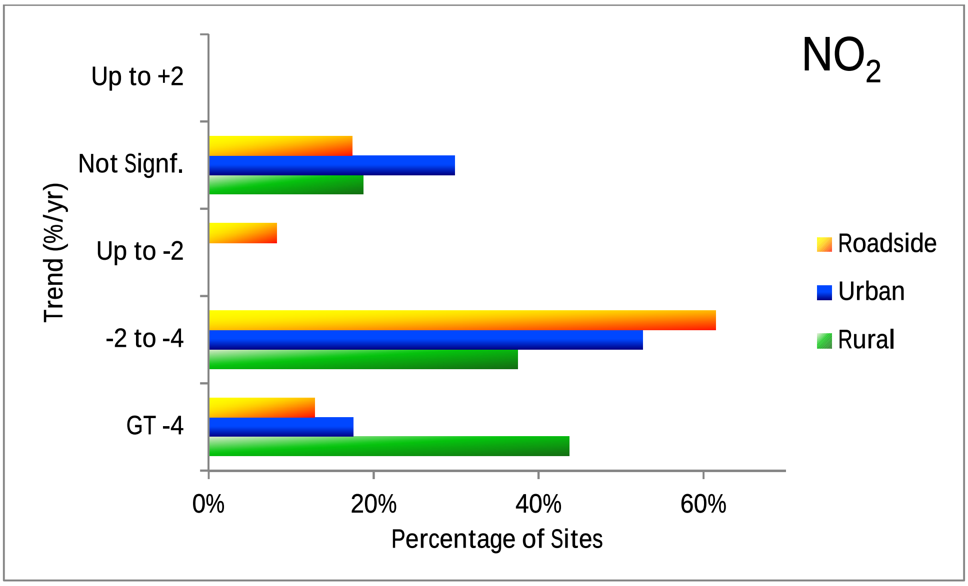

Figure 14: Significance and Magnitude of NO_2 Trends at All UK Sites, 2010 to 2018

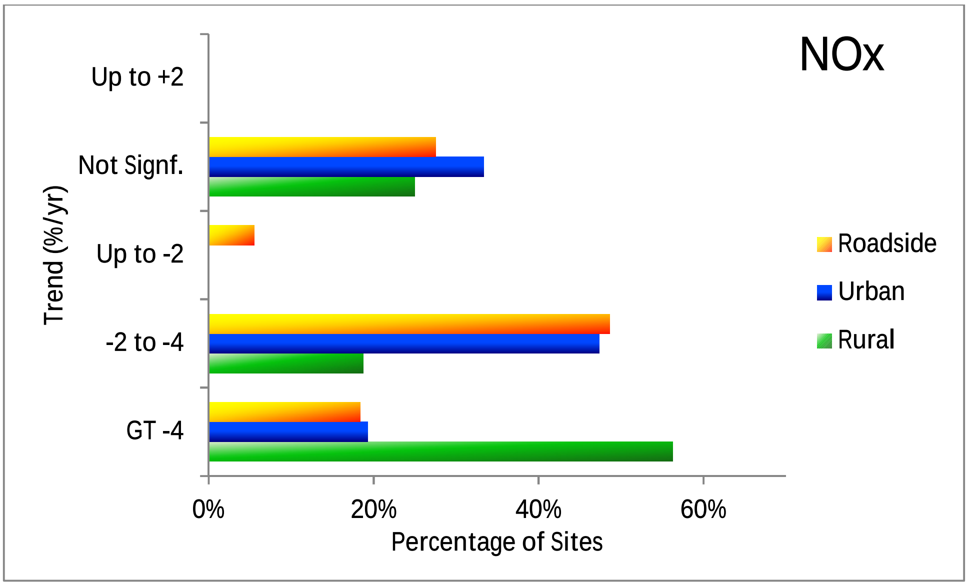

Figure 15: Significance and Magnitude of NOx Trends at All UK Sites, 2010 to 2018

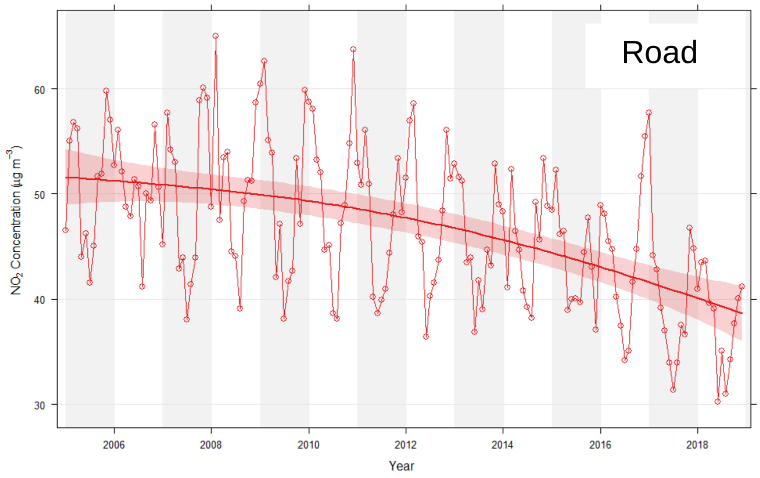

Figure 16: Overall NO_2 Trend across Road Sites and SmoothTrend Fit, 2005 to 2018

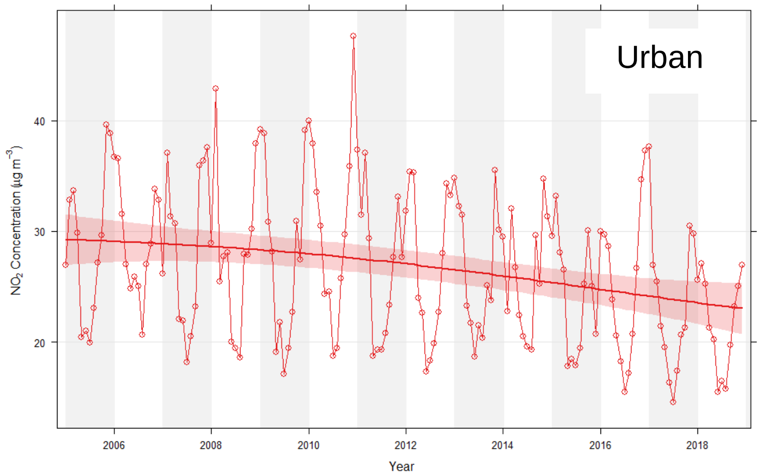

Figure 17: Overall NO_2 Trend across Urban Sites and SmoothTrend Fit, 2005 to 2018

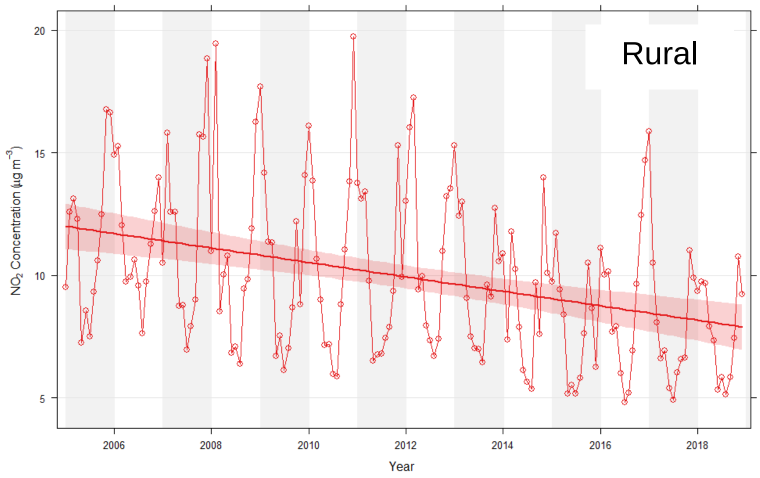

Figure 18: Overall NO_2 Trend across Rural Sites and SmoothTrend Fit, 2005 to 2018

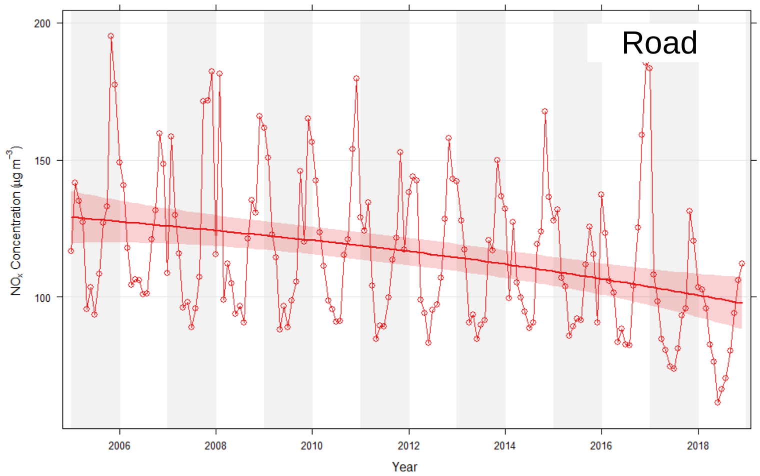

Figure 19: Overall NOx Trend across Road Sites and SmoothTrend Fit, 2005 to 2018

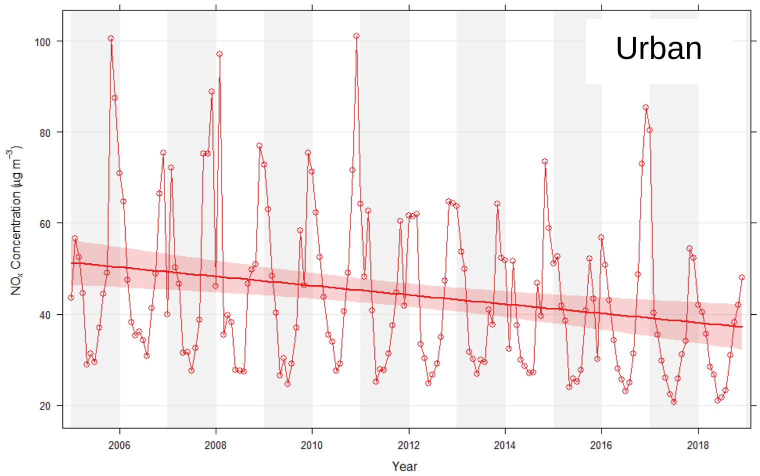

Figure 20: Overall NOx Trend across Urban Sites and SmoothTrend Fit, 2005 to 2018

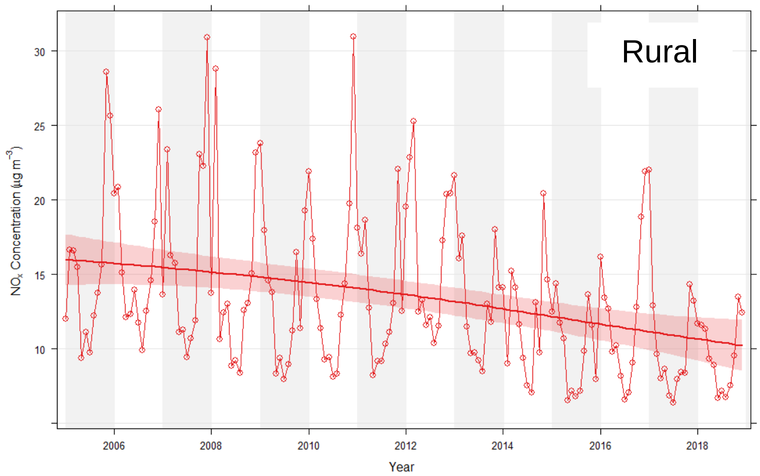

Figure 21: Overall NOx Trend across Rural Sites and SmoothTrend Fit, 2005 to 2018

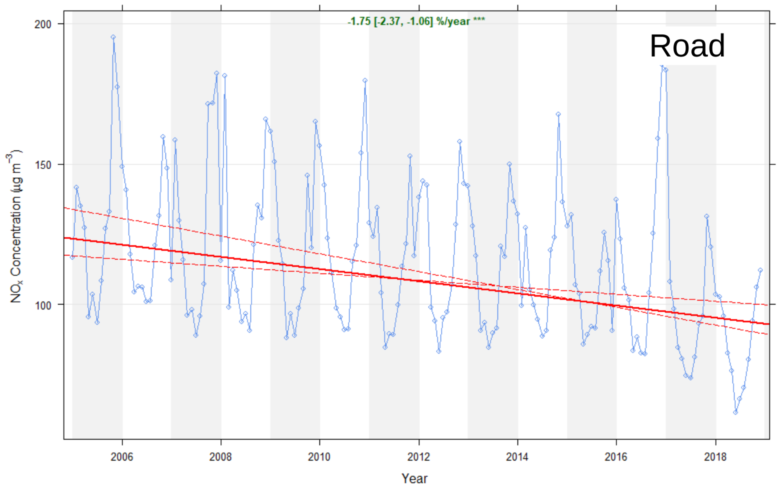

Figure 22: Overall NO_2 Trend across Road Sites and Theil-Sen Fit (% per yr), 2005 to 2018

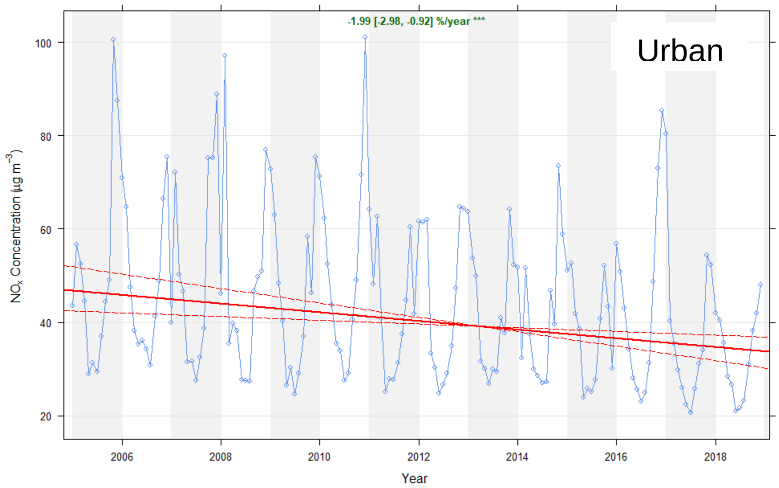

Figure 23: Overall NO_2 Trend across Urban Sites and Theil-Sen Fit (% per yr), 2005 to 2018

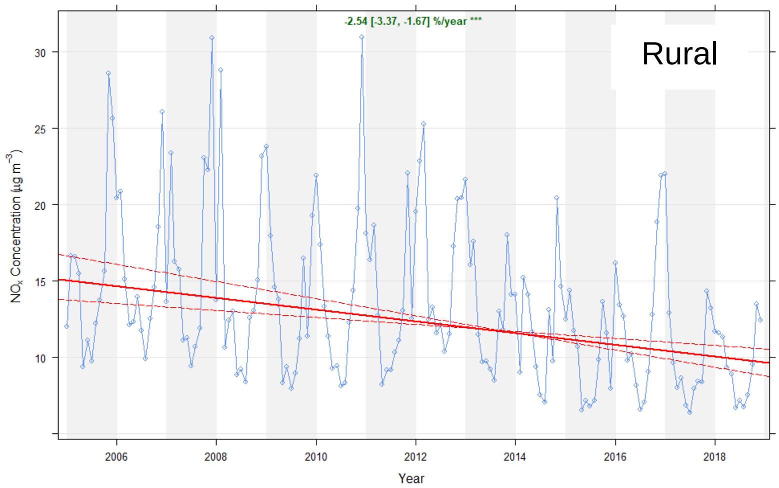

Figure 24: Overall NO_2 Trend across Rural Sites and Theil-Sen Fit (% per yr), 2005 to 2018

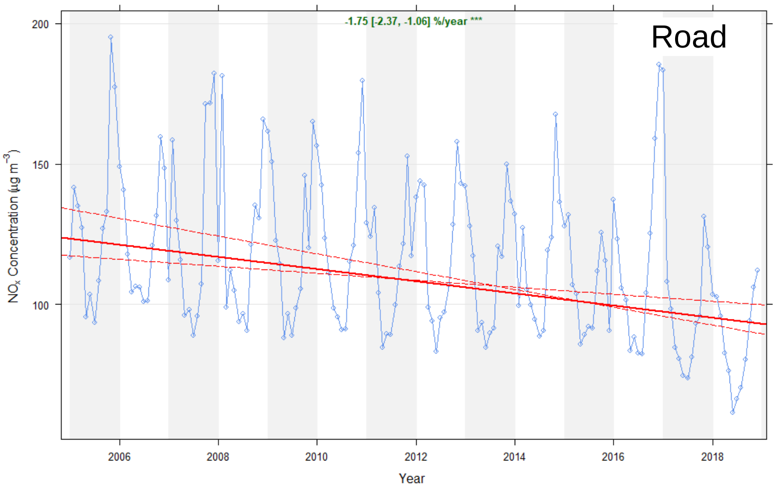

Figure 25: Overall NOx Trend across Road Sites and Theil-Sen Fit (% per yr), 2005 to 2018

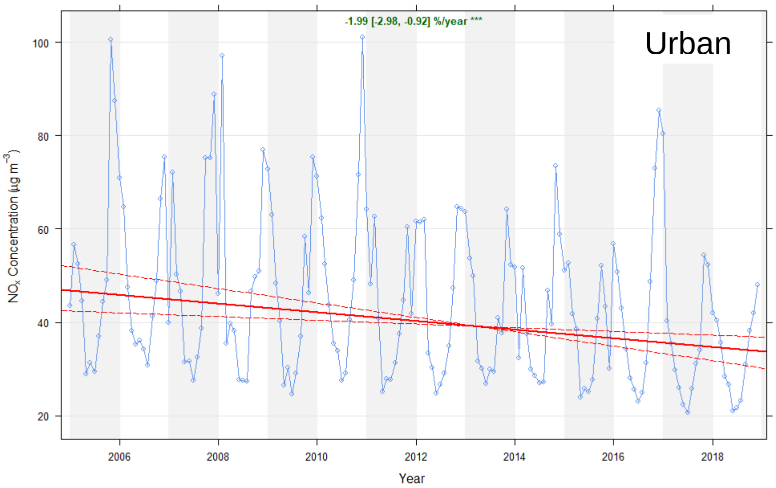

Figure 26: Overall NOx Trend across Urban Sites and Theil-Sen Fit (% per yr), 2005 to 2018

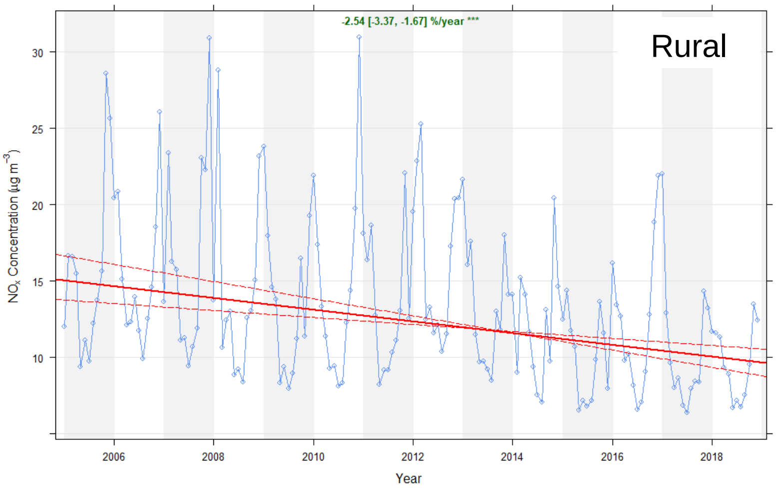

Figure 27: Overall NOx Trend across Rural Sites and Theil-Sen Fit (% per yr), 2005 to 2018

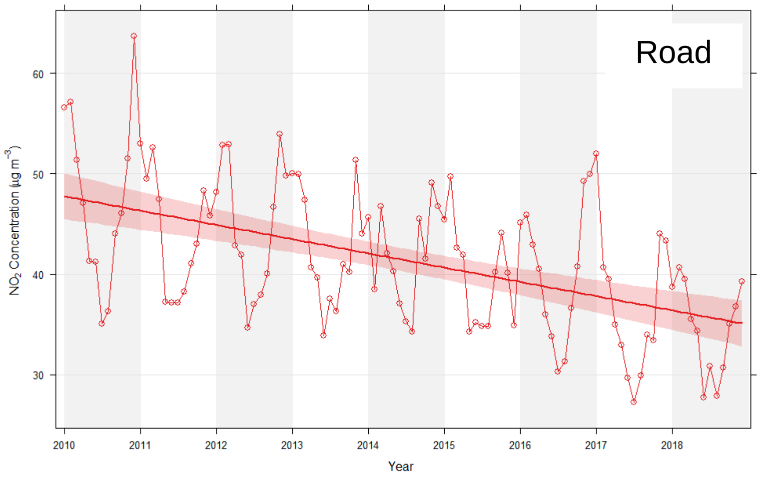

Figure 28: Overall NO_2 Trend across Road Sites and SmoothTrend Fit, 2010 to 2018

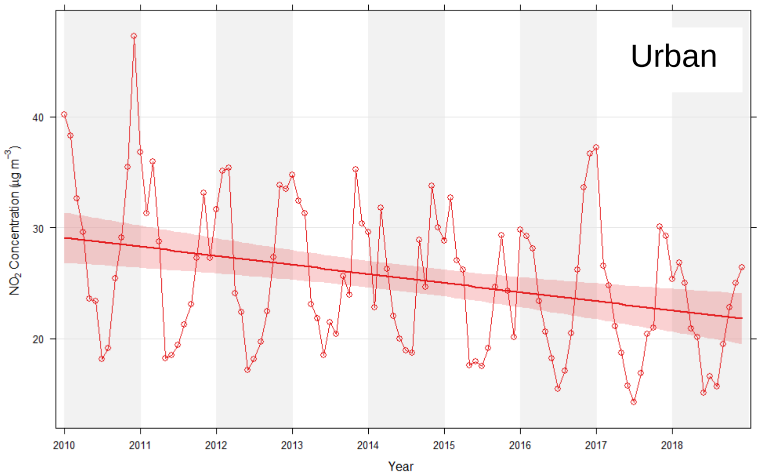

Figure 29: Overall NO_2 Trend across Urban Sites and SmoothTrend Fit, 2010 to 2018

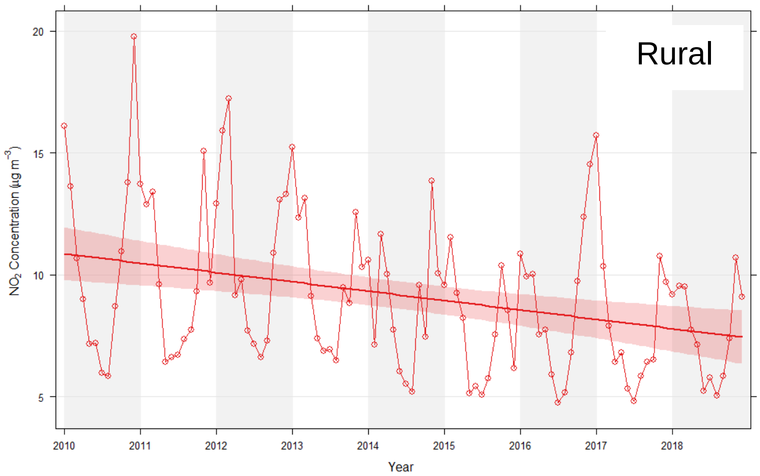

Figure 30: Overall NO_2 Trend across Rural Sites and SmoothTrend Fit, 2010 to 2018

Figure 31: Overall NOx Trend across Road Sites and SmoothTrend Fit, 2010 to 2018

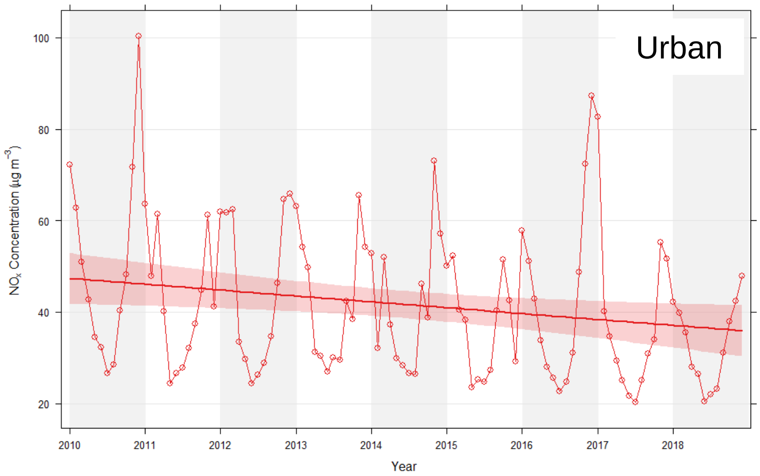

Figure 32: Overall NOx Trend across Urban Sites and SmoothTrend Fit, 2010 to 2018

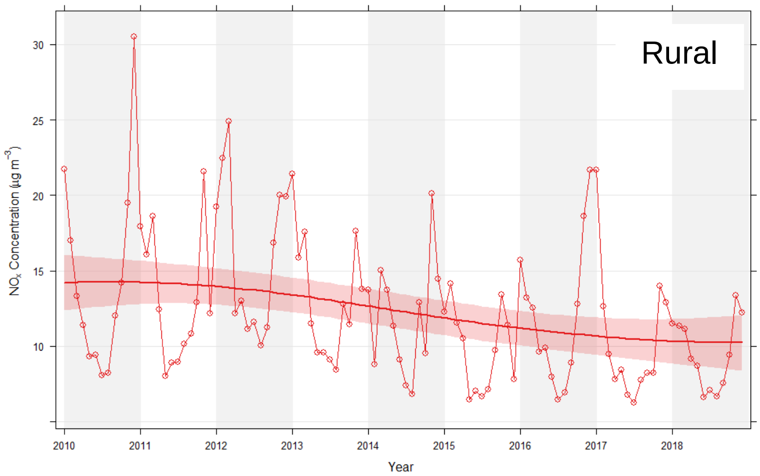

Figure 33: Overall NOx Trend across Rural Sites and SmoothTrend Fit, 2010 to 2018

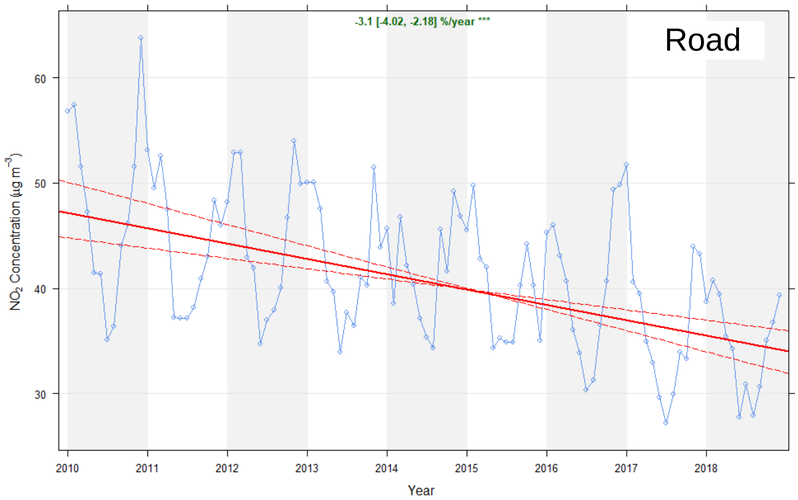

Figure 34: Overall NO_2 Trend across Road Sites and Theil-Sen Fit (% per yr), 2010 to 2018

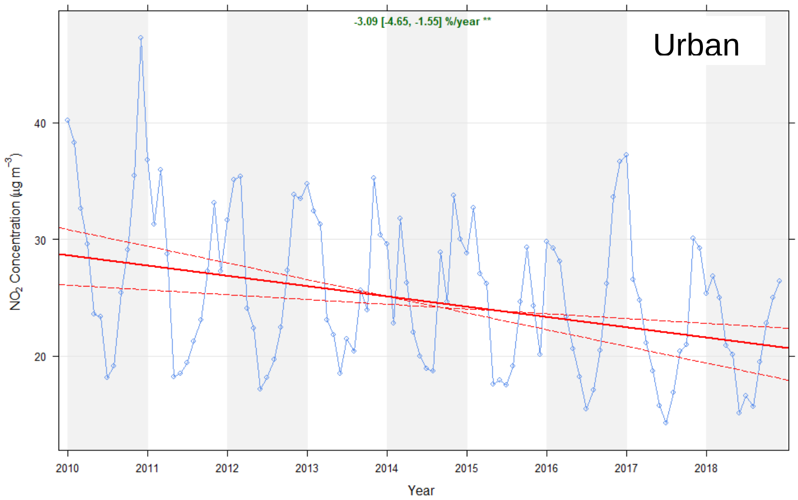

Figure 35: Overall NO_2 Trend across Urban Sites and Theil-Sen Fit (% per yr), 2010 to 2018

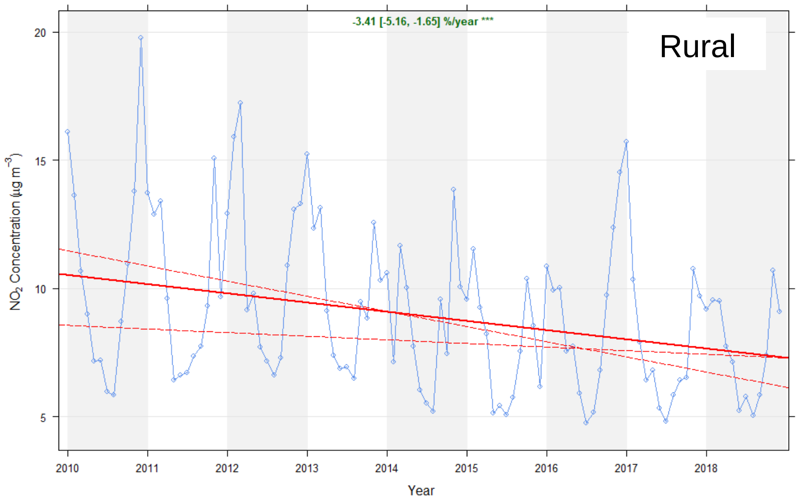

Figure 36: Overall NO_2 Trend across Rural Sites and Theil-Sen Fit (% per yr), 2010 to 2018

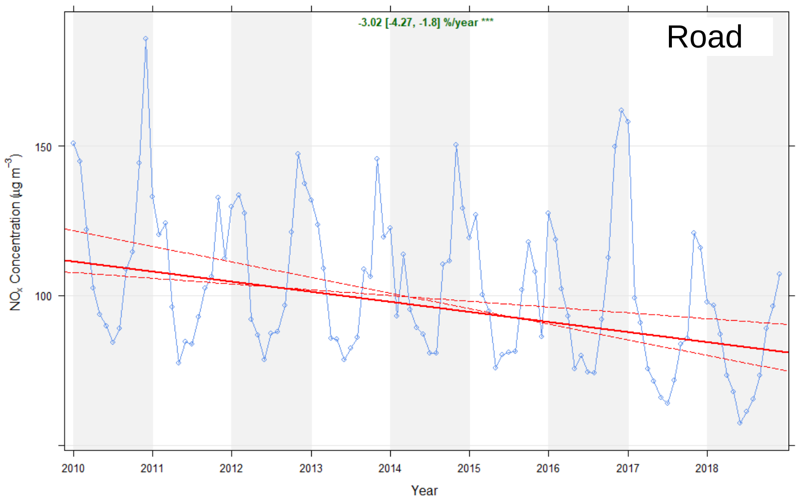

Figure 37: Overall NOx Trend across Road Sites and Theil-Sen Fit (% per yr), 2010 to 2018

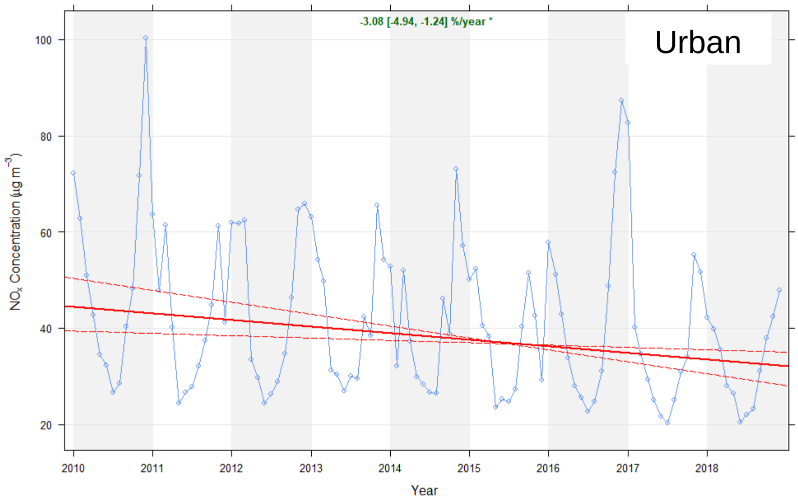

Figure 38: Overall NOx Trend across Urban Sites and Theil-Sen Fit (% per yr), 2010 to 2018

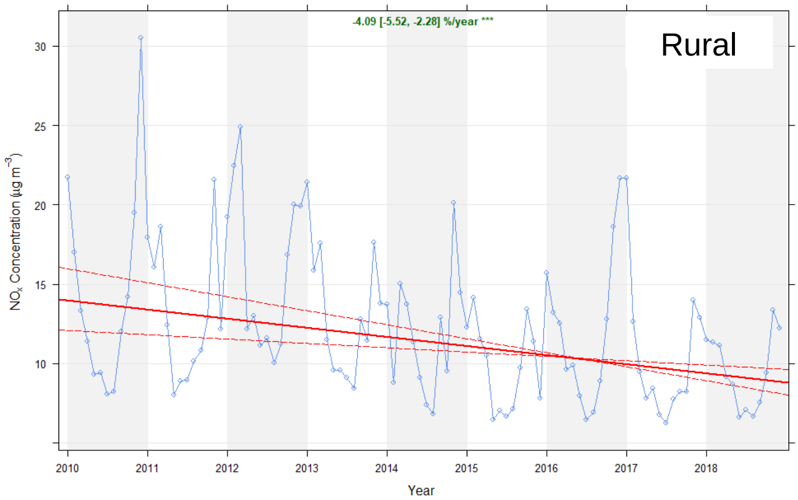

Figure 39: Overall NOx Trend across Rural Sites and Theil-Sen Fit (% per yr), 2010 to 2018

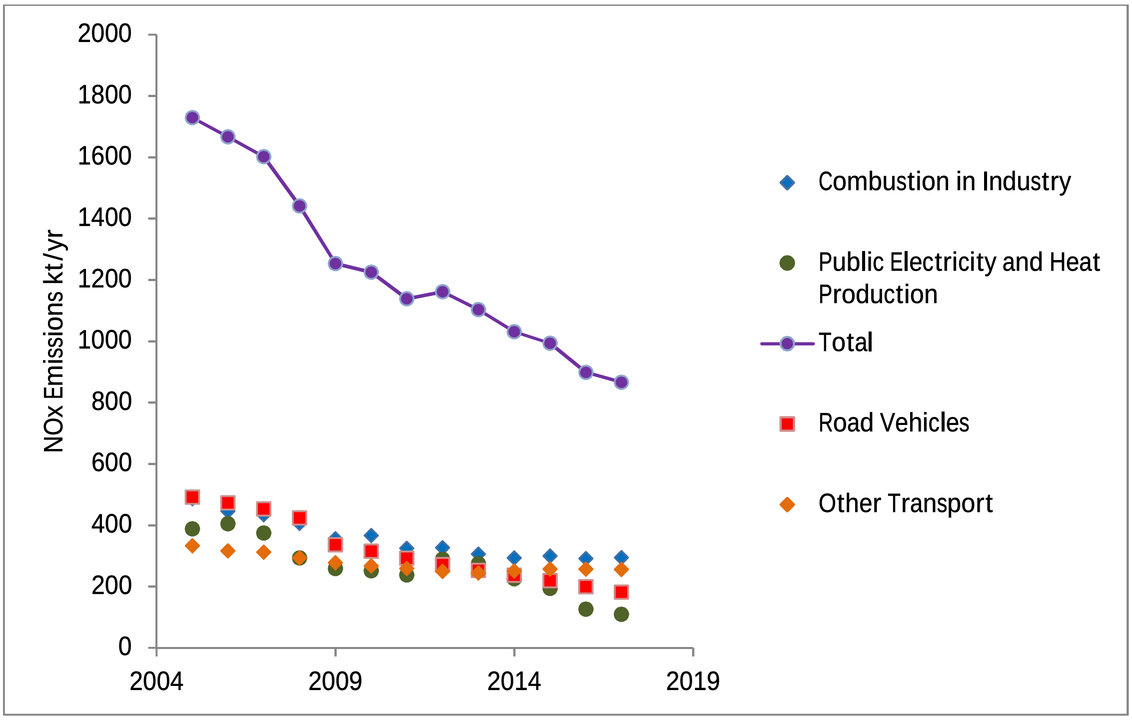

Figure 40: Estimated UK NOx Emissions, 2005 to 2017[5].

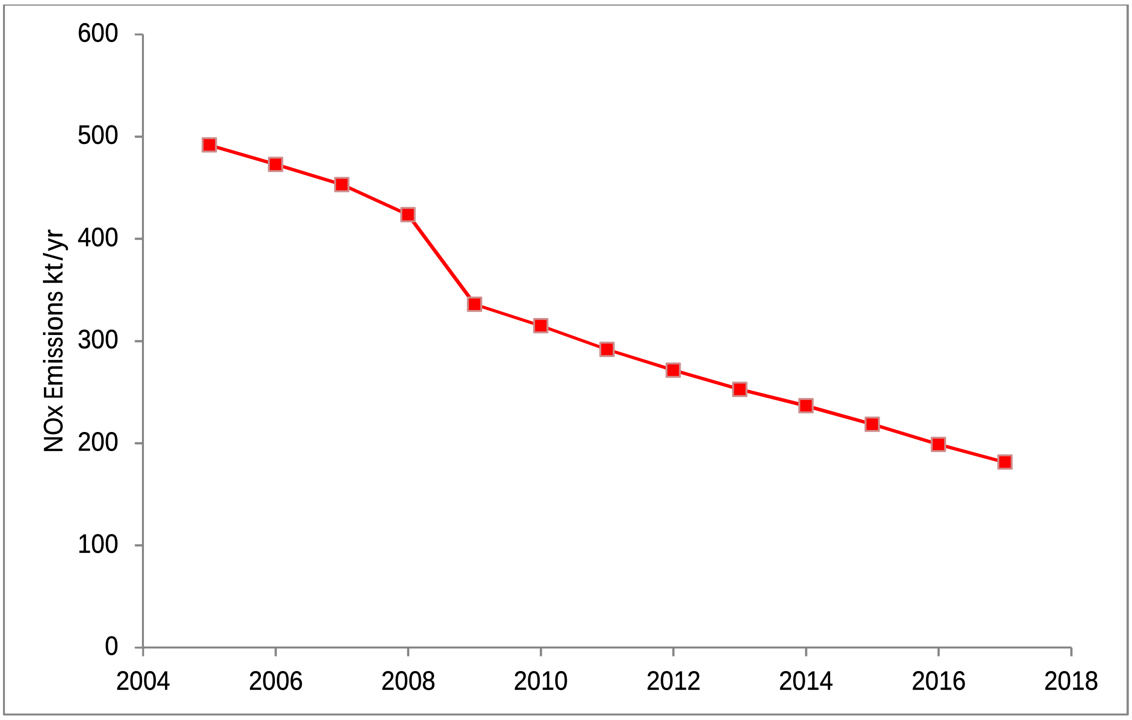

Figure 41: Estimated UK NOx Emissions from Road Vehicles (HDV and LDV), 2005 to 2017[5].

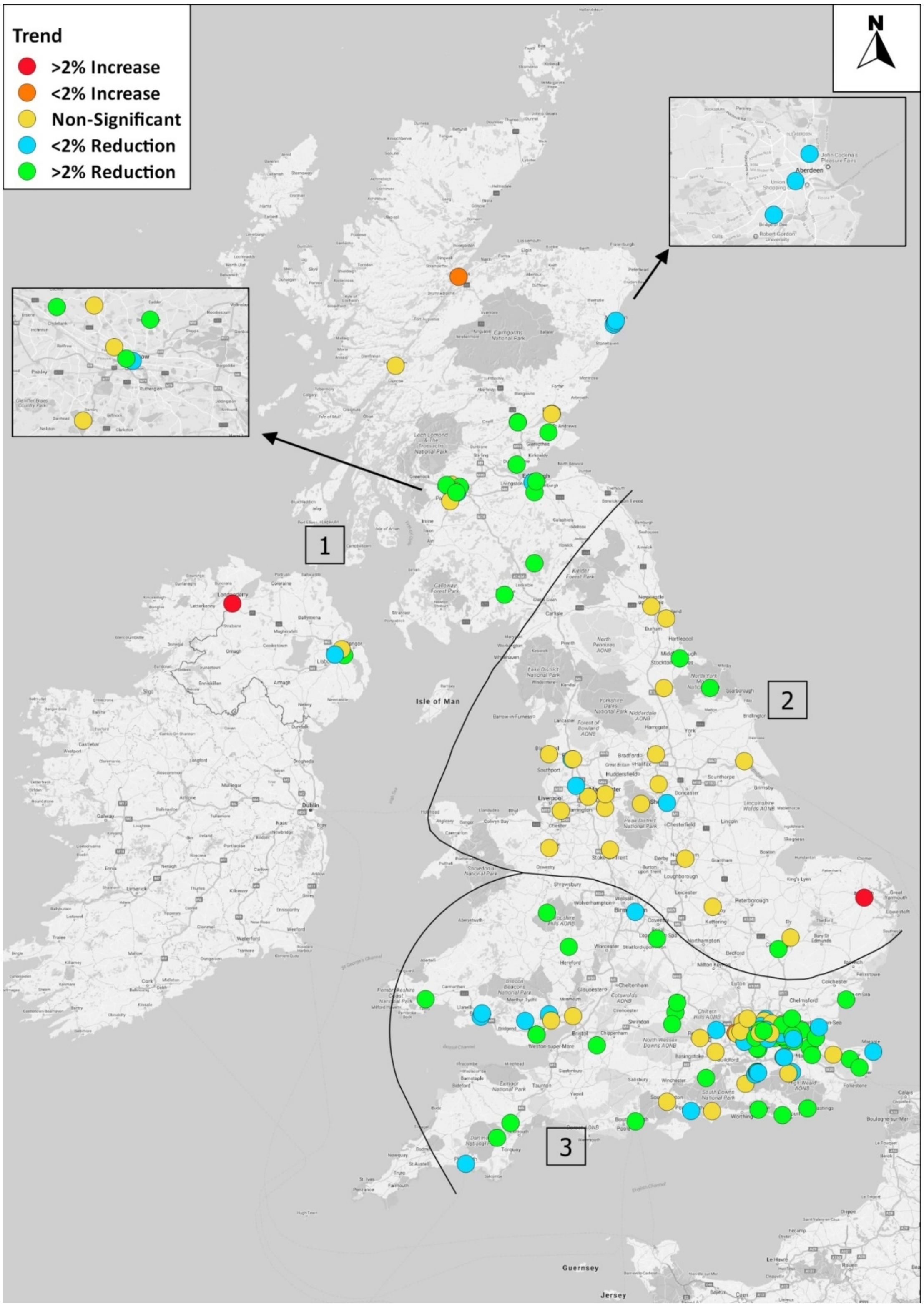

Figure 42 **Significance of NO_2 Trends for 3 Areas 1) Scotland and Northern Ireland, 2) Central & Northern England + North Wales, 3) Southern England and Southern Wales, 2005 to 2016**

Reproduced from: (Laxen, Zygmunt and Laxen, 2018)

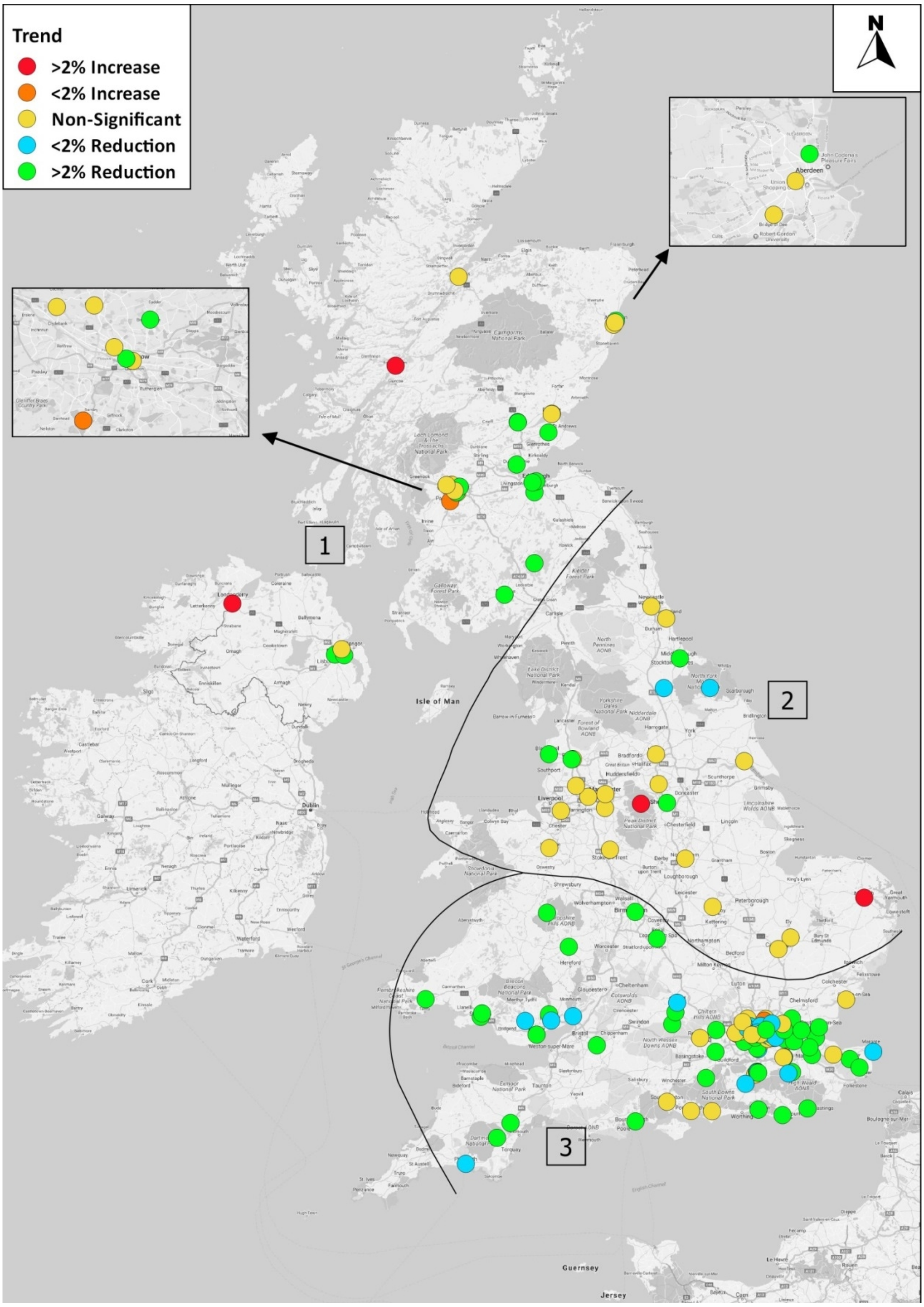

Figure 43: Significance of NOx Trends for 3 Areas 1) Scotland and Northern Ireland, 2) Central & Northern England + North Wales, 3) Southern England and Southern Wales, 2005 to 2016

Reproduced from: (Laxen, Zygmunt and Laxen, 2018)

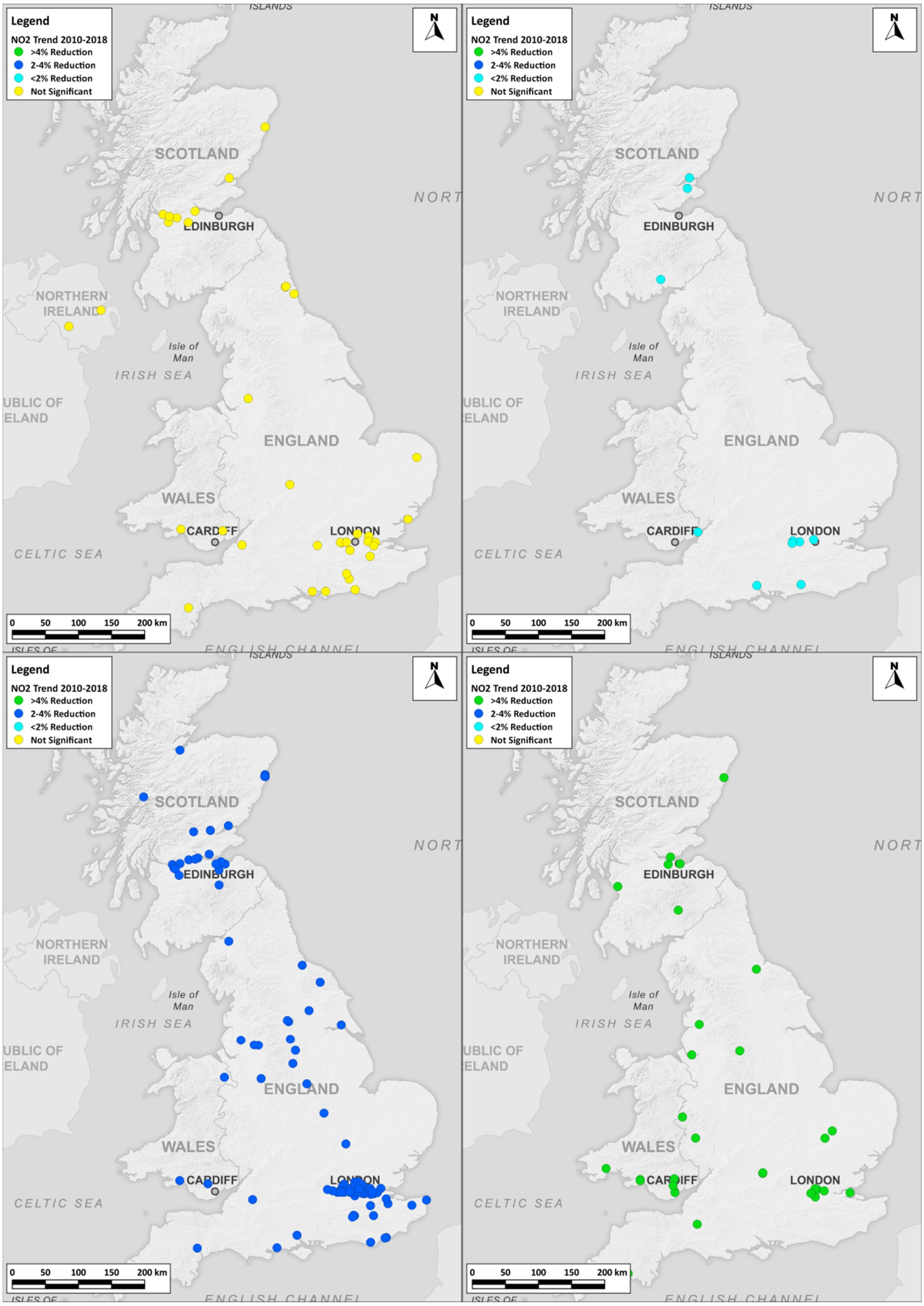

Figure 44 Significance and Magnitude of NO_2 Trends (%/yr) at All UK Sites, 2010-2018

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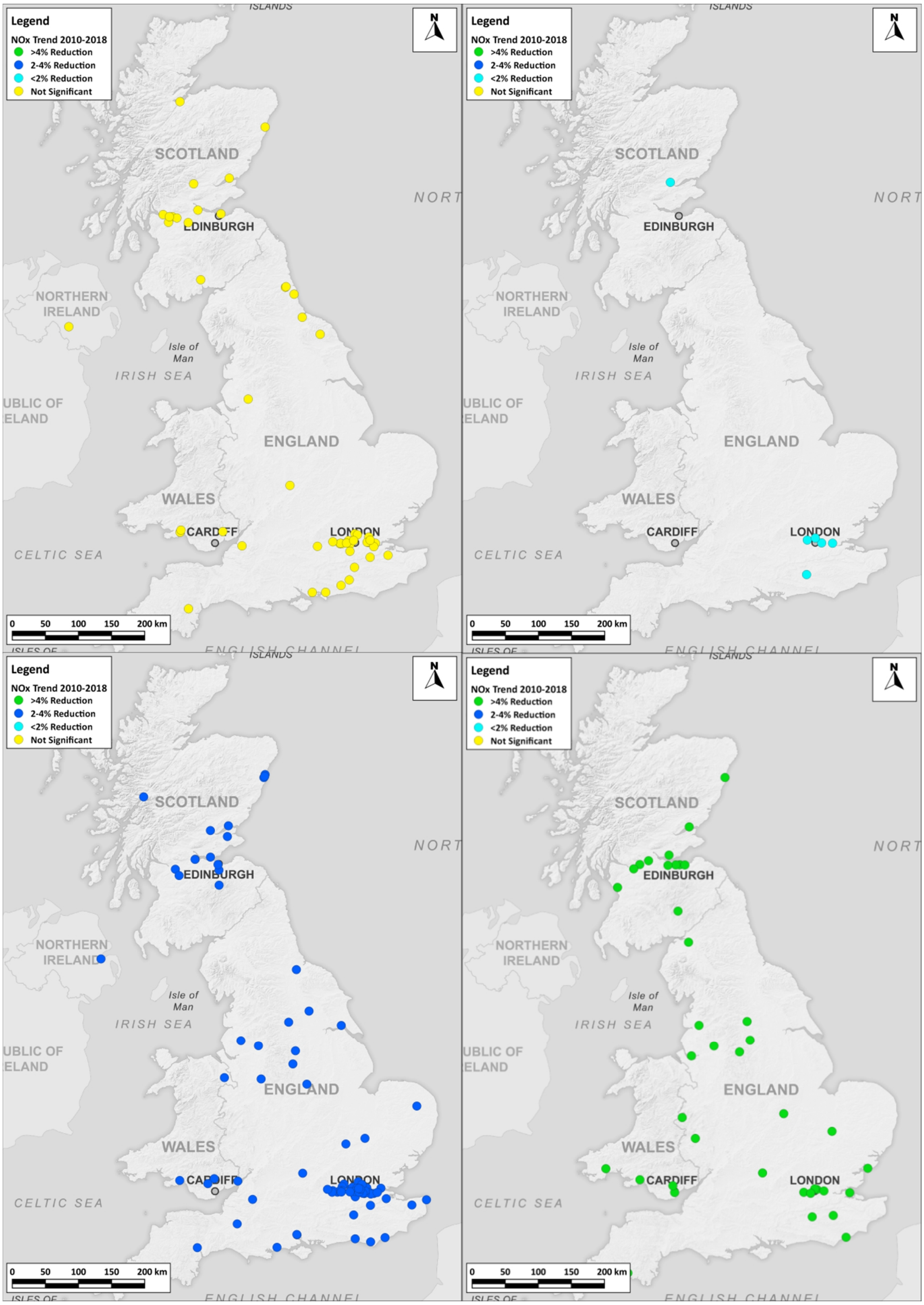

Figure 45: **Significance and Magnitude of NOx Trends (%/yr) at All UK Sites, 2010-2018**

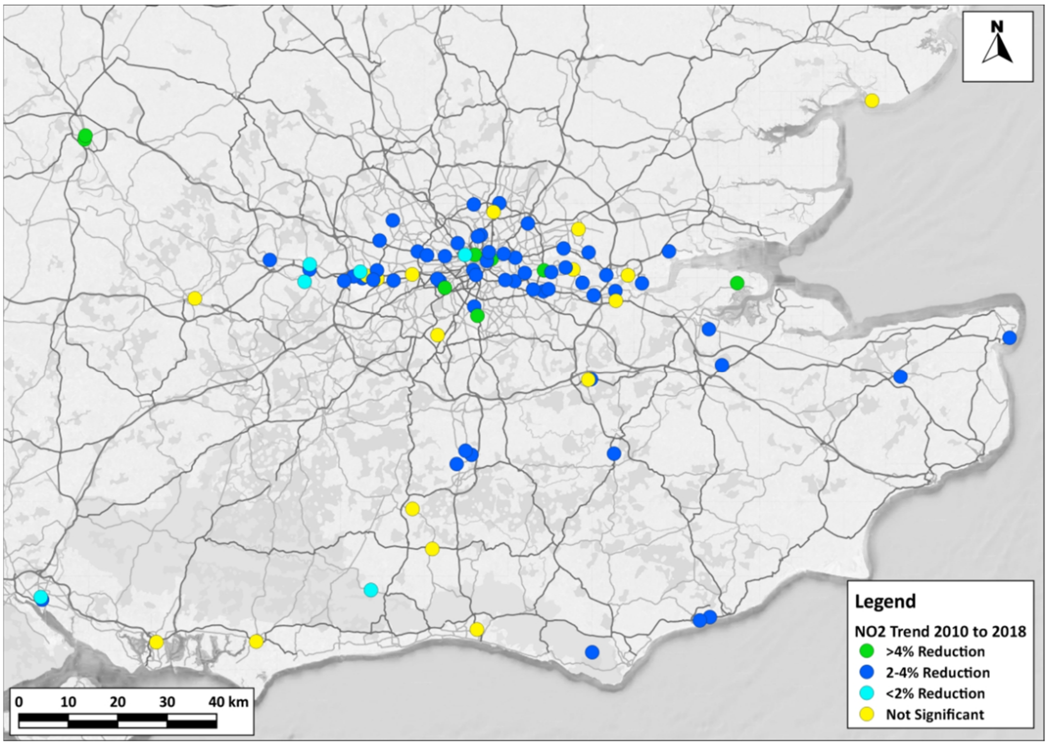

Figure 46: Significance and Magnitude of NO_2 Trends at All Sites in London and SE England, 2010-2018

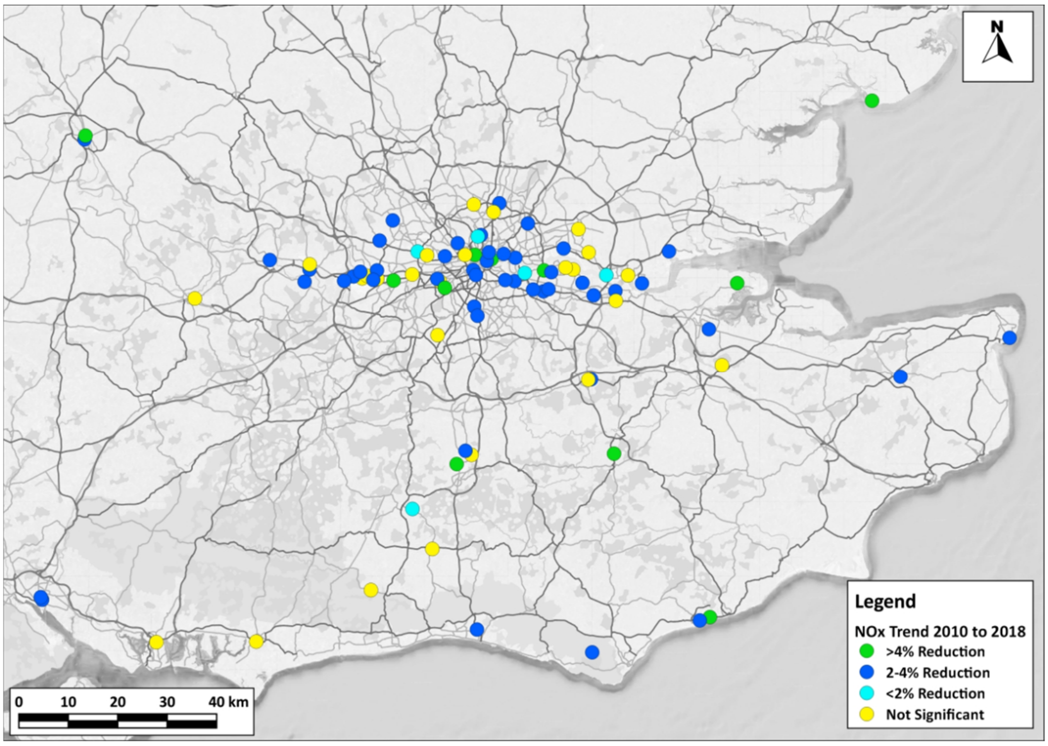

Figure 47: Significance and Magnitude of NO_x Trends at All Sites in London and SE England, 2010-2018

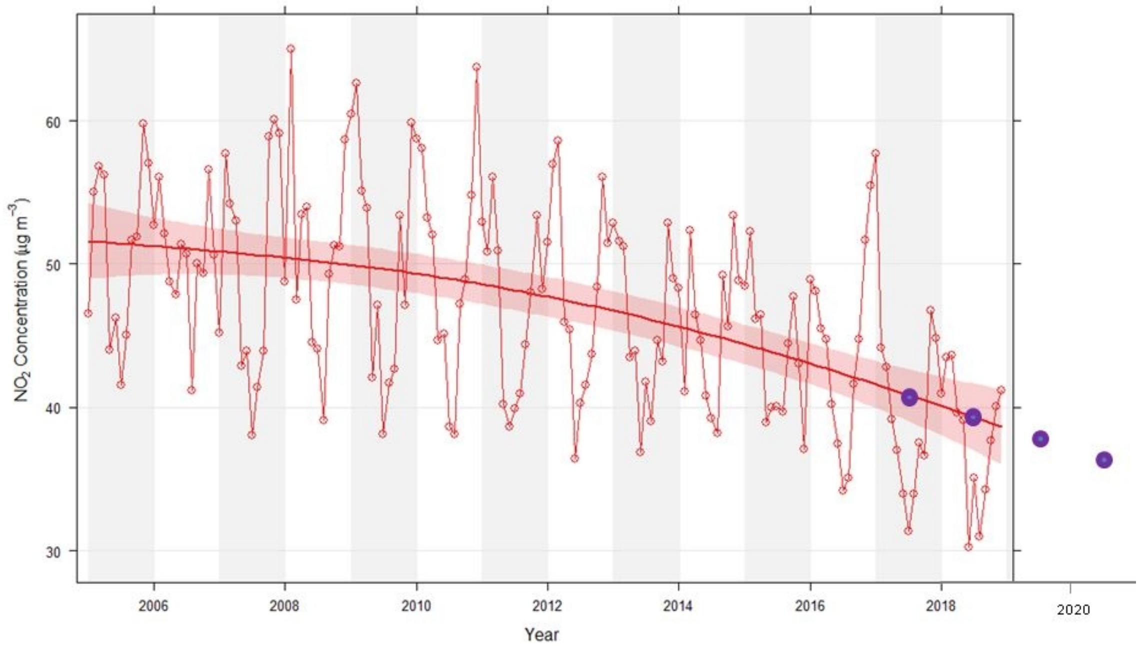

Figure 48 NO$_2$ Trends at Roadside Sites (Figure 16) with Projections for 2017 to 2020 Superimposed from Defra Table [8]

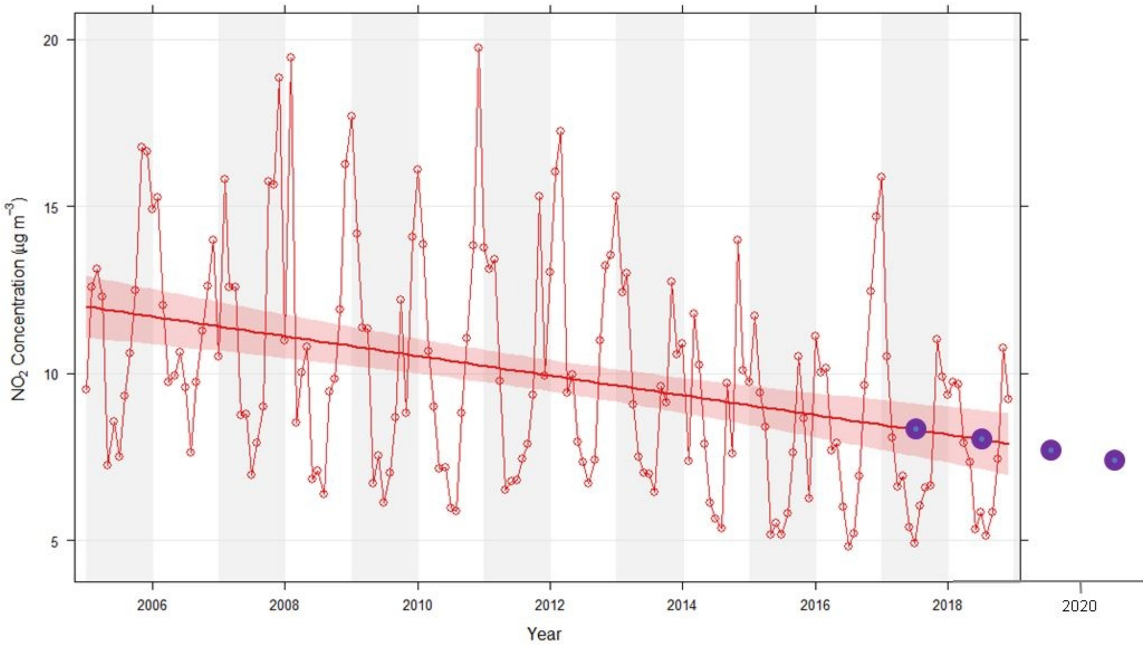

Figure 49 NO$_2$ Trends at Rural Sites (Figure 18) with Projections for 2017 to 2020 Superimposed from Defra Background Maps [9]

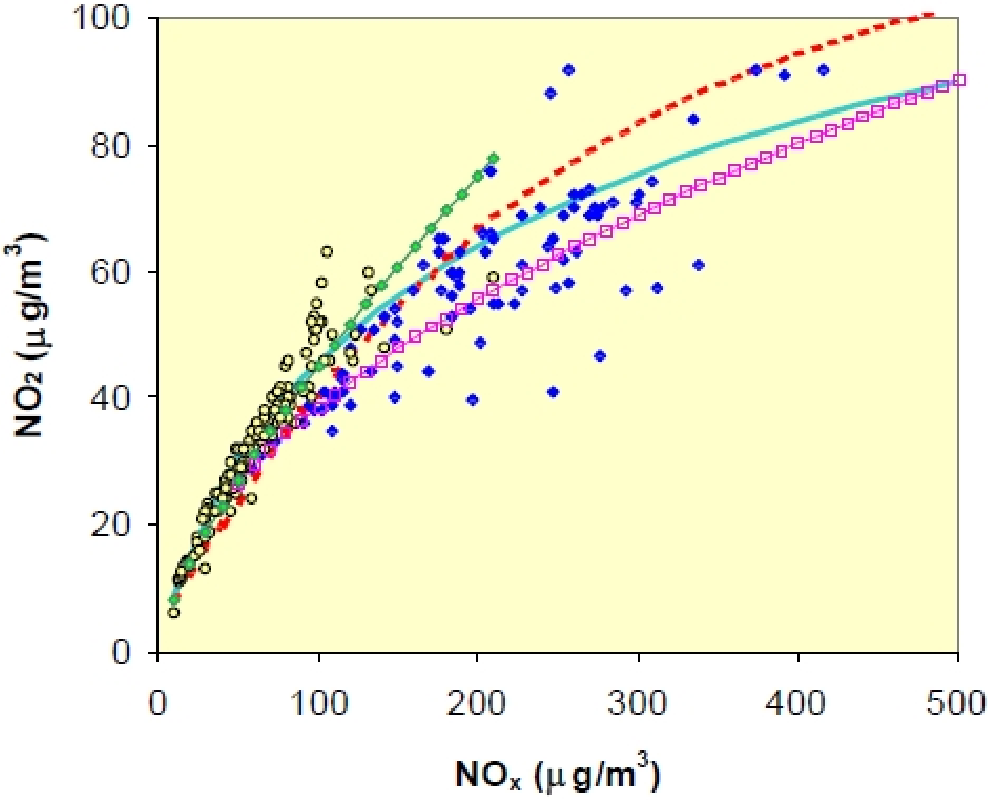

Figure 50 **Relationships Between Annual Mean NO_2 and NOx Concentrations (reproduced from (Laxen & Wilson, 2002))**

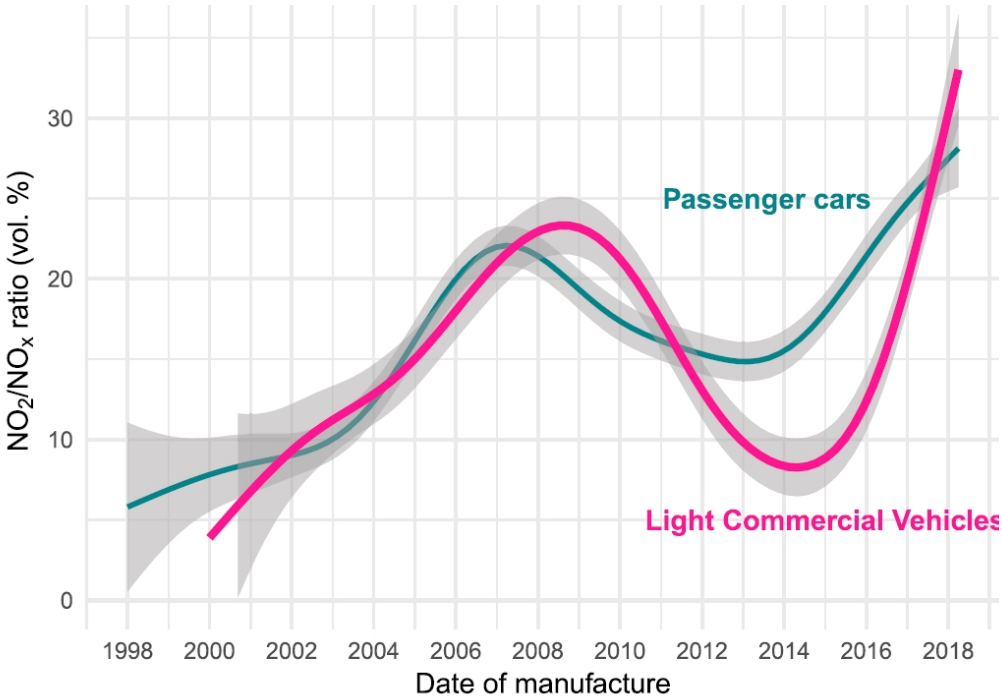

Figure 51 **NO_2:NOx ratio in emissions from diesel vehicles as a function of Date of Manufacture (reproduced from Carslaw et al (2019c))**

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7 Appendices

A1 Included sites 2005 to 2018

A1.1 Table A1.1 is a list of the sites included in the analyses set out in this report, together with the Network that they are part of and the categorisation by site type and geographic area.

Table A1.1 Sites Included in the Analyses for 2005 to 2018 and their Categorisation

Name	Code	Network	Type	Category	Area [a]
Aberdeen	ABD	AURN	Urban Background	Urban	1
Aston Hill	AH	AURN	Rural Background	Rural	3
Barnsley Gawber	BAR3	AURN	Urban Background	Urban	2
Bath Roadside	BATH	AURN	Urban Traffic	Road	3
Belfast Centre	BEL2	AURN	Urban Background	Urban	1
Blackpool Marton	BLC2	AURN	Urban Background	Urban	2
Bournemouth	BORN	AURN	Urban Background	Urban	3
Brighton Preston Park	BRT3	AURN	Urban Background	Urban	3
Bush Estate	BUSH	AURN	Rural Background	Rural	1
Cambridge Roadside	CAM	AURN	Urban Traffic	Road	2
Camden Kerbside	CA1	AURN	Urban Traffic	Road	3
Canterbury	CANT	AURN	Urban Background	Urban	3
Cardiff Centre	CARD	AURN	Urban Background	Urban	3
Cwmbran	CWMB	AURN	Urban Background	Urban	3
Dumfries	DUMF	AURN	Urban Traffic	Road	1
Edinburgh St Leonards	ED3	AURN	Urban Background	Urban	1
Eskdalemuir	ESK	AURN	Rural Background	Rural	1
Exeter Roadside	EX	AURN	Urban Traffic	Road	3
Glasgow Kerbside	GLA4	AURN	Urban Traffic	Road	1
Glazebury	GLAZ	AURN	Rural Background	Rural	2
Haringey Roadside	HG1	AURN	Urban Traffic	Road	3
High Muffles	HM	AURN	Rural Background	Rural	2
Hull Freetown	HUL2	AURN	Urban Background	Urban	2
Inverness	INV2	AURN	Urban Traffic	Road	1
Ladybower	LB	AURN	Rural Background	Rural	2
Leeds Centre	LEED	AURN	Urban Background	Urban	2
Leominster	LEOM	AURN	Suburban Background	Urban	3

Name	Code	Network	Type	Category	Area [a]
Liverpool Speke	LVP	AURN	Urban Industrial	Urban	2
London Bexley	BEX	AURN	Suburban Background	Urban	3
London Bloomsbury	CLL2	AURN	Urban Background	Urban	3
London Eltham	LON6	AURN	Suburban Background	Urban	3
London Harlington	HRL	AURN	Urban Industrial	Urban	3
London Hillingdon	HIL	AURN	Urban Background	Road	3
London Marylebone Road	MY1	AURN	Urban Traffic	Road	3
London N. Kensington	KC1	AURN	Urban Background	Urban	3
London Westminster	HORS	AURN	Urban Background	Urban	3
Lullington Heath	LH	AURN	Rural Background	Rural	3
Manchester Piccadilly	MAN3	AURN	Urban Background	Urban	2
Market Harborough	MKTH	AURN	Rural Background	Rural	2
Middlesbrough	MID	AURN	Urban Industrial	Urban	2
Narberth	PEMB	AURN	Rural Background	Rural	3
Newcastle Centre	NEWC	AURN	Urban Background	Urban	2
Nottingham Centre	NOTT	AURN	Urban Background	Urban	2
Oxford Centre Roadside	OX	AURN	Urban Traffic	Road	3
Plymouth Centre	PLYM	AURN	Urban Background	Urban	3
Portsmouth	PMTH	AURN	Urban Background	Urban	3
Preston	PRES	AURN	Urban Background	Urban	2
Reading New Town	REA1	AURN	Urban Background	Urban	3
Rochester Stoke	ROCH	AURN	Rural Background	Rural	3
Salford Eccles	ECCL	AURN	Urban Background	Urban	2
Sheffield Tinsley	SHE	AURN	Urban Background	Urban	2
Southampton Centre	SOUT	AURN	Urban Background	Urban	3
Southend-on-Sea	SEND	AURN	Urban Background	Urban	3
St Osyth	OSY	AURN	Rural Background	Rural	3
Stoke-on-Trent Centre	STOK	AURN	Urban Background	Urban	2
Sunderland Silksworth	SUN2	AURN	Urban Background	Urban	2
Thurrock	THUR	AURN	Urban Background	Urban	3
Tower Hamlets Roadside	TH2	AURN	Urban Traffic	Road	3
Wicken Fen	WFEN	AURN	Rural Background	Rural	2
Wigan Centre	WIG5	AURN	Urban Background	Urban	2

Name	Code	Network	Type	Category	Area [a]
Wrexham	WREX	AURN	Urban Traffic	Road	2
Yarner Wood	YW	AURN	Rural Background	Rural	3
Hillingdon 1 - South Ruislip	-	HAW	Roadside	Road	3
Hounslow 2 - Cranford	-	HAW	Suburban	Urban	3
Hounslow 4 - Chiswick High Road	-	HAW	Roadside	Road	3
Hounslow Brentford	-	HAW	Roadside	Road	3
Slough Chalvey M4	-	HAW	Roadside	Road	3
Slough Colnbrook	-	HAW	Urban Background	Urban	3
Slough Town Centre A4	-	HAW	Roadside	Road	3
Chatham Roadside	-	KA	Roadside	Road	3
Maidstone Rural	-	KA	Rural	Rural	3
Thanet Ramsgate Roadside	-	KA	Roadside	Road	3
Barking and Dagenham - Rush Green	BG1	KCL	Suburban	Urban	3
Bexley - Belvedere	BX2	KCL	Suburban	Urban	3
Chichester - A27 Chichester Bypass	CI1	KCL	Roadside	Road	3
City of London - Sir John Cass School	CT3	KCL	Urban Background	Urban	3
Crawley - Gatwick Airport	CA2	KCL	Urban Background	Urban	3
Croydon - Norbury	CR5	KCL	Kerbside	Road	3
Dartford - St Clements	ZR1	KCL	Kerbside	Road	3
Dartford Roadside 2 - Town Centre	ZR2	KCL	Roadside	Road	3
Dartford Roadside 3 - Bean Interchange	ZR3	KCL	Roadside	Road	3
Ealing - Hanger Lane Gyratory	EA6	KCL	Roadside	Road	3
Eastbourne - Devonshire Park	EB1	KCL	Urban Background	Urban	3
Enfield - Derby Road	EN4	KCL	Roadside	Road	3
Greenwich - A206 Burrage Grove	GN0	KCL	Roadside	Road	3
Greenwich - Blackheath	GR7	KCL	Roadside	Road	3
Greenwich - Falconwood	GB6	KCL	Roadside	Road	3

Name	Code	Network	Type	Category	Area [a]
Greenwich - Westhorne Avenue	GR9	KCL	Roadside	Road	3
Greenwich - Woolwich Flyover	GR8	KCL	Roadside	Road	3
Hackney - Old Street	HK6	KCL	Roadside	Road	3
Harrow - Pinner Road	HR2	KCL	Roadside	Road	3
Hastings - Bulverhythe	HT1	KCL	Roadside	Road	3
Havering - Rainham	HV1	KCL	Roadside	Road	3
Horsham - Park Way	HO2	KCL	Roadside	Road	3
Islington - Holloway Road	IS2	KCL	Roadside	Road	3
Lambeth - Bondway Interchange	LB5	KCL	Industrial	Road	3
Lewisham - New Cross	LW2	KCL	Roadside	Road	3
Redbridge - Gardner Close	RB4	KCL	Roadside	Road	3
Reigate and Banstead - Poles Lane	RG3	KCL	Rural	Rural	3
Richmond Upon Thames - Barnes Wetlands	RI2	KCL	Suburban	Urban	3
Richmond Upon Thames - Castelnau	RI1	KCL	Roadside	Road	3
Sevenoaks - Bat and Ball	ZV2	KCL	Roadside	Road	3
Sevenoaks - Greatness Park	ZV1	KCL	Urban Background	Urban	3
Sutton - Wallington	ST4	KCL	Kerbside	Road	3
Tunbridge Wells Roadside - St Johns	ZT4	KCL	Roadside	Road	3
Windsor and Maidenhead - Clarence Road	MW2	KCL	Roadside	Road	3
Windsor and Maidenhead - Frascati Way	MW1	KCL	Roadside	Road	3
East Dunbartonshire Bearsden	EDB2	SAQN	Roadside	Road	1
East Dunbartonshire Bishopbriggs	EDB1	SAQN	Roadside	Road	1
Glasgow Byres Road	GLA6	SAQN	Roadside	Road	1
Perth Atholl Street	PET2	SAQN	Roadside	Road	1
Perth High Street	PETH	SAQN	Roadside	Road	1

[a] Area – (1) Scotland and Northern Ireland, (2) Central & Northern England + North Wales, (3) Southern England and Southern Wales

A2 Included sites 2010 to 2018

A2.1 Table A2.1 is a list of the sites included in the analyses set out in this report, together with the Network that they are part of and the categorisation by site type and geographic area.

Table A2.1 Sites Included in the Analyses for 2010 to 2018 and their Categorisation

Name	Code	Network	Type	Category	Area [a]
Aberdeen	ABD	AURN	Urban Background	Urban	1
Aberdeen Union Street Roadside	ABD7	AURN	Urban Traffic	Road	1
Armagh Roadside	ARM6	AURN	Urban Traffic	Road	1
Aston Hill	AH	AURN	Rural Background	Rural	3
Barnsley Gawber	BAR3	AURN	Urban Background	Urban	2
Bath Roadside	BATH	AURN	Urban Traffic	Road	3
Belfast Centre	BEL2	AURN	Urban Background	Urban	1
Bournemouth	BORN	AURN	Urban Background	Urban	3
Brighton Preston Park	BRT3	AURN	Urban Background	Urban	3
Bristol St Paul's	BRS8	AURN	Urban Background	Urban	3
Bush Estate	BUSH	AURN	Rural Background	Rural	1
Cambridge Roadside	CAM	AURN	Urban Traffic	Road	2
Camden Kerbside	CA1	AURN	Urban Traffic	Road	3
Canterbury	CANT	AURN	Urban Background	Urban	3
Cardiff Centre	CARD	AURN	Urban Background	Urban	3
Carlisle Roadside	CARL	AURN	Urban Traffic	Road	2
Charlton Mackrell	MACK	AURN	Rural Background	Rural	3
Chatham Roadside	CHAT	AURN	Urban Traffic	Road	3
Chepstow A48	CHP	AURN	Urban Traffic	Road	3
Chesterfield Roadside	CHS7	AURN	Urban Traffic	Road	2
Cwmbran	CWMB	AURN	Urban Background	Urban	3
Dumbarton Roadside	DUMB	AURN	Urban Traffic	Road	1
Dumfries	DUMF	AURN	Urban Traffic	Road	1
Edinburgh St Leonards	ED3	AURN	Urban Background	Urban	1
Eskdalemuir	ESK	AURN	Rural Background	Rural	1
Exeter Roadside	EX	AURN	Urban Traffic	Road	3

Name	Code	Network	Type	Category	Area [a]
Fort William	FW	AURN	Suburban Background	Urban	1
Glasgow Kerbside	GLA4	AURN	Urban Traffic	Road	1
Glazebury	GLAZ	AURN	Rural Background	Rural	2
Haringey Roadside	HG1	AURN	Urban Traffic	Road	3
High Muffles	HM	AURN	Rural Background	Rural	2
Horley	HORE	AURN	Suburban Industrial	Urban	3
Hull Freetown	HUL2	AURN	Urban Background	Urban	2
Inverness	INV2	AURN	Urban Traffic	Road	1
Ladybower	LB	AURN	Rural Background	Rural	2
Leamington Spa	LEAM	AURN	Urban Background	Urban	3
Leeds Centre	LEED	AURN	Urban Background	Urban	2
Leeds Headingley Kerbside	LED6	AURN	Urban Traffic	Road	2
Leominster	LEOM	AURN	Suburban Background	Urban	3
Liverpool Speke	LVP	AURN	Urban Industrial	Urban	2
London Bexley	BEX	AURN	Suburban Background	Urban	3
London Bloomsbury	CLL2	AURN	Urban Background	Urban	3
London Eltham	LON6	AURN	Suburban Background	Urban	3
London Harlington	HRL	AURN	Urban Industrial	Urban	3
London Hillingdon	HIL	AURN	Urban Background	Road	3
London Marylebone Road	MY1	AURN	Urban Traffic	Road	3
London N. Kensington	KC1	AURN	Urban Background	Urban	3
London Westminster	HORS	AURN	Urban Background	Urban	3
Lullington Heath	LH	AURN	Rural Background	Rural	3
Manchester Piccadilly	MAN3	AURN	Urban Background	Urban	2
Market Harborough	MKTH	AURN	Rural Background	Rural	2
Middlesbrough	MID	AURN	Urban Industrial	Urban	2
Narberth	PEMB	AURN	Rural Background	Rural	3
Newcastle Centre	NEWC	AURN	Urban Background	Urban	2
Newcastle Cradlewell Roadside	NCA3	AURN	Urban Traffic	Road	2
Norwich Lakenfields	NO12	AURN	Urban Background	Urban	2
Nottingham Centre	NOTT	AURN	Urban Background	Urban	2

Name	Code	Network	Type	Category	Area [a]
Oxford Centre Roadside	OX	AURN	Urban Traffic	Road	3
Oxford St Ebbes	OX8	AURN	Urban Background	Urban	3
Peebles	PEEB	AURN	Urban Background	Urban	1
Plymouth Centre	PLYM	AURN	Urban Background	Urban	3
Portsmouth	PMTH	AURN	Urban Background	Urban	3
Preston	PRES	AURN	Urban Background	Urban	2
Reading New Town	REA1	AURN	Urban Background	Urban	3
Rochester Stoke	ROCH	AURN	Rural Background	Rural	3
Salford Eccles	ECCL	AURN	Urban Background	Urban	2
Sandy Roadside	SDY	AURN	Urban Traffic	Road	2
Sheffield Tinsley	SHE	AURN	Urban Background	Urban	2
Southampton Centre	SOUT	AURN	Urban Background	Urban	3
St Osyth	OSY	AURN	Rural Background	Rural	3
Stanford-le-Hope Roadside	HOPE	AURN	Urban Traffic	Road	3
Stockton-on-Tees Eaglescliffe	EAGL	AURN	Urban Traffic	Road	2
Stoke-on-Trent Centre	STOK	AURN	Urban Background	Urban	2
Storrington Roadside	STOR	AURN	Urban Traffic	Road	3
Sunderland Silksworth	SUN2	AURN	Urban Background	Urban	2
Swansea Roadside	SWA1	AURN	Urban Traffic	Road	3
Thurrock	THUR	AURN	Urban Background	Urban	3
Tower Hamlets Roadside	TH2	AURN	Urban Traffic	Road	3
Wicken Fen	WFEN	AURN	Rural Background	Rural	2
Wigan Centre	WIG5	AURN	Urban Background	Urban	2
Wrexham	WREX	AURN	Urban Traffic	Road	2
Yarner Wood	YW	AURN	Rural Background	Rural	3
York Fishergate	YK11	AURN	Urban Traffic	Road	2
Hillingdon 1 - South Ruislip	-	HAW	Roadside	Road	3
Hillingdon Hayes	-	HAW	Roadside	Road	3
Hillingdon Sipson	-	HAW	Suburban	Urban	3
Hounslow 2 - Cranford	-	HAW	Suburban	Urban	3
Hounslow Brentford	-	HAW	Roadside	Road	3
Hounslow Heston Road	-	HAW	Roadside	Road	3

Name	Code	Network	Type	Category	Area [a]
London Hillingdon Harmondsworth	-	HAW	Suburban	Urban	3
London Hillingdon Oxford Avenue	-	HAW	Roadside	Road	3
Slough Chalvey M4	-	HAW	Roadside	Road	3
Slough Colnbrook	-	HAW	Urban Background	Urban	3
Slough Town Centre A4	-	HAW	Roadside	Road	3
Maidstone Rural	-	KA	Rural	Rural	3
Thanet Ramsgate Roadside	-	KA	Roadside	Road	3
Barking and Dagenham - Rush Green	BG1	KCL	Suburban	Urban	3
Barking and Dagenham - Scrattons Farm	BG2	KCL	Suburban	Urban	3
Bexley - Belvedere	BX2	KCL	Suburban	Urban	3
Bexley - Belvedere West	BQ7	KCL	Urban Background	Urban	3
Chichester - A27 Chichester Bypass	CI1	KCL	Roadside	Road	3
City of London - Sir John Cass School	CT3	KCL	Urban Background	Urban	3
City of London - Walbrook Wharf	CT6	KCL	Roadside	Road	3
Crawley - Gatwick Airport	CA2	KCL	Urban Background	Urban	3
Croydon - Norbury	CR5	KCL	Kerbside	Road	3
Dartford - St Clements	ZR1	KCL	Kerbside	Road	3
Dartford Roadside 2 - Town Centre	ZR2	KCL	Roadside	Road	3
Dartford Roadside 3 - Bean Interchange	ZR3	KCL	Roadside	Road	3
Ealing - Hanger Lane Gyratory	EA6	KCL	Roadside	Road	3
Ealing - Western Avenue	EI1	KCL	Roadside	Road	3
Enfield - Bowes Primary School	EN5	KCL	Roadside	Road	3
Enfield - Derby Road	EN4	KCL	Roadside	Road	3
Greenwich - A206 Burrage Grove	GN0	KCL	Roadside	Road	3
Greenwich - Blackheath	GR7	KCL	Roadside	Road	3
Greenwich - Falconwood	GB6	KCL	Roadside	Road	3

Name	Code	Network	Type	Category	Area [a]
Greenwich - Plumstead High Street	GN3	KCL	Roadside	Road	3
Greenwich - Westhorne Avenue	GR9	KCL	Roadside	Road	3
Greenwich - Woolwich Flyover	GR8	KCL	Roadside	Road	3
Hackney - Old Street	HK6	KCL	Roadside	Road	3
Harrow - Pinner Road	HR2	KCL	Roadside	Road	3
Hastings - Bulverhythe	HT1	KCL	Roadside	Road	3
Havering - Rainham	HV1	KCL	Roadside	Road	3
Horsham - Cowfold	HO5	KCL	Roadside	Road	3
Horsham - Park Way	HO2	KCL	Roadside	Road	3
Islington - Arsenal	IS6	KCL	Urban Background	Urban	3
Islington - Holloway Road	IS2	KCL	Roadside	Road	3
Lambeth - Bondway Interchange	LB5	KCL	Industrial	Road	3
Lambeth - Streatham Green	LB6	KCL	Urban Background	Urban	3
Lewisham - New Cross	LW2	KCL	Roadside	Road	3
Redbridge - Gardner Close	RB4	KCL	Roadside	Road	3
Reigate and Banstead - Poles Lane	RG3	KCL	Rural	Rural	3
Richmond Upon Thames - Barnes Wetlands	RI2	KCL	Suburban	Urban	3
Richmond Upon Thames - Castelnau	RI1	KCL	Roadside	Road	3
Rother - De La Warr Road	RY2	KCL	Roadside	Road	3
Sevenoaks - Bat and Ball	ZV2	KCL	Roadside	Road	3
Sevenoaks - Greatness Park	ZV1	KCL	Urban Background	Urban	3
Southampton - Onslow Road	SH3	KCL	Roadside	Road	3
Sutton - Worcester Park	ST6	KCL	Kerbside	Road	3
Thurrock - Calcutta Road Tilbury	TK4	KCL	Roadside	Road	3
Thurrock - London Road (Purfleet)	TK8	KCL	Roadside	Road	3
Tower Hamlets - Blackwall	TH4	KCL	Roadside	Road	3

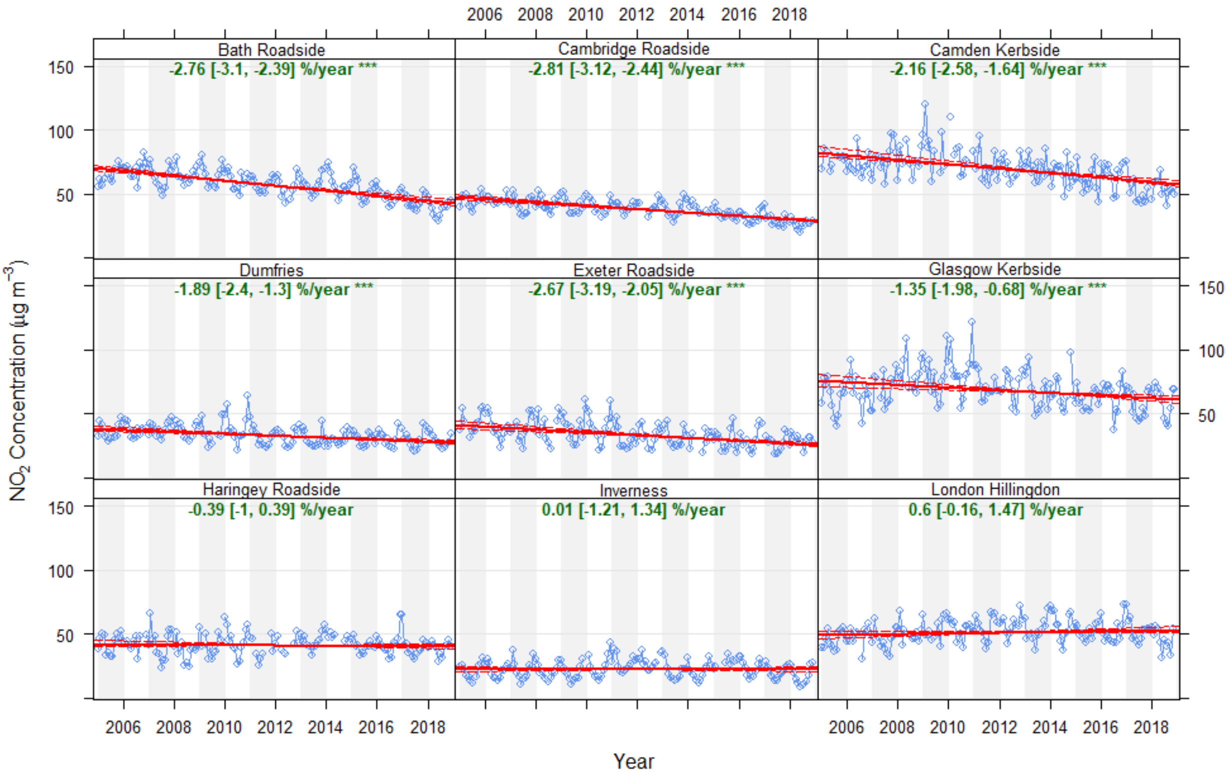
Name	Code	Network	Type	Category	Area [a]
Tunbridge Wells Roadside - St Johns	ZT4	KCL	Roadside	Road	3
Wandsworth - Putney High Street	WA7	KCL	Kerbside	Road	3
Wandsworth - Putney High Street Facade	WA8	KCL	Roadside	Road	3
Windsor and Maidenhead - Clarence Road	MW2	KCL	Roadside	Road	3
Windsor and Maidenhead - Frascati Way	MW1	KCL	Roadside	Road	3
Aberdeen Anderson Dr	ABD1	SAQN	Roadside	Road	1
Aberdeen King Street	AD1	SAQN	Roadside	Road	1
Aberdeen Market Street 2	ABD0	SAQN	Roadside	Road	1
Dundee Lochee Road	DUN6	SAQN	Kerbside	Road	1
Dundee Seagate	DUN5	SAQN	Kerbside	Road	1
Dundee Whitehall Street	DUN7	SAQN	Roadside	Road	1
East Dunbartonshire Bearsden	EDB2	SAQN	Roadside	Road	1
East Dunbartonshire Bishopbriggs	EDB1	SAQN	Roadside	Road	1
East Dunbartonshire Kirkintilloch	EDB3	SAQN	Roadside	Road	1
East Lothian Musselburgh N High St	MUSS	SAQN	Roadside	Road	1
Edinburgh Gorgie Road	ED5	SAQN	Roadside	Road	1
Edinburgh Salamander St	ED8	SAQN	Roadside	Road	1
Edinburgh St John's Road	ED1	SAQN	Kerbside	Road	1
Falkirk Grangemouth MC	FALK	SAQN	Urban Background	Urban	1
Falkirk Haggs	FAL5	SAQN	Roadside	Road	1
Falkirk Hope St	FAL3	SAQN	Roadside	Road	1
Falkirk West Bridge Street	FAL6	SAQN	Roadside	Road	1
Fife Cupar	CUPA	SAQN	Roadside	Road	1
Fife Dunfermline	DUNF	SAQN	Roadside	Road	1
Fife Rosyth	ROSY	SAQN	Roadside	Road	1
Glasgow Byres Road	GLA6	SAQN	Roadside	Road	1
N Lanarkshire Chapelhall	NL3	SAQN	Roadside	Road	1
North Ayrshire Irvine High St	IRV	SAQN	Kerbside	Road	1

Name	Code	Network	Type	Category	Area [a]
Paisley Gordon Street	PAI3	SAQN	Roadside	Road	1
Perth Atholl Street	PET2	SAQN	Roadside	Road	1
Perth Crieff	PET1	SAQN	Roadside	Road	1
Perth High Street	PETH	SAQN	Roadside	Road	1
South Lanarkshire East Kilbride	EK0	SAQN	Roadside	Road	1
West Dunbartonshire Clydebank	WDB3	SAQN	Roadside	Road	1
West Lothian Broxburn	BRX	SAQN	Roadside	Road	1
Caerphilly Blackwood High Street	CAE5	WAQN	Roadside	Road	3
Caerphilly White Street	CAE4	WAQN	Roadside	Road	3
Rhondda-Cynon-Taf Broadway	RHD4	WAQN	Roadside	Road	3
Swansea Cwm Level Park	SWA9	WAQN	Urban Background	Urban	3
Swansea Hafod DOAS	SWA7	WAQN	Roadside	Road	3
Swansea Morriston Roadside	SWA5	WAQN	Roadside	Road	3

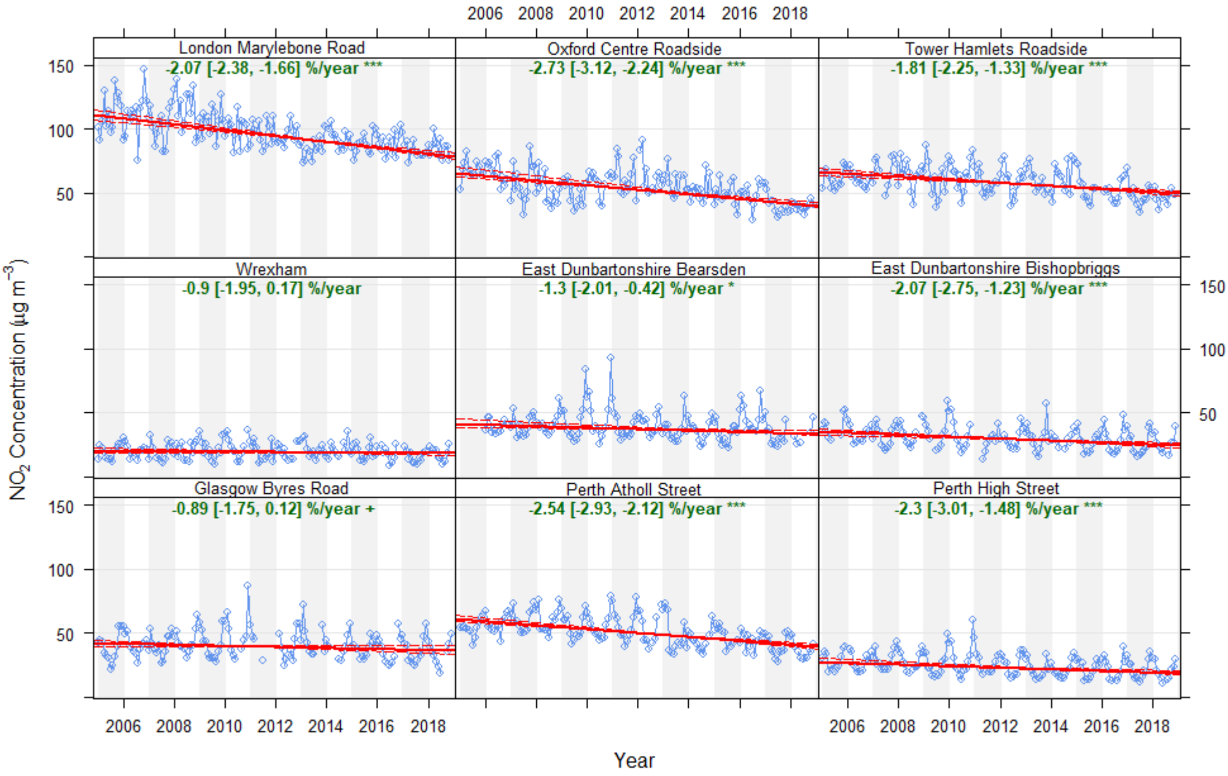
A3 Plots for Individual Sites 2005 to 2018

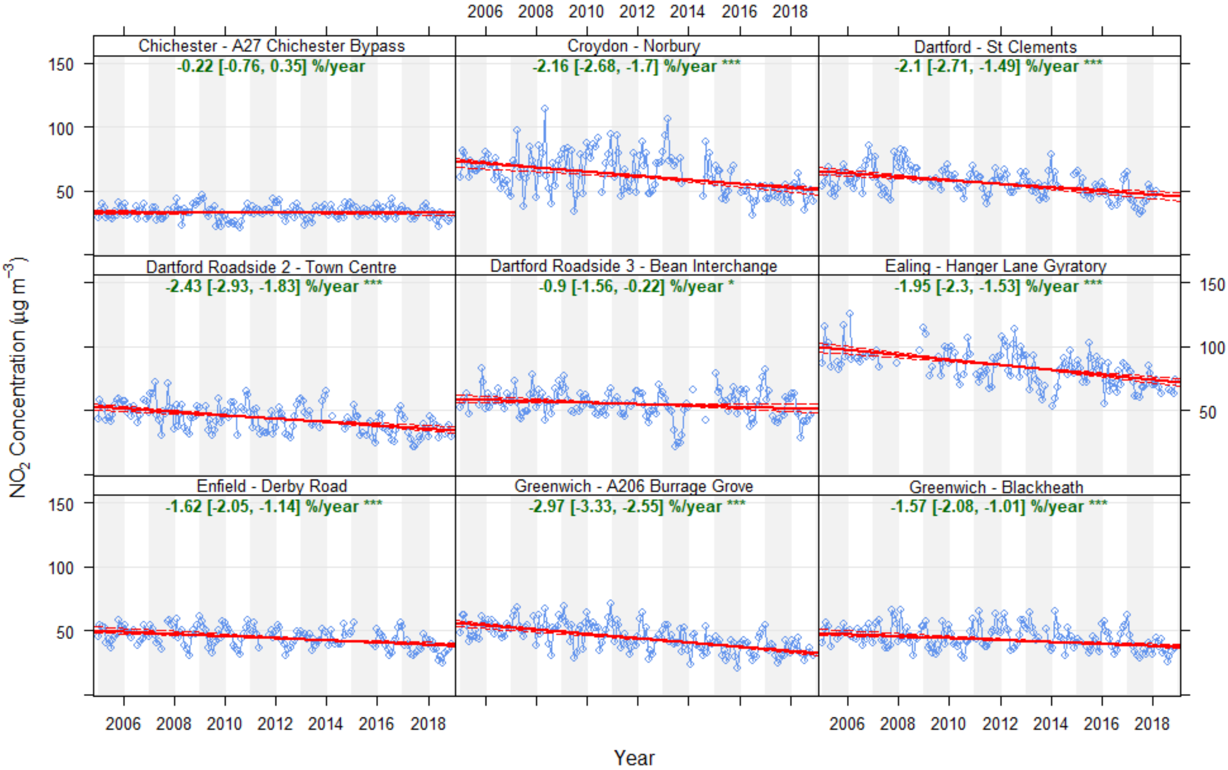
A3.1 This appendix sets out the Theil-Sen plots for the individual sites included in the analyses presented in this report. The numbers at the top of each graph show the trend and the confidence interval, and the significance of the trend, as follows: *** for p=0.001, ** for p=0.01, * for p=0.05 and + for p=0.1. The trends are shown as % per year.

Road Sites NO_2 2005 to 2018

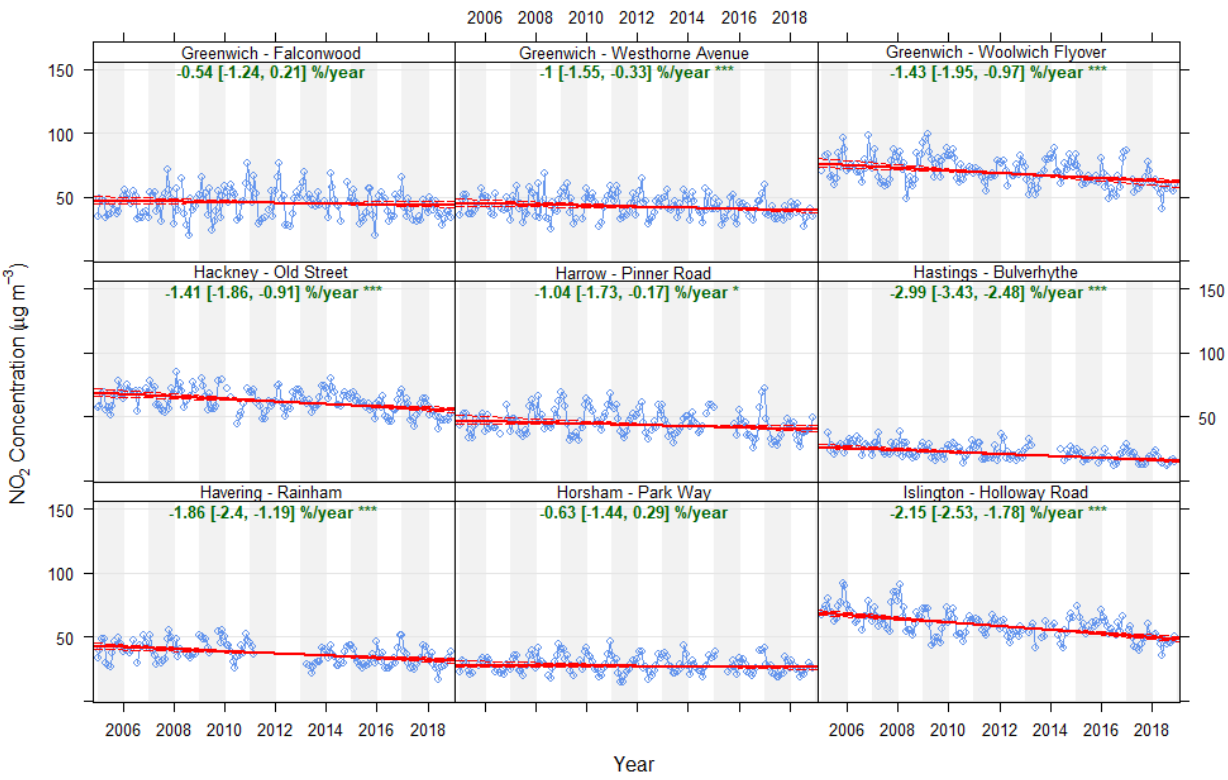


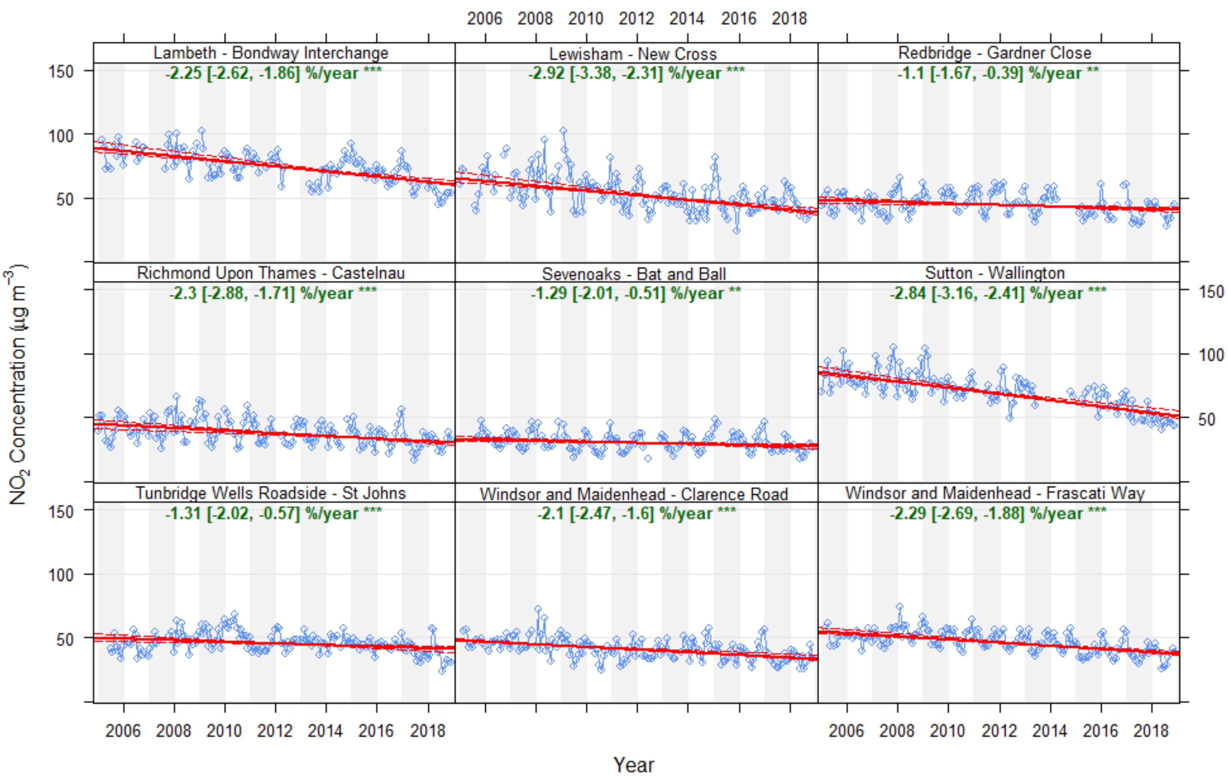
Road Sites NO_2 2005 to 2018



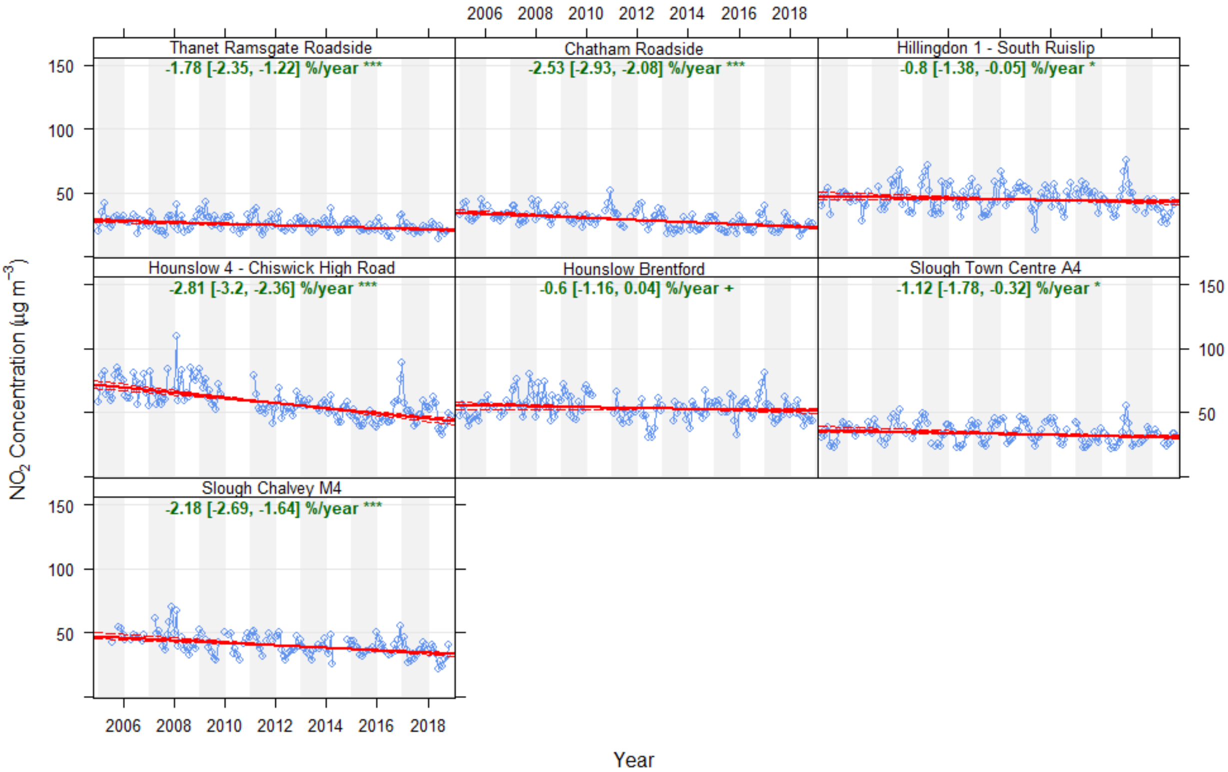


Road Sites NO_2 2005 to 2018

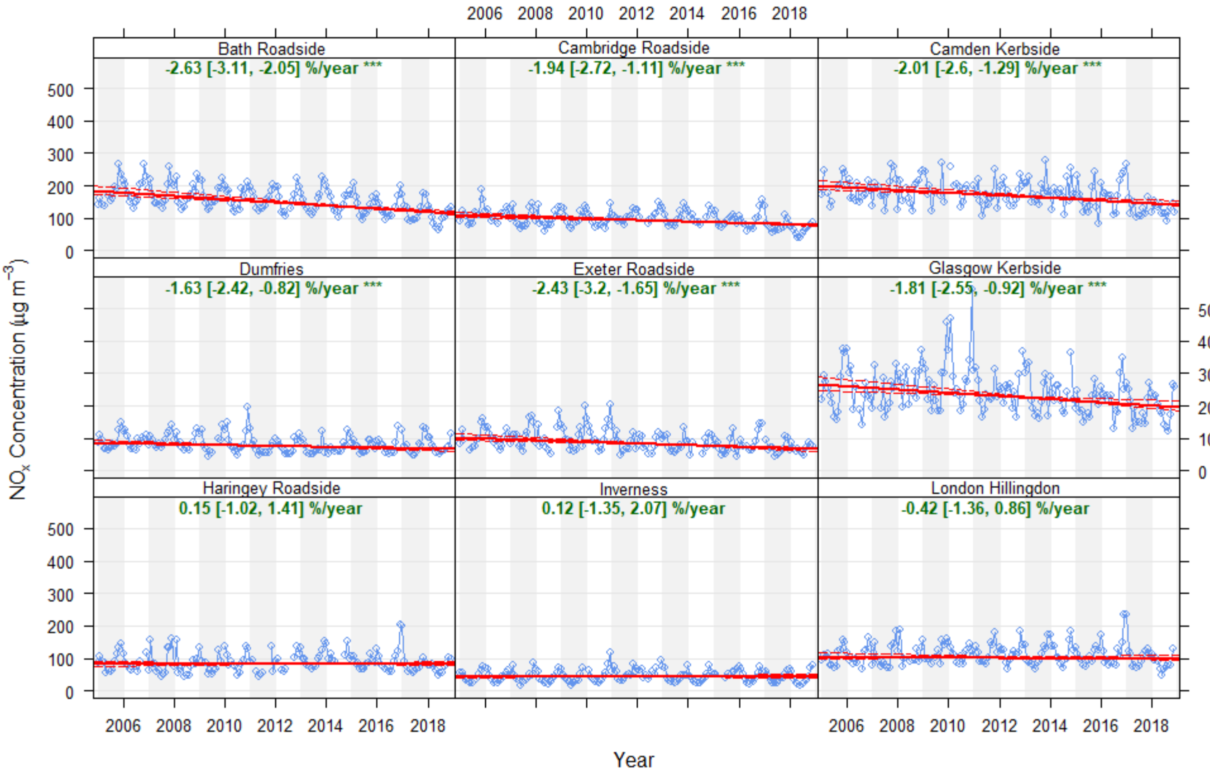


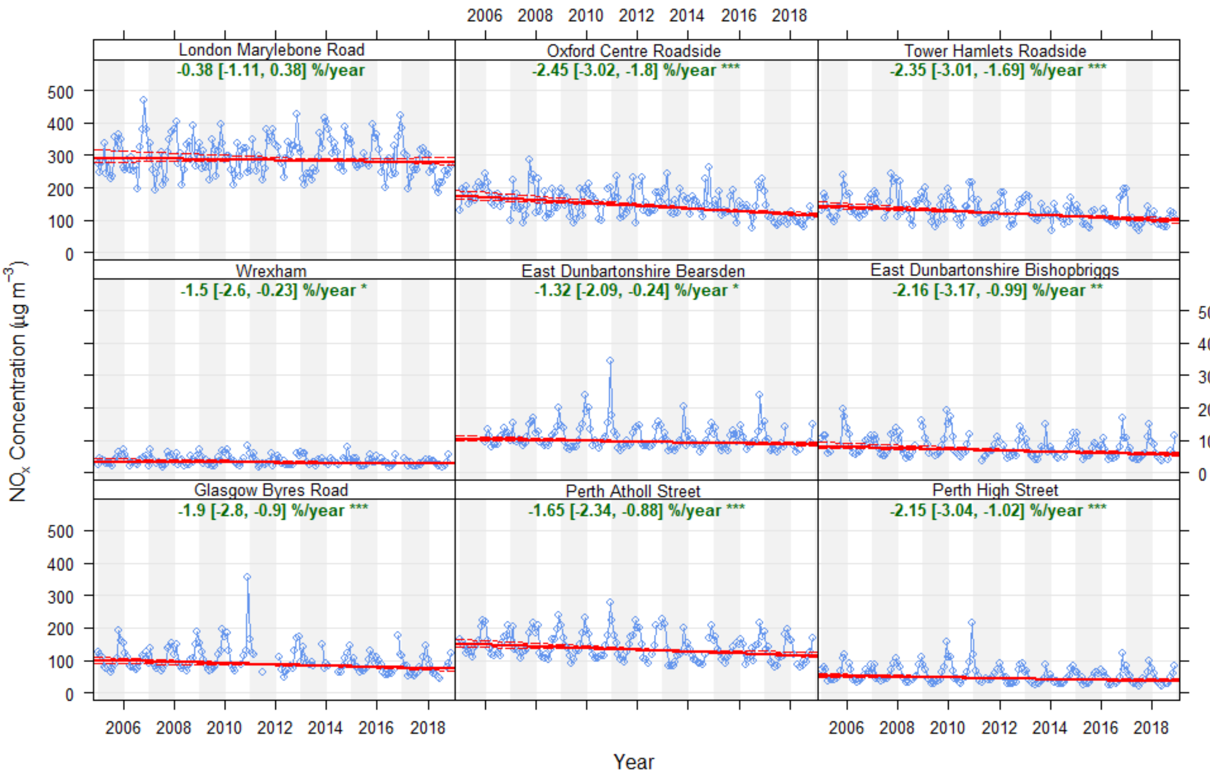


Road Sites NO_2 2005 to 2018

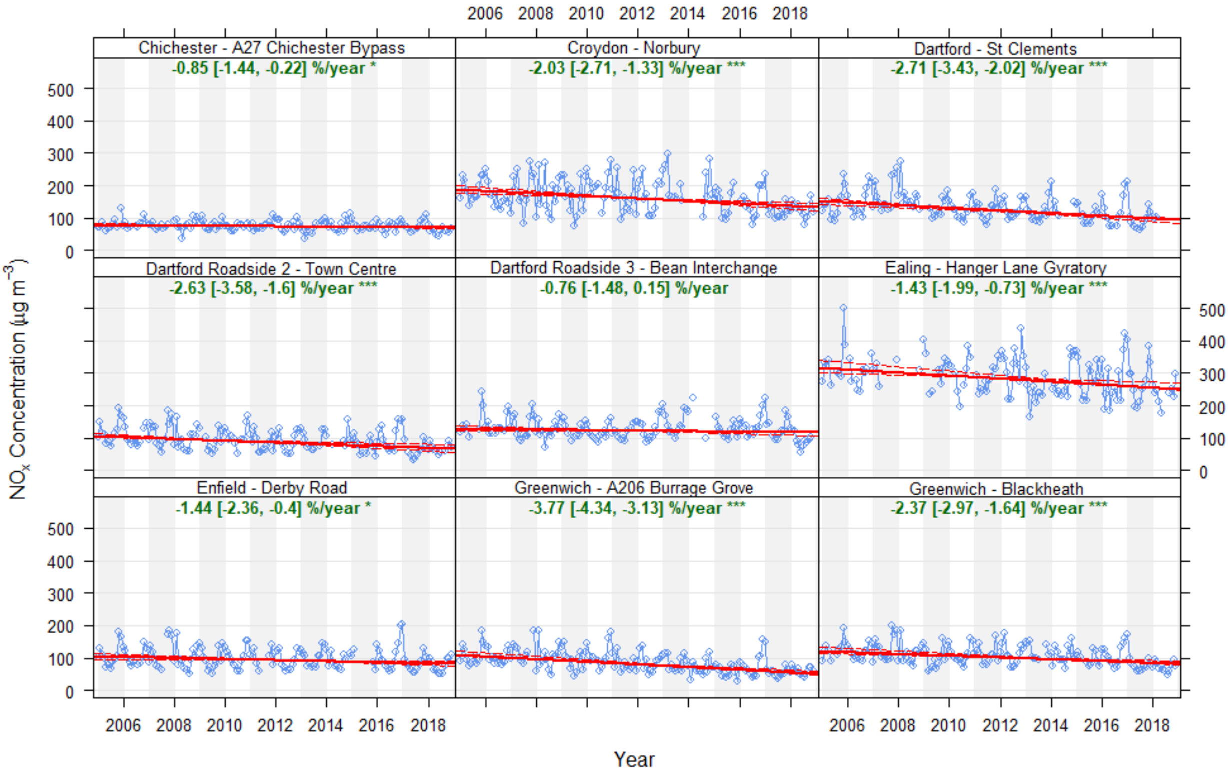


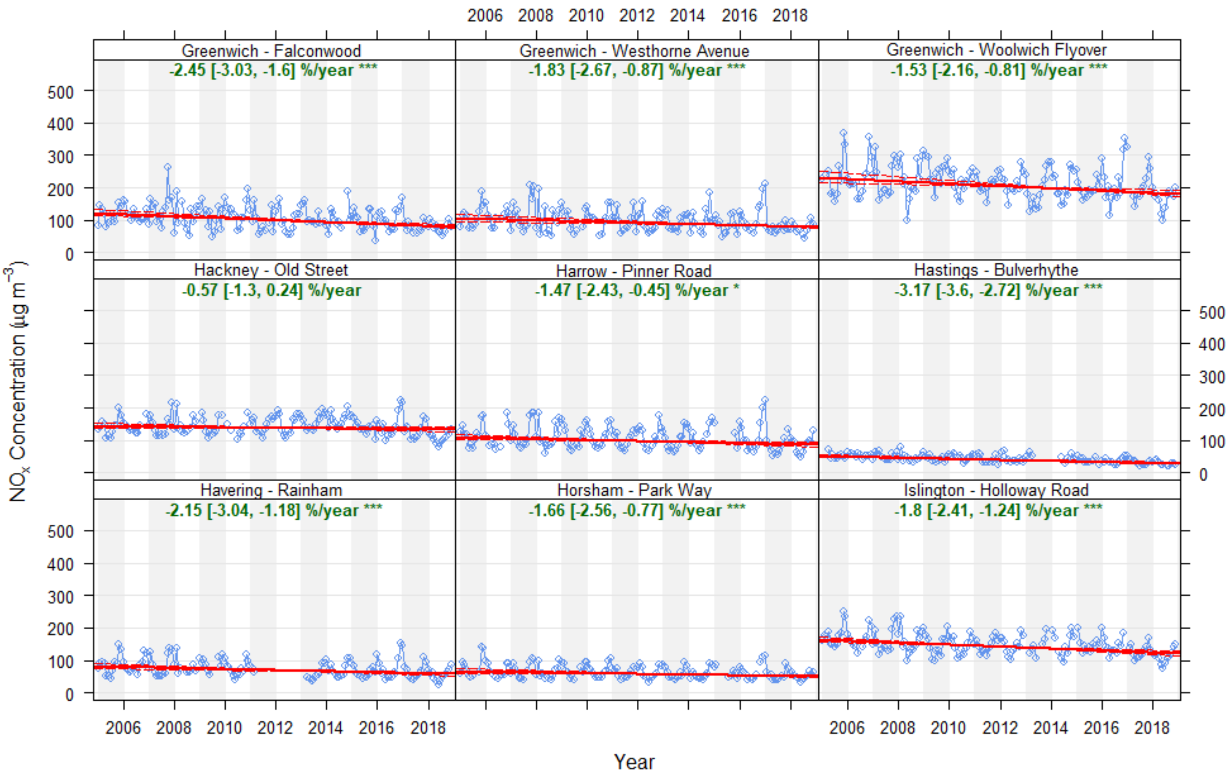
Road Sites NOx 2005 to 2018



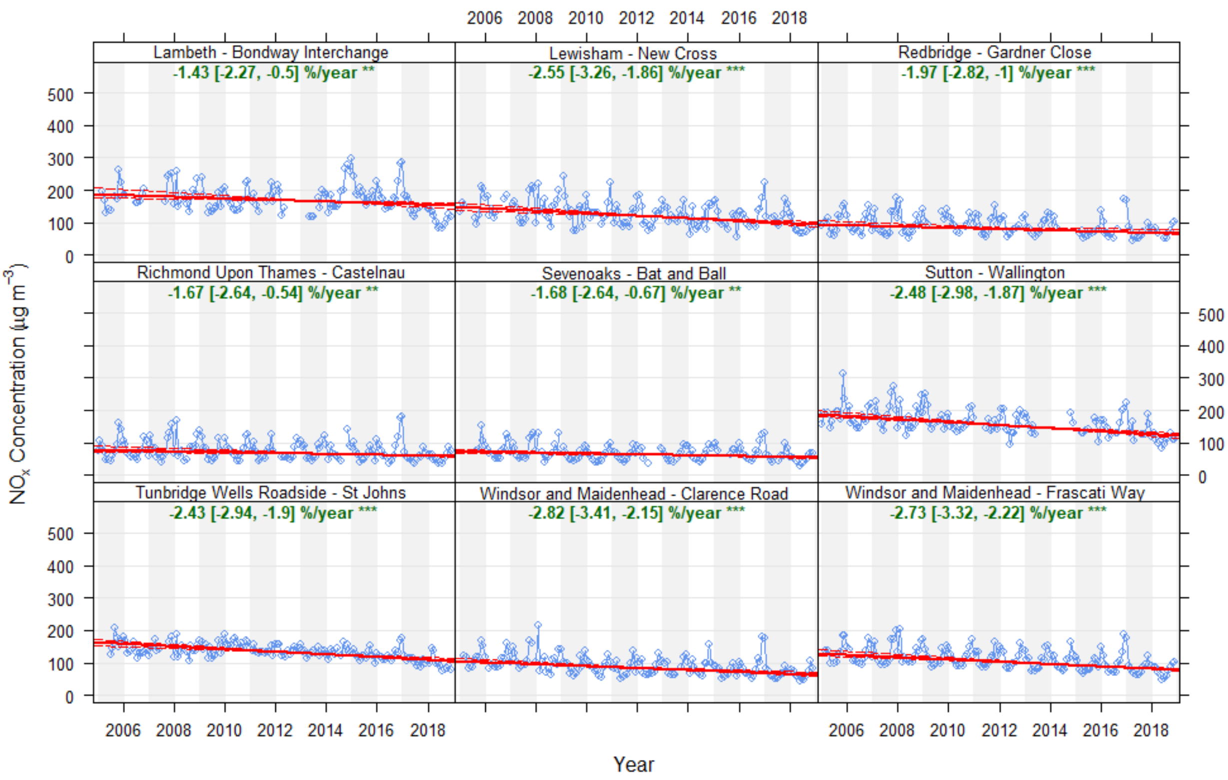


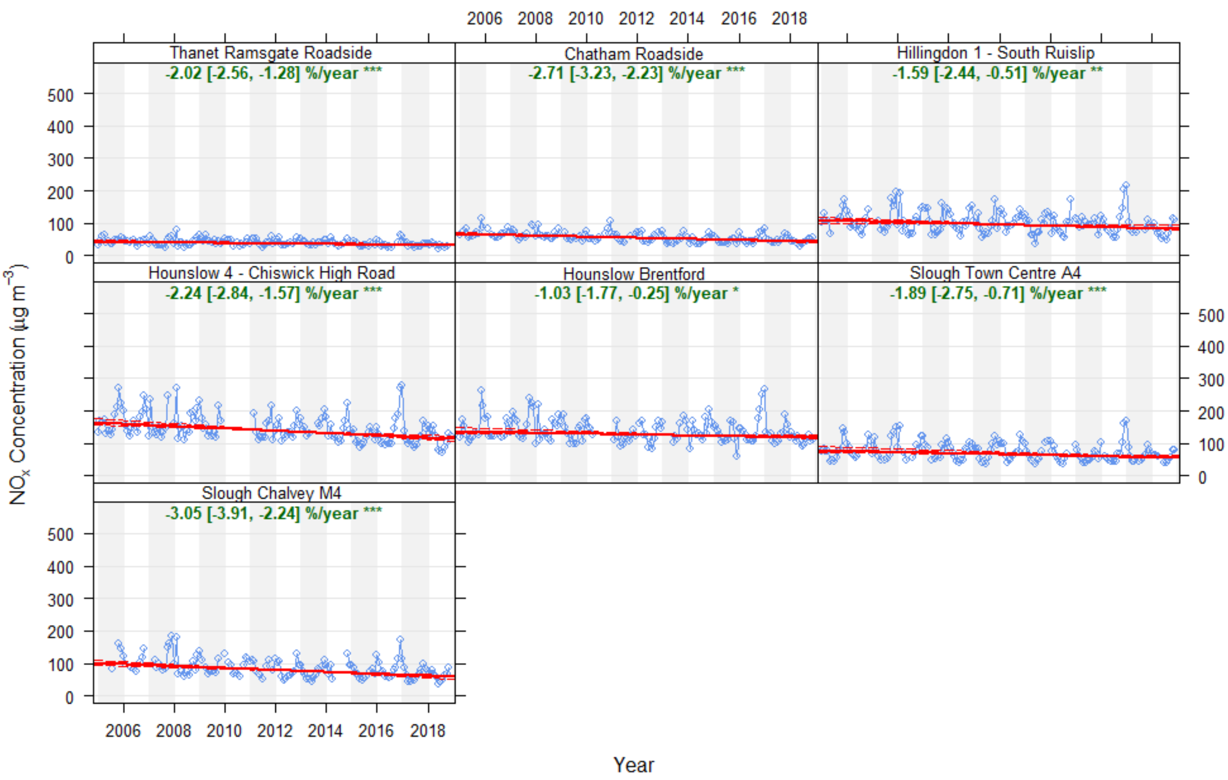
Road Sites NOx 2005 to 2018



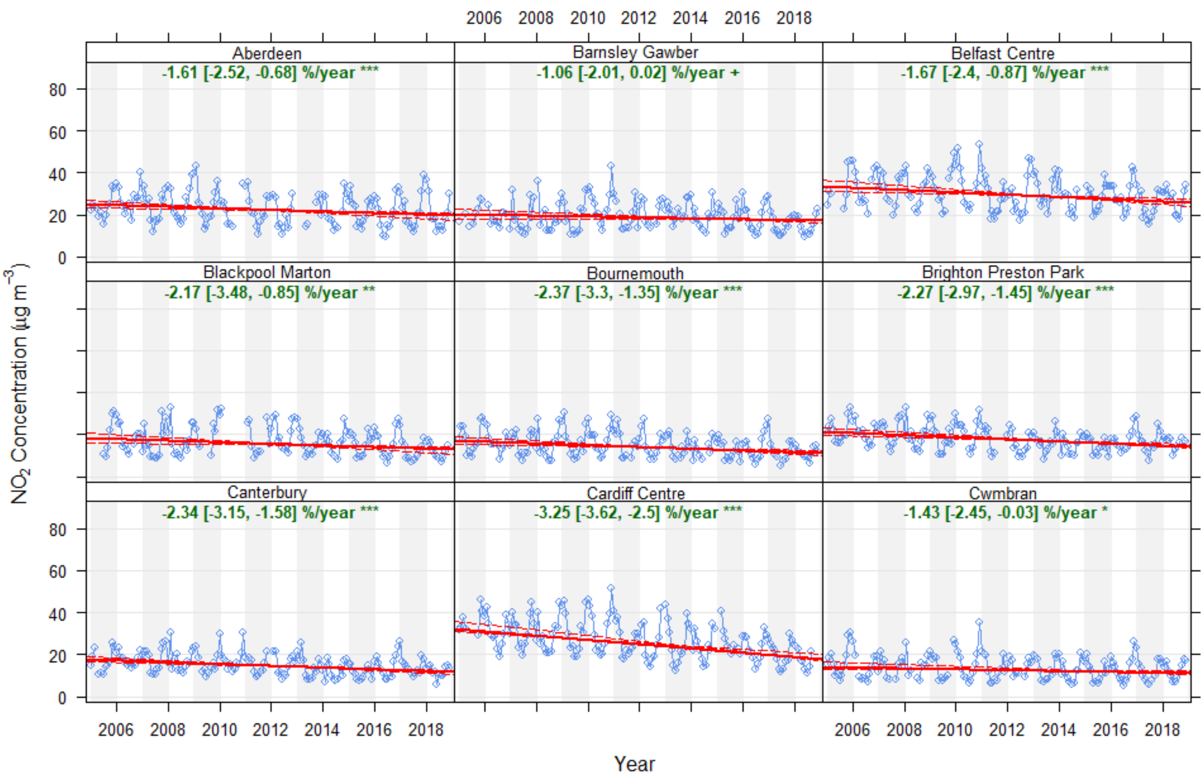


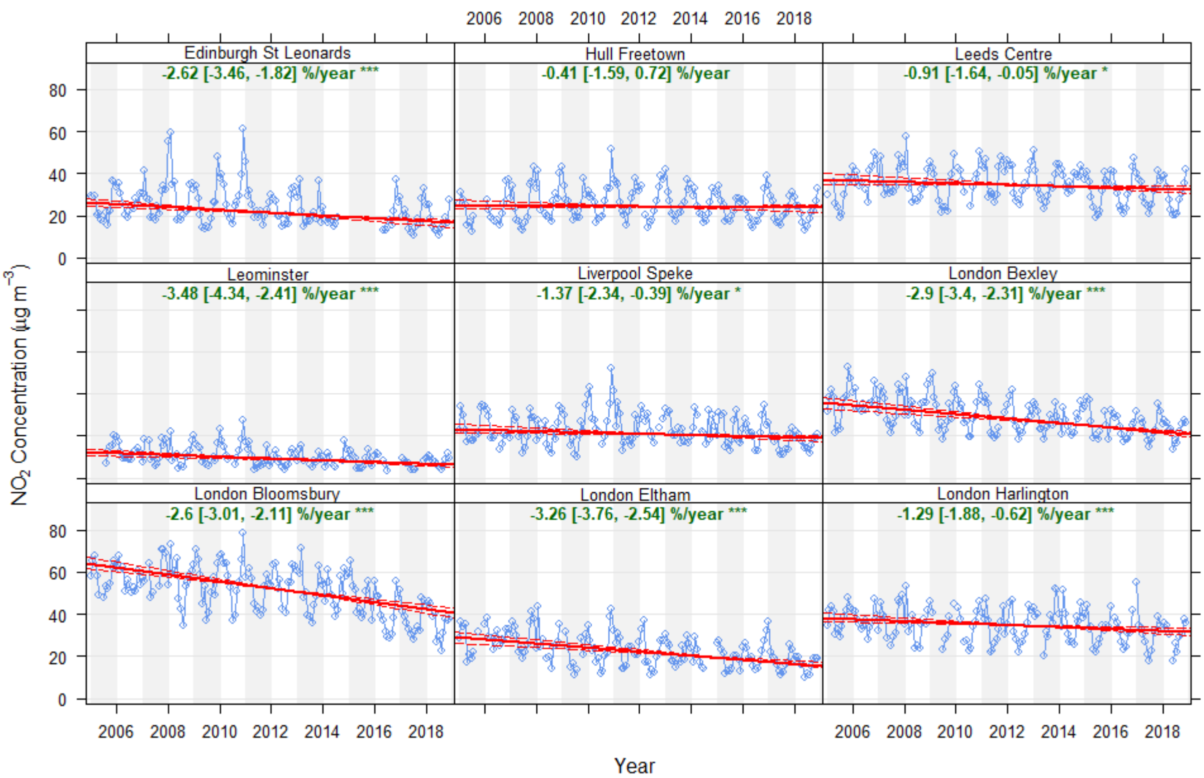
Road Sites NOx 2005 to 2018



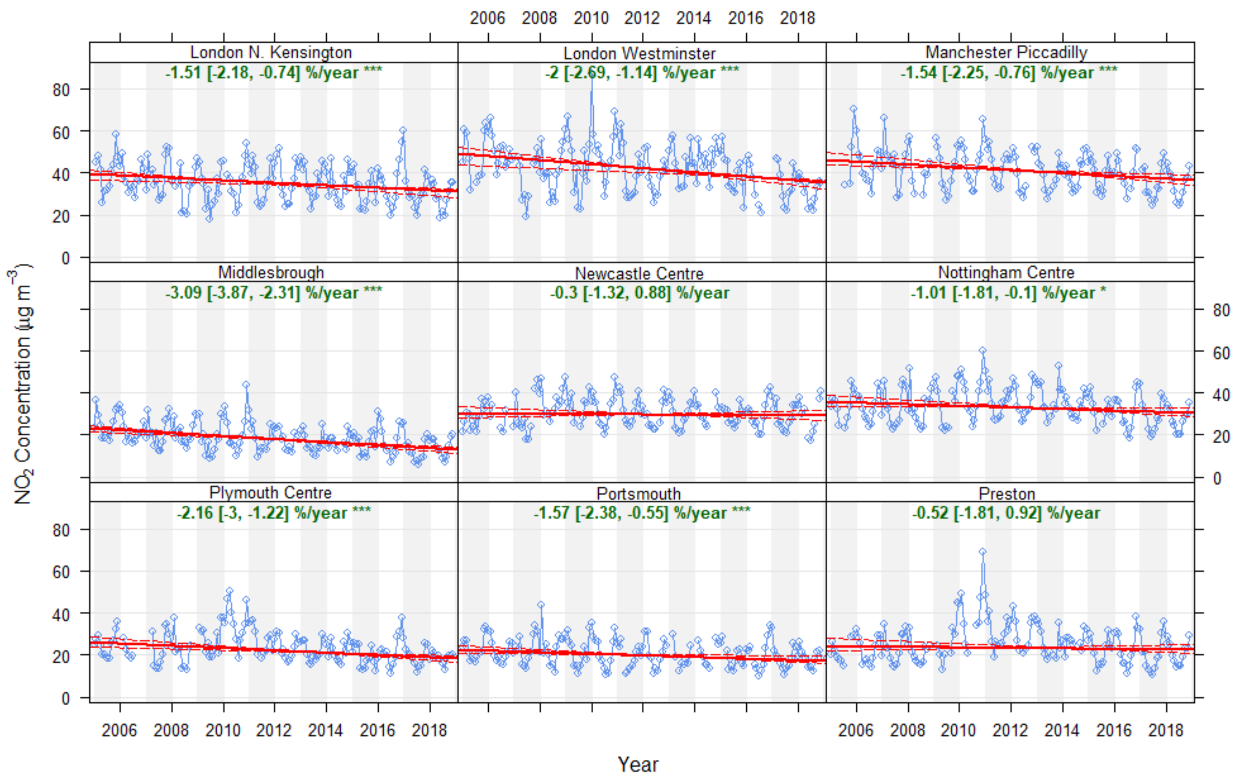


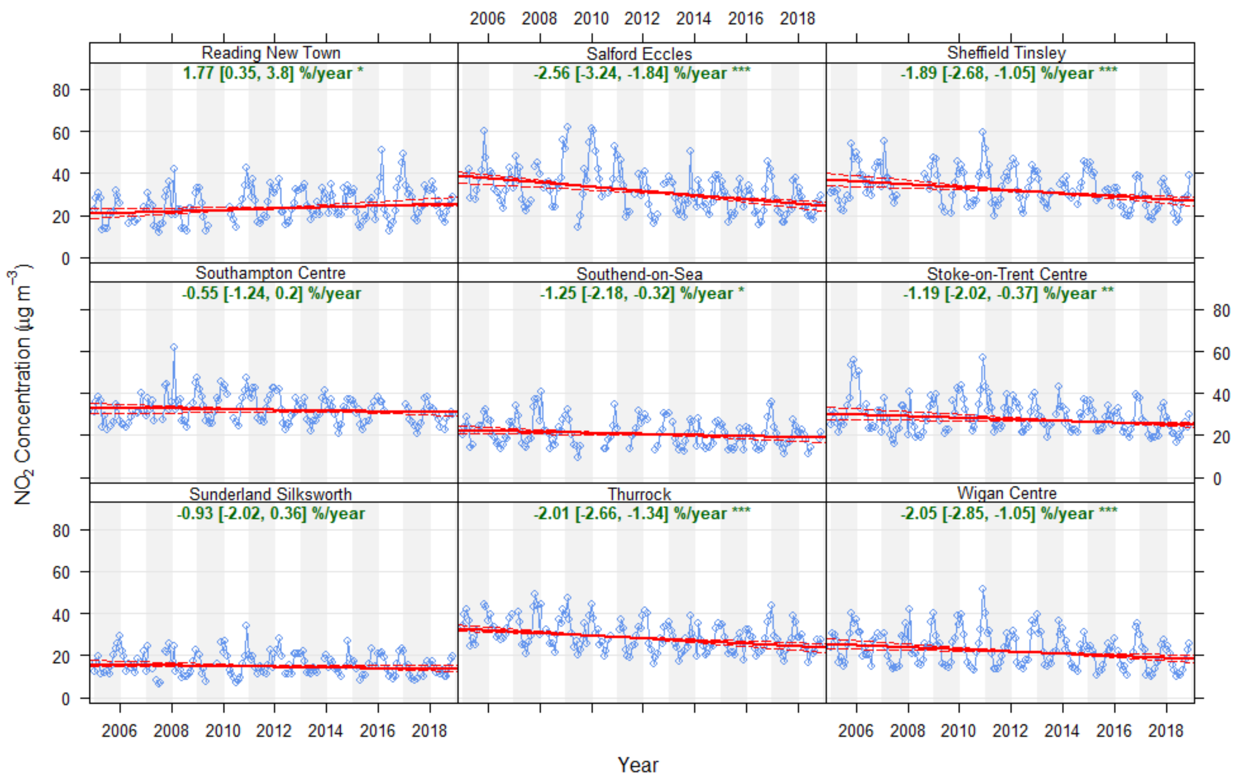
Urban Sites NO_2 2005 to 2018



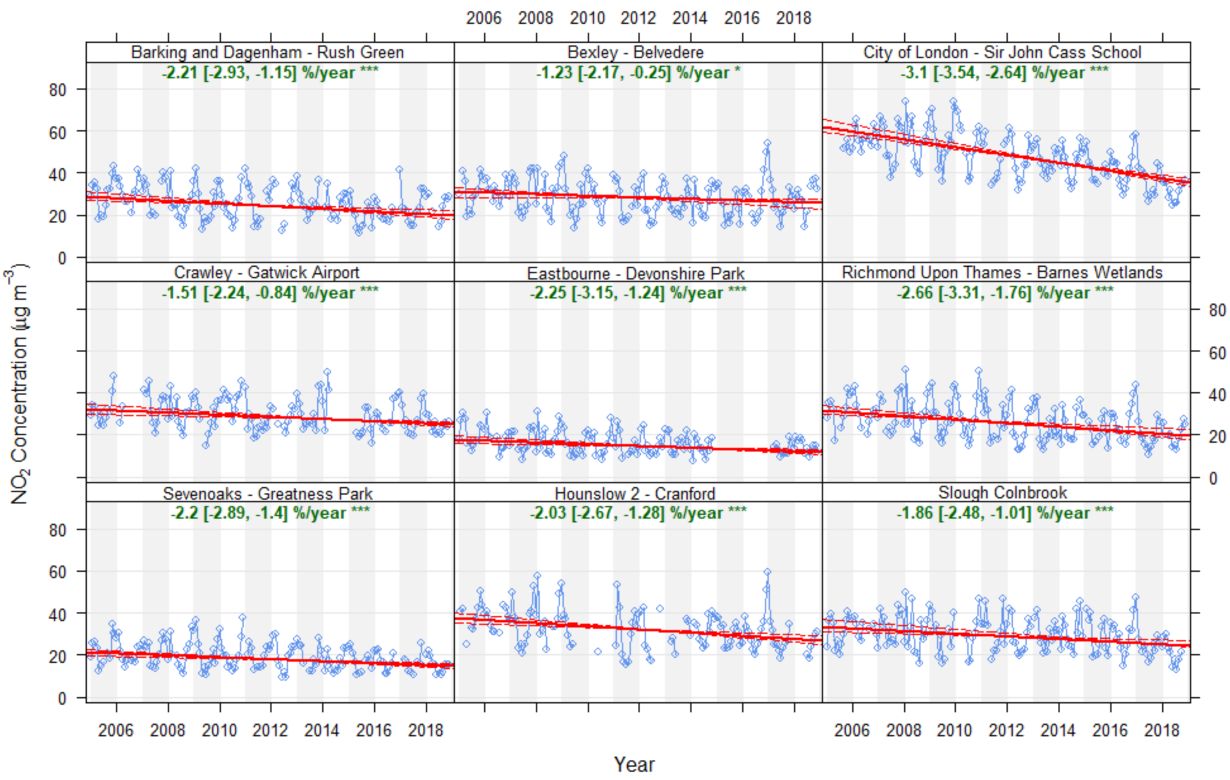


Urban Sites NO_2 2005 to 2018





Urban Sites NO_2 2005 to 2018



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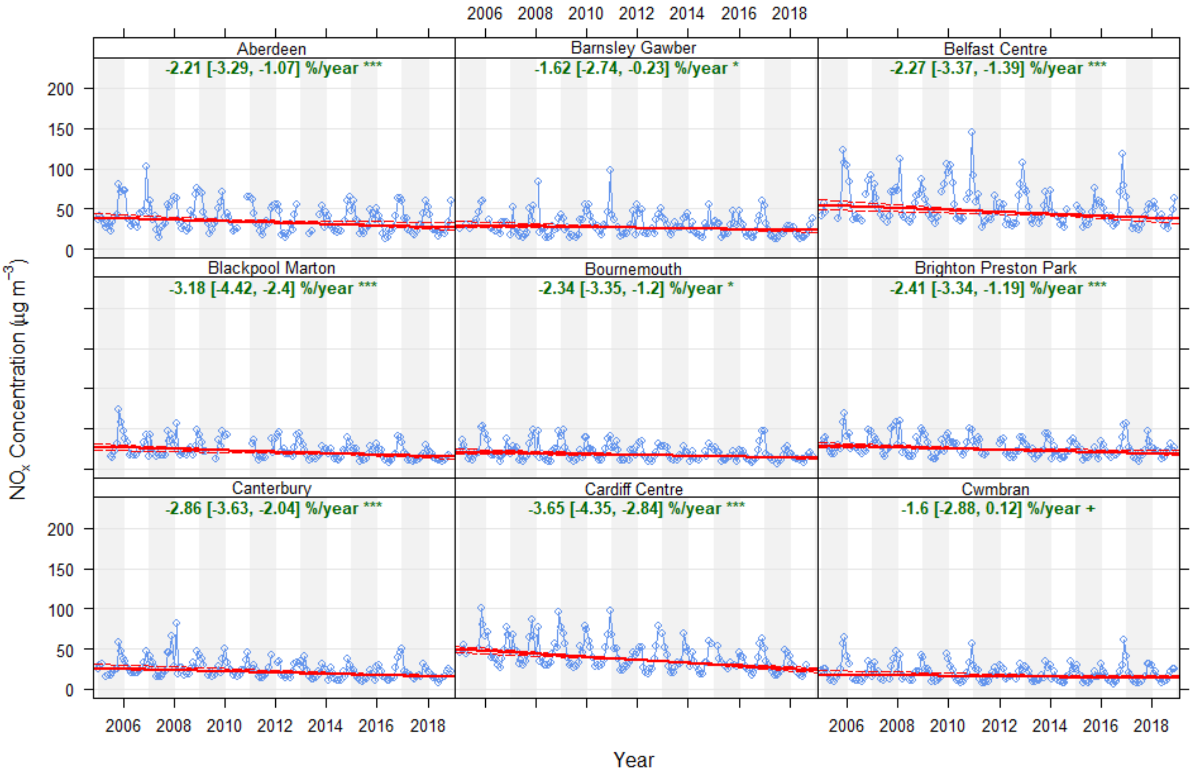

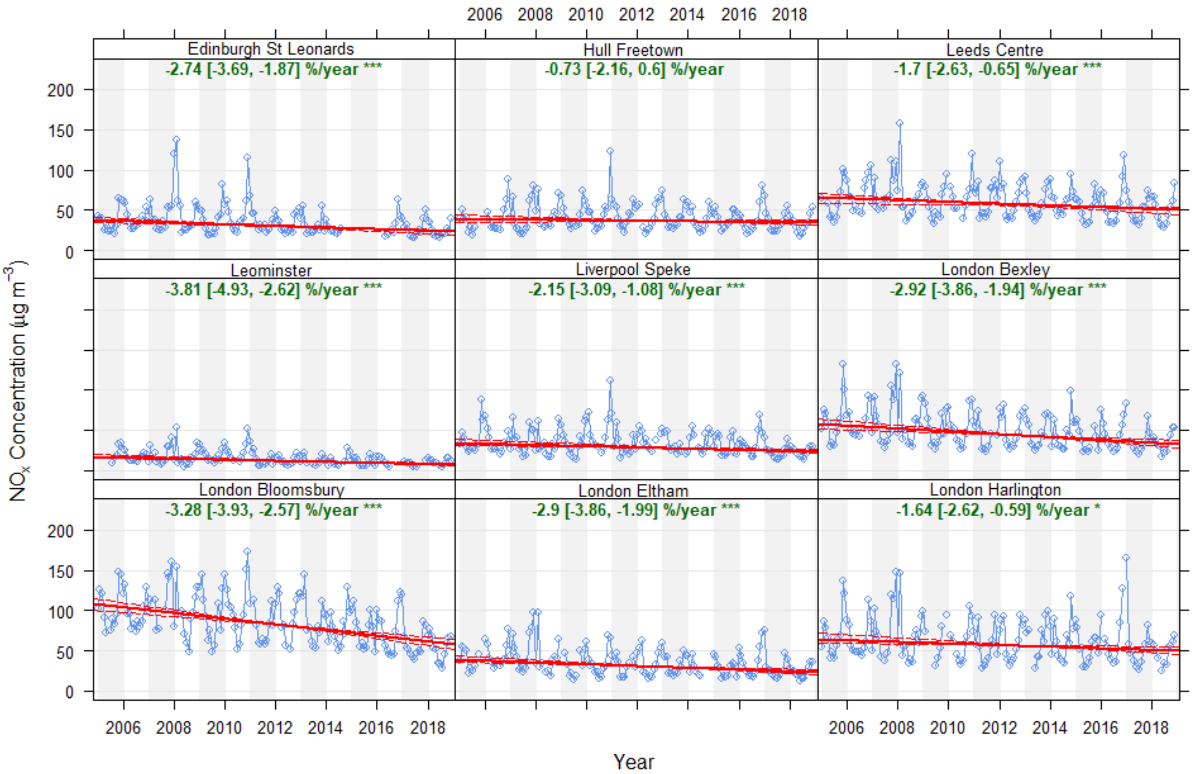

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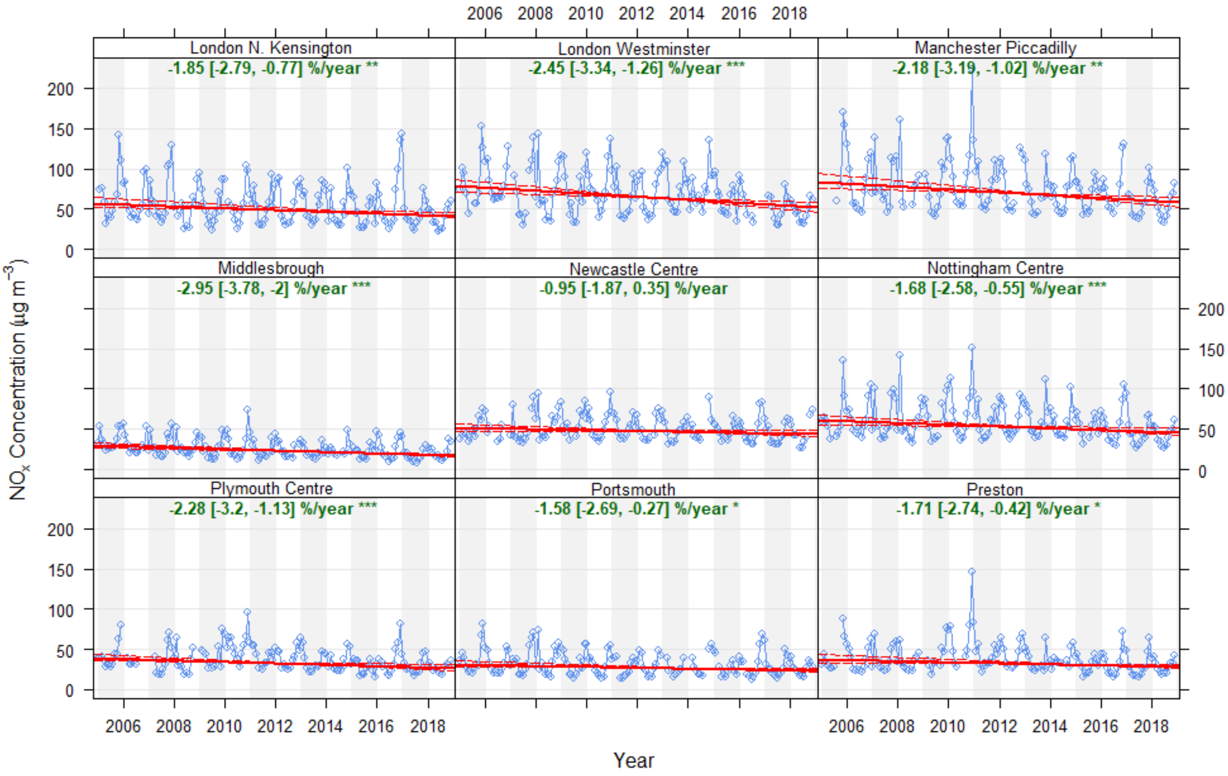
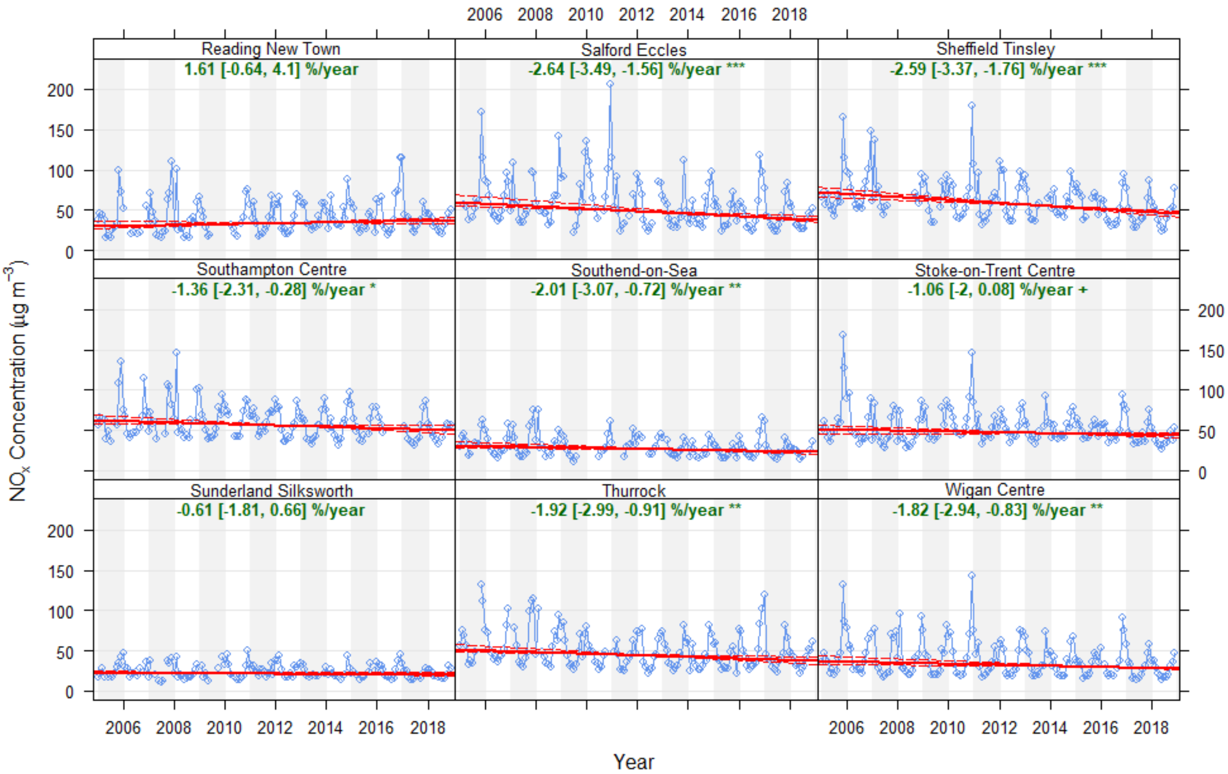
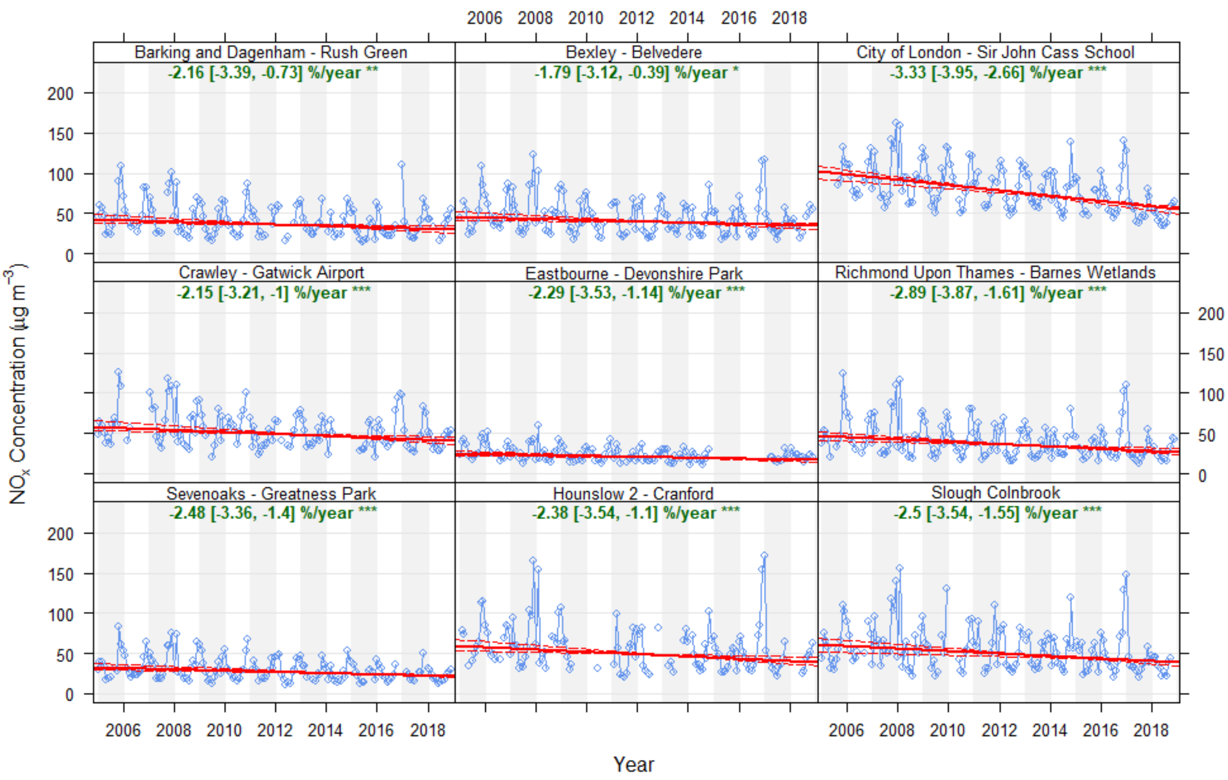
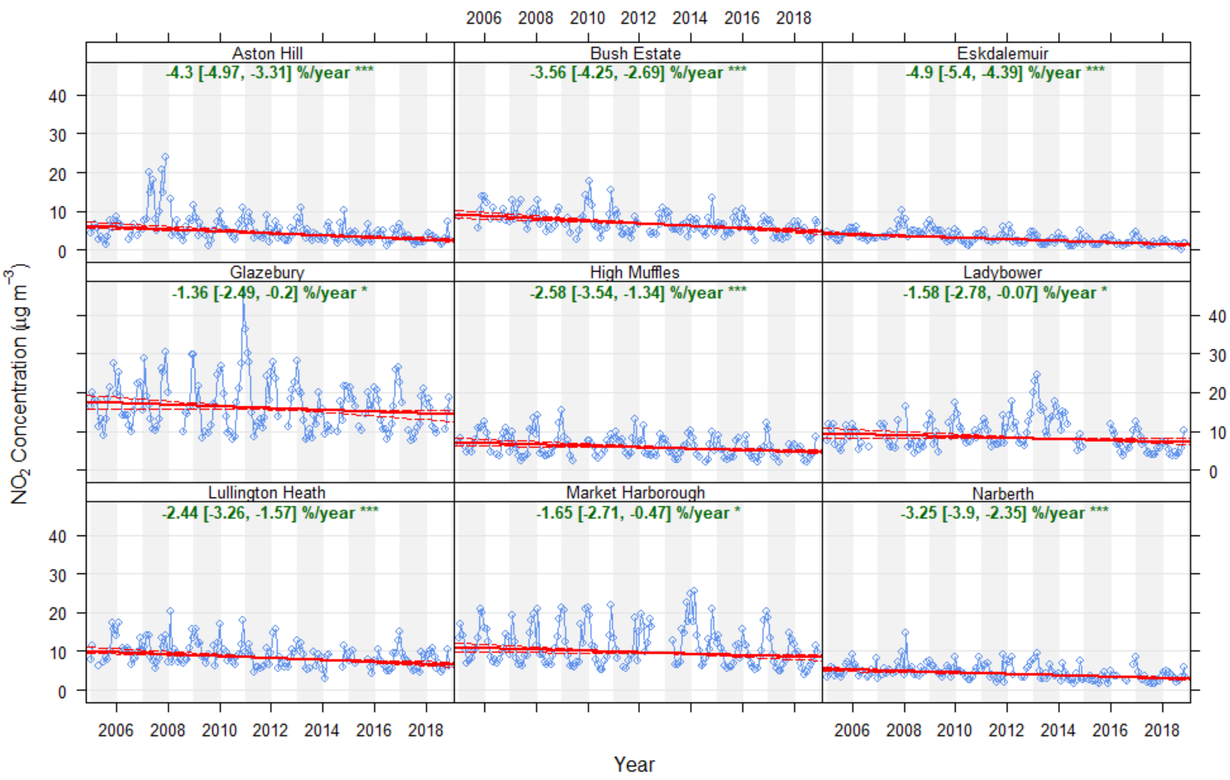


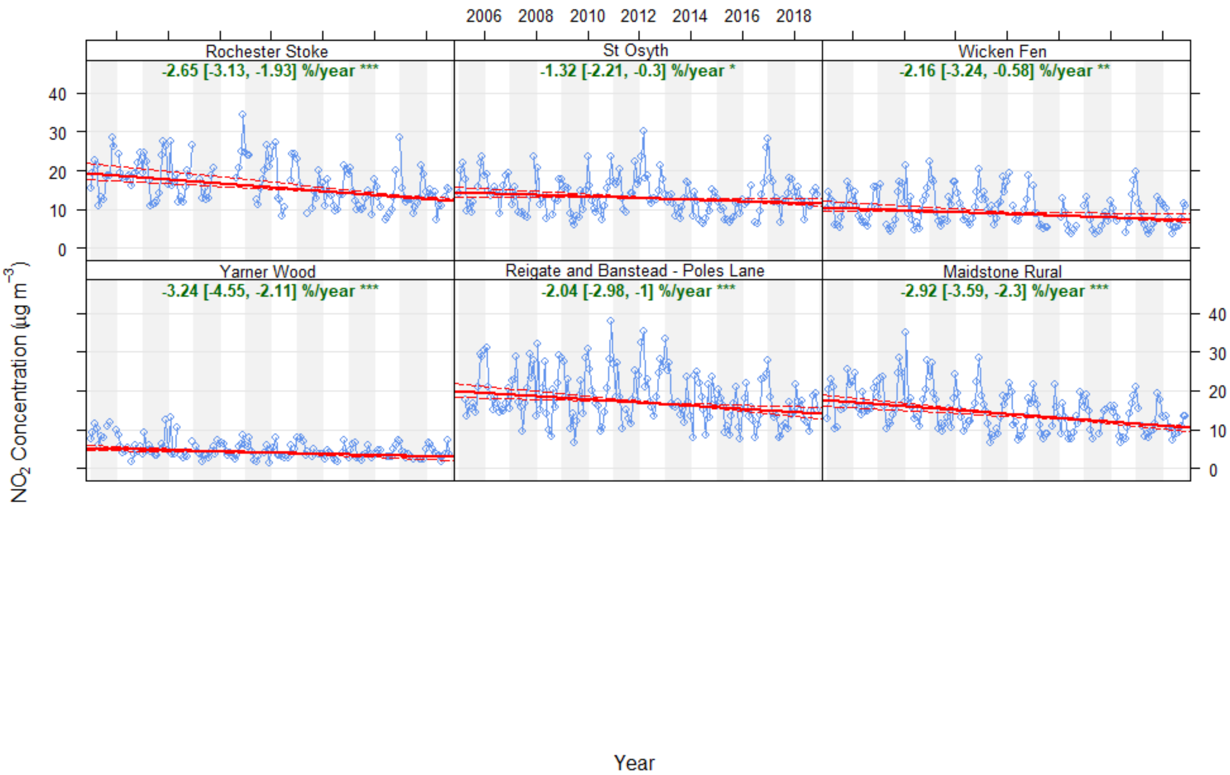


Urban Sites NOx 2005 to 2018

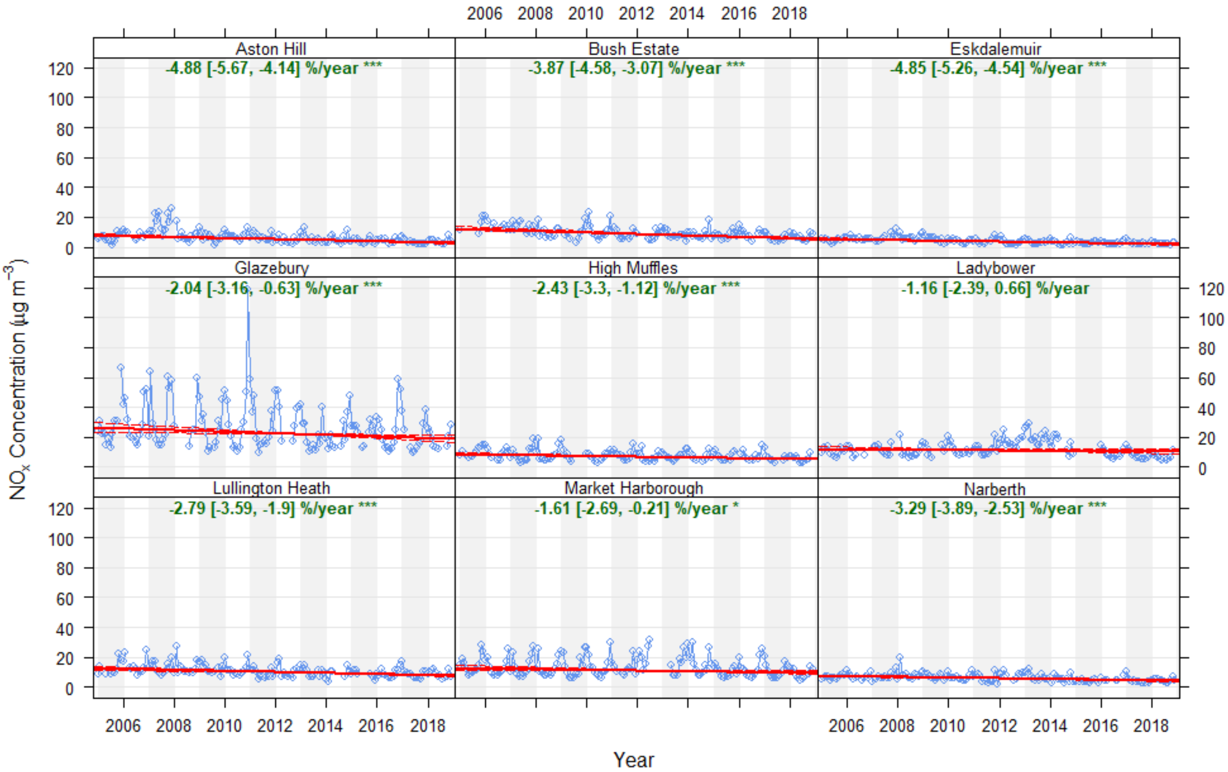


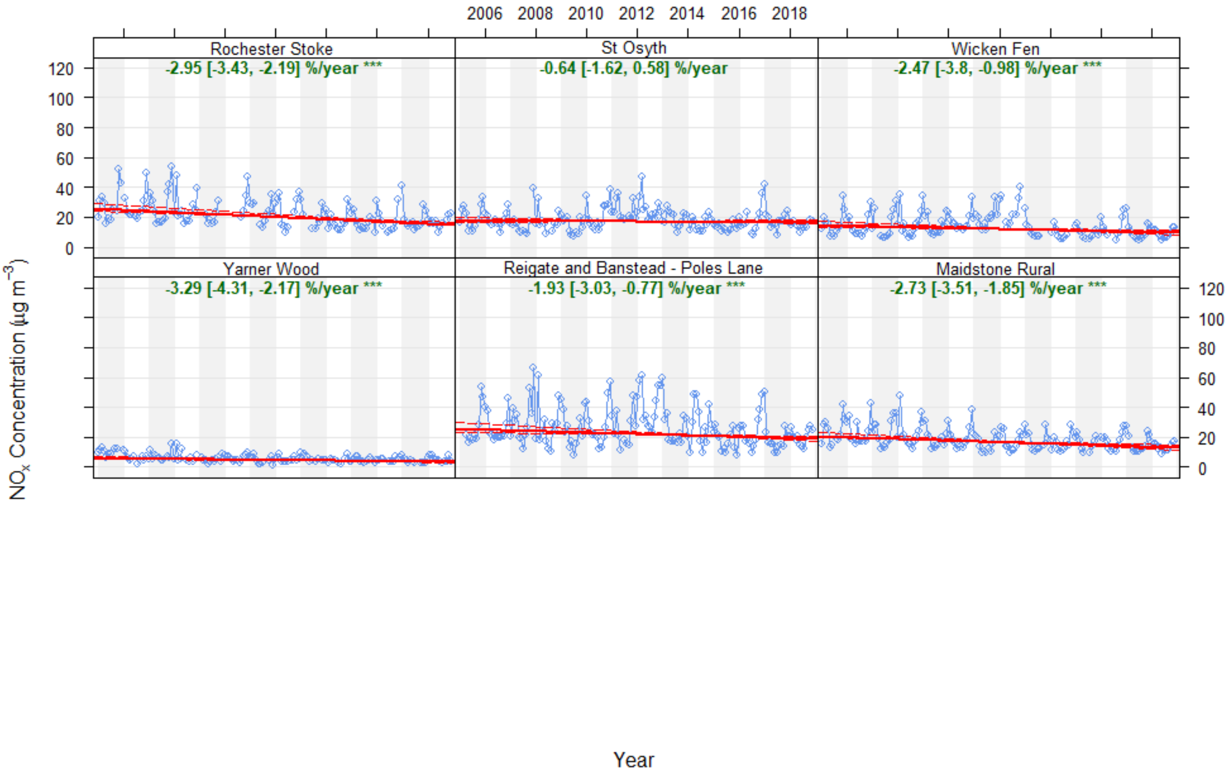
Rural Sites NO_2 2005 to 2018





Rural Sites NOx 2005 to 2018

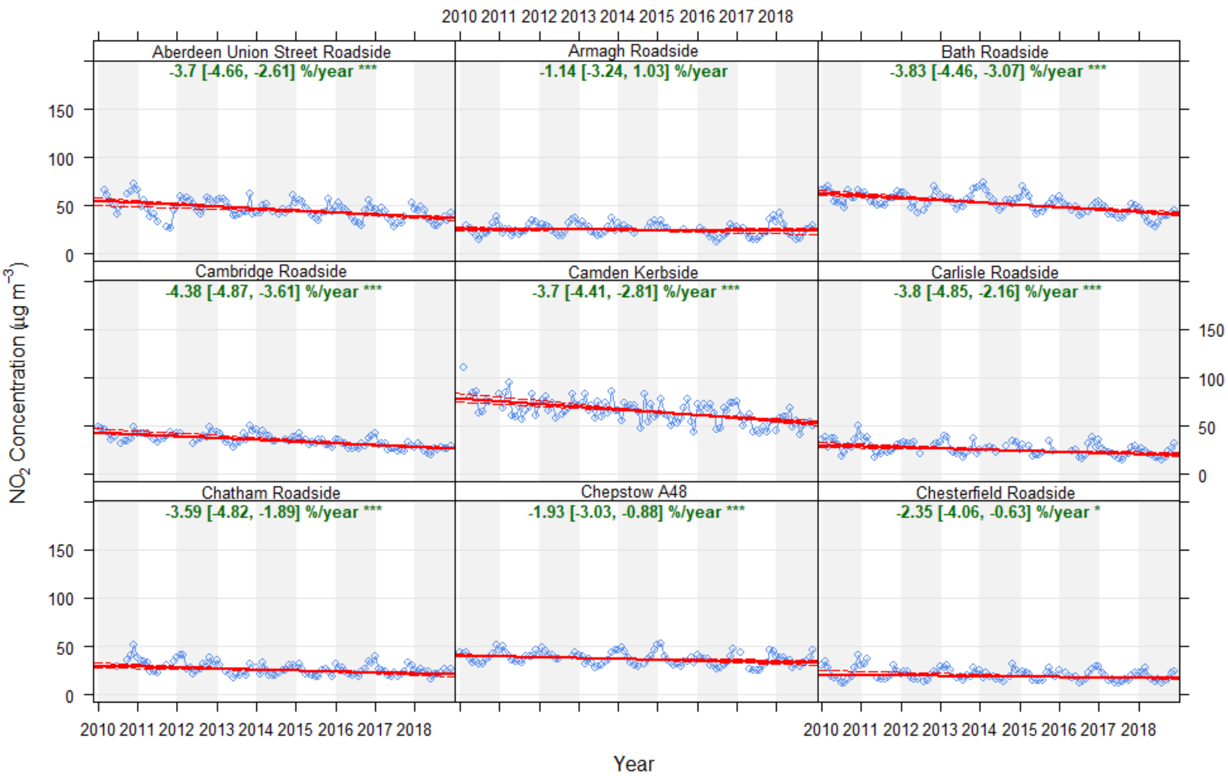




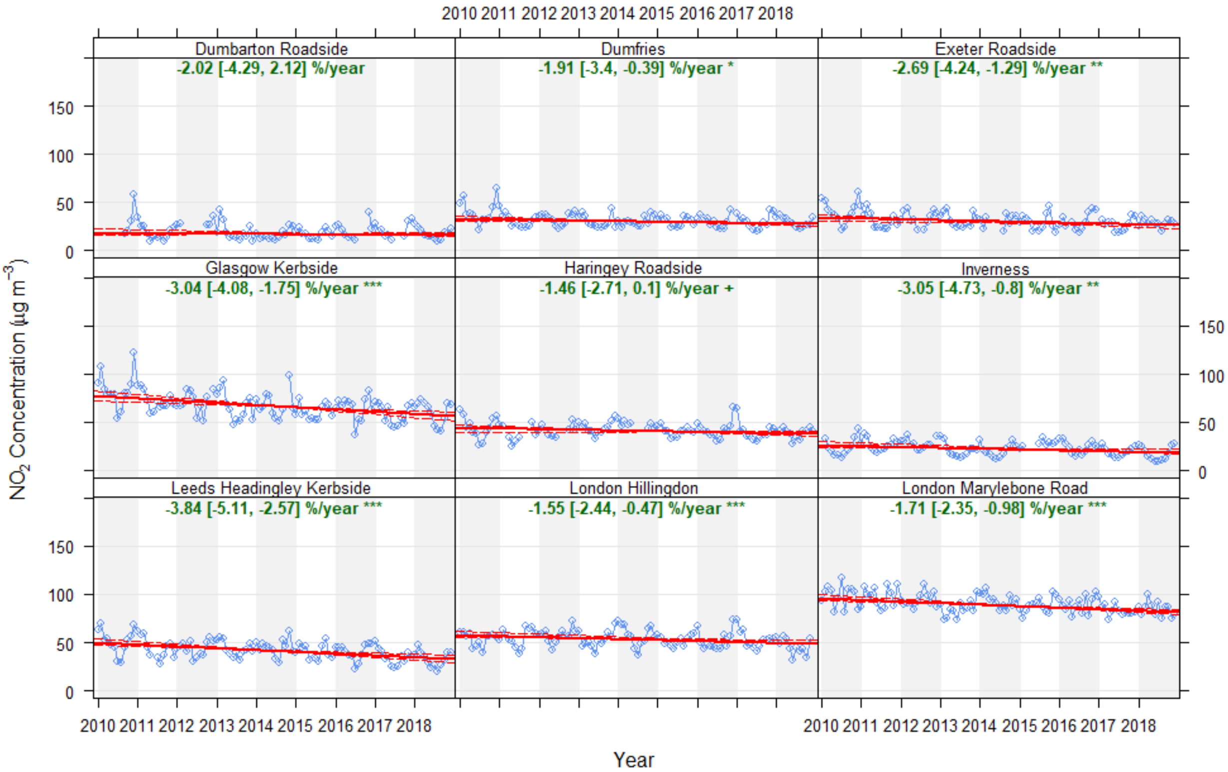
A4 Plots for Individual Sites 2010 to 2018

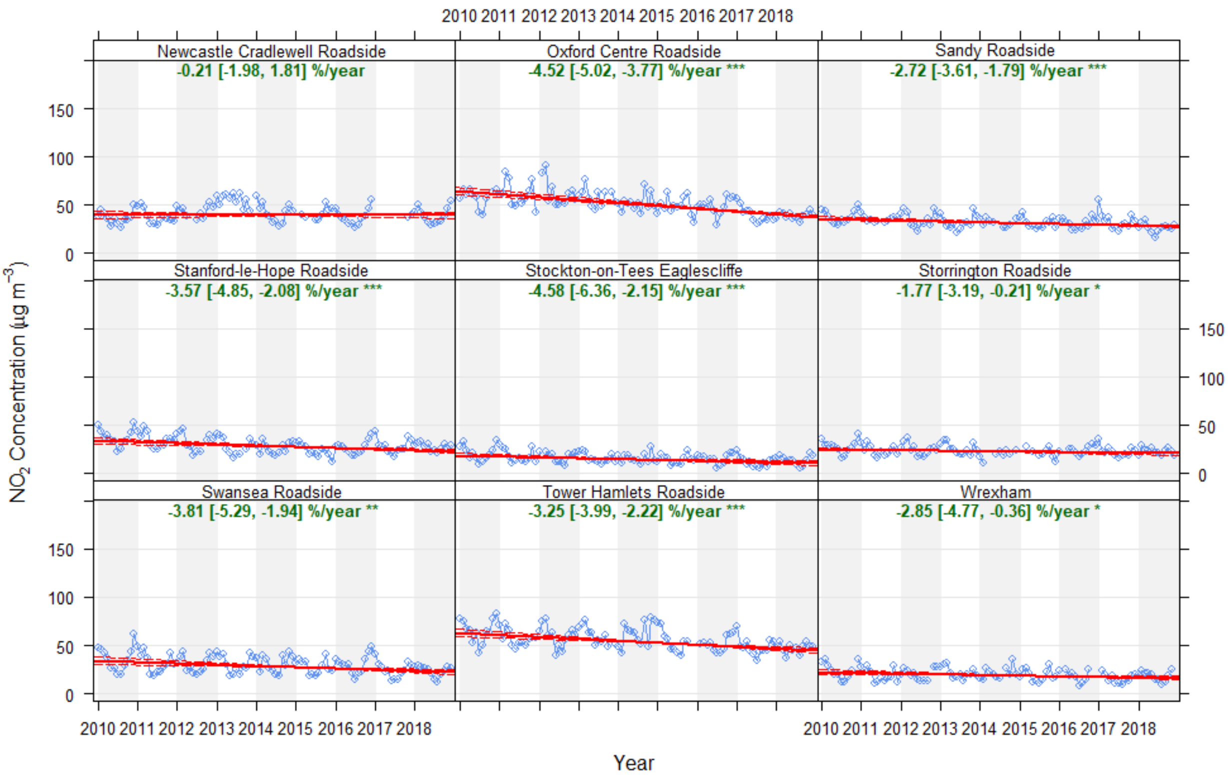
A4.1 This appendix sets out the Theil-Sen plots for the individual sites included in the analyses presented in this report. The numbers at the top of each graph show the trend and the confidence interval, and the significance of the trend, as follows: *** for p=0.001, ** for p=0.01, * for p=0.05 and + for p=0.1. The trends are shown as % per year.

Road Sites NO_2 2010 to 2018

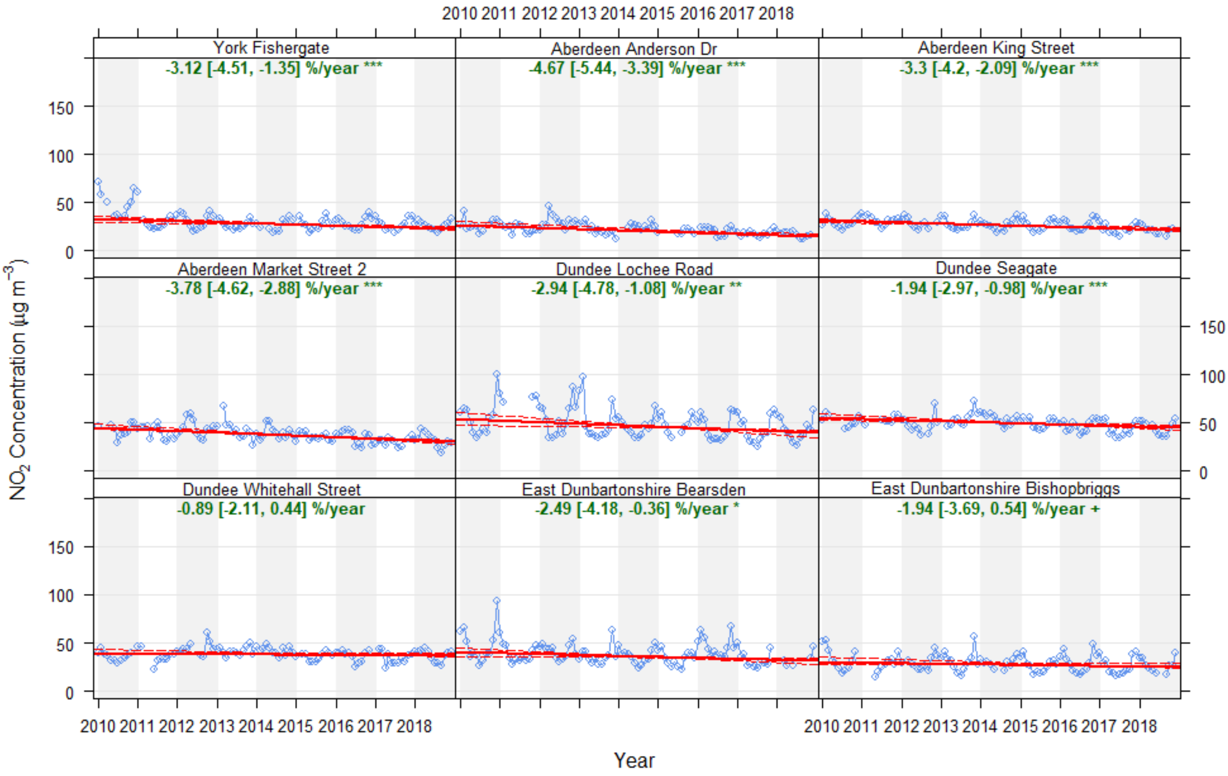


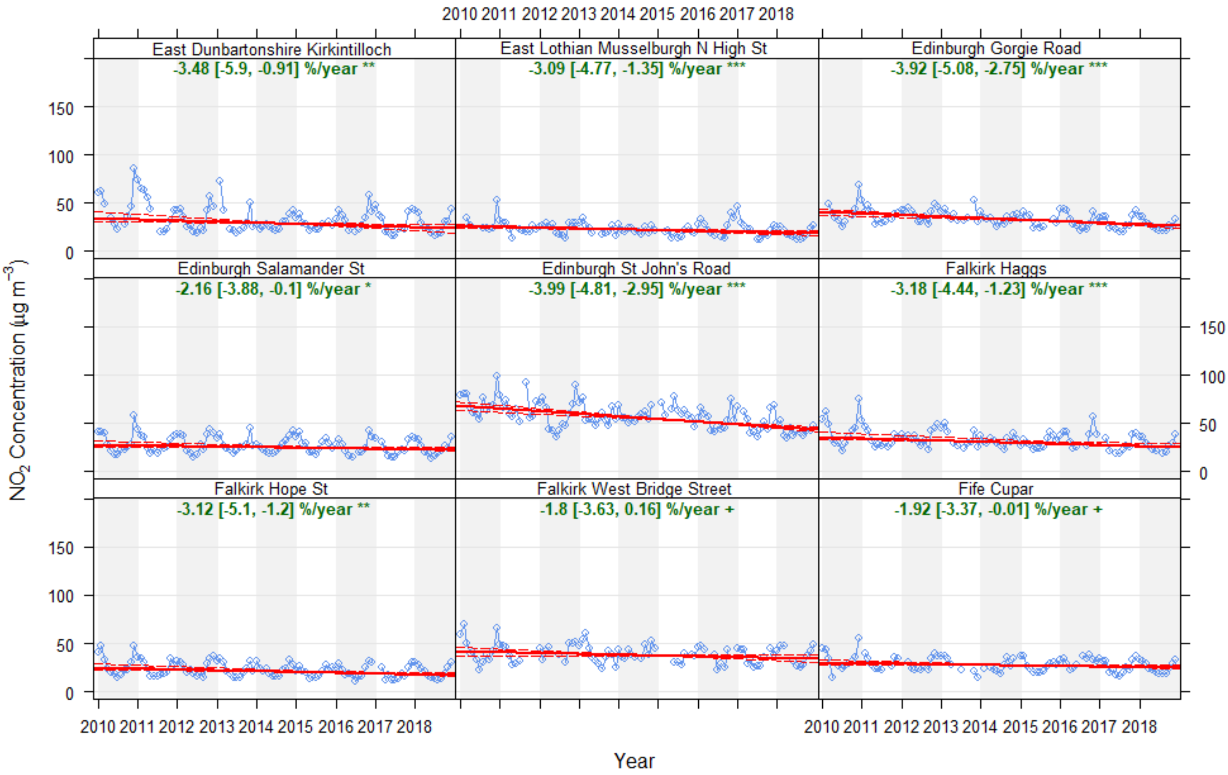
Road Sites NO_2 2010 to 2018



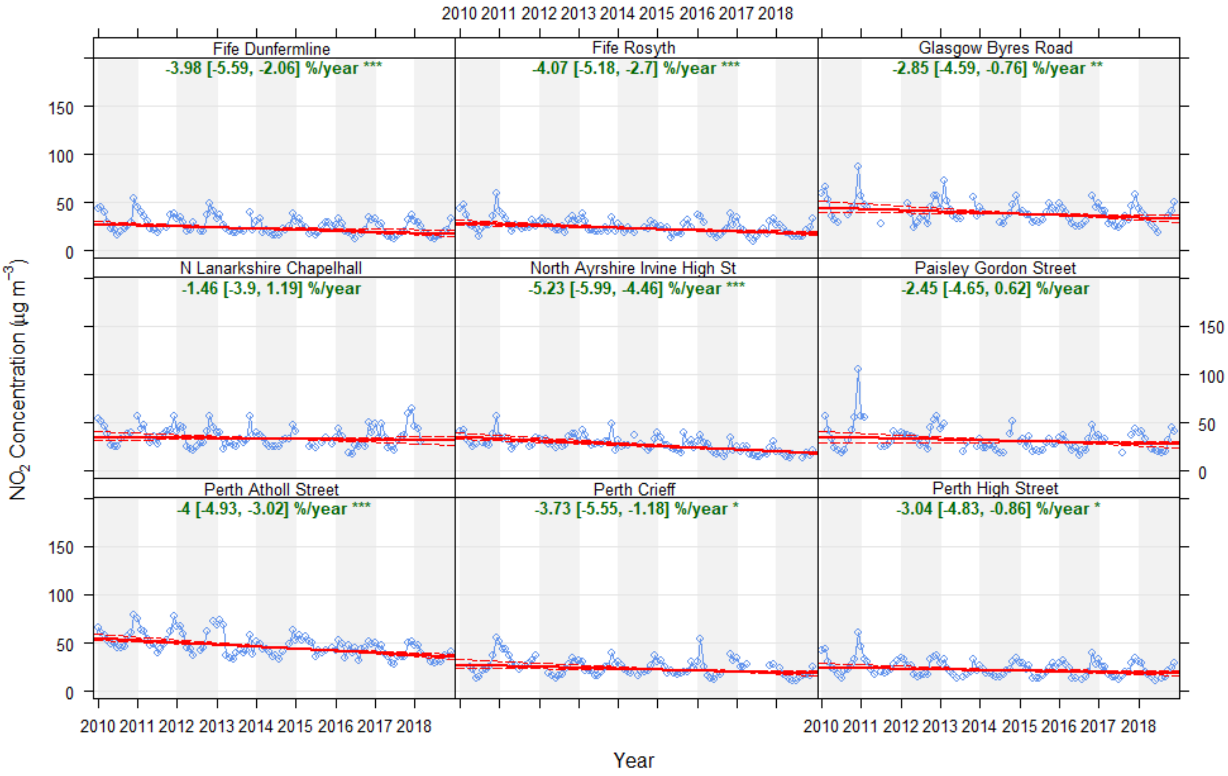


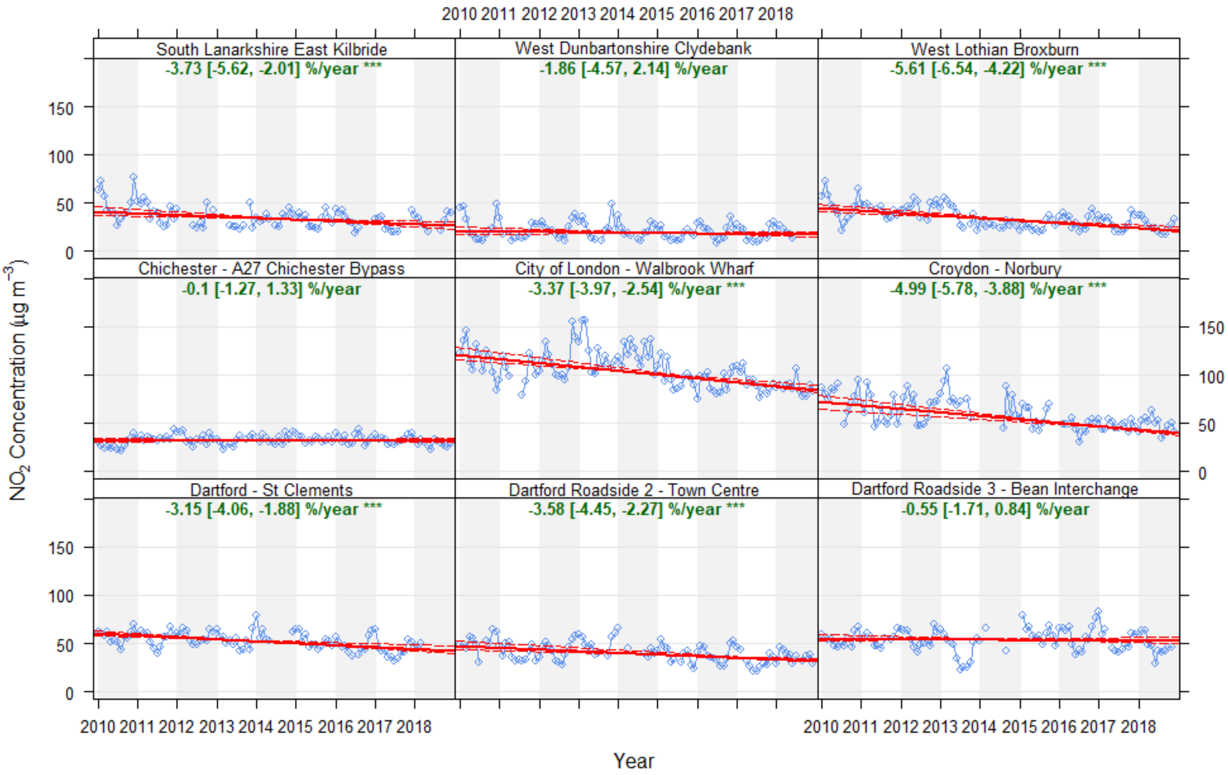
Road Sites NO_2 2010 to 2018





Road Sites NO_2 2010 to 2018





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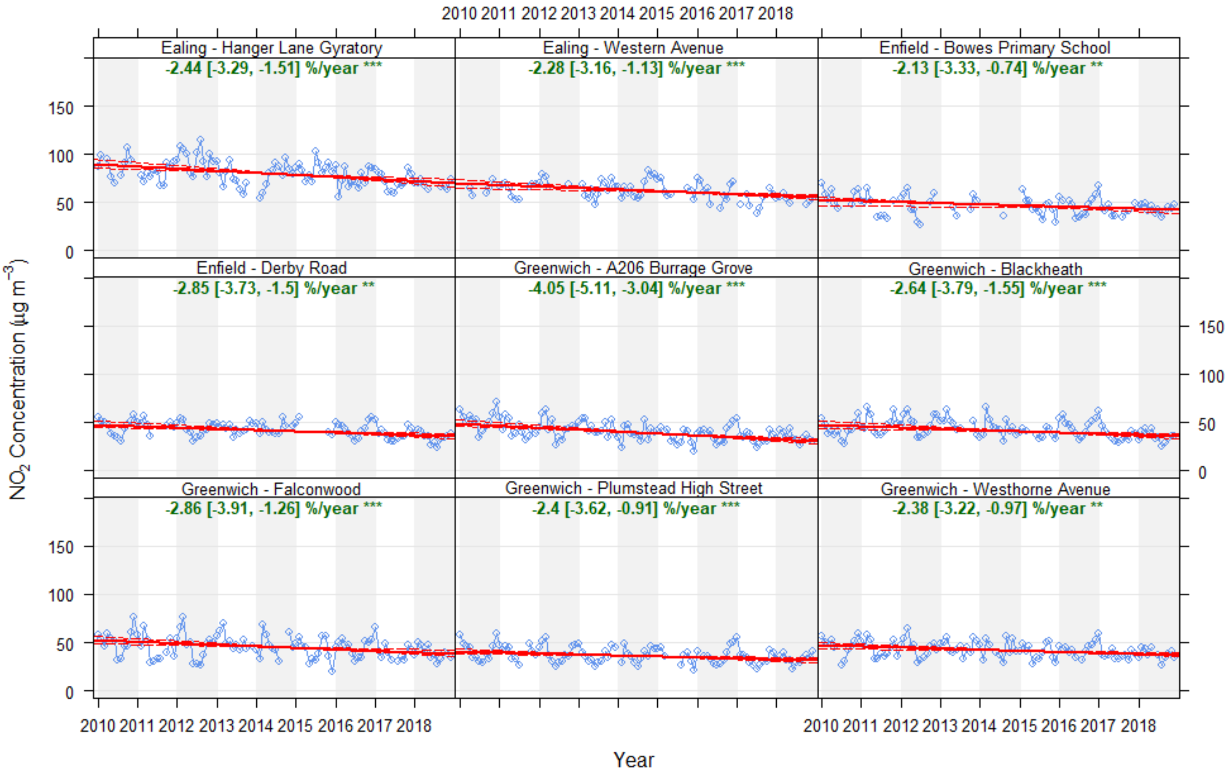

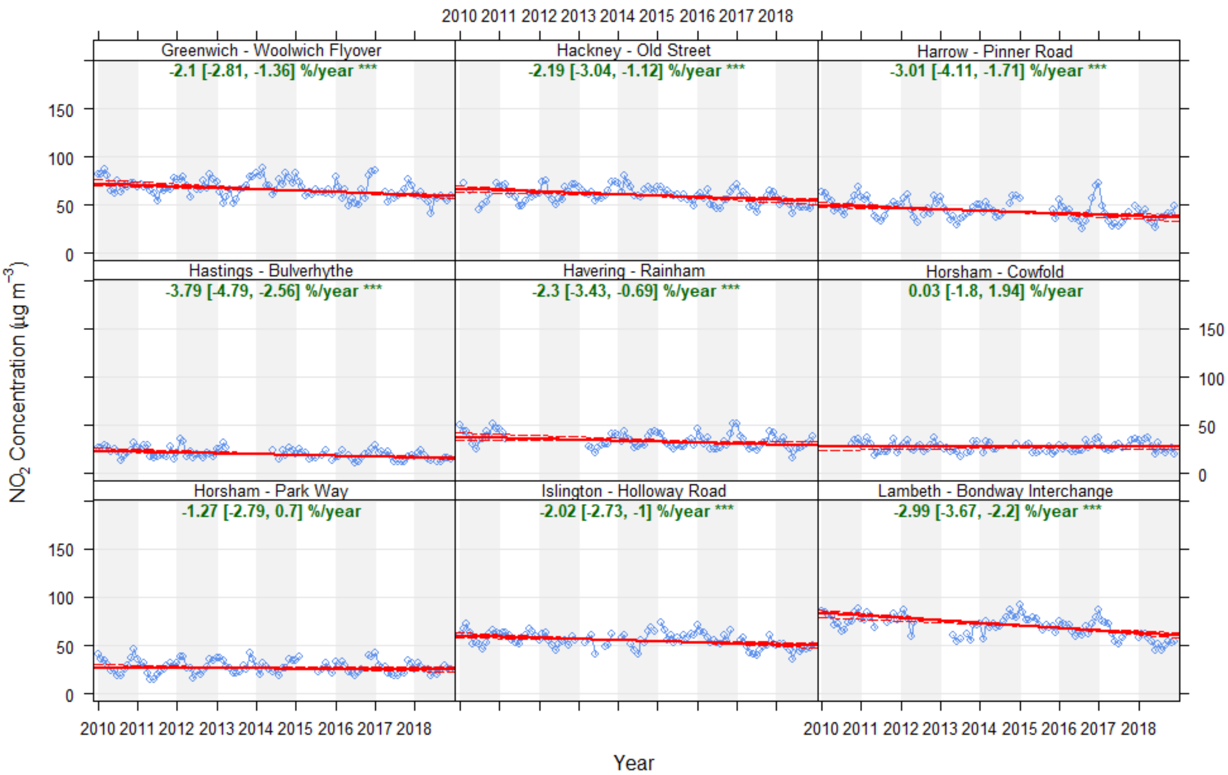

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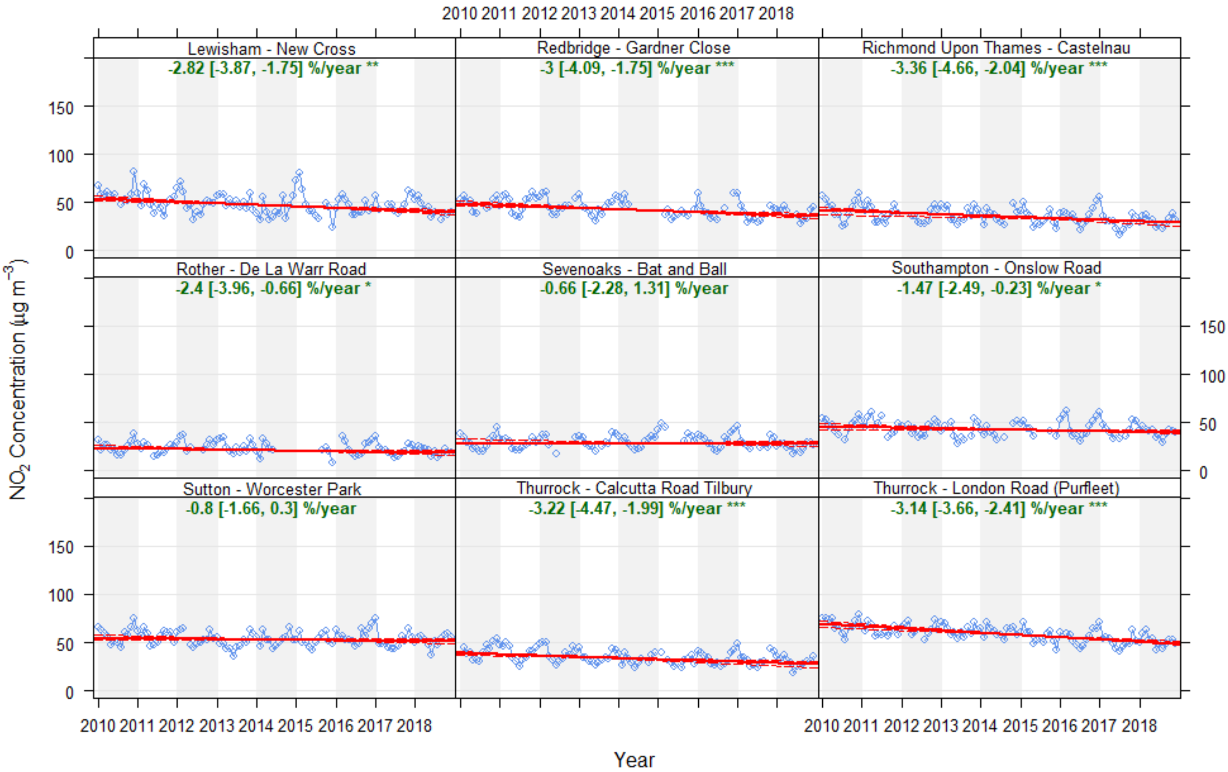
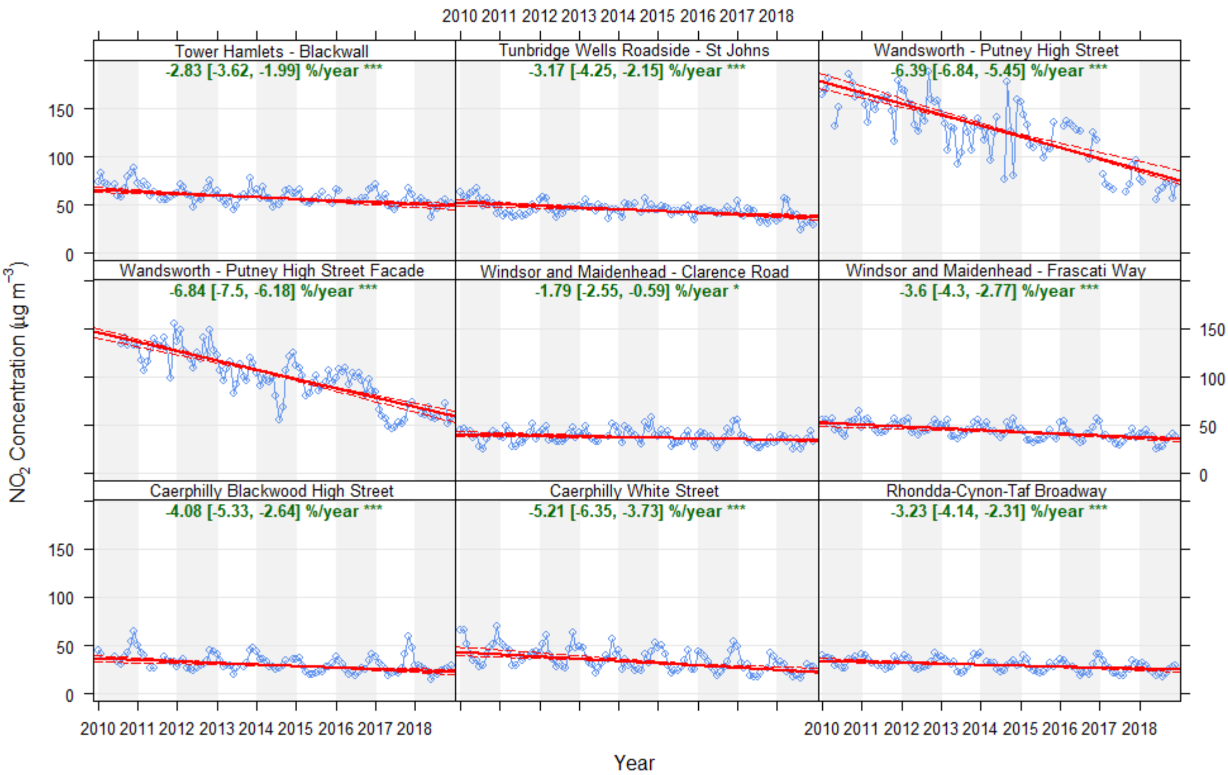
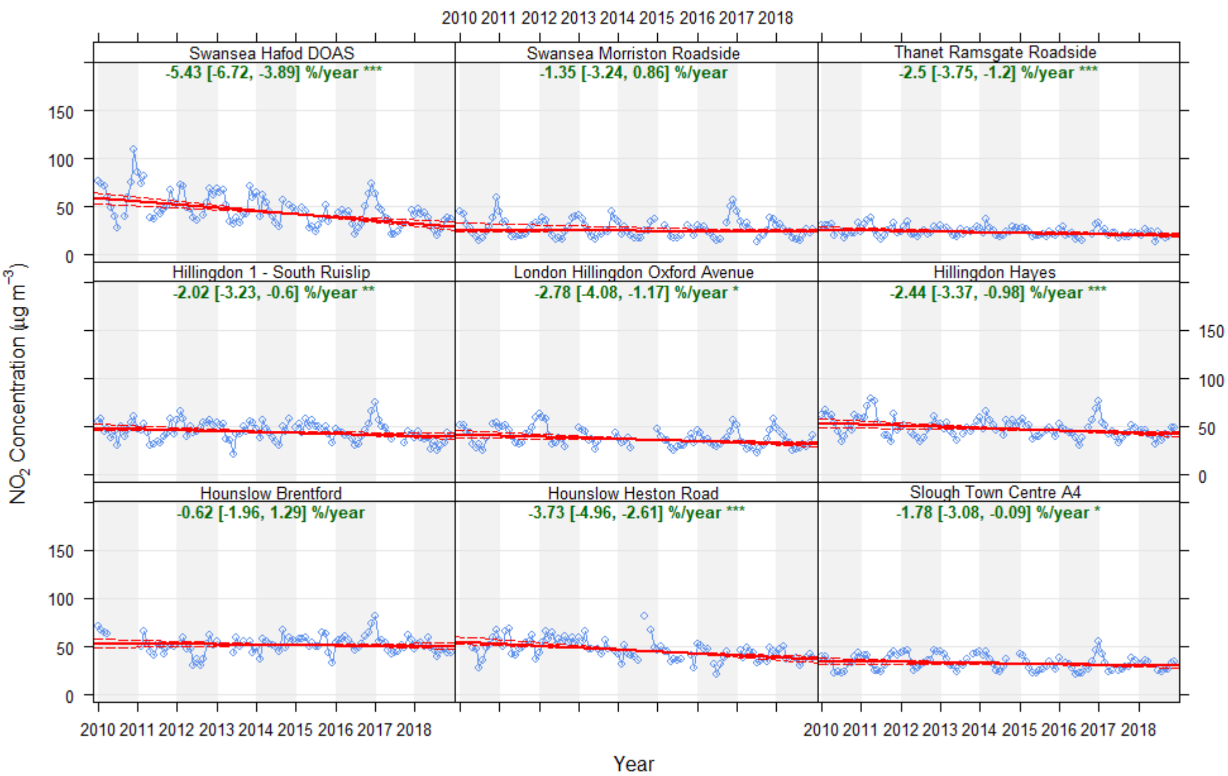
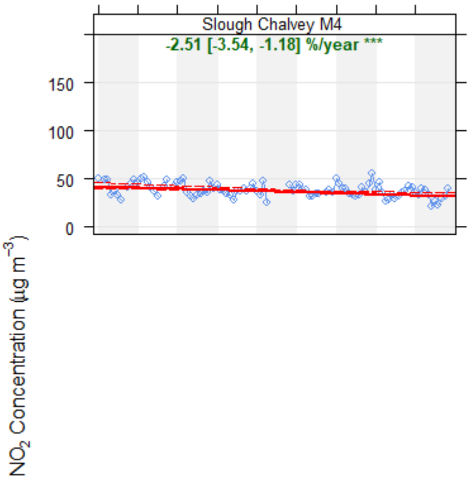


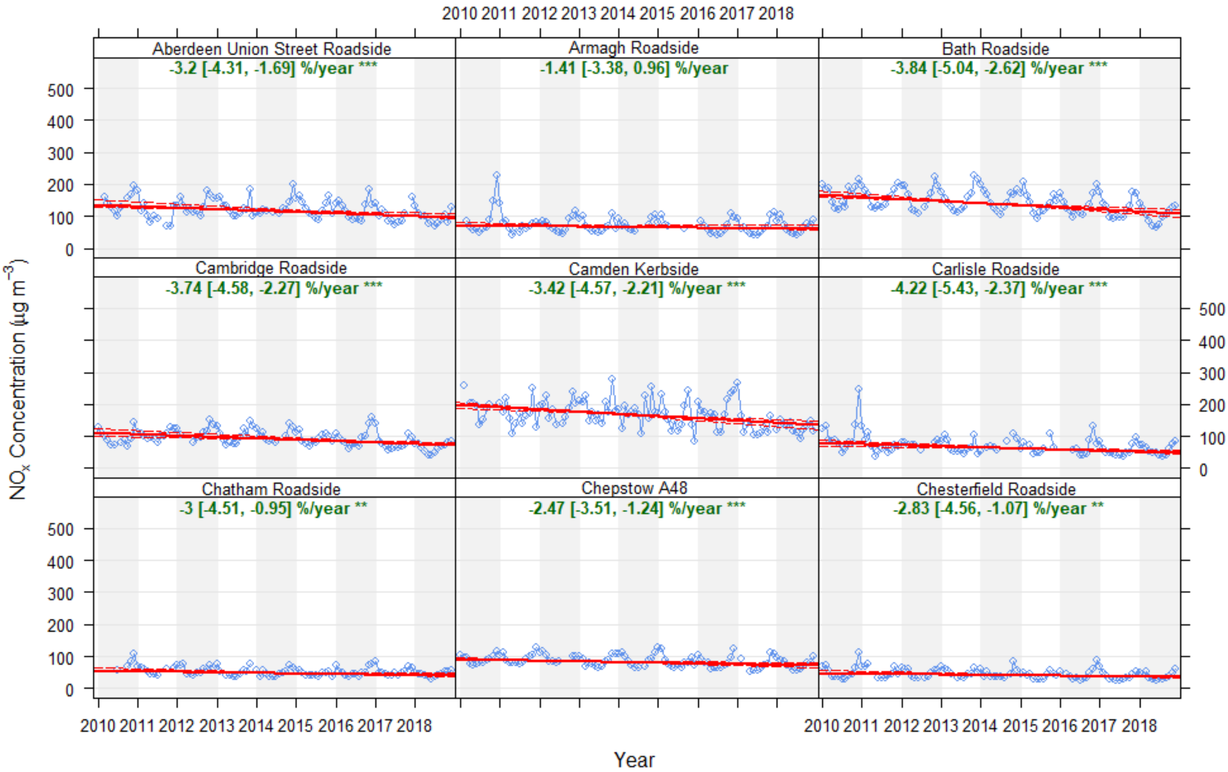


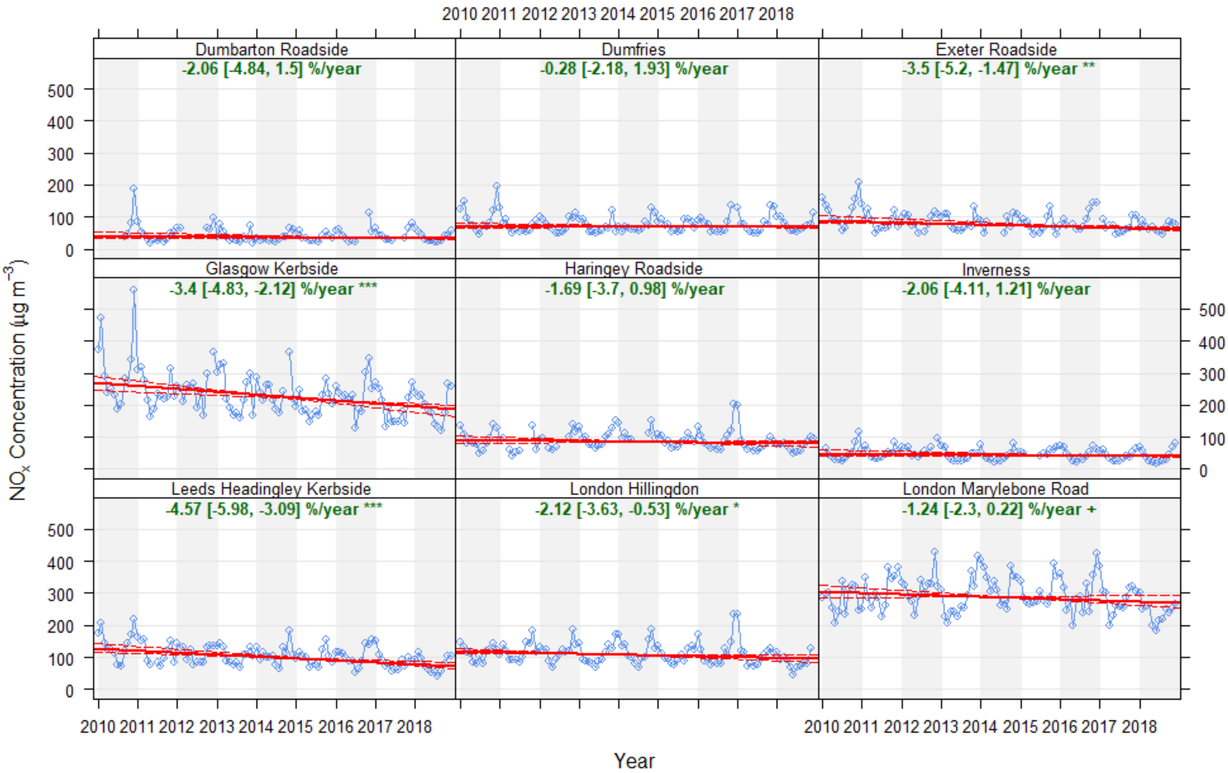
Road Sites NO_2 2010 to 2018



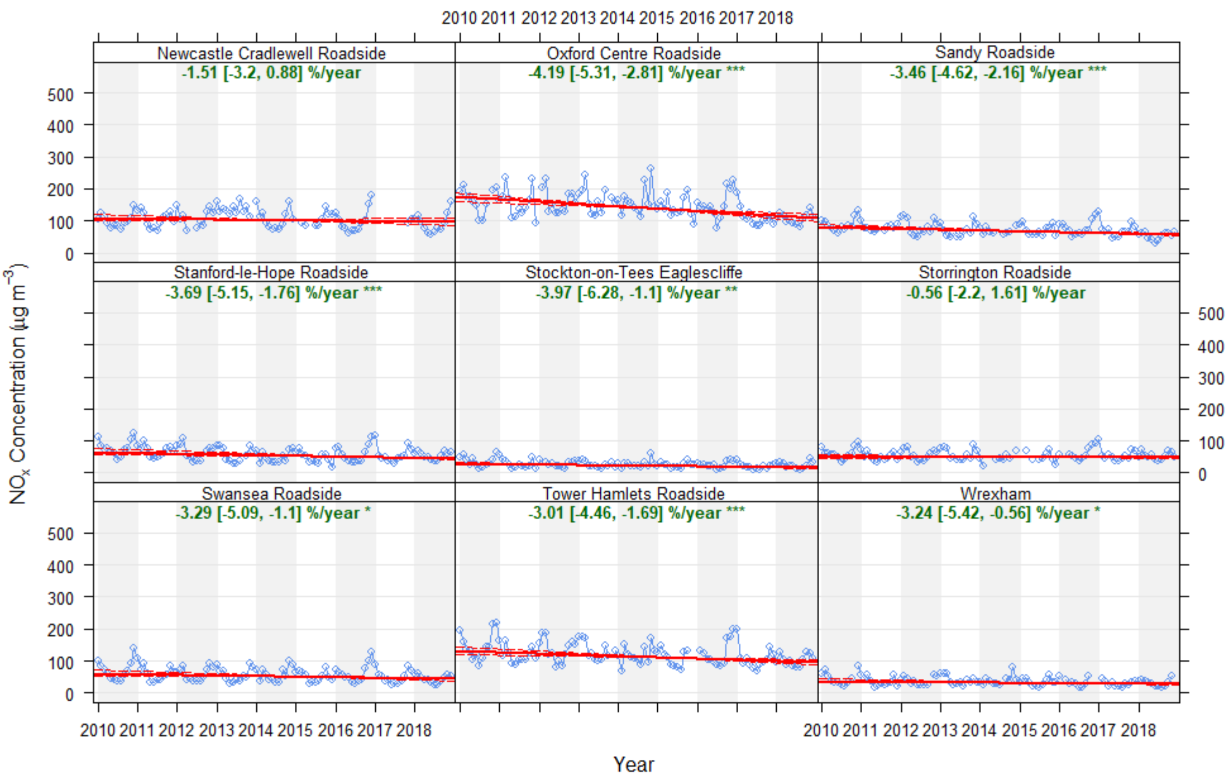


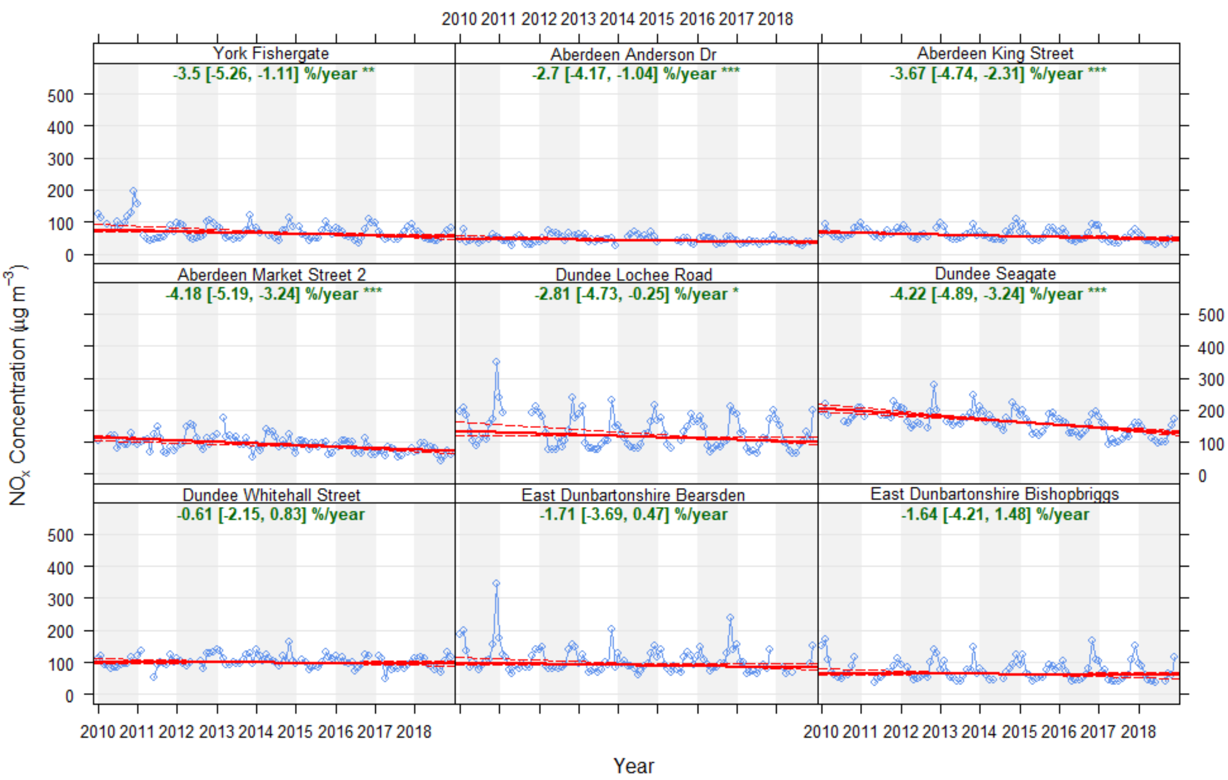
Road Sites NOx 2010 to 2018



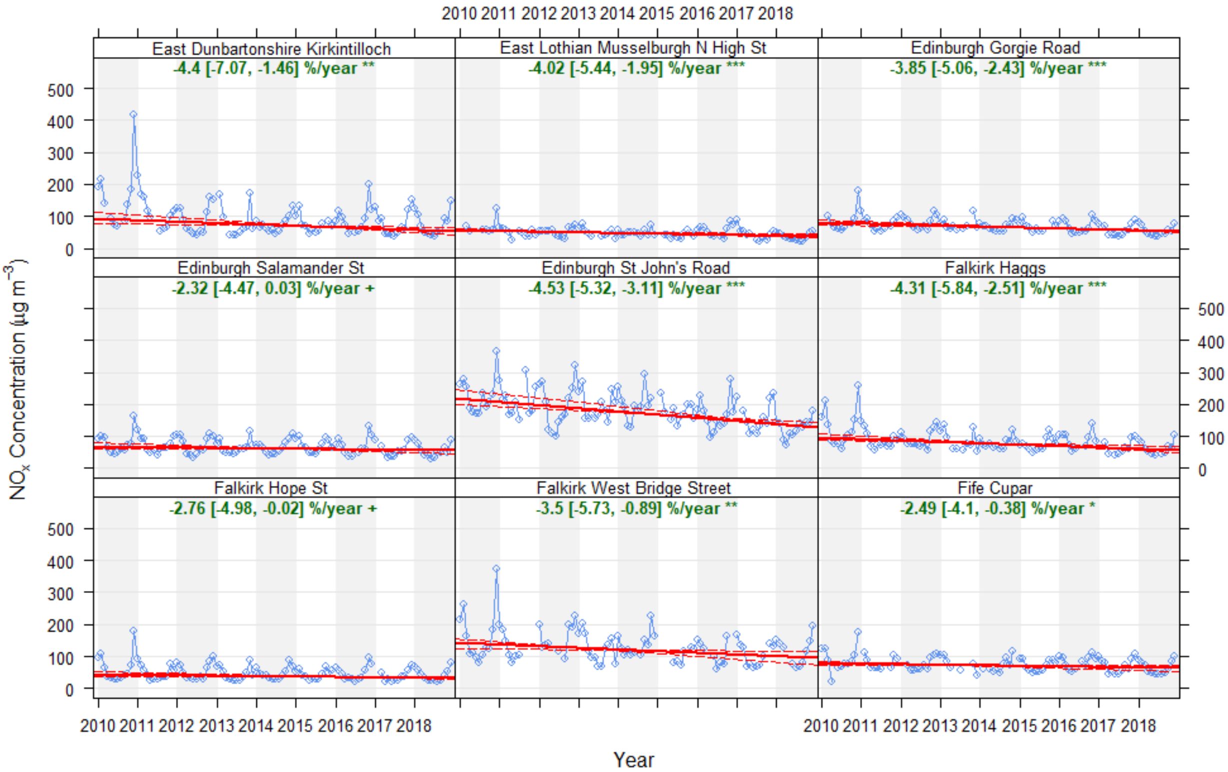


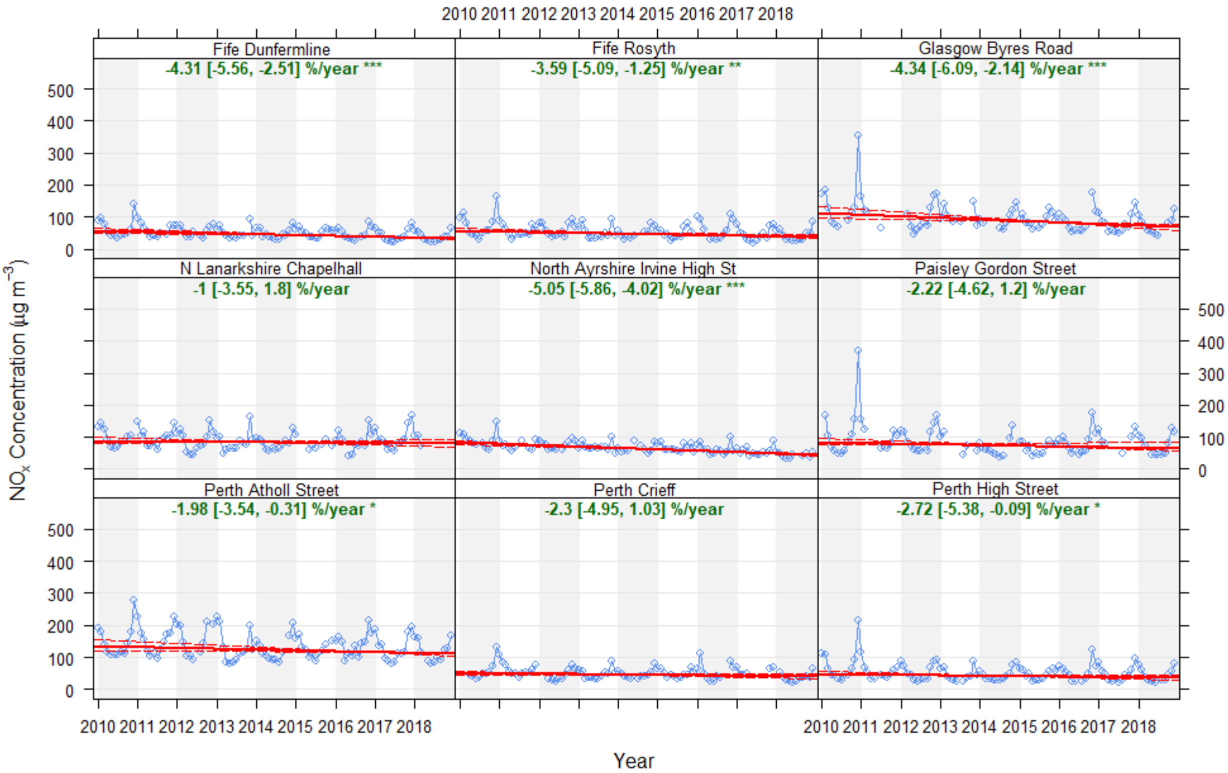
Road Sites NOx 2010 to 2018



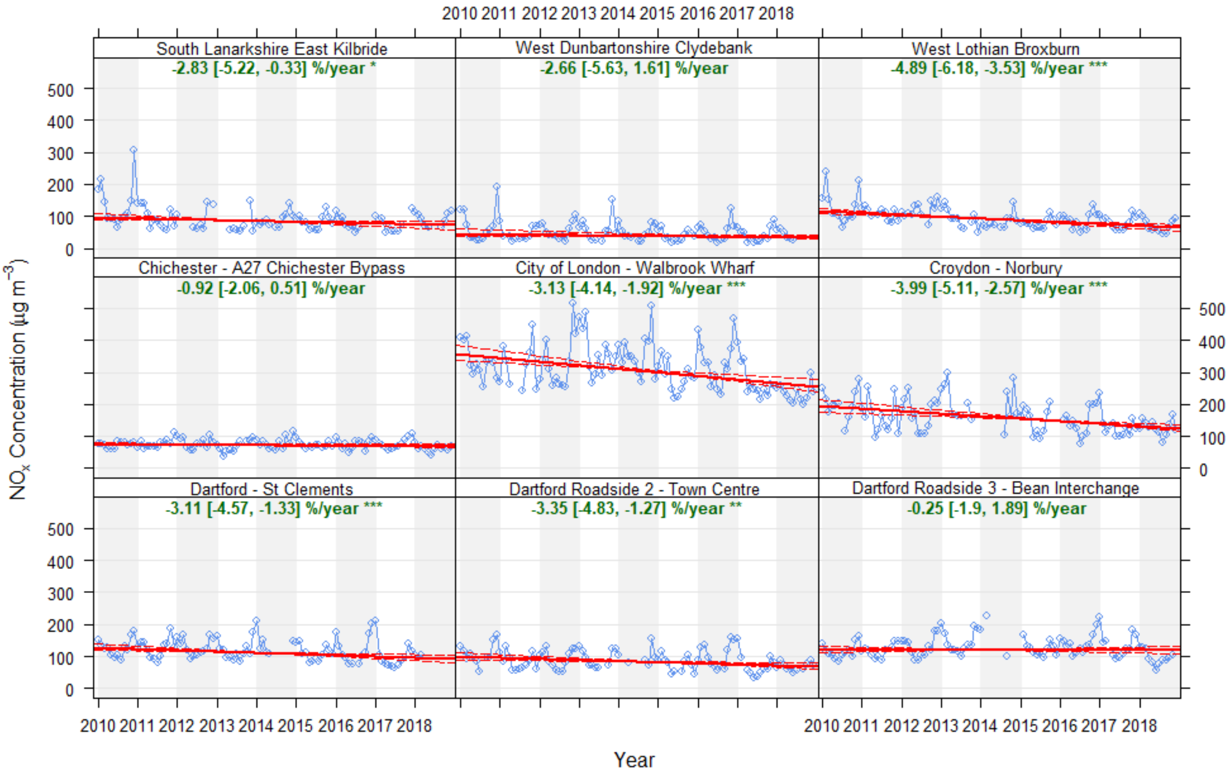


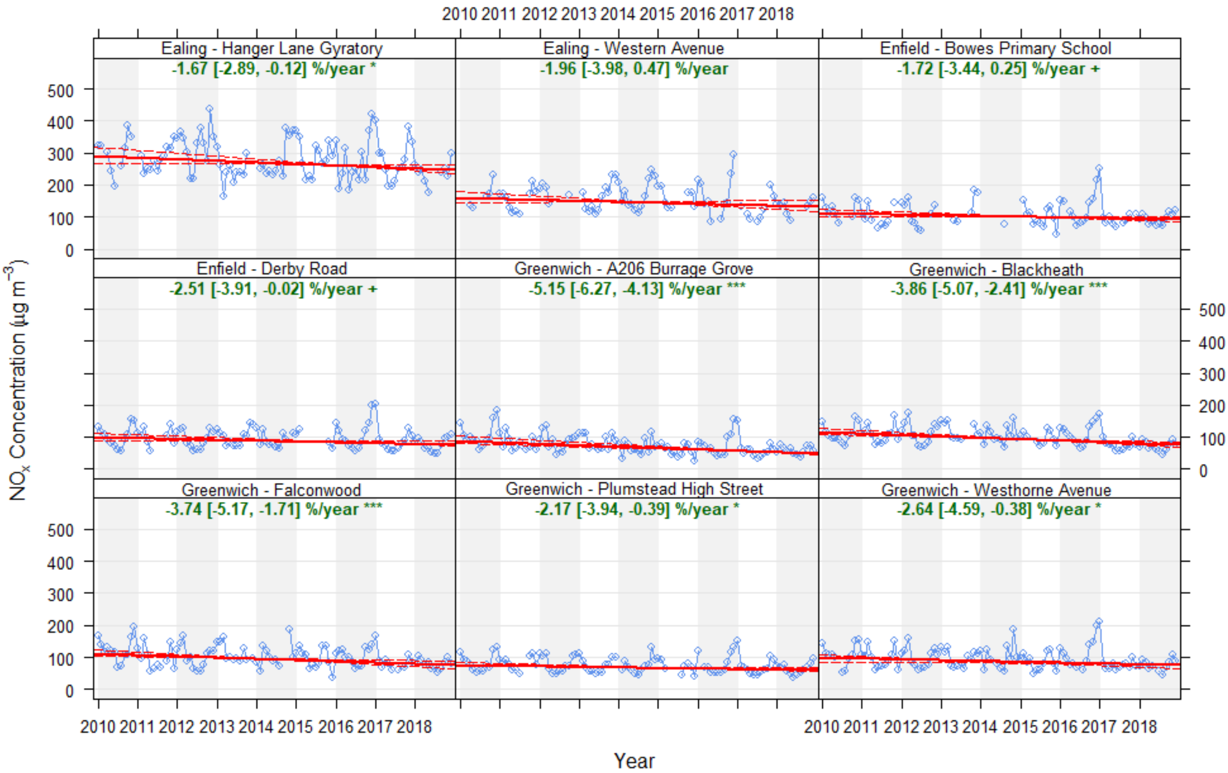
Road Sites NOx 2010 to 2018



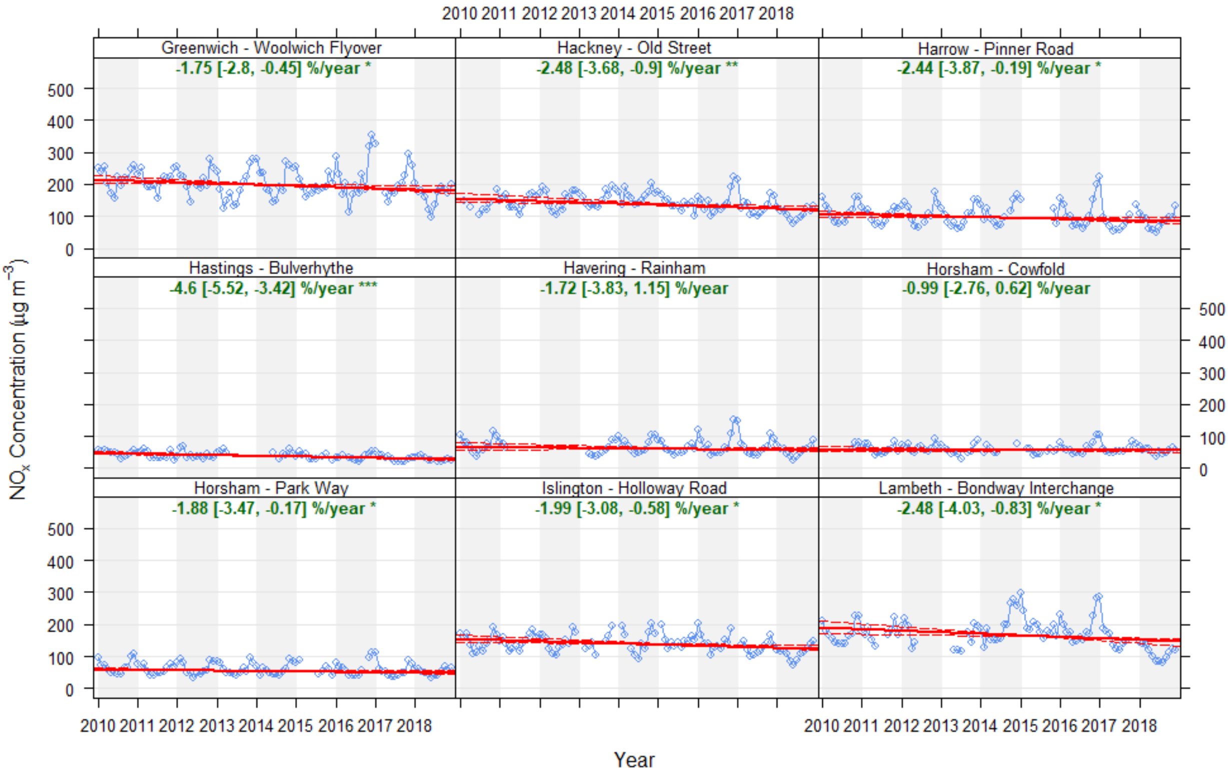


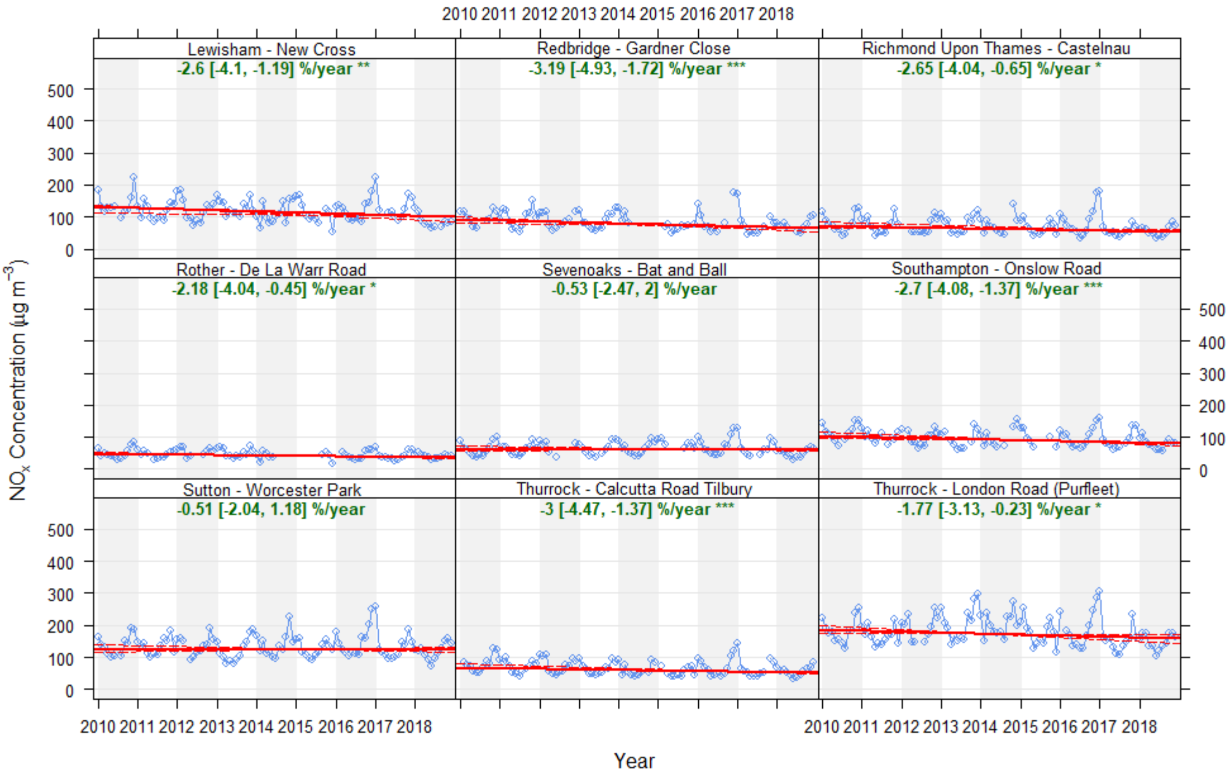
Road Sites NOx 2010 to 2018



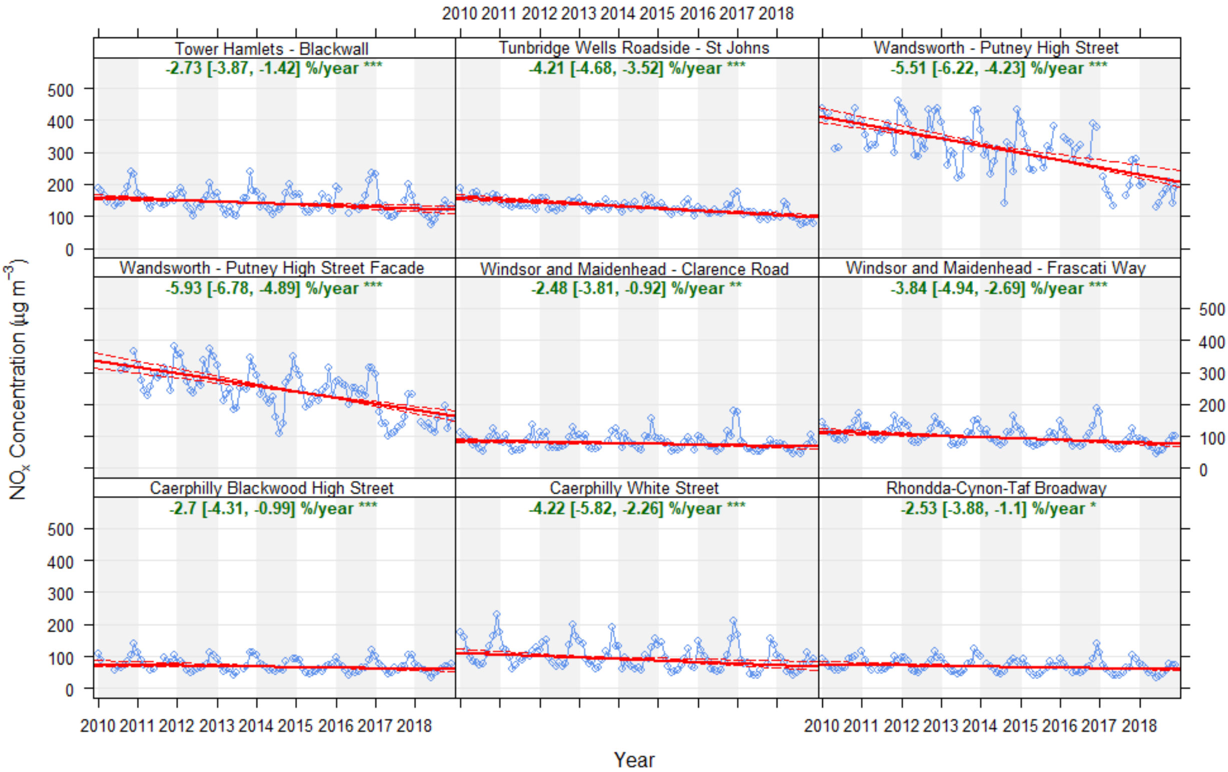


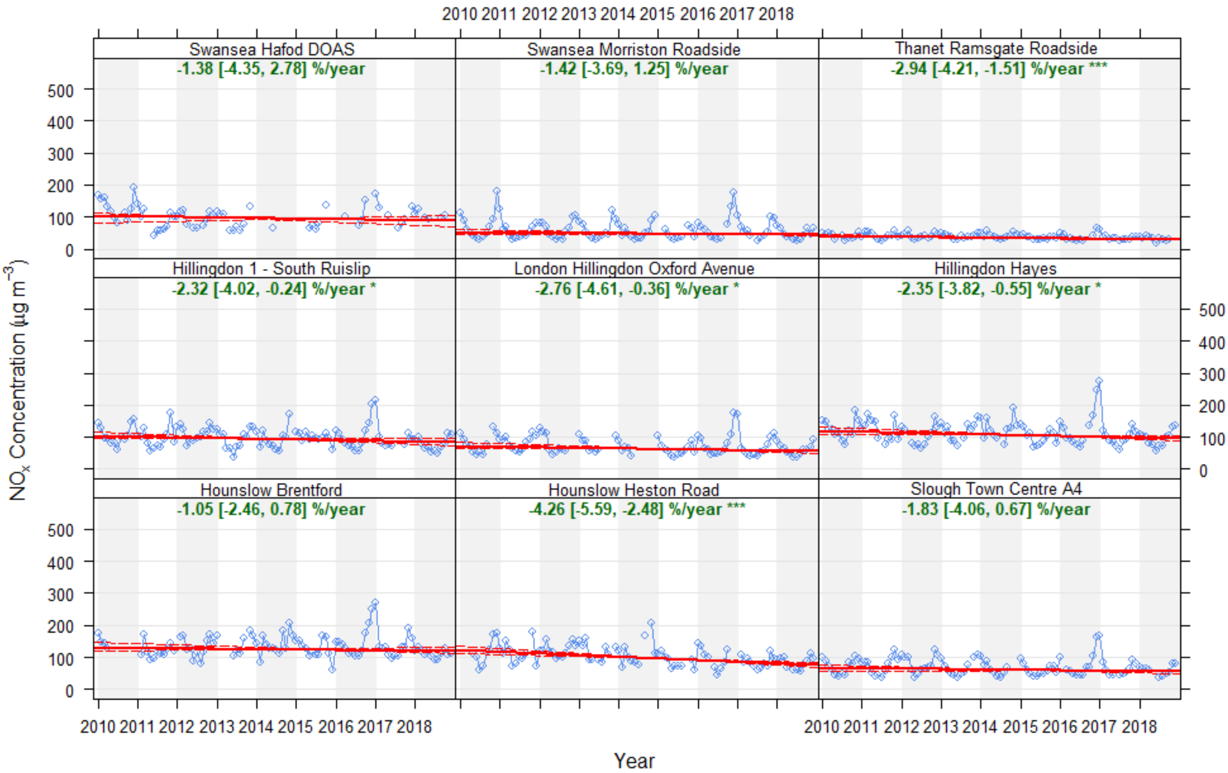
Road Sites NOx 2010 to 2018



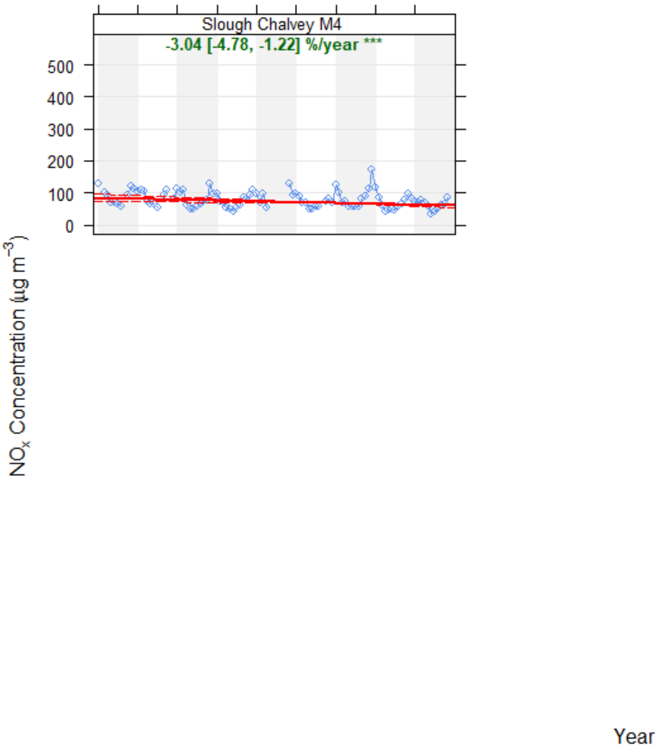


Road Sites NOx 2010 to 2018

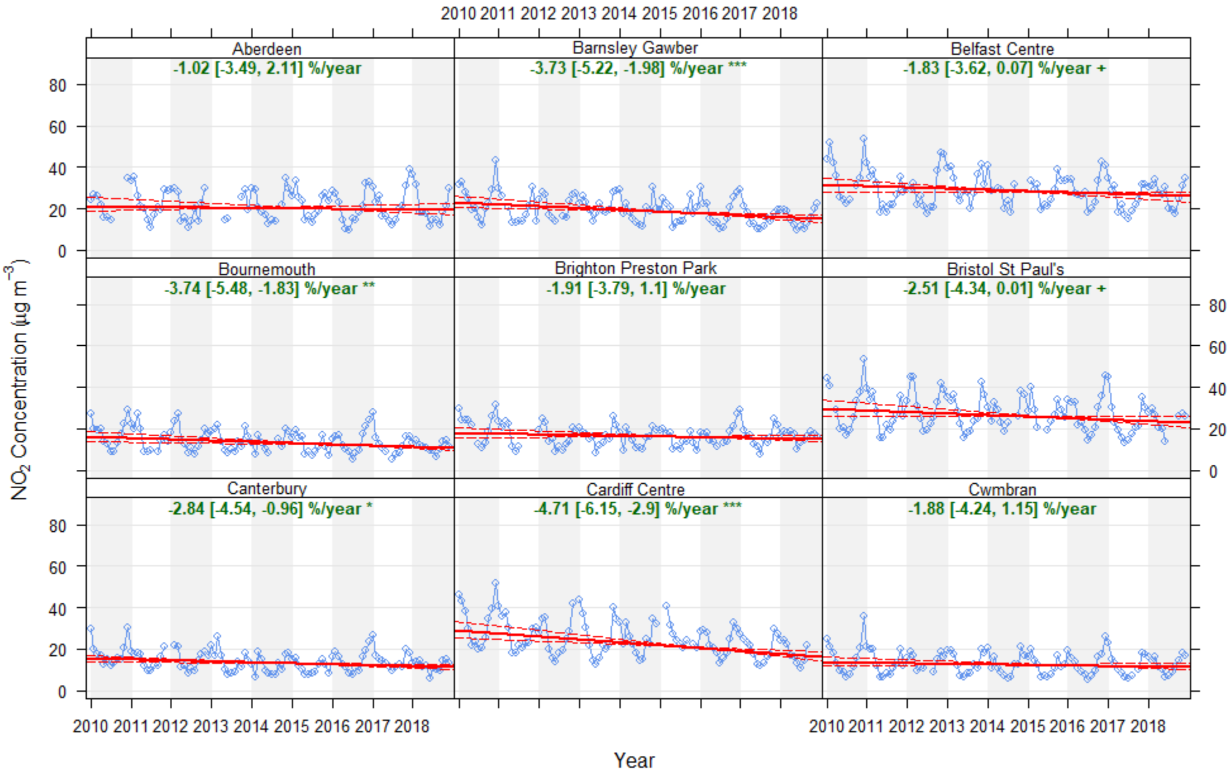


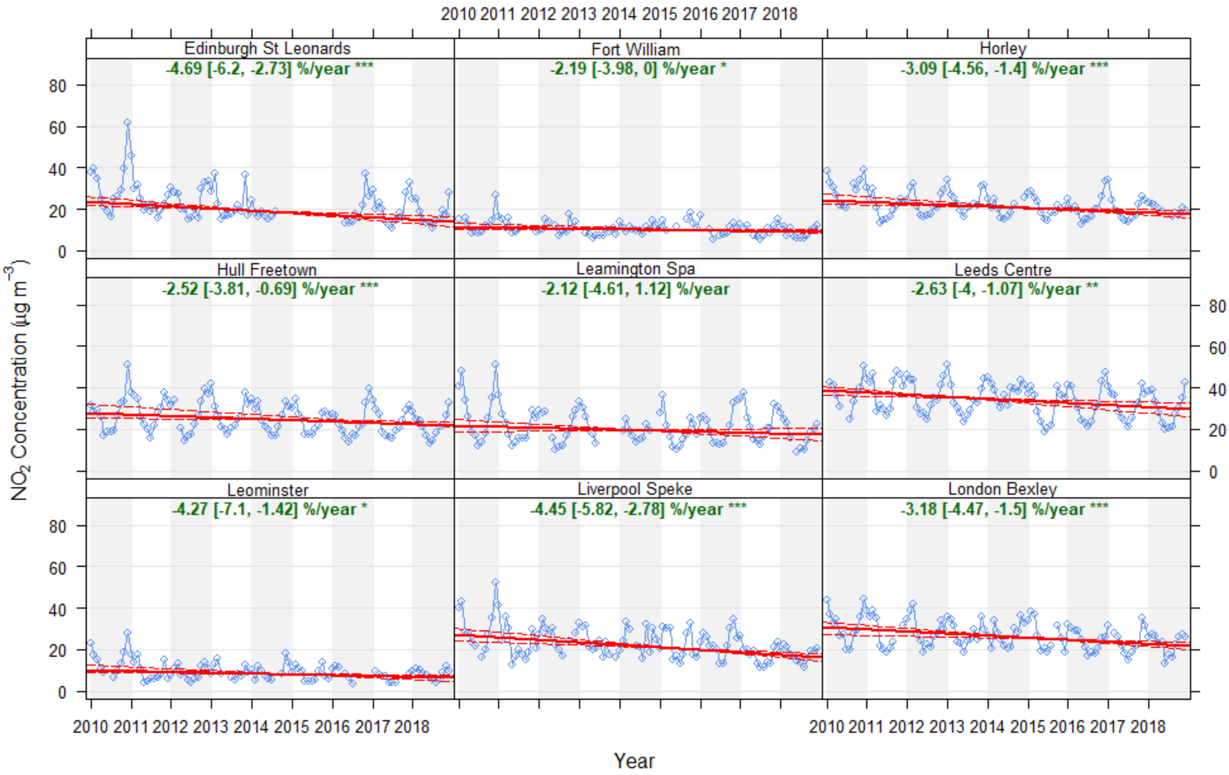


Road Sites NOx 2010 to 2018

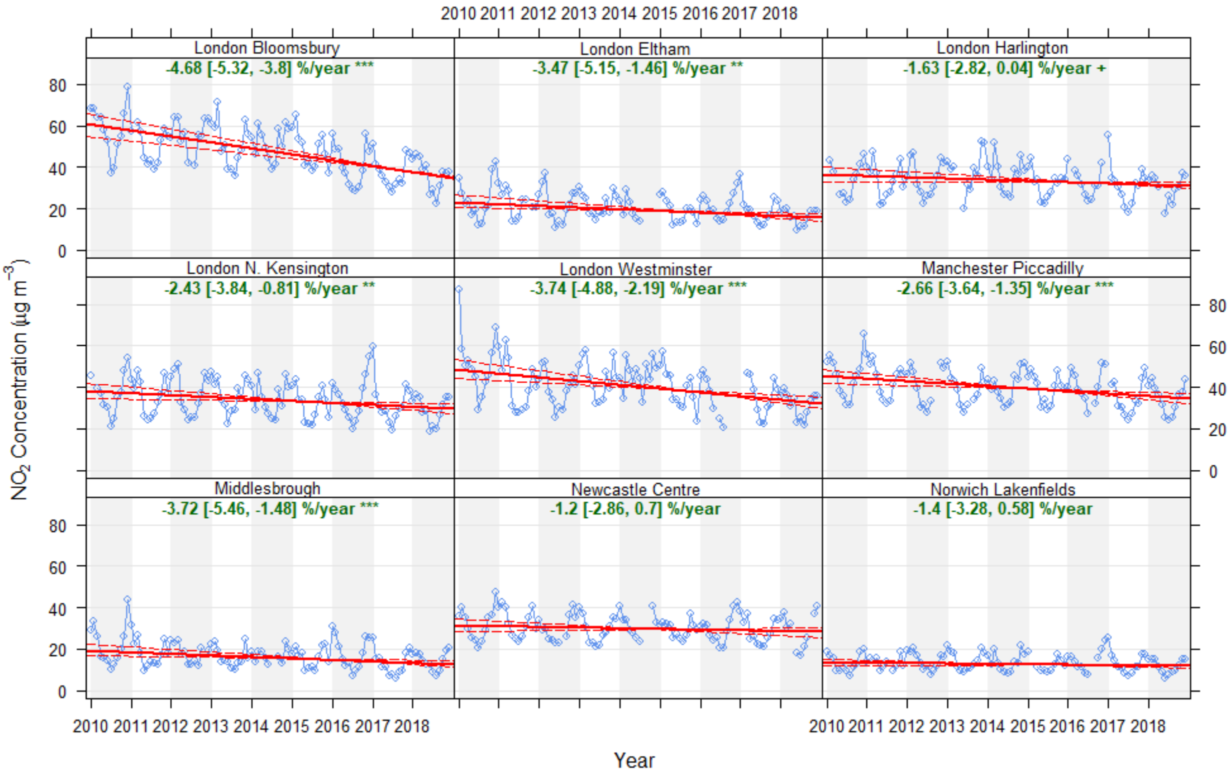


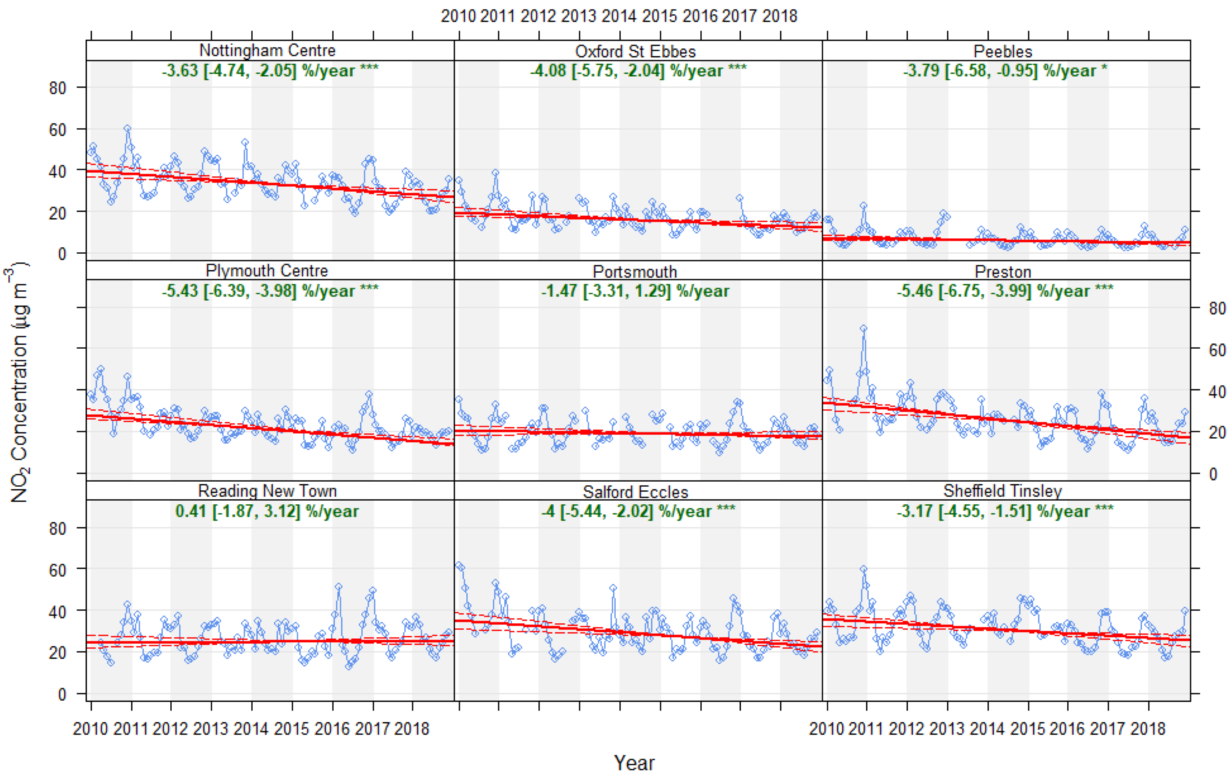
Urban Sites NO_2 2010 to 2018



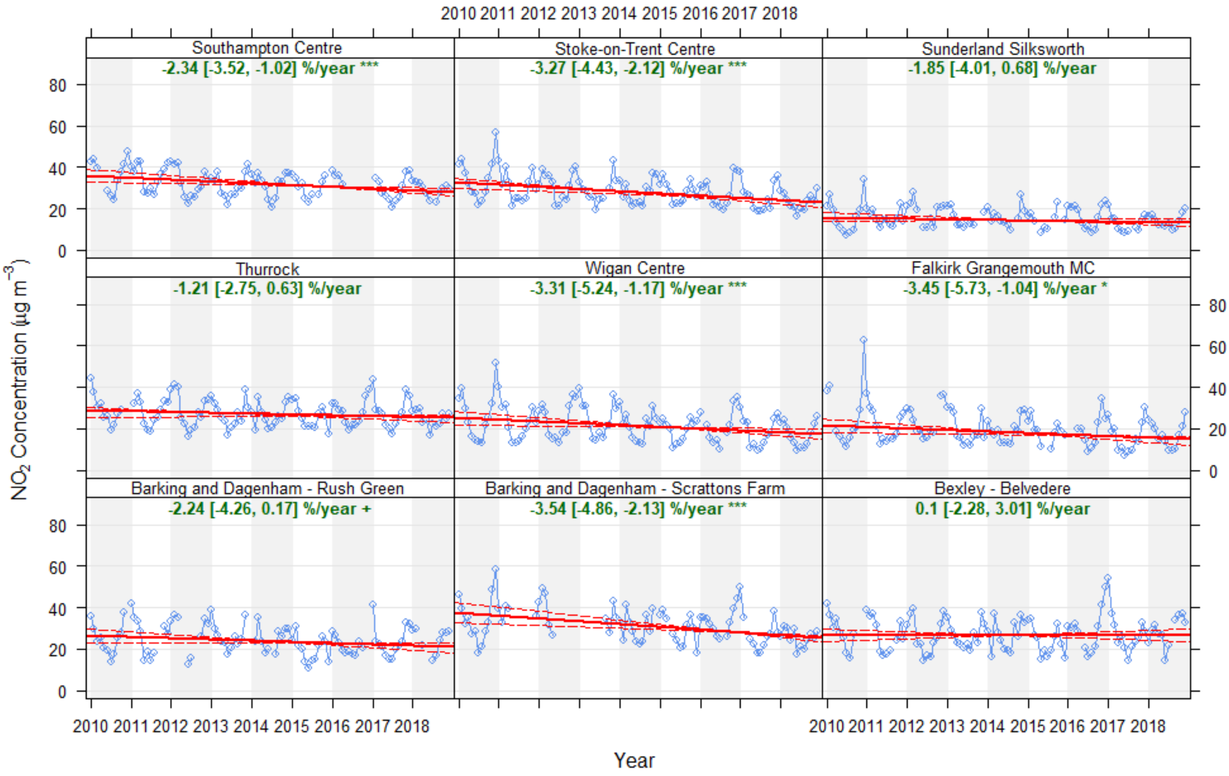


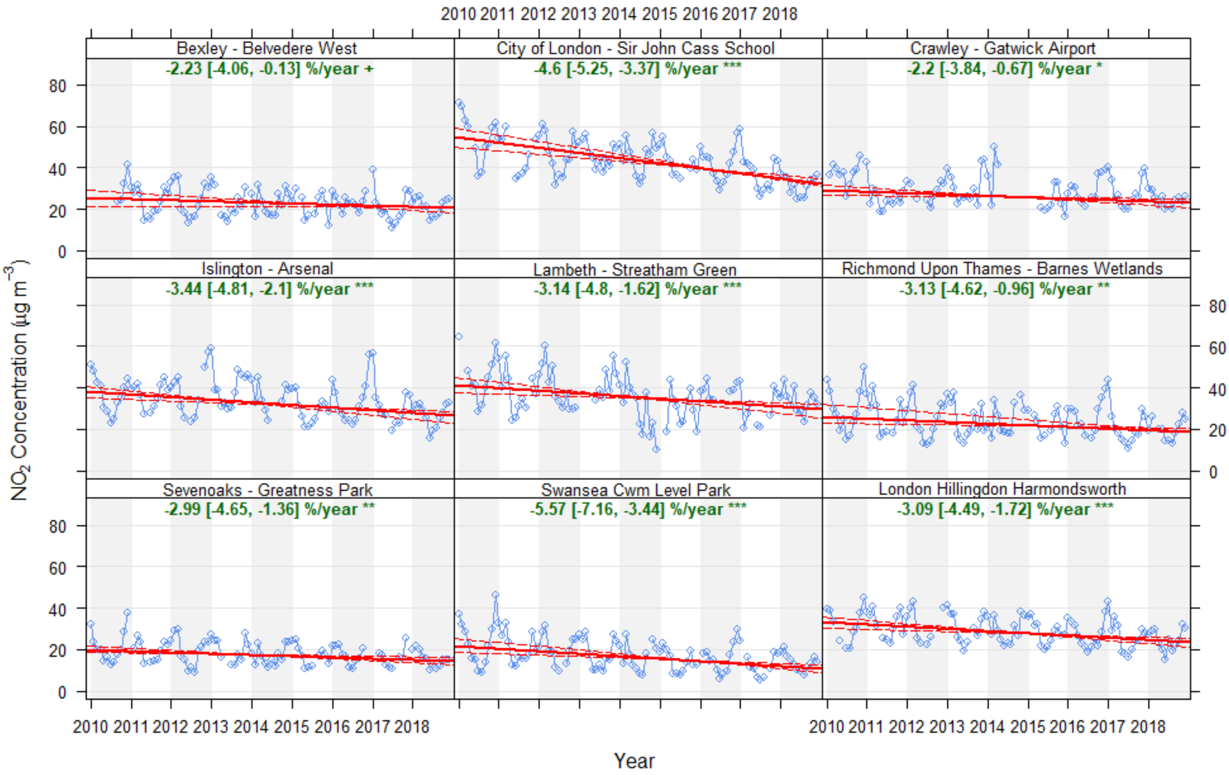
Urban Sites NO_2 2010 to 2018





Urban Sites NO_2 2010 to 2018





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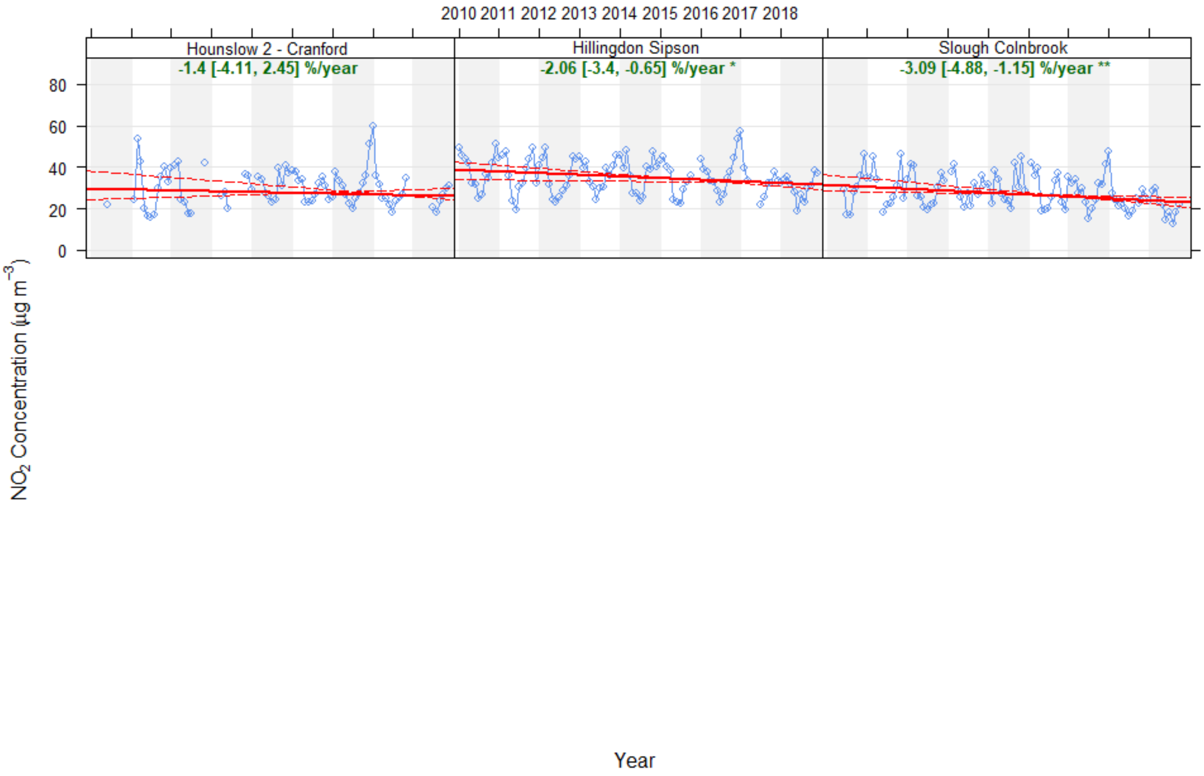

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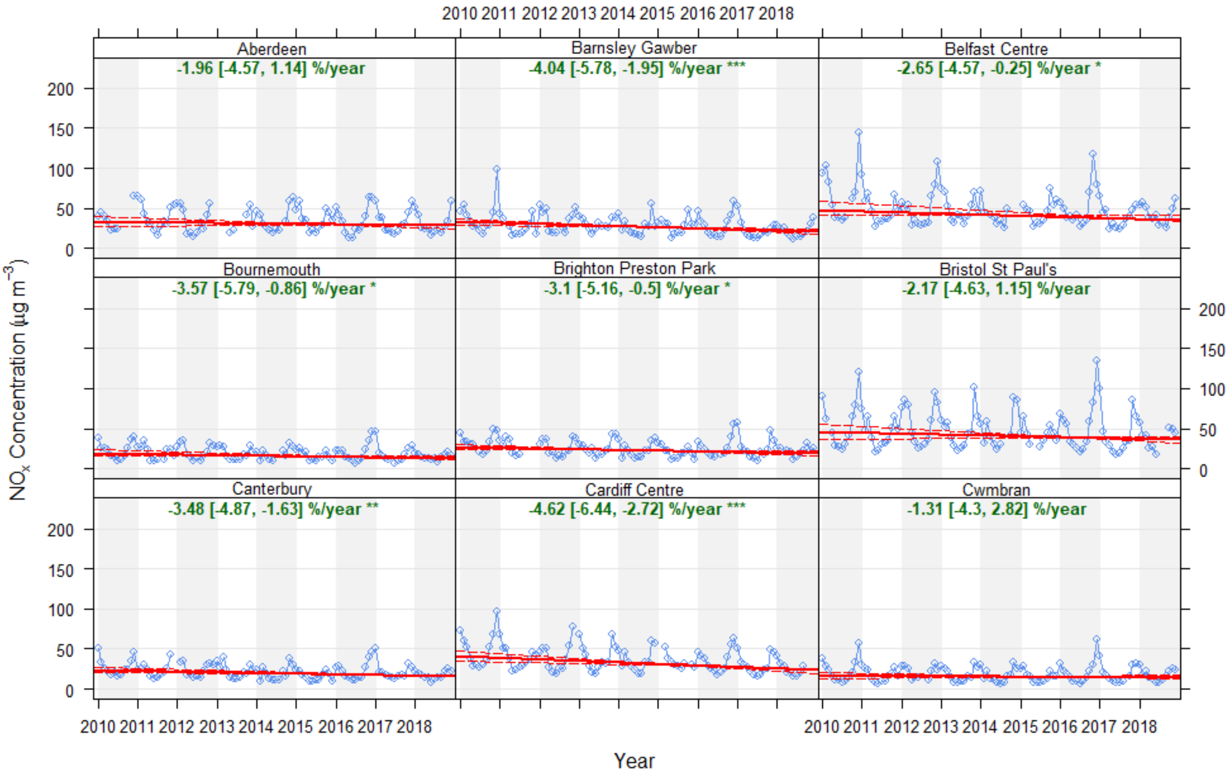
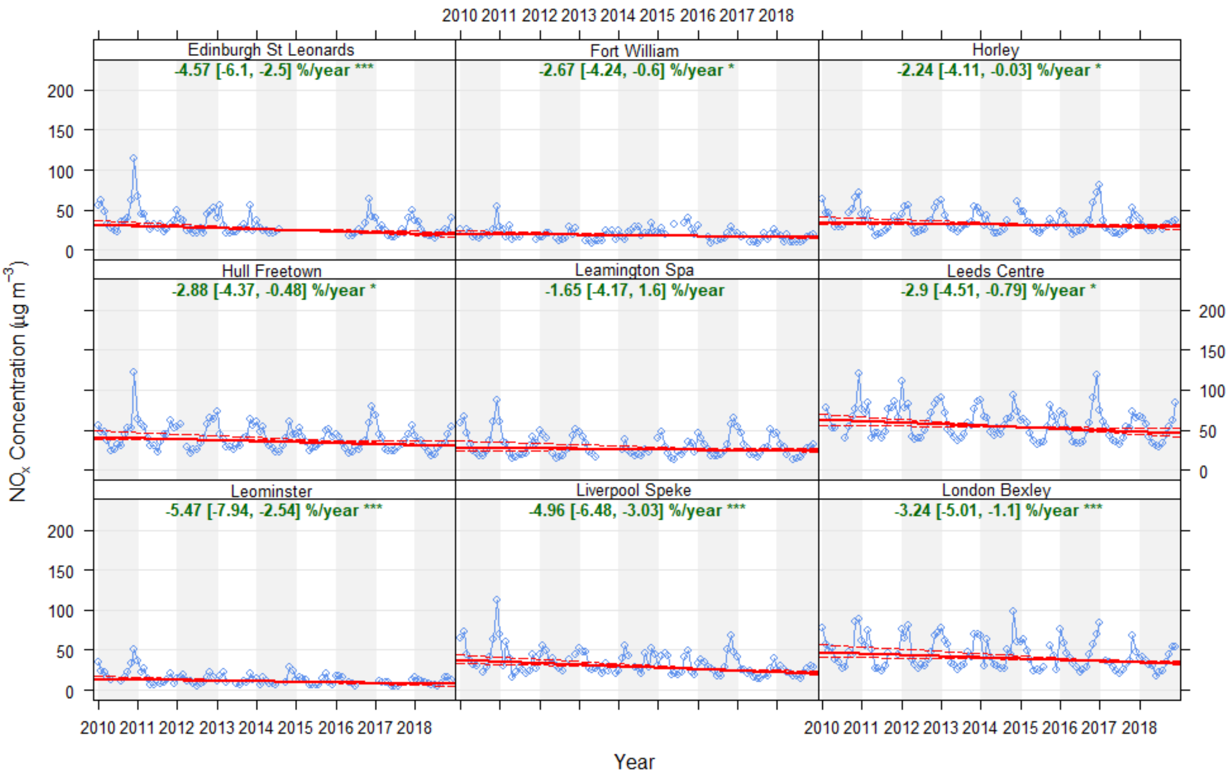
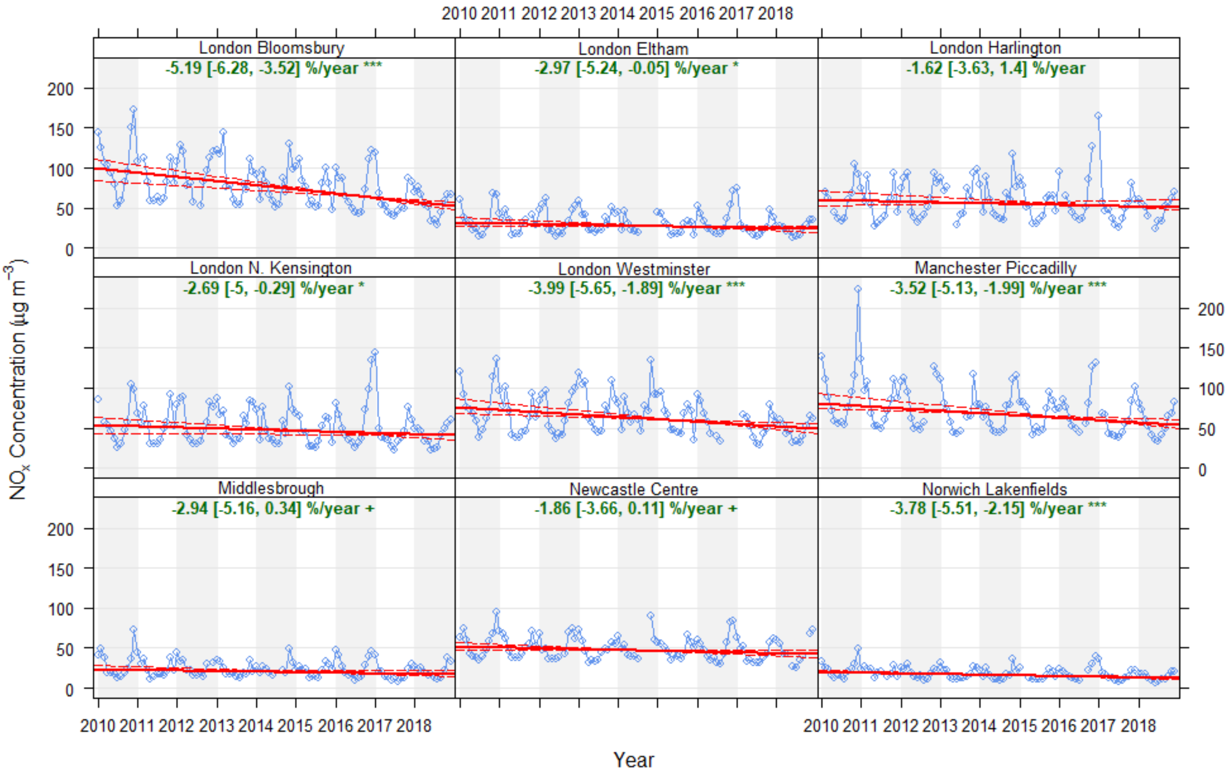
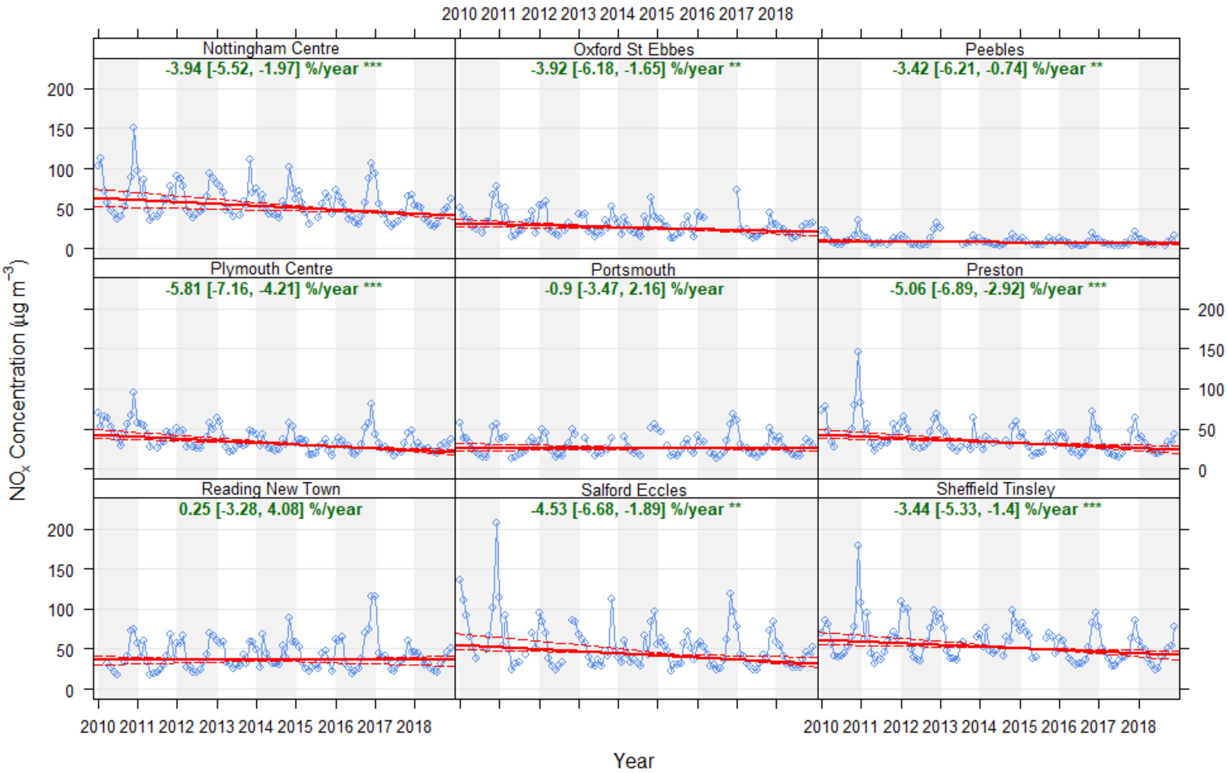




Urban Sites NOx 2010 to 2018





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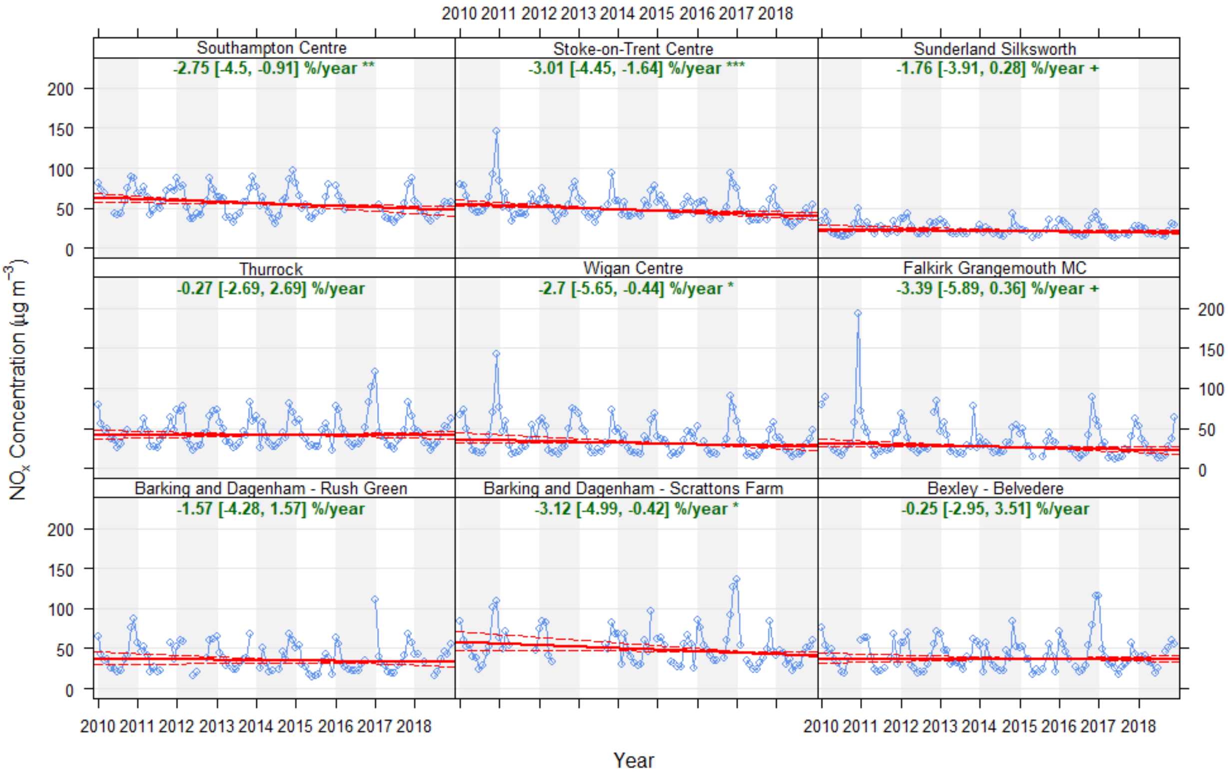
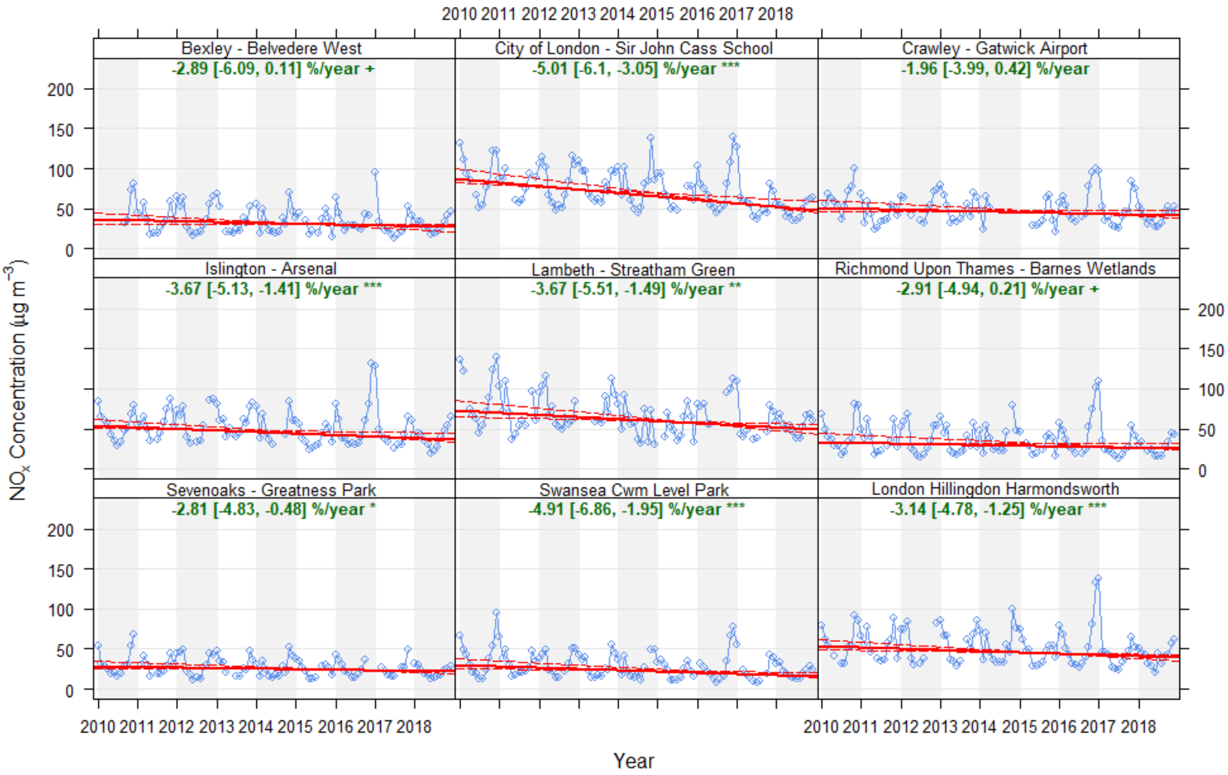
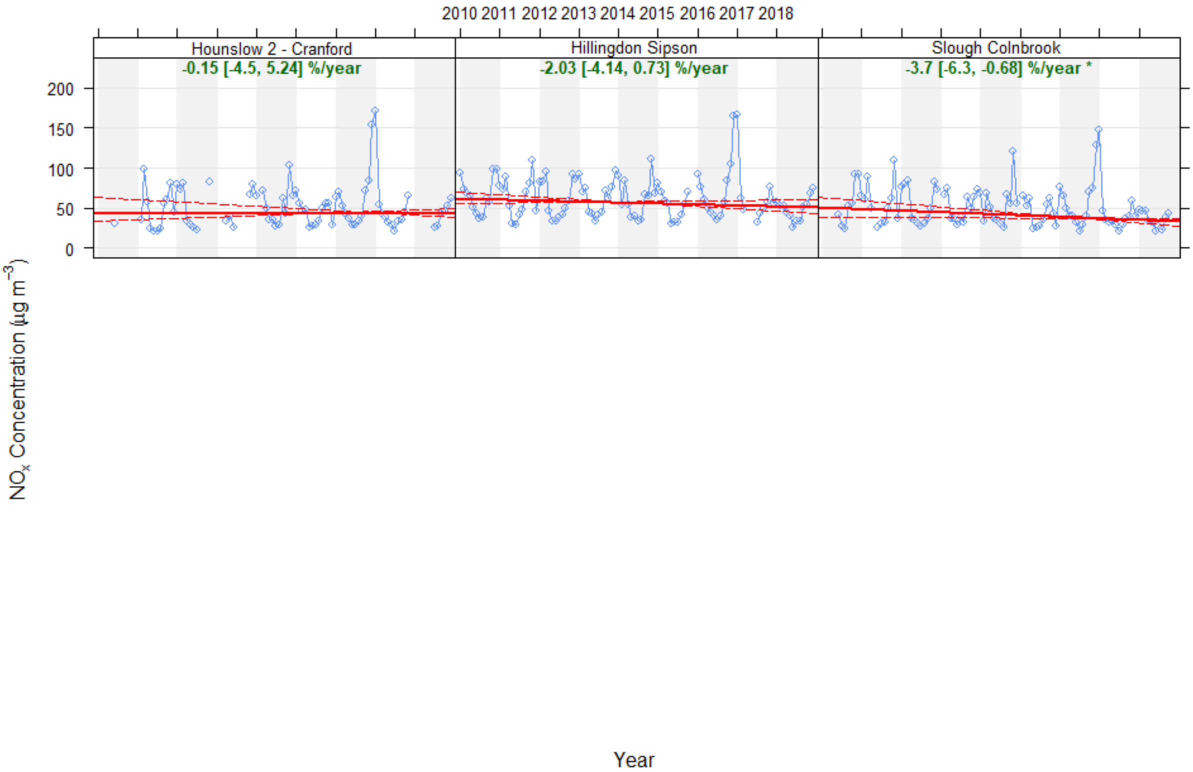
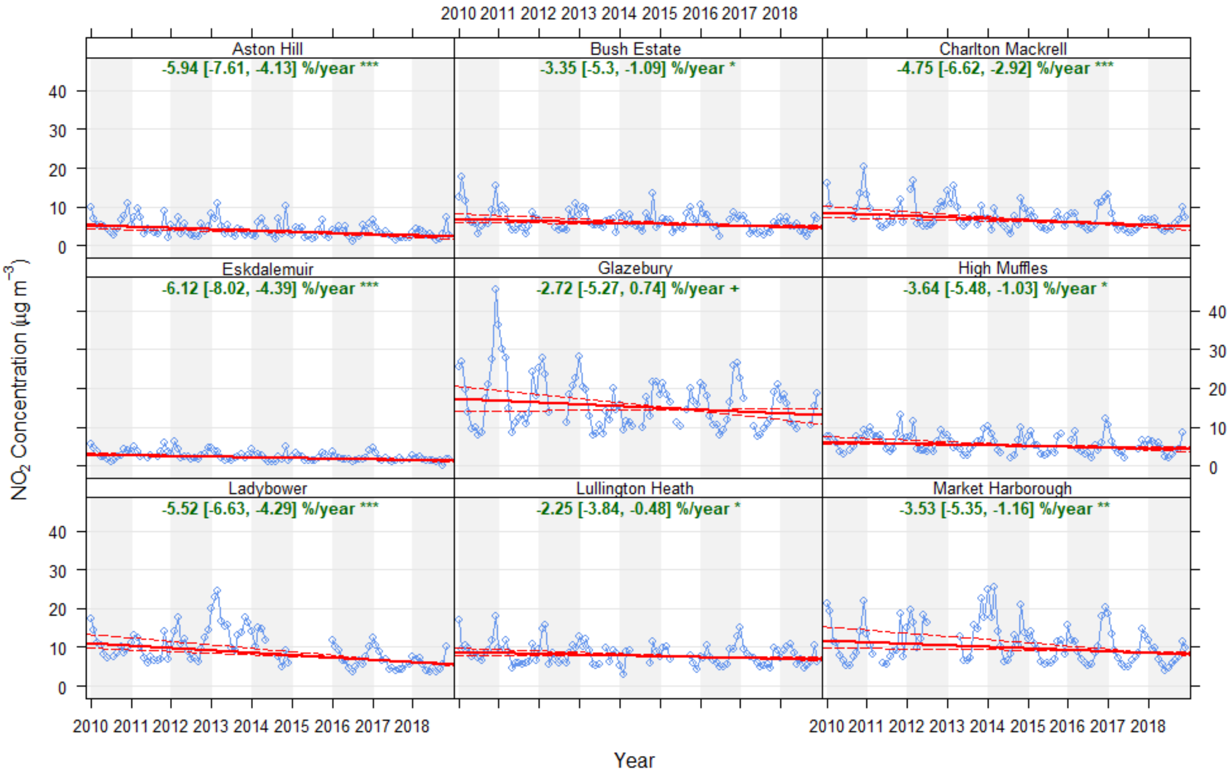


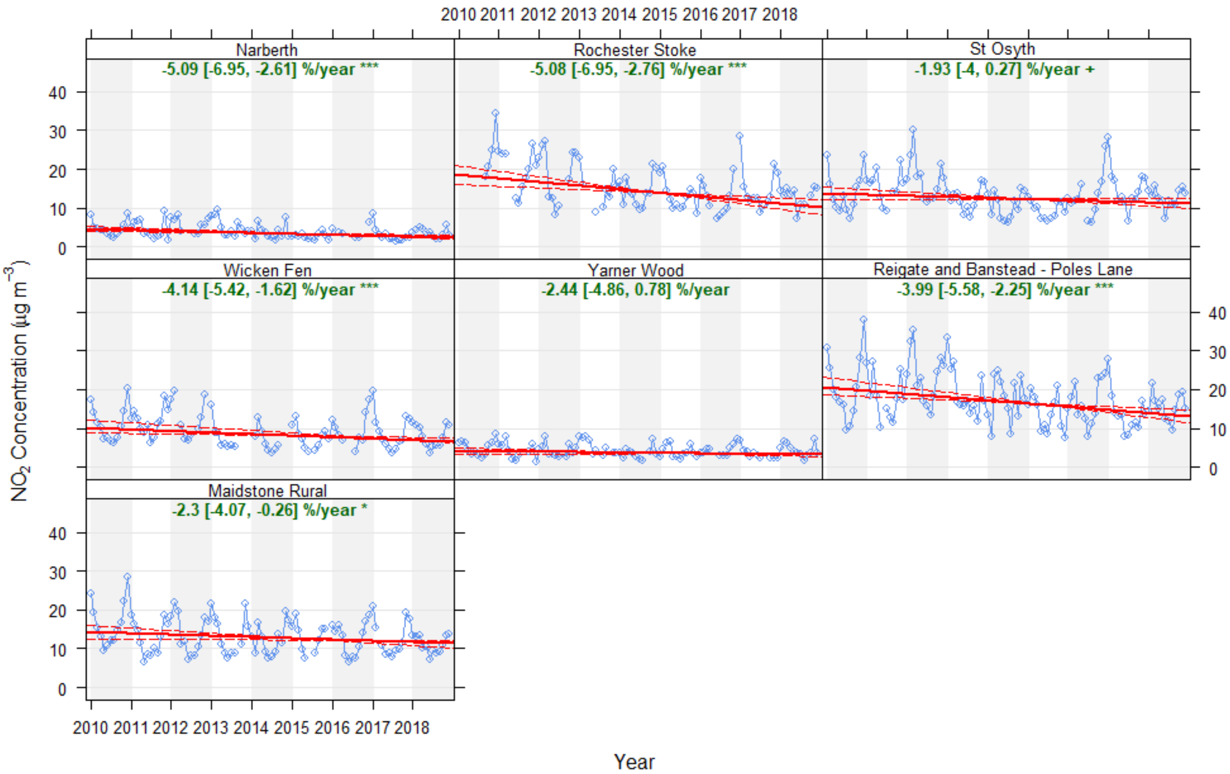


Urban Sites NOx 2010 to 2018



Rural Sites NO_2 2010 to 2018





Rural Sites NOx 2010 to 2018