Species-specific effects of the Urban Heat Island on tree growth across Berlin

Alexander G. Hurley, Ingo Heinrich

*Joint Geoforschungszentrum Potsdam, Section 4.3, Germany*

\* Corresponding author: [hurley@gfz-potsdam.de](mailto:hurley@gfz-potsdam.de)

06 March, 2020

**This document serves as a brief overview and outline** .

# Introduction

Berlin is subject to the most intense Urban Heat Island in Germany due to its large extent and development intensity. Here, substantially higher temperatures have been observed for urban as compared to rural areas, with differences of up to 12 K during day-time and 6 K on average for night-time temperatures (2001-2010).

Consequently, urban green (infrastructure) systems are subjected to increased heat more frequently than rural ecosystems, potentially affecting their process dynamics positively or adversely. Their performance and health, however, is closely tied to local energy budgets (Grimmond et al., 1996 ; Pretzsch et al., 2019), which in turn are decisive for controlling human wellbeing (e.g. Amini Parsa et al., 2019), amongst other factors. Assessing the effect of increased temperatures on green infrastructure, as part of the urban landscape, is therefore instrumental for understanding, and ultimately mitigating, the potential impact of future warming and (continued) development on increasingly urban societies (Kijowska-Oberc et al., 2020).

Trees, in particular, provide shading as well as transpirative cooling in their vicinity (e.g. Stratópoulos et al., 2019), and therefore can reduce ambient temperatures, infrastructure power-consumption and (human) thermal discomfort (e.g. Gulyás et al., 2006; Akbari et al., 2001; Hoyano, 1988; Mayer and Höppe, 1987); simultaneously, they provide numerous other environmental, cultural and psychological services and/or benefits (see Perkins et al., 2018 for review).

Tree growth dynamics in urban areas are modulated by air temperature, amongst other factors, with a tendency for enhanced growth rates (compared to rural individuals) as reported by Pretzsch et al. (2017). Hence, temperature increases may also allow using recent tree growth dynamics and trajectories as a proxy for on-going and future warming, providing an additional line of evidence to support the growing knowledge base on future climate-vegetation dynamics. For Berlin, Dahlhausen et al. (2018), showed divergent patterns for young and old trees dependent on urban development intensity for *Tilia cordata* Mill, the most abundant tree of the city, but overall reported an increased growth rate which they attributed to the urban heat island effect (UHI). Similarly, Moser-Reischl et al. (2019) showed positive associations between air temperature and radial growth for two species commonly selected by urban planners (*T. cordata*, *Rubinia pseudoacacia*) in Munich. By contrast, Gillner et al. (2014) highlight decreased growth for *Acer* species (*A. platanoides* and *pseudoplatanus*), *Platanus x hispanica* and *Quercus rubra* with higher summer temperatures of the preceding year, especially when compounded with drought, in another German metropolis (Dresden).

These results indicate a high degree of complexity in effect sizes and directions specific to species and locality. Tree growth in urban settings is affected by myriad processes and factors, such as water availability, pollution and road-salt loading, structural impedance through infrastructure or management, etc. (Pauleit et al., 2002). Therefore, studies reliant on labor-intensive sampling (e.g. based on increment cores; dendroecological methods), must carefully address confounding factors to ensure effect sizes are estimated adequately. While multiple (locally) important species have been assessed along urban and UHI gradients, studies are limited logistically by sampling effort, reducing sample size and coverage (i.e. genera and/or species, and space), which typically hinders highly-resolved predictions of effect sizes across entire urban areas and tree stocks. To complement detailed dendroecological analyses in Berlin for key species, we propose inferring growth modulation from a large data set in excess of 650000 individual trees provided by the Berlin Senate Administration (Senatsverwaltung). This data set contains information on location, species, trunk diameter (at breast height; DBH), and height, amongst others. In a space-for-time substitution, the absolute growth potential of species can assessed across the entire urban area, and related to effects of the UHI, as well as other location-specific factors, such as road type, development intensity, available soil volume, etc.

# Background

# Methods

# Results

Some results

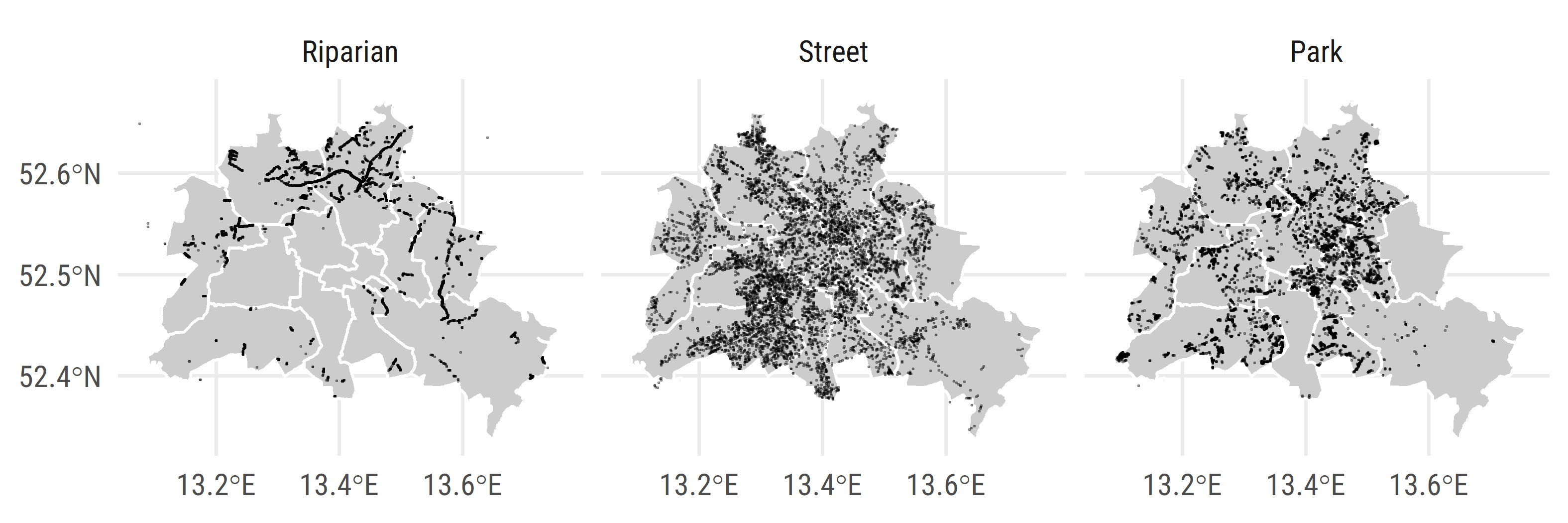


Figure 1: A plot of random numbers

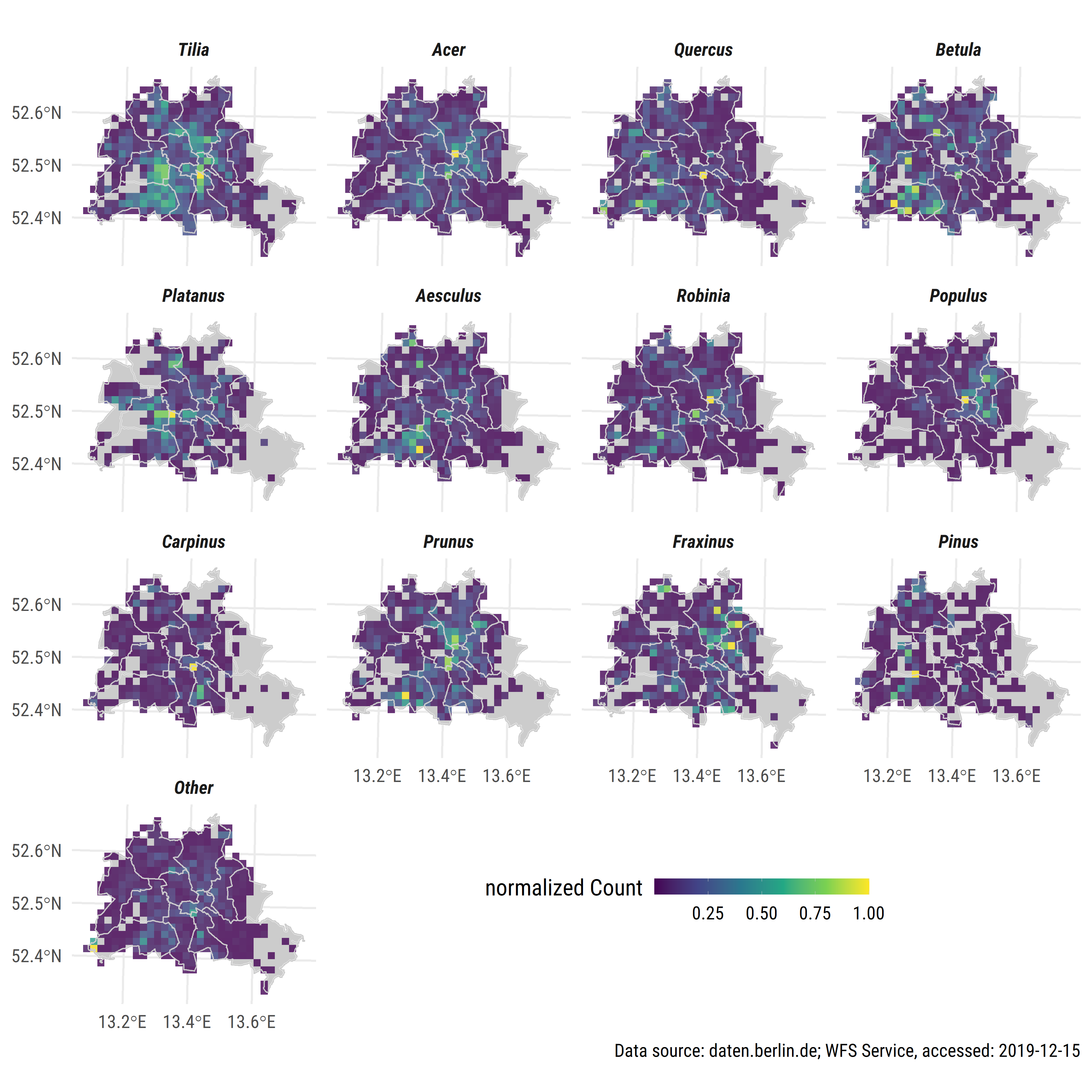


Figure 2: A plot of random numbers

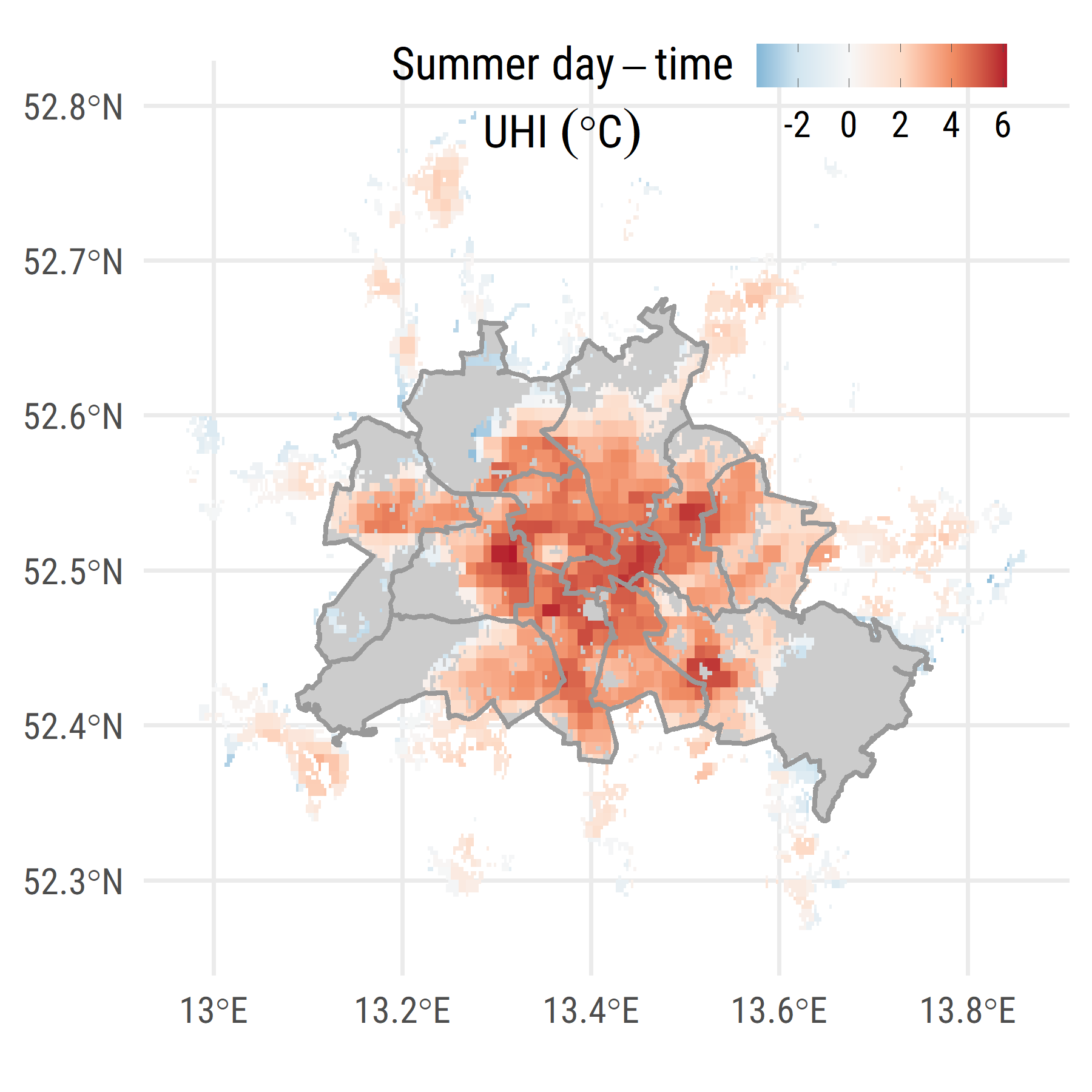


Figure 3: A plot of random numbers

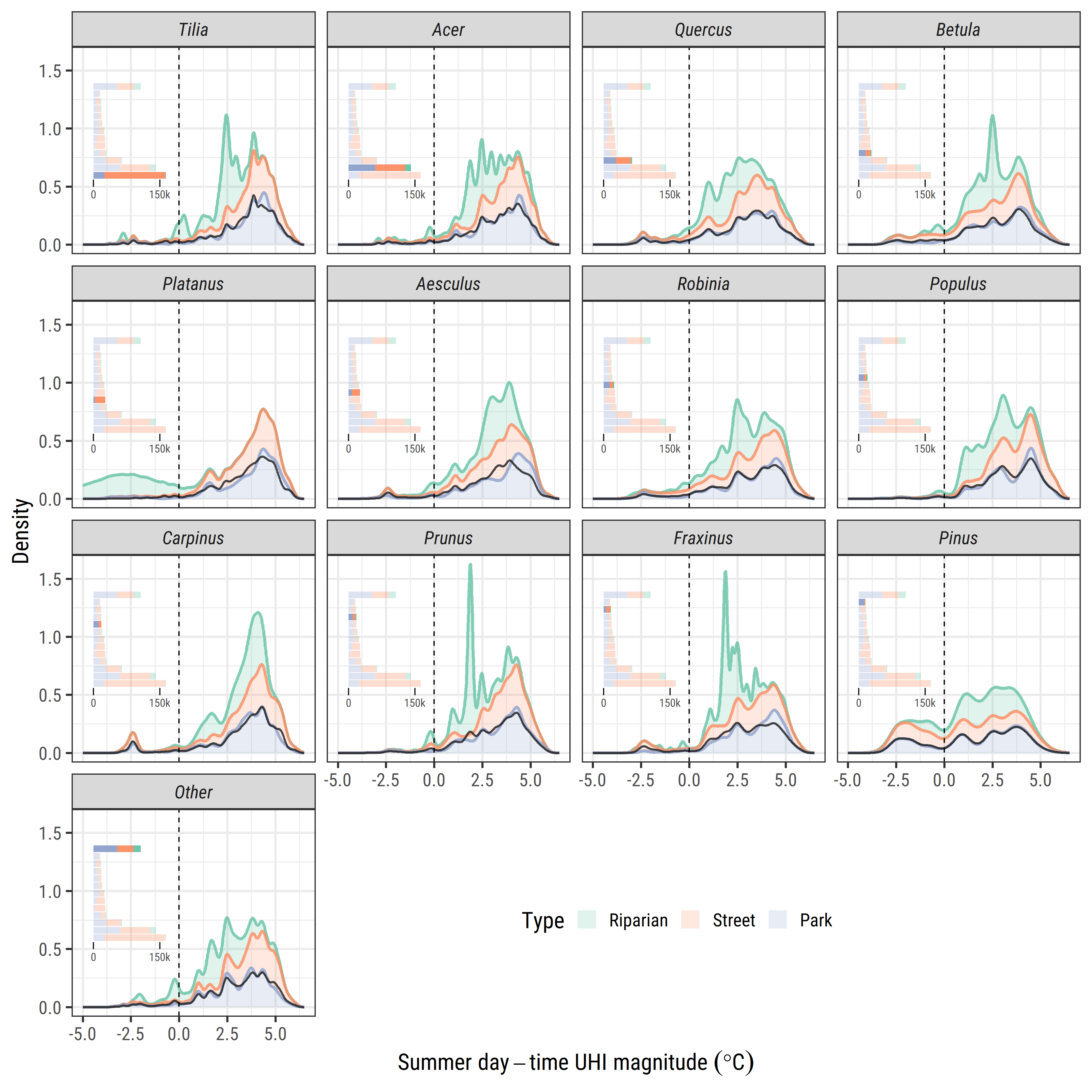


Figure 4: A plot of random numbers

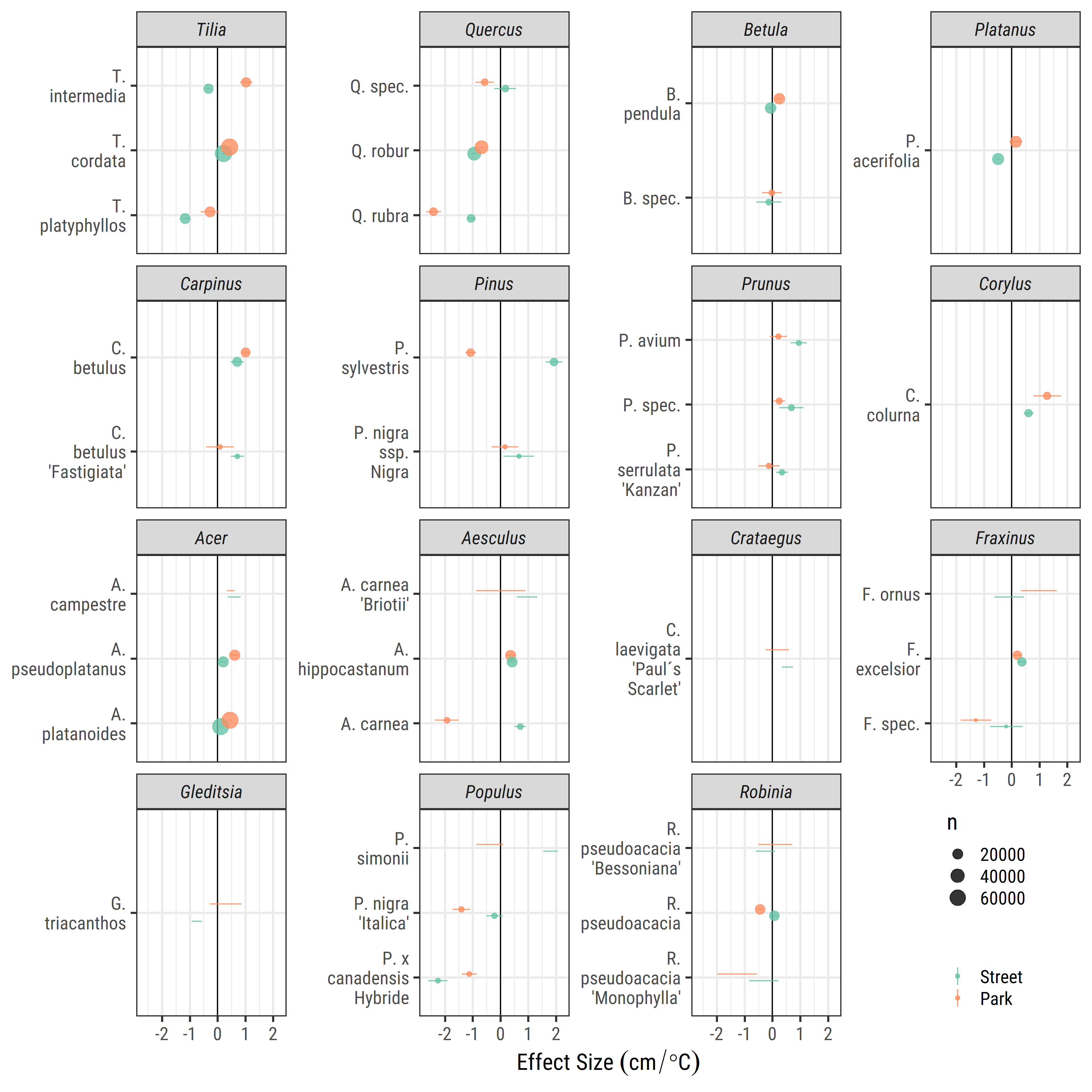


Figure 5: A plot of random numbers

Figure ?? shows how we can have a caption and cross-reference for a plot

# Discussion

# Conclusion

# Acknowledgements

# References

Akbari, H., Pomerantz, M., Taha, H., 2001. Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. Solar Energy, Urban Environment 70, 295–310. <https://doi.org/10.1016/S0038-092X(00)00089-X>

Amini Parsa, V., Salehi, E., Yavari, A.R., van Bodegom, P.M., 2019. Evaluating the potential contribution of urban ecosystem service to climate change mitigation. Urban Ecosyst 22, 989–1006. <https://doi.org/10.1007/s11252-019-00870-w>

Dahlhausen, J., Rötzer, T., Biber, P., Uhl, E., Pretzsch, H., 2018. Urban climate modifies tree growth in Berlin. Int J Biometeorol 62, 795–808. <https://doi.org/10.1007/s00484-017-1481-3>

Gillner, S., Bräuning, A., Roloff, A., 2014. Dendrochronological analysis of urban trees: Climatic response and impact of drought on frequently used tree species. Trees 28, 1079–1093. <https://doi.org/10.1007/s00468-014-1019-9>

Grimmond, C., Souch, C., Hubble, M., 1996. Influence of tree cover on summertime surface energy balance fluxes, San Gabriel Valley, Los Angeles. Clim. Res. 6, 45–57. <https://doi.org/10.3354/cr006045>

Gulyás, Á., Unger, J., Matzarakis, A., 2006. Assessment of the microclimatic and human comfort conditions in a complex urban environment: Modelling and measurements. Building and Environment 41, 1713–1722. <https://doi.org/10.1016/j.buildenv.2005.07.001>

Hoyano, A., 1988. Climatological uses of plants for solar control and the effects on the thermal environment of a building. Energy and Buildings 11, 181–199. <https://doi.org/10.1016/0378-7788(88)90035-7>

Kijowska-Oberc, J., Staszak, A.M., Kamiński, J., Ratajczak, E., 2020. Adaptation of Forest Trees to Rapidly Changing Climate. Forests 11, 123. <https://doi.org/10.3390/f11020123>

Mayer, H., Höppe, P., 1987. Thermal comfort of man in different urban environments. Theor Appl Climatol 38, 43–49. <https://doi.org/10.1007/BF00866252>

Moser-Reischl, A., Rahman, M.A., Pauleit, S., Pretzsch, H., Rötzer, T., 2019. Growth patterns and effects of urban micro-climate on two physiologically contrasting urban tree species. Landscape and Urban Planning 183, 88–99. <https://doi.org/10.1016/j.landurbplan.2018.11.004>

Pauleit, S., Jones, N., Garcia-Martin, G., Garcia-Valdecantos, J.L., Rivière, L.M., Vidal-Beaudet, L., Bodson, M., Randrup, T.B., 2002. Tree establishment practice in towns and cities – Results from a European survey. Urban Forestry & Urban Greening 1, 83–96. <https://doi.org/10.1078/1618-8667-00009>

Perkins, D., Uhl, E., Biber, P., Du Toit, B., Carraro, V., Rötzer, T., Pretzsch, H., 2018. Impact of Climate Trends and Drought Events on the Growth of Oaks (Quercus robur L. And Quercus petraea (Matt.) Liebl.) Within and beyond Their Natural Range. Forests 9, 108. <https://doi.org/10.3390/f9030108>

Pretzsch, H., Biber, P., Uhl, E., Dahlhausen, J., Schütze, G., Perkins, D., Rötzer, T., Caldentey, J., Koike, T., Con, T. van, Chavanne, A., Toit, B. du, Foster, K., Lefer, B., 2017. Climate change accelerates growth of urban trees in metropolises worldwide. Scientific Reports 7, 1–10. <https://doi.org/10.1038/s41598-017-14831-w>

Pretzsch, H., del Río, M., Biber, P., Arcangeli, C., Bielak, K., Brang, P., Dudzinska, M., Forrester, D.I., Klädtke, J., Kohnle, U., Ledermann, T., Matthews, R., Nagel, J., Nagel, R., Nilsson, U., Ningre, F., Nord-Larsen, T., Wernsdörfer, H., Sycheva, E., 2019. Maintenance of long-term experiments for unique insights into forest growth dynamics and trends: Review and perspectives. Eur J Forest Res 138, 165–185. <https://doi.org/10.1007/s10342-018-1151-y>

Stratópoulos, L.M.F., Zhang, C., Häberle, K.-H., Pauleit, S., Duthweiler, S., Pretzsch, H., Rötzer, T., 2019. Effects of Drought on the Phenology, Growth, and Morphological Development of Three Urban Tree Species and Cultivars. Sustainability 11, 5117. <https://doi.org/10.3390/su11185117>

### Colophon

This report was generated on 2020-03-06 17:31:15 using the following computational environment and dependencies:

#> - Session info ---------------------------------------------------------------  
#> setting value   
#> version R version 3.6.3 (2020-02-29)  
#> os Windows 10 x64   
#> system x86\_64, mingw32   
#> ui RTerm   
#> language (EN)   
#> collate English\_United States.1252   
#> ctype English\_United States.1252   
#> tz Europe/Berlin   
#> date 2020-03-06   
#>   
#> - Packages -------------------------------------------------------------------  
#> package \* version date lib source   
#> assertthat 0.2.1 2019-03-21 [1] CRAN (R 3.6.2)   
#> backports 1.1.5 2019-10-02 [1] CRAN (R 3.6.1)   
#> base64url 1.4 2018-05-14 [1] CRAN (R 3.6.2)   
#> berlin.trees 0.0.0.9000 2020-03-06 [1] local   
#> bookdown 0.18 2020-03-05 [1] CRAN (R 3.6.3)   
#> boot 1.3-24 2019-12-20 [1] CRAN (R 3.6.3)   
#> callr 3.4.2 2020-02-12 [1] CRAN (R 3.6.2)   
#> ckanr 0.4.0 2019-10-11 [1] CRAN (R 3.6.2)   
#> class 7.3-15 2019-01-01 [1] CRAN (R 3.6.3)   
#> classInt 0.4-2 2019-10-17 [1] CRAN (R 3.6.2)   
#> cli 2.0.2 2020-02-28 [1] CRAN (R 3.6.3)   
#> codetools 0.2-16 2018-12-24 [1] CRAN (R 3.6.3)   
#> colorspace 1.4-1 2019-03-18 [1] CRAN (R 3.6.1)   
#> crayon 1.3.4 2017-09-16 [1] CRAN (R 3.6.2)   
#> DBI 1.1.0 2019-12-15 [1] CRAN (R 3.6.2)   
#> dbplyr 1.4.2 2019-06-17 [1] CRAN (R 3.6.2)   
#> desc 1.2.0 2018-05-01 [1] CRAN (R 3.6.2)   
#> devtools 2.2.2 2020-02-17 [1] CRAN (R 3.6.2)   
#> digest 0.6.25 2020-02-23 [1] CRAN (R 3.6.2)   
#> dplyr \* 0.8.4 2020-01-31 [1] CRAN (R 3.6.2)   
#> drake \* 7.11.0 2020-03-01 [1] CRAN (R 3.6.3)   
#> e1071 1.7-3 2019-11-26 [1] CRAN (R 3.6.2)   
#> ellipsis 0.3.0 2019-09-20 [1] CRAN (R 3.6.2)   
#> evaluate 0.14 2019-05-28 [1] CRAN (R 3.6.2)   
#> fansi 0.4.1 2020-01-08 [1] CRAN (R 3.6.2)   
#> filelock 1.0.2 2018-10-05 [1] CRAN (R 3.6.2)   
#> fs 1.3.1 2019-05-06 [1] CRAN (R 3.6.2)   
#> furrr 0.1.0 2018-05-16 [1] CRAN (R 3.6.2)   
#> future \* 1.16.0 2020-01-16 [1] CRAN (R 3.6.2)   
#> future.callr \* 0.5.0 2019-09-28 [1] CRAN (R 3.6.2)   
#> ggplot2 3.3.0.9000 2020-03-06 [1] Github (tidyverse/ggplot2@1223de2)  
#> git2r 0.26.1 2019-06-29 [1] CRAN (R 3.6.2)   
#> globals 0.12.5 2019-12-07 [1] CRAN (R 3.6.1)   
#> glue 1.3.1 2019-03-12 [1] CRAN (R 3.6.2)   
#> gtable 0.3.0 2019-03-25 [1] CRAN (R 3.6.2)   
#> here 0.1 2017-05-28 [1] CRAN (R 3.6.2)   
#> hms 0.5.3 2020-01-08 [1] CRAN (R 3.6.3)   
#> htmltools 0.4.0 2019-10-04 [1] CRAN (R 3.6.2)   
#> httr 1.4.1 2019-08-05 [1] CRAN (R 3.6.2)   
#> igraph 1.2.4.2 2019-11-27 [1] CRAN (R 3.6.2)   
#> jsonlite 1.6.1 2020-02-02 [1] CRAN (R 3.6.2)   
#> KernSmooth 2.23-16 2019-10-15 [1] CRAN (R 3.6.3)   
#> knitr 1.28 2020-02-06 [1] CRAN (R 3.6.2)   
#> lattice 0.20-38 2018-11-04 [1] CRAN (R 3.6.3)   
#> lifecycle 0.1.0 2019-08-01 [1] CRAN (R 3.6.2)   
#> listenv 0.8.0 2019-12-05 [1] CRAN (R 3.6.2)   
#> lme4 1.1-21 2019-03-05 [1] CRAN (R 3.6.2)   
#> magrittr 1.5 2014-11-22 [1] CRAN (R 3.6.2)   
#> MASS 7.3-51.5 2019-12-20 [1] CRAN (R 3.6.3)   
#> Matrix 1.2-18 2019-11-27 [1] CRAN (R 3.6.3)   
#> memoise 1.1.0 2017-04-21 [1] CRAN (R 3.6.2)   
#> minqa 1.2.4 2014-10-09 [1] CRAN (R 3.6.2)   
#> munsell 0.5.0 2018-06-12 [1] CRAN (R 3.6.2)   
#> nlme 3.1-144 2020-02-06 [1] CRAN (R 3.6.3)   
#> nloptr 1.2.2 2020-02-29 [1] CRAN (R 3.6.3)   
#> pillar 1.4.3 2019-12-20 [1] CRAN (R 3.6.2)   
#> pkgbuild 1.0.6 2019-10-09 [1] CRAN (R 3.6.2)   
#> pkgconfig 2.0.3 2019-09-22 [1] CRAN (R 3.6.2)   
#> pkgload 1.0.2 2018-10-29 [1] CRAN (R 3.6.2)   
#> prettyunits 1.1.1 2020-01-24 [1] CRAN (R 3.6.2)   
#> processx 3.4.2 2020-02-09 [1] CRAN (R 3.6.2)   
#> progress 1.2.2 2019-05-16 [1] CRAN (R 3.6.3)   
#> ps 1.3.2 2020-02-13 [1] CRAN (R 3.6.2)   
#> purrr 0.3.3 2019-10-18 [1] CRAN (R 3.6.2)   
#> R6 2.4.1 2019-11-12 [1] CRAN (R 3.6.2)   
#> raster 3.0-12 2020-01-30 [1] CRAN (R 3.6.3)   
#> Rcpp 1.0.3 2019-11-08 [1] CRAN (R 3.6.2)   
#> remotes 2.1.1 2020-02-15 [1] CRAN (R 3.6.2)   
#> rlang 0.4.5 2020-03-01 [1] CRAN (R 3.6.3)   
#> rmarkdown 2.1 2020-01-20 [1] CRAN (R 3.6.2)   
#> rprojroot 1.3-2 2018-01-03 [1] CRAN (R 3.6.2)   
#> rstudioapi 0.11 2020-02-07 [1] CRAN (R 3.6.2)   
#> scales 1.1.0 2019-11-18 [1] CRAN (R 3.6.2)   
#> sessioninfo 1.1.1 2018-11-05 [1] CRAN (R 3.6.2)   
#> sf 0.8-1 2020-01-28 [1] CRAN (R 3.6.2)   
#> sp 1.4-1 2020-02-28 [1] CRAN (R 3.6.3)   
#> storr 1.2.1 2018-10-18 [1] CRAN (R 3.6.2)   
#> stringi 1.4.6 2020-02-17 [1] CRAN (R 3.6.2)   
#> stringr 1.4.0 2019-02-10 [1] CRAN (R 3.6.2)   
#> testthat 2.3.2 2020-03-02 [1] CRAN (R 3.6.3)   
#> tibble 2.1.3 2019-06-06 [1] CRAN (R 3.6.2)   
#> tidyselect 1.0.0 2020-01-27 [1] CRAN (R 3.6.2)   
#> tinytex 0.20 2020-02-25 [1] CRAN (R 3.6.2)   
#> txtq 0.2.0 2019-10-15 [1] CRAN (R 3.6.2)   
#> units 0.6-5 2019-10-08 [1] CRAN (R 3.6.2)   
#> usethis 1.5.1 2019-07-04 [1] CRAN (R 3.6.2)   
#> vctrs 0.2.3 2020-02-20 [1] CRAN (R 3.6.2)   
#> withr 2.1.2 2018-03-15 [1] CRAN (R 3.6.2)   
#> xfun 0.12 2020-01-13 [1] CRAN (R 3.6.2)   
#> yaml 2.2.1 2020-02-01 [1] CRAN (R 3.6.2)   
#>   
#> [1] C:/Program Files/R/R-3.6.3/library

The current Git commit details are:

#> Local: master C:/Users/ahurl/Documents/\_work/p024\_gfz\_berlin-trees/berlin.trees  
#> Remote: master @ origin (https://github.com/the-Hull/berlin.trees.git)  
#> Head: [ba256a2] 2020-03-05: Merge branch 'master' of https://github.com/the-Hull/berlin.trees