Monte Carlo Simulation Tools for REDD+ Uncertainty Estimates

2024-12-19

Contents

Import data

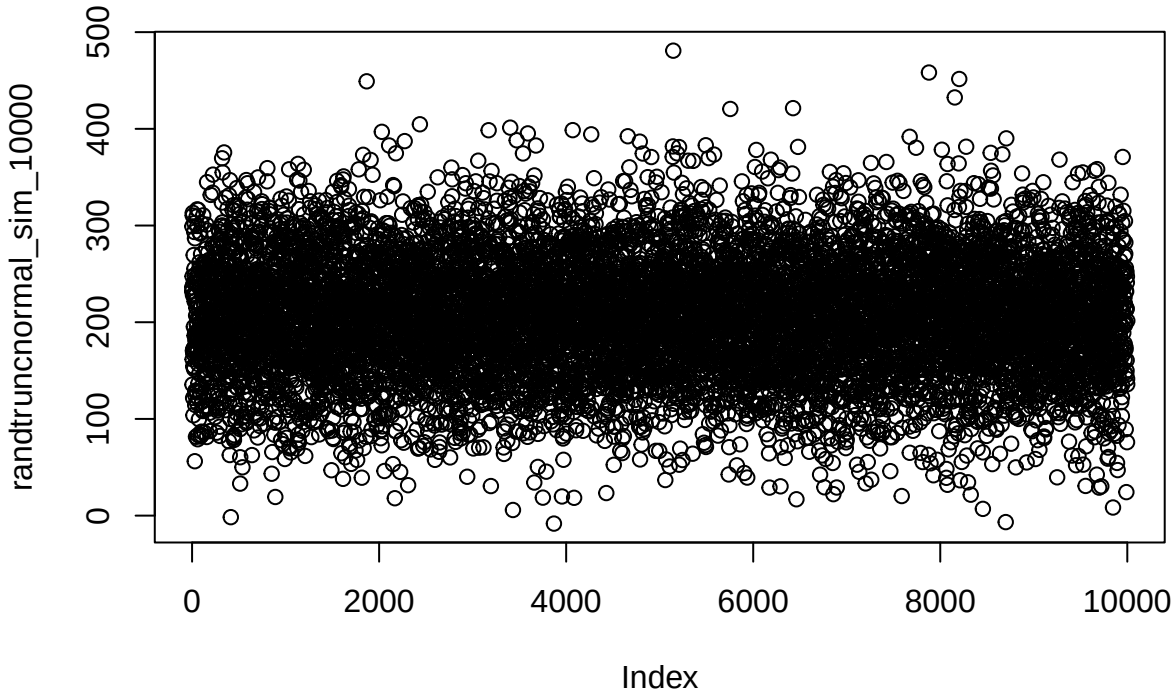
```
workbook = "./data/testdata/GuyanaARTWorkbookMC_thru2022_April2024_copy.xlsx"
worksheet = readxl::read_excel(workbook, "CarbonStocks")
head(worksheet)
```

```
# A tibble: 6 x 15
  ...1                    `AG Tree (tC/ha)` `BG Tree (tC/ha)` `Saplings (tC/ha)`
  <chr>                               <dbl>             <dbl>              <dbl>
1 mean of all plots (cal~           206.               48.3               3.67
2 std. dev                           60.4              14.3               2.04
3 minimum                            91.6              21.2               0.547
4 maximum                           354.               83.1              18.8
5 90% CI                              9.21              2.18              0.312
6 CI as % of mean                     0.0448            0.0450            0.0850
# i 11 more variables: `Standing Dead Wood (tC/ha)` <dbl>,
#   `Lying Dead Wood (tC/ha)` <dbl>,
#   `Sum Carbon pools w/o litter (t C/ha)` <dbl>, `Litter (tC/ha)` <dbl>,
#   `Sum C pool w/ litter (t C/ha)` <dbl>, `Sum CO2e (t CO2e/ha)` <dbl>,
#   ...11 <lgl>, `Soil tC/ha` <dbl>, ...13 <lgl>,
#   `Sum ALL POOLS (t CO2e/ha)` <dbl>, `Sum AG & BG live tree` <dbl>
```

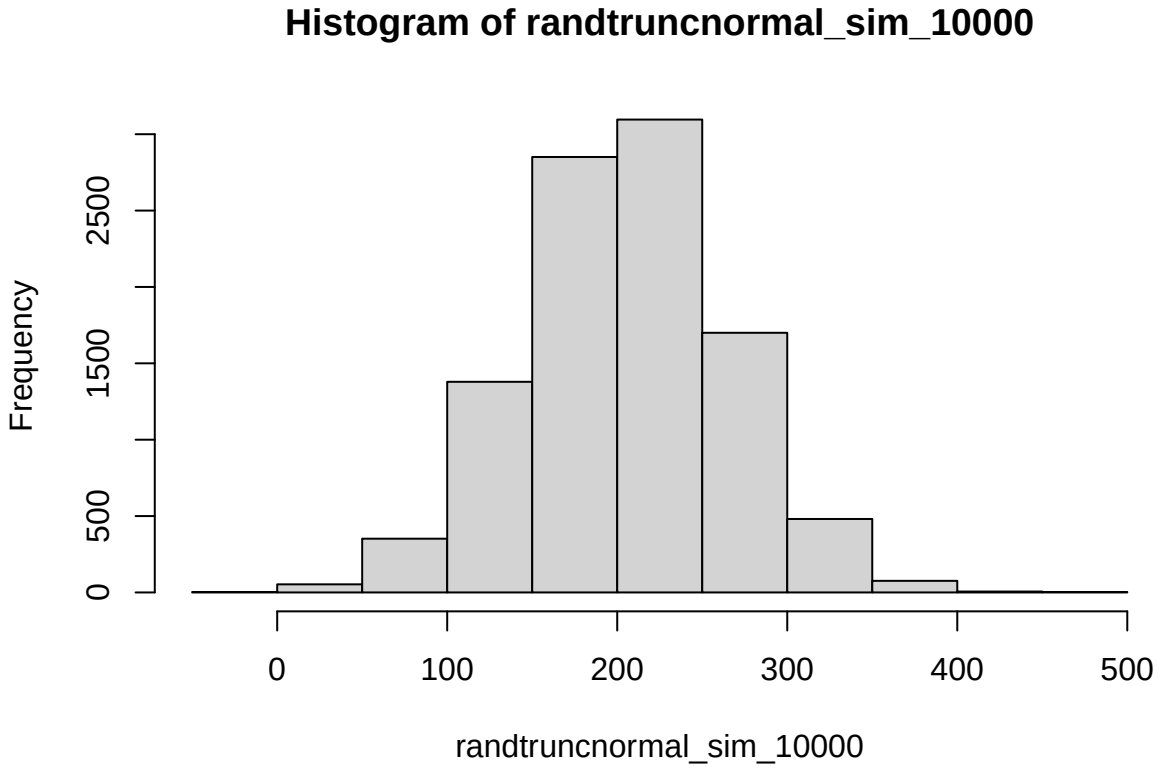
Replicate SimVoi

We utilize the replicate function to execute the simulation multiple times with `replicate(n=10000`, while determining the size of the sampled subset with `rnorm(n=100`. The first model explores sample size parameters only, replication parameters are tested below this in comparisons.

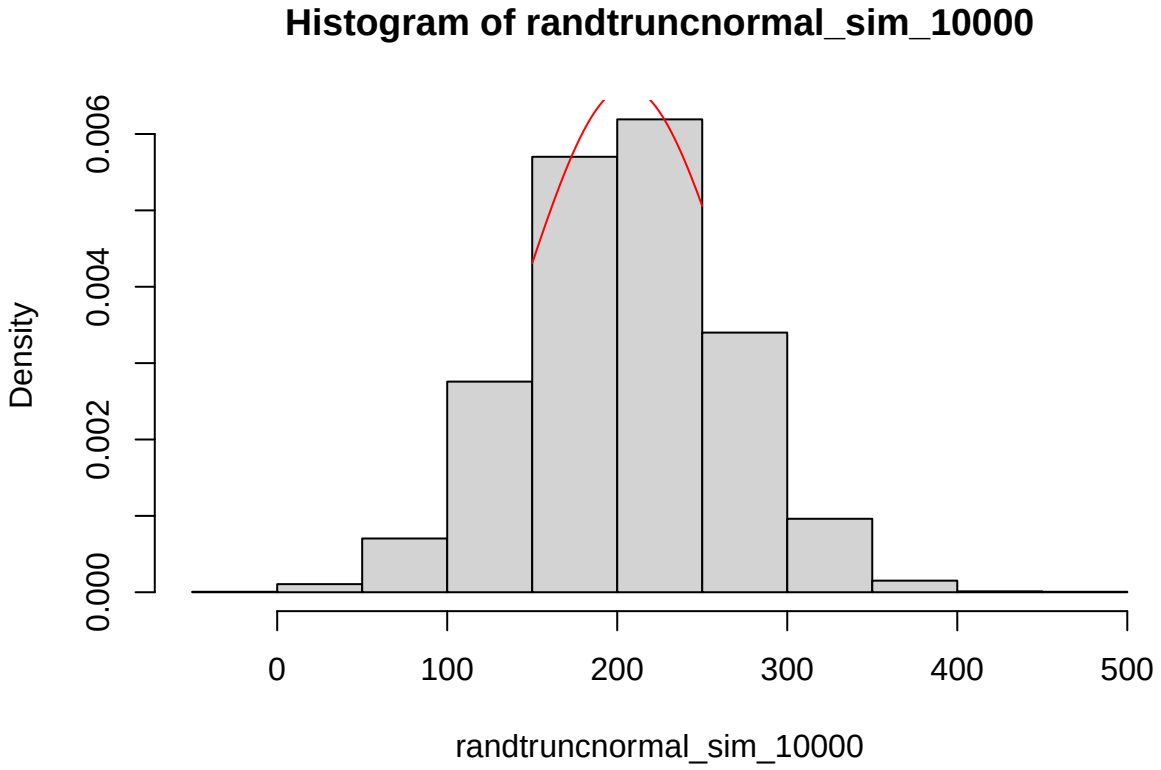
```
MEAN = worksheet$`AG Tree (tC/ha)`[1]
SD = worksheet$`AG Tree (tC/ha)`[2]

randtruncnormal_sim_10000 <- rnorm(n = 10000, mean = MEAN, sd = SD)
plot(randtruncnormal_sim_10000)
```




```
hist(randtruncnormal_sim_10000)
```




```
hist(randtruncnormal_sim_10000, freq = F)
curve(dnorm(x, mean = MEAN, sd = SD), from = 150, to = 250, add = T, col = "red")
```



Compare simulations

```
# 10,000 simulations sampling 10 observations
randtruncnormal_sim_10000_10 = replicate(n = 10000, rnorm(n = 10, mean = MEAN, sd = SD))
hist(apply(X = randtruncnormal_sim_10000_10, MARGIN = 2, FUN = mean))
hist(apply(X = randtruncnormal_sim_10000_10, MARGIN = 2, FUN = sd))
sd(apply(X = randtruncnormal_sim_10000_10, MARGIN = 2, FUN = mean))
```

```
[1] 19.03301
```

```
# 10,000 simulations sampling 100 observations
randtruncnormal_sim_10000_100 = replicate(n = 10000, rnorm(n = 100, mean = MEAN,
    sd = SD))
hist(apply(X = randtruncnormal_sim_10000_100, MARGIN = 2, FUN = mean))
hist(apply(X = randtruncnormal_sim_10000_100, MARGIN = 2, FUN = sd))
sd(apply(X = randtruncnormal_sim_10000_100, MARGIN = 2, FUN = mean))
```

```
[1] 6.091315
```

```
# 10,000 simulations sampling 1,000 observations
randtruncnormal_sim_10000_1000 = replicate(n = 10000, rnorm(n = 1000, mean = MEAN,
    sd = SD))
hist(apply(X = randtruncnormal_sim_10000_1000, MARGIN = 2, FUN = mean))
hist(apply(X = randtruncnormal_sim_10000_1000, MARGIN = 2, FUN = sd))
sd(apply(X = randtruncnormal_sim_10000_1000, MARGIN = 2, FUN = mean))
```

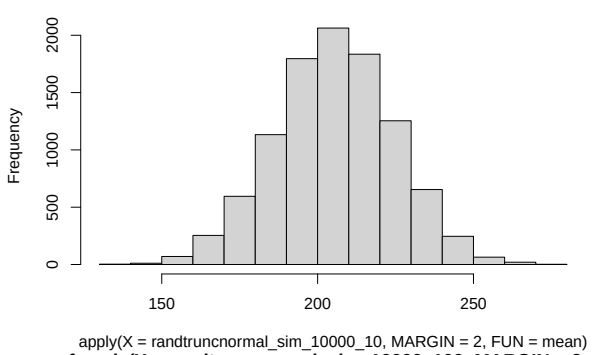
```
[1] 1.924734
```

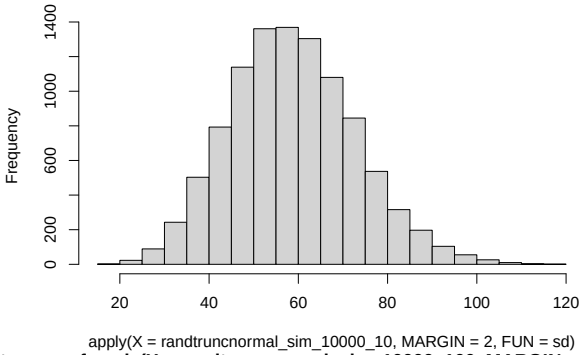
```
# 10,000 simulations sampling 10,000 observations
randtruncnormal_sim_10000_10000 = replicate(n = 10000, rnorm(n = 10000, mean = MEAN,
    sd = SD))
hist(apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FUN = mean))
```

```r
hist(apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FUN = sd))
sd(apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FUN = mean))
```

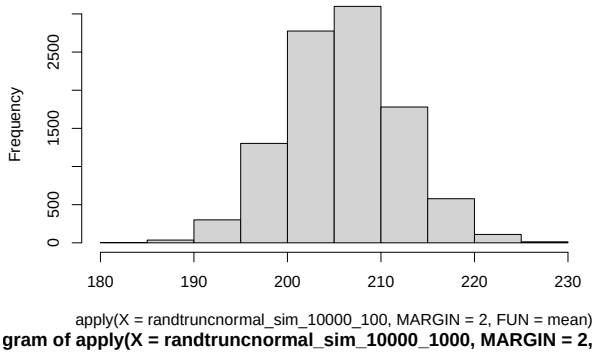
```
[1] 0.6024686
```

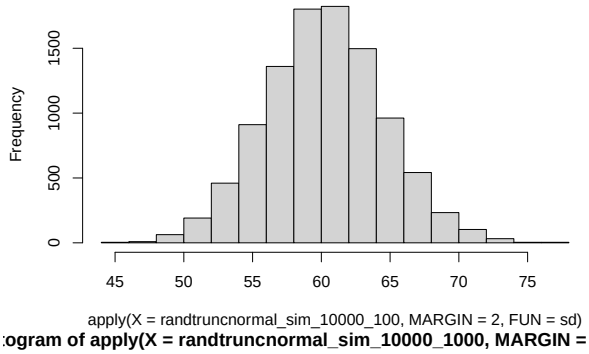
ogram of apply(X = randtruncnormal_sim_10000_10, MARGIN = 2, FUN stogram of apply(X = randtruncnormal_sim_10000_10, MARGIN = 2, FU



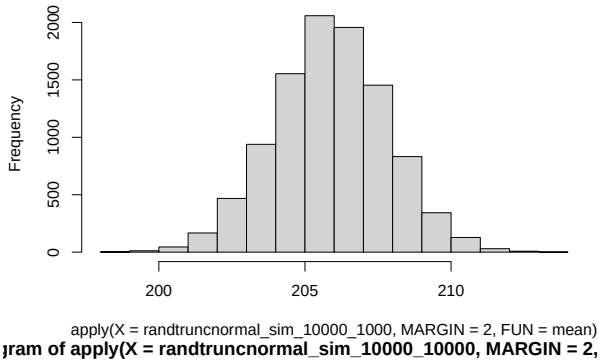


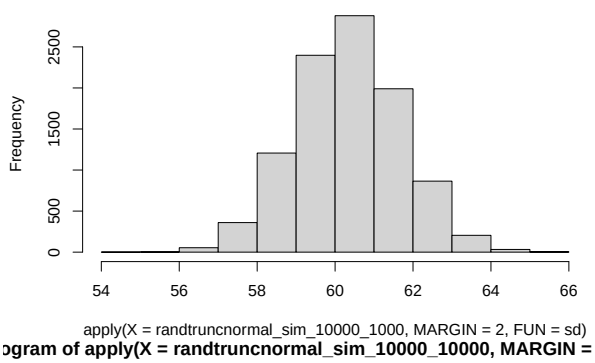
ɔgram of apply(X = randtruncnormal_sim_10000_100, MARGIN = 2, FUN togram of apply(X = randtruncnormal_sim_10000_100, MARGIN = 2, FU



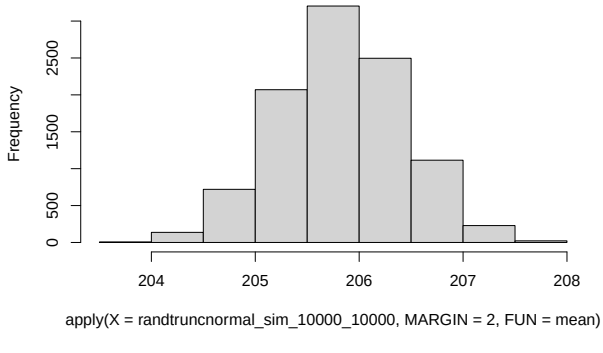


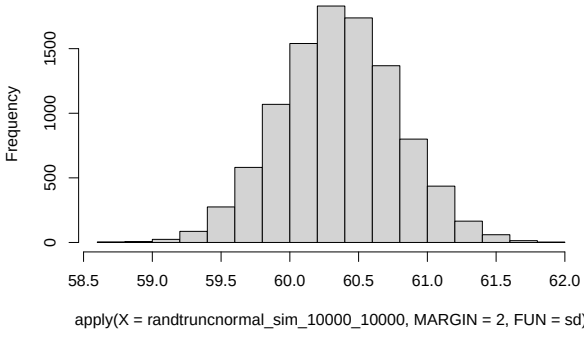
gram of apply(X = randtruncnormal_sim_10000_1000, MARGIN = 2, FUI ogram of apply(X = randtruncnormal_sim_10000_1000, MARGIN = 2, FI





ɹram of apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FU ɔgram of apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, F






```r
devtools::session_info()
```

```
- Session info -------------------------------------------------------------
 setting  value
 version  R version 4.4.2 (2024-10-31)
 os       Fedora Linux 40 (Workstation Edition)
 system   x86_64, linux-gnu
 ui       X11
 language (EN)
 collate  en_CA.UTF-8
 ctype    en_CA.UTF-8
 tz       America/Vancouver
 date     2025-02-04
 pandoc   3.1.3 @ /usr/libexec/rstudio/bin/pandoc/ (via rmarkdown)

- Packages -----------------------------------------------------------------
 package      * version    date (UTC) lib source
 abind          1.4-8      2024-09-12 [2] CRAN (R 4.4.1)
 allodb       * 0.0.1.9000 2024-12-19 [1] Github (ropensci/allodb@4207f86)
 animation    * 2.7        2021-10-07 [2] CRAN (R 4.4.0)
 assertthat     0.2.1      2019-03-21 [2] CRAN (R 4.4.0)
 backports      1.5.0      2024-05-23 [2] CRAN (R 4.4.0)
 BIOMASS      * 2.1.11     2023-09-29 [2] CRAN (R 4.4.0)
 boot           1.3-31     2024-08-28 [2] CRAN (R 4.4.1)
 broom        * 1.0.7      2024-09-26 [2] CRAN (R 4.4.1)
 c2z          * 0.2.0      2023-08-10 [2] CRAN (R 4.4.0)
 cachem         1.1.0      2024-05-16 [2] CRAN (R 4.4.0)
 car            3.1-3      2024-09-27 [2] CRAN (R 4.4.1)
 carData        3.0-5      2022-01-06 [2] CRAN (R 4.4.0)
 caret        * 7.0-1      2024-12-10 [2] CRAN (R 4.4.2)
 cellranger     1.1.0      2016-07-27 [2] CRAN (R 4.4.0)
 chromote       0.3.1      2024-08-30 [2] CRAN (R 4.4.1)
 class          7.3-23     2025-01-01 [2] CRAN (R 4.4.2)
 classInt       0.4-11     2025-01-08 [2] CRAN (R 4.4.2)
 cli            3.6.3      2024-06-21 [2] CRAN (R 4.4.0)
 codetools      0.2-20     2024-03-31 [2] CRAN (R 4.4.0)
 colorspace     2.1-1      2024-07-26 [2] CRAN (R 4.4.1)
 CoprManager    0.5.7      2024-10-31 [4] local
 data.table     1.16.4     2024-12-06 [2] CRAN (R 4.4.2)
 dataMaid     * 1.4.1      2021-10-08 [2] CRAN (R 4.4.1)
 DBI            1.2.3      2024-06-02 [2] CRAN (R 4.4.0)
 DEoptimR       1.1-3-1    2024-11-23 [2] CRAN (R 4.4.2)
 DescTools    * 0.99.58    2024-11-08 [2] CRAN (R 4.4.1)
 devtools       2.4.5      2022-10-11 [2] CRAN (R 4.4.0)
 dials        * 1.3.0      2024-07-30 [2] CRAN (R 4.4.1)
 DiceDesign     1.10       2023-12-07 [2] CRAN (R 4.4.0)
 digest         0.6.37     2024-08-19 [2] CRAN (R 4.4.1)
 dplyr        * 1.1.4      2023-11-17 [2] CRAN (R 4.4.0)
 e1071          1.7-16     2024-09-16 [2] CRAN (R 4.4.1)
 easypackages   0.1.0      2016-12-05 [2] CRAN (R 4.4.0)
 ellipsis       0.3.2      2021-04-29 [2] CRAN (R 4.4.0)
 evaluate       1.0.3      2025-01-10 [2] CRAN (R 4.4.2)
 Exact          3.3        2024-07-21 [2] CRAN (R 4.4.1)
 expm           1.0-0      2024-08-19 [2] CRAN (R 4.4.1)
 extrafont    * 0.19       2023-01-18 [2] CRAN (R 4.4.0)
 extrafontdb    1.0        2012-06-11 [2] CRAN (R 4.4.0)
```

```
fastmap        1.2.0      2024-05-15 [2] CRAN (R 4.4.0)
forcats      * 1.0.0      2023-01-29 [2] CRAN (R 4.4.0)
foreach        1.5.2      2022-02-02 [2] CRAN (R 4.4.0)
formatR      * 1.14       2023-01-17 [2] CRAN (R 4.4.0)
Formula        1.2-5      2023-02-24 [2] CRAN (R 4.4.0)
fs             1.6.5      2024-10-30 [2] CRAN (R 4.4.1)
furrr          0.3.1      2022-08-15 [2] CRAN (R 4.4.0)
future         1.34.0     2024-07-29 [2] CRAN (R 4.4.1)
future.apply   1.11.3     2024-10-27 [2] CRAN (R 4.4.1)
generics       0.1.3      2022-07-05 [2] CRAN (R 4.4.0)
ggplot2      * 3.5.1      2024-04-23 [2] CRAN (R 4.4.0)
gld            2.6.6      2022-10-23 [2] CRAN (R 4.4.0)
globals        0.16.3     2024-03-08 [2] CRAN (R 4.4.0)
glue           1.8.0      2024-09-30 [2] CRAN (R 4.4.1)
goftest        1.2-3      2021-10-07 [2] CRAN (R 4.4.0)
gower          1.0.2      2024-12-17 [2] CRAN (R 4.4.2)
GPfit          1.0-8      2019-02-08 [2] CRAN (R 4.4.0)
gridExtra      2.3        2017-09-09 [2] CRAN (R 4.4.0)
gtable         0.3.6      2024-10-25 [2] CRAN (R 4.4.1)
hardhat        1.4.0      2024-06-02 [2] CRAN (R 4.4.0)
haven          2.5.4      2023-11-30 [2] CRAN (R 4.4.0)
hms            1.1.3      2023-03-21 [2] CRAN (R 4.4.0)
htmltools    * 0.5.8.1    2024-04-04 [2] CRAN (R 4.4.0)
htmlwidgets    1.6.4      2023-12-06 [2] CRAN (R 4.4.0)
httpuv         1.6.15     2024-03-26 [2] CRAN (R 4.4.0)
httr           1.4.7      2023-08-15 [2] CRAN (R 4.4.0)
infer        * 1.0.7      2024-03-25 [2] CRAN (R 4.4.0)
ipred          0.9-15     2024-07-18 [2] CRAN (R 4.4.1)
iterators      1.0.14     2022-02-05 [2] CRAN (R 4.4.0)
janitor      * 2.2.1      2024-12-22 [2] CRAN (R 4.4.2)
jsonlite     * 1.8.9      2024-09-20 [2] CRAN (R 4.4.1)
kableExtra   * 1.4.0      2024-01-24 [2] CRAN (R 4.4.0)
kernlab      * 0.9-33     2024-08-13 [2] CRAN (R 4.4.1)
KernSmooth     2.23-26    2025-01-01 [2] CRAN (R 4.4.2)
knitr        * 1.49       2024-11-08 [2] CRAN (R 4.4.1)
later          1.4.1      2024-11-27 [2] CRAN (R 4.4.2)
lattice      * 0.22-6     2024-03-20 [2] CRAN (R 4.4.0)
lava           1.8.1      2025-01-12 [2] CRAN (R 4.4.2)
lazyeval       0.2.2      2019-03-15 [2] CRAN (R 4.4.0)
lhs            1.2.0      2024-06-30 [2] CRAN (R 4.4.1)
lifecycle      1.0.4      2023-11-07 [2] CRAN (R 4.4.0)
listenv        0.9.1      2024-01-29 [2] CRAN (R 4.4.0)
lmom           3.2        2024-09-30 [2] CRAN (R 4.4.1)
lubridate    * 1.9.4      2024-12-08 [2] CRAN (R 4.4.2)
magrittr       2.0.3      2022-03-30 [2] CRAN (R 4.4.0)
MASS           7.3-64     2025-01-04 [2] CRAN (R 4.4.2)
Matrix         1.7-1      2024-10-18 [2] CRAN (R 4.4.1)
memoise        2.0.1      2021-11-26 [2] CRAN (R 4.4.0)
mime           0.12       2021-09-28 [2] CRAN (R 4.4.0)
miniUI         0.1.1.1    2018-05-18 [2] CRAN (R 4.4.0)
minpack.lm     1.2-4      2023-09-11 [2] CRAN (R 4.4.0)
mnormt         2.1.1      2022-09-26 [2] CRAN (R 4.4.0)
modeldata    * 1.4.0      2024-06-19 [2] CRAN (R 4.4.0)
ModelMetrics   1.2.2.2    2020-03-17 [2] CRAN (R 4.4.0)
```

```
munsell        0.5.1      2024-04-01 [2] CRAN (R 4.4.0)
mvtnorm        1.3-3      2025-01-10 [2] CRAN (R 4.4.2)
nlme           3.1-166    2024-08-14 [2] CRAN (R 4.4.1)
nnet           7.3-20     2025-01-01 [2] CRAN (R 4.4.2)
nortest        1.0-4      2015-07-30 [2] CRAN (R 4.4.0)
olsrr        * 0.6.1      2024-11-06 [2] CRAN (R 4.4.1)
pander         0.6.5      2022-03-18 [2] CRAN (R 4.4.0)
parallelly     1.41.0     2024-12-18 [2] CRAN (R 4.4.2)
parsnip      * 1.2.1      2024-03-22 [2] CRAN (R 4.4.0)
pillar         1.10.1     2025-01-07 [2] CRAN (R 4.4.2)
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pkgconfig      2.0.3      2019-09-22 [2] CRAN (R 4.4.0)
pkgload        1.4.0      2024-06-28 [2] CRAN (R 4.4.1)
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plyr           1.8.9      2023-10-02 [2] CRAN (R 4.4.0)
pROC           1.18.5     2023-11-01 [2] CRAN (R 4.4.0)
processx       3.8.5      2025-01-08 [2] CRAN (R 4.4.2)
prodlim        2024.06.25 2024-06-24 [2] CRAN (R 4.4.0)
profvis        0.4.0      2024-09-20 [2] CRAN (R 4.4.1)
promises       1.3.2      2024-11-28 [2] CRAN (R 4.4.2)
proxy          0.4-27     2022-06-09 [2] CRAN (R 4.4.0)
ps             1.8.1      2024-10-28 [2] CRAN (R 4.4.1)
psych        * 2.4.12     2024-12-23 [2] CRAN (R 4.4.2)
purrr        * 1.0.2      2023-08-10 [2] CRAN (R 4.4.0)
R6             2.5.1      2021-08-19 [2] CRAN (R 4.4.0)
rappdirs       0.3.3      2021-01-31 [2] CRAN (R 4.4.1)
RColorBrewer * 1.1-3      2022-04-03 [2] CRAN (R 4.4.0)
Rcpp           1.0.14     2025-01-12 [2] CRAN (R 4.4.2)
readr        * 2.1.5      2024-01-10 [2] CRAN (R 4.4.0)
readxl       * 1.4.3      2023-07-06 [2] CRAN (R 4.4.0)
recipes      * 1.1.0      2024-07-04 [2] CRAN (R 4.4.1)
remotes        2.5.0      2024-03-17 [2] CRAN (R 4.4.0)
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rlang          1.1.4      2024-06-04 [2] CRAN (R 4.4.0)
rmarkdown    * 2.29       2024-11-04 [1] CRAN (R 4.4.2)
robustbase     0.99-4-1   2024-09-27 [2] CRAN (R 4.4.1)
rootSolve      1.8.2.4    2023-09-21 [2] CRAN (R 4.4.0)
rpart          4.1.24     2025-01-07 [2] CRAN (R 4.4.2)
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Rttf2pt1       1.3.12     2023-01-22 [2] CRAN (R 4.4.0)
rvest          1.0.4      2024-02-12 [2] CRAN (R 4.4.0)
scales       * 1.3.0      2023-11-28 [2] CRAN (R 4.4.0)
sessioninfo    1.2.2      2021-12-06 [2] CRAN (R 4.4.0)
sf             1.0-19     2024-11-05 [1] CRAN (R 4.4.2)
shiny          1.10.0     2024-12-14 [2] CRAN (R 4.4.2)
snakecase      0.11.1     2023-08-27 [2] CRAN (R 4.4.0)
stringi        1.8.4      2024-05-06 [2] CRAN (R 4.4.0)
stringr      * 1.5.1      2023-11-14 [2] CRAN (R 4.4.0)
survival       3.8-3      2024-12-17 [2] CRAN (R 4.4.2)
svglite        2.1.3      2023-12-08 [2] CRAN (R 4.4.0)
systemfonts    1.1.0      2024-05-15 [2] CRAN (R 4.4.0)
terra          1.8-10     2025-01-14 [1] CRAN (R 4.4.2)
tibble       * 3.2.1      2023-03-20 [2] CRAN (R 4.4.0)
```

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 tidymodels   * 1.2.0      2024-03-25 [2] CRAN (R 4.4.0)
 tidyr        * 1.3.1      2024-01-24 [2] CRAN (R 4.4.0)
 tidyselect     1.2.1      2024-03-11 [2] CRAN (R 4.4.0)
 tidyverse    * 2.0.0      2023-02-22 [2] CRAN (R 4.4.0)
 timechange     0.3.0      2024-01-18 [2] CRAN (R 4.4.1)
 timeDate       4041.110   2024-09-22 [2] CRAN (R 4.4.1)
 tinytex      * 0.54       2024-11-01 [2] CRAN (R 4.4.1)
 tune         * 1.2.1      2024-04-18 [2] CRAN (R 4.4.0)
 tzdb           0.4.0      2023-05-12 [2] CRAN (R 4.4.0)
 units          0.8-5      2023-11-28 [2] CRAN (R 4.4.0)
 urlchecker     1.0.1      2021-11-30 [2] CRAN (R 4.4.0)
 useful       * 1.2.6.1    2023-10-24 [2] CRAN (R 4.4.0)
 usethis        3.1.0      2024-11-26 [2] CRAN (R 4.4.2)
 utf8           1.2.4      2023-10-22 [2] CRAN (R 4.4.0)
 vctrs          0.6.5      2023-12-01 [2] CRAN (R 4.4.0)
 viridisLite    0.4.2      2023-05-02 [2] CRAN (R 4.4.0)
 webshot      * 0.5.5      2023-06-26 [2] CRAN (R 4.4.0)
 webshot2     * 0.1.1      2023-08-11 [2] CRAN (R 4.4.0)
 websocket      1.4.2      2024-07-22 [2] CRAN (R 4.4.1)
 withr          3.0.2      2024-10-28 [2] CRAN (R 4.4.1)
 workflows    * 1.1.4      2024-02-19 [2] CRAN (R 4.4.0)
 workflowsets * 1.1.0      2024-03-21 [2] CRAN (R 4.4.0)
 xfun           0.50       2025-01-07 [2] CRAN (R 4.4.2)
 xml2           1.3.6      2023-12-04 [2] CRAN (R 4.4.0)
 xtable         1.8-4      2019-04-21 [2] CRAN (R 4.4.0)
 yaml           2.3.10     2024-07-26 [2] CRAN (R 4.4.1)
 yardstick    * 1.3.1      2024-03-21 [2] CRAN (R 4.4.0)

 [1] /home/seamus/R/x86_64-redhat-linux-gnu-library/4.4
 [2] /usr/local/lib/R/library
 [3] /usr/lib64/R/library
 [4] /usr/share/R/library
```

```
# Sys.getenv() .libPaths()
```

References