

Monte Carlo Simulation Tools for REDD+ Uncertainty Estimates

2024-12-19

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Import data

```
workbook = "./data/art/GuyanaARTWorkbookMC-thru2022-April2024_values.xlsx"
CarbonStocks_in = readxl::read_excel(workbook, "CarbonStocks")
CarbonStocks_out = readxl::read_excel(workbook, "CarbonStocks (MC)")
flectable(head(CarbonStocks_in[, 1:8])) |>
  fontsize(size = 8, part = "all")
```

...1	AG Tree (tC/ha)	BG Tree (tC/ha)	Saplings (tC/ha)	Standing Dead Wood (tC/ha)	Lying Dead Wood (tC/ha)	Sum Carbon pools w/o litter (t C/ha)	Litter (tC/ha)
mean of all plots (calculated)	205.8372980848	32814069	3.66739184	2.5549682	8.6215853	269.00938413	3.2979805
std. dev	60.35237120	14.25211139	2.04233991	3.9776535	8.1020488	75.24584233	1.2899640
minimum	91.57487432	21.16838708	0.54709512	0.0000000	0.0000000		1.1539246
maximum	353.7412897883	12920310	18.82007202	13.6730807	42.3071657		8.6540798
90% CI	9.21155726	2.17529382	0.31172149	0.6071076	1.2366123	11.48474155	0.2464314
CI as % of mean	0.04475164	0.04501091	0.08499814	0.2376185	0.1434321	0.04269272	

```
flectable(head(CarbonStocks_out[, 1:8])) |>
  fontsize(size = 8, part = "all")
```

...1	AG Tree (tC/ha)	BG Tree (tC/ha)	Saplings (tC/ha)	Standing Dead Wood (tC/ha)	Lying Dead Wood (tC/ha)	Sum Carbon pools w/o litter (t C/ha)	Litter (tC/ha)
tC/ha	181.1462	64.95662	3.493188	7.324769	17.07410		3.742932
tCO2/ha	664.2028	238.17428	12.808355	26.857486	62.60504		13.724083

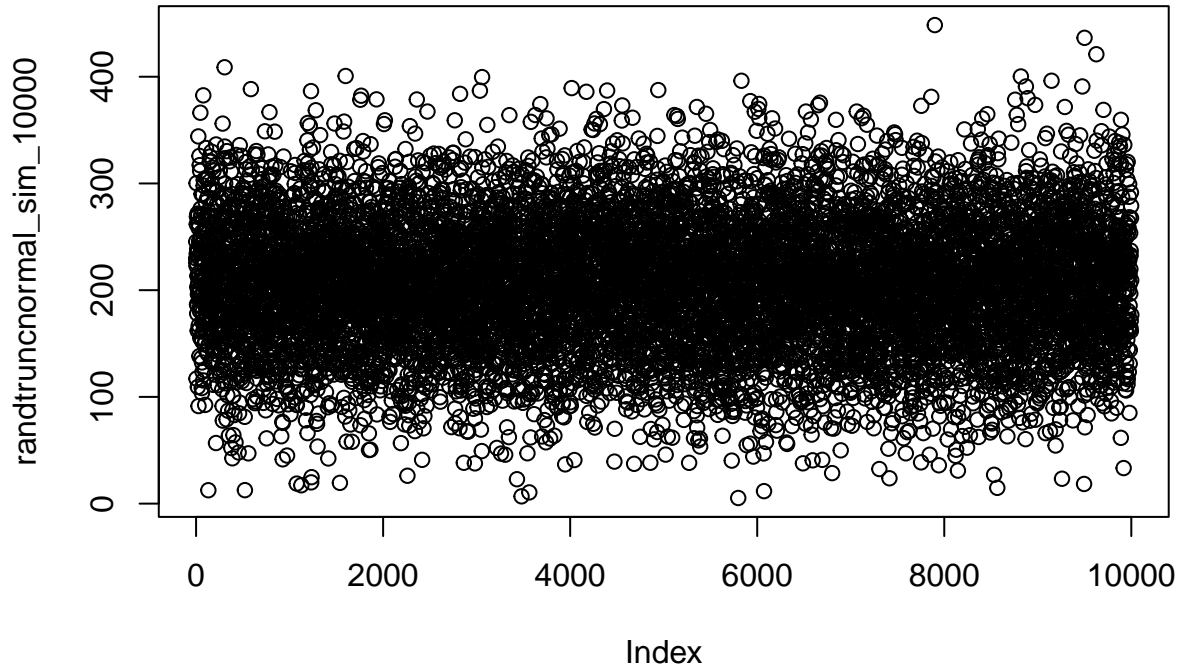
Replicate SimVoi

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.

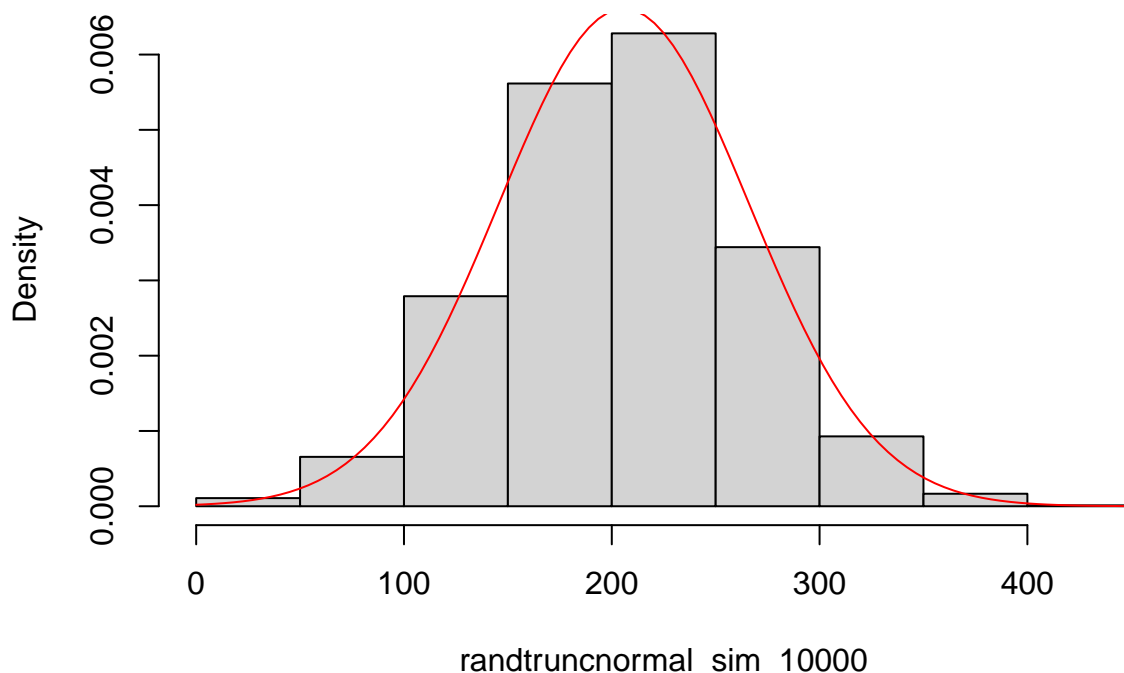
```
MEAN = CarbonStocks_in$`AG Tree (tC/ha)`[1]  
SD = CarbonStocks_in$`AG Tree (tC/ha)`[2]
```

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



```
hist(randtruncnormal_sim_10000, freq = F)  
curve(dnorm(x, mean = MEAN, sd = SD), from = 0, to = 450, add = T, col = "red")
```

Histogram of randtruncnormal_sim_10000



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] 19.06237

# 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] 6.103901

# 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))

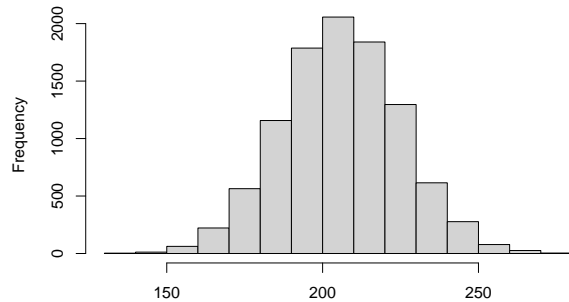
[1] 1.900528

# 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))
```

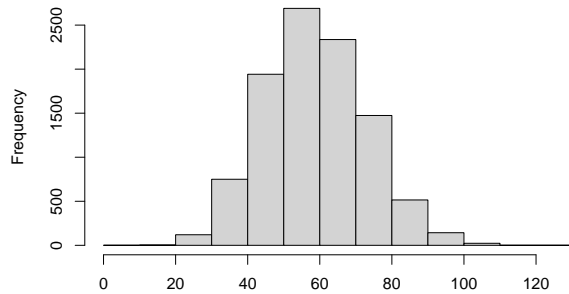
```
hist(apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FUN = sd))
sd(apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FUN = mean))
```

```
[1] 0.6041261
```

ogram of apply(X = randtruncnormal_sim_10000_10, MARGIN = 2, FUN = mean) histogram of apply(X = randtruncnormal_sim_10000_10, MARGIN = 2, FUN = sd)

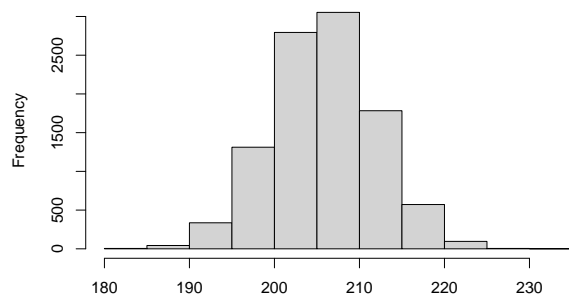


apply(X = randtruncnormal_sim_10000_10, MARGIN = 2, FUN = mean)

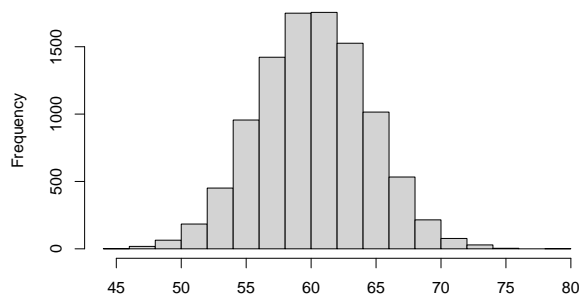


apply(X = randtruncnormal_sim_10000_10, MARGIN = 2, FUN = sd)

ogram of apply(X = randtruncnormal_sim_10000_100, MARGIN = 2, FUN = mean) histogram of apply(X = randtruncnormal_sim_10000_100, MARGIN = 2, FUN = sd)

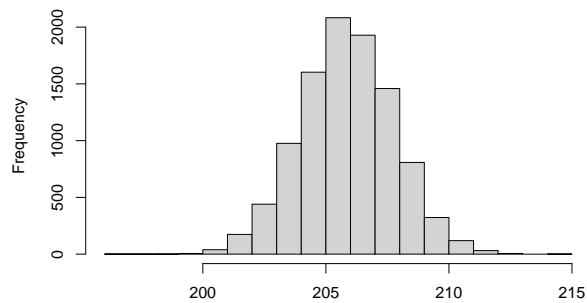


apply(X = randtruncnormal_sim_10000_100, MARGIN = 2, FUN = mean)

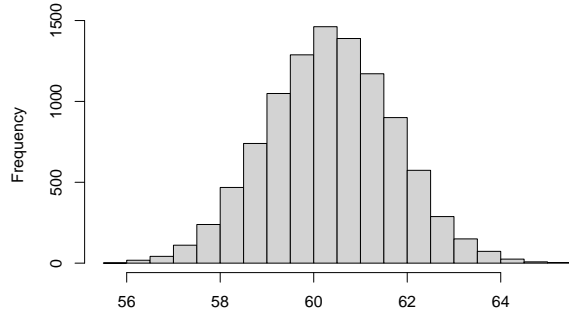


apply(X = randtruncnormal_sim_10000_100, MARGIN = 2, FUN = sd)

ogram of apply(X = randtruncnormal_sim_10000_1000, MARGIN = 2, FUN = mean) histogram of apply(X = randtruncnormal_sim_10000_1000, MARGIN = 2, FUN = sd)

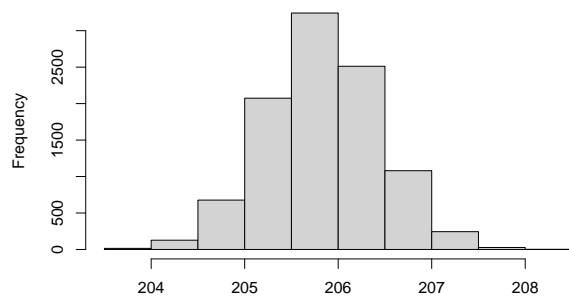


apply(X = randtruncnormal_sim_10000_1000, MARGIN = 2, FUN = mean)

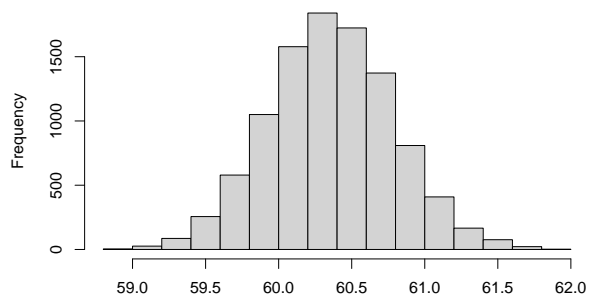


apply(X = randtruncnormal_sim_10000_1000, MARGIN = 2, FUN = sd)

ogram of apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FUN = mean) histogram of apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FUN = sd)



apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FUN = mean)



apply(X = randtruncnormal_sim_10000_10000, MARGIN = 2, FUN = sd)

```
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)
askpass       1.2.1         2024-10-04 [2] CRAN (R 4.4.1)
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      0.4.0         2025-01-25 [2] CRAN (R 4.4.2)
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     * 0.99.59       2025-01-26 [2] CRAN (R 4.4.2)
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)
flextable	* 0.9.7	2024-10-27	[2]	CRAN	(R 4.4.1)
fontBitstreamVera	0.1.1	2017-02-01	[2]	CRAN	(R 4.4.0)
fontLiberation	0.1.0	2016-10-15	[2]	CRAN	(R 4.4.0)
fontquiver	0.2.1	2017-02-01	[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)
gdtools	0.4.1	2024-11-04	[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	2.6.7	2025-01-17	[2]	CRAN	(R 4.4.2)
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	1.4.1	2025-01-31	[2]	CRAN	(R 4.4.2)
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	1.7-2	2025-01-23	[2]	CRAN	(R 4.4.2)
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	3.1-167	2025-01-27	[2]	CRAN	(R 4.4.2)
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)
officer	0.6.7	2024-10-09	[2]	CRAN	(R 4.4.1)
olsrr	* 0.6.1	2024-11-06	[2]	CRAN	(R 4.4.1)
openssl	2.3.1	2025-01-09	[2]	CRAN	(R 4.4.2)
pander	0.6.5	2022-03-18	[2]	CRAN	(R 4.4.0)
parallelly	1.42.0	2025-01-30	[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)
pkgbuild	1.4.6	2025-01-16	[2]	CRAN	(R 4.4.2)
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)
plotly	* 4.10.4	2024-01-13	[2]	CRAN	(R 4.4.0)
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)
ragg	1.3.3	2024-09-11	[2]	CRAN	(R 4.4.1)
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)
reshape2	1.4.4	2020-04-09	[2]	CRAN	(R 4.4.0)
rlang	1.1.5	2025-01-17	[2]	CRAN	(R 4.4.2)
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)
rsample	* 1.2.1	2024-03-25	[2]	CRAN	(R 4.4.0)
rstudioapi	0.17.1	2024-10-22	[2]	CRAN	(R 4.4.1)
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	1.2.1	2025-01-20	[2]	CRAN	(R 4.4.2)
terra	1.8-10	2025-01-14	[1]	CRAN	(R 4.4.2)
textshaping	1.0.0	2025-01-20	[2]	CRAN	(R 4.4.2)
tibble	* 3.2.1	2023-03-20	[2]	CRAN	(R 4.4.0)
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)
uuid	1.2-1	2024-07-29	[2]	CRAN	(R 4.4.1)
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	* 1.3.2	2025-01-22	[2]	CRAN	(R 4.4.2)
zip	2.3.2	2025-02-01	[2]	CRAN	(R 4.4.2)

[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