The treatment of uncertainties in global water models

R code

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1 Preliminary functions

```
# PRELIMINARY FUNCTIONS #######################################################

# Function to read in all required packages in one go
loadPackages <- function(x) {
  for(i in x) {
    if(!require(i, character.only = TRUE)) {
      install.packages(i, dependencies = TRUE)
      library(i, character.only = TRUE)
    }
  }
}

# Load the packages
loadPackages(c(
  "bibliometrix", "tidyverse", "data.table", "scales", "pdfsearch", "pdftools",
  "openxlsx", "cowplot", "wesanderson", "sjmisc", "ggpubr", "tm", "syuzhet",
  "qdapRegex", "tidytext", "igraph", "ggraph", "benchmarkme", "parallel"))

# Create custom theme
theme_AP <- function() {
  theme_bw() +
    theme(panel.grid.major = element_blank(),
          panel.grid.minor = element_blank(),
          legend.background = element_rect(fill = "transparent",
                                           color = NA),
          legend.key = element_rect(fill = "transparent",
                                    color = NA),
          strip.background = element_rect(fill = "white"),
          legend.margin = margin(0.5, 0.1, 0.1, 0.1),
          legend.box.margin = margin(0.2,-2,-7,-7))
}

# Set checkpoint
dir.create(".checkpoint")
library("checkpoint")

checkpoint("2022-05-30",
           R.version ="4.2.0",
           checkpointLocation = getwd())
```

```
# FUNCTION TO CLEAN TEXT ######################################################

# Function to remove punctuation, citations, numbers, stopwords in english,
# bring to lowercase and strip whitespace, and especial characters, etc...
clear_text <- function(x) {
  y <- gsub("-", "", x)
```

```r
  y <- rm_citation(y)
  y <- tm::removePunctuation(y)
  y <- tm::removeNumbers(y)
  y <- tm::removeWords(y, stopwords::stopwords(language = "en"))
  y <- tolower(y)
  y <- str_replace_all(y, "[[:punct:]]", "") # Remove punctuation characters
  y <- y <- str_remove_all(y, "[^[\\da-zA-Z ]]")# Remove all non-alphanumerical
  y <- stemDocument(y) # Stem the document and keep only the root of the word
  y <- tm::stripWhitespace(y)
  y <- str_squish(y)
  y <- tm::removeWords(y, c(" et ", "al", "table", "figure", "fig",
                            "figs", "can", "eg", "mm", "yr",
                            "last", "access", "see", "section"))
  y <- gsub(" ?doi\\w+ ?", "", y) # Remove words that start with doi
  y <- str_replace(y, "http", "") # Remove https
  y <- tm::removeWords(y, stopwords::stopwords(language = "en"))
  y <- trimws(y) # Remove leading/trailing white space
  y <- tm::stripWhitespace(y)
  y <- gsub("\\s[A-Za-z](?= )", "", y, perl = TRUE) # Remove isolated letters
  y <- gsub("\\s[A-Za-z]$", "", y, perl = TRUE) # Remove isolated letters end of string
  y <- str_squish(y)

  return(y)
}
```

2 Models under study

```r
# VECTOR WITH NAME OF MODELS ###################################################

models <- c("WaterGAP", "PCR-GLOBWB", "MATSIRO", "H08", "JULES-W1", "MPI-HM",
            "MHM", "LPJmL", "CWatM", "CLM", "DBHM", "ORCHIDEE", "GR4J",
            "SACRAMENTO", "PRMS")

models_vec <- paste(models, "_ref.bib", sep = "")
```

3 Bibliometric analysis

```r
# BIBLIOMETRIC ANALYSIS ########################################################

output <- results <- years <- journals <- dt <- dt.clean <- list()

selected_cols <- c("title", "abstract", "keywords", "keywords.plus")

for (i in 1:length(models_vec)) {

  output[[i]] <- convert2df(file = models_vec[i],
                            dbsource = "wos",
                            format = "bibtex")

  # Extract title --------------------------------------------------------------

  title <- output[[i]]$TI

  # Extract Authors, Countries and Universities -------------------------------

  # Authors
  tmp.authors <- output[[i]]$AU
  first.author <- sub(" *\\;.*", "", tmp.authors)
  last.author <- sub(".*\\;","", tmp.authors)

  # First author affiliation and country
  country.first <- sub(".*\\,", "", output[[i]]$RP)
  university.first <- sub(" *\\;.*", "", output[[i]]$affiliations)

  # Last author affiliation and country
  last.affiliation <- sub(".*\\;", "", output[[i]]$C1)
  country.last <- sub("\\.", "", sub(".*\\, ", "", last.affiliation))
  university.last <- sub(".*\\;", "", output[[i]]$affiliations)

  # Extract keywords ----------------------------------------------------------
  keywords <- gsub(";;", ";", output[[i]]$DE)
  keywords.plus <- gsub(";;", ";", output[[i]]$ID)

  # Create data.table ----------------------------------------------------------

  dt[[i]] <- data.table("WOS" = output[[i]]$UT,
                        "title" = title,
                        "year" = output[[i]]$PY,
                        "keywords" = keywords,
                        "keywords.plus" = keywords.plus,
                        "first.author" = first.author,
                        "last.author" = last.author,
                        "country.first" = country.first,
                        "country.last" = country.last,
                        "university.first" = university.first,
                        "university.last" = university.last,
                        "abstract" = output[[i]]$AB)

  dt.clean[[i]] <- copy(dt[[i]])

  dt.clean[[i]][, (selected_cols):= lapply(.SD, function(x)
    clear_text(x)), .SDcols = selected_cols]

  # Export data dirty and clean
  write.xlsx(dt[[i]], file = paste(models[i], "_bibliometric.xlsx", sep = ""))
  write.xlsx(dt.clean[[i]], file = paste(models[i], "_bibliometric_clean.xlsx", sep = ""))

  # Retrieve analysis bibliometrix ---------------------------------------------

  results[[i]] <- biblioAnalysis(output[[i]], sep = ";")
  years[[i]] <- data.table(results[[i]]$Years)
  journals[[i]] <- data.table(results[[i]]$Sources) %>%
    .[, SO:= str_to_title(SO)]
}

# Fill out affiliations erroneously labelled as NA -----------------------------

# Watergap (1)
for(i in c(1, 4, 5)) {
  output[[1]]$affiliations[[i]] <- "UNIVERSITAT KASSEL"
}


# Add names of models ----------------------------------------------------------
names(years) <- models
names(journals) <- models
names(dt.clean) <- models
names(dt.clean) <- models
```

4 Keywords analysis: “uncertainty” and “sensitivity”

```
# KEYWORDS ANALYSIS ############################################################

# Define vectors for search ---------------------------------------------------
directory <- "/Users/arnaldpuy/Documents/papers/ghms_bibliometric/"
directory_vec <- paste(directory, models, "_pdfs", sep = "")
filename_keywords <- paste(models, "keywords", sep = "_")

# Define vectors with keywords ------------------------------------------------
keywords_vec <- c("uncertainty", "sensitivity")
keywords_vec_stemmed <- stemDocument(keywords_vec)

# Loop -------------------------------------------------------------------------
dt.keyword <- dt.keyword.clean <- output <- list()
for (i in 1:length(directory_vec)) {

  output[[i]] <- keyword_directory(directory_vec[i],
                                   keyword = keywords_vec_stemmed,
                                   split_pdf = TRUE)

  dt.keyword[[i]] <- data.table("name" = output[[i]]$pdf_name,
                                "keyword" = output[[i]]$keyword,
                                "text" = output[[i]]$line_text)

  dt.keyword.clean[[i]] <- copy(dt.keyword[[i]])

  # Clean the text where the keywords are located
  dt.keyword.clean[[i]] <- dt.keyword.clean[[i]][, text:= clear_text(text)]

  # Write dirty and clean data
  fwrite(dt.keyword[[i]], file = paste(filename_keywords[i], ".csv", sep = ""))
  fwrite(dt.keyword.clean[[i]], file = paste(filename_keywords[i], "_clean.csv", sep = ""))
}

names(output) <- models
names(dt.keyword) <- models
names(dt.keyword.clean) <- models
```

5 Arrange the data

```
# ARRANGE DATA #################################################################
# Bibliometric analysis -------------------------

# Correct for USA and China
colsName <- c("country.first", "country.last")
full.dt <- rbindlist(dt.clean, idcol = "Model") %>%
  .[, (colsName):= lapply(.SD, function(x)
    ifelse(grepl("USA", x), "USA", x)), .SDcols = colsName] %>%
  .[, (colsName):= lapply(.SD, function(x)
    ifelse(grepl("CHINA", x), "CHINA", x)), .SDcols = colsName]

# Export
fwrite(full.dt, "full.dt.csv")

# Keywords analysis -----------------------------
full.keyword.dt <- rbindlist(dt.keyword.clean, idcol = "Model")

# Export
fwrite(full.keyword.dt, "full.keyword.dt.csv")
```

6 Descriptive analysis

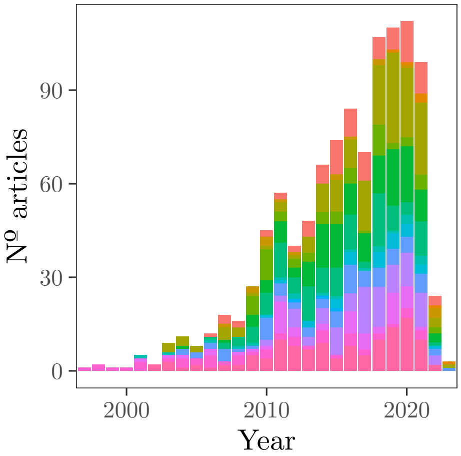
```
# DESCRIPTIVE STUDY ############################################################

# Total number of studies
total.n <- full.dt[, .(Model, WOS)] %>%
  .[, .(total.papers = .N), Model] %>%
  .[order(-total.papers)]

total.n
```

```
##          Model total.papers
##  1:       GR4J          167
##  2:   JULES-W1          136
##  3:   WaterGAP          126
##  4:      LPJmL          116
##  5: PCR-GLOBWB           95
##  6:        CLM           92
##  7:   ORCHIDEE           75
##  8:        H08           61
##  9:       PRMS           55
## 10: SACRAMENTO           52
## 11:        MHM           29
## 12:    MATSIRO           21
## 13:       DBHM           17
## 14:      CWatM            7
## 15:     MPI-HM            3
```

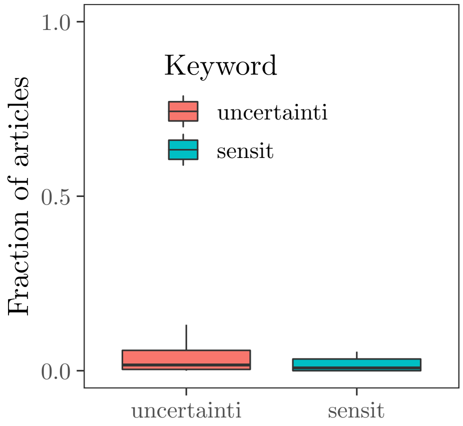
```
sum(total.n$total.papers)
```

```
## [1] 1052
```

```
# NUMBER OF STUDIES THROUGHT TIME ##############################################

plot.time <- rbindlist(years, idcol = "Model")[, .N, .(V1, Model)] %>%
  .[, V1:= as.factor(V1)] %>%
  ggplot(., aes(V1, N, fill = Model)) +
  geom_col() +
  scale_x_discrete(breaks = pretty_breaks(n = 3)) +
  labs(x = "Year", y = "Nº articles") +
  theme_AP() +
  theme(legend.position = "none")

plot.time
```



```
# FRACTION OF STUDIES WITH UNCERTAINTI AND SENSIT* AS KEYWORDS ################

full.dt <- full.dt[, `:=` (uncertainti = str_detect(keywords, keywords_vec_stemmed[1]),
                            sensit = str_detect(keywords, keywords_vec_stemmed[2]))]

plot.n.keywords <- full.dt[, lapply(.SD, function(x)
  sum(x) / .N), .SDcols = (keywords_vec_stemmed), Model] %>%
  melt(., measure.vars = keywords_vec_stemmed) %>%
  ggplot(., aes(variable, value, fill = variable)) +
  geom_boxplot() +
  labs(y = "Fraction of articles", x = "") +
  scale_y_continuous(breaks = pretty_breaks(n = 3),
                     limits = c(0, 1)) +
  scale_fill_discrete(name = "Keyword") +
  theme_AP() +
  theme(legend.position = c(0.45, 0.75))

plot.n.keywords
```

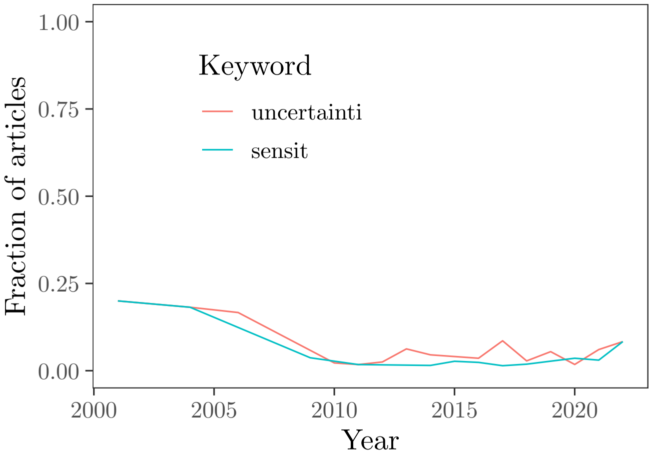


```
# Fraction of studies with both keywords in the abstract
full.dt[uncertainti == "TRUE" & sensit == "TRUE", .N] / full.dt[, .N]
```

```
## [1] 0.002851711
```

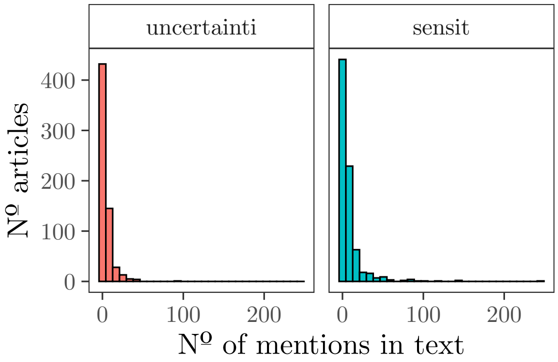
```
# FRACTION OF STUDIES WITH KEYWORDS THROUGH TIME ###############################

total.n.year <- rbindlist(years, idcol = "Model") %>%
  .[, .(total.n = .N), V1] %>%
  setnames(., "V1", "year")

plot.fraction.years <- full.dt[, .(WOS, uncertainti, sensit, year)] %>%
  melt(., measure.var = keywords_vec_stemmed) %>%
  .[value == TRUE, .N, .(year, variable)] %>%
  merge(., total.n.year, by = "year") %>%
  .[, fraction:= N / total.n] %>%
  ggplot(., aes(year, fraction, color = variable, group = variable)) +
  geom_line() +
  scale_color_discrete(name = "Keyword") +
  scale_y_continuous(limits = c(0, 1)) +
  labs(x = "Year", y = "Fraction of articles") +
  theme_AP() +
  theme(legend.position = c(0.35, 0.75))

plot.fraction.years
```

```
## Warning: Removed 1 row(s) containing missing values (geom_path).
```



```
# PLOT HISTOGRAM ##############################################################

dist.plot <- full.keyword.dt[, .N, .(name, keyword)] %>%
  .[, keyword:= factor(keyword, levels = keywords_vec_stemmed)] %>%
  ggplot(., aes(N, fill = keyword)) +
  geom_histogram(color = "black") +
  labs(x = "Nº of mentions in text", y = "Nº articles") +
  facet_wrap(~keyword) +
  scale_x_continuous(breaks = pretty_breaks(n = 3)) +
  theme_AP() +
  theme(legend.position = "none")

dist.plot
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



```
# How many articles have 1, 2, ... N mentions of uncertainti and sensit in the
# main text ---------------------------------------------------
full.keyword.dt[, .N, .(name, keyword)] %>%
  .[, .(number.articles = .N), .(N, keyword)] %>%
  .[.[order(N),.I[1:.N],"keyword"]$V1]
```

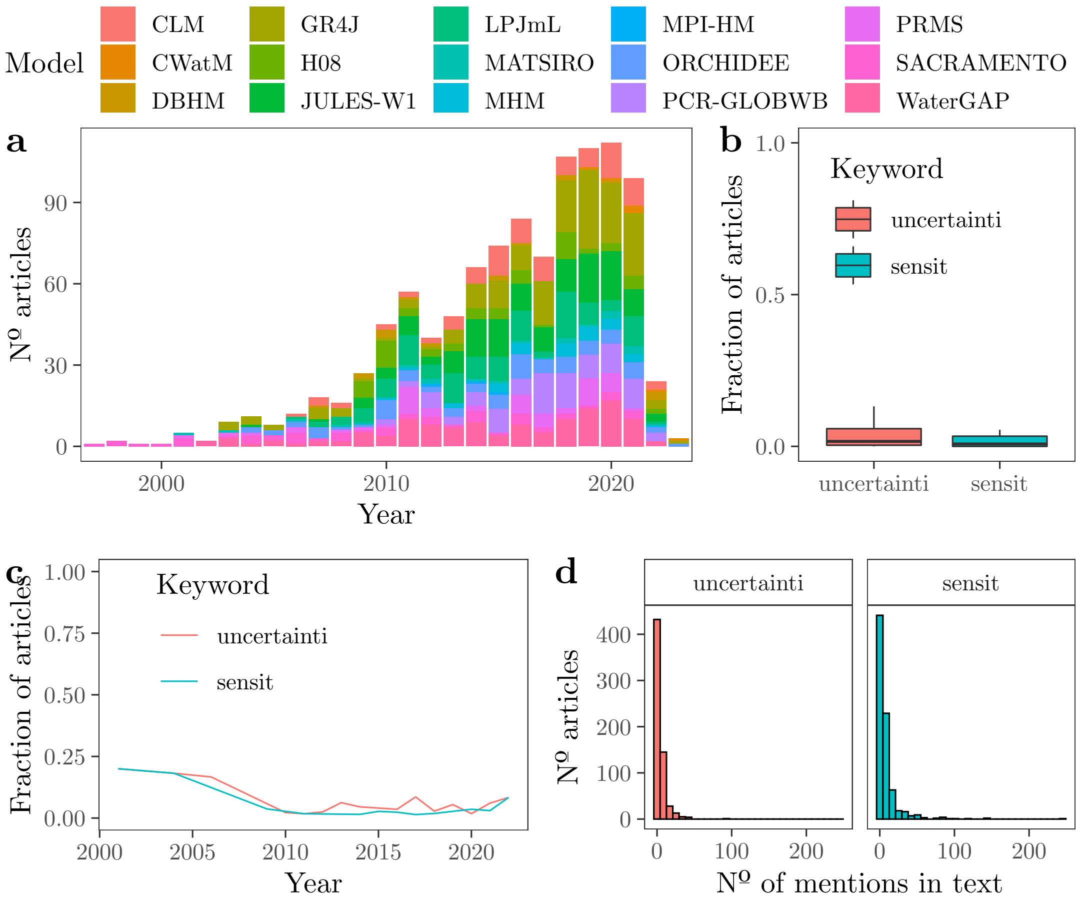
```
##        N     keyword number.articles
##   1:   1      sensit             157
##   2:   2      sensit             117
##  3:  3      sensit              96
##  4:  4      sensit              71
##  5:  5      sensit              58
##  6:  6      sensit              42
##  7:  7      sensit              39
##  8:  8      sensit              22
##  9:  9      sensit              25
## 10: 10      sensit              15
## 11: 11      sensit               9
## 12: 12      sensit              19
## 13: 13      sensit               9
## 14: 14      sensit              10
## 15: 15      sensit              10
## 16: 16      sensit               3
## 17: 17      sensit              10
## 18: 18      sensit               5
## 19: 19      sensit               4
## 20: 20      sensit               6
## 21: 21      sensit               6
## 22: 22      sensit               2
## 23: 23      sensit               4
## 24: 24      sensit               3
## 25: 25      sensit               5
## 26: 26      sensit               4
## 27: 30      sensit               3
## 28: 32      sensit               4
## 29: 33      sensit               1
## 30: 34      sensit               3
## 31: 35      sensit               1
## 32: 36      sensit               1
## 33: 37      sensit               1
## 34: 38      sensit               2
## 35: 39      sensit               1
## 36: 41      sensit               2
## 37: 43      sensit               1
## 38: 44      sensit               1
## 39: 45      sensit               1
## 40: 46      sensit               1
## 41: 47      sensit               1
## 42: 48      sensit               3
## 43: 51      sensit               1
## 44: 53      sensit               2
## 45: 54      sensit               2
## 46: 55      sensit               1
## 47: 59      sensit               1
## 48: 60      sensit               1
## 49: 78      sensit               1
## 50: 80      sensit               1
## 51:  81      sensit               1
## 52:  85      sensit               1
## 53:  86      sensit               1
## 54:  88      sensit               1
## 55:  95      sensit               1
## 56: 104      sensit               1
## 57: 119      sensit               1
## 58: 142      sensit               1
## 59: 143      sensit               1
## 60: 246      sensit               1
## 61:   1 uncertainti             187
## 62:   2 uncertainti             111
## 63:   3 uncertainti              78
## 64:   4 uncertainti              56
## 65:   5 uncertainti              36
## 66:   6 uncertainti              28
## 67:   7 uncertainti              19
## 68:   8 uncertainti              15
## 69:   9 uncertainti              15
## 70:  10 uncertainti              14
## 71:  11 uncertainti              10
## 72:  12 uncertainti               8
## 73:  13 uncertainti               6
## 74:  14 uncertainti               6
## 75:  15 uncertainti               1
## 76:  16 uncertainti               3
## 77:  17 uncertainti               3
## 78:  18 uncertainti               2
## 79:  19 uncertainti               1
## 80:  20 uncertainti               3
## 81:  21 uncertainti               3
## 82:  22 uncertainti               2
## 83:  23 uncertainti               2
## 84:  24 uncertainti               2
## 85:  25 uncertainti               2
## 86:  27 uncertainti               4
## 87:  28 uncertainti               1
## 88:  30 uncertainti               1
## 89:  32 uncertainti               3
## 90:  33 uncertainti               1
## 91:  39 uncertainti               2
## 92:  41 uncertainti               1
## 93:  46 uncertainti               1
## 94:  93 uncertainti               1
##       N     keyword number.articles
```

```
# MERGE DESCRIPTIVE PLOTS ######################################################
```

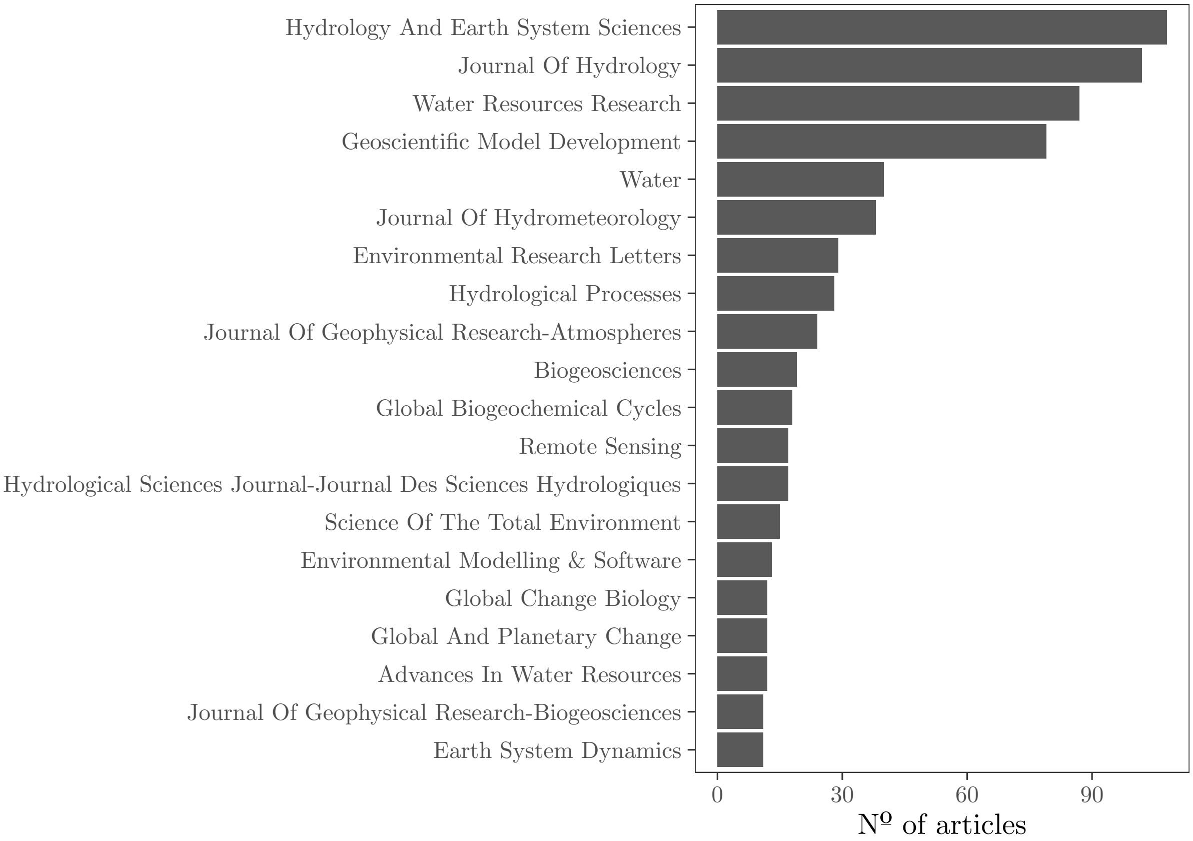
```
legend <- get_legend(plot.time + theme(legend.position = "top"))
top <- plot_grid(plot.time, plot.n.keywords, ncol = 2, labels = "auto",
                 rel_widths = c(0.65, 0.35))
all <- plot_grid(legend, top, ncol = 1, rel_heights = c(0.22, 0.78))
bottom <- plot_grid(plot.fraction.years, dist.plot, ncol = 2, labels = c("c", "d"),
                    rel_widths = c(0.5, 0.5))
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

```
plot_grid(all, bottom,
          ncol = 1, labels = "", rel_heights = c(0.6, 0.4))
```



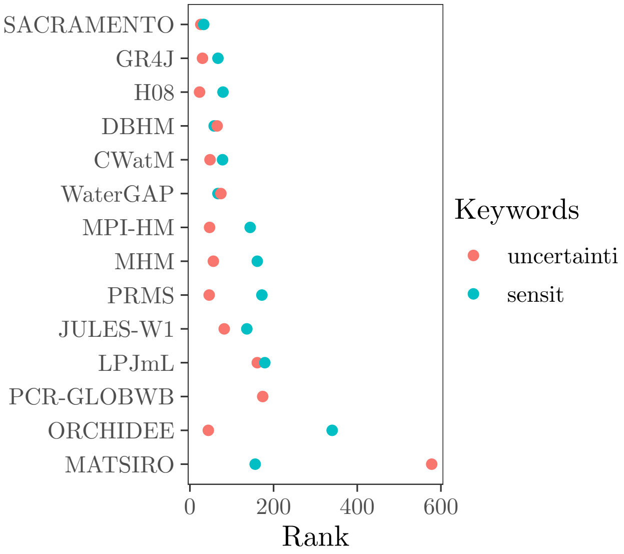
```
# PLOT JOURNALS ################################################################

rbindlist(journals, idcol = "Model") %>%
  .[, sum(N), SO] %>%
  .[order(-V1)] %>%
  .[1:20] %>%
  na.omit() %>%
  ggplot(., aes(reorder(SO, V1, sum), V1)) +
  geom_bar(stat = "identity") +
  coord_flip() +
  labs(x = "", y = "Nº of articles") +
  theme_AP()
```



```
# WORDCLOUD OF WORDS IN ABSTRACT ###############################################

tmp <- split(full.dt, full.dt$Model)
names(tmp) <- models

out <- dtm <- m <- v <- word.count <- list()
for (i in names(tmp)) {
  out[[i]] <- Corpus(VectorSource(tmp[[i]]$abstract))
  dtm[[i]] <- tm::TermDocumentMatrix(out[[i]])
  m[[i]] <- as.matrix(dtm[[i]])
  v[[i]] <- sort(rowSums(m[[i]]), decreasing=TRUE)
  word.count[[i]] <- data.table(word = names(v[[i]]), freq = v[[i]])
}

word.count.dt <- rbindlist(word.count, idcol = "Model")

# Plot wordcloud -------------------------------------------

plots.wordcloud <- list()

for(i in names(word.count)) {
  plots.wordcloud[[i]] <- word.count.dt[Model == i] %>%
    .[1:50] %>%
    ggplot(., aes(label = word, size = freq)) +
    ggwordcloud::geom_text_wordcloud_area(eccentricity = 1, shape = "square") +
    scale_size_area(max_size = 10) +
    theme_AP() +
    ggtitle(names(word.count[i]))
}

# Check rank of the terms "uncertainty" and "sensitivity" in the abstract -----

word.count.dt[, rank:= frank(-freq, ties.method = "first"), Model]

rank.keywords <- word.count.dt[word %chin% keywords_vec_stemmed] %>%
  merge(., total.n, by = "Model") %>%
  .[, word:= factor(word, levels = keywords_vec_stemmed)]

rank.keywords[order(word, rank)]
```

```
##          Model        word freq rank total.papers
##  1:        H08 uncertainti  137   23           61
##  2: SACRAMENTO uncertainti   37   26           52
##  3:       GR4J uncertainti   37   30          167
##  4:   ORCHIDEE uncertainti   52   44           75
##  5:       PRMS uncertainti   64   46           55
##  6:     MPI-HM uncertainti   68   47            3
##  7:      CWatM uncertainti   17   48            7
##  8:        MHM uncertainti   52   56           29
##  9:       DBHM uncertainti   34   65           17
## 10:   WaterGAP uncertainti   33   74          126
## 11:   JULES-W1 uncertainti   17   82          136
## 12:      LPJmL uncertainti    5  161          116
## 13: PCR-GLOBWB uncertainti    2  174           95
## 14:    MATSIRO uncertainti    1  578           21
## 15: SACRAMENTO      sensit   32   33           52
## 16:       DBHM      sensit   38   58           17
## 17:       GR4J      sensit   24   67          167
## 18:   WaterGAP      sensit   35   67          126
## 19:      CWatM      sensit   12   78            7
## 20:        H08      sensit   53   79           61
## 21:   JULES-W1      sensit   12  136          136
## 22:     MPI-HM      sensit   31  144            3
## 23:    MATSIRO      sensit    4  156           21
## 24:        MHM      sensit   26  161           29
## 25:       PRMS      sensit   26  172           55
## 26:      LPJmL      sensit    4  179          116
## 27:   ORCHIDEE      sensit   11  340           75
##          Model        word freq rank total.papers
```

```r
# Plot-------------------------------------------

ggplot(rank.keywords, aes(reorder(Model, -rank), rank, color = word)) +
  geom_point() +
  coord_flip() +
  labs(x = "", y = "Rank") +
  scale_color_discrete(name = "Keywords") +
  theme_AP() +
  theme(legend.position = "right")
```

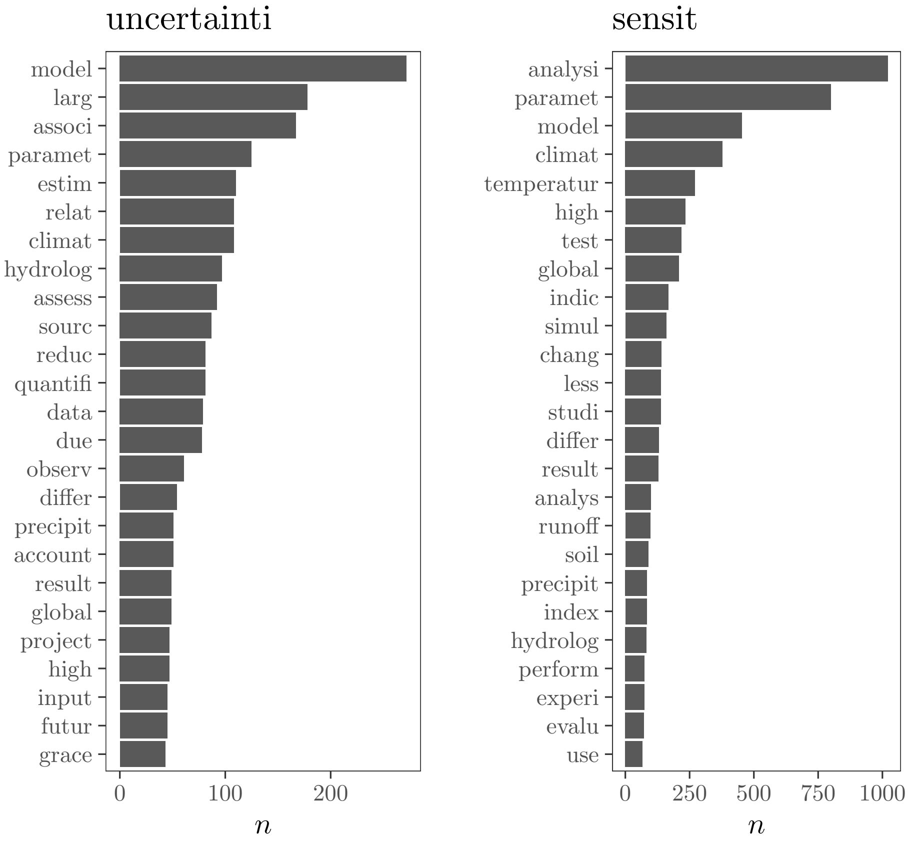


7 Study of n-tokens

```r
# STUDY OF N-TOKENS ###########################################################

# Number of tokens ------------------------------
N.tokens <- 2

# For loop --------------------------------------
output <- token.analysis <- vec <- plot.token <-
  plot.token.model <- graph_plot <- list()

for (i in 1:length(keywords_vec)) {

  output[[i]] <- full.keyword.dt %>%
    .[keyword == keywords_vec_stemmed[i]]

  # Token analysis ------------------------------------------------------------

  token.analysis[[i]] <- output[[i]] %>%
    unnest_tokens(bigram, text, token = "ngrams", n = N.tokens) %>%
    separate(bigram, into = c("word1", "word2"), sep = " ") %>%
    # We count the co-occurences of words without taking into account their order
    # within the n-token
    .[, `:=`(word1= pmin(word1, word2), word2 = pmax(word1, word2))] %>%
    count(word1, word2, Model, sort = TRUE) %>%
    unite(., col = "bigram", c("word1", "word2"), sep = " ")

  vec[[i]] <- token.analysis[[i]] %>%
    .[, str_detect(bigram, keywords_vec_stemmed[i])]

  plot.token[[i]] <-   token.analysis[[i]][vec[[i]]] %>%
    .[, sum(n), bigram] %>%
    .[order(-V1)] %>%
    .[, head(.SD, 25)] %>%
    .[, bigram:= str_remove(bigram, keywords_vec_stemmed[i])] %>%
    ggplot(., aes(reorder(bigram, V1, sum), V1)) +
    geom_bar(stat = "identity") +
    coord_flip() +
    theme_AP() +
    labs(y = "$n$", x = "") +
    theme(legend.position = "none") +
    ggtitle(keywords_vec_stemmed[i])

  plot.token.model[[i]] <- token.analysis[[i]][vec[[i]]] %>%
    .[, head(.SD, 5), Model] %>%
    .[, `:=` (bigram = str_remove(bigram, keywords_vec_stemmed[i]),
              Model = as.factor(Model))] %>%
    .[, bigram:= reorder_within(bigram, n, Model)] %>%
    ggplot(., aes(reorder(bigram, n, sum), n, fill = Model)) +
    geom_bar(stat = "identity") +
    coord_flip() +
    theme_AP() +
    labs(y = "$n$", x = "") +
    scale_x_reordered() +
    theme(legend.position = "none") +
    ggtitle(keywords_vec_stemmed[i]) +
    facet_wrap(~Model, scales = "free", ncol = 3)

  # Graph analysis -------------------------------------------------------------

  bigram_graph <- token.analysis[[i]] %>%
    separate(., col = "bigram", into = c("word1", "word2"), sep = " ") %>%
    .[n > 20] %>%
    graph_from_data_frame()

  set.seed(666)
```

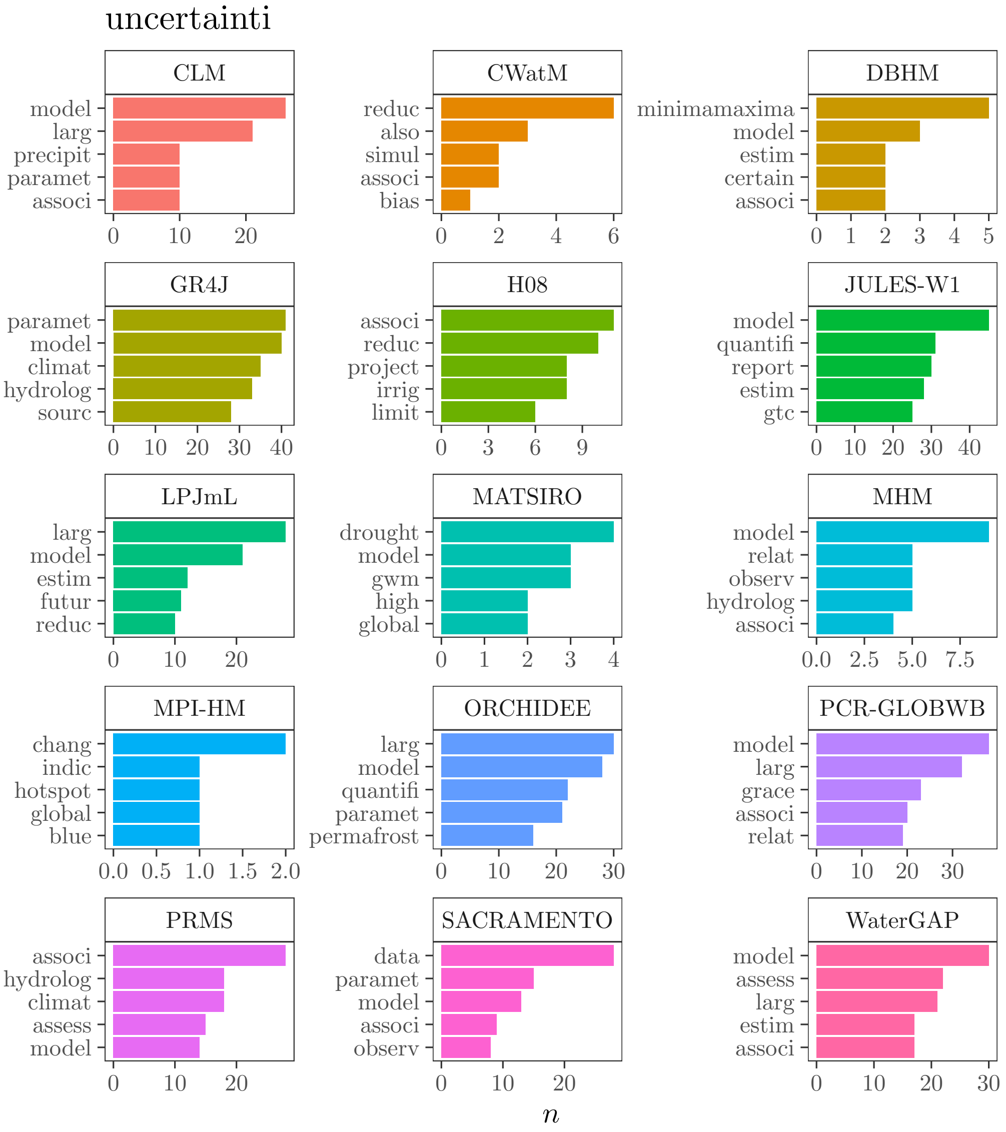
```
  a <- grid::arrow(type = "closed", length = unit(.08, "inches"))

  graph_plot[[i]] <- ggraph(bigram_graph, layout = "fr") +
    geom_edge_link(aes(edge_alpha = n), show.legend = FALSE,
                   arrow = a, end_cap = circle(.02, 'inches')) +
    geom_node_point(color = "lightblue", size = 1.2) +
    geom_node_text(aes(label = name), vjust = 1, hjust = 1, size = 2.5) +
    labs(x = "", y = "") +
    theme_AP() +
    ggtitle(keywords_vec_stemmed[i])
}
```

```
# PLOT 25 MOST COMMON BIGRAMS ###################################################

plot_grid(plotlist = plot.token, ncol = 2, labels = "")
```



```
# PLOT 5 MOST BIGRAMS ###########################################################

sapply(1:2, function(i) plot.token.model[i])
```

```
## [[1]]
```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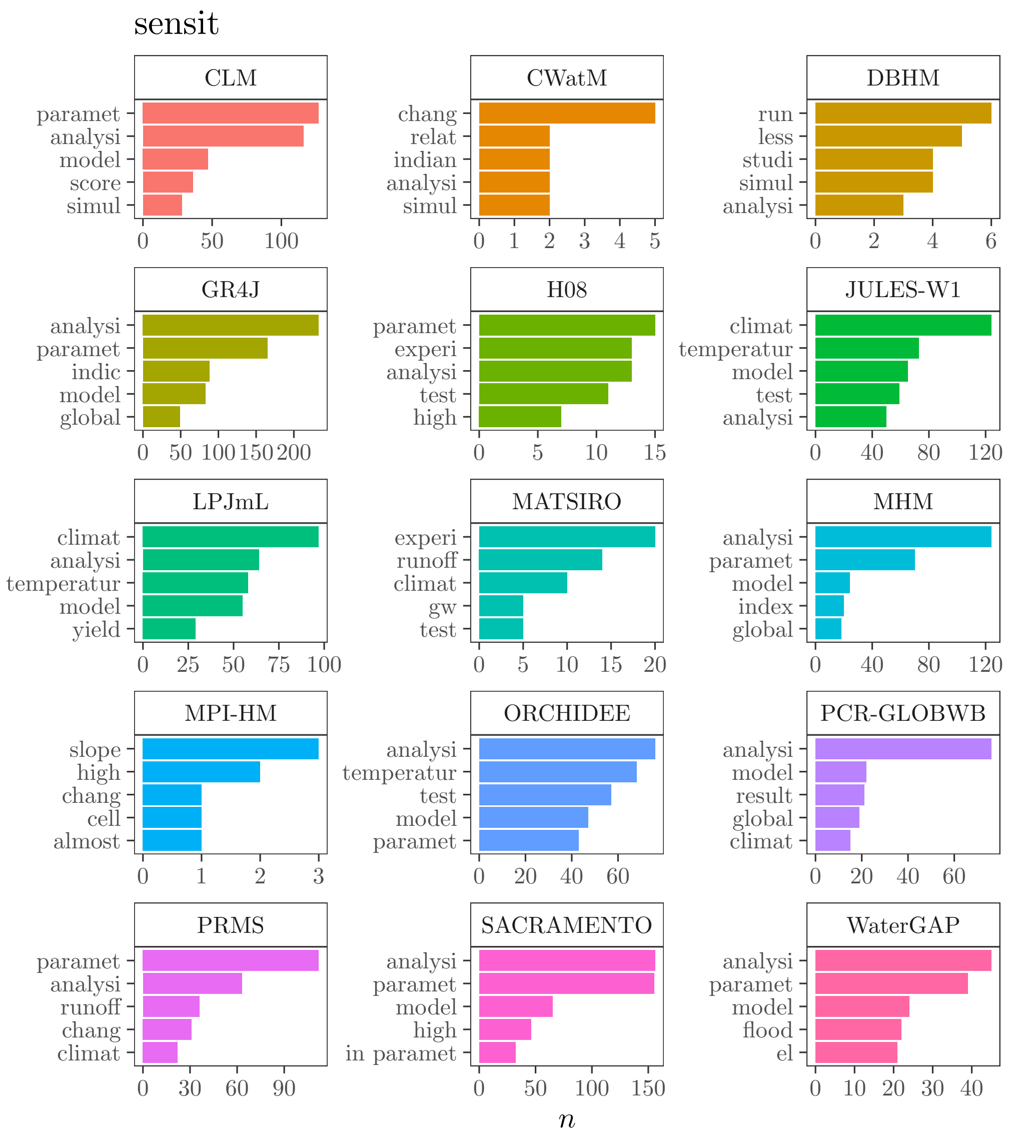
n

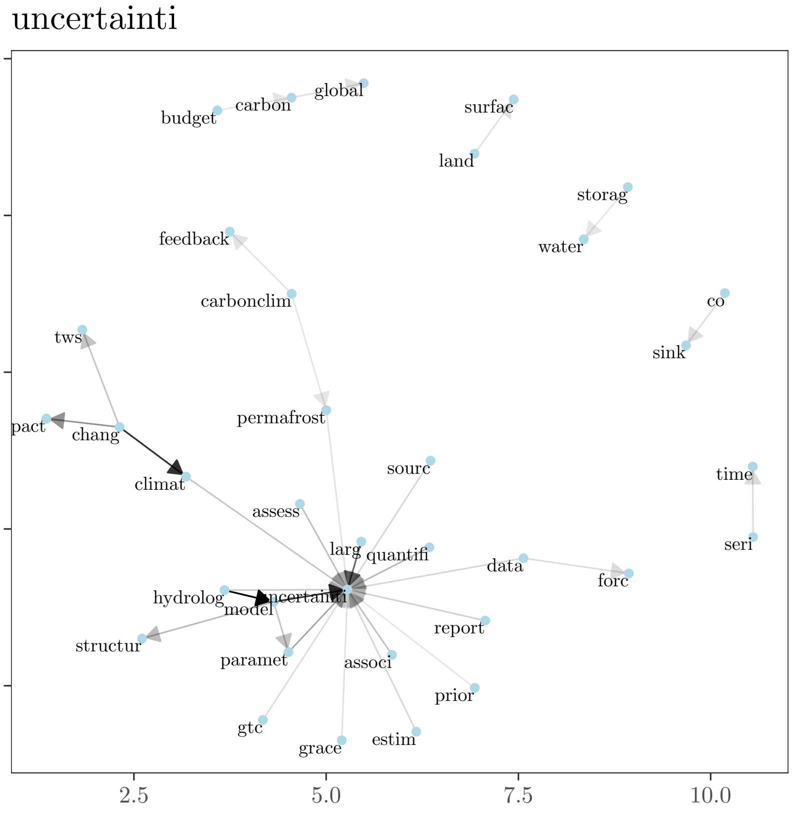
```
##
## [[2]]
```



```
# PLOT NETWORKS OF BIGRAMS #####################################################

sapply(1:2, function(i) graph_plot[i])
```

```
## [[1]]
```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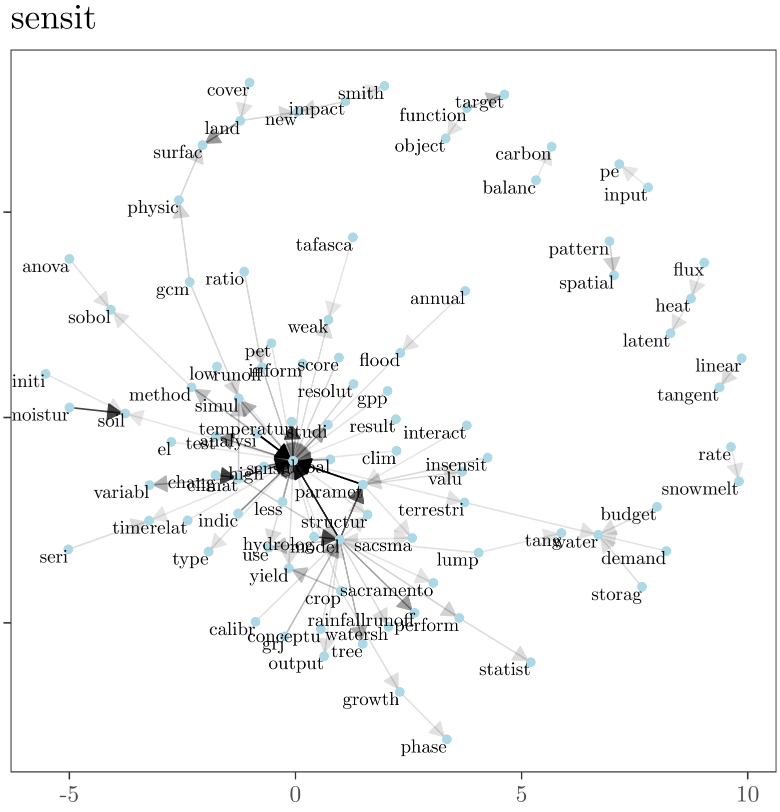
7.5
10.0

```
##
## [[2]]
```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8 Session information

```
# SESSION INFORMATION ##########################################################

sessionInfo()
```

```
## R version 4.2.0 (2022-04-22)
## Platform: aarch64-apple-darwin20 (64-bit)
## Running under: macOS Monterey 12.4
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/4.2-arm64/Resources/lib/libRblas.0.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.2-arm64/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] parallel  stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
##  [1] benchmarkme_1.0.7  ggraph_2.0.5       igraph_1.3.1       tidytext_0.3.3
##  [5] qdapRegex_0.7.5    syuzhet_1.0.6      tm_0.7-8           NLP_0.2-1
##  [9] ggpubr_0.4.0       sjmisc_2.8.9       checkpoint_1.0.2   wesanderson_0.3.6
## [13] cowplot_1.1.1      openxlsx_4.2.5     pdftools_3.2.0     pdfsearch_0.3.0
## [17] scales_1.2.0       data.table_1.14.2  forcats_0.5.1      stringr_1.4.0
## [21] dplyr_1.0.9        purrr_0.3.4        readr_2.1.2        tidyr_1.2.0
## [25] tibble_3.1.7       ggplot2_3.3.6      tidyverse_1.3.1    bibliometrix_3.2.1
##
## loaded via a namespace (and not attached):
##   [1] readxl_1.4.0             backports_1.4.1        plyr_1.8.7
##   [4] lazyeval_0.2.2           SnowballC_0.7.0        digest_0.6.29
##   [7] foreach_1.5.2            htmltools_0.5.2        viridis_0.6.2
##  [10] fansi_1.0.3              magrittr_2.0.3         cluster_2.1.3
##  [13] doParallel_1.0.17        tzdb_0.3.0             graphlayouts_0.8.0
##  [16] modelr_0.1.8             tikzDevice_0.12.3.1    vroom_1.5.7
##  [19] askpass_1.1              colorspace_2.0-3       rvest_1.0.2
##  [22] ggrepel_0.9.1            pubmedR_0.0.3          haven_2.5.0
##  [25] xfun_0.31                crayon_1.5.1           jsonlite_1.8.0
##  [28] bibliometrixData_0.3.0 iterators_1.0.14       glue_1.6.2
##  [31] polyclip_1.10-0          stopwords_2.3          gtable_0.3.0
##  [34] car_3.0-13               rentrez_1.2.3          abind_1.4-5
##  [37] qpdf_1.1                 DBI_1.1.2              rstatix_0.7.0
##  [40] Rcpp_1.0.8.3             viridisLite_0.4.0      xtable_1.8-4
##  [43] dimensionsR_0.0.3        bit_4.0.4              flashClust_1.01-2
##  [46] DT_0.23                  htmlwidgets_1.5.4      httr_1.4.3
##  [49] ggwordcloud_0.5.0        RColorBrewer_1.1-3     ellipsis_0.3.2
##  [52] factoextra_1.0.7       pkgconfig_2.0.3        XML_3.99-0.9
##  [55] farver_2.1.0           dbplyr_2.1.1           utf8_1.2.2
##  [58] labeling_0.4.2         tidyselect_1.1.2       rlang_1.0.2
##  [61] later_1.3.0            munsell_0.5.0          cellranger_1.1.0
##  [64] tools_4.2.0            cli_3.3.0              generics_0.1.2
##  [67] sjlabelled_1.2.0       broom_0.8.0            evaluate_0.15
##  [70] fastmap_1.1.0          yaml_2.3.5             bit64_4.0.5
##  [73] knitr_1.39             fs_1.5.2               filehash_2.4-3
##  [76] tidygraph_1.2.1        zip_2.2.0              mime_0.12
##  [79] slam_0.1-50            leaps_3.1              xml2_1.3.3
##  [82] tokenizers_0.2.1       compiler_4.2.0         rstudioapi_0.13
##  [85] png_0.1-7              plotly_4.10.0          ggsignif_0.6.3
##  [88] reprex_2.0.1           tweenr_1.0.2           stringi_1.7.6
##  [91] highr_0.9              lattice_0.20-45        Matrix_1.4-1
##  [94] vctrs_0.4.1            stringdist_0.9.8       pillar_1.7.0
##  [97] lifecycle_1.0.1        rscopus_0.6.6          insight_0.17.1
## [100] httpuv_1.6.5           R6_2.5.1               promises_1.2.0.1
## [103] gridExtra_2.3          janeaustenr_0.1.5      codetools_0.2-18
## [106] benchmarkmeData_1.0.4  MASS_7.3-57            assertthat_0.2.1
## [109] withr_2.5.0            hms_1.1.1              grid_4.2.0
## [112] rmarkdown_2.14         carData_3.0-5          ggforce_0.3.3
## [115] scatterplot3d_0.3-41   shiny_1.7.1            lubridate_1.8.0
## [118] tinytex_0.39           FactoMineR_2.4
```

```
## Return the machine CPU
cat("Machine:     "); print(get_cpu()$model_name)
```

```
## Machine:
```

```
## [1] "Apple M1 Max"
```

```
## Return number of true cores
cat("Num cores:   "); print(detectCores(logical = FALSE))
```

```
## Num cores:
```

```
## [1] 10
```

```
## Return number of threads
cat("Num threads: "); print(detectCores(logical = FALSE))
```

```
## Num threads:
```

```
## [1] 10
```

“‘