Hotspot Extraction

vv0.4.1

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1 Setup and Libraries

Load all core packages (tidyverse, spatial, plotting helpers) and initialize reproducibility settings. This chunk also sources `R/paths.R` and runs `devtools::load_all()` so downstream chunks can reuse helper functions.

2 Run Metadata Banner

Print run metadata (analysis version, timestamp, git commit, data root) so exported reports remain traceable.

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Note

Run metadata

- Analysis version: v0.4.1
- Rendered: 2025-12-02 08:26 PST
- Git: main @ e20e5d9
- Data root: /home/jeronimo/data/global_ncp

3 Add regional attributes to Grid (countries & biomes)

Attach country and biome IDs to the 10 km grid (`sf_f`) so downstream aggregation/hotspot steps can group by region. This chunk only runs if the processed GPKG is missing.

We enrich the 10 km grid (`sf_f`) with country and WWF biome IDs so we can aggregate and compare change by subregions (World Bank region, income group, continent, UN region, and biome). We use a point-on-surface join to avoid sliver/overlap issues, keep only the needed fields, and write a single enriched GPKG for downstream grouping, hotspot extraction, and plotting.

Tip

What this step does

- Reads country and biome layers from `vectors/`.
- Joins them to the 10 km grid via point-on-surface.
- Writes `processed/10k_change_calc.gpkg` for downstream analysis (pivoting, hotspots, plots). **Inputs:** `sf_f` grid; `vectors/cartographic_ee_ee_r264_correspondence.gpkg`; `vectors/Biome.gpkg` **Output:** `processed/10k_change_calc.gpkg` (grid + regional attributes)

Why point-on-surface? It's robust for odd cell shapes and avoids polygon–polygon sliver issues.
When to bump the version? If the joined attributes change schema/meaning (e.g., new grouping columns), bump **MINOR**; if file name/structure changes in a breaking way, bump **MAJOR**.

4 Reshape grid data to a service-long table

Pivot the processed grid into a tidy `plt_long` table (one row per cell × service) and standardize service labels/factor order. Cached so we only rebuild when inputs change.

Start by turning the wide grid table (one row per 10 km cell with many *_abs_chg / *_pct_chg columns) into an **analysis-ready long format**: one row per **cell × service** with two value

columns: `abs_chg` and `pct_chg`. This makes it easy to rank, filter, and facet by service in later hotspot steps.

What this chunk does 1) Reads the processed grid from `processed/10k_change_calc.gpkg` and ensures a unique `fid`.
2) Splits "ID/grouping" columns from change columns.
3) Pivots *_abs_chg / *_pct_chg to long, then back to wide as `abs_chg` / `pct_chg` per service.
4) Cleans obvious issues (drops `Inf`/`NA` where appropriate) so plots and tests won't choke.
5) Applies a human-readable service label mapping (e.g., `n_export → N_export`).
6) Sets a canonical facet order (`svc_order`) so plots are consistent across the report.

Inputs: `processed/10k_change_calc.gpkg` (contains `fid`, `c_fid`, service change fields, and sub-regional tags like `region_wb`, `income_grp`, `BIOME`, etc.).
Output: `plt_long` (tidy tibble) with columns
`fid, c_fid, service, abs_chg, pct_chg, <grouping/socio vars>`.

> Tip
>
> **Why long format?**
> Ranking, percentile cuts, ECDFs, and faceted plots are all simpler and faster when each **service** is a row attribute rather than a separate column.

4.1 QA: sanity checks on `plt_long`

Before ranking/thresholding, a lightweight QA helps catch silent problems (e.g., an empty service, unexpected sparsity, or leftover `Inf`s):

- Confirm `plt_long` exists and peek the structure.
- Count rows per `service` to spot outliers in coverage (e.g., a service that only exists in a few countries).

4.1.1 Inspect pivot output

```
# ---- Quick sanity -------------------------------------------------------

stopifnot(exists("plt_long"))

# Peek a few rows & structure

dplyr::glimpse(head(plt_long, 5), width = 80)
```

```
Rows: 5
Columns: 12
$ fid                                   <int> 5, 5, 5, 5, 5
$ c_fid                                 <dbl> 43, 43, 43, 43, 43
$ service                               <fct> Nature_Access, N_export, N_ret~
```

```
$ abs_chg                                  <dbl> 0, 0, 0, 0, 0
$ pct_chg                                  <dbl> NA, NA, NA, NA, NA
$ GHS_BUILT_S_E2020_mean                   <dbl> 0.07022214, 0.07022214, 0.0702~
$ fields_mehrabi_2017_mean                 <dbl> NA, NA, NA, NA, NA
$ hdi_raster_predictions_2020_mean         <dbl> 0.7197492, 0.7197492, 0.719749~
$ rast_adm1_gini_disp_2020_mean            <dbl> 0.474, 0.474, 0.474, 0.474, 0.~
$ rast_gdpTot_1990_2020_30arcsec_2020_sum <dbl> 138537, 138537, 138537, 138537~
$ GHS_POP_E2020_GLOBE_sum                  <dbl> 7.198403, 7.198403, 7.198403, ~
$ GlobPOP_Count_30arc_2020_sum             <dbl> 0, 0, 0, 0, 0
```

```r
# Counts per service (helps spot weird sparsity)

plt_long |>
dplyr::count(service, name = "rows") |>
dplyr::arrange(dplyr::desc(rows)) |>
print(n = 50)
```

```
# A tibble: 12 x 2
   service             rows
   <fct>              <int>
 1 Sed_export       2685468
 2 N_export         2685190
 3 N_retention      2684972
 4 Nature_Access    2674685
 5 Pollination      2672876
 6 USLE             1847909
 7 Sed_Ret_Ratio    1797561
 8 N_Ret_Ratio      1795552
 9 C_Risk            277744
10 Rt_nohab          277744
11 C_Risk_Red_Ratio  257976
12 C_Prot_service    257976
```

5 Hotspot extraction workflow (global + subregional)

We identify per-service hotspots using a 5% percentile rule and **direction vectors**: - `loss_services` (e.g., Nature_Access, Pollination, N/Sed_Ret_Ratio, C_Risk_Red_Ratio) → we flag the **lowest** values; - `gain_services` (Sed_export, N_export, C_Risk) → we flag the **highest** values.

We run this **once globally** and then **once per subregion** (World Bank region, income group, continent, UN region, WWF biome). For each run and for each metric (absolute and percent change) we write a compact **GPKG** containing only the hotspot cells, plus a CSV index:

- Output root: `processed/hotspots/`
  - `abs/global/hotspots_global_abs.gpkg`
  - `pct/global/hotspots_global_pct.gpkg`

  - abs/<group_col>/hotspots_<group_col>_<group_val>_abs.gpkg
  - pct/<group_col>/hotspots_<group_col>_<group_val>_pct.gpkg

- Index: processed/hotspots/_hotspots_index.csv (columns: scope, group_col, group_val, metric, n_hot, gpkg).

These files are meant for QGIS/QA and downstream stats (e.g., KS) without recomputing hotspots.

5.1 Hotspot rules & export configuration

The analysis uses a single, central configuration so the hotspot rules are consistent everywhere:

Thresholding: we flag hotspots using the top/bottom tails of the distribution per service. Here we use a percentile cutoff (e.g., 5%) rather than a fixed count.

Direction of concern: services in loss are "worse when they go down" (we keep the lowest tail); services in gain are "worse when they go up" (we keep the highest tail).

Combos (optional): grouped service sets that we count per cell for quick composite summaries.

Export switches: choose whether to write GPKGs and/or the CSV index.

```
HOTS_CFG <- list(
  analysis_name   = "global_NCP_hotspots",
  pct_cutoff      = 0.05,
  threshold_mode  = "percent",
  rule_mode       = "vectors",
  loss = c("Nature_Access","Pollination","N_Ret_Ratio","Sed_Ret_Ratio","C_Risk_Red_Ratio"),
  gain = c("Sed_export","N_export","C_Risk"),
  combos = list(
    deg_combo = c("Nature_Access","Pollination","N_export","Sed_export","C_Risk"),
    rec_combo = c("Nature_Access","Pollination","N_Ret_Ratio","Sed_Ret_Ratio","C_Risk_Red_Ratio
  ),
# centralize the grouping columns here
  groupings = c("income_grp","region_wb","continent","region_un","WWF_biome"),
  # IO
  write_layers = TRUE,
  write_index  = TRUE,
  out_dir      = file.path(data_dir(), "processed", "hotspots")
)
```

```
::: callout-note
**Hotspot configuration**

- Cutoff: 5% (percent)
- Rule mode: vectors
- Loss services: Nature_Access, Pollination, N_Ret_Ratio, Sed_Ret_Ratio, C_Risk_Red_Ratio
- Gain services: Sed_export, N_export, C_Risk
- Combos: **deg_combo**: Nature_Access, Pollination, N_export, Sed_export, C_Risk<br>**rec_comb
```

```
…
- Groupings: income_grp, region_wb, continent, region_un, WWF_biome
…- Write layers: TRUE | Write index: TRUE
- Output dir: `/home/jeronimo/data/global_ncp/processed/hotspots`
:::
```

5.2 Validate hotspot configuration

```
stopifnot(exists("plt_long"))
svc_all <- unique(plt_long$service)

# No service should be in both loss and gain
if (length(intersect(HOTS_CFG$loss, HOTS_CFG$gain)) > 0) {
  stop("A service appears in BOTH `loss` and `gain`. Fix HOTS_CFG.")
}

miss_loss <- setdiff(HOTS_CFG$loss, svc_all)
miss_gain <- setdiff(HOTS_CFG$gain, svc_all)
if (length(miss_loss) > 0 || length(miss_gain) > 0) {
  warning("Services in HOTS_CFG not found in `plt_long$service`:\n",
          if (length(miss_loss)) paste0("  - missing loss: ", paste(miss_loss, collapse=", "),
          if (length(miss_gain)) paste0("  - missing gain: ", paste(miss_gain, collapse=", "),
}
```

5.3 Export hotspot layers

> **Note**
>
> **Hotspot export module**
> - Computes hotspot cells once (global + by subregion) for ABS and PCT change.
> - Writes compact GPKGs for mapping/QA and maintains `_hotspots_index.csv`.
> - Prereqs: `plt_long` in memory, `HOTS_CFG` defined (loss/gain/combos/etc.).

6 Checkpoint recap

Wired the project with a metadata banner (version, git, data root) for reproducibility.

Enriched the 10 km grid with country/biome tags (documented chunk, eval: false) and standardized the working input at processed/10k_change_calc.gpkg.

Reshaped to analysis-ready long format (plt_long), cleaned basic issues, harmonized service labels, and set a canonical facet order.

Centralized hotspot rules in HOTS_CFG (loss/gain, combos, cutoff, groupings, IO).

Exported hotspots once (global + by subregion, for abs/pct change) to compact GPKGs under processed/hotspots/, and wrote a manifest: processed/hotspots/_hotspots_index.csv.

Why this structure? Heavy work (ranking/thresholding/joining) is done once. The manifest gives us traceability and fast loading for downstream steps (bar plots, violins, KS tests) without re-computation.

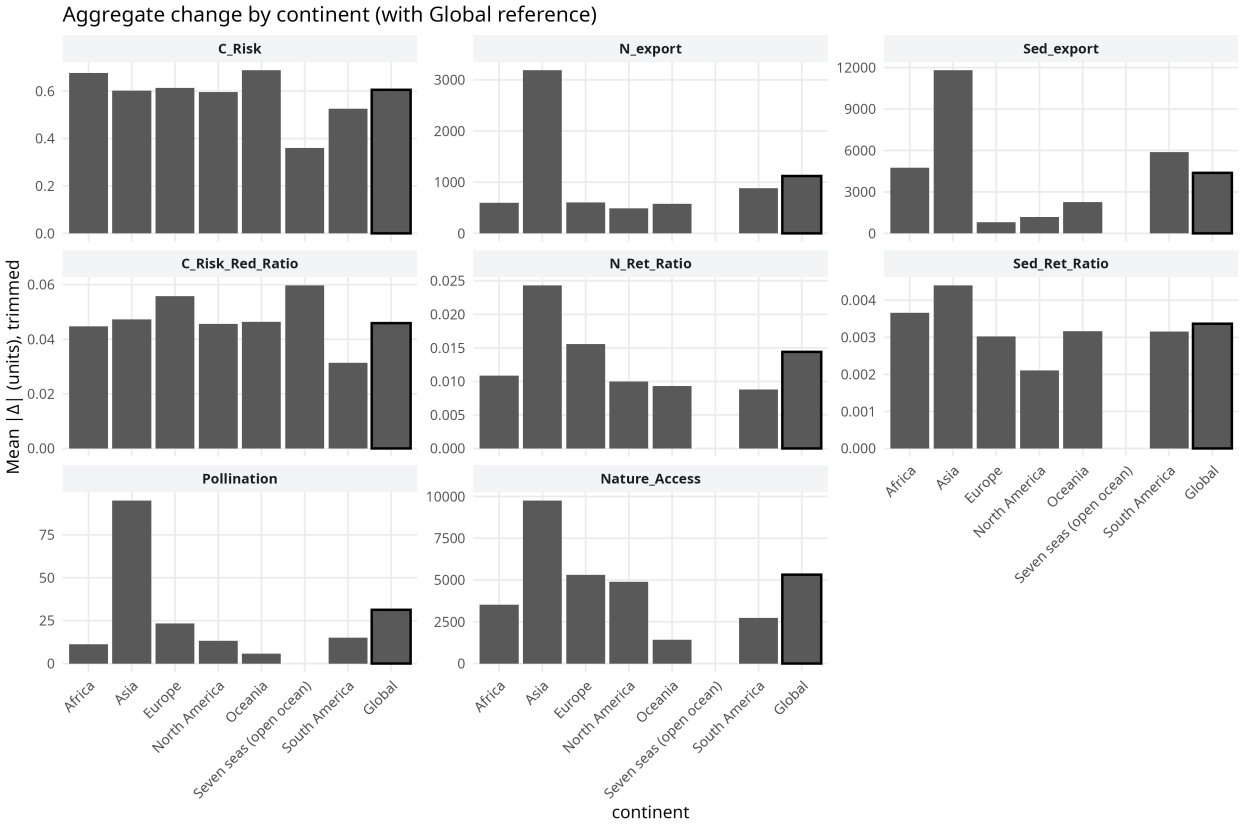
7 Trimmed change bar plots

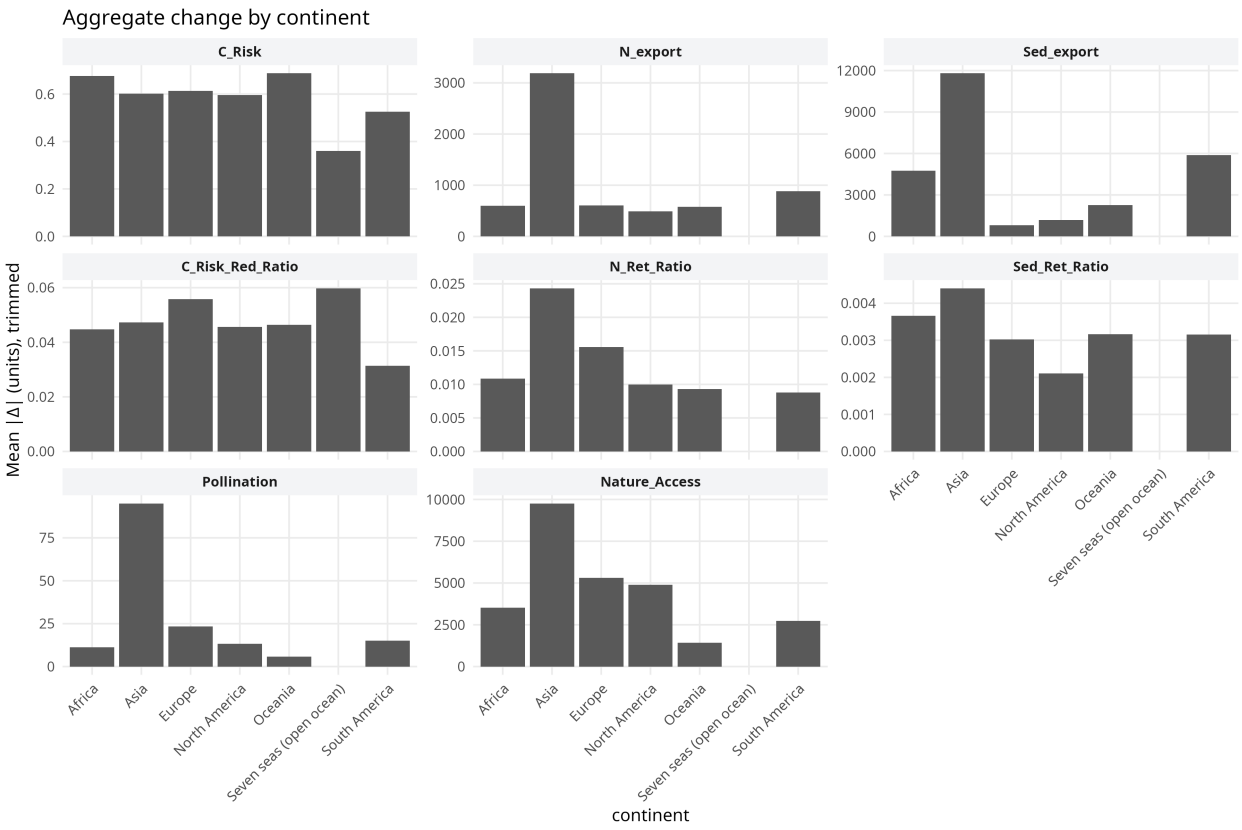
> **Note**
>
> **How to read these bars**
>
> - Each bar shows the **trimmed mean absolute change** ($|\Delta|$) per service within each group; facet axes are free.
> - Bars are **always positive** by design: height = **magnitude of change**, not direction.
> - Direction-of-concern used elsewhere in the analysis:
>   - Worse when **up** `Sed_export`, `N_export`, `C_Risk`.
>   - Worse when **down** `Nature_Access`, `Pollination`, `N_Ret_Ratio`, `Sed_Ret_Ratio`, `C_Risk_Red_Ratio`.
> - These bars answer **"where is change largest?"**. See hotspot maps/violins for **up vs. down** patterns.

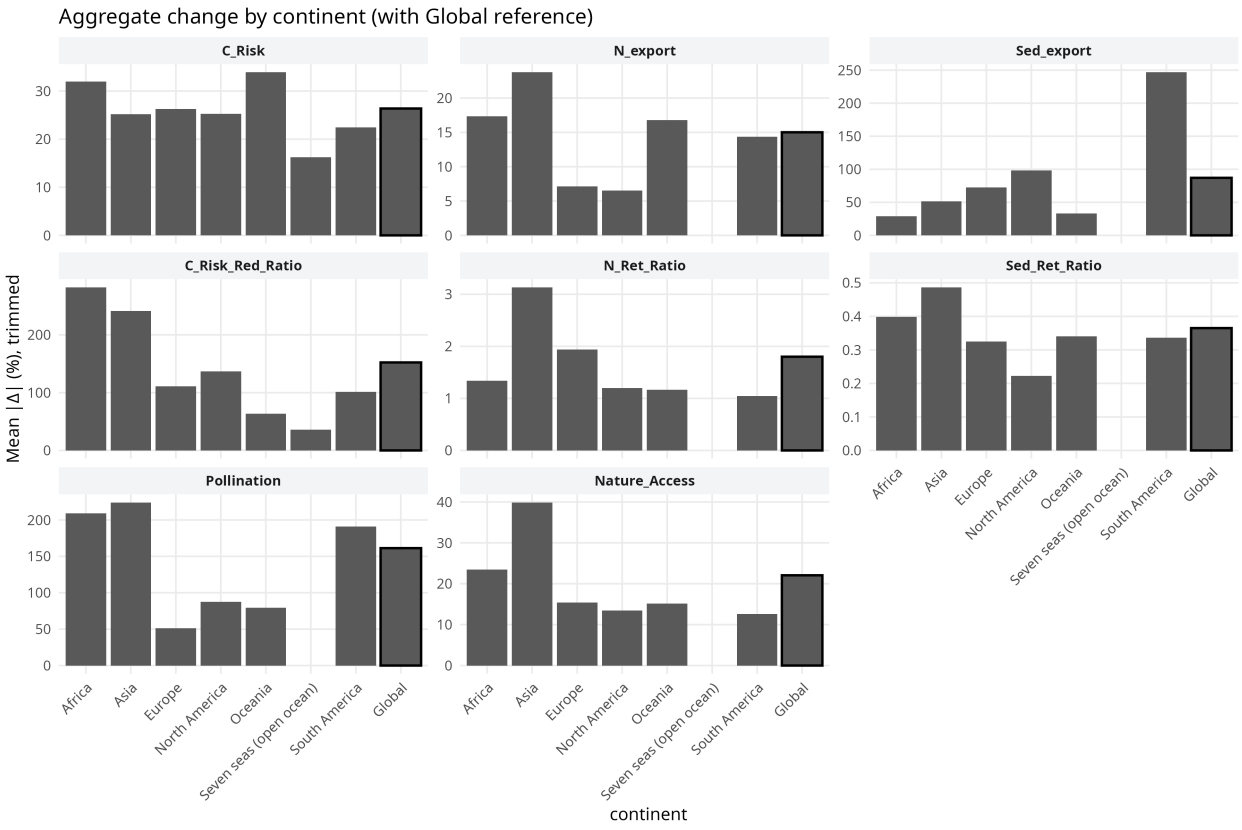
Short answer: your current barplots use all grid cells (the full 10-km population), not just hotspots. They summarize trimmed means per subregion/global from plt_long via aggregate_change_simple(), with cut_q=0.999 to cap outliers and (optionally) drop_zeros=TRUE. That's why every bar is positive—those bars are the magnitude of change, not the direction.

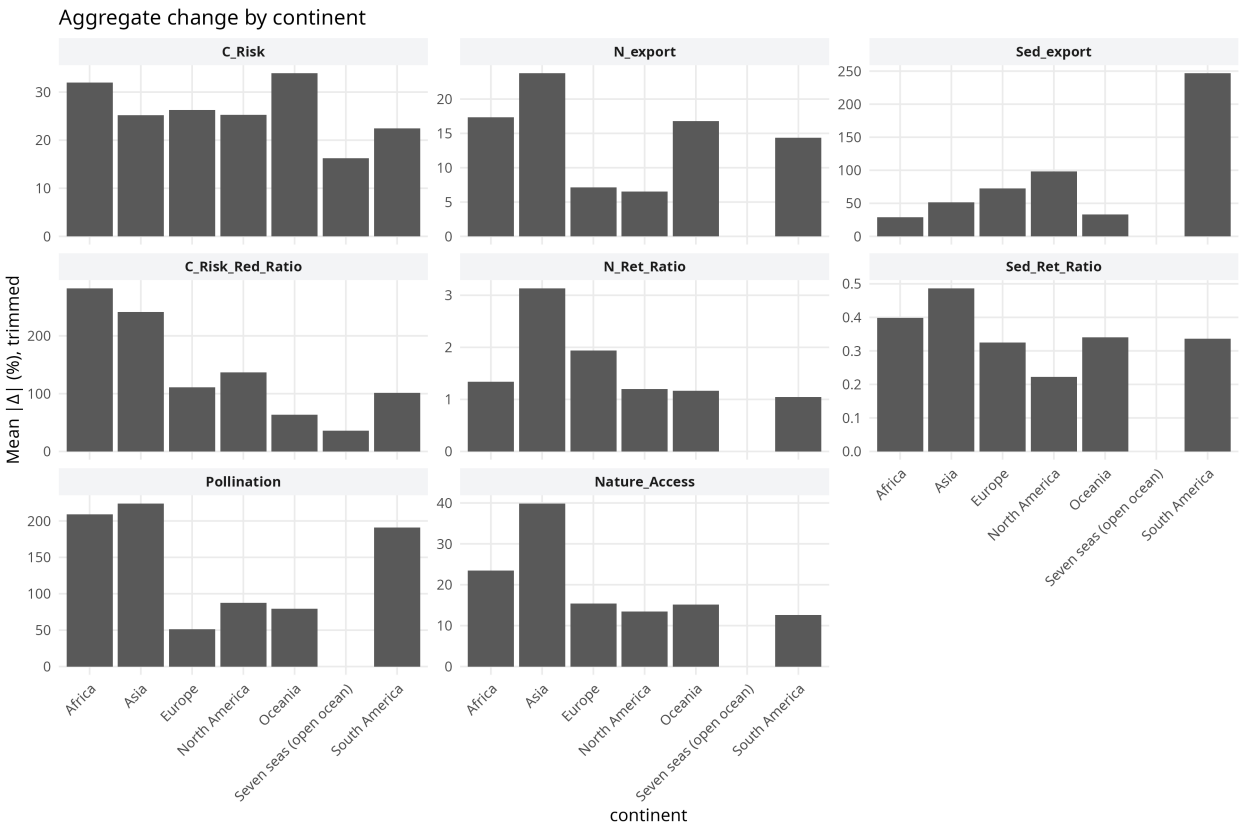
Outputs: PNGs land in `outputs/plots/{abs|pct}/<group_col>/bars_*.png` plus a flat copy in `outputs/plots/latest/bars/` for embedding here. The legacy global-only single-bar chart was removed to keep the gallery focused on grouped views.

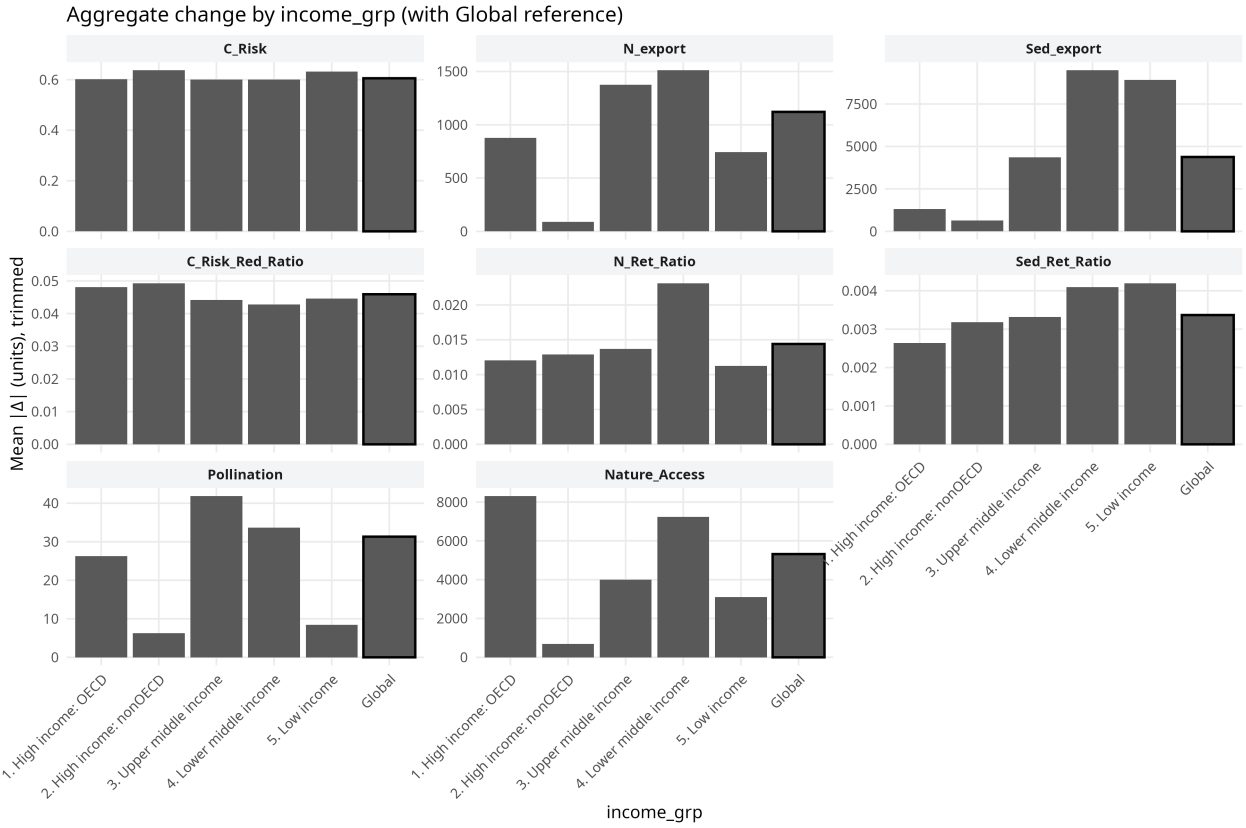
Generate trimmed-mean bar plots (abs & pct) for each grouping. Plots save to `outputs/plots/...` and are embedded below.

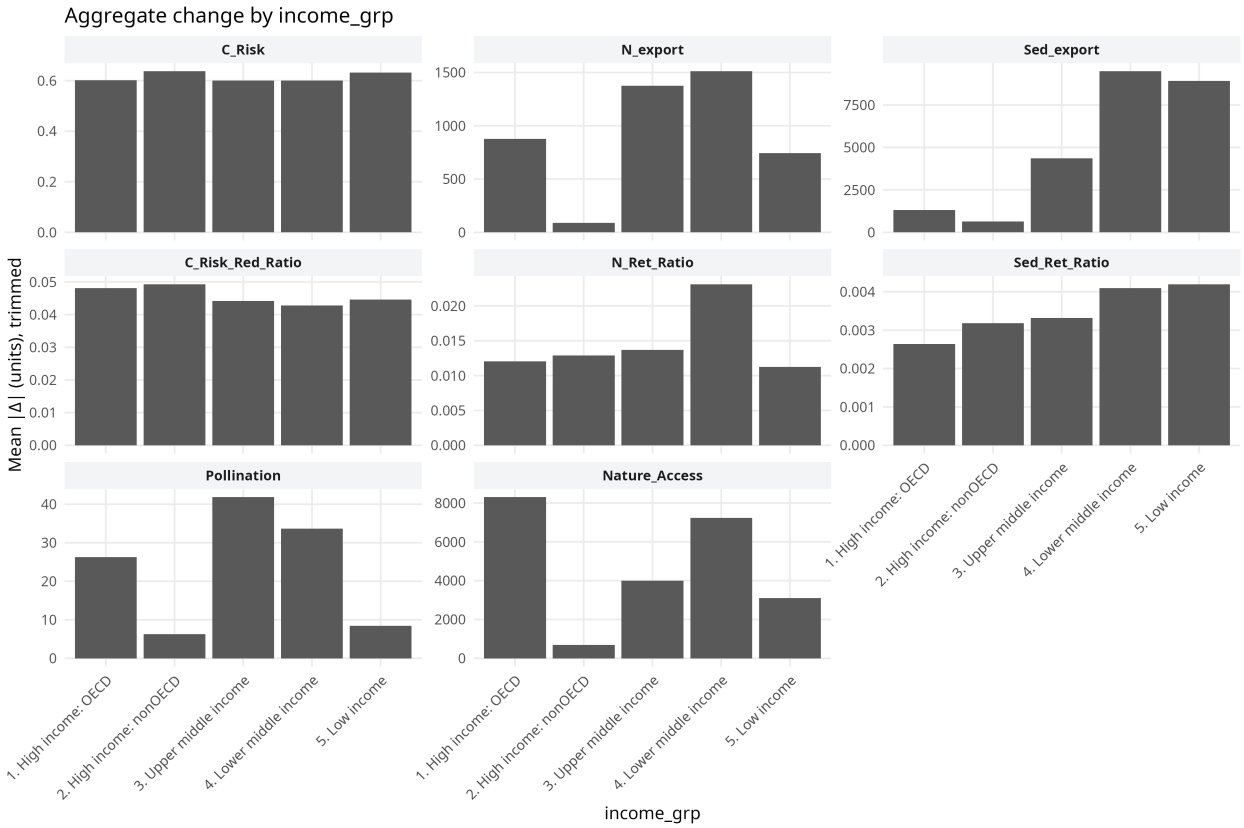

Aggregate change by continent (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
Africa
Asia
Europe
North America
Oceania
Seven seas (open ocean)
South America
Global
continent

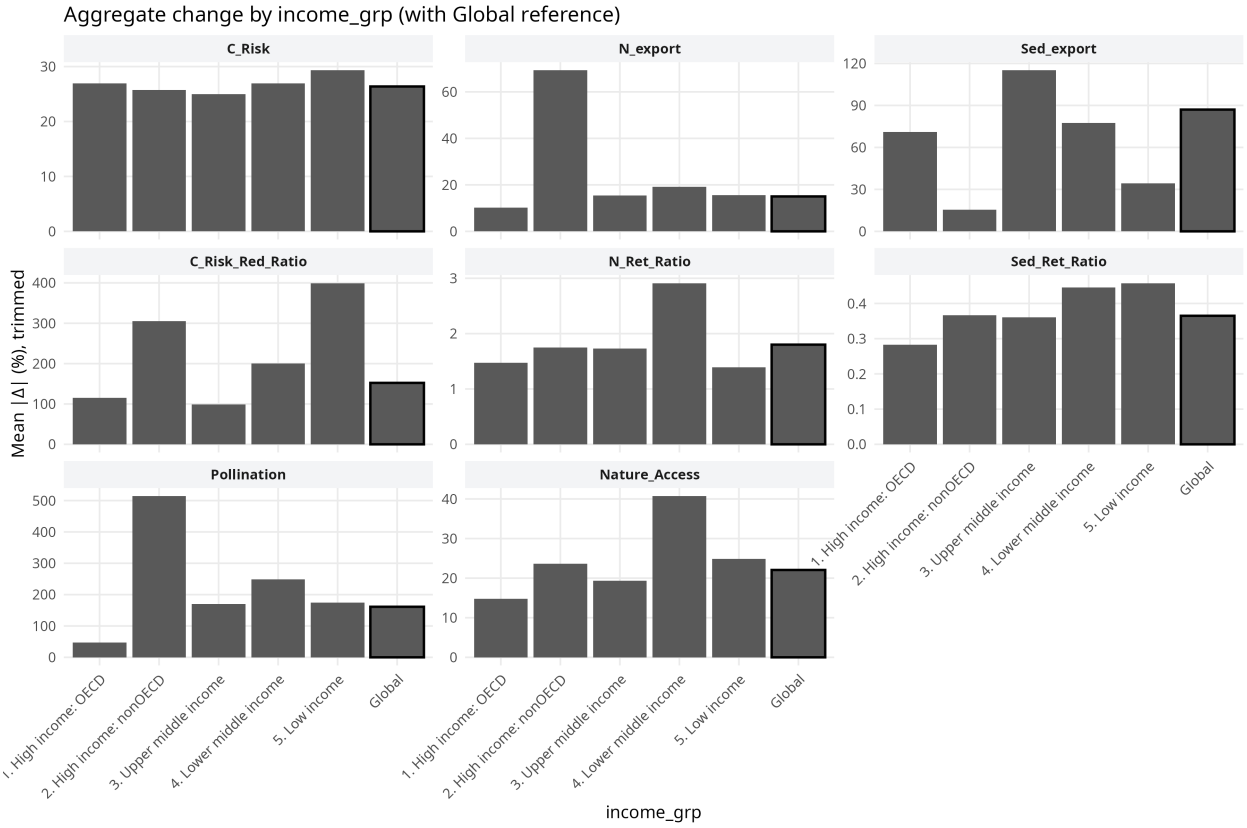

Aggregate change by continent
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
Africa
Asia
Europe
North America
Oceania
Seven seas (open ocean)
South America
continent

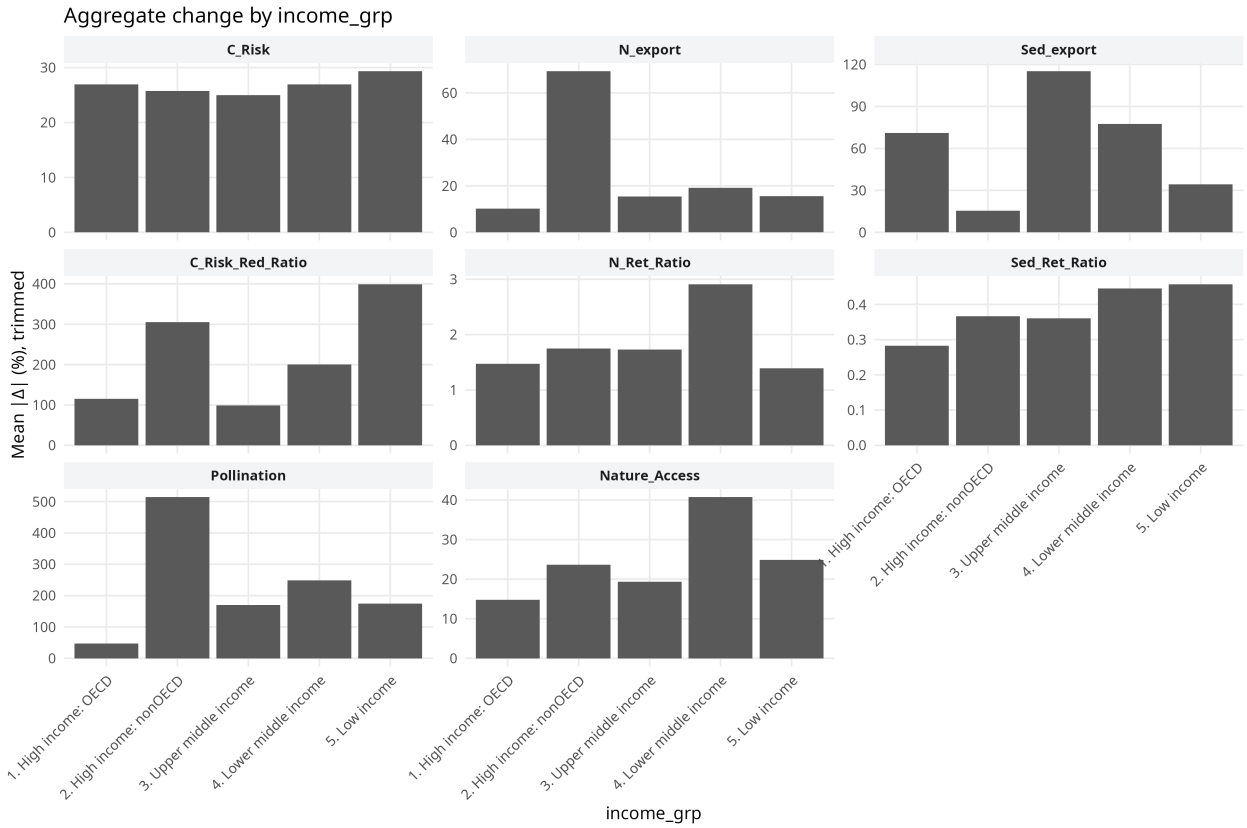

Aggregate change by continent (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
Africa
Asia
Europe
North America
Oceania
Seven seas (open ocean)
South America
Global
continent

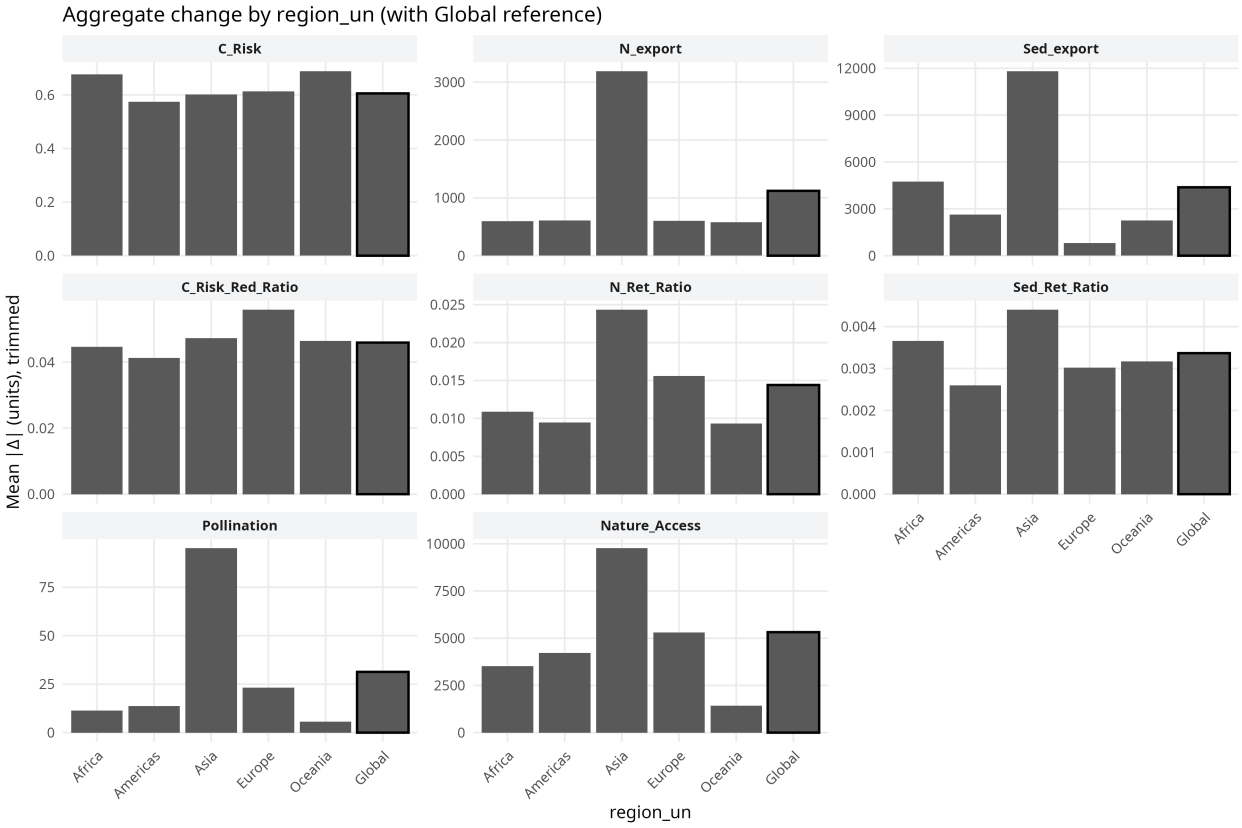

Aggregate change by continent
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
Africa
Asia
Europe
North America
Oceania
Seven seas (open ocean)
South America
continent

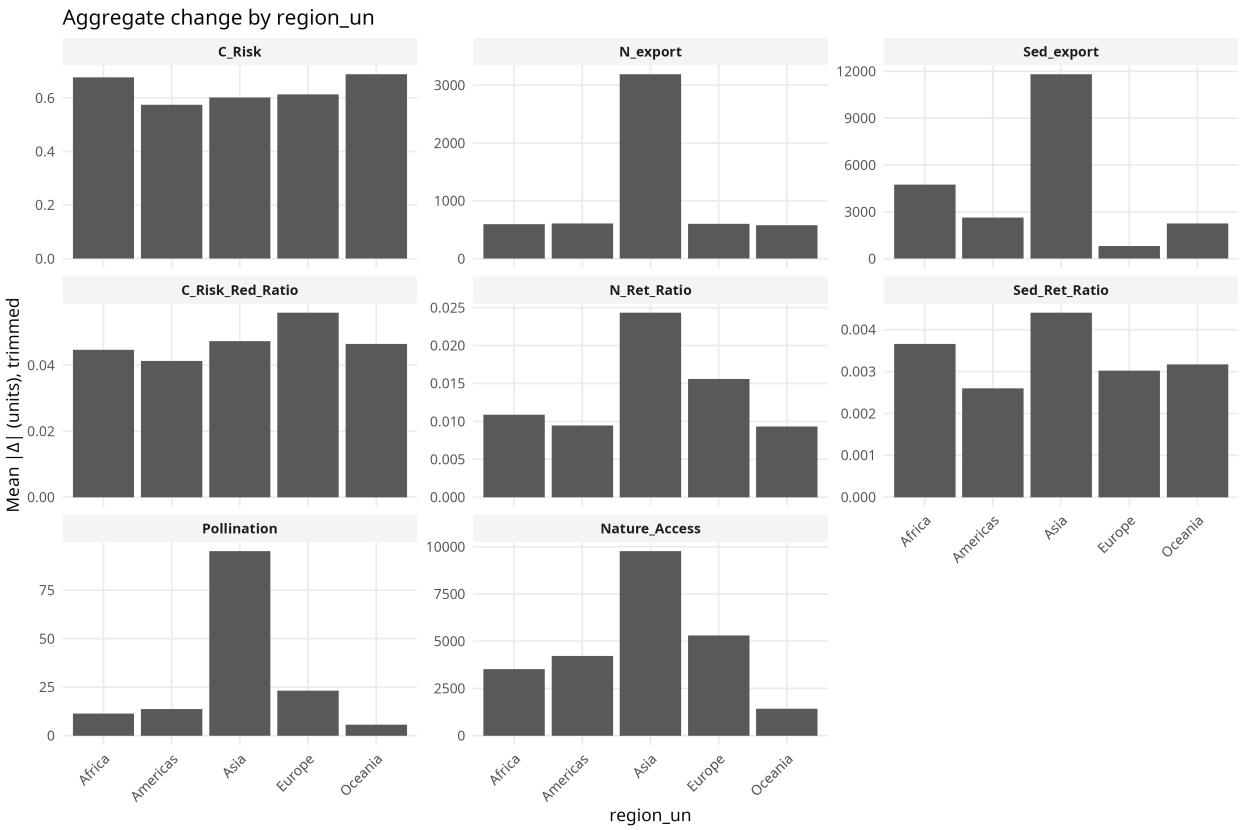

Aggregate change by income_grp (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
1. High income: OECD
2. High income: nonOECD
3. Upper middle income
4. Lower middle income
5. Low income
Global
income_grp

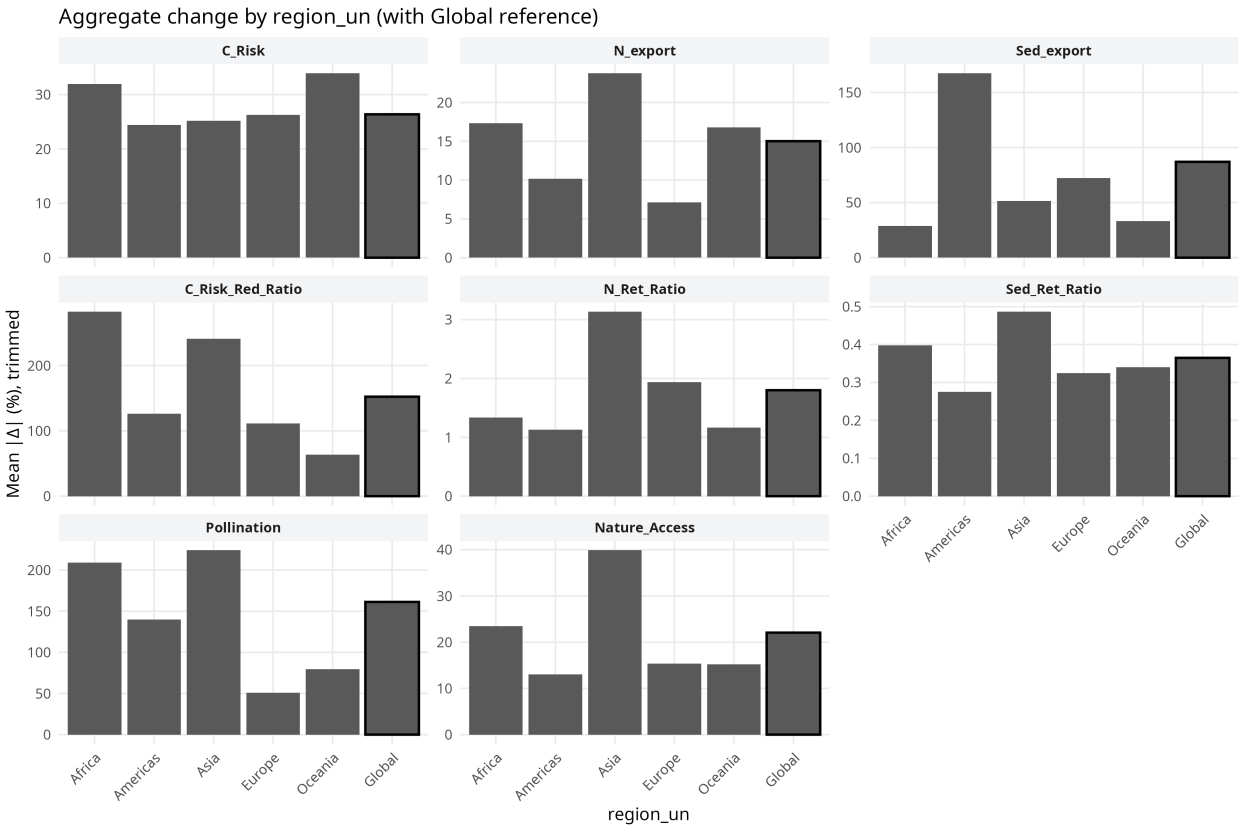

Aggregate change by income_grp
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
1. High income: OECD
2. High income: nonOECD
3. Upper middle income
4. Lower middle income
5. Low income
income_grp

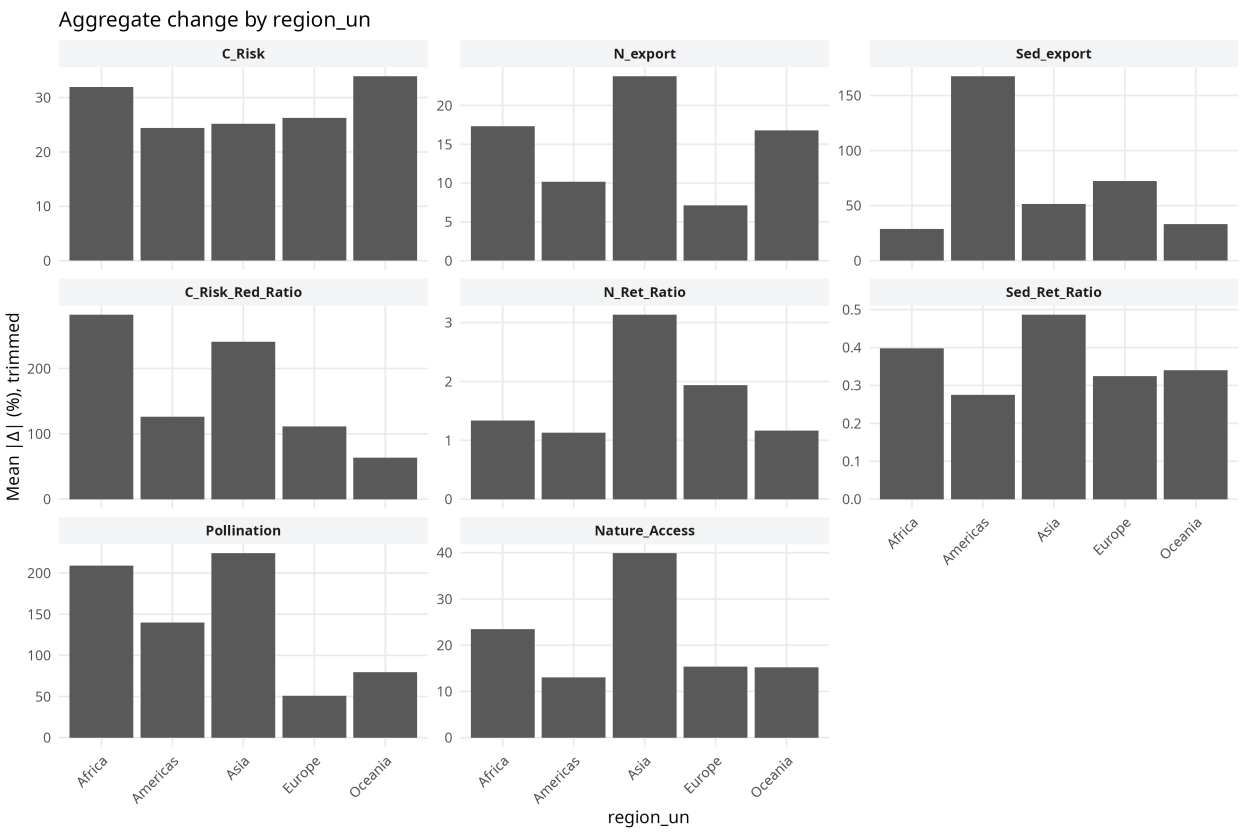

Aggregate change by income_grp (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
1. High income: OECD
2. High income: nonOECD
3. Upper middle income
4. Lower middle income
5. Low income
Global
income_grp

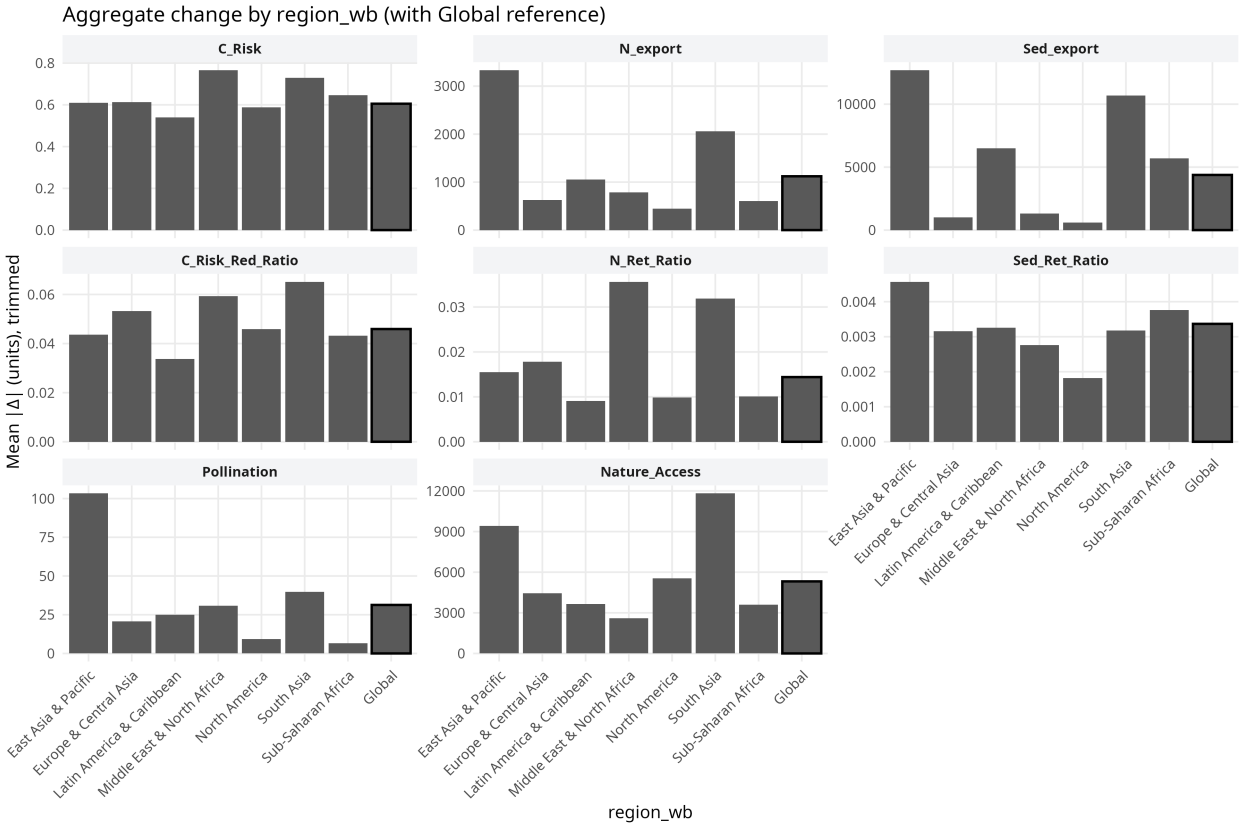

Aggregate change by income_grp
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
1. High income: OECD
2. High income: nonOECD
3. Upper middle income
4. Lower middle income
5. Low income
income_grp

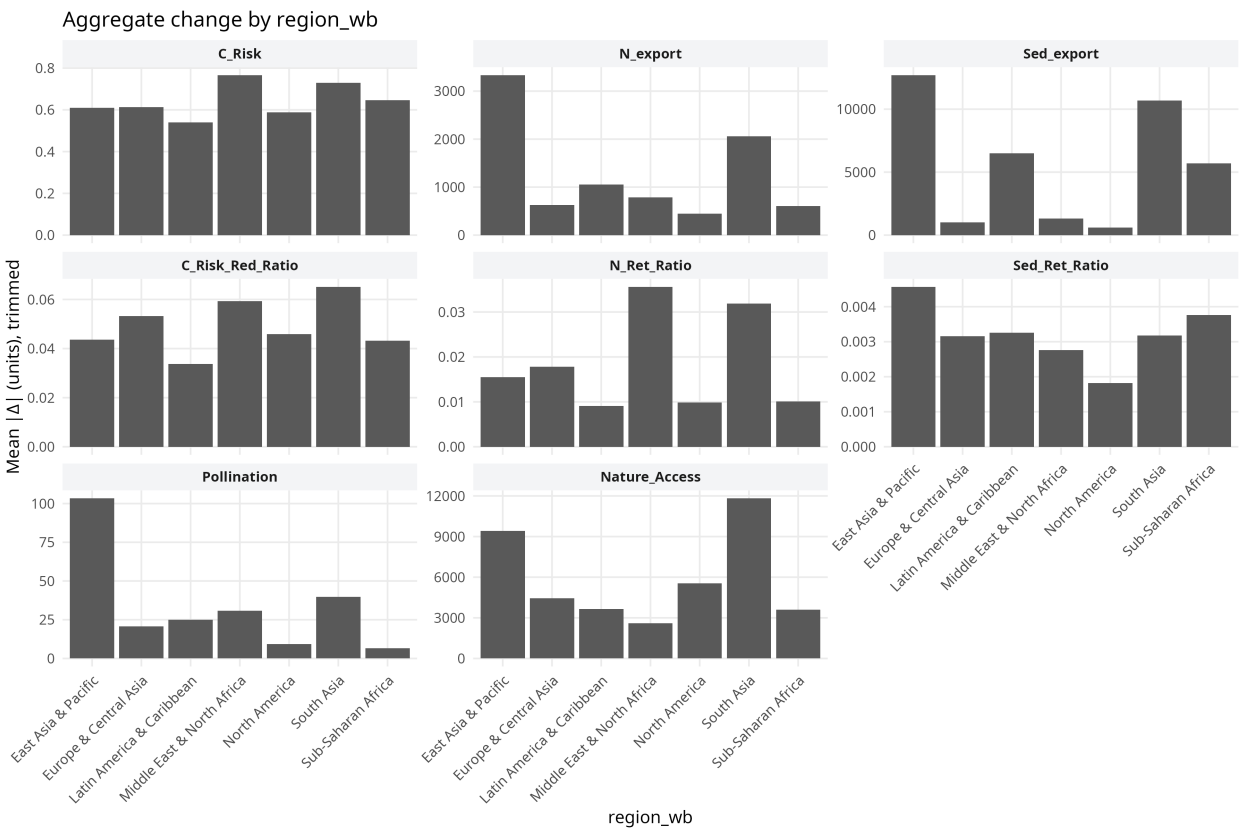

Aggregate change by region_un (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
Africa
Americas
Asia
Europe
Oceania
Global
region_un

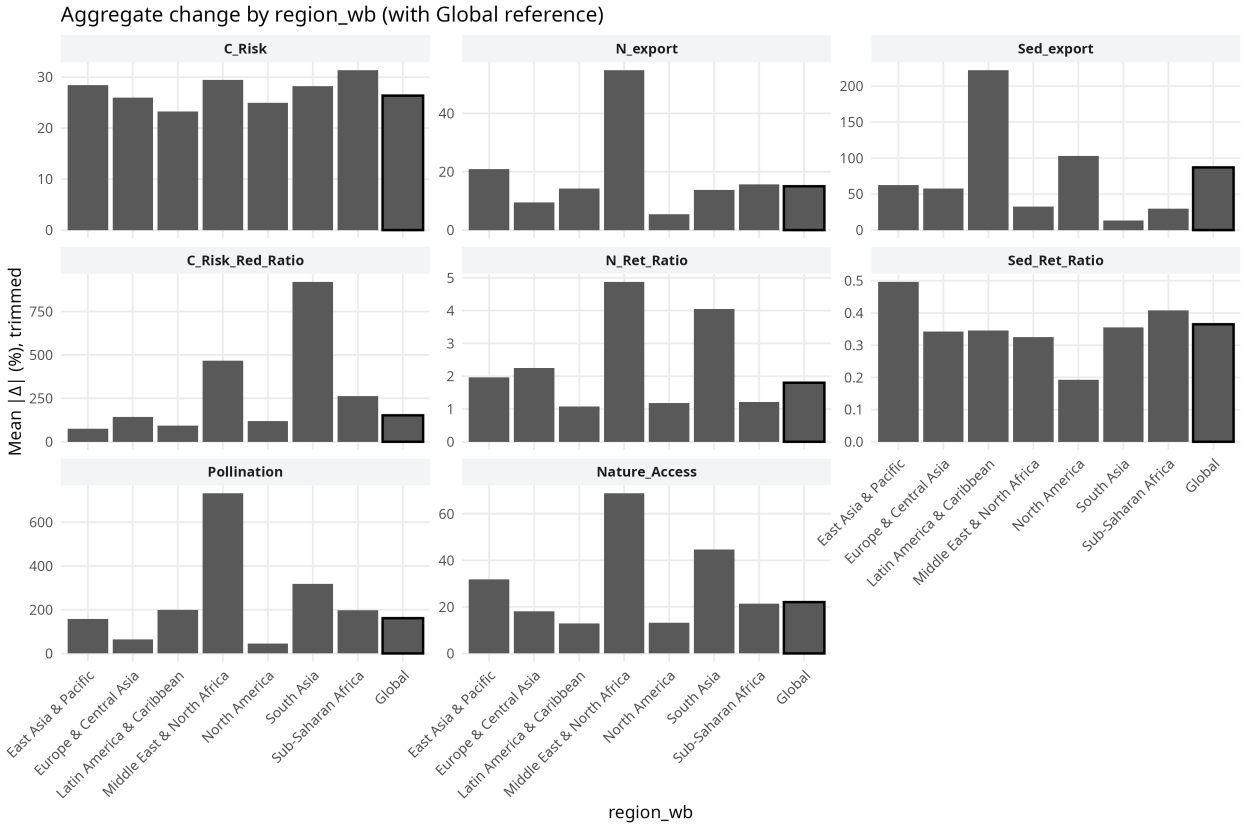

Aggregate change by region_un
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
Africa
Americas
Asia
Europe
Oceania
region_un

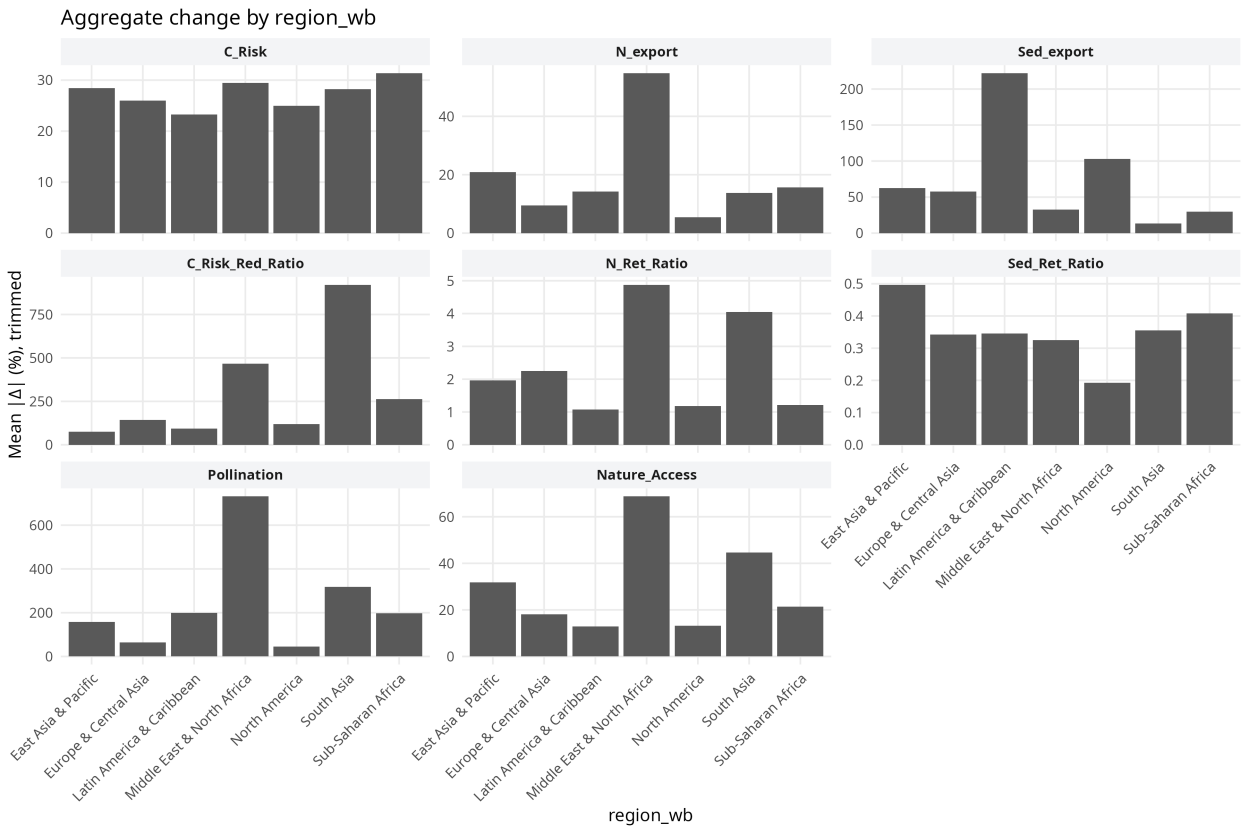

Aggregate change by region_un (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
Africa
Americas
Asia
Europe
Oceania
Global
region_un

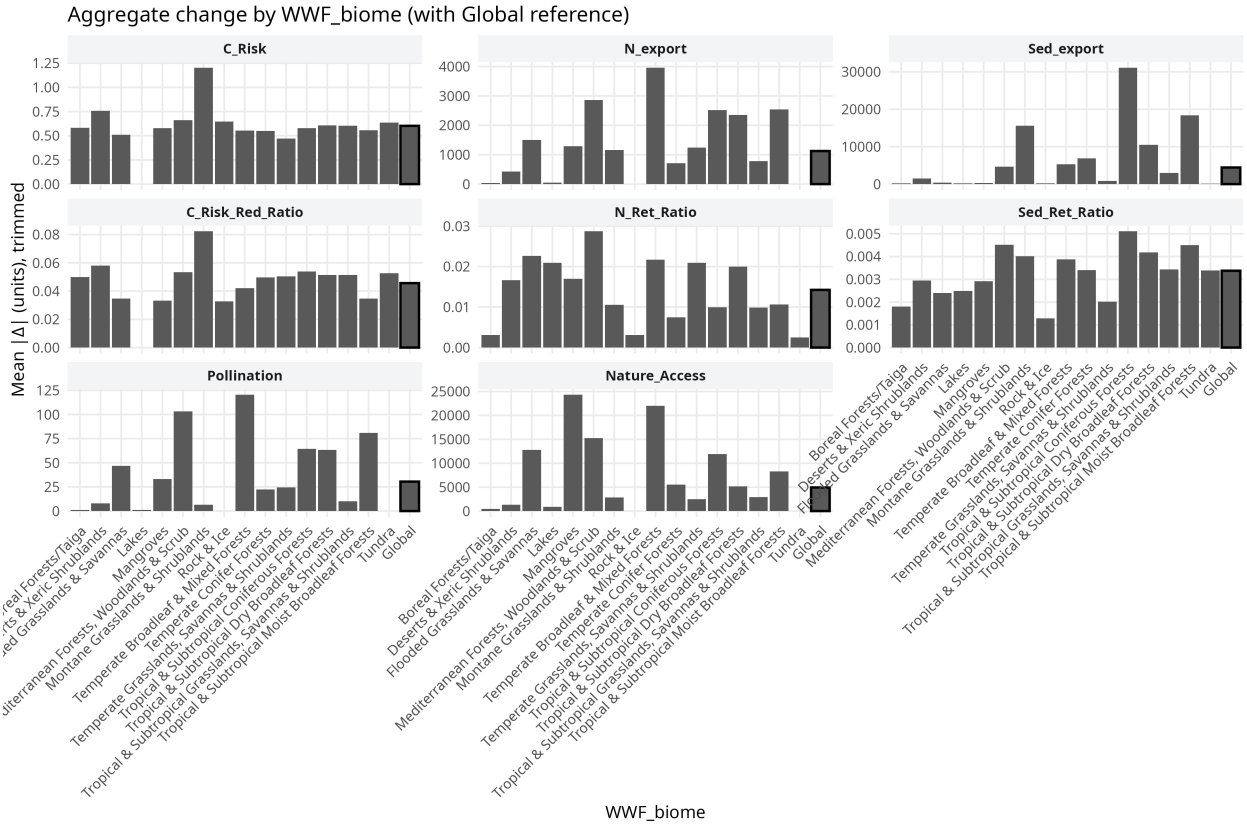

Aggregate change by region_un
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
Africa
Americas
Asia
Europe
Oceania
region_un

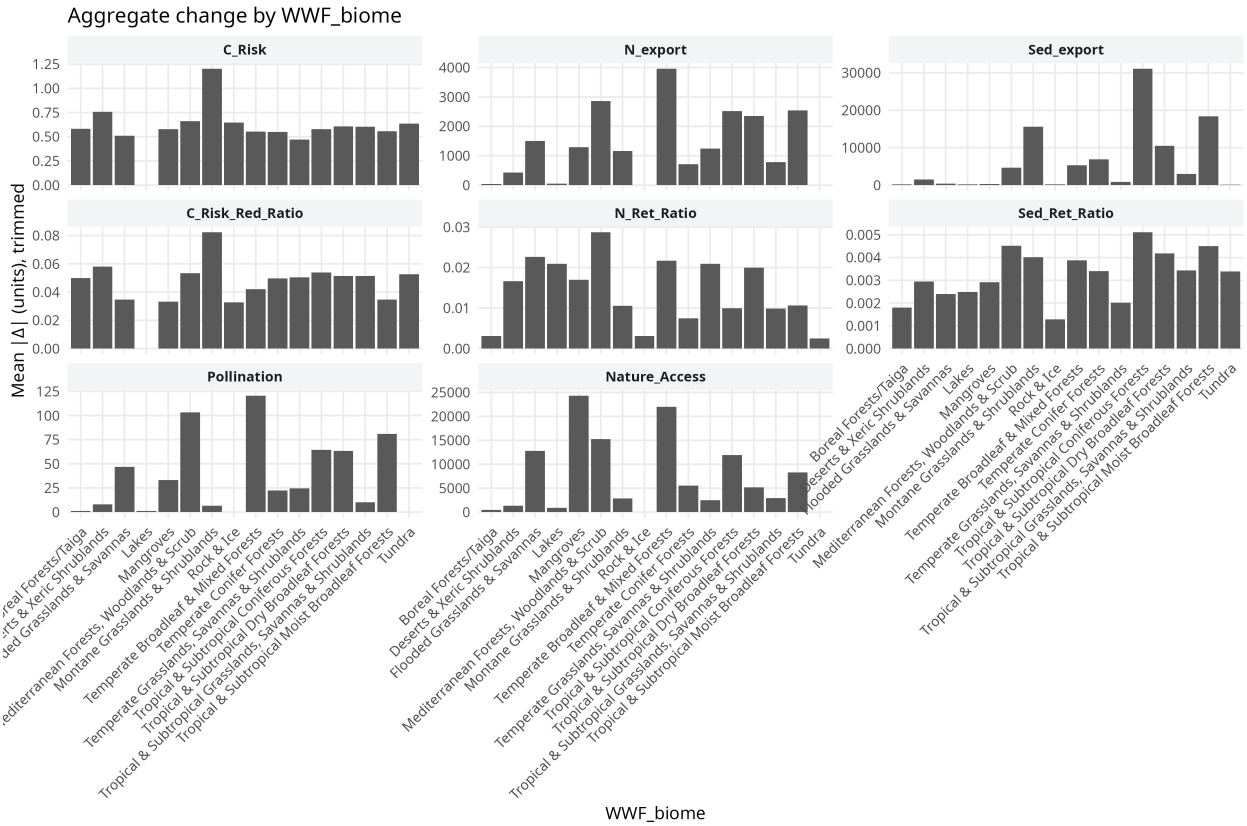

Aggregate change by region_wb (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
East Asia & Pacific
Europe & Central Asia
Latin America & Caribbean
Middle East & North Africa
North America
South Asia
Sub-Saharan Africa
Global
region_wb

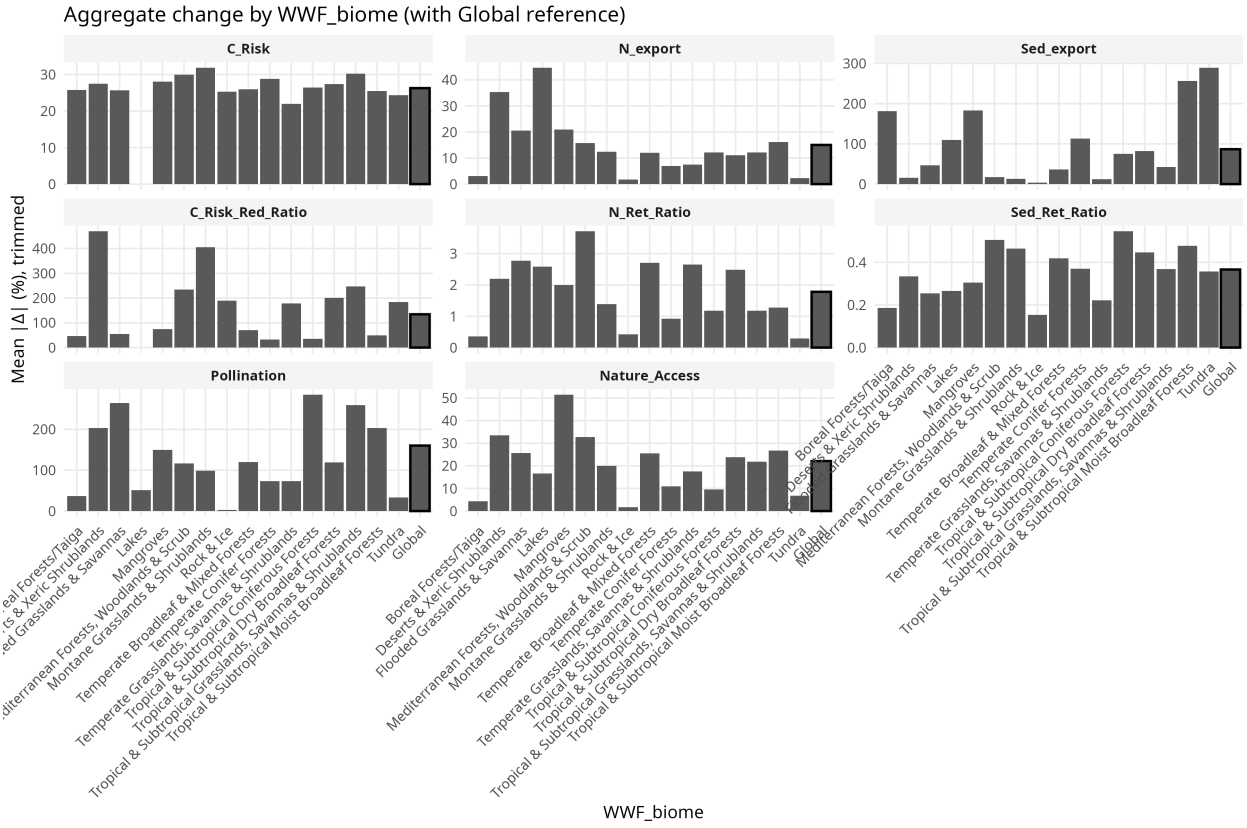

Aggregate change by region_wb
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
East Asia & Pacific
Europe & Central Asia
Latin America & Caribbean
Middle East & North Africa
North America
South Asia
Sub-Saharan Africa
region_wb

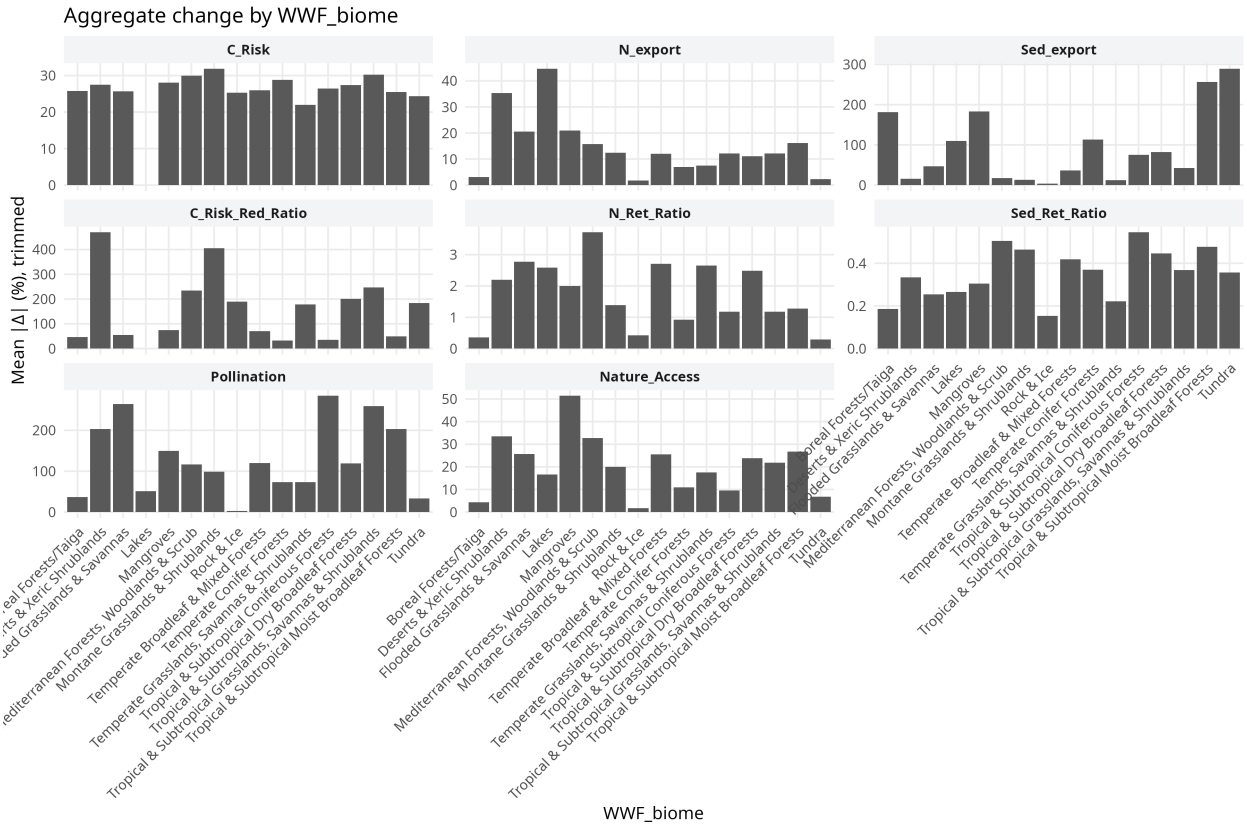

Aggregate change by region_wb (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
East Asia & Pacific
Europe & Central Asia
Latin America & Caribbean
Middle East & North Africa
North America
South Asia
Sub-Saharan Africa
Global
region_wb

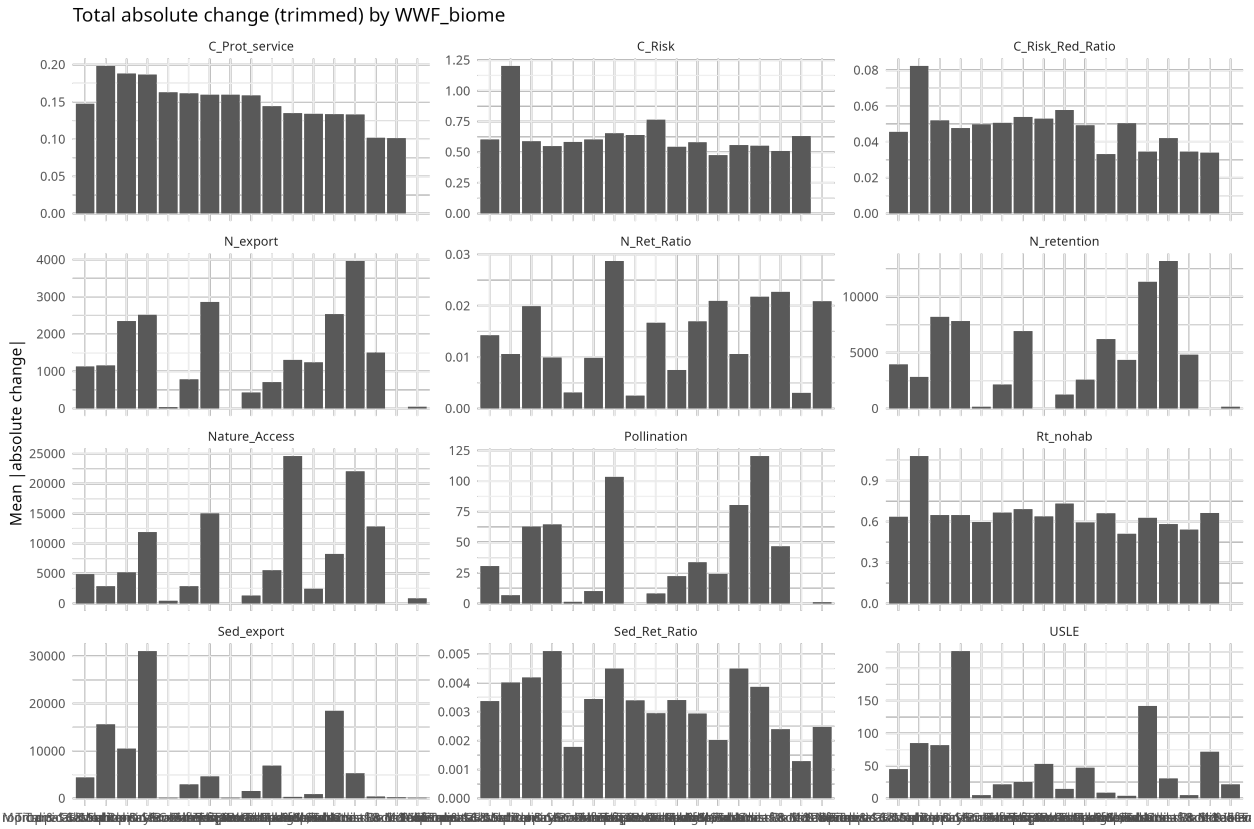

Aggregate change by region_wb
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
East Asia & Pacific
Europe & Central Asia
Latin America & Caribbean
Middle East & North Africa
North America
South Asia
Sub-Saharan Africa
region_wb

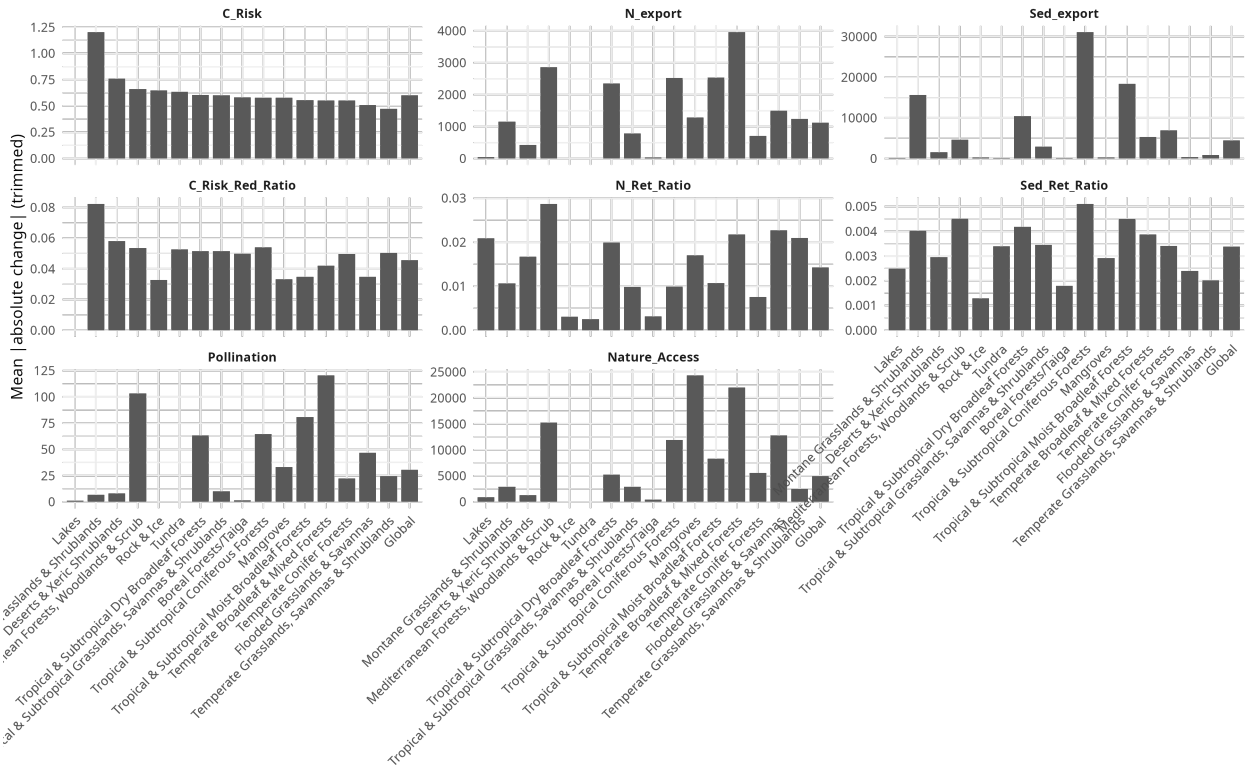

Aggregate change by WWF_biome (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
Boreal Forests/Taiga
Deserts & Xeric Shrublands
Flooded Grasslands & Savannas
Lakes
Mangroves
Mediterranean Forests, Woodlands & Scrub
Montane Grasslands & Shrublands
Rock & Ice
Temperate Broadleaf & Mixed Forests
Temperate Conifer Forests
Temperate Grasslands, Savannas & Shrublands
Tropical & Subtropical Coniferous Forests
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Grasslands, Savannas & Shrublands
Tropical & Subtropical Moist Broadleaf Forests
Tundra
Global
WWF_biome

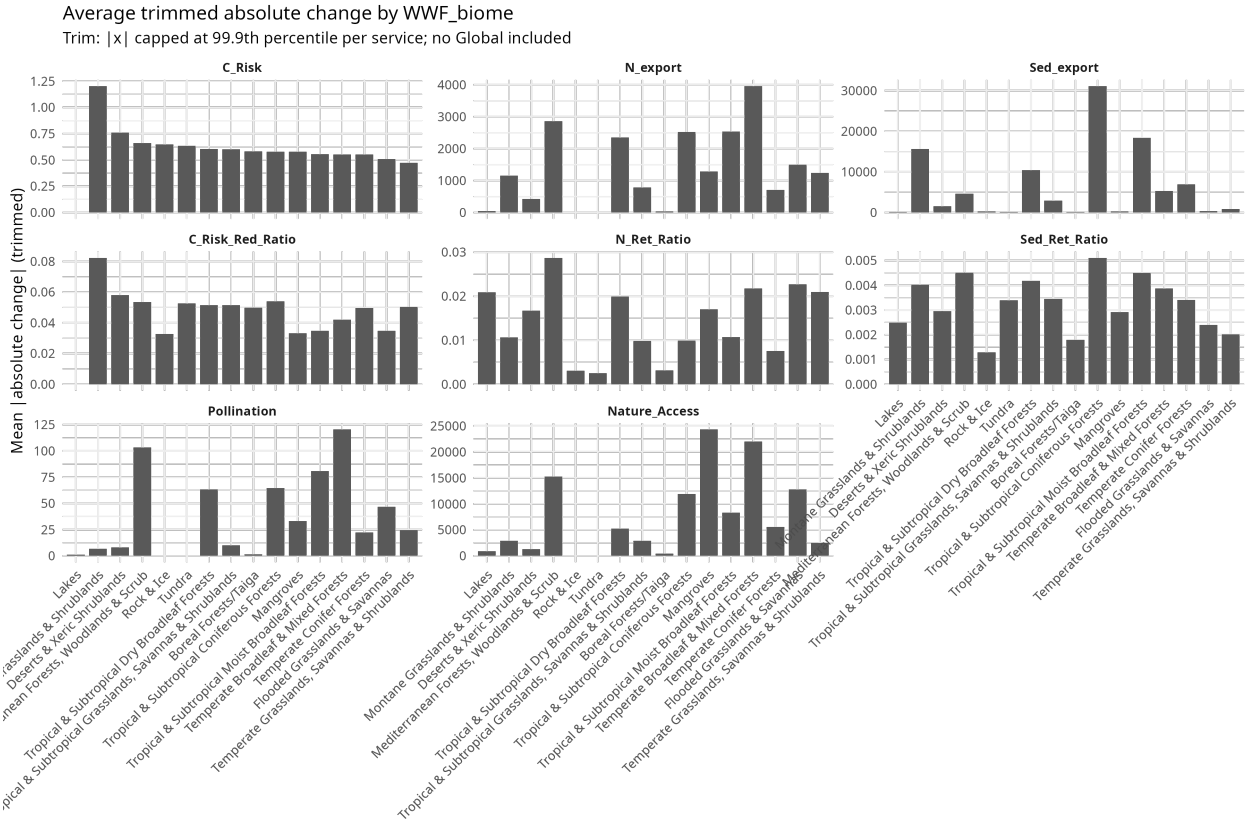

Aggregate change by WWF_biome
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (units), trimmed
Boreal Forests/Taiga
Deserts & Xeric Shrublands
Flooded Grasslands & Savannas
Lakes
Mangroves
Mediterranean Forests, Woodlands & Scrub
Montane Grasslands & Shrublands
Rock & Ice
Temperate Broadleaf & Mixed Forests
Temperate Conifer Forests
Temperate Grasslands, Savannas & Shrublands
Tropical & Subtropical Coniferous Forests
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Grasslands, Savannas & Shrublands
Tropical & Subtropical Moist Broadleaf Forests
Tundra
WWF_biome

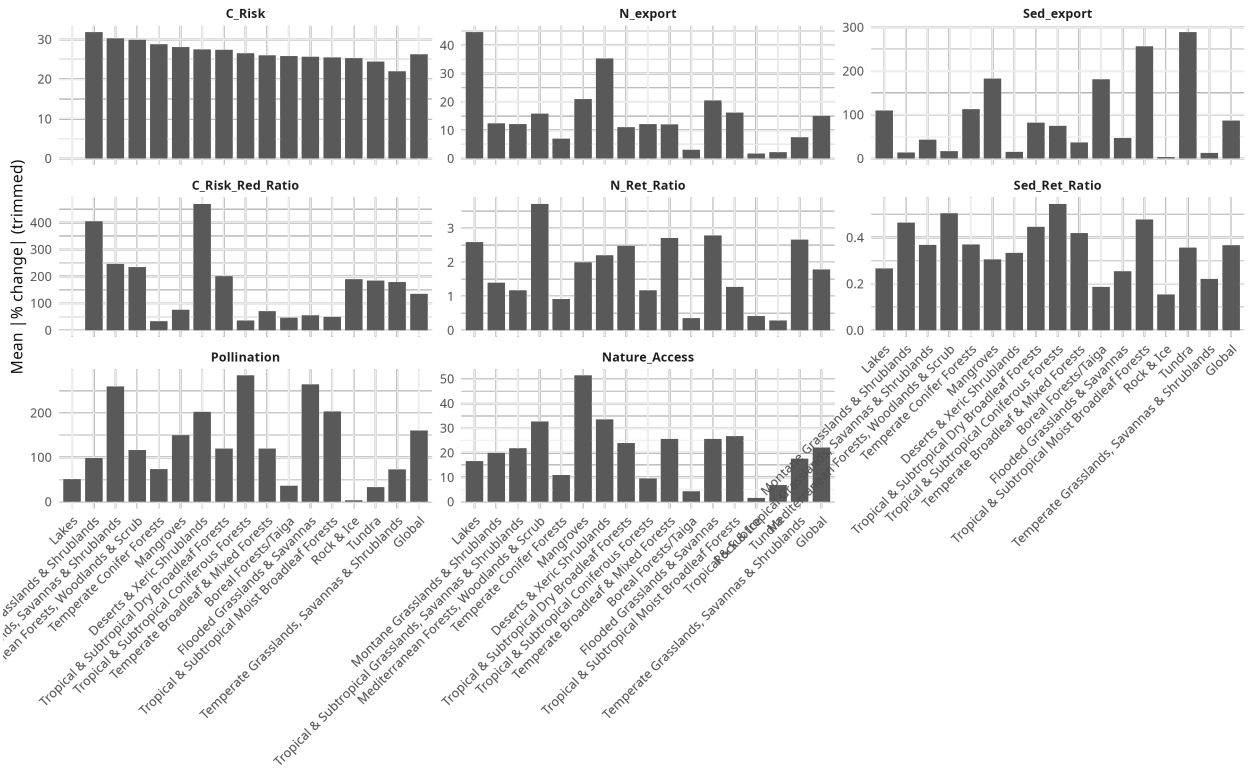

Aggregate change by WWF_biome (with Global reference)
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
Boreal Forests/Taiga
Deserts & Xeric Shrublands
Flooded Grasslands & Savannas
Lakes
Mangroves
Mediterranean Forests, Woodlands & Scrub
Montane Grasslands & Shrublands
Rock & Ice
Temperate Broadleaf & Mixed Forests
Temperate Conifer Forests
Temperate Grasslands, Savannas & Shrublands
Tropical & Subtropical Coniferous Forests
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Grasslands, Savannas & Shrublands
Tropical & Subtropical Moist Broadleaf Forests
Tundra
Global
WWF_biome

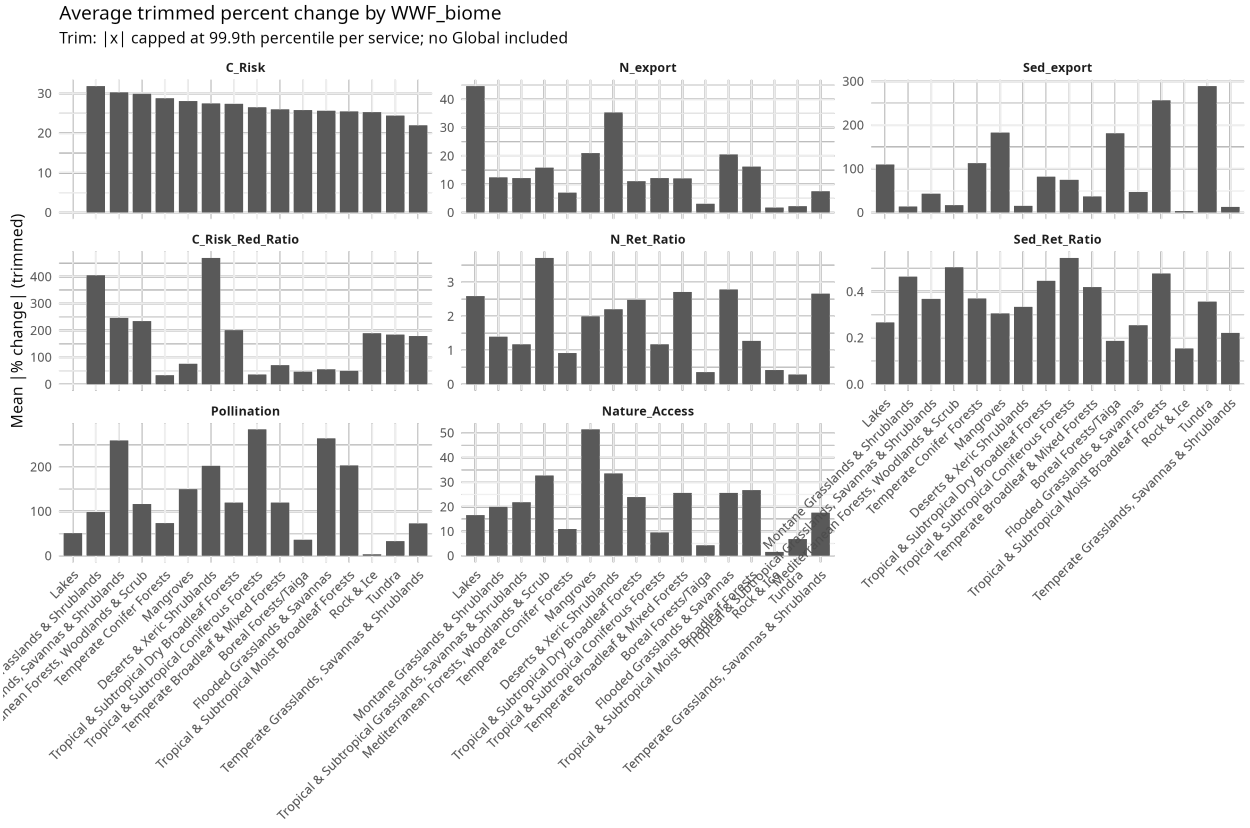

Aggregate change by WWF_biome
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |Δ| (%), trimmed
Boreal Forests/Taiga
Deserts & Xeric Shrublands
Flooded Grasslands & Savannas
Lakes
Mangroves
Mediterranean Forests, Woodlands & Scrub
Montane Grasslands & Shrublands
Rock & Ice
Temperate Broadleaf & Mixed Forests
Temperate Conifer Forests
Temperate Grasslands, Savannas & Shrublands
Tropical & Subtropical Coniferous Forests
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Grasslands, Savannas & Shrublands
Tropical & Subtropical Moist Broadleaf Forests
Tundra
WWF_biome

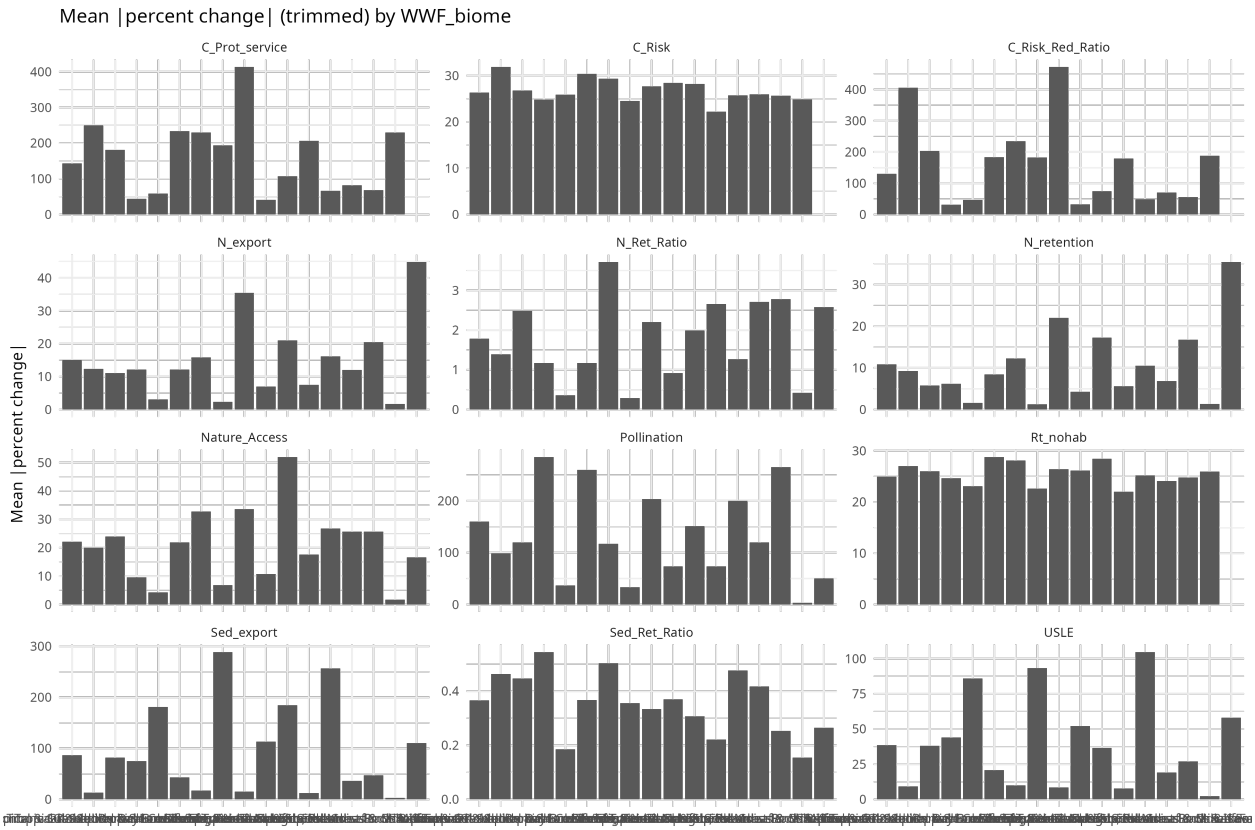

Total absolute change (trimmed) by WWF_biome
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |absolute change|

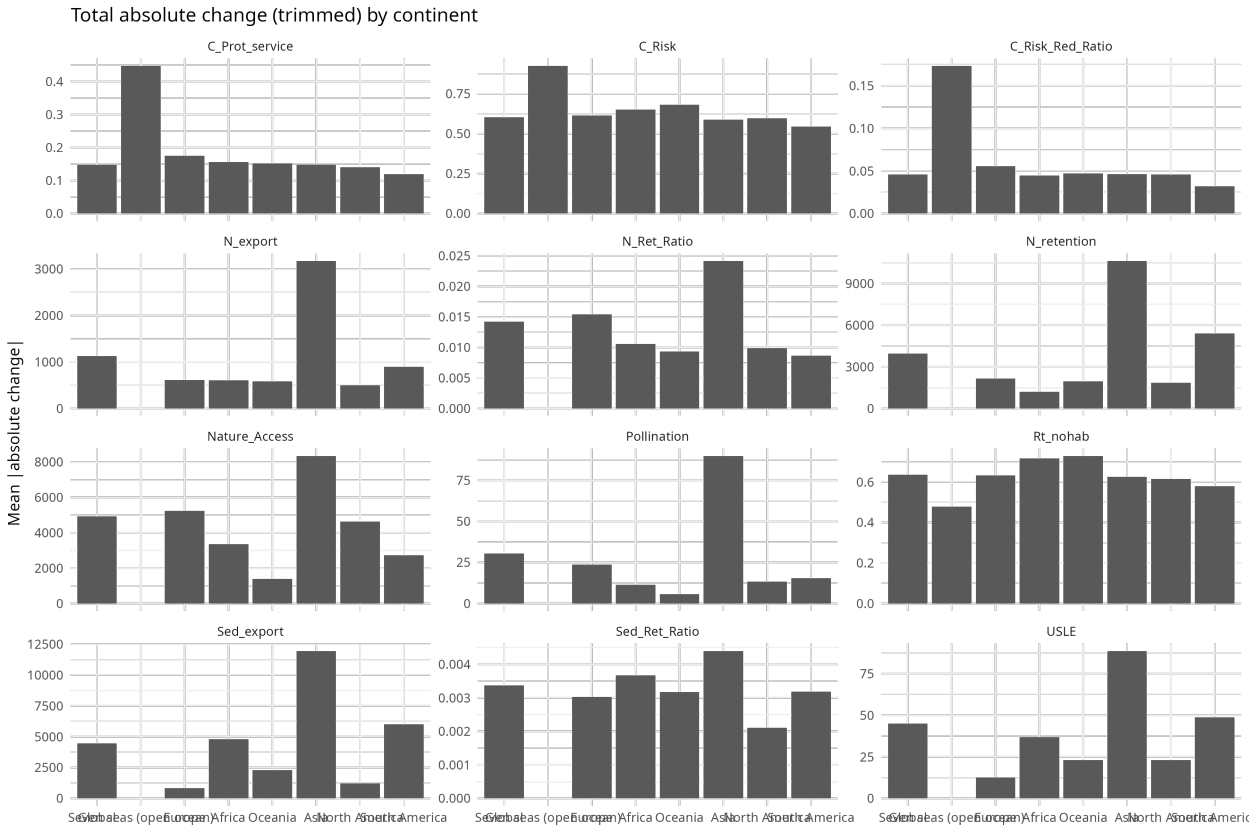

Average trimmed absolute change by WWF_biome
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
Lakes
Montane Grasslands & Shrublands
Deserts & Xeric Shrublands
Mediterranean Forests, Woodlands & Scrub
Rock & Ice
Tundra
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Grasslands, Savannas & Shrublands
Boreal Forests/Taiga
Tropical & Subtropical Coniferous Forests
Tropical & Subtropical Moist Broadleaf Forests
Temperate Broadleaf & Mixed Forests
Temperate Conifer Forests
Flooded Grasslands & Savannas
Temperate Grasslands, Savannas & Shrublands
Global

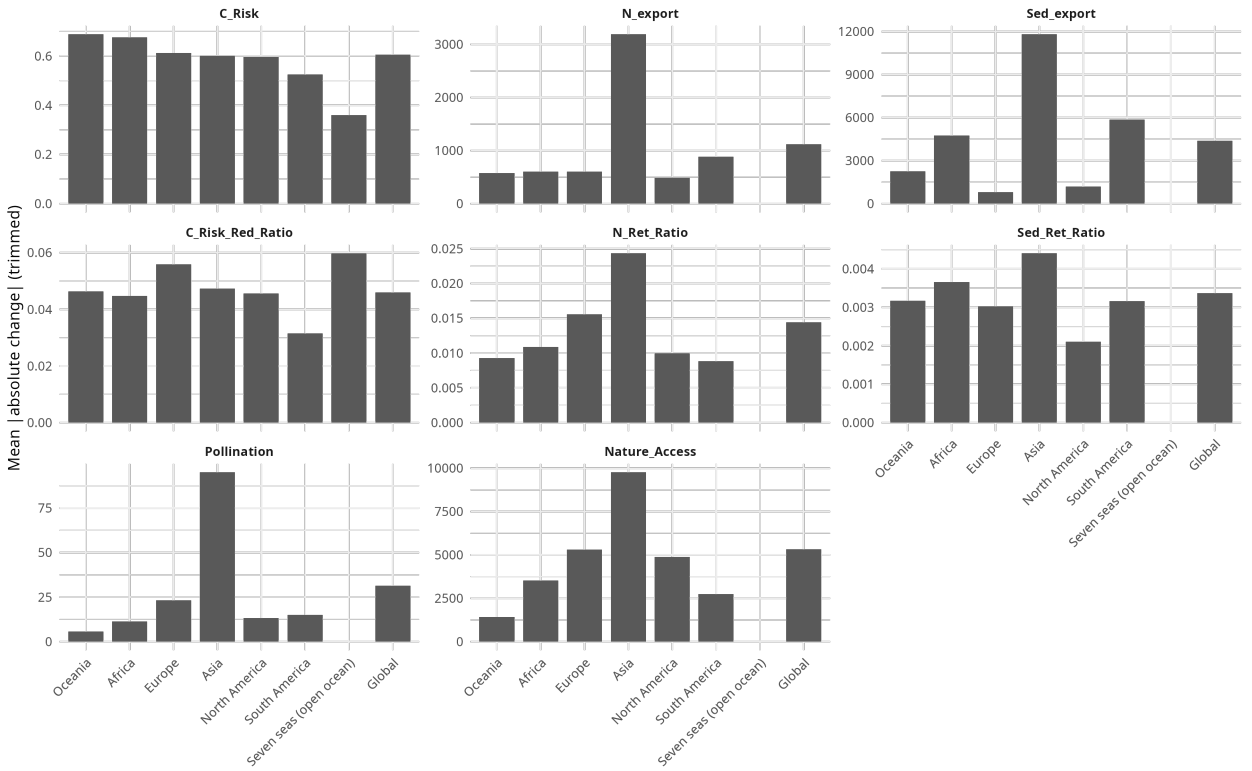

Average trimmed absolute change by WWF_biome
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
Lakes
Montane Grasslands & Shrublands
Deserts & Xeric Shrublands
Mediterranean Forests, Woodlands & Scrub
Rock & Ice
Tundra
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Grasslands, Savannas & Shrublands
Boreal Forests/Taiga
Tropical & Subtropical Coniferous Forests
Tropical & Subtropical Moist Broadleaf Forests
Temperate Broadleaf & Mixed Forests
Temperate Conifer Forests
Flooded Grasslands & Savannas
Temperate Grasslands, Savannas & Shrublands
Mangroves

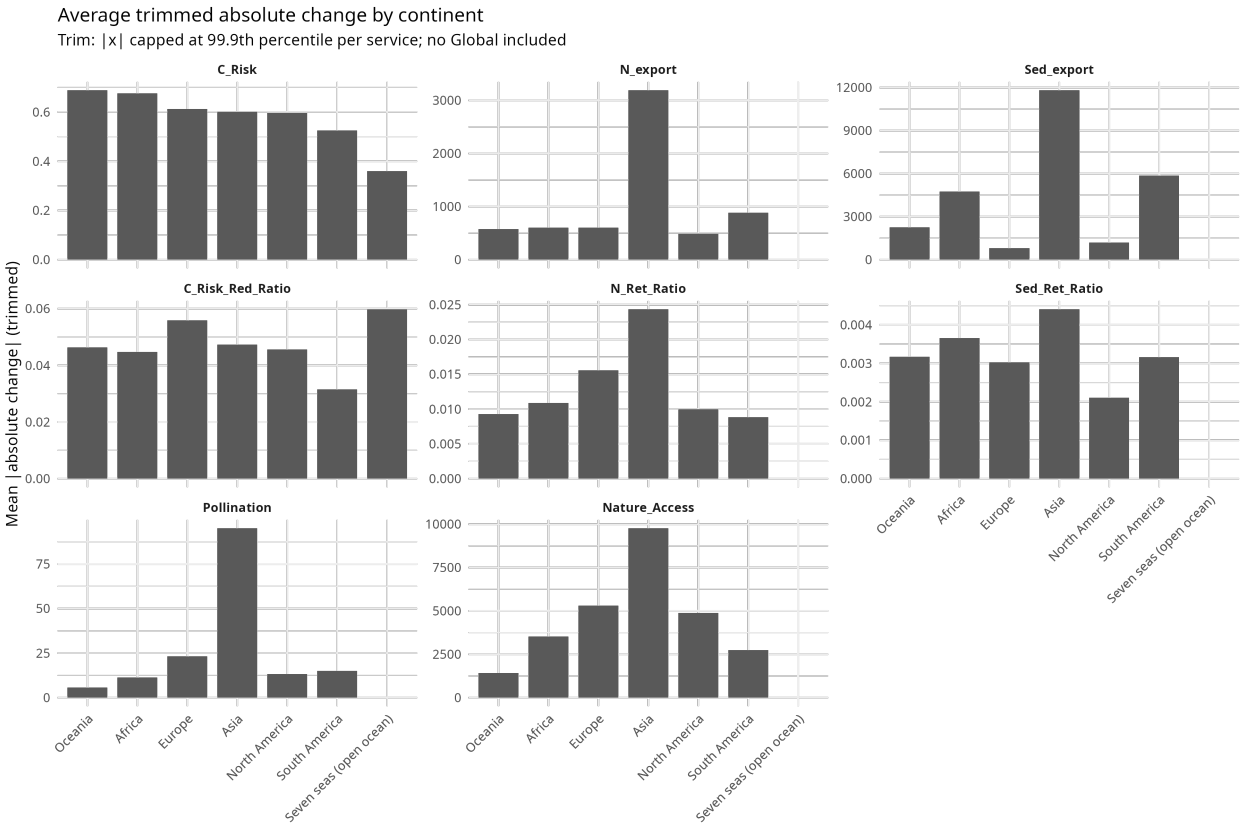

Average trimmed percent change by WWF_biome
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
Lakes
Montane Grasslands & Shrublands
Deserts & Xeric Shrublands
Mediterranean Forests, Woodlands & Scrub
Temperate Conifer Forests
Mangroves
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Grasslands, Savannas & Shrublands
Boreal Forests/Taiga
Tropical & Subtropical Coniferous Forests
Tropical & Subtropical Moist Broadleaf Forests
Temperate Broadleaf & Mixed Forests
Flooded Grasslands & Savannas
Temperate Grasslands, Savannas & Shrublands
Rock & Ice
Tundra
Global

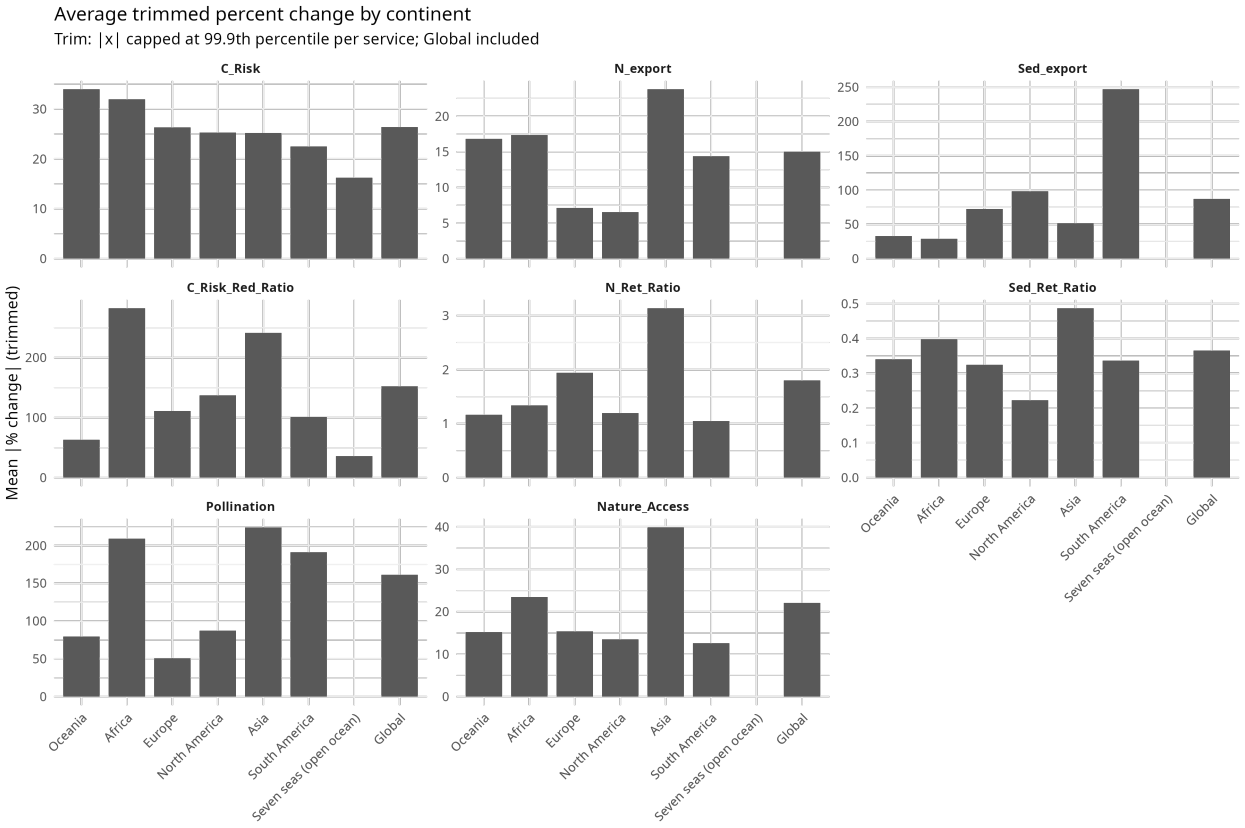

Average trimmed percent change by WWF_biome
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
Lakes
Montane Grasslands & Shrublands
Tropical & Subtropical Grasslands, Savannas & Shrublands
Mediterranean Forests, Woodlands & Scrub
Temperate Conifer Forests
Mangroves
Deserts & Xeric Shrublands
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Coniferous Forests
Temperate Broadleaf & Mixed Forests
Boreal Forests/Taiga
Flooded Grasslands & Savannas
Tropical & Subtropical Moist Broadleaf Forests
Rock & Ice
Tundra
Temperate Grasslands, Savannas & Shrublands

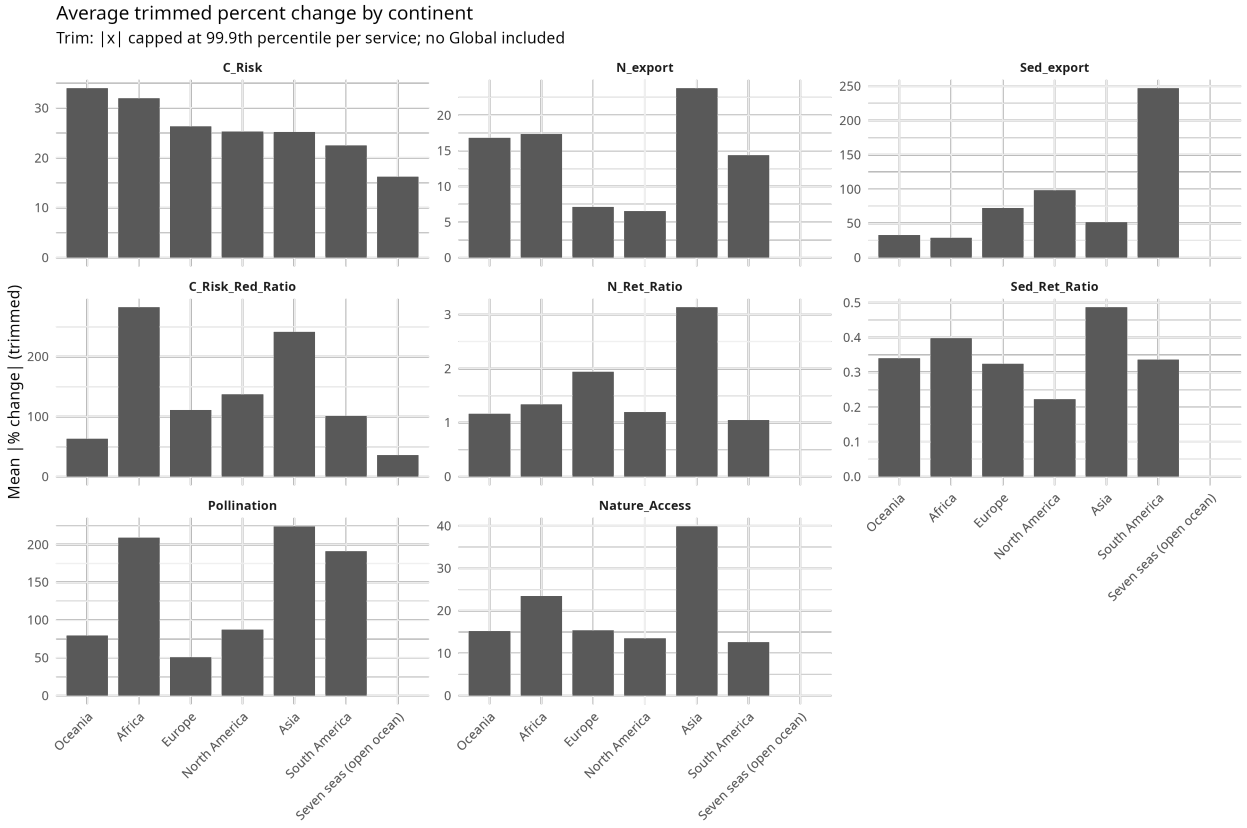

Mean |percent change| (trimmed) by WWF_biome
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |percent change|

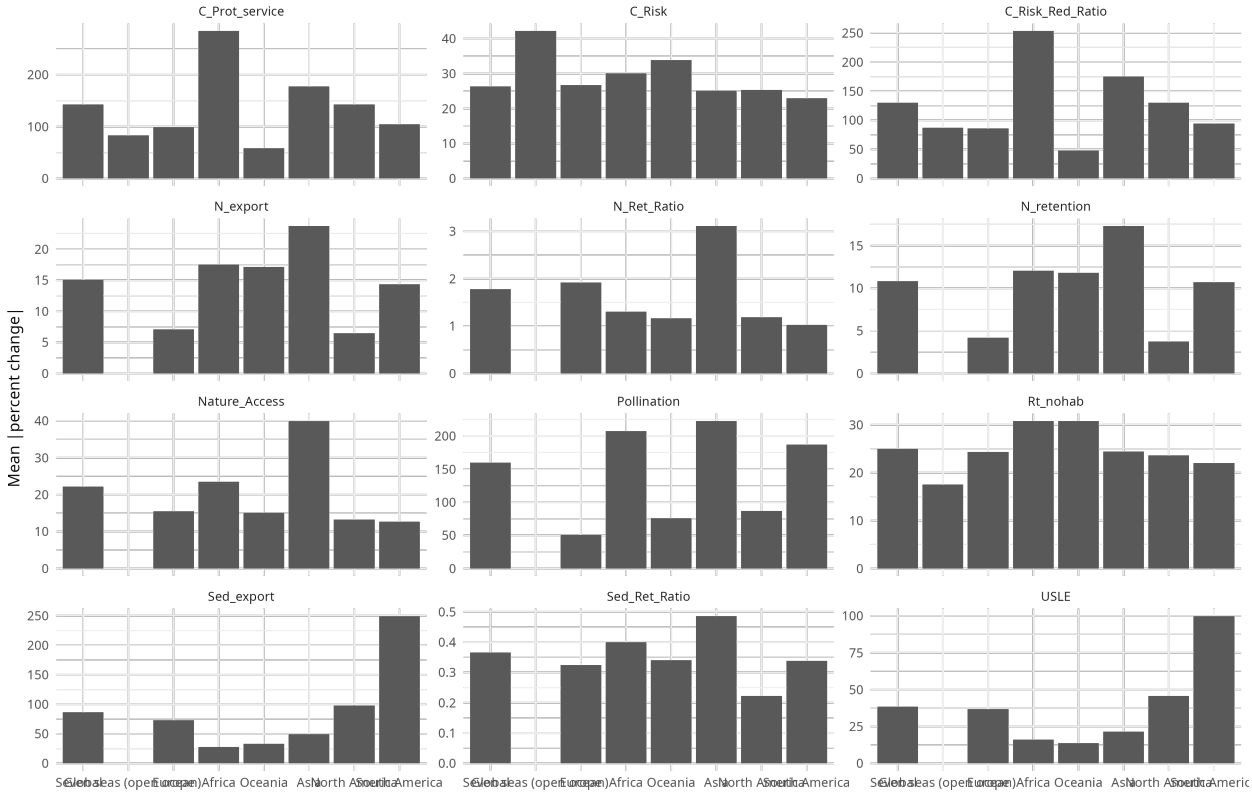

Total absolute change (trimmed) by continent
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |absolute change|
Oceania
Africa
Europe
Asia
North America
South America

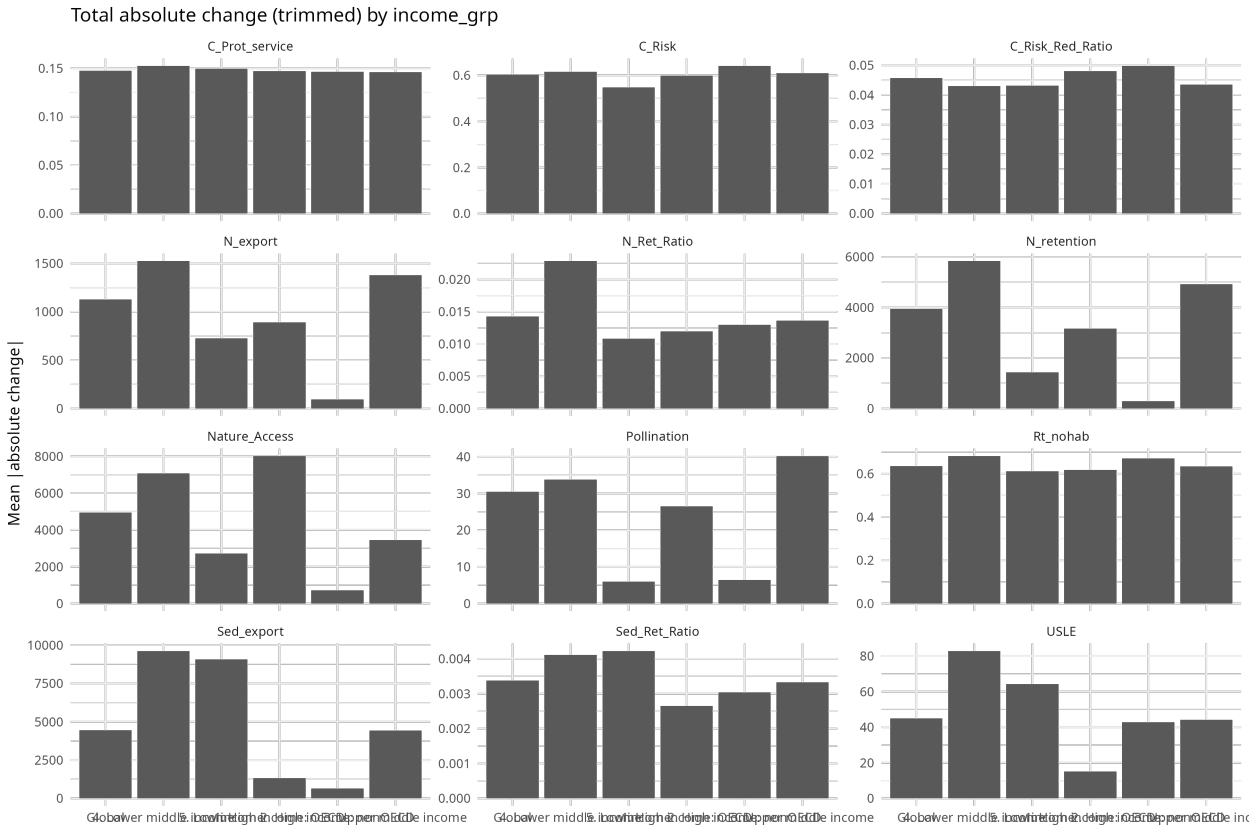

Average trimmed absolute change by continent
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
Oceania
Africa
Europe
Asia
North America
South America
Seven seas (open ocean)
Global

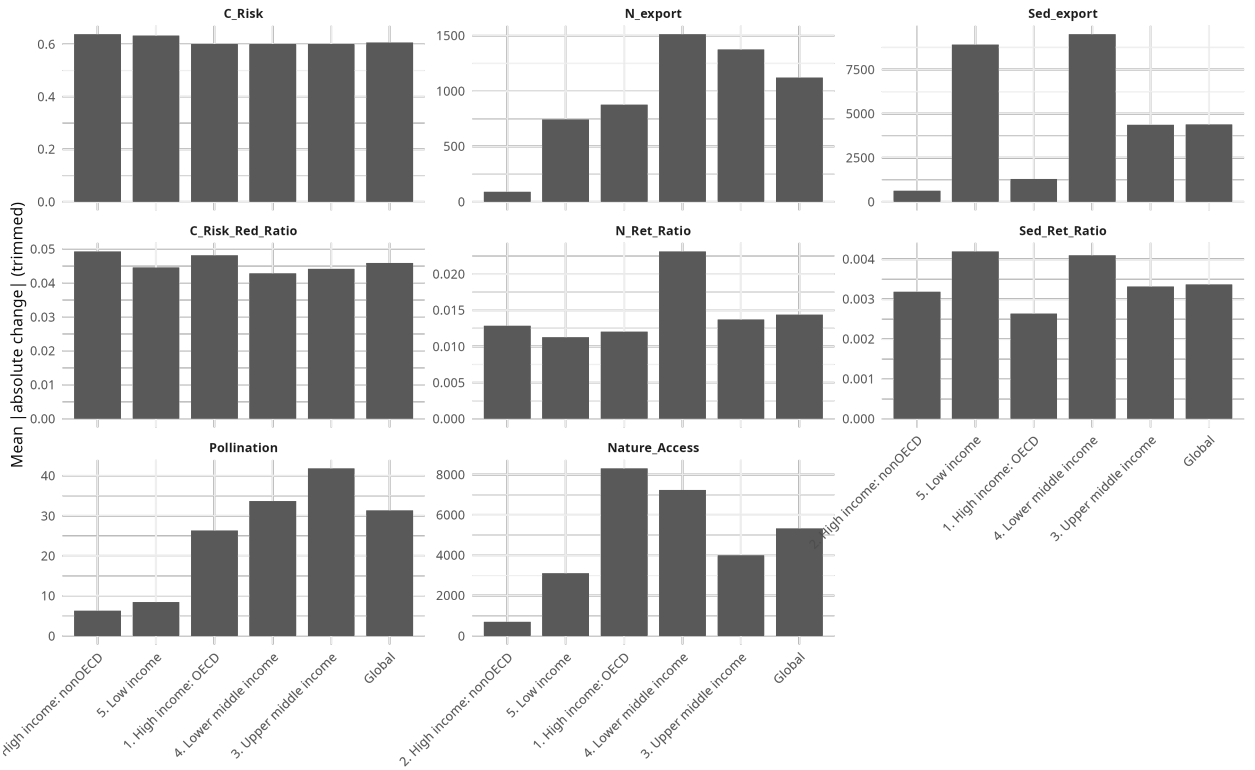

Average trimmed absolute change by continent
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
Oceania
Africa
Europe
Asia
North America
South America
Seven seas (open ocean)

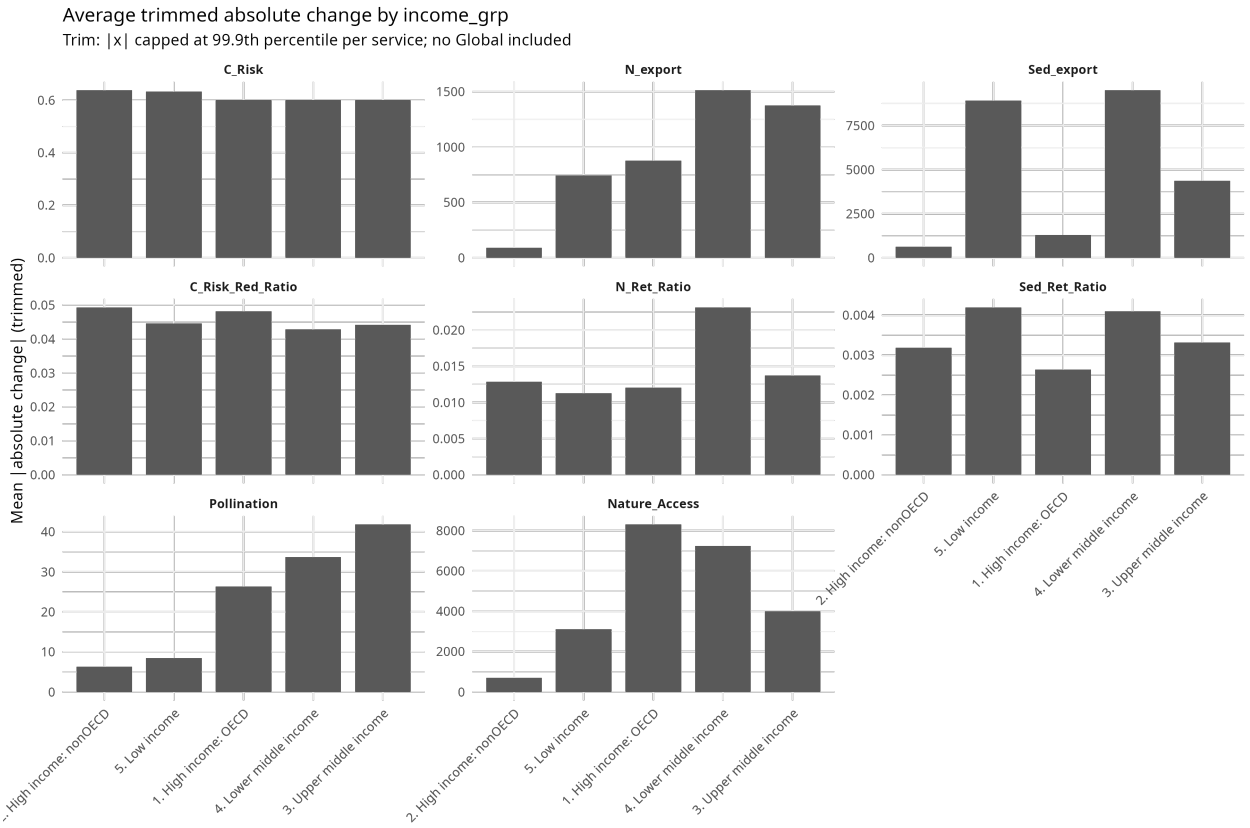

Average trimmed percent change by continent
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
Oceania
Africa
Europe
North America
Asia
South America
Seven seas (open ocean)
Global

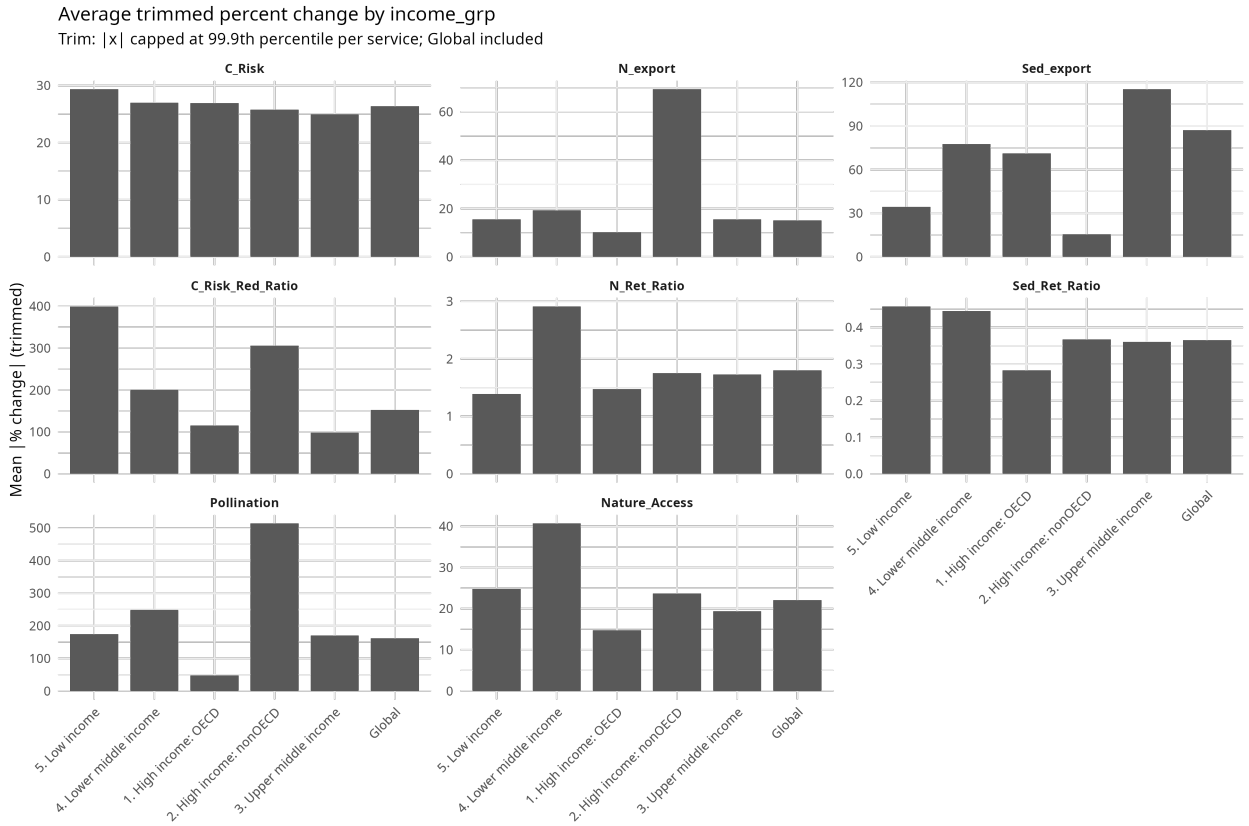

Average trimmed percent change by continent
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
Oceania
Africa
Europe
North America
Asia
South America
Seven seas (open ocean)

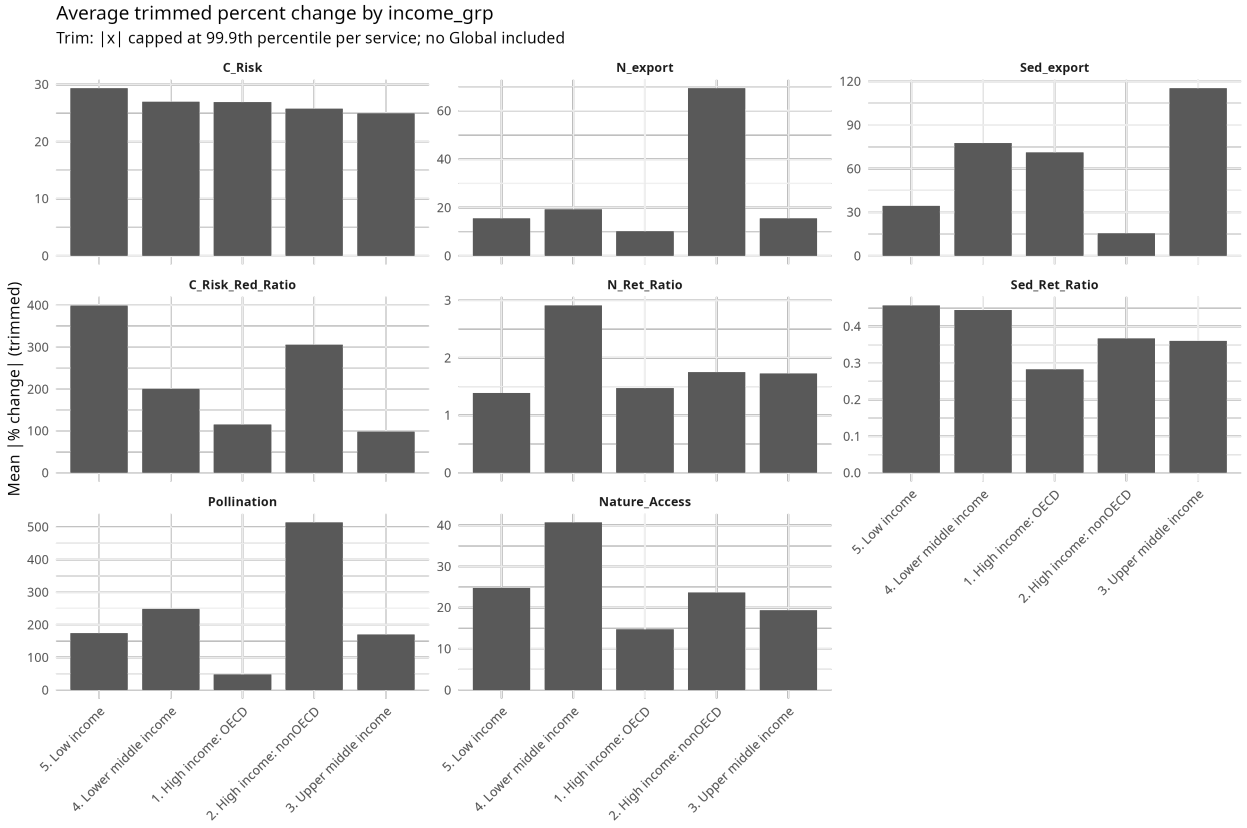

Mean |percent change| (trimmed) by continent
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |percent change|
Seven seas (open ocean)
Europe
Africa
Oceania
Asia
North America
South America

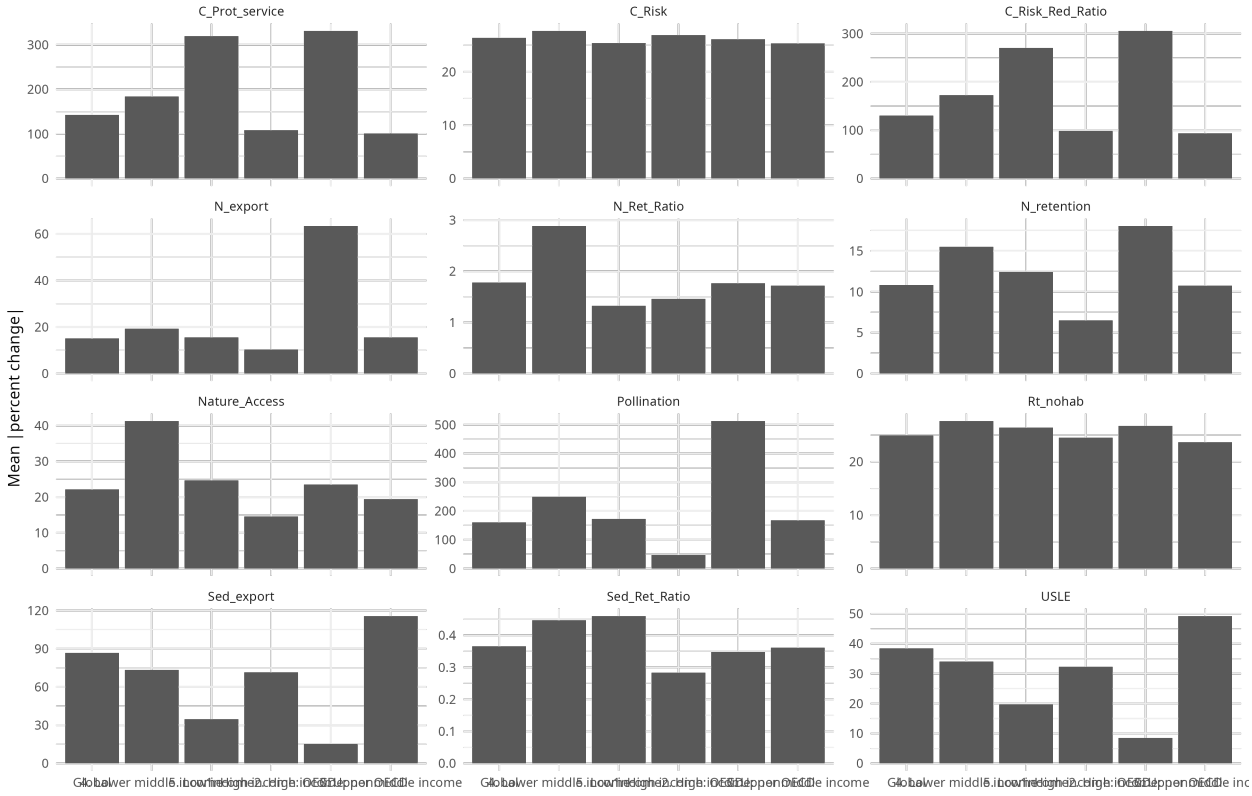

Total absolute change (trimmed) by income_grp
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |absolute change|

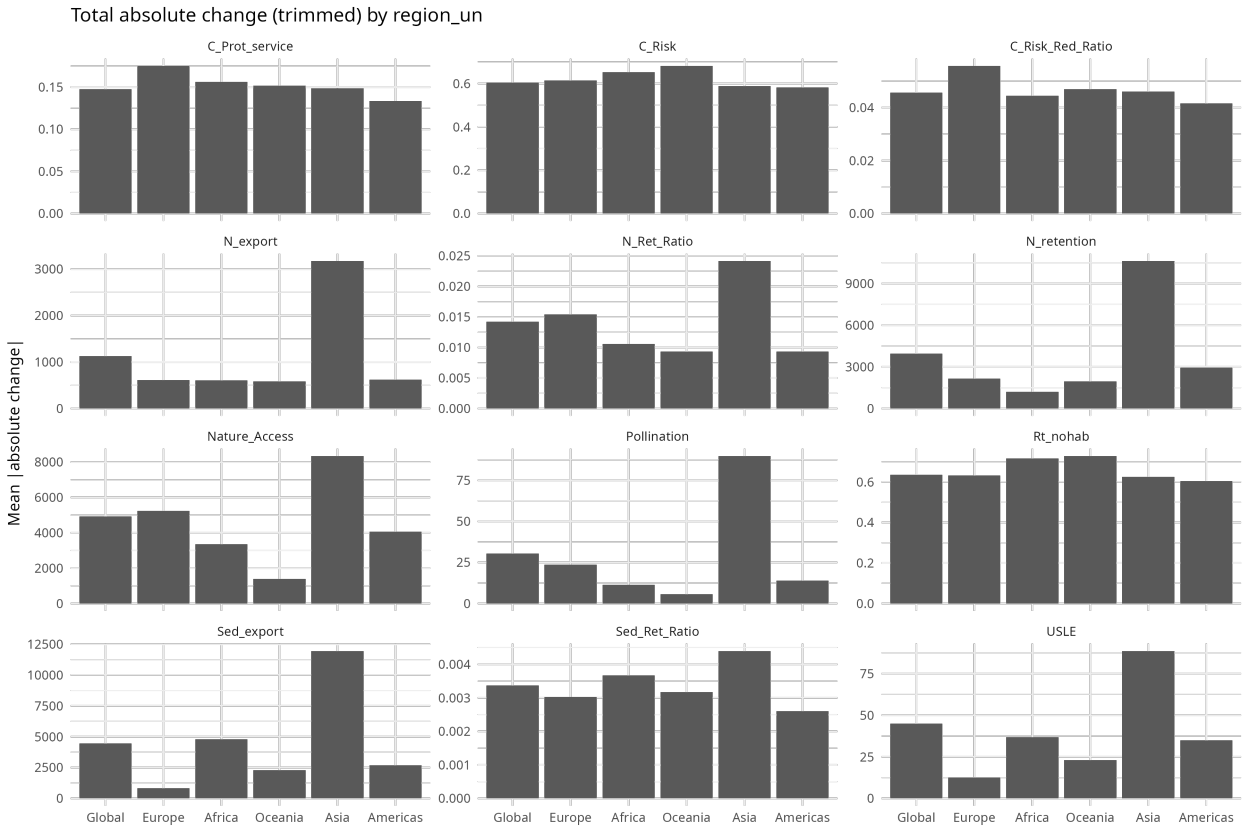

Average trimmed absolute change by income_grp
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
5. Low income
1. High income: OECD
4. Lower middle income
3. Upper middle income
Global

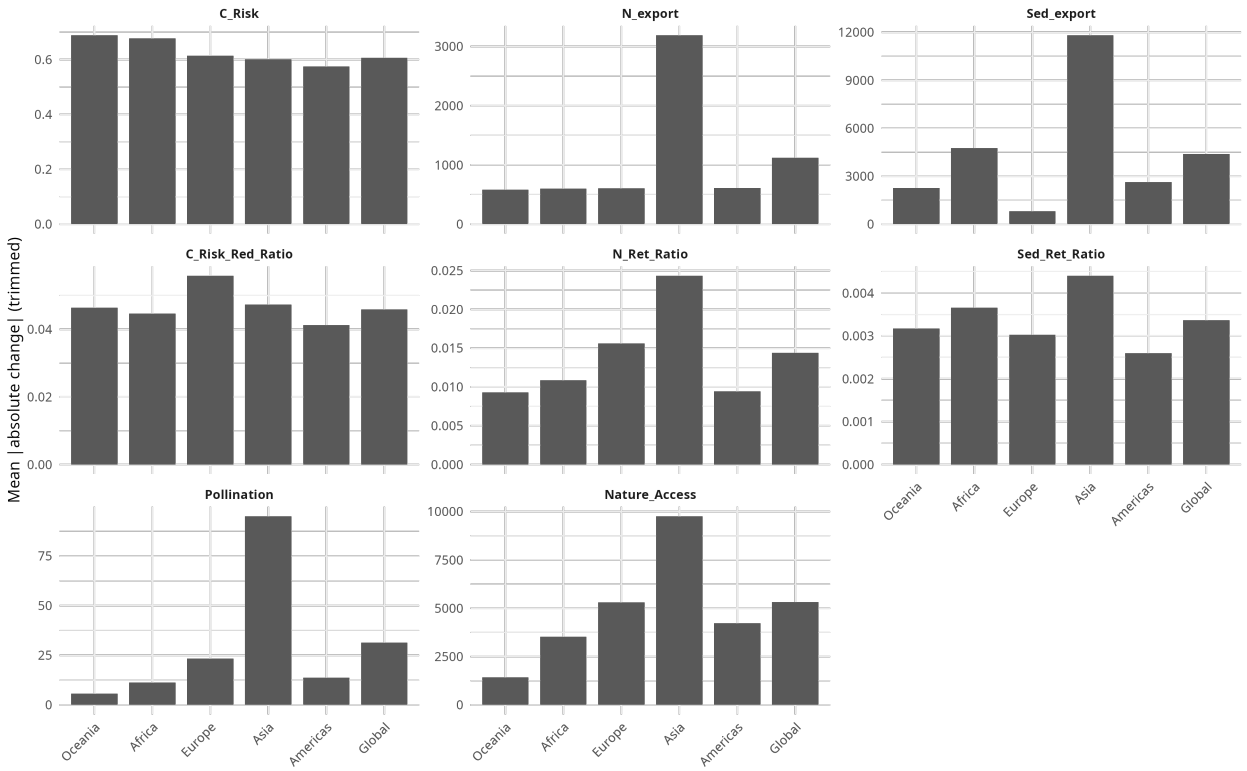

Average trimmed absolute change by income_grp
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
2. High income: nonOECD
5. Low income
1. High income: OECD
4. Lower middle income
3. Upper middle income

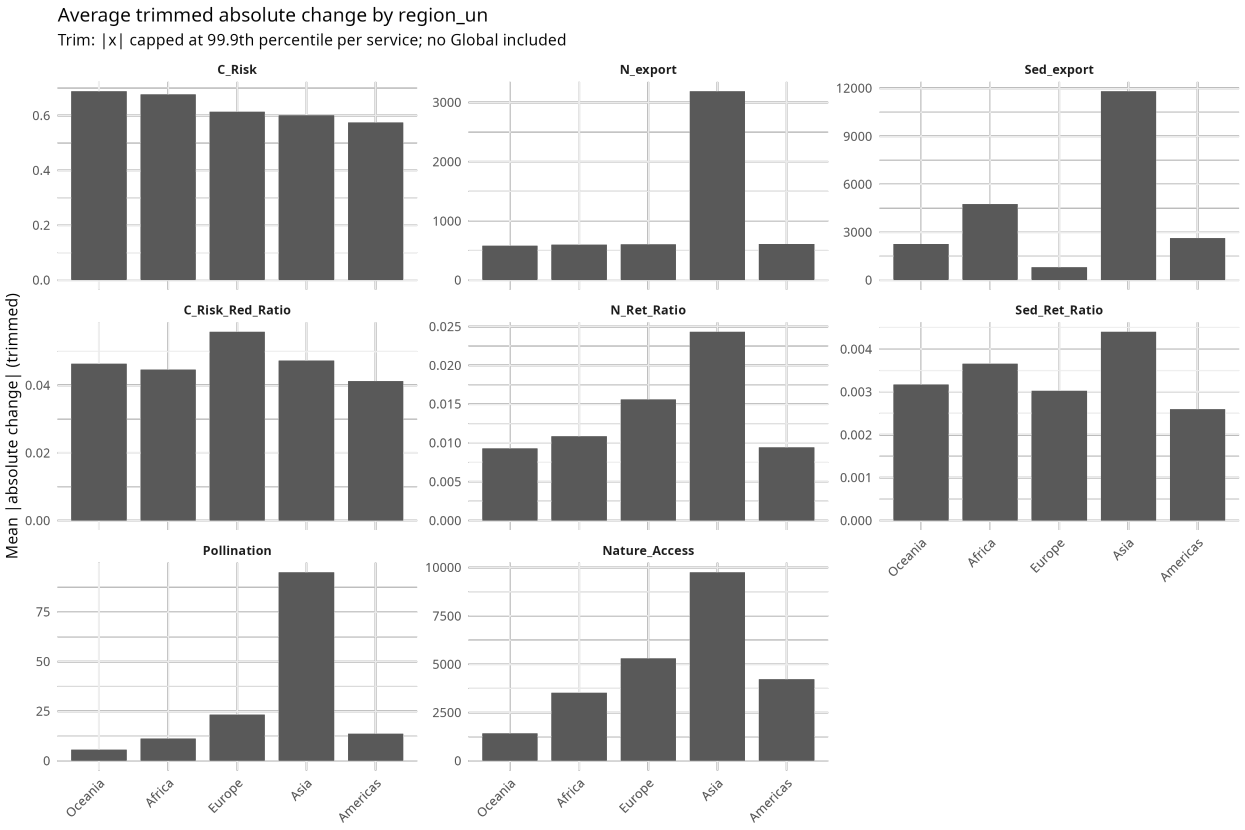

Average trimmed percent change by income_grp
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
5. Low income
4. Lower middle income
1. High income: OECD
2. High income: nonOECD
3. Upper middle income
Global

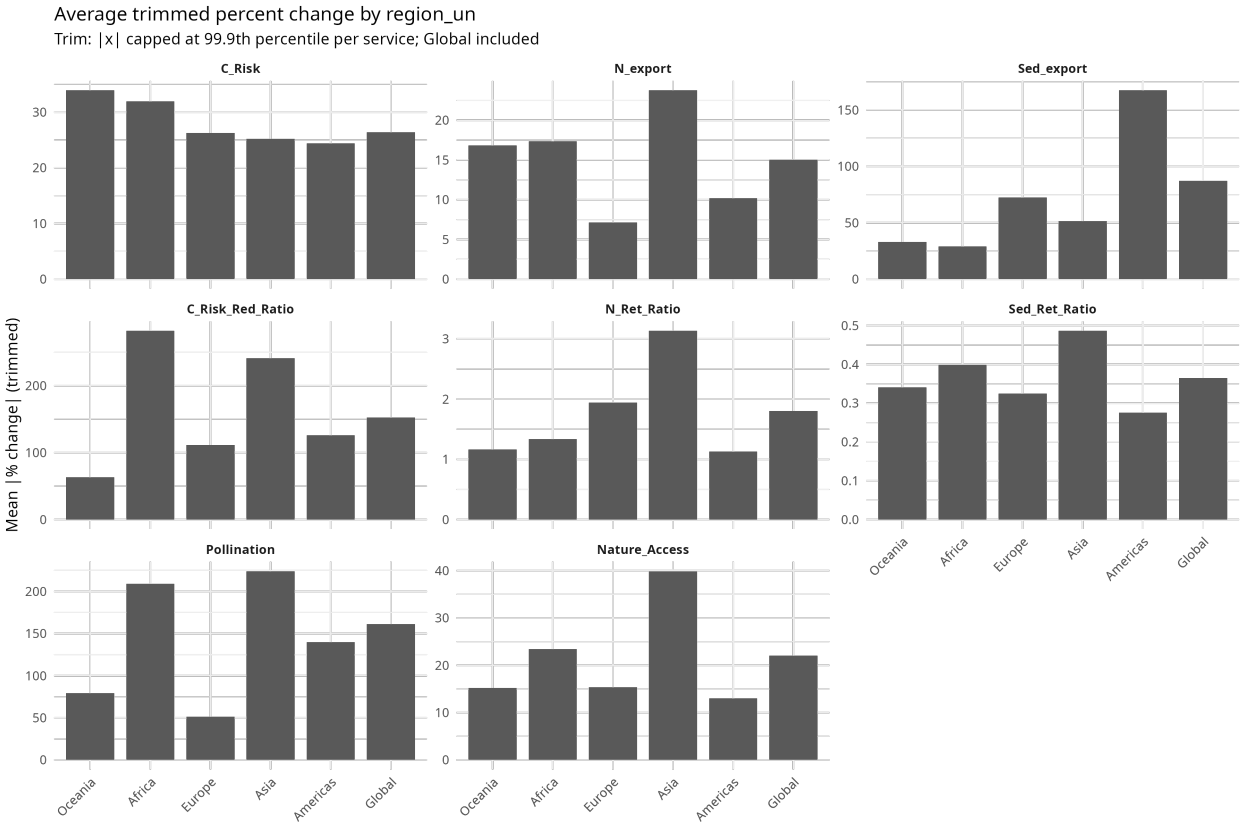

Average trimmed percent change by income_grp
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
5. Low income
4. Lower middle income
1. High income: OECD
2. High income: nonOECD
3. Upper middle income

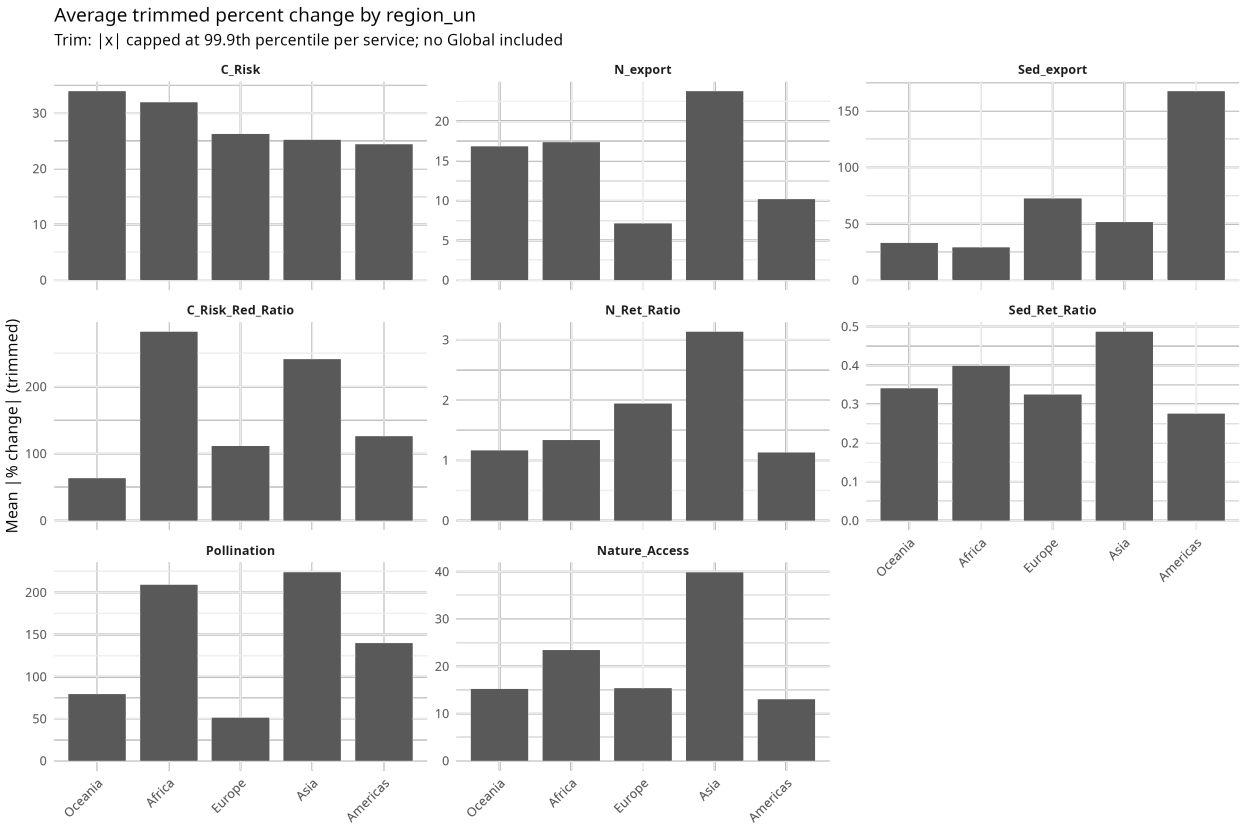

Mean |percent change| (trimmed) by income_grp
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |percent change|

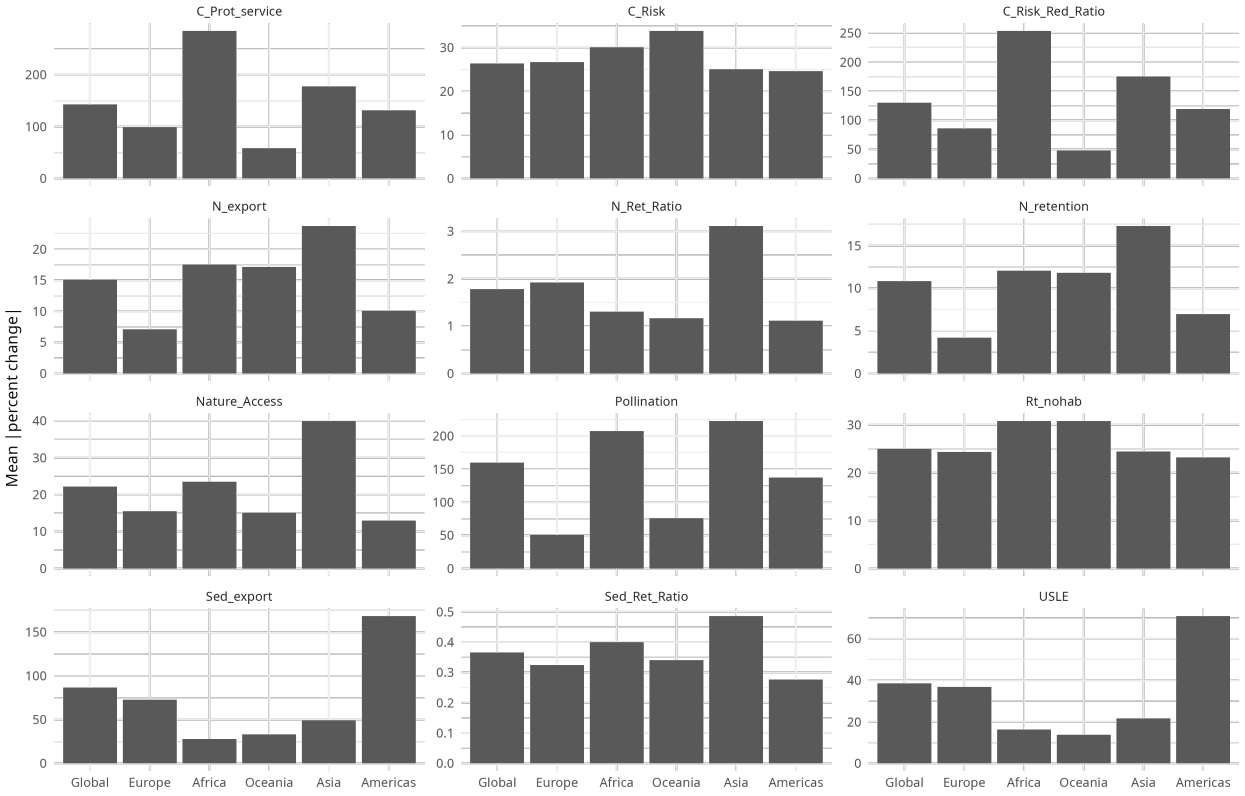

Total absolute change (trimmed) by region_un
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |absolute change|
Global
Europe
Africa
Oceania
Asia
Americas

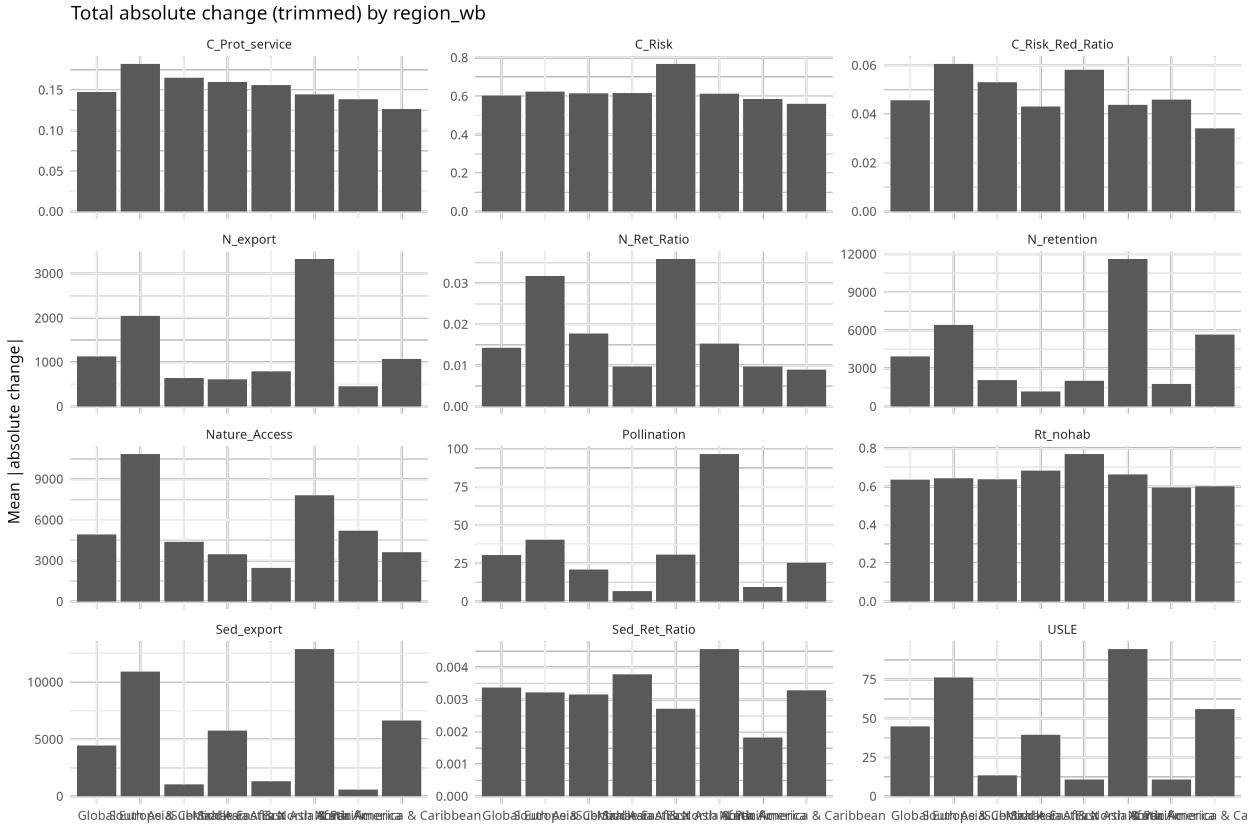

Average trimmed absolute change by region_un
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
Oceania
Africa
Europe
Asia
Americas
Global

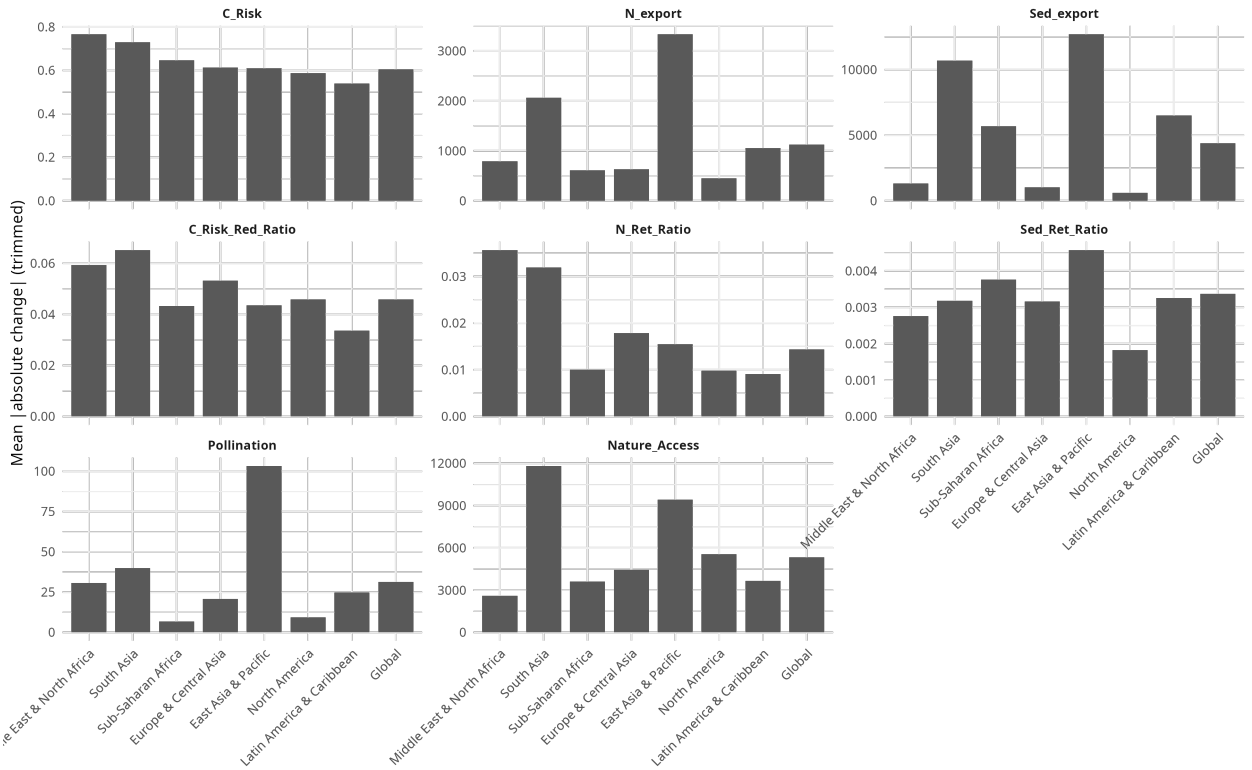

Average trimmed absolute change by region_un
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
Oceania
Africa
Europe
Asia
Americas

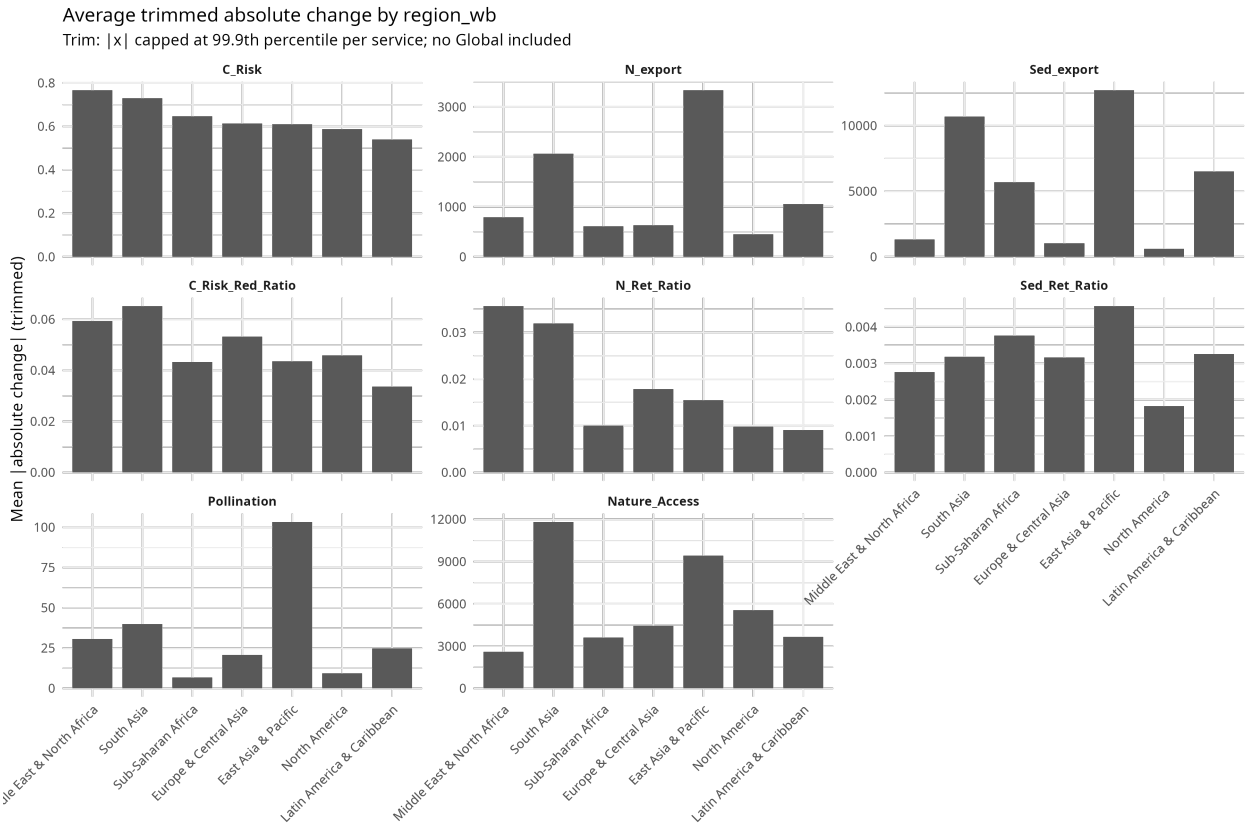

Average trimmed percent change by region_un
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
Oceania
Africa
Europe
Asia
Americas
Global

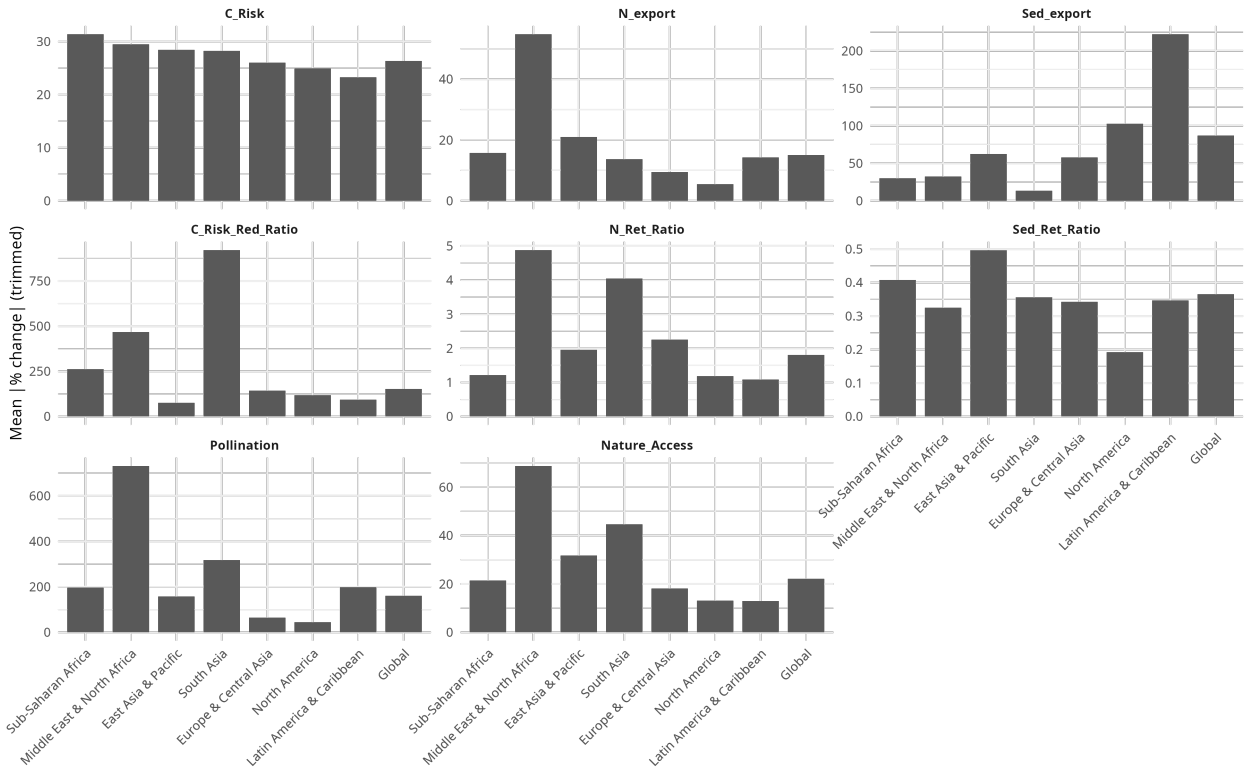

Average trimmed percent change by region_un
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
Oceania
Africa
Europe
Asia
Americas

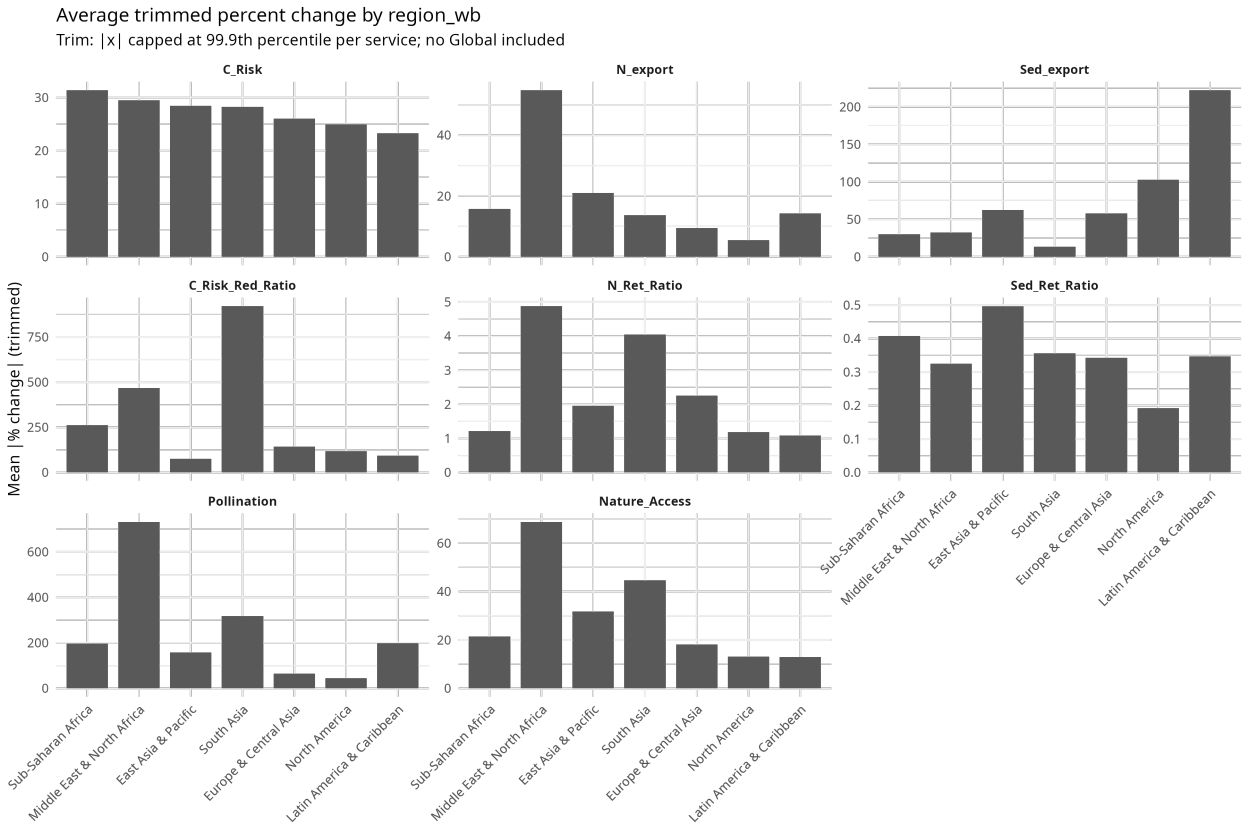

Mean |percent change| (trimmed) by region_un
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |percent change|
Global
Europe
Africa
Oceania
Asia
Americas

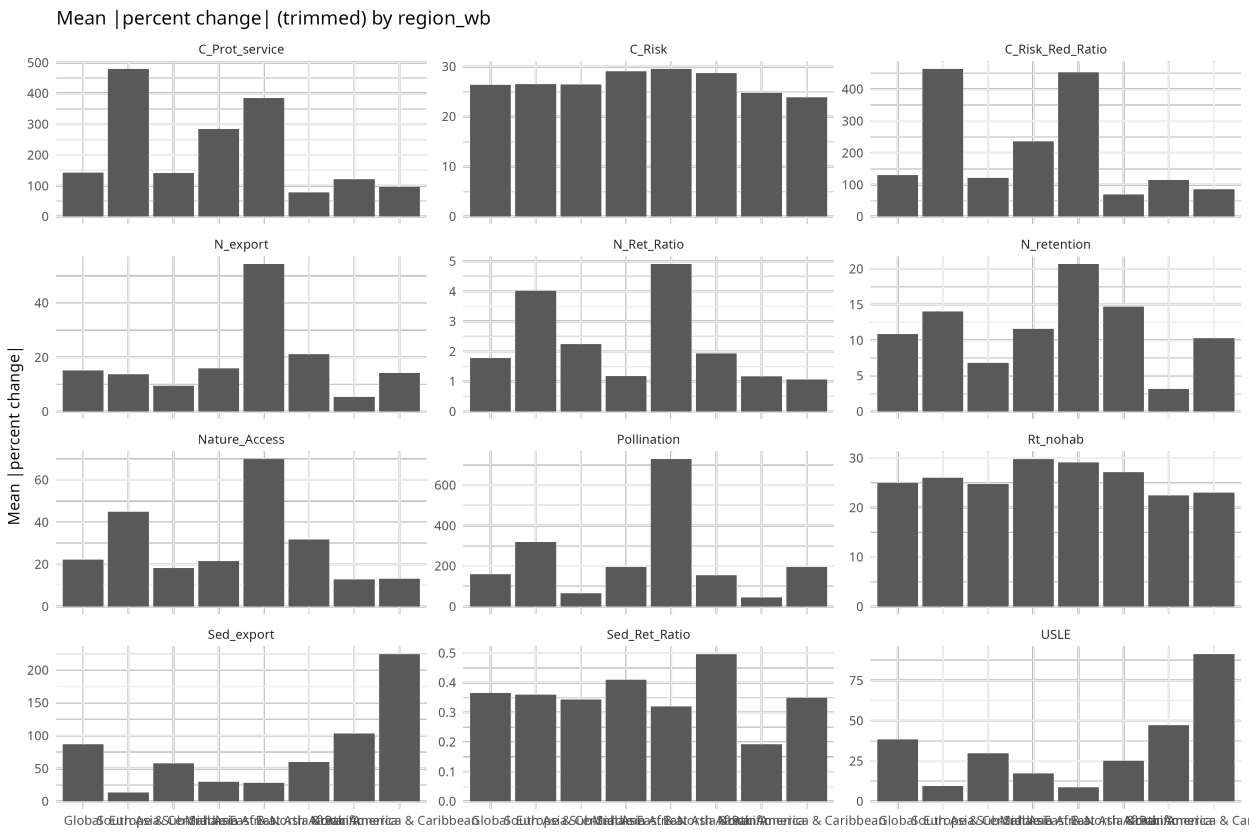

Total absolute change (trimmed) by region_wb
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |absolute change|
Global
Latin America & Caribbean


Average trimmed absolute change by region_wb
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
Middle East & North Africa
South Asia
Sub-Saharan Africa
Europe & Central Asia
East Asia & Pacific
North America
Latin America & Caribbean
Global


Average trimmed absolute change by region_wb
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |absolute change| (trimmed)
Middle East & North Africa
South Asia
Sub-Saharan Africa
Europe & Central Asia
East Asia & Pacific
North America
Latin America & Caribbean


Average trimmed percent change by region_wb
Trim: |x| capped at 99.9th percentile per service; Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
Sub-Saharan Africa
Middle East & North Africa
East Asia & Pacific
South Asia
Europe & Central Asia
North America
Latin America & Caribbean
Global

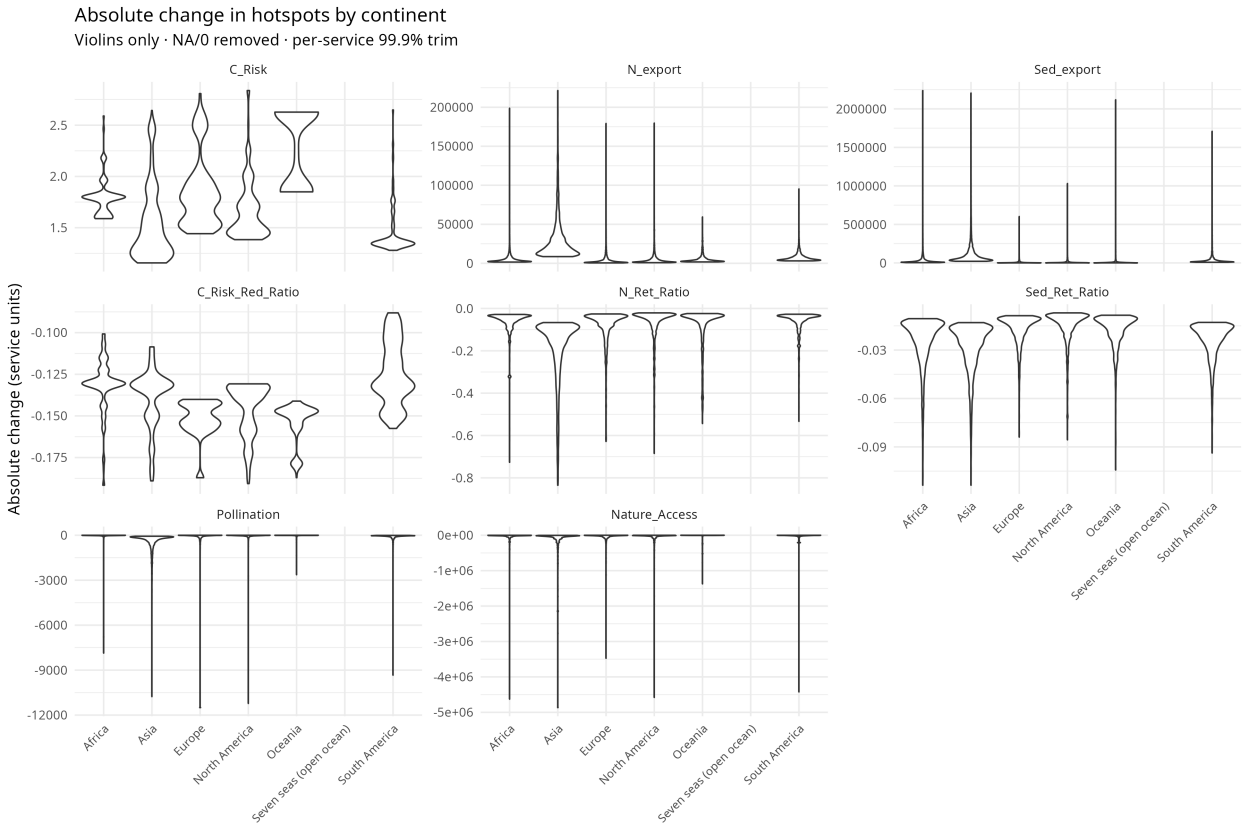

Average trimmed percent change by region_wb
Trim: |x| capped at 99.9th percentile per service; no Global included
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Mean |% change| (trimmed)
Sub-Saharan Africa
Middle East & North Africa
East Asia & Pacific
South Asia
Europe & Central Asia
North America
Latin America & Caribbean

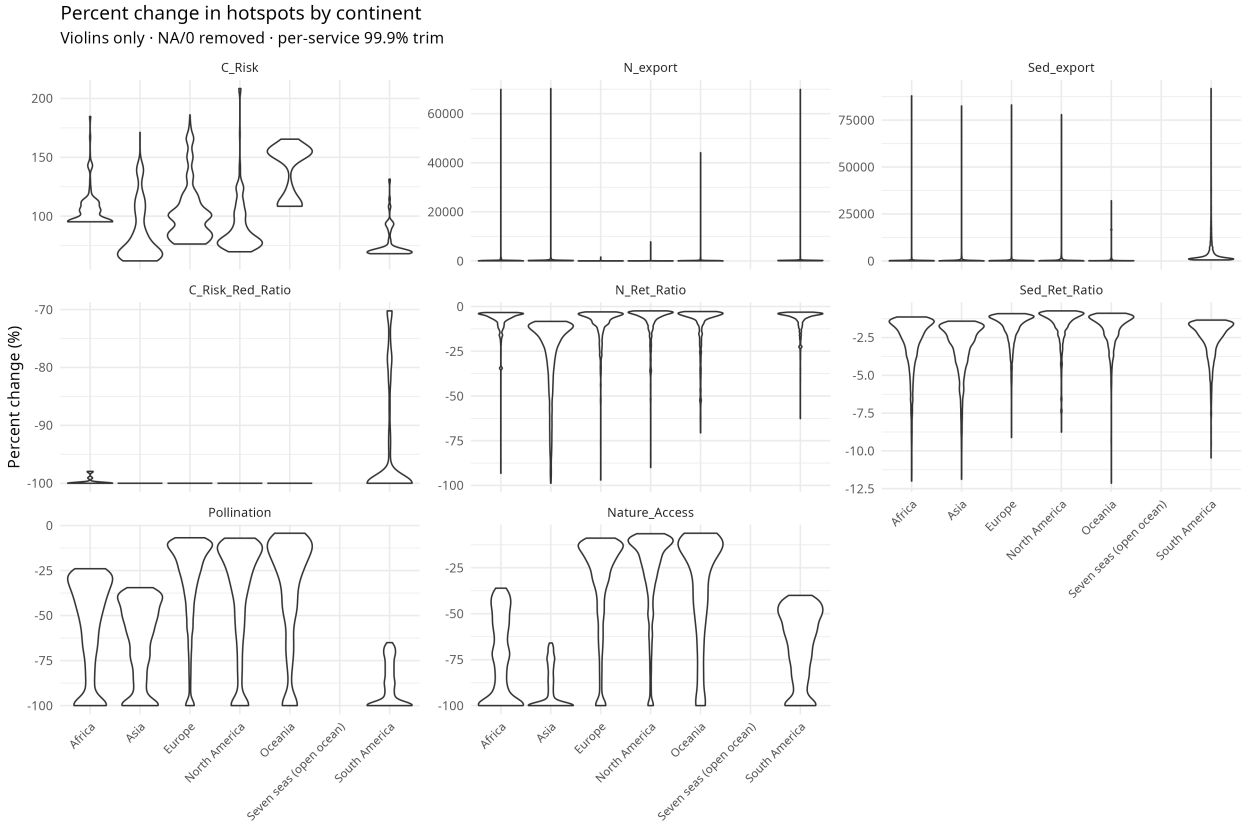

Mean |percent change| (trimmed) by region_wb
C_Prot_service
C_Risk
C_Risk_Red_Ratio
N_export
N_Ret_Ratio
N_retention
Nature_Access
Pollination
Rt_nohab
Sed_export
Sed_Ret_Ratio
USLE
Mean |percent change|

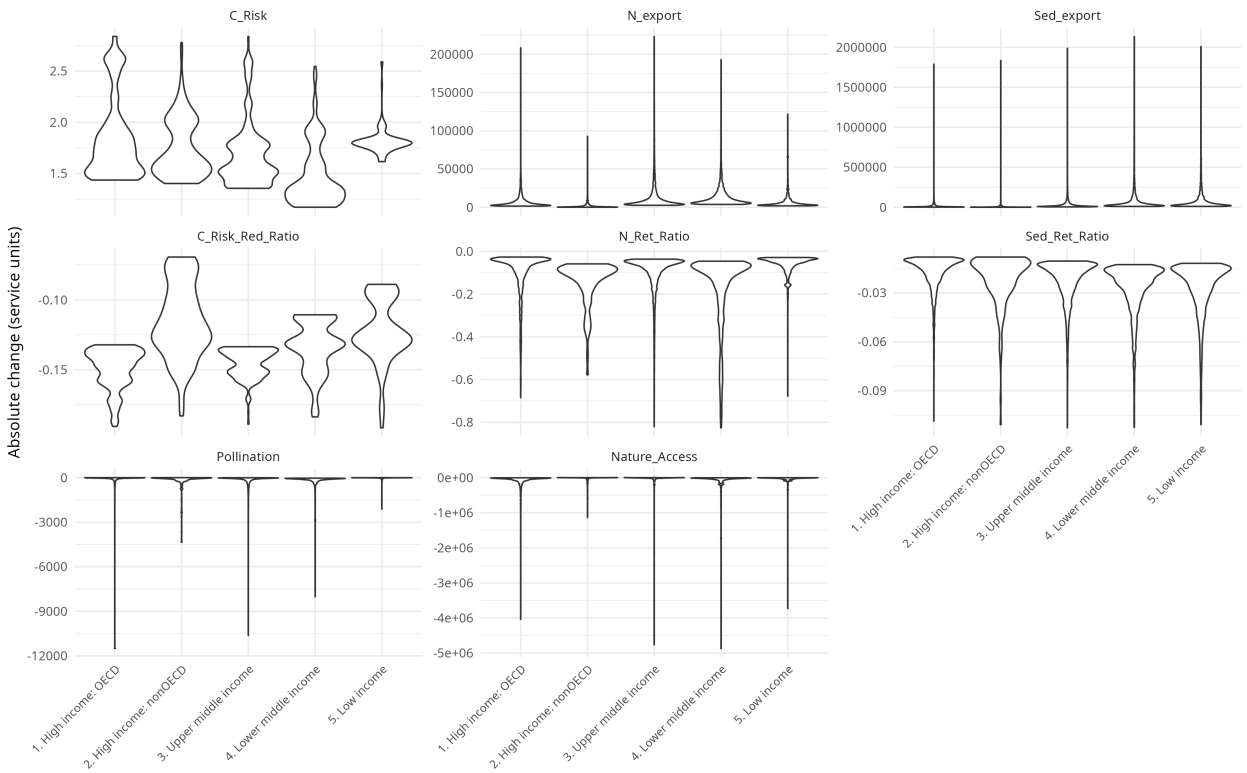
8 Hotspot violin plots

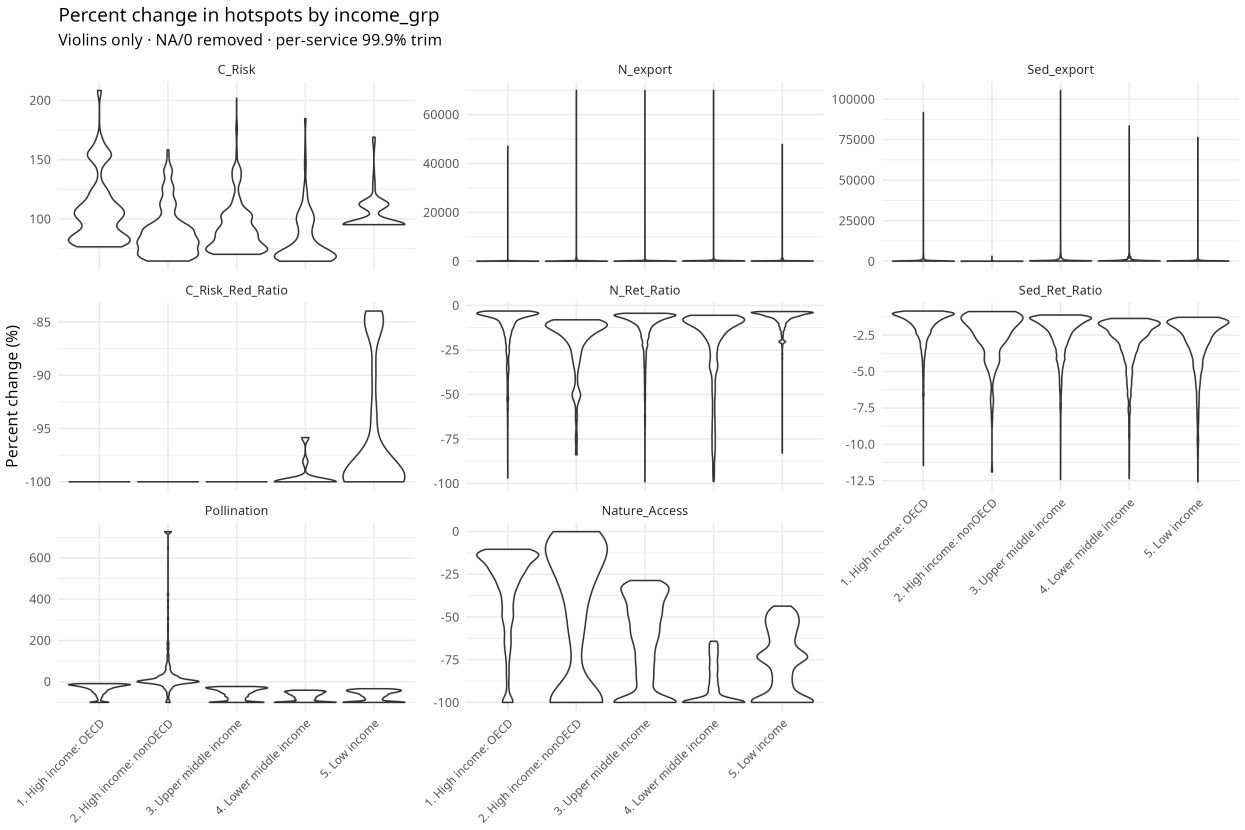
Summarize hotspot distributions by group using saved PNGs; skip computation if group columns are absent. Helper `run_hotspot_violins_by()` now lives in `R/hotspot_violins.R`, so we just call it from this report.

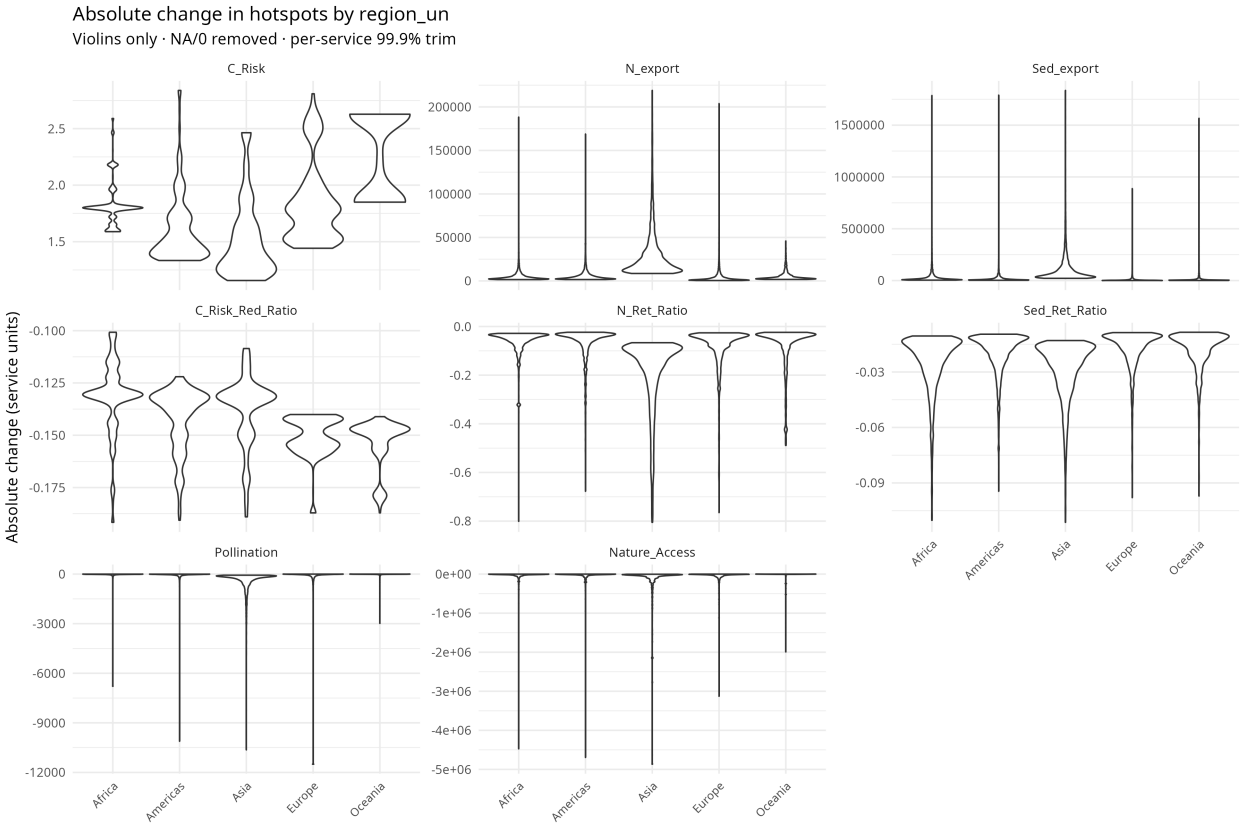
Outputs: PNGs are written to `outputs/plots/{abs|pct}/<group_col>/violins_*.png` and mirrored into `outputs/plots/latest/violins/` for embedding.

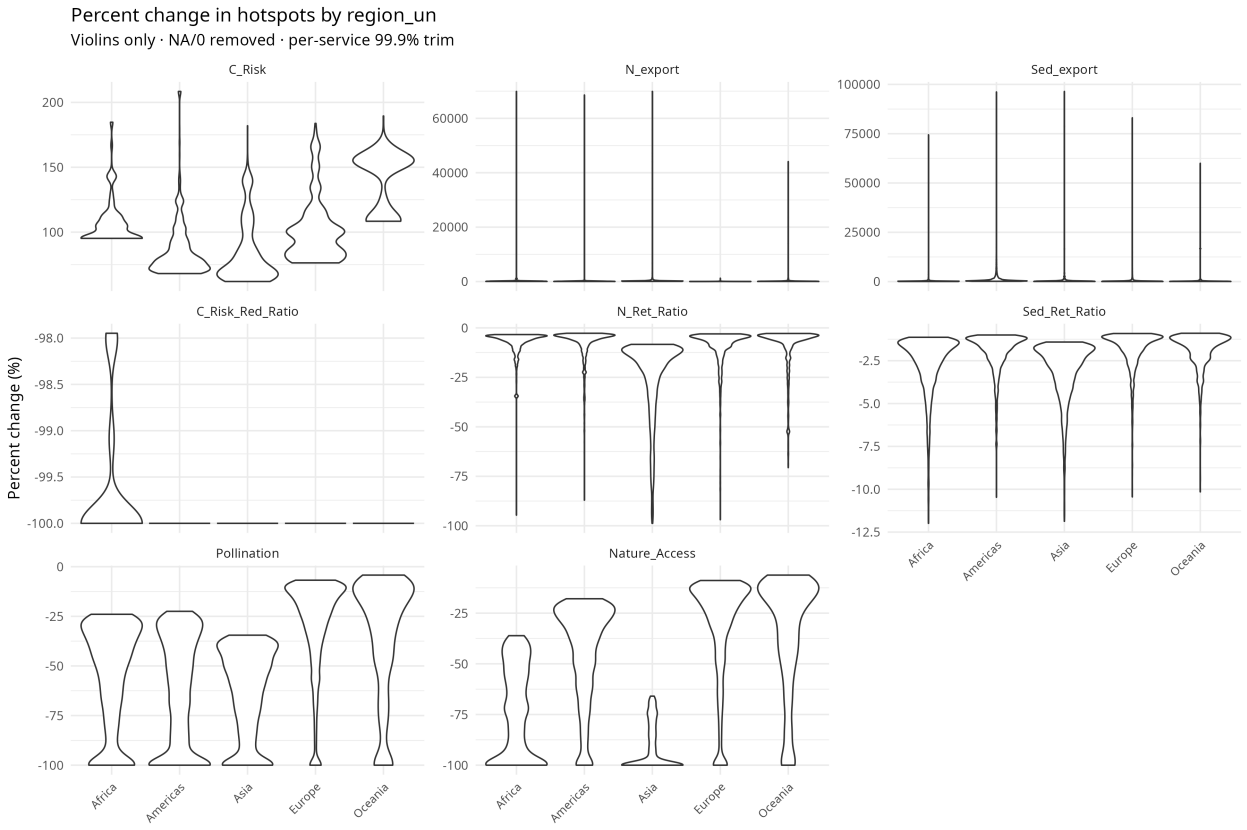


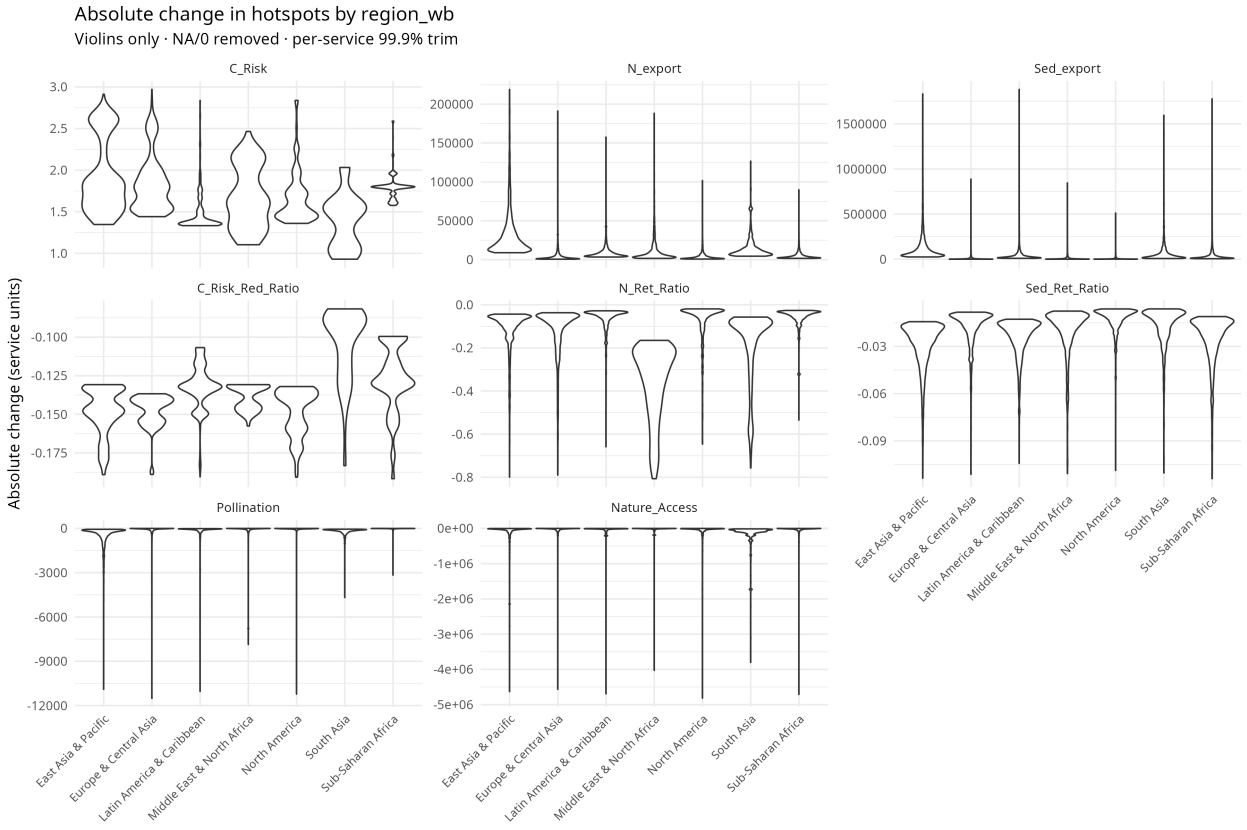

Percent change in hotspots by continent
Violins only · NA/0 removed · per-service 99.9% trim
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Percent change (%)
Africa
Asia
Europe
North America
Oceania
Seven seas (open ocean)
South America

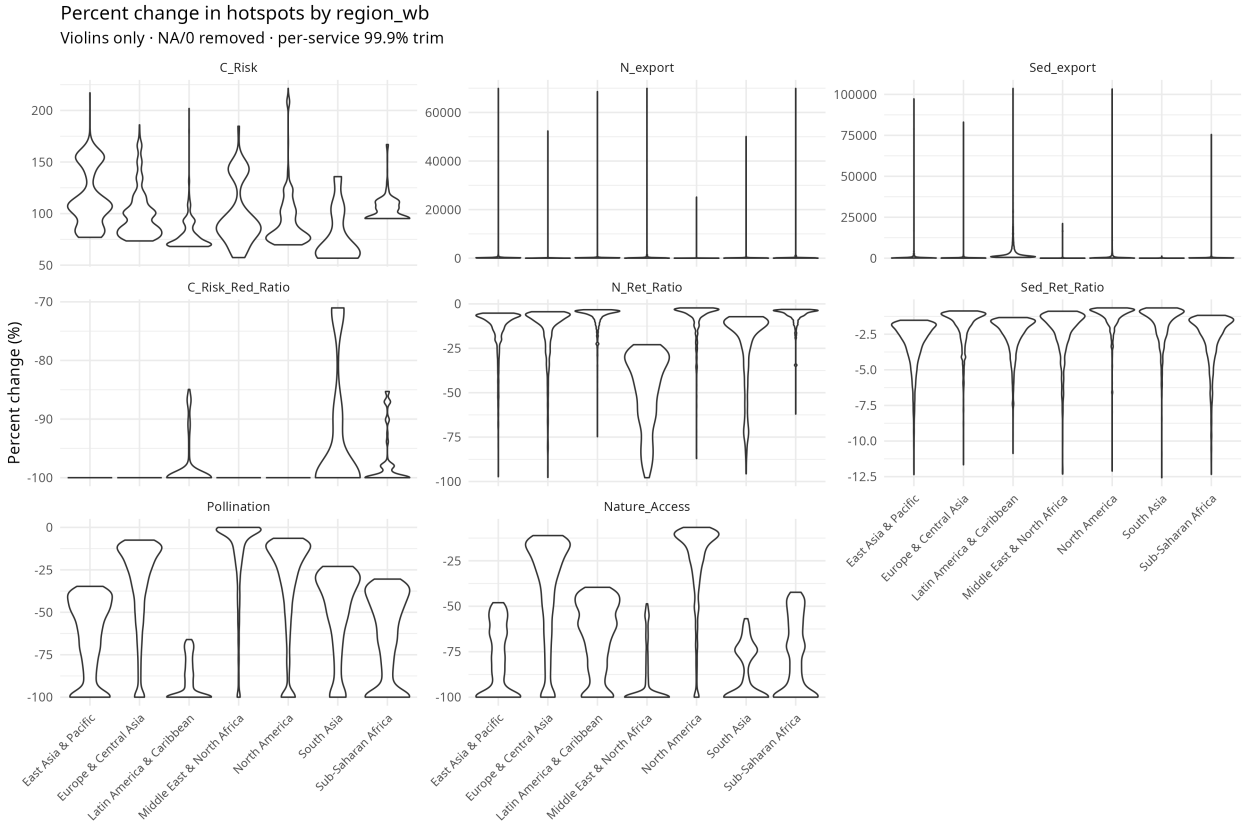

Absolute change in hotspots by income_grp
Violins only · NA/0 removed · per-service 99.9% trim
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Absolute change (service units)
1. High income: OECD
2. High income: nonOECD
3. Upper middle income
4. Lower middle income
5. Low income

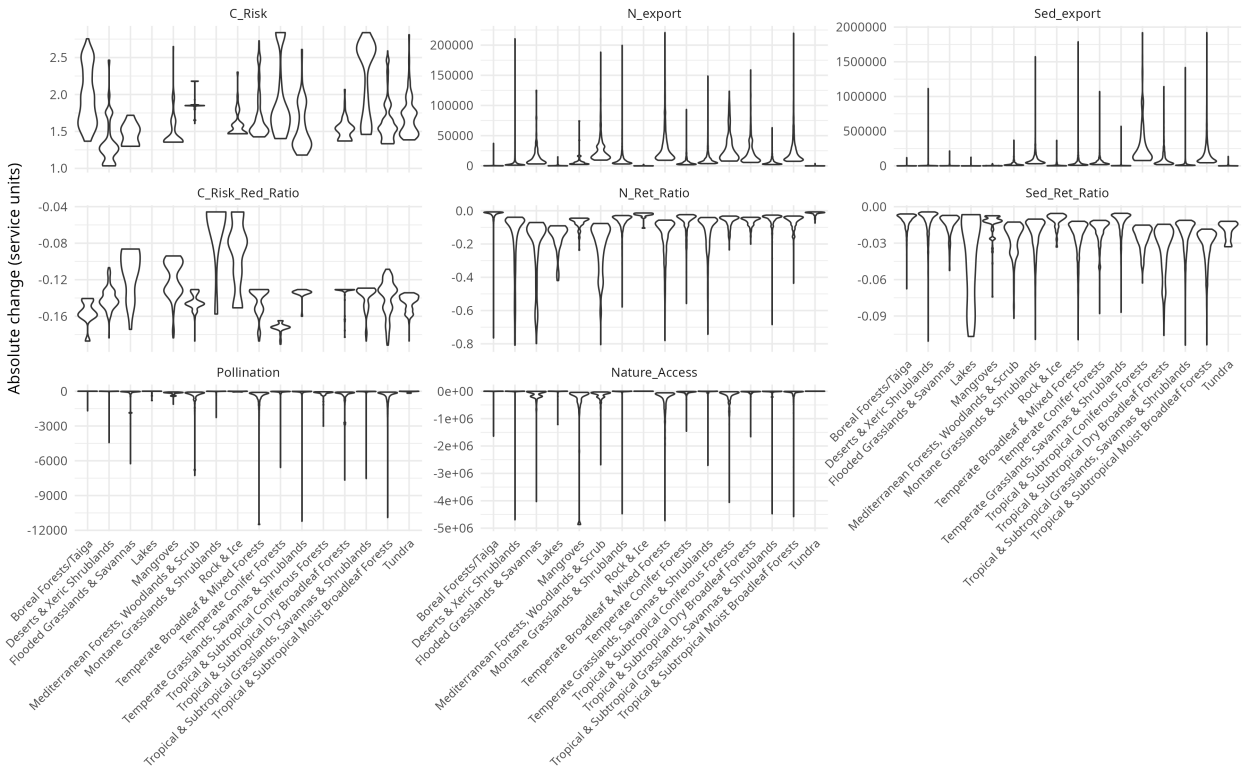

Percent change in hotspots by income_grp
Violins only · NA/0 removed · per-service 99.9% trim
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Percent change (%)
1. High income: OECD
2. High income: nonOECD
3. Upper middle income
4. Lower middle income
5. Low income

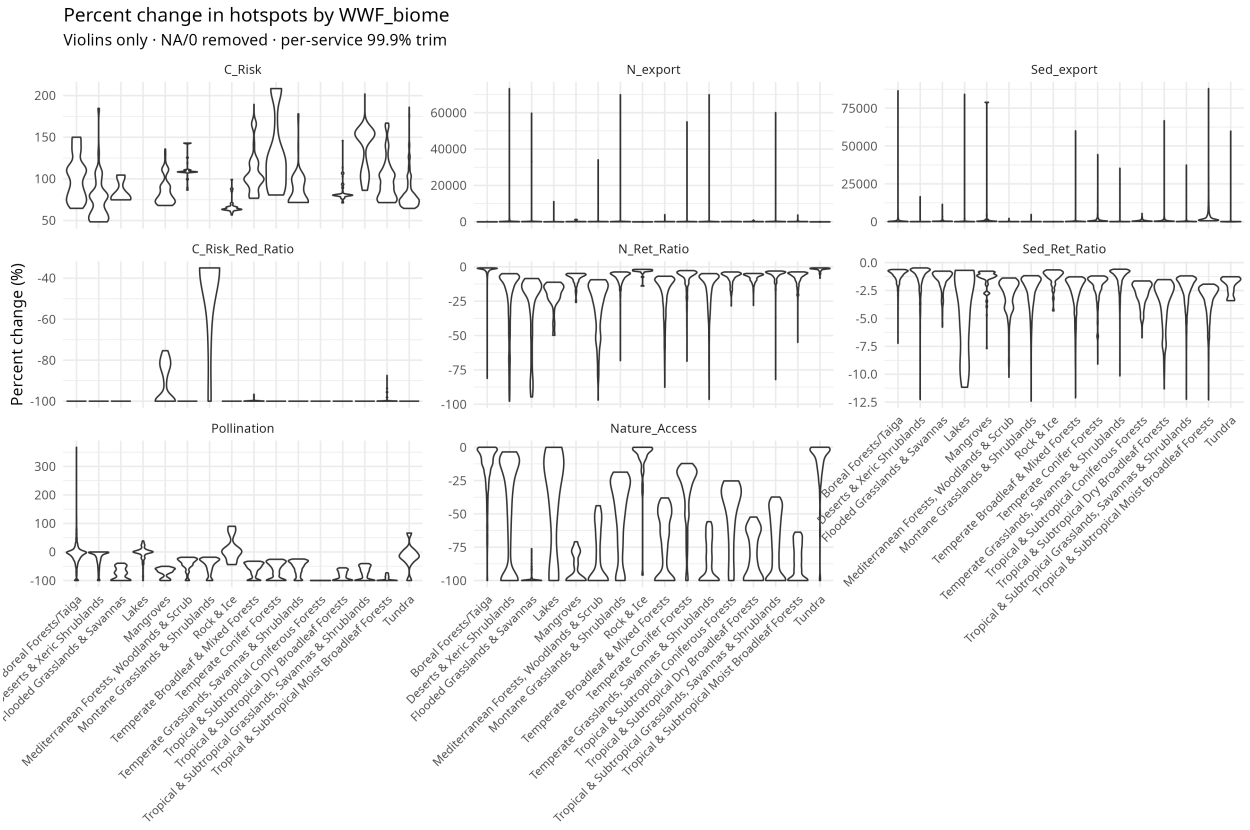

Absolute change in hotspots by region_un
Violins only · NA/0 removed · per-service 99.9% trim
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Absolute change (service units)
Africa
Americas
Asia
Europe
Oceania


Percent change in hotspots by region_un
Violins only · NA/0 removed · per-service 99.9% trim
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Percent change (%)
Africa
Americas
Asia
Europe
Oceania


Absolute change in hotspots by region_wb
Violins only · NA/0 removed · per-service 99.9% trim
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Absolute change (service units)
East Asia & Pacific
Europe & Central Asia
Latin America & Caribbean
Middle East & North Africa
North America
South Asia
Sub-Saharan Africa


Percent change in hotspots by region_wb
Violins only · NA/0 removed · per-service 99.9% trim
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Percent change (%)
East Asia & Pacific
Europe & Central Asia
Latin America & Caribbean
Middle East & North Africa
North America
South Asia
Sub-Saharan Africa


Absolute change in hotspots by WWF_biome
Violins only · NA/0 removed · per-service 99.9% trim
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Absolute change (service units)
Boreal Forests/Taiga
Deserts & Xeric Shrublands
Flooded Grasslands & Savannas
Lakes
Mangroves
Mediterranean Forests, Woodlands & Scrub
Montane Grasslands & Shrublands
Rock & Ice
Temperate Broadleaf & Mixed Forests
Temperate Conifer Forests
Temperate Grasslands, Savannas & Shrublands
Tropical & Subtropical Coniferous Forests
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Grasslands, Savannas & Shrublands
Tropical & Subtropical Moist Broadleaf Forests
Tundra


Percent change in hotspots by WWF_biome
Violins only · NA/0 removed · per-service 99.9% trim
C_Risk
N_export
Sed_export
C_Risk_Red_Ratio
N_Ret_Ratio
Sed_Ret_Ratio
Pollination
Nature_Access
Percent change (%)
Boreal Forests/Taiga
Deserts & Xeric Shrublands
Flooded Grasslands & Savannas
Lakes
Mangroves
Mediterranean Forests, Woodlands & Scrub
Montane Grasslands & Shrublands
Rock & Ice
Temperate Broadleaf & Mixed Forests
Temperate Conifer Forests
Temperate Grasslands, Savannas & Shrublands
Tropical & Subtropical Coniferous Forests
Tropical & Subtropical Dry Broadleaf Forests
Tropical & Subtropical Grasslands, Savannas & Shrublands
Tropical & Subtropical Moist Broadleaf Forests
Tundra