Reproducible R code for the manuscript entitled 'Forest loss and fire in the Dominican Republic during the 21st Century': Data transformation, exploratory spatial data analysis (ESDA) and modelling

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Contents

1 Description and URLs

This is a reproducible notebook of the manuscript entitled 'Forest loss and fire in the Dominican Republic during the 21st Century' (Martínez Batlle, 2021). Useful URLs are listed below:

- This document: https://github.com/geofis/forest-loss-fire-reproducible/modelling.pdf
- Source repo: https://github.com/geofis/forest-loss-fire-reproducible
- Associated preprint DOI: https://www.biorxiv.org/content/10.1101/2021.06.15.448604v1
- Associated preprint full text: https://www.biorxiv.org/content/10.1101/2021.06.15.448604v1.full
- Dataset: `forest-loss-fire-reproducible-data-repo.zip`. Download it from ZENODO
- Cite the preprint using the following format: Martínez Batlle, J. R. (2021). Forest loss and fire in the Dominican Republic during the 21st Century. *bioRxiv*. https://doi.org/10.1101/2021.06.15.448604

2 Instructions for downloading the source data

Visit ZENODO, download `forest-loss-fire-reproducible-data-repo.zip` (preserve its name, otherwise, won't work) and place the ZIP file in this repo (e.g. in the same directory containing this document).

3 Unzip source data

```
if (any(dir.exists("out"), dir.exists("data"))) {
    "Directories 'out' and/or 'data' already available in the repo dir. Skipping unzip."
} else {
    unzip("forest-loss-fire-reproducible-data-repo.zip")
}
## [1] "Directories 'out' and/or 'data' already available in the repo dir. Skipping unzip."
```

4 Prepare the environment

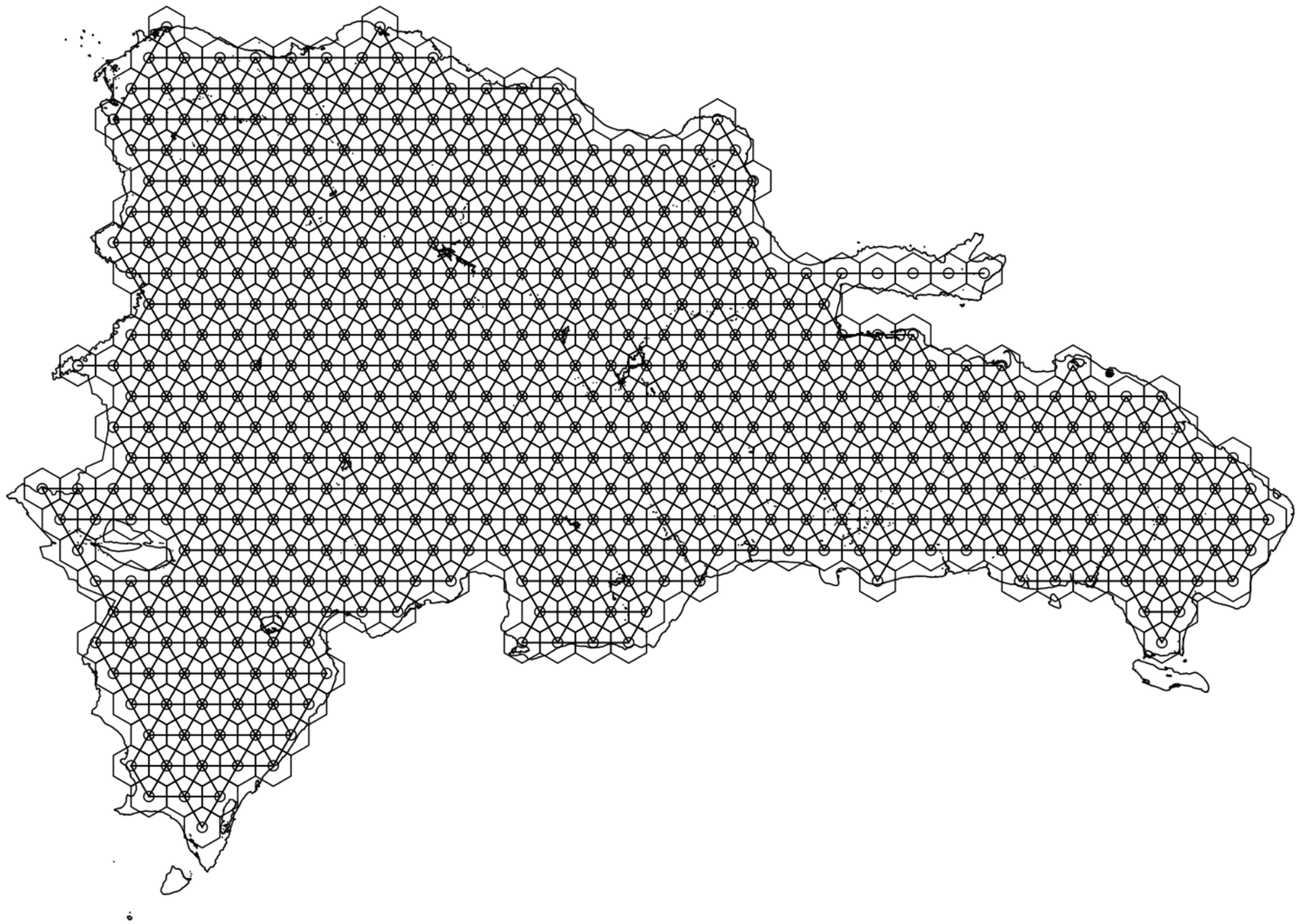
```
source("R/load-packages.R")
source("R/load-functions.R")
UseCores <- detectCores() - 1
source("R/load-cutline.R")
## Reading layer `cutline' from data source
##   `/home/jose/Documentos/git/forest-loss-fire-reproducible/out/cutline.geojson'
##   using driver `GeoJSON'
## Simple feature collection with 222 features and 2 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: 182239.3 ymin: 1933574 xmax: 571425.3 ymax: 2205219
## Projected CRS: WGS 84 / UTM zone 19N
admpath <- "data/administrative/administrative.gpkg"
prov <- st_read(admpath, "PROVCenso2010", quiet = T)
# Read seaocean mask and points_of_interest layers The following mask was
# generated using the 'original-script-used-to-generate-sea-ocean-mask.R' This
# mask, as well as the points_of_interest source, are used for enhancing the
# visualization of spatial data in different maps of the ESDA
seaocean <- st_read("out/gadm_mask_inv.gpkg")
## Reading layer `gadm_mask_inv' from data source
##   `/home/jose/Documentos/git/forest-loss-fire-reproducible/out/gadm_mask_inv.gpkg'
##   using driver `GPKG'
## Simple feature collection with 141 features and 2 fields
## Geometry type: POLYGON
## Dimension:     XY
## Bounding box:  xmin: -1020132 ymin: 879641.3 xmax: 1298683 ymax: 3130786
## Projected CRS: WGS 84 / UTM zone 19N
points_of_interest <- st_read("out/points_of_interest.gpkg")
## Reading layer `points_of_interest' from data source
##   `/home/jose/Documentos/git/forest-loss-fire-reproducible/out/points_of_interest.gpkg'
##   using driver `GPKG'
## Simple feature collection with 7 features and 3 fields
## Geometry type: POINT
## Dimension:     XY
## Bounding box:  xmin: 235042.4 ymin: 2009336 xmax: 543157.4 ymax: 2179514
## Projected CRS: WGS 84 / UTM zone 19N
```

5 Modelling for the long-term approach, using forest-loss as dependent variable, and fires M6 (2001-2018) and V1 (2012-2018) as independent variables

5.1 Exploratory Spatial Data Analysis (ESDA)

```
# Zonal statistics object
grdzonal <- readRDS("out/grd_zonal_statistics.RDS")
# * Neighbours, weight
```

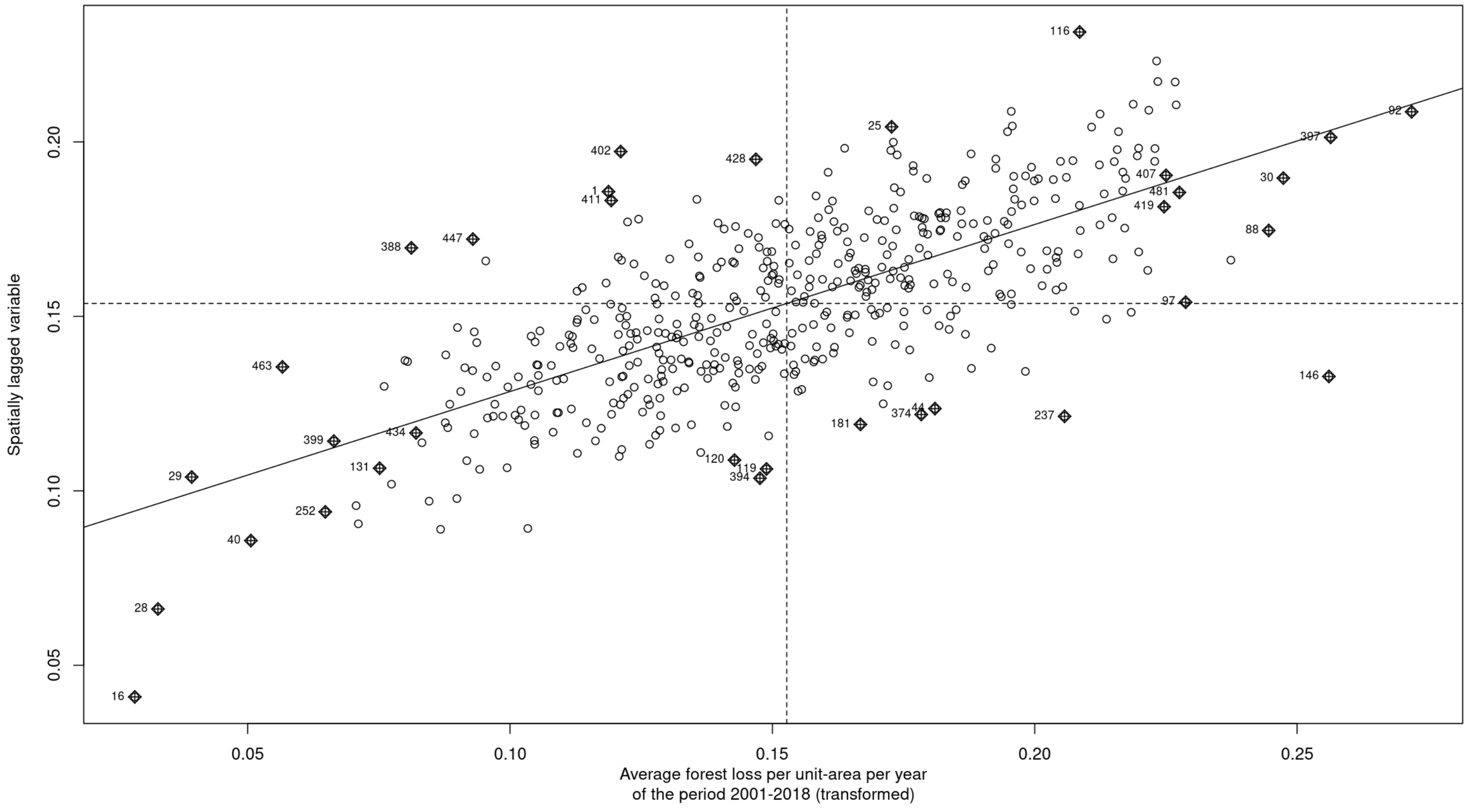
```r
grdnb <- poly2nb(grdzonal)
plot(as_Spatial(cline))
plot(as_Spatial(grdzonal), add = T)
plot(grdnb, coords = coordinates(as_Spatial(grdzonal)), add = T)
```



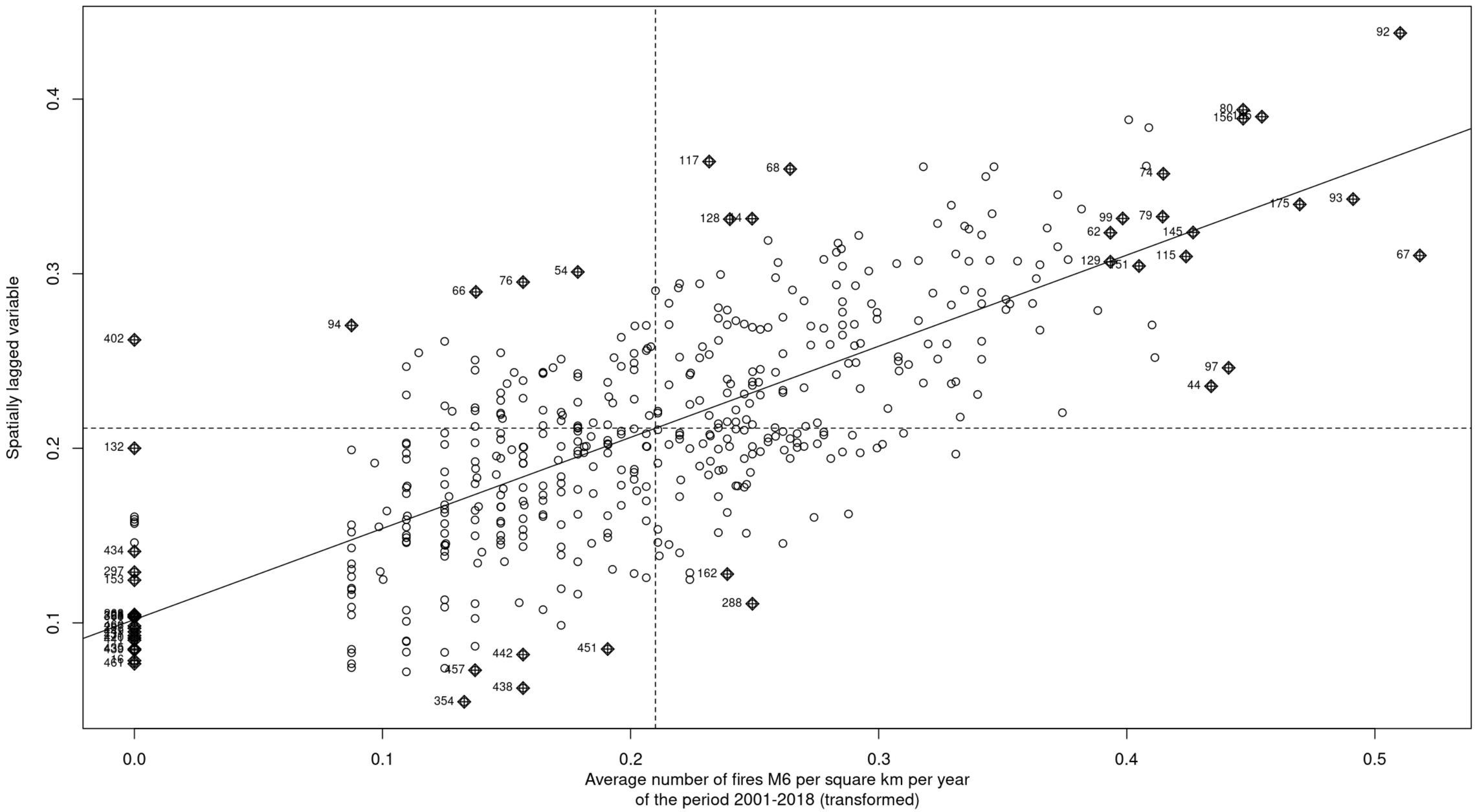
```r
attr(grdnb, "region.id") <- grdzonal$ENLACE
grdww <- nb2listw(grdnb, zero.policy = T)
grdww
## Characteristics of weights list object:
## Neighbour list object:
## Number of regions: 482
## Number of nonzero links: 2622
## Percentage nonzero weights: 1.128596
## Average number of links: 5.439834
##
## Weights style: W
```

```
## Weights constants summary:
##     n     nn  S0       S1       S2
## W 482 232324 482 186.8356 1940.897

# * Moran test per unit area (PUA)
grdzonal$LOSS0118_PUA_PYR_NORM <- transformTukey(grdzonal$LOSS0118_PUA_PYR %>%
    replace(is.na(.), 0), plotit = F)
##
##     lambda      W Shapiro.p.value
## 414  0.325 0.9979          0.8116
##
## if (lambda >  0){TRANS = x ^ lambda}
## if (lambda == 0){TRANS = log(x)}
## if (lambda <  0){TRANS = -1 * x ^ lambda}
# lambda W Shapiro.p.value 414 0.325 0.9979 0.8116 if (lambda > 0){TRANS = x ^
# lambda} if (lambda == 0){TRANS = log(x)} if (lambda < 0){TRANS = -1 * x ^
# lambda}
moran.test(grdzonal$LOSS0118_PUA_PYR_NORM, listw = grdww, na.action = na.exclude,
    zero.policy = T)
##
##  Moran I test under randomisation
##
## data:  grdzonal$LOSS0118_PUA_PYR_NORM
## weights: grdww
##
## Moran I statistic standard deviate = 17.048, p-value < 2.2e-16
## alternative hypothesis: greater
## sample estimates:
## Moran I statistic       Expectation          Variance
##      0.4787566369     -0.0020790021      0.0007955173

# * Moran test per unit area (PUA)
grdzonal$LOSS1218_PUA_PYR_NORM <- transformTukey(grdzonal$LOSS1218_PUA_PYR %>%
    replace(is.na(.), 0), plotit = F)
##
##     lambda      W Shapiro.p.value
## 410  0.225 0.9977          0.7475
##
## if (lambda >  0){TRANS = x ^ lambda}
## if (lambda == 0){TRANS = log(x)}
## if (lambda <  0){TRANS = -1 * x ^ lambda}
# lambda W Shapiro.p.value 410 0.225 0.9977 0.7475 if (lambda > 0){TRANS = x ^
# lambda} if (lambda == 0){TRANS = log(x)} if (lambda < 0){TRANS = -1 * x ^
# lambda}
moran.test(grdzonal$LOSS1218_PUA_PYR_NORM, listw = grdww, na.action = na.exclude,
    zero.policy = T)
##
##  Moran I test under randomisation
##
## data:  grdzonal$LOSS1218_PUA_PYR_NORM
## weights: grdww
##
## Moran I statistic standard deviate = 17.045, p-value < 2.2e-16
## alternative hypothesis: greater
## sample estimates:
## Moran I statistic       Expectation          Variance
##      0.4785687944     -0.0020790021      0.0007951648
```

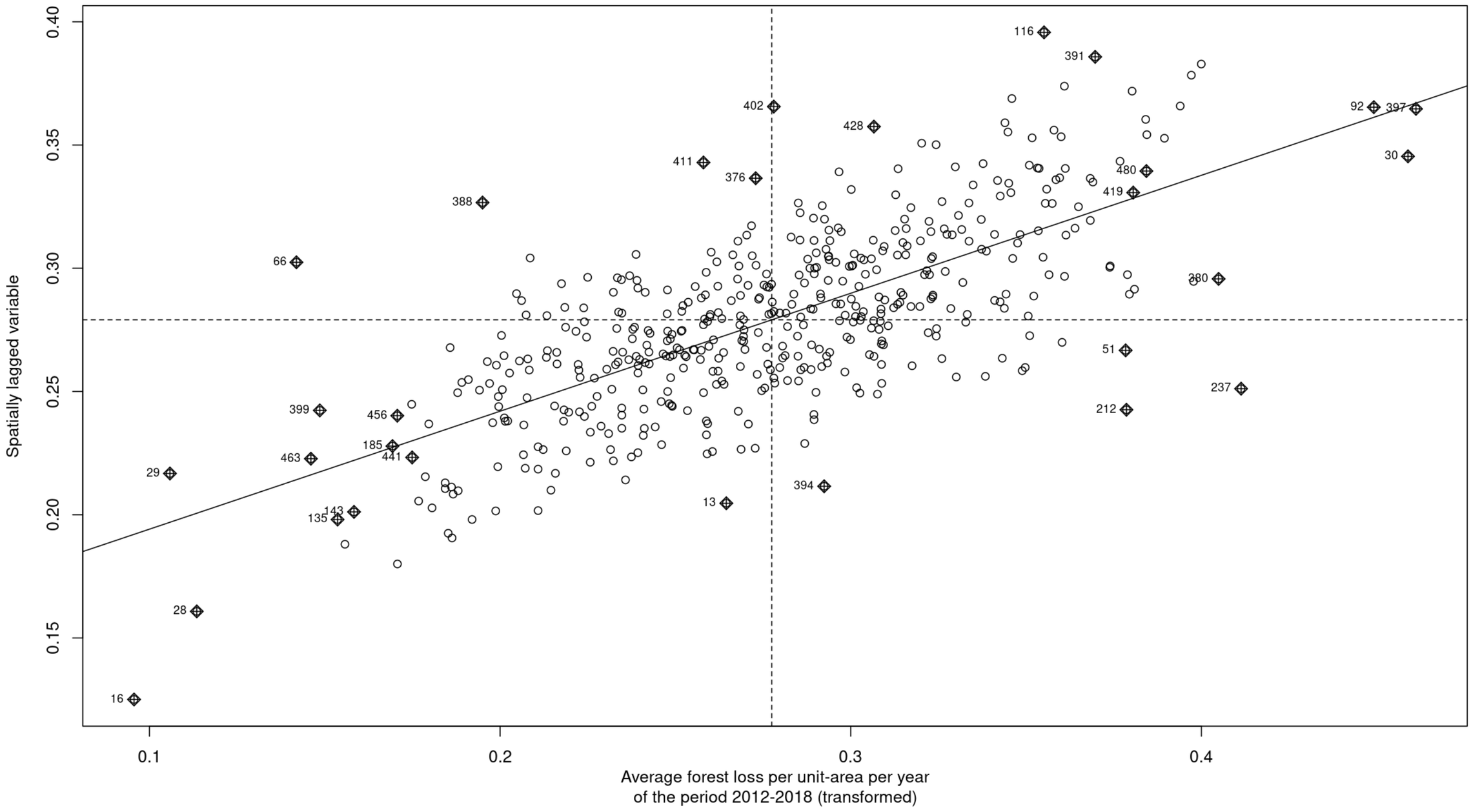
```r
# * Transformation of fires M6 per sq. km using Tukey's Ladder of Powers
grdzonal$NFIRESM6_PSQKM_PYR_TLP <- transformTukey(grdzonal$NFIRESM6_PSQKM_PYR %>%
    replace(is.na(.), 0), plotit = F)
##
##     lambda      W Shapiro.p.value
## 414  0.325 0.9833         2.5e-05
##
## if (lambda >  0){TRANS = x ^ lambda}
## if (lambda == 0){TRANS = log(x)}
## if (lambda <  0){TRANS = -1 * x ^ lambda}
# lambda W Shapiro.p.value 414 0.325 0.9833 2.5e-05 if (lambda > 0){TRANS = x ^
# lambda} if (lambda == 0){TRANS = log(x)} if (lambda < 0){TRANS = -1 * x ^
# lambda}

# * Transformation of fires V1 per sq. km using Tukey's Ladder of Powers
grdzonal$NFIRESV1_PSQKM_PYR_TLP <- transformTukey(grdzonal$NFIRESV1_PSQKM_PYR %>%
    replace(is.na(.), 0), plotit = F)
##
##     lambda      W Shapiro.p.value
## 413    0.3 0.9886        0.000823
##
## if (lambda >  0){TRANS = x ^ lambda}
## if (lambda == 0){TRANS = log(x)}
## if (lambda <  0){TRANS = -1 * x ^ lambda}
# lambda W Shapiro.p.value 413 0.3 0.9886 0.000823 if (lambda > 0){TRANS = x ^
# lambda} if (lambda == 0){TRANS = log(x)} if (lambda < 0){TRANS = -1 * x ^
# lambda}
moran.test(grdzonal$NFIRESM6_PSQKM_PYR_TLP, listw = grdww, na.action = na.exclude,
    zero.policy = T)
##
##  Moran I test under randomisation
##
## data:  grdzonal$NFIRESM6_PSQKM_PYR_TLP
## weights: grdww
##
## Moran I statistic standard deviate = 18.585, p-value < 2.2e-16
## alternative hypothesis: greater
## sample estimates:
## Moran I statistic       Expectation          Variance
##      0.5219024882     -0.0020790021      0.0007949039
moran.test(grdzonal$NFIRESV1_PSQKM_PYR_TLP, listw = grdww, na.action = na.exclude,
    zero.policy = T)
##
##  Moran I test under randomisation
##
## data:  grdzonal$NFIRESV1_PSQKM_PYR_TLP
## weights: grdww
##
## Moran I statistic standard deviate = 18.272, p-value < 2.2e-16
## alternative hypothesis: greater
## sample estimates:
## Moran I statistic       Expectation          Variance
##      0.5130675981     -0.0020790021      0.0007948482

# * Moran plot
mploss0118 <- moran.plot(x = replace_na(grdzonal$LOSS0118_PUA_PYR_NORM, 0), listw = grdww,
    zero.policy = T, quiet = T, xlab = "Average forest loss per unit-area per year\nof the period 2001-2018 (transformed)",
    ylab = "Spatially lagged variable", return_df = T)
```



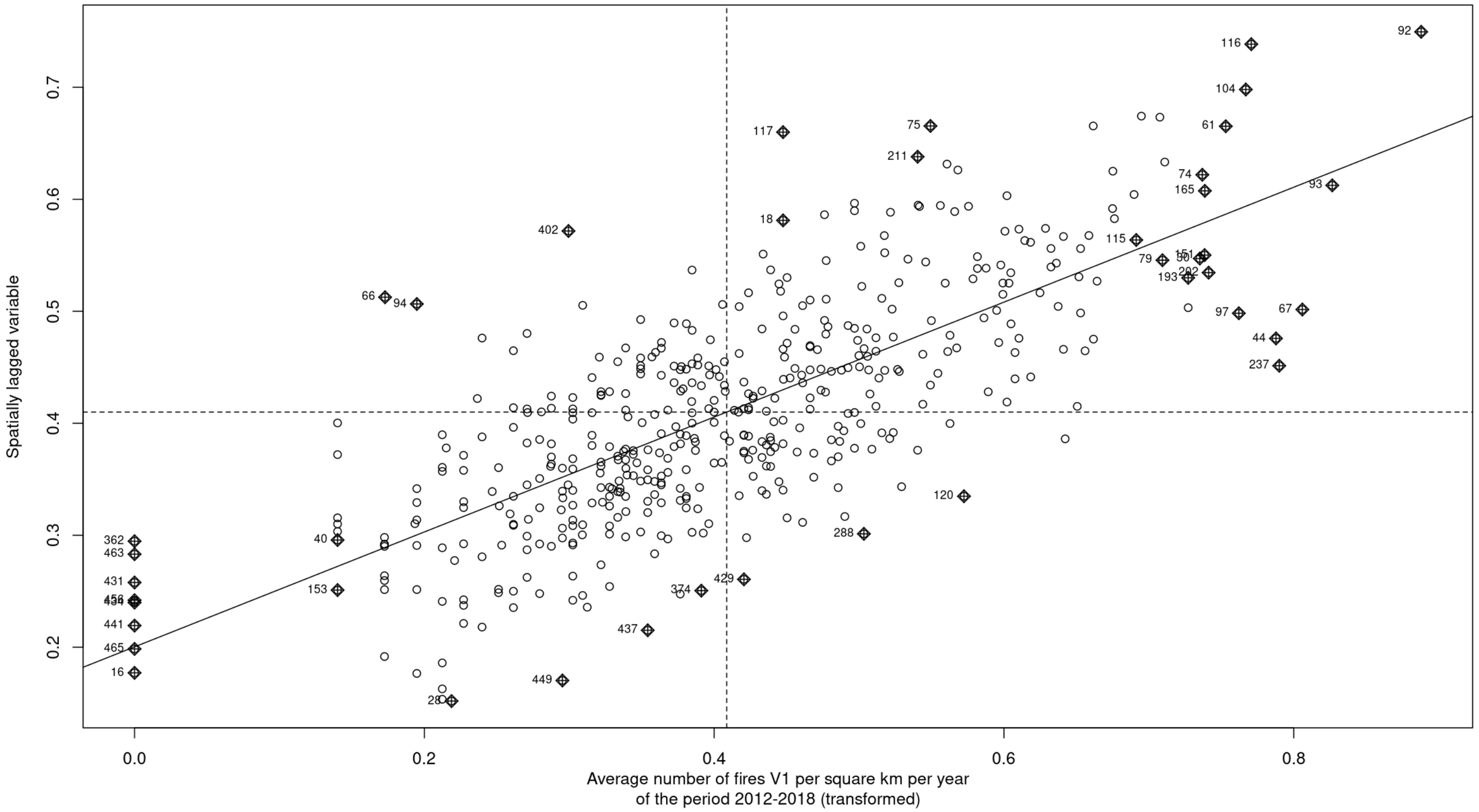

```
mpfiresm60118 <- moran.plot(x = replace_na(grdzonal$NFIRESM6_PSQKM_PYR_TLP, 0), listw = grdww,
    zero.policy = T, quiet = T, xlab = "Average number of fires M6 per square km per year\nof the period 2001-2018 (transformed)",
    ylab = "Spatially lagged variable", return_df = T)
```




```
mploss1218 <- moran.plot(x = replace_na(grdzonal$LOSS1218_PUA_PYR_NORM, 0), listw = grdww,
    zero.policy = T, quiet = T, xlab = "Average forest loss per unit-area per year\nof the period 2012-2018 (transformed)",
    ylab = "Spatially lagged variable", return_df = T)
```

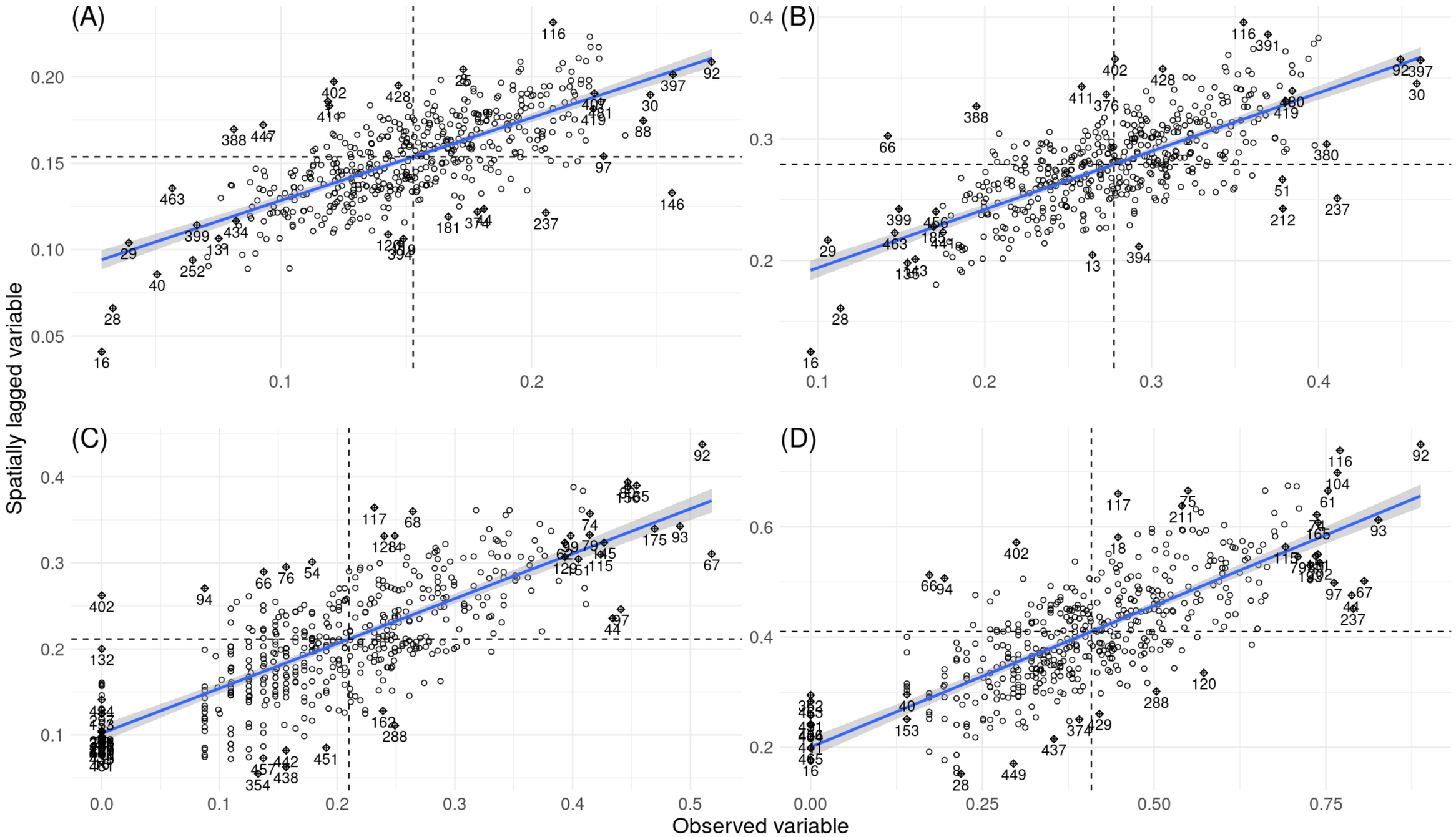



```
mpfiresv11218 <- moran.plot(x = replace_na(grdzonal$NFIRESV1_PSQKM_PYR_TLP, 0), listw = grdww,
    zero.policy = T, quiet = T, xlab = "Average number of fires V1 per square km per year\nof the period 2012-2018 (transformed)",
    ylab = "Spatially lagged variable", return_df = T)
```



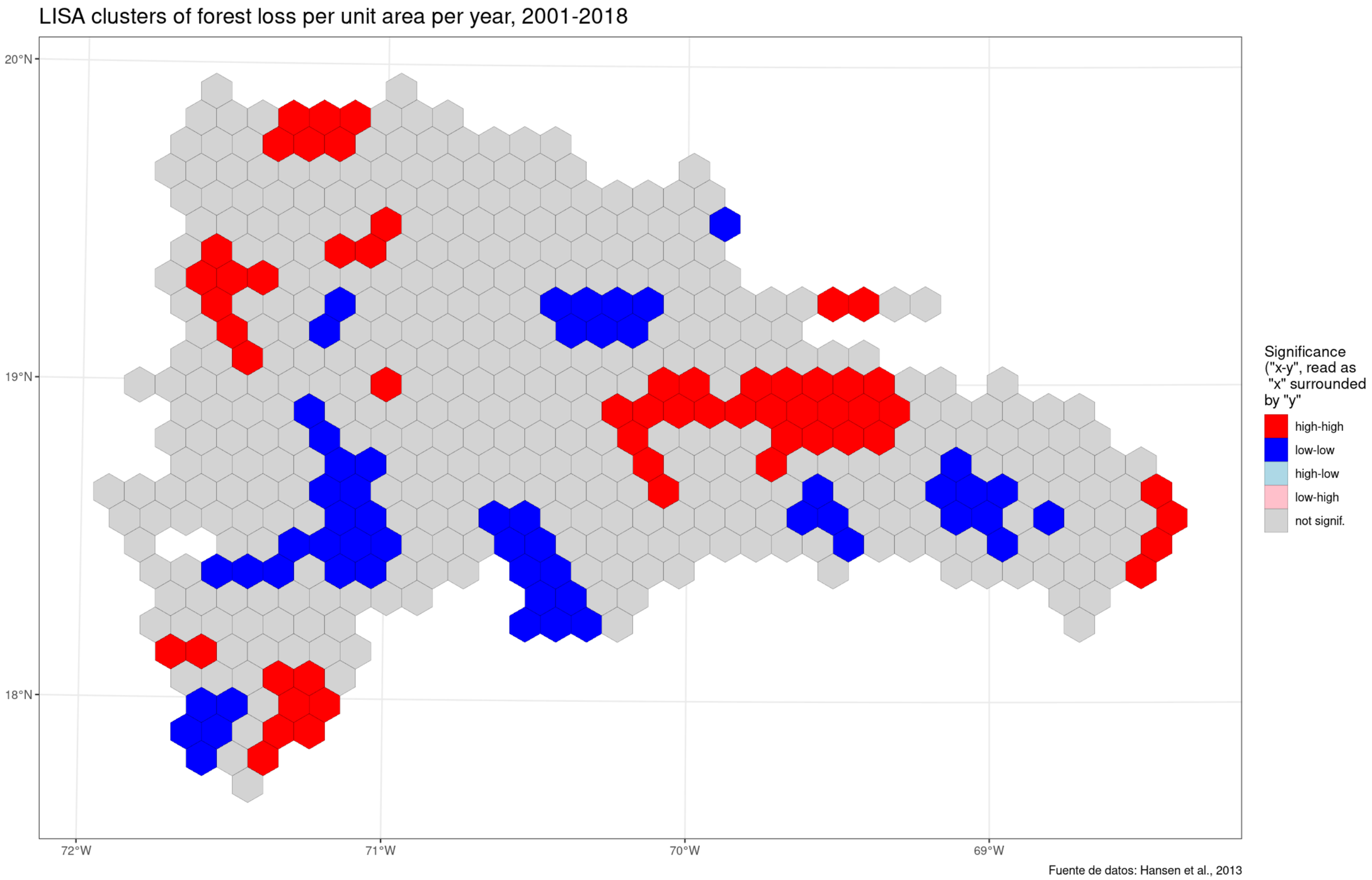

```
# gg Moran plot
{
    all_mp <- plyr::ldply(list(mploss0118 = mploss0118, mploss1218 = mploss1218,
        mpfiresm60118 = mpfiresm60118, mpfiresv11218 = mpfiresv11218), .id = "name") %>%
        mutate(name = case_when(name == "mploss0118" ~ "(A)", name == "mploss1218" ~
            "(B)", name == "mpfiresm60118" ~ "(C)", name == "mpfiresv11218" ~ "(D)",
            TRUE ~ as.character(x)))
    all_mp_sum <- all_mp %>%
```

```
        group_by(name) %>%
        summarize(x = mean(x), wx = mean(wx))
    # jpeg('out/moran_plots_forest_loss_fires_0118_1218.jpg', width = 3840,
    # height = 2160, res = 300)
    moran_plot_gg(mp = all_mp, mp_sum = all_mp_sum, textsize = 16)
    # dev.off()
}
```

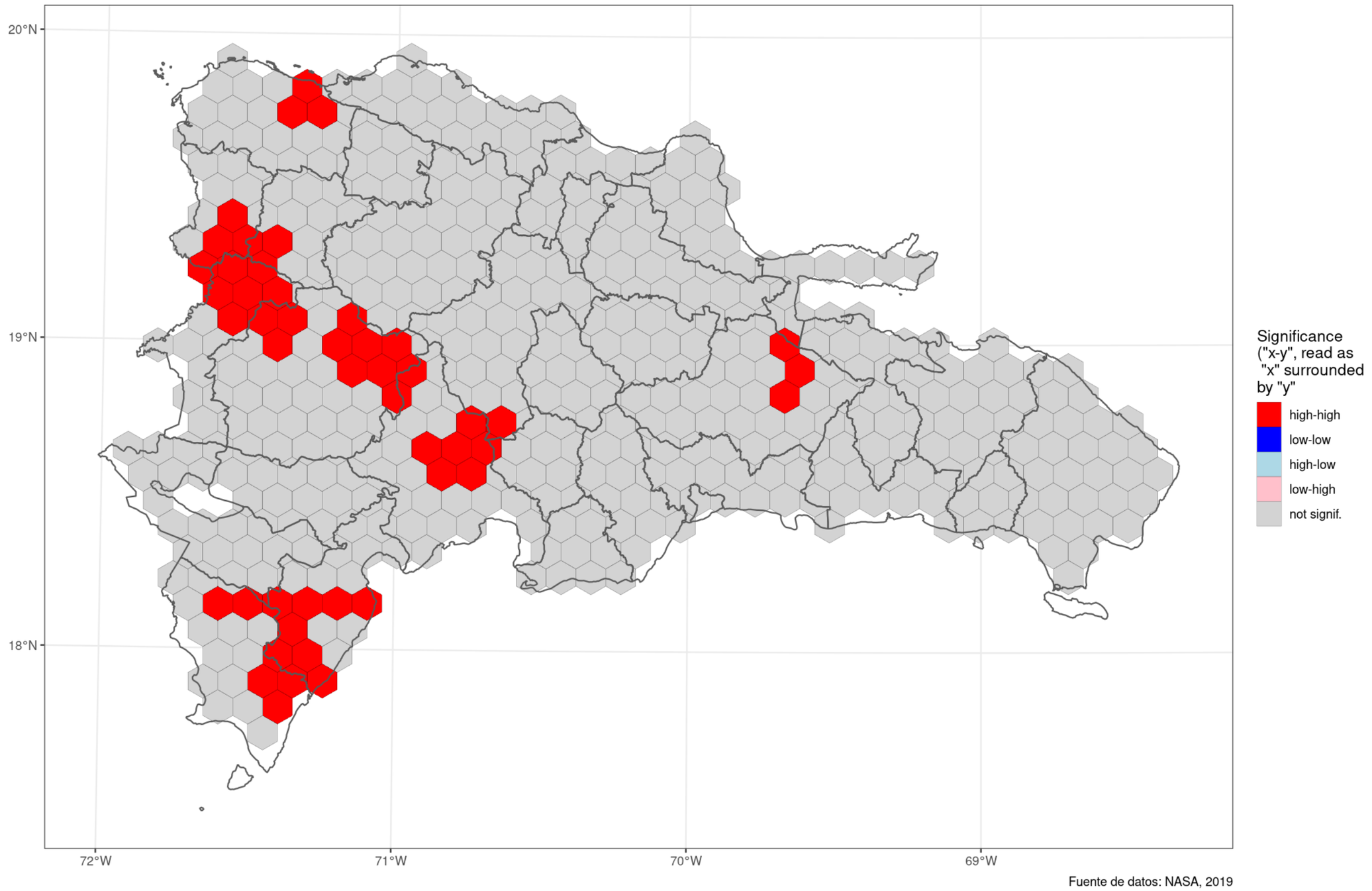



```
# * LISA Map LOSS0118_PUA_PYR_NORM
grdlisamapl0118 <- lisamap(objesp = grdzonal %>%
    replace(is.na(.), 0), var = "LOSS0118_PUA_PYR_NORM", pesos = grdww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
    leyenda = T, anchuratitulo = 1000, tamanotitulo = 16, fuentedatos = "Hansen et al., 2013",
    titulomapa = paste0("LISA clusters of forest loss per unit area per year, 2001-2018"))
```

```
# grdlisamapl0118$grafico$layers <- c(grdlisamapl0118$grafico$layers,
# geom_sf(data=prov, fill = 'transparent')[[1]])
grdlisamapl0118$grafico
```

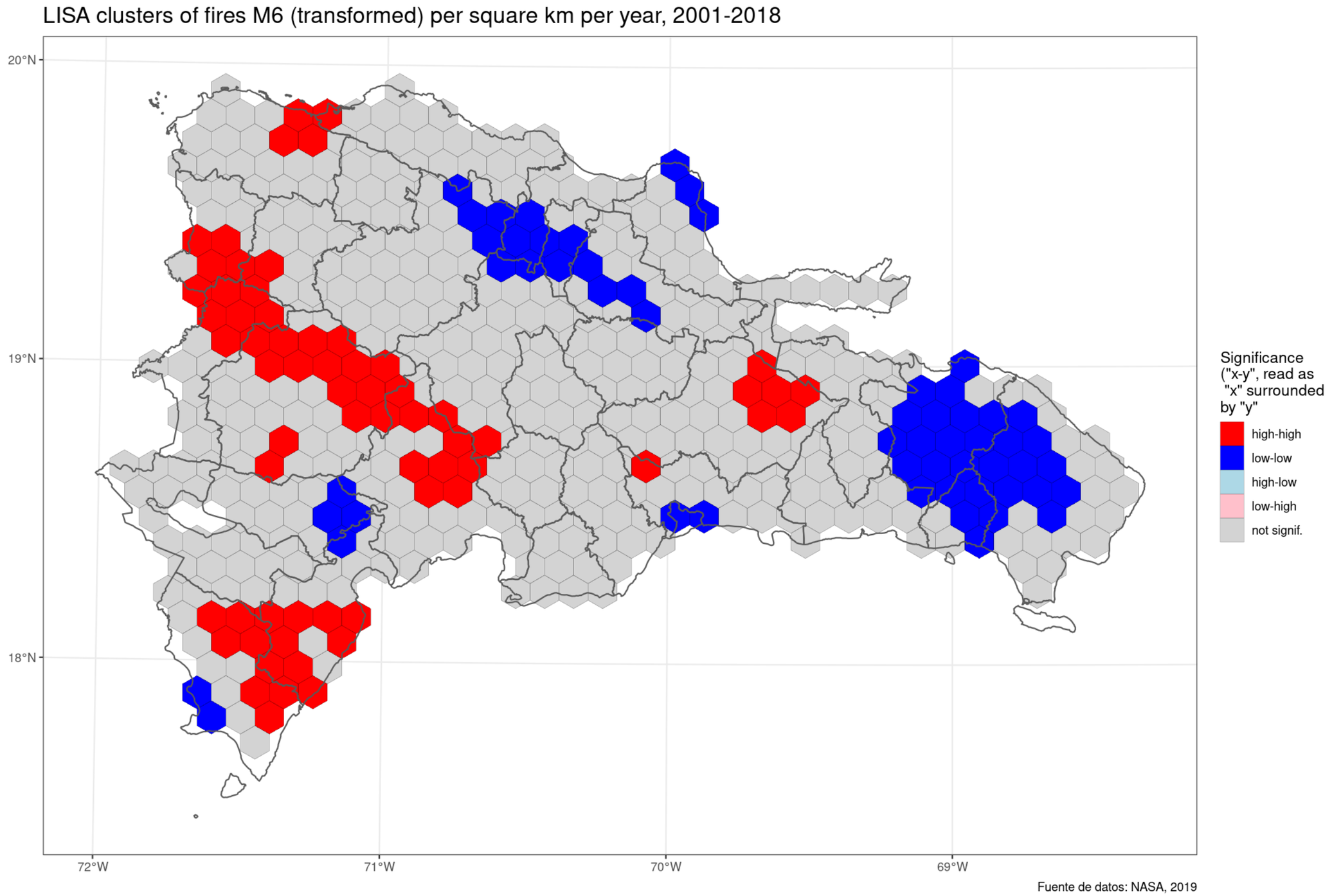


```r
# * LISA Map FIRESM6_PSQKM_PYR per square km per year
grdlisamapfm6 <- lisamap(objesp = grdzonal %>%
    replace(is.na(.), 0), var = "NFIRESM6_PSQKM_PYR", pesos = grdww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
    leyenda = T, anchuratitulo = 1000, tamanotitulo = 16, fuentedatos = "NASA, 2019",
    titulomapa = paste0("LISA clusters of fires M6 per square km per year, 2001-2018"))
grdlisamapfm6$grafico$layers <- c(grdlisamapfm6$grafico$layers, geom_sf(data = prov,
    fill = "transparent")[[1]])
grdlisamapfm6$grafico
```



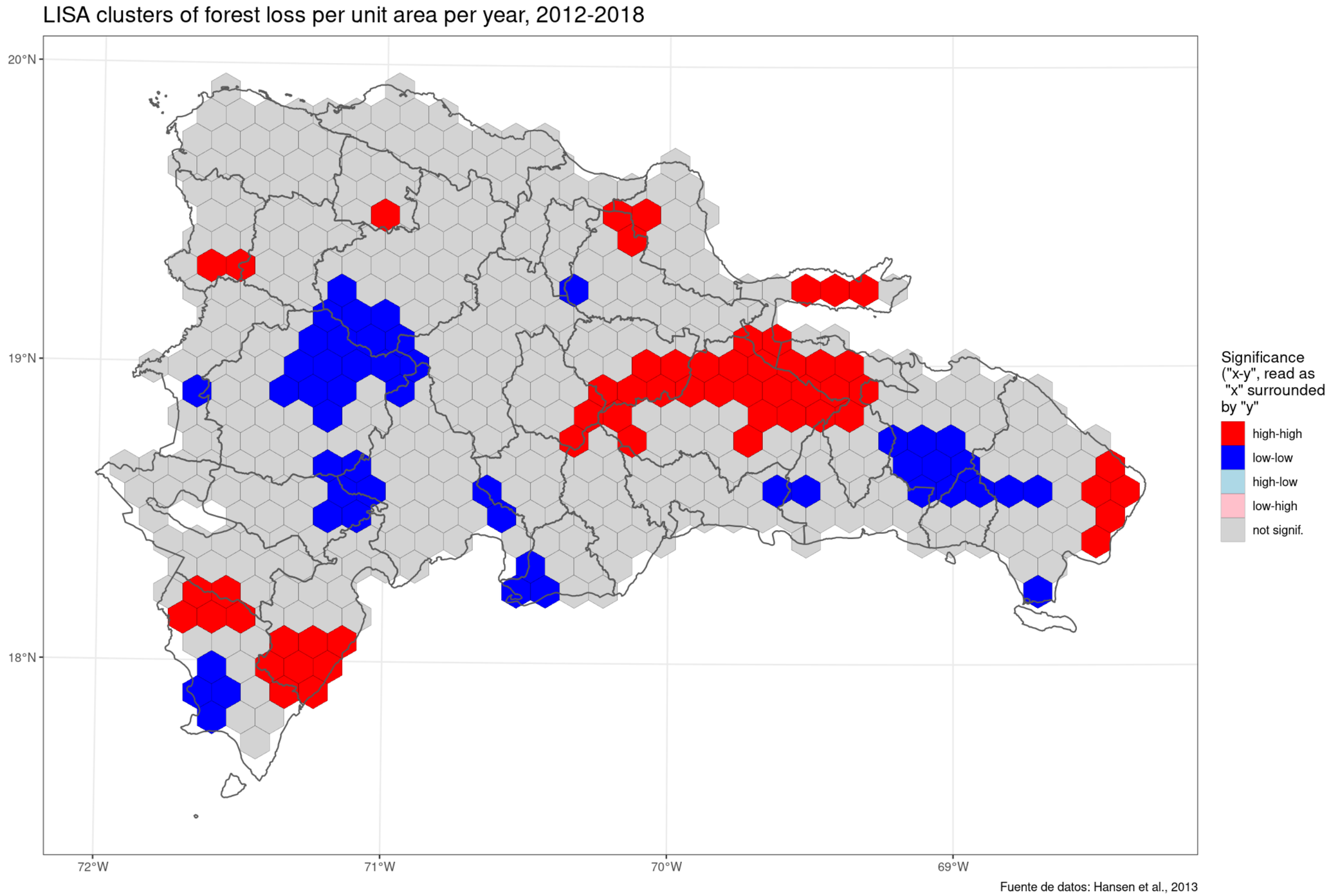

```
# * LISA Map FIRESM6_PSQKM_PYR_TLP per square km per year
grdlisamapfm6tlp <- lisamap(objesp = grdzonal %>%
    replace(is.na(.), 0), var = "NFIRESM6_PSQKM_PYR_TLP", pesos = grdww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
```

```
    leyenda = T, anchuratitulo = 1000, tamanotitulo = 16, fuentedatos = "NASA, 2019",
    titulomapa = paste0("LISA clusters of fires M6 (transformed) per square km per year, 2001-2018"))
grdlisamapfm6tlp$grafico$layers <- c(grdlisamapfm6tlp$grafico$layers, geom_sf(data = prov,
    fill = "transparent")[[1]])
grdlisamapfm6tlp$grafico
```



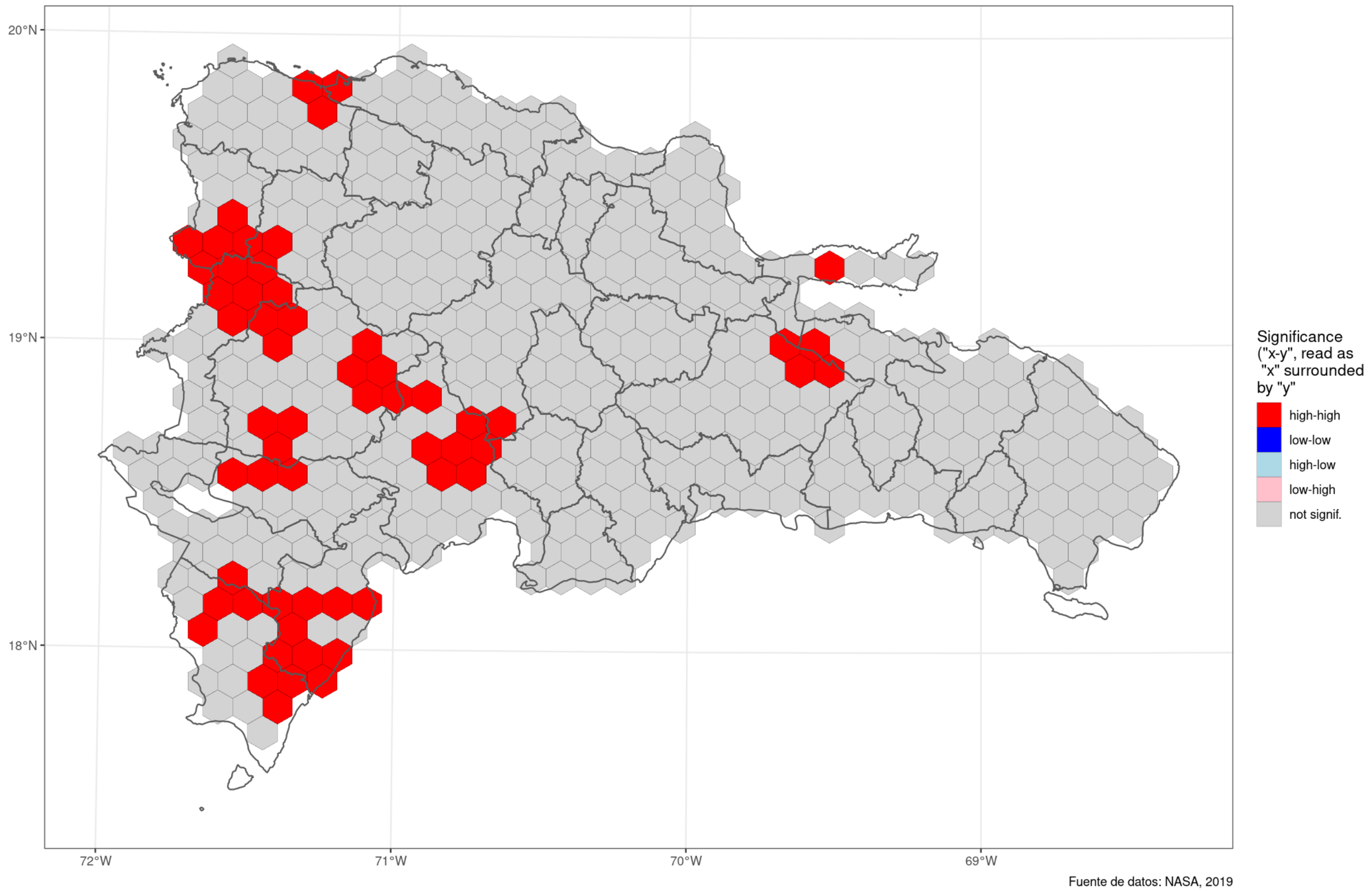

```
# * LISA Map LOSS1218_PUA_PYR_NORM
grdlisamapl1218 <- lisamap(objesp = grdzonal %>%
    replace(is.na(.), 0), var = "LOSS1218_PUA_PYR_NORM", pesos = grdww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
```

```
    leyenda = T, anchuratitulo = 1000, tamanotitulo = 16, fuentedatos = "Hansen et al., 2013",
    titulomapa = paste0("LISA clusters of forest loss per unit area per year, 2012-2018"))
grdlisamapl1218$grafico$layers <- c(grdlisamapl1218$grafico$layers, geom_sf(data = prov,
    fill = "transparent")[[1]])
grdlisamapl1218$grafico
```



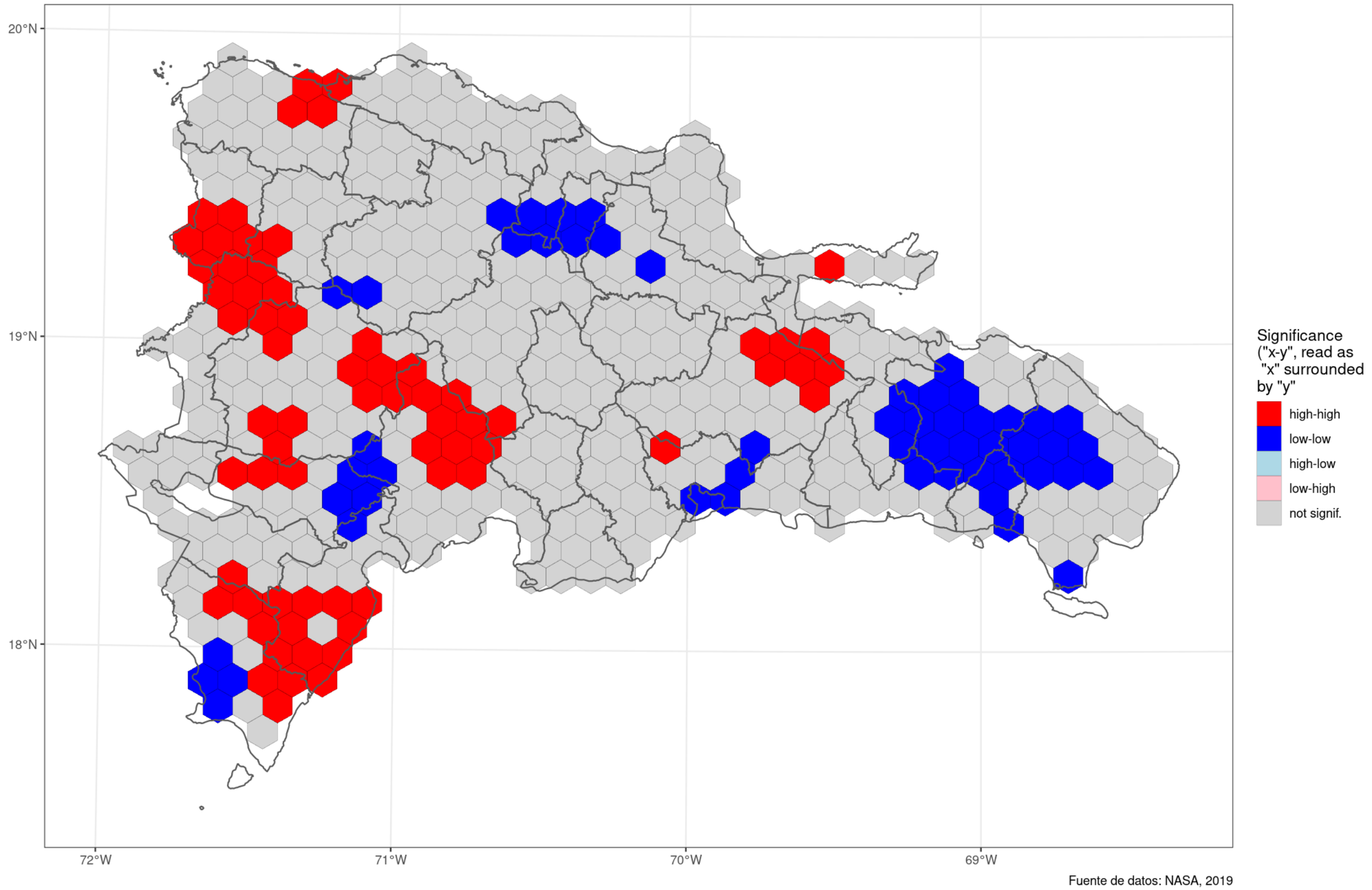

```
# * LISA Map FIRESV1_PSQKM_PYR per square km per year
grdlisamapfv1 <- lisamap(objesp = grdzonal %>%
    replace(is.na(.), 0), var = "NFIRESV1_PSQKM_PYR", pesos = grdww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
```

```
    leyenda = T, anchuratitulo = 1000, tamanotitulo = 16, fuentedatos = "NASA, 2019",
    titulomapa = paste0("LISA clusters of fires V1 per square km per year, 2012-2018"))
grdlisamapfv1$grafico$layers <- c(grdlisamapfv1$grafico$layers, geom_sf(data = prov,
    fill = "transparent")[[1]])
grdlisamapfv1$grafico
```



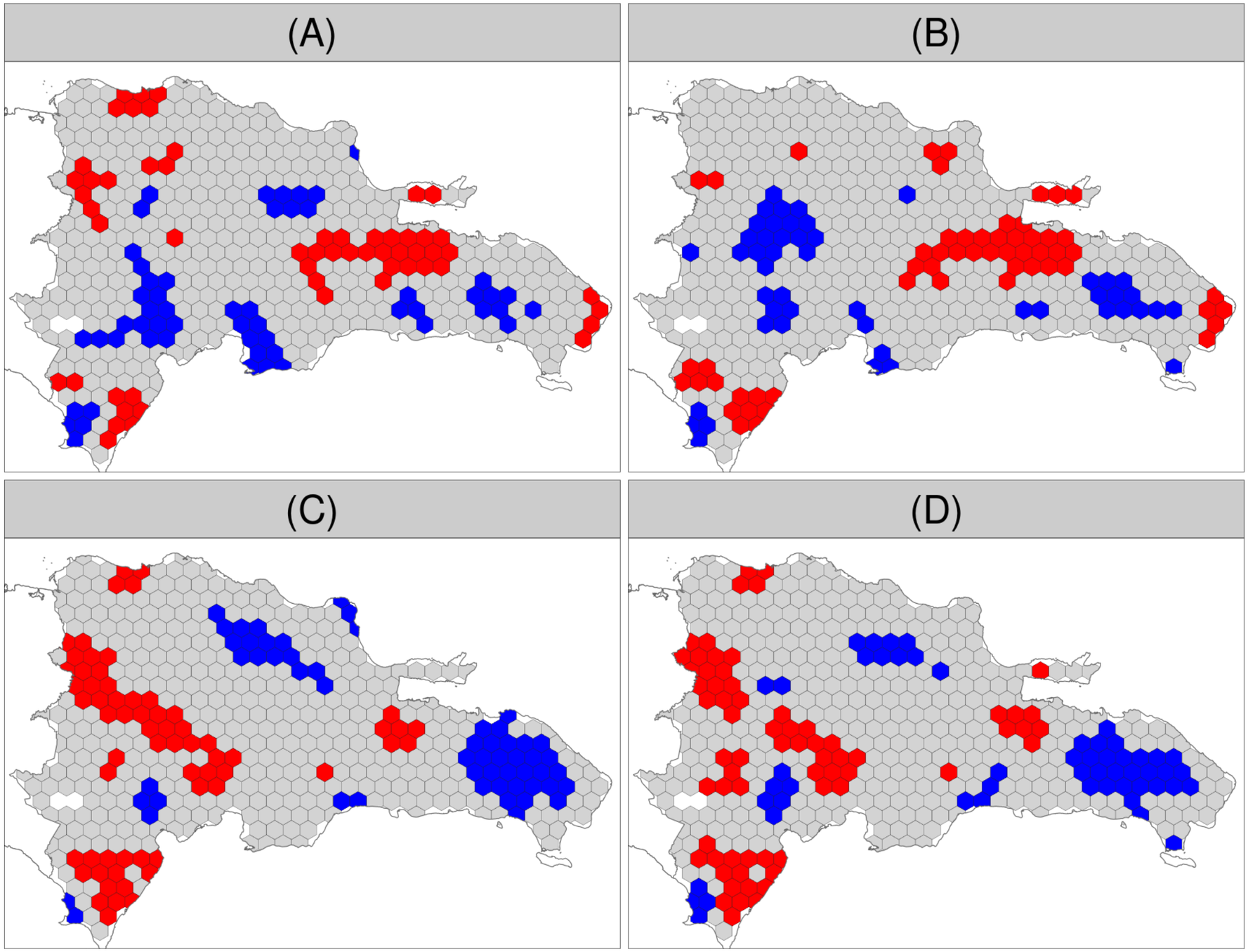

```
# * LISA Map FIRESV1_PSQKM_PYR_TLP per square km per year
grdlisamapfv1tlp <- lisamap(objesp = grdzonal %>%
    replace(is.na(.), 0), var = "NFIRESV1_PSQKM_PYR_TLP", pesos = grdww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
```

```
    leyenda = T, anchuratitulo = 1000, tamanotitulo = 16, fuentedatos = "NASA, 2019",
    titulomapa = paste0("LISA clusters of fires V1 (transformed) per square km per year, 2012-2018"))
grdlisamapfv1tlp$grafico$layers <- c(grdlisamapfv1tlp$grafico$layers, geom_sf(data = prov,
    fill = "transparent")[[1]])
grdlisamapfv1tlp$grafico
```




```
# * LISA Map FIRESM6_PSQKM_PYR_TLP per square km per year {tmap} (for
# manuscript)
grdlisamapl0118_obj <- lisamap_tmap_obj(objesp = grdzonal %>%
```

```
    replace(is.na(.), 0), var = "LOSS0118_PUA_PYR_NORM", pesos = grdww)
grdlisamapl1218_obj <- lisamap_tmap_obj(objesp = grdzonal %>%
    replace(is.na(.), 0), var = "LOSS1218_PUA_PYR_NORM", pesos = grdww)
grdlisamapfm6tlp_obj <- lisamap_tmap_obj(objesp = grdzonal %>%
    replace(is.na(.), 0), var = "NFIRESM6_PSQKM_PYR_TLP", pesos = grdww)
grdlisamapfv1tlp_obj <- lisamap_tmap_obj(objesp = grdzonal %>%
    replace(is.na(.), 0), var = "NFIRESV1_PSQKM_PYR_TLP", pesos = grdww)

grdlisamap_objs <- grdlisamapl0118_obj %>%
    select(-LOSS0118_PUA_PYR_NORM) %>%
    inner_join(Reduce(function(...) merge(..., by = "ENLACE", all.x = TRUE), list(grdlisamapl0118_obj %>%
        st_drop_geometry(), grdlisamapl1218_obj %>%
        st_drop_geometry(), grdlisamapfm6tlp_obj %>%
        st_drop_geometry(), grdlisamapfv1tlp_obj %>%
        st_drop_geometry())), by = "ENLACE")
# jpeg('out/lisamaps_loss0118_loss1218_firesm6_firesv1.jpg', width = 3840,
# height = 2160, res = 250)
{
    grdlisamap_objs %>%
        dplyr::select(`(A)` = LOSS0118_PUA_PYR_NORM, `(B)` = LOSS1218_PUA_PYR_NORM,
            `(C)` = NFIRESM6_PSQKM_PYR_TLP, `(D)` = NFIRESV1_PSQKM_PYR_TLP) %>%
        replace(is.na(.), 0) %>%
        gather(variable, value, -geometry) %>%
        mutate(variable = factor(variable, levels = unique(variable))) %>%
        mutate(color = case_when(value == "high-high" ~ "red", value == "low-low" ~
            "blue", value == "high-low" ~ "lightblue", value == "low-high" ~ "pink",
            value == "not signif." ~ "lightgrey")) %>%
        tm_shape() + tm_fill(col = "color", size = 0.1, legend.is.portrait = T, legend.format = list(digits = 2,
        text.separator = "-")) + tm_borders(col = "grey15", lwd = 0.3) + tm_facets(by = "variable",
        nrow = 2, free.coords = FALSE, free.scales = TRUE) + tm_layout(panel.label.size = 3,
        legend.title.size = 1e-04, legend.text.size = 1.8, bg.color = "white", legend.format = list(fun = function(x) formatC(x,
            digits = 2, format = "f"))) + tm_shape(seaocean) + tm_borders() + tm_fill(col = "white")  #+
    # tm_shape(points_of_interest) + tm_text('code', size = 2, col = 'black',
    # fontface = 'bold', bg.color = 'white', bg.alpha = 0.5)
}
```

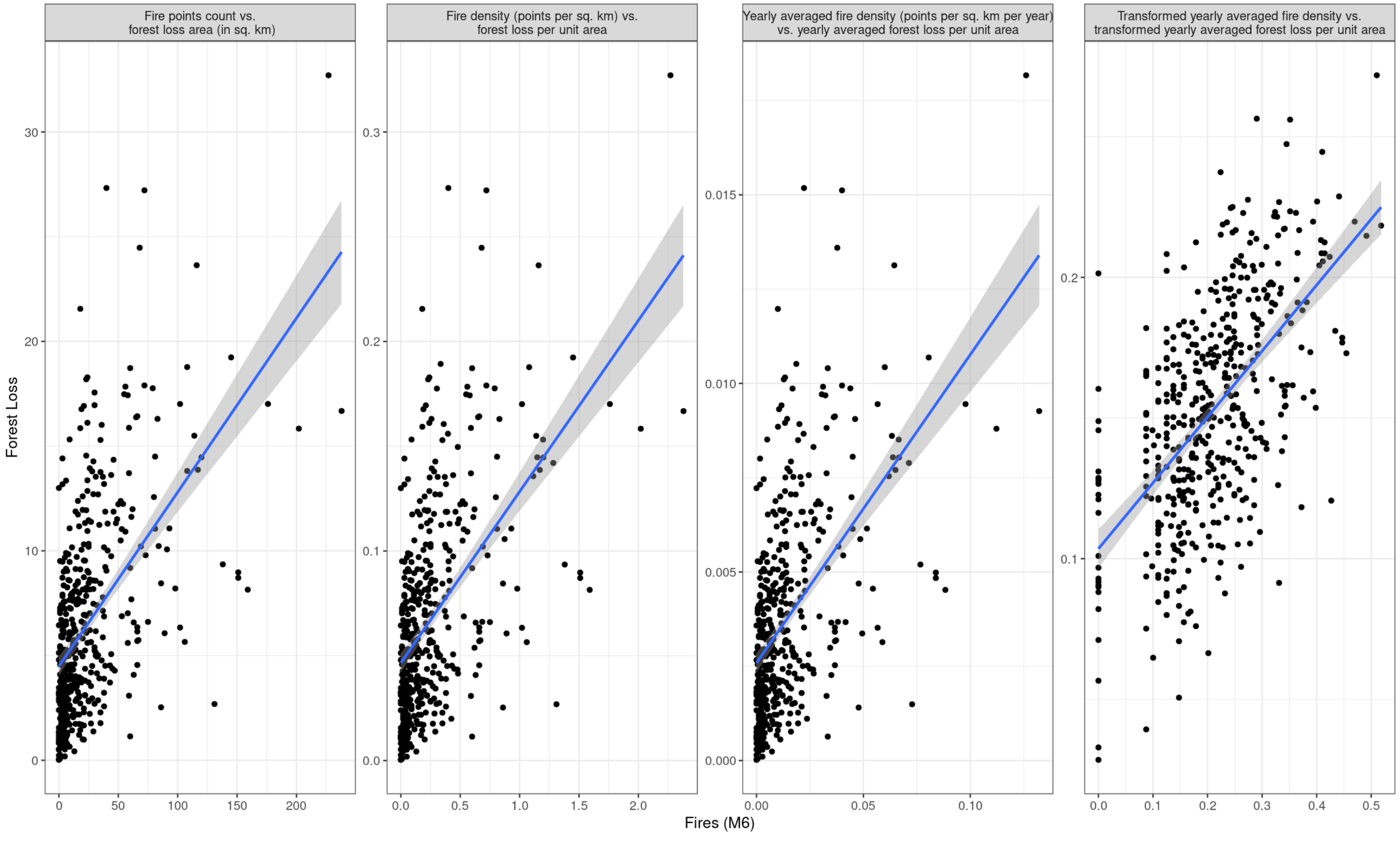



```
# dev.off()

# Statistical summaries
grdzonaledam6 <- grdzonal %>%
    mutate(LOSS0118_AREASQKM = LOSS0118_AREASQM/1e+06) %>%
```

```
    dplyr::select(ENLACE, NFIRESM6, NFIRESM6_PSQKM, NFIRESM6_PSQKM_PYR, NFIRESM6_PSQKM_PYR_TLP,
        LOSS0118_AREASQKM, LOSS0118_PUA, LOSS0118_PUA_PYR, LOSS0118_PUA_PYR_NORM) %>%
    replace(is.na(.), 0)

grdzonaledav1 <- grdzonal %>%
    mutate(LOSS1218_AREASQKM = LOSS1218_AREASQM/1e+06) %>%
    dplyr::select(ENLACE, NFIRESV1, NFIRESV1_PSQKM, NFIRESV1_PSQKM_PYR, NFIRESV1_PSQKM_PYR_TLP,
        LOSS1218_AREASQKM, LOSS1218_PUA, LOSS1218_PUA_PYR, LOSS1218_PUA_PYR_NORM) %>%
    replace(is.na(.), 0)
# Statistical summaries (latex table for manuscript)
grdzonaledam6 %>%
    st_drop_geometry %>%
    gather(key, val) %>%
    distinct(key)
##                     key
## 1                ENLACE
## 2              NFIRESM6
## 3         NFIRESM6_PSQKM
## 4     NFIRESM6_PSQKM_PYR
## 5 NFIRESM6_PSQKM_PYR_TLP
## 6      LOSS0118_AREASQKM
## 7           LOSS0118_PUA
## 8       LOSS0118_PUA_PYR
## 9  LOSS0118_PUA_PYR_NORM
grdzonaledam6 %>%
    st_drop_geometry %>%
    summarise(`Total number of fire points` = sum(NFIRESM6), `Average number of fire points per 100 sq. km` = mean(NFIRESM6_PSQKM) *
        100, `Average number of fire points per 100 sq. km per year` = mean(NFIRESM6_PSQKM_PYR) *
        100, `Maximum number of fire points per 100 sq. km per year` = max(NFIRESM6_PSQKM_PYR) *
        100, `Total forest loss area (sq. km)` = sum(LOSS0118_AREASQKM), `Average forest loss area (sq. km) per 100 sq. km` = mean(LOSS0118_PUA) *
        100, `Average forest loss area (sq. km) per 100 sq. km per year` = mean(LOSS0118_PUA_PYR) *
        100, `Maximum forest loss area (sq. km) per 100 sq. km per year` = max(LOSS0118_PUA_PYR) *
        100) %>%
    gather(Attribute, `Period 2001-2018, MODIS fire points`) %>%
    inner_join(grdzonaledav1 %>%
        st_drop_geometry %>%
        summarise(`Total number of fire points` = sum(NFIRESV1), `Average number of fire points per 100 sq. km` = mean(NFIRESV1_PSQKM) *
            100, `Average number of fire points per 100 sq. km per year` = mean(NFIRESV1_PSQKM_PYR) *
            100, `Maximum number of fire points per 100 sq. km per year` = max(NFIRESV1_PSQKM_PYR) *
            100, `Total forest loss area (sq. km)` = sum(LOSS1218_AREASQKM), `Average forest loss area (sq. km) per 100 sq. km` = mean(LOSS1218_PUA) *
            100, `Average forest loss area (sq. km) per 100 sq. km per year` = mean(LOSS1218_PUA_PYR) *
            100, `Maximum forest loss area (sq. km) per 100 sq. km per year` = max(LOSS1218_PUA_PYR) *
            100) %>%
        gather(Attribute, `Period 2012-2018, VIIRS fire points`)) %>%
    mutate_if(is.numeric, round, 2) %>%
    mutate_if(is.numeric, as.character) %>%
    knitr::kable(format = "latex", digits = 2)
```

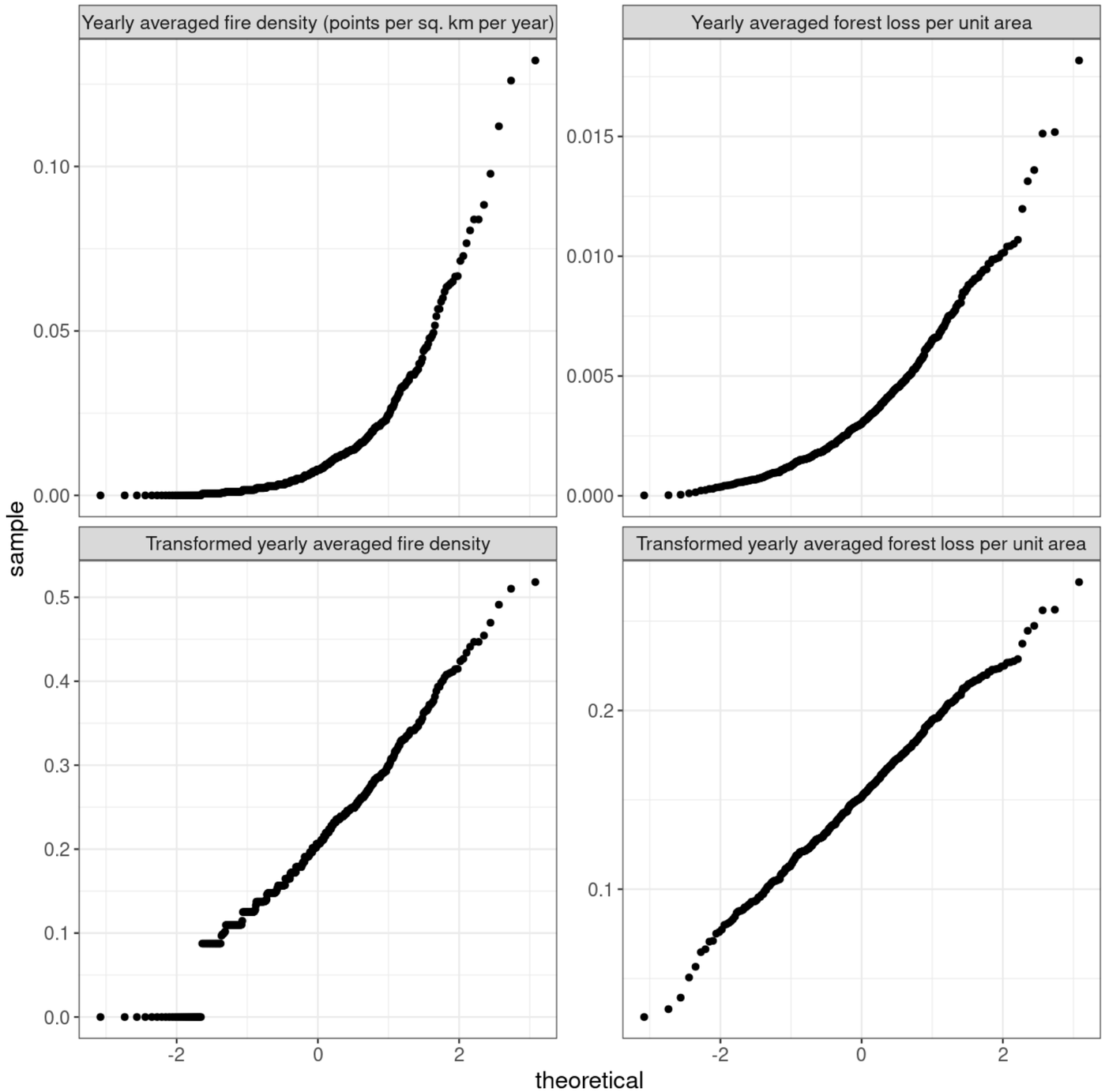
Attribute	Period 2001-2018, MODIS fire points	Period 2012-2018, VIIRS fire points
Total number of fire points	11666	25231
Average number of fire points per 100 sq. km	25.13	54.86
Average number of fire points per 100 sq. km per year	1.4	7.84
Maximum number of fire points per 100 sq. km per year	13.22	67.29
Total forest loss area (sq. km)	3135.22	1461.42
Average forest loss area (sq. km) per 100 sq. km	6.72	3.13
Average forest loss area (sq. km) per 100 sq. km per year	0.37	0.45
Maximum forest loss area (sq. km) per 100 sq. km per year	1.82	3.21

```r
# Scatterplots
grdzonaledam6 %>%
    st_drop_geometry %>%
    gather(key, val, -ENLACE) %>%
    mutate(axes = stringi::stri_replace_all_regex(str = key, pattern = c("NFIRESM6.*",
        "LOSS.*"), replacement = c("Fires (M6)", "Forest Loss"), vectorize_all = F),
        pane = stringi::stri_replace_all_regex(str = key, pattern = c(".*M6$|.*AREASQKM$",
            ".*PSQKM$|.*PUA$", ".*PSQKM_PYR$|.*PUA_PYR$", ".*PYR_TLP$|.*PYR_NORM$"),
            replacement = c("Fire points count vs.\n forest loss area (in sq. km)",
                "Fire density (points per sq. km) vs.\nforest loss per unit area",
                "Yearly averaged fire density (points per sq. km per year)\nvs. yearly averaged forest loss per unit area",
                "Transformed yearly averaged fire density vs.\ntransformed yearly averaged forest loss per unit area"),
            vectorize_all = F)) %>%
    dplyr::select(-key) %>%
    tidyr::spread(axes, val) %>%
    mutate(pane = factor(pane, levels = unique(pane)[c(2, 1, 4, 3)])) %>%
    ggplot() + aes(x = `Fires (M6)`, y = `Forest Loss`) + geom_point() + geom_smooth(method = "lm") +
    facet_wrap(~pane, scales = "free", ncol = 4) + theme_bw() + theme(text = element_text(size = 12))
```



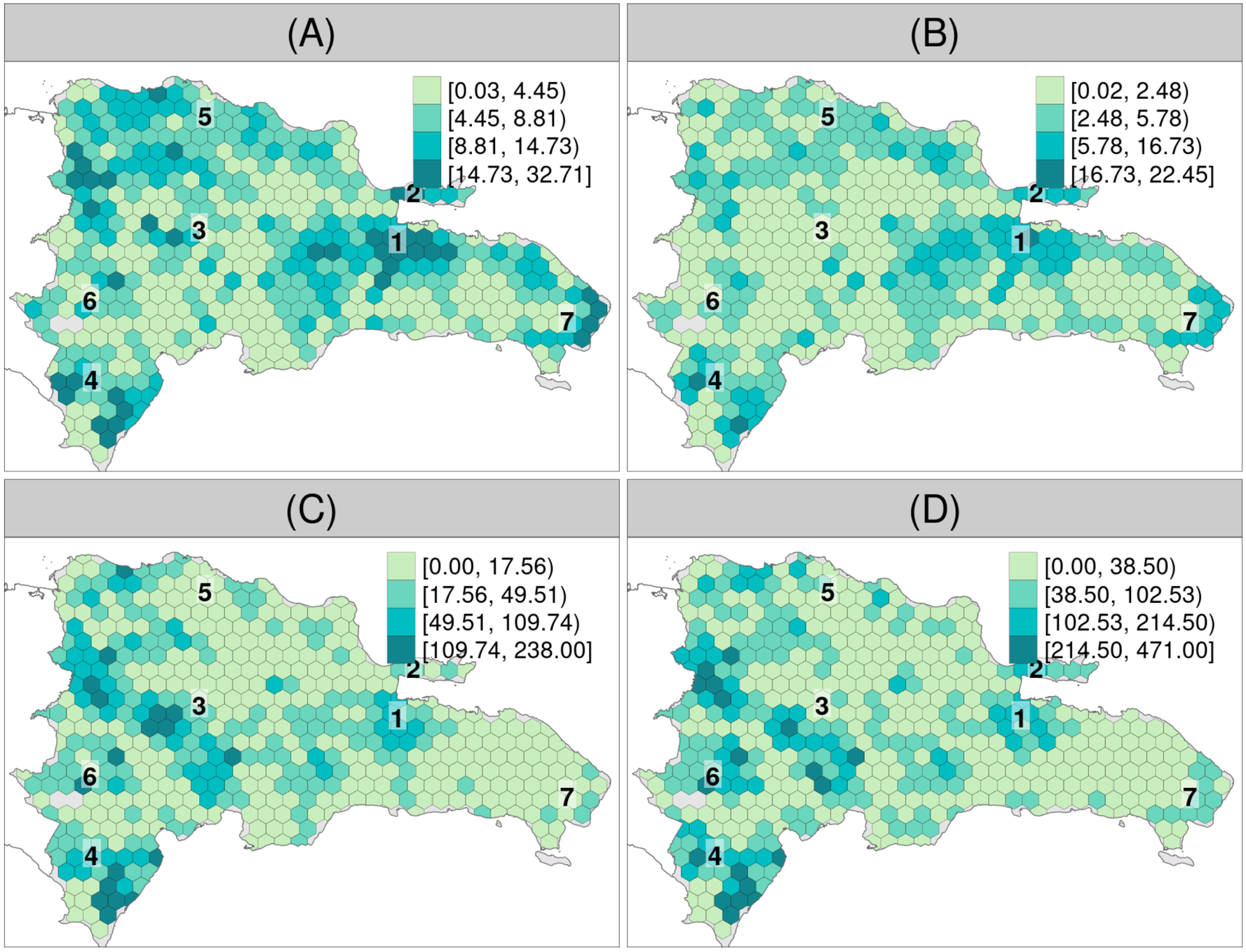

```
# QQ-norm
grdzonaledam6 %>%
    st_drop_geometry %>%
    dplyr::select(matches(".*PSQKM_PYR$|.*PUA_PYR$|.*PYR_TLP$|.*PYR_NORM$")) %>%
```

```
    gather(key, val) %>%
    mutate(key = stringi::stri_replace_all_regex(str = key, pattern = c(".*PSQKM_PYR$",
        ".*PUA_PYR$", ".*PYR_TLP$", ".*PYR_NORM$"), replacement = c("Yearly averaged fire density (points per sq. km per year)",
        "Yearly averaged forest loss per unit area", "Transformed yearly averaged fire density",
        "Transformed yearly averaged forest loss per unit area"), vectorize_all = F)) %>%
    mutate(key = factor(key, levels = sort(unique(key))[c(3, 4, 1, 2)])) %>%
    ggplot + aes(sample = val) + geom_qq() + facet_wrap(~key, scales = "free_y",
    nrow = 2, dir = "h") + theme_bw() + theme(text = element_text(size = 14), aspect.ratio = 1)
```




```
# Maps (for manuscript)
{
    # jpeg('out/maps_loss0118_loss1218_firesm6_firesv1.jpg', width = 3840,
    # height = 2160, res = 250)
```

```
    grdzonal %>%
        dplyr::select(`(A)` = LOSS0118_PUA, `(B)` = LOSS1218_PUA, `(C)` = NFIRESM6_PSQKM,
            `(D)` = NFIRESV1_PSQKM) %>%
        mutate_if(is.numeric, funs(. * 100)) %>%
        replace(is.na(.), 0) %>%
        gather(variable, value, -geometry) %>%
        mutate(variable = factor(variable, levels = unique(variable))) %>%
        tm_shape() + tm_fill(col = "value", palette = c("#c9eebd", "#69d6bd", "#00bdc1",
        "#10858d"), size = 0.1, style = "kmeans", legend.is.portrait = T, legend.format = list(digits = 2,
        text.separator = "-"), n = 4) + tm_borders(col = "grey15", lwd = 0.3) + tm_facets(by = "variable",
        nrow = 2, free.coords = FALSE, free.scales = TRUE) + tm_layout(panel.label.size = 3,
        legend.title.size = 1e-04, legend.text.size = 1.8, bg.color = "grey90", legend.format = list(scientific = TRUE,
            fun = function(x) formatC(x, digits = 2, format = "f"))) + tm_shape(seaocean) +
        tm_borders() + tm_fill(col = "white") + tm_shape(points_of_interest) + tm_text("code",
        size = 2, col = "black", fontface = "bold", bg.color = "white", bg.alpha = 0.5)
    # dev.off()
}
```


(A)
[0.03, 4.45)
[4.45, 8.81)
[8.81, 14.73)
[14.73, 32.71]
1
2
3
4
5
6
7
(B)
[0.02, 2.48)
[2.48, 5.78)
[5.78, 16.73)
[16.73, 22.45]
1
2
3
4
5
6
7
(C)
[0.00, 17.56)
[17.56, 49.51)
[49.51, 109.74)
[109.74, 238.00]
1
2
3
4
5
6
7
(D)
[0.00, 38.50)
[38.50, 102.53)
[102.53, 214.50)
[214.50, 471.00]
1
2
3
4
5
6
7

```
# ** LM LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP
grdzonal %>%
    st_drop_geometry() %>%
    replace(is.na(.), 0) %>%
    remove_rownames %>%
    column_to_rownames("ENLACE") %>%
    lm(LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP, data = .) -> grdlm4
grdlm4 %>%
    summary()
##
## Call:
## lm(formula = LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP,
##     data = .)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.089725 -0.022791  0.001563  0.022809  0.097884
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)           0.103522   0.003509   29.50   <2e-16 ***
## NFIRESM6_PSQKM_PYR_TLP 0.234352   0.015184   15.43   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.03212 on 480 degrees of freedom
## Multiple R-squared:  0.3317, Adjusted R-squared:  0.3303
## F-statistic: 238.2 on 1 and 480 DF,  p-value: < 2.2e-16
grdlm4 %>%
    AIC()
## [1] -1942.651
grdlm4 %>%
    logLik()
## 'log Lik.' 974.3256 (df=3)
grdlm4 %>%
    lmtest::bptest()  #Heteroscedastic model
##
##  studentized Breusch-Pagan test
##
## data:  .
## BP = 0.091206, df = 1, p-value = 0.7626
lm.morantest(grdlm4, grdww)
##
##  Global Moran I for regression residuals
##
## data:
## model: lm(formula = LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP,
## data = .)
## weights: grdww
##
## Moran I statistic standard deviate = 18.413, p-value < 2.2e-16
## alternative hypothesis: greater
## sample estimates:
## Observed Moran I      Expectation         Variance
##     0.5151532429    -0.0031706302     0.0007924433
# Note to self: spatially autocorrelated residuals. This model is not suitable
```

```r
# to predict loss 01-18

# Lagrange multiplier test
lmultests <- lm.LMtests(model = grdlm4, listw = grdww, test = c("LMerr", "LMlag",
    "RLMerr", "RLMlag"))
lmultests
##
##  Lagrange multiplier diagnostics for spatial dependence
##
## data:
## model: lm(formula = LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP,
## data = .)
## weights: grdww
##
## LMerr = 330, df = 1, p-value < 2.2e-16
##
##
##  Lagrange multiplier diagnostics for spatial dependence
##
## data:
## model: lm(formula = LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP,
## data = .)
## weights: grdww
##
## LMlag = 227.22, df = 1, p-value < 2.2e-16
##
##
##  Lagrange multiplier diagnostics for spatial dependence
##
## data:
## model: lm(formula = LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP,
## data = .)
## weights: grdww
##
## RLMerr = 106.49, df = 1, p-value < 2.2e-16
##
##
##  Lagrange multiplier diagnostics for spatial dependence
##
## data:
## model: lm(formula = LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP,
## data = .)
## weights: grdww
##
## RLMlag = 3.7185, df = 1, p-value = 0.05381
tlmultests <- t(sapply(lmultests, function(x) c(x$statistic, x$p.value)))
colnames(tlmultests) <- c("Statistic", "p-value")
printCoefmat(tlmultests) %>%
    knitr::kable(format = "latex", digits = 2)  #Latex output for manuscript
##        Statistic p-value
## LMerr   329.9950  0.0000
## LMlag   227.2204  0.0000
## RLMerr  106.4931  0.0000
## RLMlag    3.7185  0.0538
```

	Statistic	p-value
LMerr	330.00	0.00
LMlag	227.22	0.00
RLMerr	106.49	0.00
RLMlag	3.72	0.05

```
# Both LMerr and LMlag are statistically significant, so it is assumed that
# either the lagged variable (with a lagsarlm model) or the error dependence
# (with a errorsarlm model) improve the result. However, the robust counterpart
# of LMlag, RLMlag, is not significant, so the error dependence robust test
# (RLMerr) suggests that errorsarlm model is the most likely alternative.

# ** ERROR SAR, LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP
grdzonal %>%
    st_drop_geometry() %>%
    replace(is.na(.), 0) %>%
    spatialreg::errorsarlm(LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP, data = .,
        listw = grdww) -> grdesar1
grdesar1 %>%
    summary(Nagelkerke = T)
##
## Call:
## spatialreg::errorsarlm(formula = LOSS0118_PUA_PYR_NORM ~ NFIRESM6_PSQKM_PYR_TLP,
##     data = ., listw = grdww)
##
## Residuals:
##         Min          1Q      Median          3Q         Max
## -0.08081042 -0.01558612  0.00064743  0.01430194  0.09576362
##
## Type: error
## Coefficients: (asymptotic standard errors)
##                          Estimate Std. Error z value  Pr(>|z|)
## (Intercept)             0.0986476  0.0050648  19.477 < 2.2e-16
## NFIRESM6_PSQKM_PYR_TLP 0.2497097  0.0154632  16.149 < 2.2e-16
##
## Lambda: 0.73146, LR test value: 243.26, p-value: < 2.22e-16
## Asymptotic standard error: 0.036645
##     z-value: 19.96, p-value: < 2.22e-16
## Wald statistic: 398.42, p-value: < 2.22e-16
##
## Log likelihood: 1095.956 for error model
## ML residual variance (sigma squared): 0.00053902, (sigma: 0.023217)
## Nagelkerke pseudo-R-squared: 0.59654
## Number of observations: 482
## Number of parameters estimated: 4
## AIC: -2183.9, (AIC for lm: -1942.7)
spatialreg::bptest.Sarlm(grdesar1)
##
##  studentized Breusch-Pagan test
##
## data:
## BP = 0.45483, df = 1, p-value = 0.5001
grdesar1 %>%
    residuals.sarlm() %>%
    moran.test(listw = grdww)
##
##  Moran I test under randomisation
##
```

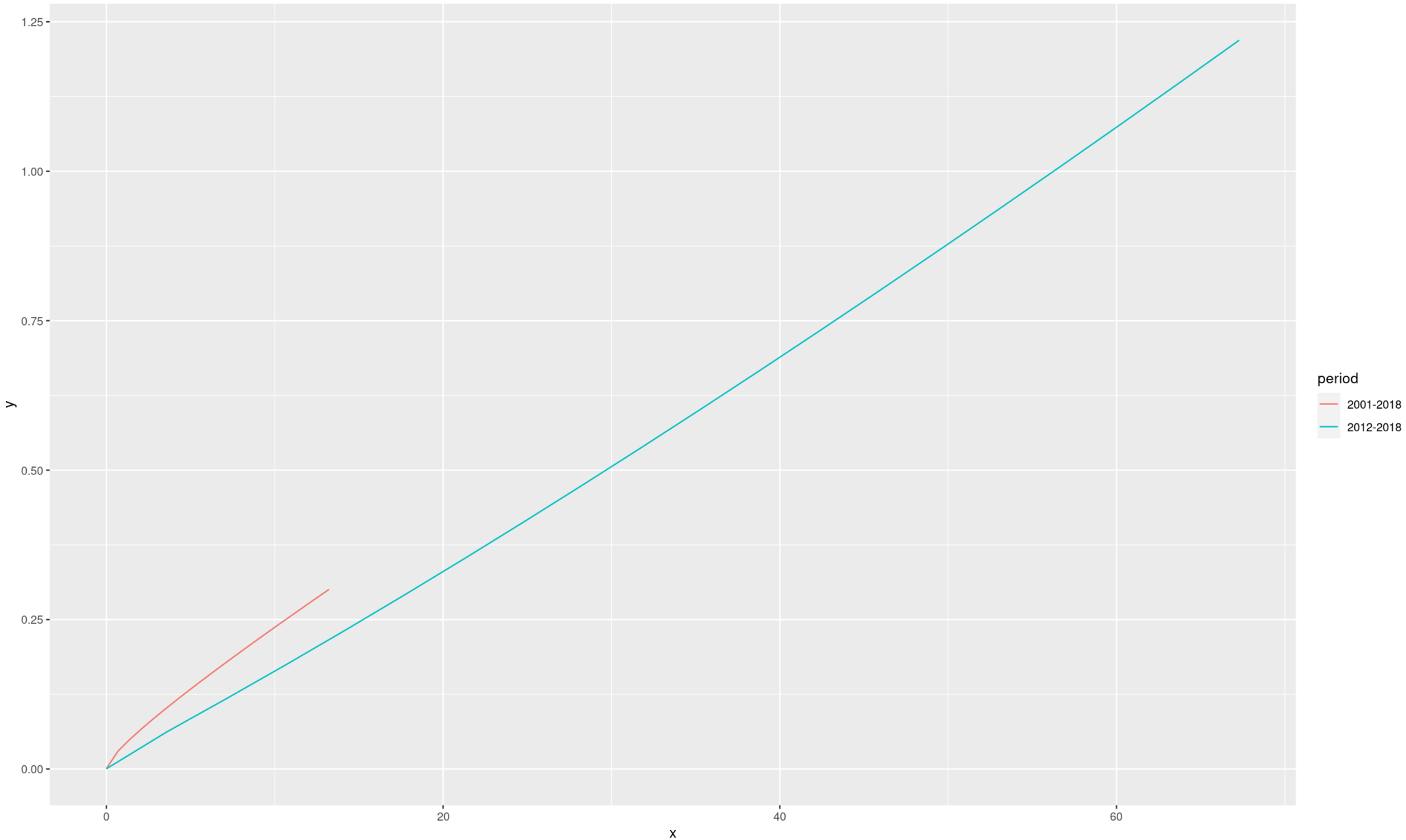
```
## data:  .
## weights: grdww
##
## Moran I statistic standard deviate = -0.0012016, p-value = 0.5005
## alternative hypothesis: greater
## sample estimates:
## Moran I statistic       Expectation          Variance
##      -0.002112870      -0.002079002       0.000794349

# Summaries
grdzonal$NFIRESM6 %>%
    summary()
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
##    1.00    5.25   14.00   25.47   30.75  238.00      24
grdzonal$NFIRESM6_PSQKM %>%
    summary()
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
##  0.0100  0.0600  0.1500  0.2645  0.3200  2.3800      24
grdzonal$NFIRESM6_PSQKM_PYR %>%
    summary()
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.     NA's
## 0.000556 0.003333 0.008333 0.014694 0.017778 0.132222       24

# * Predict forest loss per unit area per year, based on number of fires per
# 100 sq. km per year
rangenfm6_100sqkm <- seq(0, max(grdzonal$NFIRESM6_PSQKM_PYR, na.rm = T), length.out = 20) *
    100
fl <- NULL
nf <- NULL
predictfor_100 <- NULL
for (nf in 1:20) {
    # These are actual figures of number of fires
    fl <- (coef.sarlm(grdesar1)[[3]] * (rangenfm6_100sqkm[nf]^0.325) + coef.sarlm(grdesar1)[[2]])^(1/0.325)
    predictfor_100[nf] <- fl
}
rangenfm6_100sqkm
##  [1]  0.0000000  0.6959064  1.3918129  2.0877193  2.7836257  3.4795322
##  [7]  4.1754386  4.8713450  5.5672515  6.2631579  6.9590643  7.6549708
## [13]  8.3508772  9.0467836  9.7426901 10.4385965 11.1345029 11.8304094
## [19] 12.5263158 13.2222222
predictfor_100
##  [1] 0.0008033077 0.0301924015 0.0495802699 0.0672171021 0.0839111640
##  [6] 0.0999852339 0.1156086838 0.1308840303 0.1458791457 0.1606418403
## [11] 0.1752073637 0.1896026301 0.2038487673 0.2179627389 0.2319584219
## [16] 0.2458473484 0.2596392313 0.2733423477 0.2869638222 0.3005098430
diff((predictfor_100 * 1e+06))
##  [1] 29389.09 19387.87 17636.83 16694.06 16074.07 15623.45 15275.35 14995.12
##  [9] 14762.69 14565.52 14395.27 14246.14 14113.97 13995.68 13888.93 13791.88
## [17] 13703.12 13621.47 13546.02
mean(diff((predictfor_100 * 1e+06)))
## [1] 15774.03
```

```
# ** ERROR SAR, LOSS1218_PUA_PYR_NORM ~ NFIRESV1_PSQKM_PYR_TLP
grdzonal %>%
    st_drop_geometry() %>%
    replace(is.na(.), 0) %>%
    spatialreg::errorsarlm(LOSS1218_PUA_PYR_NORM ~ NFIRESV1_PSQKM_PYR_TLP, data = .,
        listw = grdww) -> grdesarv1
grdesarv1 %>%
    summary(Nagelkerke = T)
##
## Call:
## spatialreg::errorsarlm(formula = LOSS1218_PUA_PYR_NORM ~ NFIRESV1_PSQKM_PYR_TLP,
##     data = ., listw = grdww)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -0.1306098 -0.0207140  0.0020657  0.0194729  0.1263294
##
## Type: error
## Coefficients: (asymptotic standard errors)
##                         Estimate Std. Error z value  Pr(>|z|)
## (Intercept)            0.1729754  0.0079585  21.735 < 2.2e-16
## NFIRESV1_PSQKM_PYR_TLP 0.2468619  0.0138606  17.810 < 2.2e-16
##
## Lambda: 0.73987, LR test value: 252.43, p-value: < 2.22e-16
## Asymptotic standard error: 0.035926
##     z-value: 20.595, p-value: < 2.22e-16
## Wald statistic: 424.14, p-value: < 2.22e-16
##
## Log likelihood: 936.7731 for error model
## ML residual variance (sigma squared): 0.0010389, (sigma: 0.032232)
## Nagelkerke pseudo-R-squared: 0.62438
## Number of observations: 482
## Number of parameters estimated: 4
## AIC: -1865.5, (AIC for lm: -1615.1)
spatialreg::bptest.Sarlm(grdesarv1)
##
##  studentized Breusch-Pagan test
##
## data:
## BP = 3.5829, df = 1, p-value = 0.05838
grdesarv1 %>%
    residuals.sarlm() %>%
    moran.test(listw = grdww)
##
##  Moran I test under randomisation
##
## data:  .
## weights: grdww
##
## Moran I statistic standard deviate = -0.48027, p-value = 0.6845
## alternative hypothesis: greater
## sample estimates:
## Moran I statistic       Expectation          Variance
##     -0.0156087685     -0.0020790021      0.0007936127

# * Predict forest loss per unit area per year, based on number of fires per
```

```r
# 100 sq. km per year
rangenfv1_100sqkm <- seq(0, max(grdzonal$NFIRESV1_PSQKM_PYR, na.rm = T), length.out = 20) *
    100
fl <- NULL
nf <- NULL
predictfor1218_100 <- NULL
for (nf in 1:20) {
    # These are actual figures of number of fires
    fl <- (coef.sarlm(grdesarv1)[[3]] * (rangenfv1_100sqkm[nf]^0.3) + coef.sarlm(grdesarv1)[[2]])^(1/0.225)
    predictfor1218_100[nf] <- fl
}
rangenfv1_100sqkm
##  [1]  0.000000  3.541353  7.082707 10.624060 14.165414 17.706767 21.248120
##  [8] 24.789474 28.330827 31.872180 35.413534 38.954887 42.496241 46.037594
## [15] 49.578947 53.120301 56.661654 60.203008 63.744361 67.285714
predictfor1218_100
##  [1] 0.0004104529 0.0613867361 0.1170241017 0.1738126082 0.2318998617
##  [6] 0.2912336711 0.3517354422 0.4133290569 0.4759463524 0.5395274084
## [11] 0.6040196344 0.6693766847 0.7355574747 0.8025253515 0.8702474117
## [16] 0.9386939454 1.0078379800 1.0776549064 1.1481221694 1.2192190098
diff((predictfor1218_100 * 1e+06))
##  [1] 60976.28 55637.37 56788.51 58087.25 59333.81 60501.77 61593.61 62617.30
##  [9] 63581.06 64492.23 65357.05 66180.79 66967.88 67722.06 68446.53 69144.03
## [17] 69816.93 70467.26 71096.84
mean(diff((predictfor1218_100 * 1e+06)))
## [1] 64147.82
```

5.4 Model prediction comparison: 2001-2018 and 2012-2018

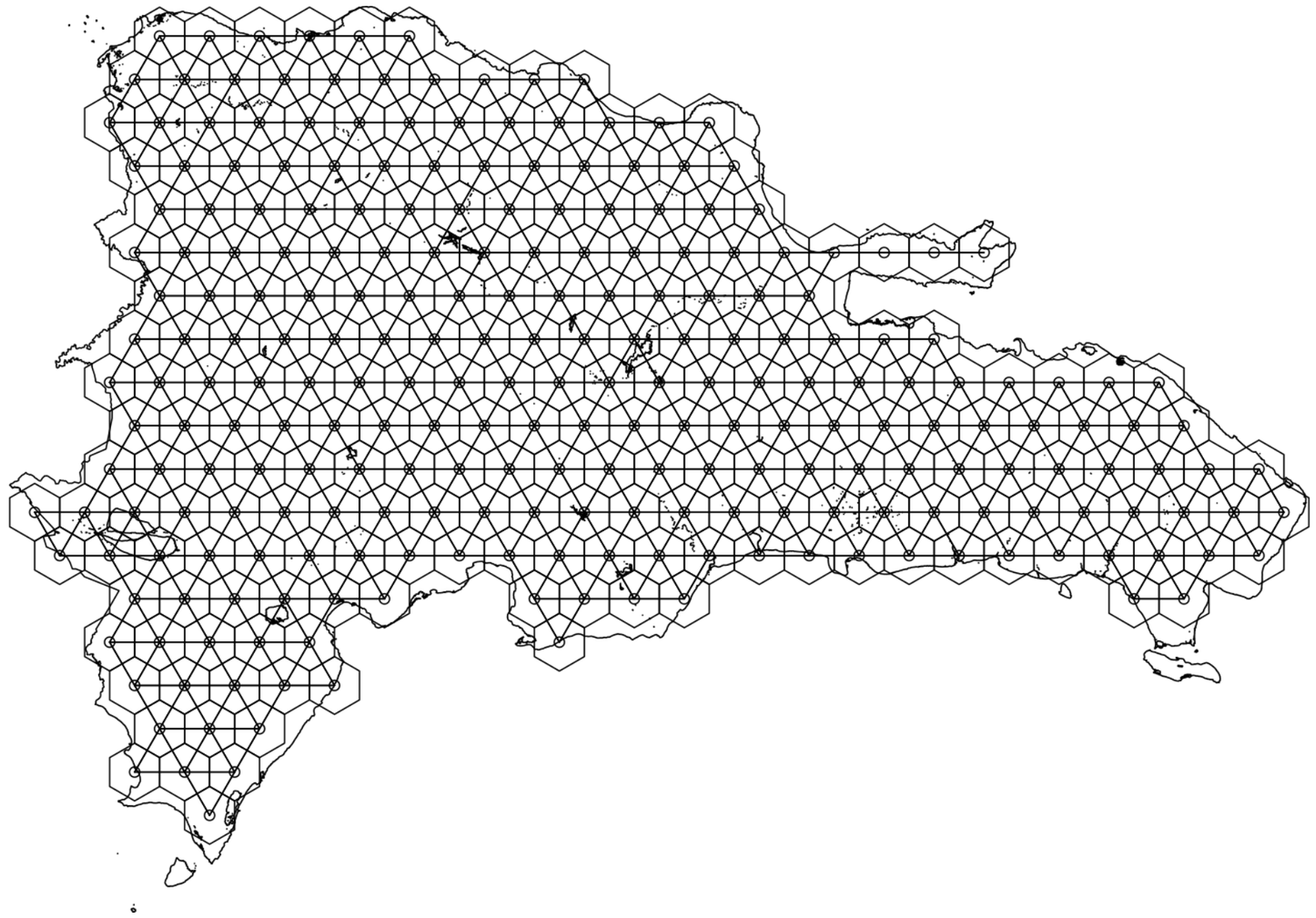
```r
# Plot
loss_fire_assoc_df <- data.frame(rangenfm6_100sqkm, rangenfv1_100sqkm, predictfor_100,
    predictfor1218_100)
loss_fire_assoc_df %>%
    gather(variable, value) %>%
    mutate(period = ifelse(grepl("v1|1218", variable), "2012-2018", "2001-2018"),
        axis = ifelse(grepl("range", variable), "x", "y"), id = 1:nrow(.)) %>%
    select(period, axis, value) %>%
    group_by(period, axis) %>%
    mutate(rn = row_number()) %>%
    ungroup() %>%
    spread(axis, value) %>%
    ggplot() + aes(x = x, y = y, colour = period) + geom_path()
```


1.25
1.00
0.75
0.50
0.25
0.00
y
0
20
40
60
x
period
2001-2018
2012-2018

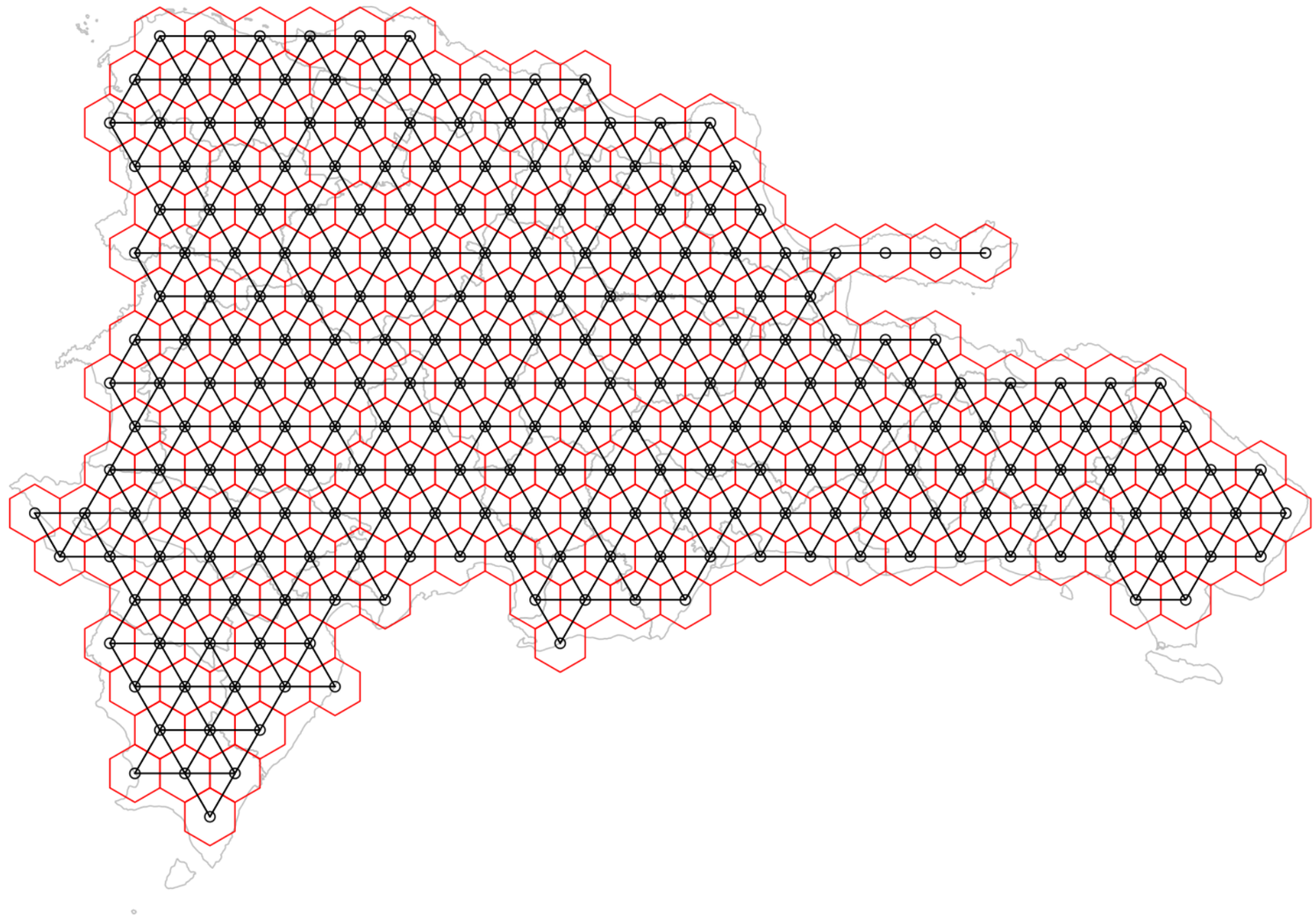
6 Modelling for the annual approach, using forest-loss as dependent variable, and fires M6 (2001-2018) and V1 (2012-2018) as independent variables

6.1 Neighbours

```
#Zonal statistics object
hexzonal <- readRDS('out/hex_zonal_statistics.RDS')
hexzonalfm <- hexzonal %>% # "fm" stands for "for modelling"
  dplyr::select(matches('^ENLACE$|^AREASQM$|^year([0-9]){,2}.loss1ha_PCT$|NFIRES|NCLUMPSSMALLER1HA')) %>%
  mutate_at(vars(matches('NFIRES|NCLUMPSSMALLER1HA')), funs("PSQKM" = ./(AREASQM/1000000))) %>%
  mutate_at(vars(matches('PCT')), funs("PUA" = ./100)) %>% #Proportion per unit area
  rename_with(.cols = matches('PCT_PUA'), .fn = ~ gsub('PCT_PUA', 'PUA', .)) %>%
  rename_with(.cols = matches('\\.'), .fn = ~ gsub('\\.', '_', .)) %>%
  rename_with(.fn = ~ gsub('loss1ha', 'lossgreater1ha', .)) %>%
  dplyr::select(matches('^ENLACE$|^AREASQM$|PUA$|PSQKM$')) %>%
  rename_at(vars(!matches('^geometry$')), funs(toupper(.))) %>%
  replace(is.na(.), 0)

# * Neighbours, weight
hexnb <- poly2nb(hexzonalfm)
plot(as_Spatial(cline))
plot(as_Spatial(hexzonalfm), add=T)
plot(hexnb, coords = coordinates(as_Spatial(hexzonalfm)), add=T)
```



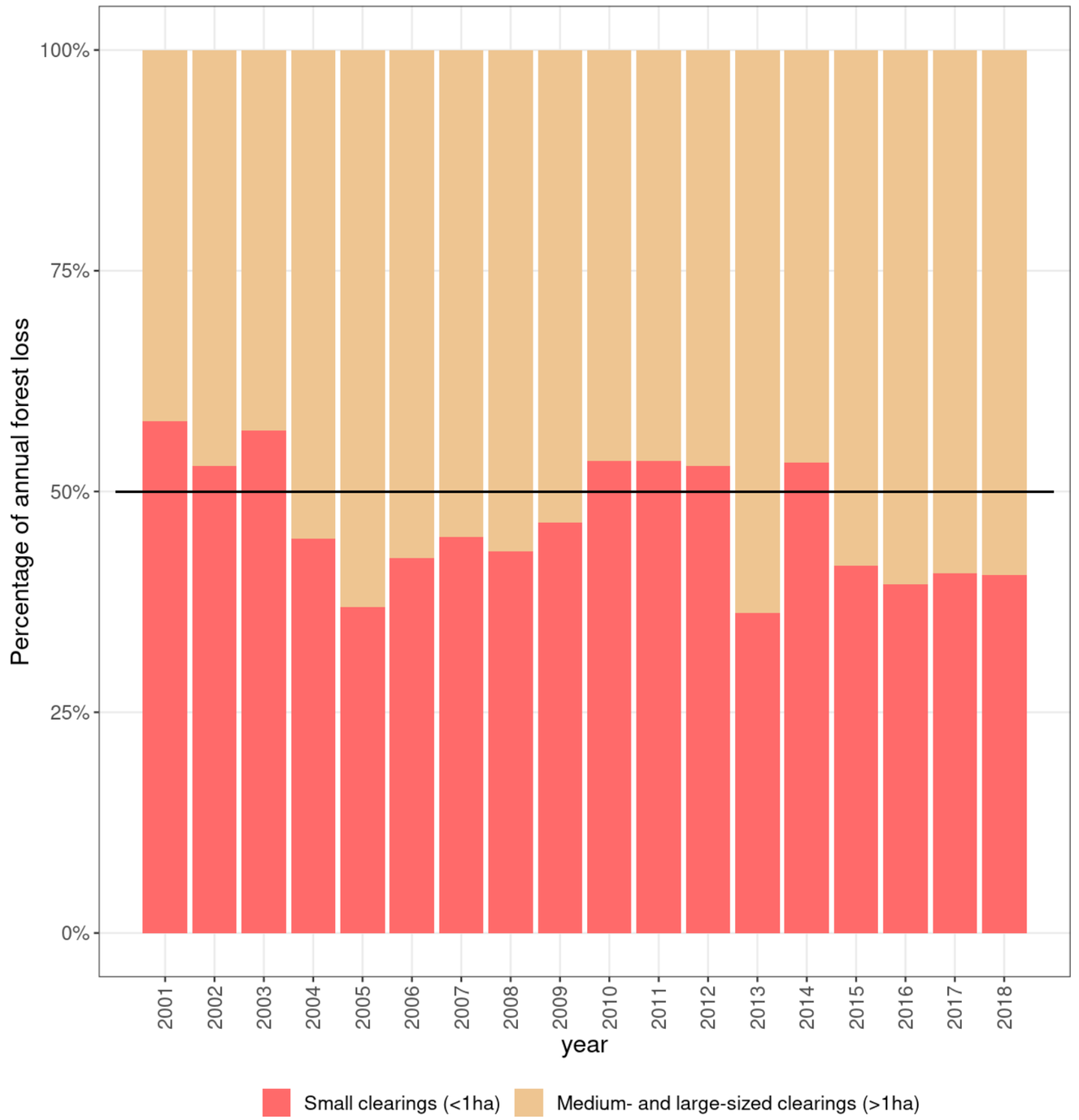
```
attr(hexnb, 'region.id') <- hexzonalfm$ENLACE
hexww <- nb2listw(hexnb, zero.policy = T)
hexww
## Characteristics of weights list object:
## Neighbour list object:
## Number of regions: 253
## Number of nonzero links: 1342
## Percentage nonzero weights: 2.09658
## Average number of links: 5.304348
##
## Weights style: W
## Weights constants summary:
##     n    nn  S0       S1       S2
## W 253 64009 253 101.2822 1020.272
plot(prov %>% st_geometry(), border = 'grey')
plot(hexzonalfm %>% st_geometry(), add=T, border = 'red')
plot(hexnb, coords = coordinates(as_Spatial(hexzonalfm)), add=T)
```



```
hexwb <- nb2listw(hexnb, style = 'B', zero.policy = T)
hexwb
## Characteristics of weights list object:
## Neighbour list object:
## Number of regions: 253
## Number of nonzero links: 1342
## Percentage nonzero weights: 2.09658
## Average number of links: 5.304348
##
## Weights style: B
## Weights constants summary:
##     n    nn   S0   S1    S2
## B 253 64009 1342 2684 29808
```

```
# ENTIRE DATASETS VALUES, SOURCES ARE VALUE RASTERS OF BOTH SMALL AND LARGE CLUMPS OF FOREST LOSS (SMALL CLEARINGS AND LARGE CLEARINGS). NO ZONAL DATA USED HERE
# Forest loss from small clearings
# losssmaller1ha_byyear <- readRDS('out/forest_loss_clumps_smaller_than_1ha_by_year.RDS') # This file is big and when loaded as object "losssmaller1ha_byyear" will take at least 20 GB of RAM. This is the reason why
# foo <- sapply(names(losssmaller1ha_byyear),
#         function(x) {
#           length(which(!is.na(losssmaller1ha_byyear[[x]][])))*prod(res(losssmaller1ha_byyear[[x]]))
#         }
# )
# foo
# saveRDS(foo, 'out/summary_of_forest_loss_from_small_clearings.RDS')
# rm(losssmaller1ha_byyear)
# gc()
(foo <- readRDS('out/summary_of_forest_loss_from_small_clearings.RDS'))
##     year1     year2     year3     year4     year5     year6     year7     year8
##  68097779  57987394  64155296  90843387  95712821  61348695  76193150  97650590
##     year9    year10    year11    year12    year13    year14    year15    year16
##  68417798  78545839  73057702 102396431  64542997  95576721  77698341 114961029
##    year17    year18
## 134721266  73972882
forest_loss_small_clumps_by_year <- foo %>%
  enframe(name = 'year', value = 'Small clearings (<1ha)') %>%
  mutate(year = as.numeric(gsub('year', '', year)) + 2000)

# Forest loss from medium- and large clearings
# loss1ha_firesm6_2500_byyear <- readRDS('out/forest_loss_1ha_firesm6_2500_buffer_by_year.RDS') # This file is big and when loaded as object "loss1ha_firesm6_2500_byyear" will take at least 20 GB of RAM. This is th
# loss1ha_solo <- loss1ha_firesm6_2500_byyear[grep('loss1ha$', names(loss1ha_firesm6_2500_byyear))]
# bar <- sapply(names(loss1ha_solo),
#         function(x) {
#           length(which(!is.na(loss1ha_solo[[x]][])))*prod(res(loss1ha_solo[[x]]))
#         }
# )
# names(bar) <- gsub('(.*)(year[0-9]{,2})(.*)', '\\2', names(bar))
# saveRDS(bar, 'out/summary_of_forest_loss_from_medium_large_clearings.RDS')
# rm(loss1ha_solo)
# rm(loss1ha_firesm6_2500_byyear)
# gc()
(bar <- readRDS('out/summary_of_forest_loss_from_medium_large_clearings.RDS'))
##     year1     year2     year3     year4     year5     year6     year7     year8
##  49320404  51640724  48640640 112483274 163901824  83138660  93631596 128039127
##     year9    year10    year11    year12    year13    year14    year15    year16
##  78809947  68351587  63621931  91351003 113665504  83709544 108977782 176083871
##    year17    year18
## 195739642 108533434
forest_loss_large_clumps_by_year <- bar %>%
  enframe(name = 'year', value = 'Medium- and large-sized clearings (>1ha)') %>%
  mutate(year = as.numeric(gsub('year', '', year)) + 2000)
# Join
areasqm_small_large_clearings <- forest_loss_small_clumps_by_year %>%
  inner_join(forest_loss_large_clumps_by_year, by = 'year') %>%
  mutate(total = rowSums(.[,2:3])) %>%
  mutate_at(.vars = vars(matches('clearing')), .funs = list(PCT = ~ ./total))

# Small clearings (<1ha) vs. large clearings (>1ha)
CPCOLS <- c("#FF6A6A", "#EEC591") # > Addins > Plot Colour Helper
# jpeg('out/small_clearings_and_medium_large_sized_clearings_per_year.jpg', width = 2500, height = 2500, res = 300)
areasqm_small_large_clearings %>%
```

```
select(1:3) %>%
pivot_longer(cols = -year, names_to = 'variable', values_to = 'value') %>%
mutate(variable=factor(variable, levels = sort(unique(variable), decreasing = T))) %>%
ggplot + aes(x = year, y = value, fill = variable) + geom_bar(position = position_fill(reverse = T), stat="identity") +
scale_x_continuous(breaks = 2001:2018) +
scale_y_continuous(labels = percent) +
scale_fill_manual(values = CPCOLS) +
geom_segment(y = 0.5, yend = 0.5, x = 2000, xend = 2019, colour="black") +
theme_bw() +
theme(axis.text.x = element_text(angle = 90, vjust = 0.5), panel.grid.minor = element_blank(),
      legend.title = element_blank(), legend.position = 'bottom',
      text = element_text(size = 14), aspect.ratio = 1) +
ylab('Percentage of annual forest loss')
```




```
# dev.off()

# Tests
# areasqm_small_large_clearings <- readRDS('out/deforestation_area_m2_small_and_large_clearings.RDS')
```

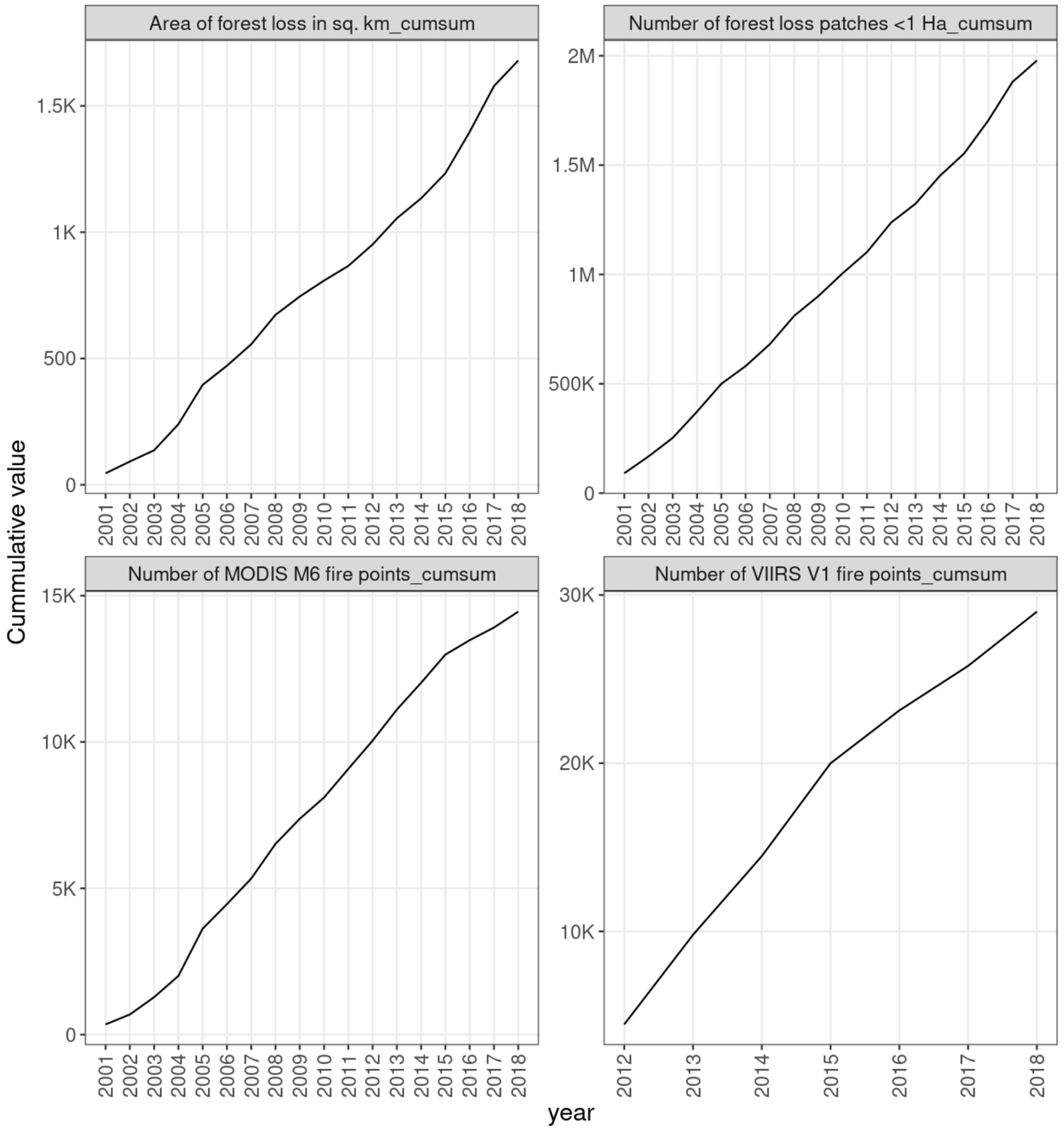
```r
sapply(areasqm_small_large_clearings %>% select(matches('PCT')), shapiro.test) #Not significant
##           Small clearings (<1ha)_PCT
## statistic 0.9174942
## p.value   0.1167148
## method    "Shapiro-Wilk normality test"
## data.name "X[[i]]"
##           Medium- and large-sized clearings (>1ha)_PCT
## statistic 0.9174942
## p.value   0.1167148
## method    "Shapiro-Wilk normality test"
## data.name "X[[i]]"
with(
  areasqm_small_large_clearings,
  t.test(`Small clearings (<1ha)_PCT`, `Medium- and large-sized clearings (>1ha)_PCT`, paired = T)) #Not significant
##
##  Paired t-test
##
## data:  Small clearings (<1ha)_PCT and Medium- and large-sized clearings (>1ha)_PCT
## t = -2.0796, df = 17, p-value = 0.05301
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.1385610332  0.0009999261
## sample estimates:
## mean of the differences
##             -0.06878055
## Small clearings accounted for more than half of the deforested area in 7 of the first 18 years of this Century in the Dominican Republic.

# THESE ANALYSES USE ZONAL STATISTICS FROM SIMPLE FEATURES OBJECTS
# Four variables: absolute values per year, including cum.sum
four_variables_abs_pct_cumsum <- hexzonal[, grep('NFIRES|NCLUMPS|loss1ha_AREASQM', colnames(hexzonal))] %>%
  st_drop_geometry() %>%
  pivot_longer(cols = everything(), names_to = 'variable', values_to = 'value') %>%
  mutate(year = as.numeric(gsub('.*year([0-9]{,2}).*', '\\1', variable)) + 2000) %>%
  mutate(variable = gsub('_year[0-9]{,2}|year[0-9]{,2}\\.', '', variable)) %>%
  mutate(variable = case_when(
    variable == 'NFIRESM6' ~ 'Number of MODIS M6 fire points',
    variable == 'NFIRESV1' ~ 'Number of VIIRS V1 fire points',
    variable == 'NCLUMPSSMALLER1HA' ~ 'Number of forest loss patches <1 Ha',
    variable == 'loss1ha_AREASQM' ~ 'Area of forest loss in sq. km'
  )) %>%
  replace(is.na(.), 0) %>%
  pivot_wider(names_from = 'variable', values_from = 'value', values_fn = sum) %>%
  # inner_join(forest_loss_small_clumps_by_year, by = 'year') %>%
  mutate_at(vars(contains('Area')), ~ ./1000000) %>%
  replace(is.na(.), 0) %>%
  mutate_at(vars(-'year'), funs("pct" = ./sum(.))) %>%
  mutate_at(vars(-'year'), funs("cumsum" = cumsum(.)))
four_variables_abs_pct_cumsum %>%
  adorn_totals(where = 'row')
##   year Area of forest loss in sq. km Number of MODIS M6 fire points
##   2001                      45.65251                            351
##   2002                      46.57304                            339
##   2003                      44.48116                            592
##   2004                     103.33296                            726
##   2005                     155.73127                           1615
##   2006                      75.61087                            837
##   2007                      84.86968                            874
```

```
##   2008                     116.53683                          1184
##   2009                      72.66717                           858
##   2010                      63.06058                           727
##   2011                      58.09915                           977
##   2012                      84.69065                           966
##   2013                     103.79518                          1061
##   2014                      78.99691                           917
##   2015                      99.24526                           962
##   2016                     164.00154                           492
##   2017                     181.01097                           432
##   2018                     101.21935                           543
##  Total                    1679.57507                         14453
##  Number of VIIRS V1 fire points Number of forest loss patches <1 Ha
##                               0                             90802
##                               0                             77007
##                               0                             85248
##                               0                            119844
##                               0                            127058
##                               0                             80934
##                               0                            100542
##                               0                            129162
##                               0                             90651
##                               0                            104346
##                               0                             96694
##                            4470                            135449
##                            5326                             85798
##                            4679                            127090
##                            5521                            102245
##                            3141                            151781
##                            2649                            176204
##                            3224                             97408
##                           29010                           1978263
##  Area of forest loss in sq. km_pct Number of MODIS M6 fire points_pct
##                         0.02718099                         0.02428562
##                         0.02772906                         0.02345534
##                         0.02648358                         0.04096035
##                         0.06152328                         0.05023179
##                         0.09272064                         0.11174151
##                         0.04501785                         0.05791185
##                         0.05053045                         0.06047187
##                         0.06938471                         0.08192071
##                         0.04326521                         0.05936484
##                         0.03754555                         0.05030098
##                         0.03459157                         0.06759842
##                         0.05042385                         0.06683733
##                         0.06179848                         0.07341036
##                         0.04703387                         0.06344704
##                         0.05908950                         0.06656058
##                         0.09764466                         0.03404138
##                         0.10777188                         0.02988999
##                         0.06026485                         0.03757005
##                         1.00000000                         1.00000000
##  Number of VIIRS V1 fire points_pct Number of forest loss patches <1 Ha_pct
##                          0.00000000                            0.04589986
##                          0.00000000                            0.03892657
##                          0.00000000                            0.04309235
##                          0.00000000                            0.06058042
##                          0.00000000                            0.06422705
```

```
##                          0.00000000                              0.04091165
##                          0.00000000                              0.05082337
##                          0.00000000                              0.06529061
##                          0.00000000                              0.04582353
##                          0.00000000                              0.05274627
##                          0.00000000                              0.04887823
##                          0.15408480                              0.06846865
##                          0.18359186                              0.04337037
##                          0.16128921                              0.06424323
##                          0.19031368                              0.05168423
##                          0.10827301                              0.07672438
##                          0.09131334                              0.08907006
##                          0.11113409                              0.04923916
##                          1.00000000                              1.00000000
##  Area of forest loss in sq. km_cumsum Number of MODIS M6 fire points_cumsum
##                              45.65251                                   351
##                              92.22555                                   690
##                             136.70671                                  1282
##                             240.03967                                  2008
##                             395.77095                                  3623
##                             471.38181                                  4460
##                             556.25150                                  5334
##                             672.78833                                  6518
##                             745.45549                                  7376
##                             808.51607                                  8103
##                             866.61521                                  9080
##                             951.30586                                 10046
##                            1055.10104                                 11107
##                            1134.09796                                 12024
##                            1233.34322                                 12986
##                            1397.34476                                 13478
##                            1578.35573                                 13910
##                            1679.57507                                 14453
##                           14060.52743                                136829
##  Number of VIIRS V1 fire points_cumsum
##                                     0
##                                     0
##                                     0
##                                     0
##                                     0
##                                     0
##                                     0
##                                     0
##                                     0
##                                     0
##                                     0
##                                  4470
##                                  9796
##                                 14475
##                                 19996
##                                 23137
##                                 25786
##                                 29010
##                                126670
##  Number of forest loss patches <1 Ha_cumsum
##                                       90802
##                                      167809
##                                      253057
```

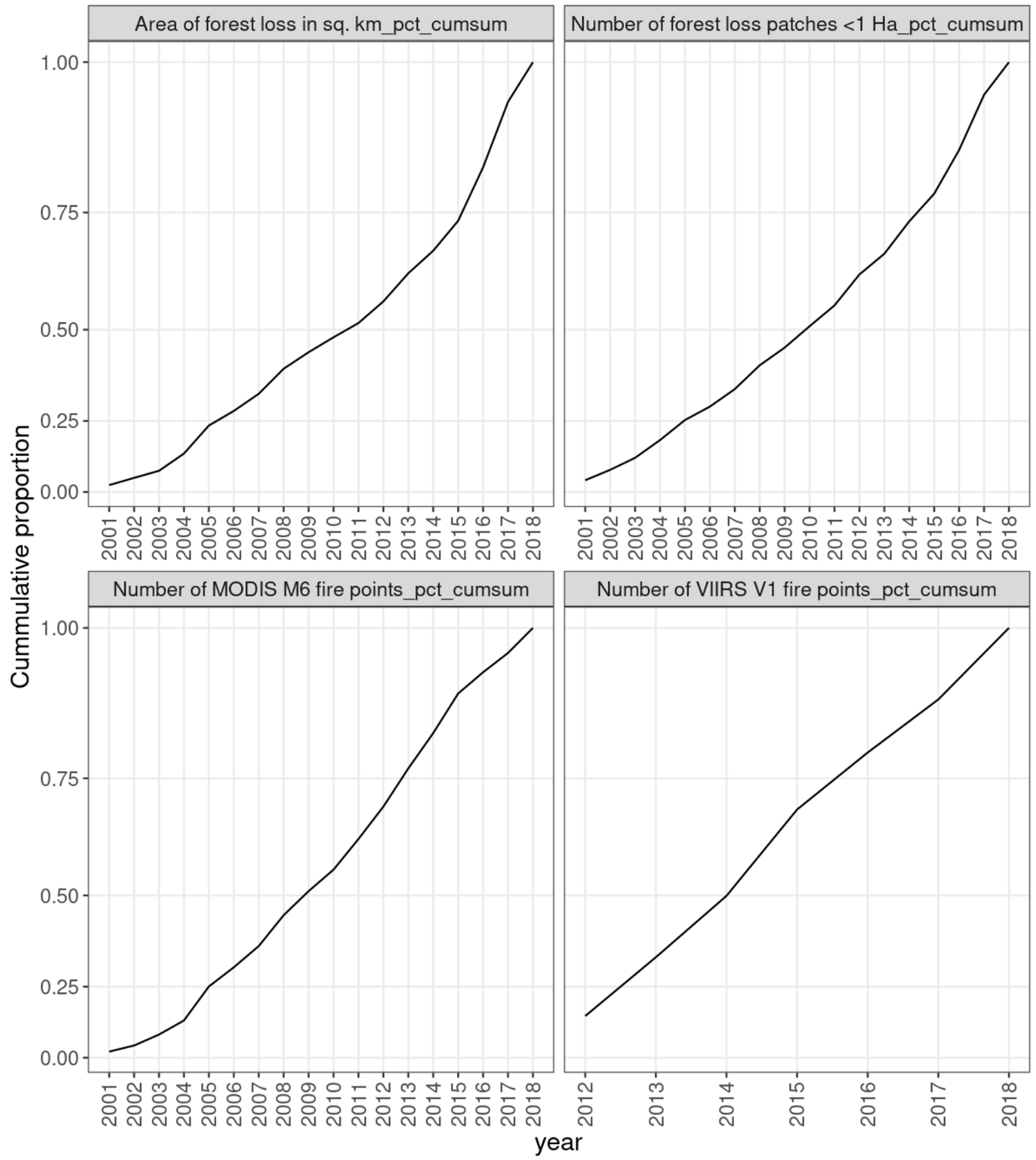
```
##                                    372901
##                                    499959
##                                    580893
##                                    681435
##                                    810597
##                                    901248
##                                   1005594
##                                   1102288
##                                   1237737
##                                   1323535
##                                   1450625
##                                   1552870
##                                   1704651
##                                   1880855
##                                   1978263
##                                  17595119
##  Area of forest loss in sq. km_pct_cumsum
##                                0.02718099
##                                0.05491005
##                                0.08139363
##                                0.14291691
##                                0.23563754
##                                0.28065540
##                                0.33118585
##                                0.40057056
##                                0.44383577
##                                0.48138132
##                                0.51597290
##                                0.56639675
##                                0.62819523
##                                0.67522909
##                                0.73431860
##                                0.83196326
##                                0.93973515
##                                1.00000000
##                                8.37147898
##  Number of MODIS M6 fire points_pct_cumsum
##                                 0.02428562
##                                 0.04774095
##                                 0.08870131
##                                 0.13893309
##                                 0.25067460
##                                 0.30858645
##                                 0.36905833
##                                 0.45097904
##                                 0.51034387
##                                 0.56064485
##                                 0.62824327
##                                 0.69508061
##                                 0.76849097
##                                 0.83193801
##                                 0.89849858
##                                 0.93253996
##                                 0.96242995
##                                 1.00000000
##                                 9.46716945
##  Number of VIIRS V1 fire points_pct_cumsum
##                                  0.0000000
```

```
##                                0.0000000
##                                0.0000000
##                                0.0000000
##                                0.0000000
##                                0.0000000
##                                0.0000000
##                                0.0000000
##                                0.0000000
##                                0.0000000
##                                0.0000000
##                                0.1540848
##                                0.3376767
##                                0.4989659
##                                0.6892796
##                                0.7975526
##                                0.8888659
##                                1.0000000
##                                4.3664254
##  Number of forest loss patches <1 Ha_pct_cumsum
##                                      0.04589986
##                                      0.08482644
##                                      0.12791879
##                                      0.18849920
##                                      0.25272626
##                                      0.29363790
##                                      0.34446128
##                                      0.40975189
##                                      0.45557542
##                                      0.50832169
##                                      0.55719993
##                                      0.62566858
##                                      0.66903895
##                                      0.73328218
##                                      0.78496641
##                                      0.86169079
##                                      0.95076084
##                                      1.00000000
##                                      8.89422640

# Cumulative absolute value
four_variables_abs_pct_cumsum %>%
  dplyr::select(year, matches('[a,m,s]_cumsum', ignore.case = F)) %>%
  pivot_longer(cols = -contains('year')) %>%
  replace(. == 0, NA) %>%
  na.omit() %>%
  ggplot + aes(x = year, y = value) + geom_line() +
  scale_x_continuous(breaks = 2001:2018) +
  scale_y_continuous(labels = function(y) gsub('\\.[0]', '', label_number_si(accuracy = 0.1)(y))) +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5), panel.grid.minor = element_blank(),
        text = element_text(size = 14), aspect.ratio = 1) +
  ylab('Cummulative value') +
  facet_wrap(~ name, scales = 'free')
```



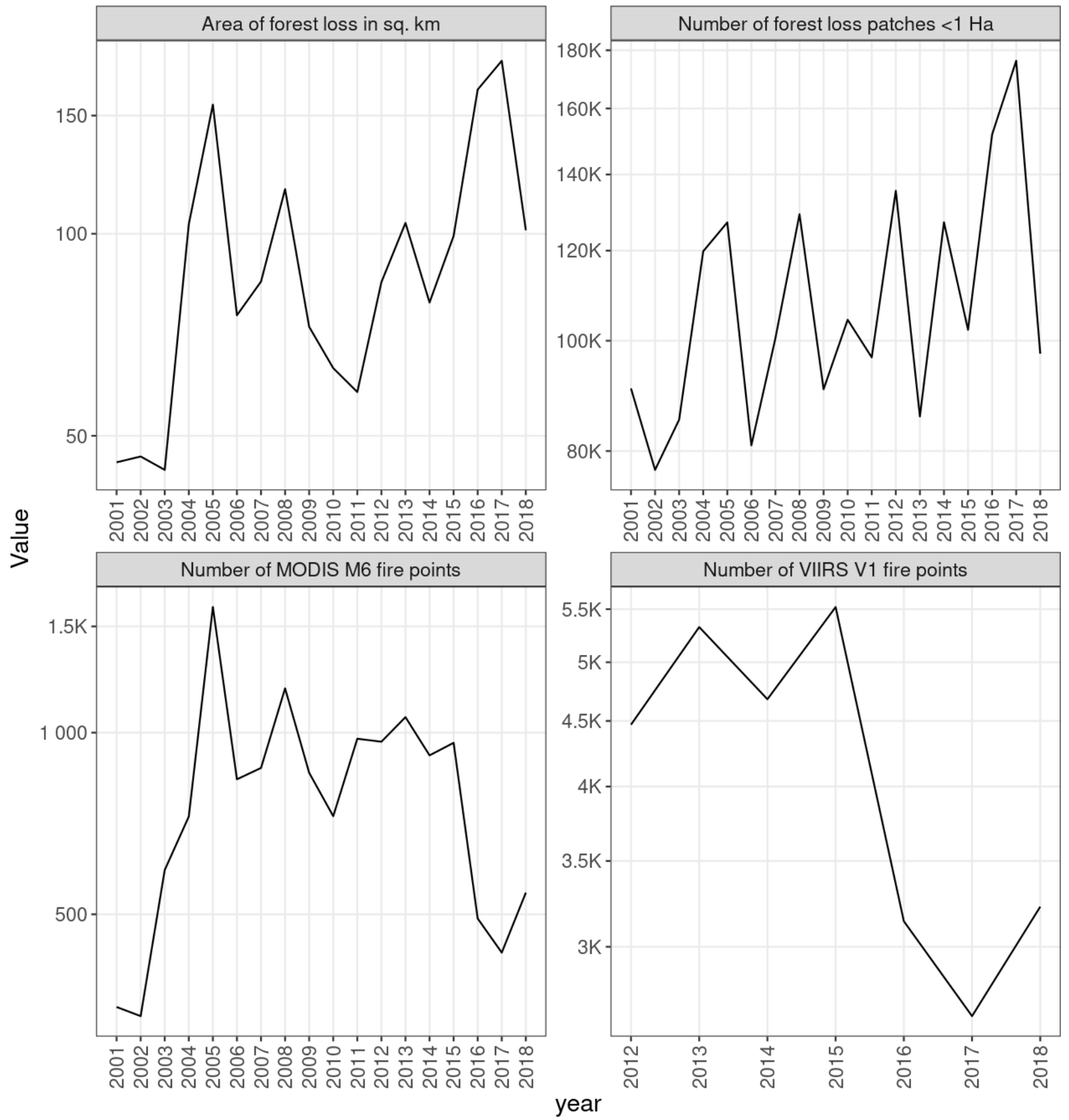

```
# Cumulative proportion
four_variables_abs_pct_cumsum %>%
  dplyr::select(matches('year|pct_cumsum')) %>%
```

```
pivot_longer(cols = contains('cumsum')) %>%
replace(. == 0, NA) %>%
na.omit() %>%
ggplot + aes(x = year, y = value) + geom_line() +
scale_y_continuous(trans = 'exp') +
scale_x_continuous(breaks = 2001:2018) +
theme_bw() +
theme(axis.text.x = element_text(angle = 90, vjust = 0.5), panel.grid.minor = element_blank(),
      text = element_text(size = 14), aspect.ratio = 1) +
ylab('Cummulative proportion') +
facet_wrap(~ name, scales = 'free_x')
```



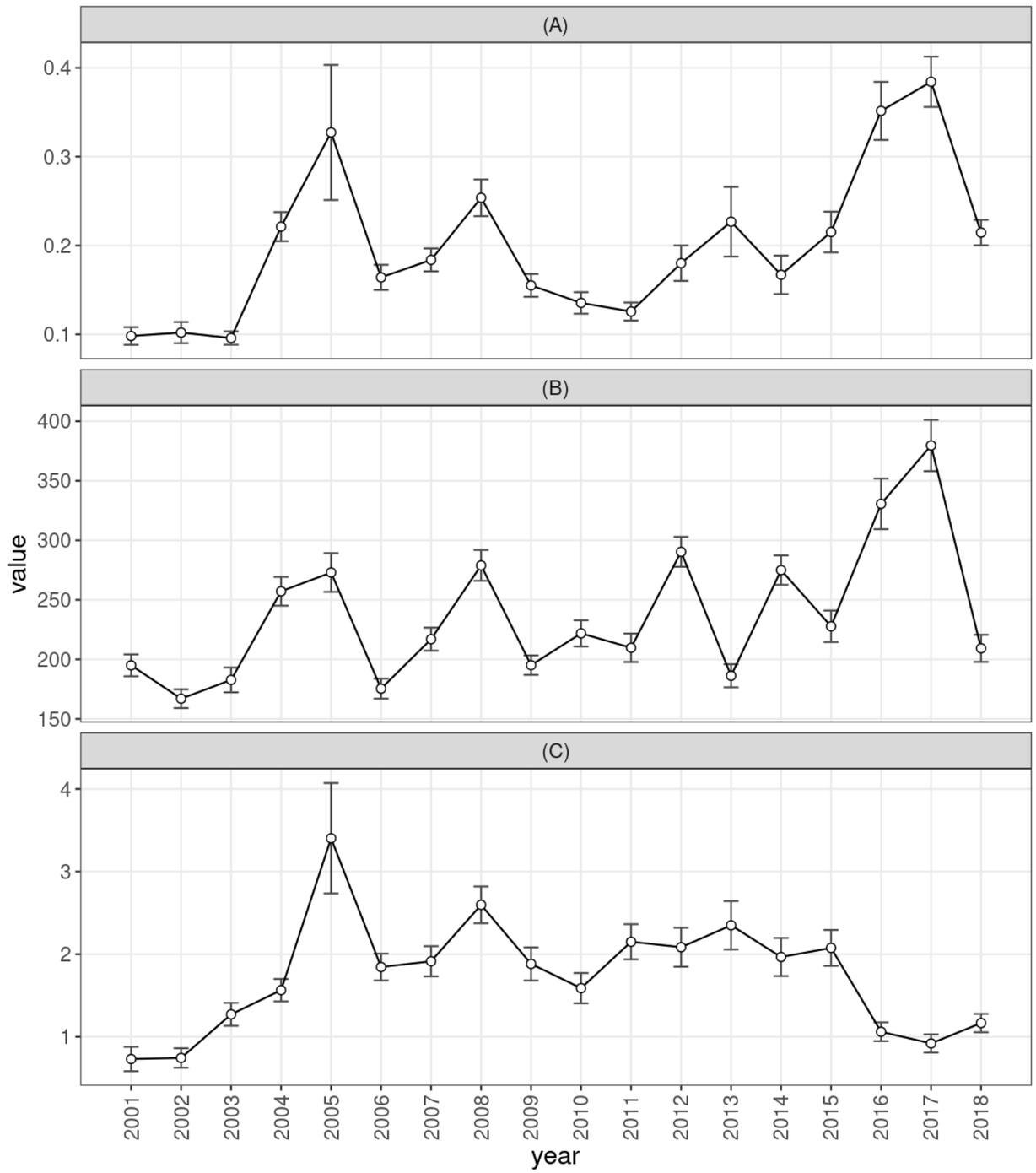

```
# Absolute values non-cumulative
four_variables_abs_pct_cumsum %>%
  dplyr::select(-matches('pct|cumsum', ignore.case = F)) %>%
```

```
pivot_longer(cols = -contains('year')) %>%
replace(. == 0, NA) %>%
na.omit() %>%
ggplot + aes(x = year, y = value) + geom_line() +
scale_x_continuous(breaks = 2001:2018) +
scale_y_continuous(trans = 'log', breaks = pretty_breaks(),
                   labels = function(y) gsub('\\.[0]', '', label_number_si(accuracy = 0.1)(y))) +
theme_bw() +
theme(axis.text.x = element_text(angle = 90, vjust = 0.5), panel.grid.minor = element_blank(),
      text = element_text(size = 14), aspect.ratio = 1) +
ylab('Value') +
facet_wrap(~ name, scales = 'free')
```

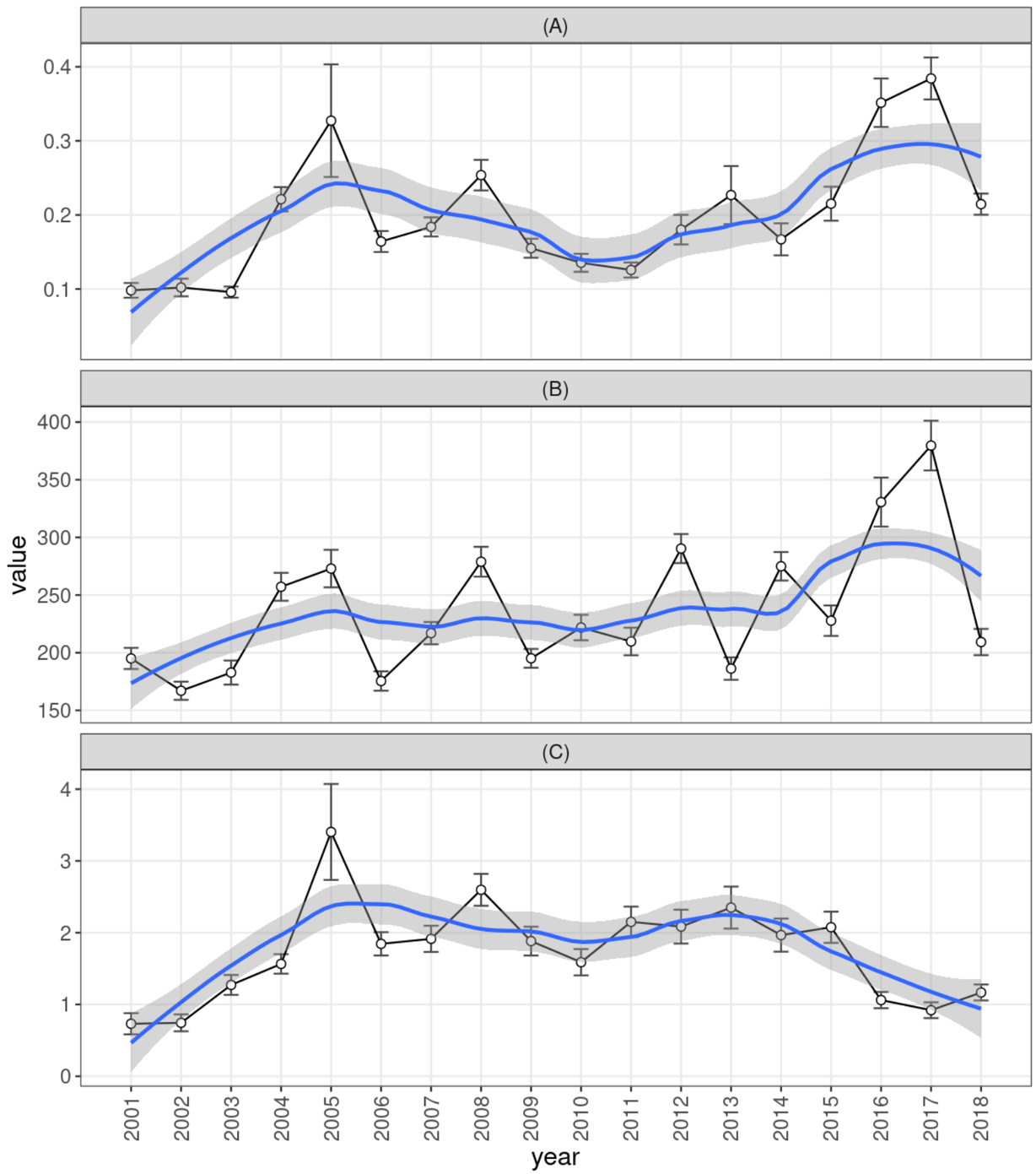



```
# Three variables: summaries, plots, standard errors, confidence intervals
three_variables_for_plots <- hexzonalfm %>%
  select(!matches('ENLACE|AREASQM')) %>%
```

```
  st_drop_geometry %>%
  gather(variable, value) %>%
  mutate(year = as.numeric(create_year_from_string(variable)) + 2000,
         variable2 = create_variable_name_from_string(variable)) %>%
  mutate(value = value * 100) %>%
  mutate(variable2 = case_when(
    variable2 == 'NFIRESM6PSQKM' ~ '(C)',
    variable2 == 'NFIRESV1PSQKM' ~ '(D)',
    variable2 == 'NCLUMPSSMALLER1HAPSQKM' ~ '(B)',
    variable2 == 'LOSSGREATER1HA_PUA' ~ '(A)'
  ))
three_variables_sum <- summarySE(
  three_variables_for_plots %>%
  filter(!grepl('D', variable2)),
  measurevar="value", groupvars=c('year', 'variable2'))
three_variables_plot <- three_variables_for_plots %>%
  filter(!grepl('D', variable2)) %>%
  ggplot + aes(x = year, y = value) +
  scale_x_continuous(breaks = 2001:2018) +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5), panel.grid.minor = element_blank(),
        text = element_text(size = 14), aspect.ratio = 1/3) +
  geom_errorbar(data = three_variables_sum, aes(ymin = value - se, ymax = value + se), colour = "grey30", width = .3) +
  geom_line(data = three_variables_sum) +
  geom_point(data = three_variables_sum, aes(x = year, y = value), size=2, shape=21, fill="white") +
  facet_wrap(~ variable2, scales = 'free_y', ncol = 1)
three_variables_plot
```

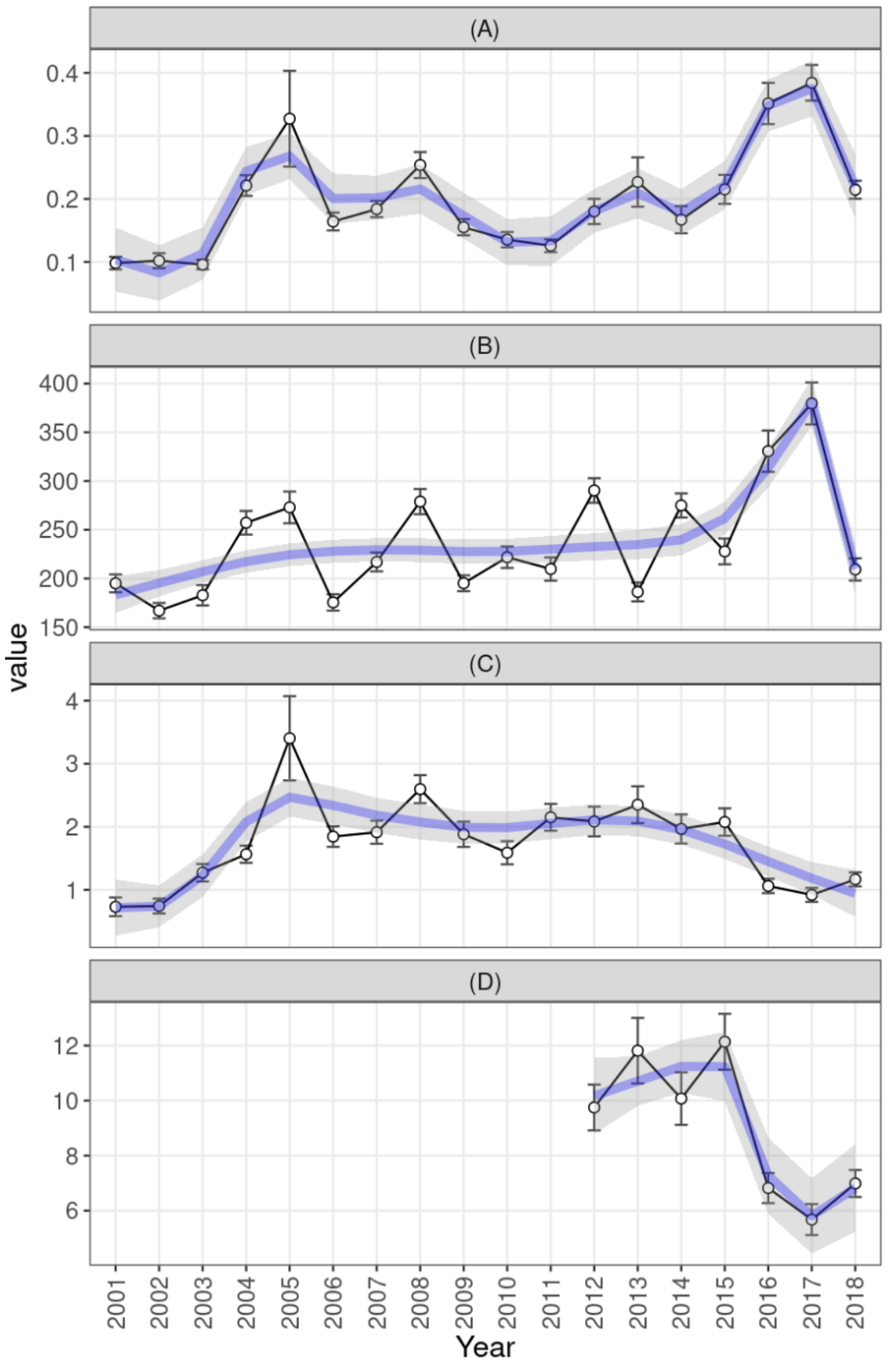



```
three_variables_plot + geom_smooth(method = 'loess', span = 0.5)
```




```
# jpeg('out/forest_loss_fire_points_line_plots_error_bars_2001_2018.jpg', width = 1800, height = 2200, res = 350)
# dev.off()
```

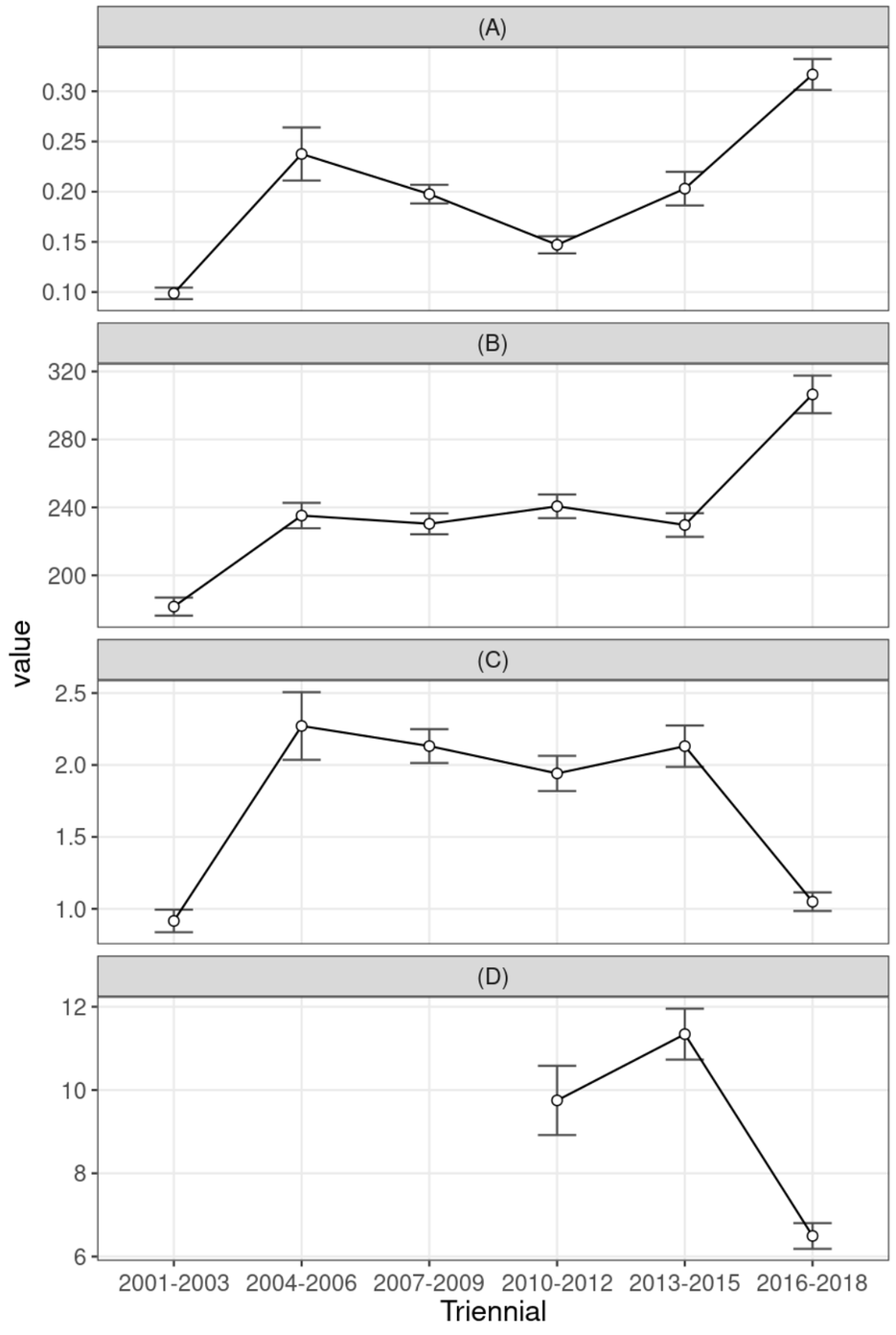
```r
# Four variables: summaries, plots, standard errors, confidence intervals. Includes summary tables for the paper
## Prepare table
four_variables_for_plots <- hexzonalfm %>%
  select(!matches('ENLACE|AREASQM')) %>%
  st_drop_geometry %>%
  gather(variable, value) %>%
  mutate(year = as.numeric(create_year_from_string(variable)) + 2000,
         variable2 = create_variable_name_from_string(variable)) %>%
  mutate(value = value * 100) %>%
  mutate(variable2 = case_when(
    variable2 == 'NFIRESM6PSQKM' ~ '(C)',
    variable2 == 'NFIRESV1PSQKM' ~ '(D)',
    variable2 == 'NCLUMPSSMALLER1HAPSQKM' ~ '(B)',
    variable2 == 'LOSSGREATER1HA_PUA' ~ '(A)'
  ))
four_variables_for_plots$year_factor <- factor(four_variables_for_plots$year)
four_variables_for_plots$decennial <- cut(
  x = four_variables_for_plots$year-2000,
  breaks = breaks  <- c(1, 10, 18), include.lowest = T,
  labels = seq_along(breaks[-1]))
four_variables_for_plots$decennial_interval <- four_variables_for_plots %>%
  group_by(decennial) %>%
  mutate(interval = factor(paste(min(year), max(year), sep = '-'))) %>%
  pull(interval)
four_variables_for_plots$quadrennial <- cut(
  x = four_variables_for_plots$year-2000,
  breaks = breaks  <- c(1, 4, 8, 12, 16, 18), include.lowest = T,
  labels = seq_along(breaks[-1]))
four_variables_for_plots$quadrennial_interval <- four_variables_for_plots %>%
  group_by(quadrennial) %>%
  mutate(interval = factor(paste(min(year), max(year), sep = '-'))) %>%
  pull(interval)
four_variables_for_plots$triennial <- cut(
  x = four_variables_for_plots$year-2000,
  breaks = breaks  <- c(1, 3, 6, 9, 12, 15, 18), include.lowest = T,
  labels = seq_along(breaks[-1]))
four_variables_for_plots$triennial_interval <- four_variables_for_plots %>%
  group_by(triennial) %>%
  mutate(interval = factor(paste(min(year), max(year), sep = '-'))) %>%
  pull(interval)
four_variables_for_plots$sexennial <- cut(
  x = four_variables_for_plots$year-2000,
  breaks = breaks  <- c(1, 6, 12, 18), include.lowest = T,
  labels = seq_along(breaks[-1]))
four_variables_for_plots$sexennial_interval <- four_variables_for_plots %>%
  group_by(sexennial) %>%
  mutate(interval = factor(paste(min(year), max(year), sep = '-'))) %>%
  pull(interval)
## Years
periodic_summaries_yearly <- periodic_summaries(
  source_table = four_variables_for_plots, measurevar = 'value',
  bins = 'year_factor', sum_variable = 'variable2', aspect_ratio = 1/3, smooth_alpha = 0.3,
  # smooth_method = 'loess', method_args = list(degree = 0),
  smooth_method = 'gam', smooth_formula = y ~ s(x, bs = 'ad', k = 13),
  smooth_span = 0.35, labels_angle = 90, xlab = 'Year', smooth = T, save = F,
  plot_filename = 'forest_loss_fire_points_line_plots_error_bars_2001_2018_four_variables.jpg',
  calc_se = F, new_dev = F
)
```



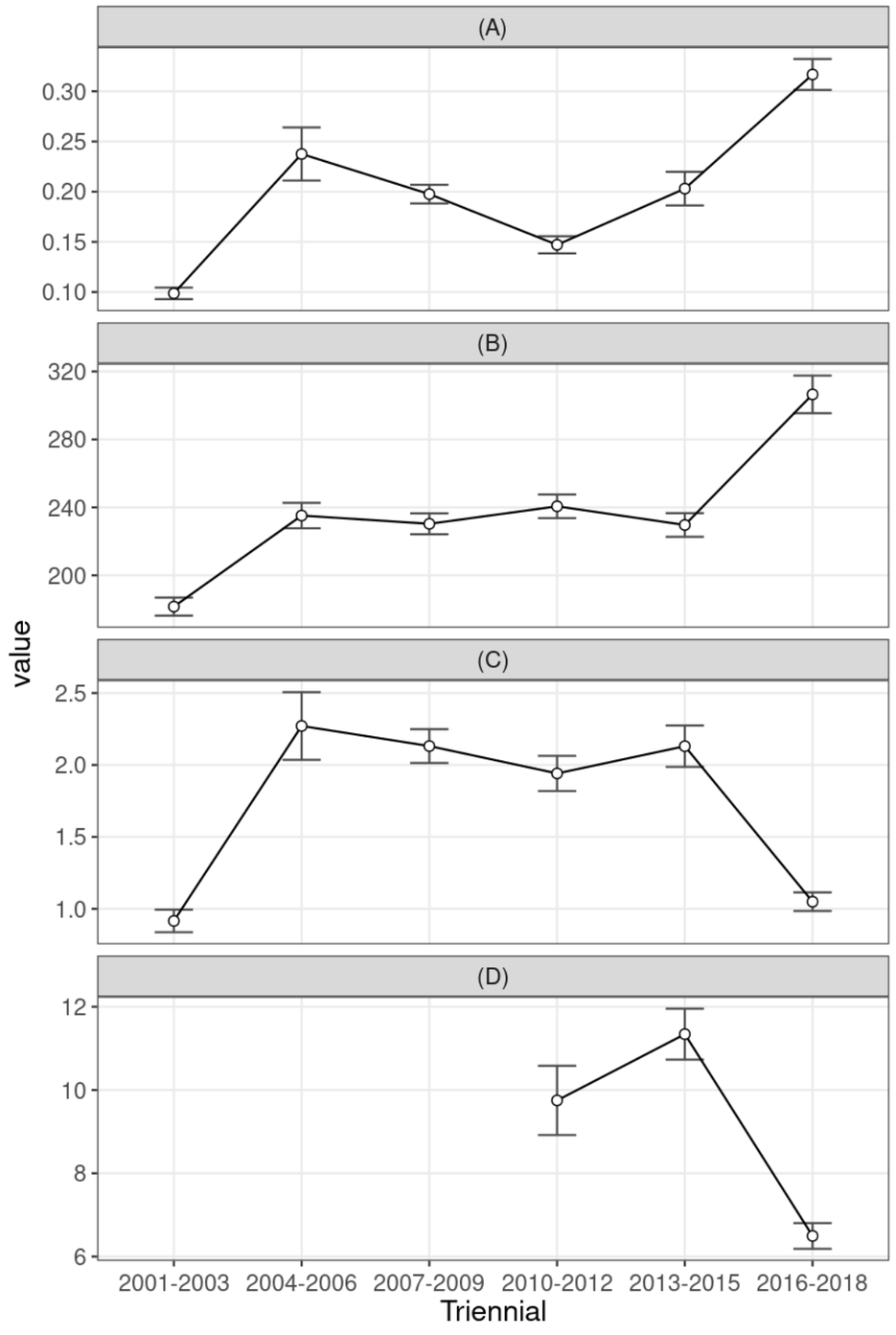

```
sapply(periodic_summaries_yearly$summaries_print_df[,-1], summary)
## $`Avg. area of forest loss in sq. km per 100 sq. km`
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 0.09586 0.14032 0.18200 0.20011 0.22541 0.38424
##
## $`Avg. number of forest loss patches $<$1 Ha per 100 sq. km`
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   167.0   195.0   219.4   237.3   274.5   379.6
##
## $`Avg. number of MODIS M6 fire points per 100 sq. km`
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##  0.7312  1.1930  1.8635  1.7398  2.0823  3.4034
##
## $`Avg. number of VIRS V1 fire points per 100 sq. km`
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
##   5.676   6.905   9.751   9.038  10.944  12.139      11
periodic_summaries_yearly$summaries_print_df %>%
  summarise_at(vars(-matches('^year')), psych::describe, na.rm = T) %>% t
##                                                                  [,1]
## Avg. area of forest loss in sq. km per 100 sq. km.vars       1.00000000
## Avg. area of forest loss in sq. km per 100 sq. km.n         18.00000000
## Avg. area of forest loss in sq. km per 100 sq. km.mean       0.20011092
## Avg. area of forest loss in sq. km per 100 sq. km.sd         0.08510730
## Avg. area of forest loss in sq. km per 100 sq. km.median     0.18200213
## Avg. area of forest loss in sq. km per 100 sq. km.trimmed    0.19511853
## Avg. area of forest loss in sq. km per 100 sq. km.mad        0.06775677
## Avg. area of forest loss in sq. km per 100 sq. km.min        0.09585689
## Avg. area of forest loss in sq. km per 100 sq. km.max        0.38424317
## Avg. area of forest loss in sq. km per 100 sq. km.range      0.28838628
## Avg. area of forest loss in sq. km per 100 sq. km.skew       0.71665840
## Avg. area of forest loss in sq. km per 100 sq. km.kurtosis  -0.54419069
## Avg. area of forest loss in sq. km per 100 sq. km.se         0.02005998
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.vars   1.00000000
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.n     18.00000000
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.mean  237.31506716
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.sd     57.80034547
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.median 219.40106620
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.trimmed 232.81564612
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.mad    55.14388620
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.min   166.99812254
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.max   379.62274836
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.range 212.62462582
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.skew    0.84411033
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.kurtosis -0.19708272
## Avg. number of forest loss patches $<$1 Ha per 100 sq. km.se     13.62367208
## Avg. number of MODIS M6 fire points per 100 sq. km.vars          1.00000000
## Avg. number of MODIS M6 fire points per 100 sq. km.n            18.00000000
## Avg. number of MODIS M6 fire points per 100 sq. km.mean          1.73980270
## Avg. number of MODIS M6 fire points per 100 sq. km.sd            0.69153799
## Avg. number of MODIS M6 fire points per 100 sq. km.median        1.86350607
## Avg. number of MODIS M6 fire points per 100 sq. km.trimmed       1.69886586
## Avg. number of MODIS M6 fire points per 100 sq. km.mad           0.58180208
## Avg. number of MODIS M6 fire points per 100 sq. km.min           0.73123822
## Avg. number of MODIS M6 fire points per 100 sq. km.max           3.40335650
## Avg. number of MODIS M6 fire points per 100 sq. km.range         2.67211829
## Avg. number of MODIS M6 fire points per 100 sq. km.skew          0.41213467
## Avg. number of MODIS M6 fire points per 100 sq. km.kurtosis     -0.27062424
## Avg. number of MODIS M6 fire points per 100 sq. km.se            0.16299707
## Avg. number of VIRS V1 fire points per 100 sq. km.vars           1.00000000
## Avg. number of VIRS V1 fire points per 100 sq. km.n              7.00000000
```

```
## Avg. number of VIRS V1 fire points per 100 sq. km.mean              9.03751742
## Avg. number of VIRS V1 fire points per 100 sq. km.sd                2.56014627
## Avg. number of VIRS V1 fire points per 100 sq. km.median            9.75085197
## Avg. number of VIRS V1 fire points per 100 sq. km.trimmed           9.03751742
## Avg. number of VIRS V1 fire points per 100 sq. km.mad               3.54111687
## Avg. number of VIRS V1 fire points per 100 sq. km.min               5.67558673
## Avg. number of VIRS V1 fire points per 100 sq. km.max              12.13930258
## Avg. number of VIRS V1 fire points per 100 sq. km.range             6.46371585
## Avg. number of VIRS V1 fire points per 100 sq. km.skew             -0.04055990
## Avg. number of VIRS V1 fire points per 100 sq. km.kurtosis         -1.92615529
## Avg. number of VIRS V1 fire points per 100 sq. km.se                0.96764434
## Triennials
periodic_summaries(
  source_table = four_variables_for_plots, measurevar = 'value',
  bins = 'triennial_interval', sum_variable = 'variable2', aspect_ratio = 1/3,
  smooth_span = 0.7, labels_angle = 0, xlab = 'Triennial', smooth = F, save = F,
  plot_filename = 'forest_loss_fire_points_line_plots_error_bars_2001_2018_four_variables_triennial.jpg',
  new_dev = F
)
```


(A)
0.30
0.25
0.20
0.15
0.10
(B)
320
280
240
200
(C)
2.5
2.0
1.5
1.0
(D)
12
10
8
6
value
2001-2003
2004-2006
2007-2009
2010-2012
2013-2015
2016-2018
Triennial

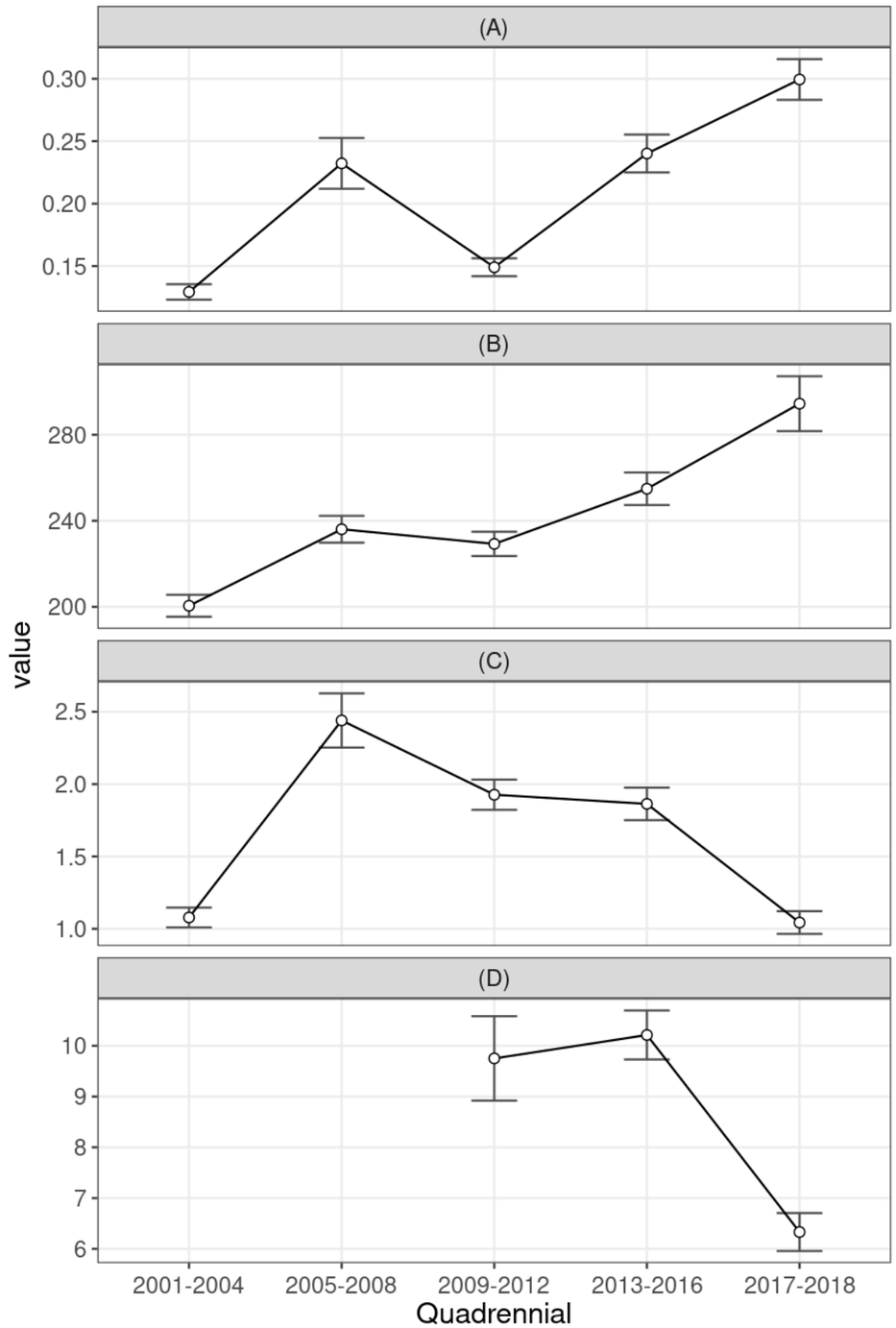
```
## $plot
```



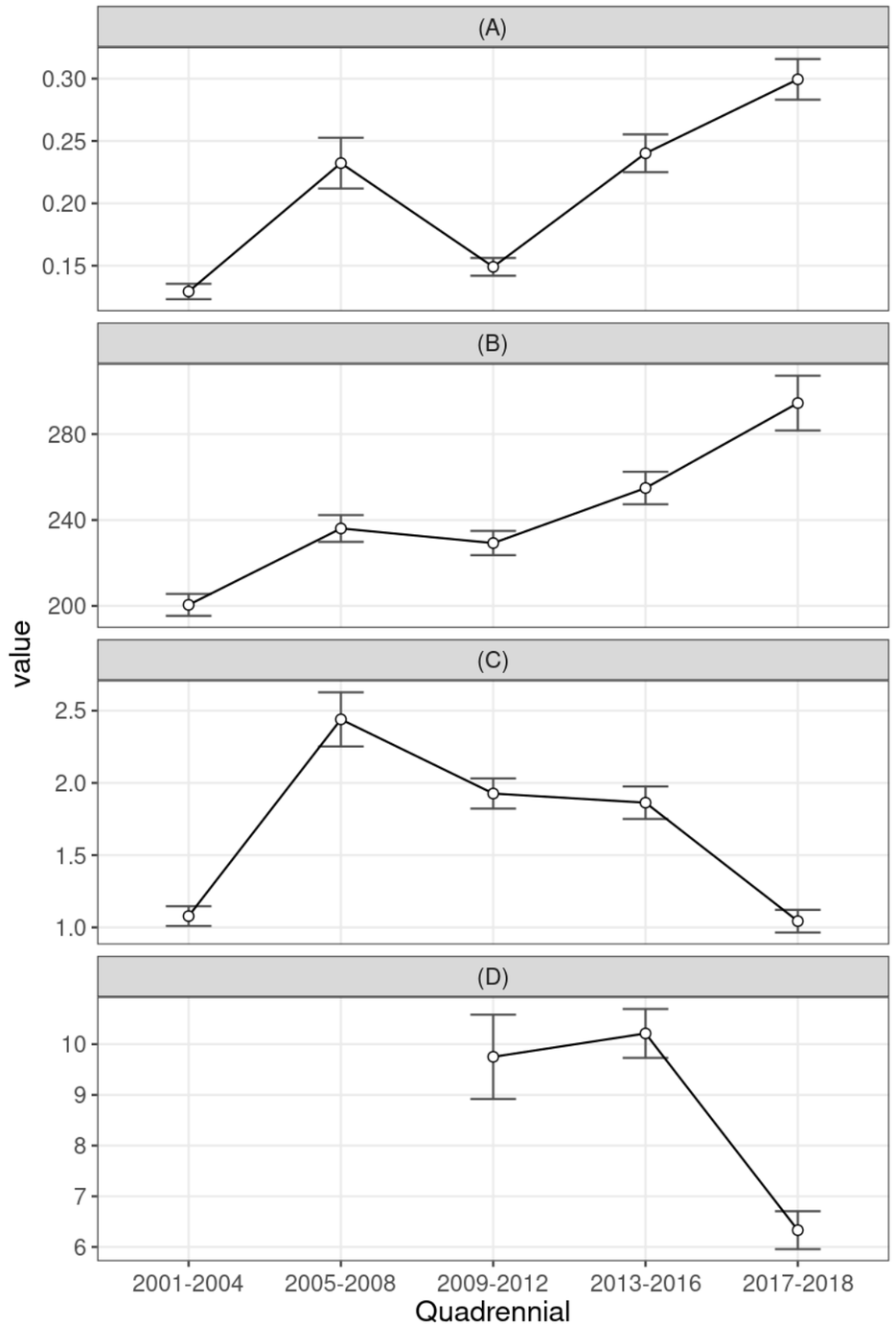

```
##
## [[2]]
##
## \begin{tabular}{l|l|l|l|l}
```

```
## \hline
## triennial\_interval & Avg. area of forest loss in sq. km per 100 sq. km & Avg. number of forest loss patches \$<\$1 Ha per 100 sq. km & Avg. number of MODIS M6 fire points per 100 sq. km & Avg. number of VIRS V1
## \hline
## 2001-2003 & 0.1 (0.01) & 181.59 (5.33) & 0.92 (0.08) & -\\
## \hline
## 2004-2006 & 0.24 (0.03) & 235.18 (7.47) & 2.27 (0.24) & -\\
## \hline
## 2007-2009 & 0.2 (0.01) & 230.33 (6.15) & 2.13 (0.12) & -\\
## \hline
## 2010-2012 & 0.15 (0.01) & 240.63 (6.97) & 1.94 (0.12) & 9.75 (0.83)\\
## \hline
## 2013-2015 & 0.2 (0.02) & 229.65 (6.96) & 2.13 (0.14) & 11.34 (0.61)\\
## \hline
## 2016-2018 & 0.32 (0.02) & 306.5 (11.08) & 1.05 (0.06) & 6.5 (0.31)\\
## \hline
## \end{tabular}
##
## $summaries_print_df
## # A tibble: 6 x 5
##   triennial_interval `Avg. area of fore~ `Avg. number of for~ `Avg. number of M~
##   <fct>              <chr>               <chr>                <chr>
## 1 2001-2003          0.1 (0.01)          181.59 (5.33)        0.92 (0.08)
## 2 2004-2006          0.24 (0.03)         235.18 (7.47)        2.27 (0.24)
## 3 2007-2009          0.2 (0.01)          230.33 (6.15)        2.13 (0.12)
## 4 2010-2012          0.15 (0.01)         240.63 (6.97)        1.94 (0.12)
## 5 2013-2015          0.2 (0.02)          229.65 (6.96)        2.13 (0.14)
## 6 2016-2018          0.32 (0.02)         306.5 (11.08)        1.05 (0.06)
## # ... with 1 more variable:
## #   Avg. number of VIRS V1 fire points per 100 sq. km <chr>
```

```
## Quadrennials
periodic_summaries(
  source_table = four_variables_for_plots, measurevar = 'value',
  bins = 'quadrennial_interval', sum_variable = 'variable2', aspect_ratio = 1/3,
  smooth_span = 0.7, labels_angle = 0, xlab = 'Quadrennial', smooth = F, save = F,
  plot_filename = 'forest_loss_fire_points_line_plots_error_bars_2001_2018_four_variables_quadrennial.jpg',
  new_dev = F
)
```

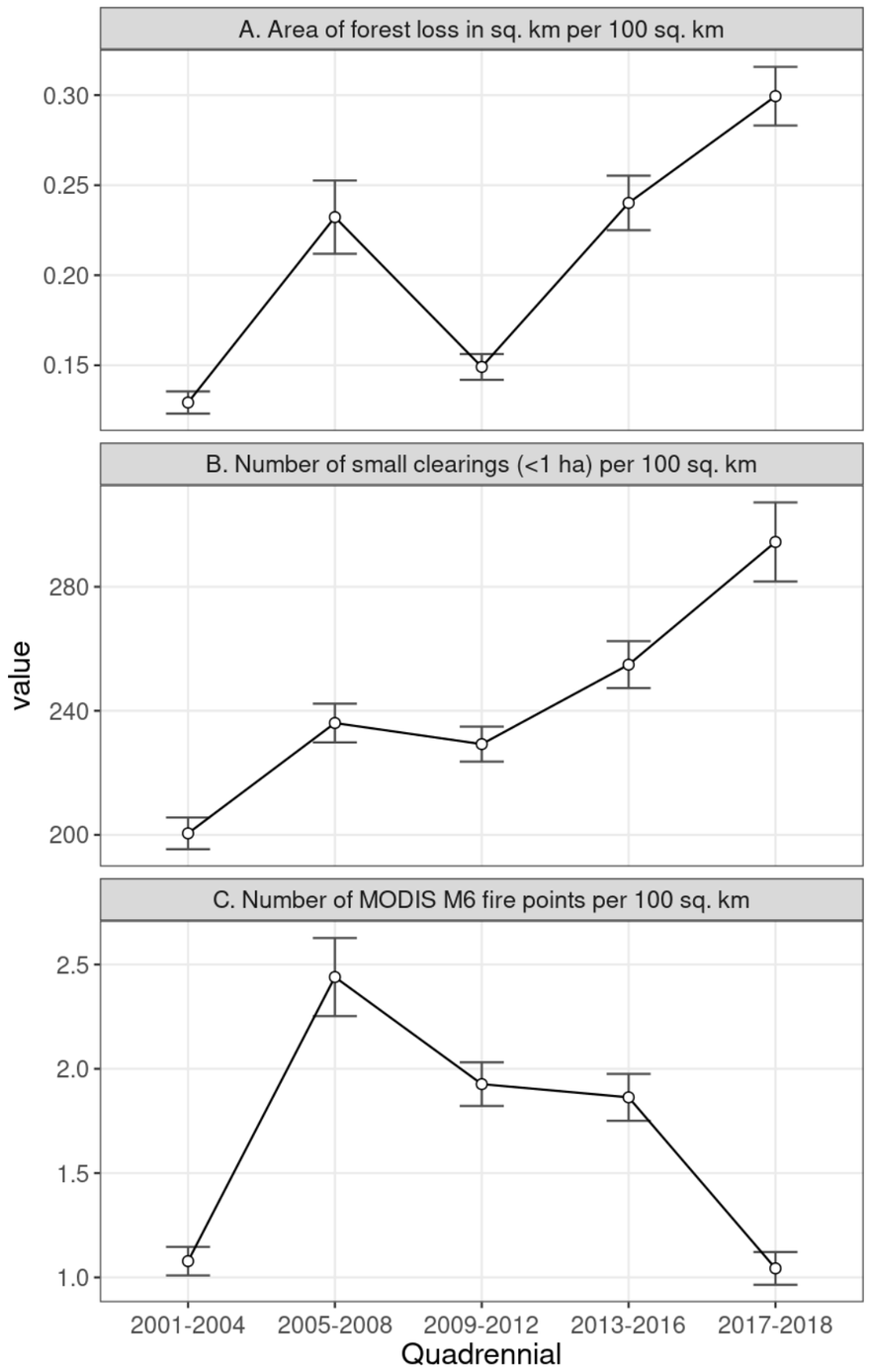

(A)
0.30
0.25
0.20
0.15
(B)
280
240
200
(C)
2.5
2.0
1.5
1.0
(D)
10
9
8
7
6
value
2001-2004
2005-2008
2009-2012
2013-2016
2017-2018
Quadrennial

```
## $plot
```

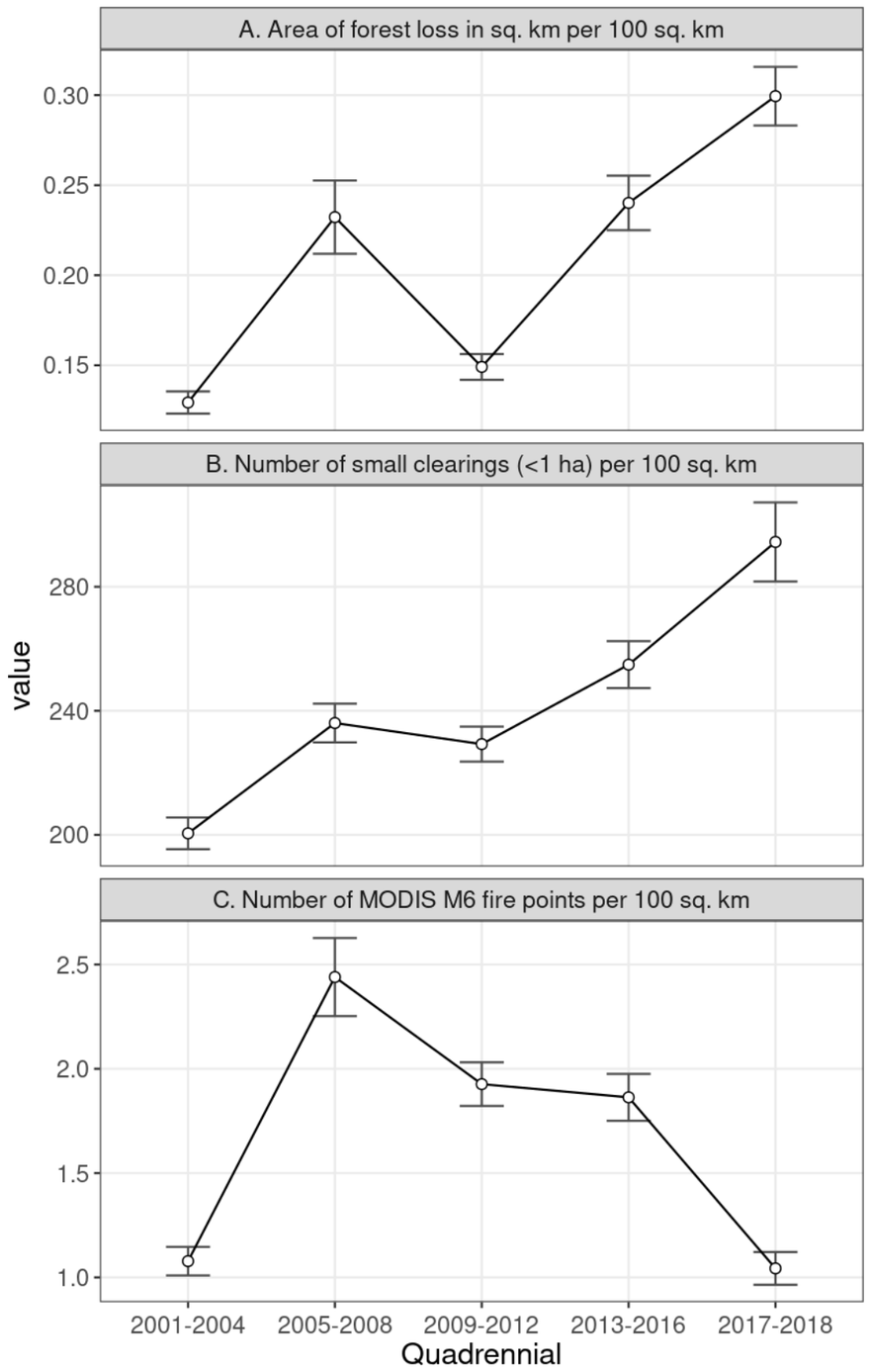



```
##
## [[2]]
##
## \begin{tabular}{l|l|l|l|l}
```

```
## \hline
## quadrennial\_interval & Avg. area of forest loss in sq. km per 100 sq. km & Avg. number of forest loss patches \$<\$1 Ha per 100 sq. km & Avg. number of MODIS M6 fire points per 100 sq. km & Avg. number of VIRS
## \hline
## 2001-2004 & 0.13 (0.01) & 200.49 (5.12) & 1.08 (0.07) & -\\
## \hline
## 2005-2008 & 0.23 (0.02) & 236.06 (6.24) & 2.44 (0.19) & -\\
## \hline
## 2009-2012 & 0.15 (0.01) & 229.26 (5.64) & 1.93 (0.1) & 9.75 (0.83)\\
## \hline
## 2013-2016 & 0.24 (0.02) & 254.89 (7.57) & 1.86 (0.11) & 10.21 (0.48)\\
## \hline
## 2017-2018 & 0.3 (0.02) & 294.45 (12.75) & 1.04 (0.08) & 6.33 (0.37)\\
## \hline
## \end{tabular}
##
## $summaries_print_df
## # A tibble: 5 x 5
##   quadrennial_interval `Avg. area of fore~ `Avg. number of f~ `Avg. number of M~
##   <fct>                <chr>               <chr>              <chr>
## 1 2001-2004            0.13 (0.01)         200.49 (5.12)      1.08 (0.07)
## 2 2005-2008            0.23 (0.02)         236.06 (6.24)      2.44 (0.19)
## 3 2009-2012            0.15 (0.01)         229.26 (5.64)      1.93 (0.1)
## 4 2013-2016            0.24 (0.02)         254.89 (7.57)      1.86 (0.11)
## 5 2017-2018            0.3 (0.02)          294.45 (12.75)     1.04 (0.08)
## # ... with 1 more variable:
## #   Avg. number of VIRS V1 fire points per 100 sq. km <chr>

# Drawing results
periodic_summaries(
  source_table = four_variables_for_plots %>% filter(!variable2 == '(D)') %>%  mutate(variable2 = case_when(
    variable2 == '(C)' ~ 'C. Number of MODIS M6 fire points per 100 sq. km',
    variable2 == '(B)' ~ 'B. Number of small clearings (<1 ha) per 100 sq. km',
    variable2 == '(A)' ~ 'A. Area of forest loss in sq. km per 100 sq. km'
  )),
  measurevar = 'value',
  bins = 'quadrennial_interval', sum_variable = 'variable2', aspect_ratio = 1/2,
  smooth_span = 0.7, labels_angle = 0, xlab = 'Quadrennial', smooth = F, save = F,
  plot_filename = 'forest_loss_fire_points_line_plots_error_bars_2001_2018_four_variables_quadrennial.jpg',
  calc_se = F, new_dev = F
)
```

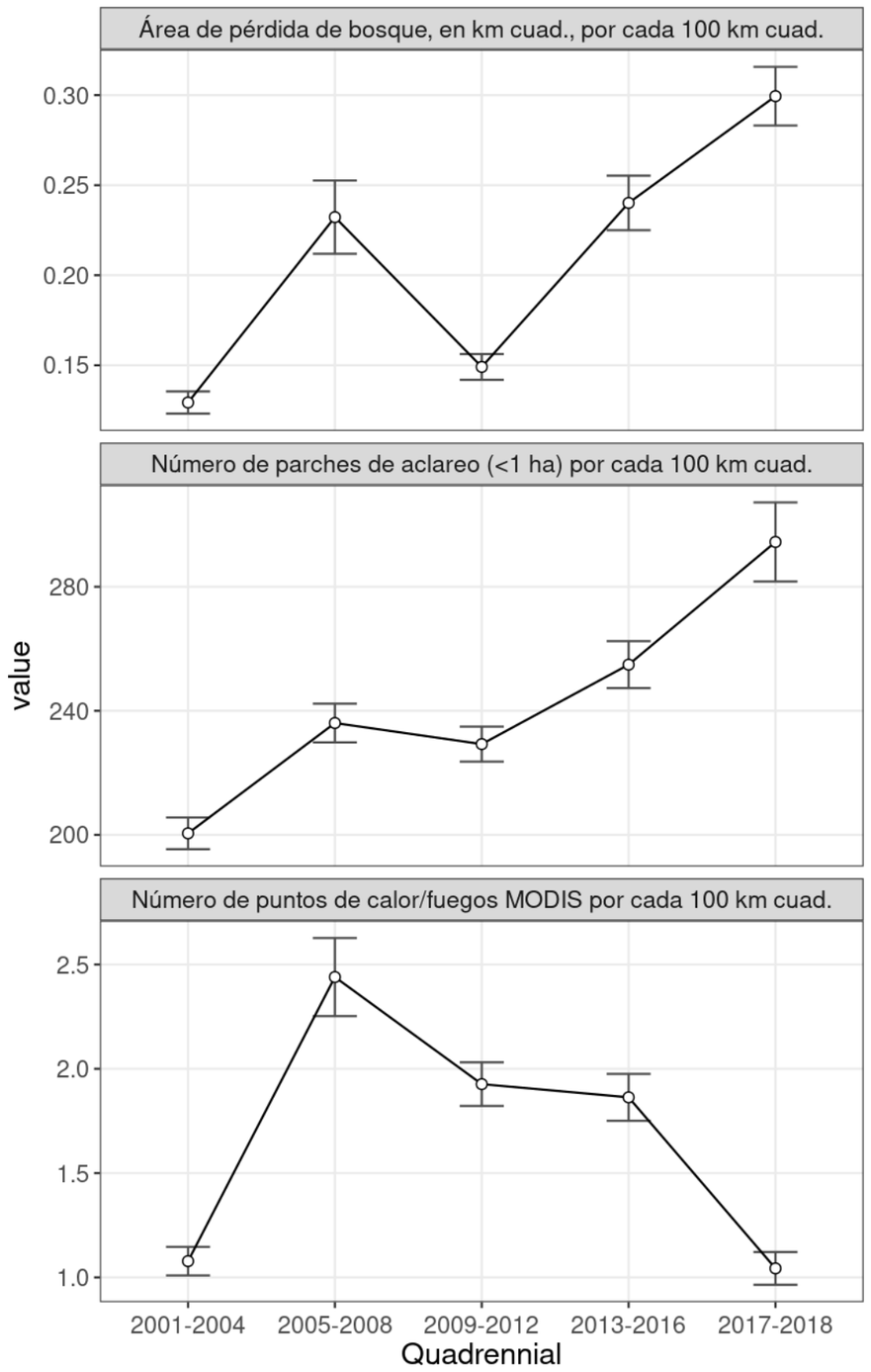

A. Area of forest loss in sq. km per 100 sq. km
0.30
0.25
0.20
0.15
B. Number of small clearings (<1 ha) per 100 sq. km
280
240
200
value
C. Number of MODIS M6 fire points per 100 sq. km
2.5
2.0
1.5
1.0
2001-2004
2005-2008
2009-2012
2013-2016
2017-2018
Quadrennial

```
## $plot
```

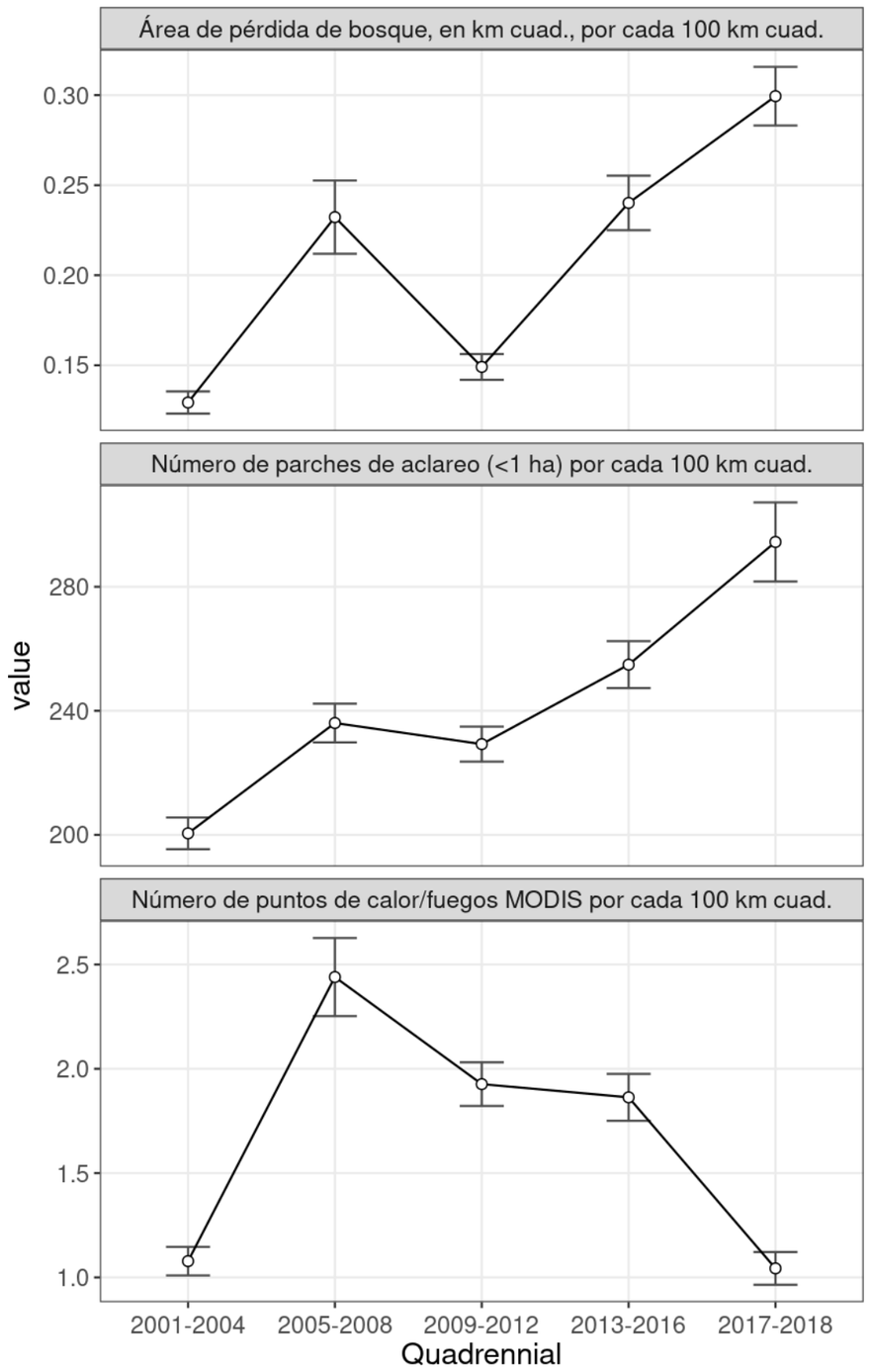



```
##
## [[2]]
##
## \begin{tabular}{l|l}
```

```
## \hline
## quadrennial\_interval & NA\\
## \hline
## 2001-2004 & 0.1293251, 200.4858820, 1.0780220\\
## \hline
## 2005-2008 & 0.2322423, 236.0592956, 2.4397988\\
## \hline
## 2009-2012 & 0.1490862, 229.2587650, 1.9264740\\
## \hline
## 2013-2016 & 0.2401406, 254.8880517, 1.8631714\\
## \hline
## 2017-2018 & 0.2994098, 294.4516158, 1.0432918\\
## \hline
## \end{tabular}
##
## $summaries_print_df
## # A tibble: 5 x 2
##   quadrennial_interval `NA`
##   <fct>                <list>
## 1 2001-2004            <dbl [3]>
## 2 2005-2008            <dbl [3]>
## 3 2009-2012            <dbl [3]>
## 4 2013-2016            <dbl [3]>
## 5 2017-2018            <dbl [3]>
# In the Dominican Republic, by four-year periods from 2001 to 2018, both the area of forest loss (top) and the number of small clearings (middle) per 100 sq. km, increased since 2013 WITHOUT the help of fire (bott
periodic_summaries(
  source_table = four_variables_for_plots %>% filter(!variable2 == '(D)') %>%  mutate(variable2 = case_when(
    variable2 == '(C)' ~ 'Número de puntos de calor/fuegos MODIS por cada 100 km cuad.',
    variable2 == '(B)' ~ 'Número de parches de aclareo (<1 ha) por cada 100 km cuad.',
    variable2 == '(A)' ~ 'Área de pérdida de bosque, en km cuad., por cada 100 km cuad.'
  )),
  measurevar = 'value',
  bins = 'quadrennial_interval', sum_variable = 'variable2', aspect_ratio = 1/2,
  smooth_span = 0.7, labels_angle = 0, xlab = 'Quadrennial', smooth = F, save = F,
  plot_filename = 'forest_loss_fire_points_line_plots_error_bars_2001_2018_four_variables_quadrennial.jpg',
  calc_se = F, new_dev = F
)
```

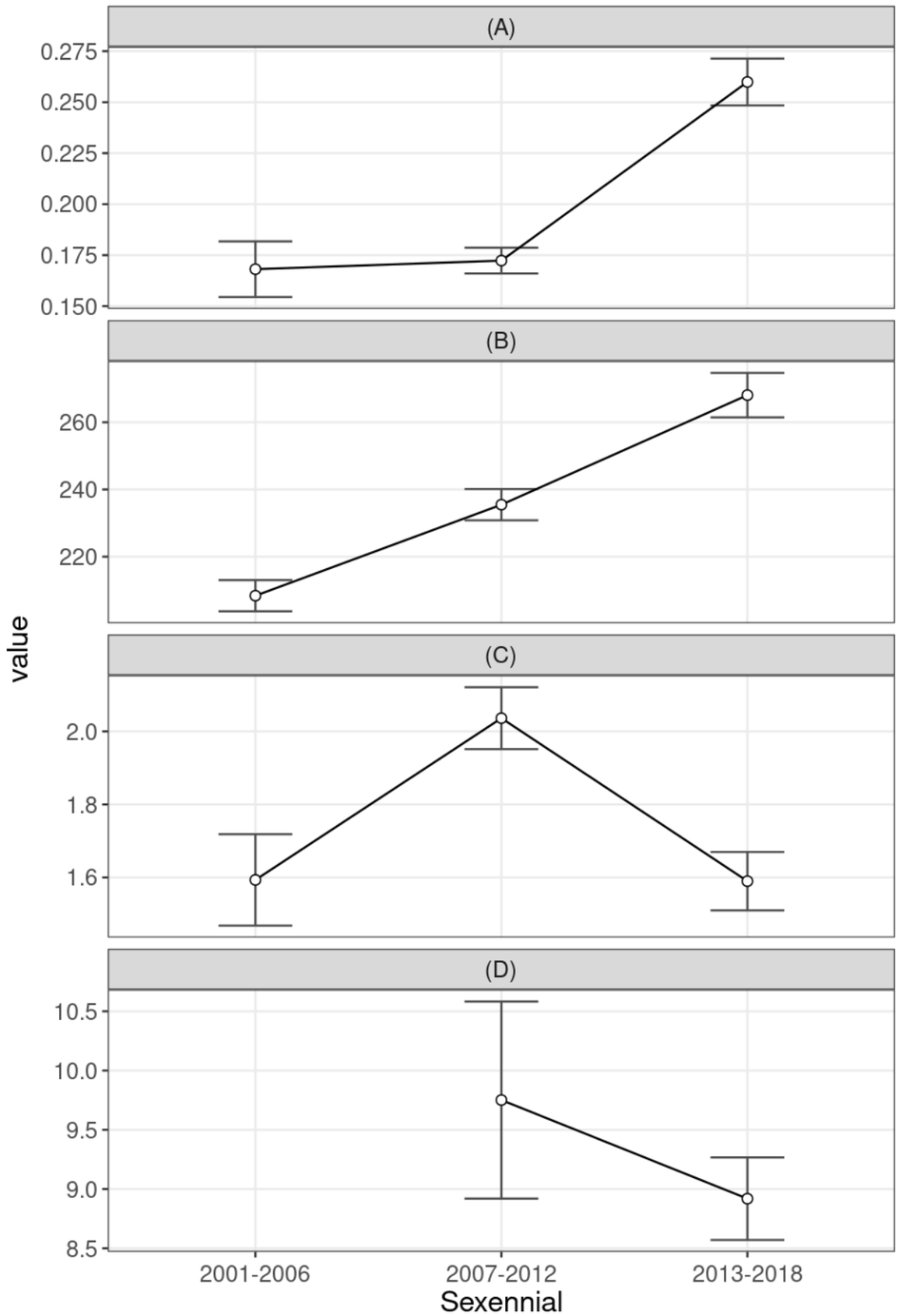

Área de pérdida de bosque, en km cuad., por cada 100 km cuad.
0.30
0.25
0.20
0.15
Número de parches de aclareo (<1 ha) por cada 100 km cuad.
280
240
200
value
Número de puntos de calor/fuegos MODIS por cada 100 km cuad.
2.5
2.0
1.5
1.0
2001-2004
2005-2008
2009-2012
2013-2016
2017-2018
Quadrennial

```
## $plot
```

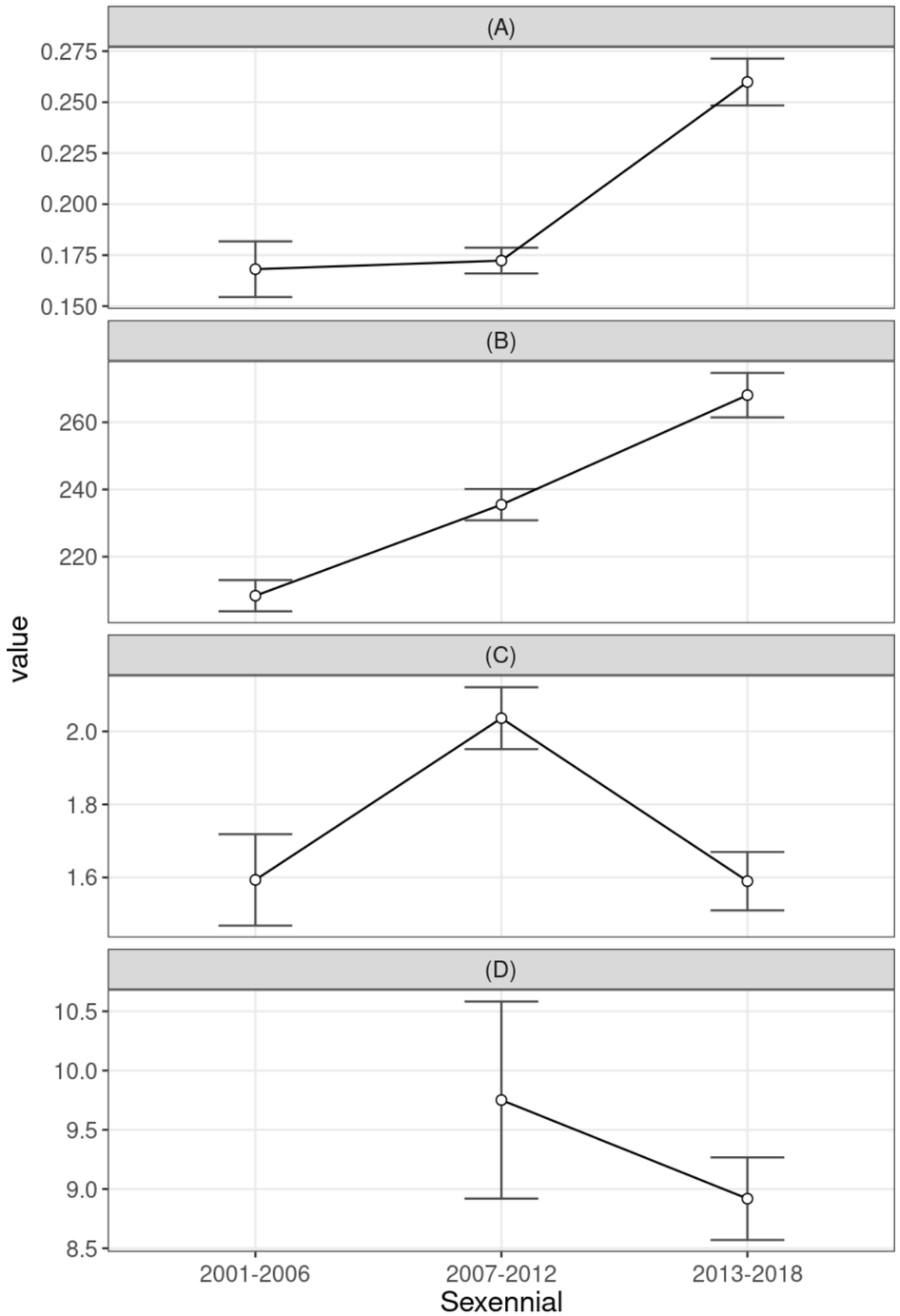



```
##
## [[2]]
##
## \begin{tabular}{l|l}
```

```
## \hline
## quadrennial\_interval & NA\\
## \hline
## 2001-2004 & 0.1293251, 200.4858820, 1.0780220\\
## \hline
## 2005-2008 & 0.2322423, 236.0592956, 2.4397988\\
## \hline
## 2009-2012 & 0.1490862, 229.2587650, 1.9264740\\
## \hline
## 2013-2016 & 0.2401406, 254.8880517, 1.8631714\\
## \hline
## 2017-2018 & 0.2994098, 294.4516158, 1.0432918\\
## \hline
## \end{tabular}
##
## $summaries_print_df
## # A tibble: 5 x 2
##   quadrennial_interval `NA`
##   <fct>                <list>
## 1 2001-2004            <dbl [3]>
## 2 2005-2008            <dbl [3]>
## 3 2009-2012            <dbl [3]>
## 4 2013-2016            <dbl [3]>
## 5 2017-2018            <dbl [3]>

## Sexennials
periodic_summaries(
  source_table = four_variables_for_plots, measurevar = 'value',
  bins = 'sexennial_interval', sum_variable = 'variable2', aspect_ratio = 1/3,
  smooth_span = 0.7, labels_angle = 0, xlab = 'Sexennial', smooth = F, save = F,
  plot_filename = 'forest_loss_fire_points_line_plots_error_bars_2001_2018_four_variables_sexennial.jpg',
  new_dev = F
)
```

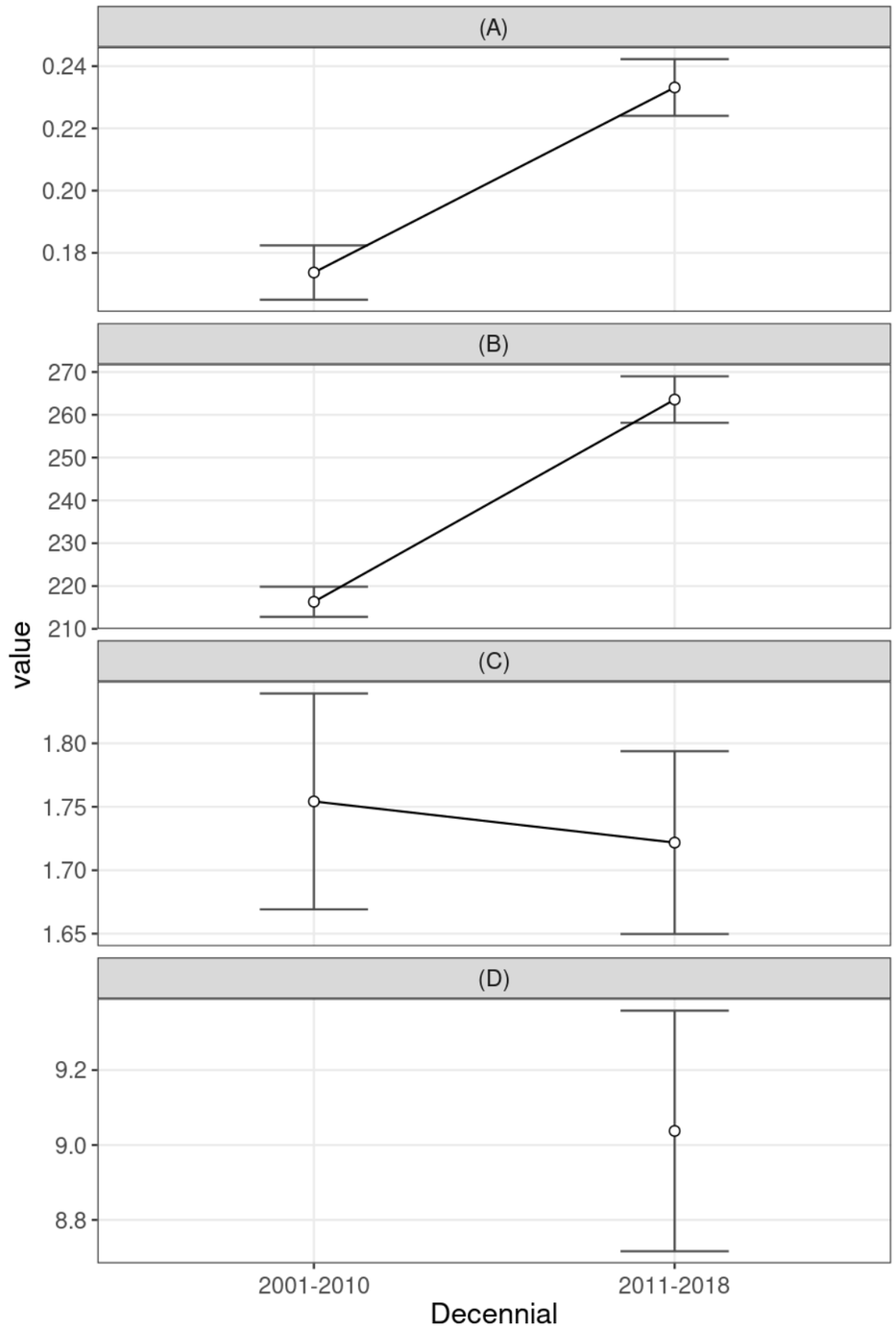

(A)
0.275
0.250
0.225
0.200
0.175
0.150
(B)
260
240
220
(C)
2.0
1.8
1.6
(D)
10.5
10.0
9.5
9.0
8.5
value
2001-2006
2007-2012
2013-2018
Sexennial

```
## $plot
```

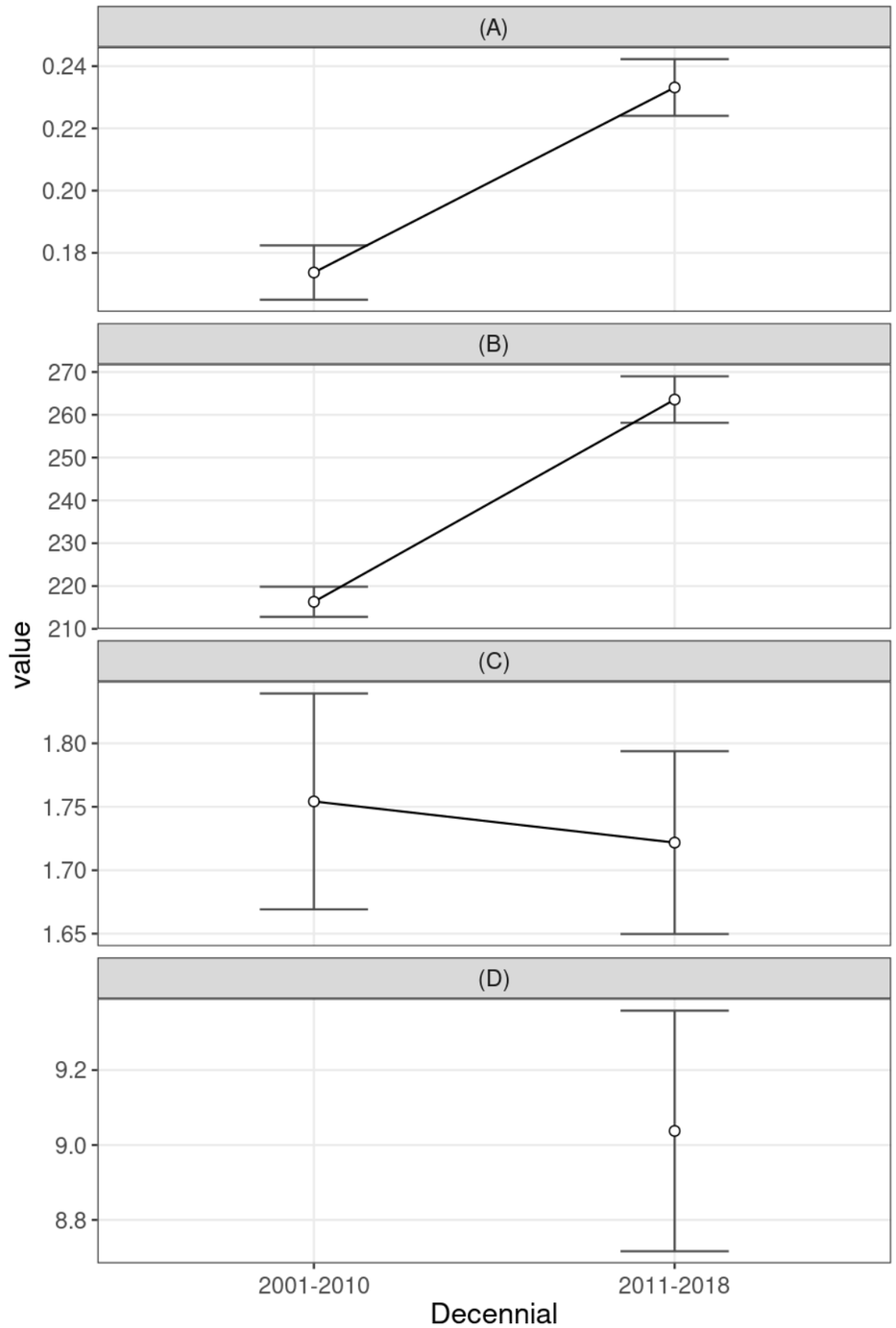



```
##
## [[2]]
##
## \begin{tabular}{l|l|l|l|l}
```

```
## \hline
## sexennial\_interval & Avg. area of forest loss in sq. km per 100 sq. km & Avg. number of forest loss patches \$<\$1 Ha per 100 sq. km & Avg. number of MODIS M6 fire points per 100 sq. km & Avg. number of VIRS V1
## \hline
## 2001-2006 & 0.17 (0.01) & 208.39 (4.64) & 1.59 (0.13) & -\\
## \hline
## 2007-2012 & 0.17 (0.01) & 235.48 (4.65) & 2.04 (0.08) & 9.75 (0.83)\\
## \hline
## 2013-2018 & 0.26 (0.01) & 268.08 (6.61) & 1.59 (0.08) & 8.92 (0.35)\\
## \hline
## \end{tabular}
##
## $summaries_print_df
## # A tibble: 3 x 5
##   sexennial_interval `Avg. area of fore~ `Avg. number of for~ `Avg. number of M~
##   <fct>              <chr>               <chr>                <chr>
## 1 2001-2006          0.17 (0.01)         208.39 (4.64)        1.59 (0.13)
## 2 2007-2012          0.17 (0.01)         235.48 (4.65)        2.04 (0.08)
## 3 2013-2018          0.26 (0.01)         268.08 (6.61)        1.59 (0.08)
## # ... with 1 more variable:
## #   Avg. number of VIRS V1 fire points per 100 sq. km <chr>
## Decennials
periodic_summaries(
  source_table = four_variables_for_plots, measurevar = 'value',
  bins = 'decennial_interval', sum_variable = 'variable2', aspect_ratio = 1/3,
  smooth_span = 0.7, labels_angle = 0, xlab = 'Decennial', smooth = F, save = F,
  plot_filename = 'forest_loss_fire_points_line_plots_error_bars_2001_2018_four_variables_decennial.jpg',
  new_dev = F
)
```

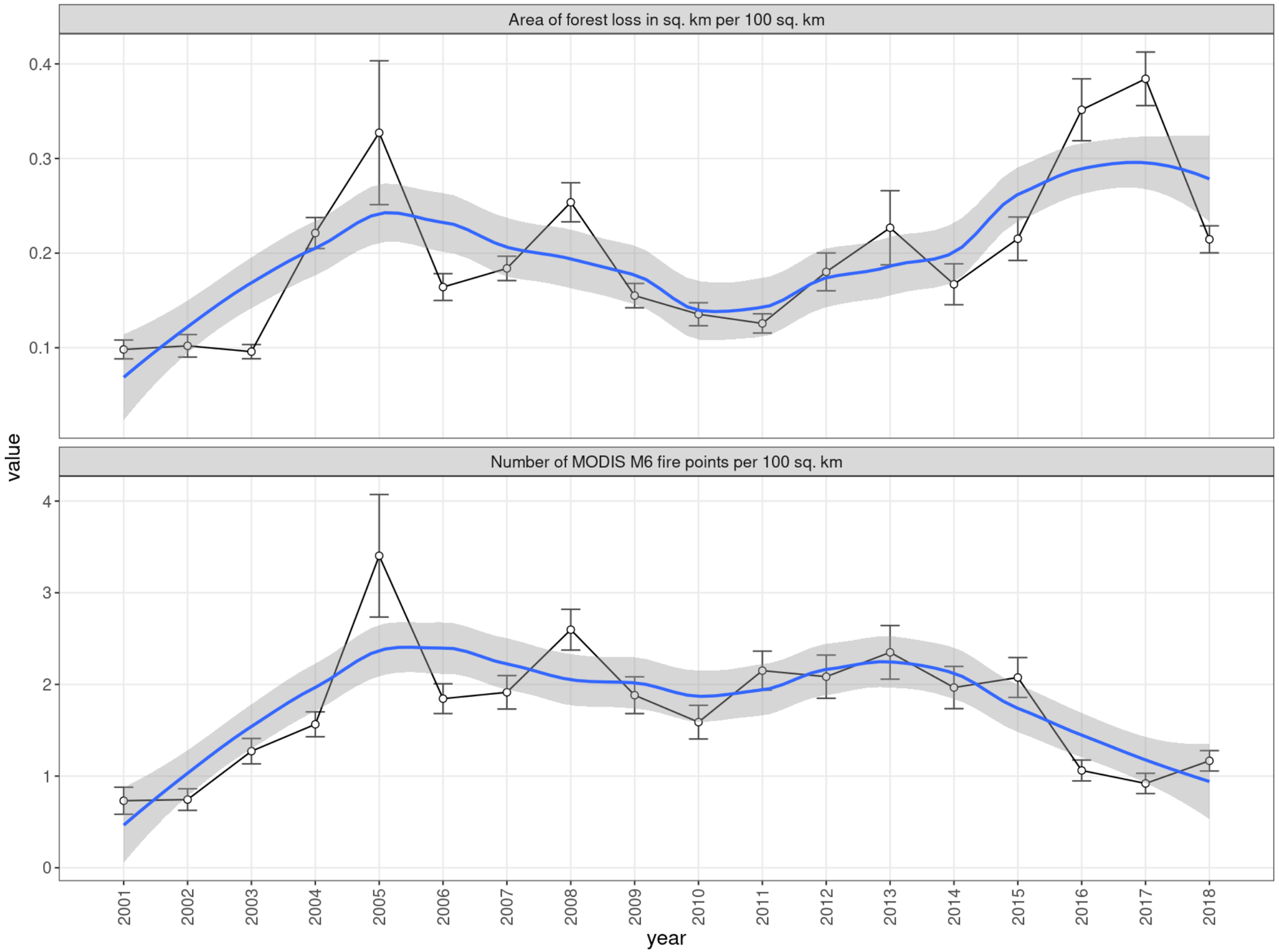

(A)
0.24
0.22
0.20
0.18
(B)
270
260
250
240
230
220
210
(C)
1.80
1.75
1.70
1.65
(D)
9.2
9.0
8.8
value
2001-2010
2011-2018
Decennial

```
## $plot
```




```
##
## [[2]]
##
## \begin{tabular}{l|l|l|l|l}
```

```
## \hline
## decennial\_interval & Avg. area of forest loss in sq. km per 100 sq. km & Avg. number of forest loss patches \$<\$1 Ha per 100 sq. km & Avg. number of MODIS M6 fire points per 100 sq. km & Avg. number of VIRS V1
## \hline
## 2001-2010 & 0.17 (0.01) & 216.32 (3.52) & 1.75 (0.09) & -\\
## \hline
## 2011-2018 & 0.23 (0.01) & 263.56 (5.43) & 1.72 (0.07) & 9.04 (0.32)\\
## \hline
## \end{tabular}
##
## $summaries_print_df
## # A tibble: 2 x 5
##   decennial_interval `Avg. area of fore~ `Avg. number of for~ `Avg. number of M~
##   <fct>              <chr>               <chr>                <chr>
## 1 2001-2010          0.17 (0.01)         216.32 (3.52)        1.75 (0.09)
## 2 2011-2018          0.23 (0.01)         263.56 (5.43)        1.72 (0.07)
## # ... with 1 more variable:
## #   Avg. number of VIRS V1 fire points per 100 sq. km <chr>

# Commented plot, only forest loss and fires modis
four_variables_for_plots_commented <- hexzonalfm %>%
  select(!matches('ENLACE|AREASQM')) %>%
  st_drop_geometry %>%
  gather(variable, value) %>%
  mutate(year = as.numeric(create_year_from_string(variable)) + 2000,
         variable2 = create_variable_name_from_string(variable)) %>%
  mutate(value = value * 100) %>%
  mutate(variable2 = case_when(
    variable2 == 'NFIRESM6PSQKM' ~ 'Number of MODIS M6 fire points per 100 sq. km',
    variable2 == 'NFIRESV1PSQKM' ~ 'Number of VIRS V1 fire points per 100 sq. km',
    variable2 == 'NCLUMPSSMALLER1HAPSQKM' ~ 'Number of forest loss patches <1 Ha per 100 sq. km',
    variable2 == 'LOSSGREATER1HA_PUA' ~ 'Area of forest loss in sq. km per 100 sq. km'
  ))
four_variables_sum_commented <- summarySE(
  four_variables_for_plots_commented %>%
  filter(grepl('MODIS|^Area of', variable2)),
  measurevar="value", groupvars=c('year', 'variable2'))
four_variables_plot_commented <- four_variables_for_plots_commented %>%
  filter(grepl('MODIS|^Area of', variable2)) %>%
  ggplot + aes(x = year, y = value) +
  scale_x_continuous(breaks = 2001:2018) +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5), panel.grid.minor = element_blank(),
        text = element_text(size = 14), aspect.ratio = 1/3) +
  geom_errorbar(data = four_variables_sum_commented, aes(ymin = value - se, ymax = value + se), colour = "grey30", width = .3) +
  geom_line(data = four_variables_sum_commented) +
  geom_point(data = four_variables_sum_commented, aes(x = year, y = value), size=2, shape=21, fill="white") +
  facet_wrap(~ variable2, scales = 'free_y', ncol = 1)
four_variables_plot_commented + geom_smooth(method = 'loess', span = 0.5)
```

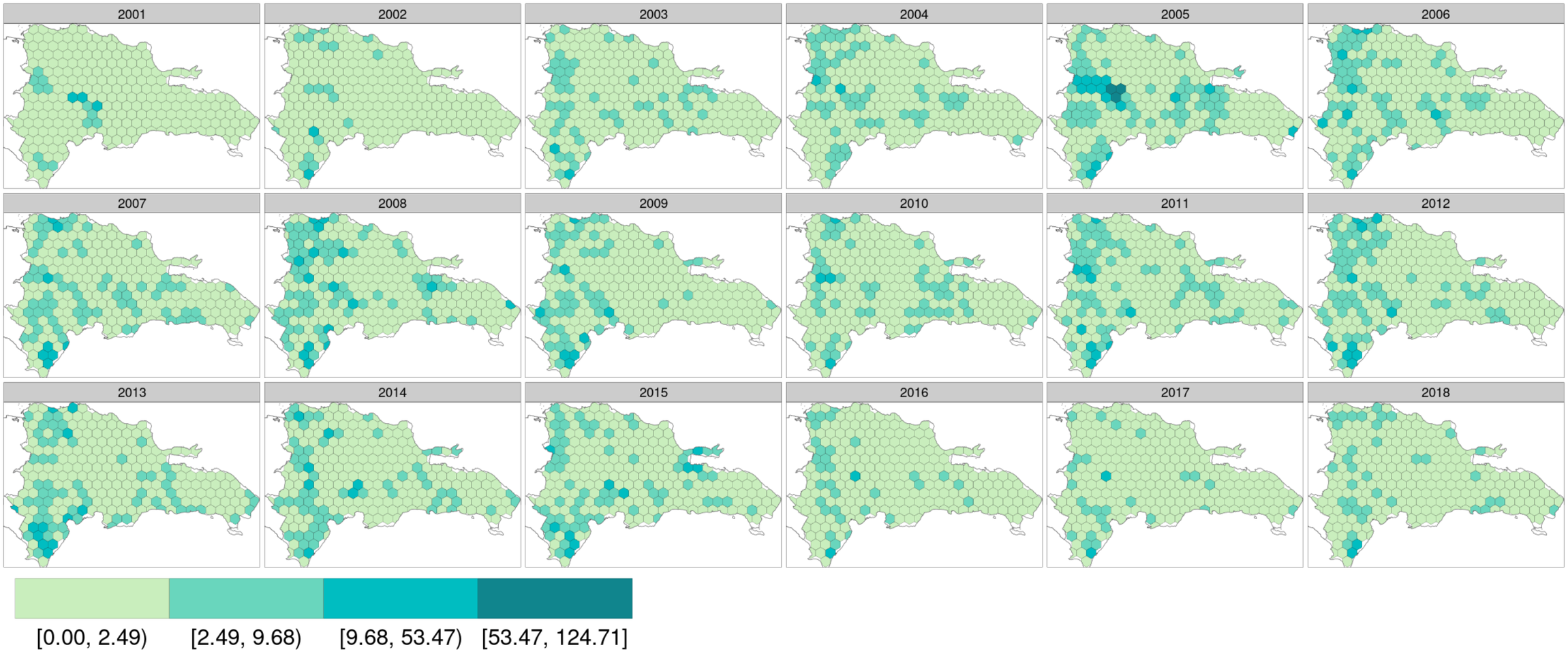


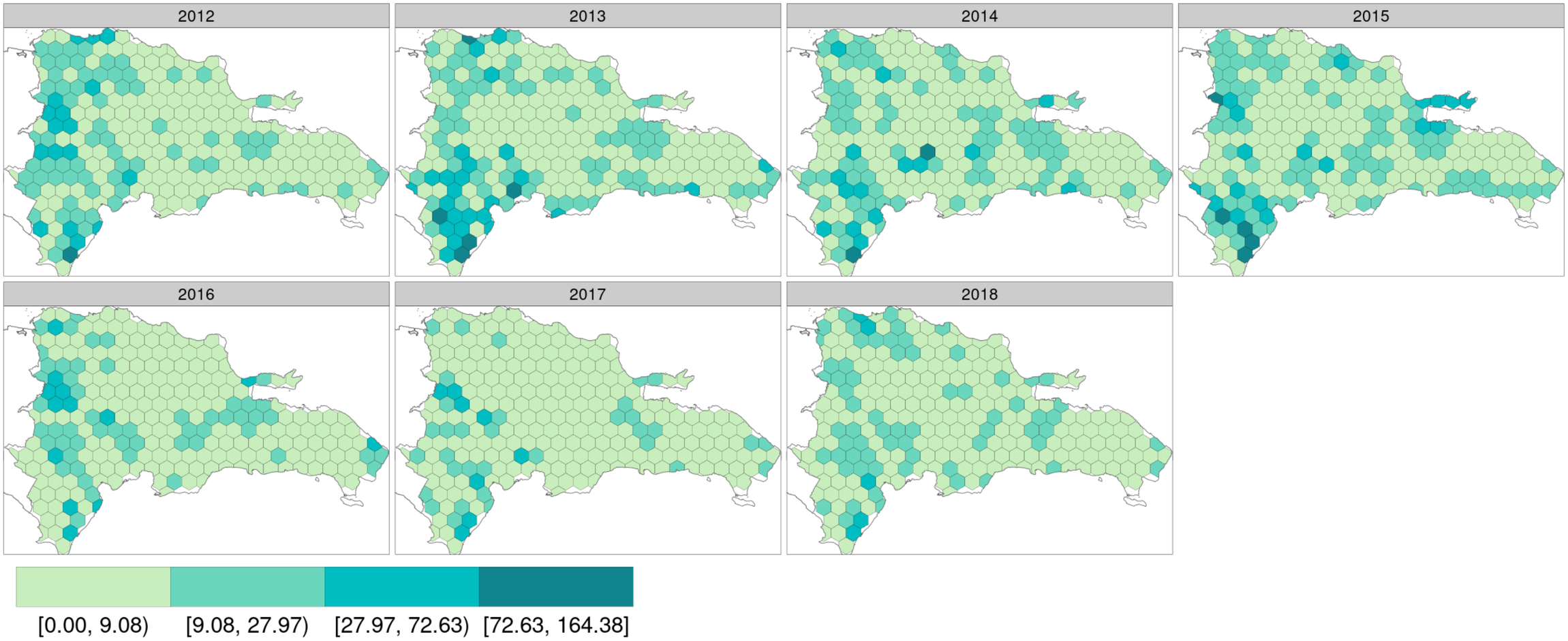

```
# Fire (bottom chart) and forest-loss (top chart), were strongly associated during the first 15 years of the 21st Century in the Dominican Republic. However, in recent years, no such association exists. And yes, 20

# Time-series decomposition
```

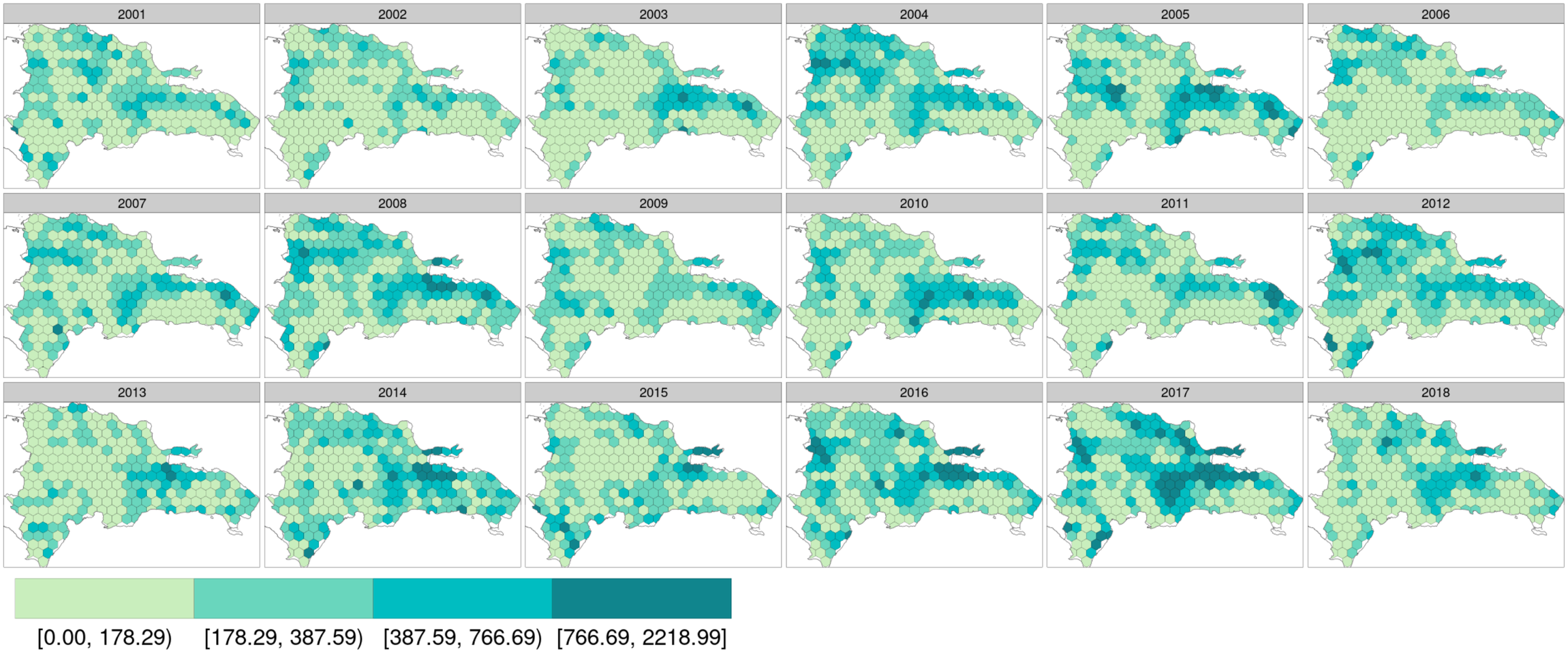
```r
four_variables_sum <- summarySE(
  four_variables_for_plots_commented,
  measurevar="value", groupvars=c('year', 'variable2')) %>%
   mutate(variable2 = case_when(
    variable2 == 'Number of MODIS M6 fire points per 100 sq. km' ~ '(C)',
    variable2 == 'Number of VIRS V1 fire points per 100 sq. km' ~ '(D)',
    variable2 == 'Number of forest loss patches <1 Ha per 100 sq. km' ~ '(B)',
    variable2 == 'Area of forest loss in sq. km per 100 sq. km' ~ '(A)'
  ))
four_variables_ts <- sapply(
  unique(four_variables_sum$variable2),
  function(x)
    ts(
      four_variables_sum[four_variables_sum$variable2 == x, 'value'],
      start = if(grepl('D', x)) 2012 else 2001, frequency = 1),
  simplify = F, USE.NAMES = T
  )
four_variables_ts_filt <- sapply(
  four_variables_ts,
  function(x) sapply(c("HP", "CF"), function(y) mFilter(x, filter = y)),
  simplify = F, USE.NAMES = T
)
four_variables_ts_filt_for_gg <- lapply(
  four_variables_ts_filt, function(x) ldply(lapply(x, crear_tabla_de_mfilter_para_gg), .id = NULL)) %>%
  plyr::ldply(.id = 'Variable')
four_variables_ts_filt_gg <- four_variables_ts_filt_for_gg %>%
  gather(Component, Value, -Variable, -Year, -Filter) %>%
  mutate(Variable = gsub(' per', '\nper', Variable)) %>%
  ggplot +
  aes(x = Year, y = Value, color = Component) +
    scale_x_continuous(breaks = 2001:2018) +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5), text = element_text(size = 14), aspect.ratio = 1/2) +
  geom_line() +
  facet_grid(Variable ~ Filter, scales = 'free_y')
four_variables_ts_filt_gg
```

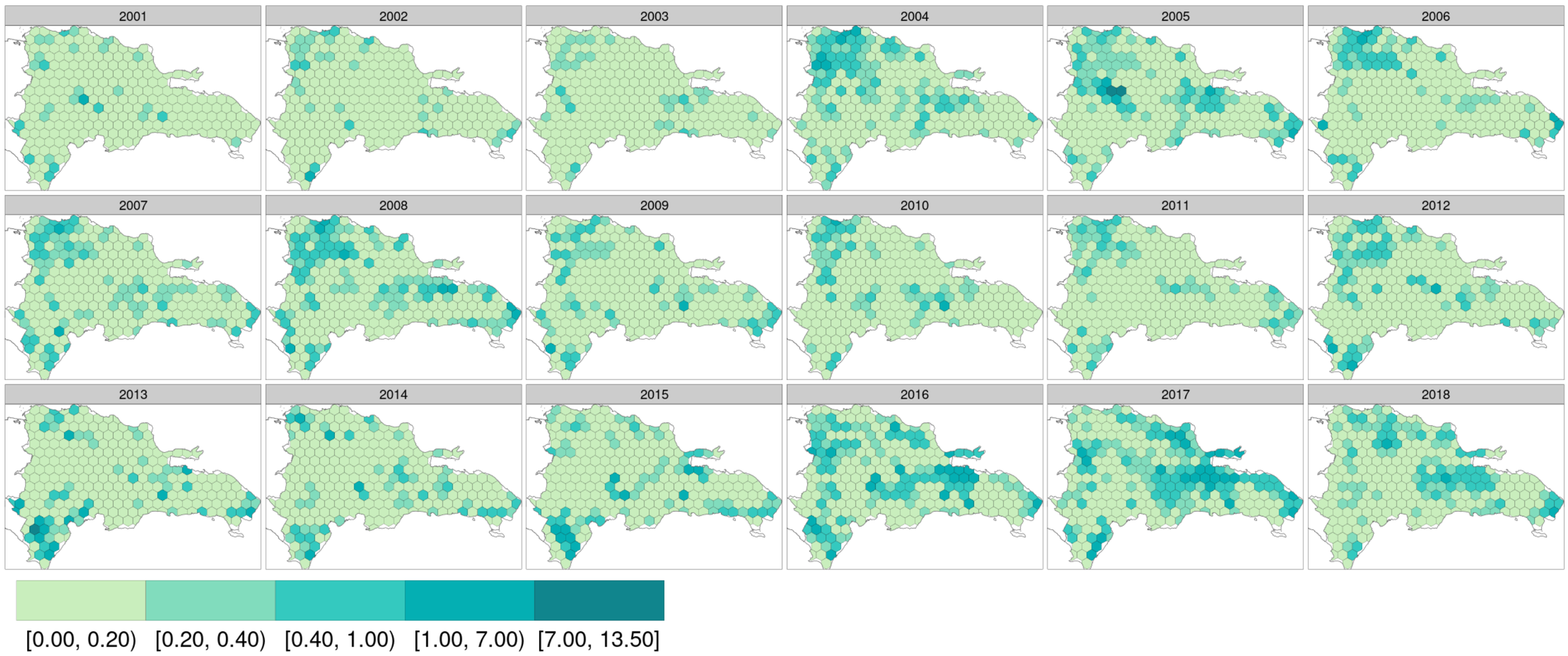

```
# jpeg('out/forest_loss_fire_points_line_plots_2001_2018_ts_decomposition.jpg', width = 2600, height = 2160, res = 250)
# four_variables_ts_filt_gg
# dev.off()
```

```
hexzonalfm_yearly_maps <- hexzonalfm %>%
    select(!matches("ENLACE|AREASQM")) %>%
    gather(variable, value, -geometry) %>%
    mutate(year = as.numeric(create_year_from_string(variable)) + 2000, variable2 = create_variable_name_from_string(variable)) %>%
    replace(is.na(.), 0) %>%
    mutate(value = value * 100) %>%
    mutate(variable2 = case_when(variable2 == "NFIRESM6PSQKM" ~ "MODIS M6 fire points per 100 sq. km",
        variable2 == "NFIRESV1PSQKM" ~ "VIRS V1 fire points per 100 sq. km", variable2 ==
            "NCLUMPSSMALLER1HAPSQKM" ~ "Forest loss patches <1 Ha per 100 sq. km",
        variable2 == "LOSSGREATER1HA_PUA" ~ "Forest loss in sq. km per 100 sq. km")) %>%
    select(-variable, variable = variable2)
invisible(map(hexzonalfm_yearly_maps$variable %>%
    unique, function(x) {
    m <- hexzonalfm_yearly_maps %>%
        filter(variable == x) %>%
        tm_shape() + {
        if (grepl("Forest loss in sq. km per 100 sq. km", x)) tm_fill(col = "value",
            palette = c("#c9eebd", "#69d6bd", "#00bdc1", "#10858d"), size = 0.1,
            style = "fixed", breaks = c(0, 0.2, 0.4, 1, 7, 13.5), legend.is.portrait = F,
            legend.format = list(digits = 2, text.separator = "-", scientific = TRUE,
                format = "f"), n = 4) else tm_fill(col = "value", palette = c("#c9eebd",
            "#69d6bd", "#00bdc1", "#10858d"), size = 0.1, style = "kmeans", legend.is.portrait = F,
            legend.format = list(digits = 2, text.separator = "-", scientific = TRUE,
                format = "f"), n = 4)
    } + tm_borders(col = "grey15", lwd = 0.3) + tm_facets(by = "year", nrow = ifelse(grepl("VIRS",
        x), 2, 3), free.coords = FALSE, free.scales = FALSE) + tm_layout(panel.label.size = 1.75,
        legend.title.size = 1e-05, legend.text.size = 3, legend.outside.position = "bottom",
        legend.outside.size = 0.1, outer.margins = c(-0.02, 0.01, -0.02, 0.01), inner.margins = 0) +
        tm_shape(seaocean) + tm_borders() + tm_fill(col = "white")  #+
    # tm_shape(points_of_interest) + tm_text('code', size = 2, col = 'black',
    # fontface = 'bold', bg.color = 'white', bg.alpha = 0.5)
    n <- paste0("out/yearly_", x %>%
        gsub(" |<|\\.", "_", .) %>%
        gsub("__", "_", .) %>%
        tolower, ".jpg")
    # jpeg(n, width = 3840, height = 1700, res = 300) dev.new()
    print(m)
    # dev.off()
}))
```


2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
[0.00, 2.49)
[2.49, 9.68)
[9.68, 53.47)
[53.47, 124.71]


2012
2013
2014
2015
2016
2017
2018
[0.00, 9.08)
[9.08, 27.97)
[27.97, 72.63)
[72.63, 164.38]


2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
[0.00, 178.29)
[178.29, 387.59)
[387.59, 766.69)
[766.69, 2218.99]



6.4 *Transformations*

```
# * Transformations using Tukey's Ladder of Powers
hexzonalfmt <- hexzonalfm %>%
  mutate(across(!matches('ENLACE|AREASQM|geometry'),
                list('TLP' = ~ transformTukey(.x, plotit = F, quiet = T),
                'LAMBDA' = ~ transformTukey(x = .x, plotit = F, returnLambda = T, quiet = T)[['lambda']]))) %>%
  mutate(across(matches('TLP$'),
                 list('SWPVAL' = ~ shapiro.test(.x)$p.value,
                      'ADPVAL' = ~ ad.test(.x)$p.value,
                      'MTPVAL' = ~ moran.test(.x, listw = hexww, na.action = na.exclude, zero.policy = T)$p.value,
                      'MIEST' = ~ moran.test(.x, listw = hexww, na.action = na.exclude, zero.policy = T)$estimate[[1]],
                      'MIVAR' = ~ moran.test(.x, listw = hexww, na.action = na.exclude, zero.policy = T)$estimate[[3]],
                      'LENGTH' = ~ length(.x))))
lambda_tests <- hexzonalfmt %>%
  st_drop_geometry %>%
  select(matches('SWPVAL$|ADPVAL$|MTPVAL|MIEST|MIVAR|LENGTH')) %>%
  unique %>%
```

```
  gather(variable, value) %>%
  separate(variable, into = c('variable', 'test'), sep = '_TLP_') %>%
  mutate(variable = paste0(variable, '_TLP')) %>%
  spread(key = test, value = value) %>%
  mutate(year = as.numeric(create_year_from_string(variable))+2000,
         variable2 = create_variable_name_from_string(variable))
lambda_tests %>% arrange(SWPVAL)
##                              variable       ADPVAL LENGTH     MIEST       MIVAR
## 1            NFIRESM6_YEAR1_PSQKM_TLP 3.700000e-24    253 0.2337788 0.001546848
## 2            NFIRESM6_YEAR2_PSQKM_TLP 3.700000e-24    253 0.3377643 0.001549263
## 3           NFIRESM6_YEAR17_PSQKM_TLP 3.700000e-24    253 0.2021339 0.001552937
## 4           NFIRESM6_YEAR16_PSQKM_TLP 3.700000e-24    253 0.2822651 0.001552164
## 5            NFIRESM6_YEAR3_PSQKM_TLP 3.700000e-24    253 0.2162494 0.001550242
## 6           NFIRESM6_YEAR18_PSQKM_TLP 3.700000e-24    253 0.2516554 0.001552536
## 7           NFIRESM6_YEAR10_PSQKM_TLP 3.700000e-24    253 0.2591194 0.001548620
## 8           NFIRESM6_YEAR12_PSQKM_TLP 3.700000e-24    253 0.3486194 0.001552495
## 9            NFIRESM6_YEAR7_PSQKM_TLP 3.700000e-24    253 0.3116846 0.001553405
## 10          NFIRESM6_YEAR13_PSQKM_TLP 3.700000e-24    253 0.3424536 0.001551612
## 11           NFIRESM6_YEAR5_PSQKM_TLP 3.700000e-24    253 0.3835136 0.001548710
## 12          NFIRESM6_YEAR14_PSQKM_TLP 8.219447e-23    253 0.2598008 0.001550306
## 13          NFIRESM6_YEAR11_PSQKM_TLP 5.658013e-23    253 0.3085412 0.001553839
## 14           NFIRESM6_YEAR4_PSQKM_TLP 1.345327e-22    253 0.3420576 0.001554705
## 15           NFIRESM6_YEAR6_PSQKM_TLP 2.644369e-21    253 0.3115173 0.001553679
## 16          NFIRESM6_YEAR15_PSQKM_TLP 3.254400e-20    253 0.2907386 0.001552204
## 17           NFIRESM6_YEAR9_PSQKM_TLP 2.576325e-20    253 0.3184660 0.001551763
## 18       YEAR5_LOSSGREATER1HA_PUA_TLP 7.452685e-10    253 0.3746342 0.001521956
## 19           NFIRESM6_YEAR8_PSQKM_TLP 5.271077e-13    253 0.2823828 0.001553801
## 20      YEAR13_LOSSGREATER1HA_PUA_TLP 3.071271e-09    253 0.4035400 0.001543450
## 21          NFIRESV1_YEAR17_PSQKM_TLP 3.154195e-07    253 0.2972833 0.001548334
## 22       YEAR2_LOSSGREATER1HA_PUA_TLP 1.684977e-05    253 0.3145905 0.001537406
## 23          NFIRESV1_YEAR16_PSQKM_TLP 3.519062e-05    253 0.3334186 0.001553566
## 24      YEAR14_LOSSGREATER1HA_PUA_TLP 1.742845e-05    253 0.2034278 0.001540054
## 25          NFIRESV1_YEAR14_PSQKM_TLP 7.589478e-05    253 0.1883641 0.001544140
## 26          NFIRESV1_YEAR13_PSQKM_TLP 3.930253e-05    253 0.3986340 0.001550418
## 27       YEAR1_LOSSGREATER1HA_PUA_TLP 4.468161e-05    253 0.1823457 0.001543320
## 28      YEAR15_LOSSGREATER1HA_PUA_TLP 7.199124e-06    253 0.3558061 0.001544521
## 29      YEAR12_LOSSGREATER1HA_PUA_TLP 3.652148e-05    253 0.2499134 0.001541624
## 30          NFIRESV1_YEAR15_PSQKM_TLP 3.120724e-04    253 0.3574704 0.001548291
## 31          NFIRESV1_YEAR12_PSQKM_TLP 5.516181e-04    253 0.3264984 0.001549331
## 32       YEAR3_LOSSGREATER1HA_PUA_TLP 2.024899e-03    253 0.2045038 0.001547191
## 33       YEAR6_LOSSGREATER1HA_PUA_TLP 1.135303e-03    253 0.4201354 0.001549351
## 34      YEAR11_LOSSGREATER1HA_PUA_TLP 3.310997e-03    253 0.4093635 0.001552594
## 35          NFIRESV1_YEAR18_PSQKM_TLP 1.942503e-02    253 0.3097203 0.001550336
## 36       YEAR9_LOSSGREATER1HA_PUA_TLP 8.395511e-03    253 0.3020721 0.001548113
## 37      YEAR10_LOSSGREATER1HA_PUA_TLP 1.533671e-02    253 0.3355577 0.001547599
## 38      YEAR16_LOSSGREATER1HA_PUA_TLP 3.135870e-02    253 0.3785848 0.001547795
## 39 NCLUMPSSMALLER1HA_YEAR15_PSQKM_TLP 3.025917e-02    253 0.4670470 0.001543966
## 40       YEAR8_LOSSGREATER1HA_PUA_TLP 3.598151e-02    253 0.3817155 0.001547634
## 41      YEAR18_LOSSGREATER1HA_PUA_TLP 1.137622e-01    253 0.4523400 0.001552081
## 42       YEAR4_LOSSGREATER1HA_PUA_TLP 1.666697e-01    253 0.4489153 0.001549675
## 43       YEAR7_LOSSGREATER1HA_PUA_TLP 4.817272e-02    253 0.3354710 0.001551609
## 44  NCLUMPSSMALLER1HA_YEAR6_PSQKM_TLP 1.597245e-01    253 0.5529876 0.001553275
## 45  NCLUMPSSMALLER1HA_YEAR5_PSQKM_TLP 3.202336e-02    253 0.5654756 0.001546217
## 46      YEAR17_LOSSGREATER1HA_PUA_TLP 3.857454e-01    253 0.4656550 0.001551202
## 47 NCLUMPSSMALLER1HA_YEAR16_PSQKM_TLP 6.648748e-02    253 0.5020020 0.001546628
## 48 NCLUMPSSMALLER1HA_YEAR17_PSQKM_TLP 7.455826e-01    253 0.5597302 0.001553129
## 49 NCLUMPSSMALLER1HA_YEAR18_PSQKM_TLP 6.480536e-01    253 0.5327632 0.001551403
```

```
## 50  NCLUMPSSMALLER1HA_YEAR2_PSQKM_TLP 6.783075e-01    253 0.4853745 0.001552623
## 51 NCLUMPSSMALLER1HA_YEAR14_PSQKM_TLP 5.108259e-01    253 0.4254865 0.001549887
## 52  NCLUMPSSMALLER1HA_YEAR9_PSQKM_TLP 4.712184e-01    253 0.4642466 0.001553335
## 53  NCLUMPSSMALLER1HA_YEAR8_PSQKM_TLP 7.387968e-01    253 0.5479653 0.001552470
## 54 NCLUMPSSMALLER1HA_YEAR13_PSQKM_TLP 3.552775e-01    253 0.4913922 0.001548249
## 55  NCLUMPSSMALLER1HA_YEAR7_PSQKM_TLP 5.218663e-01    253 0.4578194 0.001549336
## 56  NCLUMPSSMALLER1HA_YEAR4_PSQKM_TLP 4.095683e-01    253 0.5931522 0.001552440
## 57 NCLUMPSSMALLER1HA_YEAR12_PSQKM_TLP 8.930608e-01    253 0.4392756 0.001551148
## 58  NCLUMPSSMALLER1HA_YEAR3_PSQKM_TLP 5.789775e-01    253 0.5685404 0.001550321
## 59 NCLUMPSSMALLER1HA_YEAR11_PSQKM_TLP 8.312023e-01    253 0.6050384 0.001550152
## 60  NCLUMPSSMALLER1HA_YEAR1_PSQKM_TLP 9.154352e-01    253 0.3554933 0.001551502
## 61 NCLUMPSSMALLER1HA_YEAR10_PSQKM_TLP 9.049471e-01    253 0.5461478 0.001551624
##          MTPVAL       SWPVAL year               variable2
## 1  7.473777e-10 4.447394e-21 2001          NFIRESM6PSQKM_TLP
## 2  1.942940e-18 6.027179e-19 2002          NFIRESM6PSQKM_TLP
## 3  8.473342e-08 4.018176e-17 2017          NFIRESM6PSQKM_TLP
## 4  1.861544e-13 1.007430e-15 2016          NFIRESM6PSQKM_TLP
## 5  1.115277e-08 1.032084e-14 2003          NFIRESM6PSQKM_TLP
## 6  4.362386e-11 3.076276e-14 2018          NFIRESM6PSQKM_TLP
## 7  1.151396e-11 1.476240e-13 2010          NFIRESM6PSQKM_TLP
## 8  1.801156e-19 1.912238e-13 2012          NFIRESM6PSQKM_TLP
## 9  5.791724e-16 4.942056e-13 2007          NFIRESM6PSQKM_TLP
## 10 7.180968e-19 5.826912e-13 2013          NFIRESM6PSQKM_TLP
## 11 3.561104e-23 5.925658e-13 2005          NFIRESM6PSQKM_TLP
## 12 1.048697e-11 1.439206e-12 2014          NFIRESM6PSQKM_TLP
## 13 1.114077e-15 1.531725e-12 2011          NFIRESM6PSQKM_TLP
## 14 8.487918e-19 1.853404e-12 2004          NFIRESM6PSQKM_TLP
## 15 6.029528e-16 3.803953e-12 2006          NFIRESM6PSQKM_TLP
## 16 3.709139e-14 9.600338e-12 2015          NFIRESM6PSQKM_TLP
## 17 1.359432e-16 1.024070e-11 2009          NFIRESM6PSQKM_TLP
## 18 1.439531e-22 5.150125e-11 2005     LOSSGREATER1HA_PUA_TLP
## 19 1.873177e-13 7.819175e-10 2008          NFIRESM6PSQKM_TLP
## 20 1.651046e-25 1.791557e-07 2013     LOSSGREATER1HA_PUA_TLP
## 21 9.597089e-15 3.859220e-07 2017          NFIRESV1PSQKM_TLP
## 22 2.246515e-16 6.244556e-07 2002     LOSSGREATER1HA_PUA_TLP
## 23 5.653438e-18 2.715985e-06 2016          NFIRESV1PSQKM_TLP
## 24 6.290510e-08 3.062659e-06 2014     LOSSGREATER1HA_PUA_TLP
## 25 4.927582e-07 5.504462e-06 2014          NFIRESV1PSQKM_TLP
## 26 7.682839e-25 7.438337e-06 2013          NFIRESV1PSQKM_TLP
## 27 1.054918e-06 8.396220e-06 2001     LOSSGREATER1HA_PUA_TLP
## 28 2.731196e-20 8.853935e-06 2015     LOSSGREATER1HA_PUA_TLP
## 29 5.028446e-11 1.536026e-05 2012     LOSSGREATER1HA_PUA_TLP
## 30 2.045870e-20 4.968208e-05 2015          NFIRESV1PSQKM_TLP
## 31 2.316165e-17 1.158393e-04 2012          NFIRESV1PSQKM_TLP
## 32 5.790081e-08 1.558964e-04 2003     LOSSGREATER1HA_PUA_TLP
## 33 2.271202e-27 4.431232e-04 2006     LOSSGREATER1HA_PUA_TLP
## 34 4.808361e-26 5.990192e-04 2011     LOSSGREATER1HA_PUA_TLP
## 35 8.139498e-16 1.653264e-03 2018          NFIRESV1PSQKM_TLP
## 36 3.679056e-15 3.178474e-03 2009     LOSSGREATER1HA_PUA_TLP
## 37 3.050067e-18 5.557022e-03 2010     LOSSGREATER1HA_PUA_TLP
## 38 1.193796e-22 5.793614e-03 2016     LOSSGREATER1HA_PUA_TLP
## 39 2.074517e-33 7.481544e-03 2015 NCLUMPSSMALLER1HAPSQKM_TLP
## 40 5.417965e-23 9.775631e-03 2008     LOSSGREATER1HA_PUA_TLP
## 41 2.528432e-31 2.637941e-02 2018     LOSSGREATER1HA_PUA_TLP
## 42 6.263536e-31 3.265303e-02 2004     LOSSGREATER1HA_PUA_TLP
## 43 3.427726e-18 3.367129e-02 2007     LOSSGREATER1HA_PUA_TLP
## 44 1.209856e-45 8.131076e-02 2006 NCLUMPSSMALLER1HAPSQKM_TLP
## 45 7.921558e-48 1.018180e-01 2005 NCLUMPSSMALLER1HAPSQKM_TLP
```

```
## 46 4.446704e-33 1.203359e-01 2017     LOSSGREATER1HA_PUA_TLP
## 47 3.512041e-38 1.961793e-01 2016 NCLUMPSSMALLER1HAPSQKM_TLP
## 48 1.039989e-46 3.622059e-01 2017 NCLUMPSSMALLER1HAPSQKM_TLP
## 49 1.386967e-42 4.482731e-01 2018 NCLUMPSSMALLER1HAPSQKM_TLP
## 50 1.033000e-35 4.750287e-01 2002 NCLUMPSSMALLER1HAPSQKM_TLP
## 51 5.245399e-28 4.790428e-01 2014 NCLUMPSSMALLER1HAPSQKM_TLP
## 52 7.527649e-33 4.936702e-01 2009 NCLUMPSSMALLER1HAPSQKM_TLP
## 53 6.966444e-45 5.620248e-01 2008 NCLUMPSSMALLER1HAPSQKM_TLP
## 54 1.209308e-36 5.871250e-01 2013 NCLUMPSSMALLER1HAPSQKM_TLP
## 55 4.372048e-32 5.961799e-01 2007 NCLUMPSSMALLER1HAPSQKM_TLP
## 56 3.513335e-52 6.337729e-01 2004 NCLUMPSSMALLER1HAPSQKM_TLP
## 57 1.103641e-29 7.482668e-01 2012 NCLUMPSSMALLER1HAPSQKM_TLP
## 58 3.368359e-48 8.416220e-01 2003 NCLUMPSSMALLER1HAPSQKM_TLP
## 59 2.851523e-54 8.893429e-01 2011 NCLUMPSSMALLER1HAPSQKM_TLP
## 60 3.556694e-20 9.094261e-01 2001 NCLUMPSSMALLER1HAPSQKM_TLP
## 61 1.263021e-44 9.305300e-01 2010 NCLUMPSSMALLER1HAPSQKM_TLP
lambda_tests %>% arrange(MTPVAL)
##                            variable       ADPVAL LENGTH     MIEST       MIVAR
## 1  NCLUMPSSMALLER1HA_YEAR11_PSQKM_TLP 8.312023e-01    253 0.6050384 0.001550152
## 2   NCLUMPSSMALLER1HA_YEAR4_PSQKM_TLP 4.095683e-01    253 0.5931522 0.001552440
## 3   NCLUMPSSMALLER1HA_YEAR3_PSQKM_TLP 5.789775e-01    253 0.5685404 0.001550321
## 4   NCLUMPSSMALLER1HA_YEAR5_PSQKM_TLP 3.202336e-02    253 0.5654756 0.001546217
## 5  NCLUMPSSMALLER1HA_YEAR17_PSQKM_TLP 7.455826e-01    253 0.5597302 0.001553129
## 6   NCLUMPSSMALLER1HA_YEAR6_PSQKM_TLP 1.597245e-01    253 0.5529876 0.001553275
## 7   NCLUMPSSMALLER1HA_YEAR8_PSQKM_TLP 7.387968e-01    253 0.5479653 0.001552470
## 8  NCLUMPSSMALLER1HA_YEAR10_PSQKM_TLP 9.049471e-01    253 0.5461478 0.001551624
## 9  NCLUMPSSMALLER1HA_YEAR18_PSQKM_TLP 6.480536e-01    253 0.5327632 0.001551403
## 10 NCLUMPSSMALLER1HA_YEAR16_PSQKM_TLP 6.648748e-02    253 0.5020020 0.001546628
## 11 NCLUMPSSMALLER1HA_YEAR13_PSQKM_TLP 3.552775e-01    253 0.4913922 0.001548249
## 12  NCLUMPSSMALLER1HA_YEAR2_PSQKM_TLP 6.783075e-01    253 0.4853745 0.001552623
## 13 NCLUMPSSMALLER1HA_YEAR15_PSQKM_TLP 3.025917e-02    253 0.4670470 0.001543966
## 14      YEAR17_LOSSGREATER1HA_PUA_TLP 3.857454e-01    253 0.4656550 0.001551202
## 15  NCLUMPSSMALLER1HA_YEAR9_PSQKM_TLP 4.712184e-01    253 0.4642466 0.001553335
## 16  NCLUMPSSMALLER1HA_YEAR7_PSQKM_TLP 5.218663e-01    253 0.4578194 0.001549336
## 17      YEAR18_LOSSGREATER1HA_PUA_TLP 1.137622e-01    253 0.4523400 0.001552081
## 18       YEAR4_LOSSGREATER1HA_PUA_TLP 1.666697e-01    253 0.4489153 0.001549675
## 19 NCLUMPSSMALLER1HA_YEAR12_PSQKM_TLP 8.930608e-01    253 0.4392756 0.001551148
## 20 NCLUMPSSMALLER1HA_YEAR14_PSQKM_TLP 5.108259e-01    253 0.4254865 0.001549887
## 21       YEAR6_LOSSGREATER1HA_PUA_TLP 1.135303e-03    253 0.4201354 0.001549351
## 22      YEAR11_LOSSGREATER1HA_PUA_TLP 3.310997e-03    253 0.4093635 0.001552594
## 23      YEAR13_LOSSGREATER1HA_PUA_TLP 3.071271e-09    253 0.4035400 0.001543450
## 24          NFIRESV1_YEAR13_PSQKM_TLP 3.930253e-05    253 0.3986340 0.001550418
## 25           NFIRESM6_YEAR5_PSQKM_TLP 3.700000e-24    253 0.3835136 0.001548710
## 26       YEAR8_LOSSGREATER1HA_PUA_TLP 3.598151e-02    253 0.3817155 0.001547634
## 27      YEAR16_LOSSGREATER1HA_PUA_TLP 3.135870e-02    253 0.3785848 0.001547795
## 28       YEAR5_LOSSGREATER1HA_PUA_TLP 7.452685e-10    253 0.3746342 0.001521956
## 29          NFIRESV1_YEAR15_PSQKM_TLP 3.120724e-04    253 0.3574704 0.001548291
## 30      YEAR15_LOSSGREATER1HA_PUA_TLP 7.199124e-06    253 0.3558061 0.001544521
## 31  NCLUMPSSMALLER1HA_YEAR1_PSQKM_TLP 9.154352e-01    253 0.3554933 0.001551502
## 32          NFIRESM6_YEAR12_PSQKM_TLP 3.700000e-24    253 0.3486194 0.001552495
## 33          NFIRESM6_YEAR13_PSQKM_TLP 3.700000e-24    253 0.3424536 0.001551612
## 34           NFIRESM6_YEAR4_PSQKM_TLP 1.345327e-22    253 0.3420576 0.001554705
## 35           NFIRESM6_YEAR2_PSQKM_TLP 3.700000e-24    253 0.3377643 0.001549263
## 36      YEAR10_LOSSGREATER1HA_PUA_TLP 1.533671e-02    253 0.3355577 0.001547599
## 37       YEAR7_LOSSGREATER1HA_PUA_TLP 4.817272e-02    253 0.3354710 0.001551609
## 38          NFIRESV1_YEAR16_PSQKM_TLP 3.519062e-05    253 0.3334186 0.001553566
## 39          NFIRESV1_YEAR12_PSQKM_TLP 5.516181e-04    253 0.3264984 0.001549331
## 40           NFIRESM6_YEAR9_PSQKM_TLP 2.576325e-20    253 0.3184660 0.001551763
```

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## 41       YEAR2_LOSSGREATER1HA_PUA_TLP 1.684977e-05    253 0.3145905 0.001537406
## 42           NFIRESM6_YEAR7_PSQKM_TLP 3.700000e-24    253 0.3116846 0.001553405
## 43           NFIRESM6_YEAR6_PSQKM_TLP 2.644369e-21    253 0.3115173 0.001553679
## 44          NFIRESV1_YEAR18_PSQKM_TLP 1.942503e-02    253 0.3097203 0.001550336
## 45          NFIRESM6_YEAR11_PSQKM_TLP 5.658013e-23    253 0.3085412 0.001553839
## 46       YEAR9_LOSSGREATER1HA_PUA_TLP 8.395511e-03    253 0.3020721 0.001548113
## 47          NFIRESV1_YEAR17_PSQKM_TLP 3.154195e-07    253 0.2972833 0.001548334
## 48          NFIRESM6_YEAR15_PSQKM_TLP 3.254400e-20    253 0.2907386 0.001552204
## 49          NFIRESM6_YEAR16_PSQKM_TLP 3.700000e-24    253 0.2822651 0.001552164
## 50           NFIRESM6_YEAR8_PSQKM_TLP 5.271077e-13    253 0.2823828 0.001553801
## 51          NFIRESM6_YEAR14_PSQKM_TLP 8.219447e-23    253 0.2598008 0.001550306
## 52          NFIRESM6_YEAR10_PSQKM_TLP 3.700000e-24    253 0.2591194 0.001548620
## 53          NFIRESM6_YEAR18_PSQKM_TLP 3.700000e-24    253 0.2516554 0.001552536
## 54      YEAR12_LOSSGREATER1HA_PUA_TLP 3.652148e-05    253 0.2499134 0.001541624
## 55           NFIRESM6_YEAR1_PSQKM_TLP 3.700000e-24    253 0.2337788 0.001546848
## 56           NFIRESM6_YEAR3_PSQKM_TLP 3.700000e-24    253 0.2162494 0.001550242
## 57       YEAR3_LOSSGREATER1HA_PUA_TLP 2.024899e-03    253 0.2045038 0.001547191
## 58      YEAR14_LOSSGREATER1HA_PUA_TLP 1.742845e-05    253 0.2034278 0.001540054
## 59          NFIRESM6_YEAR17_PSQKM_TLP 3.700000e-24    253 0.2021339 0.001552937
## 60          NFIRESV1_YEAR14_PSQKM_TLP 7.589478e-05    253 0.1883641 0.001544140
## 61       YEAR1_LOSSGREATER1HA_PUA_TLP 4.468161e-05    253 0.1823457 0.001543320
##          MTPVAL       SWPVAL year                 variable2
## 1  2.851523e-54 8.893429e-01 2011 NCLUMPSSMALLER1HAPSQKM_TLP
## 2  3.513335e-52 6.337729e-01 2004 NCLUMPSSMALLER1HAPSQKM_TLP
## 3  3.368359e-48 8.416220e-01 2003 NCLUMPSSMALLER1HAPSQKM_TLP
## 4  7.921558e-48 1.018180e-01 2005 NCLUMPSSMALLER1HAPSQKM_TLP
## 5  1.039989e-46 3.622059e-01 2017 NCLUMPSSMALLER1HAPSQKM_TLP
## 6  1.209856e-45 8.131076e-02 2006 NCLUMPSSMALLER1HAPSQKM_TLP
## 7  6.966444e-45 5.620248e-01 2008 NCLUMPSSMALLER1HAPSQKM_TLP
## 8  1.263021e-44 9.305300e-01 2010 NCLUMPSSMALLER1HAPSQKM_TLP
## 9  1.386967e-42 4.482731e-01 2018 NCLUMPSSMALLER1HAPSQKM_TLP
## 10 3.512041e-38 1.961793e-01 2016 NCLUMPSSMALLER1HAPSQKM_TLP
## 11 1.209308e-36 5.871250e-01 2013 NCLUMPSSMALLER1HAPSQKM_TLP
## 12 1.033000e-35 4.750287e-01 2002 NCLUMPSSMALLER1HAPSQKM_TLP
## 13 2.074517e-33 7.481544e-03 2015 NCLUMPSSMALLER1HAPSQKM_TLP
## 14 4.446704e-33 1.203359e-01 2017     LOSSGREATER1HA_PUA_TLP
## 15 7.527649e-33 4.936702e-01 2009 NCLUMPSSMALLER1HAPSQKM_TLP
## 16 4.372048e-32 5.961799e-01 2007 NCLUMPSSMALLER1HAPSQKM_TLP
## 17 2.528432e-31 2.637941e-02 2018     LOSSGREATER1HA_PUA_TLP
## 18 6.263536e-31 3.265303e-02 2004     LOSSGREATER1HA_PUA_TLP
## 19 1.103641e-29 7.482668e-01 2012 NCLUMPSSMALLER1HAPSQKM_TLP
## 20 5.245399e-28 4.790428e-01 2014 NCLUMPSSMALLER1HAPSQKM_TLP
## 21 2.271202e-27 4.431232e-04 2006     LOSSGREATER1HA_PUA_TLP
## 22 4.808361e-26 5.990192e-04 2011     LOSSGREATER1HA_PUA_TLP
## 23 1.651046e-25 1.791557e-07 2013     LOSSGREATER1HA_PUA_TLP
## 24 7.682839e-25 7.438337e-06 2013          NFIRESV1PSQKM_TLP
## 25 3.561104e-23 5.925658e-13 2005          NFIRESM6PSQKM_TLP
## 26 5.417965e-23 9.775631e-03 2008     LOSSGREATER1HA_PUA_TLP
## 27 1.193796e-22 5.793614e-03 2016     LOSSGREATER1HA_PUA_TLP
## 28 1.439531e-22 5.150125e-11 2005     LOSSGREATER1HA_PUA_TLP
## 29 2.045870e-20 4.968208e-05 2015          NFIRESV1PSQKM_TLP
## 30 2.731196e-20 8.853935e-06 2015     LOSSGREATER1HA_PUA_TLP
## 31 3.556694e-20 9.094261e-01 2001 NCLUMPSSMALLER1HAPSQKM_TLP
## 32 1.801156e-19 1.912238e-13 2012          NFIRESM6PSQKM_TLP
## 33 7.180968e-19 5.826912e-13 2013          NFIRESM6PSQKM_TLP
## 34 8.487918e-19 1.853404e-12 2004          NFIRESM6PSQKM_TLP
## 35 1.942940e-18 6.027179e-19 2002          NFIRESM6PSQKM_TLP
## 36 3.050067e-18 5.557022e-03 2010     LOSSGREATER1HA_PUA_TLP
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## 37 3.427726e-18 3.367129e-02 2007     LOSSGREATER1HA_PUA_TLP
## 38 5.653438e-18 2.715985e-06 2016          NFIRESV1PSQKM_TLP
## 39 2.316165e-17 1.158393e-04 2012          NFIRESV1PSQKM_TLP
## 40 1.359432e-16 1.024070e-11 2009          NFIRESM6PSQKM_TLP
## 41 2.246515e-16 6.244556e-07 2002     LOSSGREATER1HA_PUA_TLP
## 42 5.791724e-16 4.942056e-13 2007          NFIRESM6PSQKM_TLP
## 43 6.029528e-16 3.803953e-12 2006          NFIRESM6PSQKM_TLP
## 44 8.139498e-16 1.653264e-03 2018          NFIRESV1PSQKM_TLP
## 45 1.114077e-15 1.531725e-12 2011          NFIRESM6PSQKM_TLP
## 46 3.679056e-15 3.178474e-03 2009     LOSSGREATER1HA_PUA_TLP
## 47 9.597089e-15 3.859220e-07 2017          NFIRESV1PSQKM_TLP
## 48 3.709139e-14 9.600338e-12 2015          NFIRESM6PSQKM_TLP
## 49 1.861544e-13 1.007430e-15 2016          NFIRESM6PSQKM_TLP
## 50 1.873177e-13 7.819175e-10 2008          NFIRESM6PSQKM_TLP
## 51 1.048697e-11 1.439206e-12 2014          NFIRESM6PSQKM_TLP
## 52 1.151396e-11 1.476240e-13 2010          NFIRESM6PSQKM_TLP
## 53 4.362386e-11 3.076276e-14 2018          NFIRESM6PSQKM_TLP
## 54 5.028446e-11 1.536026e-05 2012     LOSSGREATER1HA_PUA_TLP
## 55 7.473777e-10 4.447394e-21 2001          NFIRESM6PSQKM_TLP
## 56 1.115277e-08 1.032084e-14 2003          NFIRESM6PSQKM_TLP
## 57 5.790081e-08 1.558964e-04 2003     LOSSGREATER1HA_PUA_TLP
## 58 6.290510e-08 3.062659e-06 2014     LOSSGREATER1HA_PUA_TLP
## 59 8.473342e-08 4.018176e-17 2017          NFIRESM6PSQKM_TLP
## 60 4.927582e-07 5.504462e-06 2014          NFIRESV1PSQKM_TLP
## 61 1.054918e-06 8.396220e-06 2001     LOSSGREATER1HA_PUA_TLP
lambda_tests %>% arrange(MIEST)
##                              variable       ADPVAL LENGTH     MIEST       MIVAR
## 1        YEAR1_LOSSGREATER1HA_PUA_TLP 4.468161e-05    253 0.1823457 0.001543320
## 2           NFIRESV1_YEAR14_PSQKM_TLP 7.589478e-05    253 0.1883641 0.001544140
## 3           NFIRESM6_YEAR17_PSQKM_TLP 3.700000e-24    253 0.2021339 0.001552937
## 4       YEAR14_LOSSGREATER1HA_PUA_TLP 1.742845e-05    253 0.2034278 0.001540054
## 5        YEAR3_LOSSGREATER1HA_PUA_TLP 2.024899e-03    253 0.2045038 0.001547191
## 6           NFIRESM6_YEAR3_PSQKM_TLP 3.700000e-24    253 0.2162494 0.001550242
## 7           NFIRESM6_YEAR1_PSQKM_TLP 3.700000e-24    253 0.2337788 0.001546848
## 8       YEAR12_LOSSGREATER1HA_PUA_TLP 3.652148e-05    253 0.2499134 0.001541624
## 9           NFIRESM6_YEAR18_PSQKM_TLP 3.700000e-24    253 0.2516554 0.001552536
## 10          NFIRESM6_YEAR10_PSQKM_TLP 3.700000e-24    253 0.2591194 0.001548620
## 11          NFIRESM6_YEAR14_PSQKM_TLP 8.219447e-23    253 0.2598008 0.001550306
## 12          NFIRESM6_YEAR16_PSQKM_TLP 3.700000e-24    253 0.2822651 0.001552164
## 13           NFIRESM6_YEAR8_PSQKM_TLP 5.271077e-13    253 0.2823828 0.001553801
## 14          NFIRESM6_YEAR15_PSQKM_TLP 3.254400e-20    253 0.2907386 0.001552204
## 15          NFIRESV1_YEAR17_PSQKM_TLP 3.154195e-07    253 0.2972833 0.001548334
## 16       YEAR9_LOSSGREATER1HA_PUA_TLP 8.395511e-03    253 0.3020721 0.001548113
## 17          NFIRESM6_YEAR11_PSQKM_TLP 5.658013e-23    253 0.3085412 0.001553839
## 18          NFIRESV1_YEAR18_PSQKM_TLP 1.942503e-02    253 0.3097203 0.001550336
## 19           NFIRESM6_YEAR6_PSQKM_TLP 2.644369e-21    253 0.3115173 0.001553679
## 20           NFIRESM6_YEAR7_PSQKM_TLP 3.700000e-24    253 0.3116846 0.001553405
## 21       YEAR2_LOSSGREATER1HA_PUA_TLP 1.684977e-05    253 0.3145905 0.001537406
## 22           NFIRESM6_YEAR9_PSQKM_TLP 2.576325e-20    253 0.3184660 0.001551763
## 23          NFIRESV1_YEAR12_PSQKM_TLP 5.516181e-04    253 0.3264984 0.001549331
## 24          NFIRESV1_YEAR16_PSQKM_TLP 3.519062e-05    253 0.3334186 0.001553566
## 25       YEAR7_LOSSGREATER1HA_PUA_TLP 4.817272e-02    253 0.3354710 0.001551609
## 26      YEAR10_LOSSGREATER1HA_PUA_TLP 1.533671e-02    253 0.3355577 0.001547599
## 27          NFIRESM6_YEAR2_PSQKM_TLP 3.700000e-24    253 0.3377643 0.001549263
## 28          NFIRESM6_YEAR4_PSQKM_TLP 1.345327e-22    253 0.3420576 0.001554705
## 29          NFIRESM6_YEAR13_PSQKM_TLP 3.700000e-24    253 0.3424536 0.001551612
## 30          NFIRESM6_YEAR12_PSQKM_TLP 3.700000e-24    253 0.3486194 0.001552495
## 31  NCLUMPSSMALLER1HA_YEAR1_PSQKM_TLP 9.154352e-01    253 0.3554933 0.001551502
```

```
## 32      YEAR15_LOSSGREATER1HA_PUA_TLP 7.199124e-06    253 0.3558061 0.001544521
## 33          NFIRESV1_YEAR15_PSQKM_TLP 3.120724e-04    253 0.3574704 0.001548291
## 34       YEAR5_LOSSGREATER1HA_PUA_TLP 7.452685e-10    253 0.3746342 0.001521956
## 35      YEAR16_LOSSGREATER1HA_PUA_TLP 3.135870e-02    253 0.3785848 0.001547795
## 36       YEAR8_LOSSGREATER1HA_PUA_TLP 3.598151e-02    253 0.3817155 0.001547634
## 37           NFIRESM6_YEAR5_PSQKM_TLP 3.700000e-24    253 0.3835136 0.001548710
## 38          NFIRESV1_YEAR13_PSQKM_TLP 3.930253e-05    253 0.3986340 0.001550418
## 39      YEAR13_LOSSGREATER1HA_PUA_TLP 3.071271e-09    253 0.4035400 0.001543450
## 40      YEAR11_LOSSGREATER1HA_PUA_TLP 3.310997e-03    253 0.4093635 0.001552594
## 41       YEAR6_LOSSGREATER1HA_PUA_TLP 1.135303e-03    253 0.4201354 0.001549351
## 42 NCLUMPSSMALLER1HA_YEAR14_PSQKM_TLP 5.108259e-01    253 0.4254865 0.001549887
## 43 NCLUMPSSMALLER1HA_YEAR12_PSQKM_TLP 8.930608e-01    253 0.4392756 0.001551148
## 44       YEAR4_LOSSGREATER1HA_PUA_TLP 1.666697e-01    253 0.4489153 0.001549675
## 45      YEAR18_LOSSGREATER1HA_PUA_TLP 1.137622e-01    253 0.4523400 0.001552081
## 46  NCLUMPSSMALLER1HA_YEAR7_PSQKM_TLP 5.218663e-01    253 0.4578194 0.001549336
## 47  NCLUMPSSMALLER1HA_YEAR9_PSQKM_TLP 4.712184e-01    253 0.4642466 0.001553335
## 48      YEAR17_LOSSGREATER1HA_PUA_TLP 3.857454e-01    253 0.4656550 0.001551202
## 49 NCLUMPSSMALLER1HA_YEAR15_PSQKM_TLP 3.025917e-02    253 0.4670470 0.001543966
## 50  NCLUMPSSMALLER1HA_YEAR2_PSQKM_TLP 6.783075e-01    253 0.4853745 0.001552623
## 51 NCLUMPSSMALLER1HA_YEAR13_PSQKM_TLP 3.552775e-01    253 0.4913922 0.001548249
## 52 NCLUMPSSMALLER1HA_YEAR16_PSQKM_TLP 6.648748e-02    253 0.5020020 0.001546628
## 53 NCLUMPSSMALLER1HA_YEAR18_PSQKM_TLP 6.480536e-01    253 0.5327632 0.001551403
## 54 NCLUMPSSMALLER1HA_YEAR10_PSQKM_TLP 9.049471e-01    253 0.5461478 0.001551624
## 55  NCLUMPSSMALLER1HA_YEAR8_PSQKM_TLP 7.387968e-01    253 0.5479653 0.001552470
## 56  NCLUMPSSMALLER1HA_YEAR6_PSQKM_TLP 1.597245e-01    253 0.5529876 0.001553275
## 57 NCLUMPSSMALLER1HA_YEAR17_PSQKM_TLP 7.455826e-01    253 0.5597302 0.001553129
## 58  NCLUMPSSMALLER1HA_YEAR5_PSQKM_TLP 3.202336e-02    253 0.5654756 0.001546217
## 59  NCLUMPSSMALLER1HA_YEAR3_PSQKM_TLP 5.789775e-01    253 0.5685404 0.001550321
## 60  NCLUMPSSMALLER1HA_YEAR4_PSQKM_TLP 4.095683e-01    253 0.5931522 0.001552440
## 61 NCLUMPSSMALLER1HA_YEAR11_PSQKM_TLP 8.312023e-01    253 0.6050384 0.001550152
##          MTPVAL       SWPVAL year              variable2
## 1  1.054918e-06 8.396220e-06 2001     LOSSGREATER1HA_PUA_TLP
## 2  4.927582e-07 5.504462e-06 2014          NFIRESV1PSQKM_TLP
## 3  8.473342e-08 4.018176e-17 2017          NFIRESM6PSQKM_TLP
## 4  6.290510e-08 3.062659e-06 2014     LOSSGREATER1HA_PUA_TLP
## 5  5.790081e-08 1.558964e-04 2003     LOSSGREATER1HA_PUA_TLP
## 6  1.115277e-08 1.032084e-14 2003          NFIRESM6PSQKM_TLP
## 7  7.473777e-10 4.447394e-21 2001          NFIRESM6PSQKM_TLP
## 8  5.028446e-11 1.536026e-05 2012     LOSSGREATER1HA_PUA_TLP
## 9  4.362386e-11 3.076276e-14 2018          NFIRESM6PSQKM_TLP
## 10 1.151396e-11 1.476240e-13 2010          NFIRESM6PSQKM_TLP
## 11 1.048697e-11 1.439206e-12 2014          NFIRESM6PSQKM_TLP
## 12 1.861544e-13 1.007430e-15 2016          NFIRESM6PSQKM_TLP
## 13 1.873177e-13 7.819175e-10 2008          NFIRESM6PSQKM_TLP
## 14 3.709139e-14 9.600338e-12 2015          NFIRESM6PSQKM_TLP
## 15 9.597089e-15 3.859220e-07 2017          NFIRESV1PSQKM_TLP
## 16 3.679056e-15 3.178474e-03 2009     LOSSGREATER1HA_PUA_TLP
## 17 1.114077e-15 1.531725e-12 2011          NFIRESM6PSQKM_TLP
## 18 8.139498e-16 1.653264e-03 2018          NFIRESV1PSQKM_TLP
## 19 6.029528e-16 3.803953e-12 2006          NFIRESM6PSQKM_TLP
## 20 5.791724e-16 4.942056e-13 2007          NFIRESM6PSQKM_TLP
## 21 2.246515e-16 6.244556e-07 2002     LOSSGREATER1HA_PUA_TLP
## 22 1.359432e-16 1.024070e-11 2009          NFIRESM6PSQKM_TLP
## 23 2.316165e-17 1.158393e-04 2012          NFIRESV1PSQKM_TLP
## 24 5.653438e-18 2.715985e-06 2016          NFIRESV1PSQKM_TLP
## 25 3.427726e-18 3.367129e-02 2007     LOSSGREATER1HA_PUA_TLP
## 26 3.050067e-18 5.557022e-03 2010     LOSSGREATER1HA_PUA_TLP
## 27 1.942940e-18 6.027179e-19 2002          NFIRESM6PSQKM_TLP
```

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## 28 8.487918e-19 1.853404e-12 2004          NFIRESM6PSQKM_TLP
## 29 7.180968e-19 5.826912e-13 2013          NFIRESM6PSQKM_TLP
## 30 1.801156e-19 1.912238e-13 2012          NFIRESM6PSQKM_TLP
## 31 3.556694e-20 9.094261e-01 2001 NCLUMPSSMALLER1HAPSQKM_TLP
## 32 2.731196e-20 8.853935e-06 2015     LOSSGREATER1HA_PUA_TLP
## 33 2.045870e-20 4.968208e-05 2015          NFIRESV1PSQKM_TLP
## 34 1.439531e-22 5.150125e-11 2005     LOSSGREATER1HA_PUA_TLP
## 35 1.193796e-22 5.793614e-03 2016     LOSSGREATER1HA_PUA_TLP
## 36 5.417965e-23 9.775631e-03 2008     LOSSGREATER1HA_PUA_TLP
## 37 3.561104e-23 5.925658e-13 2005          NFIRESM6PSQKM_TLP
## 38 7.682839e-25 7.438337e-06 2013          NFIRESV1PSQKM_TLP
## 39 1.651046e-25 1.791557e-07 2013     LOSSGREATER1HA_PUA_TLP
## 40 4.808361e-26 5.990192e-04 2011     LOSSGREATER1HA_PUA_TLP
## 41 2.271202e-27 4.431232e-04 2006     LOSSGREATER1HA_PUA_TLP
## 42 5.245399e-28 4.790428e-01 2014 NCLUMPSSMALLER1HAPSQKM_TLP
## 43 1.103641e-29 7.482668e-01 2012 NCLUMPSSMALLER1HAPSQKM_TLP
## 44 6.263536e-31 3.265303e-02 2004     LOSSGREATER1HA_PUA_TLP
## 45 2.528432e-31 2.637941e-02 2018     LOSSGREATER1HA_PUA_TLP
## 46 4.372048e-32 5.961799e-01 2007 NCLUMPSSMALLER1HAPSQKM_TLP
## 47 7.527649e-33 4.936702e-01 2009 NCLUMPSSMALLER1HAPSQKM_TLP
## 48 4.446704e-33 1.203359e-01 2017     LOSSGREATER1HA_PUA_TLP
## 49 2.074517e-33 7.481544e-03 2015 NCLUMPSSMALLER1HAPSQKM_TLP
## 50 1.033000e-35 4.750287e-01 2002 NCLUMPSSMALLER1HAPSQKM_TLP
## 51 1.209308e-36 5.871250e-01 2013 NCLUMPSSMALLER1HAPSQKM_TLP
## 52 3.512041e-38 1.961793e-01 2016 NCLUMPSSMALLER1HAPSQKM_TLP
## 53 1.386967e-42 4.482731e-01 2018 NCLUMPSSMALLER1HAPSQKM_TLP
## 54 1.263021e-44 9.305300e-01 2010 NCLUMPSSMALLER1HAPSQKM_TLP
## 55 6.966444e-45 5.620248e-01 2008 NCLUMPSSMALLER1HAPSQKM_TLP
## 56 1.209856e-45 8.131076e-02 2006 NCLUMPSSMALLER1HAPSQKM_TLP
## 57 1.039989e-46 3.622059e-01 2017 NCLUMPSSMALLER1HAPSQKM_TLP
## 58 7.921558e-48 1.018180e-01 2005 NCLUMPSSMALLER1HAPSQKM_TLP
## 59 3.368359e-48 8.416220e-01 2003 NCLUMPSSMALLER1HAPSQKM_TLP
## 60 3.513335e-52 6.337729e-01 2004 NCLUMPSSMALLER1HAPSQKM_TLP
## 61 2.851523e-54 8.893429e-01 2011 NCLUMPSSMALLER1HAPSQKM_TLP
lambda_tests %>% arrange(MIVAR)
##                             variable       ADPVAL LENGTH     MIEST       MIVAR
## 1        YEAR5_LOSSGREATER1HA_PUA_TLP 7.452685e-10    253 0.3746342 0.001521956
## 2        YEAR2_LOSSGREATER1HA_PUA_TLP 1.684977e-05    253 0.3145905 0.001537406
## 3       YEAR14_LOSSGREATER1HA_PUA_TLP 1.742845e-05    253 0.2034278 0.001540054
## 4       YEAR12_LOSSGREATER1HA_PUA_TLP 3.652148e-05    253 0.2499134 0.001541624
## 5        YEAR1_LOSSGREATER1HA_PUA_TLP 4.468161e-05    253 0.1823457 0.001543320
## 6       YEAR13_LOSSGREATER1HA_PUA_TLP 3.071271e-09    253 0.4035400 0.001543450
## 7  NCLUMPSSMALLER1HA_YEAR15_PSQKM_TLP 3.025917e-02    253 0.4670470 0.001543966
## 8           NFIRESV1_YEAR14_PSQKM_TLP 7.589478e-05    253 0.1883641 0.001544140
## 9       YEAR15_LOSSGREATER1HA_PUA_TLP 7.199124e-06    253 0.3558061 0.001544521
## 10  NCLUMPSSMALLER1HA_YEAR5_PSQKM_TLP 3.202336e-02    253 0.5654756 0.001546217
## 11 NCLUMPSSMALLER1HA_YEAR16_PSQKM_TLP 6.648748e-02    253 0.5020020 0.001546628
## 12           NFIRESM6_YEAR1_PSQKM_TLP 3.700000e-24    253 0.2337788 0.001546848
## 13       YEAR3_LOSSGREATER1HA_PUA_TLP 2.024899e-03    253 0.2045038 0.001547191
## 14      YEAR10_LOSSGREATER1HA_PUA_TLP 1.533671e-02    253 0.3355577 0.001547599
## 15       YEAR8_LOSSGREATER1HA_PUA_TLP 3.598151e-02    253 0.3817155 0.001547634
## 16      YEAR16_LOSSGREATER1HA_PUA_TLP 3.135870e-02    253 0.3785848 0.001547795
## 17       YEAR9_LOSSGREATER1HA_PUA_TLP 8.395511e-03    253 0.3020721 0.001548113
## 18 NCLUMPSSMALLER1HA_YEAR13_PSQKM_TLP 3.552775e-01    253 0.4913922 0.001548249
## 19          NFIRESV1_YEAR15_PSQKM_TLP 3.120724e-04    253 0.3574704 0.001548291
## 20          NFIRESV1_YEAR17_PSQKM_TLP 3.154195e-07    253 0.2972833 0.001548334
## 21          NFIRESM6_YEAR10_PSQKM_TLP 3.700000e-24    253 0.2591194 0.001548620
## 22           NFIRESM6_YEAR5_PSQKM_TLP 3.700000e-24    253 0.3835136 0.001548710
```

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## 23           NFIRESM6_YEAR2_PSQKM_TLP 3.700000e-24    253 0.3377643 0.001549263
## 24          NFIRESV1_YEAR12_PSQKM_TLP 5.516181e-04    253 0.3264984 0.001549331
## 25  NCLUMPSSMALLER1HA_YEAR7_PSQKM_TLP 5.218663e-01    253 0.4578194 0.001549336
## 26       YEAR6_LOSSGREATER1HA_PUA_TLP 1.135303e-03    253 0.4201354 0.001549351
## 27       YEAR4_LOSSGREATER1HA_PUA_TLP 1.666697e-01    253 0.4489153 0.001549675
## 28 NCLUMPSSMALLER1HA_YEAR14_PSQKM_TLP 5.108259e-01    253 0.4254865 0.001549887
## 29 NCLUMPSSMALLER1HA_YEAR11_PSQKM_TLP 8.312023e-01    253 0.6050384 0.001550152
## 30           NFIRESM6_YEAR3_PSQKM_TLP 3.700000e-24    253 0.2162494 0.001550242
## 31          NFIRESM6_YEAR14_PSQKM_TLP 8.219447e-23    253 0.2598008 0.001550306
## 32  NCLUMPSSMALLER1HA_YEAR3_PSQKM_TLP 5.789775e-01    253 0.5685404 0.001550321
## 33          NFIRESV1_YEAR18_PSQKM_TLP 1.942503e-02    253 0.3097203 0.001550336
## 34          NFIRESV1_YEAR13_PSQKM_TLP 3.930253e-05    253 0.3986340 0.001550418
## 35 NCLUMPSSMALLER1HA_YEAR12_PSQKM_TLP 8.930608e-01    253 0.4392756 0.001551148
## 36      YEAR17_LOSSGREATER1HA_PUA_TLP 3.857454e-01    253 0.4656550 0.001551202
## 37 NCLUMPSSMALLER1HA_YEAR18_PSQKM_TLP 6.480536e-01    253 0.5327632 0.001551403
## 38  NCLUMPSSMALLER1HA_YEAR1_PSQKM_TLP 9.154352e-01    253 0.3554933 0.001551502
## 39       YEAR7_LOSSGREATER1HA_PUA_TLP 4.817272e-02    253 0.3354710 0.001551609
## 40          NFIRESM6_YEAR13_PSQKM_TLP 3.700000e-24    253 0.3424536 0.001551612
## 41 NCLUMPSSMALLER1HA_YEAR10_PSQKM_TLP 9.049471e-01    253 0.5461478 0.001551624
## 42           NFIRESM6_YEAR9_PSQKM_TLP 2.576325e-20    253 0.3184660 0.001551763
## 43      YEAR18_LOSSGREATER1HA_PUA_TLP 1.137622e-01    253 0.4523400 0.001552081
## 44          NFIRESM6_YEAR16_PSQKM_TLP 3.700000e-24    253 0.2822651 0.001552164
## 45          NFIRESM6_YEAR15_PSQKM_TLP 3.254400e-20    253 0.2907386 0.001552204
## 46  NCLUMPSSMALLER1HA_YEAR4_PSQKM_TLP 4.095683e-01    253 0.5931522 0.001552440
## 47  NCLUMPSSMALLER1HA_YEAR8_PSQKM_TLP 7.387968e-01    253 0.5479653 0.001552470
## 48          NFIRESM6_YEAR12_PSQKM_TLP 3.700000e-24    253 0.3486194 0.001552495
## 49          NFIRESM6_YEAR18_PSQKM_TLP 3.700000e-24    253 0.2516554 0.001552536
## 50      YEAR11_LOSSGREATER1HA_PUA_TLP 3.310997e-03    253 0.4093635 0.001552594
## 51  NCLUMPSSMALLER1HA_YEAR2_PSQKM_TLP 6.783075e-01    253 0.4853745 0.001552623
## 52          NFIRESM6_YEAR17_PSQKM_TLP 3.700000e-24    253 0.2021339 0.001552937
## 53 NCLUMPSSMALLER1HA_YEAR17_PSQKM_TLP 7.455826e-01    253 0.5597302 0.001553129
## 54  NCLUMPSSMALLER1HA_YEAR6_PSQKM_TLP 1.597245e-01    253 0.5529876 0.001553275
## 55  NCLUMPSSMALLER1HA_YEAR9_PSQKM_TLP 4.712184e-01    253 0.4642466 0.001553335
## 56           NFIRESM6_YEAR7_PSQKM_TLP 3.700000e-24    253 0.3116846 0.001553405
## 57          NFIRESV1_YEAR16_PSQKM_TLP 3.519062e-05    253 0.3334186 0.001553566
## 58           NFIRESM6_YEAR6_PSQKM_TLP 2.644369e-21    253 0.3115173 0.001553679
## 59           NFIRESM6_YEAR8_PSQKM_TLP 5.271077e-13    253 0.2823828 0.001553801
## 60          NFIRESM6_YEAR11_PSQKM_TLP 5.658013e-23    253 0.3085412 0.001553839
## 61           NFIRESM6_YEAR4_PSQKM_TLP 1.345327e-22    253 0.3420576 0.001554705
##          MTPVAL       SWPVAL year                  variable2
## 1  1.439531e-22 5.150125e-11 2005     LOSSGREATER1HA_PUA_TLP
## 2  2.246515e-16 6.244556e-07 2002     LOSSGREATER1HA_PUA_TLP
## 3  6.290510e-08 3.062659e-06 2014     LOSSGREATER1HA_PUA_TLP
## 4  5.028446e-11 1.536026e-05 2012     LOSSGREATER1HA_PUA_TLP
## 5  1.054918e-06 8.396220e-06 2001     LOSSGREATER1HA_PUA_TLP
## 6  1.651046e-25 1.791557e-07 2013     LOSSGREATER1HA_PUA_TLP
## 7  2.074517e-33 7.481544e-03 2015 NCLUMPSSMALLER1HAPSQKM_TLP
## 8  4.927582e-07 5.504462e-06 2014          NFIRESV1PSQKM_TLP
## 9  2.731196e-20 8.853935e-06 2015     LOSSGREATER1HA_PUA_TLP
## 10 7.921558e-48 1.018180e-01 2005 NCLUMPSSMALLER1HAPSQKM_TLP
## 11 3.512041e-38 1.961793e-01 2016 NCLUMPSSMALLER1HAPSQKM_TLP
## 12 7.473777e-10 4.447394e-21 2001          NFIRESM6PSQKM_TLP
## 13 5.790081e-08 1.558964e-04 2003     LOSSGREATER1HA_PUA_TLP
## 14 3.050067e-18 5.557022e-03 2010     LOSSGREATER1HA_PUA_TLP
## 15 5.417965e-23 9.775631e-03 2008     LOSSGREATER1HA_PUA_TLP
## 16 1.193796e-22 5.793614e-03 2016     LOSSGREATER1HA_PUA_TLP
## 17 3.679056e-15 3.178474e-03 2009     LOSSGREATER1HA_PUA_TLP
## 18 1.209308e-36 5.871250e-01 2013 NCLUMPSSMALLER1HAPSQKM_TLP
```

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## 19 2.045870e-20 4.968208e-05 2015          NFIRESV1PSQKM_TLP
## 20 9.597089e-15 3.859220e-07 2017          NFIRESV1PSQKM_TLP
## 21 1.151396e-11 1.476240e-13 2010          NFIRESM6PSQKM_TLP
## 22 3.561104e-23 5.925658e-13 2005          NFIRESM6PSQKM_TLP
## 23 1.942940e-18 6.027179e-19 2002          NFIRESM6PSQKM_TLP
## 24 2.316165e-17 1.158393e-04 2012          NFIRESV1PSQKM_TLP
## 25 4.372048e-32 5.961799e-01 2007 NCLUMPSSMALLER1HAPSQKM_TLP
## 26 2.271202e-27 4.431232e-04 2006     LOSSGREATER1HA_PUA_TLP
## 27 6.263536e-31 3.265303e-02 2004     LOSSGREATER1HA_PUA_TLP
## 28 5.245399e-28 4.790428e-01 2014 NCLUMPSSMALLER1HAPSQKM_TLP
## 29 2.851523e-54 8.893429e-01 2011 NCLUMPSSMALLER1HAPSQKM_TLP
## 30 1.115277e-08 1.032084e-14 2003          NFIRESM6PSQKM_TLP
## 31 1.048697e-11 1.439206e-12 2014          NFIRESM6PSQKM_TLP
## 32 3.368359e-48 8.416220e-01 2003 NCLUMPSSMALLER1HAPSQKM_TLP
## 33 8.139498e-16 1.653264e-03 2018          NFIRESV1PSQKM_TLP
## 34 7.682839e-25 7.438337e-06 2013          NFIRESV1PSQKM_TLP
## 35 1.103641e-29 7.482668e-01 2012 NCLUMPSSMALLER1HAPSQKM_TLP
## 36 4.446704e-33 1.203359e-01 2017     LOSSGREATER1HA_PUA_TLP
## 37 1.386967e-42 4.482731e-01 2018 NCLUMPSSMALLER1HAPSQKM_TLP
## 38 3.556694e-20 9.094261e-01 2001 NCLUMPSSMALLER1HAPSQKM_TLP
## 39 3.427726e-18 3.367129e-02 2007     LOSSGREATER1HA_PUA_TLP
## 40 7.180968e-19 5.826912e-13 2013          NFIRESM6PSQKM_TLP
## 41 1.263021e-44 9.305300e-01 2010 NCLUMPSSMALLER1HAPSQKM_TLP
## 42 1.359432e-16 1.024070e-11 2009          NFIRESM6PSQKM_TLP
## 43 2.528432e-31 2.637941e-02 2018     LOSSGREATER1HA_PUA_TLP
## 44 1.861544e-13 1.007430e-15 2016          NFIRESM6PSQKM_TLP
## 45 3.709139e-14 9.600338e-12 2015          NFIRESM6PSQKM_TLP
## 46 3.513335e-52 6.337729e-01 2004 NCLUMPSSMALLER1HAPSQKM_TLP
## 47 6.966444e-45 5.620248e-01 2008 NCLUMPSSMALLER1HAPSQKM_TLP
## 48 1.801156e-19 1.912238e-13 2012          NFIRESM6PSQKM_TLP
## 49 4.362386e-11 3.076276e-14 2018          NFIRESM6PSQKM_TLP
## 50 4.808361e-26 5.990192e-04 2011     LOSSGREATER1HA_PUA_TLP
## 51 1.033000e-35 4.750287e-01 2002 NCLUMPSSMALLER1HAPSQKM_TLP
## 52 8.473342e-08 4.018176e-17 2017          NFIRESM6PSQKM_TLP
## 53 1.039989e-46 3.622059e-01 2017 NCLUMPSSMALLER1HAPSQKM_TLP
## 54 1.209856e-45 8.131076e-02 2006 NCLUMPSSMALLER1HAPSQKM_TLP
## 55 7.527649e-33 4.936702e-01 2009 NCLUMPSSMALLER1HAPSQKM_TLP
## 56 5.791724e-16 4.942056e-13 2007          NFIRESM6PSQKM_TLP
## 57 5.653438e-18 2.715985e-06 2016          NFIRESV1PSQKM_TLP
## 58 6.029528e-16 3.803953e-12 2006          NFIRESM6PSQKM_TLP
## 59 1.873177e-13 7.819175e-10 2008          NFIRESM6PSQKM_TLP
## 60 1.114077e-15 1.531725e-12 2011          NFIRESM6PSQKM_TLP
## 61 8.487918e-19 1.853404e-12 2004          NFIRESM6PSQKM_TLP
# dev.new()
lambda_tests %>%
  ggplot + aes(x = year, y = MIEST) +
  scale_x_continuous(breaks = 2001:2018) +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5)) +
  geom_line() + facet_wrap(~ variable2, scales = 'free_y')
```
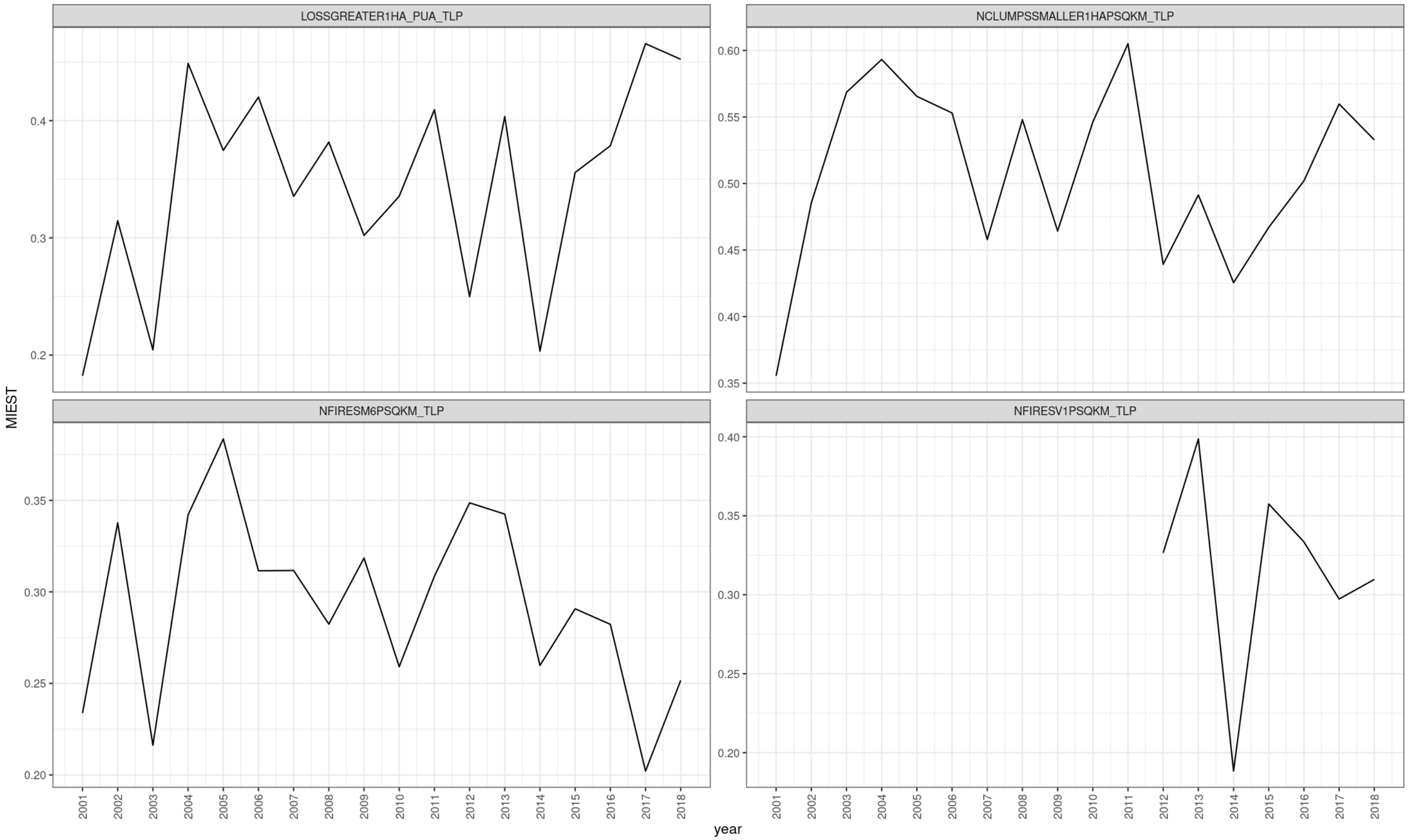
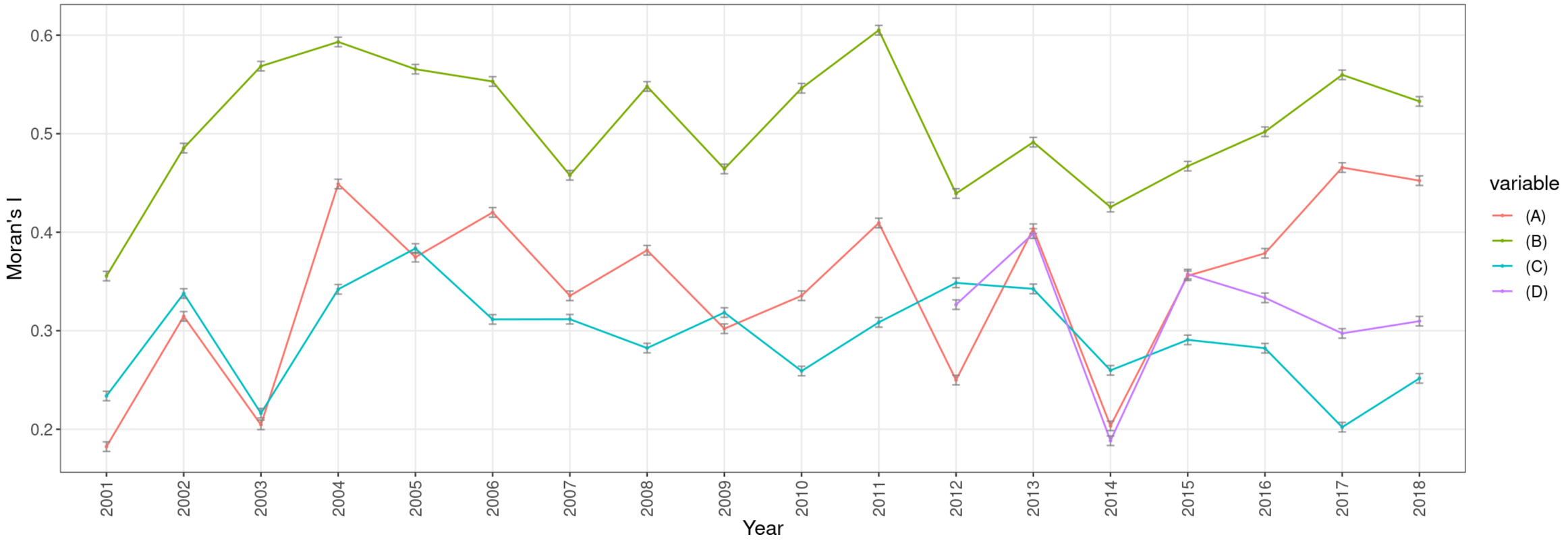




```
# jpeg('out/morans_i_time_series_four_variables_tlp.jpg', width = 3840, height = 1600, res = 350)
lambda_tests %>%
  dplyr::select(value = MIEST, MIVAR, LENGTH, variable2, year) %>%
  mutate(year_factor = factor(year)) %>%
```

```
  mutate(variable = case_when(
  variable2 == 'NFIRESM6PSQKM_TLP' ~ '(C)',
  variable2 == 'NFIRESV1PSQKM_TLP' ~ '(D)',
  variable2 == 'NCLUMPSSMALLER1HAPSQKM_TLP' ~ '(B)',
  variable2 == 'LOSSGREATER1HA_PUA_TLP' ~ '(A)'
  )) %>%
ggplot +
aes(x = year_factor, y = value, group = variable, color = variable) +
theme_bw() +
theme(
  axis.text.x = element_text(angle = 90, vjust = 0.5),
  panel.grid.minor = element_blank(),
  text = element_text(size = 14), aspect.ratio = 1/3) +
geom_line(lwd = 0.6) +
geom_errorbar(
  aes(
    ymin = value - qnorm(p=(0.05/2)+(1-0.05))*sqrt(MIVAR)/sqrt(LENGTH),
    ymax = value + qnorm(p=(0.05/2)+(1-0.05))*sqrt(MIVAR)/sqrt(LENGTH)),
    #color = variable),
  alpha = 0.75,
  colour = "grey50",
  width = .1) +
geom_point(size=0.5, shape=21) +
xlab('Year') +
ylab("Moran's I")
```



```
# dev.off()
```

6.5 LISA maps

```
# Large clearings
loss1hagreatercols <- grep("^YEAR[0-9]{,2}_LOSS.*_TLP$", names(hexzonalfmt), value = T)
hexlisamaps <- map(loss1hagreatercols, function(x) {
    lm <- lisamap(objesp = hexzonalfmt, var = x, pesos = hexww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
        leyenda = T, anchuratitulo = 1000, tamanotitulo = 14, fuentedatos = "Hansen et al., 2013",
        titulomapa = paste0(2000 + as.numeric(create_year_from_string(x))))
    lm$grafico$layers <- c(lm$grafico$layers, geom_sf(data = seaocean, fill = "white")[[1]])
    return(lm$grafico)
})
legendhexlisamaps <- get_legend(hexlisamaps[[1]] + guides(color = guide_legend(nrow = 1)) +
    theme(legend.position = "bottom"))
hexlisamapsnl <- map(hexlisamaps, function(x) {
    mapRange <- c(range(st_coordinates(hexzonalfmt)[, 1]), range(st_coordinates(hexzonalfmt)[,
        2]))
    x + theme(legend.position = "none") + labs(caption = NULL) + coord_sf(xlim = mapRange[c(1:2)],
        ylim = mapRange[c(3:4)]) + theme(plot.title = element_text(hjust = 0.5, vjust = -0.5,
        size = 12), plot.background = element_rect(fill = "white", color = "black",
        size = 0), axis.text = element_blank(), axis.ticks = element_blank(), plot.margin = unit(c(2,
        2, 2, 2), "mm"))
})
# jpeg('out/yearly_lisamaps_forestloss1ha_tlp.jpg', width = 3840, height =
# 1600, res = 350)
plot_grid(plotlist = hexlisamapsnl, nrow = 3)
# dev.off()

# Small clearings
nclumpssmall1hacols <- grep("^NCLUMPSSMALLER1HA_YEAR[0-9]{,2}.*_TLP$", names(hexzonalfmt),
    value = T)
hexlisamapssmal1ha <- map(nclumpssmall1hacols, function(x) {
    lm <- lisamap(objesp = hexzonalfmt, var = x, pesos = hexww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
        leyenda = T, anchuratitulo = 1000, tamanotitulo = 14, fuentedatos = "Hansen et al., 2013",
        titulomapa = paste0(2000 + as.numeric(create_year_from_string(x))))
    lm$grafico$layers <- c(lm$grafico$layers, geom_sf(data = seaocean, fill = "white")[[1]])
    return(lm$grafico)
})
legendhexlisamapssmal1ha <- get_legend(hexlisamapssmal1ha[[1]] + guides(color = guide_legend(nrow = 1)) +
    theme(legend.position = "bottom"))
hexlisamapsnlsmal1ha <- map(hexlisamapssmal1ha, function(x) {
    mapRange <- c(range(st_coordinates(hexzonalfmt)[, 1]), range(st_coordinates(hexzonalfmt)[,
        2]))
    x + theme(legend.position = "none") + labs(caption = NULL) + coord_sf(xlim = mapRange[c(1:2)],
        ylim = mapRange[c(3:4)]) + theme(plot.title = element_text(hjust = 0.5, vjust = -0.5,
        size = 12), plot.background = element_rect(fill = "white", color = "black",
        size = 0), axis.text = element_blank(), axis.ticks = element_blank(), plot.margin = unit(c(2,
        2, 2, 2), "mm"))
})
# jpeg('out/yearly_lisamaps_nclumpssmaller1ha_tlp.jpg', width = 3840, height =
# 1600, res = 350)
plot_grid(plotlist = hexlisamapsnlsmal1ha, nrow = 3)
# dev.off()
```

```r
# Fire points MODIS
firemodiscols <- grep("^NFIRESM6_YEAR[0-9]{,2}.*_TLP$", names(hexzonalfmt), value = T)
hexlisamapsfiremodis <- map(firemodiscols, function(x) {
    lm <- lisamap(objesp = hexzonalfmt, var = x, pesos = hexww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
        leyenda = T, anchuratitulo = 1000, tamanotitulo = 14, fuentedatos = "Hansen et al., 2013",
        titulomapa = paste0(2000 + as.numeric(create_year_from_string(x))))
    lm$grafico$layers <- c(lm$grafico$layers, geom_sf(data = seaocean, fill = "white")[[1]])
    return(lm$grafico)
})
legendhexlisamapsfiremodis <- get_legend(hexlisamapsfiremodis[[1]] + guides(color = guide_legend(nrow = 1)) +
    theme(legend.position = "bottom"))
hexlisamapsnlfiremodis <- map(hexlisamapsfiremodis, function(x) {
    mapRange <- c(range(st_coordinates(hexzonalfmt)[, 1]), range(st_coordinates(hexzonalfmt)[,
        2]))
    x + theme(legend.position = "none") + labs(caption = NULL) + coord_sf(xlim = mapRange[c(1:2)],
        ylim = mapRange[c(3:4)]) + theme(plot.title = element_text(hjust = 0.5, vjust = -0.5,
        size = 12), plot.background = element_rect(fill = "white", color = "black",
        size = 0), axis.text = element_blank(), axis.ticks = element_blank(), plot.margin = unit(c(2,
        2, 2, 2), "mm"))
})
# jpeg('out/yearly_lisamaps_firemodis_tlp.jpg', width = 3840, height = 1600,
# res = 350)
plot_grid(plotlist = hexlisamapsnlfiremodis, nrow = 3)
# dev.off()

# Fire points VIIRS
fireviirscols <- grep("^NFIRESV1_YEAR[0-9]{,2}.*_TLP$", names(hexzonalfmt), value = T)
hexlisamapsfireviirs <- map(fireviirscols, function(x) {
    lm <- lisamap(objesp = hexzonalfmt, var = x, pesos = hexww, tituloleyenda = "Significance\n(\"x-y\", read as\n \"x\" surrounded\nby \"y\"",
        leyenda = T, anchuratitulo = 1000, tamanotitulo = 14, fuentedatos = "Hansen et al., 2013",
        titulomapa = paste0(2000 + as.numeric(create_year_from_string(x))))
    lm$grafico$layers <- c(lm$grafico$layers, geom_sf(data = seaocean, fill = "white")[[1]])
    return(lm$grafico)
})
legendhexlisamapsfireviirs <- get_legend(hexlisamapsfireviirs[[1]] + guides(color = guide_legend(nrow = 1)) +
    theme(legend.position = "bottom"))
hexlisamapsnlfireviirs <- map(hexlisamapsfireviirs, function(x) {
    mapRange <- c(range(st_coordinates(hexzonalfmt)[, 1]), range(st_coordinates(hexzonalfmt)[,
        2]))
    x + theme(legend.position = "none") + labs(caption = NULL) + coord_sf(xlim = mapRange[c(1:2)],
        ylim = mapRange[c(3:4)]) + theme(plot.title = element_text(hjust = 0.5, vjust = -0.5,
        size = 12), plot.background = element_rect(fill = "white", color = "black",
        size = 0), axis.text = element_blank(), axis.ticks = element_blank(), plot.margin = unit(c(2,
        2, 2, 2), "mm"))
})
# jpeg('out/yearly_lisamaps_fireviirs_tlp.jpg', width = 3840, height = 1600,
# res = 350)
plot_grid(plotlist = hexlisamapsnlfireviirs, nrow = 2, ncol = 4)
# dev.off()
```

6.6 Models

```r
# LARGE CLEARINGS TRANS
annual_models_folossg1ha_trans_formulas <- data.frame(y = grep("^YEAR[0-9]{,2}_LOSS.*_TLP$",
    names(hexzonalfmt), value = T), x = grep("^NFIRESM6_YEAR[0-9]{,2}.*_TLP$", names(hexzonalfmt),
```

```
    value = T)) %>%
    mutate(formula = paste(y, x, sep = " ~ ")) %>%
    pull(formula)
annual_models_folossg1ha_trans <- sapply(annual_models_folossg1ha_trans_formulas,
    function(x) hexzonalfmt %>%
        st_drop_geometry() %>%
        replace(is.na(.), 0) %>%
        spatialreg::errorsarlm(formula = x, data = ., listw = hexww), simplify = F)
lapply(annual_models_folossg1ha_trans, function(x) summary(x, Nagelkerke = T))
lapply(annual_models_folossg1ha_trans, function(x) x$coefficients[[1]]) %>%
    unlist %>%
    plot
lapply(annual_models_folossg1ha_trans, function(x) x$coefficients[[2]]) %>%
    unlist %>%
    plot
lapply(annual_models_folossg1ha_trans, function(x) summary(x, Nagelkerke = T)$NK) %>%
    unlist %>%
    plot
lapply(annual_models_folossg1ha_trans, function(x) summary(x, Nagelkerke = T)$Coef[,
    4])
lapply(annual_models_folossg1ha_trans, function(x) summary(x, Nagelkerke = T)$Coef[,
    c(1, 4)] %>%
    as.data.frame %>%
    rownames_to_column(var = "variable")) %>%
    plyr::ldply() %>%
    format(., scientific = F)
annual_models_sign_coefs(annual_models_folossg1ha_trans)  #Coefficient is significant in each annual model

# LARGE CLEARINGS UNTRANS
annual_models_folossg1ha_untrans_formulas <- data.frame(y = grep("^YEAR[0-9]{,2}_LOSS.*PUA$",
    names(hexzonalfmt), value = T), x = grep("^NFIRESM6_YEAR[0-9]{,2}.*KM$", names(hexzonalfmt),
    value = T)) %>%
    mutate(formula = paste(y, x, sep = " ~ ")) %>%
    pull(formula)
annual_models_folossg1ha_untrans <- sapply(annual_models_folossg1ha_untrans_formulas,
    function(x) hexzonalfmt %>%
        st_drop_geometry() %>%
        replace(is.na(.), 0) %>%
        spatialreg::errorsarlm(formula = x, data = ., listw = hexww), simplify = F)
lapply(annual_models_folossg1ha_untrans, function(x) summary(x, Nagelkerke = T))
lapply(annual_models_folossg1ha_untrans, function(x) x$coefficients[[1]]) %>%
    unlist %>%
    plot
lapply(annual_models_folossg1ha_untrans, function(x) x$coefficients[[2]]) %>%
    unlist %>%
    plot
lapply(annual_models_folossg1ha_untrans, function(x) summary(x, Nagelkerke = T)$NK) %>%
    unlist %>%
    plot
lapply(annual_models_folossg1ha_untrans, function(x) summary(x, Nagelkerke = T)$Coef[,
    4])
lapply(annual_models_folossg1ha_untrans, function(x) summary(x, Nagelkerke = T)$Coef[,
    c(1, 4)] %>%
    as.data.frame %>%
    rownames_to_column(var = "variable")) %>%
    plyr::ldply() %>%
    format(., scientific = F)
```

```r
annual_models_sign_coefs(annual_models_folossg1ha_untrans)  #Intercept not significant in years 5, 13 and 14

# NCLUMPS TRANS
annual_models_folossnclumpsl1ha_trans_formulas <- data.frame(y = grep("^NCLUMPSSMALLER1HA_YEAR[0-9]{,2}.*_TLP$",
    names(hexzonalfmt), value = T), x = grep("^NFIRESM6_YEAR[0-9]{,2}.*_TLP$", names(hexzonalfmt),
    value = T)) %>%
    mutate(formula = paste(y, x, sep = " ~ ")) %>%
    pull(formula)
annual_models_folossnclumpsl1ha_trans <- sapply(annual_models_folossnclumpsl1ha_trans_formulas,
    function(x) hexzonalfmt %>%
        st_drop_geometry() %>%
        replace(is.na(.), 0) %>%
        spatialreg::errorsarlm(formula = x, data = ., listw = hexww), simplify = F)
lapply(annual_models_folossnclumpsl1ha_trans, function(x) summary(x, Nagelkerke = T))
lapply(annual_models_folossnclumpsl1ha_trans, function(x) x$coefficients[[1]]) %>%
    unlist %>%
    plot
lapply(annual_models_folossnclumpsl1ha_trans, function(x) x$coefficients[[2]]) %>%
    unlist %>%
    plot
lapply(annual_models_folossnclumpsl1ha_trans, function(x) summary(x, Nagelkerke = T)$NK) %>%
    unlist %>%
    plot
lapply(annual_models_folossnclumpsl1ha_trans, function(x) summary(x, Nagelkerke = T)$Coef[,
    c(1, 4)] %>%
    as.data.frame %>%
    rownames_to_column(var = "variable")) %>%
    plyr::ldply() %>%
    format(., scientific = F)
annual_models_sign_coefs(annual_models_folossnclumpsl1ha_trans)  #NFIRESM6 coefficient is significant in every annual model

# NCLUMPS UNTRANS
annual_models_folossnclumpsl1ha_untrans_formulas <- data.frame(y = grep("^NCLUMPSSMALLER1HA_YEAR[0-9]{,2}.*KM$",
    names(hexzonalfmt), value = T), x = grep("^NFIRESM6_YEAR[0-9]{,2}.*KM$", names(hexzonalfmt),
    value = T)) %>%
    mutate(formula = paste(y, x, sep = " ~ ")) %>%
    pull(formula)
annual_models_folossnclumpsl1ha_untrans <- sapply(annual_models_folossnclumpsl1ha_untrans_formulas,
    function(x) hexzonalfmt %>%
        st_drop_geometry() %>%
        replace(is.na(.), 0) %>%
        spatialreg::errorsarlm(formula = x, data = ., listw = hexww), simplify = F)
lapply(annual_models_folossnclumpsl1ha_untrans, function(x) summary(x, Nagelkerke = T))
lapply(annual_models_folossnclumpsl1ha_untrans, function(x) x$coefficients[[1]]) %>%
    unlist %>%
    plot
lapply(annual_models_folossnclumpsl1ha_untrans, function(x) x$coefficients[[2]]) %>%
    unlist %>%
    plot
lapply(annual_models_folossnclumpsl1ha_untrans, function(x) summary(x, Nagelkerke = T)$NK) %>%
    unlist %>%
    plot
lapply(annual_models_folossnclumpsl1ha_untrans, function(x) summary(x, Nagelkerke = T)$Coef[,
    c(1, 4)] %>%
    as.data.frame %>%
    rownames_to_column(var = "variable")) %>%
    plyr::ldply() %>%
```

```
    format(., scientific = F)
annual_models_sign_coefs(annual_models_folossnclumpsl1ha_untrans)  #NFIRESM6 coefficient is significant in every annual model
```

6.7 Local models

```
# Eastern Region, large clearings ~ fire
hexzonalfmter <- hexzonalfmt %>%
  mutate(x = st_coordinates(st_centroid(.))[,1], y = st_coordinates(st_centroid(.))[,2]) %>%
  filter(x > ((max(x) - min(x)) * 4/5) + min(x) & y < ((max(y) - min(y)) * 2/3) + min(y))
hexnber <- poly2nb(hexzonalfmter)
hexwwer <- nb2listw(hexnber, zero.policy = T)
annual_models_folossg1ha_trans_er <- sapply(annual_models_folossg1ha_trans_formulas,
                        function(x)
                          hexzonalfmter %>%
                          st_drop_geometry() %>%
                          replace(is.na(.), 0) %>%
                          spatialreg::errorsarlm(formula = x,
                                                 data = ., # zero.policy = T,
                                                 listw = hexwwer),
                        simplify = F)
annual_models_sign_coefs(annual_models_folossg1ha_trans_er) #NFIRESM6 coefficient not significant in many years

# Eastern Region, small clearings ~ fire
annual_models_folossnclumpsl1ha_trans_er <- sapply(annual_models_folossnclumpsl1ha_trans_formulas,
                        function(x)
                          hexzonalfmter %>%
                          st_drop_geometry() %>%
                          replace(is.na(.), 0) %>%
                          spatialreg::errorsarlm(formula = x,
                                                 data = ., # zero.policy = T,
                                                 listw = hexwwer),
                       simplify = F)
annual_models_sign_coefs(annual_models_folossnclumpsl1ha_trans_er) #NFIRESM6 coefficient not significant almost every year

# Los Haitises-Samaná, large clearings ~ fire
hexzonalfmtlhs <- hexzonalfmt %>%
  mutate(x = st_coordinates(st_centroid(.))[,1], y = st_coordinates(st_centroid(.))[,2]) %>%
  filter(x > ((max(x) - min(x)) * 3/5) + min(x) & x < ((max(x) - min(x)) * 4/5) + min(x))
hexnblhs <- poly2nb(hexzonalfmtlhs)
hexwwlhs <- nb2listw(hexnblhs, zero.policy = T)
annual_models_folossg1ha_trans_lhs <- sapply(annual_models_folossg1ha_trans_formulas,
                        function(x)
                          hexzonalfmtlhs %>%
                          st_drop_geometry() %>%
                          replace(is.na(.), 0) %>%
                          spatialreg::errorsarlm(formula = x,
                                                 data = ., # zero.policy = T,
                                                 listw = hexwwlhs),
                        simplify = F)
annual_models_sign_coefs(annual_models_folossg1ha_trans_lhs) #NFIRESM6 coefficient not significant in many years

# Los Haitises-Samaná, small clearings ~ fire
annual_models_folossnclumpsl1ha_trans_lhs <- sapply(annual_models_folossnclumpsl1ha_trans_formulas,
                        function(x)
                          hexzonalfmtlhs %>%
```

```
                          st_drop_geometry() %>%
                          replace(is.na(.), 0) %>%
                          spatialreg::errorsarlm(formula = x,
                                                 data = ., # zero.policy = T,
                                                 listw = hexwwlhs),
                        simplify = F)
annual_models_sign_coefs(annual_models_folossnclumpsl1ha_trans_lhs) #NFIRESM6 coefficient is significant in seven years

# Central, large clearings ~ fire
hexzonalfmtcent <- hexzonalfmt %>%
  mutate(x = st_coordinates(st_centroid(.))[,1], y = st_coordinates(st_centroid(.))[,2]) %>%
  filter(x > ((max(x) - min(x)) * 1/5) + min(x) & x < ((max(x) - min(x)) * 3/5) + min(x))
hexnbcent <- poly2nb(hexzonalfmtcent)
hexwwcent <- nb2listw(hexnbcent, zero.policy = T)
annual_models_folossg1ha_trans_cent <- sapply(annual_models_folossg1ha_trans_formulas,
                        function(x)
                          hexzonalfmtcent %>%
                          st_drop_geometry() %>%
                          replace(is.na(.), 0) %>%
                          spatialreg::errorsarlm(formula = x,
                                                 data = ., # zero.policy = T,
                                                 listw = hexwwcent),
                        simplify = F)
annual_models_sign_coefs(annual_models_folossg1ha_trans_cent) #NFIRESM6 coefficient is not significant only in 2016

# Central, small clearings ~ fire
annual_models_folossnclumpsl1ha_trans_cent <- sapply(annual_models_folossnclumpsl1ha_trans_formulas,
                        function(x)
                          hexzonalfmtcent %>%
                          st_drop_geometry() %>%
                          replace(is.na(.), 0) %>%
                          spatialreg::errorsarlm(formula = x,
                                                 data = ., # zero.policy = T,
                                                 listw = hexwwcent),
                        simplify = F)
annual_models_sign_coefs(annual_models_folossnclumpsl1ha_trans_cent) #NFIRESM6 coefficient is not significant only in 4, 12 and 16

# Western, large clearings ~ fire
hexzonalfmtwr <- hexzonalfmt %>%
  mutate(x = st_coordinates(st_centroid(.))[,1], y = st_coordinates(st_centroid(.))[,2]) %>%
  filter(x < ((max(x) - min(x)) * 1/5) + min(x))
hexnbwr <- poly2nb(hexzonalfmtwr)
hexwwwr <- nb2listw(hexnbwr, zero.policy = T)
annual_models_folossg1ha_trans_wr <- sapply(annual_models_folossg1ha_trans_formulas,
                        function(x)
                          hexzonalfmtwr %>%
                          st_drop_geometry() %>%
                          replace(is.na(.), 0) %>%
                          spatialreg::errorsarlm(formula = x,
                                                 data = ., # zero.policy = T,
                                                 listw = hexwwwr),
                        simplify = F)
annual_models_sign_coefs(annual_models_folossg1ha_trans_wr) #NFIRESM6 coefficient is significant in every annual model

# Western, small clearings ~ fire
annual_models_folossnclumpsl1ha_trans_wr <- sapply(annual_models_folossnclumpsl1ha_trans_formulas,
                        function(x)
```

```
                          hexzonalfmtwr %>%
                          st_drop_geometry() %>%
                          replace(is.na(.), 0) %>%
                          spatialreg::errorsarlm(formula = x,
                                                 data = ., # zero.policy = T,
                                                 listw = hexwwwr),
                        simplify = F)
annual_models_sign_coefs(annual_models_folossnclumpsl1ha_trans_wr) #NFIRESM6 coefficient is significant in every annual model

# Maps
# jpeg('out/east_west_regions_maps.jpg', width = 2000, height = 1600, res = 350)
plot_grid(plotlist = list(
  small_map(hexzonalfmtwr),
  small_map(hexzonalfmtcent),
  small_map(hexzonalfmtlhs),
  small_map(hexzonalfmter)),
  labels = c('(A)', '(B)', '(C)', '(D)'),
  label_size = 14, nrow = 2, scale = 1, hjust = -4.9, vjust = 1.2,
  align = 'v', axis = 't')
# dev.off()
# system(
#   paste('convert out/east_west_regions_maps.jpg -gravity South -chop 0x70',
#         'out/east_west_regions_maps_cropped.jpg')
# )
```

10 Martínez Batlle, J. R. (2021). Forest loss and fire in the Dominican Republic during the 21st Century. *bioRxiv*. https://doi.org/10.1101/2021.06.15.448604