Multi-temporal analysis of RS data via the ‘*ggridges’ package*

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PROPOSAL 1: Plant Phenology

- **Scope**: Use ridgeplots to display the variation of important vegetation parameters (vegetation indices) related to phenology on annual and multi-year scales.

- **Data**: Normalized Difference Vegetation Index 2014-2020 (raster 300m), global, 10-daily – version 1; 24 rasters (2014 and 2017)

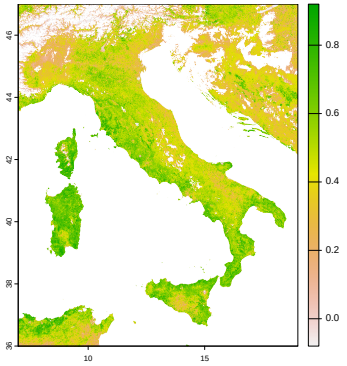
- **Packages**: ‘raster’, ‘terra’, ‘purrr’, ‘furrr’, ‘tidyverse’, ‘ggridges’

Codes #1

- #### **Import data** ####

  NDVI_300m <- list.files(pattern = "NDVI300_2014", recursive = T)

  %>% map(~rast(.))



- #### **Pre-processing** ####

  # crop the rasters on Italy

  IT_extent <- ext(7, 19, 36, 47)

  NDVI_300m_crop <- lapply(NDVI_300m, crop, IT_extent)

Codes #2

- **#### Extract NDVI values in a list ####**

```
values_NDVI_300m <- list()

for (i in 1:12) {

  new_object <- terra::as.data.frame(NDVI_300m_crop[[i]])              # extract values from each raster

  values_NDVI_300m[[paste0("NDVI_300m_", i)]] <- new_object        # add each extracted dataframe to the list

  values_NDVI_300m[[i]]$month <- as.numeric(paste(i))                  # create a column reporting the month of reference for each NDVI value

  rm(new_object)

}
```

Codes #3

- **# Merge list objects into a single dataframe**

  values_NDVI300_tot <- do.call(rbind, values_NDVI_300m) %>% # bind by rows

    subset(NDVI >= 0.2 | is.na(NDVI)) # set the condition excluding uninteresting cover types

- **# order rows according to month**

  values_NDVI300_tot <- values_NDVI300_tot[order(values_NDVI300_tot$month),]

Codes #4

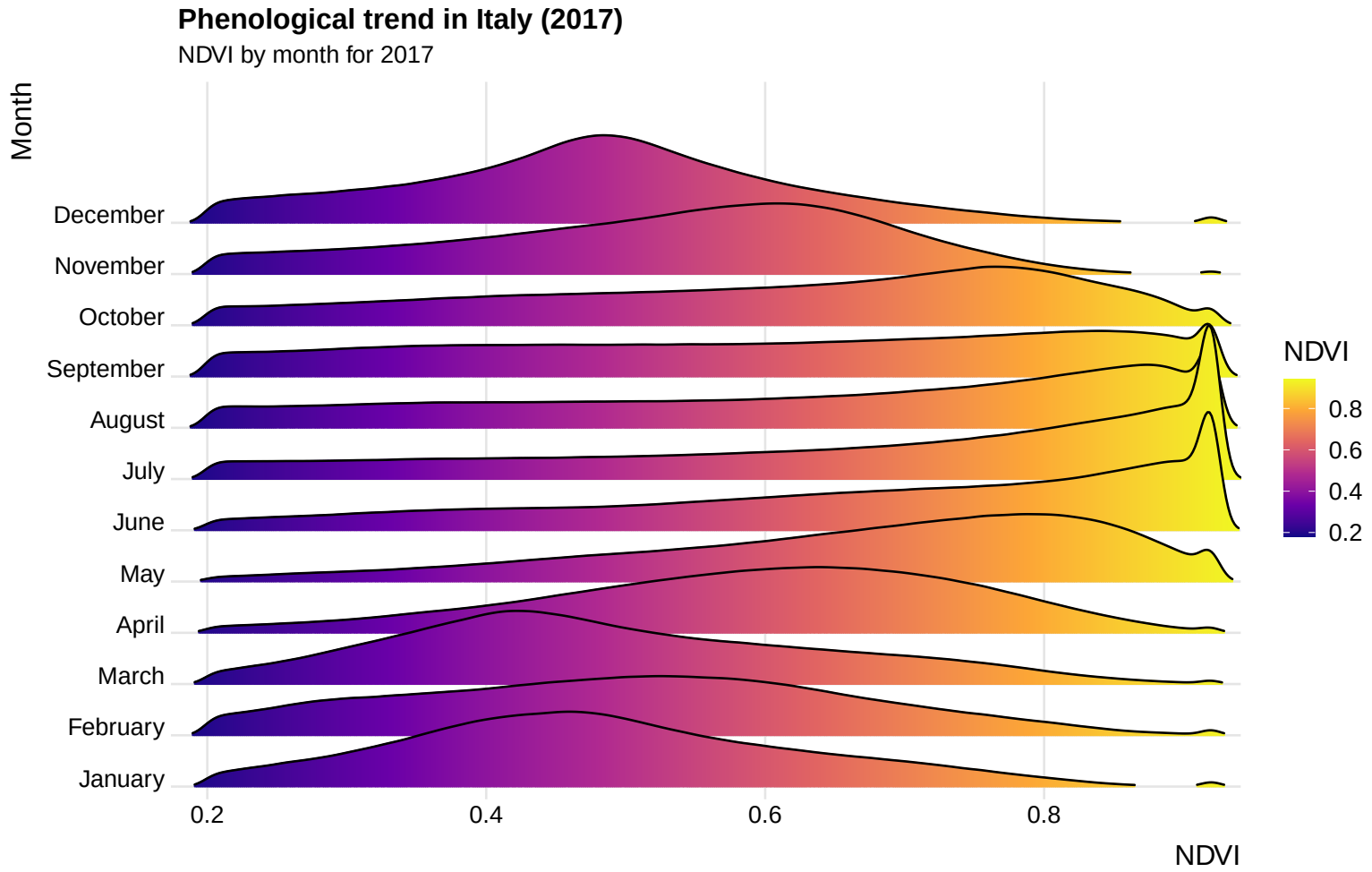
- **# Change months names**

```
values_NDVI300_tot$month <- fct_recode(values_NDVI300_tot$month,
                                       January = "1",
                                       February = "2",
                                       March = "3",
                                       April = "4",
                                       May = "5",
                                       June = "6",
                                       July = "7",
                                       August = "8",
                                       September ="9",
                                       October = "10",
                                       November = "11",
                                       December = "12")
```

Phenology single year - Ridgeplot Code

- **# Gradient ridgeplot type**

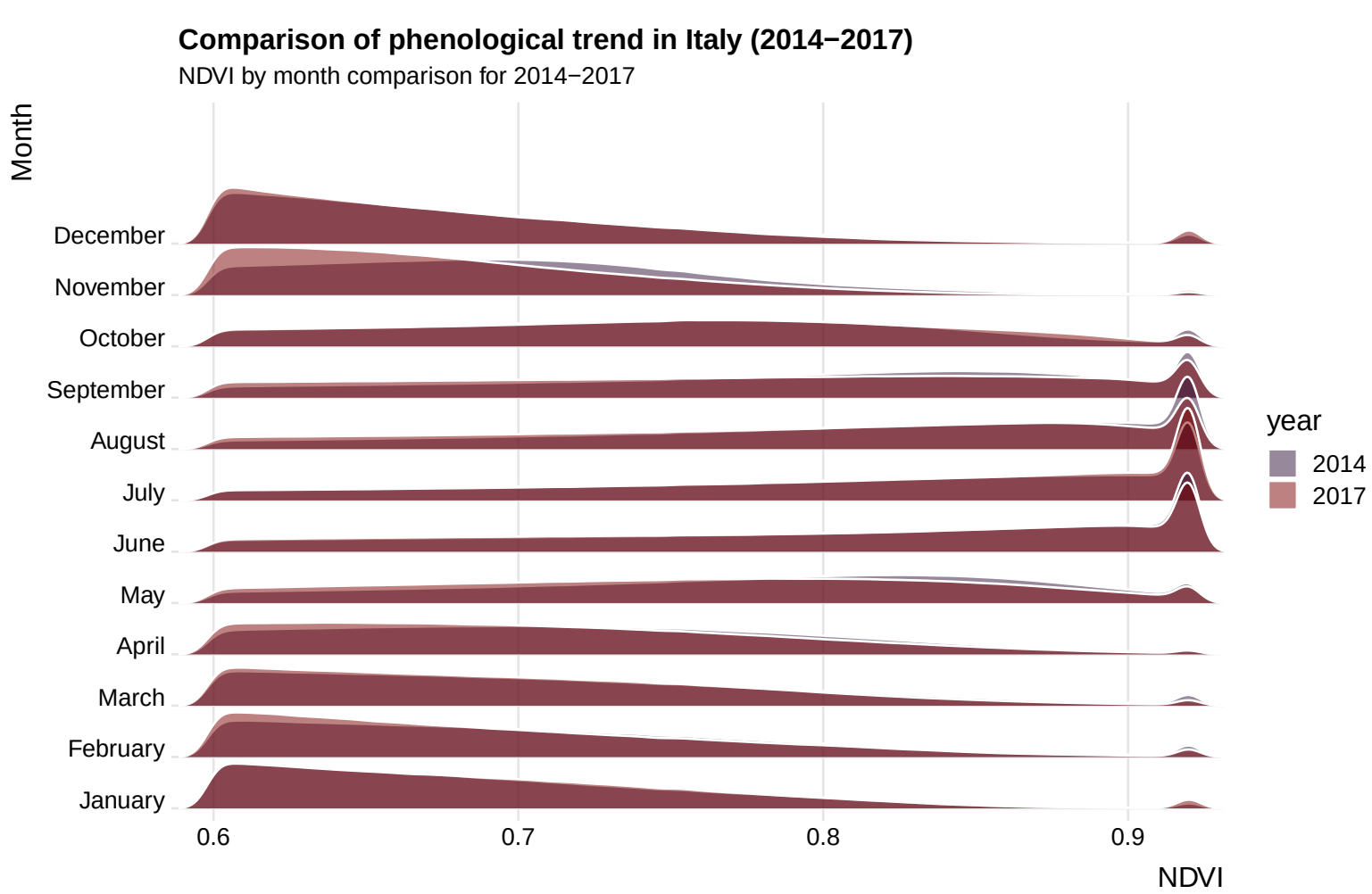
```
ridgeplot_NDVI <- ggplot(values_NDVI300_tot, aes(x = `NDVI`, y = month, fill = after_stat(x))) +
  geom_density_ridges_gradient(scale = 3, rel_min_height = 0.01, gradient_lwd = 1.) +        # gradient fill
  scale_x_continuous(expand = c(0, 0)) +                                                     # extend x axis
  scale_y_discrete(expand = expansion(mult = c(0.01, 0.25))) +                               # visible range y axis

  scale_fill_viridis_c(name = "NDVI", option = "C") +                                        # Viridis color scale
  labs(x = "NDVI",                                                                           # set axis labels, title, subtitle
       y = "Month",
    title = 'Phenological trend in Italy (2017)',
    subtitle = 'NDVI by month for 2017'
  ) +
  theme_ridges(font_size = 13, grid = TRUE)                                                  # increase font size, add grid lines
```


Phenological trend in Italy (2017)
NDVI by month for 2017
Month
December
November
October
September
August
July
June
May
April
March
February
January
0.2
0.4
0.6
0.8
NDVI
NDVI
0.8
0.6
0.4
0.2

Phenology multiple years - Ridgeplot Code

- **#### Ridgeplots ####**

```
values_NDVI300 %>%
  ggplot(aes(y = month)) +
  geom_density_ridges(aes(x = NDVI, fill = year),                    # add year variable as fill
                      alpha = 0.5, color = "white") +
  labs(x = "NDVI",
       y = "Month",
       title = 'Comparison of phenological trend in Italy (2014-2017)',
       subtitle = 'NDVI by month comparison for 2014-2017') +
  scale_x_continuous(expand = c(0, 0)) +
  scale_y_discrete(expand = expansion(mult = c(0.01, 0.25))) +
  scale_fill_viridis_d(option = "cividis") +
  theme_ridges(font_size = 13, grid = TRUE)
```


Comparison of phenological trend in Italy (2014−2017)
NDVI by month comparison for 2014−2017
Month
December
November
October
September
August
July
June
May
April
March
February
January
0.6
0.7
0.8
0.9
NDVI
year
2014
2017

PROPOSAL 2: Copernicus Land Surface Temperature

- **Scope**: Land Surface Temperature Change from 2011 to 2020 in EU**.** Useful to visualize if and how climate changes in the last 10 years had an impact on surface temperatures.

- **Data**: Land Surface Temperature 2010-2021 (raster 5 km), global, hourly – version 1); 24 rasters (2011 and 2017)

- **Packages**: ‘raster’, ‘terra’, ‘purrr’, ‘furrr’, ‘tidyverse’, ‘forcats’ ‘ggridges’

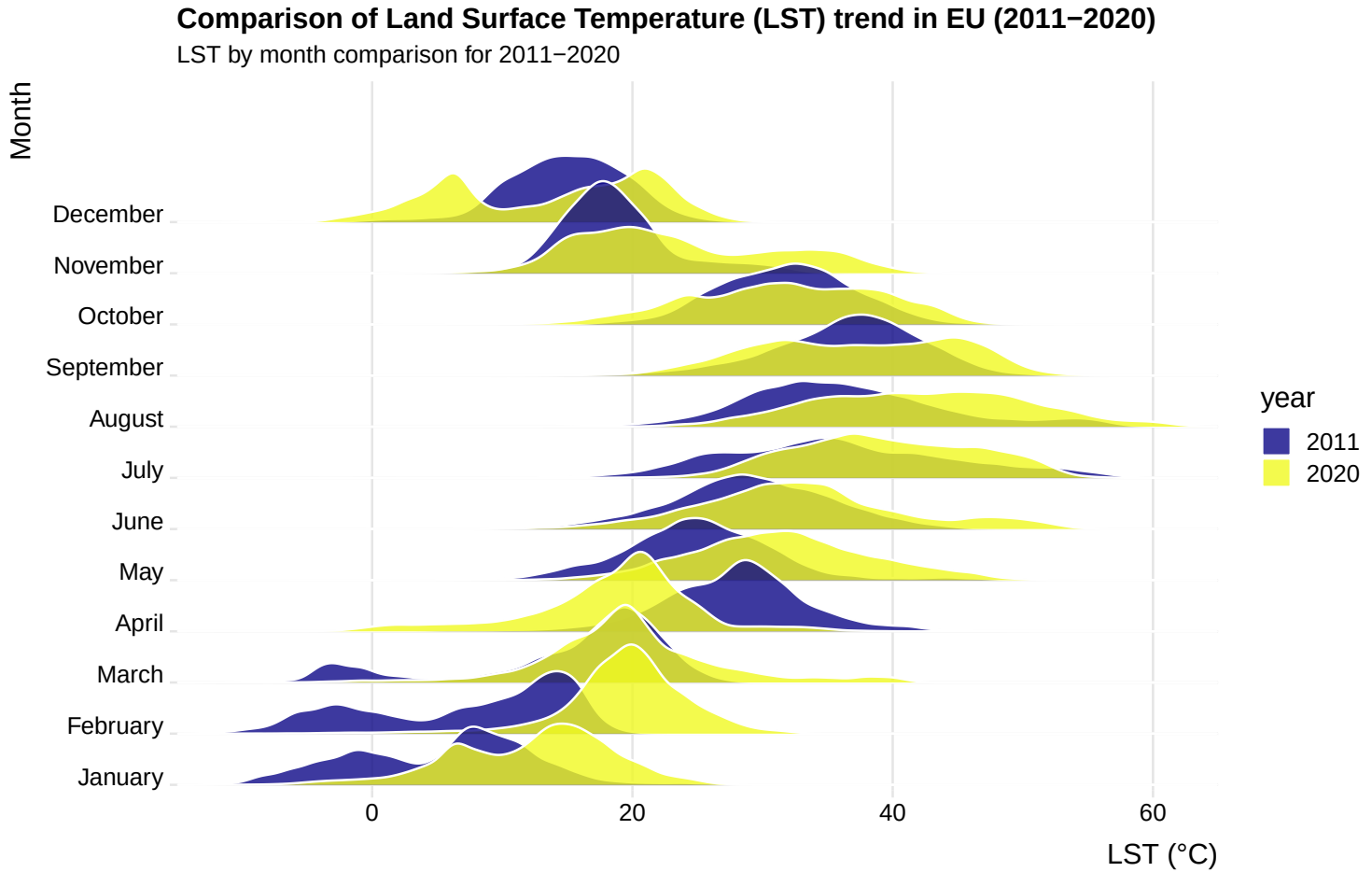
LST Processing scheme:

- #### **Import data** ####
- #### **Pre-processing** ####

  - crop (European Union),
  - value extraction (24 objects),
  - merging into single data frame,
  - convert temperatures from Kelvin to Celsius,
  - adjust variable names and order

Land surface temperature multiple years - Ridgeplot Code

```
values_LST_EU %>%
  ggplot(aes(y = month)) +
  geom_density_ridges(aes(x = LST, fill = year),
                      alpha = 0.8, color = "white") +                    # alpha: adjusts the transparency of the ridges
  labs(x = "LST (°C)",
       y = "Month",
       title = 'Comparison of Land Surface Temperature (LST) trend in EU (2011-2020)',
       subtitle = 'LST by month comparison for 2011-2020') +
  scale_x_continuous(expand = c(0, 0), limits = c(-15, 65)) +        # removes margins, set x axis limits
  scale_y_discrete(expand = expansion(mult = c(0.01, 0.25))) +    # set y axis limits
  scale_fill_viridis_d(option = "plasma") +                                  # set color scale for the ‘year’ variable
  theme_ridges(font_size = 13, grid = T)                                  # adjust font size and add grid lines
```


Comparison of Land Surface Temperature (LST) trend in EU (2011−2020)
LST by month comparison for 2011−2020
Month
December
November
October
September
August
July
June
May
April
March
February
January
0
20
40
60
LST (°C)
year
2011
2020

PROPOSAL 3: Analysis on Emilia-Romagna Forest Maps

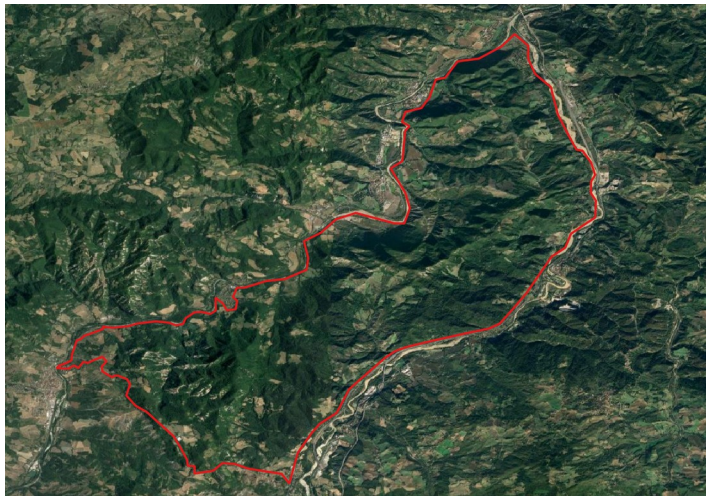
- **Scope**: Use ridgeplots to draw the distribution of values of spectral bands in relation to forest main species and management

- **Possible application**: Test the use of ridgeplots as a tool for visualization and preliminary analysis for remote forest type classifications

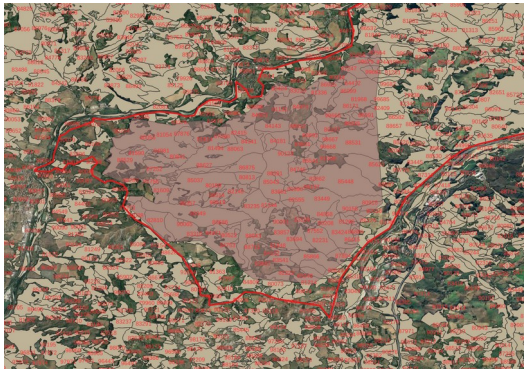
- **Data**: Emilia-Romagna orthophoto (Google Satellite), Forest maps of the Emilia-Romagna region, Montesole Polygon

- **Packages**: ‘sf’, ‘raster’, ‘terra’, ‘purrr’, ‘furrr’, ‘tidyverse’, ‘ggridges’

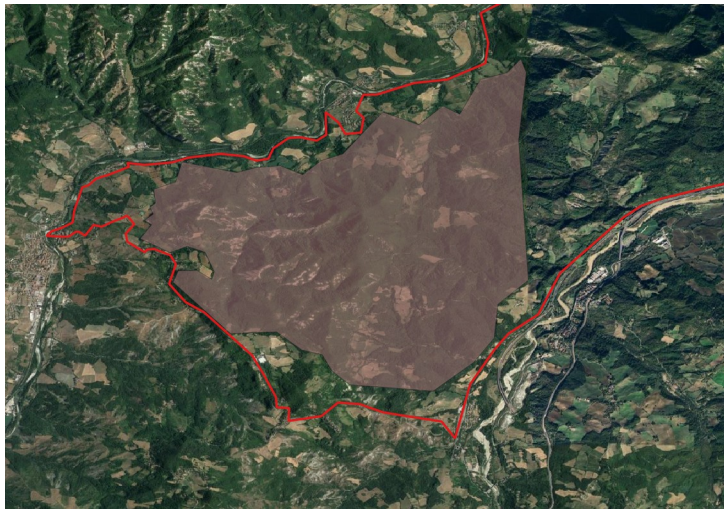
QGIS



Montesole



ER Forest map



Section of Montesole

Codes #1

- **# Import data**

  montesole <- stack("/home/alessio/Tirocinio/Foresta/montesole.tif") # stack o brick per importare più immagini o una sola immagine con diverse bande

  buffer <- st_read("/home/alessio/Tirocinio/Foresta/buffer_c.shp")

  foreste <- st_read("/home/alessio/Tirocinio/Foresta/AreeForestali2014BO.shp")

Codes #2

- **# Make sure CRS match**
  foreste <- st_transform(foreste, crs = st_crs(buffer)) # convert coordinates of simple feature (‘sf’)

- # Now, the CRS should be the same
  print(st_crs(foreste))
  print(st_crs(buffer))

- **# Check validity of geometries**
  print(st_is_valid(foreste))
  print(st_is_valid(buffer))

- **# Fix invalid geometries**
  foreste <- st_make_valid(foreste)

Codes #3

- **# Crop foreste according to Monte Sole buffer**

  foreste <- st_intersection(foreste, buffer)

- **# Crop and mask montesole.tif according to Monte Sole buffer**

  montesole <- crop(montesole, buffer)

  montesole <- mask(montesole, buffer)

- **# Extract Values ####**

  df_montesole <- terra::extract(montesole, foreste, df = TRUE)

  # df = TRUE: makes sure that each row in the dataframe corresponds to a spatial feature in ‘foreste’

Codes #4

- **# add columns with information from original forest chart polygons**

  unique(df_montesole$ID) # check variable levels

  unique(foreste$TIPO_CARTA)

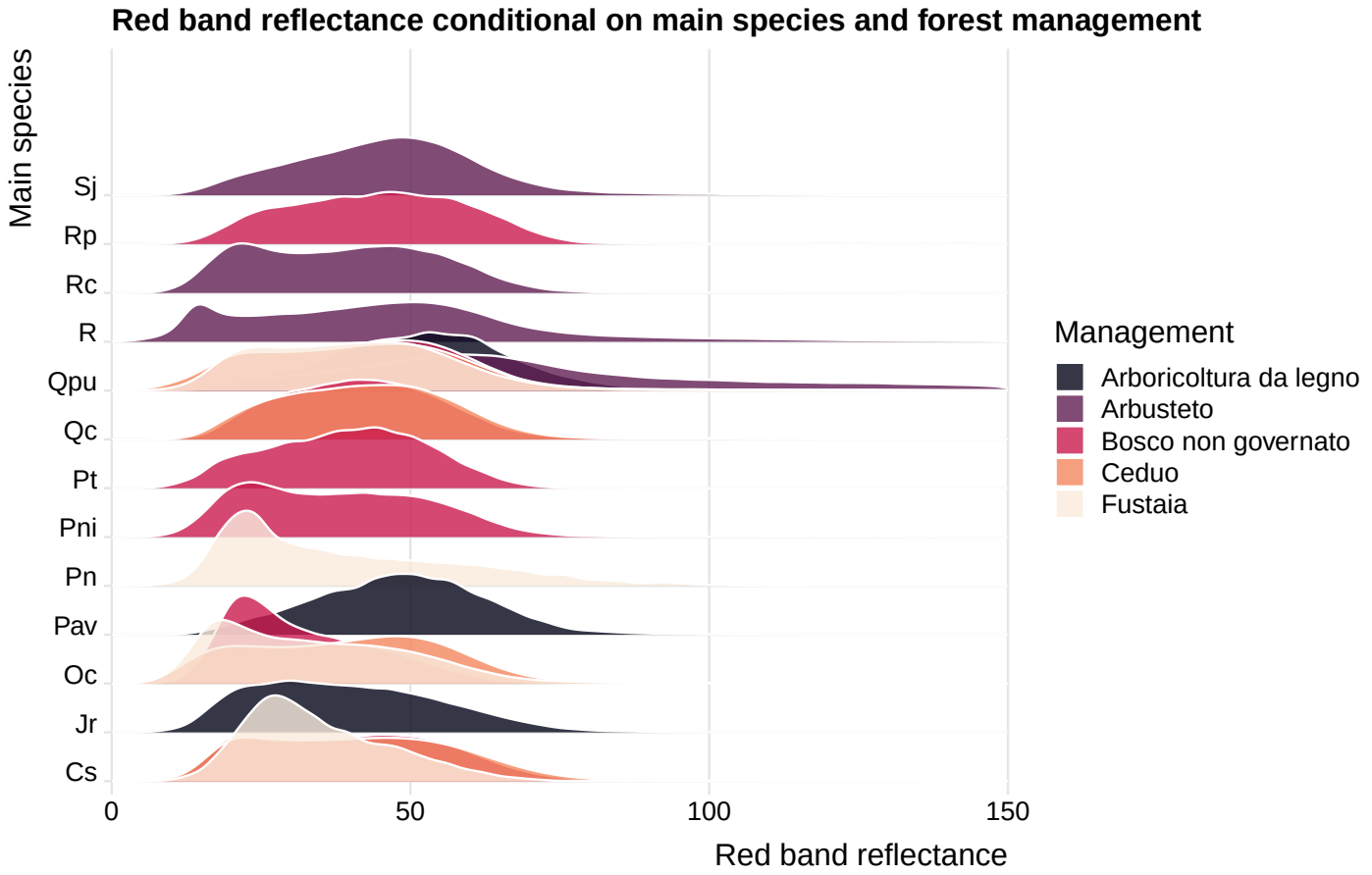
  unique(foreste$PRIMA_SP)

- df_montesole$specie <- foreste$PRIMA_SP[df_montesole$ID] # add the new species column
- df_montesole$management <- foreste$TIPO_CARTA[df_montesole$ID] # add the management column

Forest single band - Ridgeplot Code

- **# Ridgeplot on single spectral band**

```
df_montesole %>%
  ggplot(aes(y = Species)) +
  geom_density_ridges(aes(x = Blue, fill = Management),
                      alpha = 0.8, color = "white") +
  labs(x = "Blue band reflectance",                                          # add labels to the axis
       y = "Main species",
       title = "Blue band reflectance conditional on main species and forest management") +
  scale_x_continuous(expand = c(0, 0), limits = c(0, 150)) +                 # adjust the x axis
  scale_y_discrete(expand = expansion(mult = c(0.01, 0.25))) +               # adjust the y axis
  scale_fill_viridis_d(option = "plasma") +                                  # set color scale
  theme_ridges(grid = T)
```




```
 [1] "Castanea sativa - Castagno"          "Ostrya carpinifolia - Carpino nero"  "Quercus pubescens - Roverella"
 [4] "Rubus (genere) - Rovo"               "Spartium junceum - Ginestra odorosa" "Quercus cerris - Cerro"
 [7] "Populus nigra - Pioppo nero"         "Rosa canina"                         "Robinia pseudoacacia - Robinia"
[10] "Pinus nigra - Pino nero"             "Populus tremula - Pioppo tremolo"    "Juglans regia - Noce comune"
[13] "Prunus avium - Ciliegio selvatico"
```

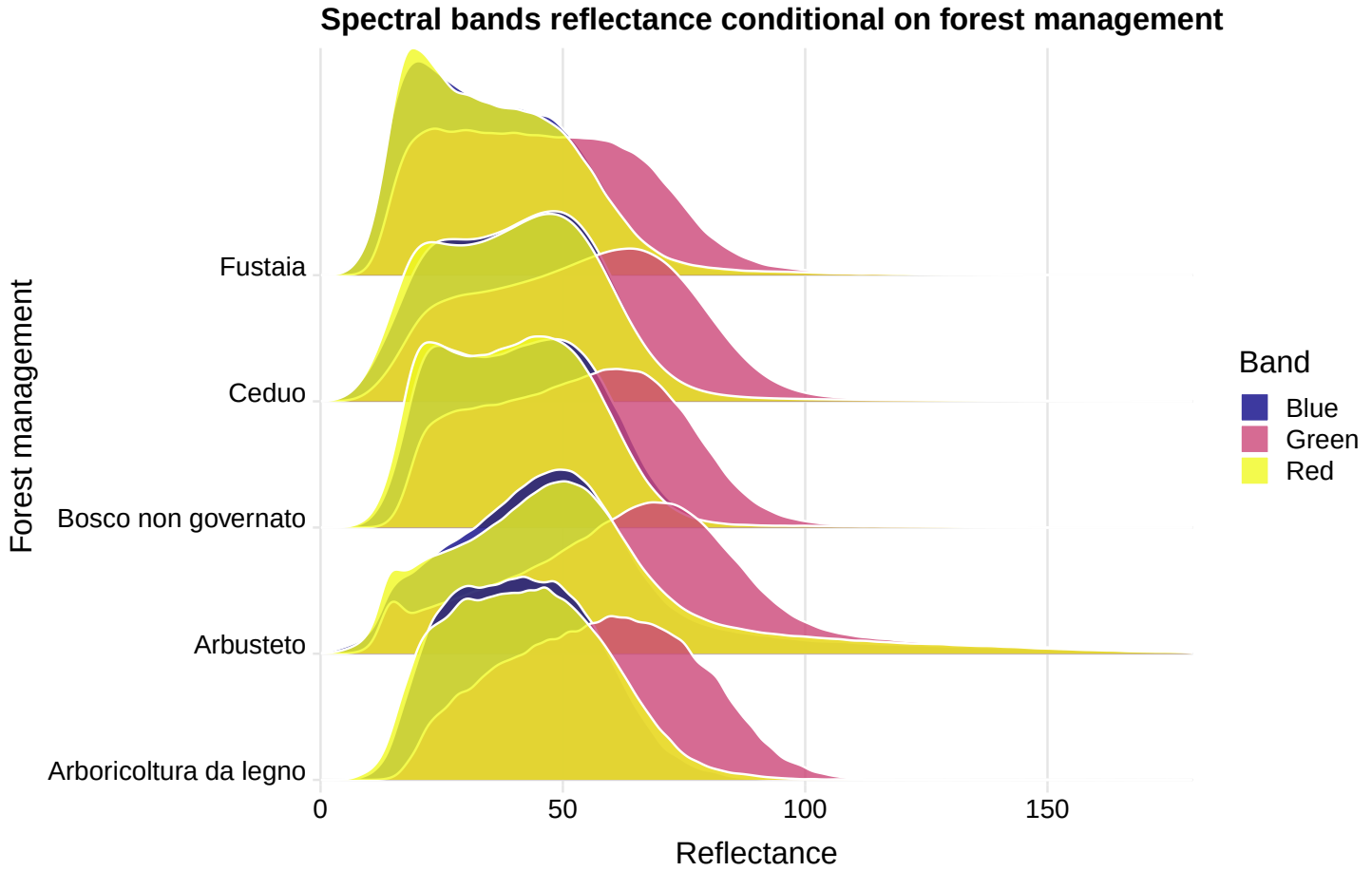
Codes #5

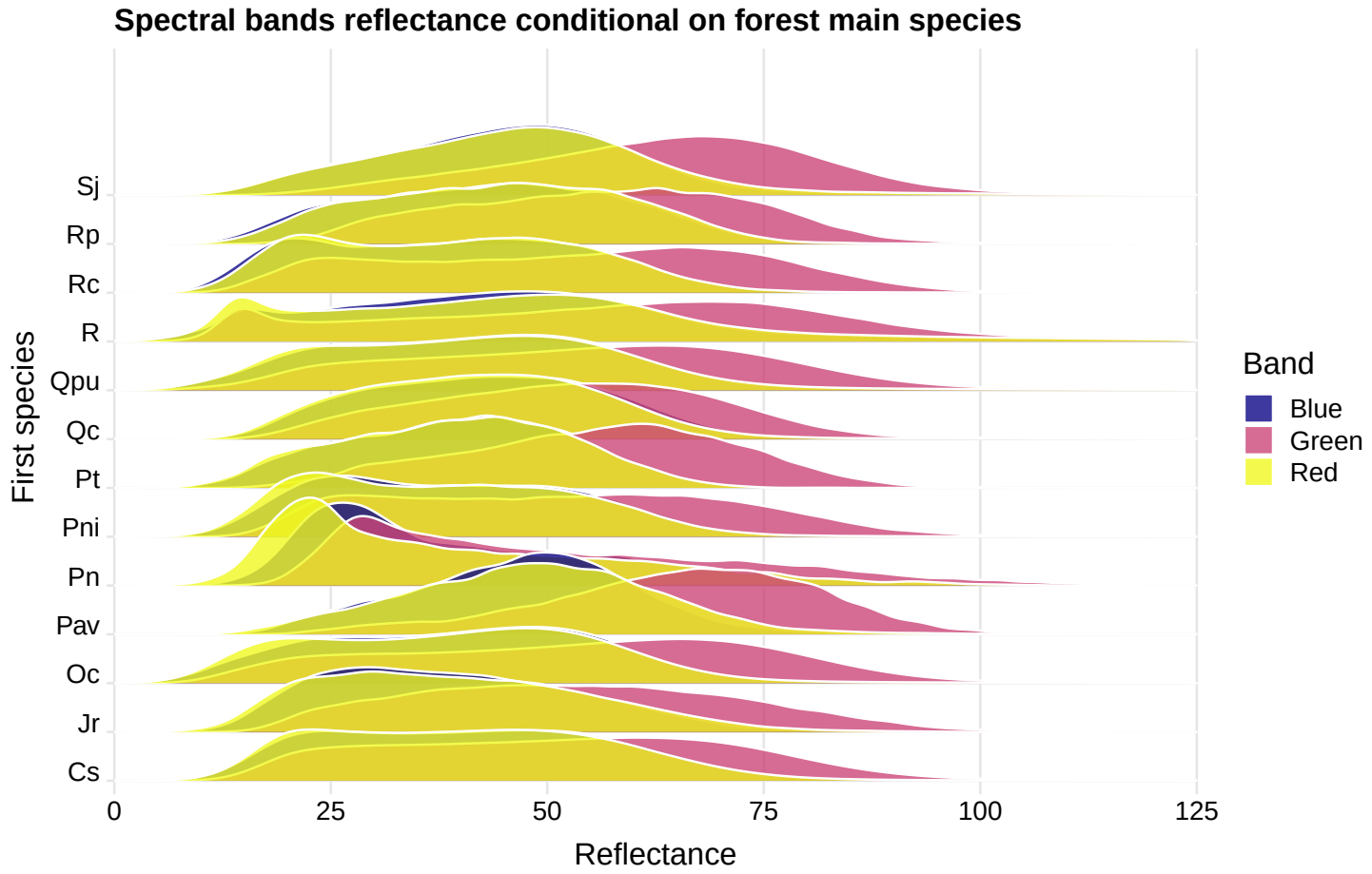
- **# Ridgeplot on multiple spectral bands**
- **# Stack columns bands into a single column: transform the dataframe from wide to long format**

```
df_montesole_stacked <- df_montesole %>%
  pivot_longer(cols = c(Red, Green, Blue), names_to = "Band",
                        values_to = "Reflectance") %>%
  arrange(ID)
```

Forest multiple bands - Ridgeplot Code

```
df_montesole_stacked %>%
  ggplot(aes(y = Management)) +
  geom_density_ridges(aes(x = Reflectance, fill = Band),                    # add new ‘Band’ variable as fill
                      alpha = 0.8, color = "white") +
  labs(x = "Reflectance",
       y = "Forest management") +
  scale_x_continuous(expand = c(0, 0), limits = c(0, 180)) +                # adjust the x axis
  scale_y_discrete(expand = expansion(mult = c(0.01, 0.25))) +              # adjust the y axis
  scale_fill_viridis_d(option = "plasma") +                                 # set color scale
  coord_cartesian(clip = "off") +
  ggtitle("Difference in spectral bands conditional on forest management") +
  theme_ridges(center = T, grid = T)
```


Spectral bands reflectance conditional on forest management
Forest management
Fustaia
Ceduo
Bosco non governato
Arbusteto
Arboricoltura da legno
0
50
100
150
Reflectance
Band
Blue
Green
Red


Spectral bands reflectance conditional on forest main species
First species
Sj
Rp
Rc
R
Qpu
Qc
Pt
Pni
Pn
Pav
Oc
Jr
Cs
0
25
50
75
100
125
Reflectance
Band
Blue
Green
Red

The end

Thanks for the attention :)