Soil threats bundles for France by 2050

```
library(terra)
```

```
terra 1.7.80
```

```
library(tmap)
```

```
Attaching package: 'tmap'
```

```
The following object is masked from 'package:datasets':

    rivers
```

```
library(tibble)
library(dplyr)
```

```
Attaching package: 'dplyr'
```

```
The following objects are masked from 'package:terra':

    intersect, union
```

```
The following objects are masked from 'package:stats':

    filter, lag
```

```
The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union
```

```
library(ggplot2)
library(gridExtra)
```

```
Attaching package: 'gridExtra'

The following object is masked from 'package:dplyr':

    combine
```

1. Introduction

Soil are threatened by rapid environmental changes and anthropic activities identified as the so-called soil threats (STs). The STs are processes that could degrade the soil functions and services. Moreover, STs do not vary independently; they co-occur as bundles in a given spatial-temporal scale. At the French scale, there is a growing recognition of the importance of the spatial quantification and mapping of STs, their evolution under climate and land use change scenarios to compute bundles. This report present the quantification and mapping of compaction, soil organic carbon (SOC) loss, sealing and erosion (Table 1) in arable land in France and their evolution under land use and climate change scenarios to compute bundles by 2050. We use digital soil mapping approach (SERENA D5.1)

Table 1. List of indicators ("ideal" or "realistic") used for the different soil threats selected for a harmonization of assessment of soil threats at the French territory scale (based on SERENA T2.3, extracted from D5.1)

Soil threats	Type	Indicator	Short definition
SOC loss	Ideal	Change in SOC stocks (kC ha^{-1} yr^{-1})	Change over time in soil organic carbon stocks over the whole soil depth
Soil erosion	Realistic	Soil loss by water erosion (t ha^{-1} yr^{-1})	Yearly soil losses by water erosion
Soil compaction	Ideal	Change in topsoil bulk density (kg m^{-3} yr^{-1})	Change over time in topsoil bulk density

Soil threats	Type	Indicator	Short definition
Soil sealing	Realistic	Degree of soil sealing change (%)	Change in the proportion of an area that is covered by artificial,

2. Map quality

2.1. Soil organic carbon content (SOC) as common variable in soil threats assessment

SOC is used as covariate in the DSM modelling of compaction and erosion. We computed the SOC present, stable and dynamic fractions. The dynamic fraction, expected to evolve in time was predicted under land use and climate change scenarios (SSP1 and SSP5).

2.1.1. DSM predictive model for SOC present, stable and dynamic

Table 2. Cross-validation performances of the prediction model for SOC applying the QRF algorithm

Indicator	Unit	R^2	RMSE	MAE	CCC	MEC
SOC present	%	0.42	15.52	9.44	0.59	0.42
SOC stable	%	0.42	11.63	7.06	0.59	0.42
SOC dynamic	%	0.42	5.44	3.31	0.59	0.42

I) Variable importance

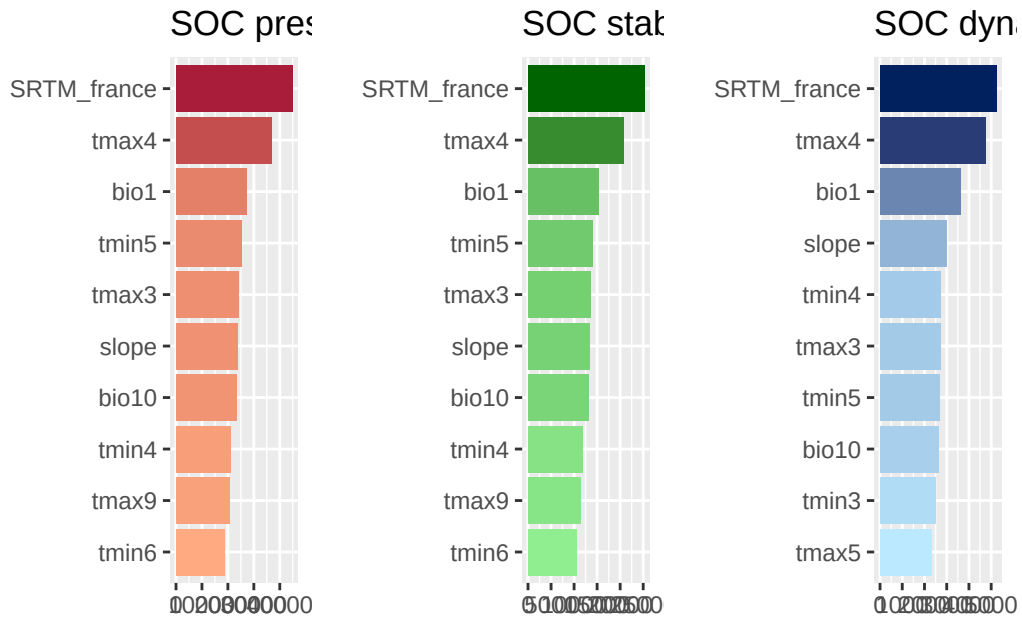
```
###model SOC present
# List of file paths and plot titles
plots_list <- list(
  list(file_path = "E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France/soca
       title = "SOC present",
       low_color = "#FFAA80", high_color = "#A91D3A"),
  list(file_path = "E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France/socg
       title = "SOC stable",
       low_color = "lightgreen", high_color = "darkgreen"),
  list(file_path = "E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France/socl
       title = "SOC dynamic",
       low_color = "#BBE9FF", high_color = "#00215E")
)
```

```
# Function to create plot
create_plot <- function(file_path, title, low_color, high_color) {
  rf <- readRDS(file_path)
  rf_var <- as.data.frame(rf$variable.importance)
  rf_var <- rownames_to_column(rf_var, var = "Covariate")
  colnames(rf_var)[2] <- "Importance"
  rf_var10 <- rf_var %>% slice_max(rf_var$Importance, n=10)
  plot <- ggplot(data = rf_var10, aes(x = reorder(Covariate , Importance), y = Importance, fi
    geom_bar(stat = "identity", position = "dodge") +
    coord_flip() +
    ylab("") +
    xlab("") +
    guides(fill = FALSE) +
    scale_fill_gradient(low = low_color, high = high_color) +
    theme(text = element_text(size = 11)) +
    ggtitle(title)
  return(plot)
}

# Create list of plots
plots <- lapply(plots_list, function(plot_info) {
  create_plot(plot_info$file_path, plot_info$title, plot_info$low_color, plot_info$high_colo
})
```

```
Warning: The `<scale>` argument of `guides()` cannot be `FALSE`. Use "none" instead as
of ggplot2 3.3.4.
```

```
# Arrange plots in one row
grid.arrange(grobs = plots, nrow = 1)
```



II) Map SOC present and under future land use and climate scenarios (SSP1 and SSP5)

```
# List of raster file paths
SOC_present <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Covariates/soildsm/soc
```

```
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```

```
names(SOC_present) <- "SOC_present"

map1 <- tm_shape(SOC_present[[1]]) +
  tm_raster(style="quantile",
            n=12,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "Present SOC content"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("left",
    tm_layout(legend.outside = T)
```

```
-- tmap v3 code detected --

[v3->v4] tm_raster(): instead of 'style = "quantile"', use 'col.scale = tm_scale_intervals()

[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
#---------------------------------
SOC_2050_ssp1 <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Covariates/soildsm/s
```

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```

```
names(SOC_2050_ssp1) <- "Future SOC content (SSP1)"

map2 <- tm_shape(SOC_2050_ssp1 [[1]]) +
  tm_raster(style="quantile",
            n=12,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "Future SOC content (SSP1)"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("left",
   tm_layout(legend.outside = T)
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
#---------------------------------------
SOC_2050_ssp5 <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Covariates/soildsm/s
```

```
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```

```
names(SOC_2050_ssp5) <- "SOC_2050_SSP5"

map3 <- tm_shape(SOC_2050_ssp5 [[1]]) +
  tm_raster(style="quantile",
```

```
            n=12,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "Future SOC content (SSP5)"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("left", "
  tm_layout(legend.outside = T)
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
tmap_arrange(map1, map2, map3, nrow = 1)
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

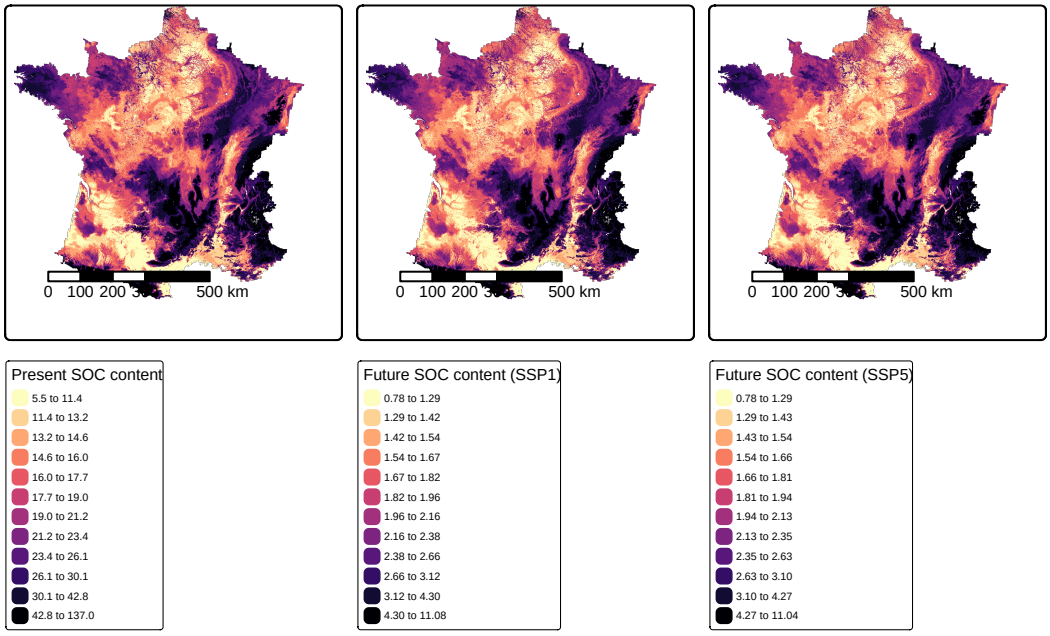
```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```



```
#difference_soc_ssp1_ssp5 <- SOC_2050_ssp1-SOC_2050_ssp5
#plot(difference_soc_ssp1_ssp5)
```

Difference between SOC content present and future maps

```
SOC_SSP1_Less_SOC_actual= (SOC_present-SOC_2050_ssp1)/SOC_present
```

```
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```

```
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```

```
names(SOC_SSP1_Less_SOC_actual) <- "SOC_ssp1_less-SOC_actual"

map4 <- tm_shape(SOC_SSP1_Less_SOC_actual[[1]]) +
  tm_raster(n=10,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "Difference present SOC
  less future SOC SSP1"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("right",
  tm_layout(legend.outside = T,
            inner.margins=c(.06,.05, .04, .03))
```

```
-- tmap v3 code detected --

[v3->v4] tm_raster(): migrate the argument(s) related to the scale of the visual variable 'co

[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
SOC_SSP5_Less_SOC_actual= (SOC_present-SOC_2050_ssp5)/SOC_present
```

```
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```

```
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```

```
names(SOC_SSP5_Less_SOC_actual) <- "SOC_actual_less_ssp5"

map5 <- tm_shape(SOC_SSP5_Less_SOC_actual[[1]]) +
  tm_raster(n=10,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "Difference present SOC
 less future SOC SSP5"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("right",
    tm_layout(legend.outside = T,
              inner.margins=c(.06,.05, .04, .03))
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
tmap_arrange(map4, map5,nrow = 1)
```

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SpatRaster object downsampled to 1027 by 975 cells.
```
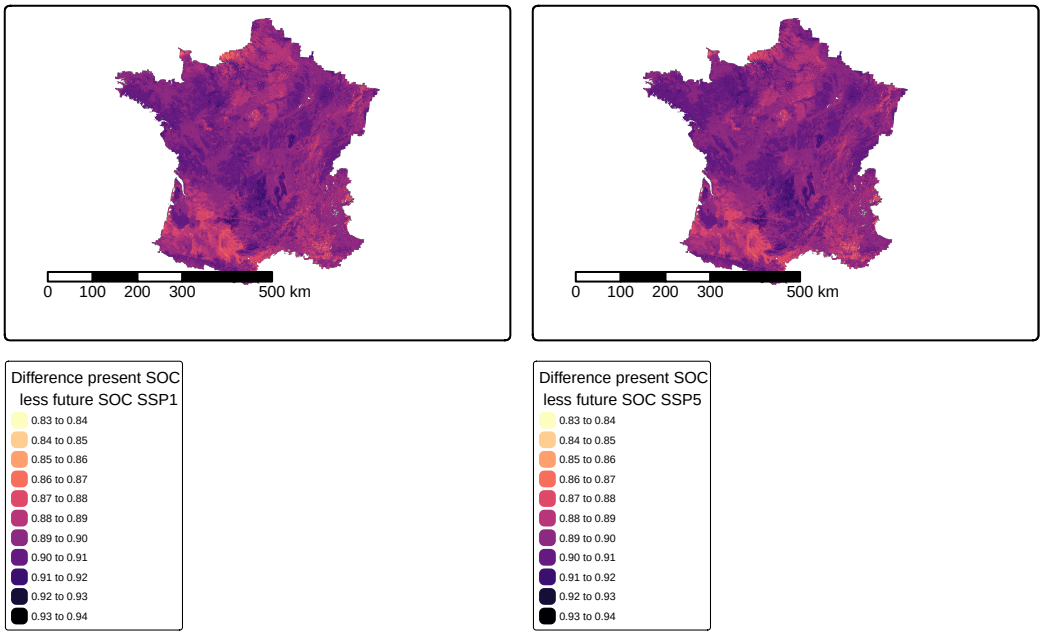

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```



2.2. Compaction

2.2.1. DSM predictive model for bulk density

Changes in bulk density (BD) in topsoil (0-30 cm), the chosen indicator for soil compaction, was calculated as the difference in bulk density in the topsoil between 2005 (date of soil sampling in the French soil database) and 2050.

To project bulk density to 2050, we applied a DSM approach (Grunwald et al., 2011; McBratney et al., 2003; Minasny and McBratney, 2016) based on the Quantile Regression Forest (QRF) algorithm that was built up on the current map in a first step. In a second step, the covariates supposed to evolve from present to 2050 (land use and climate) were replaced in the model for the 2050 projection.

We used QRF in the R package ranger package. Four different values were computed to characterize the distribution of BD: median (0.50 quantile), mean (0.05 quantile) and 0.95 quantile. The model was tuned by 10 fold cross-validation and 10 repetitions?. The *ntree* number was set at 500.

Table 3. Cross-validation performances of the prediction model for bulk density applying the QRF algorithm

Indicator	Unit	R^2	RMSE	MAE	CCC	MEC
Bulk density actual	kg/m^3	0.40	0.17	0.13	0.54	0.40

```
rf_gsm <- readRDS("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France/da_por

rf_gsm_var <- as.data.frame(rf_gsm$variable.importance)

rf_gsm_var <- rownames_to_column(rf_gsm_var, var = "Covariate")

colnames(rf_gsm_var)[2] <- "Importance"

head(rf_gsm_var)
```

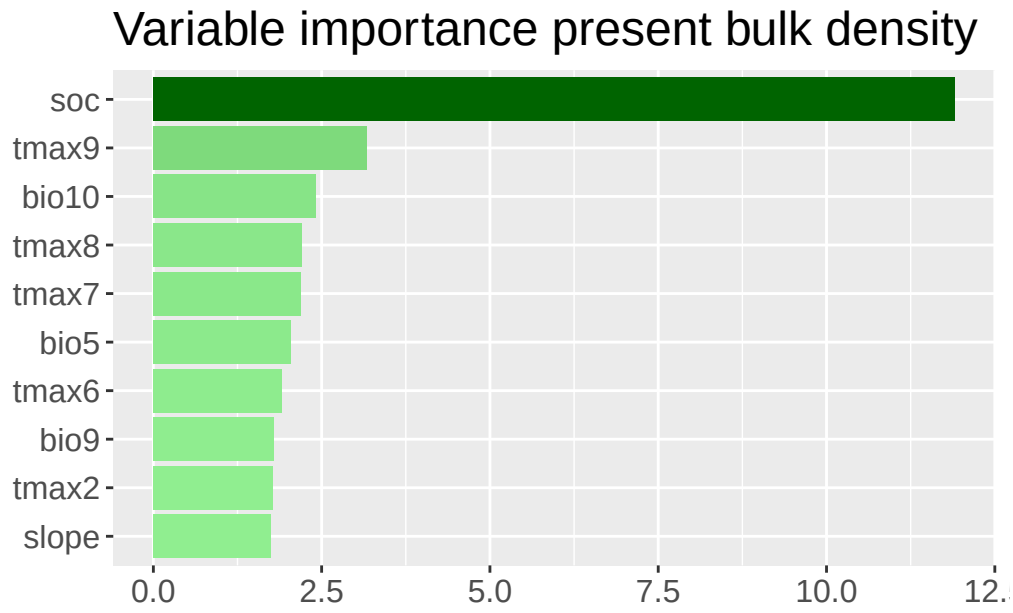
```
    Covariate Importance
1 Arablecrops  0.3354652
2        bio1  1.1930885
3       bio10  2.4171226
4       bio11  1.3122483
5       bio12  1.2525224
6       bio13  1.0016509
```

```
#select top 10 variables

rf_gsm_var10 <-  rf_gsm_var %>% slice_max(rf_gsm_var$Importance, n=10)

head(rf_gsm_var)
```

```
    Covariate Importance
1 Arablecrops  0.3354652
2        bio1  1.1930885
3       bio10  2.4171226
4       bio11  1.3122483
5       bio12  1.2525224
6       bio13  1.0016509
```

```
ggplot(data = rf_gsm_var10, aes(x = reorder(Covariate , Importance), y = Importance, fill = I

  geom_bar(stat = "identity", position = "dodge") +
```

```
  coord_flip() +

  ylab("") +

  xlab("") +

  guides(fill = FALSE) +

  scale_fill_gradient(low = "lightgreen", high = "darkgreen") +

  theme(text = element_text(size = 15)) + ggtitle("Variable importance present bulk density")
```



II) Map present bulk density

Low bulk density is present in the mountain areas, and higher bulk density if found in the lowlands.

```
Bulk_density_present <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_Fr
```

```
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```

```
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```

```r
names(Bulk_density_present) <- "Present_Bulk_density"

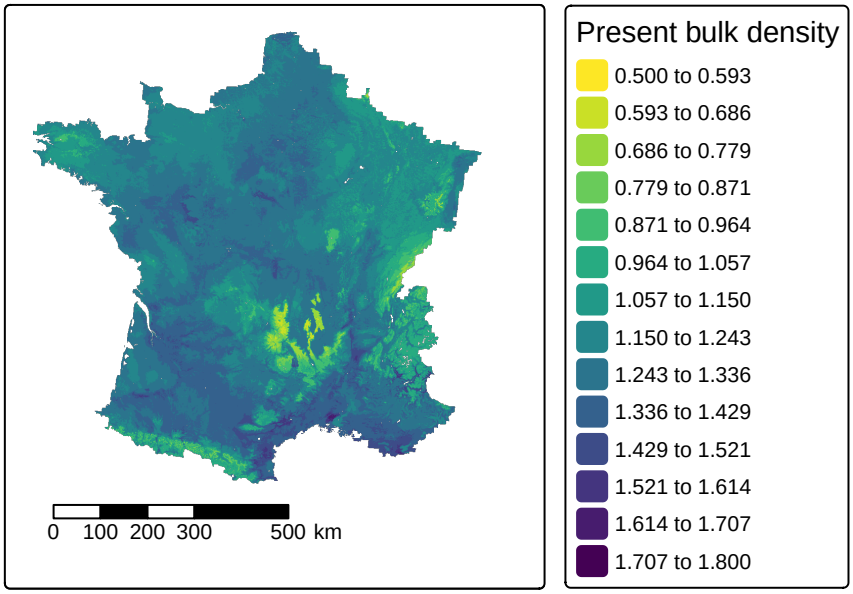
tm_shape(Bulk_density_present[[1]]) +
  tm_raster(style="quantile",
            n=14,
           palette = "viridis",
            midpoint = NA, #  median(r[[1]],na.rm=T),
           title= "Present bulk density"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.7,position=c("left",
     tm_layout(legend.outside = T,
             inner.margins=c(.08,.06, .05, .04))
```

```
-- tmap v3 code detected --

[v3->v4] tm_raster(): instead of 'style = "quantile"', use 'col.scale = tm_scale_intervals()

[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '

SpatRaster object downsampled to 1027 by 975 cells.
```



III) Map bulk density under land use change and climate scenarios (SSP1 and SSP5)

```
BD_2050_ssp1 <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France/da
```

```
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```

```
names(BD_2050_ssp1) <- "Bulk_density_2050_SSP1"

map6 <- tm_shape(BD_2050_ssp1[[1]]) +
  tm_raster(style="quantile",
            n=10,
            palette = "viridis",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "Future bulk density (SSP1)") +
  tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.7,position=c("left", "bottom"))+
   tm_layout(legend.outside = T,
            inner.margins=c(.08,.06, .05, .04))
```

```
-- tmap v3 code detected --

[v3->v4] tm_raster(): instead of 'style = "quantile"', use 'col.scale = tm_scale_intervals()

[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
#-------------------------------------
BD_2050_ssp5 <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France/da
```

```
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```

```
names(BD_2050_ssp5) <- "Bulk_density_2050_SSP5"

map7 <- tm_shape(BD_2050_ssp5[[1]]) +
  tm_raster(style="quantile",
```

```
            n=10,
            palette = "viridis",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "Future bulk density (SSP5)") +
  tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.7,position=c("left", "bottom"))+
    tm_layout(legend.outside = T,
            inner.margins=c(.08,.06, .05, .04))
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

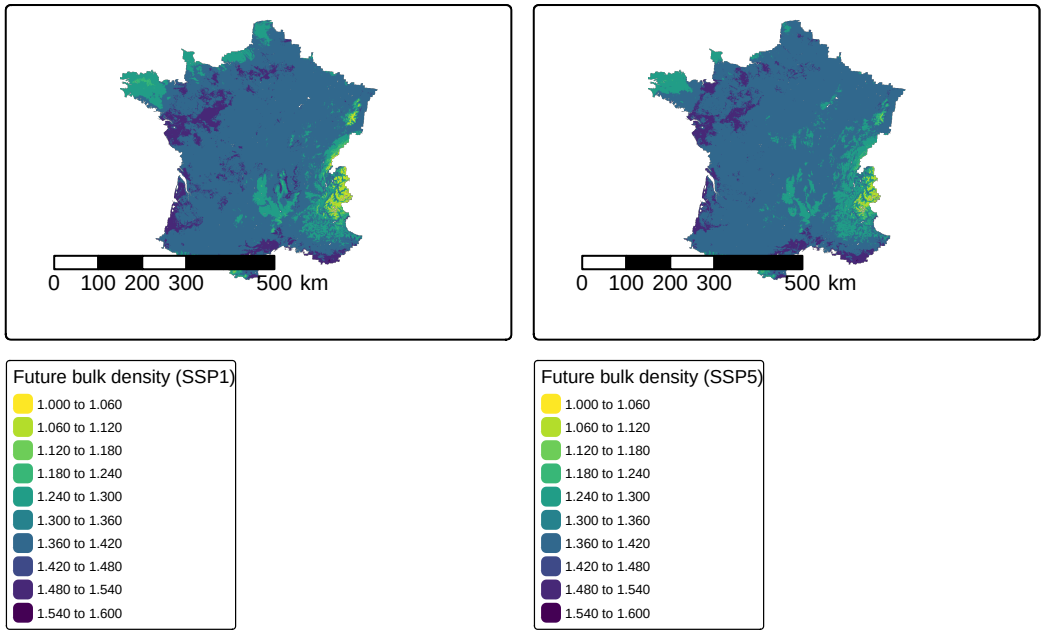
```
tmap_arrange(map6 , map7,nrow = 1)
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```



VI) Compaction Map bulk density under land use change and climate scenarios (SSP1 and SSP5)

There is high compaction in the mountain areas. This means that with increasing temperature, there is spected faster decomposition of SOC content and those areas would be more prone to increase the bulk density because of the land use change that would driver the compaction. This trend is confirmed in the variable importance where the SOC content and the maximum temperature are the most relevant.

```
#Compaction 1= diference between future bulk density ssp1 and present bulk density

Compaction_1 = BD_2050_ssp1 - Bulk_density_present
```

```
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```

```
map8 <- tm_shape(Compaction_1 [[1]]) +
  tm_raster(#style="quantile",
            n=10,
            palette = "viridis",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "Compaction 1") +
  tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.7,position=c("left", "bottom"))+tm
            inner.margins=c(.08,.06, .05, .04))
```

```
-- tmap v3 code detected --

[v3->v4] tm_raster(): migrate the argument(s) related to the scale of the visual variable 'c

[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
#-----------------------------------

#Compaction 2= diference between future bulk density ssp5 and present bulk density

Compaction_2= BD_2050_ssp5 - Bulk_density_present
```

```
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```

```
map9 <- tm_shape(Compaction_2[[1]]) +
  tm_raster(#style="quantile",
            n=10,
            palette = "viridis",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "Compaction 2") +
  tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.7,position=c("left", "bottom"))+
            inner.margins=c(.08,.06, .05, .04))
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
tmap_arrange(map8, map9,nrow = 1)
```

```
SpatRaster object downsampled to 1027 by 975 cells.
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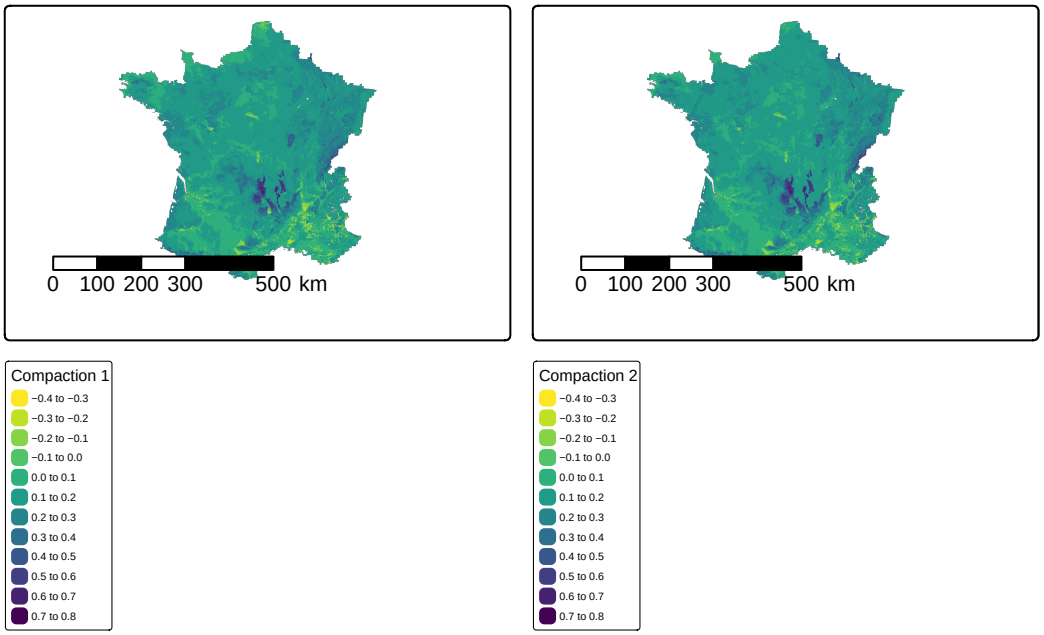
```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```



2.3. Soil organic carbon (SOC) stock loss

2.3.1. DSM predictive model for SOC stock present, stable and dynamic fractions

Overall the model performance is poor

Indicator	Unit	R^2	RMSE	MAE	CCC	MEC
Present SOC stock	%	0.32	28.09	20.26	0.48	0.32
SOC stock stable fraction	%	0.32	18.28	13.16	0.48	0.32
SOC stock dynamic fraction	%	0.32	9.83	7.07	0.48	0.32

I) Variable importance

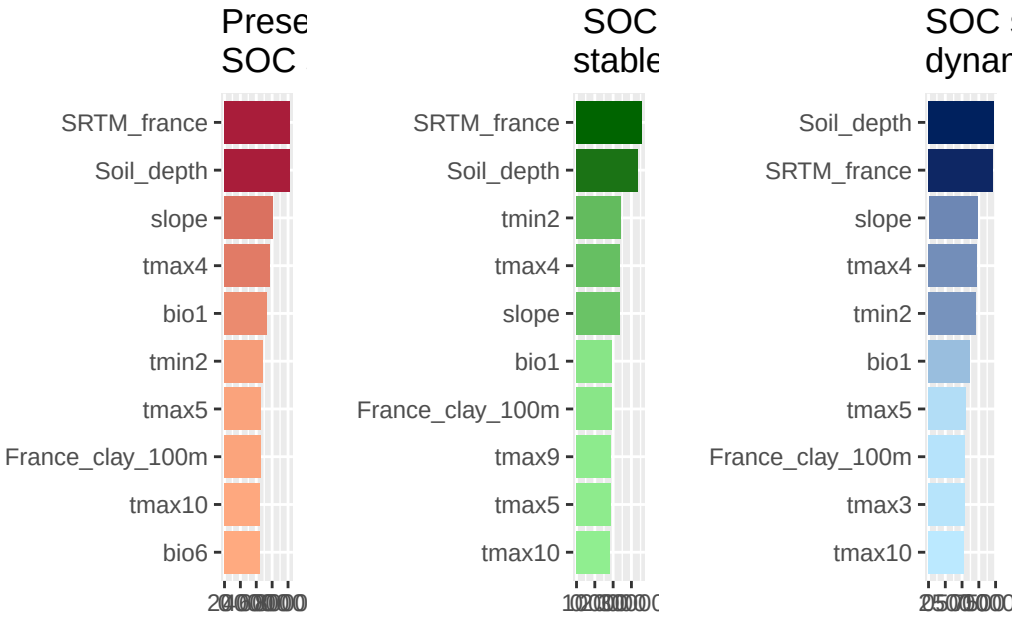
```
###model Present SOC stock
# List of file paths and plot titles
plots_list <- list(
  list(file_path = "E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France/SOC_s
       title = "Present
SOC stock",
       low_color = "#FFAA80", high_color = "#A91D3A"),
  list(file_path = "E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France/SOC_s
```

```
       title = " SOC stock
stable fraction",
       low_color = "lightgreen", high_color = "darkgreen"),
  list(file_path = "E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France/SOC_s
       title = "SOC stock
dynamic fraction",
       low_color = "#BBE9FF", high_color = "#00215E")
)

# Function to create plot
create_plot <- function(file_path, title, low_color, high_color) {
  rf <- readRDS(file_path)
  rf_var <- as.data.frame(rf$variable.importance)
  rf_var <- rownames_to_column(rf_var, var = "Covariate")
  colnames(rf_var)[2] <- "Importance"
  rf_var10 <- rf_var %>% slice_max(rf_var$Importance, n=10)
  plot <- ggplot(data = rf_var10, aes(x = reorder(Covariate , Importance), y = Importance, fi
    geom_bar(stat = "identity", position = "dodge") +
    coord_flip() +
    ylab("") +
    xlab("") +
    guides(fill = FALSE) +
    scale_fill_gradient(low = low_color, high = high_color) +
    theme(text = element_text(size = 11)) +
    ggtitle(title)
  return(plot)
}

# Create list of plots
plots <- lapply(plots_list, function(plot_info) {
  create_plot(plot_info$file_path, plot_info$title, plot_info$low_color, plot_info$high_colo
})

# Arrange plots in one row
grid.arrange(grobs = plots, nrow = 1)
```



II) Map present SOC stock

```
# List of raster file paths
SOC_stock_present <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_Franc
```

```
|---------|---------|---------|---------|
=========================================
```

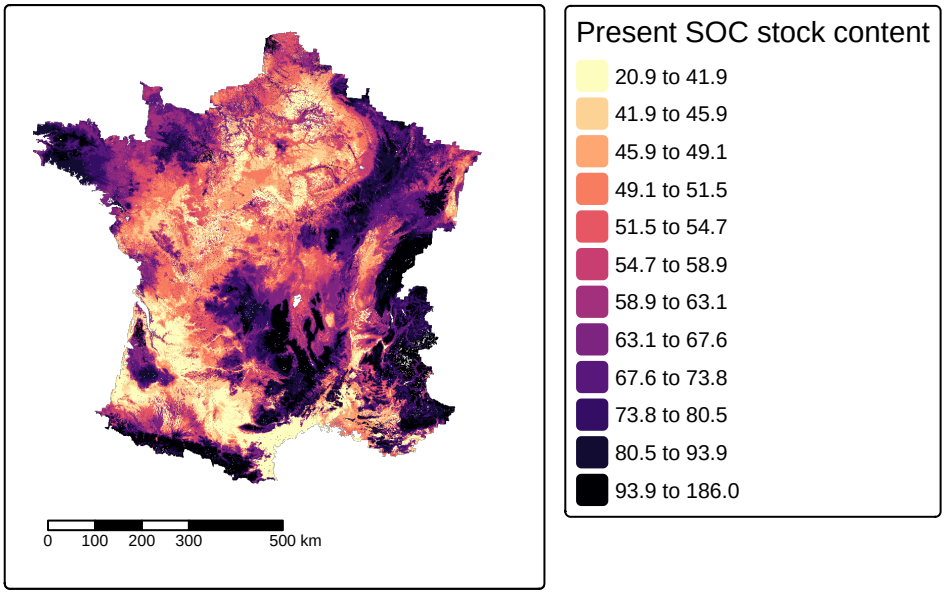
```
tm_shape(SOC_stock_present [[1]]) +
 tm_raster(style="quantile",
           n=12,
           palette = "magma",
           midpoint = NA, #  median(r[[1]],na.rm=T)
           title= "Present SOC stock content"
           ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("left",
  tm_layout(legend.outside = T,
            inner.margins=c(.08,.06, .05, .04))
```

```
-- tmap v3 code detected --
```

```
[v3->v4] tm_raster(): instead of 'style = "quantile"', use 'col.scale = tm_scale_intervals()
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```



III) Map SOC stock stable and dynamic fractions (SSP1), (SSP5)

```
SOC_stock_stable <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_France
```

```
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```

```
map10 <- tm_shape(SOC_stock_stable [[1]]) +
  tm_raster(style="quantile",
            n=12,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
```

```
            title= "SOC stock stable fraction"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("left",
  tm_layout(legend.outside = T,
            inner.margins=c(.08,.06, .05, .04))
```

```
-- tmap v3 code detected --
```

```
[v3->v4] tm_raster(): instead of 'style = "quantile"', use 'col.scale = tm_scale_intervals()
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
#--------------------------------
SOC_stock_dyn_ssp1 <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_Fra
```

```
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```

```
map11 <- tm_shape(SOC_stock_dyn_ssp1 [[1]]) +
  tm_raster(style="quantile",
            n=12,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "SOC stock dynamic fraction (SSP1)"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("left",
  tm_layout(legend.outside = T,
            inner.margins=c(.08,.06, .05, .04))
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
#--------------------------------------
SOC_stock_dyn_ssp5 <- rast("E:/SERENA/WP5_bundles/France/ISRIC_threats_France/Output_SOC_Fra
```

```
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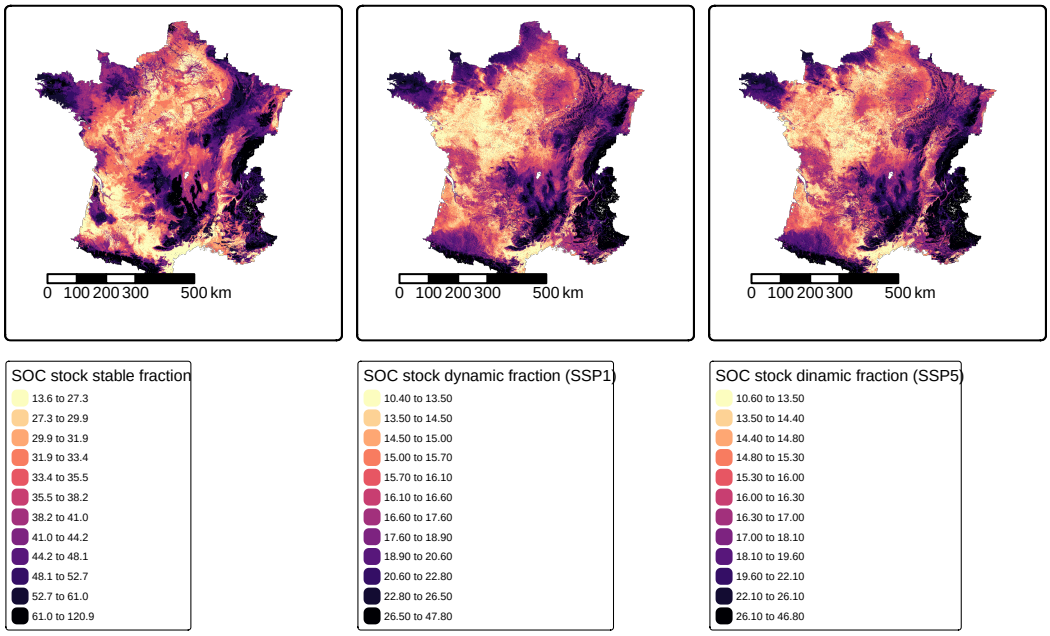
```

```r
map12 <- tm_shape(SOC_stock_dyn_ssp5[[1]]) +
  tm_raster(style="quantile",
            n=12,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "SOC stock dinamic fraction (SSP5)"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("left",
   tm_layout(legend.outside = T,
             inner.margins=c(.08,.06, .05, .04))
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```r
tmap_arrange(map10, map11, map12, nrow = 1)
```

```
SpatRaster object downsampled to 1027 by 975 cells.

[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar

SpatRaster object downsampled to 1027 by 975 cells.

[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar

SpatRaster object downsampled to 1027 by 975 cells.

[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```



IV) Future SOC stock under land use and climate change scenarios SSP1 and SSP5

This maps are the result of adding the stable and the dynamic fraction predicted under land use and climate change SSP1 and SSP5 scenarios

```
#SOC stock future SSP1
SOC_stock_ssp1= SOC_stock_stable+SOC_stock_dyn_ssp1
```

```
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```

```
map13 <- tm_shape(SOC_stock_ssp1 [[1]]) +
  tm_raster(style="quantile",
            n=12,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "SOC stock future SSP1"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("left",
  tm_layout(legend.outside = T,
            inner.margins=c(.08,.06, .05, .04))
```

```
-- tmap v3 code detected --
```

```
[v3->v4] tm_raster(): instead of 'style = "quantile"', use 'col.scale = tm_scale_intervals()
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
#------------------------------------------------------------------------
#SOC stock future SSP5
SOC_stock_ssp5= SOC_stock_stable+SOC_stock_dyn_ssp5
```

```
|---------|---------|---------|---------|
=========================================
```

```
map14<- tm_shape(SOC_stock_ssp5 [[1]]) +
  tm_raster(style="quantile",
            n=12,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "SOC stock future SSP5"
            ) +tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.5,position=c("left", '
  tm_layout(legend.outside = T,
            inner.margins=c(.08,.06, .05, .04))
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

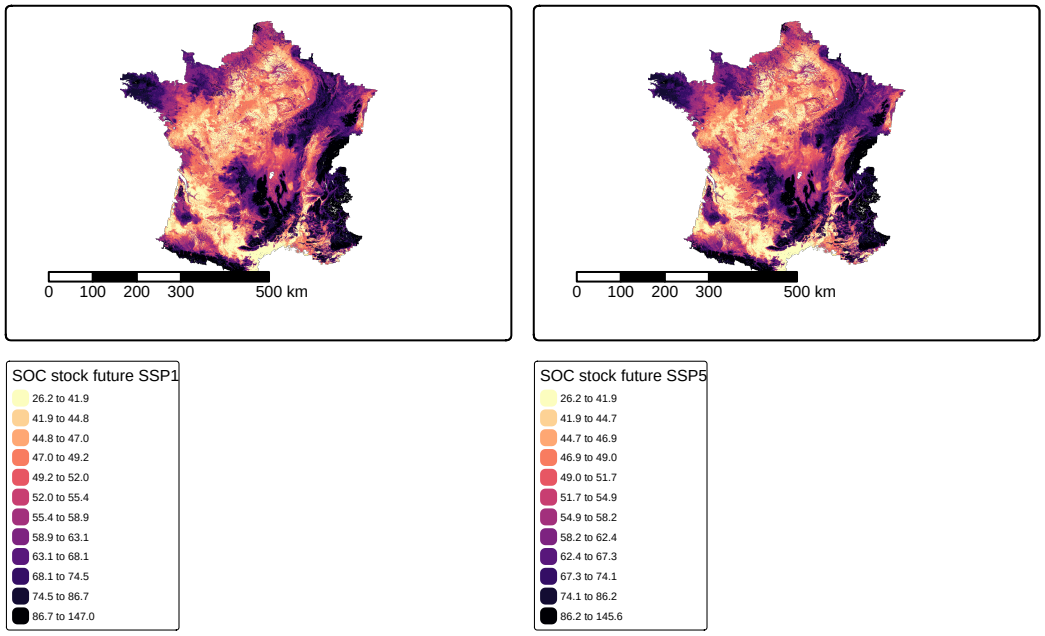
```
tmap_arrange(map13, map14, nrow = 1)
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```



V) SOC stock loss

SOC stock loss is the result of the difference between present SOC stock and the future SOC stock

```
#SOC stock loss 1= diference between future SOC stock ssp1 and present sock

SOC_stock_loss_1= SOC_stock_ssp1 - SOC_stock_present
```

```
|---------|---------|---------|---------|
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```

```
map15 <- tm_shape(SOC_stock_loss_1 [[1]]) +
  tm_raster(style="quantile",
            n=15,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "SOC stock loss 1") +
  tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.7,position=c("left", "bottom"))+
```

```
  tm_layout(legend.outside = T,
            inner.margins=c(.08,.06, .05, .04))
```

```
-- tmap v3 code detected --
```

```
[v3->v4] tm_raster(): instead of 'style = "quantile"', use 'col.scale = tm_scale_intervals()
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

```
#-----------------------------------

#SOC stock loss 2= diference between future SOC stock ssp5 and present sock stock

SOC_stock_loss_2= SOC_stock_ssp5 - SOC_stock_present
```

```
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```

```
map16 <- tm_shape(SOC_stock_loss_2[[1]]) +
  tm_raster(style="quantile",
            n=15,
            palette = "magma",
            midpoint = NA, #  median(r[[1]],na.rm=T)
            title= "SOC stock loss 2") +
  tm_scalebar(breaks=c(0, 100,200, 300,500),text.size = 0.7,position=c("left", "bottom"))+
  tm_layout(legend.outside = T,
            inner.margins=c(.08,.06, .05, .04))
```

```
[v3->v4] tm_raster(): migrate the argument(s) related to the legend of the visual variable '
```

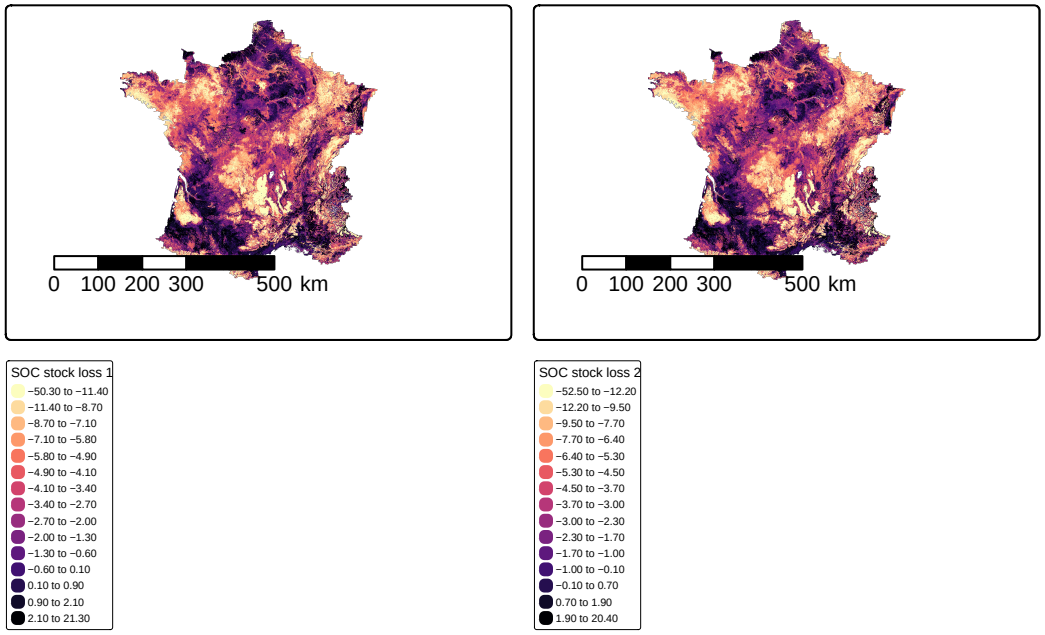
```
tmap_arrange(map15, map16,nrow = 1)
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```

```
SpatRaster object downsampled to 1027 by 975 cells.
```

```
[plot mode] fit legend/component: Some legend items or map compoments do not fit well, and ar
```



2.4. Soil sealing

2.5. Soil erosion

Conclusion

```
#tinytex::install_tinytex()
#library(tinytex)
```