

# Package ‘bayesEO’

May 7, 2026

**Type** Package

**Version** 0.2.2

**Title** Bayesian Smoothing of Remote Sensing Image Classification

**Maintainer** Gilberto Camara <gilberto.camara.inpe@gmail.com>

**Description** A Bayesian smoothing method for post-processing of remote sensing image classification which refines the labelling in a classified image in order to enhance its classification accuracy. Combines pixel-based classification methods with a spatial post-processing method to remove outliers and misclassified pixels.

**Encoding** UTF-8

**Language** en-US

**Depends** R (>= 4.1.0)

**URL** <https://github.com/e-sensing/bayesEO/>

**BugReports** <https://github.com/e-sensing/bayesEO/issues>

**License** GPL-3

**ByteCompile** true

**Imports** dplyr, ggplot2, grDevices, purrr, Rcpp, stars, stats, terra, tibble, tidyr, tmap, yaml

**Suggests** RcppArmadillo, testthat

**LinkingTo** Rcpp, RcppArmadillo

**RoxygenNote** 7.3.2

**Collate** 'api\_check.R' 'bayes\_colors.R' 'bayes\_label.R' 'bayes\_plot.R' 'bayes\_read.R' 'bayes\_smooth.R' 'bayes\_utils.R' 'bayes\_variance.R' 'RcppExports.R' 'zzz.R'

**NeedsCompilation** yes

**Author** Gilberto Camara [aut, cre],  
Renato Assuncao [aut],  
Rolf Simoes [aut],  
Felipe Souza [aut]

**Repository** CRAN

**Date/Publication** 2025-09-24 15:00:02 UTC

## Contents

bayes_colors . . . . .	2
bayes_colors_show . . . . .	3
bayes_label . . . . .	3
bayes_plot_hist . . . . .	4
bayes_plot_map . . . . .	5
bayes_plot_probs . . . . .	7
bayes_plot_rgb . . . . .	8
bayes_plot_var . . . . .	9
bayes_read_image . . . . .	10
bayes_read_probs . . . . .	11
bayes_run_examples . . . . .	12
bayes_run_tests . . . . .	12
bayes_smooth . . . . .	13
bayes_summary . . . . .	14
bayes_variance . . . . .	15
bilateral_smooth . . . . .	16
gaussian_smooth . . . . .	17
<b>Index</b>	<b>19</b>

---

bayes_colors	<i>Function to retrieve bayesEO color table</i>
--------------	---

---

### Description

Returns a color table

### Usage

```
bayes_colors()
```

### Value

A tibble with color names and values

### Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

---

bayes\_colors\_show      *Function to show colors in SITS*

---

**Description**

Shows the default SITS colors

**Usage**

bayes\_colors\_show()

**Value**

no return, called for side effects

**Author(s)**

Gilberto Camara, <gilberto.camara@inpe.br>

---

bayes\_label      *Label probability images to create categorical maps*

---

**Description**

Takes a classified image with probabilities, and labels the image with the pixel of higher probability

**Usage**

bayes\_label(x)

**Arguments**

x      SpatRaster object with probabilities images

**Value**

A SpatRaster object

**Author(s)**

Gilberto Camara, <gilberto.camara@inpe.br>

## Examples

```
if (bayes_run_examples()) {  
  # select a file with probability values  
  data_dir <- system.file("/extdata/probs/", package = "bayesE0")  
  file <- list.files(data_dir)  
  # create a SpatRaster object from the file  
  probs_file <- paste0(data_dir, "/", file)  
  # provide the labels  
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",  
             "ClearCut_Veg", "Forest", "Wetland")  
  # read the probs file  
  probs <- bayes_read_probs(probs_file, labels)  
  # produce a labelled map  
  map <- bayes_label(probs)  
  # plot the labelled map  
  bayes_plot_map(map)  
}
```

---

bayes\_plot\_hist

*Plot histogram*

---

## Description

Plot histogram

## Usage

```
bayes_plot_hist(x, scale = 1, quantile = NULL, sample_size = 15000)
```

## Arguments

x	SpatRaster to be plotted.
scale	Scale factor for SpatRaster
quantile	Threshold of values that will be plotted
sample_size	Number of samples to extract values

## Value

A plot object

## Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

**Examples**

```

if (bayes_run_examples()) {
  # get the probability file
  data_dir <- system.file("/extdata/probs/", package = "bayesE0")
  file <- list.files(data_dir)
  # read the probability file into a SpatRaster
  x <- terra::rast(paste0(data_dir, "/", file))
  # include the labels
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
  # associate the labels to the names of the SpatRaster
  names(x) <- labels
  # calculate the variance
  v <- bayes_variance(x)
  # Plot the variance histogram
  bayes_hist(v, quantile = 0.75)
}

```

---

 bayes\_plot\_map

*Plot labelled map*


---

**Description**

Plot labelled map

**Usage**

```

bayes_plot_map(
  x,
  legend = NULL,
  palette = "Spectral",
  xmin = NULL,
  xmax = NULL,
  ymin = NULL,
  ymax = NULL,
  tmap_graticules_labels_size = 0.6,
  tmap_legend_title_size = 0.7,
  tmap_legend_text_size = 0.7,
  tmap_legend_bg_color = "white",
  tmap_legend_bg_alpha = 0.5,
  tmap_max_cells = 1e+06
)

```

**Arguments**

x	SpatRaster to be plotted.
legend	Named vector that associates labels to colors.

**palette** A sequential RColorBrewer palette  
**xmin** Subset to be shown (xmin)  
**xmax** Subset to be shown (xmax)  
**ymin** Subset to be shown (ymin)  
**ymax** Subset to be shown (ymax)  
**tmap\_graticules\_labels\_size**  
 Size of graticules labels (default: 0.7)  
**tmap\_legend\_title\_size**  
 Size of legend title (default: 1.5)  
**tmap\_legend\_text\_size**  
 Size of legend text (default: 1.2)  
**tmap\_legend\_bg\_color**  
 Color of legend background (default: "white")  
**tmap\_legend\_bg\_alpha**  
 Transparency of legend background (default: 0.5)  
**tmap\_max\_cells** Maximum number of cells for tmap (default = 1e+06)

**Value**

A plot object

**Author(s)**

Gilberto Camara <gilberto.camara@inpe.br>

**Examples**

```

if (bayes_run_examples()) {
  # Define location of a probability file
  data_dir <- system.file("/extdata/probs",
    package = "bayesE0")
  # list the file
  file <- list.files(data_dir)
  # build the full path
  probs_file <- paste0(data_dir, "/", file)
  # define labels
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
    "ClearCut_Veg", "Forest", "Wetland")

  probs_image <- bayes_read_probs(probs_file, labels)
  # Label the probs image
  y <- bayes_label(x)
  # produce a map of the labelled image
  bayes_plot_map(y)
}

```

---

bayes_plot_probs	<i>Plot probability maps</i>
------------------	------------------------------

---

**Description**

Plot probability maps

**Usage**

```
bayes_plot_probs(  
  x,  
  scale = 1e-04,  
  labels = NULL,  
  palette = "YlGnBu",  
  tmap_scale = 1  
)
```

**Arguments**

x	SpatRaster to be plotted.
scale	Scaling factor to apply to the data
labels	Labels to be plotted
palette	An RColorBrewer palette
tmap_scale	Global scale parameter for map (default: 1.0)

**Value**

A plot object

**Author(s)**

Gilberto Camara, <gilberto.camara@inpe.br>

**Examples**

```
if (bayes_run_examples()) {  
  # get the probability file  
  data_dir <- system.file("/extdata/probs/", package = "bayesE0")  
  file <- list.files(data_dir)  
  # build the full path  
  probs_file <- paste0(data_dir, "/", file)  
  # include the labels  
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",  
             "ClearCut_Veg", "Forest", "Wetland")  
  # associate the labels to the names of the SpatRaster  
  probs <- bayes_read_probs(probs_file, labels)  
  # Plot the probability image
```

```
bayes_plot_probs(probs,  
                 scale = 0.0001,  
                 tmap_scale = 1.0)  
}
```

---

bayes_plot_rgb	<i>Plot RGB data cubes</i>
----------------	----------------------------

---

### Description

Plot RGB raster cube

### Usage

```
bayes_plot_rgb(  
  image,  
  red,  
  green,  
  blue,  
  xmin = NULL,  
  xmax = NULL,  
  ymin = NULL,  
  ymax = NULL  
)
```

### Arguments

image	Object of class SpatRaster.
red	Band for red color.
green	Band for green color.
blue	Band for blue color.
xmin	Subset to be shown (xmin)
xmax	Subset to be shown (xmax)
ymin	Subset to be shown (ymin)
ymax	Subset to be shown (ymax)

### Value

A plot object with an RGB image

### Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

**Examples**

```

if (bayes_run_examples()) {
# Define location of a RGB files
rgb_dir <- system.file("/extdata/rgb", package = "bayesE0")
# list the file
files <- list.files(rgb_dir)
# build the full path
image_files <- paste0(rgb_dir, "/", files)
rgb_image <- bayes_read_image(image_files)
bayes_plot_rgb(rgb_image, red = "B11", green = "B8A", blue = "B03")
}

```

---

bayes_plot_var	<i>Plot variance maps</i>
----------------	---------------------------

---

**Description**

Plot variance maps

**Usage**

```

bayes_plot_var(
  x,
  labels = NULL,
  quantile = 0.75,
  n = 15,
  style = "equal",
  palette = "YlGnBu",
  tmap_scale = 1
)

```

**Arguments**

x	SpatRaster to be plotted.
labels	Labels to be plotted
quantile	Thereshold of values to be plotted
n	Preferred number of classes
style	Method to process the color scale
palette	An RColorBrewer palette
tmap_scale	Global scale parameter for map (default: 1.5)

**Value**

A plot object

**Author(s)**

Gilberto Camara, <gilberto.camara@inpe.br>

**Examples**

```
if (bayes_run_examples()) {  
  # get the probability file  
  data_dir <- system.file("/extdata/probs/", package = "bayesE0")  
  file <- list.files(data_dir)  
  # build the full path  
  probs_file <- paste0(data_dir, "/", file)  
  # include the labels  
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",  
             "ClearCut_Veg", "Forest", "Wetland")  
  # associate the labels to the names of the SpatRaster  
  probs <- bayes_read_probs(probs_file, labels)  
  # calculate the variance  
  var <- bayes_variance(probs)  
  # Plot the variance image  
  bayes_plot_var(var,  
                 n = 15,  
                 style = "order",  
                 quantile = 0.75,  
                 palette = "YlGn",  
                 labels = c("Forest", "ClearCut_Veg"))  
}
```

---

bayes\_read\_image

*Read probability maps*

---

**Description**

Read probability maps

**Usage**

```
bayes_read_image(files)
```

**Arguments**

files            Full path to raster files

**Value**

A SpatRaster object

**Author(s)**

Gilberto Camara, <gilberto.camara@inpe.br>

## Examples

```
if (bayes_run_examples()) {  
  # Define location of a probability file  
  data_dir <- system.file("/extdata/rgb", package = "bayesE0")  
  # list the file  
  files <- list.files(data_dir)  
  # build the full path  
  image_files <- paste0(data_dir, "/", files)  
  rgb_image <- bayes_read_image(image_files)  
}
```

---

bayes_read_probs	<i>Read probability maps</i>
------------------	------------------------------

---

## Description

Read probability maps

## Usage

```
bayes_read_probs(probs_file, labels)
```

## Arguments

probs_file	Full path to raster multi-band file containing probability matrices
labels	Labels to be assigned to the bands

## Value

A SpatRaster object

## Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

## Examples

```
if (bayes_run_examples()) {  
  # Define location of a probability file  
  data_dir <- system.file("/extdata/probs", package = "bayesE0")  
  # list the file  
  file <- list.files(data_dir)  
  # build the full path  
  probs_file <- paste0(data_dir, "/", file)  
  # define labels  
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",  
             "ClearCut_Veg", "Forest", "Wetland")  
  
  probs_image <- bayes_read_probs(probs_file, labels)  
}
```

---

bayes_run_examples	<i>Informs if examples should run</i>
--------------------	---------------------------------------

---

**Description**

This function informs if examples should run. To run the examples, set "BAYES\_RUN\_EXAMPLES" environment variable to "YES" using `Sys.setenv("BAYES_RUN_EXAMPLES" = "YES")` To come back to the default behaviour, please unset the environment variable `Sys.unsetenv("BAYES_RUN_EXAMPLES")`

**Usage**

```
bayes_run_examples()
```

**Value**

A logical value

---

bayes_run_tests	<i>Informs if tests should run</i>
-----------------	------------------------------------

---

**Description**

This function informs if tests should run. To run the examples, set "BAYES\_RUN\_TESTS" environment variable to "YES" using `Sys.setenv("BAYES_RUN_TESTS" = "YES")` To come back to the default behaviour, please unset the environment variable `Sys.unsetenv("BAYES_RUN_TESTS")`

**Usage**

```
bayes_run_tests()
```

**Value**

TRUE/FALSE

---

bayes_smooth	<i>Smooth probability images</i>
--------------	----------------------------------

---

### Description

Takes a classified image with probabilities, and reduces outliers and smoothens probability according to Bayesian statistics

### Usage

```
bayes_smooth(x, window_size = 7, neigh_fraction = 0.5, smoothness = 10)
```

### Arguments

x	SpatRaster object with probabilities images
window_size	Size of the neighborhood.
neigh_fraction	Fraction of neighbors with high probabilities to be used in Bayesian inference.
smoothness	Estimated variance of logit of class probabilities (Bayesian smoothing parameter). It can be either a vector or a scalar.

### Value

A SpatRaster object

### Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

### Examples

```
if (bayes_run_examples()) {  
  # select a file with probability values  
  data_dir <- system.file("/extdata/probs/", package = "bayesE0")  
  file <- list.files(data_dir)  
  # create a full path for the file  
  probs_file <- paste0(data_dir, "/", file)  
  # provide the labels  
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",  
             "ClearCut_Veg", "Forest", "Wetland")  
  # read the probs file  
  probs <- bayes_read_probs(probs_file, labels)  
  # smooth the probability image  
  probs_smooth <- bayes_smooth(probs,  
                               window_size = 7,  
                               smoothness = 20)  
}  
# plot the probability image  
bayes_plot_probs(probs_smooth)
```

```
}
```

---

bayes_summary	<i>Summary of categorical maps</i>
---------------	------------------------------------

---

### Description

Takes a classified image with probabilities, and labels the image with the pixel of higher probability

### Usage

```
bayes_summary(x, scale = 1, sample_size = 15000)
```

### Arguments

x	SpatRaster categorical object
scale	Scale to apply to data
sample_size	Sample size

### Value

A tibble with information

### Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

### Examples

```
if (bayes_run_examples()) {  
  # select a file with probability values  
  data_dir <- system.file("/extdata/probs/", package = "bayesE0")  
  file <- list.files(data_dir)  
  # create a SpatRaster object from the file  
  probs_file <- paste0(data_dir, "/", file)  
  # provide the labels  
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",  
             "ClearCut_Veg", "Forest", "Wetland")  
  # read the probs file  
  probs <- bayes_read_probs(probs_file, labels)  
  # produce a labelled map  
  map <- bayes_label(probs)  
  # plot the labelled map  
  bayes_summary(map)  
}
```

---

bayes_variance	<i>Calculate the variance of a probability cube</i>
----------------	---

---

### Description

Takes a probability cube and estimate the local variance of the logit of the probability, to support the choice of parameters for Bayesian smoothing.

### Usage

```
bayes_variance(x, window_size = 9, neigh_fraction = 0.5)
```

### Arguments

`x`                    SpatRaster object containing probabilities.  
`window_size`        Size of the neighborhood.  
`neigh_fraction`    Fraction of neighbors with highest probability to be used in Bayesian inference.

### Value

A variance SpatRaster object.

### Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>  
Rolf Simoes, <rolf.simoes@inpe.br>

### Examples

```
if (bayes_run_examples()) {  
  # select a file with probability values  
  data_dir <- system.file("/extdata/probs/", package = "bayesE0")  
  file <- list.files(data_dir)  
  # create a SpatRaster object from the file  
  x <- terra::rast(paste0(data_dir, "/", file))  
  # provide the labels  
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",  
             "ClearCut_Veg", "Forest", "Wetland")  
  # name the layers in the SpatRaster with the labels  
  names(x) <- labels  
  # calculate the variance  
  v <- bayes_variance(x)  
  # plot the variance  
  bayes_plot_var(v, quantile = 0.75)  
}
```

---

bilateral_smooth	<i>Smooth probability images with Gaussian filter</i>
------------------	---

---

**Description**

Takes a classified image with probabilities, and reduces outliers and smoothens probability according to a Gaussian filter

**Usage**

```
bilateral_smooth(x, window_size = 5, sigma = 8, tau = 0.1)
```

**Arguments**

x	SpatRaster object with probabilities images
window_size	Size of the neighborhood.
sigma	Standard deviation of the spatial Gaussian kernel
tau	Standard deviation of the class probs value

**Value**

A SpatRaster object

**Author(s)**

Gilberto Camara, <gilberto.camara@inpe.br>

**Examples**

```
if (bayes_run_examples()) {  
  # select a file with probability values  
  data_dir <- system.file("/extdata/probs/", package = "bayesE0")  
  file <- list.files(data_dir)  
  # create a full path for the file  
  probs_file <- paste0(data_dir, "/", file)  
  # provide the labels  
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",  
             "ClearCut_Veg", "Forest", "Wetland")  
  # read the probs file  
  probs <- bayes_read(probs_file, labels)  
  # smooth the probability image  
  bilat <- bilateral_smooth(probs,  
                           window_size = 5,  
                           sigma = 8,  
                           tau = 0.1  
  )  
  # plot the probability image  
  bayes_plot(bilat, scale = 0.0001)
```

```
}
```

---

gaussian_smooth	<i>Smooth probability images with Gaussian filter</i>
-----------------	---

---

### Description

Takes a classified image with probabilities, and reduces outliers and smoothens probability according to a Gaussian filter

### Usage

```
gaussian_smooth(x, window_size = 5, sigma = 1)
```

### Arguments

x	SpatRaster object with probabilities images
window_size	Size of the neighborhood.
sigma	Standard deviation of the spatial Gaussian kernel

### Value

A SpatRaster object

### Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

### Examples

```
if (bayes_run_examples()) {  
  # select a file with probability values  
  data_dir <- system.file("/extdata/probs/", package = "bayesE0")  
  file <- list.files(data_dir)  
  # create a full path for the file  
  probs_file <- paste0(data_dir, "/", file)  
  # provide the labels  
  labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",  
             "ClearCut_Veg", "Forest", "Wetland")  
  # read the probs file  
  probs <- bayes_read(probs_file, labels)  
  # smooth the probability image  
  gauss <- gaussian_smooth(probs,  
                           window_size = 5,  
                           sigma = 1)  
}  
# plot the probability image  
bayes_plot_probs(gauss)
```

}

# Index

bayes\_colors, 2  
bayes\_colors\_show, 3  
bayes\_label, 3  
bayes\_plot\_hist, 4  
bayes\_plot\_map, 5  
bayes\_plot\_probs, 7  
bayes\_plot\_rgb, 8  
bayes\_plot\_var, 9  
bayes\_read\_image, 10  
bayes\_read\_probs, 11  
bayes\_run\_examples, 12  
bayes\_run\_tests, 12  
bayes\_smooth, 13  
bayes\_summary, 14  
bayes\_variance, 15  
bilateral\_smooth, 16  
  
gaussian\_smooth, 17