

Package ‘Ternary’

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Version 2.3.4

Title Create Ternary and Holdridge Plots

Description Plots ternary diagrams (simplex plots / Gibbs triangles) and Holdridge life zone plots <[doi:10.1126/science.105.2727.367](https://doi.org/10.1126/science.105.2727.367)> using the standard graphics functions.
Allows custom annotation, interpolating, contouring and scaling of plotting region.
Includes a 'Shiny' user interface for point-and-click ternary plotting.
An alternative to 'ggtern', which uses the 'ggplot2' family of plotting functions.

URL <https://ms609.github.io/Ternary/>,
<https://github.com/ms609/Ternary/>

BugReports <https://github.com/ms609/Ternary/issues/>

License GPL (>= 2)

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Contents

AddToTernary	2
Annotate	5
cbPalettes	6
ColourTernary	7
holdridge	9
holdridgeClasses	10
HoldridgeHypsometricCol	11
HoldridgePlot	12
OutsidePlot	17
Polygon-Geometry	18
ReflectedEquivalents	19
TernaryApp	20
TernaryContour	21
TernaryCoords	24
TernaryDensityContour	26
TernaryPlot	29
TernaryPointValues	33
TernaryTiles	35
TernaryXRange	36
TriangleCentres	37
TriangleInHull	38
XYToTernary	39
Index	41

AddToTernary	<i>Add elements to ternary or Holdridge plot</i>
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Description

Plot shapes onto a ternary diagram created with [TernaryPlot\(\)](#), or a Holdridge plot created with [HoldridgePlot\(\)](#).

Usage

```
AddToTernary(PlottingFunction, coordinates, ...)

TernaryArrows(fromCoordinates, toCoordinates = fromCoordinates, ...)

TernaryLines(coordinates, ...)

TernaryPoints(coordinates, ...)

TernaryPolygon(coordinates, ...)

TernarySegments(fromCoordinates, toCoordinates = fromCoordinates, ...)

TernaryText(coordinates, ...)

JoinTheDots(coordinates, ...)

AddToHoldridge(PlottingFunction, pet, prec, ...)

HoldridgeArrows(fromCoordinates, toCoordinates = fromCoordinates, ...)

HoldridgeLines(pet, prec, ...)

HoldridgePoints(pet, prec, ...)

HoldridgePolygon(pet, prec, ...)

HoldridgeText(pet, prec, ...)
```

Arguments

PlottingFunction	Function to add data to a plot; perhaps one of points , lines or text .
coordinates	A list, matrix, data.frame or vector in which each element (or row) specifies the three coordinates of a point in ternary space.
...	Additional parameters to pass to PlottingFunction(). If using TernaryText(), this will likely include the parameter labels, to specify the text to plot. Other useful graphical parameters include srt to rotate text.
fromCoordinates, toCoordinates	For TernaryArrows(), coordinates at which arrows should begin and end; <i>cf.</i> x0, y0, x1 and y1 in arrows . Recycled as necessary.
pet, prec	Numeric vectors giving <i>potential evapotranspiration</i> ratio and annual <i>precipitation</i> (in mm).

Functions

- TernaryArrows(): Add [arrows](#)

- TernaryLines(): Add [lines](#)
- TernaryPoints(): Add [points](#)
- TernaryPolygon(): Add [polygons](#)
- TernarySegments(): Add [segments](#)
- TernaryText(): Add [text](#)
- JoinTheDots(): Add points, joined by lines
- HoldridgeArrows(): Add [arrows](#) to Holdridge plot
- HoldridgeLines(): Add [lines](#) to Holdridge plot
- HoldridgePoints(): Add [points](#) to Holdridge plot
- HoldridgePolygon(): Add [polygons](#) to Holdridge plot
- HoldridgeText(): Add [text](#) to Holdridge plot

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other Holdridge plotting functions: [HoldridgeHypsometricCol\(\)](#), [HoldridgePlot\(\)](#), [holdridge](#), [holdridgeClasses](#)

Examples

```
# Data to plot
coords <- list(
  A = c(1, 0, 2),
  B = c(1, 1, 1),
  C = c(1.5, 1.5, 0),
  D = c(0.5, 1.5, 1)
)

# Set up plot
oPar <- par(mar = rep(0, 4), xpd = NA) # reduce margins and write in them
TernaryPlot()

# Add elements to ternary diagram
AddToTernary(lines, coords, col = "darkgreen", lty = "dotted", lwd = 3)
TernaryLines(coords, col = "darkgreen")
TernaryArrows(coords[1], coords[2:4], col = "orange", length = 0.2, lwd = 1)
TernaryText(coords, cex = 0.8, col = "red", font = 2)
seeThruBlue <- rgb(0, 0.2, 1, alpha = 0.8)
TernaryPoints(coords, pch = 1, cex = 2, col = seeThruBlue)
AddToTernary(graphics::points, coords, pch = 1, cex = 3)

# An equivalent syntax applies to Holdridge plots:
HoldridgePlot()
pet <- c(0.8, 2, 0.42)
prec <- c(250, 400, 1337)
```

```

HoldridgeText(pet, prec, c("A", "B", "C"))
AddToHoldridge(graphics::points, pet, prec, cex = 3)

# Restore original plotting parameters
par(oPar)

```

Annotate

*Annotate points on a ternary plot***Description**

Annotate() identifies and label individual points on a ternary diagram in the plot margins.

Usage

```

Annotate(
  coordinates,
  labels,
  side,
  outset = 0.16,
  line.col = col,
  lty = par("lty"),
  lwd = par("lwd"),
  col = par("col"),
  font = par("font"),
  offset = 0.5,
  ...
)

```

Arguments

coordinates	A list, matrix, data.frame or vector in which each element (or row) specifies the three coordinates of a point in ternary space.
labels	Character vector specifying text with which to annotate each entry in coordinates.
side	Optional vector specifying which side of the ternary plot each point should be labelled on, using the notation "a", "b", "c" or 1, 2, 3. Entries of "n" or 0 will not be annotated (but still require an entry in labels). Entries of NA will be allocated a side automatically, based on the midpoint of coordinates.
outset	Numeric specifying distance from plot margins to labels.
line.col, lty, lwd	parameters to segments() .
col, font, offset	parameters to text() .
...	Further parameters to text() and segments() .

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

[Annotation vignette](#) gives further suggestions for manual annotation.

Examples

```
# Load some data
data("Seatbelts")
seats <- c("drivers", "front", "rear")
seat <- Seatbelts[month.abb %in% "Oct", seats]
law <- Seatbelts[month.abb %in% "Oct", "law"]

# Set up plot
oPar <- par(mar = c(2, 0, 0, 0))
TernaryPlot(alab = seats[1], blab = seats[2], clab = seats[3])
TernaryPoints(seat, cex = 0.8, col = 2 + law)

# Annotate points by year
Annotate(seat, labels = 1969:1984, col = 2 + law)

# Restore original graphical parameters
par(oPar)
```

cbPalettes

Palettes compatible with colour blindness

Description

Colour palettes recommended for use with colour blind audiences.

Usage

```
cbPalette8
cbPalette13
cbPalette15
```

Format

Character vectors of lengths 8, 13 and 15.
An object of class character of length 8.
An object of class character of length 13.
An object of class character of length 15.

Details

Since R 4.0, `cbPalette8` is available in base R as `palette.colors(8)`.

`cbPalette15` is a **Brewer palette**. Because colours 4 and 7 are difficult to distinguish from colours 13 and 3, respectively, in individuals with tritanopia, `cbPalette13` omits these colours (i.e. `cbPalette13 <- cbPalette15[-c(4, 7)]`).

Source

- `cbPalette8`: Wong B. 2011. Color blindness. *Nat. Methods*. 8:441. [doi:10.1038/nmeth.1618](https://doi.org/10.1038/nmeth.1618)
- `cbPalette15`: <http://mkweb.bcgsc.ca/biovis2012/color-blindness-palette.png>

Examples

```
data("cbPalette8")
plot.new()
plot.window(xlim = c(1, 16), ylim = c(0, 3))
text(1:8 * 2, 3, 1:8, col = cbPalette8)
points(1:8 * 2, rep(2, 8), col = cbPalette8, pch = 15)

data("cbPalette15")
text(1:15, 1, col = cbPalette15)
text(c(4, 7), 1, "[ ]")
points(1:15, rep(0, 15), col = cbPalette15, pch = 15)
```

ColourTernary

Colour ternary plot

Description

Colour a ternary plot according to the output of a function.

Usage

```
ColourTernary(
  values,
  spectrum = hcl.colors(256L, palette = "viridis", alpha = 0.6),
  resolution = sqrt(ncol(values)),
  direction = getOption("ternDirection", 1L),
  legend,
  ...
)
```

```
ColorTernary(
  values,
  spectrum = hcl.colors(256L, palette = "viridis", alpha = 0.6),
  resolution = sqrt(ncol(values)),
  direction = getOption("ternDirection", 1L),
```

```

    legend,
    ...
)

```

Arguments

values	Numeric matrix, possibly created using TernaryPointValues() , with four named rows: x, y, Cartesian coordinates of each triangle centre; z, value associated with that coordinate; down, triangle direction: 0 = point upwards; 1 = point downwards.
spectrum	Vector of colours to use as a spectrum, or NULL to use values["z",].
resolution	The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost.
direction	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.
legend	Character vector specifying annotations for colour scale. If not provided, no colour legend is displayed. Specify TRUE to generate automatically, or a single integer to generate legend annotations.
...	Further arguments to SpectrumLegend() .

Value

ColourTernary() is called for its side effect – colouring a ternary plot according to values. It invisibly returns NULL.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Fine control over continuous legends: [PlotTools::SpectrumLegend\(\)](#)

Other contour plotting functions: [TernaryContour\(\)](#), [TernaryDensityContour\(\)](#), [TernaryPointValues\(\)](#)

Other functions for colouring and shading: [TernaryTiles\(\)](#)

Examples

```

# Depict a function across a ternary plot with colour and contours

TernaryPlot(alab = "a", blab = "b", clab = "c") # Blank plot

FunctionToContour <- function (a, b, c) {
  a - c + (4 * a * b) + (27 * a * b * c)
}

# Evaluate function
values <- TernaryPointValues(FunctionToContour, resolution = 24L)

```



```

# Use the value of the function to determine the brightness of the plot
ColourTernary(
  values,
  x = "topleft",
  bty = "n", # No box
  legend = signif(seq(max(values), min(values), length.out = 4), 3)
)

# Overlay contours
TernaryContour(FunctionToContour, resolution = 36L)

# Directly specify the colour with the output of a function

# Create a function that returns a vector of rgb strings:
rgbWhite <- function (r, g, b) {
  highest <- apply(rbind(r, g, b), 2L, max)
  rgb(r/highest, g/highest, b/highest)
}

TernaryPlot()
values <- TernaryPointValues(rgbWhite, resolution = 20)
ColourTernary(values, spectrum = NULL)

```

holdridge

Random sample of points for Holdridge plotting

Description

A stratified random sampling (average of 100 points) using a global mapping of Holdridge's scheme.

Usage

```
holdridge
```

Format

An object of class `data.frame` with 39 rows and 4 columns.

Author(s)

James Lee Tsakalos

See Also

Other Holdridge plotting functions: [AddToTernary\(\)](#), [HoldridgeHypsometricCol\(\)](#), [HoldridgePlot\(\)](#), [holdridgeClasses](#)

Examples

```
data("holdridge", package = "Ternary")  
head(holdridge)
```

holdridgeClasses	<i>Names of the 38 classes defined with the Holdridge system</i>
------------------	--

Description

holdridgeClasses is a character vector naming, from left to right, top to bottom, the 38 classes defined by the International Institute for Applied Systems Analysis (IIASA).

Usage

```
holdridgeClasses  
  
holdridgeLifeZones  
  
holdridgeLifeZonesUp  
  
holdridgeClassesUp
```

Format

An object of class character of length 38.
An object of class character of length 33.
An object of class character of length 33.
An object of class character of length 38.

Details

holdridgeLifeZones is a character vector naming, from left to right, top to bottom, the 38 cells of the Holdridge classification plot.

holdridgeClassesUp and holdridgeLifeZonesUp replace spaces with new lines, for more legible plotting with [HoldridgeHexagons\(\)](#).

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

Source

Holdridge (1947), "Determination of world plant formations from simple climatic data", *Science* 105:367–368. doi:10.1126/science.105.2727.367

Holdridge (1967), *Life zone ecology*. Tropical Science Center, San José.

Leemans, R. (1990), "Possible change in natural vegetation patterns due to a global warming", *International Institute for Applied Systems Analysis* Working paper WP-90-08. <https://pure.iiasa.ac.at/id/eprint/3443/1/WP-90-008.pdf>

See Also

Other Holdridge plotting functions: [AddToTernary\(\)](#), [HoldridgeHypsometricCol\(\)](#), [HoldridgePlot\(\)](#), [holdridge](#)

HoldridgeHypsometricCol

Convert a point in evapotranspiration-precipitation space to an appropriate cross-blended hypsometric colour

Description

Used to colour HoldridgeHexagons(), and may also be used to aid the interpretation of PET + precipitation data in any graphical context.

Usage

```
HoldridgeHypsometricCol(pet, prec, opacity = NA)
```

Arguments

pet, prec	Numeric vectors giving potential evapotranspiration ratio and annual precipitation (in mm).
opacity	Opacity level to be converted to the final two characters of an RGBA hexadecimal colour definition, e.g. #000000FF. Specify a character string, which will be interpreted as a hexadecimal alpha value and appended to the six RGB hexadecimal digits; a numeric in the range 0 (transparent) to 1 (opaque); or NA, to return only the six RGB digits.

Value

Character vector listing RGB or (if opacity != NA) RGBA values corresponding to each PET-precipitation value pair.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

Palette derived from the hypsometric colour scheme presented at [Shaded Relief](#).

See Also

Other Holdridge plotting functions: [AddToTernary\(\)](#), [HoldridgePlot\(\)](#), [holdridge](#), [holdridgeClasses](#)

Examples

```
HoldridgePlot(hex.col = HoldridgeHypsometricCol)
VeryTransparent <- function(...) HoldridgeHypsometricCol(..., opacity = 0.3)
HoldridgePlot(hex.col = VeryTransparent)
pet <- holdridge$PET
prec <- holdridge$Precipitation
ptCol <- HoldridgeHypsometricCol(pet, prec)
HoldridgePoints(pet, prec, pch = 21, bg = ptCol)
```

HoldridgePlot

Plot life zones on a Holdridge plot

Description

HoldridgePlot() creates a blank triangular plot, as proposed by Holdridge (1947, 1967), onto which potential evapotranspiration (PET) ratio and annual precipitation data can be plotted (using the [AddToHoldridge\(\)](#) family of functions) in order to interpret climatic life zones.

Usage

```
HoldridgePlot(
  atip = NULL,
  btip = NULL,
  ctip = NULL,
  alab = "Potential evapotranspiration ratio",
  blab = "Annual precipitation / mm",
  clab = "Humidity province",
  lab.offset = 0.22,
  lab.col = c("#D81B60", "#1E88E5", "#111111"),
  xlim = NULL,
  ylim = NULL,
  region = NULL,
  lab.cex = 1,
  lab.font = 0,
  tip.cex = lab.cex,
  tip.font = 2,
  tip.col = "black",
  isometric = TRUE,
  atip.rotate = NULL,
```

```

    btip.rotate = NULL,
    ctip.rotate = NULL,
    atip.pos = NULL,
    btip.pos = NULL,
    ctip.pos = NULL,
    padding = 0.16,
    col = NA,
    panel.first = NULL,
    panel.last = NULL,
    grid.lines = 8,
    grid.col = c(NA, "#1E88E5", "#D81B60"),
    grid.lty = "solid",
    grid.lwd = par("lwd"),
    grid.minor.lines = 0,
    grid.minor.col = "lightgrey",
    grid.minor.lty = "solid",
    grid.minor.lwd = par("lwd"),
    hex.border = "#888888",
    hex.col = HoldridgeHypsometricCol,
    hex.lty = "solid",
    hex.lwd = par("lwd"),
    hex.cex = 0.5,
    hex.labels = NULL,
    hex.font = NULL,
    hex.text.col = "black",
    axis.cex = 0.8,
    axis.col = c(grid.col[2], grid.col[3], NA),
    axis.font = par("font"),
    axis.labels = TRUE,
    axis.lty = "solid",
    axis.lwd = 1,
    axis.rotate = TRUE,
    axis.pos = NULL,
    axis.tick = TRUE,
    ticks.lwd = axis.lwd,
    ticks.length = 0.025,
    ticks.col = grid.col,
    ...
)

HoldridgeBelts(
  grid.col = "#004D40",
  grid.lty = "dotted",
  grid.lwd = par("lwd")
)

HoldridgeHexagons(
  border = "#004D40",

```

```

hex.col = HoldridgeHypsometricCol,
lty = "dotted",
lwd = par("lwd"),
labels = NULL,
cex = 1,
text.col = NULL,
font = NULL
)

```

Arguments

- | | |
|---------------------------------------|---|
| atip, btip, ctip | Character string specifying text to title corners, proceeding clockwise from the corner specified in point (default: top). |
| alab, blab, clab | Character string specifying text with which to label the corresponding sides of the triangle. Left or right-pointing arrows are produced by typing <code>\\U2190</code> or <code>\\U2192</code> , or using expression(<code>'value' %>% '</code>). |
| lab.offset | Numeric specifying distance between midpoint of axis label and the axis. The default value is given in the 'Usage' section; a value of 0 will position the axis label directly on the axis. Increase padding if labels are being clipped. Use a vector of length three to specify a different offset for each label. |
| lab.col | Character vector specifying colours for axis labels. Use a vector of length three to specify a different colour for each label. |
| xlim, ylim | Numeric vectors of length two specifying the minimum and maximum <i>x</i> and <i>y</i> limits of the plotted area, to which padding will be added. The default is to display the complete height or width of the plot. Allows cropping to magnified region of the plot. (See vignette for diagram.) May be overridden if <code>isometric = TRUE</code> ; see documentation of <code>isometric</code> parameter. |
| region | (optional) Named list of length two specifying the the minimum and maximum values of each ternary axis to be drawn (e.g. <code>list(min = c(40, 0, 0), max = c(100, 60, 60))</code>); or a set of coordinates in a format accepted by TernaryPoints() . The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates. |
| lab.cex, tip.cex | Numeric specifying character expansion (font size) for axis labels. Use a vector of length three to specify a different value for each direction. |
| lab.font, tip.font | Numeric specifying font style (Roman, bold, italic, bold-italic) for axis titles. Use a vector of length three to set a different font for each direction. |
| isometric | Logical specifying whether to enforce an equilateral shape for the ternary plot. If only one of <code>xlim</code> and <code>ylim</code> is set, the other will be calculated to maintain an equilateral plot. If both <code>xlim</code> and <code>ylim</code> are set, but have different ranges, then the limit with the smaller range will be scaled until its range matches that of the other limit. |
| atip.rotate, btip.rotate, ctip.rotate | Integer specifying number of degrees to rotate label of rightmost apex. |

<code>atip.pos, btip.pos, ctip.pos</code>	Integer specifying positioning of labels, iff the corresponding <code>x.tip.rotate</code> parameter is set.
<code>padding</code>	Numeric specifying size of internal margin of the plot; increase if axis labels are being clipped.
<code>col</code>	The colour for filling the plot; see polygon .
<code>panel.first</code>	An expression to be evaluated after the plot axes are set up but before any plotting takes place. This can be useful for drawing backgrounds, e.g. with ColourTernary() or HorizontalGrid() . Note that this works by lazy evaluation: passing this argument from other plot methods may well not work since it may be evaluated too early.
<code>panel.last</code>	An expression to be evaluated after plotting has taken place but before the axes and box are added. See the comments about <code>panel.first</code> .
<code>grid.lines</code>	Integer specifying the number of grid lines to plot. If <code>axis.labels = TRUE</code> , this will be used as a hint to <code>pretty()</code> .
<code>grid.col, grid.minor.col</code>	Colours to draw the grid lines. Use a vector of length three to set different values for each direction.
<code>grid.lty, grid.minor.lty</code>	Character or integer vector; line type of the grid lines. Use a vector of length three to set different values for each direction.
<code>grid.lwd, grid.minor.lwd</code>	Non-negative numeric giving line width of the grid lines. Use a vector of length three to set different values for each direction.
<code>grid.minor.lines</code>	Integer specifying the number of minor (unlabelled) grid lines to plot between each major pair.
<code>hex.border, hex.lty, hex.lwd</code>	Parameters to pass to <code>HoldridgeHexagons()</code> . Set to NA to suppress hexagons.
<code>hex.col</code>	Fill colour for hexagons. Provide a vector specifying a colour for each hexagon in turn, reading from left to right and top to bottom, or a function that accepts two arguments, numerics <code>pet</code> and <code>prec</code> , and returns a colour in a format accepted by polygon() .
<code>hex.cex, hex.font, hex.text.col</code>	Parameters passed to text() to plot <code>hex.labels</code> .
<code>hex.labels</code>	38-element character vector specifying label for each hexagonal class, from top left to bottom right.
<code>axis.cex</code>	Numeric specifying character expansion (font size) for axis labels. Use a vector of length three to set a different value for each direction.
<code>axis.col, ticks.col, tip.col</code>	Colours for the axis line, tick marks and tip labels respectively. Use a vector of length three to set a different value for each direction. <code>axis.col = NULL</code> means to use <code>par('fg')</code> , possibly specified inline, and <code>ticks.col = NULL</code> means to use whatever colour <code>axis.col</code> resolved to.
<code>axis.font</code>	Font for text. Defaults to <code>par('font')</code> .

<code>axis.labels</code>	This can either be a logical value specifying whether (numerical) annotations are to be made at the tickmarks, or a character or expression vector of labels to be placed at the tick points, or a list of length three, with each entry specifying labels to be placed on each axis in turn.
<code>axis.lty</code>	Line type for both the axis line and tick marks. Use a vector of length three to set a different value for each direction.
<code>axis.lwd, ticks.lwd</code>	Line width for the axis line and tick marks. Zero or negative values will suppress the line or ticks. Use a vector of length three to set different values for each axis.
<code>axis.rotate</code>	Logical specifying whether to rotate axis labels to parallel grid lines, or numeric specifying custom rotation for each axis, to be passed as <code>srt</code> parameter to <code>text()</code> . Expand margins or set <code>par(xpd = NA)</code> if labels are clipped.
<code>axis.pos</code>	Vector of length one or three specifying position of axis labels, to be passed as <code>pos</code> parameter to <code>text()</code> ; populated automatically if NULL (the default).
<code>axis.tick</code>	Logical specifying whether to mark the axes with tick marks.
<code>ticks.length</code>	Numeric specifying distance that ticks should extend beyond the plot margin. Also affects position of axis labels, which are plotted at the end of each tick. Use a vector of length three to set a different length for each direction.
<code>...</code>	Additional parameters to plot .
<code>border</code>	Colour to use for hexagon borders.
<code>lty, lwd, cex, font</code>	Graphical parameters specifying properties of hexagons to be plotted.
<code>labels</code>	Vector specifying labels for life zone hexagons to be plotted. Suggested values: holdridgeClassesUp , holdridgeLifeZonesUp .
<code>text.col</code>	Colour of text to be printed in hexagons.

Details

[HoldridgePoints\(\)](#), [HoldridgeText\(\)](#) and related functions allow data points to be added to an existing plot; [AddToHoldridge\(\)](#) allows plotting using any of the standard plotting functions.

[HoldridgeBelts\(\)](#) and [HoldridgeHexagons\(\)](#) plot interpretative lines and hexagons allowing plotted data to be linked to interpreted climate settings.

Please cite Tsakalos *et al.* (2023) when using this function.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

Holdridge (1947), "Determination of world plant formations from simple climatic data", *Science* 105:367–368. doi:[10.1126/science.105.2727.367](https://doi.org/10.1126/science.105.2727.367)

Holdridge (1967), *Life zone ecology*. Tropical Science Center, San José

Tsakalos, Smith, Luebert & Mucina (2023). "climenv: Download, extract and visualise climatic and elevation data.", *Journal of Vegetation Science* 6:e13215. doi:[10.1111/jvs.13215](https://doi.org/10.1111/jvs.13215)

See Also

Other Holdridge plotting functions: [AddToTernary\(\)](#), [HoldridgeHypsometricCol\(\)](#), [holdridge](#), [holdridgeClasses](#)

Examples

```
data(holdridgeLifeZonesUp, package = "Ternary")
HoldridgePlot(hex.labels = holdridgeLifeZonesUp)
HoldridgeBelts()
```

OutsidePlot

Is a point in the plotting area?

Description

Evaluate whether a given set of coordinates lie outwith the boundaries of a plotted ternary diagram.

Usage

```
OutsidePlot(x, y, tolerance = 0)
```

Arguments

<code>x, y</code>	Vectors of x and y coordinates of points.
<code>tolerance</code>	Consider points this close to the edge of the plot to be inside. Set to negative values to count points that are just outside the plot as inside, and to positive values to count points that are just inside the margins as outside. Maximum positive value: $1/3$.

Value

`OutsidePlot()` returns a logical vector specifying whether each pair of x and y coordinates corresponds to a point outside the plotted ternary diagram.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other plot limits: [TernaryXRange\(\)](#)

Examples

```

TernaryPlot()
points(0.5, 0.5, col = "darkgreen")
OutsidePlot(0.5, 0.5)

points(0.1, 0.5, col = "red")
OutsidePlot(0.1, 0.5)

OutsidePlot(c(0.5, 0.1), 0.5)

```

Polygon-Geometry

Polygon geometry

Description

Geometry functions for irregular polygons.

Usage

```

PolygonArea(x, y = NULL, positive = TRUE)

PolygonCentre(x, y = NULL)

PolygonCenter(x, y = NULL)

GrowPolygon(x, y = NULL, buffer = 0)

```

Arguments

<code>x, y</code>	Vectors containing the coordinates of the vertices of the polygon.
<code>positive</code>	If vertices are specified in an anticlockwise direction, the polygon will be treated as a hole, with a negative area, unless <code>positive</code> is set to <code>TRUE</code> . Vertices specified in a clockwise sequence always yield a positive area.
<code>buffer</code>	Numeric specifying distance by which to grow polygon.

Value

`PolygonArea()` returns the area of the specified polygon.

`PolygonCentre()` returns a single-row matrix containing the x and y coordinates of the geometric centre of the polygon.

`GrowPolygon()` returns coordinates of the vertices of polygon after moving each vertex `buffer` away from the polygon's centre.

Functions

- `PolygonArea()`: Calculate the area of an irregular polygon
- `PolygonCentre()`: Locate the centre of a polygon
- `GrowPolygon()`: Enlarge a polygon in all directions

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other tiling functions: [TriangleCentres\(\)](#), [TriangleInHull\(\)](#)

Examples

```
x <- c(-3, -1, 6, 3, -4)
y <- c(-2, 4, 1, 10, 9)
plot(x, y, frame.plot = FALSE)
polygon(x, y)
PolygonArea(x, y)
points(PolygonCentre(x, y), pch = 3, cex = 2)
polygon(GrowPolygon(x, y, 1), border = "darkgreen",
        xpd = NA # Allow drawing beyond plot border
)

# Negative values shrink the polygon
polygon(GrowPolygon(x, y, -1), border = "red")
```

ReflectedEquivalents *Reflected equivalents of points outside the ternary plot*

Description

To avoid edge effects, it may be desirable to add the value of a point within a ternary plot with the value of its 'reflection' across the nearest axis or corner.

Usage

```
ReflectedEquivalents(x, y, direction = getOption("ternDirection", 1L))
```

Arguments

<code>x, y</code>	Vectors of <i>x</i> and <i>y</i> coordinates of points.
<code>direction</code>	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.

Value

`ReflectedEquivalents()` returns a list of the *x, y* coordinates of the points produced if the given point is reflected across each of the edges or corners.

See Also

Other coordinate translation functions: [TernaryCoords\(\)](#), [TriangleCentres\(\)](#), [XYToTernary\(\)](#)

Examples

```
TernaryPlot(axis.labels = FALSE, point = 4)

xy <- cbind(
  TernaryCoords(0.9, 0.08, 0.02),
  TernaryCoords(0.15, 0.8, 0.05),
  TernaryCoords(0.05, 0.1, 0.85)
)
x <- xy[1, ]
y <- xy[2, ]

points(x, y, col = "red", pch = 1:3)
ref <- ReflectedEquivalents(x, y)
points(ref[[1]][, 1], ref[[1]][, 2], col = "blue", pch = 1)
points(ref[[2]][, 1], ref[[2]][, 2], col = "green", pch = 2)
points(ref[[3]][, 1], ref[[3]][, 2], col = "orange", pch = 3)
```

TernaryApp

Graphical user interface for creating ternary plots

Description

TernaryApp() launches a 'Shiny' application for the construction of ternary plots. The 'app' allows data to be loaded and plotted, and provides code to reproduce the plot in R should more sophisticated plotting functions be desired.

Usage

```
TernaryApp()
```

Details

Load data:

The 'Load data' input tab allows for the upload of datasets. Data can be read from csv files, .txt files created with write.table(), or (if the 'readxl' package is installed) Excel spreadsheets.

Data should be provided as three columns, corresponding to the three axes of the ternary plot. Colours or point styles may be specified in columns four to six to allow different categories of point to be plotted distinctly. Example datasets are installed at system.file("TernaryApp", package = "Ternary").

Axes are automatically labelled using column names, if present; these can be edited manually on this tab.

Plot display:

Allows the orientation, colour and configuration of the plot and its axes to be adjusted,

Grids:

Adjust the number, spacing and styling of major and minor grid lines.

Labels:

Configure the colour, position and size of tip and axis labels.

Points:

Choose whether to plot points, lines, connected points, or text. Set the style of points and lines.

Exporting plots

A plot can be saved to PDF or as a PNG bitmap at a specified size. Alternatively, R script that will generate the displayed plot can be viewed (using the 'R code' output tab) or downloaded to file.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

References

If you use figures produced with this package in a publication, please cite

Smith, Martin R. (2017). *Ternary: An R Package for Creating Ternary Plots*. Zenodo, doi: [doi:10.5281/zenodo.1068996](https://doi.org/10.5281/zenodo.1068996).

See Also

Full detail of plotting with 'Ternary', including features not (yet) implemented in the application, is provided in the accompanying [vignette](#).

TernaryContour	<i>Add contours to a ternary plot</i>
----------------	---------------------------------------

Description

Draws contour lines to depict the value of a function in ternary space.

Usage

```
TernaryContour(
  Func,
  resolution = 96L,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault),
  within = NULL,
  filled = FALSE,
  legend,
  legend... = list(),
  nlevels = 10,
  levels = pretty(zlim, nlevels),
  zlim,
```

```

color.palette = function(n) hcl.colors(n, palette = "viridis", alpha = 0.6),
fill.col = color.palette(length(levels) - 1),
func... = list(),
...
)

```

Arguments

Func	Function that takes three arguments named a, b and c, and returns a numeric vector of length <i>n</i> . a, b and c will each be a vector of length <i>n</i> . Together, they specify the series of coordinates at which the function should be evaluated.
resolution	The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost.
direction	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.
region	(optional) Named list of length two specifying the the minimum and maximum values of each ternary axis to be drawn (e.g. <code>list(min = c(40, 0, 0), max = c(100, 60, 60))</code>); or a set of coordinates in a format accepted by TernaryPoints() . The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates.
within	List or matrix of x, y coordinates within which contours should be evaluated, in any format supported by xy.coords(x = within) . If NULL, defaults to a region slightly smaller than the ternary plot. The <code>\$hull</code> entry generated by <code>TriangleInHull()</code> may also be used.
filled	Logical; if TRUE, contours will be filled (using .filled.contour()).
legend	Character vector specifying annotations for colour scale. If not provided, no colour legend is displayed. Specify TRUE to generate automatically, or a single integer to generate legend annotations.
legend...	List of additional parameters to send to SpectrumLegend() .
nlevels, levels, zlim, ...	parameters to pass to contour() .
color.palette	parameters to pass to .filled.contour() .
fill.col	Sent as col parameter to .filled.contour() . Computed from <code>color.palette</code> if not specified.
func...	List of additional parameters to send to <code>Func()</code> .

Value

`TernaryContour()` is called for its side effect – adding contours to a Ternary plot according to the value of `Func(a, b, c)` at each coordinate. It invisibly returns a list containing:

- x,y: the Cartesian coordinates of each evaluated point;
- z: The value of `Func()` at each coordinate.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other contour plotting functions: [ColourTernary\(\)](#), [TernaryDensityContour\(\)](#), [TernaryPointValues\(\)](#)

Examples

```
FunctionToContour <- function (a, b, c) {
  a - c + (4 * a * b) + (27 * a * b * c)
}

# Set up plot
originalPar <- par(mar = rep(0, 4))
TernaryPlot(alab = "a", blab = "b", clab = "c")
values <- TernaryPointValues(FunctionToContour, resolution = 24L)
ColourTernary(
  values,
  legend = signif(seq(max(values), min(values), length.out = 4), 2),
  bty = "n"
)
TernaryContour(FunctionToContour, resolution = 36L)

# Note that FunctionToContour() is sent vectors of all values of a, b and
# c at which it will be evaluated.
# Instead of
BadMax <- function (a, b, c) {
  max(a, b, c) # Not vectorized
  # Will return the single maximum of ALL a, b and c coordinates
}

# Use
GoodMax <- function (a, b, c) {
  pmax(a, b, c) # Vectorized
  # Will return the maximum of each trio of a, b and c coordinates
}
TernaryPlot(alab = "a", blab = "b", clab = "c")
ColourTernary(TernaryPointValues(GoodMax))
TernaryContour(GoodMax)

# When a vectorized version of a function is not available, you will need to
# apply the function to each combination of a, b and c in turn:
GeneralMax <- function (a, b, c) {
  abc.matrix <- rbind(a, b, c) # Matrix where each column gives an a,b,c trio
  apply(abc.matrix, 2, max)    # Apply non-vectorized function to each trio
  # Returns a vector with the maximum value of a,b,c at each coordinate.
}
TernaryPlot(alab = "a", blab = "b", clab = "c")
# Fill the contour areas, rather than using tiles
TernaryContour(GeneralMax, filled = TRUE,
  legend = c("Max", "...", "Min"),
```

```

        legend... = list(bty = "n", xpd = NA), # Tweak legend display
        fill.col = hcl.colors(14, palette = "viridis", alpha = 0.6))
# Re-draw edges of plot triangle over fill
TernaryPolygon(diag(3))

# Restore plotting parameters
par(originalPar)

```

TernaryCoords

Convert ternary coordinates to Cartesian space

Description

Convert coordinates of a point in ternary space, in the format (a, b, c) , to x and y coordinates of Cartesian space, which can be sent to standard functions in the 'graphics' package.

Usage

```

TernaryCoords(
  abc,
  b_coord = NULL,
  c_coord = NULL,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault)
)

## S3 method for class 'matrix'
TernaryToXY(
  abc,
  b_coord = NULL,
  c_coord = NULL,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault)
)

## S3 method for class 'numeric'
TernaryToXY(
  abc,
  b_coord = NULL,
  c_coord = NULL,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault)
)

TernaryToXY(
  abc,
  b_coord = NULL,

```



```

    c_coord = NULL,
    direction = getOption("ternDirection", 1L),
    region = getOption("ternRegion", ternRegionDefault)
  )

```

Arguments

<code>abc</code>	A vector of length three giving the position on a ternary plot that points in the direction specified by <code>direction</code> (1 = up, 2 = right, 3 = down, 4 = left). <code>c(100, 0, 0)</code> will plot in the direction-most corner; <code>c(0, 100, 0)</code> will plot in the corner clockwise of direction; <code>c(0, 0, 100)</code> will plot in the corner anti-clockwise of direction. Alternatively, the a coordinate can be specified as the first parameter, in which case the b and c coordinates must be specified via <code>b_coord</code> and <code>c_coord</code> . Or, a matrix with three rows, representing in turn the a, b and c coordinates of points.
<code>b_coord</code>	The b coordinate, if <code>abc</code> is a single number.
<code>c_coord</code>	The c coordinate, if <code>abc</code> is a single number.
<code>direction</code>	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.
<code>region</code>	(optional) Named list of length two specifying the the minimum and maximum values of each ternary axis to be drawn (e.g. <code>list(min = c(40, 0, 0), max = c(100, 60, 60))</code>); or a set of coordinates in a format accepted by TernaryPoints() . The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates.

Value

`TernaryCoords()` returns a vector of length two that converts the coordinates given in `abc` into Cartesian (x, y) coordinates corresponding to the plot created by the last call of [TernaryPlot\(\)](#).

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

- [TernaryPlot\(\)](#)

Other coordinate translation functions: [ReflectedEquivalents\(\)](#), [TriangleCentres\(\)](#), [XYToTernary\(\)](#)

Examples

```

TernaryCoords(100, 0, 0)
TernaryCoords(c(0, 100, 0))

coords <- matrix(1:12, nrow = 3)
TernaryToXY(coords)

```

TernaryDensityContour *Add contours of estimated point density to a ternary plot*

Description

Use two-dimensional kernel density estimation to plot contours of point density.

Usage

```
TernaryDensityContour(
  coordinates,
  bandwidth,
  resolution = 25L,
  tolerance = -0.2/resolution,
  edgeCorrection = TRUE,
  direction = getOption("ternDirection", 1L),
  filled = FALSE,
  nlevels = 10,
  levels = pretty(zlim, nlevels),
  zlim,
  color.palette = function(n) hcl.colors(n, palette = "viridis", alpha = 0.6),
  fill.col = color.palette(length(levels) - 1),
  ...
)
```

Arguments

coordinates	A list, matrix, data.frame or vector in which each element (or row) specifies the three coordinates of a point in ternary space.
bandwidth	Vector of bandwidths for x and y directions. Defaults to normal reference bandwidth (see MASS::bandwidth.nrd). A scalar value will be taken to apply to both directions.
resolution	The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost.
tolerance	Numeric specifying how close to the margins the contours should be plotted, as a fraction of the size of the triangle. Negative values will cause contour lines to extend beyond the margins of the plot.
edgeCorrection	Logical specifying whether to correct for edge effects (see details).
direction	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.
filled	Logical; if TRUE, contours will be filled (using <code>.filled.contour()</code>).
nlevels, levels, zlim, ...	parameters to pass to <code>contour()</code> .
color.palette	parameters to pass to <code>.filled.contour()</code> .

`fill.col` Sent as `col` parameter to `.filled.contour()`. Computed from `color.palette` if not specified.

Details

This function is modelled on `MASS::kde2d()`, which uses "an axis-aligned bivariate normal kernel, evaluated on a square grid".

This is to say, values are calculated on a square grid, and contours fitted between these points. This produces a couple of artefacts. Firstly, contours may not extend beyond the outermost point within the diagram, which may fall some distance from the margin of the plot if a low resolution is used. Setting a negative `tolerance` parameter allows these contours to extend closer to (or beyond) the margin of the plot.

Individual points cannot fall outside the margins of the ternary diagram, but their associated kernels can. In order to sample regions of the kernels that have "bled" outside the ternary diagram, each point's value is calculated by summing the point density at that point and at equivalent points outside the ternary diagram, "reflected" across the margin of the plot (see function [ReflectedEquivalents](#)). This correction can be disabled by setting the `edgeCorrection` parameter to `FALSE`.

A model based on a triangular grid may be more appropriate in certain situations, but is non-trivial to implement; if this distinction is important to you, please let the maintainers know by opening a [Github issue](#).

Value

`TernaryDensityContour()` invisibly returns a list containing:

- `x,y`: the Cartesian coordinates of each grid coordinate;
- `z`: The density at each grid coordinate.

Author(s)

Adapted from `MASS::kde2d()` by Martin R. Smith

See Also

Other contour plotting functions: [ColourTernary\(\)](#), [TernaryContour\(\)](#), [TernaryPointValues\(\)](#)

Examples

```
# Generate some example data
nPoints <- 400L
coordinates <- cbind(abs(rnorm(nPoints, 2, 3)),
                    abs(rnorm(nPoints, 1, 1.5)),
                    abs(rnorm(nPoints, 1, 0.5)))

# Set up plot
oPar <- par(mar = rep(0, 4))
TernaryPlot(axis.labels = seq(0, 10, by = 1))

# Colour background by density
ColourTernary(TernaryDensity(coordinates, resolution = 10L),
```

```

      legend = TRUE, bty = "n", title = "Density")

# Plot points
TernaryPoints(coordinates, col = "red", pch = ".")

# Contour by density
TernaryDensityContour(coordinates, resolution = 30L)

# The following demonstrates the behaviour of the density estimates when
# points fall on boundaries of the triangular grid cells; text denotes the
# number of points within the cell, with cells straddling _n_ cells
# contributing 1/_n_ of a point to each cell straddled.

coordinates <- list(middle = c(1, 1, 1),
                    top = c(3, 0, 0),
                    belowTop = c(2, 1, 1),
                    leftSideSolid = c(9, 2, 9),
                    leftSideSolid2 = c(9.5, 2, 8.5),
                    right3way = c(1, 2, 0),
                    rightEdge = c(2.5, 0.5, 0),
                    leftBorder = c(1, 1, 4),
                    topBorder = c(2, 1, 3),
                    rightBorder = c(1, 2, 3)
)
par(mfrow = c(2, 2), mar = rep(0.2, 4))
TernaryPlot(grid.lines = 3, axis.labels = 1:3, point = "up")
values <- TernaryDensity(coordinates, resolution = 3L)
ColourTernary(values)
TernaryPoints(coordinates, col = "red")
text(values[1, ], values[2, ], paste(values[3, ], "/ 6"), cex = 0.8)

TernaryPlot(grid.lines = 3, axis.labels = 1:3, point = "right")
values <- TernaryDensity(coordinates, resolution = 3L)
ColourTernary(values)
TernaryPoints(coordinates, col = "red")
text(values[1, ], values[2, ], paste(values[3, ], "/ 6"), cex = 0.8)

TernaryPlot(grid.lines = 3, axis.labels = 1:3, point = "down")
values <- TernaryDensity(coordinates, resolution = 3L)
ColourTernary(values)
TernaryPoints(coordinates, col = "red")
text(values[1, ], values[2, ], paste(values[3, ], "/ 6"), cex = 0.8)

TernaryPlot(grid.lines = 3, axis.labels = 1:3, point = "left")
values <- TernaryDensity(coordinates, resolution = 3L)
ColourTernary(values)
TernaryPoints(coordinates, col = "red")
text(values[1, ], values[2, ], paste(values[3, ], "/ 6"), cex = 0.8)

TernaryDensityContour(t(vapply(coordinates, I, double(3L))),
                      resolution = 24L, tolerance = -0.02, col = "orange")

```

```
# Reset plotting parameters
par(oPar)
```

TernaryPlot	<i>Create a ternary plot</i>
-------------	------------------------------

Description

Create and style a blank ternary plot.

Usage

```
TernaryPlot(
  atip = NULL,
  btip = NULL,
  ctip = NULL,
  alab = NULL,
  blab = NULL,
  clab = NULL,
  lab.offset = 0.16,
  lab.col = NULL,
  point = "up",
  clockwise = TRUE,
  xlim = NULL,
  ylim = NULL,
  region = ternRegionDefault,
  lab.cex = 1,
  lab.font = 0,
  tip.cex = lab.cex,
  tip.font = 2,
  tip.col = "black",
  isometric = TRUE,
  atip.rotate = NULL,
  btip.rotate = NULL,
  ctip.rotate = NULL,
  atip.pos = NULL,
  btip.pos = NULL,
  ctip.pos = NULL,
  padding = 0.08,
  col = NA,
  panel.first = NULL,
  panel.last = NULL,
  grid.lines = 10,
  grid.col = "darkgrey",
  grid.lty = "solid",
  grid.lwd = par("lwd"),
  grid.minor.lines = 4,
```

```

    grid.minor.col = "lightgrey",
    grid.minor.lty = "solid",
    grid.minor.lwd = par("lwd"),
    axis.lty = "solid",
    axis.labels = TRUE,
    axis.cex = 0.8,
    axis.font = par("font"),
    axis.rotate = TRUE,
    axis.pos = NULL,
    axis.tick = TRUE,
    axis.lwd = 1,
    ticks.lwd = axis.lwd,
    ticks.length = 0.025,
    axis.col = "black",
    ticks.col = grid.col,
    ...
)

HorizontalGrid(
  grid.lines = 10,
  grid.col = "grey",
  grid.lty = "dotted",
  grid.lwd = par("lwd"),
  direction = getOption("ternDirection", 1L)
)

```

Arguments

atip, btip, ctip	Character string specifying text to title corners, proceeding clockwise from the corner specified in point (default: top).
alab, blab, clab	Character string specifying text with which to label the corresponding sides of the triangle. Left or right-pointing arrows are produced by typing <code>\\U2190</code> or <code>\\U2192</code> , or using expression(<code>'value' %>% '</code>).
lab.offset	Numeric specifying distance between midpoint of axis label and the axis. The default value is given in the 'Usage' section; a value of 0 will position the axis label directly on the axis. Increase padding if labels are being clipped. Use a vector of length three to specify a different offset for each label.
lab.col	Character vector specifying colours for axis labels. Use a vector of length three to specify a different colour for each label.
point	Character string specifying the orientation of the ternary plot: should the triangle point "up", "right", "down" or "left"? The integers 1 to 4 can be used in place of the character strings.
clockwise	Logical specifying the direction of axes. If TRUE (the default), each axis runs from zero to its maximum value in a clockwise direction around the plot.
xlim, ylim	Numeric vectors of length two specifying the minimum and maximum <i>x</i> and <i>y</i> limits of the plotted area, to which padding will be added. The default is to display the complete height or width of the plot. Allows cropping to magnified

	region of the plot. (See vignette for diagram.) May be overridden if <code>isometric = TRUE</code> ; see documentation of <code>isometric</code> parameter.
<code>region</code>	(optional) Named list of length two specifying the the minimum and maximum values of each ternary axis to be drawn (e.g. <code>list(min = c(40, 0, 0), max = c(100, 60, 60))</code>); or a set of coordinates in a format accepted by <code>TernaryPoints()</code> . The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates.
<code>lab.cex, tip.cex</code>	Numeric specifying character expansion (font size) for axis labels. Use a vector of length three to specify a different value for each direction.
<code>lab.font, tip.font</code>	Numeric specifying font style (Roman, bold, italic, bold-italic) for axis titles. Use a vector of length three to set a different font for each direction.
<code>isometric</code>	Logical specifying whether to enforce an equilateral shape for the ternary plot. If only one of <code>xlim</code> and <code>ylim</code> is set, the other will be calculated to maintain an equilateral plot. If both <code>xlim</code> and <code>ylim</code> are set, but have different ranges, then the limit with the smaller range will be scaled until its range matches that of the other limit.
<code>atip.rotate, btip.rotate, ctip.rotate</code>	Integer specifying number of degrees to rotate label of rightmost apex.
<code>atip.pos, btip.pos, ctip.pos</code>	Integer specifying positioning of labels, iff the corresponding <code>x.tip.rotate</code> parameter is set.
<code>padding</code>	Numeric specifying size of internal margin of the plot; increase if axis labels are being clipped.
<code>col</code>	The colour for filling the plot; see polygon .
<code>panel.first</code>	An expression to be evaluated after the plot axes are set up but before any plotting takes place. This can be useful for drawing backgrounds, e.g. with ColourTernary() or HorizontalGrid() . Note that this works by lazy evaluation: passing this argument from other plot methods may well not work since it may be evaluated too early.
<code>panel.last</code>	An expression to be evaluated after plotting has taken place but before the axes and box are added. See the comments about <code>panel.first</code> .
<code>grid.lines</code>	Integer specifying the number of grid lines to plot. If <code>axis.labels = TRUE</code> , this will be used as a hint to <code>pretty()</code> .
<code>grid.col, grid.minor.col</code>	Colours to draw the grid lines. Use a vector of length three to set different values for each direction.
<code>grid.lty, grid.minor.lty</code>	Character or integer vector; line type of the grid lines. Use a vector of length three to set different values for each direction.
<code>grid.lwd, grid.minor.lwd</code>	Non-negative numeric giving line width of the grid lines. Use a vector of length three to set different values for each direction.

<code>grid.minor.lines</code>	Integer specifying the number of minor (unlabelled) grid lines to plot between each major pair.
<code>axis.lty</code>	Line type for both the axis line and tick marks. Use a vector of length three to set a different value for each direction.
<code>axis.labels</code>	This can either be a logical value specifying whether (numerical) annotations are to be made at the tickmarks, or a character or expression vector of labels to be placed at the tick points, or a list of length three, with each entry specifying labels to be placed on each axis in turn.
<code>axis.cex</code>	Numeric specifying character expansion (font size) for axis labels. Use a vector of length three to set a different value for each direction.
<code>axis.font</code>	Font for text. Defaults to <code>par('font')</code> .
<code>axis.rotate</code>	Logical specifying whether to rotate axis labels to parallel grid lines, or numeric specifying custom rotation for each axis, to be passed as <code>srt</code> parameter to <code>text()</code> . Expand margins or set <code>par(xpd = NA)</code> if labels are clipped.
<code>axis.pos</code>	Vector of length one or three specifying position of axis labels, to be passed as <code>pos</code> parameter to <code>text()</code> ; populated automatically if <code>NULL</code> (the default).
<code>axis.tick</code>	Logical specifying whether to mark the axes with tick marks.
<code>axis.lwd, ticks.lwd</code>	Line width for the axis line and tick marks. Zero or negative values will suppress the line or ticks. Use a vector of length three to set different values for each axis.
<code>ticks.length</code>	Numeric specifying distance that ticks should extend beyond the plot margin. Also affects position of axis labels, which are plotted at the end of each tick. Use a vector of length three to set a different length for each direction.
<code>axis.col, ticks.col, tip.col</code>	Colours for the axis line, tick marks and tip labels respectively. Use a vector of length three to set a different value for each direction. <code>axis.col = NULL</code> means to use <code>par('fg')</code> , possibly specified inline, and <code>ticks.col = NULL</code> means to use whatever colour <code>axis.col</code> resolved to.
<code>...</code>	Additional parameters to plot .
<code>direction</code>	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.

Details

The plot will be generated using the standard 'graphics' plot functions, on which additional elements can be added using Cartesian coordinates, perhaps using functions such as [arrows](#), [legend](#) or [text](#).

Functions

- `HorizontalGrid()`: Add `grid.lines` horizontal lines to the ternary plot

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

- Detailed usage examples are available in the [package vignette](#)
- [AddToTernary\(\)](#): Add elements to a ternary plot
- [TernaryCoords\(\)](#): Convert ternary coordinates to Cartesian (x and y) coordinates
- [TernaryXRange\(\)](#), [TernaryYRange\(\)](#): What are the x and y limits of the plotted region?

Examples

```
TernaryPlot(
  atip = "Top", btip = "Bottom", ctip = "Right", axis.col = "red",
  col = rgb(0.8, 0.8, 0.8)
)
HorizontalGrid(grid.lines = 2, grid.col = "blue", grid.lty = 1)
# the second line corresponds to the base of the triangle, and is not drawn
```

TernaryPointValues	<i>Evaluate function over a grid</i>
--------------------	--------------------------------------

Description

Intended to facilitate coloured contour plots with [ColourTernary\(\)](#), [TernaryPointValue\(\)](#) evaluates a function at points on a triangular grid; [TernaryDensity\(\)](#) calculates the density of points in each grid cell.

Usage

```
TernaryPointValues(
  Func,
  resolution = 48L,
  direction = getOption("ternDirection", 1L),
  ...
)

TernaryDensity(
  coordinates,
  resolution = 48L,
  direction = getOption("ternDirection", 1L)
)
```

Arguments

Func	Function that takes three arguments named a , b and c , and returns a numeric vector of length n . a , b and c will each be a vector of length n . Together, they specify the series of coordinates at which the function should be evaluated.
resolution	The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost.

direction	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.
...	Additional parameters to Func().
coordinates	A list, matrix, data.frame or vector in which each element (or row) specifies the three coordinates of a point in ternary space.

Value

TernaryPointValues() returns a matrix whose rows correspond to:

- **x, y:** co-ordinates of the centres of smaller triangles
- **z:** The value of Func(a, b, c, ...), where a, b and c are the ternary coordinates of x and y.
- **down:** 0 if the triangle concerned points upwards (or right), 1 otherwise

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other contour plotting functions: [ColourTernary\(\)](#), [TernaryContour\(\)](#), [TernaryDensityContour\(\)](#)

Examples

```
TernaryPointValues(function (a, b, c) a * b * c, resolution = 2)

TernaryPlot(grid.lines = 4)
cols <- TernaryPointValues(rgb, resolution = 4)
text(as.numeric(cols["x", ]), as.numeric(cols["y", ]),
     labels = ifelse(cols["down", ] == "1", "v", "^"),
     col = cols["z", ])

TernaryPlot(axis.labels = seq(0, 10, by = 1))

nPoints <- 4000L
coordinates <- cbind(abs(rnorm(nPoints, 2, 3)),
                    abs(rnorm(nPoints, 1, 1.5)),
                    abs(rnorm(nPoints, 1, 0.5)))

density <- TernaryDensity(coordinates, resolution = 10L)
ColourTernary(density, legend = TRUE, bty = "n", title = "Density")
TernaryPoints(coordinates, col = "red", pch = ".")
```

TernaryTiles

Paint tiles on ternary plot

Description

Function to fill a ternary plot with coloured tiles. Useful in combination with [TernaryPointValues\(\)](#) and [TernaryContour\(\)](#).

Usage

```
TernaryTiles(
  x,
  y,
  down,
  resolution,
  col,
  direction = getOption("ternDirection", 1L)
)
```

Arguments

x, y	Numeric vectors specifying x and y coordinates of centres of each triangle.
down	Logical vector specifying TRUE if each triangle should point down (or right), FALSE otherwise.
resolution	The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost.
col	Vector specifying the colour with which to fill each triangle.
direction	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.

Value

`TernaryTiles()` is called for its side effect – painting a ternary plot with coloured tiles. It invisibly returns NULL.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other functions for colouring and shading: [ColourTernary\(\)](#)

Examples

```

TernaryPlot()
TernaryXRange()
TernaryYRange()

TernaryTiles(0, 0.5, TRUE, 10, "red")
xy <- TernaryCoords(c(4, 3, 3))
TernaryTiles(xy[1], xy[2], FALSE, 5, "darkblue")

```

TernaryXRange	<i>X and Y coordinates of ternary plotting area</i>
---------------	---

Description

X and Y coordinates of ternary plotting area

Usage

```

TernaryXRange(direction = getOption("ternDirection", 1L))

TernaryYRange(direction = getOption("ternDirection", 1L))

```

Arguments

direction (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.

Value

TernaryXRange() and TernaryYRange() return the minimum and maximum X or Y coordinate of the area in which a ternary plot is drawn, oriented in the specified direction. Because the plotting area is a square, the triangle of the ternary plot will not occupy the full range in one direction. Assumes that the defaults have not been overwritten by specifying `xlim` or `ylim`.

Functions

- TernaryYRange(): Returns the minimum and maximum Y coordinate for a ternary plot in the specified direction.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other plot limits: [OutsidePlot\(\)](#)

TriangleCentres	<i>Coordinates of triangle mid-points</i>
-----------------	---

Description

Calculate x and y coordinates of the midpoints of triangles tiled to cover a ternary plot.

Usage

```
TriangleCentres(resolution = 48L, direction = getOption("ternDirection", 1L))
```

Arguments

resolution	The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost.
direction	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.

Value

TriangleCentres() returns a matrix with three named rows:

- x x coordinates of triangle midpoints;
- y y coordinates of triangle midpoints;
- triDown 0 for upwards-pointing triangles, 1 for downwards-pointing.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Add triangles to a plot: [TernaryTiles\(\)](#)

Other coordinate translation functions: [ReflectedEquivalents\(\)](#), [TernaryCoords\(\)](#), [XYToTernary\(\)](#)

Other tiling functions: [PolygonGeometry](#), [TriangleInHull\(\)](#)

Examples

```
TernaryPlot(grid.lines = 4)
centres <- TriangleCentres(4)
text(centres["x", ], centres["y", ], ifelse(centres["triDown", ], "v", "^"))
```

TriangleInHull	<i>Does triangle overlap convex hull of points?</i>
----------------	---

Description

Does triangle overlap convex hull of points?

Usage

```
TriangleInHull(triangles, coordinates, buffer)
```

Arguments

triangles	Three-row matrix as produced by TriangleCentres() .
coordinates	A matrix with two or three rows specifying the coordinates of points in <i>x</i> , <i>y</i> or <i>a</i> , <i>b</i> , <i>c</i> format.
buffer	Include triangles whose centres lie within buffer triangles widths (i.e. edge lengths) of the convex hull.

Value

TriangleInHull() returns a list with the elements:

- `$inside`: vector specifying whether each of a set of triangles produced by [TriangleCentres\(\)](#) overlaps the convex hull of points specified by `coordinates`.
- `$hull`: Coordinates of convex hull of `coordinates`, after expansion to cover overlapping triangles.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other tiling functions: [Polygon-Geometry](#), [TriangleCentres\(\)](#)

Examples

```
set.seed(0)
nPts <- 50
a <- runif(nPts, 0.3, 0.7)
b <- 0.15 + runif(nPts, 0, 0.7 - a)
c <- 1 - a - b
coordinates <- rbind(a, b, c)

TernaryPlot(grid.lines = 5)
TernaryPoints(coordinates, pch = 3, col = 4)
triangles <- TriangleCentres(resolution = 5)
```

```

inHull <- TriangleInHull(triangles, coordinates)
polygon(inHull$hull, border = 4)
values <- rbind(triangles,
                z = ifelse(inHull$inside, "#33cc3333", "#cc333333"))
points(triangles["x", ], triangles["y", ],
       pch = ifelse(triangles["triDown", ], 6, 2),
       col = ifelse(inHull$inside, "#33cc33", "#cc3333"))
ColourTernary(values)

```

XYToTernary

*Cartesian coordinates to ternary point***Description**

Convert Cartesian (x, y) coordinates to a point in ternary space.

Usage

```

XYToTernary(
  x,
  y,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault)
)

XYToHoldridge(x, y)

XYToPetPrec(x, y)

```

Arguments

x, y	Numeric values giving the x and y coordinates of a point or points.
direction	(optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.
region	(optional) Named list of length two specifying the the minimum and maximum values of each ternary axis to be drawn (e.g. <code>list(min = c(40, 0, 0), max = c(100, 60, 60))</code>); or a set of coordinates in a format accepted by TernaryPoints() . The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates.

Value

XYToTernary() Returns the ternary point(s) corresponding to the specified x and y coordinates, where $a + b + c = 1$.

Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

See Also

Other coordinate translation functions: [ReflectedEquivalents\(\)](#), [TernaryCoords\(\)](#), [TriangleCentres\(\)](#)

Examples

```
XYToTernary(c(0.1, 0.2), 0.5)
```


Index

- * **Holdridge plotting functions**
 - AddToTernary, [2](#)
 - holdridge, [9](#)
 - holdridgeClasses, [10](#)
 - HoldridgeHypsometricCol, [11](#)
 - HoldridgePlot, [12](#)
- * **contour plotting functions**
 - ColourTernary, [7](#)
 - TernaryContour, [21](#)
 - TernaryDensityContour, [26](#)
 - TernaryPointValues, [33](#)
- * **coordinate translation functions**
 - ReflectedEquivalents, [19](#)
 - TernaryCoords, [24](#)
 - TriangleCentres, [37](#)
 - XYToTernary, [39](#)
- * **datasets**
 - cbPalettes, [6](#)
 - holdridge, [9](#)
 - holdridgeClasses, [10](#)
- * **functions for colouring and shading**
 - ColourTernary, [7](#)
 - TernaryTiles, [35](#)
- * **plot limits**
 - OutsidePlot, [17](#)
 - TernaryXRange, [36](#)
- * **tiling functions**
 - Polygon-Geometry, [18](#)
 - TriangleCentres, [37](#)
 - TriangleInHull, [38](#)
- .filled.contour, [22](#), [26](#), [27](#)
- AddToHoldridge (AddToTernary), [2](#)
- AddToHoldridge(), [12](#), [16](#)
- AddToTernary, [2](#), [9](#), [11](#), [12](#), [17](#)
- AddToTernary(), [33](#)
- Annotate, [5](#)
- arrows, [3](#), [4](#), [32](#)
- cbPalette13 (cbPalettes), [6](#)
- cbPalette15 (cbPalettes), [6](#)
- cbPalette8 (cbPalettes), [6](#)
- cbPalettes, [6](#)
- ColorTernary (ColourTernary), [7](#)
- ColourTernary, [7](#), [23](#), [27](#), [34](#), [35](#)
- ColourTernary(), [15](#), [31](#), [33](#)
- contour, [22](#), [26](#)
- Graphical parameters, [16](#)
- graphical parameters, [3](#)
- GrowPolygon (Polygon-Geometry), [18](#)
- holdridge, [4](#), [9](#), [11](#), [12](#), [17](#)
- HoldridgeArrows (AddToTernary), [2](#)
- HoldridgeBelts (HoldridgePlot), [12](#)
- HoldridgeBelts(), [16](#)
- holdridgeClasses, [4](#), [9](#), [10](#), [12](#), [17](#)
- holdridgeClassesUp, [16](#)
- holdridgeClassesUp (holdridgeClasses), [10](#)
- HoldridgeHexagons (HoldridgePlot), [12](#)
- HoldridgeHexagons(), [10](#), [16](#)
- HoldridgeHypsometricCol, [4](#), [9](#), [11](#), [11](#), [17](#)
- holdridgeLifeZones (holdridgeClasses), [10](#)
- holdridgeLifeZonesUp, [16](#)
- holdridgeLifeZonesUp (holdridgeClasses), [10](#)
- HoldridgeLines (AddToTernary), [2](#)
- HoldridgePlot, [4](#), [9](#), [11](#), [12](#), [12](#)
- HoldridgePlot(), [2](#)
- HoldridgePoints (AddToTernary), [2](#)
- HoldridgePoints(), [16](#)
- HoldridgePolygon (AddToTernary), [2](#)
- HoldridgeText (AddToTernary), [2](#)
- HoldridgeText(), [16](#)
- HorizontalGrid (TernaryPlot), [29](#)
- HorizontalGrid(), [15](#), [31](#)
- JoinTheDots (AddToTernary), [2](#)

legend, [32](#)
 lines, [3](#), [4](#)

 OutsidePlot, [17](#), [36](#)

 plot, [16](#), [32](#)
 PlotTools::SpectrumLegend(), [8](#)
 points, [3](#), [4](#)
 polygon, [15](#), [31](#)
 polygon(), [15](#)
 Polygon-Geometry, [18](#)
 PolygonArea (Polygon-Geometry), [18](#)
 PolygonCenter (Polygon-Geometry), [18](#)
 PolygonCentre (Polygon-Geometry), [18](#)
 polygons, [4](#)

 ReflectedEquivalents, [19](#), [25](#), [27](#), [37](#), [40](#)

 segments, [4](#)
 segments(), [5](#)
 SpectrumLegend(), [8](#), [22](#)

 TernaryApp, [20](#)
 TernaryArrows (AddToTernary), [2](#)
 TernaryContour, [8](#), [21](#), [27](#), [34](#)
 TernaryContour(), [35](#)
 TernaryCoords, [19](#), [24](#), [37](#), [40](#)
 TernaryCoords(), [33](#)
 TernaryDensity (TernaryPointValues), [33](#)
 TernaryDensityContour, [8](#), [23](#), [26](#), [34](#)
 TernaryDownTiles (TernaryTiles), [35](#)
 TernaryLeftTiles (TernaryTiles), [35](#)
 TernaryLines (AddToTernary), [2](#)
 TernaryPlot, [29](#)
 TernaryPlot(), [2](#), [25](#)
 TernaryPoints (AddToTernary), [2](#)
 TernaryPoints(), [14](#), [22](#), [25](#), [31](#), [39](#)
 TernaryPointValues, [8](#), [23](#), [27](#), [33](#)
 TernaryPointValues(), [8](#), [35](#)
 TernaryPolygon (AddToTernary), [2](#)
 TernaryRightTiles (TernaryTiles), [35](#)
 TernarySegments (AddToTernary), [2](#)
 TernaryText (AddToTernary), [2](#)
 TernaryTiles, [8](#), [35](#)
 TernaryTiles(), [37](#)
 TernaryToXY (TernaryCoords), [24](#)
 TernaryUpTiles (TernaryTiles), [35](#)
 TernaryXRange, [17](#), [36](#)
 TernaryXRange(), [33](#)

 TernaryYRange (TernaryXRange), [36](#)
 TernaryYRange(), [33](#)
 text, [3](#), [4](#), [32](#)
 text(), [5](#), [15](#)
 TriangleCentres, [19](#), [25](#), [37](#), [38](#), [40](#)
 TriangleCentres(), [38](#)
 TriangleInHull, [19](#), [37](#), [38](#)

 XYToHoldridge (XYToTernary), [39](#)
 XYToPetPrec (XYToTernary), [39](#)
 XYToTernary, [19](#), [25](#), [37](#), [39](#)