

# Package ‘soiltestcorr’

May 9, 2026

**Title** Soil Test Correlation and Calibration

**Version** 2.2.1

**Date** 2024-06-30

**Description** A compilation of functions designed to assist users on the correlation analysis of crop yield and soil test values. Functions to estimate crop response patterns to soil nutrient availability and critical soil test values using various approaches such as: 1) the modified arc-sine-log calibration curve (Correndo et al. (2017) <[doi:10.1071/CP16444](https://doi.org/10.1071/CP16444)>); 2) the graphical Cate-Nelson quadrants analysis (Cate & Nelson (1965)), 3) the statistical Cate-Nelson quadrants analysis (Cate & Nelson (1971) <[doi:10.2136/sssaj1971.03615995003500040048x](https://doi.org/10.2136/sssaj1971.03615995003500040048x)>), 4) the linear-plateau regression (Anderson & Nelson (1975) <[doi:10.2307/2529422](https://doi.org/10.2307/2529422)>), 5) the quadratic-plateau regression (Bullock & Bullock (1994) <[doi:10.2134/agronj1994.00021962008600010033x](https://doi.org/10.2134/agronj1994.00021962008600010033x)>), and 6) the Mitscherlich-type exponential regression (Melsted & Peck (1977) <[doi:10.2134/asaspecpub29.c1](https://doi.org/10.2134/asaspecpub29.c1)>). The package development stemmed from ongoing work with the Fertilizer Recommendation Support Tool (FRST) and Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL) projects.

**License** MIT + file LICENSE

**Encoding** UTF-8

**RoxygenNote** 7.3.2

**Suggests** knitr, rmarkdown, testthat

**Imports** stats, dplyr, rlang, tidyr, utils, purrr, data.table, ggplot2, ggpp, nlstools, minpack.lm, modelr, nlraa, AICcmodavg, smatr

**Depends** R (>= 3.6.0)

**LazyData** true

**VignetteBuilder** knitr

**URL** <https://adriancorrendo.github.io/soiltestcorr/>,  
<https://soiltestfrst.org/>,  
<https://www.siildigitalagconsortium.com/>

**BugReports** <https://github.com/adriancorrendo/soiltestcorr/issues>

**NeedsCompilation** no

**Author** Adrian A. Correndo [aut, cre, cph] (ORCID: <https://orcid.org/0000-0002-4172-289X>),  
 Austin Pearce [aut] (ORCID: <https://orcid.org/0000-0002-2541-896X>),  
 Fernando Miguez [ctb] (ORCID: <https://orcid.org/0000-0002-4627-8329>),  
 Deanna Osmond [aut] (ORCID: <https://orcid.org/0000-0002-6336-8318>),  
 Ignacio A. Ciampitti [aut] (ORCID: <https://orcid.org/0000-0001-9619-5129>)

**Maintainer** Adrian A. Correndo <acorrend@uoguelph.ca>

**Repository** CRAN

**Date/Publication** 2024-07-01 06:30:02 UTC

## Contents

cate_nelson_1965 . . . . .	2
cate_nelson_1971 . . . . .	4
data_test . . . . .	5
freitas1966 . . . . .	6
linear_plateau . . . . .	6
mitscherlich . . . . .	8
mod_alcc . . . . .	10
quadratic_plateau . . . . .	12

**Index** 15

---

cate_nelson_1965	<i>Cate &amp; Nelson quadrants analysis (graphical)</i>
------------------	---

---

## Description

This function runs the quadrants analysis suggested by Cate and Nelson (1965)

## Usage

```
cate_nelson_1965(data = NULL, stv, ry, target, tidy = TRUE, plot = FALSE)
```

```
boot_cn_1965(data, ry, stv, target = 90, n = 5, ...)
```

## Arguments

data	argument to call a data.frame or data.table containing the data
stv	argument to call the vector or column containing the soil test value (stv) data
ry	argument to call the vector or column containing the relative yield (ry) data
target	argument to specify the ry target (numeric) to estimate the critical stv for
tidy	logical operator (TRUE/FALSE) to decide the type of return. TRUE returns a tibble, FALSE returns a list. Default: TRUE.

plot	logical operator (TRUE/FALSE) to decide the type of return. TRUE returns a ggplot, FALSE returns either a list (tidy == FALSE) or a tibble (tidy == TRUE).
n	sample size for the bootstrapping Default: 500
...	when running bootstrapped samples, the ... (open arguments) allows to add grouping variable/s (factor or character) Default: NULL

### Details

See [online-documentation](#) for additional details.

### Value

returns an object of type ggplot if plot = TRUE.

returns an object of class data.frame if tidy = TRUE,

returns an object of class list if tidy = FALSE.

boot\_cn\_1965: bootstrapping function

### Note

This code was adapted from Mangiafico, S. S. (2013). Cate-Nelson Analysis for Bivariate Data Using R-project. *The Journal of Extension*, 51(5), Article 33. <https://tigerprints.clemson.edu/joe/vol51/iss5/33/>

### References

Cate & Nelson (1965). A rapid method for correlation of soil test analysis with plant response data. *North Carolina Agric. Exp. Stn., International soil Testing Series I. No. 1.*

### See Also

[eval\\_tidy](#), [defusing-advanced](#) [lm](#), [anova](#) [ggplot](#), [aes](#), [geom\\_point](#), [labs](#), [geom\\_abline](#), [annotate](#), [theme](#)

### Examples

```
# Example 1 dataset
dat <- data.frame("ry" = c(65,80,85,88,90,94,93,96,97,95,98,100,99,99,100),
                 "stv" = c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15))

# Run
fit_example_cn_1965 <- cate_nelson_1965(data = dat,
ry = ry, stv = stv, target = 90, tidy=FALSE, plot=FALSE)

fit_example_cn_1965
```

---

cate\_nelson\_1971      *Cate & Nelson quadrants analysis (statistical)*

---

### Description

This function runs the quadrants analysis suggested by Cate and Nelson (1971)

### Usage

```
cate_nelson_1971(data = NULL, stv, ry, tidy = TRUE, plot = FALSE)
```

```
boot_cn_1971(data, ry, stv, n = 5, ...)
```

### Arguments

data	argument to call a data.frame or data.table containing the data
stv	argument to call the vector or column containing the soil test value (stv) data
ry	argument to call the vector or column containing the relative yield (ry) data
tidy	logical operator (TRUE/FALSE) to decide the type of return. TRUE returns a data.frame, FALSE returns a list. Default: TRUE.
plot	logical operator (TRUE/FALSE) to decide the type of return. TRUE returns a ggplot, FALSE returns either a list (tidy == FALSE) or a data.frame (tidy == TRUE).
n	sample size for the bootstrapping Default: 500
...	when running bootstrapped samples, the ... (open arguments) allows to add grouping variable/s (factor or character) Default: NULL

### Details

See [online-documentation](#) for additional details.

### Value

returns an object of type ggplot if plot = TRUE.

returns an object of class data.frame if tidy = TRUE,

returns an object of class list if tidy = FALSE.

boot\_cn\_1971: bootstrapping function

### Note

This code was adapted from Mangiafico, S. S. (2013). Cate-Nelson Analysis for Bivariate Data Using R-project. *The Journal of Extension*, 51(5), Article 33. <https://tigerprints.clemson.edu/joe/vol51/iss5/33/>

## References

Cate & Nelson (1971). A simple statistical procedure for partitioning soil test correlation data into two classes. *Soil Sci. Soc. Am. Proc.* 35:658-660. doi:10.2136/sssaj1971.03615995003500040048x

## See Also

[eval\\_tidy](#), [defusing-advanced lm](#), [anova ggplot](#), [aes](#), [geom\\_point](#), [labs](#), [geom\\_abline](#), [annotate](#), [theme](#)

## Examples

```
# Example 1 dataset
dat <- data.frame("ry" = c(65,80,85,88,90,94,93,96,97,95,98,100,99,99,100),
                 "stv" = c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15))
# Run
fit_example_cn_1971 <- cate_nelson_1971(data = dat,
ry = ry, stv = stv, tidy=FALSE, plot=FALSE)

fit_example_cn_1971
```

---

data\_test

*Dataset 1*

---

## Description

Example dataset containing hypothetical pairs of soil test value (STV) and relative yield (RY).

## Usage

```
data_test
```

## Format

this data frame has 137 rows and the following 2 columns:

**STV** soil test value

**RY** relative yield, %

## Source

doi:10.7910/DVN/NABA57

---

```
freitas1966
```

```
Dataset 2
```

---

### Description

Example dataset containing real data reported by Cate & Nelson (1971) from Freitas et al. (1966). Soil test potassium values (STK) and relative yield as percentage (RY).

### Usage

```
freitas1966
```

### Format

this data frame has 24 rows and the following 2 columns:

**RY** relative yield, %

**STK** soil test potassium, ppm

### Source

Freitas et al. (1966) cited and used by Cate & Nelson (1971). Soil Sci. Soc. Am. Proc. 35:658-659

---

```
linear_plateau
```

```
Linear-plateau response function
```

---

### Description

This function helps to fit a linear-plateau model in order to estimate critical soil test values (CSTV) above which yield response becomes flat.

### Usage

```
SS_LP(x, a, b, xs)
```

```
linear_plateau(
  data = NULL,
  stv,
  ry,
  target = NULL,
  tidy = TRUE,
  plot = FALSE,
  resid = FALSE
)
```

```
boot_linear_plateau(data, stv, ry, n = 1000, target = NULL, ...)
```

**Arguments**

x	selfstart arg. for explanatory variable in SSlinp Default: NULL
a	selfstart arg. for intercept Default: NULL
b	selfstart arg. for slope Default: NULL
xs	selfstart arg. for break/join point in SSlinp Default: NULL
data	Optional argument to call and object of type data.frame or data.table containing the soil test value (STV) and relative yield (RY) data, Default: NULL
stv	name of the vector containing soil test values (-) of type numeric.
ry	name of the vector containing relative yield values (%) of type numeric.
target	numeric value of relative yield target (e.g. 90 for 90%) to estimate the CSTV. The target needs to be < plateau, otherwise, target = plateau.
tidy	logical operator (TRUE/FALSE) to decide the type of return. TRUE returns a tidy data frame or tibble (default), FALSE returns a list.
plot	logical operator (TRUE/FALSE) to plot the linear-plateau model, Default: FALSE
resid	logical operator (TRUE/FALSE) to plot residuals analysis, Default: FALSE
n	sample size for the bootstrapping Default: 500
...	when running bootstrapped samples, the ... (open arguments) allows to add grouping variable/s (factor or character) Default: NULL

**Details**

See [online-documentation](#) for additional details.

**Value**

returns an object of type ggplot if plot = TRUE.

returns a residuals plot if resid = TRUE.

returns an object of class data.frame if tidy = TRUE,

returns an object of class list if tidy = FALSE.

SS\_LP: selfStart function to pass into the linear\_plateau fit

linear\_plateau: function

boot\_linear\_plateau: bootstrapping function

**Note**

For extended reference, we recommend to visit: <https://gradcylinder.org/post/linear-plateau/> by Austin Pearce. Self-start function code adapted from nlraa package by F. Miguez <https://github.com/femiguez/nlraa>

**References**

Anderson, R. L., and Nelson, L. A. (1975). A Family of Models Involving Intersecting Straight Lines and Concomitant Experimental Designs Useful in Evaluating Response to Fertilizer Nutrients. *Biometrics*, 31(2), 303–318. doi:10.2307/2529422

**See Also**

[eval\\_tidy](#), [defusing-advanced](#), [nlsLM](#), [SSlinp](#), [AIC](#), [lm](#), [optim](#), [coef](#), [predict](#), [AICc](#), [model-quality](#), [nlsResiduals](#), [bind](#), [ggplot](#), [aes](#), [geom\\_rug](#), [geom\\_point](#), [geom\\_abline](#), [geom\\_path](#), [annotate](#), [labs](#), [theme](#), [annotate](#)

**Examples**

```
# Example dataset
dat <- data.frame("ry" = c(65,80,85,88,90,94,93,96,97,95,98,100,99,99,100),
                 "stv" = c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15))

# Run
fit_example_lp <- linear_plateau(data = dat,
                                ry = ry, stv = stv, resid = TRUE, plot = FALSE)
fit_example_lp
```

---

mitscherlich

*Mitscherlich response function*


---

**Description**

This function helps to fit a Mitscherlich-style exponential response model for relative yield (ry) as a function of soil test values (stv).

**Usage**

```
mits_formula_1(x, a, b, c)
```

```
mits_formula_2(x, b, c)
```

```
mits_formula_3(x, c)
```

```
mitscherlich(
  data = NULL,
  stv,
  ry,
  type = 1,
  target = 95,
  tidy = TRUE,
  plot = FALSE,
  resid = FALSE
)
```

```
boot_mitscherlich(data, stv, ry, type = 1, n = 999, target = 95, ...)
```

**Arguments**

x	selfstart vector. for model fit Default: NULL
a	selfstart arg. for asymptote parameter, Default: NULL
b	selfstart arg. for b parameter (b = -X_intercept) Default: NULL
c	selfstart arg. for curvature parameter Default: NULL
data	Optional argument to call and object of type data.frame or data.table containing the stv and ry data, Default: NULL
stv	name of the vector containing soil test values (-) of type numeric.
ry	name of the vector containing relative yield values (%) of type numeric.
type	string or number that indicates the type of Mitscherlich model to fit. Default: 1. For model with 'no restrictions' use type = 1, type = "no restriction", or type = "free"; For model with 'asymptote = 100' use type = 2, type = "asymptote 100", or type = "100"; For model with 'asymptote = 100 and xintercept = 0' type = 3, type = "asymptote 100 from 0", or type = "fixed".
target	numeric value of relative yield target (e.g. 90 for 90%) to estimate the CSTV. Default: NULL
tidy	logical operator (TRUE/FALSE) to decide the type of return. TRUE returns a tidy data frame or tibble (default), FALSE returns a list.
plot	logical operator (TRUE/FALSE) to plot the Mitscherlich model, Default: FALSE
resid	logical operator (TRUE/FALSE) to plot residuals analysis, Default: FALSE
n	sample size for the bootstrapping Default: 500
...	when running bootstrapped samples, the ... (open arguments) allows to add grouping variable/s (factor or character) Default: NULL

**Details**

See [online-documentation](#) for additional details.

**Value**

returns an object of type `ggplot` if `plot = TRUE`.

returns a residuals plot if `resid = TRUE`.

returns an object of class `data.frame` if `tidy = TRUE`,

returns an object of class `list` if `tidy = FALSE`.

Mitscherlich type 1 formula

Mitscherlich type 2 formula

Mitscherlich type 3 formula

`mitscherlich`: function

`boot_mitscherlich`: bootstrapping function

**Note**

For extended reference, we recommend to visit: <https://github.com/austinwpearce/SoilTestCocaCola> by Austin Pearce.

**References**

Melsted, S.W. and Peck, T.R. (1977). The Mitscherlich-Bray Growth Function. *In Soil Testing (eds T. Peck, J. Cope and D. Whitney)*. doi:10.2134/asaspecpub29.c1

**See Also**

[eval\\_tidy](#), [defusing-advanced](#), [nlsLM](#), [AIC](#), [lm](#), [optim](#), [coef](#), [predict](#), [AICc](#), [model-quality](#), [nlsResiduals](#), [bind](#), [ggplot](#), [aes](#), [geom\\_rug](#), [geom\\_point](#), [geom\\_abline](#), [geom\\_path](#), [annotate](#), [labs](#), [theme](#)

**Examples**

```
# Example dataset
dat <- data.frame("ry" = c(65,80,85,88,90,94,93,96,97,95,98,100,99,99,100),
                 "stv" = c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15))

# Run
fit_example_mits <- mitscherlich(data = dat, type = 1,
                                ry = ry, stv = stv, resid = TRUE, plot = FALSE)

fit_example_mits
```

---

 mod\_alcc

---

*Modified Arcsine-Log Calibration Curve*


---

**Description**

This function runs the modified arcsine-log calibration curve to estimate critical soil test values (CSTV) following Correndo et al. (2017)

**Usage**

```
mod_alcc(
  data = NULL,
  ry,
  stv,
  target,
  confidence = 0.95,
  tidy = TRUE,
  plot = FALSE
)

logLik_alcc(object, ...)

boot_mod_alcc(data, ry, stv, n = 500, target = 90, confidence = 0.95, ...)
```

**Arguments**

data	Optional argument to call and object of type <code>data.frame</code> or <code>data.table</code> containing the stv and ry data, Default: <code>NULL</code>
ry	name of the vector containing relative yield values (%) of type <code>numeric</code> .
stv	name of the vector containing soil test values of type <code>numeric</code> .
target	numeric value of relative yield target (e.g. 90 for 90%) to estimate the CSTV.
confidence	numeric value of confidence level (e.g. 0.95 for significance = 0.05)
tidy	logical operator ( <code>TRUE/FALSE</code> ) to decide the type of return. <code>TRUE</code> returns a tidy data frame or tibble (default), <code>FALSE</code> returns a list.
plot	logical operator ( <code>TRUE/FALSE</code> ) to decide the type of return. <code>TRUE</code> returns a <code>ggplot</code> , <code>FALSE</code> returns either a list ( <code>tidy == FALSE</code> ) or a <code>data.frame</code> ( <code>tidy == TRUE</code> ).
object	the "object" is the output data frame from <code>approx</code> with <code>resid</code> column
...	when running bootstrapped samples, the ... (open arguments) allows to add grouping variable/s (factor or character) Default: <code>NULL</code>
n	sample size for the bootstrapping Default: 500

**Details**

See [online-documentation](#) for additional details.

**Value**

returns an object of type `ggplot` if `plot = TRUE`.

returns an object of class `data.frame` if `tidy = TRUE`,

returns an object of class `list` if `tidy = FALSE`.

`logLik_alcc`: AIC on original scale function

`boot_mod_alcc`: bootstrapping function

**Note**

For extended reference, we recommend to visit [doi:10.7910/DVN/NABA57](https://doi.org/10.7910/DVN/NABA57) and <https://github.com/adriancorrendo/modified-ALCC> by Adrian Correndo.

**References**

Correndo et al. (2017). A modification of the arcsine–log calibration curve for analysing soil test value–relative yield relationships. *Crop and Pasture Science*, 68(3), 297-304. [doi:10.1071/CP16444](https://doi.org/10.1071/CP16444)

**See Also**

[eval\\_tidy](#), [defusing-advanced TDist](#), [cor](#), [cor.test](#), [sd](#), [approx](#), [bind](#), [filter](#), [nest](#), [ggplot](#), [aes](#), [geom\\_point](#), [scale\\_manu](#), [annotate](#)

**Examples**

```
# Example 1 dataset
dat <- data.frame("ry" = c(65,80,85,88,90,94,93,96,97,95,98,100,99,99,100),
                  "stv" = c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15))

# Run
fit_example <- mod_alcc(data = dat, ry = ry, stv = stv, target=90, confidence = 0.95)
fit_example
```

---

quadratic\_plateau      *Quadratic-plateau response function*

---

**Description**

This function helps to fit a quadratic-plateau response model and to estimate a critical soil test values (CSTV) above which yield response becomes flat.

**Usage**

```
SS_QP(x, a, b, xs)
```

```
quadratic_plateau(
  data = NULL,
  stv,
  ry,
  target = NULL,
  tidy = TRUE,
  plot = FALSE,
  resid = FALSE
)
```

```
boot_quadratic_plateau(data, stv, ry, n = 1000, target = NULL, ...)
```

**Arguments**

x	selfstart arg. for explanatory variable in SSquadp3xs Default: NULL
a	selfstart arg. for intercept Default: NULL
b	selfstart arg. for slope Default: NULL
xs	selfstart arg. for break/join point in SSquadp3xs Default: NULL
data	Optional argument to call and object of type data.frame or data.table containing the stv and ry data, Default: NULL
stv	name of the vector containing soil test values (-) of type numeric.
ry	name of the vector containing relative yield values (%) of type numeric.
target	numeric value of relative yield target (e.g. 90 for 90%) to estimate the CSTV. The target needs to be < plateau, otherwise, target = plateau.

tidy	logical operator (TRUE/FALSE) to decide the type of return. TRUE returns a tidy data frame or tibble (default), FALSE returns a list.
plot	logical operator (TRUE/FALSE) to plot the quadratic-plateau model, Default: FALSE
resid	logical operator (TRUE/FALSE) to plot residuals analysis, Default: FALSE
n	sample size for the bootstrapping Default: 500
...	when running bootstrapped samples, the ... (open arguments) allows to add grouping variable/s (factor or character) Default: NULL

## Details

See [online-documentation](#) for additional details.

## Value

returns an object of type `ggplot` if `plot = TRUE`.

returns a residuals plot if `resid = TRUE`.

returns an object of class `data.frame` if `tidy = TRUE`,

returns an object of class `list` if `tidy = FALSE`.

SS\_QP: selfStart function to pass into the `quadratic_plateau` fit

`quadratic_plateau`: function

`boot_quadratic_plateau`: bootstrapping function

## Note

For extended reference, we recommend to visit <https://gradcylinder.org/post/quad-plateau/> by Austin Pearce. Self-start function code adapted from `nlraa` package by F. Miguez <https://github.com/femiguez/nlraa>

## References

Bullock, D.G. and Bullock, D.S. (1994) Quadratic and Quadratic-Plus-Plateau Models for Predicting Optimal Nitrogen Rate of Corn: A Comparison. *Agron. J.*, 86: 191-195. doi:10.2134/agronj1994.00021962008600010033x

## See Also

[eval\\_tidy](#), [defusing-advanced-nlsLM](#), [SSlinp](#), [AIC](#), [lm](#), [optim](#), [coef](#), [predict](#), [AICc](#), [model-quality](#), [nlsResiduals](#), [bind](#), [ggplot](#), [aes](#), [geom\\_rug](#), [geom\\_point](#), [geom\\_abline](#), [geom\\_path](#), [annotate](#), [labs](#), [theme](#), [annotate](#)

**Examples**

```
# Example dataset
df <- data.frame("ry" = c(65,80,85,88,90,94,93,96,97,95,98,100,99,99,100),
                 "stv" = c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15))

# Run
fit_example_qp <- quadratic_plateau(data = df,
  stv = stv, ry = ry, resid = TRUE, plot = FALSE)
fit_example_qp
```

# Index

## \* datasets

- data\_test, 5
- freitas1966, 6
  
- aes, 3, 5, 8, 10, 11, 13
- AIC, 8, 10, 13
- AICc, 8, 10, 13
- annotate, 3, 5, 8, 10, 11, 13
- anova, 3, 5
- approx, 11
  
- bind, 8, 10, 11, 13
- boot\_cn\_1965 (cate\_nelson\_1965), 2
- boot\_cn\_1971 (cate\_nelson\_1971), 4
- boot\_linear\_plateau (linear\_plateau), 6
- boot\_mitscherlich (mitscherlich), 8
- boot\_mod\_alcc (mod\_alcc), 10
- boot\_quadratic\_plateau (quadratic\_plateau), 12
  
- cate\_nelson\_1965, 2
- cate\_nelson\_1971, 4
- coef, 8, 10, 13
- cor, 11
- cor.test, 11
  
- data\_test, 5
  
- eval\_tidy, 3, 5, 8, 10, 11, 13
  
- filter, 11
- freitas1966, 6
  
- geom\_abline, 3, 5, 8, 10, 11, 13
- geom\_path, 8, 10, 11, 13
- geom\_point, 3, 5, 8, 10, 11, 13
- geom\_rug, 8, 10, 11, 13
- ggplot, 3, 5, 8, 10, 11, 13
  
- labs, 3, 5, 8, 10, 11, 13
- linear\_plateau, 6
  
- lm, 3, 5, 8, 10, 13
- logLik\_alcc (mod\_alcc), 10
  
- mits\_formula\_1 (mitscherlich), 8
- mits\_formula\_2 (mitscherlich), 8
- mits\_formula\_3 (mitscherlich), 8
- mitscherlich, 8
- mod\_alcc, 10
  
- nest, 11
- nlsLM, 8, 10, 13
- nlsResiduals, 8, 10, 13
  
- optim, 8, 10, 13
  
- predict, 8, 10, 13
  
- quadratic\_plateau, 12
  
- scale\_manual, 11
- sd, 11
- SS\_LP (linear\_plateau), 6
- SS\_QP (quadratic\_plateau), 12
- SSlinp, 8, 13
  
- TDist, 11
- theme, 3, 5, 8, 10, 11, 13